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THE MOSASAUR *PROGNATHODON* FROM THE UPPER CRETACEOUS LEWIS SHALE NEAR DURANGO, COLORADO AND THE DISTRIBUTION OF *PROGNATHODON* IN NORTH AMERICA

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ABSTRACT.—We document an incomplete skeleton of the mosasaur *Prognathodon overtoni* (Williston) from the middle part of the Lewis Shale southwest of Durango, Colorado. The locality's stratigraphic position below the Huerfanito Bentonite Bed and associated ammonites of the zone of *Baculites perplexus* Cobban indicate that the mosasaur is of middle Campanian age. In North America, *Prognathodon* has a remarkably long (essentially all of the Campanian-Maastrichtian) and geographically broad (west to east coasts) distribution. *Prognathodon* was a large, deep water predator of the Late Cretaceous seas.

INTRODUCTION

Identifiable mosasaur remains are rare in the Upper Cretaceous Lewis Shale of the San Juan Basin of northwestern New Mexico and southwestern Colorado. Only two records are documented in the literature: (1) a partial skeleton identified as cf. Platecarpus sp. from near Dulce, New Mexico (Lucas and Reser, 1981), and (2) a partial but very fragmentary skeleton of Prognathodon overtoni from near Pagosa Springs, Colorado (Kues and Lucas, 1985) (Fig. 1). Here, we document a third record, an incomplete skeleton of P. overtoni from near Durango, Colorado (Fig. 1), and review the geographic and biostratigraphic distribution of Prognathodon in North America. Institutional abbreviations: ANSP, Academy of National Sciences of Philadelphia, Philadelphia, Pennsylvania; AMNH, American Museum of Natural History, New York; BYU, Brigham Young University Earth Science Museum, Provo, Utah; CU, University of Colorado Museum, Boulder; DMNH, Denver Museum of Nature and Science (formerly the Denver Museum of National History), Denver, Colorado; FMNH=Field Museum of Natural History; KUVP, University of Kansas Vertebrate Paleontology Collection, Lawrence; NJSM, New Jersey State Museum, Trenton; NMMNH, New Mexico Museum of Natural History, Albuquerque; RTMP, Royal Tyrrell Museum of Paleontology, Drumheller, Alberta; SDSM, South Dakota School of Mine and Technology, Rapid City; UCMP, University of California Museum of Paleontology, Berkeley; UNM, University of New Mexico, Albuquerque; UNO, University of New Orleans, Louisiana; YPM, Yale Peabody Museum, New Haven.

PROVENANCE

The newly discovered partial skeleton of *Prognathodon overtoni* is NMMNH P-41767. It was discovered during the construction of a house near East Gap on the Basin Mountain Quadrangle, southwest of Durango, Colorado (sec. 7, T34N, R10W, La Plata County). The fossil comes from NMMNH locality 4547, approximately in the middle of the Lewis Shale (Fig. 1), and is preserved in four broken blocks of dark yellowish brown to yellowish orange, limestone concretion.

In the vicinity of NMMNH locality 4547, the Lewis Shale is approximately 730 m thick (Aubry, 1991). Lack of exposure makes it necessary to estimate the stratigraphic position of NMMNH locality 4547 from isopach data. Such an estimate indicates that the Huerfanito Bentonite Bed is about 286 m below the top of the Pictured Cliffs Sandstone, which overlies the Lewis Shale (Sandberg, 1990). NMMNH locality 4547 is estimated to



FIGURE 1. Location map of mosasaur localities in the Lewis Shale of the northern San Juan Basin, New Mexico-Colorado. Localities are: 1 = Prognathodon locality reported here; 2 = Prognathodon locality reported by Kues and Lucas (1985); 3 = cf. *Platecarpus* locality reported by Lucas and Reser (1981). Generalized stratigraphic section shows position of *Prognathodon* locality reported here.

be about 21 meters below the Huerfanito Bentonite Bed, which has an Ar/Ar radioisotopic age of 75.76 ± 0.34 Ma (Fassett et al., 1997). Specimens of the heteromorph ammonite Baculites perplexus Cobban are associated with the mosasaur and support assignment of a middle Campanian age in the zone of Baculites perplexus (late form) to NMMNH locality 4547 (Maisch, 2002).

IDENTIFICATION

Three of the four blocks of NMMNH P-41767 contain vertebrae, ribs and a few appendicular bones that are not generically diagnostic. However, the largest block (Fig. 2) preserves an incomplete skull, including the right quadrate, pieces of both lower jaws, including a dentulous piece with seven broken teeth, seven articulated cervical vertebrae, ribs and other bone fragments. The following diagnostic features of Prognathodon are evident in NMMNH P-41767: (1) robust, bicarinate mandibular teeth with symmetrical cross sections, (2) short and very massive jaws, (3) nearly circular stapedial pit on the quadrate, and (4) a medial wing from the coronoid contacts the angular (Russell,

1967, p. 162). Additional features justify a species-level assignment to P. overtoni: very smooth tooth surfaces, no tuberosity on anteromedian edge of quadrate shaft and a broad, thin vertical ridge on the quadrate ala that are expanded anteriorly (Russell, 1967, p. 165-166; Bell, 1997, p. 311, "characters 55 and 61").

NORTH AMERICAN DISTRIBUTION OF PROGANTHODON

Prognathodon has a geographically very wide distribution in North America. Specimens of the genus are found four areas: (1) Western Interior seaway, (2) Gulf of Mexico, (3) Atlantic Coast, and (4) Pacific Coast (Fig. 3). Prognathodon thus is only the mosasaur genus to have been found in the Pacific Coast, Atlantic Coast and the Western Interior seaway.

Over a dozen specimens of Prognathodon are known from Colorado, Wyoming, South Dakota, and Alberta. A large, fairly complete skeleton (BYU 13082) is the type and only known specimen of P. stadtmani, which was found in Mesa County, western Colorado and is the westernmost record in the Western

FIGURE 2. NMMNH P-41767, Prognathodon overtoni, block containing skull and mandibular fragments, cervical vertebrae and ribs (A-B). Detail of lower jaw fragment (C) and right quadrate (D).





FIGURE 3. Representative fossil localities of *Prognathodon* in North America, on a late Campanian base map (after Obradovich and Cobban, 1975). Localities are: 1 = Fresno County, California; 2 = Red Rock Coulee, southern Alberta; 3 = Shannon County, South Dakota; 4 = Pagosa Springs, southwestern Colorado; 5 = Durango and Delta, western Colorado; 6 = central and western Alabama; 7 = New Jersey.

Interior seaway (Kass, 1999). NMMNH P-41767 (*P. overtoni*) is also from western Colorado (see above). Kues and Lucas (1985) documented a partial skeleton of *P. overtoni* (originally UNM LK-2; now catalogued as NMMNH P-27584) from near Pagosa Springs, southwestern Colorado. A specimen of *P. overtoni* from Shannon County, South Dakota (SDSM 3393) preserves one of the most complete skulls of the genus. Another partial skeleton (including a jaw fragment, some teeth, and some skull fragments) of *P. overtoni* (RTMP 83.164.1) from near Red Rock Coulee, southern Alberta is the northernmost North American record of *Prognathodon*.

Kiernan (2002) reported several specimens of *Prognathodon* from central and western Alabama (the Gulf of Mexico). They include *P*. cf. *P. solvayi* (unnumbered UNO specimen) and *Prognathodon* sp. (FMNH 143, 146, 165, 193).

Several specimens of *Prognathodon* are known from New Jersey. Cope (1869-1870) first described AMNH 1490, which later became the holotype of *P. rapax* (Hay), based on only two right quadrates. A left quadrate of another New Jersey specimen, *P. rapax* (NJSM 9827), resembles the elements of AMNH 1490. The specimen also has a few well-preserved teeth, jaw fragments,

and several trunk vertebrae. Gallagher (1993, p. 103) also listed a few other fragmentary skeletons of *P. rapax* from New Jersey, including ANSP 9632-3 and AMNH 1395.

In the Pacific Coast area, Bell (1997, p. 328) identified two specimens, UCMP 126280 and 126715, as *P. rapax*. Both specimens were found in the Moreno Formation of Fresno County, California.

BIOSTRATIGRAPHY

Prognathodon has the longest stratigraphic duration of a genus of North American mosasaurs, ranging from the very early Campanian to the end of the Maastrichtian (Fig. 4). Based on the stratigraphic distribution of *Prognathodon* fossils, we identify three zones based on the distribution of species of the genus.

The oldest zone is the poorly known *P. stadtmani* Zone (lower Campanian). The zone is based on the oldest known species of *Prognathodon, P. stadtmani*, found near the top of the Mancos Shale, western Colorado in the *Scaphites hippocrepis* Zone of the lower Campanian (Franczyk et al., 1992; Kass, 1999).

The succeeding zone is the *P. overtoni* Zone, which ranges from middle Campanian to lower Maastrichtian. One of the earliest known *P. overtoni* (DMNH 18352) was found in the Lewis Shale (middle Campanian) in the Western Interior Seaway (Martz et al., 1999). NMMNH P-41767 is in the *Baculites perplexus* zone (Maisch, 2002), and NMMNH P-27584 is from the lower Lewis Shale (*Didymoceras nebrascense* zone) (Kues and Lucas, 1985).

Prognathodon overtoni is also fairly common in the upper Pierre Shale and Bearpaw Shale (upper Campanian-lower Maastrichtian). The Virgin Creek Member (Pierre Shale) in South

	STAGE		Pacific Coast	Pacific Interior Coast Seaway		East Coast	key specimens
	Maastrichtian	U	P. rapax			P. rapax	AMNH 1490, NJSM 9827, YPM 1597
		L					CU 14767
	Campanian	U			P. overtoni		KUVP 950 SDSMT 3393
		М					NMMNH P-41767, P-27584, DMNH 18352
		L			P. stadtmani		BYU 13082
	Santo	onian					

FIGURE 4. Stratigraphic and geographic distribution of *Prognathodon*.

Dakota (Russell, 1967) produced the holotype of the species (KUVP 950) from the top of the Pierre Shale near the Cheyenne River (Williston, 1897; Russell, 1967, p. 165), as well as another large specimen (SDSM 3339). Another partial skeleton of *P. rapax* (RTMP 83.164.1) from Alberta probably is of late Campanian age. On the Atlantic Coast, at least four partial skeletons (AMNH 1490, NJSM 9827, YPM 1597, ANSP 9623-3) are assigned to *Prognathodon* sp. The first two specimens are probably from the upper part of the Navesink (= New Egypt) Formation (Gallagher, 1993). The Navesink Formation is regarded as either late Campanian to early Maastrichtian (Owens et al., 1970; Kennedy, et al., 2000) or as Maastrichtian (Gallagher, 2002).

The youngest zone is the *Prognathodon rapax* Zone of late Maastrichtian age. The holotype of *Liodon validus* Cope 1869-1870 (AMNH 1395), later assigned to *P. rapax*, was found in the Hornerstown Formation in Swell, Gloucester County, New Jersey (Gallagher, 1993). Gallagher (2002, p. 294) suggested that the boundary between the Navesink and Hornerstown formations is near the middle-upper Maastrichtian boundary (*Jeletzkytes nebrascensis* Zone), which means the *P. rapax* record from Gloucester County is late Maastrichtian. It is thus one of the youngest known specimens of *Prognathodon* from the Atlantic Coast.

According to Bell (1997), UCMP 126280 is also *Prognathodon rapax*. This California specimen is from the late Maastrichtian interval of the Moreno Formation. It is one of more than a dozen mosasaur specimens, including *Plotosaurus* and *Plesiotylosaurus*, that were collected at the top of the Panoche beds just above the base of the Moreno Formation (Camp, 1942, p. 8).

DISCUSSION

The very broad geographical distribution in North America of *Prognathodon* distinguishes it from other mosasaur genera because it is the only genus found on the Pacific Coast, in the Western Interior seaway and on the Atlantic Coast. Furthermore, *Prognathodon* is known to exhibit a broad distribution in Europe and the Middle East as well, including records in Israel (Christiansen and Bonde, 2002), Jordan (Bardet and Superbiola, 2002), Belgium (Dollo, 1904) and France (Bardet et al., 1997). *Prognathodon* also exhibits one of the longest stratigraphic distributions of North American mosasaurs: from the beginning of the Campanian to the end of Maastrichtian.

We suggest that *Prognathodon* may have occupied a relatively specialized habitat as a very large, relatively deep water predator. In North America, *Prognathodon* is only found in very dark shale deposits, such as the Pierre Shale, Bearpaw Shale, Lewis Shale, Navesink and Moreno formations. Those sediments are interpreted to represent relatively deep water, offshore environments during the Late Cretaceous. Indeed, no evidence indicates that the genus lived in relatively shallow water.

Prognathodon is thought to have been one of the top predators of the Late Cretaceous marine environment. Thus, Christiansen and Bonde (2002) suggested that *Prognathodon* had a very large, heavily built skull and jaws (e.g., 1422 mm is the total skull length of the holotype of *P. currii*) with massive teeth that were used to crush and hold large prey items. The large body size of *Prognathodon* also reasonably supports the idea that the genus could swim long distances leading to a very broad geographical distribution.

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