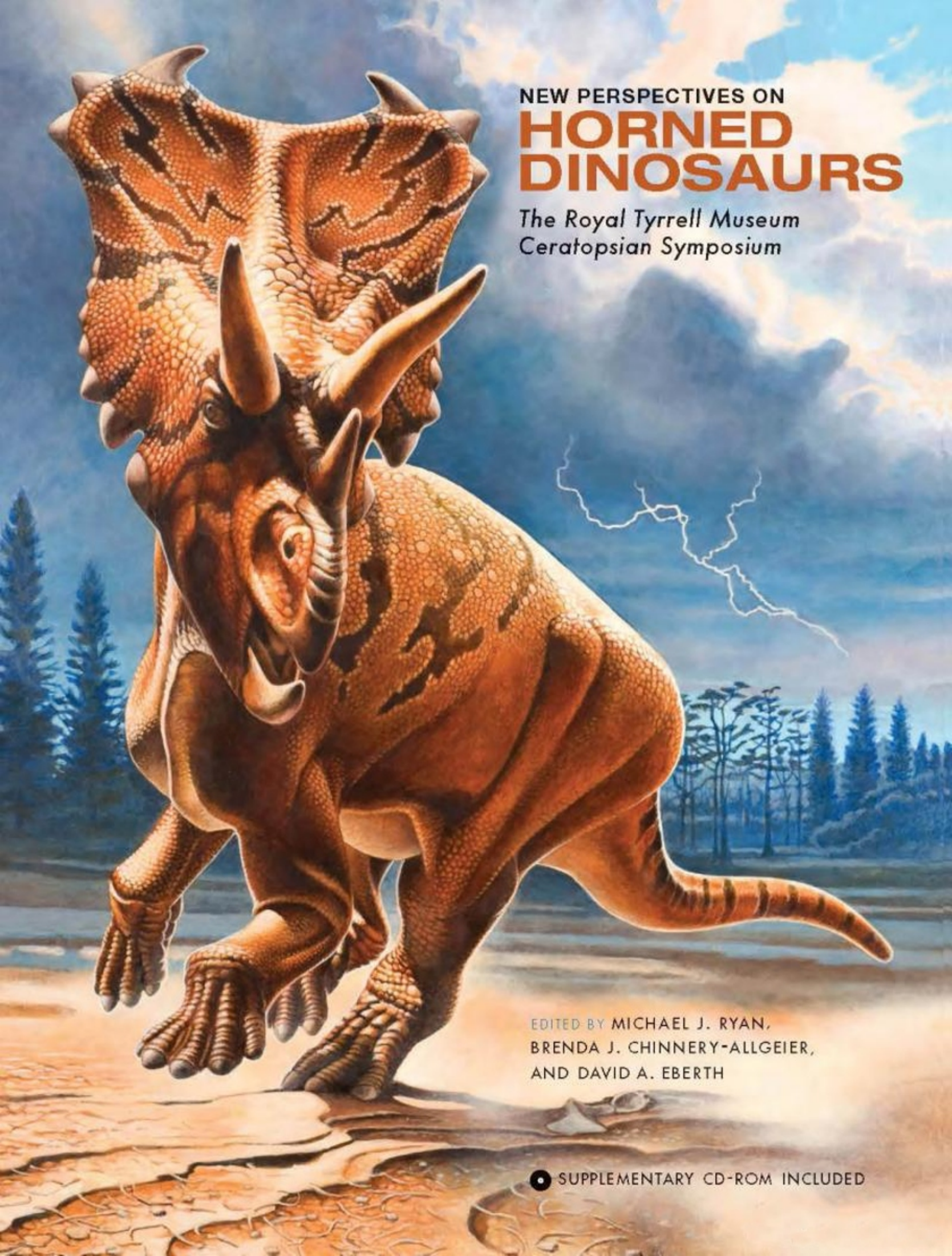

NEW PERSPECTIVES ON

# HORNED DINOSAURS

*The Royal Tyrrell Museum Ceratopsian Symposium*

EDITED BY MICHAEL J. RYAN, BRENDA J. CHINNERY-ALLGEIER, AND DAVID A. EBERTH

SUPPLEMENTARY CD-ROM INCLUDED

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# 5

# First Basal Neoceratopsian from the Oldman Formation (Belly River Group), Southern Alberta

TETSUTO MIYASHITA, PHILIP J. CURRIE, AND BRENDA J. CHINNERY-ALLGEIER

AN ISOLATED FRONTAL (TMP 87.89.8) referred to *Prenoceratops* sp. from the Oldman Formation of southern Alberta is a recent addition to the scarce record of North American basal neoceratopsians. TMP 87.89.9 shares the diagnostic characters of *Prenoceratops,* such as the transverse postorbital ridge and the deep frontal depression. The crista cranii coinciding with the interfrontal suture is identified as a new autapomorphy for the genus *Prenoceratops*. A unique combination of characters in TMP 87.89.8 includes the absence of the olfactory bulb impression, presence of the cerebral fossa, and a fossa that probably represents part of the nasal cavity. Although this suggests that TMP 87.89.8 may represent a distinct species of *Prenoceratops,* the possibility of ontogenetic variation cannot be ruled out. There were at least three distinct basal neoceratopsian taxa in the Campanian of southern Alberta and northwestern Montana: *Cerasinops, Leptoceratops,* and *Prenoceratops*. *Prenoceratops* is the second ornithischian genus exclusively occurring in the upper Oldman and upper Two Medicine formations, suggesting a faunal link due to the similar inland, relatively dry environments.

## Introduction

Despite our understanding of the richness of Late Cretaceous dinosaur faunas, the North American record of basal neoceratopsians (non-ceratopsid neoceratopsians) is surprisingly poor (Ryan and Currie 1998; You and Dodson 2004). This contrasts with the remarkable diversity of Asian basal neoceratopsians during this time (You and Dodson 2004; Makovicky and Norell 2006). Recent discoveries (Ryan and Currie 1998; Chinnery 2004; Chinnery and Horner 2007) strongly suggest that the diversity of North American basal neoceratopsians is greater than previously thought. Basal neoceratopsians have been identified from the Milk River, Dinosaur Park, Horseshoe Canyon, St. Mary River, and Scollard formations in southern Alberta, Canada, and from the Two Medicine and St. Mary River formations in northwestern Montana, in the United States (Brown 1914; Sternberg 1951; Chinnery and Weishampel 1998; Ryan and Currie 1998; Makovicky 2001; Chinnery 2004; Chinnery and Horner 2007). The chronological range of the basal neoceratopsians in Alberta thus spans from the latest Santonian to latest Maastrichtian (Ryan and Currie 1998), although there are several long gaps within this range where basal neoceratopsian material has not been recovered. The longest of these gaps occurs between the Milk River and Dinosaur Park formations. Although cf. *Montanoceratops* (TMP 82.11.1) was reportedly collected from the Belly River Group and could have potentially filled this gap, the specimen is likely to have been recovered from the Willow Creek Formation (a rationale for this interpretation in "Discussion"). Except for excellent skeletons of *Leptoceratops* (Brown 1914; Sternberg 1951) from the Scollard Formation and that of cf.

**FIGURE 5.1.**
Geologic correlation chart for Upper Cretaceous strata in southern Alberta and northwestern Montana. The grey shade indicates formations from which basal neoceratopsian material has been collected (sources cited in the text). Marine units are shaded black. Radiometric dates and nomenclature from Brinkman (2003), Eberth (2005), Eberth et al. (2001), Horner et al. (2001), Rogers (1997, 1998), and Rogers et al. (1993).

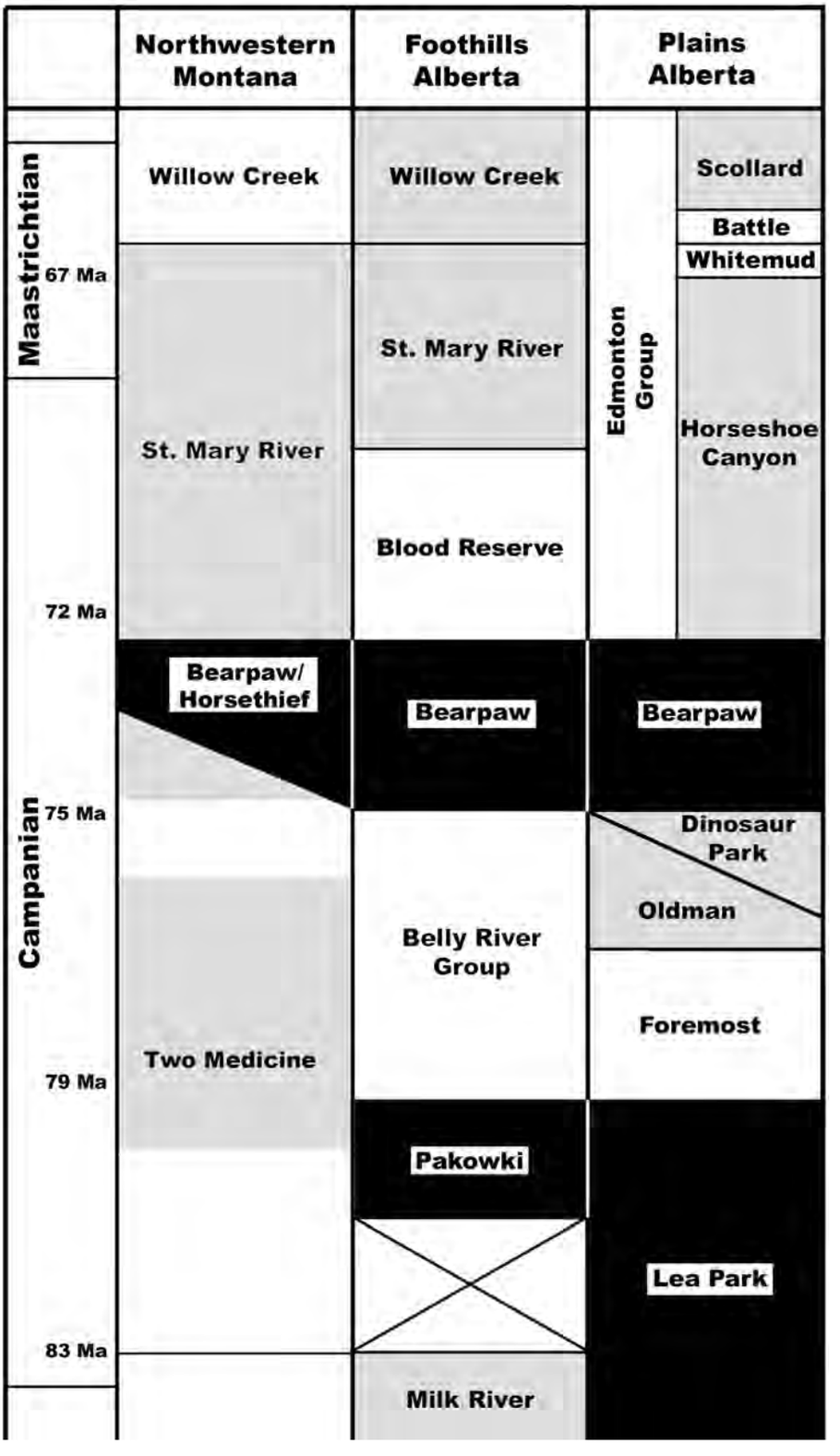


**FIGURE 5.2.** Locality map showing Devil's Coulee, where TMP 87.89.8 was collected. The map is modified after Horner and Currie (1994).

*Montanoceratops* (TMP 82.11.1; Ryan and Currie 1998) from the Willow Creek Formation, the basal neoceratopsian specimens from Alberta are mostly fragmentary and often represented only by teeth from microvertebrate localities.

A basal neoceratopsian frontal (TMP 87.89.8) represents the first record of this group from the Oldman Formation of Alberta, and provides new information on the cranial anatomy of basal neoceratopsians.

*Institutional Abbreviations*. CMN: Canadian Museum of Nature, Ottawa; ICM: Children's Museum of Indianapolis, Indianapolis; MNHCM: Mokpo Natural History and Culture Museum, Mokpo; TMP: Royal Tyrrell Museum of Palaeontology, Drumheller; UWGM: University of Wisconsin Geology Museum, Madison.

*Anatomical Abbreviations*. cc: crista cranii; ci: impression of cerebrum; fd: frontal depression; if: interfrontal suture; ls: laterosphenoid suture; na: nasal contact; nc: nasal cavity; ob: olfactory bulb impression; or: orbital rim; os: orbitosphenoid suture; pa: parietal suture; po: postorbital contact; pr: postorbital ridge; sr: sagittal ridge.

## Systematic Paleontology

Ornithischia Seeley 1888
Ceratopsia Marsh 1890
Neoceratopsia Sereno 1986
*Prenoceratops* Chinnery 2004
*Prenoceratops* sp.

*Referred Specimen*. TMP 87.89.8, an isolated right frontal.

*Locality*. TMP 87.89.8 was surface collected from the upper Oldman Formation (Fig. 5.1) at Devil's Coulee, southern Alberta (Fig. 5.2), close to the nesting site of *Hypacrosaurus stebingeri* (Horner and Currie 1994). The upper Oldman Formation exposed at Devil's Coulee is dated at 75.05 Ma (Eberth and Deino 1992). The Devil's Coulee locality is approximately correlated with the Lethbridge Coal Zone in the uppermost part of the Dinosaur Park Formation in Dinosaur Provincial Park, which marks an early westward transgression of the Bearpaw Sea in the southern plains of Alberta.

*Comments*. The basal neoceratopsian affinity of TMP 87.89.9 is supported by the combination of the following characters: medially emarginated orbital rim of thick frontal; prefrontal separated by nasal from protruding anterior process of frontal; wide and flat orbital depression; and unfused frontal suture. TMP 87.89.8 is referred to *Prenoceratops* Chinnery 2004 based on the following diagnostic characters: crista cranii coalesced to the interfrontal suture; straight, transverse postorbital ridge; and frontal depression excavated deeper than one-third the thickness of frontal (Chinnery 2004).

## Description

TMP 87.89.8 (Fig. 5.3) is an isolated right frontal. The anterior portion and much of the lateral margin were lost due to erosion. As preserved, the specimen measures 98.4 mm in length. The bone is deep medially, but becomes shallower anteriorly, laterally, and posteriorly. The frontal of TMP 87.89.8, *Leptoceratops* CMN 8889, and UWGM 3992.05 (Fig. 5.4C, D) is thicker and wider than it is in *Prenoceratops* (Fig. 5.4A, B). *Leptoceratops* and the animal represented by TMP 87.89.8 are larger than *Prenoceratops* (ICM 2003.1.1; MNHCM field number 61, Fig. 5.4A). This is consistent with an allometric trend in dinosaurs that the skull roof generally becomes wider and thicker as body size increases. As in most ceratopsians (Dodson et al. 2004), the frontal is not fused to its counterpart but the medial frontal sutural surface is sculpted by numerous grooves. A mid-height longitudinal groove separates this surface into upper and lower parts (Fig. 5.3D).

In dorsal view (Fig. 5.3A), a sutural surface at the anterior edge represents the posterior end of the nasal contact, suggesting that the nasal excluded the prefrontals from contacting each other. Most basal neoceratopsians share this character, whereas in at least some ceratopsids (e.g., *Centrosaurus* and *Styracosaurus;* Sampson et al. 1997), the prefrontals meet each other at the midline and prevent frontal-nasals contact. The orbital rim is gently emarginated as in other basal ceratopsians. The deeply sculpted grooves associated with vascular pits on the dorsal surface are similar to cranial ornamentation present on most ceratopsids. *Leptoceratops* (UWGM 31992.05; Fig. 5.4C) and *Prenoceratops* (MNHCM field num-

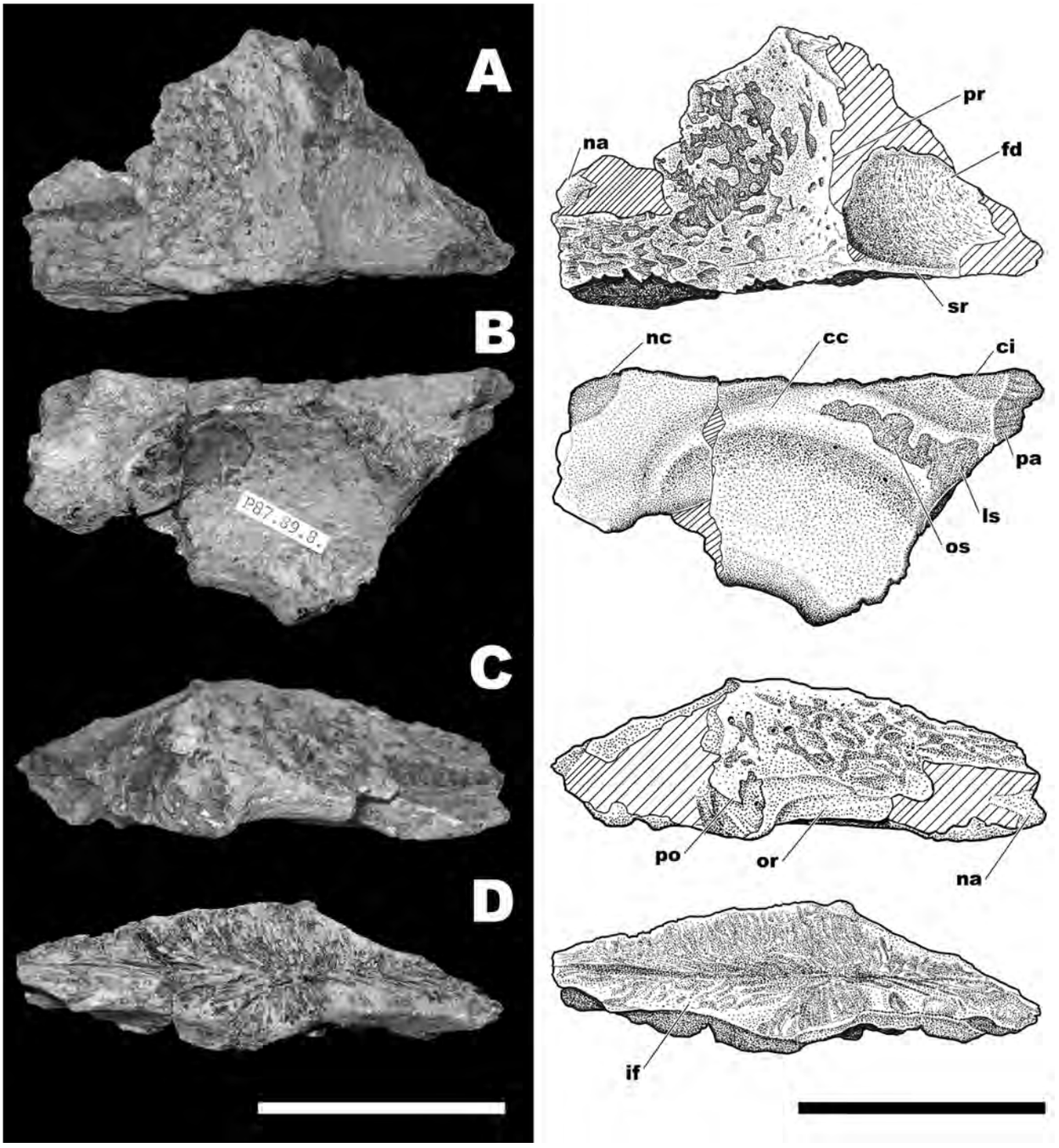


**FIGURE 5.3.** TMP 87.89.8 in (A) dorsal, (B) ventral, (C) right lateral, and (D) medial views. Scale bars are 5 cm.

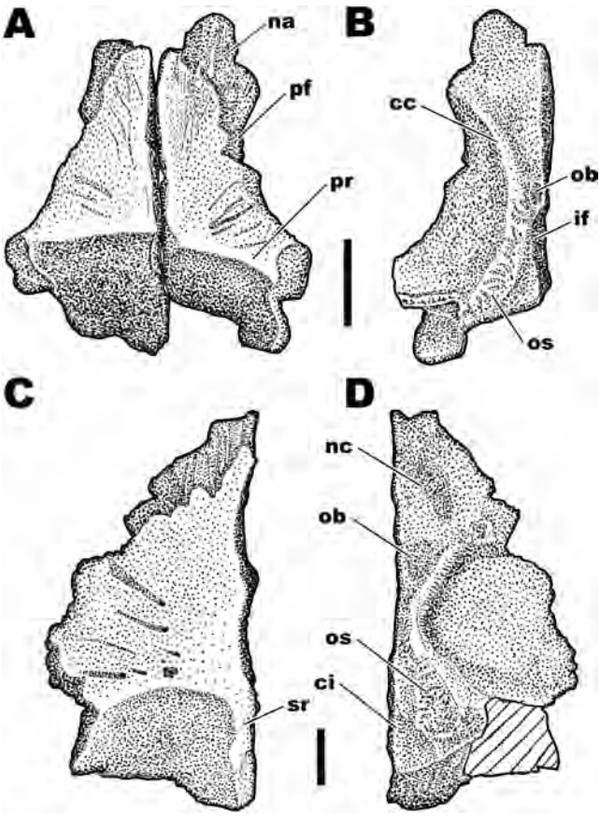


**FIGURE 5.4.** *Prenoceratops* frontals in (A) dorsal view (MNHCM field number 65 on left, MNHCM field number 61 on right) based on Chinnery (2004); (B) ventral view (field number 65). *Leptoceratops* frontals (UWGM 3992.05) in (C) dorsal and (D) ventral views based on Ott (2003). Scale bars are 2 cm.

bers 61 [Fig. 5.4A] and 65 [Fig. 5.4A]) have less conspicuous pitting, with shallow parallel grooves occurring on the dorsal surface of the frontals. The postorbital contact is partially preserved in TMP 87.89.8, and indicates that the postorbital overlapped the frontal posteriorly as it does in other basal ceratopsians including *Leptoceratops, Liaoceratops, Psittacosaurus,* and *Yamaceratops* (Makovicky and Norell 2006).

The posterior one-third of the bone is marked by the deep frontal depression (Fig. 5.3A). As in *Prenoceratops* (Chinnery 2004) and *Cerasinops* (Chinnery and Horner 2007), the frontal depression is deeper than one-third of the total frontal thickness. A sharply defined, straight transverse postorbital ridge separates the frontal depression from the rest of the bone. This is diagnostic for *Prenoceratops* (Chinnery 2004), but is more dorsally pronounced in TMP 87.89.8. In other basal ceratopsians, this postorbital ridge is gently curved. A low, narrow sagittal ridge separates the frontal depression from the midline at least anteriorly in TMP 87.89.8. *Leptoceratops* (CMN 8889; UWGM 31992.05) shares with TMP 87.89.8 the morphology of the sagittal ridge, but the ridge is absent on *Prenoceratops* frontals (MNCHM field numbers 61, 65). The partially preserved parietal sutural surface indicates that the frontals were wedged between the parietals on the midline. The frontal-parietal suture is roughly transverse in other basal ceratopsians such as *Protoceratops* (Gregory and Mook 1925).

In ventral view (Fig. 5.3B), the crista cranii delineates the wide orbital space medially and coalesces with the interfrontal suture. The right and left cristae would have met at the midline, constricting the dorsal sulcus for passage of the olfactory tract. The olfactory tract then would have exited anteriorly below this constriction. *Prenoceratops* frontals (MNHCM field numbers 61 and 65) show the same condition, but *Leptoceratops* (UWGM 31992.05; Fig. 5.4D) retains separation between the right and left cristae as in other dinosaurs. Ceratopsids have a transverse ridge connecting the cristae cranii at about the same position (Lehman 1989). A similar transverse ridge is also observed in hadrosaurids (Horner 1992; Evans 2006) and in basal euornithopods (Weishampel et al. 2003), in which the sphenethmoid suture extends onto the ridge. Such a ridge is absent in basal ornithopods (Sues 1980; Galton 1989, 1997) and pachycephalosaurs (TM pers. obs.). The connection between the crista cranii and the orbitosphenoid is substantial, occurring from the constriction between the cristae posterolaterally and extending to the laterosphenoid suture. Based on the position of this suture, the laterosphenoid of TMP 87.89.8 would have had an exceptionally long lateral process to contact the postorbital. There is no clear indication of the sphenethmoid contact, which has been observed on the transverse ridge between cristae cranii in euornithopods (Horner 1992; Weishampel et al. 2003; Evans 2006). The crista cranii of *Leptoceratops* have a rough texture along the anteromedial margin of the orbital depression that probably marks the sphenethmoid suture (UWGM 31992.05; Fig. 5.4D).

A deep, wide depression occurs near the interfrontal suture on the ventral surface at the broken anterior end (Fig. 5.3B) that most likely marks the posterior end of the nasal cavity. *Leptoceratops* has a shallow, wide trough for the nasal that extends to the ventral surface of the frontal (Ott 2003). The depression may be absent in *Prenoceratops,* although the corresponding area seems to be slightly depressed in two of the three *Prenoceratops* frontal specimens (MNHCM field numbers 48 and 61 [Fig. 5.4B]). The presumed nasal cavity depression is much deeper in TMP 87.89.8 than it is in either *Prenoceratops* or *Leptoceratops*. One of the frontals of *Prenoceratops* (MNHCM field number 65, Fig. 5.4A) preserves a clear olfactory bulb impression behind the nasal cavity (TM pers. obs.), but TMP 87.89.8 has no recognizable feature in the same position. In TMP 87.89.8, there is a shallow, small depression near the interfrontal suture on the ventral surface at the posterior end of the specimen, which represents the cerebral fossa (Fig. 5.3B). Since size and depth is much smaller than that expected

for a cerebrum from a basal neoceratopsian of this size, the cerebrum must have been only in a partial contact with the frontal. *Prenoceratops* frontals do not form a distinct depression for the cerebrum.

## Discussion

TMP 87.89.8 shares with *Prenoceratops* the autapomorphies of (1) transversely straight postorbital ridge, (2) frontal depression that is deeper than one-third the thickness of the frontal, and (3) crista cranii that coincides with the interfrontal suture (Chinnery 2004). TMP 87.89.8 has four possible autapomorphic characters: a deeply sculpted dorsal surface of the frontal; a deep nasal cavity depression; an interfrontal suture that is divided into upper and lower parts; and an unequivocal sagittal ridge along the interfrontal suture that would have separated right and left frontal depressions at least anteriorly. Unfortunately, these characters are not consistently present on the remaining North American neoceratopsians (*Cerasinops, Leptoceratops, Montanoceratops,* and *Zuniceratops*) to facilitate a robust phylogenetic analysis. It is possible that these differences, in addition to the width and the thickness of the frontals, are the result of individual variation, or are size-related. The frontal of TMP 87.89.8 would have been at least approximately 30% longer than the frontals of *Prenoceratops* (MNHCM field numbers 61 and 65; Fig. 5.4A, B) suggesting that it may represent a large adult of *Prenoceratops pieganensis*. Alternatively, TMP 87.89.8 may have come from a new species of *Prenoceratops*. Until more material can be recovered from the Oldman Formation of Alberta, we conservatively refer TMP 87.89.8 to *Prenoceratops* sp.

Comparison of TMP 87.89.8 to other basal neoceratopsians from North America indicates that there is significant morphological variation in skull roof characters (e.g., shape of the crista cranii, depth of frontal depressions, and presence or absence of nasal cavity, impression of olfactory bulb, and cerebral fossa) within these taxa. These characters are candidates for a refined phylogenetic analysis of ceratopsians in the future.

Finally, it must be noted that the sculpturing on the dorsal frontal surface of *Leptoceratops* (UWGM 31992.05; Fig. 5.4C), *Prenoceratops* (MNCHM field number 61), and TMP 87.89.8 implies the presence of a thick keratinous covering (Horner and Marshall 2002) over at least this portion of the skull.

### CAMPANIAN BASAL NEOCERATOPSIAN DIVERSITY IN NORTH AMERICA

TMP 87.89.8 is the first basal neoceratopsian material from the Oldman Formation, helping to fill in one of the longest gaps in the basal neoceratopsian record in Alberta. In addition to *Prenoceratops, Leptoceratops* sp. is known from the Dinosaur Park Formation (Ryan and Currie 1998) and *Cerasinops* from the Two Medicine Formation below the interval that produced *Prenoceratops* (Chinnery and Horner 2007).

Ryan and Currie (1998) also reported a basal neoceratopsian tentatively identified as *Montanoceratops* sp. (TMP 82.11.1) recovered from a massive yellow sandstone block located on the Oldman River (Tanke 2007). Examination of the specimen suggests that the preserved matrix is more consistent with sediments from the Maastrichtian-aged portion of the Willow Creek Formation (Fig. 5.1) that predominantly crops out along the Oldman River, rather than from the Belly River Group that is not widely exposed along the river (Wall and Rosene 1977). Grain size of the matrix associated with TMP 82.11.1 is finer than the typical medium-to-fine sands in the Belly River Group, and the matrix contains more cement than typical sandstone from the Belly River Group (TM unpublished data). Therefore, we propose that TMP 82.11.1 most likely came from the Maastrichtian-aged Willow Creek Formation and, therefore, can no longer be included in consideration of the diversity of North American basal neoceratopsians from the Campanian.

*Prenoceratops* and the lambeosaurine *Hypacrosaurus stebingeri* (Horner and Currie 1994) are the only two ornithischians shared between the upper Oldman Formation (OF) of Alberta and the upper Two Medicine Formation (TMF) of Montana. These formations represent similarly well-drained, seasonally dry floodplain environments (OF, D. A. Eberth pers. com. 2007; TMF, Rogers 1997). The type material of *Prenoceratops* (ICM 2003.1.1) was recovered from a bonebed 50 m below the Bearpaw Formation (Chinnery 2004), which places its stratigraphic position close to the bentonite dated at 74.3 Ma in the upper Two Medicine Formation (Horner et al. 1992). With the radiometric dating of the Devil's Coulee locality at 75.05 Ma (Eberth and Deino 1992), the type material of *Prenoceratops* is less than 1.0 Ma younger than TMP 87.89.8. Presence of *Prenoceratops* and *Hypacrosaurus stebingeri* in the upper Two Medicine formations suggests persistence of the Oldman Formation ornithischian fauna from Alberta in the inland setting of Montana up to the maximum westward transgression of the Bearpaw Sea. It is also possible that the younger occurrences of *Prenoceratops* and *Hypacrosaurus stebingeri* in the Two Medicine Formation are a result of inland migration in response to the westward Bearpaw transgression, a hypothesis supported by the suggestions of a number of authors (e.g., Sternberg 1951; Ryan and Currie 1998; Ott 2006; You and Dodson 2004) who have attributed the rarity of basal neoceratopsians in western North America to their preference for an inland, drier habitat. The seasonally dry floodplain depositional setting of the strata at Devil's Coulee (D.A. Eberth pers. comm. 2007) also supports this hypothesis.

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