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THE VERTEBRATE FAUNA OF THE UPPER TRIASSIC (REVUELTIAN: EARLY-MID NORIAN) PAINTED DESERT MEMBER (PETRIFIED FOREST FORMATION: CHINLE GROUP) IN THE CHAMA BASIN, NORTHERN NEW MEXICO

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Abstract.—The Upper Triassic Painted Desert Member of the Petrified Forest Formation in north-central New Mexico yields one of the most extensive and significant Revueltian (early-mid Norian) tetrapod faunas known. Particularly significant aspects of this fauna are: (1) its long history of collection and study, including designation of important type specimens; and (2) the richness of the unit, including no fewer than three major vertebrate quarries (the Canjilon, Snyder, and Hayden quarries). Beginning with the work of Cope and extending to the present day, the bulk of the Triassic vertebrates recovered from the Chama Basin have been derived from the Painted Desert Member. This includes tetrapod faunas collected at Gallina, Orphan Mesa, and the Canjilon, Snyder, and Hayden quarries. Although any one of these localities can be exceptionally rich, the Painted Desert Member fauna in the Chama Basin is a relatively low-diversity assemblage dominated by the phytosaur *Pseudopalatus* and the aetosaur *Typothorax*. The vast majority of the known diversity of the unit in the Chama Basin was derived from a single locality, the Snyder quarry. We also review the stratigraphic and biostratigraphic evidence that suggest that this fauna may be slightly younger (Lucianoan) than the type Revueltian (Barrancan) assemblage, although this argument is weakened by the fact that it is based at least in part on the absence of characteristic Revueltian (Barrancan) taxa such as *Revueltosaurus callenderi*.

INTRODUCTION

The strata of the Upper Triassic Chine Group in the Chama Basin have the longest, most storied, and arguably most important history of vertebrate fossil collection of any nonmarine Triassic collecting area in the American West. Many famous paleontologists, their collectors, and field crews have extracted vertebrate fossils from the Chama Basin, and particularly from the Painted Desert Member of the Petrified Forest Formation, including Cope, Baldwin, Williston, Case, Huene, Camp, Colbert, Crompton, and Berman. Consequently, these collectors ended up in established museums on the east and west coast. Only in the past 20 years, with the birth of the NMMNH have vertebrate fossils from this area been retained in New Mexico (Table 1).

Although the Whitaker (*Coelophysis*) quarry at Ghost Ranch is the most spectacular locality in the Chinle Group, the vast majority of vertebrate fossils from the Chama Basin were recovered from what is now recognized as the Painted Desert Member of the Petrified Forest Formation. Thus, although there is still great potential to improve the paleontological record of the Painted Desert Member in the Chama Basin, we use this opportunity to summarize what is known of the geology and paleontology of the Painted Desert Member and, from there, expound on its biostratigraphic and biochronological significance. In this paper we examine the spatial and stratigraphic distribution of vertebrate fossil occurrences on the Painted Desert Member (Figs. 1-3), review the taxonomy of the fossils in question, illustrate much previously figured and unfigured material (Figs. 4-8), and examine the significance of this record in the larger context of the vertebrate fossil record of the Upper Triassic System in the American Southwest and Late Triassic vertebrate evolution.

Institutional abbreviations: In this paper, AMNH = American Museum of Natural History, New York; ANSP = Academy of Natural Sciences, Philadelphia; MCZ = Museum of Comparative Zoology (Harvard), Cambridge; NMMNH = New Mexico Museum of Natural History and Science, Albuquerque; GR =

TABLE 1. History of vertebrate collection in the Chama Basin.

Date	Collector(s)	Area(s)	Repository*
1874	Cope (Wheeler)	Gallina	USNM, ANSP
1880	Baldwin (for Cope)	Gallina, Arroyo Seco, Orphan Mesa	AMNH
1912	Williston, Camp, Huene	Chama Basin	?
1930s	Camp	Canjilon quarry	UCMP
1930s	Price/White	Canjilon quarry	MCZ
1947-48	Colbert	Ghost Ranch area	AMNH
1960s-1970s	Hall	Canjilon quarry, Orphan Mesa	GR
1970s-1980s	Berman	Various localities, primarily higher & lower in the section	CM
1980s-1990s	Sullivan, Lucas	Orphan Mesa	NMMNH, SMP
1989	Lucas et al.	Coyote Amphitheater, Gallina, Orphan Mesa	NMMNH
1998-current	Heckert, Zeigler	Snyder quarry	NMMNH
1999-current	Downs	Canjilon, Hayden quarries, Orphan Mesa	GR
2002-current	Zeigler	Coyote Amphitheater and rest of basin	NMMNH

*Not including Whitaker (*Coelophysis*) quarry specimens, which are now reposited across North America

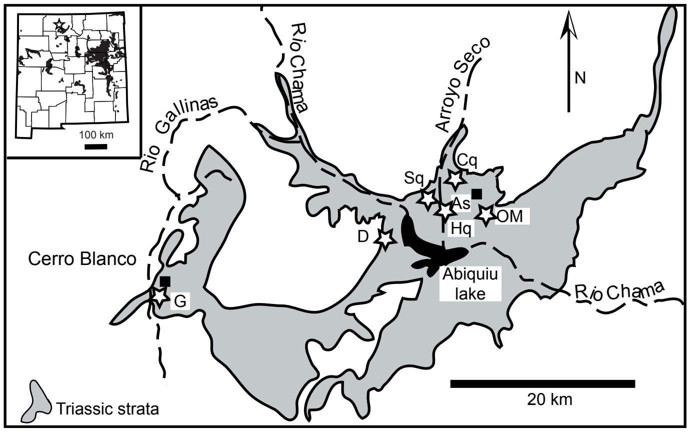

FIGURE 1. Locality map showing geographic distribution of Painted Desert Member localities in the Chama Basin. Cq = Canjilon quarry, D = *Dolabrosaurus* type locality, G = Gallina, Hq = Hayden quarry, OM = Orphan Mesa, Sq = Snyder quarry.

Ruth Hall Museum of Paleontology, Ghost Ranch; SMP VP = State Museum of Paleontology, Harrisburg; UCMP = University of California Museum of Paleontology, Berkeley; UNM = University of New Mexico, Albuquerque; USNM = National Museum of Natural History (Smithsonian), Washington, D.C.

GEOLOGIC SETTING

Paleogeography

During much of Late Triassic time, the Chama Basin lay just north (~10˚) of the equator near the west coast of Pangea (e.g., Golonka et al., 1994). The study area appears to have been near or just north of the axis of a trunk drainage system integrating fluvial systems ranging from paleohighlands in modern-day Texas to near shore systems at or near the present-day Utah-Nevada state line (Lucas, 1993; Riggs et al., 1996; Lucas et al., 2005; Fig. 2).

Paleotectonics

Various publications typically describe the paleotectonic setting of the Chinle depositional system as that of a "back-arc" system (e.g., Stewart et al., 1972; Blakey and Gubitosa, 1984; Lucas, 1993; Tanner, 2003). Seldom is much attention paid to underlying, principally late Paleozoic, structures that influenced Chinle deposition. In the case of the Chama Basin, it is important to note that, at the onset of Late Triassic time, the Chama Basin still contained remnant highlands of the Ancestral Rocky Mountain (ARM) orogenic system. These include remnant Uncompagre uplands (sometimes termed the San Luis uplift), principally to the north but also to the east (Pazzaglia et al., 1999; Woodward et al., 1999) that served as a source area for sediments as well as a possibly higher (more "upland") biome than that typically sampled in Chinle Group deposits of Texas, New Mexico, and Arizona (Fig. 2).

Lithostratigraphy

In the Chama Basin, the Chinle Group consists of six formations, the Zuni Mountains, Shinarump, Salitral, Poleo, Petrified Forest, and Rock Point formations, in ascending order. Lucas et al. (2003b, 2005) well-document the stratigraphy of the Chinle Group in the Chama Basin, so for purposes of this paper we restrict our focus to the Petrified Forest Formation, the thickest and most fossiliferous unit in the basin.

Historically, stratigraphers studying the Chinle Group (including the Dockum Group and other homotaxial strata) tended to work either on the Colorado Plateau (e.g., Gregory, 1917; Stewart et al., 1972) or completely off it (Gould, 1907; McGowen et al, 1979). A natural, but unfortunate, consequence of this divided effort is that separate lithostratigraphic nomenclatures evolved for Upper Triassic strata based more on modern-day physiography than on Triassic depositional systems. Similarly, vertebrate paleontologists tended to focus either on Chinle strata on the Plateau (e.g., Camp, Colbert), or "Dockum" strata off it (e.g., Case,

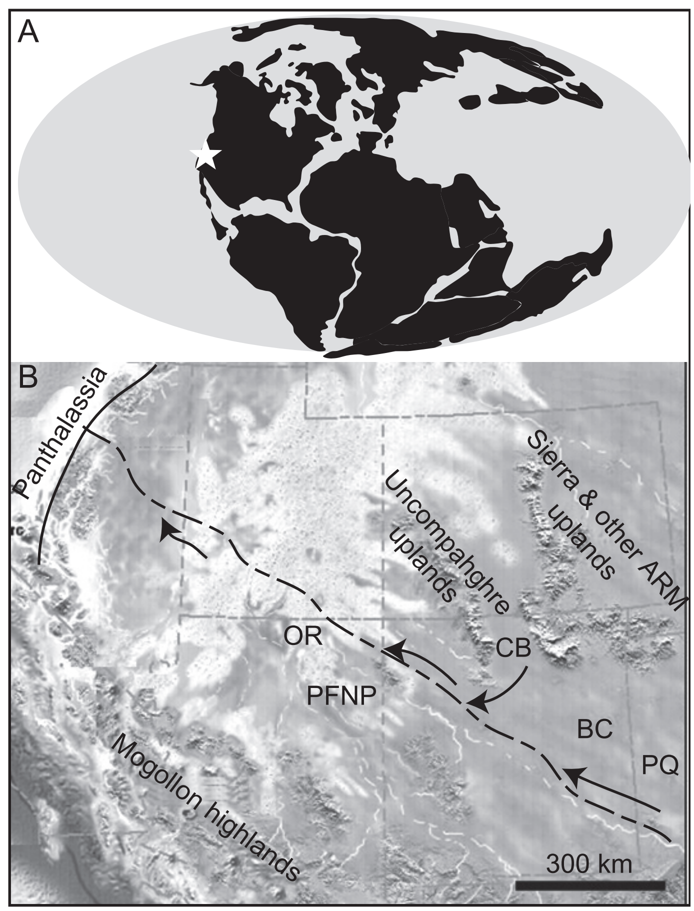

FIGURE 2. Paleogeography of the Chama Basin during Late Triassic time. A, Index map showing approximate position of the Chama Basin on Triassic Pangea. B, Detail showing distribution of highlands and basins, paleoflow (arrows) and primary vertebrate collecting areas during Revueltian time (modified from Blakey (2003: http://jan.ucc.nau.edu/~rcb7/jurpaleo.html). BC = Bull Canyon Formation localities; CB = Chama Basin, OR = Owl Rock Formation localities; PFNP = Petrified Forest National Park and vicinity; PQ = Post quarry.

Gregory). The historical development of the lithostratigraphic framework of the Chama Basin is therefore interesting because it is similar to that of Upper Triassic strata in eastern New Mexico even though it is, of course, on the eastern edge of the Colorado Plateau.

A consequence of this is that, as in east-central New Mexico, the terms “Chinle Formation” or “Petrified Forest Member” in the Chama Basin traditionally only referred to the uppermost (super-Poleo) stratigraphic units in the basin (e.g., Wood and Northrop, 1946; Stewart et al., 1972; O’Sullivan, 1974; Lucas and Hunt, 1992; Hunt and Lucas, 1993b; Lucas, 1993, 1997, 2004; Lucas et al., 2003a, 2005), much as it often did in eastern New Mexico (e.g., Griggs and Read, 1959; Kelley, 1972; Lucas et al., 1985) for strata now properly termed the Bull Canyon Formation (Lucas and Hunt, 1989; Lucas et al., 2001). Smith et al. (1961) published geologic maps of parts of the Chama Basin, but used a simplified nomenclature that essentially combined all Triassic strata from the Poleo down to the Zuni Mountains formations as “Lower sandstone member” of the Chinle, and combined the Petrified Forest Formation with the Rock Point Formation as the “Upper shale member.” We note here that the stratigraphic nomenclature we utilize here, as developed by Lucas et al. (2003a, 2005), is more precise than these traditional usages, both in terms of recognizing distinct lithostratigraphic units and correlating similar ones. That is, at the formation level, only the Petrified Forest and Rock Point formations have obvious equivalents elsewhere in the Four Corners, as recognized by Stewart et al. (1972) and Lucas (1993, 1997, 2004). To the east, these units have lithologically distinct correlatives, principally the Bull Canyon and Redonda formations, respectively.

Within the Petrified Forest Formation, Lucas et al. (2003a, 2005) recognized two distinct stratigraphic units, the thinner, lower, sandier Mesa Montosa Member and the thick, upper, mudstone-dominated Painted Desert Member (Fig. 3). Traditionally, almost all vertebrate fossils reported from the Petrified Forest Formation, and indeed most Triassic vertebrates outside of the Whitaker quarry, were derived from the Painted Desert Member (Fig. 3). Zeigler et al. (2005) describe Late Triassic vertebrates derived from the Mesa Montosa Member elsewhere in this volume. This paper focuses instead on the vertebrate fauna of the Painted Desert Member, including famous collections from Gallina, Arroyo Seco, Orphan Mesa, the Canjilon quarry, the Snyder quarry, the Hayden quarry, and a few other isolated occurrences.

HISTORY OF COLLECTING

Edward Drinker Cope was the first paleontologist to collect Triassic vertebrate fossils from the Chama Basin, passing through in Fall, 1874, as part of the Wheeler Survey (Simpson, 1950; Lucas and Hunt, 1992) (Table 1). Cope published his collections shortly thereafter (Cope, 1875, 1877), naming the aetosaur *Typothorax coccinarum* (Cope, 1875; Lucas and Hunt, 1992; Heckert and Lucas, 2002a). Cope’s localities were in the general vicinity of Cerro Blanco near Gallina, and Lucas and Hunt (1992, fig. 9) relocated the exact area from which Cope collected (see also Lucas et al., 2005).

Subsequently, Cope dispatched one of his collectors, David Baldwin, to the area, and Baldwin collected Triassic vertebrates from several localities, including “Gallina” and “Arroyo Seco near Huerfano Camp.” Among these fossils are the holotypes of the phytosaur *Pseudopalatus* (=*Belodon*) *buceros* (Cope) (Fig. 4), the aetosaur *Episcoposaurus horridus* Cope, and, more famously, the original types of the dinosaur *Coelophysis* (=*Coelurus*) (Cope, 1881, 1887a,b, 1889).

After Baldwin, the next vertebrate paleontologists to work in the Chama Basin were S.W. Williston, E.C. Case, and F. von Huene, who apparently were interested in relocating Baldwin’s Permian and Triassic localities. Williston and Case (1912) reported that they relocated Cope’s collecting areas in the vicinity of Gallina during this expedition. Also as a result of this expedition, von Huene (1911) published the first named stratigraphic unit (Poleo-Top Sandstone) for the Triassic System in the Chama Basin, and eventually (von Huene, 1915) redescribed and illustrated or re-illustrated much of Cope’s collections.

Subsequently, Charles Camp came to the area in the 1920s, and his field party discovered the Canjilon quarry in October, 1928 (Long et al., 1989; Hunt and Downs, 2002; Martz, 2002). Crews from the UCMP excavated the quarry in 1928, 1930, and 1933, resulting in extensive collections of phytosaurs (11+ skulls) and smaller numbers of aetosaurs at the UCMP. Long and Ballew (1985) noted that Llewellyn Price and Theodore White of Harvard University also collected aetosaurs at the Canjilon quarry in the late 1930s.

In 1947 Edwin Colbert led an AMNH expedition to Ghost Ranch. There, Colbert’s preparator and field assistant George Whitaker found first an isolated phytosaur skull and then the

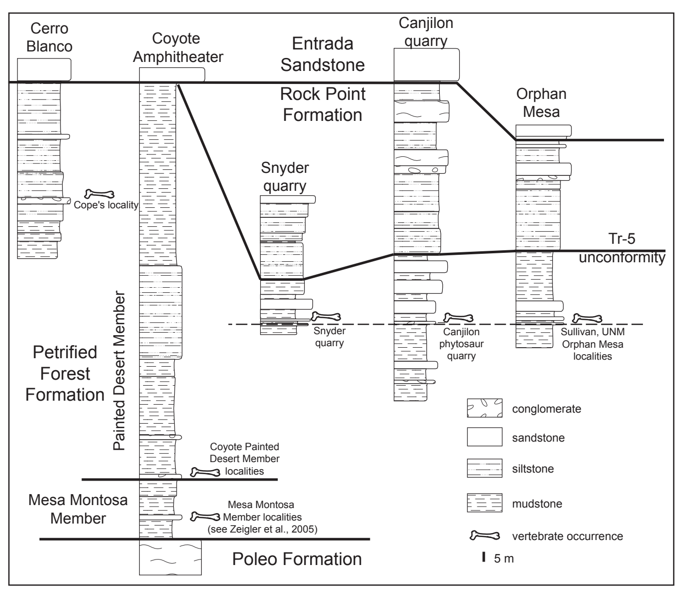

FIGURE 3. Correlated measured sections of the Painted Desert Member in the Chama Basin showing the stratigraphic distribution of vertebrate localities described in the text. Localities in the vicinity of Arroyo Seco are hung on a green conglomerate and mudstone bed that is traceable from Orphan Mesa west to the Rio Chama.

famous Whitaker quarry, although both of these are in the Rock Point Formation, stratigraphically much higher than where the previous collectors had operated (Whitaker and Meyers, 1965; Colbert, 1989; Lucas and Hunt, 1992).

Following the AMNH's efforts, the next paleontological work conducted on the vertebrate fauna of the Painted Desert Member in the Chama Basin was by Ruth Hall at Ghost Ranch itself. During the 1960s and 1970s, Hall amassed a small collection of representative Chinle vertebrates, principally phytosaurs, from the Painted Desert Member. Much of this collection consists of fragmentary fossils from the Canjilon quarry, but it also includes some specimens from Orphan Mesa and vicinity. During this time A.W. Crompton (MCZ) and/or E.H. Colbert (AMNH) occasionally assisted Hall, but neither appears to have retained specimens for their collections.

In the 1970s and 1980s, David Berman of the Carnegie Museum led numerous prospecting and collecting trips to the Chama Basin, although his efforts focused primarily on Permian strata and then, from 1981-1982, on the Whitaker quarry. However, the holotype of the drepanosaurid *Dolabrosaurus aquitilis* was recovered from the Painted Desert Member during one of these trips (Berman and Reisz, 1992).

Also during the 1980s, one of us (RMS), then of the University of Southern Alabama, collected vertebrates, including the holotype of *Eucoelophysis baldwini* Sullivan and Lucas, from the Cross quarry, at the base of the north flank of Orphan Mesa. Sullivan also collected vertebrates from other localities around Orphan Mesa at this time, and again in 1993.

Another of us (SGL) led a UNM summer paleontology field school to the area. A significant fact about this latter venture is that it was the first systematic attempt to collect vertebrates from throughout the Triassic stratigraphic section in the Chama Basin (see Lucas and Hunt, 1992).

Beginning in the 1990s, research on the vertebrate faunas of the Painted Desert Member accelerated with the discovery of the Snyder quarry in June, 1998 by Mark Snyder of Del Mar, California (Heckert and Zeigler, 2003). Since 1998, the NMMNH has conducted excavations at the Snyder quarry, especially in 1998-2001, resulting in a collection of over 1200 catalogued vertebrate fossils (e.g., Zeigler et al., 2003a and papers therein), with probably an equal volume of unprepared material remaining. Also during the 1990s, Alex Downs of Ghost Ranch began to collect in the area, re-collecting the Canjilon quarry with A.P. Hunt (e.g., Hunt and Downs, 2002). In this decade, Downs began another excavation at the newly discovered Hayden quarry, a locality on Ghost Ranch land that appears to yield a similar fauna, and lie at a similar stratigraphic level, as the Snyder quarry (Downs, 2005). Thus, as the 21st century begins, there is every indication that the Chama Basin will continue to yield important fossils documenting Late Triassic tetrapod evolution.

FAUNAS OF THE PAINTED DESERT MEMBER IN THE CHAMA BASIN

In the following sections we outline the history, stratigraphy, fauna, sedimentology/taphonomy, and significance of each the principal collecting sites (localities in the broad sense) of the Painted Desert Member of the Chama Basin. Table 2 summarizes much of this information as well.

TABLE 2. Vertebrate fauna of the Painted Desert Member by collecting area.

Gallina	
	Typothorax coccinarum Cope*
	"Episcoposaurus horridus" Cope*
	Coelophysidae indet.
Orphan Mesa/Arroyo Seco	
	Vertebrate coprolites (osteichthyan?)
Phytosauridae indet.	
	Stagonolepididae indet.
	Typothorax coccinarum
	Pseudopalatus buceros (Cope)*
	Rauisuchidae indet.
Coelophysidae indet.	
	*Eucoelophysis baldwini** Sullivan and Lucas
Canjilon quarry	
	Temnospondyli(?) indet.
	Pseudopalatus buceros
	Typothorax coccinarum
	Vancleavea
	Archosauria indet.
Snyder quarry	
	Lonchidion humblei
	Chondrichthyes indet.
	Palaeoniscidae indet. aff. *Turseodus*
	Redfieldiidae indet
	Semionotidae indet.
	aff. *Buettneria*
	Metoposauridae indet.
	Cynodontia indet.
	Pseudopalatus buceros
	Typothorax coccinarum
	Desmatosuchus chamaensis
	Poposauridae indet.
	Eucoelophysis spp.
Hayden quarry	
	Metoposauridae indet.
Phytosauridae indet.	
	Typothorax sp.
	Vancleavea sp.
	Herrerasauridae(?) indet.
Cañon del Cobre	
	Typothorax coccinarum
	Archosauromorpha indet.
	Parasuchidae indet.
Coyote Amphitheater	
	Phytosauridae indet.
	Typothorax coccinarum
Miscellaneous Painted Desert Member localities	
	Phytosauridae indet
	Typothorax coccinarum
	Dolabrosaurs aquitilis Berman and Reisz*

* denotes type locality

Gallina

Gallina was the area from which Cope first collected Triassic vertebrates in the Chama Basin (Cope, 1875, 1877). Surprisingly,

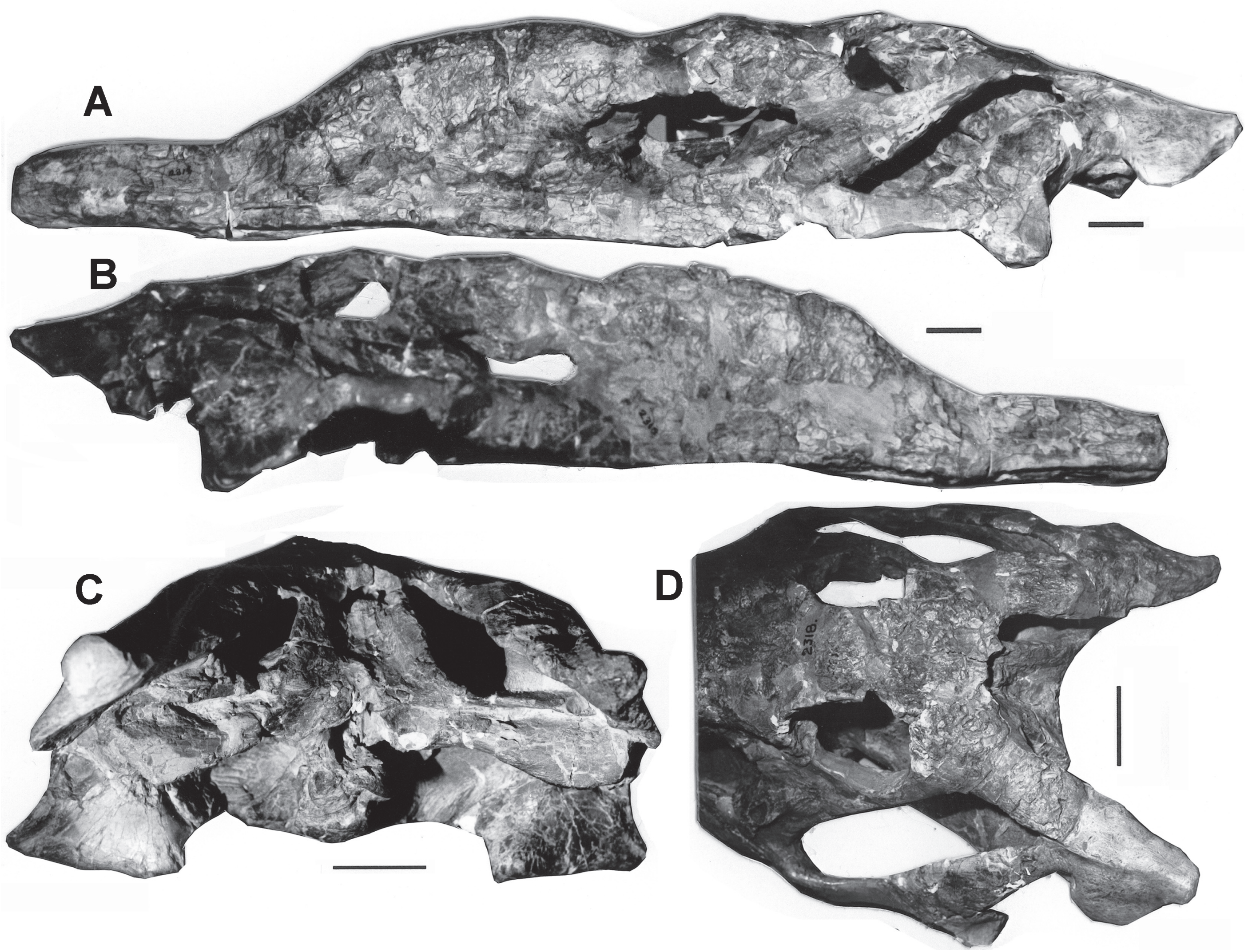

FIGURE 4. AMNH 2318, holotype skull of *Pseudopalatus buceros* (Cope), collected by D. Baldwin from the Painted Desert Member near Orphan Mesa. **A**, skull in left lateral view; **B**, right lateral view; **C**, occipital view; **D**, close-up of posterior portion of skull in dorsal view. All scale bars = 4 cm.

after Cope, the only party to successfully collected in the area prior to 1989 was Baldwin, who sent Cope some fragmentary material from Gallina. Baldwin's letters to Cope indicate that, at most, he collected a vertebra and three reptile teeth from the locality. Although Williston and Case (1912) reported phytosaur fossils from the general area, these specimens are not reposited anywhere that we are aware of.

Lucas and Hunt (1992, fig. 9) relocated Cope's collecting areas, which include the type locality of *Typothorax coccinarum* (Heckert and Lucas, 2002a), although they did not make additional collections from the area. Interestingly, the area is much more wooded now than it appears in Cope's drawing (see Lucas and Hunt, 1992, fig. 9). Perhaps this area held better exposures then than it does now, and the best localities may therefore be covered now.

Stratigraphically, Cope's locality at Gallina appears to lie high in the Painted Desert Member (Fig. 3), but pre-Entrada erosion removed any overlying Triassic strata and the fact that the underlying Mesa Montosa Member and/or Poleo Formation are not exposed, make it unclear exactly where these beds sit relative to other Chama Basin vertebrate occurrences (Fig. 3). The fauna at Gallina thus consists solely of the aetosaur *Typothorax coccinarum* Cope and, possibly, some of the original type series of *Coelophysis* (=*Coelurus*) (Cope, 1887a), presumably the teeth. *Contra* Long and Murry (1995), this is not the type locality of *Pseudopalatus* (=*Belodon*, = *Arribasuchus*) *buceros*, which is instead in the Arroyo Seco area (Lucas et al., 2002a; see below).

Arroyo Seco/Orphan Mesa

As used here, "Arroyo Seco" essentially refers to the badlands surrounding the topographic feature known locally as Orphan Mesa (essentially T24N R5E, section 18 and T24N R4E, section 12 and immediately adjoining area; Orphan Mesa itself is the prominent feature of 7074' [2130 m] elevation). Three other prominent localities are known in the general vicinity of the Arroyo Seco drainage—the Canjilon, Snyder, and Hayden quarries (Fig. 2). However, two of these, the Snyder and Hayden quarries, preserve black bone unlike that of historical "Arroyo Seco" collections such as Baldwin's (which, while dark, are much more gray), and the Canjilon quarry bones are typically lighter in color than those of Baldwin's finds, so we are reasonably confident that none of the earliest Arroyo Seco materials come from any of the more recently discovered, extremely productive localities.

The area surrounding Orphan Mesa thus has a rich and complicated history. In addition to Baldwin's fossils (Fig. 4), several other fossiliferous localities are known from the area. These include Ruth Hall's "Old Phytie" specimen, an incomplete but articulated phytosaur skeleton found near Orphan Mesa in 1970 that is now in the collections of the Ruth Hall Museum of Paleontology (see Heckert et al., 2005), the "Cross quarry" excavated by Sullivan (including the holotype of *Eucoelophysis baldwini)* (Fig. 5), and, most recently, an isolated large, crested phytosaur skull excavated by Alex Downs that we believe pertains to the male morph of *P. buceros*.

Importantly, all of these localities, including the type locality of *Eucoelophysis baldwini*, are low on the flanks of Orphan Mesa and surrounding areas, in a prominent greenish band of sediment that consists primarily of mudstone with minor intraformational conglomerate. It is now apparent that this is the same stratigraphic horizon as the other localities in the Arroyo Seco drainage (Canjilon, Snyder, and, most likely, Hayden quarries).

The fauna of Arroyo Seco/Orphan Mesa thus encompasses much of Baldwin's collections, including the holotypes of *Pseudopalatus* (=*Belodon*) *buceros* and *Episcoposaurus horridus* (a junior subjective synonym of *Typothorax coccinarum*; Gregory, 1953; Heckert and Lucas, 2000), at least some of the type series of *Coelophysis bauri*, other, less determinate phytosaurs such as those collected by Hall, and the holotype of *Eucoelophysis baldwini* collected by Sullivan (Cope, 1881, 1887a,b, 1892; Sullivan et al., 1996; Sullivan and Lucas, 1999) (Fig. 5J-O). We also illustrate here some fragmentary fossils collected by one of us (RMS) in this area (Fig. 5A-I), as the fauna of this collecting area is relatively under-documented relative to the rest of the basin.

Coprolites are relatively rare in the Painted Desert Member in the Chama Basin. Here, we illustrate a typical specimen from the vicinity of Orphan Mesa (SMP VP-452—Fig. 5A-B). This spiral coprolite is probably the trace of a large osteichthyan.

The Orphan Mesa area also yields a variety of problematic, yet interesting, archosaurs. One such specimen (SMP VP-500—Fig. 5C) is an incomplete left(?) dentary(?) with two partially erupted teeth. The teeth are clearly laterally compressed and serrated, and thus not those of an ornithischian or similar animal. However, they are also too laterally compressed to represent a phytosaur. Therefore, it is likely that these are the teeth of either a rauisuchian (*sensu lato*) or a theropod dinosaur. The bone fragment is more robust than that of most Triassic dinosaurs, so it is probably not a coelophysoid like *Eucoelophysis*. We also illustrate an archosaur tarsal(?) (SMP VP-466—Fig. 5D-E) from this area here.

Another theropod fossil from the vicinity of Orphan Mesa is SMP VP-469, a proximal tibia (Fig. 5F-I). This specimen is clearly referable to Theropoda based on the presence of a well-developed cnemial crest (Fig. 5I) and a hollow shaft (Fig. 5J). This specimen is interesting as the cnemial crest is much more strongly developed than we have observed in, for example, *Eucoelophysis* and the Snyder quarry theropods (Heckert et al., 2000b, 2003b).

Bone density is lower in the vicinity of Orphan Mesa than at the other quarries in the area. Still, recovered specimens range from broken and isolated bones to incomplete, but otherwise articulated, skeletons. We therefore hypothesize that these localities are somewhat more distal to the main channel than the other bonebeds in the region, so vertebrate skeletons were not as quickly buried, and therefore fossils remain comparatively rare.

Canjilon quarry

The Canjilon quarry was discovered on October, 13, 1928, and was subsequently excavated by UCMP personnel in 1928, 1930, and 1933, with the greatest effort expended in 1933 (Long et al., 1989; Hunt and Downs, 2002; Martz, 2002). Collected specimens were prepared largely by Works Progress Administration (WPA) workers in the late 1930s, and later by Lawler (Lawler, 1974). Ongoing work by Martz (2002) demonstrates that many specimens in the UCMP collection can be matched to the existing quarry map, published first by Long et al. (1989, fig. 1) and subsequently by Lucas and Hunt (1992, fig. 7), Zeigler et al., (2002c, fig. 2; 2003f, fig. 2) and in Martz's thesis (2002, fig. 2.2a). As noted previously, the MCZ retains some collections from the quarry that were extracted in the late 1930s. Later, Ruth Hall made minor (mostly surface) collections from the area. Since 1999, Alex Downs, Adrian Hunt, and others have reopened the quarry, excavating additional specimens, principally of phytosaurs, and this work continues to date.

Stratigraphically, the quarry sits just above the low flats between Arroyo Seco and Ghost Ranch and Orphan Mesa. The quarry is ~30.8 m below the contact of the Painted Desert Member with the overlying Rock Point Formation (Lucas and Hunt, 1992; Fig. 3). This horizon is traceable eastward to Orphan Mesa and westward across Arroyo Seco to the Snyder quarry (Lucas et al., 2003b). The encasing strata at the Canjilon quarry, however, tend to be redder and have less of the green mudstones typical in those areas (Hunt and Downs, 2002).

The fauna of the Canjilon quarry is not diverse, but is disproportionately significant. This locality is the richest assemblage of associated and/or articulated phytosaurs in the Western Hemisphere, and the only locality that yields multiple partial skeletons of *Typothorax*. Therefore, the collections from here have been instrumental in our understanding of phytosaurs (Gregory, 1962a,b; Lawler, 1974; Ballew, 1986, 1989; Hunt, 1994; Long and Murry, 1995; Hurlburt et al., 2003), including the strong possibility that *P. buceros* and *P. pristinus* are in fact sexual dimorphs (male and female morphs, respectively—Zeigler et al., 2002c, 2003f) (Figs. 6-7). Otherwise, the quarry is of remarkably low diversity—there are persistent reports of some possible

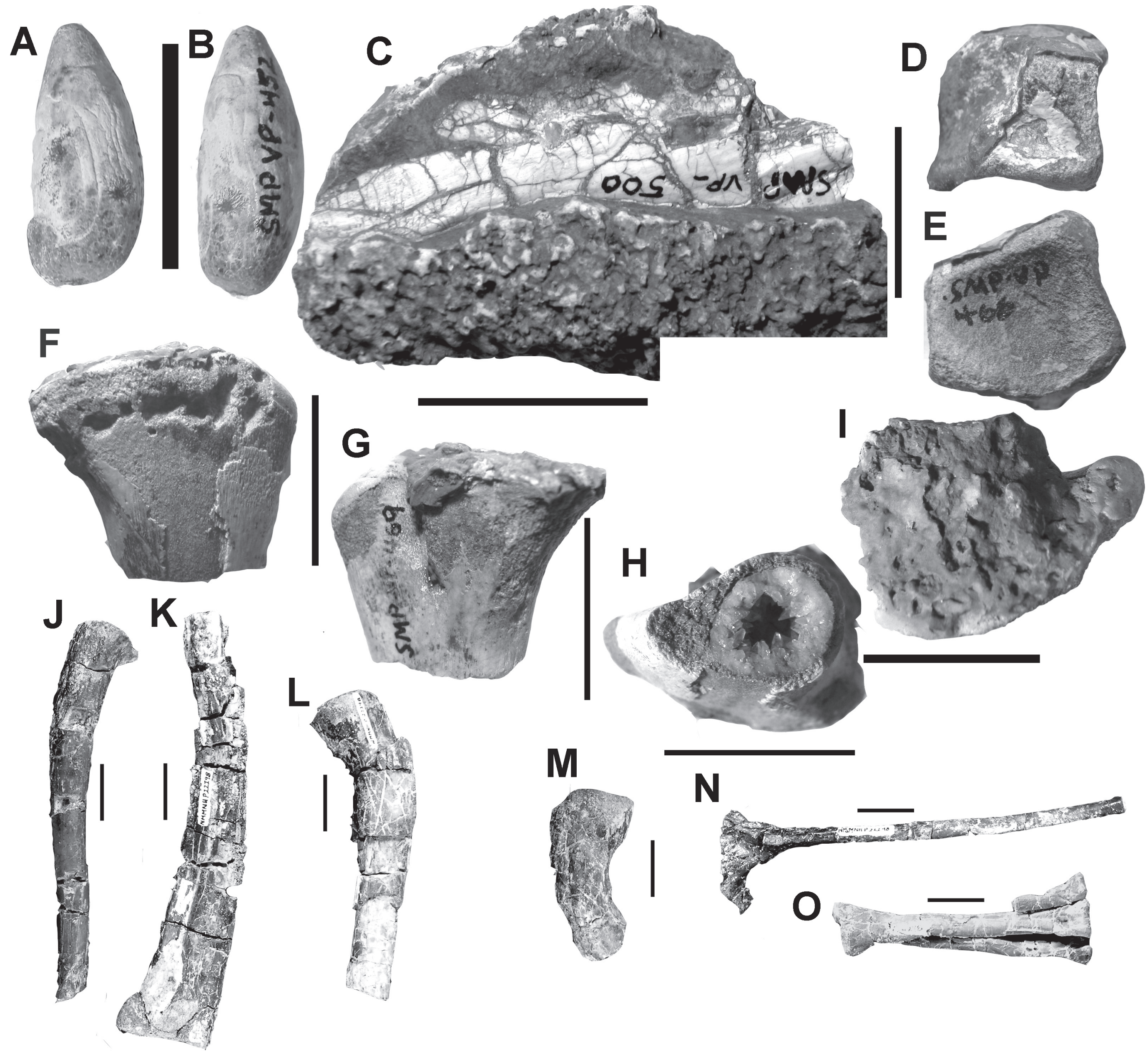

FIGURE 5. Diverse vertebrates from the Painted Desert Member in the Orphan Mesa area. **A-B,** SMP VP-452, a coprolite; **C**, SMP VP-500, archosaur dentary(?) fragment in lateral view; **D-E**, SMP VP-466, archosaur tarsal(?) (calcaneum?) in **D**, distal, and **E**, proximal views; **F-I**, SMP VP-469, proximal theropod tibia in **F**, medial, **G**, lateral, **H**, distal, and **I**, proximal views. **J-L**, holotype femora of *Eucoelophysis baldwini* Sullivan and Lucas in **J**, anterior, **K**, posterior, and **L**, posterior views. **N**, holotype pubis of *Eucoelophysis baldwini* Sullivan and Lucas in lateral view. **O**, holotype metatarsals of *Eucoelophysis baldwini* Sullivan and Lucas in dorsal view. All scale bars = 2 cm.

metoposaurids (Hunt and Downs, 2002; Martz, 2002) and referrals of isolated rauisuchian and/or theropod fossils in the Ghost Ranch collection to the Canjilon quarry (Long and Murry, 1995), although, given the lack of data associated with most of the older collections at Ghost Ranch, we are skeptical of the latter records. Doubtless there were "rauisuchians" in the general vicinity (e.g., large rauisuchian right femur mentioned by Long and Murry, 1995; GR 1028), but there is very little evidence for non-phytosaurian, non-aetosaurian tetrapods at the Canjilon quarry otherwise.

Hunt and Downs (2002) and Martz (2002) independently studied the taphonomy of the Canjilon quarry, both determining that the published quarry maps, based on the UCMP's 1933 excavations, are oriented with south at the top. Intuitively, this makes sense as the mapper (possibly Camp himself) probably chose to view the quarry from higher ground, which is only possible from the north. Hunt and Downs (2002) based their studies principally on a field investigation of the quarry itself, measuring three microstratigraphic sections in addition to documenting new excavations. Therefore, they (Hunt and Downs, 2002,

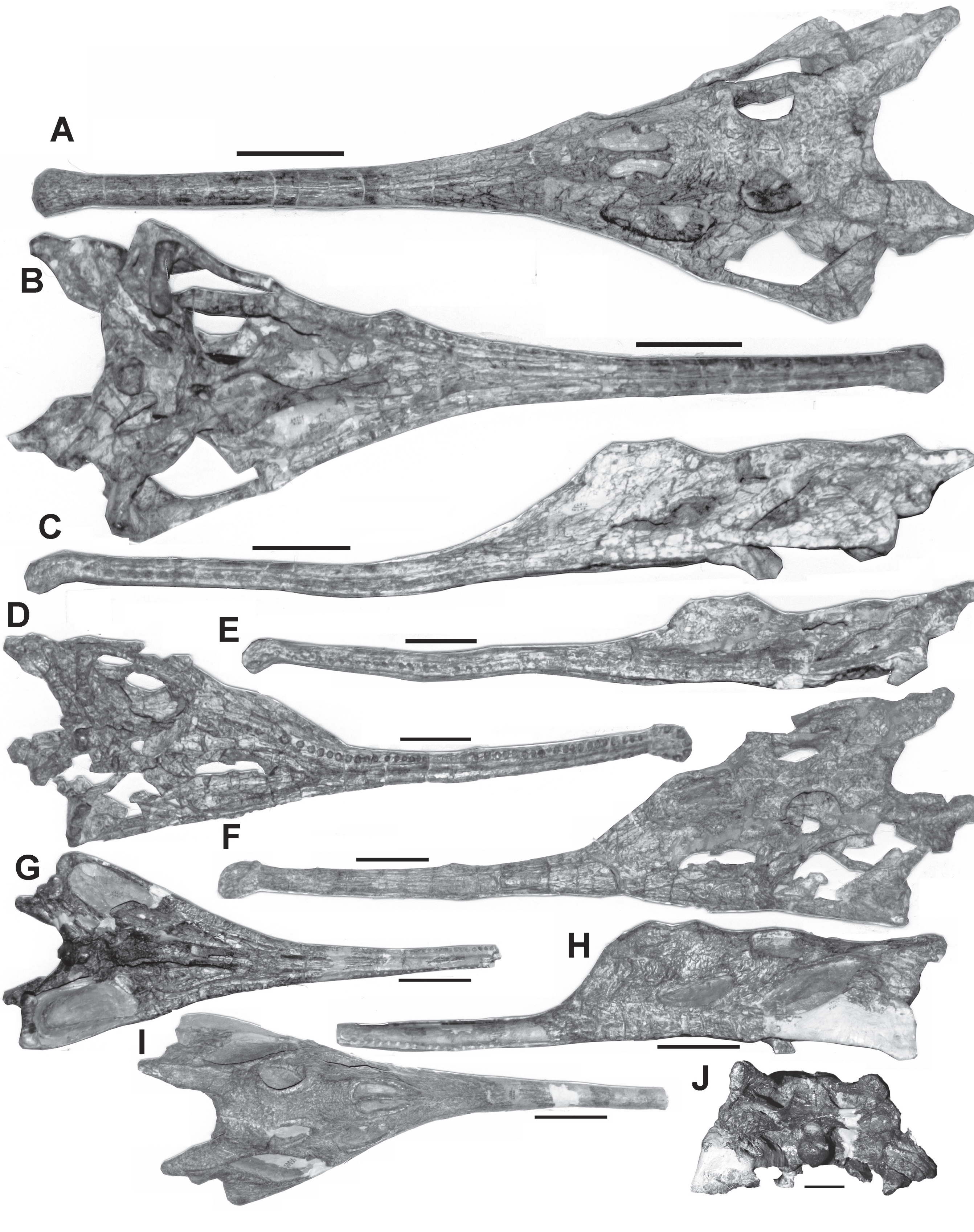

FIGURE 6. Skulls of female(?) specimens of *Pseudopalatus buceros* from the Canjilon quarry. **A-C**, UCMP 34249 in **A**, dorsal, **B**, ventral, and **C**, left lateral views; **D-F**, UCMP 34245 in **D**, ventral, **E**, left lateral, and **F**, dorsal views; **G-J**, UCMP 27231 in **G**, ventral, **H**, left lateral, **I**, dorsal, and **J**, occipital views. All scale bars = 10 cm except J = 5 cm.

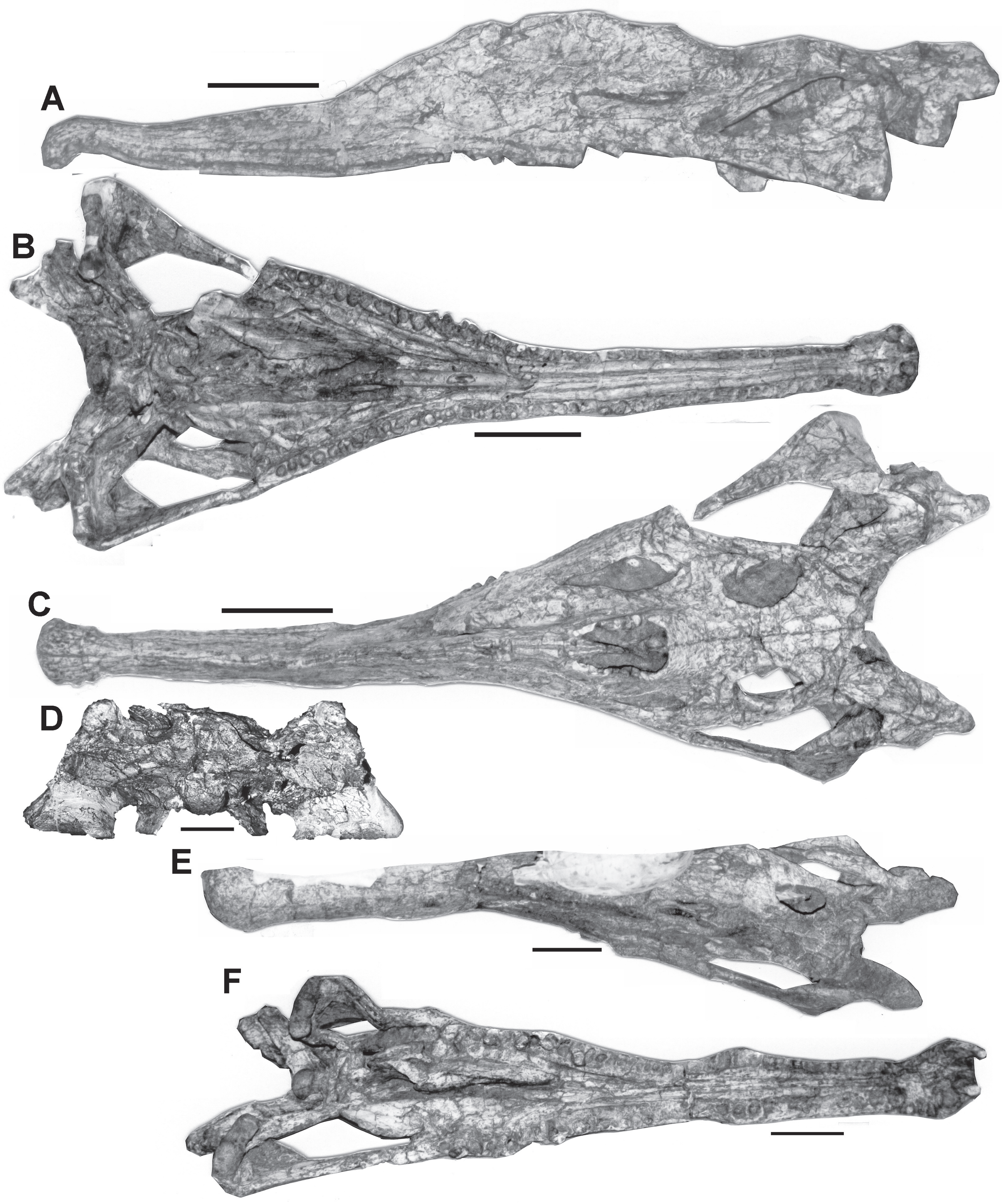

FIGURE 7. Skulls of male (?) specimens of *Pseudopalatus buceros* from the Canjilon quarry. **A-D**, UCMP 34250 in **A**, left lateral, **B**, ventral, **C**, dorsal, and **D**, occipital views; **E-F**, UCMP 34246 in **E**, dorsal, and **F**, ventral views.

p. 294) concluded "the most likely scenario for the origin of the Canjilon quarry is that a flood event enveloped a fluvial margin community of phytosaurs and transported carcasses and isolated bones that were laying on the surface to a topographic low." Hunt and Downs (2002) also documented that paleosol formation (indicated by reduction spots and other indications of pedogenic modification) occurred after this event.

Martz (2002) worked primarily with the field notes of Camp and his students to determine the association of elements in the UCMP collection, concluding that most of the specimens were from the main bone bed (as Hunt and Downs, 2002 suspected) but that at least one incomplete phytosaur skeleton (UCMP V2816/34258). one *Typothorax* skeleton (UCMP V2816/34255) and, possibly, one *Pseudopalatus* skull, were discovered in the upper layer. Both Martz (2002) and Hunt and Downs (2002) independently concluded that the *Typothorax* specimens, including both isolated scutes and associated to articulated skeletons, are more common at the quarry than is apparent from the quarry map.

Snyder quarry

In an extremely fossiliferous stratigraphic interval in a fossiliferous region, the Snyder quarry (NMMNH locality 3845) is perhaps the most exceptional. This extraordinarily rich Painted Desert Member fossil assemblage was only discovered in 1998, yet has been the focus of much recent study (Heckert et al., 2000b,c, 2003a,b, 2004; Zeigler et al., 2002a,b,d; Heckert and Zeigler, 2003; Hurlburt et al., 2003; Lucas et al., 2003a,b; Rinehart et al., 2003; Tanner et al., 2003; Zeigler, 2002, 2003; Zeigler et al., 2003a,b,c,d,e). Macrofossil vertebrates, principally the bones and teeth of the archosaurian phytosaurs, aetosaurs, dinosaurs, and rauisuchians, dominate the assemblage. However, one of us (ABH), supervised screenwashing of matrix from the principal bone-bearing interval of the site from both bulk samples and jackets as they were prepared, adding a substantial microvertebrate component to the fauna as well (Heckert et al., 2004; Jenkins, 2004; Jenkins and Heckert, 2004a,b; Heckert and Jenkins, 2005). This is the only microvertebrate assemblage from the Painted Desert Member in this region.

The Snyder quarry is in the Painted Desert Member of the Petrified Forest Formation, 28.5 m below the contact with the overlying Rock Point Formation (Fig. 3). This stratigraphic position is approximately equivalent to the Canjilon quarry 4 km to the east and, probably, the Hayden quarry approximately 6 km to the south and east. The Snyder quarry is also at nearly the same stratigraphic horizon as the Orphan Mesa and other localities in the general vicinity of Arroyo Seco (Lucas and Hunt, 1992; Hunt and Lucas, 1993a; Sullivan et al., 1996; Sullivan and Lucas, 1999; Lucas et al., 2002a, 2003a).

The fauna of the Snyder quarry includes chondrichthyans (*Lonchidion* and other, indeterminate forms), osteichthyans (palaeoniscids [aff. *Turseodus*], redfieldiids, and semionotids), amphibians (aff. *Buettneria*), a cynodont, the phytosaur *Pseudopalatus buceros*, aetosaurs (*Typothorax coccinarum* and *Desmatosuchus chamaensis*), a large rauisuchian (poposaurid?), and theropods provisionally assigned to *Eucoelophysis* sp. (Heckert et al., 2000, 2003a,b, 2004; Zeigler et al., 2002a,b,c; Heckert and Zeigler, 2003; Hurlburt et al., 2003; Zeigler, 2002, 2003; Zeigler et al., 2003a,b,c,d,e; Jenkins, 2004; Jenkins and Heckert, 2004a,b; Heckert and Jenkins, 2005) (Fig. 8). Particularly important records are of *Desmatosuchus chamaensis* (this is the type locality—Zeigler et al,. 2002a), the phytosaurs, which are especially numerous (at least 11 skulls recovered to date, equaling the number known from the Canjilon quarry; Fig. 8I-O)), and the coelophysids, which include the oldest known coelophysid skull (Heckert et al., 2000, 2003a) (Fig. 8A-H).

The taphonomy of the Snyder quarry macrovertebrate assemblage has been studied extensively (Zeigler, 2002, 2003; Zeigler et al., 2002b; Tanner et al., 2003), and data from the microvertebrate assemblage complements those analyses (Heckert and Jenkins, 2005). Essentially, it is clear that the following sequence of events transpired (e.g., Tanner et al, 2003, fig. 7; Zeigler, 2003), although of course determination of causal factors remains somewhat problematic: (1) the area was generally wet, and the Snyder quarry probably occupied a topographic low that was either a small channel or localized pond that aggraded intermittently in response to rising base level; (2) a large fire swept through the area, accounting for charcoalized wood found here and elsewhere at the same stratigraphic level; (3) subsequent rainfall mobilized large volumes of sediment from the denuded floodplain, including vertebrate carcasses in various stages of decay and disarticulation; (4) this material was swept into topographic lows such as the Snyder quarry; (5) later base level rise facilitated continued aggradation and eventual burial of the principal bonebed.

Hayden quarry

In 2002, a participant in one of Ghost Ranch's summer hiking programs discovered a new locality in the Painted Desert Member. This locality, named the Hayden quarry after its discoverer, is south of US 84 on the west bank of Arroyo Seco, and occurs on a fault block (mapped by Smith et al., 1961) that has been downthrown relative to the other Arroyo Seco localities described here. Since 2001, Alex Downs of Ghost Ranch has led excavations at the quarry. The quarry appears to be at the same stratigraphic level as the other Arroyo Seco localities, even though it is now topographically lower than the other strata. The quarry lies in greenish conglomerates and mudstones that overlie typical redbed mudstones of the Painted Desert Member. The preservation of the bones and associated plant matter is identical to that of the Snyder quarry, so it appears likely that it not only lies at the same stratigraphic level as the Snyder quarry, but may well record the same sequence of events.

The Hayden quarry has only been documented in preliminary fashion (e.g., Downs, 2005). Alex Downs has generously shown us material, and between his observations and our own we can report an assemblage consisting of one or more metoposaurids, phytosaurs, *Typothorax coccinarum*, a probable herrerasaurid (="*Chindesaurus*") and a possible *Vancleavea* or *Vancleavea*-like taxon (Downs, pers. comm.). Although the bone density reported by Downs (2005) is not as high as at the Snyder quarry, this quarry still has great potential to yield significant fossil vertebrates.

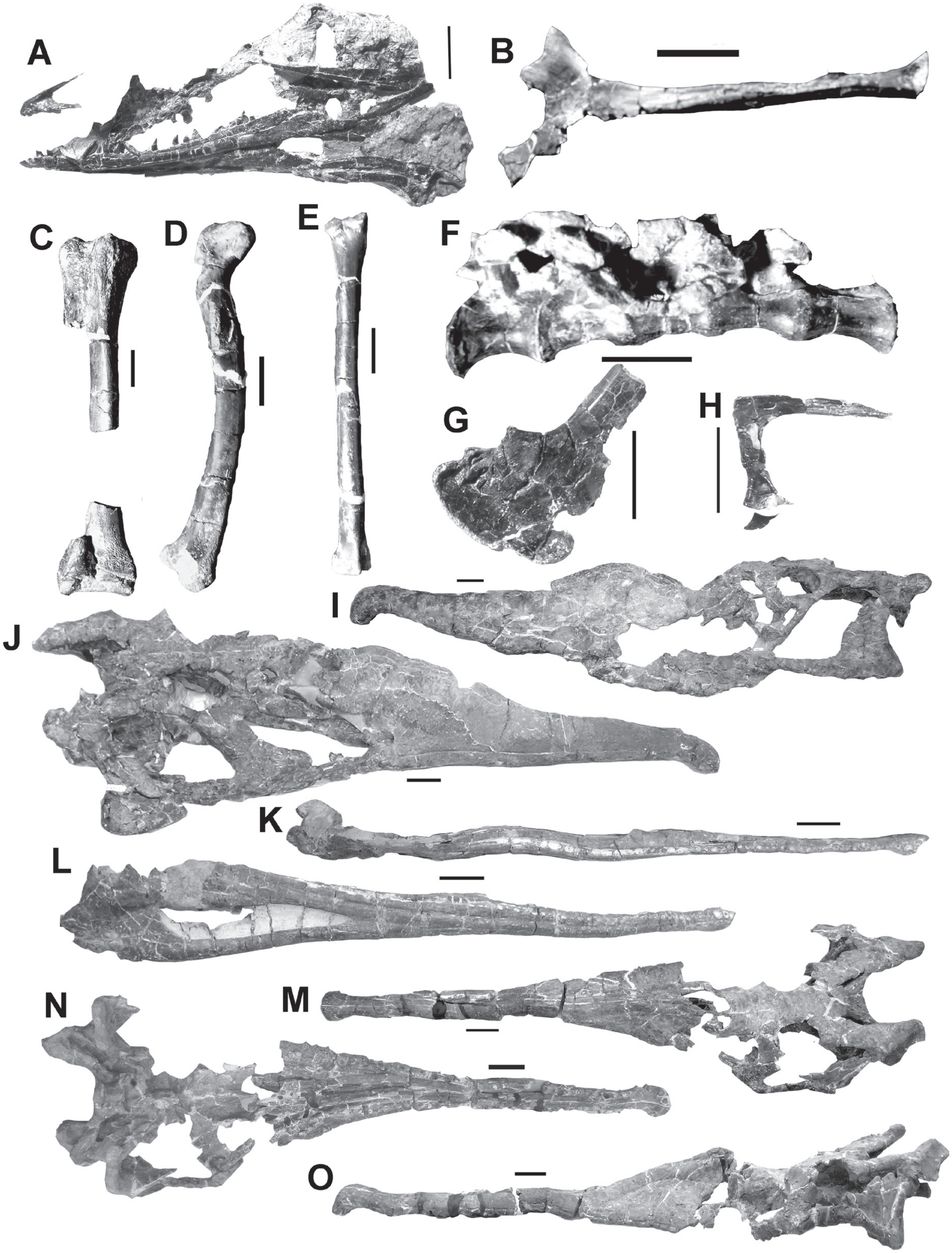

FIGURE 8. Representative dinosaurs and phytosaurs from the Snyder quarry. **A-H**, coelophysid fossils, including: **A**, skull (NMMNH P-30852) in lateral view; **B**, right ischium (NMMNH P-29047) in medial view; **C**, Fused tibia-fibula-astragalus-calcaneum (NMMNH P-29168) in anterior view; **D**, left femur (NMMNH P-29046) in posterior view; **E**, left tibia (NMMNH P-29046) in posterior view; **F**, fused sacral centra (NMMNH P-31661); **G**, incomplete left scapulocoracoid (NMMNH P-31661) in medial view; **H**, right lacrimal (NMMNH P-30852) in lateral view. **I-O**, phytosaur fossils attributable to *Pseudopalatus buceros*, including **I**, large male(?) skull (NMMNH P-40000) in left lateral view; **J**, medium-sized male(?) skull (NMMNH P-39700) in oblique right dorso-lateral view; **K-L**, right mandible (NMMNH P-44291) in **K**, occlusal, and **L**, lateral views. **M-O**, male(?) skull (NMMNH P-45650) in **M**, dorsal, **N**, ventral, and **O**, left lateral views. All coelophysid scale bars = 2 cm; phytosaur scale bars = 5 cm.

Miscellaneous Chama Basin localities

A variety of localities across the southern Chama Basin yield fossils from Painted Desert Member strata, but most of these are comparatively isolated occurrences. These include vertebrates recovered from Cañon del Cobre, "Coyote amphitheater," and other, individual localities that yield only isolated specimens. Long and Murry (1995) recorded three fragmentary skeletons of *Typothorax coccinarum* in the AMNH collections (only two numbers: AMNH 7634 and AMNH 7635) from the Painted Desert Member in Cañon del Cobre. It appears likely that these were collected by Baldwin, perhaps his "Sack 7. Box 8. Bones, up side of Cristones, west Cave Camp, El Cobre, Permian. 12 or 15 vertebrae, large package, no teeth seen, July 5 & 6, highest horizon up to date" (from AMNH archives).

Most of the "Petrified Forest Member" vertebrates from Coyote amphitheater documented by Lucas and Hunt (1992) and Hunt and Lucas (1993a) were derived from what is now recognized as the Mesa Montosa Member of the Petrified Forest Formation (Lucas et al., 2003a; Zeigler et al., 2005), leaving only a very fragmentary "fauna" of indeterminate phytosaurs and *Typothorax* scutes from the Painted Desert Member there.

One of the more important single occurrences in the Chama Basin is the type specimen of *Dolabrosaurus aquitilis* Berman and Reisz (1992), found at the base of Loma Prieta on the west flank of Abiquiu Reservoir where the Chama River empties into it. This specimen is an extremely rare occurrence of a drepanosaurid in the Chinle Group (the only other one being in at the Whitaker quarry itself—Harris and Downs, 2002). However, little is known about its stratigraphic provenance or taphonomy (Berman and Reisz, 1992).

Finally, a locality (NMMNH locality 5055) discovered during excavation of the Snyder quarry appears to sample the underlying red beds. This site yields a fauna of small vertebrates and is also the richest single coprolite locality in the Painted Desert Member of the Chama Basin. Consequently, it holds great potential to improve the diversity of small vertebrates known from the Painted Desert Member, although it has yet to be fully exploited.

VERTEBRATE PALEONTOLOGY

As should be clear from the preceding discussion, the vertebrate fauna of the Painted Desert Member in the Chama Basin is, in spite of several rich localities, not particularly diverse, although recent collecting efforts have more than doubled the diversity reported a little more than a decade ago (Compare Table 3 to Lucas and Hunt, 1992; Hunt and Lucas, 1993a,b). Among broadly correlative faunas, those from the Bull Canyon Formation in eastern New Mexico (Hunt, 2001) and from the Painted Desert Member in the Petrified Forest National Park in Arizona (Long and Murry, 1995) are both richer in terms of taxic diversity. Indeed, much of the total diversity of the Painted Desert Member in the Chama Basin comes from the Snyder quarry (Heckert and Jenkins, 2005, and references cited therein), which is the most diverse locality in the Chama Basin even if the increased diversity from screenwashing is ignored. Otherwise, the Painted Desert Member in the Chama Basin yields a "typical" Chinle fauna dominated by phytosaurs and aetosaurs. Even the Owl Rock Formation faunas described by Kirby (1989, 1991, 1993) hint at a greater diversity, particularly of tetrapods, than the Chama Basin faunas. Here, we review the vertebrate fauna of the Painted Desert Member systematically, with particular attention to the archosaurian records.

TABLE 3. Vertebrate fauna of the Painted Desert Member

Chondrichthyes:	
	Lonchidion humblei
	Chondrichthyes indet.
Osteichthyes	
	Palaeoniscidae indet. aff. *Turseodus*
	Redfieldiidae indet
	Semionotidae indet.
	Arganodus (?)
Amphibia	
	Apachesaurus
	aff. *Buettneria*
	Metoposauridae indet
Reptilia	
	Cynodontia indet.
	Lepidosauromorpha indet.
	Dolabrosaurus aquitilus
	Vancleavea sp.
	Pseudopalatus buceros
	Typothorax coccinarum
	Desmatosuchus chamaensis
	Poposauridae indet.
	Herrerasauridae(?) indet.
	Eucoelophysis baldwini

Chondrichthyes

The Chama Basin is unusual among Chinle faunas in that there are almost no chondrichthyan records. The only exceptions are a single tooth of *Lissodus* (=*Lonchidion*) and some more fragmentary, problematic chondrichthyan(?) fossils from the Snyder quarry (Heckert and Jenkins, 2005). The paucity of screenwashing sites in the Chama Basin doubtless contributes to this lack of diversity, but it is still interesting that it lacks the records of *Reticulodus* known from correlative strata elsewhere in the Chinle (Huber et al., 1993; Murry and Kirby, 2002).

Osteichthyes

In the Chama Basin, osteichthyans are only slightly more diverse and abundant than chondrichthyans. To date, all actinopterygian records from the Painted Desert Member in the Chama Basin come from the Snyder quarry (Heckert et al., 2000; Zeigler et al., 2003b,d,e; Heckert and Jenkins, 2005). These include palaeoniscids, redfieldiids, and semionotids, although only the semionotid is represented by more than isolated scales.

Amphibia

Metoposaurid amphibians are relatively rare in the Painted Desert Member of the Chama Basin. The few known records—including an isolated centrum from the Snyder quarry and a lower jaw from the Hayden quarry—are much too large to pertain to *Apachesaurus* (ABH pers. obs.). Thus, while not actually diagnostic to the species level, they almost surely pertain to *Buettneria sensu* Hunt (1993), and are among the stratigraphically highest records of the genus.

Reptilia

The strength of the vertebrate fossil record of the Painted Desert Member in the Chama Basin lies in its amniote record, which has grown much more diverse—doubling at the generic level—in the last decade. The record is dominated by archosauromorphs, and is especially rich in phytosaurs and aetosaurs and surprisingly rich in dinosaurs, but depauperate in synapsids and lepidosauromorphs.

Non-archosauromorphs

To date, the only non-archosaurian amniote fossils found in the Painted Desert Member of the Chama Basin are an isolated cynodont humerus and an incomplete lepidosauromorph jaw from the Snyder quarry (Zeigler et al., 2003e; Heckert and Jenkins, 2005). Berman and Reisz (1992) originally described *Dolabrosaurus aquatilis* as a possible lepidosauromorph, but Renesto and Paganoni (1995) considered it a drepanosaurid, so it is covered in the section on archosauromorphs, following Renesto (2000).

Archosauromorpha

From the first fragmentary osteoderms collected by Cope to the enormous excavations at the Canjilon and Snyder quarries, archosauromorphs have always dominated the Chama Basin's Painted Desert Member vertebrate faunas, both in terms of volume and diversity. Like many Chinle sites, especially those of Norian and younger age, phytosaur fossils are the most commonly recovered identifiable vertebrates in the Painted Desert Member of the Chama Basin, but aetosaur and dinosaur fossils are remarkably abundant as well.

It is difficult to overstate the importance of the phytosaur record of the Chama Basin. Cope's initial recognition of phytosaurs ("*Belodon*" *buceros*; Fig. 4) in the 1870s was key to his identification of Triassic strata in the American Southwest. Doubtless the specimens collected from the Canjilon quarry influenced Camp's thinking, even if they made essentially no appearance in his classic monograph (Camp, 1930). Gregory (1962a,b) had the advantage of studying these specimens, and Lawler (1974), Ballew (1986, 1989) and Hunt (1994) also utilized them in their graduate studies. Thus, between these workers and Long and Murry (1995), much of what has been written about pseudopalatine phytosaurs in the American Southwest in the latter part of the 20th century was based, in whole or in part, on the Canjilon quarry sample. More recently, the Canjilon quarry sample formed the foundation of Zeigler et al.'s (2002c, 2003f) study of sexual dimorphism in phytosaurs (Figs. 6-7), something borne out in their studies of the Snyder quarry sample as well (e.g., Zeigler et al., 2003c) (Fig. 8I-O). These samples were also key to Hurlburt et al.'s (2003) body mass estimations of phytosaurs. With this wealth of study, it is ironic that it was not until 2002 that the taxonomic status of Cope's (Lucas et al., 2002a) and the Canjilon phytosaurs (Zeigler et al, 2002c) was resolved with any certainty.

The aetosaurian record of the Chama Basin is no less important, or ironic. Cope was, by modern standards, a splitter of prodigious proportions, but his recognition of *Typothorax coccinarum* from fragmentary osteoderms 130 years ago (Cope, 1875) not only has stood the test of time (Long and Ballew, 1985; Lucas and Hunt, 1992; Heckert and Lucas, 2000, 2002a; Lucas et al., 2002b), but, with his (Cope, 1881) use of the phytosaur "*Belodon*" *buceros* to correlate to the German Keuper, was also the first step in developing a testable biostratigraphic framework using Triassic tetrapods (Lucas and Hunt, 1993; Lucas and Heckert, 1996; Lucas, 1998, 2005). More than 125 years later, another aetosaur, *Desmatosuchus chamaensis*, would be discovered and described on the basis of even more distinct osteoderms (Zeigler et al., 2002a). This taxon has already demonstrated some use as a Revueltian index fossil, occurring in the Bull Canyon Formation of eastern New Mexico (Zeigler et al., 2002a) and the Painted Desert Member of the Petrified Forest Formation in Petrified Forest National Park (Stocker et al., 2004)

Crocodylotarsans more derived than aetosaurs and phytosaurs are surprisingly uncommon in the Painted Desert Member in the Chama Basin. Various "rauisuchian" specimens are in the Ghost Ranch collections and may have come from the Canjilon quarry and vicinity (Long and Murry, 1995). Fragmentary rauisuchian fossils, including both a juvenile and an adult femur broadly similar to that of *Postosuchus* have been recovered from the Snyder quarry (Zeigler et al., 2003e). To date, no other derived crurotarsans have been reported from the Painted Desert Member in the Chama Basin, with the possible exception of the specimen illustrated here in Figure 5C.

The Chama Basin has a remarkable dinosaur record. Of course, the Whitaker quarry (in the Rock Point Formation) is not part of the Painted Desert Member fauna, but it is worth noting that this is probably the richest single dinosaur locality in the world. The Painted Desert Member is also remarkably rich in dinosaurs compared to correlative strata in the rest of the American Southwest (e.g., Hunt et al., 1998; Heckert et al., 2000a). Significant dinosaur records from the Painted Desert Member in the Chama Basin are entirely of theropods, principally coelophysoids. These records began with the original type material of *Coelophysis* collected by Baldwin (Cope, 1887a,b, 1889; von Huene, 1915; Padian, 1986; Colbert, 1989; Sullivan et al., 1996; Sullivan and Lucas, 1999). Since then, additional theropods have been found around Orphan Mesa, including the holotype of *Eucoelophysis baldwini* (Sullivan et al., 1996; Sullivan and Lucas, 1999) and at the Snyder quarry, which is one of the few sites in the Chinle Group that yields multiple individuals of theropod dinosaurs (Heckert et al., 2000b, 2003b). Now, with the additional report of theropods from the Hayden quarry (Downs, 2005), it is clear that theropods are a relatively common component of Painted Desert Member faunas in the Chama Basin. Whether this is a true reflection of paleoenvironmental conditions (perhaps a more "upland" setting than many Chinle sites—Fig. 2) or simply an unusual taphonomic situation remains to be seen.

BIOSTRATIGRAPHY AND BIOCHRONOLOGY

The presence of the phytosaur *Pseudopalatus* and the aetosaur *Typothorax coccinarum* Cope indicates a Revueltian (early-mid Norian) age for the Painted Desert Member in the Chama Basin (Lucas and Hunt, 1993; Hunt and Lucas, 1993a,b; Lucas, 1997, 1998; Lucas et al., 2003a, 2005). Although *Pseudopalatus* may occur in strata of Carnian age (Hunt and Lucas, 2005), occurrences of *T. coccinarum* The Painted Desert Member in north-central New Mexico is stratigraphically equivalent to the Painted Desert Member of the Petrified Forest Formation in west-central New Mexico and northern Arizona (Lucas and Hunt, 1989; Lucas, 1993; Heckert and Lucas, 2002b, 2003). This is also the same stratigraphic interval as the Bull Canyon Formation in east-central New Mexico and West Texas (Lucas, 1993, 1997; Lucas et al., 2001, 2003a). Thus, the vertebrate fauna of the Painted Desert Member in the Chama Basin is broadly correlative to the upper faunas of the Petrified Forest National Park (e.g., Long and Padian, 1986; Murry and Long, 1989; Hunt and Lucas, 1995; Long and Murry, 1995; Heckert and Lucas, 2002b), as well as Bull Canyon Formation faunas in eastern New Mexico (Hunt, 1994, 2001) and West Texas, including the Post quarry (Small, 1989; Long and Murry, 1995). It is clear, however, that most of the productive localities in the Chama Basin are relatively high stratigraphically in the Painted Desert Member (Fig. 3), and so are probably equivalent to the stratigraphically highest (youngest) faunas from broadly correlative strata.

Elsewhere in this volume, Heckert and Jenkins (2005) noted that, in spite of extensive collecting efforts, several taxa that are otherwise typical of Revueltian faunas in the Chinle Group have not been recovered from the Painted Desert Member of the Chama Basin. Taxa known from strata of Revueltian age elsewhere that are "missing" from the Chama Basin assemblage include the dipnoan *Arganodus*, the metoposaur *Apachesaurus*, the aetosaur *Aetosaurus* and the putative ornithischian *Revueltosaurus callenderi*. Heckert and Jenkins (2005) demonstrate that most of these taxa are probably absent because of taphonomic and/or ecological effects, but there may be some stratigraphic, and therefore biochronological implications to the absence of *Revueltosaurus callenderi*.

The putative ornithischian dinosaur *Revueltosaurus callenderi* is readily identifiable from isolated teeth and is known from diverse localities of Revueltian age in the American Southwest (Hunt, 1989, 2001; Padian, 1990; Long and Murry, 1995; Heckert, 2002). Indeed, it appears to be an index taxon of the Revueltian (Hunt and Lucas, 1994; Lucas, 1998; Heckert, 2002), although Parker et al. (pers. comm.) have identified additional material that suggests that *R. callenderi* is actually a crurotarsan, not a dinosaur. Like *Apachesaurus*, *Revueltosaurus* often co-occurs with other Revueltian taxa. However, unlike *Apachesaurus*, *Revueltosaurus* does not occur in younger (Apachean) strata. It is therefore possible that Painted Desert Member in the Chama Basin represents strata somewhat younger than the last appearance of *R. callenderi*.

Indeed, Hunt (2001) proposed subdividing the Revueltian lvf into an older, Barrancan (R1) interval and a younger, Lucianoan (R2) interval (concepts first articulated by Lucas and Hunt, 1993 and Lucas, 1997). The Lucianoan interval is based in part on problematic index taxa, namely the cynodont *Pseudotriconodon chatterjeei* and the putative ornithischian *Lucianosaurus wildi* (both microvertebrates only known from their type locality), but is also noteworthy in that it lacks *Revueltosaurus*. If further collecting, particularly in the Bull Canyon Formation and the Painted Desert Member of the Petrified Formation validates Hunt's (2001) biostratigraphic hypothesis, the Painted Desert Member in the Chama Basin may represent the equivalent of Hunt's (2001) Lucianoan sub-lvf of the Revueltian. Hunt (2001) indicated that he thought the Canjilon quarry was in this stratigraphic interval, as were Kirby's (1989, 1991, 1993) Owl Rock localities. Although we have not found any of Hunt's (2001) putative Lucianoan index taxa, the fauna of this interval is similar to that predicted by Hunt's hypothesis. That is, the Chama Basin Painted Desert Member lacks typical Barrancan taxa such as *Revueltosaurus*, *Aetosaurus*, and the rauisuchian(?) *Shuvosaurus*. However, we note that if the Chama Basin fauna is indeed Lucianoan in age, then *D. chamaensis* is now known from both the Barrancan (R1) and Lucianoan (R2) sub-lvfs.

Thus, the biostratigraphy of the Painted Desert Member in the Chama Basin is both simple and complex. At the simplest level, the macrovertebrate assemblage clearly indicates a Revueltian age, based on the presence of *Typothorax coccinarum*. More difficult to assess is whether it may pertain to Hunt's (2001) Lucianoan sub-lvf. We tentatively suggest that it does. While Hunt (2001) listed some of the biases and other problems inherent in identifying the Lucianoan sub-lvf, we note that the long history of collecting in the Chama Basin effectively comprises a test of Hunt's (2001) biostratigraphic hypothesis, and the absence of identifiable *Revueltosaurus* teeth from this stratigraphic interval, the upper Bull Canyon Formation and the Owl Rock Formation corroborates at least part of his biostratigraphic hypothesis.

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