THE TETRAPOD FAUNA OF THE UPPER TRIASSIC LOWER CHINLE GROUP (ADAMANIAN: LATEST CARNIAN) OF THE ZUNI MOUNTAINS, WEST-CENTRAL NEW MEXICO

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ABSTRACT—Numerous localities in the Bluewater Creek Formation in the Zuni Mountains of west-central New Mexico produce a tetrapod fauna that includes the metoposaurid amphibian *Buettneria* sp., indeterminate phytosaurs, the aetosaurs *Stagonolepis*, *Desmatosuchus*, and *Paratypothorax*, two theropod dinosaurs, at least two ornithischian dinosaurs, including one identified here as aff. *Tecovasaurus*, and trace fossils consisting of a footprint of an ?ornithischian, and vertebrate coprolites. The most frequently encountered fossils are abundant cranial and postcranial fragments of metoposaurid amphibians and indeterminate phytosaurs. *Stagonolepis* is an index taxon of the Adamanian land-vertebrate faunachron, indicating that the Bluewater Creek Formation is latest Carnian in age, an observation consistent with abundant *Desmatosuchus* and large metoposaurid amphibians. The overlying Blue Mesa Member of the Petrified Forest Formation is relatively unfossiliferous in the Zuni Mountains, and has only produced fragmentary remains of indeterminate metoposaurs and phytosaurs, but produces an Adamanian fauna from various localities in Arizona. The dinosaur fauna from the Bluewater Creek Formation comes from a single locality, is the most diverse late Carnian dinosaur assemblage in North America, and includes some of the oldest known dinosaurs.

INTRODUCTION

Exposures of the lower Chinle Group crop out as discontinuous badlands in the Zuni Mountains from Fort Wingate in the west to Bluewater in the east (Fig. 1). Although these outcrops are well-known in the literature, attempts to collect vertebrate fossils here have been both infrequent and relatively unsuccessful. This paper will briefly summarize the lower Chinle Group lithostratigraphy of the area, provide an overview of the past history of vertebrate collecting in the Zuni Mountains, and document new tetrapod collections made in the last few years. It will then examine the significance of this fauna temporally and in terms of the appearance and evolution of early dinosaurs. Abbreviations used in this paper: NMMNH, New Mexico Museum of Natural History and Science, Albuquerque; PFNP, Petrified Forest National Park, Arizona; SMNS, Staatliches Museum für Naturkunde, Stuttgart.

LITHOSTRATIGRAPHY

The lower Chinle Group succession in the Zuni Mountains consists of (in ascending order): the "mottled strata," the Shinarump Formation, the Bluewater Creek Formation, and the Blue Mesa Member of the Petrified Forest Formation (Fig. 2). This sequence rests disconformably on the Middle Triassic Moenkopi Formation and is overlain unconformably by the Sonsela Member of the Petrified Forest Formation.

Most recent workers recognize the base of the Chinle as the first deposits above the Moenkopi Formation (Stewart et al., 1972; Lucas, 1993), the top of which is the unconformable surface that represents the Tr-3 unconformity of Pipiringos and O'Sullivan (1978). In the Zuni Mountains, the base of the Chinle Group generally consists of pedogenically modified siliciclastic deposits assigned to the mottled strata, although channel-fill conglomerates of the Shinarump Formation locally overlie either the mottled strata or the Moenkopi Formation (Lucas and Hayden, 1989; Lucas et al., 1997a; Heckert, 1997). Red beds of the Bluewater Creek Formation conformably overlie these units throughout the Zuni Mountains. Within the Bluewater Creek Formation, the McGaffey Member crops out as a regionally persistent, 4- to 20-m-thick, bench-forming ripple-laminated sandstone, in the upper half of the formation (Anderson and Lucas, 1993; Heckert, 1997). The Bluewater Creek Formation is conformably overlain by muddy sandstones and highly bentonitic mudstones of the Blue Mesa Member of the Petrified Forest Formation. The Tr-4 unconformity of Lucas (1991) is expressed as an erosional surface between the Sonsela Member and the underlying Blue Mesa Member, which thins eastward from 45 to 22 m as a result of erosion during that hiatus (Heckert and Lucas, 1996a; Heckert, 1997).

Lower Chinle Group strata in the Zuni Mountains crop out extensively along the northern edge of the uplift (Fig. 1), with complete sections from the "mottled strata" to the Sonsela Member easily pieced together in a few transects. Most of these sections are inside the northern limb of the Triassic outcrop belt in the Zuni Mountains beneath the resistant bluffs of the Sonsela Member, which forms an elongate northwest-trending cuesta between Grants and Fort Wingate. The primary fossiliferous areas are just to the south of this Sonsela ridge line because, farther south, outcrops of Chinle strata are sparse, poorly exposed, and structurally complex.

HISTORY OF STUDY

Vertebrate collection in the Upper Triassic Series of the Zuni Mountains has been both infrequent and, largely, unsuccessful. Almost all diagnostic Upper Triassic vertebrate material known from the Zuni Mountains thus far has been derived from the Bluewater Creek Formation. Some of the earliest material described may have been found in the Blue Mesa Member of the Petrified Forest Formation, but this is highly doubtful. Using the lithostratigraphy and biostratigraphy advocated here, all existing Zuni Mountains collections are thus from horizons correlative with lower Chinle Group exposures in eastern Arizona (Heckert, 1997; Heckert and Lucas, 1997a).

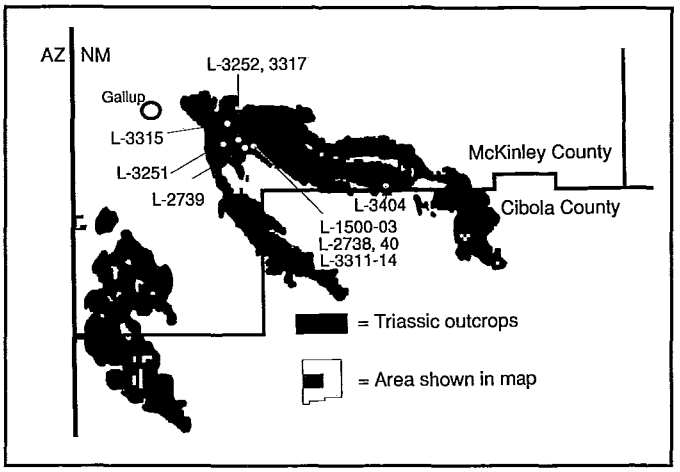

FIGURE 1. Distribution of lower Chinle Group bedrock (shown in black) and tetrapod localities in the Zuni Mountains.

Mehl et al. (1916) first described fossils from the Triassic strata near Fort Wingate, although Darton (1910, p. 46) earlier mentioned indeterminate bone fragments from this region. The material described by Mehl et al. (1916) was derived entirely from the Bluewater Creek Formation and included an aetosaur pelvis they named *Acompsosaurus wingatensis* and a partial phytosaur snout attributed to *Paleorhinus* sp. Unfortunately, all of this material is now lost. Camp (1930) also briefly mentioned indeterminate postcrania of metoposaurids and phytosaurs from the Fort Wingate area.

Ash (1967, 1970) primarily reported on various megafossil plants from the Fort Wingate area and only briefly noted the presence of an amphibian and a phytosaur in the lower units of the Chinle. Stewart et al. (1972) found and documented isolated fossil bones from the area, but these were not identifiable and were incidental to the stratigraphic work that was the focus of their interests. Ash (1978) reported some fragmentary vertebrate material, including scales of the coelacanth *Chinlea* and vertebrate coprolites from his "Lake Ciniza" localities in the Bluewater Creek Formation.

Hunt and Lucas (1989) identified an additional, unnamed coelacanth from this material. Hunt and Lucas (1989) mentioned, and Lucas and Hayden (1989) published, photographs of phytosaur material collected by Camp, but these specimens were found in Arizona and not in the Zuni Mountains (Hunt, 1994). Hasiotis et al. (1994) reported the footprints of a small, ?ornithischian dinosaur from near Fort Wingate, but these have yet to be illustrated. In a summary article on the Triassic paleontology of New Mexico, Hunt and Lucas (1993a) provided a faunal list for the lower Chinle Group in the Zuni Mountains, including some unpublished material collected by those authors catalogued at the NMMNH.

LATE TRIASSIC VERTEBRATE PALEONTOLOGY OF THE ZUNI MOUNTAINS

Prior to this investigation, S.G. Lucas and A.P. Hunt had identified several promising localities, including NMMNH L-2739, that had produced fragmentary postcrania of a dinosaur, but none of these had been systematically described, and only preliminary information had been published (Hunt and Lucas, 1989, 1993a). Here, I provide an annotated faunal list of lower Chinle Group vertebrate localities in the Zuni Mountains. Approximate locations of these localities are shown in Figure 1, and stratigraphic information, plotted in Figure 2, is provided later in the text. The most important specimens are described in detail, and all specimens collected in the Zuni Mountains currently reposited at the NMMNH are listed in systematic fashion in the appendix.

Metoposauridae indet.

Fragmentary skull, clavicle, and interclavicle material of metoposaurid amphibians are the most frequently encountered identifiable vertebrate fossils in the lower Chinle Group in the Zuni Mountains. Generally undiagnostic below the family level, some of these remains were collected simply to document the presence of large metoposaurid amphibians, and thus confirm a Late Triassic age at various localities. Most of this material probably pertains to the genus *Buettneria*, but cannot be distinguished from similar material of *Metoposaurus*. Almost all of the material listed in the appendix is too large to belong to *Apachesaurus*, a contemporaneous metoposaur that can be diagnosed by its combination of small size but relatively elongate centra, among other features (Hunt, 1993). Here, I reassign NMMNH P-10735, a fragment of an interclavicle, to the Metoposauridae. Lucas and Hayden (1989, fig. 8a, p. 200) originally assigned this specimen to the Capitosauridae, in large part because they believed it had been found in a siliciclastic tongue of the San Andres Formation. Instead, NMMNH L-355, the locality which produced NMMNH P-10735, is low in the Bluewater Creek Formation in outcrops just above the mottled strata and below lacustrine limestones in the Bluewater Creek Formation near Cottonwood Canyon (Heckert, 1997; Heckert and Lucas, 1997b).

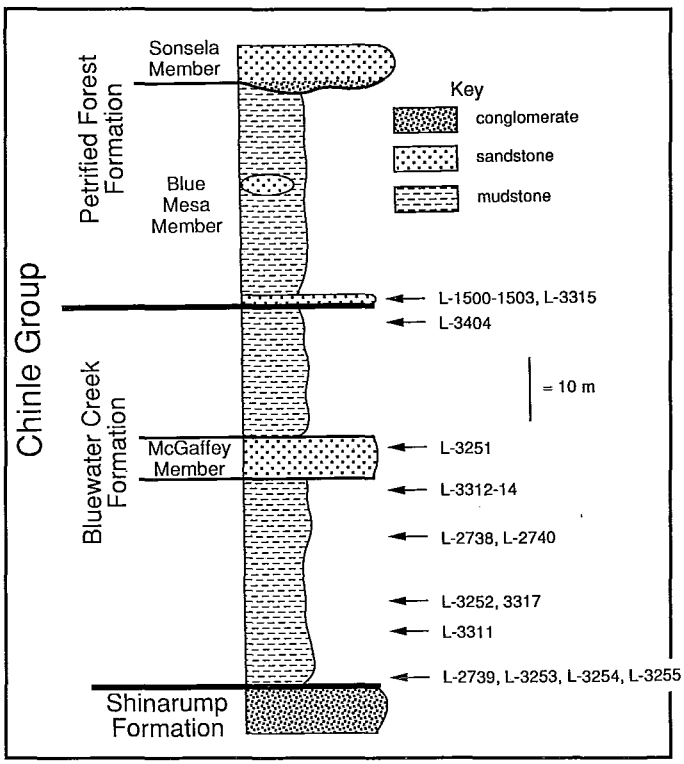

FIGURE 2. Generalized stratigraphic column of the lower Chinle Group in the Zuni Mountains, west-central New Mexico, with stratigraphic position of tetrapod localities described in this paper indicated.

Buettneria sp.

It is possible to diagnose some metoposaurids to genus level from incomplete clavicles and interclavicles (e.g., Colbert and Imbrie, 1956; Hunt, 1993). Hunt (1993) revised the Metoposauridae, noting that among the large metoposaurids, *Buettneria* exhibits more pitting and fewer radial ridge-and-groove features over its clavicles and interclavicles than *Metoposaurus*, in addition to several differences in skull morphology. Using the taxonomy of Hunt (1993), I identify partial interclavicles such as NMMNH P-18311, from L-3251, and P-18326, from L-3255, as well as the specimens listed in the appendix, as *Buettneria* cf. *B. perfecta*. A high abundance of *Buettneria* relative to *Apachesaurus* is characteristic of the Adamanian land-vertebrate faunachron (lvf) of Lucas and Hunt, (1993a) and thus suggests an Adamanian age for these localities (Hunt and Lucas, 1993b).

cf. *Buettneria* sp.

A skull fragment from NMMNH L-3251, NMMNH P-18312, also clearly represents a metoposaurid. Generic distinction of metoposaurid taxa from skull material is determined principally by the position of the lachrymal relative to the orbit (the lachrymal is excluded from the orbit in all metoposaurid taxa except *Buettneria*) and the development of the otic notch region on the posterior margin of the skull (Hunt, 1993). Neither of these is preserved in NMMNH P-18312, but *Metoposaurus* and *Buettneria* are the only large metoposaurid taxa known from the Chinle Group (Hunt, 1993). Of these, *Metoposaurus bakeri* is much rarer, known only from Otischalkian strata in Texas. Therefore, I tentatively identify NMMNH P-18312 as cf. *Buettneria* sp. The material identified here and in the appendix as cf. *Buettneria* is generally more fragmentary and less diagnostic than the material assigned to *Buettneria* in the previous section. In all likelihood, all of these specimens are probably *Buettneria perfecta*, but the available material precludes making that taxonomic assignment with certainty.

?Dicynodontia indet.

Several fragmentary limb elements discovered at NMMNH L-3251, NMMNH P-18448 and P-18449, are too large to assign to any known archosaur from the Chinle Group. The sheer size of these specimens suggests that they belong to one of the following: (1) a dicynodont; (2) a prosauropod dinosaur; or (3) a large reptile that has not been found previously. Unfortunately, the preservation of these fossils is poor, and most of the material is quite fragmentary. In general, the bones resemble those of dicynodonts, although they are too fragmentary to identify as either *Placerias* or *Ischigualastia*, the only dicynodonts identified from the Chinle thus far (Camp and Welles, 1956; Lucas and Hunt 1993b). The preserved elements do not appear to be sufficiently gracile to correspond to a prosauropod dinosaur (e.g., Galton, 1990), and, without additional material, I am unwilling to declare that they pertain to a previously undiscovered taxon. Therefore, I identify P-18448 and P-18449 as ?Dicynodontia indet.

Archosauria indet.

The head of a left humerus, NMMNH P-18485, collected from the Bluewater Creek Formation at NMMNH L-2740, closely resembles those of either aetosaurs or phytosaurs. The head is broadly expanded antero-posteriorly, with the deltopectoral crest deflected slightly medially. This specimen is not diagnostic below the level of Archosauria, but was collected in case additional material turned up in later visits to the site. Some specimens from NMMNH L-3251 also appear to represent indeterminate archosaurs, including NMMNH P-18396, a dorsal centrum, and NMMNH P-18397, a partial pubis or ischium.

Parasuchidae indet.

After the nearly ubiquitous fragmentary metoposaurid material, the most frequently encountered identifiable fossil vertebrate material found in the Zuni Mountains are teeth, skull fragments, and scutes of phytosaurs. Unlike aetosaurs, phytosaurs cannot be identified on the basis of their scutellation. The one exception being the phytosaur *Angistorhinus*, which appears to have the least decoration (smallest pits) on its scutes (Hunt, 1994, 1997). Like the metoposaurs, some of this material was collected simply to document the presence of phytosaurs at various localities and thus confirm the Late Triassic age of the units in question.

Of particular interest is a very large phytosaur tooth, NMMNH P-18306, from NMMNH L-3254 low in the Bluewater Creek Formation (Fig. 3A-B). This tooth measures 7.4 cm in length and possesses serrations on both the anterior and posterior edges, as well as a peculiar third series of serrations on the ?labial surface of the tooth. This tooth suggests the presence of large, heterodont phytosaurs in the Bluewater Creek Formation, possibly *Smilosuchus* or, less likely, *Angistorhinus* (Hunt, 1994; Long and Murry, 1995). The phytosaur snout assigned to *Paleorhinus* sp. by Mehl et al. (1916) is now lost. However, based on their published illustrations of the snout I agree with most later workers that this specimen was too incomplete to identify more precisely than Parasuchidae indet.

Stagonolepidae indet.

Some peculiar spikes and scute fragments at three localities in the Bluewater Creek Formation in the Zuni Mountains most closely resemble the lateral scutes of aetosaurs such as *Desmatosuchus*, but are not diagnostic of that or any other aetosaur taxon. These specimens are: NMMNH P-18279, lateral spike (L-2740); NMMNH P-18356, two lateral spikes (L-3311); NMMNH P-18451, five small scute fragments (L-3251); NMMNH P-18472, three small scute fragments (L-3251).

Desmatosuchus sp.

The monospecific genus *Desmatosuchus* is one of the most ubiquitous Chinle aetosaurs, and is known from strata of Otischalkian to early Revueltian age (early late Carnian to early–mid Norian) in Texas, New Mexico, and Arizona (Lucas and Hunt, 1993a; Long and Murry, 1995; Lucas, 1997). *Desmatosuchus haplocerus* was perhaps the largest Chinle aetosaur, with a maximum length estimated to be as much as 6 m (Case, 1922; Long and Murry, 1995). *Desmatosuchus* may also have the longest temporal range of any aetosaur, as it is known from sediments of early late Carnian to early–mid Norian age (Lucas and Hunt, 1993a). Numerous specimens of *Desmatosuchus* have been collected below and above the Sonsela Member in the PFNP as well as from the Bluewater Creek Formation at the *Placerias* quarry in Arizona (Long and Ballew, 1985; Long and Murry, 1995). Additionally, NMMNH specimens P-18293, P-

18308, and P-18330 from L-3251 in the Bluewater Creek Formation all pertain to *Desmatosuchus*. Because of the possibility that there are multiple species of *Desmatosuchus*, I prefer to identify all material that pertains to *Desmatosuchus* as *Desmatosuchus* sp.

NMMNH P-18308 (Fig. 3C) represents a partial right ilium and pubis of *Desmatosuchus* sp. Although Case (1922) illustrated excellent and nearly complete material of *Desmatosuchus*, Long and Murry (1995) were the first to publish photographs of the ilia of this nearly ubiquitous lower Chinle taxon. NMMNH P-18308 is very similar to UMMP 7322 (Long and Murry, 1995: fig. 91). Although the anterior process of the iliac blade is missing in the NMMNH specimen, the intact posterior process is triangular in lateral view with a transversely thickened dorsal margin. The posterior process is almost entirely posterior to the ischiatic process. The acetabulum is deep with a well-developed brevis fossa. The pubis is badly damaged and incomplete but still well-fused to the ilium. The pubo-iliac articulation is transversely broad, approximately 2.5 times wider than dorso-ventrally tall. In these features, NMMNH P-18308 is identical to *Desmatosuchus* and is distinct from *Stagonolepis*, which possesses a posterior iliac process that is quadrilateral in lateral view and a more robust anterior iliac process than could have existed on NMMNH P-18308 (Long and Murry, 1995:86–87, figs. 79–80). Similarly, a

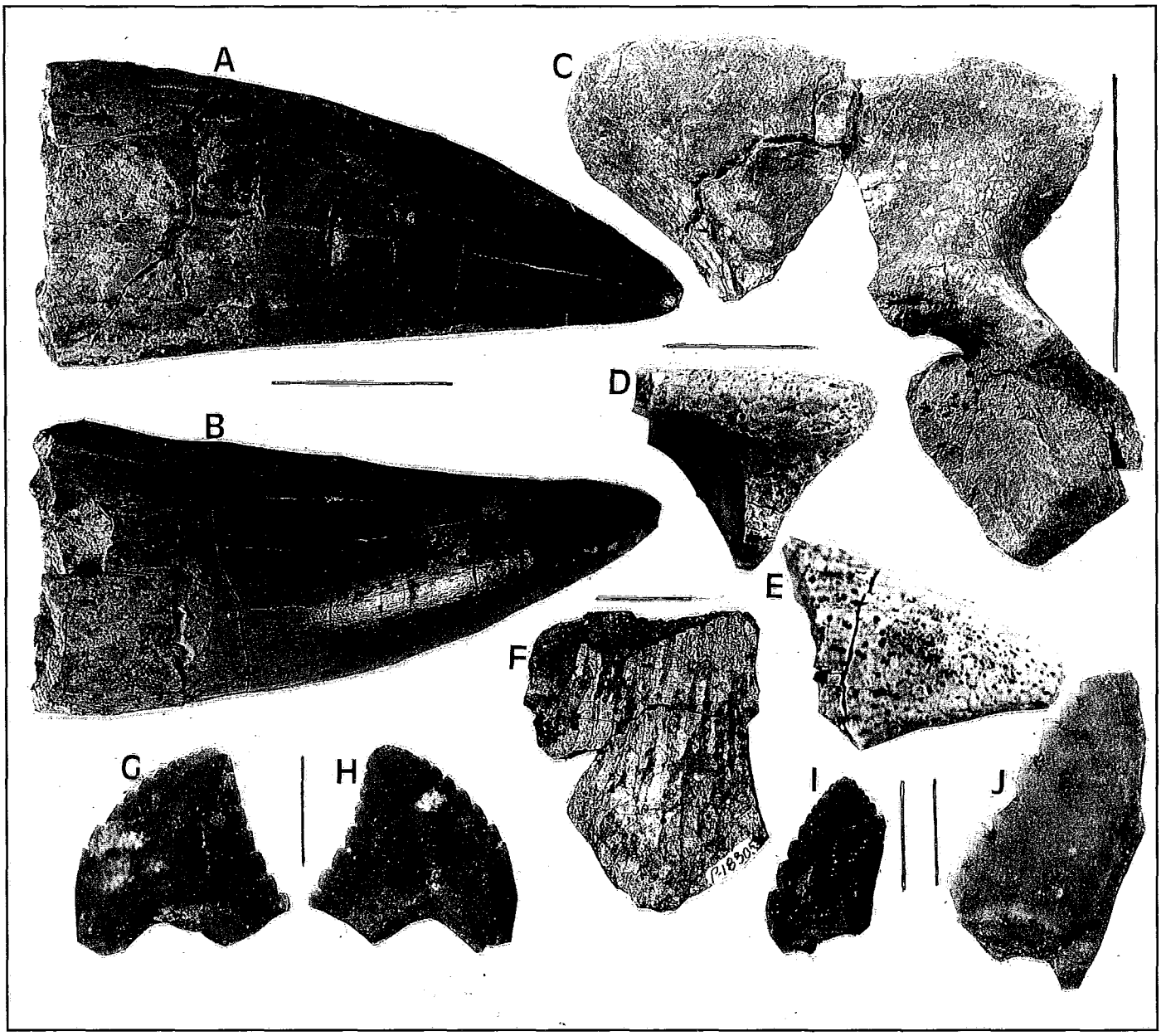

FIGURE 3. Representative tetrapod fossils from the Bluewater Creek Formation in the Zuni Mountains. **A–B**, NMMNH P-18306, large phytosaur tooth from L-3254 in lingual (A) and labial (B) views. **C**, NMMNH P-18308, partial right ilium and pubis of *Desmatosuchus* sp. from L-3251 in left lateral view. **D–E**, NMMNH P-18293, right lateral scute of *Desmatosuchus* sp. from L-3251 in posterior (D) and anterior (E) view. **F**, NMMNH P-18305, ventral flange of left lateral scute of *Paratypothorax* sp. in ventral view. **G–H**, NMMNH P-18402 aff. *Tecovasaurus* sp. tooth crown from L-2739 in ?labial (G) and ?lingual (H) views;. **I**, NMMNH P-18403, small ornithischian tooth crown in ?labial view. **J**, NMMNH P-18404, large ?ornithischian tooth from L-2739 in ?lingual view. Scales for A–B, D–F = 2 cm; C = 10 cm; all other scales = 1 mm.

variety of characters also prevent assignment of this ilium to any of the other Chinle aetosaurs, including *Longosuchus*, *Typothorax*, and *Paratypothorax* (Long and Murry, 1995). Its sheer size precludes assignment to the small-bodied *Aetosaurus*. Nor does it pertain to *Neoaetosauroides*, an aetosaur known only from the uppermost Triassic of Argentina.

A lateral spike, complete except for parts of both the dorsal and lateral flange, from NMMNH L-3251 (Fig. 3D–E), NMMNH P-18293, is typical of *Desmatosuchus* lateral scutes (Case, 1922; Long and Ballew, 1985; Long and Murry, 1995; Heckert et al., 1996). This scute is strongly flexed, with the dorsal and lateral flanges meeting at an approximate right angle. A posteriorly recurved spike projects laterally from the scute and is round with a slightly concave posterior margin. Pitting in the scute surface is faint and randomly distributed. This specimen represents a right lateral scute of *Desmatosuchus* sp., probably from posterior to the forelimb.

NMMNH P-18330 from NMMNH L-3251 consists of four fragments of lateral spikes of *Desmatosuchus*. All of these pieces are subcircular in cross-section with varying degrees of recurvature. *Desmatosuchus* is well-characterized by its cervical lateral scutes, which bear prominent horns up to a half meter long and are strongly recurved posteriorly. No other aetosaur is similarly armored, although *Longosuchus* in particular has significant spike development (Long and Ballew, 1985; Hunt and Lucas, 1990; Long and Murry, 1995; Heckert et al., 1996). For these reasons, I consider NMMNH P-18330 to represent portions of several spikes of a subadult to adult *Desmatosuchus*.

There was also some rare additional material that may pertain to *Desmatosuchus*. A few fragments of bone found in association with NMMNH P-18308, the diagnostic ilium and pubis of *Desmatosuchus*, may represent additional material of that taxon, but are too incomplete to identify with confidence. Therefore, specimens attributed to cf. *Desmatosuchus* include: NMMNH P-18325, right ischium fragment (L-3251); NMMNH P-18399, partial left ilium (L-3251); NMMNH P-18320, scute fragment (L-3256).

Paratypothorax sp.

Long and Ballew (1985) named *Paratypothorax* for a wide-bodied aetosaur known from numerous disarticulated scutes found in the PFNP. They named the type species after the Andress family, *Paratypothorax andressi* (Long and Ballew, 1985:57). However, the specific epithet is grammatically incorrect as, according to the International Code of Zoological Nomenclature, species named after two or more individuals, at least one of which is male, must utilize the Latin suffix *-orum*. Therefore, the proper name of the type and only known species of *Paratypothorax* is *P. andressorum*.

Nomenclatural concerns aside, specimens of *Paratypothorax* most commonly occur in strata of Norian age (Hunt and Lucas, 1992; Heckert et al., 1996; Lucas and Heckert, 1996a,b), although one specimen was documented from the latest Carnian Blue Mesa Member within the PFNP (Hunt and Lucas, 1992; Long and Murry, 1995). However, this was the only known specimen of *Paratypothorax* from Carnian strata, and it was actually very high in the section, only about 2–3 m below the Sonsela (Hunt and Lucas, 1992). At NMMNH L-3252, very low in the Bluewater Creek Formation in Sixmile Canyon, I found a partial lateral scute of *Paratypothorax* now catalogued as NMMNH P-18305 (Fig. 3F). This scute consists of a flange that is trapezoidal in shape and wider medially than laterally, where its junction with another flange is broken. A radial pattern of recurved grooves and ridges radiates from the broken lateral margin. In these respects, this scute exactly conforms to the morphology of the ventral flange of *Paratypothorax* lateral scutes, such as the uncatalogued SMNS specimens illustrated by Long and Murry (1995:111, fig. 114F). NMMNH P-18305 marks the oldest known occurrence of *Paratypothorax* and represents a range extension for this taxon from the end of the Adamanian lvf, to its beginning.

Stagonolepis sp.

Stagonolepis possesses a prototypical aetosaurian carapace that has typically been considered primitive for the group by most workers (e.g., Walker, 1961; Parrish, 1994; Long and Murry, 1995; Heckert et al., 1996). This carapace consists of dorsal paramedian scutes that are roughly two to three times as wide as long with a radial pattern of pits, grooves, and ridges emanating from a dorsal prominence at or near the posterior margin of the scute. These scutes are distinct from *Desmatosuchus* in possessing this pattern and anterior bars while lacking distinct articulations for the lateral scutes. Lateral scutes are similar, except that they are nearly square, although *S. wellesi* appears to have spines on its cervical lateral scutes (Long and Murry, 1995). Because this scutellation is rather primitive among aetosaurs, including both known species of *Stagonolepis*, scutes of *Stagonolepis* are readily identified to genus, but do not permit identification at the species level, except, as noted above, in the case of cervical lateral scutes of *S. wellesi*.

Long and Murry (1995) posited that all Chinle specimens of *Stagonolepis* pertain to *S. wellesi* (Long and Ballew, 1985), citing differences in the cervical lateral scutes and the transverse processes of the presacral vertebrae, but I cannot justify identification of any portion of the anatomy outside of complete vertebrae and cervical lateral scutes to the species level. Therefore, I identify NMMNH P-18362, the specimen of *Stagonolepis* described here from L-3312, as *Stagonolepis* sp. Another specimen tentatively assigned to *Stagonolepis* from this area is a fragmentary dorsal centrum, NMMNH P-18327, from NMMNH L-3251 in the Bluewater Creek Formation. This centrum is strongly constricted, quadrilateral in cross-section, and bears a prominent keel along the ventral surface. In these features it resembles *Stagonolepis* as described by Walker (1961) and Long and Murry (1995). *Stagonolepis* is an index taxon of the Adamanian lvf (Lucas and Hunt, 1993a; Lucas et al., 1997b) and thus indicates a latest Carnian age for the Bluewater Creek Formation.

The pelvis named *Acompsosaurus wingatensis* by Mehl et al. (1916) is now lost. I agree with Hunt and Lucas (1989) and Long and Murry (1995) and consider this specimen to represent a pelvis of *Stagonolepis*, based on the illustrations and photographs published by Mehl et al. (1916). Stratigraphic columns and descriptions published by Mehl et al. (1916) indicate that this fossil was probably derived from low in the Bluewater Creek Formation.

Ornithischia indet.

Ornithischian dinosaurs are known from deposits of late Carnian age in South America, Africa, and North America. Late Carnian ornithischian skeletal remains, however, are extremely rare, and to this point consist only of a partial skeleton of *Pisanosaurus mertii* from the Ischigualasto Formation of

Argentina (Casamiquela, 1967). All other late Carnian ornithischians are known only from isolated teeth (e.g., Galton, 1983; Weishampel and Witmer, 1990; Lucas and Hunt, 1994). These teeth are readily differentiated from those of theropods or other carnivorous archosaurs by the presence of denticles that are considerably larger than serrations and intersect the tooth margin at an angle of approximately 30–60° (Sereno, 1991; Hunt and Lucas, 1994). Ornithischian teeth are readily differentiated from prosauropod teeth in that the teeth of ornithischians are markedly asymmetrical in mesial or distal view, with the base considerably more bulbous across the labial surface (Galton, 1990; Sereno, 1991; Hunt and Lucas, 1994).

Given these criteria, several specimens discovered while picking screenwashed sediments from L-2739 in the lower Bluewater Creek Formation represent the teeth of ornithischians. NMMNH P-18402 is a partial tooth that is also markedly asymmetrical in labial/lingual views (Fig. 3G–H). It superficially resembles *Tecovasaurus murryi* Hunt and Lucas (1994) in this respect, but possesses a nearly equal number of denticles on the anterior (6–7) and posterior (7–8) margins. I suspect that this tooth does pertain to *Tecovasaurus* based on overall similarity, but at this time *Tecovasaurus* is too incompletely known to validate this taxonomic assignment, so I assign this tooth to Ornithischia indet. (aff. *Tecovasaurus*).

NMMNH P-18404 (Fig. 3I) is a particularly small ornithischian tooth, measuring just over 1 mm high and 1 mm wide, although it is not complete. The tip is symmetrical, with the denticles increasing in size down the more complete (anterior?) margin. There are a total of eight denticles on this side. NMMNH P-18403 (Fig. 3J) is a partial tooth that may also represent an ornithischian dinosaur, although the denticles are not strong and intersect the tooth margin at a fairly high angle. However, the tooth is markedly asymmetrical in mesial/distal views. I consider this tooth to represent an indeterminate ornithischian, notably the largest ornithischian from this locality. All of these teeth were found very low in the Bluewater Creek Formation and are among the oldest known dinosaurs.

Theropoda *incertae sedis*

The bones of at least two theropod dinosaurs occur low in the Bluewater Creek Formation at NMMNH L-2739 at the same locality as the ornithischian dinosaurs described above (Fig. 4). The first theropod, NMMNH P-18400, is represented by numerous dorsal and caudal centra, a distal left humerus, proximal left tibia, proximal left fibula, and numerous distal limb elements, principally metatarsals, metacarpals, and phalanges (Fig. 4A–E). All of the partial centra are clearly hollow, with flat neural canals across the top of the central body. Centra from the dorsal series often preserve portions of the neural arches and transverse processes, establishing that this theropod was an adult, and therefore that the small size of the specimen is an accurate representation of the adult morphology of the theropod. The dorsal centra show no evidence of being foreshortened in the

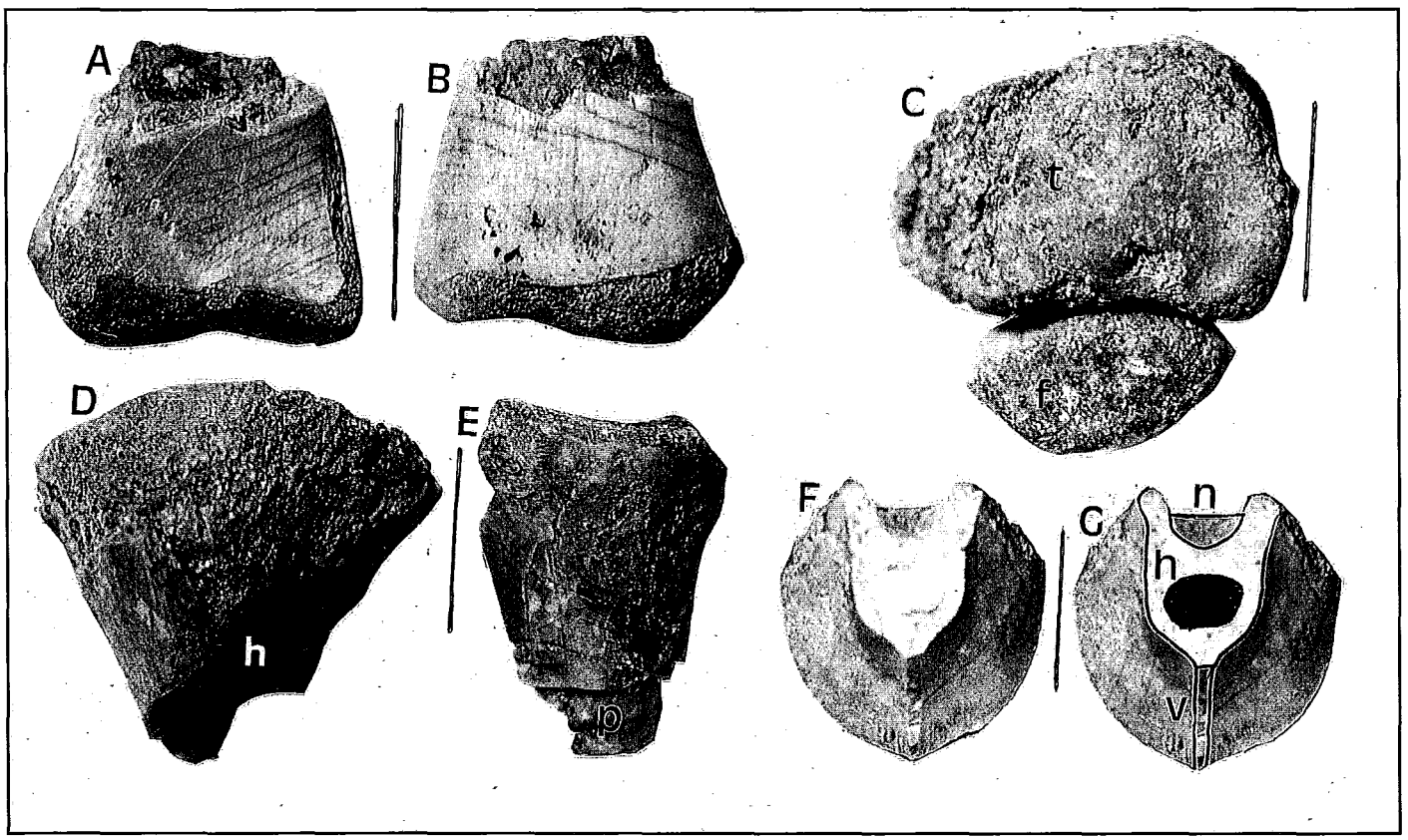

FIGURE 4. Theropod fossils from L-2739 in the Bluewater Creek Formation in the Zuni Mountains. **A–B**, NMMNH P-18400 distal left humerus of small theropod in anterior (A) and posterior (B) views. **C**, NMMNH P-18400 proximal left tibia (t) and fibula (f) in proximal view. **D**, NMMNH P-18400 proximal left tibia in anterior view, dark area (h) is hollow cavity. **E**, NMMNH P-18400 proximal left fibula in posterior view, descending "process" (p) is diagenetic barite infilling of hollow bone. **F–G**, NMMNH P-18401 cross-sectional views of dorsal centrum of a second small theropod, (F) cross-sectional view of dorsal centrum, (G) same centrum with central hollow (h), prominent ventral keel (v) and neural concavity (n) demarcated and central hollow shaded. Scales for A–B = 2 cm, all other scales = 1 cm.

manner of herrerasaurids (Novas, 1993), so this theropod is potentially more derived than the herrerasaurids. The articular facet of the caudal centra are thickened ventrally, and the chevron facets are preserved as twinned, elongate ridges that run the length of the preserved ventral surfaces.

Most of the small limb bones found in association with NMMNH P-18400 are indeterminate, and therefore undiagnostic: carpals, metacarpals, tarsals, metatarsals, and phalanges. However, the distal left humerus, a proximal left tibia, and a proximal left fibula, all of a size consistent for this theropod, were also present in the quarry (Fig. 4A–E). These bones, including many of the phalanges and other small elements, are also hollow, indicating that they belong to a small theropod. Based on the extremely common occurrence of vertebrae of the first theropod relative to those of another theropod in the quarry (see below), I interpret these elements to be representative of the first theropod. Based on the typical length of the vertebrae and the general proportions of the limbs, this theropod had a very gracile build and was probably approximately 1 m long.

The second theropod from L-2739, NMMNH P-18401, consists of ten vertebral fragments representing nine centra. These centra are all amphicoelous and hollow with deeply excavated articular facets (Fig. 4F–G). The largest element consists of two fragments of a single centrum that measures 25 mm long and 17 mm across at the ?anterior articular facet. This articular facet is 16 mm high. At the midpoint, this centrum is highly constricted and measures only 7 mm across and 7 mm high from the ventral keel to the excavated neural canal. The centrum is 12 mm high from the base of the ventral keel to the suture with the neural arch at this point. In cross-section the body of the centrum is shield-shaped (Fig. 4G), not subcircular, as in the cross sections of the vertebrae of the other theropod (P-18400).

Most other centra assigned to NMMNH P-18401 exhibit a similar morphology, yet are considerably smaller and appear to represent distal caudal vertebrae. These centra are also medially constricted, hollow, and possess ventral keels. No neural arches are present, even as broken pieces fused to the bodies of the centra, so it appears that this specimen represents a juvenile or subadult theropod. Reconstructing from the larger, dorsal centrum gives a presacral column length of 0.5–0.6 m. Unlike the first theropod, there is no indication that the tail was particularly long, as most of the presumably caudal vertebrae are not measurably longer than wide. Therefore, I do not believe that this animal was more than 1.1 to 1.2 m in length.

Trace fossils

Ash (1978) noted vertebrate coprolites among the specimens collected from his "Ciniza Lake Beds" near the base of the Bluewater Creek Formation. Similarly, the only ichnofossils I report from the lower Chinle Group of the Zuni Mountains are miscellaneous vertebrate coprolites. Hasiotis et al. (1994) reported the tracks of an ?ornithischian dinosaur from very low in the Bluewater Creek Formation near Ash's (1978) Lake Ciniza localities, but these are the only Upper Triassic footprints known from the area. Coprolites from the Bluewater Creek Formation and Blue Mesa Member of the Zuni Mountains include NMMNH P-22474, two coprolites from L-1503 and NMMNH P-18454, five coprolites from L-3251. Although Hunt and Lucas (1997) are publishing an ichnotaxonomy of Chinle coprolites, I choose not to refer these specimens to any ichnotaxa at this time.

STRATIGRAPHY OF TETRAPOD LOCALITIES IN THE ZUNI MOUNTAINS

The lower Chinle Group tetrapod localities I document here occur primarily in the Bluewater Creek Formation, although isolated material has been collected from the overlying Blue Mesa Member (Table 1; Fig. 2). To this date, the McGaffey Member of the Bluewater Creek Formation has not produced any vertebrate fossils, although NMMNH L-3251 occurs in an intraformational conglomerate that approximates the stratigraphic level of the McGaffey Member (Fig. 2). No vertebrate localities were discovered in either the Shinarump Formation or the mottled strata. It is too early at this time to attempt to place much significance on the stratigraphic distribution of tetrapod localities, other than to note that the Blue Mesa Member is largely unfossiliferous in the Zuni Mountains and that many of the localities described here are located relatively low in the Bluewater Creek Formation, typically in the bottom half of that unit.

The preliminary reconnaissance conducted by Hunt and Lucas in the Zuni Mountains prior to this project had resulted in the identification of eight tetrapod localities. Four of these (NMMNH L-2733, 2738–2740) were in the Bluewater Creek Formation, with the other four (NMMNH L-1500–1503) in the Blue Mesa Member of the Petrified Forest Formation (Fig. 2). Of these, NMMNH L-2739 was the stratigraphically lowest and most productive of the Bluewater Creek Formation localities, and NMMNH L-1503 was the most productive Blue Mesa Member locality.

As part of this study, I collected additional material from these localities, particularly NMMNH L-2739, and found and documented additional localities. To this end I have already documented the important specimens from this area. Here, I document the stratigraphic and lateral range of these localities.

Bluewater Creek Formation localities

The dinosaur-bearing locality NMMNH L-2739 is one of the stratigraphically lowest Upper Triassic tetrapod localities in the Zuni Mountains. A few other localities, such as NMMNH L-3254 and L-3255, are equally low, as are the "Ciniza Lake Beds" localities of Ash (1978), including NMMNH L-3253. These localities typically occur in bentonitic, silty mudstones that are slightly color mottled. These lithologies represent deposits of poorly drained wetlands that lay in the paleotopography generated during the development of the Tr-3 unconformity (Heckert, 1997).

Most other localities in the area occur above this zone in the first, red-beds lithofacies of the Bluewater Creek Formation, below sandstones of the McGaffey Member. This is, at least in part, an artifact of the outcrop trend. Throughout the Zuni Mountains the most extensive badlands are of the lower Bluewater Creek Formation, with much of the upper portion of the unit exposed as sheer slopes that are more difficult to prospect and do not preserve as much area as the low badlands of the lower portion of the unit. Otherwise, there is no reason to assume that these strata are any less fossiliferous than the underlying strata. I have had particular success prospecting above the first band of red sediments low in the Bluewater Creek Formation, which has produced localities NMMNH L-3252 and L-3317. Similar localities include NMMNH L-2738 and L-2740, found by Lucas and Hunt, and NMMNH L-3311 through L-3314.

The stratigraphically highest, and most productive, vertebrate locality is NMMNH L-3251 in the Bluewater Creek Formation of the Zuni Mountains near the town of Fort Wingate. This site has produced numerous specimens of phytosaurs, the metoposaurid amphibian *Buettneria* sp., the aetosaurs *Desmatosuchus* sp., and cf. *Stagonolepis* sp., a ?dicynodont, and other unidentified reptiles. NMMNH L-03251 is in a very well-indurated intraformational conglomerate at a horizon approximately 40 m above the base of the Bluewater Creek Formation, 20 m below the Blue Mesa Member at the approximate stratigraphic level of the McGaffey Member, which is absent locally (Fig. 2). The presence of the aetosaur *Stagonolepis* in the Bluewater Creek Formation indicates that the tetrapod fauna of the Bluewater Creek Formation is of Adamanian (latest Carnian) age.

Blue Mesa Member localities

The westernmost locality in the Blue Mesa Member of the Zuni Mountains is NMMNH L-3315, located very low in the Blue Mesa Member. Some fragmentary material is evident in other places, and Hunt and Lucas discovered fairly significant vertebrate specimens from four closely spaced localities (NMMNH L-1500 to L-1503) in the Blue Mesa Member in the extreme northwest corner of section 30, T14N R15W. All of these localities are very low in the Blue Mesa Member.

As with the upper Bluewater Creek Formation, a lack of good badlands outcrops hinders prospecting in the Blue Mesa Member. The less than ideal exposure is caused in large part by the reinforced dipslope of the overlying Sonsela Member, which enables Blue Mesa Member strata to weather to high-angle walls along strike. The distal floodplains and paleosol facies, consisting of fine-grained bentonitic mudstones and calcrete-bearing horizons of pedogenically modified mudstones, that dominate the Blue Mesa Member also are relatively unproductive. This is probably in large part because these deposits do not represent facies with depositional rates that were fast enough to preserve tetrapod material on a regular basis, unlike the more proximal floodplain and channel deposits of the underlying Bluewater Creek Formation (Heckert, 1997). Although a series of fluvial sandstones and mudstones in the Blue Mesa Member are highly fossiliferous in the PFNP, these horizons are not preserved in the Zuni Mountains, in large part because they were removed during development of the Tr-4 unconformity (Heckert and Lucas, 1996a; Heckert, 1997).

CONCLUSIONS

In spite of a long, if episodic, history of collecting, few lower Chinle Group tetrapod localities were known from the Zuni Mountains at the outset of the study, and none of these had been thoroughly documented. This report documents numerous additional specimens and localities, as described above and summarized in Table 1. The tetrapod fauna from the Bluewater Creek Formation of the Zuni Mountains now includes the metoposaurid amphibian *Buettneria*, the aetosaurs *Stagonolepis*, *Desmatosuchus*, and *Paratypothorax*, at least two ornithischian dinosaurs, two theropod dinosaurs, as-yet indeterminate phytosaurs, possible dicynodonts, and abundant coprolites. The Blue Mesa Member of the Zuni Mountains is relatively unfossiliferous, but has produced fragmentary bone of archosaurs and metoposaurid amphibians.

TABLE 1. Tetrapod faunal list of the lower Chinle Group in the Zuni Mountains.

Unit	Taxa
Blue Mesa Member	Metoposauridae indet.
Petrified Forest Formation	Reptilia indet.
	Parasuchidae indet.
	vertebrate coprolites
Bluewater Creek Formation	*Buettneria* sp.
	Metoposauridae indet.
	?Dicynodontia indet.
	Archosauria indet.
	Parasuchidae indet.
	Stagonolepidae indet.
	Desmatosuchus sp.
	Paratypothorax sp.
	Stagonolepis sp.
	cf. *Stagonolepis* sp.
	Theropoda (2 species)
	Ornithischia indet.
	vertebrate coprolites

The presence of the aetosaur *Stagonolepis* in the Bluewater Creek Formation of the Zuni Mountains indicates an Adamanian (latest Carnian) age for that unit. Although the Blue Mesa Member does not produce age-diagnostic tetrapods in the Zuni Mountains, it does produce Adamanian tetrapods in Arizona (Lucas and Hunt, 1993; Lucas and Heckert, 1996). The latest Carnian age of the dinosaur fauna from the Bluewater Creek Formation is important because dinosaurs appear to make a nearly synchronous first appearance in the late Carnian on multiple continents (Hunt, 1991; Lucas et al., 1992; Heckert and Lucas, 1995, 1996b). Because of this nearly synchronous appearance of the first dinosaurs, the discovery of any late Carnian dinosaur is significant in any attempt to document the early evolution and dispersal of the dinosaurs. Therefore, a locality such as NMMNH L-2739, which has produced at least four late Carnian dinosaurs and thus contains the most diverse late Carnian dinosaur fauna known to date, is particularly important in understanding the early radiation of dinosaurs.

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on National Forest Service land in the Zuni Mountains. Logistical support was provided by the New Mexico Museum of Natural History and Science and by the Department of Earth and Planetary Sciences, UNM. K. Cockerill and S. Harris helped pick screenwash concentrate and found some of the microvertebrate fossils described here. My thesis committee, S.G. Lucas, B.S. Kues, and M. Elrick reviewed an earlier version of this manuscript that appeared in my thesis.

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APPENDIX: REFERRED SPECIMENS

This appendix is a list of all referred specimens from the lower Chinle Group in the Zuni Mountains, west-central New Mexico in the collections of the New Mexico Museum of Natural History and Science, Albuquerque. Refer to the text and Figure 2 for stratigraphic information on individual localities. Geographic information on all localities is available at the NMMNH.

Metoposauridae indet.

Specimens that pertain to the Metoposauridae but are otherwise undiagnostic include the following: NMMNH P-22485, five skull fragments (L-1501); NMMNH P-22484, 11 skull fragments (L-1502); NMMNH P-22472, interclavicle fragment (L-1503); NMMNH P-25645, 22 interclavicle fragments (L-1503); NMMNH P-25622, two interclavicle fragments (L-2733); NMMNH P-18268, two skull fragments (L-2738); NMMNH P-18269, two centra fragments (L-2738); NMMNH P-18280, two interclavicle fragments (L-2740); NMMNH P-18295, two interclavicle fragments (L-3251); NMMNH P-18296, eight clavicle fragments (L-3251); NMMNH P-18309, 12 clavicle fragments (L-3251); NMMNH P-18313, dentary fragment with six teeth (L-3251); NMMNH P-18316, interclavicle fragment (L-3251); NMMNH P-18344, centrum (L-3251); NMMNH P-18351, four jaw fragments (L-3251); NMMNH P-18457, right maxillary fragment (L-3251); NMMNH P-18458, numerous skull and pectoral girdle fragments (L-3251); NMMNH P-18459, numerous skull fragments (L-3251); NMMNH P-18460, interclavicle fragment (L-3251); NMMNH P-18365, numerous skull fragments (L-3315); NMMNH P-18474, jaw fragment (L-3404).

Buettneria sp.

Specimens that can be tentatively assigned to the genus *Buettneria* include: NMMNH P-18310, interclavicle fragment (L-3251); NMMNH P-18311, five interclavicle fragments (L-3251); NMMNH P-18315, interclavicle fragment (L-3255); NMMNH P-18326, interclavicle fragment (L-3255); NMMNH P-18358, interclavicle in concretion (L-3312).

cf. *Buettneria* sp.

Material tentatively assigned to cf. *Buettneria* sp. includes the following: NMMNH P-18312, left skull fragment (L-3251); NMMNH P-18343, centrum (L-3251); NMMNH P-18345, three interclavicle fragments (L-3251); NMMNH P-18346, seven skull fragments (L-3251); NMMNH P-18347, numerous skull fragments (L-3251); NMMNH P-18348, numerous assorted interclavicle fragments (L-3251); NMMNH P-18349, interclavicle fragment (L-3251); NMMNH P-18350, interclavicle fragment (L-3251); NMMNH P-18455, ten skull fragments (L-3251); NMMNH P-18456, numerous clavicle and interclavicle fragments (L-3251).

?Dicynodontia indet.

Material from the Bluewater Creek Formation in the Zuni Mountains tentatively identified as dicynodont includes: NMMNH P-18448, four large limb bone fragments (L-3251); NMMNH P-18449, partial femur and associated fragments (L-3251).

Archosauria indet.

Material assigned to Archosauria indet. from the Bluewater Creek Formation in the Zuni Mountains includes: NMMNH P-18485, head of left humerus (L-2740); NMMNH P-18398, dorsal centrum (L-3251); NMMNH P-18399, partial pelvic girdle element (L-3251).

Parasuchidae indet.

Isolated phytosaur material that is not diagnostic below the family level includes: NMMNH P-22479, two scutes (L-1501); NMMNH P-25650, many pelvic, limb, scute, vertebral, skull, and tooth fragments (L-1501); NMMNH P-22469, four tooth fragments (L-1502); NMMNH P-22470, limb bone fragment (L-1502); NMMNH P-22471, five scute fragments (L-1502); NMMNH P-22482, seven skull fragments (L-1502); NMMNH P-22483, seven skull fragments (L-1503); NMMNH P-18267, three skull fragments (L-2738); NMMNH P-18270, occipital condyle (L-2739); NMMNH P-18271, dorsal centrum (L-2739); NMMNH P-18272, two neural spine fragments (L-2739); NMMNH P-18273, cervical centrum (L-2739); NMMNH P-18274, cervical centrum (L-2739); NMMNH 18275, four centrum fragments (L-2739); NMMNH P-18276, ?quadrate fragment (L-2740); NMMNH P-18277, isolated tooth fragment (L-2740); NMMNH P-18278, three scute fragments (L-2740); NMMNH P-18484, partial vertebra (L-2740); NMMNH P-18293, centrum fragment (L-3251); NMMNH P-18304, dorsal centrum (L-3251); NMMNH P-18314, centrum fragment (L-3251); NMMNH P-18452, partial squamosal (L-3251); NMMNH P-18453, scute (L-3251); NMMNH P-18298, seven scute fragments (L-3252); NMMNH P-18300, centrum fragment (L-3252); NMMNH P-18333, twelve partial scutes (L-3252); NMMNH P-18334, four centrum fragments (L-3252); NMMNH P-18335, two neural spines

(L-3252); NMMNH P-18336, two teeth (L-3252); NMMNH P-18337, two teeth (L-3252); NMMNH P-18337, numerous tooth fragments (L-3252); NMMNH P-18317, eleven femur fragments (L-3253); NMMNH P-18318, two fragmentary teeth (L-3253); NMMNH P-18306, isolated tooth (L-3254); NMMNH P-18307, nine isolated teeth (L-3254); NMMNH P-18354, eight jaw fragments (L-3311); NMMNH P-18355, partial tooth (L-3311); NMMNH P-18360, partial proximal right ?pubis (L-3312); NMMNH P-18361, girdle element (L-3312); NMMNH P-18363, two partial scutes (L-3313); NMMNH P-18364, occipital condyle (L-3314); NMMNH P-18366, neural spine (L-3315); NMMNH P-18367, nine scute fragments (L-3316); NMMNH P-18368, numerous jaw fragments (L-3317).

?Parasuchidae indet.

The following material is not in itself diagnostic of the Parasuchidae, but based on what morphology is preserved and associated specimens, likely represents fragmentary remains of phytosaurs: NMMNH P-18275, four centrum fragments (L-2739); NMMNH P-18303, proximal ?ischium fragment (L-3251); NMMNH P-18339, centrum fragment (L-3251); NMMNH P-18299, skull fragment (L-3252); NMMNH P-18302, dorsal centrum fragment (L-3252).

Stagonolepidae indet.

Fossils that represent indeterminate aetosaur include: NMMNH P-18279, lateral spike (L-2740); NMMNH P-18356, two lateral spikes (L-3311); NMMNH P-18451, five small scute fragments (L-3251); NMMNH P-18472, three small scute fragments (L-3251).

Desmatosuchus sp.

Material assigned to *Desmatosuchus* sp. includes: NMMNH P-18293, right lateral scute fragment (L-3251); NMMNH P-18308, right ilium and partial pubis (L-3251); NMMNH P-18330, four scute fragments (L-3251).

?Desmatosuchus sp.

Specimens tentatively assigned to *Desmatosuchus* include: NMMNH P-18325, right ischium fragment (L-3251); NMMNH P-18399, partial left ilium (L-3251); NMMNH P-18320, scute fragment (L-3256).

Paratypothorax sp.

The only known *Paratypothorax* material from the Zuni Mountains is NMMNH P-18305, a ventral flange of a lateral scute fragment from NMMNH L-3252.

Stagonolepis sp.

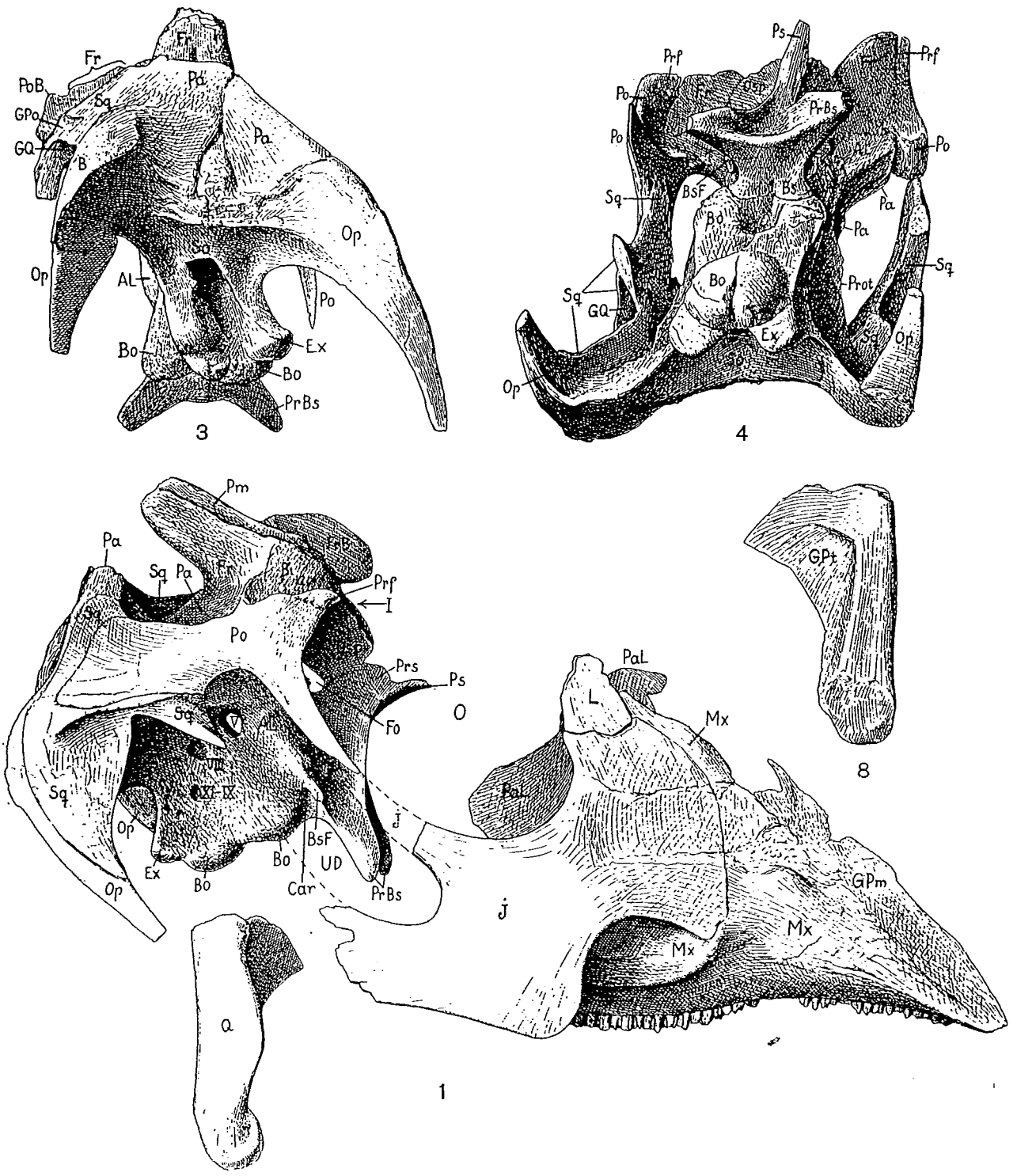
Specimens assigned to *Stagonolepis* include: NMMNH P-18327, cervical centrum (L-3251); NMMNH P-18450, partial left dorsal paramedian scute (L-3251); NMMNH P-18328, six partial lateral scutes (L-3251); NMMNH P-18398, partial scute (L-3251); NMMNH P-18329, dorsal lateral scute (L-3251); NMMNH P-18359, three dorsal paramedian scute fragments (L-3312); NMMNH P-18362 (L-3312), partial dorsal paramedian scute.

Ornithischia indet.

Ornithischian teeth from the Bluewater Creek Formation in the Zuni Mountains include: NMMNH P-18402, partial tooth (L-2739); NMMNH P-18403, partial tooth (L-2739); NMMNH P-18404, partial tooth (L-2739). NMMNH P-18402 is identified here as aff. *Tecovasaurus*.

Trace fossils

Coprolites from the Bluewater Creek Formation and Blue Mesa Member of the Zuni Mountains include: NMMNH P-22474, two coprolites (L-1503); NMMNH P-18454, five coprolites (L-3251).



Skull fragments of the type specimen of the hadrosaurian dinosaur *Parasaurolophus tubicen* from the Upper Cretaceous of the San Juan Basin, New Mexico (from Wiman, C. 1931. *Parasaurolophus tubicen* n. sp. aus der Kreide in New Mexico: Nova Acta Regiae Societatis Scientarium Upsaliensis, volume 7).