

RE-EVALUATION OF *PENTACERATOPS* AND *CHASMOSAURUS* (ORNITHISCHIA: CERATOPSIDAE) IN THE UPPER CRETACEOUS OF THE WESTERN INTERIOR

SPENCER G. LUCAS¹, ROBERT M. SULLIVAN² AND ADRIAN P. HUNT¹

¹New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, NM 87104; ²Section of Paleontology and Geology, State Museum of Pennsylvania, 300 North Street, Harrisburg, PA 17120

Abstract—*Pentaceratops sternbergii* is an index fossil of the Kirtlandian LVA, and is known from the Fruitland and Kirtland formations, San Juan Basin, New Mexico and from the Williams Fork Formation of Colorado. We remove *Chasmosaurus mariscalensis* (Aguja Formation, Big Bend National Park, Texas) from *Chasmosaurus* and make it the type species of a new genus, *Agujaceratops*. Supposed chasmosaurine endemism or provincialism during the late Campanian in the Western Interior is not clear, as most of the southern chasmosaurines are younger than their northern counterparts

INTRODUCTION

Pentaceratops is a large ceratopsid dinosaur long known only from Upper Cretaceous strata in the San Juan Basin, New Mexico (e.g., Osborn, 1923; Wiman, 1930; Rowe et al., 1981; Lehman, 1993; Dodson et al., 2004). Recently, Diem and Archibald (2005) documented an incomplete ceratopsid skull from the Upper Cretaceous Williams Fork Formation in Colorado (Fig. 1) that they identified as a generically indeterminate chasmosaurine. Here, following Sullivan and Lucas (2006) we re-confirm that this skull pertains to *Pentaceratops sternbergii*. We also remove *Chasmosaurus mariscalensis* Lehman, 1989 from *Chasmosaurus* and make it the type of a new genus, *Agujaceratops*. Supposed chasmosaurine endemism or provincialism during the late Campanian in the Western Interior is not clear, as most of the southern chasmosaurines are younger than their northern counterparts.

In this paper, NMMNH = New Mexico Museum of Natural History and Science, Albuquerque; SDMNH = San Diego Museum of Natural History, San Diego; UTEP = University of Texas, El Paso.

PENTACERATOPS FROM COLORADO

SDMNH 43470 is an incomplete skull of a ceratopsid (Fig. 2) that was well described by Diem and Archibald (2005), obviating the need for further description here. Thus, we focus on the taxonomic identity of this fossil.

After describing SDMNH 43470, Diem and Archibald (2005) closely, and we believe appropriately, compared it to the most morphologically similar ceratopsids, which are the genera *Chasmosaurus* and *Pentaceratops*, relying explicitly on the cladistic analysis of Holmes et al. (2001). However, despite the fact that their analysis demonstrated that SDMNH 43470 is most similar to *Pentaceratops*, Diem and Archibald (2005, p. 257) concluded that “given both the subadult condition and rather biogeographically isolated status of the Williams Fork specimen, a more definitive taxonomic assessment is not warranted” and they did not assign it to a genus. We note, however, that earlier Diem (1999) and Diem and Archibald (2000) identified SDMNH 43470 as *Pentaceratops*, as did Sullivan and Lucas (2003, 2006).

Indeed, the Williams Fork specimen demonstrates key diagnostic features of *Pentaceratops* and is readily assigned to that genus (reviewed below). Also, we stress that perceived “biogeographic isolation” should play no role in identifying this fossil. Indeed, we find it internally inconsistent that Diem and Archibald (2005) drew a paleobiogeographic inference—that the Williams Fork specimen represents a northern extension of a southern clade of chasmosaurines—yet at the same time invoked “biogeographic isolation” as a factor in not identifying the specimen.

Lehman (1993, p. 279) provided a diagnosis of the single valid (and type) species of *Pentaceratops*, *P. sternbergii*, and the Williams Fork specimen displays most of these diagnostic features, including: long narrow squa-

mosal with numerous (8-12) epoccipitals (note that this character now is known to overlap with *Agujaceratops*); a slender, strap-like parietal with indented posterior margin; moderately sized, elongate parietal fenestrae (based on the lateral preserved margin of the median bar); and posteriorly directed jugals with very large epijugal horncores (incipient horncore base preserved, see Diem and Archibald 2005, fig. 3). In addition, the jugal and squamosal do not make contact beneath the infratemporal fenestra as illustrated by Diem and Archibald (2005, fig. 3), unlike the condition seen in all three species of *Chasmosaurus* from the Dinosaur Park Formation (Holmes et al., 2001; Ryan and Evans, 2005). These are diagnostic features of *Pentaceratops* recognized by all workers (e.g., Dodson, 1996; Dodson et al., 2004; Sullivan et al., 2005) and can also be recovered from the cladistic analysis of Holmes et al. (2001), which, like the analysis of Dodson et al. (2004), unites *Pentaceratops* and *Chasmosaurus* as a clade. Thus, the Williams Fork specimen lacks the autapomorphies of the *Chasmosaurus* clade in the analysis of Holmes et al. (2001) and has these characteristics that are unique to *Pentaceratops* in their analysis. Particularly striking in the Williams Fork specimen is the long and narrow squamosal and the deep posterior emargination of the parietal, which is evocative of the “keyhole” indentation that characterizes *Pentaceratops*. Moreover, Diem and Archibald (2005, fig 5) illustrated and described two processes on the inner lower margin of the keyhole, which we infer are bases for the fusion of the epoccipitals, which is exactly the position of the epoccipitals in *Pentaceratops sternbergii*. In addition to its smaller size compared to most *Pentaceratops*, SDMNH 43470 is immature based on the lack of fusion between the epoccipitals on the squamosals and parietal.

Certainly, a thorough, more complete phylogenetic analysis of the Chasmosaurinae needs to be undertaken (Holmes et al., 2001), but the species have been adequately revised to allow for characterization and recognition despite morphologic variation within the species (Godfrey and Holmes, 1995; Lehman, 1998). Furthermore, the species of *Chasmosaurus* are sufficiently well known for characterization, and the chasmosaurine genera and species are also stratigraphically segregated (Holmes et al., 2001; *contra* Lehman, 1998). Thus, we have reviewed the attributes cited for SDMNH 43470 and have identified additional diagnostic characters (above) that reinforce the original generic identification given by Diem (1999), and the re-assignment by Sullivan and Lucas (2006).

Total length of the squamosal of SDMNH 43470 is 765 mm. Lehman (1993, fig. 2) illustrated a series of skulls of *Pentaceratops* in which squamosal length ranges from ~1 to 1.6 m (note that the smallest, incomplete squamosal illustrated by Lehman, 1993, fig. 2.1 [NMMNH P-25084, formerly UNM FKK-035] is not *Pentaceratops*: Sullivan et al., 2005). There is no compelling evidence that diagnostic features of the squamosal, parietal, jugal of *Pentaceratops* change ontogenetically. The only differences are increased robustness and fusion of epoccipitals that occur with maturity, which SDMNH 43470 has not yet attained.

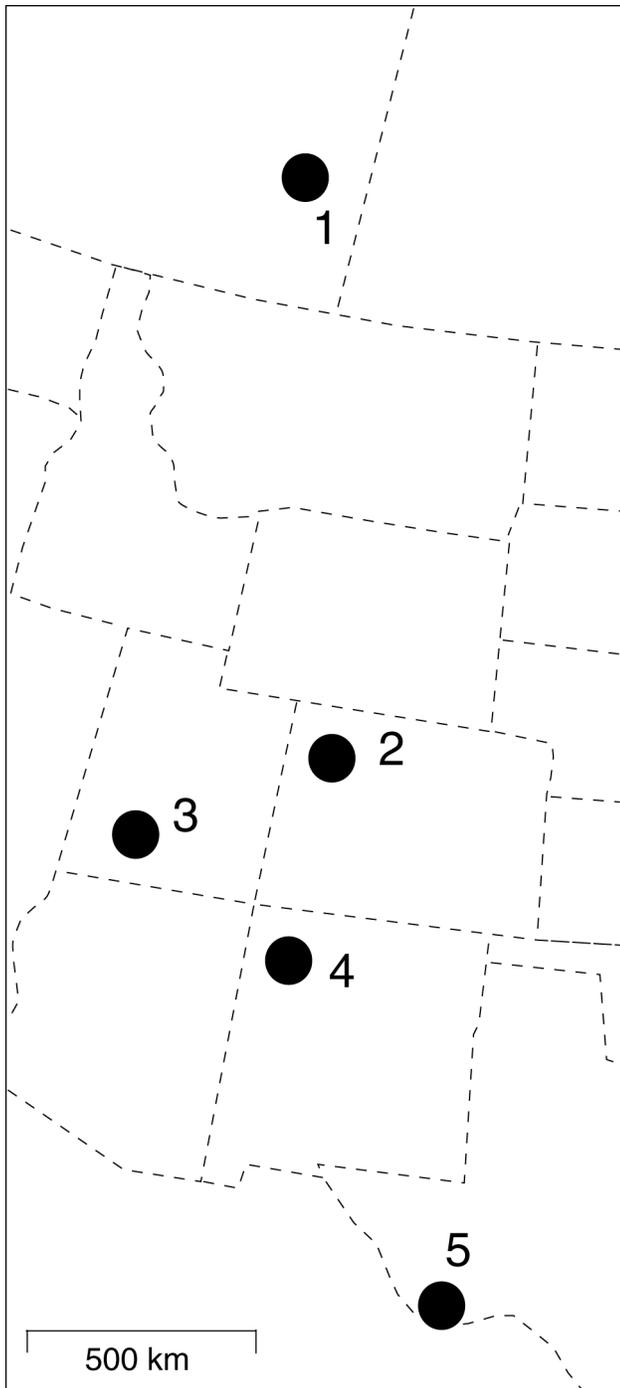


FIGURE 1. Distribution of some chasmosaurines in the Upper Cretaceous of the Western Interior. Localities are: 1 = *Chasmosaurus*, Dinosaur Park Formation, Alberta; 2 = *Pentaceratops*, Williams Fork Formation, Colorado; 3 = new taxon (Smith et al., 2004), Kaiparowits Formation, Utah; 4 = *Pentaceratops*, Fruitland and Kirtland formations, New Mexico; 5 = *Agujaceratops*, Aguja Formation, Texas.

TAXONOMIC STATUS OF *CHASMOSAURUS* *MARISCALENSIS*

Lehman (1989) named the species *Chasmosaurus mariscalensis* based on a braincase, left supraorbital horncore, left maxilla and a right dentary (UTEP P.37.7.086). Additional material associated with the holotype, but not considered to be part of it, included a right pubis and right coracoid (Lehman, 1989). The specimens were collected in the upper part of the Aguja Formation, Big Bend National Park, Brewster County, Texas.

Specimens of this species were recovered from three separate localities (representing five sites from different stratigraphic horizons) within the Aguja Formation (Lehman, 1989). The upper part of the Aguja Formation is of Kirtlandian age (Sullivan and Lucas, 2006).

Lehman (1989) diagnosed *C. mariscalensis* as being differentiated from other *Chasmosaurus* species in having a short, broad squamosal with large epoccipitals, maxilla lacking a lateral horizontal shelf, and longer supraorbital horncores. We note, too, that in his diagnosis of *C. mariscalensis* the premaxilla is stated to lack a posterior extension.

We consider *C. mariscalensis* to be very different from other *Chasmosaurus* (also see Holmes et al., 2001), so we make it the type species of a new genus, *Agujaceratops* (see Appendix). The distribution of *Chasmosaurus* is thus restricted to Alberta during the Judithian (Figs. 1, 3).

DISTRIBUTION AND AGE OF *CHASMOSAURUS*

Chasmosaurus records in the Western Interior are from the late Judithian Dinosaur Park Formation in Alberta (Figs. 1, 3). Three species are currently recognized: *C. belli*, *C. russelli* and *C. irvinensis* (e.g., Holmes et al., 2001; Dodson et al., 2004; Ryan and Evans, 2005). It is not clear that all three species are morphologically distinct, but they are segregated stratigraphically (Ryan and Evans, 2005). *C. russelli* is from the lower part of the Dinosaur Park Formation, *C. belli* is from the middle to upper part of the Dinosaur Park Formation and *C. irvinensis* is from the uppermost part of the Dinosaur Park Formation.

BIOSTRATIGRAPHY AND PALEOBIOGEOGRAPHY

The presence of *Pentaceratops sternbergii* in northwestern Colorado is of biostratigraphic and paleobiogeographic significance. Sullivan and Lucas (2003, 2006) identify *P. sternbergii* as an index fossil of the Kirtlandian LVA, so part of the Williams Fork Formation is of Kirtlandian age. Age constraints on the Williams Fork Formation from ammonite biostratigraphy (it is younger than the *Exiteloceras jenneyi* zone in the underlying Iles Formation) and palynostratigraphy (pollen near its top is equivalent to the *Baculites baculus* zone) support the correlation of the Williams Fork vertebrate fossil assemblage to the Kirtlandian interval in the San Juan Basin, New Mexico (Sullivan and Lucas, 2006).

We view the first confirmed record of *Pentaceratops* outside the San Juan Basin as long overdue. It long seemed strange that so large an animal as *Pentaceratops* would only be endemic to northwestern New Mexico. Indeed, we predict that its geographic distribution will expand as vertebrate assemblages of Kirtlandian age become better known.

The distributions of *Pentaceratops* and *Chasmosaurus* in the Western Interior Upper Cretaceous have been used to suggest endemism of chasmosaurines, at least at the generic level. This endemism apparently increases with the separation of *C. mariscalensis* from *Chasmosaurus*, and its assignment to the new genus *Agujaceratops*. However, the age relationships of these taxa also need to be considered, given that *Chasmosaurus* is older than both *Pentaceratops* and *Agujaceratops*. Thus, some of the north-south or region-to-region differences among these chasmosaurines are probably age related, and not necessarily of paleobiogeographic significance. Clearly, more needs to be discovered of Judithian chasmosaurines in the southern Western Interior, and of Kirtlandian chasmosaurines in the northern Western Interior before valid paleobiogeographic inferences can be made.

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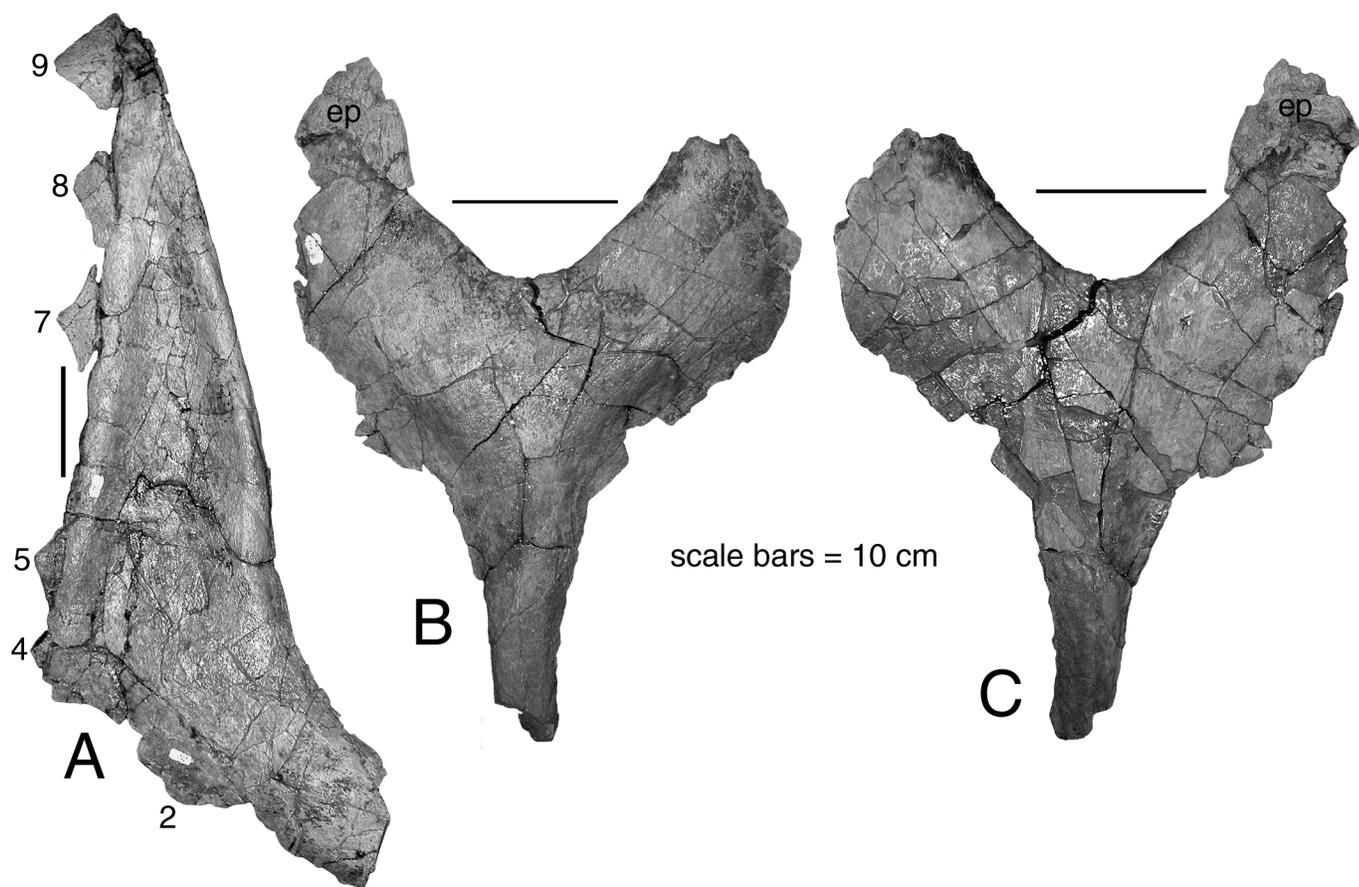


FIGURE 2. Selected elements of SDMNH 43470, *Pentaceratops sternbergii* from the Williams Fork Formation, Colorado. **A**, Right squamosal with some epoccipitals (numbered) attached. **B-C**, incomplete median ramus of parietal with epoccipital attached in dorsal (**B**) and ventral (**C**) views.

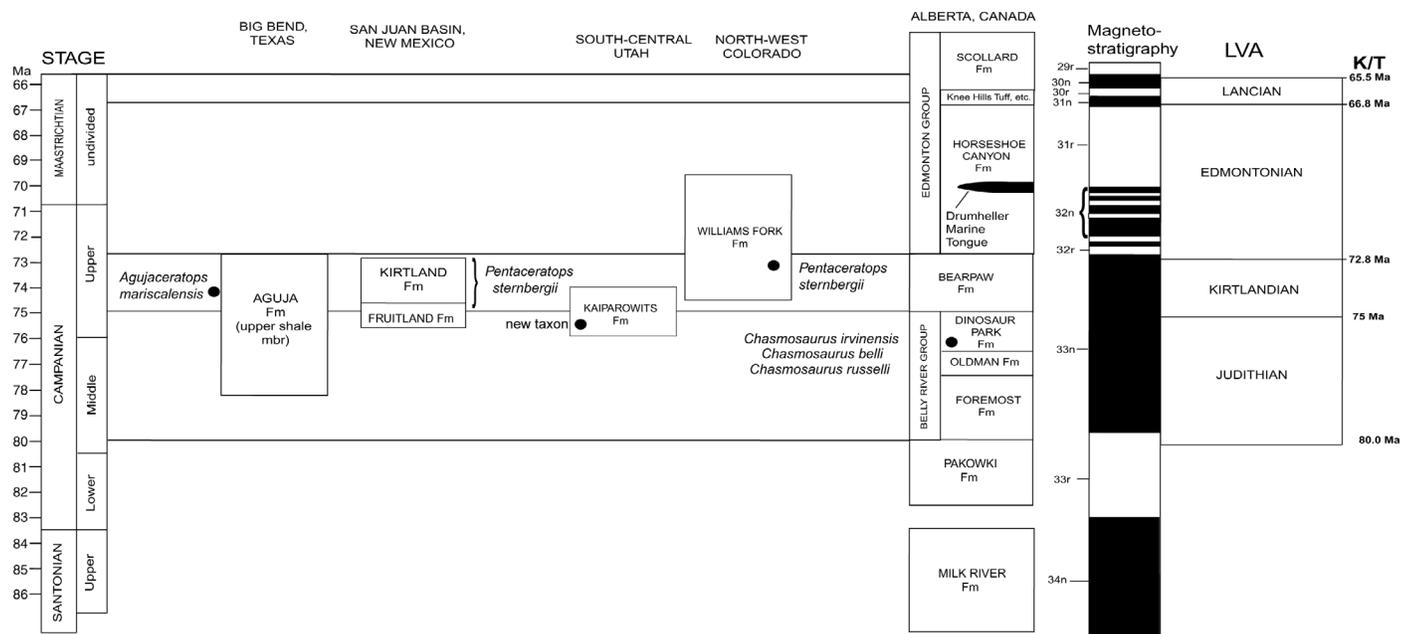


FIGURE 3. Correlation of selected chasmosaurine localities in the Western Interior.

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APPENDIX—SYSTEMATIC PALEONTOLOGY

Family CERATOPSIDAE

Subfamily CHASMOSAURINAE

Genus *AGUJACERATOPS*, new genus

Type species—*Chasmosaurus mariscalensis* Lehman, 1989.

Included species—Only the type species.

Distribution—Upper part of the Aguja Formation, Big Bend National Park, Texas, Kirtlandian land-vertebrate age.

Etymology—Aguja, for the Aguja Formation in Texas, and *ceratops* (Greek: "horned face"), a common suffix for the generic name of ceratopsians.

Diagnosis—*Agujaceratops* is a large ceratopsid most similar to *Chasmosaurus* and *Pentaceratops*. *Agujaceratops* differs from *Chasmosaurus* in having a relatively deep facial skeleton (at the orbit, though this varies somewhat ontogenetically), relatively short and broad squamosal (length/width < 2), more than 6 relatively large epoccipitals on the squamosal (though some *Chasmosaurus* have as many as 9), lacking a parietal median bar that is deep or deeper dorsoventrally than wide with a rectangular/subrectangular cross section and flat lateral sides, lacking a jugal flange that contacts the squamosal below the infratemporal fenestra, having a maxilla without a lateral horizontal shelf and a premaxilla without a posterodorsal extension, having relatively long supraorbital horncores and a relatively deep embayment of the posterior median parietal. *Agujaceratops* differs from *Pentaceratops* in being smaller, having a premaxilla septal flange along the entire anterior edge of the naris (as in *Chasmosaurus*), having a nasal horncore

that is not centered above the external naris, having a relatively broader and shorter squamosal and a relatively wide frill with a convex lateral margin, that is widest posteriorly (as in *Chasmosaurus*), having supraorbital horncores that are curved posteriorly (not anteriorly), a posterior border of the parietal that is flattened and plate-like (rather than square and bar like) and a marked but shallower embayment of the posterior median parietal.

Comments—Lehman (1989, p. 157) distinguished *Chasmosaurus mariscalensis* from the other named species of *Chasmosaurus* and from *Pentaceratops*, concluding that "*C. mariscalensis* is the most advanced species of *Chasmosaurus* and the most similar to *Pentaceratops*." However, given the morphological differences between *C. mariscalensis* and *Chasmosaurus*, and its similarities to *Pentaceratops*, it is surprising that Lehman made no strong argument to justify including the species in *Chasmosaurus*.

Nevertheless, Forster et al. (1993) did make such an argument in their cladistic analysis, basing inclusion of *Chasmosaurus mariscalensis* in *Chasmosaurus* on four characteristics: presence of a thin premaxillary flange along the entire anterior margin of the external naris, posteriorly curved supraorbital horncores, strap-like posterior border of the parietal fenestra and a very broad posterior frill. Although these are valid similarities, they pale in comparison to the number of differences between *C. mariscalensis* and Canadian *Chasmosaurus* listed in the diagnosis above. Furthermore, a cladistic analysis by Holmes et al. (2001) grouped *C. mariscalensis* with *Pentaceratops* in a clade separate from Canadian *Chasmosaurus*. Cladistic analysis aside, a suite of valid morphological differences exists that distinguishes *C. mariscalensis* from Canadian *Chasmosaurus*. A similar suite of features distinguishes it from *Pentaceratops*. This justifies our recognition of *C. mariscalensis* as a distinct genus (*Agujaceratops*) from both *Chasmosaurus* and *Pentaceratops*.