

A CERATOPSID DINOSAUR PARIETAL FROM NEW MEXICO AND ITS IMPLICATIONS FOR CERATOPSID BIOGEOGRAPHY AND SYSTEMATICS

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Ceratopsid (horned dinosaur) cranial material is relatively common in the Upper Cretaceous Naashoibito Member of the Kirtland Formation, San Juan Basin, New Mexico. However, the specimens are fragmentary, making identification problematic. Previously, it has been suggested that the Naashoibito specimens represent *Torosaurus utahensis*, a chasmosaurine taxon originally known from the North Horn Formation of Utah. This identification has been used to support a Lancian age for the Naashoibito Member and the Alamo Wash local fauna of the Kirtland Formation (e.g., Lehman, 1981; Lucas et al., 1987). Others (e.g., Lehman, 1990) have synonymized *T. utahensis* with *Torosaurus latus*, a taxon otherwise known only from the late Maastrichtian Lance and Hell Creek formations. Recent work has upheld the validity of *T. utahensis* (Sullivan et al., 2005). However, Sullivan and colleagues (2005) have also argued that no previously described ceratopsid specimens from the Naashoibito Member are identifiable beyond the level of Chasmosaurinae indeterminate and therefore are not useful for assessing biostratigraphic correlations and ceratopsid biogeography.

Here we describe a partial chasmosaurine ceratopsid parietal from the Naashoibito Member of the Kirtland Formation. Although other fragmentary parietals have been recovered from this unit (e.g., Lehman, 1981; Lucas et al., 1987), the new specimen exhibits unusual morphology: an epoccipital element positioned along the midline. This feature has previously been reported only in *Triceratops*, a taxon not known from south of the Denver Basin. The occurrence of such a feature in a ceratopsid from New Mexico has implications for ceratopsian systematics and biogeography.

Institutional Abbreviations—NMMNH, New Mexico Museum of Natural History and Science, Albuquerque; YPM, Yale Peabody Museum of Natural History, New Haven, Connecticut.

SYSTEMATIC PALEONTOLOGY

ORNITHISCHIA Seeley, 1888
CERATOPSIA Marsh, 1890
NEOCERATOPSIA Sereno, 1986
CERATOPSIDAE Marsh, 1888
CHASMOSAURINAE Lambe, 1915

Chasmosaurinae indet.
(Fig. 1)

Referred Specimen—NMMNH P-44477, a partial parietal with attached epoccipital (Fig. 1).

Locality—NMMNH locality 5841, near head of Willow Wash within the Bisti/De-na-zin Wilderness Area, northwestern New Mexico. More detailed locality information is on file at the NMMNH.

Horizon and Age—Naashoibito Member, Kirtland Formation.

Description—The parietal measures 572 mm in width by 413 mm in length as preserved. Relative to the midline, the parietal is gently dorso-

ventrally arched (Fig. 1B). By comparison with other ceratopsian specimens, the convex surface of the parietal is identified as the dorsal surface.

In coronal cross-sectional view (Fig. 1B), the parietal thickens gently towards the midline. The parietal displays a low, unornamented ridge at the midline, where maximum thickness measures 30 mm. By comparison with other ceratopsid parietals, the ridge allows confident identification of the midline in this specimen. The parietal is between 16 and 19 mm thick at its caudal margin and between 15 and 21 mm thick along the squamosal-parietal suture. Away from the midline, the preserved rostral limit of the bone has a minimum thickness of approximately 13 mm. The presence of parietal fenestrae cannot be determined. A low transverse ridge, positioned about 50 mm rostral to the caudal margin of the parietal at the base of the median epoccipital, extends for about 200 mm from the midline.

A single partial epoccipital is preserved on the midline at the caudal border of the parietal (Fig. 1). The epoccipital measures 95 mm wide as preserved; its complete width is estimated as at least 135 mm. The element measures 32 mm in caudorostral length and 22 mm in dorsoventral height. In dorsal view, the element is almost trapezoidal in shape. In sagittal cross-sectional view, the epoccipital has the appearance of a rounded triangle (Fig. 1C). The base of the epoccipital is clearly defined and partly fused to the parietal.

A possible squamosal-parietal suture is preserved along the left lateral margin of the element. Although this suture has the flattened appearance typical for large ceratopsids, no original bone surface is preserved. Thus, the possibility remains open that this is not a true suture, but a fracture similar to the “pseudo-sutural divisions” reported in *Torosaurus utahensis* specimens from the North Horn Formation of Utah (Gilmore, 1946: 45).

In addition to prominent neurovascular channels (Fig. 1A), the dorsal surface of the parietal displays a woven pattern of bone. This is similar to the bone pattern seen in other adult ceratopsids (e.g., Sampson et al., 1997). The bone texture on the ventral surface is not as well preserved as that on the dorsal surface of the parietal. Some parallel, mostly unbranching neurovascular channels are present towards the squamosal-parietal suture, and a branching neurovascular channel is present medially (Fig. 1C). This difference in bone patterns on the dorsal and ventral surface of the parietal is consistent with that observed in some other chasmosaurines (e.g., *Torosaurus* and *Triceratops*).

The caudal border of the parietal exhibits three crenulations to the left of the midline (Fig. 1A). A possible crenulation exists beneath the midline epoccipital. Assuming that the complete width of the parietal is preserved on the left side, and assuming that each crenulation is associated with an epoccipital, NMMNH P-44477 had a total of seven parietal epoccipitals. Despite the incomplete nature of the parietal, the identification of the epoccipital as a midline element is supported by the fact that it occurs in the same sagittal plane as a prominent ridge, comparable to the midline ridge on the parietal seen in many other ceratopsians.

Computed Tomography—To study the interface between the epoccipital and parietal, NMMNH P-44477 was subjected to computed tomography (CT) on a GE Medical Systems LightSpeed 16 machine. One hundred twenty-two parasagittal slices were taken at 5.0 mm slice spacing, with a pixel size of 0.703125 mm by 0.703125 mm. The specimen was reconstructed using 3D Slicer 2.5 (Open Source, 2005). Importantly, the boundary between the epoccipital and parietal is readily visualized along

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most of its length (Fig. 1C). This allowed digital removal of the epoccipital and subsequent reconstruction of the parietal. Significantly, only a small midline bump can be visualized on the caudal margin of the parietal (Fig. 1E). This contrasts with the pronounced scallops lateral to the

midline (Fig. 1A, 1C). Thus, this indicates that lack of a midline bump does not necessarily indicate lack of a midline epoccipital. Alternatively, fusion of the epoccipital may have remodeled an original crenulation at the midline.

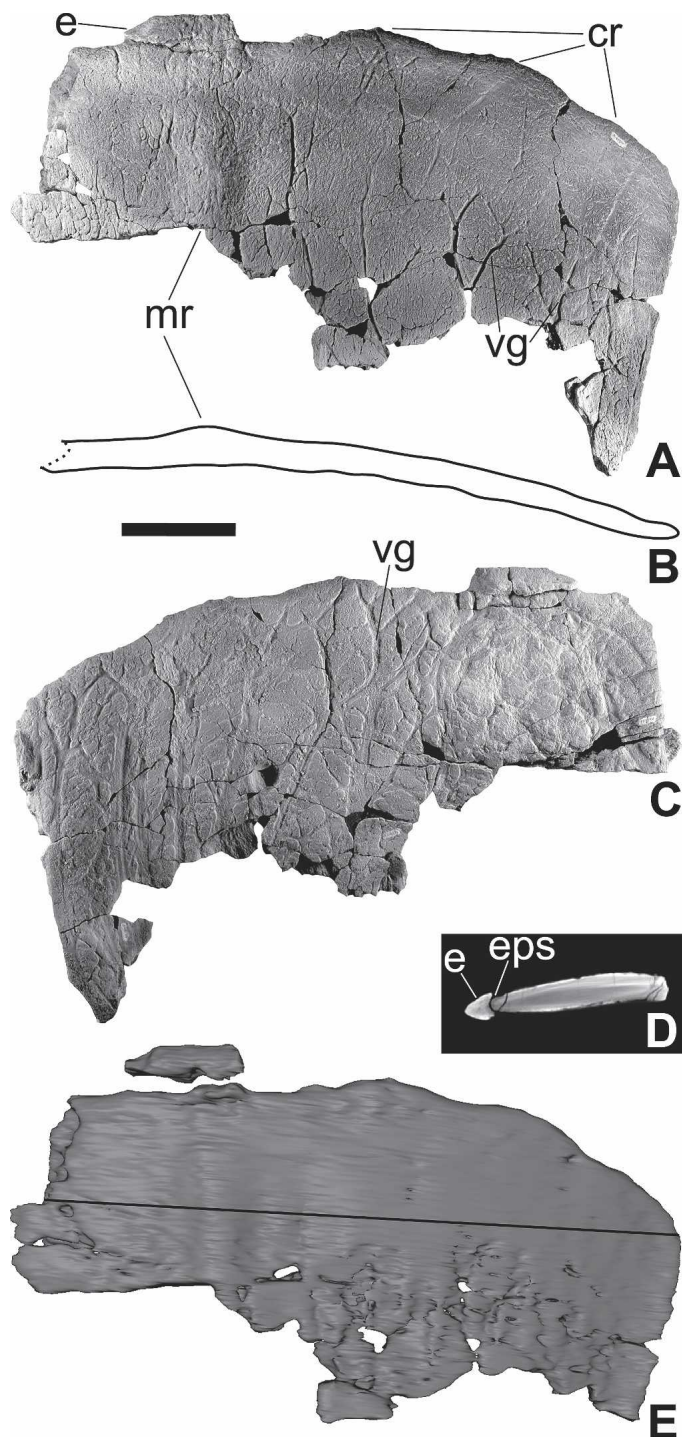


FIGURE 1. Parietal of NMMNH P-44477. **A**, dorsal view; **B**, transverse cross-section with broken edge dashed (dorsal surface of specimen is to the top of the figure; line of section shown on E); **C**, ventral view; **D**, parasagittal cross-sectional view at slice 17 of the CT dataset (arrow indicates junction between parietal and epoccipital; the caudal end of the parietal is at the left side of the image); **E**, parietal reconstructed digitally without epoccipital. The epoccipital has been displaced directly caudally to show its relationship to the caudal border of the parietal. **Abbreviations:** **cr**, marginal crenulation; **e**, epoccipital; **eps**, epoccipital/parietal suture; **mr**, midline ridge; **vg**, vascular grooves. Scale bar equals 10 cm.

DISCUSSION

Affinities of NMMNH P-44477—NMMNH P-44477 is distinctive in combining a thin parietal with a median epoccipital. Thin parietals are found in a number of chasmosaurine taxa (*Torosaurus latus*, *Torosaurus utahensis*, *Arrhinoceratops brachyops*, *Diceratops hatcheri*, and the “El Picacho” ceratopsian), and this character alone cannot be used to identify isolated parietals (Lehman, 1996; Sullivan et al., 2005). Among chasmosaurines, *Triceratops* is the only taxon known to possess a single midline epoccipital on the parietal (Forster, 1996). In *T. latus*, no midline epoccipital existed (Farke, in press), and the condition is unknown in *T. utahensis* and *D. hatcheri*. Paired midline epoccipitals are found on the dorsal surface of the parietal in *Pentaceratops* and *Anchiceratops* (Lehman, 1993), differing markedly from the position of the single midline epoccipital on the caudal border of the parietal in *Triceratops* and NMMNH P-44477. The juvenile centrosaurine *Avaceratops* exhibits a midline crenulation on the caudal border of the parietal, but the total number of crenulations seen in this taxon is estimated at 11, greater than seen in NMMNH P-44477 or *Triceratops* (Penkalski and Dodson, 1999). Thus, *Avaceratops* is also excluded as a possibility. Furthermore, no evidence for centrosaurine ceratopsids has been found in the Naashoibito Member.

NMMNH P-44477 exhibits a higher estimated epoccipital count (seven parietal epoccipitals) than in any *Triceratops* (five parietal epoccipitals; Forster, 1996), arguing against its placement in this taxon. Additionally, the thin and flat parietal of NMMNH P-44477 also argues against its placement in *Triceratops*. In *Triceratops*, the parietal is usually strongly arched and saddle-shaped, and unusually thick (Forster, 1996), characters not seen in NMMNH P-44477. Although the arch of the parietal may be distorted during preservation, and thickness may vary ontogenetically and between individuals (ranging from 23 mm to 30 mm at the caudal border in *Triceratops* specimens YPM 1822 and YPM 1823, compared with a range of 16 to 19 mm in NMMNH P-44477), the epoccipital count unambiguously excludes NMMNH P-44477 from *Triceratops*.

We conclude that NMMNH P-44477 does not represent *T. latus*, because this taxon does not possess a single midline parietal epoccipital (Farke, in press). This is consistent with the claims of Sullivan et al. (2005) that *T. latus* is not known from south of Wyoming.

NMMNH P-44477 may represent *T. utahensis*, another ceratopsid from southwestern North America with a thin and flat parietal. However, this cannot be tested without information on the pattern of epoccipitals in *T. utahensis*; currently known specimens do not preserve parietals with articulated epoccipitals. NMMNH P-44477 compares with the “El Picacho ceratopsian” in the thin parietal (Lehman, 1996); however, the scrappy nature of both specimens prevents any further comparison. Alternatively, NMMNH P-44477 may represent a new taxon of chasmosaurine ceratopsian. Again, the material is too incomplete to support this claim.

Significance—The presence of a single midline epoccipital on the parietal should no longer be considered an autapomorphy for *Triceratops* (contra Forster, 1996). However, the fragmentary nature of NMMNH P-44477 does not allow an assessment of whether the midline parietal epoccipital is a homoplastic character or a synapomorphy for a clade including *Triceratops* and NMMNH P-44477. Although the specimen may pertain to *T. utahensis*, this cannot be confirmed given that the pattern of parietal epoccipitals is unknown in *T. utahensis*.

Torosaurus utahensis is currently known only from the North Horn Formation, with *Alamosaurus sanjuanensis*, *Tyrannosaurus rex*, and the Lancian index mammals *Pediomys hatcheri* and *Mesodma* cf. *M. hensleighi* (Cifelli et al., 1999). We agree with the conclusions of Sullivan et al. (2005) that material referred to *T. utahensis* from outside of the North Horn Formation is not diagnostic.

The Naashoibito Member of the Kirtland Formation contains the Alamo Wash local fauna (Lehman, 1981). We consider the Naashoibito Member and the Alamo Wash local fauna to be of latest Cretaceous age (Lancian land-mammal age) based on the presence of cf. *T. rex* (Carr and Williamson, 2000) and the Lancian index mammal *Essonodon browni* (Lehman, 1984; Williamson and Weil, 2003). This correlation refutes a late Campanian or early Maastrichtian age for the Naashoibito Member (e.g., Sullivan et al., 2005). An early Paleocene age (e.g., Fassett and

Lucas, 2000) for the Naashoibito Member has also been discounted (Sullivan et al., 2002).

Ceratopsid fossils from the Naashoibito Member are consistent with the presence of only one taxon of chasmosaurine. Although *Pentaceratops* has been reported from the Naashoibito Member (Lucas et al., 1987), the stratigraphic placement of these specimens was erroneous (Lehman, 1993).

Therefore, the Alamo Wash local fauna can be distinguished from the underlying Willow Wash local fauna of the De-na-zin Member of the Kirtland Formation, the Hunter Wash local fauna of the Hunter Wash Member, Kirtland Formation, and the Fossil Forest Member of the Fruitland Formation by the lack of *Pentaceratops* and the presence of a distinct chasmosaurine possessing a midline epoccipital on the parietal. Although this does not necessarily support a Lancian age for the Alamo Wash local fauna, it is consistent with a marked faunal difference between the Alamo Wash local fauna and older local faunas. This supports the presence of a significant hiatus between these faunas.

NMMNH P-44477 also illustrates that the ceratopsids from the Naashoibito Member of the Kirtland Formation, New Mexico, are distinct from ceratopsids found in the north-central United States and southern Canada. This adds further support for latitudinal variation in ceratopsid fauna during the close of the Cretaceous (e.g., Lehman, 2001).

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