Ceratopsid dinosaurs from the Upper Cretaceous Almond Formation of southwestern Wyoming

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ABSTRACT

The 1937 American Museum of Natural History (AMNH)–Sinclair Oil Company joint expedition to the late Campanian and early Maastrichtian Almond Formation of the Rock Springs Uplift, southern Wyoming, recovered two ceratopsid cranial specimens. AMNH 3652, a partial skull lacking the frill, is characterized by elongate, procurving postorbital horns and a deep rostrum. Although the specimen cannot be identified to the generic or specific level, it appears to be closely related to the clade of chasmosaurine ceratopsids including *Anchiceratops*, *Arrhinoceratops*, *Diceratops*, *Torosaurus,* and *Triceratops*, exclusive of *Pentaceratops* and *Chasmosaurus*. AMNH 3656, a frill fragment, is characterized by large, triangular marginal processes and an average thickness in excess of 40 mm. This specimen is similar to previously reported frills from *Anchiceratops*. The ceratopsid specimens from the Almond Formation are significant because they represent two early occurrences of chasmosaurine ceratopsids as well as a unique occurrence in southern Wyoming.

KEY WORDS: Almond Formation, *Anchiceratops*, Ceratopsia, Ceratopsidae, Chasmosaurinae, Late Cretaceous, Mesaverde Group.

INTRODUCTION

The 1937 American Museum of Natural History–Sinclair Oil Company joint expedition into the Mesaverde Group of southern Wyoming and northern Colorado recovered the remains of a variety of Late Cretaceous plants and animals (Brown, 1938). The expedition collected in units deposited during the late Campanian and early Maastrichtian, particularly the Almond Formation near Rock Springs, Sweetwater County, Wyoming (Fig. 1). Well-preserved, contemporaneous terrestrial faunas have been described from Alberta, Montana, Texas, and New Mexico (e.g., Ryan and Russell, 2001), but few vertebrate fossils of that age are known from Wyoming and Colorado. Consequently, the AMNH/Sinclair expedition collections represent an important additional source of information. Many of these specimens remain undescribed, although Carpenter (1992) briefly reviewed them.

In a popular account of the 1937 AMNH/Sinclair expedition, Brown (1938) mentioned two ceratopsid (horned dinosaur) specimens. Of particular interest is a "skull [that] proved to be fairly complete and . . . is undoubtedly a new species—the first of its kind known from this horizon" (Brown, 1938, p. 192). Brown did not give a specimen number for the skull, and he never published descriptions of any of the Mesaverde ceratopsid material. A search through the AMNH specimen catalogue

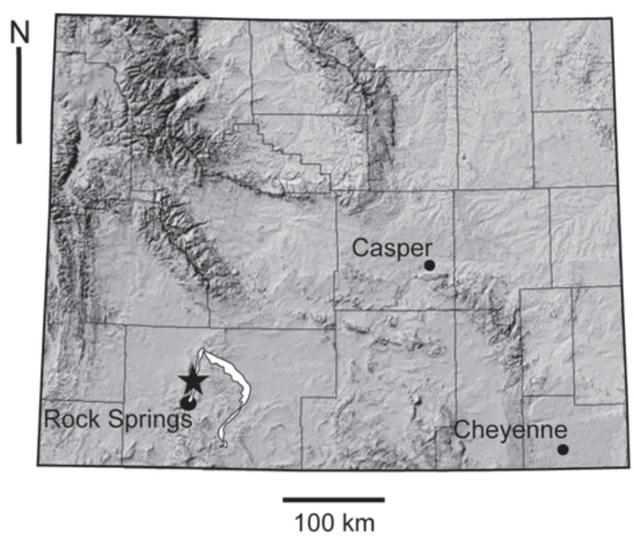

Figure 1. Map of Wyoming showing collection localities of AMNH 3652 and 3656 in Almond Formation. Outcrops of Almond Formation as they occur on the Rock Springs Uplift (modified after Love and Christiansen, 1985) are indicated in white. Approximate locations of fossil localities are indicated by black star.

located only one partial ceratopsid skull collected in 1937, AMNH 3652. It is nearly certain that this is the skull to which Brown referred.

Carpenter (1992) tentatively identified AMNH 3652 as the chasmosaurine ceratopsid *Anchiceratops* sp., based on perceived similarities between AMNH 3652 and known *Anchiceratops* skulls. During his research, Carpenter was unable to examine AMNH 3652, so he used an AMNH archival field photograph as the basis for his drawing of the specimen (Carpenter, 1992, fig. 4*I*). A number of differences exist between the actual specimen (Fig. 2*A–B*) and Carpenter's rendering, particularly in snout length, horn size, and other cranial proportions. These discrepancies may be due to the angle at which the field photograph was taken. Because Carpenter was unable to examine the specimen, it is fully described here, along with a second fragmentary ceratopsid specimen, AMNH 3656.

GEOLOGY OF ALMOND FORMATION

The Upper Cretaceous Almond Formation is exposed in southwestern Wyoming as an upper part of the Mesaverde Group. The formation is underlain conformably by the Ericson Sandstone and overlain conformably by the Lewis Shale or unconformably by the Fort Union Formation (Roehler, 1990). AMNH 3652 and 3656 were

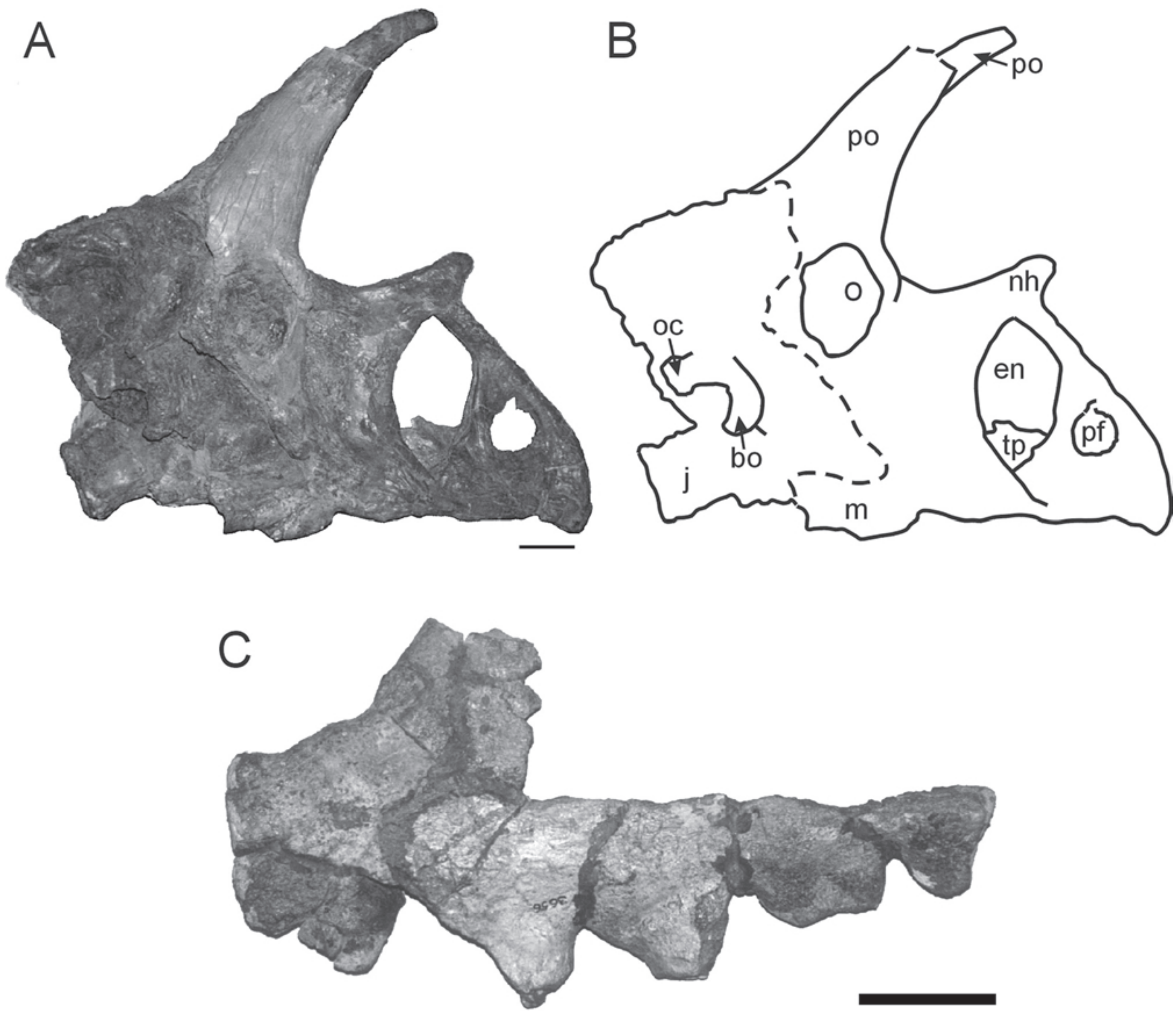

Figure 2. Chasmosaurine ceratopsid cranial material from the Almond Formation of Wyoming. AMNH 3652, partial skull in right lateral view (***A***) and outline drawing with relevant features marked (***B***); AMNH 3656, fragmentary frill in ?dorsal view (***C***). Scale bar = 10 cm. Abbreviations: **bo**, basioccipital; **en**, external naris; **j**, jugal; **m**, maxilla; **nh**, nasal horncore; **o**, orbit; **oc**, occipital condyle; **pf**, premaxillary foramen; **po**, postorbital horncore; and **tp**, triangular process of premaxilla. Dashed lines in (***B***) indicate broken bone surfaces.

collected approximately 10 km apart, in the Almond Formation on the western flank of the Rock Springs Uplift, a north–south trending, asymmetrical dome (Fig. 1). Detailed locality data are on file at the AMNH and available upon request to qualified investigators.

AMNH 3652 and AMNH 3656 were found approximately 30.6 m above the Almond Formation/Ericson Sandstone contact; the Almond Formation is over 190 m thick in this area. Here, ammonites indicate a late Campanian and early Maastrichtian age for the unit (Roehler, 1990). The low stratigraphic position of the fossils within the formation suggests that they are probably late Campanian in age. Roehler (1990) interprets this part of the Almond Formation as representing a coastal plain depositional environment.

INSTITUTIONAL ABBREVIATIONS

AMNH	American Museum of Natural History, New York, NY, USA
ROM	Royal Ontario Museum, Toronto, ON, Canada

SYSTEMATIC PALEONTOLOGY

ORNITHISCHIA
CERATOPSIDAE
CHASMOSAURINAE
Chasmosaurinae indet.
Figure 2, Table 1

Material.—AMNH 3652, a partial skull lacking the frill and parts of the right side of the face, associated with unidentifiable cranial and postcranial fragments; and AMNH 3656, a fragmentary frill.

Description of AMNH 3652.—The skull (Fig. 2*A–B*) is mediolaterally crushed, and its left side is hidden by a plaster support jacket. Parts of the right side of the skull are obscured by plaster and crushing. Consequently, most of the cranial sutures are unrecognizable. Table 1 presents selected measurements for this specimen.

The snout is deep relative to that of other chasmosaurine specimens; this is probably somewhat exaggerated by crushing. The lateral profile of the ventral edge of the snout, comprising the rostral and premaxillary bones, is relatively straight. The rostral bone is rostrocaudally short and dorsoventrally deep. The premaxilla also is quite short and deep; its sutural relations to the rostral and nasal are obscured by co-ossification, crushing, and plaster. The premaxilla is divided into rostral and caudal halves by the premaxillary bar. The rostral half has a subcircular premaxillary foramen, surrounded by the premaxillary fossa. A wide, robust narial strut is caudal to these structures, separated medially by the premaxillary sutures. The premaxillary fossa extends onto the dorsolateral limits of the narial strut. Matrix and plaster obscure the ventral surfaces of the premaxillae, so the number of ventral premaxillary foramina is unknown. A thin flange of bone, crushed so as to appear attached to the left premaxilla, probably represents the median triangular process. Dorsally, the conjoined premaxillae project beneath the nasal horn. A sharp sulcus marking the premaxillary suture occurs on the ventral surface of the dorsal projection of the premaxillae, terminating immediately ventral to the nasal horn. The external naris is dorsoventrally elongated, the dorsal narial margin is squared off, and the ventral margin comes to a rounded "V."

The nasal horn is short compared to that of many other chasmosaurines; the horn's median axis is located just

Table 1. Selected measurements of AMNH 3652. (* Indicates estimated or restored measurement.)

Descriptions of Measurements	Measurements (mm)
Basal skull length, from tip of rostrum to caudal end of occipital condyle	960
Basal skull length, from tip of rostrum to caudal end of maxilla	769
External naris height	285
External naris width	151
Jugal length, from tip of epijugal to ventral border of orbit	370*
Nasal horncore height, from top of external naris to tip of horncore	130
Occipital condyle diameter	68
Postorbital horncore length, from top of orbit to tip of horn	572
Snout length, from tip of rostrum to rostral border of orbit	655
Snout length, from caudal end of external naris to rostral border of orbit	231
Snout depth, just caudal to nasal horn	450

dorsal to the caudal border of the naris. The rostral edge of the nasal horn is located approximately over the middle of the external naris. The nasal horn curves forward, and its caudal surface has a convex profile in lateral view. The distal tip of the horn is blunt. The horn's base is ovate.

The facial region between the orbits and the external naris is relatively short and deep. Plaster obscures all sutural relations. The right maxilla is mostly missing. Parts of the dental battery are exposed; approximately 10 teeth are preserved on the caudal end of the maxilla. The left maxilla exhibits at least 17 tooth positions, but the total tooth count is unknown.

The medial surface of the left jugal is exposed. This bone projects well behind the orbit (Fig. 2*B*), and a small, pyramidal epijugal is fused to the distal end. No diagnostic features occur on the preserved rostral part of the left squamosal.

The right lateral aspect of the braincase is exposed, showing a small, incomplete occipital condyle with an estimated diameter of 68 mm. The basioccipitals are prominent and typical of ceratopsids, comprising rounded, laterally projecting tuberosities. The rest of the braincase is preserved, but its features are obscured by matrix and crushing.

The orbital horns are elongate and procurved; both the right and the left horns are preserved, although the right horn is missing its distal end. The bases of the horns are ovate and longer than wide. Parts of the frontal sinus complex are exposed, but matrix obscures details of this region.

Description of AMNH 3656.—This specimen is poorly preserved; its identification as a chasmosaurine ceratopsid frill fragment is based on the presence of large, triangular processes on the bone's margin, possibly representing fused epoccipitals (Fig. 2*C*). The frill fragment measures between 40 and 62 mm in thickness. Most of the triangular processes are incomplete; the most complete one measures 92 mm wide as preserved. One frill fragment preserves at least four processes (Fig. 2*C*). A second fragment (not illustrated) preserves three processes. The relation of the two fragments could not be determined.

DISCUSSION

Affinities of Ceratopsids from Almond Formation

AMNH 3652 is placed within the ceratopsid subfamily Chasmosaurinae based on the presence of a premaxillary fossa (Lehman, 1990). The elongate postorbital horncores and the relatively small nasal horn also are suggestive of the Chasmosaurinae, but they are not limited to chasmosaurines (Penkalski and Dodson, 1999).

Unfortunately, AMNH 3652 lacks the frill, an important diagnostic feature for most species of chasmosaurines. Consequently, the specimen cannot be identified to the generic or specific level. AMNH 3652 is not *Chasmosaurus*, because species of this genus have relatively slender, recurved postorbital horns (contrasting with the robust, procurved horns of AMNH 3652) and a premaxillary septal flange (lacking in AMNH 3652; Forster et al., 1993; Holmes et al., 2001). The lack of a premaxillary septal flange also excludes identification as *Pentaceratops*, although this flange can be quite small in some specimens of that genus (Holmes et al., 2001). The structure simply may not be preserved in AMNH 3652. The caudally placed nasal horn (relative to the caudal borders of the external nares) distinguishes AMNH 3652 from *Triceratops* and *Torosaurus* (Holmes et al., 2001). This leaves *Anchiceratops* and *Arrhinoceratops* as two possibilities among known chasmosaurine genera. The depth of the snout of AMNH 3652 is reminiscent of the type specimen of *Arrhinoceratops brachyops* (ROM 796). AMNH 3652 may indeed represent a new taxon as originally believed by Brown (1938), but this cannot be verified without more complete material. Clearly, it is a chasmosaurine of the clade including *Anchiceratops*, *Arrhinoceratops*, *Diceratops*, *Torosaurus*, and *Triceratops*, exclusive of *Chasmosaurus* and *Pentaceratops* (as established in the cladistic analysis by Holmes et al., 2001).

The extremely fragmentary nature of the frill fragment (AMNH 3656) precludes a definite identification of the specimen, but its prominent triangular marginal processes are most similar to morphology observed in some specimens of *Anchiceratops*. In *Anchiceratops*, at least six large, triangular epoccipitals are present on the caudal border of the parietal, three on each side. The squamosal bears up to seven large, triangular epoccipitals. The thickness of the parietal in the area of the epoccipitals is up to 49 mm in the holotype specimen of *Anchiceratops ornatus* (AMNH 5251), and the areas around the squamosal epoccipitals in this specimen are between 32 mm and 40 mm thick. This is within the range of thickness (40 to 62 mm) for the AMNH 3656 frill fragment. Some specimens of *Pentaceratops sternbergi* (e.g., AMNH 6325) also display large triangular epoccipitals on the parietal and squamosal. However, Lehman (1998) indicated a maximum squamosal thickness of 25 mm for *Pentaceratops*. It is unlikely that AMNH 3656 represents a parietal fragment of *Pentaceratops*, as the parietal is slender and straplike in this genus. The thickness of the frill fragment (AMNH 3656) is similar to that of the squamosal from the "El Picacho ceratopsian" described by Lehman (1996), but the marginal undulations are considerably smaller in the latter animal.

Because AMNH 3652 and 3656 were found approximately 10 km apart, they almost certainly represent two different individuals. No elements are common to the two specimens, so it cannot be determined if the specimens represent the same species.

Importance of Ceratopsids from Almond Formation

Ceratopsids, including members of the subfamilies Centrosaurinae and Chasmosaurinae, underwent a period of rapid evolution during the late Campanian and early Maastrichtian. Both centrosaurine and chasmosaurine ceratopsids were relatively common at that time, including the centrosaurines *Achelousaurus*, *Avaceratops*, *Centrosaurus*, *Pachyrhinosaurus*, and *Styracosaurus* and the chasmosaurines *Anchiceratops*, *Arrhinoceratops*, *Chasmosaurus*, and *Pentaceratops* (not necessarily all sympatric). If the ceratopsid specimens from the Almond Formation are indeed chasmosaurines with possible affinities to *Anchiceratops* and *Arrhinoceratops*, they are among the earliest-recognized occurrences of this part of the chasmosaurine lineage. The oldest known specimen of *Anchiceratops* is from the late Campanian Dinosaur Park Formation of Alberta (Ryan and Russell, 2001; Langston, 1959), a unit roughly contemporaneous with the Almond Formation. The only known skull of *Arrhinoceratops* was recovered from the Maastrichtian Horseshoe Canyon Formation of Alberta (Ryan and Russell, 2001). The other lineage of the Chasmosaurinae, including *Chasmosaurus* and *Pentaceratops*, existed from the late Campanian into the Maastrichtian (Holmes et al., 2001).

CONCLUSIONS

Although the ceratopsid fossils currently known from the Almond Formation are not diagnostic to genus or species, they do indicate the strong potential for future discoveries within this formation. These discoveries could be important for understanding ceratopsid evolution and biogeography, especially because dinosaurian fossils representing the late Campanian and early Maastrichtian of Wyoming are poorly known.

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