The vertebrate fauna, biostratigraphy and biocrhonology of the type Revultian land vertebrate faunachron, Bull Canyon Formation (Upper Triassic), east-central New Mexico

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THE VERTEBRATE FAUNA, BIOSTRATIGRAPHY AND BIOCHRONOLOGY OF THE TYPE REVUELTIAN LAND-VERTEBRATE FAUNACHRON, BULL CANYON FORMATION (UPPER TRIASSIC), EAST-CENTRAL NEW MEXICO

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Abstract.— The Bull Canyon Formation of east-central New Mexico contains a large vertebrate fauna that is the type fauna of the Revueltian land-vertebrate faunachron. The Bull Canyon vertebrate fauna includes ?Colobodontidae indet., Redfieldiidae indet., *Semionotus* cf. *S. brauni*, ?*Tanaocrossus kallikoski*, Actinopterygii indet., ?Arganodontidae indet., *Quayia zideki*, *Apachesaurus gregorii*, Metoposauridae indet. (large), ?Squamata indet., Rhynchosauridae indet., *Vancleavia campi*, *Pseudopalatus pristinus*, *P. andersoni*, *P.* n. sp., *Typothorax coccinarum*, *Aetosaurus arcuatus*, Stagonolepididae ?gen. et sp. nov., *Paratypothorax* sp., *Desmatosuchus* n. sp., *Postosuchus kirkpatricki*, *Shuvosaurus inexpectatus*, Sphenosuchidae indet., Crocodylotarsi gen. et sp. nov., Herrerasauridae gen. et sp. nov. (2), *Gojirasaurus quayi*, Theropoda gen. et sp. nov., *Revueltosaurus callenderi*, *Lucianosaurus wildi* and *Pseudotriconodon chatterjeei*. The Revueltian can be divided into a lower R1 (Barrancan) defined by the FAD of *Pseudopalatus* and R2 (Lucianoan) defined by the FAD of *Lucianosaurus*. There is possibly an RO (Rainbowforestan) interval which has the co-occurrence of *Typothorax* and *Nicrosaurus* prior to the FAD of *Pseudopalatus*. The Revueltian represents most of Norian time.

INTRODUCTION

The Upper Triassic Bull Canyon Formation is widely exposed in east-central New Mexico. Vertebrate paleontologists have collected specimens from this formation for more than 80 years, but most of this collecting was sporadic, and most specimens were never described. However, prior to 1986, the few published accounts of the vertebrate fauna of the Bull Canyon Formation suggested that this unit is, at least locally, very fossiliferous and contained many new taxa (e.g., Case, 1922; Gregory, 1972; Lucas et al, 1985a,d; Parrish and Carpenter, 1986; Lucas and Oakes, 1988). These factors were the impetus for this study, which was part of a Ph.D. dissertation at the University of New Mexico (Hunt, 1994). From 1986 to 1991, I led field parties to collect from exposures of the Bull Canyon Formation in Quay County, New Mexico. This collecting effort was very successful and yielded about 2500 macro- and microvertebrate specimens. Subsequent to the development of this large fauna, Lucas and Hunt (1993) designated the fauna from the lower Bull Canyon Formation as the type fauna of the Revueltian land-vertebrate faunachron (lvf). Several publications have addressed aspects of the vertebrate paleontology of this extensive Bull Canyon fauna (Heckert and Lucas, 1998; Huber et al., 1991, 1993; Hunt, 1991c, 1992, 1993a-b, 1994, 1997a-b: Hunt and Lucas, 1989a-b, 1993b-d, 1997; Hunt et al., 1993a-b, 1988, 2001c; Lucas and Hunt, 1989a, 1993; Lucas and Oakes, 1998; Lucas et al., 1985a-d, 2000, 2001a). The purpose of this paper is to give an overview of the vertebrate fauna of the Bull Canyon Formation and to discuss its biostratigraphy and biochronology as it relates to the biochronology of the Revueltian lvf. Several new taxa from this fauna will be described elsewhere. Abbreviations are: AMNH, American Museum of Natural History, New York; CMNH, Carnegie Museum of Natural History, Pittsburgh; MDM, Mesalands Dinosaur Museum, Tucumcari; NMMNH, New Mexico Museum of Natural History and Science, Albuquerque; RHMP, Ruth Hall Museum of Paleontology, Ghost Ranch, Abiquiu; UCM, University of Colorado Museum, Boulder; UMMP, University of Michigan Museum of Paleontology, Ann Arbor; TTUP, Texas Tech University, Lubbock; YPM, Yale Peabody Museum, New Haven.

STUDY AREA

The majority of the specimens described here are from three areas in Quay and Guadalupe Counties, east-central New Mexico: (1) Bull Canyon; (2) Revuelto Creek area; and (3) Barranca Creek area (Fig. 1). For convenience, these areas will be referred to as Bull Canyon, the Barranca badlands and the Revuelto badlands (Fig. 2). The locations of some vertebrate localities have been published elsewhere, and these have been subsequently collected without the permission of land-managing agencies, so explicit locality information will not be presented here. The majority of fossils that form the basis of this study are reposited at NMMNH, and locality data are on file at that institution.

Bull Canyon is located near the border between Guadalupe and Quay Counties. Vertebrate fossil localities occur in secs. 10, 19-23, 27-29, 33, T9N, R26E, Guadalupe County. Bull Canyon is a 150-m-deep canyon that is a reentrant in the Llano Estacado. It exposes strata from the Trujillo Formation of the Chinle Group at its base through (in ascending order), the Bull Canyon and Redonda formations of the Upper Triassic Chinle Group, the Entrada Sandstone and Todilto Formation (Middle Jurassic), the Summerville and Morrison formations (Upper Jurassic) and

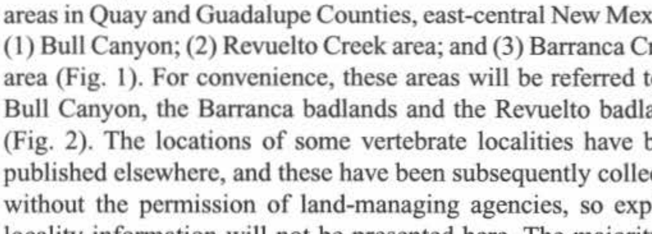
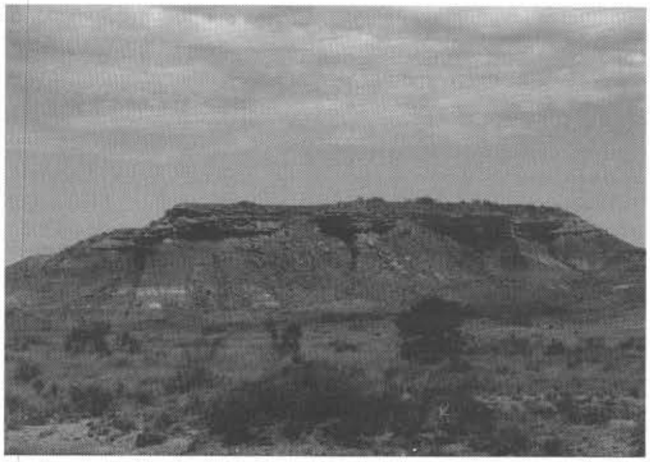


FIGURE 1. Principal collecting localities in the Bull Canyon Formation of east-central New Mexico.

A



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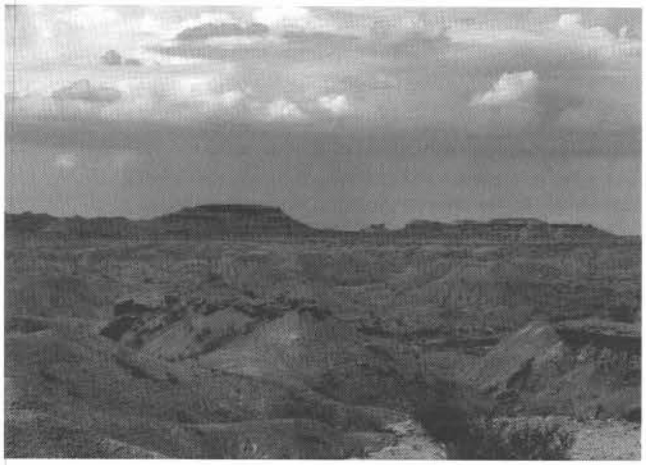

FIGURE 2. Outcrops of the Bull Canyon Formation in east-central New Mexico. A. Revuelto Creek badlands. B. Barranca Creek badlands.

the Tucumcari Formation and Mesa Rica Sandstone (Lower Cretaceous)(Lucas et al., 2001b). There are extensive badlands of the Bull Canyon Formation at the base of the canyon, and the entire thickness of the formation is exposed, including its type section (Lucas and Hunt, 1989a). A significant number of vertebrate fossils from this area are derived from the upper half of the Bull Canyon Formation, whereas all the fossils from the Revuelto and Barranca badlands are from the lower half of the unit.

The Revuelto badlands are an area of low relief badlands in Quay County. They lie mainly to the east and partly to the west of Revuelto Creek, where it flows through exposures of the upper Trujillo Formation and lower Bull Canyon Formation. Vertebrate localities are in secs. 3-5, 8-11, 14-17, 20-22, T10N, R33E.

The Barranca badlands are an area of high-relief badlands in Quay County located just to the west of the Revuelto badlands. The Barranca badlands are to the southeast of Barranca Creek and expose the upper Trujillo Formation and the lower half of the Bull Canyon Formation. Vertebrate localities are in secs. 1-2, 11-12 T10N, R32E, sec. 36 T11N, R32E, secs. 6-7 T10N, R33E and secs. 30-31 R33E, T11N. The Barranca badlands are separated by a drainage divide from the Revuelto badlands.

GEOLOGIC SETTING

Tectonics

During the Late Triassic, the area that is currently New Mexico lay on the western equatorial edge of Pangaea at a paleolatitude of 5-15° N (Van der Voo et al., 1976). An evolving magmatic arch lay to the west and southwest of New Mexico, from western Nevada to southeastern Arizona (Coney, 1978; Dickinson, 1981). To the east and southeast there was arching and graben formation associated with the creation of the Gulf of Mexico (McGowan et al., 1983). New Mexico itself was tectonically stable in the Late Triassic, with no evidence of active faulting, folding or magmatic activity.

Paleogeography

Traditionally, the "Dockum" basin of eastern New Mexico and western Texas was perceived as being separated from a "Chinle" basin (Dubiel, 1989, fig. 2). There is no stratigraphic or sedimentologic evidence of such a drainage divide (Lucas, 1991). Most of New Mexico appears to have been an area of low relief in the Late Triassic, with a paleoslope to the north or northwest (e.g., Lucas and Anderson, 1993, fig. 4). The closest highlands would have been in north-central New Mexico (Chama) and southwestern Colorado (Colorado National Monument), where Chinle Group strata rest nonconformably on Precambrian basement.

Sedimentology

With the notable exception of Branson (1927, 1928; Branson and Mehl, 1929)(see reply by Reeside, 1928), all early workers considered the strata of the current Chinle Group to have been of broadly fluviolacustrine origin. With a few exceptions (e.g., Kiatta, 1960), detailed sedimentological studies have been conducted in the Chinle Group of eastern New Mexico and West Texas only in the past 12 years. The majority of these studies originated from two institutions, the University of Texas at Austin and Texas Tech University.

Several master's students of J. H. McGowan at Austin studied the sedimentology of the Chinle Group in eastern New Mexico (Granata, 1981) and West Texas (Seni, 1978; Boone, 1979) and subsequently co-authored papers on this topic (McGowan et al., 1979, 1983; Johns and Granata, 1987). The Austin sedimentologists subscribed to a single depositional model--the Chinle Group (their Dockum Group) of eastern New Mexico and West Texas was deposited in environments associated with a major, internally drained, lacustrine system (e.g., McGowan et al., 1983, figs. 25-27). Much of this model was developed from subsurface data with the explicit assumption that large thicknesses of mudrocks must be of lacustrine origin.

Another group of master's students of T. Lehman at Lubbock concentrated on deriving a depositional model based on outcrop studies. These students also studied the Chinle Group in both eastern New Mexico (Fritz, 1992) and West Texas (Frelier, 1987; May, 1988). They found no evidence of a major lacustrine system in the area and attributed virtually all Chinle Group strata to a fluvial (*sensu lato*) origin. Lucas and Anderson (1992, 1993) and Hunt et al. (2001c) have also challenged the lacustrine model, noting that paleontological and paleocurrent data are not consistent with this hypothesis.

Newell (1992, 1993) analyzed the sedimentology of the Bull Canyon Formation of eastern New Mexico and similarly reconstructed a broadly fluvial environment. In conclusion, the bulk of sedimentological and paleontological evidence indicates a fluvial environment for the Chinle Group of eastern New Mexico and West Texas. The only truly lacustrine strata in the Chinle Group in eastern New Mexico and west Texas are in the Redonda Formation (Hester, 1988; Hester and Lucas, 2001).

Only two of the above studies explicitly addressed the sedimentology of the Bull Canyon Formation in New Mexico (Granata, 1981; Newell, 1992), although Granata's conclusions were repeated by McGowan et al. (1979, 1983). Granata (1981, p. 56) dismissed the sedimentology of the Bull Canyon Formation in less than a page as "in general to be lacustrine mudstone." McGowan et al. (1983, fig. 9) explicitly presented Granata's views schematically and showed the Bull Canyon Formation as "lacustrine and prodelta mudstones."

Newell (1992) conducted a detailed sedimentological study of the lower Bull Canyon Formation in Quay, County, New Mexico, in conjunction with this study. Newell (1992, 1993) recognized channel, levee, and proximal and distal floodbasin deposits and demonstrated that the mudrocks do not represent a lacustrine environment. The Bull Canyon Formation formed in an aggrading alluvial floodplain. The channel deposits are the product of fixed, low-sinuosity, mixed-load streams characterized by fluctuating discharge (Newell, 1992, 1993). Floodbasin deposits represent overbank sheetfloods, crevasse channels and calcareous soils (Newell, 1992, 1993).

Taphonomy

Few early collectors made any taphonomic comments on the Bull Canyon Formation. Case (1922, p. 11) noted that rocks of the Chinle Group in West Texas and eastern and central New Mexico were formed in conditions unfavorable to the preservation of vertebrate fossils. He speculated that most of these rocks were formed in lacustrine offshore environments and that vertebrate fossils were preserved only locally in flood deposits. He interpreted very fossiliferous areas, such as Crosby County, Texas, as having formed on a rare "large river floodplain."

Newell (1992; Newell and Hunt, in prep.) recognized three taphofacies in the Bull Canyon Formation of the Barranca badlands: (1) channel-hosted assemblages; (2) floodplain (mudrock) assemblages; and (3) paleosol assemblages. Channel-hosted assemblages consist of abraded and/or fragmentary specimens principally of phytosaurs. Floodplain (mudrock) assemblages produce the bulk of the vertebrate specimens, including partial skeletons of large (dorsal centra > 2 cm in length) vertebrates (phytosaurs and aetosaurs). Paleosol assemblages are localized, but productive localities are dominated by fossils of terrestrial tetrapods, including partial skeletons of small animals (dorsal centra < 2 cm in length).

STRATIGRAPHY

Lithostratigraphy

Marcou (1855) first recognized the presence of Triassic rocks in east-central New Mexico, which included what is now known as the Bull Canyon Formation (Kues, 1985a, c). Marcou (1858) published a map that showed the Bull Canyon Formation (and other units of the Chinle Group) as New Red Sandstone (European stratigraphic name), which he identified as Triassic in age. In his text, Marcou (1858, p. 18) noted that the Redonda Formation and upper Bull Canyon Formation (e.g., at Pyramid Mountain) had "the same appearance as the upper part of the Keuper" [Carnian-Norian stratigraphic unit] in France. The Triassic age of these strata was the subject of heated debate for several years (Kues, 1985a, c).

Drake (1892) was the first to apply formal stratigraphic nomenclature to the Bull Canyon Formation in east-central New Mexico. He measured a series of stratigraphic sections in West Texas and eastern New Mexico and brought Cummins' (1889) name Dockum beds into Quay County. One of his measured sections is at the head of "east Fossil Creek." Marcou (1858) showed a "Fossil Creek" as a north-south flowing stream northeast of Mesa Redonda (Big Tucumcari Mountain of Marcou). The geographic location of Fossil Creek identifies it as Barranca Creek (compare Kues, 1985a, fig. 11 and Kues, 1985c, fig. 2), even though Marcou shows the location of the headwaters incorrectly. By inference, East Fossil Creek must be Revuelto Creek, which joins Barranca Creek near I-40. I also note that there are no other areas east of Fossil Creek (Barranca Creek) where Drake (1896, pl. 5) could have measured his thick section of "Dockum beds" (approximately 181 ft estimated from his plate) in Quay County. Drake (1896, plate 5) apparently measured 81 ft of lower beds, 25 ft of central beds and 75 ft of upper beds, but these thicknesses are much too thin to assign the strata to the Garita Creek, Trujillo and Bull Canyon formation. Indeed, the Garita Creek Formation does not crop out in this area, so the entire section was probably measured in the Bull Canyon and ?upper Trujillo formations.

The next major contribution to the stratigraphy of the Bull Canyon Formation was by Darton (1922, 1928), who recognized that the Dockum Group of east-central New Mexico consisted of a lower sandstone interval that he named the Santa Rosa Sandstone and an upper mud-rich interval. In 1928, he noted that the Dockum Group consisted of a lower Santa Rosa Sandstone, overlain by a tripartite sequence that he questionably assigned to the Chinle. The ?Chinle consisted of a basal shale interval, a medial sandstone-dominated interval and an upper shale interval. With the exception of the separation as the Redonda Formation of the upper part of this sequence by Dobrovolny et al. (1946), Darton's (1928) divisions have been used with minor adjustments until the present. Kelley (1972) named the medial sandstones the Cuervo Sandstone Member and referred to the units above and below it as the upper and lower shale members of the Chinle Formation. In 1989, Lucas and Hunt named the upper shale member the Bull Canyon Formation, the lower shale member the Garita Creek Formation and recognized that the Cuervo is Gould's (1907) Trujillo Formation. At its type section, the Bull Canyon Formation is 95 m of mudstone (80% of section), sandstone (16%) with minor amounts (2% each) of siltstone and conglomerate (Lucas and Hunt, 1989a). In West Texas, the Bull Canyon Formation is over 160 m thick (Lehman et al., 1992). Lucas (1993) raised the Chinle to Group status and included in it all the Upper Triassic formations in east-central New Mexico.

Chatterjee (1986) named a homotaxial equivalent of the Bull Canyon Formation in Garza County, Texas, the Cooper Member of the Dockum Formation. The "type section" of this unit is only 16 m thick and lacks an upper contact with Triassic strata. The name Cooper is preoccupied by several other stratigraphic units. Subsequently, Lehman et al. (1992) redefined the Cooper as the Cooper Canyon Formation with a new type section and suggested that this is the valid name for the upper mudrock-dominated part of the Dockum. Thus, Lehman et al. (1992; Lehman, 1994) suggested suppressing a validly defined stratigraphic name with a redefinition and renaming of an ill-defined and improperly named stratigraphic unit name. Clearly, as noted by Lucas and Anderson (1993, p. 60), "the Cooper Canyon Formation of Lehman et al. (1992) is simply an unneeded synonym of the Bull Canyon Formation of Lucas and Hunt (1989)"(Lucas et al., 1994).

It is worth noting that many of the vertebrate paleontologists who have worked in the Bull Canyon Formation were not aware of the local stratigraphy. Gregory (e.g., 1972) knew that he was collecting in the upper "Chinle" below the Redonda, but Carpenter and Parrish (1985; Parrish and Carpenter, 1986) and Murry (1982, 1986, 1987, 1989) wrote of the undivided Dockum Formation or Group.

Magnetostratigraphy

Reeve and Helsley (1972) measured a magnetostratigraphic section of the upper Bull Canyon Formation at Luciano Mesa. This section revealed mixed polarity zones, which they took to mean that this part of the Chinle Group was partially, or wholly, older than the Upper Triassic Newark Supergroup of the eastern United States, which had not yielded many reversed intervals prior to that time. At that time, the Newark Supergroup was considered Late Triassic in age, but it is now known to be Middle Triassic-Early Jurassic in age. Reeve and Helsley (1972) concluded that the Bull Canyon Formation was early Late Triassic in age. McIntosh et al. (1985) thought that this section was late Carnian in age based on the biostratigraphic correlations of Olsen et al. (1982). Witte et al. (1991) argued that the Bull Canyon Formation had been remagnetized and that the magnetostratigraphic polarity scheme was in error. Lucas et al. (1993b) noted that the Bull Canyon polarity sequence is compatible with Norian sequences of the Newark Supergroup and concluded that the Bull Canyon rocks had not been remagnetized.

Biostratigraphy/Biochronology (Previous work)

Marcou (1855, 1858) first indicated that the Bull Canyon Formation and super- and subjacent formations of the Chinle Group were Late Triassic in age. He noted what Ager (1993) later referred to as the persistence of facies, that is that certain facies and sequences of facies are correlatable over large areas of the Earth's surface. Thus, Marcou in eastern New Mexico saw redbeds (Chinle Group) overlain by yellow sandstone and shale (Entrada and Morrison Formations), in turn overlain by marine shale (Tucumcari Formation) that contain *Gryphaea*-like bivalves. This is reminiscent of the European section that consists of Upper Triassic redbeds (upper New Red Sandstone of older terminology) overlain by transitional marine beds (Rhaetic beds *sensu lato*) in turn overlain by marine Liassic strata containing *Gryphaea*. Thus, it is clear why Marcou (1855, 1858) referred the upper Chinle Group to the Upper Triassic by analogy with the European section. Even though the marine fossils from the Tucumcari Formation are Early Cretaceous in age, Marcou was still correct about the age of the Chinle Group. The sequence of facies is different between New Mexico and Europe, but it is still notable that the youngest redbeds in both areas are Late Triassic in age.

For 70 years it was generally accepted that Chinle Group strata in eastern New Mexico are Late Triassic in age. Huene (1922, 1927), however, suggested that part of the Chinle Group (his Dockum Formation) in West Texas (and by implication eastern New Mexico) is late Middle Triassic and part is early Late Triassic. In the United States, only Camp (1930), in his influential monograph on phytosaurs, followed this view. Camp (1930, table 1) considered the "Dockum" of eastern New Mexico to be equivalent to the upper Muschelkalk and Lettenkohle of Germany. He considered the ages of the German units to be late Middle Triassic and early Late Triassic, respectively, although they are now both considered to be of Middle Triassic age. The Huene/Camp correlation received no further support in this country.

The first major correlation of Triassic formations of North America by Reeside et al. (1957) included a section by Colbert and Gregory on vertebrate correlations. By this time, J. T. Gregory had collected a reasonably large vertebrate fauna from the Bull Canyon Formation to give him a more precise idea of its correlation. Colbert and Gregory (1957) noted that the fauna of the Bull Canyon Formation (their upper part of the clay member of the "Chinle" Formation below the Redonda) contained an advanced phytosaur comparable with those from Ghost Ranch and from the upper portion of the Petrified Forest Formation in northeastern Arizona. This taxon is now known as *Pseudopalatus* and does indeed occur at the Canjilon quarry at Ghost Ranch in the Petrified Forest Formation and in the Painted Desert Member of the Petrified Forest Formation in northeastern Arizona. Colbert and Gregory (1957) used the presence of this phytosaur and a perceived occurrence in eastern New Mexico above a Trujillo equivalent sandstone to correlate. They proposed that the Bull Canyon Formation correlated with (using current stratigraphic terminology) the Travesser Formation in northeastern New Mexico, the Petrified Forest Formation in north-central New Mexico and the Painted Desert Member of the Petrified Forest Formation and the Owl Rock Formation in northeastern Arizona. Their correlation with the Travesser was in error because they did not realize that an advanced phytosaur, now known as *Redondasaurus*, actually came from this formation rather than from the overlying Sloan Canyon Formation. Aside from this, the correlation of Colbert and Gregory is essentially the correlation advocated here.

Gregory (1957, 1969) essentially presented the same correlations, although he considered the Owl Rock Formation to be younger than the Bull Canyon Formation. This correlation scheme has been followed by most recent workers (e.g., Lucas et al., 1985c; Hunt and Lucas, 1989; Lucas and Hunt, 1989b; Murry, 1989; Lucas, 1993; Lucas and Hunt, 1993). Several workers have disputed these correlations. Long and Ballew (1985) misidentified two important specimens from the Bull Canyon Formation. They identified a paramedian osteoderm of *Paratypothorax* as *Stagonolepis* (=*Calyptosuchus*) and a skull of *Pseudopalatus* n. sp. as *Rutiodon* (their *Rutiodon* group A). Thus, they miscorrelated the Bull Canyon Formation with older strata (e.g., Tecovas Member of Dockum Formation) that do indeed contain *Rutiodon* and *Stagonolepis*. Carpenter and Parrish (1985) and Parrish and Carpenter (1986) misidentified another skull of *Pseudopalatus* n. sp. as *Rutiodon* and recognized the presence of *Desmatosuchus* in the Bull Canyon fauna. However, they did not realize that *Desmatosuchus* was not restricted to *Rutiodon*-bearing faunas, and so they followed the miscorrelation of Long and Ballew (1985). Chatterjee (1986, table 10.3) thought that the entire Chinle Group (his Dockum Formation) in eastern New Mexico was equivalent to the Bull Canyon Member of the Dockum Formation (his Cooper Member of the Dockum Formation), which contradicts all recent biostratigraphic and lithostratigraphic data (e.g., Lucas and Anderson, 1993). Following Long and Ballew (1985) and Chatterjee (1986), most recent authors have considered the Bull Canyon Formation and equivalent strata in the Chinle Group to be of Norian age either on the basis of invertebrate (Good, 1993) or vertebrate fossils (e.g., Lucas et al., 1985a; Ballew, 1989; Hunt and Lucas, 1989b; Murry, 1989; Lucas and Hunt, 1993).

HISTORY OF COLLECTING

Vertebrate fossils

Drake (1892, p. 244) was the first to mention vertebrate fossils ("reptilian bones") from the Bull Canyon Formation of New Mexico. He stated that they were "still [compared to west Texas] sparsely scattered through the conglomerates and sandstone." Lee (1907) reported finding Triassic vertebrates from the E. O. Davis ranch, 20 mi SE of Tucumcari, which were presumably from the Bull Canyon Formation.

E. C. Case was the first vertebrate paleontologist to investigate east-central New Mexico. He first collected the Bull Canyon Formation in 1912 (Case, 1914). That year he was traversing Permo-Triassic outcrops from north Texas to northeastern New Mexico to study their stratigraphic relationships. Case collected a number of fossils in this area. Specimen labels on vertebrate specimens at UMMP indicate collection dates of 1912 and 1915 (?misprint). Case (1922, p. 11) was not impressed by the Triassic paleontological resources of east-central New Mexico, stating that "it is evident that the great bulk of the Triassic beds revealed on the borders of the Staked Plains and in eastern and central New Mexico were deposited under conditions unfavorable to the preservation of vertebrate fossils." Case's (1914, 1922) publications, UMMP locality records and surviving field notes (Hunt, 1997) indicate that he principally collected in only one area in the Bull Canyon Formation in Quay County. This fossiliferous area is variously described as "the breaks of San Juan Arroya or Trujillo Creek" the "Badlands" (Case, 1914, p. 252) and lies 5 miles west of San Jon (Case, 1922, p. 11; UMMP specimen labels). Case (1914, figs. 4-7) illustrated several views of this area. Three lines of evidence pinpoint this area as approximately secs. 9-11 and 14-16, T10N, R33E, which is referred to in this report as part of the Revuelto badlands: (1) the prominent rock pillar illustrated by Case (1914, figs. 4-5) has now fallen but it was a prominent landmark in SW1/4 NE1/4 NE1/4 sec. 11, T10N, R33E (J. B. Cresap, oral commun., 1991); (2) J. T. Gregory, who later collected in this area, mentioned in his field notes for 1947 (Hunt, 1997b) that a local rancher named Cosner stated that the Michigan parties collected north of his house (house site is in NW1/4 SE1/4 NW1/4 SE1/4 sec. 15, T10N, R33E; J. B. Cresap, oral commun., 1986) and not to the west (i.e., not in Barranca badlands); and (3) UMMP 7441 is a collection of fragmentary specimens of seven taxa (six rare) of tetrapods, which only co-occur at NMMNH locality 1 (two taxa are unique to this site), which is in this area. Case's specimens from this area included UMMP 7274, 7313, 7438, 7441, 7442. Case evidently returned to this area later with Buettner and White, notably in July 1934 (Gregory, 1972; Hunt, 1997b).

An unknown collector obtained a phytosaur skull from near Santa Rosa, probably Bull Canyon (Gregory, 1972; J. T. Gregory, oral commun., 1986), which was initially at the New Mexico School of Mines (now New Mexico Institute of Mining and Technology) and was later transferred to the University of Chicago and ultimately to the Field Museum of Natural History. Mehl (1922) described this skull as a new species of *Machaeroprosopus*, *M. andersoni*. This skull is presumed to have come from the Bull Canyon Formation because this is the only Upper Triassic unit yielding vertebrate fossils near Santa Rosa and because it represents a grade of phytosaur that could only occur in that unit in that area.

J. T. Gregory of Yale University, and later of the University of California at Berkeley (from 1960 on), collected Triassic vertebrates from eastern New Mexico from 1947 until the early 1960's. However, most of his collections were from the Redonda Formation, and only in 1947 and 1948 did he collect much in the Bull Canyon Formation (Gregory, 1972; J. T. Gregory, oral commun., 1990; Hunt, 1997b). Although Gregory prospected several areas in Guadalupe and Quay Counties, the majority of YPM specimens from the Bull Canyon Formation come from three areas: (1) a few specimens from the base of Mesa Redonda; (2) a large collection from Bull Canyon; and (3) a large collection from the Revuelto badlands area (Cosner ranch).

Mesa Redonda specimens include an uncataloged phytosaur vertebra and distal humerus, and six *Apachesaurus* centra from YPM locality 6649. Note that YPM locality 6649 also includes specimens from the Bull Canyon Formation of Mesa Redonda, the Redonda Formation at "shark tooth hill" (e.g., uncataloged juvenile phytosaur dentary fragment) and many from the Redonda Formation of Apache Canyon (e.g., YPM 9897, phytosaur ilium).

All these specimens were apparently collected in 1958.

All the YPM specimens from Bull Canyon were collected in 1947 (Hunt, 1997b) and included a partial phytosaur skull and associated fragmentary skeleton (YPM 3300 from YPM locality 5831). J. T. Gregory went to the Revuelto badlands, then the Cosner ranch, in 1947 to collect fossil vertebrates and in 1948 to locate his localities on aerial photographs and to place them in stratigraphic context (J. T. Gregory, oral commun., 1986, 1990). In 1947, Gregory had plotted his localities on a road map of New Mexico, the best map at that time of Guadalupe and Quay Counties (J. T. Gregory, oral commun., 1986). Notable among Gregory's finds at Revuelto Creek were a large phytosaur skull with lower jaws (YPM 3293) and an aetosaur paramedian osteoderm with radial ornamentation (YPM 3695), both from YPM locality 5833. J. T. Gregory (oral commun., 1986, 1990) also collected two partial phytosaur skulls, one with a good palate and one with a good skull roof, which were "combined" and traded to the Cleveland Museum of Natural History (?specimens numbered 52 and 53 in Gregory's field notes: Hunt, 1997b). There is a much reconstructed, and possibly composite phytosaur skull on display at CMNH. However, CMNH has no record of a trade with YPM. CMNH 11162 is listed as a cast of *Phytosaurus* (*Machaeroprosopus*) *gregorii* (original at USNM), which was received from USNM in 1973. This cast could not be found, and the skull on display could have been identified as *P. gregorii* in older classifications (e.g., Gregory, 1962). Presumably the CMNH skull on display is from the Revuelto badlands.

Gregory did collect a couple of specimens from the Harmon ranch, just west of the Cosner ranch. The north end of the former Harmon ranch is the Barranca badlands of this report (J. Cresap, née Harmon, oral commun., 1986). However, I believe that Gregory prospected the less fossiliferous southern end of the ranch for the following reasons: (1) J. T. Gregory (oral commun., 1986, 1990) does not recall prospecting in a large area of badlands to the west of Revuelto; (2) Gregory evidently found few fossils on the Harmon ranch, whereas the Barranca badlands are very fossiliferous; and (3) access to the Barranca badlands was very difficult, whereas the southern end of the Harmon ranch was at the end of a county road. In 1983, P. A. Murry briefly prospected the Revuelto badlands (J. B. Cresap, oral commun., 1986). K. C. Carpenter visited the Revuelto badlands in 1982 to collect Triassic vertebrate fossils for the University of Colorado Museum. He collected a few specimens from UCM locality 82021, including a partial dinosaur skeleton (UCM 47221) and a partial phytosaur skull (UCM 48441)(Carpenter and Parrish, 1985; Parrish and Carpenter, 1986; Carpenter, 1997), and noted specimens nearby (UCM localities 82017-82020). Both Murry and Carpenter were revisiting an area whose location had been documented by Gregory (1972). From 1983 to 1986, field parties from the University of New Mexico under Drs. J. W. Froehlich, B. S. Kues and S. G. Lucas collected vertebrate fossils from the Bull Canyon area.

In 1986, I began working in the Revuelto badlands, initially with help from a UNM field party led by S. G. Lucas and J. W. Froehlich and later with members of the New Mexico Friends of Paleontology (FOP) and various volunteers. In 1987, we began prospecting the Barranca badlands, and this quickly became the main focus of collecting. The Revuelto area was depauperate in large specimens (e.g., phytosaur skulls), presumably because of previous collecting, but was rich in specimens of small terrestrial reptiles. A notable exception is NMMNH P-12964, a complete skeleton of *Typothorax coccinarum* (Hunt et al., 1993b) that was below the highly fossiliferous interval mentioned by Gregory (1972) and Carpenter and Parrish (1985). The Barranca badlands had never been collected and yielded many large specimens (e.g., 19 phytosaur skulls/lower jaws and partial phytosaur skeletons) as well as sites rich in terrestrial tetrapods. Field parties under my direction spent about 450-500 person-days collecting fossil vertebrates in the Revuelto and Barranca badlands from 1986 until 1991.

The reason why the highly fossiliferous and extensive Barranca badlands have not previously been collected is that access has always been difficult. The original highway US-66 followed the railroad for much of its route. However, it swung north from the Revuelto badlands and avoided the Barranca badlands, hence Case's failure to investigate this area as he followed the road along the railroad. The highway went north in order to avoid having to construct three bridges over the large drainages of Revuelto, Barranca and Plaza Larga Creeks, as did the railroad. Instead, the highway went north to where the three drainages coalesced, so only one bridge was necessary. The Barranca badlands were isolated from easy access by Barranca and Plaza Larga Creeks to the west and east and the railroad to the north. Now access is only feasible by driving across the now-abandoned railroad bridge across Plaza Larga Creek. This route was not possible until the abandonment of the railroad in the late 1960's. Thus, until recent years the difficulty of access hindered paleontological investigation of the Barranca badlands.

Invertebrate fossils

Invertebrate fossils are locally abundant in the Bull Canyon Formation, particularly in the lower half of the formation. Surprisingly, therefore, the first published reference to invertebrates from this formation is by Kues (1985b). Kues (1985b) described a large sample of unionid bivalves and gastropods from the lower Bull Canyon Formation in Bull Canyon. He recognized several taxa that included new forms designated by numbers. Kues (1985b) listed the unionid bivalves *Unio arizonensis*, *Unio* spp. 1-6, *Antediplodon dockumensis* and *Antediplodon* sp. and the hydrobiid gastropod *Triasamnicola pilsbyi* from the Bull Canyon Formation. Lucas et al. (1985c, fig. 4) illustrated the stratigraphic position of two of the localities that yielded these specimens. Carpenter and Parrish (1985) noted the presence of imbricated unionid shells in a channel in the lower Bull Canyon Formation. Carpenter (in Good, 1989, table 3) mentioned bivalves and a gastropod from the same area. Good (1993) considered invertebrate specimens from the Bull Canyon Formation as part of his *Antediplodon thomasi* biozone/paleobiogeographic unit.

The emphasis of this study was vertebrates, but numerous bivalve and gastropod specimens were collected from several localities in the lower half of the Bull Canyon Formation. Notable are juvenile unionids and many gastropods from NMMNH locality 1. All specimens are at NMMNH.

Microfossils

Kietzke (1987, 1989) described calcareous microfossils from two localities in the lower half of the Bull Canyon Formation. These microfossils include charophytes, ostracods and specimens originally identified as spirorbid worms, but which are now believed by some workers to be gastropods (Kietzke and Lucas, 1991). One locality (NMMNH locality 1) at Revuelto Creek yielded the charophytes *Altochara* sp. and *Stellatochara* sp. and the ostracodes *Darwinula* sp. A and *Gerdalia* sp. B. The other in Bull Canyon produced the ostracodes *Darwinula* sp. A, *Gerdalia* sp. B and ?*Lutkevichinella* sp. Both localities produced the spirorbid-like gastropods.

Trace fossils

Terrestrial trace fossils have largely been ignored until the last few years, and this is reflected in the sparse literature on the ichnology of the Bull Canyon Formation. Newell (1992, figs. 4.3c, 4.7a) illustrated simple and meniscate burrows from the Bull Canyon Formation, and Hunt et al. (1993) described surface trails and trackways. Hunt et al. (1993a) described abundant trails of the notostracan arthropod trackway *Acripes triassicus* and a new taxon of enigmatic vertebrate tracks (*Barrancapus cresapi*), which possibly pertains to a prosauropod (Hunt et al., 2001b). Root casts have been found in a few localities in the mudrock facies. However, it is clear that there is a need for further study of the ichnology of the Bull Canyon Formation.

Plant fossils

Drake (1892, p. 244) first mentioned plant fossils in the Bull Canyon Formation when he noted silicified wood in eastern Quay County. Case (1922, p. 8) noted wood from eastern New Mexico, that is probably from the Bull Canyon Formation. Since 1960, S. R. Ash has sporadically collected from the Chinle Group of eastern New Mexico (Ash, 1972). It is impossible to extract a floral list for the Bull Canyon Formation from Ash's work (e.g., Ash, 1972, 1987, 1989) because he did not distinguish between the "shale members/formations of the Chinle" (= Garita Creek and Bull Canyon Formations of current usage), and some specimens are reported only as being from the Chinle Group (Dockum Group of Ash). The only undoubted species to occur in the combined Garita Creek/Bull Canyon is the bennettitalean *Zamites powelli* (Ash, 1972, 1989). Lucas et al. (1985b, c) reported specimens of the horsetail *Neocalamites* sp. and the enigmatic ?angiosperm *Sanmiguelia* sp. from the Bull Canyon Formation at Bull Canyon. Newell (1992, fig. 4.3b) illustrated a fossil log from the Bull Canyon Formation and noted the presence of stumps and rootlets.

During the present study no attempt has been made to prospect systematically for plant fossils, but some specimens were noted or collected. Wood is fairly common in the lower part of the formation; it is often infested with heart-rot fungus (*Polyporites*). One 10 m log in the Barranca area (see below) is almost totally infested; isolated, spindle-shaped pieces of fungus-infected wood are common and are extremely abundant at NMMNH locality 1. One specimen worthy of note is a part of a "frond" of the enigmatic, putative angiosperm *Sanmiguelia* (NMMNH P-17597 from NMMNH locality 443). Representative plant specimens from the Bull Canyon Formation have been reposited at NMMNH.

SYSTEMATIC PALEONTOLOGY OF REVUELTIAN VERTEBRATE FOSSILS

Introduction

The Bull Canyon Formation has yielded a large, diverse vertebrate fauna. The following discussion includes all specimens from the Bull Canyon Formation. The type Revueltian fauna is from the lower Bull Canyon Formation in the Revuelto and Barranca badlands. However, as discussed below, the fauna of the upper Bull Canyon Formation is also considered to be of Revueltian age and thus is included in this discussion. Familial and higher level ranges are from the Fossil Record 2 (Benton, 1993; Gardiner, 1993; Milner, 1993; Schultze, 1993), and of lower taxonomic levels are from cited references.

Osteichthyes, Huxley, 1880
Actinopterygii, Klein, 1885
Perleidiformes Berg, 1937
?Colobodontidae Stensio, 1916
gen. et sp. indeterminate

Type Revueltian occurrence: NMMNH locality 1.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4524, toothplates; NMMNH P-4850, toothplate (Fig. 3E).

First occurrence: Several genera with worldwide distribution (Triassic: Scythian-Anisian).

Last occurrence: Several species of *Colobodus* from Europe (Triassic: Carnian-Norian: Gardiner, 1993) and indeterminate toothplates from New Mexico (Triassic: late Norian-?Rhaetian: Huber et al., 1993).

Acme zone: Scythian-Anisian (Triassic)

Discussion: Several specimens from NMMNH locality 1 represent fragments of phyllodont toothplates. These specimens consist of multiple, superposed sets of replacement teeth. Such toothplates occur in eight teleost families (Johnson and Zidek, 1981), but Late Triassic specimens have usually been referred to the Perleididae (e.g., Murry, 1986, fig. 9.5A1-A2). However, I follow Gardiner (1993) in considering Perleididae to be a synonym of Colobodontidae.

Redfieldiformes Berg, 1940
Redfieldiidae Berg, 1940
gen. et sp. indeterminate

Type Revueltian occurrences: NMMNH localities 75 and 110.

Referred specimens from type Revueltian: NMMNH locality 75; NMMNH P-17250, body segments; NMMNH P-17255, head and body fragments: NMMNH locality 110; NMMNH P-4590, scales; NMMNH P-4640, skull fragment.

First occurrence: Several genera from Gondwana (Triassic: Scythian)

Last occurrence: *Redfieldius* from eastern North America (Jurassic: Hettangian).

Acme zone: Olenekian (Triassic)

Discussion: Scale squamation of a few specimens from the Bull Canyon Formation supports their assignment to the Redfieldiidae (Schaeffer and McDonald, 1978; Huber et al., 1993).

Halecostomi, Regan, 1923
Semionotiformes Arambourg and Bertin, 1958
Semionotidae Woodward, 1890
Semionotus* cf. *S. brauni

Type Revueltian occurrence: NMMNH locality 75.

Referred specimens from type Revueltian: NMMNH locality 75; NMMNH P-4185, body fragments; NMMNH P-17312, body fragments.

First occurrence: Genus from Anisian-Ladinian (Triassic) of Europe, North America and Africa, species from Hettangian (Jurassic) of eastern North America.

Last occurrence: Genus from eastern North America (Jurassic: Hettangian),

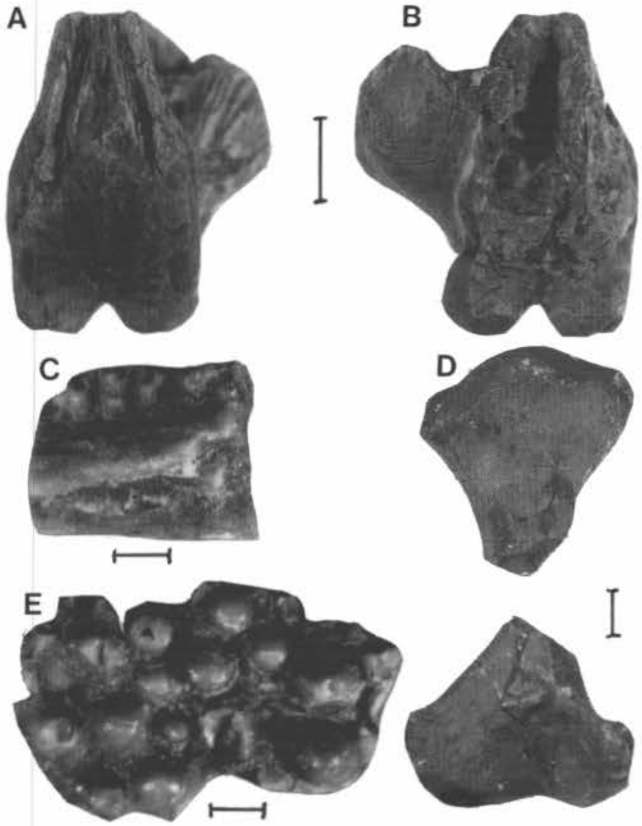

FIGURE 3. Fish and less derived reptiles from the Bull Canyon Formation. A-B. Holotype basisphenoid of *Quayia zideki* (NMMNH P-16888) in dorsal (A) and ventral (B) views. C. Dentary fragment of squamate (NMMNH P-4326) in medial view. D. Rhynchosaur humerus (UMMP 4771 [in part]) in posterior view. E. ?Colobodontid toothplate (NMMNH P-4850) in occlusal view. Scale bars are 1 cm (A-B, D) and 1 mm (C, E).

species from eastern North America (middle-late Norian).

Acme zone: Genus - Hettangian (Jurassic), species - Norian (Triassic).

Discussion: These two specimens represent a single species and resemble the *Semionotus brauni* group of Olsen et al. (1984) in having posteriorly directed spines on the dorsal midline scales (Huber et al., 1993).

Actinopterygii, Klein, 1885
incertae sedis
***?Tanaocrossus kalliokoskii* Schaeffer, 1967**

Type Revueltian occurrences: NMMNH localities 75 and 166.

Referred specimens from type Revueltian: NMMNH locality 75; NMMNH P-17306, skull; NMMNH P-17319, skeleton: NMMNH locality 166; NMMNH P-4860, skeleton.

First occurrence: Otischalkian (Triassic: late Carnian) of West Texas.

Last occurrence: Apachean (Triassic: late Norian-?Rhaetian) of southwestern Colorado.

Acme zone: ?Apachean (Triassic: late Norian-?Rhaetian).

Discussion: Huber et al. (1993) referred these specimens and AMNH 5662 from the Colorado City Formation of Howard County, Texas (Schaeffer, 1967, pl. 30, fig. 16) to *Tanaocrossus kalliokoskii* on the basis of similarities in the opercular, extrascapulars, dermopteric, elongate dorsal fin and elongate anal fin. Further preparation of the Bull Canyon specimens is required before this assignment can be fully evaluated.

Actinopterygii Klein, 1885
gen. et sp. indeterminate

Type Revueltian occurrences: NMMNH localities 1, 75, 81, 94, 97, 110, 369, 447, 501; UCM locality 82021; YPM locality 8199.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4564, body segments and scales of large fish; NMMNH P-4707, scale; NMMNH 4711, scale; NMMNH P-4749, scale; NMMNH P-4759, scale; NMMNH P-4762, scale; NMMNH P-4765, scale; NMMNH P-4768, scale; NMMNH P-4748, scale; NMMNH P-4833, scale; NMMNH P-4834, scale; NMMNH P-4835, scale; NMMNH P-4840, scale; NMMNH P-4864, scale: NMMNH locality 75; NMMNH P-4184, body segments; NMMNH P-4186, body segments; NMMNH P-17199, head, body fragments; NMMNH P-17206, body segments; NMMNH P-17254, body segments; NMMNH P-17256, body fragment; NMMNH P-4885, partial body: NMMNH locality 81; NMMNH P-4177, headless three dimensional fish: NMMNH locality 94; NMMNH P-4116, partial body: NMMNH locality 97; NMMNH P-4124, body segment: NMMNH locality 110; NMMNH P-4964, jaw fragment: NMMNH locality 369; NMMNH P-4183, body segments: NMMNH locality 447; NMMNH P-16829, bone: NMMNH locality 501; NMMNH P-17297, vertebra: UCM locality 82021; UCM 52079, partial body and uncataloged isolated scales: YPM locality 5831; YPM 8199, fragment.

First occurrence: *Naxilepis* from Late Silurian of China.

Last occurrence: Numerous Recent species.

Acme zone: Not applicable.

Discussion: The Bull Canyon Formation ichthyofauna contains a number of indeterminate actinopterygian specimens. These include isolated scales and partial fish. Some specimens may become identifiable after further preparation, for example NMMNH P-4694, which is fragments of a large fish (scales about 10 mm in length). Some of the unornamented scales may pertain to semionotids.

Sarcopterygii Romer 1955
Actinistia Cope, 1871
Dipnoi Muller, 1844
Ceratodontoidei Vorobyeva and Obruchev, 1964
?Arganodontidae Martin, 1982

Type Revueltian occurrence: NMMNH locality 1.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-16590, skull fragments; NMMNH P-16889, skull fragments.

First occurrence: *Arganodus multicristatus* from the Lower Triassic of Malagasy.

Last occurrence: *Arganodus tiguidiensis* from the Late Jurassic-early Cretaceous of the Sahara.

Acme zone: Not applicable.

Discussion: A few skull fragments from NMMNH locality 1 are similar to specimens of lungfish (e.g., Schultze, 1981). Because of their age, these specimens are tentatively assigned to the Arganodontidae. Lungfish toothplates are notably absent from the Bull Canyon Formation, but they are locally common in correlative units (Long and Murry, 1989).

Coelacanthoidei Berg, 1937
Coelacanthidae Agassiz, 1843
***Quayia zideki*, Hunt, 1997**

Type Revueltian occurrences: NMMNH localities 1 and 462.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4682, parasphenoid fragments; NMMNH P-4685, parasphenoid; NMMNH P-16588, scale; NMMNH P-16593, skull fragments; NMMNH P-16597, parasphenoid fragments; NMMNH P-16620, skull fragments; NMMNH P-16926, skull fragments; NMMNH P-16760, skull fragments; NMMNH P-16888 (Fig. 3A-B), basisphenoid lacking left antotic process (holotype); NMMNH P-16918, lower jaw; NMMNH P-16942, skull fragments; NMMNH uncataloged, three basisphenoids and fragments: NMMNH locality 462; NMMNH P-16873, skull fragments.

First occurrence: Revueltian (Triassic: early-middle Norian), New Mexico.

Last occurrence: Revueltian (Triassic: early-middle Norian), New Mexico.

Acme zone: Revueltian (Triassic: early-middle Norian), New Mexico.

Discussion: The basisphenoid of *Quayia* is about three quarters of the size of that of the living *Latimeria*. This indicates that it is the largest fish in the Bull Canyon ichthyofauna.

Quayia differs from all other coelacanths in the form of its basisphenoid, which is a generically diagnostic element (e.g., Schaeffer and Gregory, 1961). Notably, *Quayia* is distinct from *Chinlea* (Schaeffer, 1967, fig. 13A, pl. 27, 1-2), which is the genus into which all other Chinle Group coelacanth specimens have been rather arbitrarily placed. These differences are not ontogenetic, as the new genus is represented by a growth series with the posterior width varying from 20 mm to 36 mm. Diagnostic specimens of *Chinlea* are restricted to the Apachean (Late Norian-?Rhaetian) of western North America. The basisphenoid of *Quayia* differs from that element of *Chinlea* in the following features: (1) antotic processes are much narrower; (2) the portion of the pleurosphenoid that articulates with the antotic process is much smaller; (3) the sphenoid condyles do not flare posteriorly; (4) the lateral margins of the posterior part of the bone are parallel; (5) the basisphenoid extends considerably anterior to the antotic processes; (6) the basisphenoid narrows anteriorly; and (7) the dorsal depression between the antotic processes is much narrower. In overall morphology, the basisphenoid of *Quayia* is most similar to that element in *Spermatodus*, *Moenkopia*, *Latimeria* and *Chinlea* in having roughly rectangular antotic processes that have large overlap areas for the pleurosphenoid (Schaeffer and Gregory, 1961).

Family ?Coelacanthidae Agassiz, 1843

Type Revueltian occurrences: NMMNH localities 1 and 171.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-16586, skull fragment; NMMNH locality 171; NMMNH P-16706, skull fragments.

First occurrence: *Coelacanthus granulatus* from Ufimian (Permian) of Western Europe.

Last occurrence: *Heptanema* from Tithonian (Jurassic) of Germany.

Acme zone: Not applicable.

Discussion: A few skull fragments appear to have the characteristic ornamentation of coelacanth cranial elements, which consist of narrow, irregular channels (e.g., Elliot, 1987, fig. 1).

Amphibia Linnaeus, 1758
Temnospondyli Zittel, 1898
Metoposauridae Watson, 1919
***Apachesaurus gregorii* Hunt, 1993**

Type Revueltian occurrences: NMMNH localities 1, 110, 132, 160, 171, 467, 498, 499, 501, 518, 519: UMMP unnumbered.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4670, intercentra; NMMNH P-16604, intercentra; NMMNH P-16901, skull: NMMNH locality 110; NMMNH P-4398, intercentrum: NMMNH locality 132; NMMNH P-4589, centra and skull fragments: NMMNH locality 160; NMMNH P-4571, intercentrum: NMMNH locality 171; NMMNH P-4855, intercentra: NMMNH locality 467; NMMNH P-16904, intercentrum: NMMNH locality 498; NMMNH P-17181, intercentrum: NMMNH locality 499; NMMNH P-17272, intercentrum: NMMNH locality 501; NMMNH P-17296, intercentrum: NMMNH locality 518; NMMNH P-17370, intercentra: NMMNH locality 519; NMMNH P-17178, intercentrum: NMMNH locality 527; NMMNH P-17491, intercentra: 5 miles west of San Jon in badlands; UMMP 7441 (in part), one intercentrum.

First occurrence: Adamanian (Triassic: late Carnian) of West Texas.

Last occurrence: Apachean (Triassic: late Norian-?Rhaetian) of New Mexico.

Acme zone: Revueltian-Apachean (Triassic: early Norian -?Rhaetian)

Discussion: *Apachesaurus* is the only identifiable amphibian in the Bull Canyon fauna. A nearly complete skull (NMMNH P-16901) and many diagnostic intercentra occur in the Bull Canyon Formation. This species of metoposaur is distinct in that it most commonly occurs in the paleosol-hosted taphofacies in association with terrestrial reptiles. The much larger *Metoposaurus* and *Buettneria* of older intervals of the Chinle are found exclusively in floodplain-hosted taphofacies in association with semi-aquatic phytosaurs. *Apachesaurus gregorii* has several morphologic features that suggest that it was more terrestrial in its habits than other metoposaurs, including a less-developed lateral line system and a more robust ilium (Hunt, 1993a; Hunt et al, 1993c).

***?Apachesaurus* sp.**

Type Revueltian occurrences: NMMNH localities 1, 122, 154, 171, 174, 182, 451, 452, 467, 486, 520, 523, 526, 527.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4667, skull fragments; NMMNH P-4668, pectoral girdle fragments; NMMNH P-4669, mandible fragments; NMMNH P-16601, skull fragments; NMMNH P-16619, posterior mandible fragment; NMMNH P-16592, skull fragments; NMMNH P-16941, skull fragment; NMMNH P-16943, rib ends: NMMNH locality 122; NMMNH P-4439, partial clavicle: NMMNH locality 154; NMMNH P-16857, skull fragment: NMMNH locality 171; NMMNH P-4866, skull fragment; NMMNH P-4871, mandible fragment; NMMNH P-16727, interclavicle fragment; NMMNH P-16638, interclavicle fragment; NMMNH P-16893, posterior mandible fragment: NMMNH locality 174; NMMNH P-4872, mandible fragment; NMMNH P-16594, interclavicle fragment: NMMNH locality 182; NMMNH P-16595, interclavicle fragment: NMMNH locality 451; NMMNH P-16817, interclavicle fragment: NMMNH locality 452; NMMNH P-16857, skull fragment: NMMNH locality 467; NMMNH P-16906, mandible fragment; NMMNH locality 486; NMMNH P-17053, interclavicle fragment: NMMNH locality 520; NMMNH P-17192, skull fragment: NMMNH locality 523; NMMNH P-17453, mandible fragments: NMMNH locality 526; NMMNH P-17377, skull fragments; NMMNH P-17468, skull fragments: NMMNH locality 527, NMMNH P-17475, pectoral fragments.

First occurrence: Adamanian (Triassic: late Carnian) of West Texas.

Last occurrence: Apachean (Triassic: late Norian-?Rhaetian) of New Mexico.

Acme zone: Revueltian-Apachean (Triassic: early Norian -?Rhaetian)

Discussion: Many metoposaurid fragments occur in the Bull Canyon Formation. The size of these specimens is consistent with an assignment to *Apachesaurus*, the only diagnostic metoposaurid from this formation. However, these specimens can only be tentatively assigned to this genus because they lack its apomorphic characters.

Metoposauridae Watson, 1919
gen. et sp. indeterminate

Type Revueltian occurrences: NMMNH localities 175, 198, 465, 534.

Referred specimens from type Revueltian: NMMNH locality 175; NMMNH P-16567, waterworn skull fragments: NMMNH locality 198; NMMNH P-16558, ?skull fragments; NMMNH P-16583, skull fragments; NMMNH P-16585, skull fragment; NMMNH P-16602, skull fragment: NMMNH locality 465; NMMNH P-16882, skull fragment: NMMNH locality 534; NMMNH P-17388, skull fragments.

First occurrence: Several species from Otischalkian (Triassic: early late Carnian) and correlative strata worldwide. *Trigosternum* and the undescribed skull from Eschenau from the Middle Triassic Lettenkeuper of Germany do not pertain to the Metoposauridae (Hunt, 1993a; *contra* Milner, 1993).

Last occurrence: Apachean (Triassic: late Norian-?Rhaetian) of New Mexico.

Acme zone: Otischalkian-Adamanian (Triassic: early late Carnian to latest Carnian).

Discussion: Several specimens from the Bull Canyon Formation represent fragmentary skull fragments of individuals larger than known *Apachesaurus*. These specimens derive from intraformational conglomerates in the lower portion of the formation. They are probably reworked from late Carnian strata, but they could demonstrate the presence of a large metoposaur in the lowest portion of the Bull Canyon Formation.

Reptilia Laurenti, 1768
Lepidosauromorpha Benton, 1984
Lepidosauria Haeckel, 1866
?Squamata Oppel, 1811
Family indeterminate

Type Revueltian occurrences: NMMNH localities 1 and 110.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4326, jaw fragment (Fig. 3C): NMMNH locality 110; NMMNH P-4965, jaw fragments.

First occurrence: Lepidosauria - *Saurosternon bainii* from Tatarian (Permian) of South Africa, Squamata - *Dorsetisaurus purbeckensis*, *Becklesius hoffstetteri* and *Saurillodon* spp. from the Oxfordian (Jurassic) of Portugal.

Last occurrence: Lepidosauria and Squamata - numerous species from Recent.

Acme zone: Not applicable.

Discussion: Jaw fragments from two localities in the Bull Canyon Formation exhibit homodont, pleurodont dentition and apparently represent squamates. Murry (1986) noted the presence of a similar jaw fragment from the Tecovas Formation of the Chinle Group in Texas. These specimens appear to indicate the presence of a Late Triassic lizard-like animal in the upper Chinle Group, but they might also pertain to the Kuehneosauridae, a non-squamate lepidosauromorph clade of Carnian-Rhaetian gliding reptiles.

Archosauromorpha Huene, 1946
Rhynchosauria Osborn, 1903
Rhynchosauridae Huxley, 1887
gen. et sp. indet.

Type Revueltian occurrences: NMMNH locality 1: UMMP locality 5 miles west of San Jon in Badlands.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4686, right distal humerus; NMMNH P-4703, right distal humerus: 5 miles west of San Jon in badlands; UMMP 4771 (part), left distal and proximal humerus (Fig. 3D), small left distal humerus.

First occurrence: Two genera from *Cynognathus-Diademodon* Assemblage Zone (Triassic: Olenekian) of South Africa.

Last occurrence: Revueltian (Triassic: early-middle Norian), New Mexico.

Acme zone: Anisian-Ladinian (Triassic).

Discussion: The larger proximal and distal humeri of UMMP 4771 obviously represent the same taxon as NMMNH P-4703, being identical in size, preservation and morphology. A variety of evidence indicate that NMMNH locality 1 is the same as Case's locality 5 miles west of San Jon in Badlands (Hunt, 1994). These specimens pertain to a primitive reptile that has a humerus with greatly flared proximal and distal extremities. These specimens evidently represent a rhynchosaur very close in morphology to *Otischalkia* (Hunt and Lucas, 1991b, pl. 1, 4-5, fig. 2). The Bull Canyon Formation taxon differs from *Otischalkia* in the form of the ectepicondylar area--they apparently lack a supinator crest and may have had an enclosed ectepicondylar foramen.

UMMP 12972 is a complete humerus from the Tecovas Formation in West Texas that also represents a rhynchosaur. This specimen is Adamanian in age but is younger than the Otischalkian *Otischalkia*. These specimens indicate that a lineage of rhynchosaurs survived in North America through the late Carnian and into the Norian. The Bull Canyon specimens are the youngest known rhynchosaur specimens and demonstrate that rhynchosaurs persisted beyond the Carnian (*contra* Hunt and Lucas, 1991b).

Archosauromorpha Huene, 1946
incertae sedis
***Vancleavea campi* Long and Murry, 1995.**

Type Revueltian occurrence: NMMNH locality 522.

Referred specimens from type Revueltian: NMMNH locality 5; NMMNH P-20852, centra associated as stomach contents with skeleton of *Pseudopalatus andersoni*: NMMNH locality 522; NMMNH P-4984, partial articulated skeleton including limb, vertebra and osteoderms;

First occurrence: Late Carnian (Adamanian), Los Esteros Member of Santa Rosa Formation and Blue Mesa Member of Petrified Forest Formation.

Last occurrence: Late Norian-Rhaetian (Apachean) Redonda Formation and Rock Point Formation, New Mexico.

Acme zone: None

Discussion: Long and Murry (1995) named *Vancleavea campi* for a partial skeleton of an armored reptile from the Adamanian Blue Mesa Member of the Petrified Forest Formation in Petrified Forest National Park. This unusual reptile combines primitive-aspect postcrania with specialized osteoderms. The most typical osteoderms are rounded to diamond-shaped with a smooth dorsal surface. The most distinctive feature of the osteoderms is a median ridge that terminates in an arcuate anterior prong. Osteoderms of this morphology are found in New Mexico in the Los Esteros Member of the Santa Rosa Formation (Adamanian), Bull Canyon Formation (Revueltian) and Redonda and Rock Point formations (Apachean). The Redonda specimens had previously been assigned to a sphenosuchian (e.g., Hunt and Lucas, 1993d) on the basis of the anterior prong, which has been considered a crocodylomorph apomorphy (e.g., Clark et al., 2000). It is clear that one or more species of this clade of reptiles are present throughout the Adamanian-Apachean portions of the Chinle Group. Ongoing study indicates that some specimens assigned to Reptilia indet. from NMMNH locality 1 actually pertain to the same taxon as NMMNH P-4984.

Phytosauria Baur, 1898
Parasuchidae Lydekker, 1888
***Pseudopalatus pristinus* Mehl, 1928**

Type Revueltian occurrences: NMMNH localities 4, 13, 432, 442: YPM locality 5831.

Referred specimens from type Revueltian: NMMNH locality 4; NMMNH P-4654, skull: NMMNH locality 13; NMMNH P-4979, skull and partial skeleton including stomach contents (*Apachesaurus* intercentra): NMMNH locality 432; NMMNH P-4977, rostrum: NMMNH locality 442; NMMNH P-4980, half rostrum: YPM locality 5831; YPM 5831, skull and partial skeleton.

First and last occurrences: Numerous localities in Revueltian (early-middle Norian) strata in Arizona, New Mexico and Texas.

Acme zone: Revueltian (early-middle Norian).

Discussion: Diagnostic specimens of this dolichorostral (*sensu* Hunt, 1994) phytosaur are relatively uncommon in the Bull Canyon fauna. One skeleton (NMMNH P-4979) contains stomach contents consisting of *Apachesaurus* intercentra. These specimens are considered to be true gastric contents because: (1) they occur in the ribcage area; (2) there are only specimens of the phytosaur in this quarry (apart from the metoposaur intercentra); and (3) the intercentra are part of a single vertebral column.

***Pseudopalatus andersoni* (Mehl, 1922)**

Type Revueltian occurrences: NMMNH localities 5, 6, 12, 14, unknown FMNH locality.

Referred specimens from type Revueltian: NMMNH locality 5; NMMNH P-20852, skull and partial skeleton (20+ ribs, coracoid, 36+ osteoderms, 2 ilia, 3 cervical vertebrae, 9 dorsal vertebrae, 11 caudal vertebrae, pubis, 13+ neural spines, chevron, radius, ulna, 3 ?sacral vertebrae, 2 isolated teeth 5 cervical ribs, humerus, scapula, coracoid, tibia, astragalus, proximal femur) including stomach contents (one small proximal phytosaur pubis) and small centra of *Vancleavea campi*: NMMNH locality 6; NMMNH P-4973, skull; NMMNH locality 12; NMMNH P-4970, skull: NMMNH locality 14; NMMNH P-4972, skull in two pieces: UNM locality; UNM MV-650, skull (Fig. 4): Unknown FMNH locality that is probably Bull Canyon (Hunt, 1994); FMNH UC 396, skull (holotype).

First and last occurrences: Numerous localities in Revueltian (early-middle Norian) strata in Arizona, New Mexico and Texas.

Acme zone: Revueltian (early-middle Norian).

Discussion: *Pseudopalatus andersoni* is known from six skulls from the lower Bull Canyon Formation. One skull (UNM MV-650) (Fig. 4) was illustrated by Hunt and Lucas (1989b). NMMNH P-20852 is a skull and the majority of a skeleton that preserved stomach contents consisting of a proximal pubis of a smaller phytosaur and a series of vertebrae of *Vancleavea campi*.

Pseudopalatus n. sp.

Type Revueltian occurrences: NMMNH localities 2, 3 and 199: YPM locality 5833

Referred specimens from type Revueltian: NMMNH locality 2; NMMNH P-4256, skull and cervical series: NMMNH locality 3; NMMNH P-4239, anterior of skull and lower jaws: NMMNH locality 199; NMMNH P-16608, tip of rostrum: PM locality 5833; YPM 3293, skull and lower jaws.

First and last occurrences: Several localities in Revueltian (early-middle Norian) strata in Arizona and New Mexico.

Acme zone: Revueltian (early-middle Norian).

Discussion: *Pseudopalatus* n. sp. is a robust morph of the genus, analogous to *Rutiodon* (*Smilosuchus*) *gregorii*. Specimens of this species are more common in the Bull Canyon Formation than in any other units of the Chinle Group. Specimens from the Bull Canyon Formation have previously been assigned to the species "*Machaeroprosopus" gregorii* and have variously been placed in the genera *Machaeroprosopus* (Camp, 1930), *Phytosaurus* (Gregory, 1972), *Rutiodon* (Carpenter and Parrish, 1985; Parrish and Carpenter, 1986) or *Nicrosaurus* (Lucas et al., 1985a c). Three well preserved skulls of this species have been collected from the Revuelto and Barranca badlands.

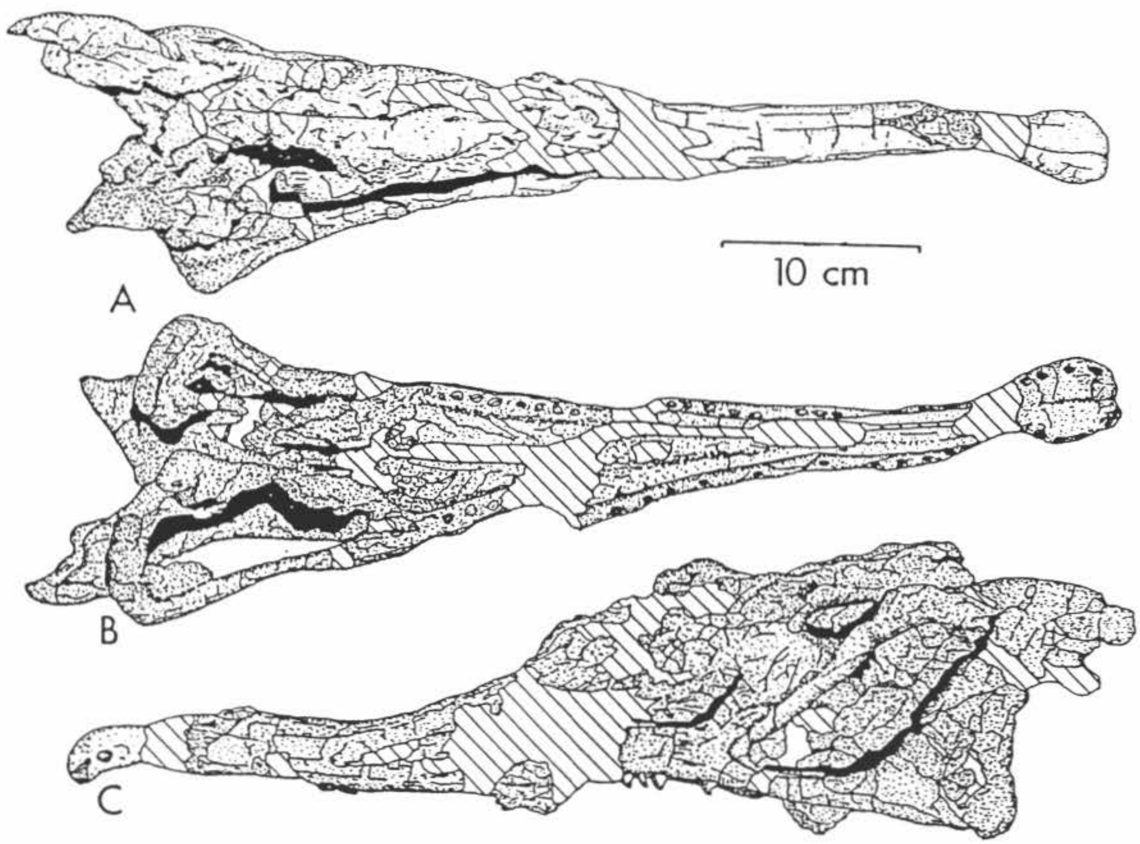

FIGURE 4. Skull of *Pseudopalatus andersoni* (UNM MV-650) from the Bull Canyon Formation at Bull Canyon in dorsal (A), ventral (B) and left lateral (C) views. Drawings by R. Pence.

?*Pseudopalatus* n. sp.

Type Revueltian occurrences: NMMNH locality 30: UCM locality 82021.

Referred specimens from type Revueltian: NMMNH locality 30; NMMNH P-4981, maxillary fragment: UCM locality 82021; UCM 48441, posterior skull.

First and last occurrences: Several localities in Revueltian (early-middle Norian) strata in Arizona and New Mexico.

Acme zone: Revueltian (early-middle Norian).

Discussion: Two skull fragments represent robust animals the size of *Pseudopalatus* n. sp. and are tentatively assigned to this taxon.

***Pseudopalatus* sp.**

Type Revueltian occurrences: NMMNH localities 1, 8, 9, 77, 89, 11, 122, 436, 542, 544-545.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-16507, juvenile right squamosal: NMMNH locality 8; NMMNH P-4974, lower jaw: NMMNH locality 9; NMMNH P-4971, lower jaws: NMMNH locality 77; NMMNH P-4194, tip of squamosal: NMMNH locality 89; NMMNH P-4978, lower jaw ramus: NMMNH locality 111; NMMNH P-4368, right squamosal: NMMNH locality 122; NMMNH P-4422, left squamosal: NMMNH locality 436; NMMNH P-4975, lower jaws: NMMNH locality 542; NMMNH P-17380, squamosal: NMMNH locality 544; NMMNH P-17323, lower jaws: NMMNH locality 545; NMMNH P-17317, left squamosal.

First and last occurrences: Numerous localities in Revueltian (early-middle Norian) strata in Arizona, New Mexico and Texas.

Acme zone: Revueltian (early-middle Norian).

Discussion: Several lower jaws and posterior skull fragments can be assigned to *Pseudopalatus*, but the species cannot be determined because of the lack of a rostrum.

Parasuchidae Lydekker, 1888
gen. et sp. indet.

Type Revueltian occurrences: NMMNH localities 1, 17, 19, 21-23, 25, 27, 30-31, 33-35, 37-43, 45-49, 51-54, 57, 59-67, 69-72, 74-81, 84, 86-89, 93-96, 100-104, 106, 110, 112-122, 124, 126, 128-129, 132-134, 136, 140-142, 146-148, 151-157, 160-166, 169-175, 177-179, 182, 185-186, 189, 191-192, 194-196, 198, 447-448, 450-452, 461-467, 497-500, 502, 506, 508, 510-512, 514, 520, 522-523, 525, 527, 529-530, 534-535-540, 542, 546, 548: YPM localities 5831, 5833, 5887, 6649.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4697, osteoderm fragment; NMMNH P-4853, tooth (type B, sensu Hunt, 1994); NMMNH P-4863, teeth (type U, I); NMMNH P-4914, osteoderm fragment; NMMNH P-4942, rostral fragments; NMMNH P-4952, fibula fragments; NMMNH P-16505, large tooth (type B); NMMNH P-16508, tooth (type I); NMMNH P-16515, rib; NMMNH P-16517, osteoderm fragments; NMMNH P-16529, maxillary fragment; NMMNH P-16605, osteoderm fragment; NMMNH P-16613, tooth fragments (type U); NMMNH P-16614, teeth (type B, I); NMMNH P-16625, skull fragments; NMMNH P-16678, teeth (type I, U); NMMNH P-16688, teeth (type U): NMMNH locality 16; NMMNH P-4350, teeth (type U); NMMNH P-4352, osteoderm fragment: NMMNH locality 17; NMMNH P-4348, jaw fragment in conglomerate: NMMNH locality 18; NMMNH P-4648, osteoderms: NMMNH locality 19; NMMNH P-4343, skull fragments; NMMNH P-4649, tooth (type U): NMMNH locality 20; NMMNH P- 4340, small osteoderm: NMMNH locality 21; NMMNH P-4313, tip of snout: NMMNH locality 22; NMMNH P-4312, large humerus; NMMNH P-4344, osteoderm fragments: NMMNH locality 23; NMMNH P-17496, juvenile jaw; NMMNH P-4200, caudal central fragments; NMMNH P-4314, rib: : NMMNH locality 24; NMMNH P-4323, dorsal vertebrae fragments: NMMNH locality 25; NMMNH P-4327, 4 teeth (types B, U) in conglomerate; NMMNH P-16528, tooth (type I); NMMNH P-17313, partial centrum: NMMNH locality 27; NMMNH P-4281, osteoderm fragments; NMMNH P-4285, skull and teeth fragments; NMMNH P-4325, teeth (types B, U) and osteoderm fragments: NMMNH locality 30; NMMNH P-4334, paramedian osteoderm fragment: NMMNH locality 31; NMMNH P-4297, osteoderm fragment: NMMNH locality 33; NMMNH P-4462, tooth; NMMNH P-4562, cranial fragment: NMMNH locality 34; NMMNH P-4143, osteoderm fragments; NMMNH P-4295, skull fragment; NMMNH P-4317, osteoderm fragments; NMMNH P-4341, osteoderm fragments: NMMNH locality 35; NMMNH P-4212, tooth (type U); NMMNH P-4301, transverse process; NMMNH P-4303, dorsal centrum; NMMNH P-4306, osteoderm fragment; NMMNH P-4307, teeth (type U); NMMNH P-4335, rib: NMMNH locality 37; NMMNH P-4298, cervical centrum and neural arch fragments: NMMNH locality 38; NMMNH P-4290, cervical vertebra fragments: NMMNH locality 39; NMMNH P-4279, skull fragments (many): NMMNH locality 40; NMMNH P-4136, skull fragment; NMMNH P-4287, skull fragments: : NMMNH locality 41; NMMNH P-4651, humerus fragments with teeth marks: NMMNH locality 42; NMMNH P-4316, tooth (type B): NMMNH locality 43; NMMNH P-4267, dorsal centrum; NMMNH P-4268, skull fragment: NMMNH locality 45; NMMNH P-4291, ulna: NMMNH locality 46; NMMNH P-4330, rib: NMMNH locality 47; NMMNH P-4204, osteoderm fragments; NMMNH P-4321, osteoderm, neural spine fragments; NMMNH locality 48; NMMNH P-4206, rib and vertebral fragments: NMMNH locality 49; NMMNH P-4201, osteoderm fragments: NMMNH locality 51; NMMNH P-4276, dorsal centra, neural arch and rib fragments; NMMNH P-17248, proximal scapula (small); NMMNH P-17252, proximal pubis; NMMNH P-17261, distal femur; NMMNH P-17260, cervical vertebrae: NMMNH locality 52; NMMNH P-4264, interclavicle and clavicle fragments: NMMNH locality 53; NMMNH P-4134, tooth (type B); NMMNH P-4159, osteoderm fragments; NMMNH P-4158, rib fragment; NMMNH P-4167, tooth (type U) in sandstone; NMMNH P-4229, cervical vertebral fragments; NMMNH P-4320, osteoderm fragments; NMMNH P-4322, centrum: NMMNH locality 54; NMMNH P-4266, osteoderm fragments: NMMNH locality 57; NMMNH P-4220, metatarsal fragment; NMMNH P-4221, ilium fragment; NMMNH P-4222, osteoderm fragments; NMMNH P-17427, atlas; NMMNH P-17433, osteoderm fragments; NMMNH P-17434, rib fragments: NMMNH locality 59; NMMNH P-4154, skull fragments: NMMNH locality 60; NMMNH P-4236, proximal and distal tibia: NMMNH locality 61; NMMNH P-4133, osteoderm fragments: NMMNH locality 62; NMMNH P-4230, osteoderm fragments; NMMNH P-4646, tip of neural spine: NMMNH locality 63; NMMNH P-4244, ilium fragments: NMMNH locality 64; NMMNH P-4132, skull fragment NMMNH; P-4241, osteoderm fragment in conglomerate: NMMNH locality 65; NMMNH P-4247, dorsal vertebra: NMMNH locality 66; NMMNH P-4243, osteoderm impression: NMMNH locality 67; NMMNH P-4217: NMMNH locality 68; NMMNH P-4131, centrum fragments; NMMNH P-4215, osteoderm fragment: NMMNH locality 69; NMMNH P-4224, osteoderm fragment: NMMNH locality 70; NMMNH P-4137, proximal chevron fragment; NMMNH P-4148, vertebral, skull and tooth (type B) fragments; NMMNH P-4149, osteoderm fragment; NMMNH P-4153, top of neural spine; NMMNH P-4146, rostral crest fragment; NMMNH P-4192, skull fragments; NMMNH P-4213, osteoderm; NMMNH P-17311, rostrum without crest: NMMNH locality 71; NMMNH P-4225, cervical and dorsal vertebral fragments; NMMNH P-17351, cervical centrum: NMMNH locality 72; NMMNH P-4231, jaw fragment: NMMNH locality 74; NMMNH P-4152, tooth fragment (type U); NMMNH P-4156, osteoderm fragments: NMMNH locality 75; NMMNH P-4180, osteoderm fragment; NMMNH P-4187; teeth fragments (type B); NMMNH P-17343, vertebral fragments; NMMNH P-18187, calcaneum, metatarsals: NMMNH locality 76; NMMNH P-4182, juvenile rostrum: NMMNH locality 77; NMMNH P-4193, osteoderm fragments: NMMNH locality 78; NMMNH P-4189, osteoderm fragments: NMMNH locality 79; NMMNH P-4174, osteoderm fragments; NMMNH P-4172, tooth fragments: NMMNH locality 80; NMMNH P-4169, cervical vertebra; NMMNH P-4170, osteoderm fragment; NMMNH P-17397, proximal femur: NMMNH locality 81; NMMNH P-17331, basicranium: NMMNH locality 84; NMMNH P-4164, skull fragments; NMMNH P-4166, tooth fragment (type U): NMMNH locality 85; NMMNH P-4144, dorsal centrum and neural arch fragments: NMMNH locality 86; NMMNH P-4140, tooth (type U) in conglomerate; NMMNH P-16523, osteoderm fragments; NMMNH P-16524, teeth (type U, B); NMMNH P-16525, top of neural spine; NMMNH P-16526, skull fragments: NMMNH locality 87; NMMNH P-4139, osteoderm fragments: NMMNH locality 88; NMMNH P-4142, osteoderm fragments; NMMNH P-4647, ?dentary fragments: NMMNH locality 89; NMMNH P-4118, skull fragment; NMMNH P-17124, vertebral fragments; NMMNH P-17143, vertebral fragments; NMMNH P-17379, rib fragments: NMMNH locality 93; NMMNH P-4138, tooth fragment (type B): NMMNH locality 94; NMMNH P-4114, caudal centrum and chevron fragments: NMMNH locality 95; NMMNH P-4117, skull fragments: NMMNH locality 96, NMMNH P-4123, jaw fragments: NMMNH locality 100; NMMNH P-4128, rib fragments; NMMNH locality 101; NMMNH P-4109, paramedian osteoderm: NMMNH locality 102; NMMNH P-4108, vertebral fragments; NMMNH P-17333, osteoderm: NMMNH locality 103; NMMNH P-4107, vertebral fragments; NMMNH P-4338, 2 small osteoderms; NMMNH P-4650, teeth (type I): NMMNH locality 104; NMMNH P-4336, neural arch fragments; NMMNH P-4337, osteoderm fragments: NMMNH locality 106; NMMNH P-4645, tip of large rostrum: NMMNH locality 109; NMMNH P-4103, skull fragments: NMMNH locality 110; NMMNH P-4355, phalanx; NMMNH P-4356, skull fragments; NMMNH P-4357, dorsal centrum fragment; NMMNH P-4358, osteoderm fragments in conglomerate; NMMNH P-4485, distal femur; NMMNH P-4488, teeth fragments; NMMNH P-4529, osteoderm fragments; NMMNH P-4530, cervical rib fragments; NMMNH P-4531, centrum; NMMNH P-4533, ilium, osteoderm and limb fragments; NMMNH P-4535, teeth (type B, U); NMMNH P-4538, tooth (type B); NMMNH P-4540, juvenile dentary tip; NMMNH P-4567, ischium fragment; NMMNH P-4577, teeth (type U, I); NMMNH P-4578, teeth (type U); NMMNH P-4579, tooth (type U): NMMNH locality 112; NMMNH P-4390, 2 articulated dorsal centra: NMMNH locality 113; NMMNH P-4411, small osteoderm; NMMNH P-4516, teeth (type B); NMMNH P-4517, tooth (type B); NMMNH P-4518, proximal coracoid; NMMNH P-4519, jaw fragment: NMMNH locality 114; NMMNH P-4477, osteoderm fragments: NMMNH locality 115; NMMNH P-4363, tooth (type B); NMMNH P-4367, tooth (type I); NMMNH P-4397, tooth (type U); NMMNH P-4408, tooth (type U); NMMNH P-4410, teeth fragments; NMMNH P-4413, tooth (type U); NMMNH P-4631, osteoderm; NMMNH P-4632, teeth fragments (type B): NMMNH locality 116; NMMNH P-4395, jaw fragments; NMMNH P-4497, dorsal vertebral fragments; NMMNH P-4501, jaw fragment: NMMNH P-4503, osteoderm fragments: NMMNH locality 117; NMMNH P-4365, centrum; NMMNH P-4392, centrum; NMMNH P-4483, osteoderm fragment: NMMNH locality 118; NMMNH P-4361, osteoderm fragment in sandstone; NMMNH P-4467, tooth (type C): NMMNH locality 119; NMMNH P-4362, mandible fragment; NMMNH P-4432, tip of snout: NMMNH locality 120; NMMNH P-4360, skull fragment (nasal area); NMMNH P-4389; NMMNH P- 4389, dorsal centrum; NMMNH P-4441, teeth (types B, U); NMMNH P-4446, jaw fragments; NMMNH P-4528, many skull fragments and caudal centra; NMMNH P-4549, proximal humerus; NMMNH P-4550, distal coracoid; NMMNH P-4551, vertebral fragments: NMMNH locality 121; NMMNH P-4642, dentary fragments: NMMNH locality 122; NMMNH P-4354, lower jaws; NMMNH P-4400, small osteoderm; NMMNH P-4468, osteoderm; NMMNH P-4493, very large cervical vertebra; NMMNH P-4523, jaw fragments; NMMNH P-4524, osteoderm fragments; NMMNH P-4525, skull fragments; NMMNH P-4526, dorsal vertebra fragments; NMMNH P-4527, scapula fragments; NMMNH P-4608, many osteoderm fragments; NMMNH P-4609, osteoderm; NMMNH P-4610, caudal centrum; NMMNH P-4611, humerus and ?limb bone fragments; NMMNH P-4619, osteoderm fragments: NMMNH locality 124; NMMNH P-4623, teeth (type I, B); NMMNH P-4624, caudal centra; NMMNH P-4626, osteoderm: NMMNH locality 126; NMMNH P-4383, jaw fragments; NMMNH P-4620, teeth fragments (Types C, I, B, U); NMMNH P-4622, skull fragments; NMMNH P-4628, pelvic fragments; NMMNH P-4629, dorsal centra; NMMNH P-4633, centra; NMMNH P-4634, osteoderms; NMMNH P-4635, skull fragments: NMMNH locality 128; NMMNH P-4419, dorsal centrum; NMMNH P-4453, skull fragments; NMMNH P-4473, dorsal centra: NMMNH locality 129; NMMNH P-4455, dentary fragment; NMMNH P-4479, distal scapula; NMMNH P-4492, osteoderm fragments: NMMNH locality 132; NMMNH P-4424, osteoderm fragments; NMMNH P-4428, teeth (types B, I, U); NMMNH P-4574, osteoderm fragment: NMMNH locality 133; NMMNH P-4511, osteoderm fragments; NMMNH P-4514, jaw fragments; NMMNH P-4515, ilium fragments: NMMNH locality 134; NMMNH P-4464, tip of dentary; NMMNH P-4472, teeth (types B, U); NMMNH P-4505, tooth fragment (type ?C); NMMNH P-4506, neural arch fragments; NMMNH P-4507, osteoderm fragment; NMMNH P-4508, cranial fragment; NMMNH P-4612, osteoderm fragments; NMMNH P-4615, skull fragments; NMMNH P-4637, dentary fragment; NMMNH P-4638, neural arch fragments: NMMNH locality 134; NMMNH P-4656, tooth: NMMNH locality 136; NMMNH P-4403, tooth (type B): NMMNH locality 140; NMMNH P-4486, neural spine and caudal centrum; NMMNH P-4544, osteoderm fragment: NMMNH locality 141; NMMNH P-4421, cervical vertebra: NMMNH locality 142; NMMNH P-4409, tooth (type B): NMMNH locality 146; NMMNH P-4457, osteoderm fragments: NMMNH locality 147; NMMNH P-4451, osteoderm fragments; NMMNH P-4521, skull fragments; NMMNH P-4546, osteoderm fragments: NMMNH locality 148; NMMNH P-4450, tooth (type U); NMMNH

P-4613, neural arch; NMMNH P-4616, skull fragment; NMMNH P-4618, teeth (type U): NMMNH locality 151; NMMNH P-4480, teeth fragments (type B, U); NMMNH P-4502, centrum fragment: NMMNH locality 152; NMMNH P-4476, osteoderm fragment: NMMNH locality 153; NMMNH P-4563, radius fragments: NMMNH locality 154; NMMNH P-4564, osteoderm fragments and small osteoderm: NMMNH locality 155; NMMNH P-4548, osteoderm fragment: NMMNH locality 156; NMMNH P-4561, osteoderm fragments: NMMNH locality 157; NMMNH P-4554, dentary fragments: NMMNH locality 160; NMMNH P-4570, osteoderm fragment; NMMNH P-4572, skull fragments: NMMNH locality 161; NMMNH P-4640, teeth (type C, U): NMMNH locality 162; NMMNH P-16629, osteoderm fragment: NMMNH locality 163; NMMNH P-4976, jaw fragments: NMMNH locality 164; NMMNH P-4690, partial crested rostrum: NMMNH locality 165; NMMNH P-4883, tooth fragment (type U); NMMNH P-4906, teeth fragments (type U); NMMNH P-4907, osteoderm fragments; NMMNH P-16511, teeth (type I, B); NMMNH P-16536, osteoderm; NMMNH P-16537, ilium fragment; NMMNH P-16584, metacarpal fragment; NMMNH P-16587, osteoderm fragment; NMMNH P-16596, rib end: NMMNH locality 166; NMMNH P-16527, pubis fragments; NMMNH P-16624, teeth fragments (type U); NMMNH P-16626, dorsal vertebral and neural arch fragments: NMMNH locality 169; NMMNH P-4899, skull fragment; NMMNH P-4900, osteoderm fragment; NMMNH P-16609, tooth fragment (type U): NMMNH locality 170; NMMNH P-16532, osteoderm fragments; NMMNH P-16834, centra: NMMNH locality 171; NMMNH P-4881, teeth fragments (type U, I); NMMNH P-16531, tibia/fibula fragments; NMMNH P-16635, teeth fragments; NMMNH P-16636, osteoderm; NMMNH P-16639, osteoderm fragments; NMMNH P-16896, tooth fragments: NMMNH locality 172; NMMNH P-4880, teeth (type I): NMMNH locality 173; NMMNH P-4857, teeth (type U, I); NMMNH P-4868, jaw fragment; NMMNH locality 174; NMMNH P-4873, teeth (type I); NMMNH P-16610, tooth fragments: NMMNH locality 175; NMMNH P-4876, dorsal rib (large); NMMNH P-4923, skull fragment; NMMNH P-16522, tooth (type U); NMMNH P-16530, mandible fragment; NMMNH P-16680, jaw fragments: NMMNH locality 177; NMMNH P-16533, sacral vertebra: NMMNH locality 178; NMMNH P-4889, pelvic fragments; NMMNH P-4892, partial dorsal centrum: NMMNH locality 179; NMMNH P-16509, osteoderm fragment: NMMNH locality 182; NMMNH P-16501, tooth fragments (type U); NMMNH P-16535, neural arch fragments: NMMNH locality 185; NMMNH P-16503, teeth (type B); NMMNH P-16534, teeth fragment: NMMNH locality 186; NMMNH P-4921, tooth (type U): NMMNH locality 189; NMMNH P-4930, osteoderm fragment: NMMNH locality 191; NMMNH P-4926, tooth (type U): NMMNH locality 192; NMMNH P-4938, femoral fragments: NMMNH locality 194; NMMNH P-16506, dentary fragment; NMMNH P-16514, osteoderms: NMMNH locality 195; NMMNH P-16516, humerus fragments; NMMNH P-16520, teeth fragments (type U); NMMNH P-16521, osteoderm fragments: NMMNH locality 196; NMMNH P-16510, proximal chevron; NMMNH P-16513, proximal calcaneum: NMMNH locality 198; NMMNH P-16502, proximal scapula; NMMNH P-16518, teeth (type B, I); NMMNH P-16519, osteoderm fragments: NMMNH locality 434; NMMNH P-17133, radius; NMMNH P-17338, tooth fragments: NMMNH locality 447; NMMNH P-16816, skull fragments; NMMNH P-16825, osteoderm: NMMNH locality 448; NMMNH P-16832, proximal coracoid; NMMNH P-16830, osteoderm fragment: NMMNH locality 450; NMMNH P-16821, osteoderm fragment: NMMNH locality 451; NMMNH P-16819, centrum; NMMNH P-16827, cervical centrum: NMMNH locality 452; NMMNH P-16850, caudal vertebra; NMMNH P-16851, osteoderms; NMMNH P-16854, teeth fragments (type U, B); NMMNH P-16856, vertebral fragments; NMMNH P-16860, teeth (type U): NMMNH locality 455; NMMNH P-16848, quadrate: NMMNH locality 461; NMMNH P-16881, osteoderm fragments: NMMNH locality 462; NMMNH P-16874, metatarsal; NMMNH P-16875, teeth fragments (type C, I, B): NMMNH locality 463; NMMNH P-16845, dorsal centrum; NMMNH P-16878, rib fragments: NMMNH locality 464; NMMNH P-16837, skull fragments: NMMNH locality 465; NMMNH P-16884, osteoderm fragments: NMMNH locality 466; NMMNH P-16900, osteoderm fragments: NMMNH locality 467; NMMNH P-16903, tooth; NMMNH P-16907, osteoderm fragment: NMMNH locality 497; NMMNH P-17170, teeth fragments; NMMNH P-17176, osteoderm fragment; NMMNH P-17244, rib fragments: NMMNH locality 498; NMMNH P-17138, juvenile hind limb (femur, tibia, fibula fragments, astragalus); NMMNH P-17185, teeth fragments (type U); NMMNH P-17190, partial juvenile pelvis: NMMNH locality 499; NMMNH P-17140, caudal vertebral fragments; NMMNH P-17173, phalanx; NMMNH P-17267, occipital condyle; NMMNH P-17269, osteoderms; NMMNH P-17273, osteoderm fragments: NMMNH locality 500; NMMNH P-17197, teeth (type I): NMMNH locality 502; NMMNH P-17128, iliac blade: NMMNH locality 506; NMMNH P-17129, rib fragments; NMMNH P-17403, osteoderm fragment; NMMNH P-17404, centrum fragment; NMMNH P-17405, metapodial fragment; NMMNH P-17407, osteoderm fragment: NMMNH locality 508; NMMNH P-17149; NMMNH P-17196, osteoderm; NMMNH P-17123, osteoderm fragments; NMMNH P-17249, teeth (type U) in conglomerate: NMMNH locality 510; NMMNH P-17204, distal neural spine: NMMNH locality 511; NMMNH P-17125, jaw fragments; NMMNH locality 512; NMMNH P-17147, central fragments; NMMNH P-17155, distal fibula; NMMNH P-17156, limb fragments; NMMNH P-17171, caudal centrum; NMMNH P-17243, ?metatarsal fragment: NMMNH locality 514; NMMNH P-17121, osteoderm; NMMNH P-17142, vertebral fragments: NMMNH locality 518; NMMNH P-17329, iliac fragments; NMMNH P-17414, osteoderms and osteoderm fragments; NMMNH P-17420, vertebral fragments; NMMNH P-17426, tip of neural spine; NMMNH P-17324, fragmentary anterior skeleton (interclavicle, vertebrae, phalange fragments); NMMNH P-17257, fragmentary skeleton (vertebrae, pubis, scapula): NMMNH locality 520; NMMNH P-17188, rib fragments: NMMNH locality 522; NMMNH P-17315, impression of tooth (?type C) in sandstone; NMMNH P-17383, caudal vertebrae; NMMNH P-17409, dorsal centrum; NMMNH P-17425, centra; NMMNH P-17428, caudal centrum; NMMNH P-17445, tooth (type I): NMMNH locality 523; NMMNH P-17452, neural spine: NMMNH locality 525; NMMNH P-17441, osteoderm; NMMNH locality 527; NMMNH P-17341, skull fragment; NMMNH P-17473, osteoderm fragments; NMMNH P-17477, jaw fragment; NMMNH P-17481, tooth fragments; NMMNH P-17484, skull fragment; NMMNH P-17502, cervical centrum: NMMNH locality 529; NMMNH P-17308, bone fragment; NMMNH P-17309, proximal ulna (large); NMMNH P-17310, femoral fragment; NMMNH P-17363, rib fragment; NMMNH P-17366, pelvic fragment; NMMNH P-17367, pelvic fragment; NMMNH P-17369, osteoderms; NMMNH P-17372, jaw fragment; NMMNH P-17393, tooth (type B) in conglomerate; NMMNH P-17395, neural arch fragments: NMMNH locality 530; NMMNH P-17439, osteoderm; NMMNH P-17447, tooth (type C); NMMNH P-17448, caudal centrum: NMMNH locality 534; NMMNH P-17387, juvenile ilium; NMMNH P-17396, juvenile ilium: NMMNH locality 535; NMMNH P-17349, osteoderm; NMMNH P-17353, cervical fragment; NMMNH P-17357, osteoderm fragment; NMMNH P-17358, tooth fragments (type U, B): NMMNH locality 536; NMMNH P-17334, rib fragments: NMMNH locality 537; NMMNH P-17298, dorsal vertebral and neural arch fragments; NMMNH P-17300, osteoderms; NMMNH P-17394, skull fragments; NMMNH P-4839, distal neural spine; NMMNH P-17437, rib fragments; NMMNH P-17438, osteoderm fragments: NMMNH locality 538; NMMNH P-17335, tooth fragment; NMMNH P-17430, proximal scapula; NMMNH P-17431, centrum; NMMNH P-17432, proximal ischium; NMMNH P-17471, osteoderm fragments: NMMNH locality 539; NMMNH P-17401, dentary fragment: NMMNH locality 540; NMMNH P-17378, cervical centrum: NMMNH locality 542; NMMNH P-17410, tooth fragment (type B); NMMNH P-17411, osteoderms; NMMNH P-17412, vertebral fragments; NMMNH P-17417, iliac blade; NMMNH P-17421, proximal ulna: NMMNH locality 546; NMMNH P-17450, skull fragments: NMMNH locality 548; NMMNH P-17348, rostrum (small): San Juan (sic), NM: UMMP 7234, cervical centra: 5 miles west of San Jon in Badlands; UMMP 7313, interclavicle; UMMP 7441 (part), juvenile rostrum tip; UMMP 7442, interclavicle: YPM locality 5831; fragmentary skull: YPM locality 5833 (in part); unnumbered osteoderms, skull fragments, teeth, ribs, dorsal vertebra, proximal pubis, partial interclavicle: YPM locality 6649 (in part); unnumbered two caudal centra, end of humerus: YPM locality 5887, unnumbered sacral vertebra.

First occurrence: *Paleorhinus* from numerous localities worldwide from the late Carnian (Triassic).

Last occurrence: *Redondasaurus* spp. From Late Norian/?Rhaetian(Triassic) of New Mexico, Utah and ?Oklahoma, *Angistorhinopsis ruetimeyeri* from the late Norian/Rhaetian of Germany and Switzerland, indeterminate phytosaurs from the Cliftonian (Rhaetian) of New Jersey and Connecticut.

Acme zone: Late Carnian-late Norian/ ?Rhaetian (Triassic) of North America and late Carnian-middle Norian of Europe.

Discussion: Clearly, specimens of indeterminate phytosaurs are the most common vertebrate fossils in the Bull Canyon Formation, as they are in all formations of the Chinle Group. Presumably the majority of specimens represent *Pseudopalatus pristinus* or *P. andersoni* because they are not very robust, as would be expected for the postcrania of *Pseudopalatus* n. sp. Skeletons from the Canjilon quarry of north-central New Mexico as well as specimens collected in this study (notably NMMNH P-20852) are adequate to allow the study of the complete osteology of *Pseudopalatus*. Such an osteological study would allow the identification of some of the Bull Canyon specimens, but most are too fragmentary to ever be diagnostic.

The acronyms for tooth types follow Hunt (1994) who recognized that there are only four types of phytosaurian teeth (Hunt, 1994, fig. 2): (1) caniniform teeth (type C) are elongate, medio-laterally compressed blades with fully serrated anterior and posterior margins that occur in the anterior portion of the jaws in very robust phytosaurs. In cross-section, these teeth are slightly asymmetrical, and the ratios of height to maximum length to maximum width are approximately 3.4:2.0:1.2; (2) "unserrated" teeth (type U) that are round to oval in cross-section, elongate and sometimes slightly recurved and have longitudinal striations or flutings. They are present in the anterior portions of most phytosaurian jaws and typically have height-to-diameter ratios of approximately 3:1; (3) intermediate teeth with incomplete serrated margins (type I). These teeth are subrounded in cross-section, bicarinate or unicarinate, elongate and sometimes slightly recurved. They form a continuum with type U teeth and occur between them and the fourth type of teeth in toothrows. Type I teeth have length to diameter ratios from 3:1 to 2.2:1; (4) blade teeth (type B) occur in the posterior portions of the dentitions of most phytosaurs. These teeth do not form a continuum with type I teeth. Type B teeth are laterally compressed but markedly asymmetrical in cross-section (rounded D-shaped) and have fully serrated anterior and posterior margins. They are relatively low-crowned (height:length approximately 1.3:1 to 2:1) and are generally restricted to the maxilla and posterior lower jaw.

?Parasuchidae Lydekker, 1888
gen. et sp. indet.

Type Revueltian occurrences: NMMNH localities 1, 16, 33, 35, 41, 53-54, 58, 67, 92, 116, 122, 127, 129, 132, 135, 145, 147, 169, 157-158, 167, 448, 523.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4789, tooth: NMMNH locality 16; NMMNH P-4353, proximal tibia: NMMNH locality 33; NMMNH P-4510, pelvis fragment with tooth marks: NMMNH locality 35; NMMNH P-4304, ?caudal vertebra: NMMNH locality 41; NMMNH P-4286, ?radius fragment: NMMNH locality 53; NMMNH P-4261, teeth: NMMNH P-4262, rib fragment: NMMNH locality 54; NMMNH P-4277, bone with invertebrate borings: NMMNH locality 58; NMMNH P-4250, tooth: NMMNH locality 67; NMMNH P-4218, jaw fragment with tooth; NMMNH P-4216, tooth: NMMNH locality 92; NMMNH P-4135, tooth: NMMNH locality 116; NMMNH P-4500, ?distal radius: NMMNH locality 122; NMMNH P-4543, ?humerus fragment; NMMNH P-4494, ?distal tibia; NMMNH P-4416, distal tibia; NMMNH P-4621, jaw fragment: NMMNH locality 127; NMMNH P-4593, distal limb: NMMNH locality 129; NMMNH P-4478, ?ilium fragment: NMMNH locality 132; NMMNH P-4587, zygapophysis: NMMNH locality 135; NMMNH P-4495, bone: NMMNH locality 145; NMMNH P-4454, ?pubic fragments: NMMNH locality 147; NMMNH P-4459, skull fragments: NMMNH locality 169; NMMNH P-16606, sacral vertebra: NMMNH locality 157; NMMNH P-4555, proximal rib: NMMNH locality 158; NMMNH P-4545, jaw fragment in sandstone: NMMNH locality 167; NMMNH P-16512, teeth: NMMNH locality 448; NMMNH P-16831, scapula fragment: NMMNH locality 523; NMMNH P-17454, osteoderm fragment.

First occurrence: *Paleorhinus* from numerous localities worldwide from the late Carnian (Triassic).

Last occurrence: *Redondasaurus* spp. From Late Norian/?Rhaetian(Triassic) of New Mexico, Utah and ?Oklahoma, *Angistorhinopsis ruetimeyeri* from the late Norian/Rhaetian of Germany and Switzerland, indeterminate phytosaurs from the Cliftonian (Rhaetian) of New Jersey and Connecticut.

Acme zone: Late Carnian-late Norian/ ?Rhaetian (Triassic) of North America and late Carnian-middle Norian of Europe.

Discussion: A large number of specimens from the Bull Canyon Formation show similarities in size and morphology to phytosaurs, but are too fragmentary to allow unequivocal assignment to the Parasuchidae.

Aetosauria Lydekker in Nicholson and Lydekker, 1889
Stagonolepididae Lydekker, 1887
Typothorax coccinarum Cope, 1875

Type Revueltian occurrences: NMMNH localities 1, 18, 22, 32, 33, 35, 38, 42-43, 46, 48, 49, 51, 53, 62, 64, 67, 70, 72, 75, 82, 86, 89, 94-95, 99, 107, 109, 110, 116-117, 125, 132, 134, 140, 146-148, 155, 157, 162, 165- 166, 169-171, 174, 177, 180, 182, 185, 194, 196-197, 401, 404, 420, 447, 449, 451-452, 454, 457, 465, 499-501, 505, 507, 513-515, 518-519, 528-530, 533-535, 537, 539, 541-542, 547, 2640; UCM locality 82021.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4671, paramedian osteoderm fragments; NMMNH P-4672, lateral osteoderm fragment; NMMNH P-4674, paramedian osteoderm fragment; NMMNH P-4675, lateral osteoderm fragments; NMMNH P-4912, osteoderms; NMMNH P-4951, paramedian osteoderm fragment; NMMNH P-16556, lateral osteoderm fragments; NMMNH P-16557, lateral osteoderm fragments; NMMNH P-16559, paramedian osteoderm fragments; NMMNH P-16562, paramedian osteoderm fragments; NMMNH P-16570, paramedian osteoderm fragments: NMMNH P-16576, paramedian osteoderm fragment; NMMNH P-16578, paramedian osteoderm fragment; NMMNH P-16580, paramedian osteoderm fragments; NMMNH P-16581, lateral osteoderm fragments; NMMNH P-16695, paramedian osteoderm fragment; NMMNH P-16686, paramedian osteoderm fragment; NMMNH P-16913, lateral osteoderm fragment: NMMNH locality 18; NMMNH P-4346, paramedian osteoderm fragments: NMMNH locality 20; NMMNH P-4349: NMMNH locality 22; NMMNH P-4345, paramedian osteoderm fragment; NMMNH locality 25; NMMNH P-4982, paramedian osteoderm: NMMNH locality 28; NMMNH P-4333, paramedian osteoderm fragments: NMMNH locality 32; NMMNH P-4296, osteoderm fragments: NMMNH locality 33; NMMNH P-4513, paramedian osteoderm fragment: NMMNH locality 34; NMMNH P-4151, paramedian osteoderm fragments; NMMNH P-4162, paramedian osteoderm fragments; NMMNH P-4293, paramedian osteoderm fragments: NMMNH locality 35; NMMNH P-4210, paramedian osteoderm fragment: NMMNH locality 38; NMMNH P-4289, lateral osteoderm fragments; NMMNH P-4288, paramedian osteoderm fragment; NMMNH P-4311, paramedian osteoderm fragments: NMMNH locality 42; NMMNH P-4282, osteoderm fragments; NMMNH P-4284, paramedian osteoderm fragments: NMMNH locality 43; NMMNH P-4269, paramedian osteoderm fragments; NMMNH P-4283, paramedian osteoderm fragments: NMMNH locality 46; NMMNH P-4205, large paramedian osteoderm fragments: NMMNH locality 48; NMMNH P-4207, paramedian osteoderm fragments: NMMNH locality 49; NMMNH P-4208, lateral osteoderm fragment: NMMNH locality 51; NMMNH P-4275, paramedian osteoderm fragments: NMMNH locality 53; NMMNH P-4189, paramedian osteoderm fragments: NMMNH P-4161, paramedian osteoderm fragments; NMMNH P-4195, paramedian osteoderm fragments: NMMNH locality 62; NMMNH P-4954, osteoderm fragments: NMMNH locality 64; NMMNH P-4242, paramedian osteoderm fragment: NMMNH locality 67; NMMNH P-4176, paramedian osteoderm fragments in sandstone; NMMNH P-4214, paramedian osteoderm fragment: NMMNH locality 70; NMMNH P-4150, paramedian osteoderm fragments: NMMNH locality 72; NMMNH P-4232, paramedian osteoderm fragment: NMMNH locality 75; NMMNH P-17303, paramedian osteoderm fragments: NMMNH locality 82; NMMNH P-4175, paramedian osteoderm fragments: NMMNH locality 86; NMMNH P-4179, paramedian osteoderm fragments; NMMNH P-16632, paramedian osteoderm fragments: NMMNH locality 89; NMMNH P-17175, paramedian osteoderm fragment: NMMNH locality 94; NMMNH P-4115, paramedian and lateral osteoderm fragments: NMMNH locality 95; NMMNH P-4121, paramedian osteoderm fragment: NMMNH locality 99; NMMNH P-4125, paramedian osteoderm fragments: NMMNH locality 107; NMMNH P-4105, paramedian osteoderm fragment: NMMNH locality 109; NMMNH P-4102, paramedian osteoderm fragment: NMMNH locality 110; NMMNH P-4532, paramedian osteoderm fragment; NMMNH P-4539, paramedian osteoderm fragment; NMMNH P-4575, small paramedian osteoderm fragment; NMMNH P-4644, paramedian osteoderm fragments: NMMNH locality 116; NMMNH P-4499, paramedian osteoderm fragment: NMMNH locality 117; NMMNH P-4482, paramedian osteoderm fragment: NMMNH locality 125; NMMNH P-4382, paramedian osteoderm fragments: NMMNH locality 132; NMMNH P-4373, caudal vertebrae; NMMNH P-4378, centra; NMMNH P-4391, paramedian osteoderm fragments; NMMNH P-4594, centrum: NMMNH locality 134; NMMNH P-4401, paramedian osteoderm fragments; NMMNH P-4639, paramedian osteoderm fragment: NMMNH locality 140; NMMNH P-4541, paramedian osteoderm fragments: NMMNH locality 146; NMMNH P-4461, paramedian osteoderm fragments: NMMNH locality 147; NMMNH P-4458, paramedian osteoderm fragment: NMMNH locality 148; NMMNH P-4617, osteoderm fragment: NMMNH locality 155; NMMNH P-4565, paramedian osteoderm fragments: NMMNH locality 157; NMMNH P-4553, paramedian and lateral osteoderm fragments: NMMNH locality 162; NMMNH P-16628, lateral osteoderm fragments; NMMNH P-16815, paramedian osteoderm fragments: NMMNH locality 165; NMMNH P-4903, paramedian osteoderm fragment; NMMNH P-4904 lateral osteoderm fragments; NMMNH P-4953, many paramedian osteoderm fragments; NMMNH P-16569, associated paramedian osteoderms; NMMNH P-16572, paramedian osteoderm fragments; NMMNH P-16579, paramedian osteoderm fragment: NMMNH locality 166; NMMNH P-4865, cervical vertebra; NMMNH P-16565, paramedian osteoderm fragments: NMMNH locality 169; NMMNH P-4915, paramedian osteoderm fragments; NMMNH P-16618, paramedian osteoderm fragment;

NMMNH P-16575, paramedian osteoderm fragments; NMMNH P-16780, paramedian osteoderm fragments: NMMNH locality 170; NMMNH P-4897, paramedian osteoderm fragments; NMMNH P-16564, paramedian osteoderm fragments: NMMNH locality 171; NMMNH P-16634, lateral osteoderm fragments: NMMNH locality 174; NMMNH P-16566, paramedian osteoderm fragment: NMMNH locality 177; NMMNH P-16577, paramedian osteoderm fragment: NMMNH locality 180; NMMNH P-4911, paramedian osteoderm fragments: NMMNH locality 182; NMMNH P-4950, lateral osteoderm; NMMNH P-16582, paramedian osteoderm fragments: NMMNH locality 185; NMMNH P-16568, paramedian osteoderm fragment: NMMNH locality 194; NMMNH P-16561, paramedian osteoderm fragments: NMMNH locality 196; NMMNH P-16555, paramedian osteoderm fragment: NMMNH locality 197; NMMNH P-16545, paramedian osteoderm fragments; NMMNH P-16560, lateral osteoderm fragments: NMMNH locality 401; NMMNH P-17581, paramedian osteoderm fragments: NMMNH locality 404; NMMNH P-3679, paramedian osteoderm fragment: NMMNH locality 420; NMMNH P-17568, paramedian osteoderm fragments: NMMNH locality 447; NMMNH P-16820, paramedian osteoderm fragments: NMMNH locality 449; NMMNH P-16833, paramedian osteoderm fragments: NMMNH locality 451; NMMNH P-16822, paramedian osteoderm fragment: NMMNH locality 452; NMMNH P-16852, paramedian and lateral osteoderm fragments: NMMNH locality 454; NMMNH P-16868, paramedian and lateral osteoderms; NMMNH P-16869, paramedian osteoderm fragments: NMMNH locality 457; NMMNH P-16880, paramedian osteoderm fragments: NMMNH locality 465; NMMNH P-16885, paramedian osteoderm fragments: NMMNH locality 499; NMMNH P-17137, many paramedian osteoderm fragments; NMMNH P-17265, paramedian osteoderm fragments: NMMNH locality 500; NMMNH P-17263, osteoderm fragment: NMMNH locality 501; NMMNH P-17116, small paramedian osteoderm fragments; NMMNH P-17118, small paramedian osteoderm fragments; NMMNH P-17127, many small paramedian osteoderm fragments; NMMNH P-17214, small paramedian osteoderm: NMMNH locality 505; NMMNH P-17208, paramedian osteoderm fragments: NMMNH locality 507; NMMNH P-17210, paramedian osteoderm fragment: NMMNH locality 513; NMMNH P-17251, paramedian osteoderm fragments: NMMNH locality 514; NMMNH P-17120, paramedian osteoderm fragments: NMMNH locality 515; NMMNH P-17135, paramedian osteoderm fragments: NMMNH locality 518; NMMNH P-17136, paramedian osteoderm fragments; NMMNH P-17419, large paramedian osteoderm fragments; NMMNH P-17429, paramedian osteoderm fragments: NMMNH locality 519; NMMNH P-17180, paramedian osteoderm fragments: NMMNH locality 528; NMMNH P-17345, osteoderm fragment: NMMNH locality 529; NMMNH P-17365, lateral osteoderm fragment; NMMNH P-17368, paramedian osteoderm fragments; NMMNH P-17371, cervical vertebrae; NMMNH P-17391, paramedian osteoderm fragment: NMMNH locality 530; NMMNH P-17440, paramedian osteoderm fragment: NMMNH locality 533; NMMNH P-17307, paramedian osteoderm: NMMNH locality 534; NMMNH P-17385, paramedian osteoderm fragments: NMMNH locality 535; NMMNH P-17350, paramedian osteoderm fragments: NMMNH locality 537; NMMNH P-17299, paramedian osteoderm fragments: NMMNH locality 539; NMMNH P-17402, lateral osteoderm fragment; NMMNH P-17408, paramedian osteoderm fragments: NMMNH locality 541; NMMNH P-17340, lateral osteoderm fragment: NMMNH locality 542; NMMNH P-17413, paramedian osteoderm fragments: NMMNH locality 547; NMMNH P-17344, paramedian osteoderm fragments: NMMNH locality 2640; NMMNH P-12964, complete articulated skeleton: UCM locality 82021; UCM 47725, paramedian osteoderms.

First and last occurrences: Several localities in Revueltian (early-middle Norian) strata in Arizona and New Mexico.

Acme zone: Revueltian (early-middle Norian).

Discussion: Osteoderm fragments of *Typothorax coccinarum* are the most common generically identifiable specimens of aetosaurs from the Bull Canyon Formation. *Typothorax* dorsal paramedian osteoderms are readily identifiable, even from fragmentary specimens, because of two features. The dorsal ornamentation is a pattern of shallow, rounded pits that are irregularly arranged, and the paramedian osteoderms have a deep ventral keel so that the ventral margin of the osteoderm is strongly convex. Dorsal lateral osteoderms are characterized by equal-sized ventral and dorsal processes, by a rounded triangular dorsal/ventral outline and by a sharp angulation in anterior/posterior view. Virtually all aetosaur osteoderms of *Typothorax* from the Bull Canyon Formation are from the dorsal series.

Few specimens of *Typothorax* from the Bull Canyon Formation are not isolated osteoderms. A notable exception is NMMNH P-12964, which is a nearly complete articulated specimen of this species (Hunt et al., 1993b, Fig. 6). Preparation of this specimen is incomplete at this time. Therefore, only a few preliminary observations can be presented.

NMMNH P-12964 is an articulated skeleton lying on its right side. The body length is approximately 2.5 m, and the entire axial body is sheathed in armor plates. Paramedian osteoderms are dominantly flat and rectangular in shape. Lateral osteoderms are nearly flat in the caudal region to highly arched in the dorsal region. Most osteoderms have an ornamentation of round shallow pits. Some osteoderms have a raised boss among the pits. The body is very wide, and the widest paramedian osteoderms are almost as long as the femur. The tibia and fibula are almost half the length of the femur. The forelimb is shorter than the hind limb. The neck is extremely short, and each cervical vertebra is at most 20% of the length of the longest of the dorsal series. Dorsal ribs appear to be fused to the vertebrae. In *Typothorax*, the gradual transition between the dorsal and cervical armor shown by Long et al. (1989, fig. 3A) is erroneous as is the shortness of the tail. The tail actually accounts for about half the length of the animal, and the carapace narrows rapidly in the shoulder region. The dorsal carapace is strongly discoid. The skull is very small, with a length of about 20 cm, and the lower jaw is relatively shallow. Teeth are bulbous, with waisted crown bases and no serrations (Fig. 6A).

NMMNH P-12964 can be assigned to the stagonolepidid species *Typothorax coccinarum* because it possessed wide paramedian osteoderms with a deep ventral keel and a dorsal ornamentation of round pits. These characters are also present in *Redondasuchus reseri* (Hunt and Lucas, 1991a) and in an undescribed genus from the Los Esteros Member of the Santa Rosa Formation. However, *T. coccinarum*, as represented by NMMNH P-12964, possesses several autapomorphies including the broad, discoid carapace, short neck, short distal lower hind limbs and small skull.

The skull, and cervical and caudal vertebrae of NMMNH P-12964 are in articulation, but the thoracic cavity is breached and disorganized. Much of the dorsal series of paramedian osteoderms is visible in ventral view, and most of the dorsal vertebrae and ribs are either absent or are dislocated. One dorsal rib was found about 1 meter from the skeleton. Obviously, an extremely wide-bodied and dorsoventrally compressed animal such as *Typothorax* would be unstable if it lay on its side. The carapace would tend to fracture and come to equilibrium in a horizontal plane. This would explain the rotation of the thoracic region relative to the rest of the skeleton. However, the internal disruption of the body cavity is best explained by scavenger activity.

The skeleton is very complete and occurs in a fine-grained matrix (silty mudstone). These features suggest a low energy environment in which the skeleton was not moved. The combination of limited scavenger damage and fine preservation of much of the skeleton suggests a short period of subaerial exposure before rapid burial.

Some *Typothorax* specimens are small (= ?juvenile) (e.g., NMMNH P-17116, 17118, 17127, 17214)(Fig. 5C-H). These indicate that the ornamentation of stagonolepidid osteoderms did not change through ontogeny. Thus, small (= ?juvenile) specimens of *Typothorax* have the same ornament as large specimens.

?Typothorax sp.

Type Revueltian occurrences: NMMNH localities 110, 134, 499-500: UMMP locality San Juan (sic).

Referred specimens from type Revueltian: NMMNH locality 110; NMMNH P-4606, tooth: NMMNH locality 134; NMMNH P-4504, paramedian osteoderm fragment: NMMNH locality 499; NMMNH P-17282, many small lateral osteoderm fragments: NMMNH locality 500; NMMNH P-17241, astragalus: San Juan (sic), New Mexico; UMMP 7241 (in part), lateral osteoderm fragment.

First and last occurrences: Several localities in Revueltian (early-middle Norian) strata in Arizona and New Mexico.

Acme zone: Revueltian (early-middle Norian).

Discussion: Some osteoderm fragments from the Bull Canyon Formation have the general morphology of *Typothorax* osteoderms, but they are too fragmentary and/or weathered to allow exact identification.

Aetosaurus arcuatus (Marsh, 1896)

Type Revueltian occurrences: NMMNH localities 499-502, 519, 521.

Referred specimens from type Revueltian: NMMNH locality 499; NMMNH P-17279, chevrons: NMMNH locality 500; NMMNH P-17145, paramedian osteoderm fragment; NMMNH P-17193, lateral osteoderm fragments; NMMNH P-17233, vertebrae; NMMNH P-17234, paramedian osteoderm fragments; NMMNH P-17280, paramedian osteoderm fragments: NMMNH locality 501; NMMNH P-17117, many paramedian osteoderm fragments; NMMNH P-17126, paramedian and lateral osteoderm fragments; NMMNH P-17130, left femur; NMMNH P-17131, many osteoderm and limb fragments; NMMNH P-17163,

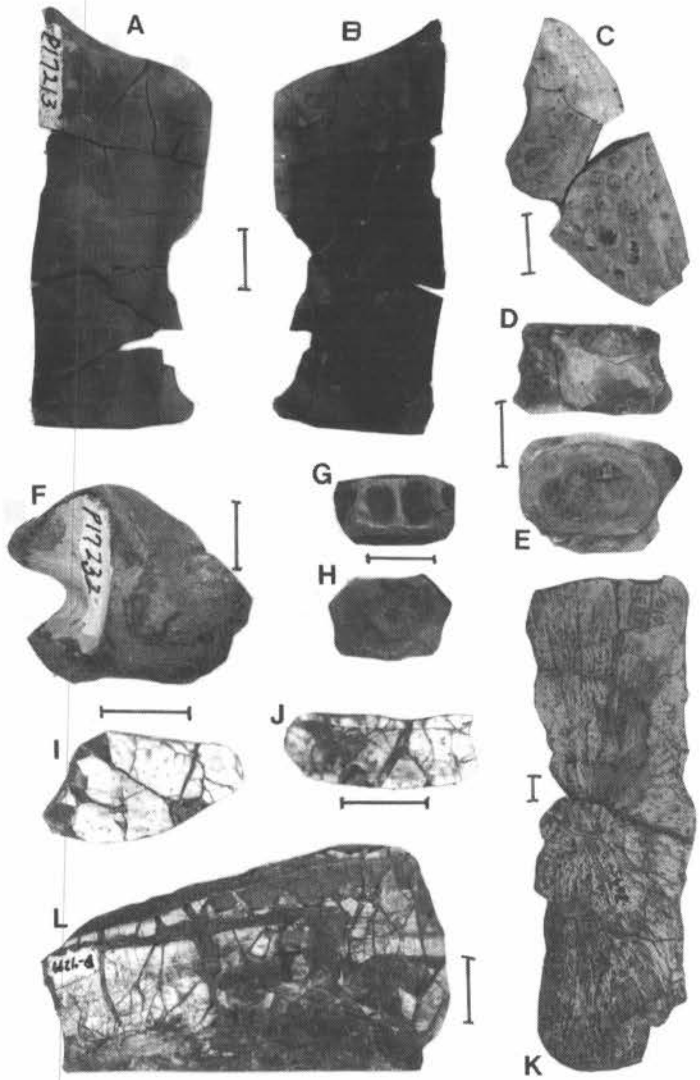

FIGURE 5. Aetosaurs from the Bull Canyon Formation. A-B. *Aetosaurus arcuatus*. A-B. Paramedian scute (NMMNH P-17213) in ventral (A) and dorsal (B) views. C-H. Juvenile *Typothorax coccinarum*, C. Lateral scute (NMMNH P-17161) in dorsal view. D-E, Cervical vertebra of NMMNH P-17231 in dorsal (D) and anterior (E) views. F. Astragalus(NMMNH P-17232) in dorsal view. G-H, Cervical vertebra (NMMNH P-17231) in ventral (G) and anterior (H) views. I. Dorsal paramedian scute of *Paratypothorax* sp. (YPM 3695) in dorsal view. J-L. Parts of skeleton of ?gen et sp. nov. (NMMNH P-4299). J. Lateral scute in dorsal view. K. ?Caudal paramedian scute in dorsal view. L. Articulated dorsal paramedian scutes. Scale bars are 1 cm.

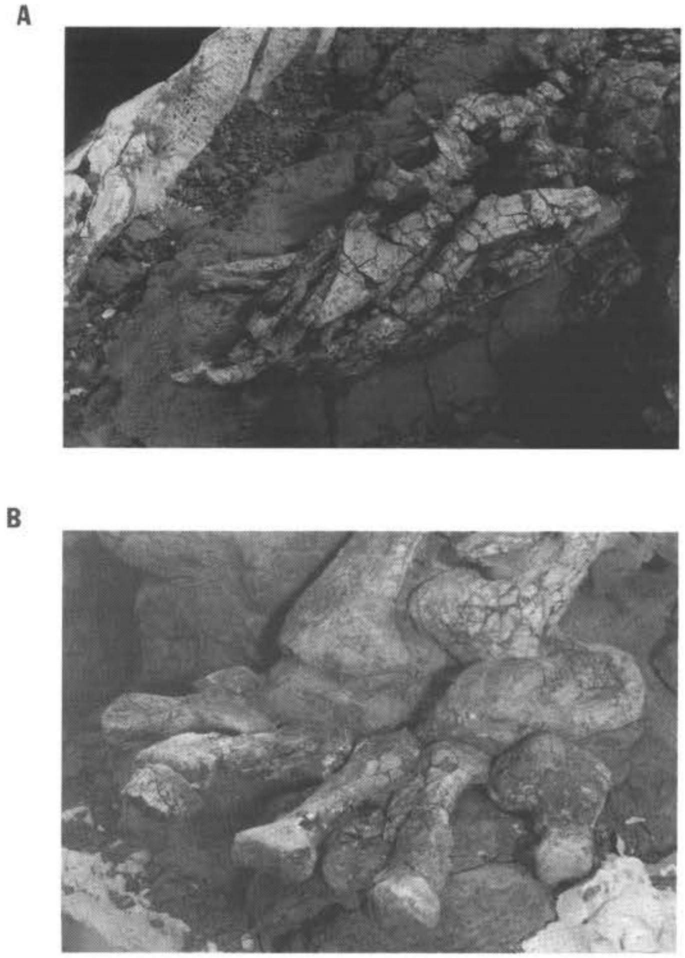

FIGURE 6. Complete skeleton of *Typothorax coccinarum* (NMMNH P-12964) from the Bull Canyon Formation. A. Detail of skull region. B. Detail of foot.

paramedian osteoderm fragments; NMMNH P-17165, paramedian osteoderm fragment; NMMNH P-17167, paramedian osteoderm fragments; NMMNH P-17168, paramedian osteoderm fragment; NMMNH P-17174, 4 cervical vertebrae; NMMNH P-17212, paramedian osteoderm fragments; NMMNH P-17213, paramedian osteoderm (Fig. 5A-B); NMMNH P-17215, paramedian osteoderm fragment ; NMMNH P-17216, paramedian osteoderm; NMMNH P-17218, mold of lateral osteoderm; NMMNH P-17220, lateral osteoderm fragments; NMMNH P-17221, osteoderm fragments; NMMNH P-17228, paramedian osteoderms; NMMNH P-17230, proximal end of left femur; NMMNH P-17231, cervical centra; NMMNH P-17232, manus, pes and tarsus elements; NMMNH P-17286, paramedian osteoderm fragment; NMMNH P-17287, paramedian and lateral osteoderm fragments; NMMNH P-17236, pubis and ischium fragments: NMMNH P-17238, ulnae; NMMNH P-17239, metapodial; NMMNH P-17247, vertebrae, osteoderms: NMMNH locality 502; NMMNH P-17161, lateral and paramedian osteoderm fragments: NMMNH locality 519; NMMNH P-17162, lateral and paramedian osteoderm fragments: NMMNH locality 521; NMMNH P-17223, paramedian osteoderm; NMMNH P-17227, osteoderm fragments.

First and last occurrence: Early-mid Norian (Triassic) of Neshanician of eastern North America and Revueltian of western North America.

Acme zone: Early-mid Norian (Triassic)

Discussion: Hunt (1994) described a number of specimens of a small aetosaur that were subsequently identified by Heckert and Lucas (1998) as pertaining to *Aetosaurus arcuatus*. NMMNH P-17213, is a left dorsal, paramedian osteoderm that is 75 mm in length and 31 mm wide (Fig. 5A-B). The medial margin is thickened to 3 mm. The lateral margin is concave, and the width of the osteoderm increases anteriorly. A narrow anterior bar widens laterally. The dorsal ornamentation is a faint radial pattern. The osteoderm is slightly concave. Another dorsal paramedian osteoderm is NMMNH P-17165, which is 76 mm in length and 27 mm wide. This osteoderm has a small, triangular, anteriorly-directed prong on the anteromedial corner. Ventral osteoderms (e.g., NMMNH P-17167) are ovoid in shape with a maximum diameter of 10 mm.

NMMNH localities 499, 500, 501, 502, 519 and 521 are discrete areas along a 30-m-long outcrop. These localities yield a fauna of small terrestrial tetrapods. To facilitate discrimination of some individual skeletons, the outcrop was divided into several localities. However, it is clear that only two taxa of aetosaurs are present in this outcrop, one is a juvenile *Typothorax* and the other is *Aetosaurus arcuatus*. The majority of *Aetosaurus arcuatus* specimens are of similar size and may represent one scattered individual.

gen. et sp. nov.?

Type Revueltian occurrence: NMMNH locality 36.

Referred specimens from type Revueltian: NMMNH locality 36; NMMNH P-4299, one partial, articulated skeleton and parts of a smaller skeleton (Fig. 5J-L).

First and last occurrence: Revueltian (Triassic: early-middle Norian) of east-central New Mexico.

Acme zone: Revueltian (Triassic: early-middle Norian).

Discussion: All specimens of this ?new taxon were found in a calcareous concretionary layer that also includes NMMNH locality 75, which yields three-dimensional fish. The aetosaur specimens are partially articulated but are imbedded in concretionary material. Much preparation will be required before the osteology of this taxon can be adequately described. However, enough morphological features can be discerned in the osteoderms for some preliminary observations. Fused neural arches indicate that the specimens do not represent juveniles.

Paramedian osteoderms are very long and narrow. A mid-dorsal paramedian osteoderm is at least 70 mm in length and 20 mm in width. The dorsal ornamentation consists of very shallow, small round indentations and shallow elongate grooves which may be slightly radial in pattern. There is a raised anterior bar, and the lateral margin is slightly sinuous. Paramedian osteoderms are a rounded triangle in dorsal view. A mid-dorsal lateral osteoderm is 22 mm long and 16 mm wide. The ornamentation is shallow, small, round indentations. Small nearly square osteoderms (18 mm by 15 mm) of the caudal series or ventral cuirass have a shallow radial pattern. A maxilla fragment preserves a portion of a laterally-compressed, but unserrated tooth. The laterally compressed teeth are unusual for aetosaurs, and their morphology and size suggests an insectivorous diet. The majority of the other skeletal remains require preparation and include femora, limb and podial fragments, cervical and dorsal vertebrae (with fused neural arches), ilia, an articulated tarsus, and a partial, slightly disarticulated dorsal carapace.

This taxon appears to be distinct in possessing very wide and narrow dorsal paramedian osteoderms (length:width ratio at least 3.5:1) with a very shallow ornamentation and a slightly sinuous lateral margin. The ornamentation of the osteoderms suggests an affinity to *Aetosaurus arcuatus*.

***Paratypothorax* sp. Long and Ballew, 1985**

Type Revueltian occurrences: NMMNH locality 165: YPM locality 3695.

Referred specimens from type Revueltian: NMMNH locality 165; NMMNH P-4937, osteoderm fragments: YPM locality 5833; YPM 3695, complete paramedian osteoderm and fragment of the lateral margin of a second (Fig. 5K).

First occurrence: Adamanian (Triassic: late Carnian) from Arizona, New Mexico and Texas.

Last occurrence: Revueltian (Triassic: early-mid Norian) of Arizona, New Mexico, Texas and Colorado.

Acme zone: None.

Discussion: YPM 3695 is a thin, long paramedian osteoderm of the dorsal series of a stagonolepidid with a radial ornamentation (Fig. 5K). This specimen has previously been incorrectly identified as the stagonolepidid *Typothorax* cf. *coccinarum*, with "grave doubts" (Gregory, 1953, p. 12), the phytosaur *Phytosaurus* (Gregory, 1962) and the stagonolepidid *Stagonolepis* (=*Calyptosuchus*) *wellesi* (Long and Ballew, 1985). However, the radial ornamentation, thinness of the osteoderm and its length clearly demonstrate that this specimen pertains to *Paratypothorax*. This specimen cannot be assigned to a particular species of the genus in the absence of more complete material, notably lateral osteoderms.

***?Paratypothorax* sp.**

Type Revueltian occurrences: NMMNH localities 113, 150, 169, 422.

Referred specimens from type Revueltian: NMMNH locality 113; NMMNH P-4387, paramedian osteoderm fragment: NMMNH locality 150; NMMNH P-4443, paramedian osteoderm fragment: NMMNH locality 169; NMMNH P-4898, paramedian osteoderm fragment: NMMNH locality 422; NMMNH P-3670, mid-cervical lateral spike.

First occurrence: Adamanian (Triassic: late Carnian) from Arizona, New Mexico and Texas.

Last occurrence: Revueltian (Triassic: early-mid Norian) of Arizona, New Mexico and Texas and Colorado.

Acme zone: None.

Discussion: Fragmentary paramedian osteoderms that apparently have a radial ornamentation are tentatively assigned to *Paratypothorax*. One lateral spike (NMMNH P-3670) is laterally compressed and may represent this genus.

***Desmatosuchus* n. sp.**

Type Revueltian occurrences: NMMNH localities 171, 420: UCM locality 82021.

Referred specimens from type Revueltian: NMMNH locality 171; NMMNH P-4894, lateral spike; NMMNH P-4895, lateral spike: NMMNH locality 420; NMMNH P-3668, small lateral spike: UCM locality 82021; UCM 47225, lateral osteoderm.

First and last occurrence: Revueltian (Triassic: early-middle Norian) of north-central and east-central New Mexico.

Acme zone: Revueltian (Triassic: early-middle Norian).

Discussion: The best specimen of *Desmatosuchus* in the Bull Canyon fauna is UCM 47225, a cervical lateral osteoderm. It differs from other specimens of this genus in having a recurved spike, but this could be a preservational artifact (it is not a preservational artifact). However, recently Heckert and Zeigler have collected new specimens from the Petrified Forest Formation of Rio Arriba County, New Mexico that demonstrate the presence of a new species of *Desmatosuchus* in the Revueltian to which UCM 47225 pertains. Parrish and Carpenter (1986) assigned paramedian osteoderm fragments to *Desmatosuchus*, but they actually pertain to *Typothorax* (see above). Fragmentary NMMNH specimens consist of broken lateral spikes. These are rounded in cross section, in contrast to the compressed spikes of an undescribed species of *Paratypothorax* from the Bull Canyon Formation of west Texas.

Stagonolepididae Lydekker, 1887
gen. et sp. indeterminate

Type Revueltian occurrences: NMMNH localities 57, 64, 75, 79, 90, 162-163, 165, 173, 181, 376, 447, 462, 497, 499: UMMP locality San Juan (sic).

Referred specimens from type Revueltian: NMMNH locality 57; NMMNH P-17436, paramedian osteoderm fragment: NMMNH locality 64; NMMNH P-4130, paramedian and lateral osteoderm fragments: NMMNH locality 75; NMMNH P-4188, rib fragment: NMMNH locality 79; NMMNH P-4171, osteoderm fragment; NMMNH P-4173, caudal centra: NMMNH locality 90; NMMNH P-17422, tibia: NMMNH locality 162; NMMNH P-16627, paramedian osteoderm fragment: NMMNH locality 163; NMMNH P-4339, osteoderm fragment: NMMNH locality 165; NMMNH P-4908, vertebral fragments; NMMNH P-4922, paramedian osteoderm fragments: NMMNH locality 173; NMMNH P-16546, paramedian osteoderm in conglomerate: NMMNH locality 181; NMMNH P-4940, ?proximal femur; NMMNH P-4941, proximal femur; NMMNH P-4943, limb fragment; NMMNH P-4944, articulated tail fragments: NMMNH locality 376; NMMNH P-14394, paramedian osteoderm fragment: NMMNH locality 447; NMMNH P-16826, paramedian osteoderm fragment: NMMNH locality 462; NMMNH P-16877, paramedian osteoderm fragment: NMMNH locality 497; NMMNH P-17172, paramedian osteoderm fragment: NMMNH locality 499; NMMNH P-17139, caudal centra: San Juan (sic), New Mexico; UMMP 7274 (in part), lateral osteoderm fragment.

First occurrence: Several genera from the Otischalkian (Triassic: late Carnian) of Texas and *Longosuchus* from Morocco.

Last occurrence: *Redondasuchus* and *Neoaetosauroides* from the Apachean (Triassic: late Norian-?Rhaetian) of New Mexico and *Neoaetosauroides* from the late Norian-?Rhaetian of Argentina.

Acme zone: None.

Discussion: A number of fragmentary and/or weathered osteoderms cannot be identified more closely than Stagonolepididae

?Stagonolepididae Lydekker, 1887

Type Revueltian occurrences: NMMNH localities 1, 134, 162.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-16891, dorsal centra: NMMNH locality 134; NMMNH P-4463, cervical centrum: NMMNH locality 162; NMMNH P-4861, caudal centra.

First occurrence: Several genera from the Otischalkian (Triassic: late Carnian) of Texas and *Longosuchus* from Morocco.

Last occurrence: *Redondasuchus* and *Neoaetosauroides* from the Apachean (Triassic: late Norian-?Rhaetian) of New Mexico and *Neoaetosauroides* from the late Norian-?Rhaetian of Argentina.

Acme zone: None.

Discussion: A few vertebral centra from the Bull Canyon Formation are similar to stagonolepidid centra but cannot be definitely assigned to the family.

Rauisuchidae Price, 1946
***Postosuchus kirkpatricki* Chatterjee, 1985**

Type Revueltian occurrence: NMMNH locality 51.

Referred specimens from type Revueltian: NMMNH locality 51; NMMNH P-4178, pubic and ilium fragments, dorsal and sacral vertebrae.

First occurrence: Adamanian (Triassic: late Carnian) of Texas and Arizona.

Last occurrence: Revueltian (Triassic: early-middle Norian) of New Mexico, Texas and Arizona. Note that I do not consider a CM specimen of a rauisuchian from the Whitaker quarry at Ghost ranch to pertain to *Postosuchus* (*contra* Long and Murry, 1995) and the RHMP ilium from the same locality that Long and Murry (1995) assign to *Postosuchus* is associated with sphenosuchian scutes and does not pertain to a rauisuchian (see below).

Acme zone: None

Discussion: NMMNH P-4178 is a partial pelvis and posterior dorsal vertebra of a large rauisuchian. The ilium has the characteristic large supracetabular shelf and vertical buttress of rauisuchians (*sensu lato*). The Rauisuchia is a group in a state of taxonomic confusion (e.g., Parrish, 1993; Long and Murry, 1995). The current usages of Rauisuchia, Rauisuchidae and Poposauridae are inconsistent. Herein, I refer to all rauisuchians (*sensu lato*) as rauisuchids.

Postosuchus kirkpatricki has a confusing and still unresolved taxonomy. Chatterjee (1985) named *Postosuchus* for numerous rauisuchian specimens from the Bull Canyon Formation of West Texas. It is clear that Chatterjee's (1985) reconstruction of the pelvis of *Postosuchus kirkpatricki* is based on three taxa from two localities of different ages (Long and Murry, 1995). Long and Murry (1995) recognized this confusion, but were not rigorous in their assignment of rauisuchian specimens to particular taxa. I note, for example, that the cervical series that they use as their basis for reconstructions of *Postosuchus* is TTUP 9235 and it pertains to a phytosaur (Long and Murry, 1995, fig. 128).

The most diagnostic element of NMMNH P-4178 is a partial ilium. Unfortunately, no complete ilium was found associated with the holotype of *Postosuchus* (smaller ilia represent *Shuvosaurus* =*Chatterjeea*) The only iliac fragment of *Postosuchus* from the Revueltian type locality is the paratype TTUP 9002 (Long and Murry, 1995, fig. 137B). Long and Murry (1995) assigned two rauisuchian ilia (UMMP 7266, 7333a), originally described by Case (1922), from the Adamanian of Texas, to *Postosuchus*.. The ilium of NMMNH P-4178 differs from UMMP 7266, the more complete of the two, in being larger, more robust and in having a ventrally deflected posterior process. However, the morphological differences between the ilia of NMMNH P-4178 and UMMP 7266 could be ontogenetic, so I refer NMMNH P-4178 to *Postosuchus kirkpatricki*.

Shuvosauridae Chatterjee, 1993
***Shuvosaurus inexpectatus* Chatterjee, 1993**

Type Revueltian occurrences: NMMNH localities 1, 110, 162, 529: UCMP locality 82081: UMMP locality 5 miles west of San Jon in badlands.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4687, proximal femur; NMMNH P-4693, astragalus; NMMNH P-4695, femur; NMMNH P-4702, distal femur: NMMNH locality 110; NMMNH P-4601, conjoined ischia: NMMNH locality 162; NMMNH P-4859, conjoined ischia: NMMNH locality 529; NMMNH P-17373, ischia, tibia: UCM locality 82081; UCM 52080, right ilium, left pubic foot; UCM 52081, left premaxilla (Fig. 7D): 5 miles west of San Jon in Badlands; UMMP 7438, sacrum.

First occurrence: Adamanian (Triassic: late Carnian) of Arizona, New Mexico and Texas.

Last occurrence: Revueltian (Triassic: early-middle Norian) of Arizona, New Mexico and Texas.

Acme zone: None.

Discussion: Parrish and Carpenter (1986, fig. 11.8) described UCM 52081, an edentulous premaxilla. They compared UCM 52081 with various groups of reptiles that lack premaxillary teeth but could find no similarities. However, this specimen is identical to *Shuvosaurus* (Chatterjee, 1993). UCM 52081 shares the following characters with *Shuvosaurus*: (1) premaxilla is edentulous; (2) ventral margin of premaxilla is concave; and (3) narial opening is small and located at the posterior end of a large narial depression. Thus, it is clear that UCM 52081 represents *Shuvosaurus*.

Chatterjee (1993) named *Shuvosaurus inexpectatus* as an ornithomimosaur from the Revueltian Post quarry, the type locality of *Postosuchus*. Hunt et al. (1998) demonstrated that *Shuvosaurus* is not dinosaurian. Long and Murry (1995) named *Chatterjeea elegans* for the smaller specimens from the Post quarry that Chatterjee (1985) had included in *Postosuchus*. They noted that the holotype skull of *Shuvosaurus* was intermixed with probable *Chatterjeea* specimens that lacked cranial material, despite being relatively complete otherwise. They also noted that in size, proportions, and preservation, the holotype skull of *Shuvosaurus inexpectus* matches the holotype skeleton of *Chatterjeea elegans* (Long and Murry, 1995, p. 162). Yet, Long and Murry (1995) still named *Chatterjeea elegans*. The most powerful evidence that these two taxa actually both pertain to *Shuvosaurus inexpectatus* outside the Post Quarry is UCM locality 82081 in the Revuelto badlands. Here, an unmistakable premaxilla of *Shuvosaurus* (Parrish and Carpenter, 1986, fig. 11.8) is associated with the equally distinctive ilium of *Chatterjeea elegans* (Parrish and Carpenter, 1986, fig. 11.4). Thus, it seems that the most parsimonious conclusion is that *Chatterjeea elegans* Long and Murry, 1995 is a subjective junior synonym of *Shuvosaurus inexpectans* Chatterjee 1993.

Rauhut (1997) suggested that *Shuvosaurus* was indeed a theropod, but failed to demonstrate that it possessed any synapomorphies of this clade.

Family Rauisuchidae Price, 1946
gen. et sp. indeterminate

Type Revueltian occurrences: NMMNH localities 1, 47, 60, 110, 115, 120, 134, 153, 156, 161-163, 165, 171, 174, 176, 177, 182-183, 198, 425-426, 452, 454, 462, 498, 507, 510, 523, 526-527, 542, 582.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4661, second sacral centrum: NMMNH P-4662, centra; NMMNH P-4718, tooth; NMMNH P-4786, tooth; NMMNH P-4787, tooth; NMMNH P-4788, tooth; NMMNH P-4893, dorsal vertebrae; NMMNH P-4913, cervical vertebrae; NMMNH P-16644, tooth; NMMNH P-16647, tooth; NMMNH P-16694, teeth; NMMNH P-16917, partial centrum: NMMNH locality 47; NMMNH P-4106, tooth: NMMNH locality 60; NMMNH P-4160, cervical vertebrae; NMMNH P-4238, tooth: NMMNH locality 110; NMMNH P-4418, centrum; NMMNH P-4537, teeth: NMMNH locality 115; NMMNH P-4852, tooth fragment: NMMNH locality 120; NMMNH P-4447, tooth: NMMNH locality 134; NMMNH P-4466, teeth; NMMNH P-4627, dorsal centrum: NMMNH locality 153; NMMNH P-4475, many teeth: NMMNH locality 156; NMMNH P-4558, tooth: NMMNH locality 161; NMMNH P-4641, tooth: NMMNH locality 162; NMMNH P-16655, sacral, iliac and vertebral fragments: NMMNH locality 163; NMMNH P-16672, vertebral, pelvic fragments: NMMNH locality 165; NMMNH P-4891, cervical vertebra; NMMNH P-4905, cervical vertebra; NMMNH P-4920, dorsal centrum; NMMNH P-16611, teeth: NMMNH locality 171; NMMNH P-16640, teeth; NMMNH P-16649, teeth; NMMNH P-16895, teeth: NMMNH locality 174; NMMNH P-16642, teeth: NMMNH locality 176; NMMNH P-16657, fragmentary skeleton: NMMNH locality 177; NMMNH P-16653, tooth: NMMNH locality 182; NMMNH P-16648, teeth: NMMNH locality 183; NMMNH P-4935, centra; NMMNH P-4946, large mandible: NMMNH locality 198; NMMNH P-16641, centrum: NMMNH locality 425; NMMNH P-4963, teeth: NMMNH locality 426; NMMNH P-17521, teeth: NMMNH locality 452; NMMNH P-4729, tooth fragment; NMMNH P-16853, tooth: NMMNH locality 454; NMMNH P-16864, centrum fragment; NMMNH P-16887, 2 cervical vertebrae: NMMNH P-16863, tooth: NMMNH locality 462; NMMNH P-16886, 3 dorsal vertebrae: NMMNH locality 498; NMMNH P-17262, vertebrae; NMMNH P-17182, caudal centra; NMMNH P-17183, centra: NMMNH locality 507; NMMNH P-17209, caudal centrum: NMMNH locality 510; NMMNH P-17198, caudal centrum: NMMNH locality 523; NMMNH P-17451, tooth: NMMNH locality 526; NMMNH P-17355, tooth; NMMNH P-17381, tooth; NMMNH P-17469, centrum fragments: NMMNH locality 527; NMMNH P-17493, teeth; NMMNH P-17356, proximal ischium: NMMNH locality 542; NMMNH P-17423, pelvic fragments, centra: NMMNH locality 582; NMMNH P-17787, tooth.

First occurrence: Several genera from the Anisian (Triassic) of Africa, Asia and Europe. Rauisuchidae as utilized here includes Poposauridae, Prestosuchidae, etc. of other workers, pending a thorough revision of these taxa.

Last occurrence: *Fasolasuchus tenax* from late Norian/?Rhaetian (Triassic) of Argentina and an undescribed taxon from the Apachean (late Norian/?Rhaetian) Whitaker quarry, New Mexico.

Acme zone: Anisian-Ladinian (Triassic).

Discussion: Indeterminate rauisuchian specimens include postcrania and teeth. I have adopted a conservative stance in identifying laterally compressed and serrated teeth. Parrish (1988) suggested that rauisuchian teeth could be distinguished from dinosaur teeth by the fact that the latter had concave posterior margins. This criterion results in the identification of all laterally compressed and serrated teeth from the Bull Canyon Formation as rauisuchian. Obviously, some of these teeth must pertain to theropods, but pending additional study, I cannot distinguish the dinosaur teeth, and I assign all such teeth to the Rauisuchia.

Family ?Rauisuchidae Price, 1946

Type Revueltian occurrence: NMMNH locality 16.

Referred specimens from type Revueltian: NMMNH locality 16; NMMNH P-4351, cervical vertebra.

First occurrence: Several genera from the Anisian (Triassic) of Africa, Asia and Europe. Rauisuchidae as utilized here includes Poposauridae, Prestosuchidae etc. of other workers pending a thorough revision of these taxa.

Last occurrence: *Fasolasuchus tenax* from late Norian/?Rhaetian (Triassic) of Argentina and undescribed taxon from the Apachean (late Norian/?Rhaetian) Whitaker quarry, New Mexico.

Acme zone: Anisian-Ladinian (Triassic).

Discussion: This specimen is similar to vertebrae of rauisuchians, but is not definitely assignable to this family.

Crocodylomorpha Hay, 1930
Sphenosuchia Bonaparte, 1971
Sphenosuchidae Huene, 1922
gen. et sp. indeterminate

Type Revueltian occurrences: NMMNH localities 1, 57, 124, 169, 459, 501: UMMP locality 5 miles west of San Jon in Badlands.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4658, 2 cervical vertebrae; NMMNH P-4659, vertebrae; NMMNH P-4663, cervical, dorsal, caudal vertebrae; NMMNH P-4673, cervical vertebra; NMMNH P-16754, vertebrae; NMMNH P-16764, premaxilla: NMMNH locality 57; NMMNH P-4120, premaxilla, vertebral fragments; NMMNH P-17346, partial skeleton (cervical, dorsal, sacral and caudal vertebrae, partial pubes, ischia and ilia, premaxilla and maxilla fragments): NMMNH locality 124; NMMNH P-4573, sacral vertebrae: NMMNH locality 169; NMMNH P-4874, lower jaw: NMMNH locality 459; NMMNH P-16839, caudal centrum: NMMNH locality 501; NMMNH P-17229, osteoderm: 5 miles west of San Jon in badlands; UMMP 4771 (in part), three dorsal and one caudal centrum.

First occurrence: *Dyoplax arenaceus* from the late Carnian (Triassic) of Germany.

Last occurrence: *Kayentasuchus* sp. from the Sinemurian/Pliensbachian (Jurassic) of the western United States.

Acme zone: None.

Discussion: Several specimens in the Bull Canyon vertebrate fauna represent a sphenosuchian. The best specimens are NMMNH P-17346, which is a partial skeleton, and NMMNH P-4663, which is a partial vertebral column. The former specimen is the most diagnostic, although elements in common between the two specimens are nearly identical in size and morphology. NMMNH P-17346 contains several vertebrae that are indistinguishable from Chinle Group sphenosuchians that have been assigned to *Hesperosuchus agilis* (Colbert, 1952; Clark et al., 2000) and cf. *Sphenosuchus* sp. (Parrish, 1991). Unfortunately, the most potentially diagnostic elements in the Bull Canyon specimen are the fragmentary ilia, ischia and pubes. These elements are totally lacking in the holotypes of *Sphenosuchus* (Walker, 1990) and *Hesperosuchus* (Colbert, 1952). Parrish's (1991) specimen from Revueltian-age strata in Arizona includes portions of the pubes that are proximally, narrower anteroposteriorly. The ilium of the Bull Canyon Formation specimen indicates an imperforate, or nearly so, acetabulum, a less derived condition than seen in the European *Terrestrisuchus* (Crush, 1984), which is also of Norian age. There is a buttress above the acetabulum in NMMNH P-17346, which has previously not been recognized in the Sphenosuchidae. This buttress was the apparently the main reason behind Long and Murry (1995, fig. 146) assigning an ilium from the Whitaker quarry to *Postosuchus* despite the fact that the specimen was surrounded by osteoderms of a sphenosuchian. The Whitaker quarry specimen obviously pertains to the taxon described by Clark et al. (2000) from the same locality. In conclusion, a distinct sphenosuchid is present in the Bull Canyon Formation, but it is not represented by diagnostic specimens. Most Bull Canyon sphenosuchias specimens probably pertain to this taxon. However, NMMNH P-4673 is a cervical vertebra that has a much wider and less longitudinally arched centrum. This probably represents a second taxon.

Family ?Sphenosuchidae Huene, 1922

Type Revueltian occurrences: NMMNH localities 1, 156.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4660, centrum: NMMNH locality 156; NMMNH P-4559, centrum.

First occurrence: *Dyoplax arenaceus* from the late Carnian (Triassic) of Germany.

Last occurrence: *Kayentasuchus* sp. from the Sinemurian/Pliensbachian (Jurassic) of the western United States.

Acme zone: None.

Discussion: These vertebrae are similar to specimens assigned above to the Sphenosuchidae but they are not diagnostic of that family.

Crocodylotarsi Benton and Clark, 1988
incertae sedis
gen. et sp. nov.

Type Revueltian occurrences: NMMNH localities 1, 162, 182, 467, 523, 527, 534-535: UMMP locality 5 miles west of San Jon in badlands.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4691, left proximal femur; NMMNH P-4888, right proximal femur (large); NMMNH P-4902, partial dorsal vertebra; NMMNH P-4869, ?scapula blade; NMMNH P-16929, sacral vertebrae; NMMNH P-16920, proximal ischium; NMMNH P-16922, many osteoderm fragments; NMMNH P-16930, cervical vertebra; NMMNH P-16923, partial carapace; NMMNH P-16685, osteoderm: NMMNH locality 162; NMMNH P-4665, 11 vertebrae (cervical [1], dorsal [7], dorso-sacral [2], anterior caudal [1]): NMMNH locality 182; NMMNH P-16912, iliac blade: NMMNH locality 523; NMMNH P-17455, many osteoderm fragments; NMMNH P-17459, dorsal vertebra: NMMNH locality 467; NMMNH P-16932; small scavenged skeleton, portions of a large specimen and rauisuchian teeth: NMMNH locality 527; NMMNH P-17474, osteoderm fragments: NMMNH locality 534; NMMNH P-17384, osteoderm fragment: NMMNH locality 535; NMMNH P-17352, distal tibia: 5 miles west of San Jon in Badlands; UMMP 4771 (in part), proximal femur.

First and last occurrence: Revueltian (Triassic: early-middle Norian) of New Mexico and Arizona.

Acme zone: Revueltian (Triassic: early-middle Norian).

Discussion: This highly distinctive crocodylotarsan is distinguished by wide, rectangular paramedian osteoderms with an irregular pattern of deep pits and no lateral osteoderms, and a wide tarsus that has a small astragalar medial process and corresponding medial calcaneal concavity. It is known from several localities in the Revuelto and Barranca badlands and has recently been recognized from the lower Painted Desert Member of the Petrified Forest Formation at Petrified Forest National Park. This distinctive new taxon will be described in more detail elsewhere.

NMMNH P-16932 is the most complete specimen and consists of an articulated series of dorsal osteoderms with associated osteoderms and two ribs, many other elements of comparable size and a proximal femur and right astragalus and calcaneum of a larger individual. The articulated block consists of seven dorsal vertebrae. The anterior three vertebrae have associated paramedian osteoderms, one pair for each vertebra. The osteoderms are thick and have a deep ornamentation of rounded, irregularly placed pits. The posterior dorsal vertebra is heavily grooved, and a laterally compressed, serrated tooth (?rauisuchian) is preserved on this vertebra. Several skull fragments are present, one of which is a portion of a maxilla which preserved the tip of a replacement tooth. This tooth has large dorsally directed denticles. A fragment of a larger isolated tooth has a 5 mm wide root that flares to a 6 mm wide crown that has longitudinal striations.

Numerous partial osteoderms and one complete osteoderm are in the collection. The complete osteoderm is rectangular and is 64 mm long, 33 mm wide and 5 mm thick. The dorsal surface is covered by an irregular pattern of deep, rounded pits. The medial end of the osteoderm is thickened. The osteoderm thins at its lateral and anterior margins. A smooth strip runs along the anterior margin and broadens near the lateral margin.

This taxon represents a crocodylotarsan because it possesses: (1) a hemicylindrical calcaneal condyle for the fibula; (2) a flexed tibial facet on astragalus; (3) a single articulation between astragalus and calcaneum; and (4) single paramedian osteoderm per vertebra (Benton and Clark, 1988; Sereno, 1991). Further, it is assignable to a clade containing derived crurotarsans (= Suchia of Sereno, 1991) on the basis of an advanced "crocodile-normal" tarsus (Benton and Clark, 1988). However, the pit in the calcaneum to receive the astragalar process is shallower than in other members of this clade and thus is arguably less derived. The heavy dorsal armor is reminiscent of the aetosaurs, but there are no lateral osteoderms preserved in this taxon, and the morphology of the lateral margins of the paramedian osteoderms indicates that none were present. I note, however, that *Redondasuchus* has no lateral osteoderms. On the basis of the tarsal configuration, this taxon might represent a sister taxon of the Stagonolepididae.

The orientation of the large denticles on its teeth indicates that this taxon was herbivorous. This is consistent with the heavy dorsal armor, which is rare in carnivores that are not semiaquatic. The articulated specimen represents an animal about 1.5 m long. Other specimens indicate individuals about twice as large.

gen. et sp. nov.?

Type Revueltian occurrences: NMMNH localities 1, 171.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4664, neural arches; NMMNH P-4680, distal femur; NMMNH P-4700, distal femur; NMMNH P-4955, caudal vertebra; NMMNH P-16687, osteoderm fragment; NMMNH P-16919, fragmentary skeleton; NMMNH P-16924, proximal ischium; NMMNH P-16925, part of carapace; NMMNH P-16928, proximal pubis; NMMNH P-16931, quadrate: NMMNH locality 171; NMMNH P-16730, neural spine.

First and last occurrence: Revueltian (Triassic: early-middle Norian) of New Mexico and Arizona.

Acme zone: Revueltian (Triassic: early-middle Norian).

Discussion: Several fragmentary specimens show similarities in morphology to the specimens of the new species discussed above.

Crocodylotarsi Benton and Clark, 1988
Family Indeterminate

Type Revueltian occurrences: NMMNH localities 1, 84, 124, 129, 162, 164-165, 171, 182, 518, 521, 523, 527, YPM locality 6649.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4870, distal femur; NMMNH P-4676, distal femur; NMMNH P-4677, distal tibia; NMMNH P-4678, distal tibia; NMMNH P-4679, distal femur; NMMNH P-4681, distal femur; NMMNH P-4858, basicranium; NMMNH P-4955, 3 caudal vertebrae; NMMNH P-16670, distal tibia; NMMNH P-16691, neural arch fragment; NMMNH P-16692, neural arch fragment; NMMNH P-16726, central fragments; NMMNH P-16743, top of neural spine; NMMNH P-16898, fragmentary skeleton of ?new animal possibly intermixed with specimen of another genus; NMMNH P-16908, proximal tibia: NMMNH locality 84; NMMNH P-16661, centrum fragment: NMMNH locality 124; NMMNH P-4625, metapodial: NMMNH locality 129; NMMNH P-4491, vertebral fragment: NMMNH locality 162; NMMNH P-16630, vertebrae: NMMNH locality 164; NMMNH P-4692, proximal tibia: NMMNH locality 165; NMMNH P-4919, distal tibia: NMMNH locality 171; NMMNH P-16897, end of centrum: NMMNH locality 182; NMMNH P-4949, scapula fragment: NMMNH locality 518; NMMNH P-17416, metapodial: NMMNH locality 521; NMMNH P-17222, vertebral fragments: NMMNH locality 523; NMMNH P-17460, centrum fragment: NMMNH locality 527; NMMNH P-17361, partial astragalus; NMMNH P-17476, distal femur; NMMNH P-17501, distal tibia: YPM locality 6649; uncataloged caudal vertebra.

First occurrence: Several genera from the Anisian (Triassic) of Africa, Asia and Europe.

Last occurrence: Several Recent genera.

Acme zone: Late Carnian-late Norian (Triassic).

Discussion: A variety of specimens show similarities to crocodylotarsan taxa but cannot be identified further.

?Crocodylotarsi Benton and Clark, 1988

Type Revueltian occurrence: NMMNH locality 132.

Referred specimens from type: NMMNH locality 132; NMMNH P-4585, femoral shaft.

First occurrence: Several genera from the Anisian (Triassic) of Africa, Asia and Europe.

Last occurrence: Several Recent genera.

Acme zone: Late Carnian-late Norian (Triassic).

Discussion: NMMNH P-4585 is a femoral shaft that is reminiscent of crocodylotarsans.

Saurischia Seeley, 1888
Theropoda Marsh, 1881
Herrerasauridae Benedetto, 1973
gen et sp. nov. 1

Type Revueltian occurrences: NMMNH localities 163, 169, 176, 499, 503: UMMP locality San Juan (sic), New Mexico.

Referred specimens from type Revueltian: NMMNH locality 163; NMMNH P-4666, pubis fragments: NMMNH locality 169; NMMNH P-16607, tooth fragment: NMMNH locality 176; NMMNH P-16656, dorsal, caudal centra: NMMNH locality 499; NMMNH P-17258, fragmentary skeleton (vertebrae, scapula fragments): NMMNH locality 503; NMMNH P-17134, dorsal and caudal vertebral and pelvic fragments: San Juan (sic), New Mexico; UMMP 7274 (in part), two dorsal centra.

First and last occurrence: Revueltian (Triassic: early-middle Norian) of New Mexico.

Acme zone: Revueltian (Triassic: early-middle Norian).

Discussion: This is the most common dinosaur in the lower Bull Canyon Formation fauna. It is represented by three fragmentary skeletons (NMMNH P-16656, NMMNH P-17134, NMMNH P-17258) from the Revuelto and Barranca Creek badlands.

NMMNH P-17134 is a partial skeleton that includes both anterior and posterior dorsal centra. An anterior dorsal centrum is 47 mm long with a width of 34 mm whereas a posterior member of the series is 39 mm long and 39 mm wide. Thus, posterior dorsal centra are shorter and wider than anterior dorsal centra. NMMNH P-16656 also includes both anterior and posterior dorsal centra.

gen et sp. nov. 1?

Type Revueltian occurrences: NMMNH localities 1, 498.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-16946, centra: NMMNH locality 498; NMMNH P-17154, centra.

First and last occurrence: Revueltian (Triassic: early-middle Norian) of New Mexico.

Acme zone: Revueltian (Triassic: early-middle Norian).

Discussion: Two poorly preserved centra are tentatively assigned to this taxon.

gen et sp. nov. 2

Type Revueltian occurrences: NMMNH localities 110, 114, 124, 128

Referred specimens from type Revueltian: NMMNH locality 110; NMMNH P-4569, partial skeleton including dorsal centra, proximal left femur, partial astragalus, metatarsal fragments and phalanges (Fig. 7A-C): NMMNH locality 114; NMMNH P-4440, centrum fragment: NMMNH locality 124; NMMNH P-4380, vertebral fragment: NMMNH locality 128; NMMNH P-4375, vertebral fragment.

First and last occurrence: Revueltian (Triassic: early-middle Norian) of New Mexico.

Acme zone: Revueltian (Triassic: early-middle Norian).

Discussion: This taxon is restricted to the upper Bull Canyon Formation. Some specimens were previously attributed to *Coelophysis* (Lucas et al., 1985d, fig. 3D-O). It is a herrerasaurid because the ascending process of the astragalus does not form a wall that separates the anterior and dorsal surfaces (Novas, 1989).

?gen et sp. nov. 2

Type Revueltian occurrence: NMMNH locality 155.

Referred specimens from type Revueltian: NMMNH locality 155; NMMNH P-4547, phalanx.

First and last occurrence: Revueltian (Triassic: early-middle Norian) of New Mexico.

Acme zone: Revueltian (Triassic: early-middle Norian).

Discussion: NMMNH P-4547 is a phalanx that appears very similar to specimens referred to gen et sp. nov. 2 in the but it cannot be definitely be placed in this genus

Herrerasauridae Benedetto, 1973
indeterminate

Type Revueltian occurrences: NMMNH localities 1, 73, 110, 463.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4927, posterior dorsal centrum: NMMNH locality 73; NMMNH P-17325, posterior dorsal centrum: NMMNH locality 110; NMMNH P-4766, posterior dorsal centrum: NMMNH locality 463; NMMNH P-16844, posterior dorsal vertebrae.

First occurrence: *Herrerasaurus* and *Staurikosaurus* from the Adamanian (late Carnian) of South America, *Caseosaurus* from the Adamanian of North America.

Last occurrence: *Chindesaurus* and two undescribed taxa from the Revueltian (early-middle Norian) of North America.

Acme zone: None.

Discussion: A number of isolated centra are identifiable as herrerasaurid posterior dorsal centra (Lucas et al., 1985d, fig. 3P-Q). These centra are relatively short and wide. The cross section through the middle of the centrum has a straight ventral margin with lateral constrictions. These centra are of a fairly uniform size and appear to represent a distinct herrerasaurid taxon of the size of *Chindesaurus bryansmalli* (Long and Murry, 1995) from the Revueltian of Petrified Forest National Park. These centra are typically about 20 mm long

Ceratosauria Gauthier, 1986
***Gojirasaurus quayi* Carpenter, 1997**

Type Revueltian occurrence: UCM locality 82021.

Referred specimens from type Revueltian: UCM locality 82821; UCM 47221, partial skeleton including right pubis, left tibia, four dorsal centra, one dorsal neural arch, four ribs, one metatarsal, one chevron and one tooth.

First and last occurrence: Revueltian (Triassic: early to middle Norian) of New Mexico.

Acme zone: Revueltian (Triassic: early to middle Norian).

Description: Parrish and Carpenter (1986, figs. 11.5B-D, 11.6, 11.7B, C, E, H and J) and Hunt (1994) described UCM 47221, and subsequently Carpenter (1997) named this partial skeleton *Gojirasaurus quayi*. This is one of the largest Late Triassic theropods.

Theropoda Marsh, 1881
incertae sedis
gen et sp. nov. 3

Type Revueltian occurrence: NMMNH locality 527

Referred specimens from type Revueltian: NMMNH locality 527; NMMNH P-17375, fragmentary skeleton including pubis, proximal femora, vertebrae (Fig. 7E-G).

First and last occurrence: Revueltian (Triassic: early to middle Norian) of New Mexico.

Acme zone: Revueltian (Triassic: early to middle Norian).

Diagnosis: This is a theropod that is distinguished from others by possession of pubes that are conjoined almost to their proximal ends and a pubic shaft that is straight, narrow and with a proximal extremity that flares both anteriorly and posteriorly.

Discussion: This taxon is only known from one partial skeleton from the lower Bull Canyon Formation in the Barranca badlands. NMMNH P-17375 consist of 10 dorsal central fragments, proximal femora and a pubis. Dorsal centra are extremely hollowed and are 33 mm in width. The anteroposterior width across the femoral heads is 33 mm. The femoral head is rectangular but is only slightly offset from the shaft. The proximal pubis is flared both anteriorly and posteriorly with an anteroposterior length of 41 mm. The pubic shaft is narrow and straight. The medial sheet of the pubis is broken but extends proximally beyond the onset of the proximal flaring of the element, e.g., the pubes are sutured together almost to their proximal ends. No obturator foramen is present.

Theropoda Marsh, 1881
indeterminate

Type Revueltian occurrences: 1, 55, 98, 108, 120, 122, 124, 134, 152, 166, 168, 171, 174, 176-177, 182, 187, 519, 526-527: UMMP localities: San Juan (sic), New Mexico; 5 miles west of San Jon in Badlands: YPM locality 5883.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4783, cervical vertebra; NMMNH P-4657, centra; NMMNH P-4701, proximal tibia; NMMNH P-4704, tibia; NMMNH P-4688, centrum; NMMNH P-4928, centrum fragments; NMMNH P-16643, centrum fragment; NMMNH P-16645, centrum fragments; NMMNH P-16650, centrum fragment; NMMNH P-16652, centrum; NMMNH P-16666, proximal ischium; NMMNH P-16674, proximal pubis; NMMNH P-16713, cervical vertebra; NMMNH P-16728, centrum; NMMNH P-16787, centrum fragment; NMMNH P-16935, centrum: NMMNH locality 55; NMMNH P-4129, caudal centrum: NMMNH locality 98; NMMNH P-4126, proximal femur: NMMNH locality 108; NMMNH P-4652, ilium, ischium: NMMNH locality 120; NMMNH P-4596, phalanx: NMMNH locality 122; NMMNH P-4465, posterior dorsal centrum; NMMNH P-4588, metapodial; NMMNH P-4636, proximal ischium: NMMNH locality 124; NMMNH P-4427, phalanx: NMMNH locality 134; NMMNH P-4984, dorsal centrum; NMMNH P-4415, proximal femur; NMMNH P-4509, metapodial: NMMNH locality 152; NMMNH P-4474, dorsal centrum: NMMNH locality 166; NMMNH P-4948, centrum fragments; NMMNH locality 168; NMMNH P-4862, centrum fragments: NMMNH locality 171; NMMNH P-4856, vertebral fragments: NMMNH locality 174; NMMNH P-16658, vertebral, scapula fragments: NMMNH locality 176; NMMNH P-4884, phalanx: NMMNH locality 177; NMMNH P-4882, vertebrae: NMMNH locality 182; NMMNH P-16761, phalanx: NMMNH locality 187; NMMNH P-4932, centrum fragment: NMMNH locality 519; NMMNH P-17179, centrum fragments: NMMNH locality 526; NMMNH P-17470, centra: NMMNH locality 527; NMMNH P-17359, caudal centra: San Juan (sic), New Mexico; UMMP 7274 (in part), caudal vertebra: 5 miles west of San Jon in badlands; UMMP 7441 (in part), caudal centrum: YPM locality 5883; uncataloged dorsal centra (distorted).

First occurrence: Several taxa from the late Carnian (Triassic) of South America and North America.

Last occurrence: Many Recent taxa.

Acme zone: None.

Discussion: A large number of isolated elements, dominantly centra, cannot be identified more precisely than Theropoda. NMMNH P-4126 and NMMNH P-4415 are the proximal ends of two femora from the lower Bull Canyon Formation that do not pertain to any of the undescribed taxa.

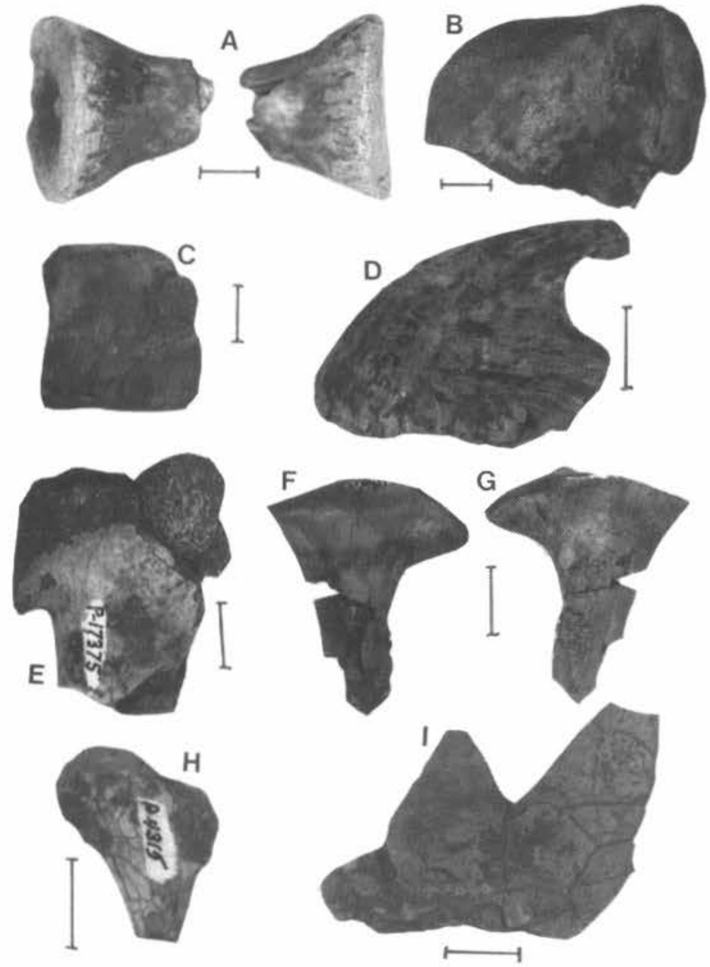

FIGURE 7. Theropods, *Shuvosaurus inexpectatus* and unidentified reptiles from the Bull Canyon Formation. A-C. Partial skeleton of Herrerasauridae gen. et sp. nov. 2 (NMMNH P-4569). A. Dorsal centra in lateral view. B. Posterior view of proximal end of left femur. C. Dorsal view of left astragalus. D. Lateral view of left premaxilla of *Shuvosaurus inexpectatus* (UCM 52081). E-G. Partial skeleton of Theropoda incertae sedis gen. et sp. nov.(NMMNH P-17375). E. Proximal left femur in anterior view. F-G. Proximal pubis in lateral (F) and medial (G) views. H. Proximal femur of unidentified reptile (NMMNH P-4315) in anterior view. I. Skull fragment of unidentified reptile, possibly turtle (NMMNH P-16697) in dorsal view. Scale bars are 1 cm.

?Theropoda Marsh, 1881
indeterminate

Type Revueltian occurrences: NMMNH localities 1, 16, 38, 73, 498-499, 507.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4698, distal tibia; NMMNH P-16793, centrum end; NMMNH P-16940, vertebra: NMMNH locality 16; NMMNH P-4653, centrum: NMMNH locality 38; NMMNH P-17342, dorsal centrum; NMMNH locality 73; NMMNH P-4223, vertebrae: NMMNH locality 498; NMMNH P-17153, pelvic fragment: NMMNH locality 499; NMMNH P-17281, centrum: NMMNH locality 507; NMMNH P-17211, centrum.

First occurrence: Several taxa from the late Carnian (Triassic) of South America and North America.

Last occurrence: Many Recent taxa.

Acme zone: None.

Discussion: Most questionable theropod specimens are vertebral fragments that are waisted as in the Theropoda.

Ornithischia Seeley, 1888
Revueltosaurus callenderi Hunt, 1989

Type Revueltian occurrences: NMMNH localities 1, 132, 171, 498, 526.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4957, incisiform tooth (holotype); NMMNH P-4958, dentary/maxillary tooth (paratype); NMMNH P-4959, premaxillary tooth (paratype); NMMNH P-4960, twenty eight premaxillary and dentary/maxillary teeth; NMMNH P-16573, teeth: NMMNH locality 132; NMMNH P-4426, tooth: NMMNH locality 171; NMMNH P-16637, tooth: NMMNH locality 498; NMMNH P-17187, tooth: NMMNH locality 526; NMMNH P-17362, teeth; NMMNH P-17382, tooth.

First and last occurrence: Revueltian (Triassic: early to middle Norian) of New Mexico and Arizona.

Acme zone: Revueltian (Triassic: early to middle Norian).

Discussion: The holotype and paratypes of *Revueltosaurus* are from NMMNH locality 1 in the Revuelto badlands, as are most of the remaining specimens. *Revueltosaurus* also occurs in the Barranca badlands and in the lower Bull Canyon Formation at Bull Canyon.

Lucianosaurus wildi Hunt and Lucas, 1994

Type Revueltian occurrence: NMMNH locality 110.

Referred specimens from type Revueltian: NMMNH locality 110; NMMNH P-18194, dentary/maxillary tooth (holotype); NMMNH P-18195, dentary/maxillary tooth.

First and last occurrence: Revueltian (Triassic: early to middle Norian) of New Mexico and Arizona.

Acme zone: Revueltian (Triassic: early to middle Norian).

Discussion: Hunt and Lucas (1994) named *Lucianosaurus* for an isolated ornithischian tooth. This taxon only occurs in the upper Bull Canyon Formation (NMMNH locality 110).

Ornithischia Seeley, 1888
indeterminate

Type Revueltian occurrence: NMMNH locality 527.

Referred specimens from type Revueltian: NMMNH locality 527; NMMNH P-17483, proximal femur.

First occurrence: Various taxa from South America, North America and Africa from the late Carnian (Triassic).

Last occurrence: Various taxa worldwide from the Maastrichtian (Cretaceous)

Acme zone: None

Discussion: NMMNH P-17483 is a fragment of a femur with a prominent fourth trochanter that is similar to specimens of this element in early ornithischians (e.g., Santa Luca, 1984).

Therapsida Broom, 1905
Cynodontia Owen, 1861
Dromatheridae Gill, 1872
Pseudotriconodon chatterjeei Lucas and Oakes, 1988

Type Revueltian occurrence: NMMNH locality 110.

Referred specimens from type Revueltian: UNM MV-518.

First and last occurrence: Revueltian (Triassic: early to middle Norian) of New Mexico.

Acme zone: Revueltian (Triassic: early to middle Norian).

Discussion: *Pseudotriconodon chatterjeei* is known only from the holotype, which is from the upper Bull Canyon Formation (NMMNH locality 110) at Bull Canyon (Lucas et al., 1985d; Lucas and Oakes, 1988).

Reptilia Laurenti, 1768
indeterminate

Type Revueltian occurrences: NMMNH localities 1, 38, 53, 57, 70, 73, 78, 89, 95, 110, 122, 133, 135, 155, 165-167, 170-171, 174, 176-177, 179, 182, 189, 193, 196, 434, 451-456, 458, 462, 464, 498-503, 508, 518, 521-524, 526-527, 530, 534-535, 537, 539, UCM locality 52081, UMMP locality San Juan (sic), 5 miles west of San Jon in badlands.

Referred specimens from type Revueltian: NMMNH locality 1; NMMNH P-4791, tooth; NMMNH P-4792, tooth; NMMNH P-4793, tooth; NMMNH P-4794, tooth; NMMNH P-4795, tooth; NMMNH P-4796, tooth; NMMNH P-4797, tooth; NMMNH P-4798, tooth; NMMNH P-4799, tooth; NMMNH P-4800, tooth; NMMNH P-16806, cervical vertebra; NMMNH P-16696, zygapophysis; NMMNH P-4683, proximal femur; NMMNH P-4696, centra; NMMNH P-4699, cervical vertebrae; NMMNH P-4705, tooth; NMMNH P-4706, tooth; NMMNH P-4708, tooth; NMMNH P-4709, tooth; NMMNH P-4710, tooth; NMMNH P-4712, tooth; NMMNH P-4714, tooth; NMMNH P-4785, tooth; NMMNH P-4814, bone; NMMNH P-4815, tooth; NMMNH P-4818, tooth; NMMNH P-4819, phalanx; NMMNH P-4820, small limb end; NMMNH P-4821, small limb end; NMMNH P-4822, bone; NMMNH P-4823, small ?limb end; NMMNH P-4824, small vertebra; NMMNH P-4825, small ungual phalanx; NMMNH P-4826, tooth; NMMNH P-4827, tooth; NMMNH P-4828, tooth; NMMNH P-4829, tooth; NMMNH P-4830, tooth; NMMNH P-4831, tooth; NMMNH P-4837, tooth; NMMNH P-4838, tooth; NMMNH P-4841, tooth; NMMNH P-4842, tooth; NMMNH P-4843, tooth; NMMNH P-4844, tooth; NMMNH P-4845, tooth; NMMNH P-4848, tooth; NMMNH P-4849, tooth; NMMNH P-16603, rib; NMMNH P-16612, ?edentulous lower jaw; NMMNH P-16623, bone; NMMNH P-16660, limb end; NMMNH P-16663, distal humerus; NMMNH P-16664, proximal ischium; NMMNH P-16665, scapula fragment; NMMNH P-16667, metapodial; NMMNH P-16668, bone; NMMNH P-16669, ?femoral end; NMMNH P-16673, osteoderm fragment; NMMNH P-16677, jaw fragment; NMMNH P-16679, elongate caudal centrum; NMMNH P-16684, jaw fragment; NMMNH P-16690, pelvic fragment; NMMNH P-16693, tooth fragment; NMMNH P-16797, skull fragment; NMMNH P-16698, skull fragment; NMMNH P-16699; NMMNH P-16701, bone; NMMNH P-16702, centrum fragment; NMMNH P-16703, centrum fragment; NMMNH P-16704, centrum fragment; NMMNH P-16705, centrum fragment; NMMNH P-16707, osteoderm fragment; NMMNH P-16708, centrum fragment; NMMNH P-16709, centrum fragment; NMMNH P-16710, centrum fragment; NMMNH P-16711, centrum fragment; NMMNH P-16712, centrum fragment; NMMNH P-16714, vertebra; NMMNH P-16715, centrum fragment; NMMNH P-16716, elongate dorsal centrum; NMMNH P-16717, centrum fragment; NMMNH P-16718, centrum; NMMNH P-16719, centrum fragment; NMMNH P-16724, vertebra; NMMNH P-16725, osteoderms; NMMNH P-16729, distal scapula; NMMNH P-16731, skull fragments; NMMNH P-16732, vertebra; NMMNH P-16737, bone; NMMNH P-16738, bone; NMMNH P-16740, vertebra; NMMNH P-16741, caudal centrum; NMMNH P-16744, very elongate centrum; NMMNH P-16746, ?scapula fragment; NMMNH P-16747, vertebra; NMMNH P-16748, very elongate centrum; NMMNH P-16749, bone fragments; NMMNH P-16751, centrum; NMMNH P-16755, long bone with step fracture; NMMNH P-16756, cranial fragments; NMMNH P-16757, atlas intercentrum; NMMNH P-16758, bone; NMMNH P-16762, centrum fragment NMMNH P-16766, centrum fragment; NMMNH P-16767, centrum fragment: NMMNH P-16768, atlas; NMMNH P-16769, centrum fragment; NMMNH P-16770, centrum fragment; NMMNH P-16771, centrum; NMMNH P-16772, centrum fragment; NMMNH P-16773, centrum fragment; NMMNH P-16774, centrum fragment; NMMNH P-16775, centrum fragment; NMMNH P-16776, osteoderm; NMMNH P-16777, vertebra; NMMNH P-16778, vertebra; NMMNH P-16781, cervical centrum; NMMNH P-16782, skull fragment; NMMNH P-16783, skull fragment; NMMNH P-16784, caudal centrum; NMMNH P-16785, centrum; NMMNH P-16786, caudal vertebra; NMMNH P-16788, limb fragment; NMMNH P-16789, phalanges; NMMNH P-16790, cervical vertebra; NMMNH P-16791, cervical vertebra; NMMNH P-16792, caudal vertebra; NMMNH P-16794, tarsals; NMMNH P-16795, anterior dorsal centrum; NMMNH P-16796, centra; NMMNH P-16797, centrum fragment; NMMNH P-16798, proximal ischium; NMMNH P-16799, vertebra; NMMNH P-16801, centra; NMMNH P-16802, centrum; NMMNH P-16803, bone; NMMNH P-16804, bone; NMMNH P-16805, centrum; NMMNH P-16807, neural spine; NMMNH P-16808, bone; NMMNH P-16809, neural spine; NMMNH P-16810, centrum; NMMNH P-16811, centrum; NMMNH P-16890, vertebral column and osteoderms (part of UMMP 7441); NMMNH P-16909, limb fragments; NMMNH P-16910, scapula fragment; NMMNH P-16911, skull fragment; NMMNH P-16914, centrum fragment; NMMNH P-16915, vertebral fragment; NMMNH P-16916, vertebral fragment; NMMNH P-16921, osteoderm and limb fragments; NMMNH P-16927, ?fragmentary skeleton; NMMNH P-16934, neural process; NMMNH P-16938, centrum fragment; NMMNH P-16939, centrum fragment; NMMNH P-16944, centrum fragment; NMMNH P-16945, centrum fragments; NMMNH P-16947, centrum fragments: NMMNH locality 38; NMMNH P-4308, rib, vertebral fragments: NMMNH locality 53; NMMNH P-4315, proximal femur; NMMNH P-4157, ilium fragment: NMMNH locality 57; NMMNH P-4253, cervical vertebrae: NMMNH locality 70; NMMNH P-17374, centrum fragment: NMMNH locality 73; NMMNH P-17326, vertebral fragment; NMMNH P-17328, vertebral fragment: NMMNH locality 78; NMMNH P-4191, skull fragments: NMMNH locality 80; NMMNH P-4168, scapula fragments: NMMNH locality 89; NMMNH P-16671, distal humerus: NMMNH locality 95; NMMNH P-4112, bone; NMMNH locality 110; NMMNH P-4487, tooth; NMMNH P-4580, tooth; NMMNH P-4595, small bones; NMMNH P-4598, elongate caudals; NMMNH P-4603, partial quadrate; NMMNH P-4605, tooth; NMMNH P-4630, bone fragments: NMMNH locality 122; NMMNH P-4388, limb end; NMMNH P-4556, bone: NMMNH locality 133; NMMNH P-4420, quadrate: NMMNH locality 135; NMMNH P-4396, quadrate: NMMNH locality 155; NMMNH P-4566, vertebral fragments: NMMNH locality 165; NMMNH P-4909, bone; NMMNH P-4910, iliac fragment; NMMNH P-4934, skull fragment; NMMNH P-16589, centrum fragment; NMMNH P-16733, centrum fragment: NMMNH P-16750, centrum fragment: NMMNH locality 166; NMMNH P-16621, bone: NMMNH locality 167; NMMNH P-4924, vertebral fragment: NMMNH locality 170; NMMNH P-4896, neural arch: NMMNH locality 171; NMMNH P-16734, small centra; NMMNH P-16735, vertebral fragments; NMMNH P-16742, bone; NMMNH P-16752, centrum fragment; NMMNH P-16759, bone; NMMNH P-16936, phalanx: NMMNH locality 174; NMMNH P-16745, transverse process; NMMNH P-16763, osteoderm: NMMNH locality 176; NMMNH P-16654, cervical vertebra: NMMNH locality 177; NMMNH P-4886, teeth; NMMNH P-16892, elongate centrum: NMMNH locality 179; NMMNH P-4890, phalanx: NMMNH locality 182; NMMNH P-16662, metapodial fragment; NMMNH P-16736, small ?limb bone: NMMNH locality 189; NMMNH P-4931, skull fragment: NMMNH locality 193; NMMNH P-4929, bone: NMMNH locality 196; NMMNH P-16765, centrum: NMMNH locality 434; NMMNH P-17195, centrum: NMMNH locality 451; NMMNH P-16816, centrum; NMMNH P-16823, centrum: NMMNH locality 452; NMMNH P-16858, phalanx; NMMNH P-16859, vertebral fragments: NMMNH locality 453; NMMNH P-16843, distal femur: NMMNH locality 454; NMMNH P-16861, vertebral fragment; NMMNH P-16862, vertebral fragment; NMMNH P-16865, vertebra; NMMNH P-16867, rib fragment; NMMNH P-16870, bone: NMMNH locality 455; NMMNH P-16849, proximal femur: NMMNH P-locality 456; NMMNH P-16879, bone: NMMNH locality 458; NMMNH P-16846, phalanges; NMMNH P-16847, vertebral fragments: NMMNH locality 462; NMMNH P-16871, vertebral fragments; NMMNH P-16872, phalanges; NMMNH P-16876, ?skull fragment: NMMNH locality 464; NMMNH P-16838, centrum: NMMNH locality 498; NMMNH P-17150, vertebrae; NMMNH P-17184, dentary fragments; NMMNH P-17191, osteoderms: NMMNH locality 499; NMMNH P-17152, occipital condyle; NMMNH P-17160, elongate centra; NMMNH P-17264, ischium; NMMNH P-17266, caudal vertebra; NMMNH P-17268, neural spine; NMMNH P-17270, caudal centrum; NMMNH P-17271, centrum fragments; NMMNH P-17274, caudal centrum; NMMNH P-17275, centrum fragment; NMMNH P-17277, bone; NMMNH P-17278, proximal pubis; NMMNH P-17283, centrum fragments; NMMNH P-17284, chevron fragment; NMMNH P-17285, centrum fragment; NMMNH P-17289, elongate centrum; NMMNH P-17290, small limb bones; NMMNH P-17291, vertebra; NMMNH P-17292, vertebra: NMMNH locality 500; NMMNH P-17194, bone fragments: NMMNH locality 501; NMMNH P-17132; NMMNH P-17164, centra; NMMNH P-17242, elongate caudals; NMMNH P-17288, vertebral fragment; NMMNH P-17294, elongate vertebra; NMMNH P-17295, small limb end: NMMNH locality 502; NMMNH P-17158, centra (cervical, sacral): NMMNH locality 503; NMMNH P-17217, sacral vertebra: NMMNH locality 508; NMMNH P-17235, vertebral fragments: NMMNH locality 517; NMMNH P-17207, centrum: NMMNH locality 518; NMMNH P-17415, limb end: NMMNH locality 521; NMMNH P-17225, phalanx; NMMNH P-17226, small vertebrae: NMMNH locality 522; NMMNH P-4984, partially articulated skeleton; NMMNH P-17418, centrum; NMMNH P-17424, centrum fragment: NMMNH locality 523; NMMNH P-17456, centrum fragment; NMMNH P-17457, vertebral fragments; NMMNH P-17458, vertebral fragments; NMMNH P-17461, limb bone: NMMNH locality 524; NMMNH P-17398, maxilla fragment: NMMNH locality 526; NMMNH P-17376, tooth; NMMNH P-17462, centrum; NMMNH P-17463, pelvic fragments; NMMNH P-17464, centrum fragment; NMMNH P-17466, 3 small vertebrae; NMMNH P-17467, partial centrum: NMMNH locality 527; NMMNH P-17360, basicranium; NMMNH P-17480, sacral vertebra; NMMNH P-17482, radius; NMMNH P-17487, quadrate; NMMNH P-17492, cervical centrum; NMMNH P-17494, skull fragment; NMMNH P-17503, pelvis fragment: NMMNH locality 530; NMMNH P-17490, vertebral fragments: NMMNH locality 534; NMMNH P-17386, centrum; NMMNH P-17390, jaw fragment: NMMNH locality 535; NMMNH P-17354, small limb end: NMMNH locality 537; NMMNH P-17301, caudal vertebrae: NMMNH locality 539; NMMNH P-17400, centrum fragment: UCM locality 82081; UCM 52081, right premaxilla; uncataloged teeth, vertebrae: San Juan (sic), New Mexico; UMMP 7274 (in part), two different cervical vertebrae: 5 miles west of San Jon in Badlands; UMMP 4771 (in part); proximal and distal humerus, partial articulated caudal series with osteoderms, femoral fragment, anterior dorsal centrum.

First occurrence: ?*Westlothiaana lizziae* from the Visean (Carboniferous) of Scotland.

Last occurrence: Many Recent species.

Acme zone: None

Discussion: A large number of generally isolated bones represent indeterminate reptiles. Many specimens hint at a diversity of small, undescribed reptiles. For example, NMMNH P-4598, 16679, 16716, 16744, 16892, 17160, 17294 represent one or more taxa of small reptiles with very elongate centra, and NMMNH P-16660, 16663 and 16670 are limb ends of one or more small, primitive reptiles.

Three specimens deserve special comment. NMMNH P-16890 is vertebral centra and osteoderms of a small reptile. Part of this individual is present within UMMP 4771, which was collected 72 years before NMMNH P-16890. This is evidenced by morphology and preservation and provides further evidence that Case collected at NMMNH locality 1. The centra are moderately waisted and are reminiscent of sphenosuchid dorsal centra, but the armor is much more robust than is found in that family.

NMMNH P-16697 is a portion of the lateral margin of a reptile skull (Fig. 7I). It consists of a series of flattened spikes, each of which preserves several sutures. Longitudinal sutures run medially down the spikes and split into two near the tips so that they are Y-shaped in dorsal view. Proximally the central spike suture is crossed by another suture running parallel to the presumed skull margin. Superficially, this specimen resembles the skull margin of *Proganochelys* and some procolophonids. However, it differs significantly in the pattern of sutures. It may represent a turtle (Lucas et al., 2000).

NMMNH P-4315 is a proximal femur from NMMNH locality 53 (Fig. 7H). The femoral head is spherical and is distinctly offset from the shaft. It is reminiscent of the femur of the primitive turtle *Proganochelys* (Gaffney, 1990, fig. 163) but differs in having a more spherical head. NMMNH P-4315 differs in the same manner from a cynodont proximal femur (Jenkins, 1971, fig. 48) and also in lacking a large lesser trochanter. This femoral fragment obviously represents a distinct taxon, but its affinities are unclear.

BIOSTRATIGRAPHY OF THE BULL CANYON FORMATION

There are clearly two fossil assemblages present within the Bull Canyon Formation (Table 1). The lower assemblage occurs in the basal 50 m of the formation in the Revuelto and Barranca badlands and in the lower part of Bull Canyon. The upper assemblage is restricted to the upper part of the formation in Bull Canyon. Taxa in common between the faunas are Colobontidae, Redfieldiidae, *Apachesaurus*, Squamata, *Pseudopalatus*, *Typothorax*, *Shuvosaurus*, Rauisuchidae and Herrerasauridae (small).

Taxa restricted to the lower assemblage are *Semionotus*, ?*Tanaocrossus*, *Quayia*, Metoposauridae (large), *Pseudopalatus n. sp.*, Crocodylotarsi incertae sedis gen. et sp. nov., *Aetosaurus*, Stagonolepididae gen. et sp. nov., *Paratypothorax*, *Desmatosuchus*, *Postosuchus*, Sphenosuchidae, Herrerasauridae gen. et sp.

nov. 1 , Theropoda incertae sedis gen. et sp. nov. *3* and *Revueltosaurus*. Taxa restricted to the upper assemblage are, Herrerasauridae gen. et sp. nov. *2, Lucianosaurus* and *Pseudotriconodon*.

The lower assemblage is more diverse in all major elements (fish, amphibians and reptiles) and also includes a higher diversity of terrestrial animals. Part of this diversity is obviously related to topographic factors. The upper Bull Canyon Formation (and overlying Redonda Formation) underlie the Jurassic Entrada Sandstone, which is a cliff-forming unit in this area, which is usually topographically high (e.g., top of mesa, edge of Llano Estacado). Thus, the upper Bull Canyon Formation often forms the basal portion of a high relief slope. The next resistant sandstone unit below the Entrada is the Trujillo Formation, which underlies the Bull Canyon. The Trujillo is a topographically low unit in east-central New Mexico, just above the level of the Canadian River. Thus, tributaries of the Canadian draining the Llano Estacado and mesas in this area have to cut through the lower Bull Canyon Formation, and in several areas (Revuelto and Barranca badlands) large areas of badlands result. Obviously, the lower relief outcrops and badland exposures of the lower Bull Canyon Formation have been more explored than the higher relief outcrops of the upper part of the formation. However, similar distribution patterns also occurs within the Revueltian Painted Desert Member of the Petrified Forest Formation in northeastern Arizona, where not only are vertebrate fossils more common in the lower portion of the unit, but they are represented by a higher diversity of terrestrial animals (e.g., Hunt and Lucas, 1993c, 1994). Thus, the distribution pattern seen within the Bull Canyon Formation is pervasive in this stratigraphic interval of the Chinle Group. Hunt and Lucas (1993c) noted that this pattern is consistent with sequence stratigraphic models of the Chinle Group. All lower Revueltian faunas occur near the base of a transgressive systems tract near the bottom of the mud-dominated sequence above its basal sandstone complex (Sonsela Member in northeastern Arizona, Trujillo in east-central New Mexico). Upper Revueltian faunas occur near the top of a transgressive systems tract. It is probable that faunas preserved during the progression of a transgressive systems tract would show an increase in semiaquatic components relative to terrestrial components as the highstand was approached. Furthermore, relatively higher rates of sedimentation in the early transgressive systems tract would preserve more fossils and more complete fossils than the later transgressive systems tract or highstand tract. Thus, the sequence stratigraphic interpretation of the Chinle group may explain some aspects of tetrapod abundance in the Revueltian.

However, there are distinct faunal differences between the upper and lower Bull Canyon Formation. These include: (1) lower diversity of fish in the upper part of the formation; (2) absence of the large predators *Pseudopalatus* n. sp. and *Postosuchus* in the upper fauna; (3) a major change in the dinosaur fauna, with the theropods Herrerasauridae gen. et sp. nov. 1 , Theropoda incertae sedis gen. et sp. nov. 3 and the ornithischian *Revueltosaurus* of the lower assemblage being are replaced by the theropod Herrerasauridae gen. et sp. nov. 2 and the ornithischian *Lucianosaurus* in the upper assemblage; (4) the diversity of aetosaurs is reduced from five to one, with only *Typothorax* remaining in the upper part of the formation, and (5) restriction of several small reptiles to the lower assemblage (e.g., *Vancleavea*-like reptile and Crocodylotarsi incertae sedis gen. et sp. nov.)

BIOCHRONOLOGY OF THE REVUELTIAN LAND-VERTEBRATE FAUNACHRON

Lucas and Hunt (1993) named a series of land-vertebrate faunachrons (lvf) for the Late Triassic of western North America. The Revueltian lvf was based on the assemblage of the Bull Canyon Formation and Trujillo Formations in the Revuelto Creek area (Barranca and Revuelto badlands of this report). Lucas (1998) provided a formal definition of the Revueltian lvf and defined its type assemblage as that of the Bull Canyon Formation in east-central New Mexico (Quay and Guadalupe counties). Lucas and Hunt (1993) listed the index taxa of the Revueltian to be *Pseudopalatus* and *Typothorax,* and Lucas (1998) added *Aetosaurus* to

TABLE 1. Two faunas from the Bull Canyon Formation of east-central New Mexico.

VERTEBRATE FAUNAS OF BULL CANYON FORMATION	
Upper fauna	?Colobodontidae indet.
	Redfieldiidae indet.
	Apachesaurus gregorii
	?Squamata indet.
	Pseudopalatus pristinus
	P. andersoni
	Typothorax coccinarum
	Shuvosaurus inexpectatus
	Herrerasauridae gen. et sp. nov. 2
	Lucianosaurus wildi
	Pseudotriconodon chatterjeei
Lower fauna	?Colobodontidae indet.
	Redfieldiidae indet.
	Semionotus cf. *S. brauni*
	?*Tanaocrossus kallikoski*
	?Arganodontidae indet
	Quayia zideki
	Apachesaurus gregorii
	Metoposauridae indet. (large)
	?Squamata indet.
	Rhynchosauridae indet.
	Vancleavia campi
	Pseudopalatus pristinus
	P. andersoni
	P. n. sp.
	Aetosaurus arcuatus
	Typothorax coccinarum
	Desmatosuchus n. sp.
	Paratypothorax sp.
	Stagonolepididae ?gen. et sp. nov.
	Postosuchus kirkpatricki
	Shuvosaurus inexpectatus
	Crocodylotarsi gen. et sp. nov.
	Sphenosuchidae indet.
	Herrerasauridae gen. et sp. nov. 1
	Gojirasaurus quayi
	Theropoda gen. et sp. nov. 3
	Revueltosaurus callenderi

this list. Lucas (1998) defined the base of the Revueltian as the First Appearance Datum (FAD) of *Pseudopalatus*. Diverse vertebrate, pollen, magnetostratigraphic and sequence stratigraphic data indicate that the Revueltian is equivalent to most, if not all, of Norian time (e.g., Litwin, 1986; Ash, 1987; Litwin et al., 1991; Lucas, 1991, 1993,1998; Good, 1993; Hunt, 1994).

I propose to divide the Revueltian into two, and possibly three sub-lvfs based on the biostratigraphy presented above (Fig. 8). R1 (Barrancan) is based on the vertebrate fauna from Barranca Creek and it begins with the FAD of the phytosaur *Pseudopalatus* spp. Index fossils for R1 are *Quayia zideki*, *Pseudopalatus n. sp.*, Crocodylotarsi incertae sedis gen. et sp. nov., *Aetosaurus arcuatus*, Stagonolepididae gen. et sp. nov., Herrerasauridae gen. et sp. nov. 1, Theropoda incertae sedis gen. et sp. nov. 3 and *Revueltosaurus callenderi*. Other elements of the type vertebrate assemblage are Perleididae, Redfieldiidae, *Semionotus*, ?*Tanaocrossus, Apachesaurus*, Metoposauridae (large), Squamata, *Pseudopalatus andersoni* and *P. pristinus*, *Typothorax coccinarum*, *Shuvosaurus*, Rauisuchidae and Herrerasauridae (small), *Paratypothorax*, *Desmatosuchus*, *Postosuchus* and Sphenosuchidae. The principal correlatives are the Post quarry and associated faunas of the lower Bull Canyon Formation, Garza County, Texas and the lower fauna of the Painted Desert Member of the Petrified Forest Formation, Petrified Forest National Park and environs, Apache County, Arizona.

R2 (Lucianoan) is based on the fauna of the upper Bull Canyon Formation at Bull Canyon and Luciano Mesa, and it begins with the FAD of *Lucianosaurus*. Index taxa are Herrerasauridae gen. et sp. nov. *2,* and *Pseudotriconodon*. Other elements of the type fauna are Colobodontidae, Redfieldiidae, *Apachesaurus*, Squamata, *Pseudopalatus*, *Typothorax*, *Shuvosaurus*, Rauisuchidae and Herrerasauridae (small). The principal correlatives are the Canjilon quarry and other localities from the upper Petrified Forest Formation, Rio Arriba County, New Mexico and the Owl Rock Formation of Arizona (Kirby, 1989, 1991). This sub-lvf is easy to recognize on the basis of an aetosaur fauna that includes *Typothorax coccinarum*, but not *Aetosaurus arcuatus*, or *Paratypothorax* sp., but the FAD of *Lucianosaurus* is weak because of its restricted distribution and low abundance.

A third possible sub-lvf would be R0 (Rainbowforestan) based on the fauna of the Sonsela Member of the Petrified Forest in the Rainbow Forest area of Petrified Forest National Park (Hunt et al., 2001a). R0 would begin with the FAD of the phytosaur *Nicrosaurus* which co-occurs in the Sonsela with *Typothorax*, apparently in the absence of *Pseudopalatus* and so possibly prior to the FAD of *Pseudopalatus* (Hunt et al., 2001a). Possible corelatives would be the Trujillo Formation in the Plaza Larga-Barranca Creek area of Quay County, New Mexico (Hunt, 1991, 2001). If this is the case, then the Revueltian should be redefined on the basis of the FAD of *Typothorax coccinarum*. This would be preferable to the FAD of *Pseudopalatus* in any case because the stagonolepidid is represented by a far greater number of identifiable specimens in Revueltian faunas as demonstrated above.

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	East-central NM	North-central NM	Northeastern AZ	West TX
Lucianoan (R2)	Upper Bull Canyon Formation	?Upper Petrified Forest Formation	Upper Painted Desert Member of Petrified Forest Formation, Owl Rock Formation	?Not present
Barrancan (R1)	Lower Bull Canyon Formation	Lower Petrified Forest Formation	Lower Painted Desert Member of Petrified Forest Formation	Lower Bull Canyon Formation
?Rainbowforestan (R0)	Trujillo Formation	Poleo Formation	Sonsela Member of Petrified Forest Formation	Trujillo Formation

FIGURE 8. Correlation of the Revueltian land-vertebrate faunachron in the Southwestern United States.

and obtained courtesy of the Polyglot Paleontologist website (www.uhmc.sunysb.edu/anatomicalsci/paleo).

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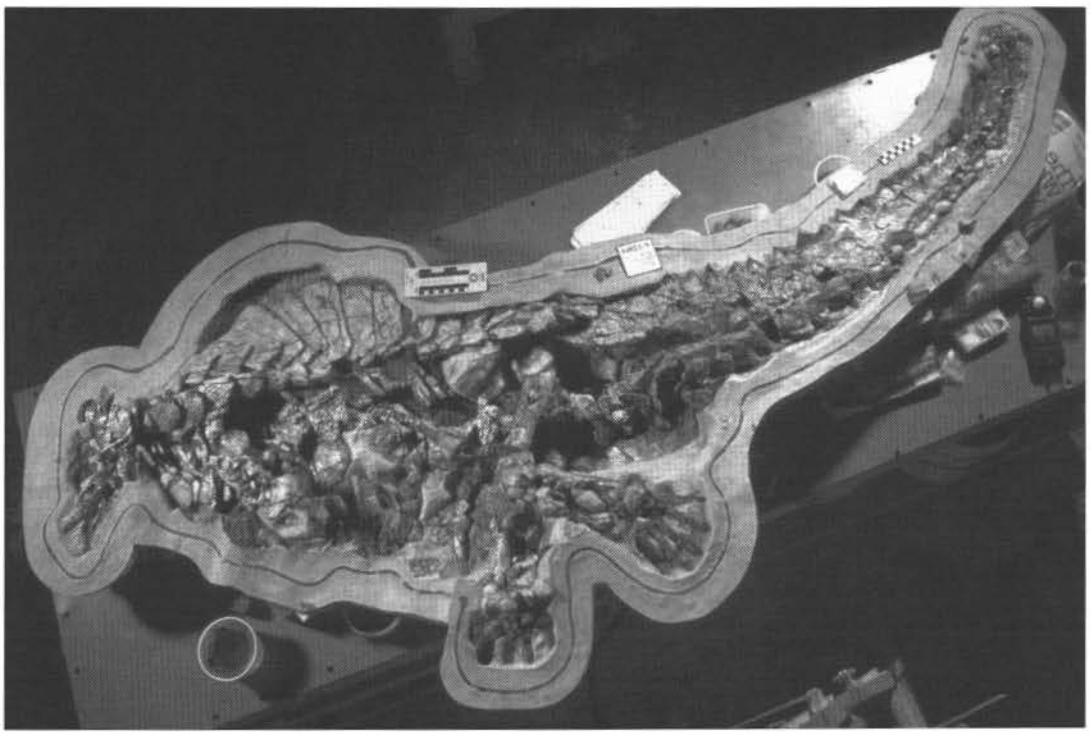

This complete skeleton of the armored reptile Typothorax coccinarum is being prepared at the New Mexico Museum of Natural History in Albuquerque. It was collected from the Upper Triassic Bull Canyon Formation near San Jon. Scale in cm.