LATE TRIASSIC VERTEBRATE LOCALITIES IN NEW MEXICO

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Abstract - Significant (and some world-class) Late Triassic vertebrate localities are present across the northern half of New Mexico. Localities reviewed here are Fort Wingate (McKinley County), Canjilon and Whitaker (Ghost Ranch) quarries (Rio Arriba County), Lamy amphibian quarry (Santa Fe County), Peacock and Sloan canyons (Union County), Bull Canyon (Guadalupe County), Mesa Redonda, Apache Canyon, Shark-Tooth Hill, Barranca Creek and Revuelto Creek (the last five in Quay County). Most of these localities are of early Norian age and represent some of the youngest Late Triassic vertebrates known from the Southwest.

INTRODUCTION

Although Upper Triassic strata were originally recognized in New Mexico by Marcou (1858), it was Cope (1875) who first reported Late Triassic vertebrate fossils from the state. Since Cope, many Late Triassic vertebrates have been collected from New Mexico. Indeed, some world-famous Late Triassic vertebrate localities are known in the state of New Mexico. Here, we review these and other scientifically significant Late Triassic vertebrate localities in New Mexico (Figs. 1, 2). The following institutional abbreviations are used: AMNH, American Museum of Natural History, New York; CM, Carnegie Museum of Natural History, Pittsburgh; CMNH, Cleveland Museum of Natural History, Cleveland; NMNH, National Museum of Natural History, Washington; NMMNH, New Mexico Museum of Natural History, Albuquerque; UCMP, University of California Museum of Paleontology, Berkeley; UMMP, University of Michigan Museum of Paleontology, Ann Arbor; UNM, University of New Mexico, Albuquerque; USNM, National Museum of Natural History, Smithsonian Institution, Washington, D. C.; YPM, Yale Peabody Museum, New Haven.

FORT WINGATE

Geographic and Stratigraphic Context

Secs. 9 and 16 (unsurveyed), T14N, R16W, McKinley County, New Mexico; ownership Federal. The fossil vertebrate and plant localities here are in the lower part of the Petrified Forest Member of the Chinle Formation(Fig.3). We do not endorse Ash's (1978b) use of Monitor Butte Member in this area, nor do we believe his "Ciniza Lake Beds," based on a unit a couple of m thick that crops out over a few tens of acres should be recognized as a formal stratigraphic unit. Furthermore, Ash's

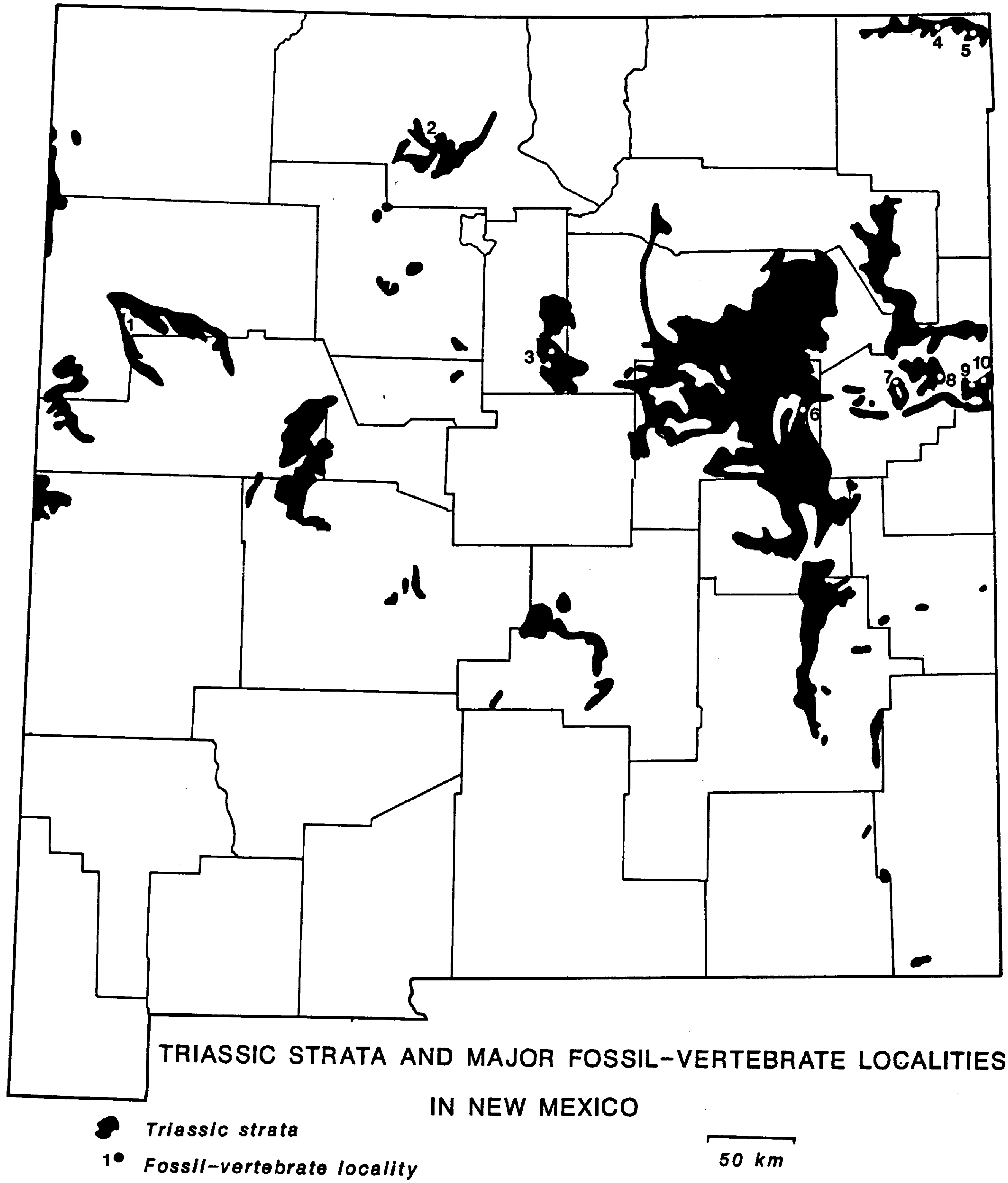

FIGURE 1. Triassic strata and major fossil-vertebrate localities in New Mexico. Localities are: 1. Fort Wingate, 2. Canjilon and Whitaker quarries, 3. Lamy amphibian quarry, 4. Peacock Canyon, 5. Sloan Canyon, 6. Bull Canyon, 7. Mesa Redonda, 8. Apache Canyon, 9. Barranca and Revuelto Creeks, 10. Shark-Tooth Hill.

	WESTERN NEW MEXICO	CENTRAL NEW MEXICO	EASTERN NEW MEXICO
EARLY NORIAN		Whitaker quarry Canjilon quarry	Mesa Redonda Apache Canyon Sloan Canyon Shark-tooth hill Peacock Canyon Bull Canyon Revuelto Creek Barranca Creek
LATE CARNIAN	Fort Wingate	Lamy amphibian quarry	

FIGURE 2. Approximate temporal distribution of major Late Triassic fossil-vertebrate localities in New Mexico.

(1978b) claims for syndepositional slumping in the Chinle here cannot be upheld. The steeply dipping Chinle beds near Fort Wingate are the result of Laramide (Late Cretaceous-early Tertiary) tectonism and/or late Cenozoic slumping. No angular unconformity exists within the Chinle Formation at Fort Wingate.

Fauna and Age

Vertebrate taxa are *Chinlea*, cf. *Metoposaurus*, cf. *Stagonolepis* and unidentified phytosaur. An extensive megaflora as well as palynomorphs, conchostracans and coprolites from near Fort Wingate are described in Ash (1978a) and references cited therein.

The *Chinlea* material only consists of scales (Ash, 1978a). Amphibian fossils from Fort Wingate in the NMMNH and UCMP indicate an animal the size of *Metoposaurus fraasi*. Mehl et al. (1916) identified phytosaur specimens from Fort Wingate as *Angistorhinus* and *Paleorhinus*. However, we believe these specimens cannot be identified to the genus level.

The best presevced vertebrate specimen from Fort Wingate is the holotype partial skeleton of the aetosaur *Acompsosaurus wingatensis* Mehl, 1916. This specimen does not pertain to *Typothorax* as suggested by Gregory (1953) (cf. Long and Ballew, 1985). It is not the oldest Chinle aetosaur (contra Long and Ballew, 1985) simply because it is not in the Monitor Butte Member of the Chinle, and therefore not demonstrably older than other lower Petrified Forest Member aetosaurs. The type specimen

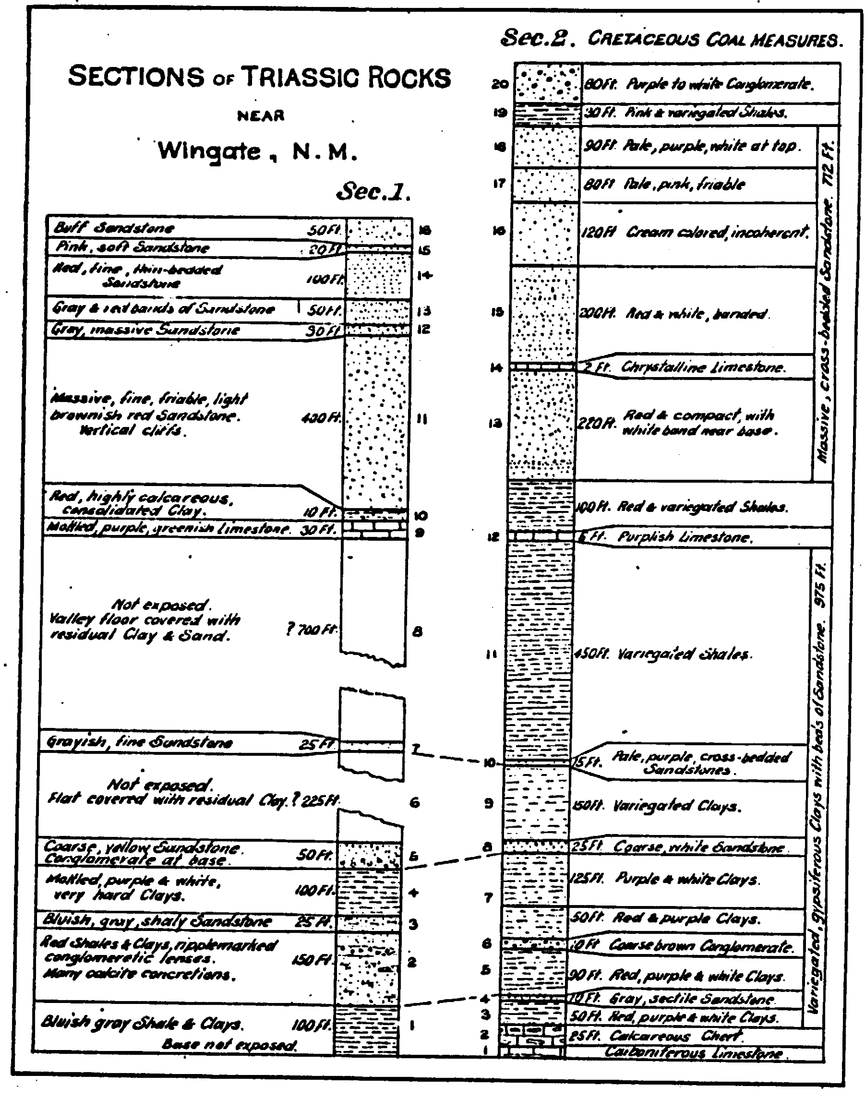

FIGURE 3. Mehl et al. (1916) stratigraphic sections at Fort Wingate. In section 1, units 11-16 are Entrada Sandstone; underlying units are Chinle; unit 5 is the Sonsela Sanstone.

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of Acompsosaurus is now lost, so it must be evaluated from published illustrations. The pelvis differs from that of Desmatosuchus in having a shorter, broader pubis and an ischium that apparently lacks a vertical supra-acetabular ridge. Instead, the pelvis of Acompsosaurus closely resembles that of Stagonolepis robertsoni (Walker, 1961, fig. 16). Therefore, we tentatively believe Acompsosaurus wingatensis is a probable species of Stagonolepis.

The probable presence of Metoposaurus and Stagonolepis and stratigraphic position (lower Petrified Forest Member) suggest a Carnian age for the Fort Wingate localities.

Sedimentology and Taphonomy

The Ciniza pond deposit is an unusual (for the Chinle) sequence of laminated carbonaceous mudstone among typical Chinle red-bed lithologies (Ash, 1978b). These strata have been interpreted as representing a small, tropical, oligomictic lake which was chemically stratified, soft and slightly alkaline with no strong currents (Ash et al., 1978). Bottom waters were stagnant, and the pond floor was composed of organic-rich mud (Ash et al., 1978).

Surrounding beds are of fluvial origin. Mehl et al. (1916) noted that bone fragments are uncommon in mudstones near Fort Wingate. It is not clear what lithology produced the Acompsosaurus type, other than it was in a "red shale" sequence (Mehl et al., 1916). Camp noted bone fragments in fluvial strata and concretions, with the best specimens coming from red-weathering, dark blue strata. The interclavicle at NMMNH came from a massive red mudstone.

History of Collection

In 1914, M. G. Mehl, assisted by G. M. Schwartz, collected vertebrate fossils in Arizona and New Mexico (Mehl et al., 1916). Some of the fossils they collected, including the holotype of Acompsosaurus wingatensis, apparently are lost. All that remains are two specimens in the Field Museum of Natural History, FMNH UC 1252, a phytosaur ilium illustrated by Mehl et al. (1916, plate 2) and FMNH PR 1694, a poorly preserved phytosaur femur.

C. L. Camp collected from near Fort Wingate in 1924. He arrived there on 19 May and was allowed to use a small house by the commander of the fort, Captain Lewis. Camp, in his unpublished field notes for 1924 (UCMP archives) noted that "the best Triassic bad-land exposures east of Gallup surround the Fort....and prospects seem favorable for finding bones." However, he was severely disappointed, noting in his field notes the very next day that the strata here were "almost non-fossiliferous." However, on 21 May he did find several phytosaur vertebrae and part of an ilium near the McGaffey mill. The next day he left Fort Wingate for Thoreau, where he found some phytosaur fossils (Camp, 1930, map A).

From the early 1960's until the present S. Ash has collected fossil plants in the Wingate area (see Ash, 1989 for a bibliography of published work on these plants). He and others also collected and studied conchostracans, coprolites, fish scales and palynomorphs from "Lake Ciniza" (Ash, 1978a). In 1987, Hunt and Kietzke collected a fragmentary metoposaurid interclavicle, plants and microfossils for NMMNH. In 1988, Lucas and others also collected similar material for NMMNH.

CANJILON QUARRY

Geographic and Stratigraphic Context

NE1/4 SW1/4 SW1/4, sec. 3, T24N, R4E, Rio Arriba County, New Mexico (Fig. 1); ownership private. The Chinle Formation in the Ghost Ranch area (Fig. 4) consists of (in ascending order) the

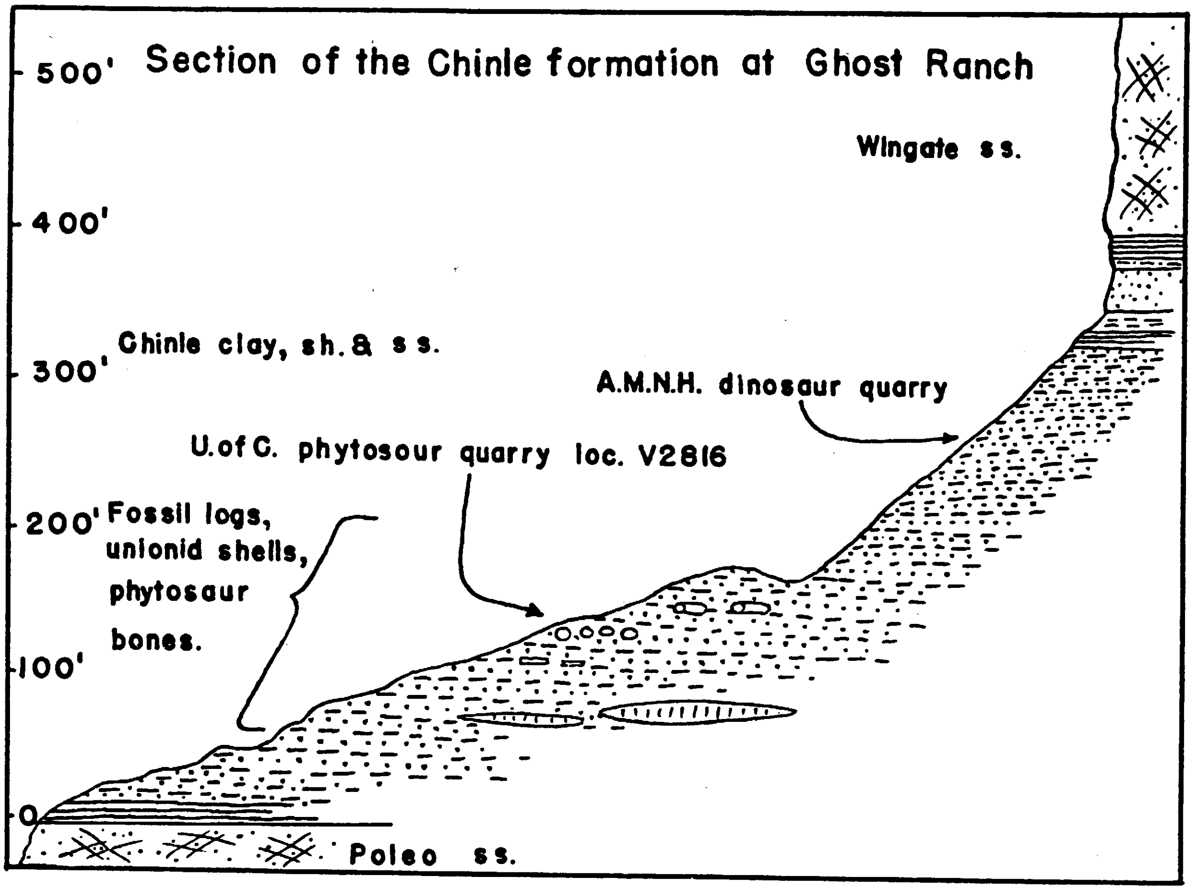

FIGURE 4. Stratigraphic section at Ghost Ranch (from Colbert, 1950) showing the Canjilon quarry ("U. of C. phytosaur quarry loc. V2816") and the Whitaker quarry ("AMNH dinosaur quarry"). Note that the unit identified as Wingate Sandstone actually is Entrada Sandstone.

Agua Zarca Sandstone Member, Salitral Shale Tongue, Poleo Sandstone Lentil, Petrified Forest Member and the siltstone member (Dubiel, in press). The Canjilon quarry is in the Petrified Forest Member (contra Litwin, 1986), 65.5 m below the Entrada Sandstone (Litwin, 1986).

Fauna and Age

The Canjilon quarry has produced abundant phytosaur material and the aetosaur Typothorax coccinarum. NMMNH has a collection from the Petrified Forest Member in the Ghost Ranch area that includes additional phytosaur specimens, Typothorax scutes, fragments of a new, small metoposaurid (see Apache Canyon below) and a partial skeleton of Coelophysis bauri. The nearby Whitaker (Coelophysis) quarry is in the siltstone member. Colbert (1974) lists Ceratodus (=Arganodus), Metoposaurus, Typothorax, "Rutiodon" and Coelophysis from the Chinle Petrified Forest Member in northern New Mexico. The phytosaur skulls from the Canjilon quarry were attributed to Rutiodon tenuis by Lawler (1976).

The phytosaur specimens from the Canjilon quarry are important in that they represent the only reasonably size quarry sample of phytosaurs known anywhere in the world. Ballew (1986, 1989) assigned these phytosaurs to two species, Pseudopalatus (=Nicrosaurus of Murry and Long, 1989) pristinus and P. buceros. She argued that these taxa inhabited different ecological niches as indicated by their dental morphology.

Litwin (1986) collected pollen from just above the Canjilon quarry which he considered of early Norian age. The presence of a Pseudopalatus/Nicrosaurus-grade phytosaur and Typothorax suggests correlation with the upper part of the Petrified Forest Member in Petrified Forest National Park and the Bull Canyon Formation in east-central New Mexico, both of which are considered to be of Norian age.

Sedimentology and Taphonomy

The Petrified Forest Member of the Chinle Formation in the eastern San Juan Basin represents the deposits of high-sinuosity river channels (Dubiel, in press). Associated floodplain areas apparently developed thick paleosols which suggests seasonal precipitation (Dubiel, in press).

The Canjilon quarry produced a nearly complete phytosaur skeleton, three incomplete skeletons and a total of 10 skulls and numerous postcrania (Lawler, 1976). Typothorax is represented by three articulated, incomplete skeletons (Long and Ballew, 1985). However, the articulated skeletons are scattered over a broad area and mixed with diarticulated specimens (Long et al., 1989, fig. 1). Unpublished field notes of C. L. Camp and S. P. Welles indicate that the quarry matrix was reddish mudstone with calcareous nodules scattered through it, particularly at the base of the bone-producing interval (Lawler, 1976).

Although no explicit taphonomic analysis has been undertaken of the Canjilon quarry, it appears to represent a hydrodynamically sorted and/or scavenged assemblage. Lawler (1976) indicates that the field notes of the quarry workers suggest the depositional environment could have been a stream channel or pond. The former seems unlikely, given the fine-grained quarry matrix and the broad area encompassed by the quarry (Long et al., 1989, fig. 1).

History of Collection

The Canjilon quarry was excavated during 1928, 1930 and 1933 by Charles L. Camp with the assistance of R. Arriss, H. Anderson, G. Barrington and S. P. Welles (Lawler, 1976). All of the fossils excavated are in the UCMP. The collection was prepared and partially curated by WPA personnel during the 1930's, and Lawler further curated the material during the early 1970's. In the late 1930's, Harvard University collected two incomplete skeletons of Typothorax from the Canjilon quarry (Long and Ballew, 1985). This materal has not been fully prepared.

WHITAKER (GHOST RANCH) QUARRY

Geographic and Stratigraphic Context

SE 1/4 SE1/4 SW1/4, sec. 1, T24N, R4E, Rio Arriba County, New Mexico; ownership private. The Whitaker quarry is in the siltstone member of the Chinle Formation 14 m below its top (Schwartz and Gillette, 1986).

Fauna and Age

The following vertebrate taxa are known from the Whitaker quarry: aff. Sinorichthys, Chinlea sorenseni, Coelophysis bauri, Nicrosaurus/Pseudopalatus-grade phytosaur, Postosuchus kirkpatricki and several new taxa of "thecodonts."

The most spectacular elements of the quarry fauna are the articulated skeletons of Coelophysis bauri (Colbert, 1947, 1964). The taxonomic status of this dinosaur, which incidentally is New Mexico's official state fossil, was discussed at length by Padian (1986), who points out two problems. First, C. bauri was named by Cope for "the rather undistinguished remains of a primitive theropod" (Padian, 1986, p. 58). Ongoing studies by Colbert must evaluate whether the excellent quarry material represents the same taxon as the holotype. Second, C. bauri has no synapomorphies and thus is a metataxon.

Coelophysis is known only from the upper part of the Petrified Forest Member of the Chinle Formation in Arizona and the Whitaker quarry (Padian, 1986), with the possible exception of specimens collected by Case in northern New Mexico (Williston and Case, 1912). The phytosaur taxon from the Whitaker quarry also occurs in the upper Petrified Forest Member, which is of Norian age (Ash et al., 1986; Litwin, 1986). Litwin (1986) obtained palynofloral samples from above and below the Whitaker quarry that he considered of early Norian age.

Sedimentology and Taphonomy

The siltstone member was deposited in the Ghost Ranch area on lacustrine and playa mudflats (Dubiel, in press). Abundant "lungfish" burrows and many smaller burrows and other bioturbation suggest periodic fluctuation in the level of standing water and corresponding transgressions and regressions of the lakeshore (Dubiel in press).

The quarry itself is in a sequence of 11 siltstone beds, many of which are discontinuous (Schwartz and Gillette, 1986). These beds are intensively bioturbated, contain many silt rip-up clasts and have been interpreted by Schwartz and Gillette (1986) to represent a pond or shallow channel facies in a depositional low.

Coelophysis specimens abound in the lower part of the quarry and become increasingly uncommon upward through the sequence. They represent all ontogenetic stages from hatchlings to adults (Colbert, 1974). Some of the adults contain, within their rib cages, partial skeletons of juveniles, apparently indicative of cannibalism, not viviparity (Colbert, 1974). Skeletons are articulated or semi-articulated and show a range of completeness. Some skeletons display arched vertebral columns indicating dessication and contraction of ligaments. Presumably a large group of Coelophysis individuals were killed, carcasses dessicated and a flood washed them into a depositional low (Schwartz and Gillette, 1986).

History of Collection

In 1874, E. D. Cope passed through the Ghost Ranch area on a journey from Santa Fe to Tierra Amarilla and collected fossil vertebrates near Gallina in Rio Arriba County. In 1881, David Baldwin, working for Cope, prospected Chinle outcrops around Capulin Mesa and at Ghost Ranch (Colbert, 1874). He discovered several bones that became the type specimen of C. bauri (see Padian, 1986). S. W. Williston and Paul Miller of the University of Chicago, E. C. Case of the University of Michigan and F. von Huene of Tubingen University explored the Ghost Ranch area in 1911, although their main collecting focus was on the older, Permian strata in the region (Colbert, 1974). Case found bones of Coelophysis just north of Cerro Blanco near Gallina. This locality was described as "less than one hundred feet above the basal Upper Trias sandstones" (Williston and Case, 1912, p. 11) and was thought to be the type locality of Coelophysis.

In June 1947, E. H. Colbert and G. G. Simpson lead an AMNH expedition to northern New Mexico. Colbert, assisted by George Whitaker and T. Ierardi, explored the Chinle Formation in the Ghost Ranch area (Whitaker and Myers, 1965). Colbert went to Ghost Ranch for two reasons. First, he wanted to find more specimens of Coelophysis which Cope (1887a, b, 1889) had described from fragmentary material. Indeed, he had examined the best locality data available, one of the labels with the Coelophysis specimens in Baldwin's handwriting. It read:

> Label Sack 2 Box 1 Prof. E. D. Cope. Contains Triassic or Jurassic bones all small and tender. Those marked little bones are many of them almost microscopic. All in this sack found in same place about four hundred feet below gypsum stratum 'Arroyo Seco' Rio Arriba Co., New Mexico. February 1881. No feet-no head- only one tooth. D. Baldwin - Abiquiu (Colbert, 1964, p. 3).

Second, Camp had decided to stop collecting Late Triassic vertebrates in New Mexico and had sent Colbert his locality data, including that concerning the Canjilon quarry at Ghost Ranch (Whitaker, 1965).

On 16 June 1947, George Whitaker found what was to become the Whitaker quarry. Colbert quickly recognized its significance, and contacted AMNH. Carl Sorensen came from New York to New Mexico to assist with the excavation. During 1947 and 1948, AMNH excavated the quarry with much help from Arthur Pack, the owner of Ghost Ranch at the time. Specimens from this excavation were collected in large blocks. Most went to AMNH, but others were dispersed to several institutions, including YPM, UNM and CMNH.

The Whitaker quarry was closed by AMNH in and reopened by CM under the direction of David Berman in the mid-1980's. Blocks from the most recent excavation are at CM, NMMNH, NMNH and MNA. The quarry is currently dormant.

LAMY AMPHIBIAN QUARRY

Geographic and Stratigraphic Context

SW1/4 SW1/4 NE1/4 NE1/4, sec. 29, T12N, R11E, Santa Fe County, New Mexico; ownership private (Fig. 1). The Upper Triassic stratigraphic section in the Lamy area closely resembles that of the Tucumcari basin in east-central New Mexico (Allen and Lucas, 1988), comprising (in ascending order) the Tecolotito, Los Esteros and Tres Lagunas members of the Santa Rosa Formation, the Garita Creek Formation, the Trujillo Formation, the Bull Canyon Formation and the Redonda Formation. The quarry is within the Garita Creek Formation.

Fauna and Age

Vertebrate taxa from the quarry are Metoposaurus fraasi and unidentified phytosaur. Other material from the Garita Creek Formation in the Lamy area includes "cones" (Ratkevich and La Fon, 1978), phytosaurids and "Chatterjeea" sp.

The metoposaurs from the quarry were initially assigned to Buettneria perfecta (Romer, 1939). Subsequently they have been considered Eupelor fraasi fraasi (Colbert and Imbrie, 1956) and Metoposaurus fraasi fraasi (Roy Chowdhury, 1965). Measurements of metoposaur skulls suggested a growth series of one taxon (Colbert and Imbrie, 1956) or possibly a bimodal distribution of two taxa (Gregory, 1980). Metoposaurs in the Harvard collection tend to have larger tabular horns than those in the USNM collection because they have been reconstructed. Most skulls from the quarry have damaged posterior margins. "Chatterjeea" is represented by a proximal femoral fragment.

The underlying Los Esteros Member of the Santa Rosa Formation yields a fauna including Calyptosuchus and Desmatosuchus, indicating an age equivalent to the lower Petrified Forest Member (LPFM) of the Chinle Formation in northeastern Arizona and the "middle Dockum" (Sierrita de la Cruz, Crosby County) of Texas (Hunt and Lucas, 1988a, b). The presence of abundant amphibian skulls at the Lamy quarry also suggests a correlation with the lower part of the Chinle Petrified Forest Member (Long and Padian, 1986).

Sedimentology and Taphonomy

Romer(1939, p.339) considered that the amphibian quarry represented "the last scene in the drama of drought - a shrinking residual pool." This view has been followed by later workers (e.g., Gregory, 1980). However, the disarticulated and mixed nature of the skeletons, the alignment of many elements and the absence of small skeletal elements indicate that this is a hydrodynamic accumulation (Voorhies, 1969).

History of Collection

Mr. and Mrs. R.V. Witter discovered the amphibian quarry while prospecting for Harvard University in 1936. The site was excavated by R. V. Witter and T.E. White in 1938 for Harvard and by D.H. Dunkle, F. Pearce and G. Sternberg for USNM in 1947 (Romer, 1939; Gregory, 1972). Both Harvard and USNM collected large slabs for display purposes.

BULL CANYON

Geographic and Stratigraphic Context

Secs. 20-21, 27-29 and 32-33, T9N, R26E and sec. 10, T9N, R26E, Guadalupe County, New Mexico; ownership private. Fossil localities in Bull Canyon occur throughout the Bull Canyon Formation, at its type section (Lucas and Hunt, 1989) and further south. Two particularly productive intervals can be delimited about 25 m and about 70 m below the base of the Redonda Formation (Fig. 5).

Fauna and Age

Fossil vertebrates are unidentified osteichthyans, new small metoposaurid, "Machaeroprosopus andersoni" and other Nicrosaurus/Pseudopalatus-grade phytosaurs, Typothorax, Paratypothorax, rauisuchid, sphenosuchian, theropod, fabrosaur?, Revueltosaurus callenderi and Pseudotriconodon chatterjeei, and a ?"prosauropod". Invertebrates are Unio arizonensis, Unio (six spp.), Antediplodon dockumensis, Antediplodon sp. and Triasamnicola pilsbryi. Plants are Sanmiguelia and Neocalamites.

One of us (APH) examined the holotype of Machaeroprosopus andersoni (Mehl, 1922) and found it to be in very poor condition. It has been reconstructed extensively, lacks most diagnostic elements and can only be assigned tentatively to the Nicrosaurus/Pseudopalatus-grade phytosaurs.

In 1983, a UNM field party collected a phytosaur skull (Fig. 6) about 70 m below the Redonda Formation (Fig. 5). This skull is currently on display at the UNM Geology Museum. It has external nares above the level of the skull roof, wide postorbital-squamosal bars and elongate posterior squamosal processes. Based on these features, this skull is what Murry and Long (1989) call Nicrosaurus and what Ballew (1989) terms Pseudopalatus. The UNM skull closely resembles Pseudopalatus buceros of Ballew (1989) but lacks the apomorphous rostrum with a v-shaped cross section.

Paratypothorax occurs at the same stratigraphic level as this phytosaur skull as do many unionids (Kues, 1985; Lucas et al., 1985b). The dromatheriid Pseudotriconodon chatterjeei (Lucas and Oakes, 1988) was found at a higher level (Fig. 5). Parrish's (1989) assertions that this was published as an ictidosaur and actually is a fish are demonstrably incorrect (cf. Lucas and Oakes, 1988).

The presence of Typothorax, Nicrosaurus/Pseudopalatus-grade

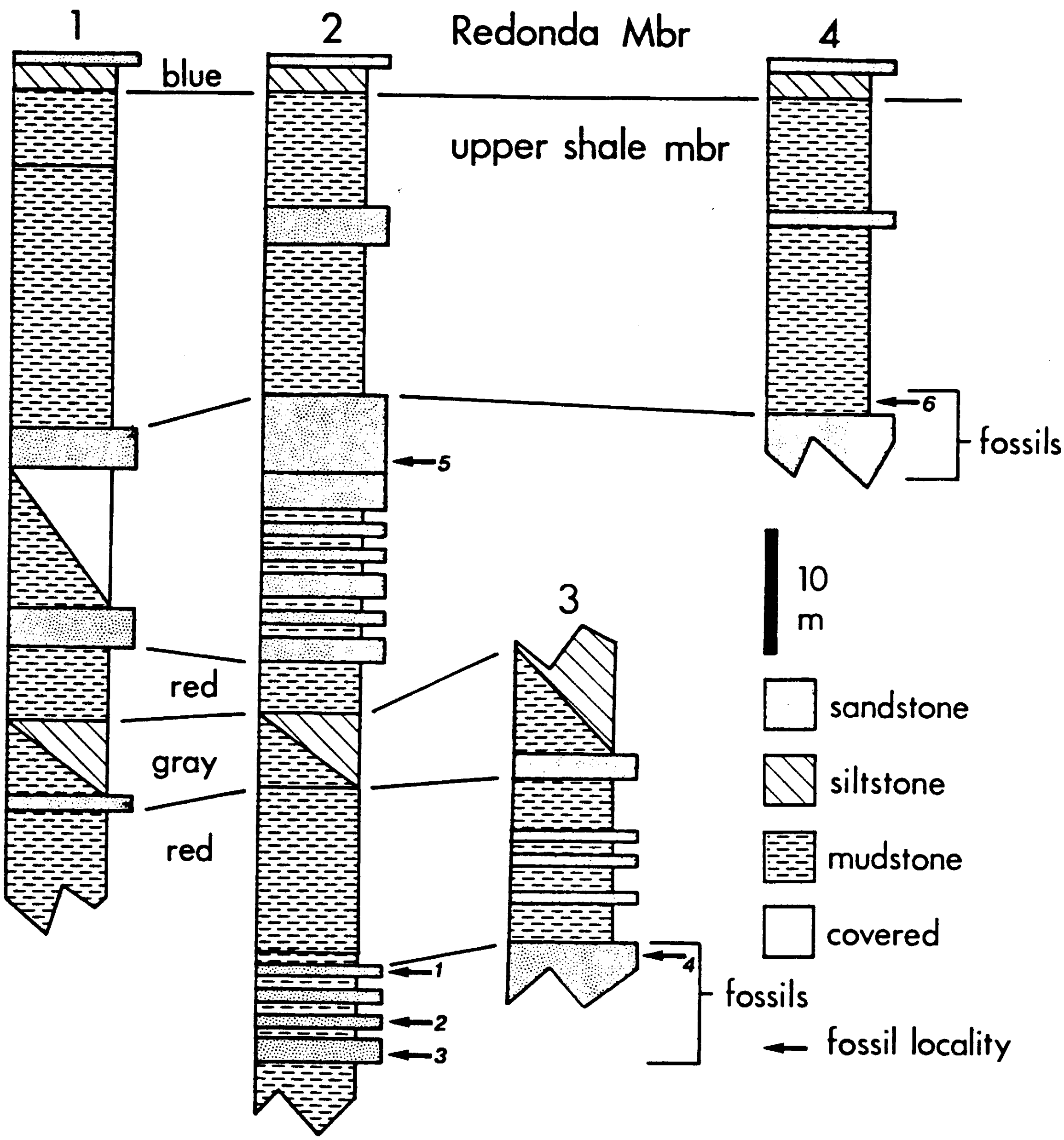

FIGURE 5. Stratigraphic distribution of fossils in the Bull Canyon Formation ("upper shale mbr" of figure) in Bull Canyon (from Lucas et al., 1985b). Localities are: Pseudopalatus buceros (Fig. 6); 2, 3, 4, Unio, Typothorax and other vertebrates; 5, phytosaurs; 6, type locality of Pseudotriconodon chatterjeei. phytosaurs and Pseudotriconodon indicate a Norian age for strata of the Bull Canyon Formation at and around its type section.

Sedimentology and Taphonomy

The Bull Canyon Formation at Bull Canyon is of fluvial origin. Fossil bone is concentrated in channel sandstone and

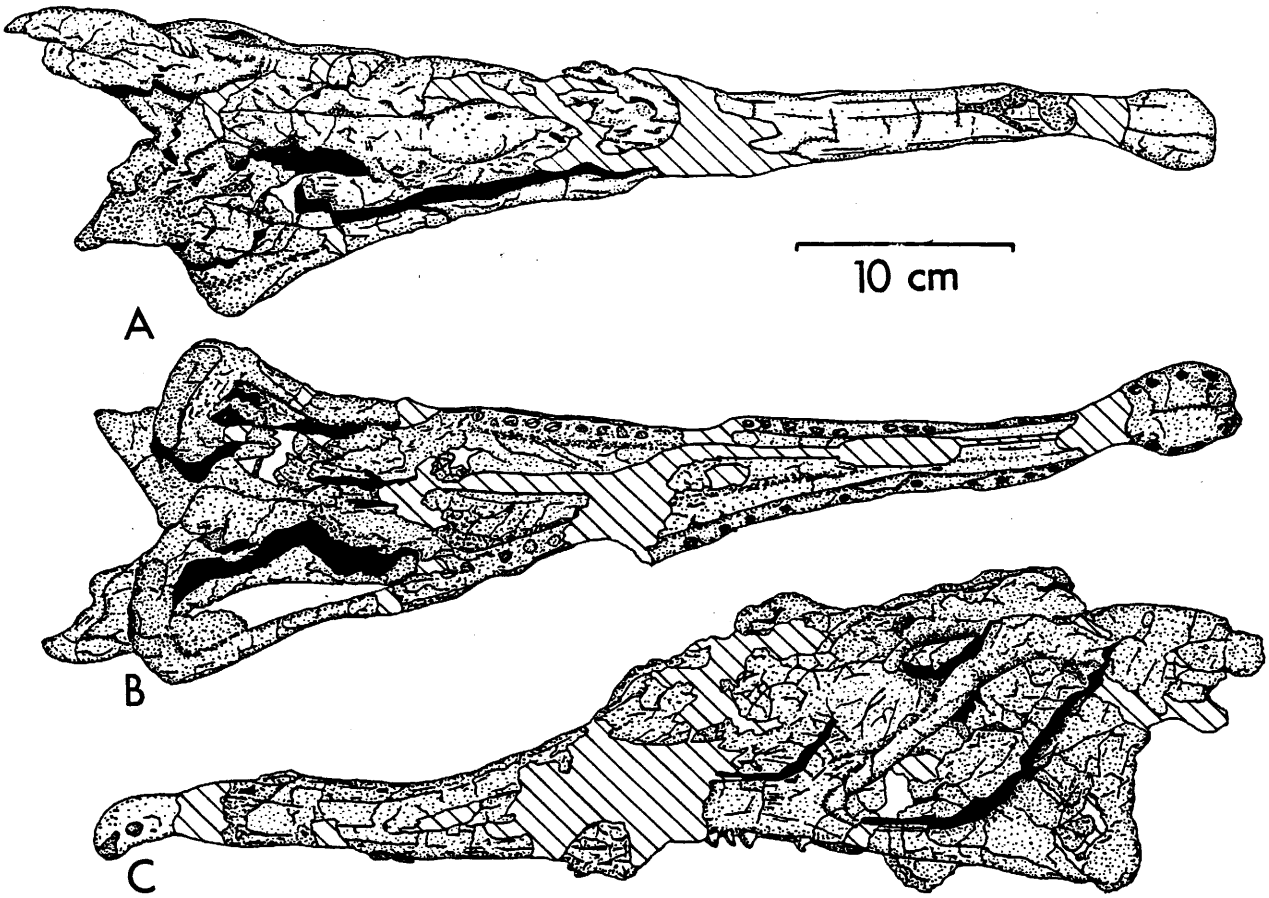

FIGURE 6. Skull of Pseudopalatus buceros now od display in the UNM Geology Museum, dorsal (A), ventral (B) and lateral (C) views (drawings by Randy Pence).

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intraformational conglomerate composed mostly of paleo-calcrete clasts (Lucas and Kietzke, 1984). Well preserved fossil vertebrates are concentrated in or near channel tops. This suggests that subaerially weathered bone on floodplains was destroyed unless it was hydrodynamically concentrated in channels (Lucas and Kietzke, 1984).

History of Collection

E.C. Case (1914) first mentioned fossils in Bull Canyon in print and illustrated an outcrop there. Maurice Mehl did not collect the type skull of Machaeroprosopus andersoni (contra Murry, 1989), but instead he obtained it from J. E. Anderson of the New Mexico School of Mines in Socorro (Mehl, 1922). Gregory (1972) suggested it was from Bull Canyon.

J. T. Gregory collected in Bull Canyon 1-16 July 1947. Among the specimens he collected is a Nicrosaurus/Pseudopalatus-grade phytosaur skull.

In 1982, two ranch hands found the phytosaur skull later collected by UNM and brought it to the attention of Barry Kues of UNM and one of us (SGL). From 1983-1987 field parties from UNM made extensive collections for UNM and NMMNH.

PEACOCK CANYON

Geographic and Stratigraphic Context

SW1/4 SE 1/4 SW 1/4, sec. 19, T31N, R34E, Union County, New Mexico; ownership is private. The vertebrate footprints are from the upper part of the Sloan Canyon Formation (Lucas and Hunt, 1987; Lucas et al., 1987). Footprints are also known from the overlying Sheep Pen Sandstone within 1 km of the tri-state (Oklahoma-Colorado-New Mexico) area (Conrad et al., 1987).

Ichnofauna and Age

Vertebrate ichnotaxa are: Brachychirotherium sp., Chirotherium sp., chirotheriid, Coelurosaurichnus, cf. therapsid, Apatopus sp. and Rhynchosauroides sp. (Conrad et al., 1987). Invertebrate ichnotaxa are: cf. Scoyenia, aff. Koupichnium and aff. Acanthichnus (Conrad et al., 1987). Scoyenia as well as Grallator sp. and Brachychirotherium sp. are known from the Sheep Pen Sandstone (Conrad et al., 1987). Barnum Brown collected phytosaur vertebrae (AMNH 6337) from a site "43 miles" east of Folsom in the same layer as dinosaur tracks that probably is Peacock Canyon. Other body fossils are known from the Sloan Canyon Formation (see below). In 1946, Dunkle and Case collected a semionotid fish from Peacock Canyon which is now CM 10028 (Schaeffer and Dunkle, 1950).

Baird (1964), Lockley (1986, 1987) and Conrad et al. (1987) studied the vertebrate footprints from Peacock Canyon. According to Conrad et al. (1987), the ichnotaxa represent sphenodontids (Rhynchosauroides), phytosaurs? (Chirotherium), aetosaurs? (Brachychirotherium), theropod dinosaurs or rauisuchians (Coelurosaurichnus), sub-thecodont diapsids (Apatopus) and therapsids.

Conrad et al. (1987) suggested that the vertebrate ichnotaxa indicate an early Norian age for the Sloan Canyon Formation. The phytosaur skull known from the underlying Travesser Formation (Stovall and Savage, 1939) is consistent with this age assignment (Lucas et al., 1987).

Sedimentology and Taphonomy

Lockley (1986, 1987) and Conrad et al. (1987) suggested that the Peacock Canyon trackway locality is an exhumed fluvial channel. However, Lucas et al. (1987) favored a lacustrine origin for these strata.

History of Collection

In 1928, Barnum Brown collected a Rhynchosauroides footprint 43 mi east of Folsom from the Sloan Canyon Formation (AMNH 6338). Parker (1933) first mentioned the Peacock Canyon locality in print, and information on the site has been published by Baird (1964), Lockley (1986, 1987), Conrad et al. (1987), Lucas and Hunt (1987) and Lucas et al. (1987).

SLOAN CANYON

Geographic and Stratigraphic Context

Secs. 11-12, T31N, R35E, Union County, New Mexico; ownership private. Outcrops in this area expose the top of the Travesser Formation, the entire Sloan Canyon Formation (including its type section) and the lower part of the Sheep Pen Sandstone. Invertebrate and vertebrate fossils are present in the Sloan Canyon and uppermost Travesser formations. Microvertebrate fossils from the Sloan Canyon Formation are currently under study by one of us (SGL) and Kenneth Kietzke.

Fauna and Age

Vertebrate taxa from the Sloan Canyon Formation (other than footprints) are: indeterminate osteichthyans, a new small metoposaurid, a Pseudopalatus/ Nicrosaurus-grade of phytosaur and cf. Typothorax. Microfossils include one charophyte taxon (Stellatochara) and one ostracode (Darwinula). The underlying Travesser Formation has also produced a Pseudopalatus/Nicrosaurus-grade phytosaur (the skull described by Stovall and Savage, 1939) and the unionid bivalve cf. Unio arizonensis.

The Sloan Canyon Formation in northwestern Oklahoma and southeastern Colorado has produced fossils of the new taxon of small metoposaurid as well as phytosaur fragments (Lucas et al., 1987; Mulvany and Mulvany, 1989).The Baldy Hill Formation, which is below the Travesser Formation, has produced Metoposaurus and phytosaur fossils in northwestern Oklahoma (Stovall, 1943; Lucas et al., 1987). See the discussion under Peacock Canyon for a synopsis of Sloan Canyon Formation and Sheep Pen Sandstone ichnotaxa.

The phytosaur skull Stovall and Savage (1939) described from the uppermost Travesser Formation has been assigned to Rutiodon sp. (Stovall and Savage, 1939), Rutiodon tenuis (Gregory, 1972, p. 122), Rutiodon validus (Gregory, 1972, p. 123) and Rutiodon "B" (Long and Ballew, 1985). We assign this skull to the Pseudopalatus/Nicrosaurus group of phytosaurs. The dorsally concealed supratemporal fenestrae of this skull led Gregory (1957) to suggest that it represents the same taxon as the phytosaur skull from Shark-Tooth Hill (see below). However, the posterior portion of the Travesser Formation skull is distorted, rendering difficult certain interpretation of its morphology (Stovall and Savage, 1939; Lucas et al., 1987).

Lucas et al. (1987) assigned a Norian age to the Travesser and Sloan Canyon formations based primarily on this putatively advanced phytosaur skull.

Sedimentology and Taphonomy

Most vertebrate fossils found in the Travesser Formation are from intraformational fluvial conglomerates. They are uncommon, though more abundant than invertebrate fossils. The majority of vertebrate fossils in the Sloan Canyon Formation occur in lacustrine beach deposits as small fragments, isolated teeth and disarticulated postcrania. Locally, vertebrate fossils are very common (Lucas et al., 1987).

History of Collection

Stovall and Savage (1939) collected a phytosaur skull along Sloan Creek, but others had earlier collected fossils at Peacock Canyon (see above). In 1986, the University of New Mexico made extensive collections in this area (Lucas et al., 1987) that are housed at NMMNH.

MESA REDONDA

Geographic and Stratigraphic Context

Mesa Redonda encompasses most of 17 sections at the confluence of T8N-T9N and R30E-R31E, Quay County, New Mexico. The best footprint localities are in the W1/4, sec. 27, T9N, R31E; ownership is private. The lower half of the side of Mesa Redonda is composed of the Redonda Formation (Dobrovolny et al., 1946). Discontinuous badlands around the base of the mesa are developed in the Bull Canyon Formation. Gregory (1972) believed that the vertebrate footprints in the Redonda Formation are from near the base of the formation, but they are actually from near the top of the formation (Hunt et al., 1989).

Fauna and Age

Body fossils of the new, small metoposaurid are known from the Redonda Formation. Vertebrate ichnotaxa are _Grallator_ sp. (Fig. 7), _Brachychirotherium_ sp. and abundant coprolites. Invertebrates are _Spirorbis_ sp., _Darwinula_ sp. and numerous tracks and trails. Fragmentary metoposaurid and phytosaur fossils are present in the Bull Canyon Formation. Other taxa known from the Redonda and Bull Canyon formations in Quay County are discussed under Apache Canyon, Shark-Tooth Hill, Revuelto Creek and Barranca Creek.

Estimates of hip height from the _Grallator_ footprints at Mesa Redonda are about 36 cm, which suggests the presence during Redonda time of a very small theropod, presently unknown from body fossils (Hunt et al., 1989). The invertebrates have been discussed by Kietzke (1987, 1989). This small fauna does not contradict the Norian age assigned to the Bull Canyon and Redonda formations based on other evidence discussed elsewhere in this article.

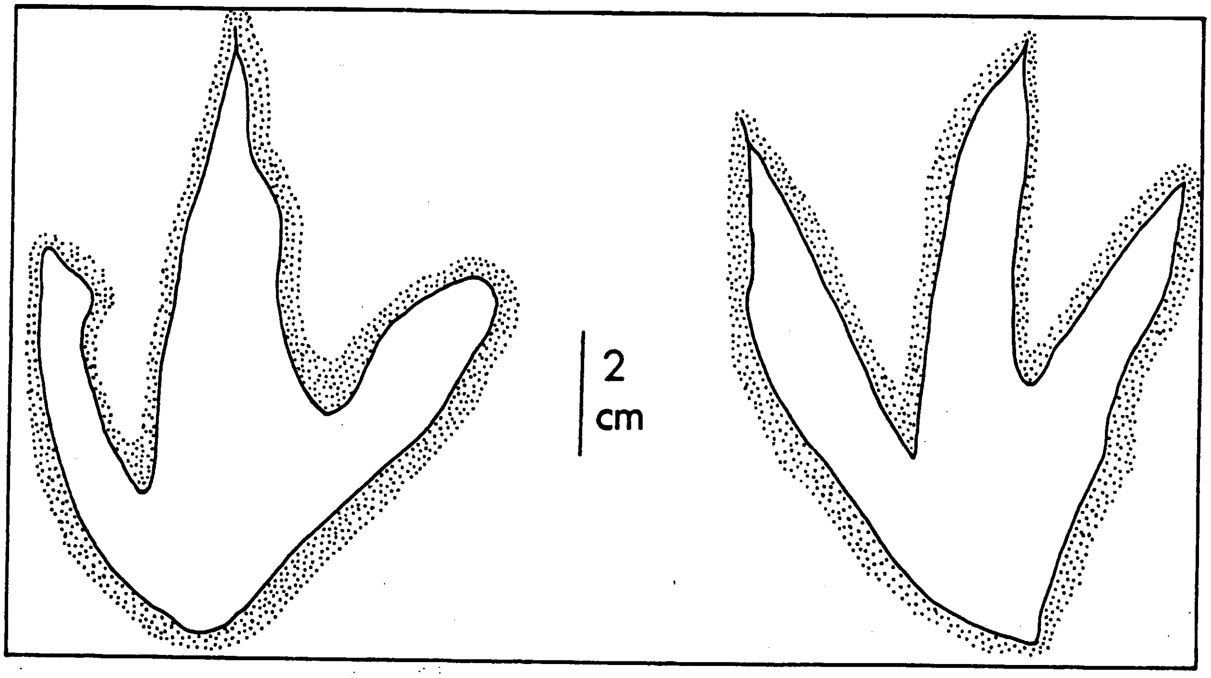

FIGURE 7. Grallator footprints from Mesa Redonda (from Hunt et al., 1989).

Sedimentology and Taphonomy

The Bull Canyon Formation localities are in fluvial strata, but the exact provenance of the specimens is unknown. At Mesa Redonda, the Redonda Formation grades upward from offshore lacustrine mudstone and sandstone into ripple-laminar micrites which represent carbonate mudflats (Hester, 1988). Vertebrate footprints here are found at the bases of ledge-forming micrites and represent animals walking through shallow water or subaerially-exposed mud (Hester, 1988). The vast majority of the footprints are Grallator (Brachychirotherium is known only from two prints) that show a strong preferred orientation to the E-NE which is very speculative evidence of gregrarious behavior among small theropods. Several footprint slabs show multiple individuals moving in the same direction (e.g., UMMP 16144).

History of Collection

In 1934, Robert Abercrombie took E. C. Case to Mesa Redonda and they collected (Abercrombie sold to Case?) four footprint slabs for the UMMP (UMMP 1644, 16160, 16161 and an uncatalogued slab). In the 1950's, J. T. Gregory collected some vertebrate material around Mesa Redonda. Four people prospected the SW side of the mesa but found little (J. T. Gregory, oral commun., 1986). Gregory noted the presence of vertebrate footprints in the Redonda Formation all around the mesa, but the best preserved ichnofossils were found on the NE corner where Abercrombie had collected (Gregory, 1972). In 1985 and 1986, UNM collected footprints from Abercrombie's locality. In 1986, C. Johnson collected a Brachychirotherium footprint from the W side of the mesa and donated it to NMMNH.

APACHE CANYON

Geographic and Stratigraphic Context

Several localities are present in secs. 3-4 and 9-10, T9N, R33E, Guadalupe County, New Mexico. Ownership is private. These localities are in the upper part of the Redonda Formation.

Fauna and Age

Osteichthyans are cf. Lasalichthys, redfieldiids, colobodontids and Arganodus. A new, small metoposaurid is present. Reptiles are a sphenodontid, trilophosaur, a giant phytosaur, a slender-snouted phytosaur, a dwarf(?) Typothorax, Postosuchus kirkpatricki, a new sphenosuchian and possibly a cynodont. Ichnotaxa are Brachycheirotherium and Grallator. Plants are Neocalamites, and conchostracans are also known.

YPM quarry 2 at Apache Canyon produced several incomplete and a nearly complete skull of a new, small metoposaurid. This quarry also produced abundant postcrania, including clavicles, interclavicles and pelvic, limb and vertebral elements. These specimens have been incorrectly assigned to Anaschisma (Gregory, 1980; Murry, 1989), Kalamoiketes (Murry and Long, 1989) and Dictyocephalus (Davidow-Henry, 1989). They actually represents new metoposaurid genus distinguished by a lachrymal that does not enter the orbit, shallow otic notches and elongate vertebral centra. This is the new, small metoposaurid referred to throughout this article.

The Typothorax from Apache Canyon, as well as other specimens of that taxon from the Redonda Formation, is a very small animal with paramedian scutes not more than 9 cm wide. Abundant material of this taxon is in the YPM collection. NMMNH collections indicate the presence of a very large phytosaur with a massive snout as well as a small, slender-snouted phytosaur (Lucas et al., 1985a, fig. 3H-I).

We assign all Redonda Formation localities a Norian age because of the phytosaur skull from Shark-Tooth Hill (see below). Murry (1987, 1989) suggested that the presence of Redfieldius-like scales in the Redonda might indicate a Jurassic age for the quarries at Apache Canyon (also see Milner, 1989). However, the presence of phytosaurs, aetosaurs and metoposaurids is compelling evidence of a Late Triassic age for the Redonda Formation.

Sedimentology and Taphonomy

The fossil quarries at Apache Canyon occur in fluvial deposits that overlie a carbonate-dominated lacustrine shoreline lithofacies (Hester, 1988). The principal YPM and NMMNH localities are in coarse, clay-pebble conglomerates. The preservation of delicate structures (e.g., sphenosuchian scutes with needle-like processes) as well as large structures (e.g., massive rostrum of a phytosaur) suggests rapid deposition of a poorly sorted death assemblage. Footprints are common at Apache

Canyon, especially in secs. 9-10, T9N, R33E, and are present at the base of micrites. They presumably represent animals walking on subaqueous or subaerial mudflats (see Mesa Redonda).

History of Collection

J.T. Gregory first collected fossils from Apache Canyon in 1958 for the YPM (Lucas et al., 1985a). Here, he opened two quarries. Quarry 1 was unproductive, but quarry 2 produced tens of specimens of metoposaurs, phytosaurs, aetosaurs, rauisuchians and sphenosuchians. Gregory later re-collected quarry 2 for the UCMP, and this collection contains the most complete metoposaurid specimens. Gregory also made a latex cast (now lost) of footprints in Apache Canyon.

Murry collected for Tarleton State near quarry 2 in 1983 (Murry, 1989). In 1986 and 1987, the UNM and NMMNH collected from several localities in Apache Canyon. These include a quarry developed in a lithology identical to YPM quarry 2 which produced abundant phytosaur material. NMMNH also collected some footprint slabs.

REVUELTO CREEK

Geographic and Stratigraphic Context

Secs. 9-10, 14-16 and 21-22, T10N, R33E, Quay County, New Mexico; ownership private and State of New Mexico. The badlands in Revuelto Creek are developed in the Bull Canyon Formation about 20 m above the underlying Trujillo Formation.

Fauna and Age

Vertebrate taxa are redfieldiids, Chinlea, new small metoposaurid, ?Metoposaurus, protorosaur, sphenodontid, "kuehneosaur", new pseudosuchian, Typothorax, Desmatosuchus, Paratypothorax, new phytosaur, Hesperosuchus, "Chatterjea", cf. Postosuchus, large procompsognathid, staurikosaurid (?"Chindesaurus"), Revueltosaurus callenderi and a large number of unidentified microvertebrates. Invertebrates are several morphologies of unionids and Triasamnicola pilsbryi. Plants are Neocalamites and Polyporites. A small vertebrate fauna has also been recovered from the Trujillo Formation at Revuelto Creek consisting of cf. Typothorax, a phytosaur and a ?rauisuchian.

The Revuelto Creek fauna is distinctive in two ways. First, it is very diverse and includes well preserved macrovertebrates as well as the most prolific microvertebrate locality known in the Upper Triassic of New Mexico. Second, the fauna is unusual in that it is depauperate in the usual Bull Canyon Formation phytosaur/aetosaur complex and contains many taxa rare at other locales.

The new, small metoposaurid taxon is well represented at Revuelto Creek by a nearly complete skull and fragments of lower jaws and postcrania. The distinctive elongate vertebrae are common at Revuelto. Two small skull? fragments from Revuelto are the only evidence in the Bull Canyon Formation of an amphibian with a head length greater than 30 cm.

The large-snouted Rutiodon gregorii-like skull from Barranca Creek is the same taxon of phytosaur known from Revuelto Creek. Protorosaurs are represented at Revuelto by partial limbs and vertebrae. A new pseudosuchian, under study by APH, is represented by remains of five individuals, including two partially articulated skeletons. This animal has a very primitive, crocodile-normal tarsus. The socket for the astragalus in the rather aetosaur-like calcaneum is very shallow. The astragalus is wider relative to the calcaneum than in any other archosaur. The femur is remarkably crocodilian in morphology, and there are at least two rows of relatively thick, overlapping paramedian scutes.

Three aetosaurs occur at Revuelto Creek. Typothorax is very common, and in 1988 a 2.5-m-long articulated skeleton was found. Desmatosuchus is represented by two lateral-scute spikes and Paratypothorax by a single paramedian scute. These taxa also co-occur in the lower portion of the upper Petrified Forest Member of the Chinle in northeastern Arizona and in the "Cooper Member" of the Dockum in Texas (Murry and Long, 1989; Small, 1989).

The dinosaur fauna at Revuelto Creek is anomalously diverse for the Upper Triassic strata of the Southwest. Taxa include a large procompsognathid, a staurikosaurid, Revueltosaurus callenderi and at least one "fabrosaur." The very diverse microvertebrates are under study by APH.

The presence of Typothorax, Desmatosuchus, Paratypothorax and Nicrosaurus/Pseudopalatus indicates correlation with the lower part of the upper Petrified Forest Member of the Chinle Formation in northeastern Arizona and with the "Cooper Member" of the Dockum in Texas. These are all horizons of Norian age (Lucas et al., 1985b).

Sedimentology and Taphonomy

As noted by Gregory (1972, oral comm., 1986) and Parrish and Carpenter (1986), virtually all of the fossils in Revuelto Creek occur in a thin (< 8-m-thick) sequence dominated by purple mudstone and siltstone. The purple beds are between two sandstone/conglomerate beds. There is much lateral variation within these beds.

These strata show similarities to rocks described by Frelier (1987) in the Tecovas Formation of West Texas and Kraus and Middleton (1987) in the Chinle Petrified Forest Member of northeastern Arizona. In effect, these strata represent low order channel deposits formed during multiple phases of floodplain degradation and aggradation and/or arroyo-fill sequences. At Revuelto, there apparently were three phases of channeled flow within a restricted area which suggests a period of degradation and geomorphic incision (cf. Frelier, 1987, fig. 8.3) was followed by aggradation and infilling of the incised landscape (cf. Frelier, 1987, figs. 8.1-8.2).

History of Collection

In 1912, E.C. Case with W. I. Robinson and others travelled from Wichita Falls, Kansas to Las Vegas, New Mexico in order to study the stratigraphy and paleontology of the red beds in this region (Case, 1914). Case collected several fossils on this trip, including some in the "bad lands....5 miles west of San Jon" (Case, 1914, 1922, p. 11). This location corresponds to an area just northeast of Revuelto Creek. However, we do know that Case was apparently following a railroad line (Chicago-Rock Island) that cuts through Revuelto Creek, and thus he must have at least passed through the area. This is confirmed by J. T. Gregory who, in his unpublished field notes for 4 August 1947, noted that the owner of a ranch at the southern end of the Revuelto Creek badlands had told him that "the Michigan parties had worked mostly the area just north of his house, and that further west on the Harmon Ranch [Barranca Creek] the country had never been prospected."

Case recovered a small but interesting collection including two phytosaur interclavicles which he illustrated in 1922. UMMP comprises five different taxa, the new small metoposaurid, a protorosaur, Hesperosuchus, a large rauisuchid and a small portion of an animal with articulated body armor. The first four taxa are known to co-occur at one of the NMMNH quarries in Revuelto.

In the early 1930's, Case returned with T. E. White to prospect exposures south of San Jon and around Tucumcari. In 1947, J. T. Gregory started working in the Triassic of east-central New Mexico.In a period of only 11 days in 1947 (1-11 August), Gregory, together with G. D. Guadagni and B. Mikula, found and excavated four phytosaur skulls and many other specimens at Revuelto Creek. The next year, Gregory returned on 24-25 June to measure a stratigraphic section through his localities.

In 1981, Ken Carpenter, then with the University of Colorado Museum, made a small but significant collection adjacent to one of Gregory's phytosaur quarries. This collection includes the partial skeleton of a large, indeterminate procompsognathid (Carpenter and Parrish, 1985; Parrish and Carpenter, 1986).

One of us (APH) has conducted extensive excavations at Revuelto Creek from 1986 to the present. The specimens recovered are in the NMMNH collection.

BARRANCA CREEK

Geographic and Stratigraphic Context

Secs. 6-7, T10N, R33E; secs. 1-2, T10N, R32E; sec. 31, T11N, R33E; ownership is private and State of New Mexico. The Barranca Creek localities span the basal 33 m of the Bull Canyon Formation, and there is continuous exposure throughout this interval.

Fauna and Age

The vertebrate fauna consists of a new palaeoniscoid, unidentified osteichthyans, Nicrosaurus/Pseudopalatus-grade phytosaurs (two or three taxa, two of them possibly new), Typothorax, new genus of aetosaurs, Postosuchus, rauisuchid, Hesperosuchus and a staurikosaurid. The invertebrates are several morphologies of unionid bivalves and various trace fossils. Polyporites is the only plant recovered thus far.

The new paleonisciform is conspecific with specimens from Howard County, Texas briefly described by Schaeffer (1967, p. 327-328, fig. 16, plate 30). The skull is distinguished by a single parietal, four extrascapulars, uniformly broad frontals and nasals as broad as the frontals.

The new aetosaur is an animal about the size of Stegomus represented by two incomplete, semi-articulated skeletons. Material includes two ilia, an articulated astragalus and calcaneum, partially articulated carapace fragments and numerous complete and fragmentary postcrania.

Specimens assigned to Hesperosuchus include vertebrae and pelvic fragments and a jaw fragment. This taxon also is present at Revuelto Creek. Although the specimens appear to represent an animal larger than typical Hesperosuchus, we preliminarily assign them to this taxon.

Phytosaurs are represented by five skulls and much isolated and disarticulated material. One skull is associated with much of a skeleton including most of the pelvis, many vertebrae, a forelimb, an astragalus and many ribs. This semi-articulated skeleton has vertebrae of a small rauisuchid? among its ribs, presumably gastric contents. One of the large phytosaur skulls is similar to Rutiodon gregorii except for its temporal region, which is identical to the Nicrosaurus/Pseudopalatus-grade of phytosaur. Another skull, currently being prepared, represents the same taxon as the skull from Shark-Tooth Hill (see below).

The presence of Typothorax and Nicrosaurus/Pseudopalatus-grade phytosaurs indicates a Norian age and correlation with the upper portion of the Petrified Forest Member of the Chinle Formation in Arizona.

Sedimentology and Taphonomy

Geologists from the Bureau of Economic Geology in Austin, Texas have published a series of studies that suggest the Upper Triassic strata in eastern New Mexico and West Texas were deposited in lakes fed by large river deltas (McGowen et al., 1979, 1983; Johns and Granata, 1987). Recent study indicates to the contrary that, except for the Redonda Formation, these strata were deposited in fluvial channels, floodplains and some small lakes and ponds (Lucas et al., 1985; Frelier, 1987; May, 1988). Particularly damaging to the lake scenario of McGowen and his colleagues is the fact that available paleocurrents actually indicate paleoflow outward from the supposed depocenter of their major lake (Cazeau, 1962; Frelier, 1987; May, 1988).

At Barranca Creek, fossils occur in four contexts. Most material is in fluvial intraformational conglomerate composed mostly of paleo-calcrete pebbles. Structureless overbank mudstones contain rare but usually articulated specimens. Some fossils, like the new aetosaur specimens, are in calcareous concretions in overbank mudstones and silstones that apparently represent proximal floodplain deposits.

History of Collection

NMMNH field parties directed by one of us (APH) discovered and began collecting from Barranca Creek in 1987.

SHARK-TOOTH HILL

Geographic and Stratigraphic Context

SE1/4 SE 1/4 NE 1/4, sec. 28, T9N, R34E; ownership private. The Shark-Tooth Hill localities are in the uppermost Redonda Formation. The name Shark-Tooth Hill is a misnomer coined by local residents who mistook phytosaur teeth for shark teeth.

Fauna and Age

Osteichthyans are cf. Lasalichthys, redfieldiids and colobodontids. Reptiles are a new(?) phytosaur, dwarf(?) Typothorax and rauisuchians. Ostracodes are Darwinula sp. and a limnocytheriine, and Spirorbis sp. is present. Other nearby localities produce indeterminate phytosaurs.

Murry (1989) reports Redfieldius-like scales from Shark-Tooth Hill, but these do not indicate a Jurassic age (see discussion above under Apache Canyon). Small, virtually complete fossil fishes have recently been collected and are under study.

J. T. Gregory collected a phytosaur skull from Shark-Tooth Hill in 1947. This specimen represents a putatively advanced phytosaur with supratemporal fenestrae that are completely obscured dorsally (Gregory, 1957, 1962, 1972; Colbert and Gregory, 1957; Lucas et al., 1985a). This phytosaur taxon, currently under study by one of us (APH), is also known from the Bull Canyon Formation at Barranca Creek. The ?Typothorax from Shark-Tooth Hill is comparable in size to material from Apache Canyon. Non-vertebrate microfossils have been stuidied by Kietzke (1989). The phytosaur from Shark-Tooth Hill is in the Pseudopalatus/Nicrosaurus group and indicates a Norian age.

Sedimentology and Taphonomy

The main locality at Shark-Tooth Hill is a 40-50-cm-thick, organized, matrix-supported conglomerate interpreted as a subaqueous debris flow or beach deposit (Hester, 1988). The coarse fraction of the conglomerate contains abundant fish scales, phytosaur teeth and clay rip-up clasts. Oolites are common in the matrix. Clearly, this is a hydrodynamic concentration. The phytosaur skull was collected from a fine-grained sandstone stratigraphically lower than the main locality. Complete fish skeletons have been collected from structureless, beach-front sandstones.

History of Collection

Local residents have known of the Shark-Tooth-Hill localities for more than 50 years. In 1929, E. B. Howard of Bryn Mawr, Pennsylvania collected phytosaur teeth here that he subsequently donated to the YPM. In 1930, Robert Abercrombie gave 12 phytosaur teeth from Shark Tooth-Hill to the American Museum of Natural History (now catalogued as AMNH 6336). Other specimens were given to the Museum of Northern Arizona.

The YPM specimens led J. T. Gregory to Shark-Tooth Hill in 1947. He first visited the locality on 17 July 1947 and found the phytosaur skull the next day. After a week's break (19-28 July), during which Gregory attended the meeting of the Society of Vertebrate Paleontology, the skull was extracted and a skid was built to bring it down the hill. It weighed 605 lb and was shipped to YPM on 1 August 1947.

In 1983, P. Murry re-collected the fish-scale conglomerates at Shark-Tooth Hill. During 1986-1987 field parties from NMMNH and UNM collected matrix for screenwashing, complete fish skeletons and many phytosaur scutes and teeth at Shark-Tooth Hill.

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