

# A new ceratopsid from the Foremost Formation (middle Campanian) of Alberta

Michael J. Ryan, David C. Evans, and Kieran M. Shepherd

**Abstract:** *Xenoceratops foremostensis* gen. et. sp. nov., a new centrosaurine ceratopsid from the Foremost Formation (Campanian) of Alberta, is described based on frill material from at least three adult-sized individuals collected from a low-density bone bed. The material can be assigned to Centrosaurinae based on features of the preserved squamosal. Although the parietals are incomplete, the shape of the diagnostic parietal can be inferred from several overlapping serial elements. The parietal of the new taxon shares with all other centrosaurines, except *Centrosaurus apertus*, spike-like ornamentation at the posterolateral (P3) locus under traditional coding methods. At approximately 78 Ma, it is the oldest known Canadian ceratopsid, approximately 0.5 Ma older than *Albertaceratops* from the lower Oldman Formation of Canada and approximately 1.0 Ma younger than *Diabloceratops* from the Wahweap Formation of Utah. A phylogenetic analysis resolves the new taxon as the basalmost centrosaurine and places *Centrosaurus brinkmani* as the sister taxon to *Styracosaurus albertensis*. The type species of *Centrosaurus brinkmani* is moved to a new genus.

**Résumé :** *Xenoceratops foremostensis* gen. et. sp. nov., un nouveau cératopsidé centrosauriné de la Formation de Foremost (Campanien) d'Alberta, est décrit à la lumière de matériel de collerette provenant d'au moins trois individus de taille adulte recueilli dans un lit à ossements de faible densité. Le matériel peut être affecté aux Centrosaurinés à la lumière de caractéristiques des os squamosaux préservés. Bien que les os pariétaux soient incomplets, la forme du pariétal diagnostique peut être inférée à la lumière de plusieurs éléments en série superposés. Le pariétal du nouveau taxon a en commun avec ceux de tous les autres centrosaurinés, à l'exception de *Centrosaurus apertus*, une ornementation d'aspect épineux de la bordure postérolatérale (P3), selon les méthodes de codage traditionnelles. Datant d'environ 78 Ma, il s'agit du plus ancien cératopsidé canadien connu, précédant d'environ 0.5 Ma *Albertaceratops*, de la partie inférieure de la Formation d'Oldman du Canada, et d'environ 1.0 Ma *Diabloceratops*, de la Formation de Wahweap de l'Utah. L'analyse phylogénétique établit que le nouveau taxon est le centrosauriné le plus basal et situe *Centrosaurus brinkmani* comme taxon-frère de *Styracosaurus albertensis*. L'espèce type de *C. brinkmani* est réaffectée à un nouveau genre.

[Traduit par la Rédaction]

## Introduction

Ceratopsidae is the most speciose clade of dinosaurs known from the Late Cretaceous of Laramidia. The fossil-rich Belly River and Edmonton groups of Alberta, Canada, alone have produced at least 13 ceratopsid species, including the centrosaurines *Albertaceratops nesmoi* Ryan, 2007, *Centrosaurus apertus* Lambe, 1904, *Centrosaurus brinkmani* Ryan and Russell, 2005, *Pachyrhinosaurus canadensis* Sternberg, 1950, *Pachyrhinosaurus lakustai* Currie et al., 2008, *Spinops sternbergorum* Farke et al., 2011, and *Styracosaurus albertensis* Lambe, 1913, and the chasmosaurines *Anchiceratops ornatus* Brown, 1914, *Arrhinoceratops brachyops* Parks, 1925, *Chasmosaurus belli* Lambe, 1902, *Chasmosaurus russelli* Sternberg, 1940, *Vagaceratops irvinensis* Holmes et al., 2001, and *Triceratops horridus* Marsh, 1889, with five of these having been named within the last two decades. Most of these taxa

have been recovered from the well-sampled sediments of the upper Belly River Group, particularly the Dinosaur Park Formation, from the region of Dinosaur Provincial Park (DPP). The Dinosaur Park Formation was deposited during a transgressive phase of the Western Interior Seaway. The older regressive phase of this clastic wedge, recorded in the rocks of the Oldman and Foremost formations, has received comparatively little attention, due in part to the perceived scarcity of dinosaur remains from these units.

The Foremost Formation is the most poorly known unit in terms of its dinosaur fauna. It comprises mostly marine sediments deposited during the transgression of the Claggett cycle, but is transitional between the underlying fully marine shales of the Pakowki Formation and the overlying fully non-marine Oldman Formation (Eberth and Hamblin 1993). The formation is bounded below by the Mackay Coal and above by the Taber Coal zones (Fig. 1), and

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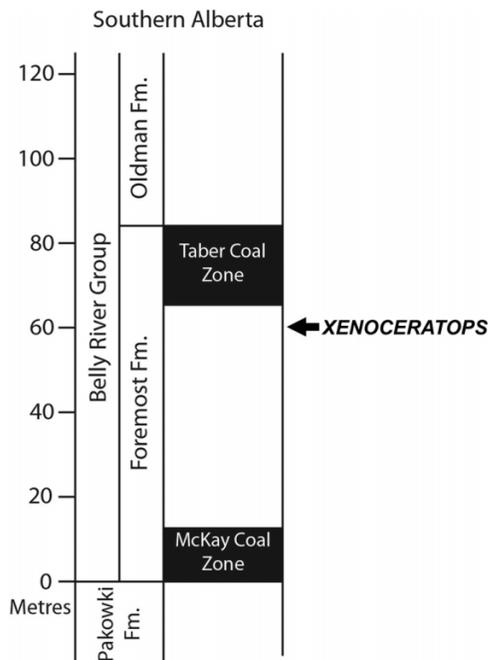
**M.J. Ryan.** Department of Vertebrate Paleontology, Cleveland Museum of Natural History, 1 Wade Oval Drive, University Circle, OH 44106, USA.

**D.C. Evans.** Department of Natural History, Royal Ontario Museum, 100 Queen's Park, Toronto, ON M5S 2C6, Canada; Department of Ecology and Evolutionary Biology, University of Toronto, 25 Willcocks Street, Toronto, ON M5S 3B2, Canada.

**K.M. Shepherd.** Earth Sciences, Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, ON K1P 6P4, Canada.

**Corresponding author:** Michael J. Ryan (e-mail: mryan@cmnh.org).

**Fig. 1.** Schematic geologic section showing placement of *Xenoceratops foremostensis*.



can be up to 83 m thick (including subsurface), but is typically limited to 10–30 m in outcrop. The upper portion of the formation contains a localized near-shore terrestrial sequence that is capped by the Harrington sandstone, which has been argued to be the lowermost portion of the Oldman Formation (Eberth and Hamblin 1993). Microvertebrate sampling has revealed a dinosaur assemblage that resembles other later units in terms of family-level representation (Baszio 1997; Ryan and Russell 2001; Brinkman et al. 2004; Frampton 2007). The only ornithischian taxon described on the basis of non-dental skeletal elements is the pachycephalosaurid *Colepiocephale lambei* (Schott et al. 2011). Several partial hadrosaurine skeletons have also been collected, and one of these has been referred to as “*Kritosaurus*” (Brett-Surman 1989), but these have not yet been formally described or placed into phylogenetic context.

The best exposures of the lower Belly River group, including the Foremost Formation, occur along the Milk, Oldman, and South Saskatchewan rivers (Fig. 2), as well as in Chin Coulee in the extreme southern part of Alberta. The region has previously been explored by crews from the National Museum of Canada (now the Canadian Museum of Nature) and the Royal Ontario Museum (ROM) in the middle of the 20th century, and more recently by crews from the Royal Tyrrell Museum (TMP), ROM, and the Cleveland Museum of Natural History. Recent examination of material collected by Wann Langston, Jr., in 1958 has revealed previously undescribed, well-preserved ceratopsid cranial material from the Foremost Formation of Alberta. Here we describe this material and refer it to a new taxon, *Xenoceratops foremostensis* gen. et. sp. nov., which represents the oldest ceratopsid taxon known from Canada.

## Institutional abbreviations

Canadian Museum of Nature (CMN), Ottawa, Ontario, Canada; Royal Ontario Museum (ROM), Toronto, Ontario, Canada; Royal Tyrrell Museum of Palaeontology (TMP), Drumheller, Alberta, Canada.

## Systematic paleontology

Order Ornithischia Seeley, 1888  
Suborder Ceratopsia Marsh, 1890  
Neoceratopsia Sereno, 1986  
Family Ceratopsidae Marsh, 1888  
Subfamily Chasmosaurinae Lambe, 1915

*Xenoceratops* gen. nov.

GENERIC ETYMOLOGY: *Xenos* (from the Greek), meaning foreign or alien, and *ceratops* (from the Greek), meaning horned face, referring to the lack of ceratopsian material known from the Foremost Formation.

DIAGNOSIS: Centrosaurine ceratopsid with two epiparietals (P2–P3) on the posterior parietal ramus; wide-based, short, thick, procurved processes (P2) adjacent to the midline bar and an elongate, dorsoventrally depressed spike (P3) at the posterolateral margin oriented posterolaterally; additional epiparietals fuse into ovoid depressions on the lateral ramus; ventral margins of parietal at the contact with the epiparietals greatly inflated.

The P1 epiparietal is missing as on the basalmost centrosaurines (*Albertaceratops* and *Diabloceratops*) as well as the derived “pachyrhinosaur”-grade (sensu Currie et al. 2008) centrosaurs *Achelousaurus*, *Einosaurus*, and *Pachyrhinosaurus*. The P2 epiparietal is a thickened protrusion compared to the elongate, medially curled, finger-like process of *Centrosaurus apertus* and *Pachyrhinosaurus* or the short tab-like processes on *Achelousaurus*, *Einosaurus*, and some specimens of *Styracosaurus*. Unlike other centrosaurines, *Xenoceratops* lacks the development of imbricated epiparietals on the lateral ramus and shares with *Albertaceratops* and most Chasmosaurinae the lack of “bumps” on the midline parietal ramus.

TYPE SPECIES: *Xenoceratops foremostensis* sp. nov.

(Figs. 3–6)

DIAGNOSIS: As for the genus.

SPECIFIC ETYMOLOGY: Named for the Village of Foremost, Alberta.

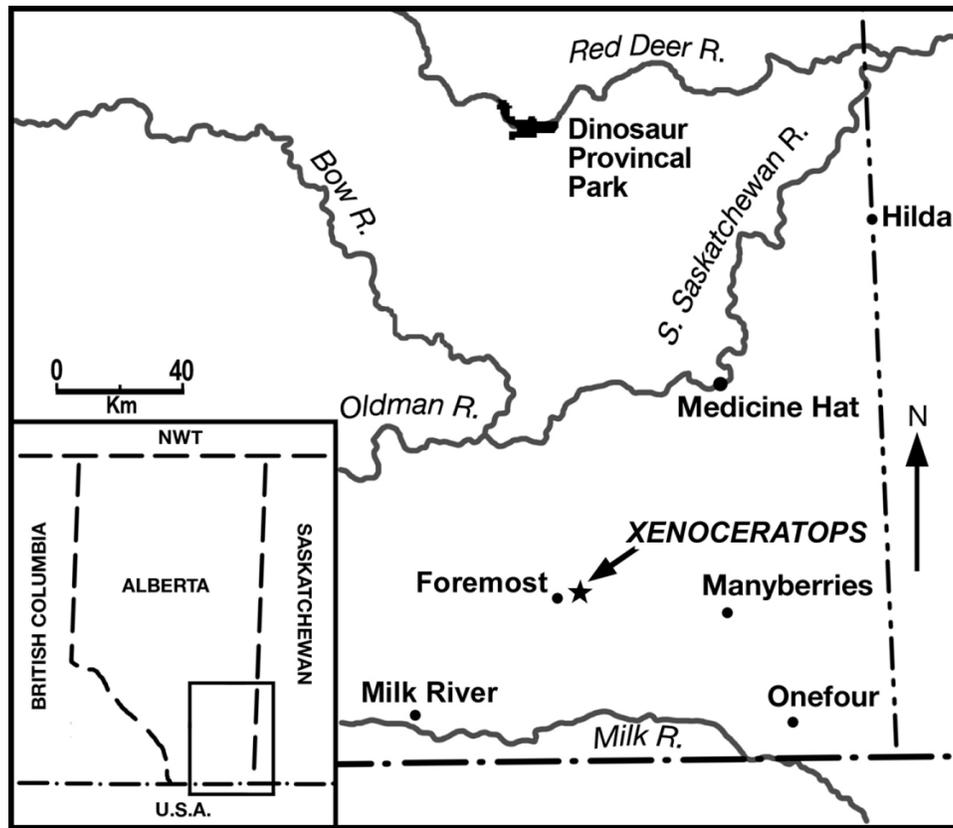
HOLOTYPE: CMN 53282. A partial parietal (Fig. 3).

PARATYPES: Parietals CMN 54950 (Fig. 4) and CMN 54951 (Fig. 5).

REFERRED MATERIAL: CMN 54952 to CMN 54965.

COMMENTS: The material originally catalogued as CMN 53282 is a composite of at least three adult-sized individuals. CMN 53282 is retained for the holotype, with CMN 54950 and CMN 54951 designated as paratype parietals representing two other individuals. The remainder of the referred material is assigned sequential specimen numbers CMN 54952 to CMN 54964 (CMN 54952, parietal (Figs. 6F, 6G); CMN 54953, parietal (Figs. 6D, 6E); CMN 54954, squamosal (Figs. 8A–8C); CMN

Fig. 2. Locality map for *Xenoceratops foremostensis*.



54955, nasal (Fig. 8D); CMN 54956, squamosal (Fig. 8E); CMN 54957, squamosal; CMN 54958, parietal (Fig. 6H); CMN 54959, parietal P4 process; CMN 54960, parietal with P3 suture; CMN 54961, epiparietal (Fig. 6C); CMN 54962, epiparietal (Fig. 6B); CMN 54963, epiparietal (Fig. 6A); CMN 54964, parietal); none of this material can be confidently referred to the holotypes or paratypes, but likely pertain to these type specimens owing to their close association. CMN 54965 is assigned to all remaining unidentified fragments originally part of the CMN 53282 designation.

**TYPE LOCALITY:** The type and referred specimens were collected by Wann Langston, Jr., in 1958, from moderately developed Foremost Formation badlands of Chin Coulee, located approximately 7 km northeast of the Village of Foremost (Fig. 2). All the material was collected from a low-diversity bone bed in a “soft gray-brown slightly carbonaceous shale that is 17 feet above the massive yellow-weathering *Ostrea* bed” (Chin Coulee Site No. 2; W. Langston, Jr., unpublished 1958 field notes on file at the Canadian Museum of Nature) in Chin Coulee (Fig. 2). More precise locality is on file with the Canadian Museum of Nature, Ottawa, Ontario, Canada.

## Description

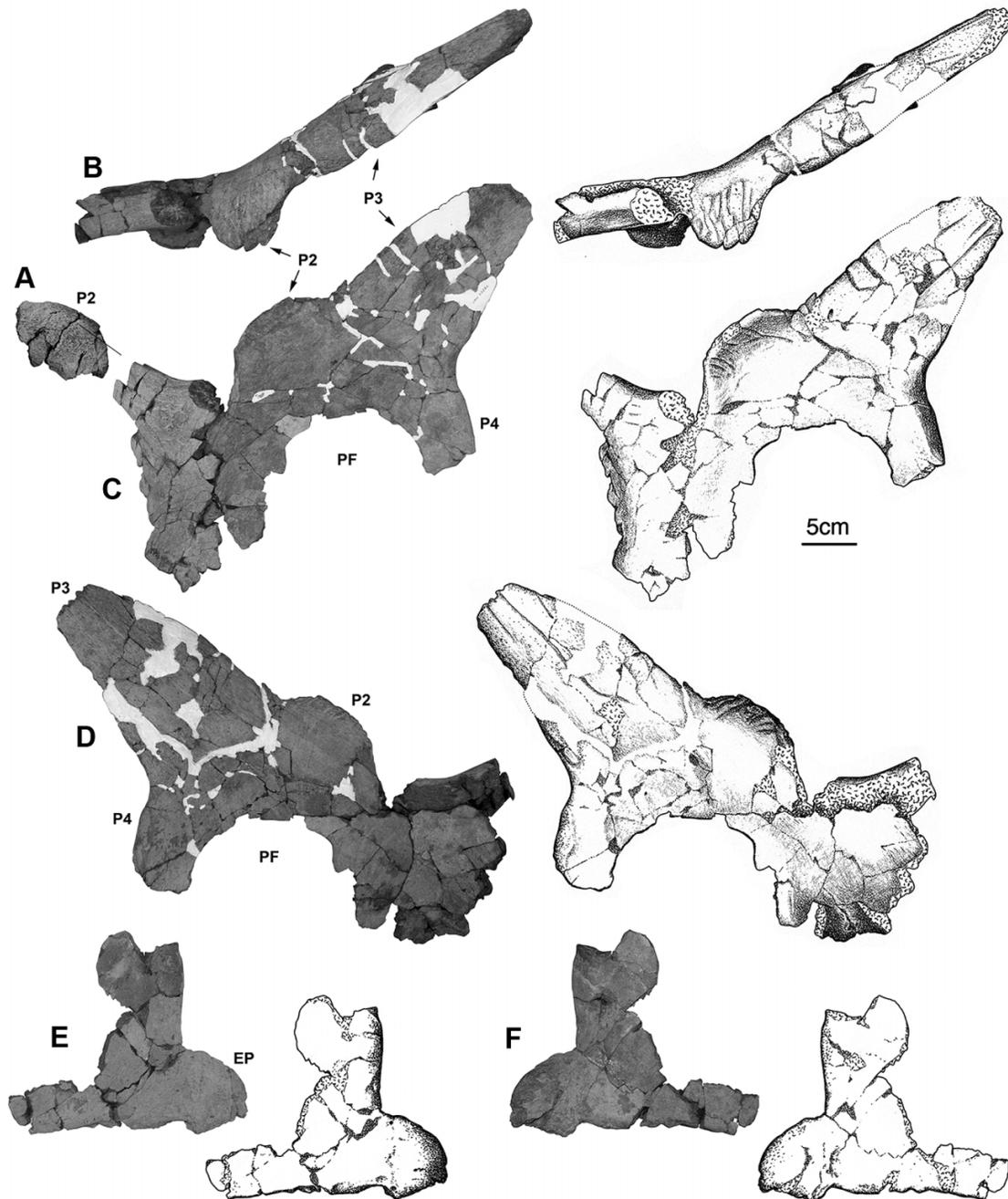
The holotype parietal (CMN 53282, Figs. 3A–3F) is the most complete element composed of three fragments; 1, most of the posterior midline ramus, a portion of the left posterior and lateral ramus preserving the P2 and P3 (and probably P4) processes, and adjacent margins of the parietal fenestra; 2, the

anteriormost right parietal ramus fragment with a fused epiparietal (Figs. 3E and 3F); and 3, the isolated right P2 process (Fig. 3A). All these fragments were collected in two small field jackets, and parts of each piece were preserved in direct contact with one another; this fact, plus their similar size, color, and texture suggests that elements pertain to the same individual. The paratypes, CMN 54950 (Fig. 4) and CMN 54951 (Fig. 5), are portions of right posterior parietal rami, which, owing to differences in their size and overlapping anatomy, must be from different individuals.

As reconstructed, when viewed dorsally, the parietal has fenestrae of typical centrosaurine size adjacent to a wide midline ramus (Fig. 7A). The parietal P1 process is not expressed in this taxon, but it does possess P2 and P3 processes and a minimum of two (probably five, as per other centrosaurines based on inference from the available fragments) additional processes are present along the margin of the lateral parietal ramus. The wide-based, short, and pachystotic P2 processes (Figs. 3A–3D, 4A–4D) lie medial to a U-shaped posterior margin and are curled slightly dorsolaterally. The P3 process is a depressed, wide-based, elongate, straight spike that is posterolaterally oriented (Figs. 3B–3D, 5A, 5B).

*Xenoceratops* appears to have lacked scalloped lateral rami. The margins of the lateral parietal rami have ovoid depressions (Figs. 6D–6G) that appear to correspond to the loci along the scalloped margins of other centrosaurines where the epiparietals fuse. The partial right anterior lateral ramus of the holotype (Figs. 3E, 3F) preserves the butt suture contact surface for the squamosal that is of typical centrosaurine shape. This surface

**Fig. 3.** *Xenoceratops foremostensis* gen. et sp. nov., CMN 53282, holotype parietal. (A) Right P2 process. (B–D) Partial midline, left posterior, and lateral ramus: (B) posterior (ventral surface up, specimen rotated around the long axis of the P3 spike); (C) dorsal; and (D) ventral views. (E, F) Anteriormost left lateral ramus with contact for squamosal: (E) dorsal and (F) ventral views. P#, parietal process No.; PF, parietal fenestra; EP, epiparietal. Scale bar = 5 cm.



forms an approximately right angle with the lateral margin of the ramus. The element has a fused sub-triangular epiparietal at the anterolateral corner that would have partially straddled the contact with the squamosal.

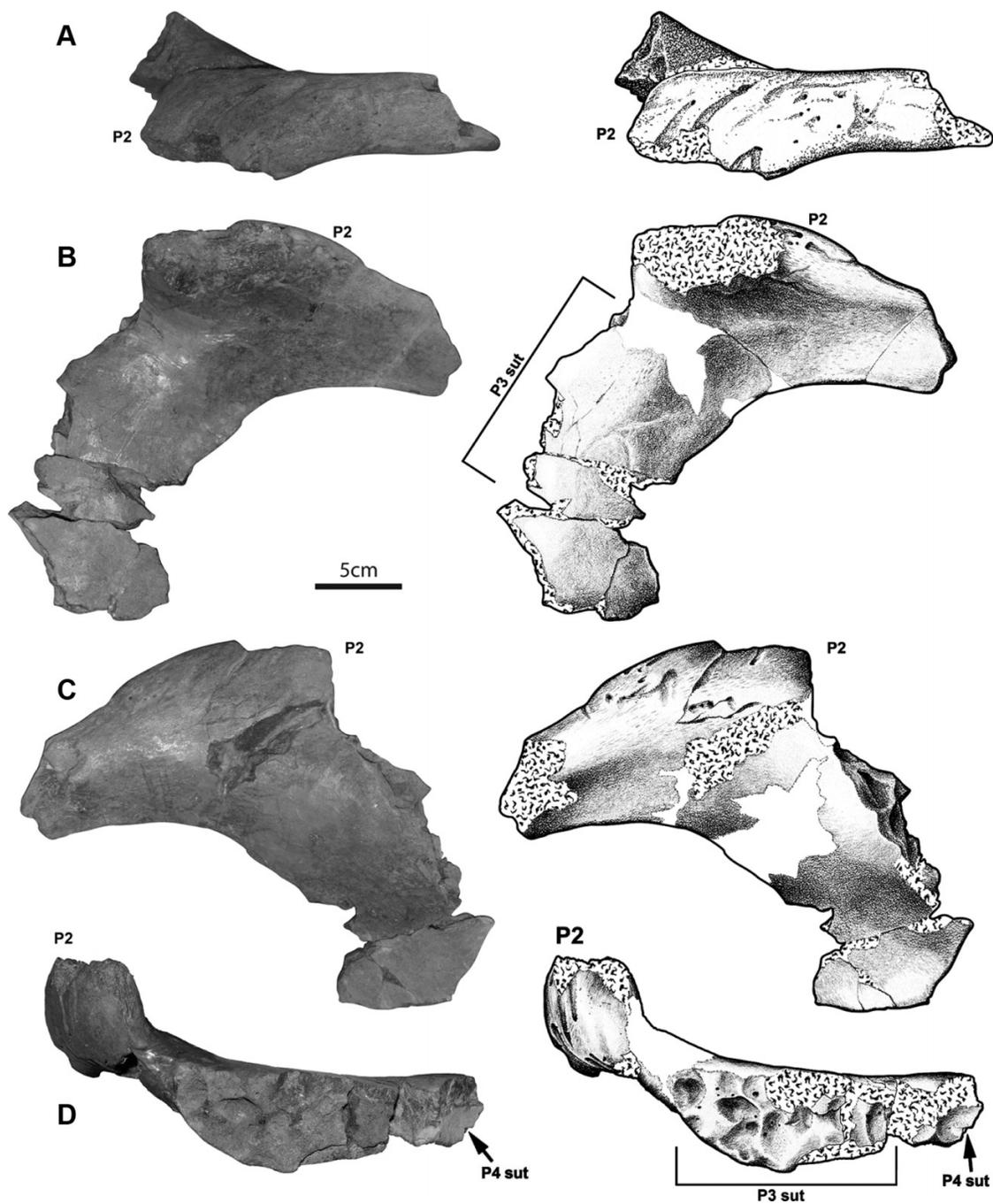
The specimens include hundreds of unidentifiable small fragments. Identifiable pieces are typically larger than 20 mm. Only diagnostic frill specimens and informative fragments will be discussed here. Numbering of the epiparietals follows

Sampson et al. 1997, but see the phylogenetic analysis section for comments about the new coding methodology of Farke et al. (2011).

#### Nasal

CMN 54955 (Fig. 8D) is a fragmentary right nasal preserving the base of the ornamentation and a portion of the lateral wall. The specimen is very similar to isolated, unfused *Me-*

**Fig. 4.** *Xenoceratops foremostensis* gen. et sp. nov., paratype right parietal, CMN 54950. (A) Posterior, (B) dorsal, and (C) ventral views; (D) close-up of open suture for P3. P#, parietal process No.; P# sut, epiparietal sutural surface. Scale bar = 10 cm.



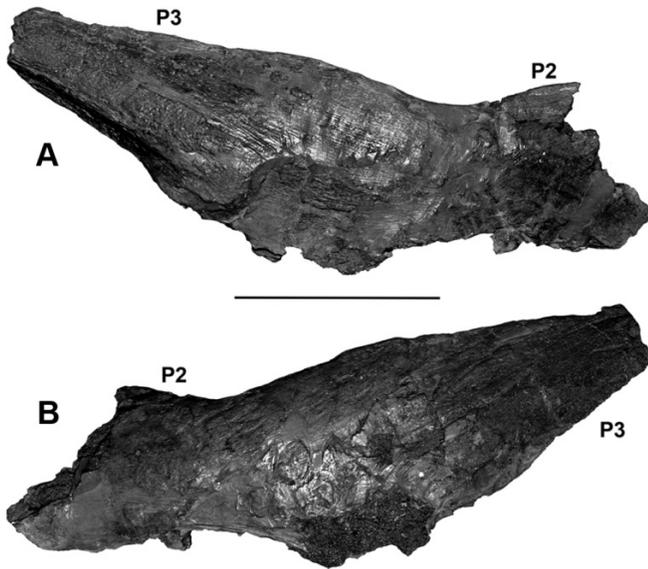
*dusaceratops* nasals recovered from the Mansfield bone bed in the Judith River Formation of Montana (Ryan 2007, fig. 5). These unfused nasals are mediolaterally flattened with low, elongate ornamentation that is also seen on the basal centrosaurines *Albertaceratops* (Ryan et al. 2010) and *Diabloceratops* (Kirkland and Deblieux 2010); CMN 54955 probably had a similar nasal ornamentation. Basal length of the ornamentation cannot be estimated owing to the incompleteness of the specimen, and the surficial texture is poorly preserved.

**Parietal**

Midline ramus: Two partial midline rami, CMN 53282 and CMN 54958, were recovered, with the former (holotype) being the most complete. It is mediolaterally wide and arched in cross-section as in *Albertaceratops* and differs from the strap-like or square-shaped rami of chasmosaurs or the depressed, triangular cross-sectional-shaped rami of most other centrosaurs.

The posterior margin has a shallow U-shaped median embayment when viewed dorsally, which is constrained by the

**Fig. 5.** *Xenoceratops foremostensis* gen. et sp. nov., CMN 54951, paratype right P3 spike and partial P2 process. (A) Dorsal and (B) ventral views. P#, parietal process No. Scale bar = 10 cm.



medially positioned P2 processes. The posterior margin of the bar is thickest (54 mm) approximately 15 mm from the posterior margin and then tapers to form a horizontal ridge. Similar to *Albertaceratops* and Chasmosaurinae, but differing from other centrosaurines, *Xenoceratops* lacks any “bumps” on the midline ramus when viewed laterally. Portions of the posterior margin of the left parietal fenestra are preserved on CMN 53282 (Figs. 3C, 3D). The bone immediately adjacent to the fenestra is thin (<2 mm) with the parietal becoming thicker towards the posterior and lateral margins. As reconstructed (Fig. 7A), the fenestrae were ovoid openings of typical centrosaurine size.

Posterior and lateral rami and ornamentation: Four significant pieces of parietal rami can be identified, including CMN 53282, the most complete parietal (in two sections) preserving left processes P2–P4 and portions of the fenestra (Figs. 3A–3F), and a portion of the left anterior ramus with the contact for the squamosal and a large fused epiparietal (Figs. 3E, 3F); CMN 55950 (Figs. 4A–4D), a partial right parietal preserving the P2 process, a large open suture for the P3 process, and a portion of the divot-like depression for the P4 epiparietal; and CMN 54951 (Figs. 5A, 5B), a right P3 spike with a portion of the P2 preserved. Other fragmentary parietal pieces include a partial posterior portion of a parietal midline ramus (CMN 54958, Fig. 6H), at least three partial epiossifications (CMN 54963, Fig. 6A; CMN 54962, Fig. 6B; CMN 54961, Fig. 6C), and fragments of the lateral parietal margin preserving ovoid divots (CMN 54953, Figs. 6D, 6E; CMN 54952, Figs. 6F, 6G; and CMN 54964).

P2: The left P2 process of CMN 53282 (Figs. 3B–3D) and the right P2 process of CMN 54950 (Figs. 4A–4D) are indistinguishably fused to the underlying parietal and have pronounced texturing on the superior surface (the right P2 process of CMN 53282 (Fig. 3A) is an isolated fragment). This texture starts just above a slight inflation that occurs at the base of the process close to the ventral parietal surface and extends across

the process to the apex. The P2 processes of CMN 53282 are smaller and more symmetrical than that of CMN 54950, which is more robust and has a more pronounced dorsolateral inflection. The dimensions of the P2 processes are as follows: CMN 53282 (left P2): 117 mm basal length, 40 mm basal thickness, and 41 mm height; CMN 54950: estimated length and thickness of 138 mm and 42 mm, respectively. The isolated right P2 fragment from CMN 53282 is similar in size and shape to its left counterpart.

P3: On CMN 53282 (Figs. 3B–3D), this process is a broad-based, depressed spike with a slight ventral inflection. It is triangular in cross-section with a distinct raised margin on the dorsal surface running perpendicular to the long axis. Both the lateral and medial surfaces have sharp margins. When viewed dorsally the lateral margin is straight and the medial margin gently curves towards the blunt apex. The maximum preserved length of P3 is 200 mm (approximately 20 mm is missing from the apex), basal width is 160 mm and basal thickness is 42 mm.

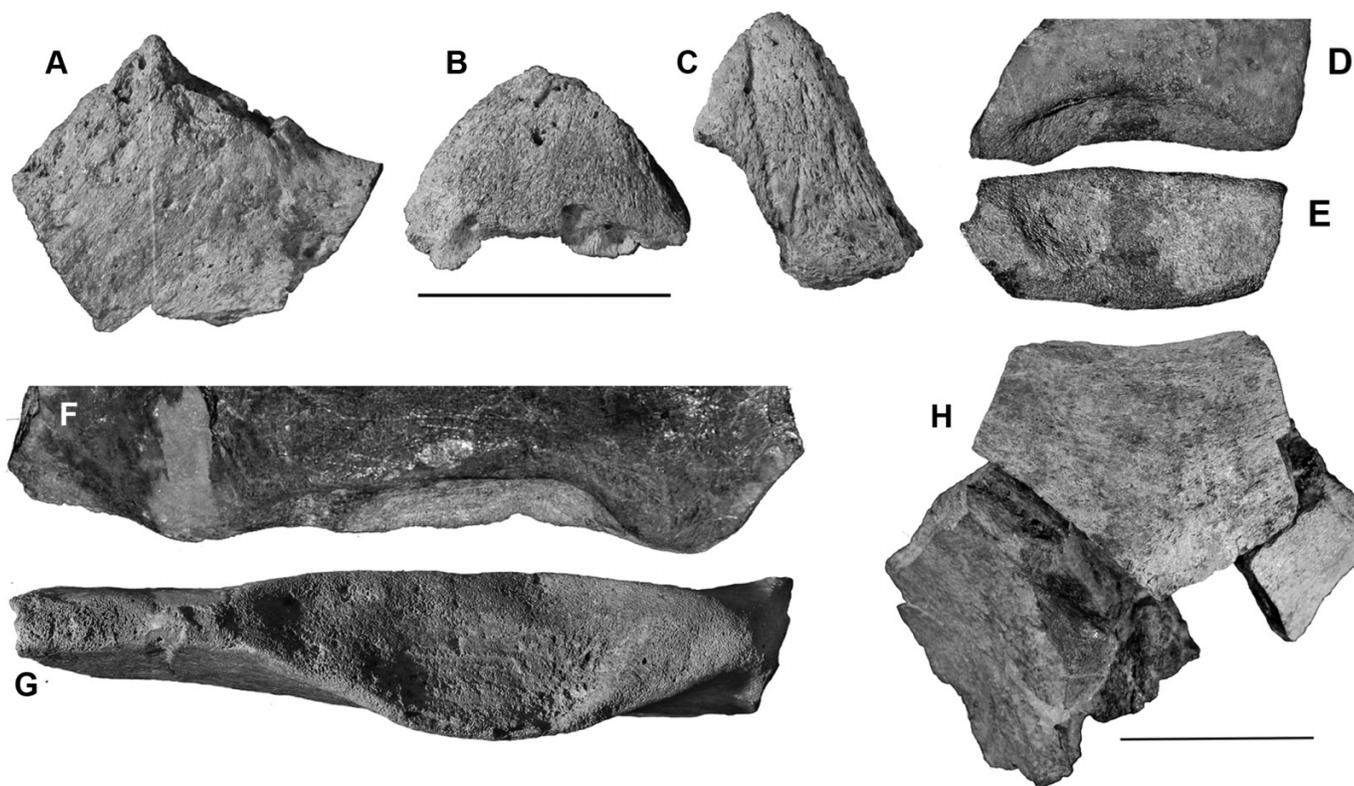
CMN 54951 (Fig. 5) is an isolated right P3 spike missing the apex that preserves a small portion of the parietal ramus and the lateral side of the P2 epiparietal. It differs from that of CMN 53282 by having a narrower base (preserved length approximately 210 mm; basal thickness 38 mm). It also has a triangular cross-section, but in this case the cross-sectional shape is defined by a flattened lateral surface.

CMN 54950 is notable for having a massive ovoid (approximately 120 mm × 56 mm) sutural surface (Fig. 4D) for a P3 process. This surface is deeply textured with wide (approximately 10 mm) pits. Although the dorsal margin of the suture is level with the surface of the adjacent ramus, the ventral margin is inflated, as is also seen on several parietal fragments that preserve the divot-like depressions for the epiparietals (CMN 54953, Figs. 6D, 6E; CMN 54952, Figs. 6F, 6G; and CMN 54964). CMN 54960 is a fragmentary left parietal that also has a P3 sutural surface; however, it is significantly smaller (approximately 83 mm × 23 mm, as preserved) than that of CMN 54950 and probably came from a smaller individual.

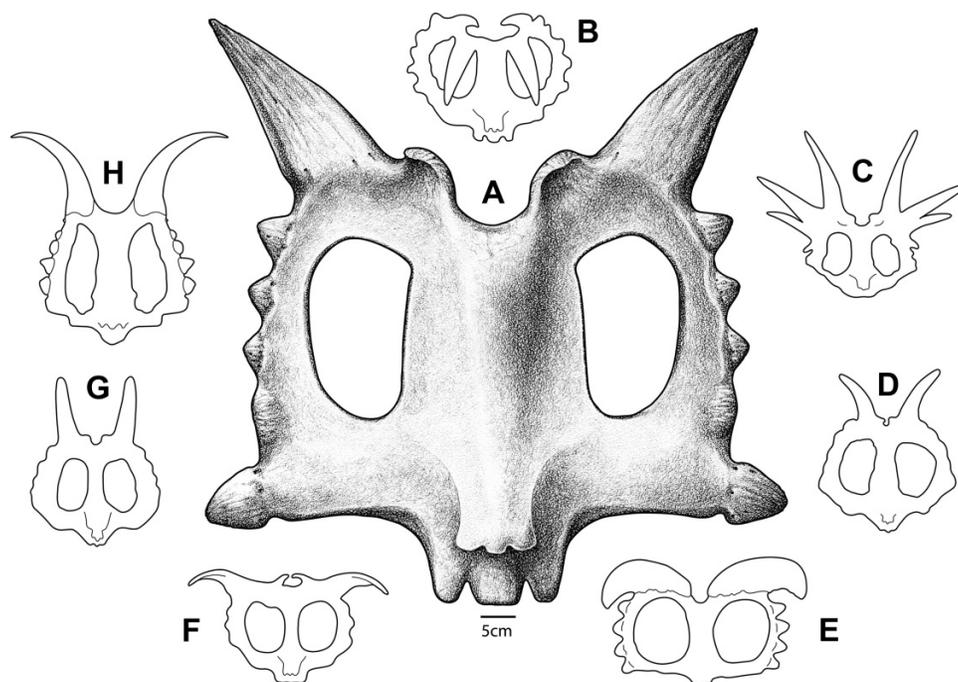
P4: Adjacent to the P3 on CMN 53282 (Figs. 3C, 3D) is an elongate, raised, ovoid surface that most likely represents a highly fused P4 epiparietal. CMN 54959 is an isolated parietal fragment that appears to preserve the same portion of the ramus from the right side. It has a ventrally inflated, ovoid lateral surface 55 mm in length with a moderately raised midline keel that probably also represents a well-fused P4 process. A partial P4 suture is preserved on CMN 54950 (Fig. 4D).

Additional parietal epiossifications: As in other centrosaurines, *Xenoceratops* has additional epiossifications along the lateral rami between P3 and the contact joint between the parietal and squamosal. The preserved epiossifications (CMN 54963, Fig. 6A; CMN 54962, Fig. 6B; CMN 54961, Fig. 6C) and the epiparietal on CMN 53282 are robust, triangular-shaped, and more typical of chasmosaurine epiossifications, although they are similar to some of those seen on the basal centrosaurine, *Diabloceratops*, from the Wahweap Formation of Utah. Unusually for any ceratopsids, these epiossifications appear to fuse into the previously described small, ovoid depressions on the margin of the lateral rami. These are probably homologous to the epiparietal fusion loci of the parietal margins of other centrosaurines. Several isolated frag-

**Fig. 6.** *Xenoceratops foremostensis* gen. et sp. nov., parietal fragments. (A) CMN 54963, epioffication (upper right surface as viewed is broken); (B) CMN 54962, epioffication; (C) CMN 54961, epioffication (lower left surface is broken); CMN 54953, lateral fragment preserving a “divot” in (D) dorsal(?), and (E) lateral views; CMN 54952, lateral fragment in (F) dorsal(?), and (G) lateral views; (H) CMN 54958, posterior midline ramus. Scale bars = 5 cm.

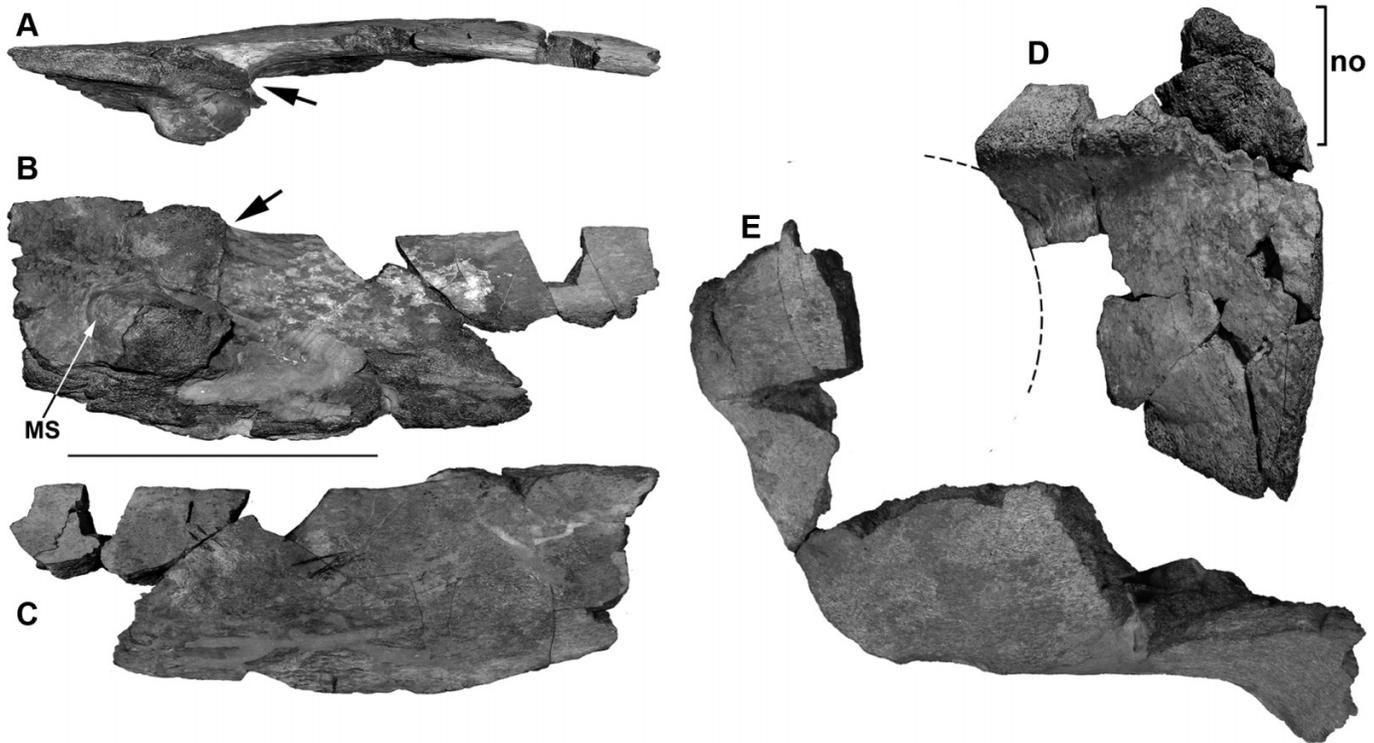


**Fig. 7.** Reconstructions of Centrosaurinae parietals. (A) *Xenoceratops foremostensis*; (B) *Centrosaurus apertus*; (C) *Styracosaurus albertensis*; (D) *Achelousaurus horneri*; (E) *Albertaceratops nesmoi*; (F) *Pachyrhinosaurus lakustai*; (G) *Einosaurus procurvicornis*; (H) *Diabloceratops eatoni*.



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**Fig. 8.** *Xenoceratops foremostensis* gen. et sp. nov., CMN 54954, partial left squamosal: (A) medial, (B) ventral, and (C) dorsal views; (D) CMN 54955, partial right nasal in medial view; (E) CMN 54956, partial left squamosal (posterior and posteroventral margin) in dorsal view. Arrows in (A) and (B) indicate “groove.” Broken lines in (D) indicate margin of external nares. MS, muscle scar; no, height of preserved nasal ornamentation. Scale bar = 10 cm.



ments from the bone bed preserve these depressions (e.g., CMN 54592 (Figs. 6F, 6G) and CMN 54593 (Figs. 6D, 6E), 73 and 50 mm in length, respectively, the latter estimated), and a portion of a very large one can be seen on CMN 54950 lateral to the open P3 suture. Notably, the ventral margins of these depressions arch below the adjacent ventral surface of the parietal.

Parietal–squamosal contact: CMN 53282 (Figs. 3E, 3F) preserves the anterior portion of the right parietal ramus including the open butt suture for the squamosal. This is broken near its lateral margin, but the preserved medial portion exhibits the typical fluted texture seen on most centrosaurs. Laterally adjacent to the suture is a large, sub-triangular epiparietal (basal width 88 mm, height 84 mm, basal thickness 33 mm). As interpreted here, this epiparietal is fused as in other centrosaurines to an outgrowth of the parietal over which it is draped. The base is well-fused along the medial margin but becomes more distinct laterally where it can be distinguished as an overgrowth of the underlying bone. Several small foramina penetrate the ventral margin and puncture the dorsal surface near the medial margin. The epiparietal has a slight dorsal inclination that is enhanced by its flat dorsal surface and inflated ventral surface. Posteriorly adjacent to the epiparietal the margin of the ramus has an ovoid thickening that is interpreted as a well-fused epiparietal. Although this epiparietal is highly modified, it retains a rugose, ventrally inflated surface typical of highly fused epiossifications (e.g., CMN 53282).

### Squamosal

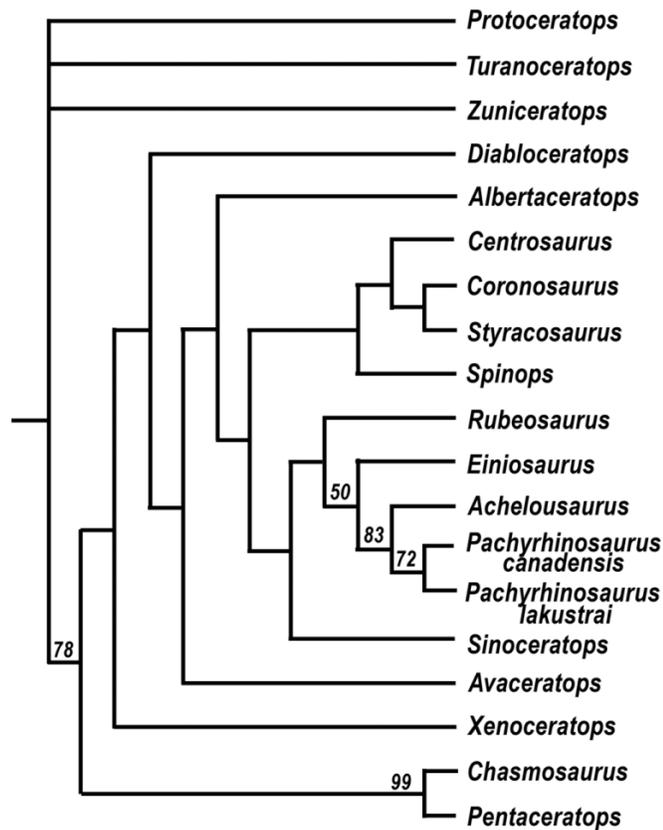
Numerous squamosal fragments were recovered. The largest, CMN 54594, is a left squamosal (Figs. 8A–8C) that preserves portions of the medial and posterolateral margins, contact surfaces for the exoccipital and quadrate, and the anterior blade. CMN 54594 preserves the diagnostic groove between the “stepped” anterior and posterior portions of the element that wraps around from the ventral and dorsal surfaces. In ceratopsids this groove is only known in centrosaurines (Ryan 2007), although it has also been noted on the non-ceratopsid neoceratopsian *Protoceratops* (A. Farke, personal communication, 2012). The muscle scar on the ventral surface behind the posterodorsal margin of the quadrate contact groove is larger and more robust than the same feature on any centrosaurine from the younger Oldman and Dinosaur Park formations. CMN 54957 is a portion of a squamosal preserving the broken muscle scar from a squamosal similar in size to CMN 54954. CMN 54956 (Fig. 8E) is a fragment of the posterolateral margin of a left squamosal of typical centrosaurine shape (e.g., ROM 1927).

### Phylogenetic analysis

To access the systematic position of *Xenoceratops foremostensis*, the holotype specimen was coded into the data matrix of Farke et al. (2011), using both “traditional” and “new” (sensu Farke et al. 2011) coding. The traditional numbering methodology applied to all centrosaurs (Sampson et al.



**Fig. 9.** Cladogram. The strict consensus tree (tree length = 137 steps, CI = 0.74, and RI = 0.76) differs only in terms of the topology of the outgroup taxa (*Protoceratops*, *Turanoceratops*, and *Zuniceratops*). Bootstrap values (1000 replicates) are mapped in bold.



## Discussion

A phylogenetic analysis of *Xenoceratops* using the assumptions of Farke et al. (2011) resulted in three most parsimonious trees of 137 steps each, differing only in the positions of the three outgroup taxa, and recovered *Xenoceratops* as the sister taxon to all other centrosaurines. This analysis has significantly better resolution than that presented by Farke et al. (2011) probably due in part to the additional scoring of missing characters for taxa such as *Centrosaurus brinkmani* and *Pachyrhinosaurus canadensis* from direct observation of original material.

Using the traditional characters of Sampson et al. (1997), *Xenoceratops* could not be resolved within Centrosaurinae. However, coding the parietal processes of *Xenoceratops* using either methodology and running the analysis using the assumptions of Farke et al. (2011) produced the same results with the same CI and RCI values. Notably, the phylogenetic analysis no longer results in a sister taxon relationship between *Centrosaurus brinkmani* and *Centrosaurus apertus*. *Centrosaurus brinkmani* is therefore referred to a new genus, *Coronosaurus brinkmani* (comb. nov.). A revised diagnosis is provided in Appendix A.

*Xenoceratops foremostensis* is the first described ceratopsian from the Foremost Formation of Alberta and represents the oldest known ceratopsid from Canada. The material comes from a small quarry that includes diagnostic parietal ornamentation from at least three individuals and can be interpreted as a bone bed (sensu Eberth et al. 2007). The morphology of the

parietal–squamosal contact and the presence on the squamosal of a narrow groove that runs across the medial surface at the angle of the “stepped up” margin identifies the material as centrosaurine (Ryan 2007). Although a complete parietal is not present, the available parietal specimens can only be reasonably assembled into one morphology (Fig. 7A).

As reconstructed, the parietal of CMN 53282 has a thickened U-shaped midline posterior margin similar to that seen in centrosaurines that support large P3 spikes (e.g., *Albertaceratops* (Fig. 7E) and *Diabloceratops* (Fig. 7H)). Similar to all centrosaurines except *Centrosaurus apertus*, *Xenoceratops* has large spikes at the P3 loci (although notably the large *Centrosaurus apertus* skull, CMN 348, has a large right P3 process that is very spike-like). These differ from all other centrosaurines except *Albertaceratops* (Fig. 7E) and the chasmosaurine *Medusaceratops lokii* (Ryan et al. 2010) from Montana in being wide-based and pachystotic, and differs from those two ceratopsids in that the processes are straight not curled. *Xenoceratops* lacks P1 processes, as do *Achelousaurus* (Fig. 7D), *Albertaceratops*, *Einiosaurus* (Fig. 7G), and *Pachyrhinosaurus* (Fig. 7F); the only other centrosaurines with large P3 spikes, *Rubeosaurus* and *Styracosaurus* (Fig. 7C), lack or have reduced P2 processes, respectively.

The P2 processes are wide-based and pachystotic and would have been positioned medial to the posterior midline. In overall morphology it resembles the P4 processes of *Albertaceratops*, but the P2 of *Xenoceratops* has a pronounced dorsal inflection. The P2 process of CMN 54950 is more robust than that of CMNH 53282 and has an almost hook-like shape when viewed in lateral profile.

*Xenoceratops* is apomorphic in having ovoid depressions with arched ventral margins occurring at the positions on the lateral parietal margin where epiparietals contact and fuse on other centrosaurines. This interpretation is confirmed by the presence of a partially preserved depression on CMN 54950 at the P4 loci and the presence of a highly fused epiparietal on CMN 53282 at the same position. As interpreted here, the epiparietals fuse into the parietal marginal depressions and then undergo the typical sequence of fusion to the underlying bone. The epiparietal that partially straddles the contact between the parietal and squamosal appears to have the typical centrosaurine contact of overlapping an outgrowth of the parietal.

The anteriormost preserved midline ramus of *Xenoceratops* has an arched cross-section rather than the triangular cross-section that is seen at this position on most centrosaurines. *Albertaceratops* appears to have a similar cross-sectional shape, but this is difficult to confirm owing to the preservation of the only known specimen.

Although no identifiable portions of the postorbitals were preserved with the specimens, an additional, unprepared fragmentary skull (TMP 2010.76.24) was collected from the Foremost Formation in the same region in 2010 that does preserve portions of two large-diameter, elongate postorbital horncores. This material can be referred to *Xenoceratops* based on the presence of apomorphic, shallow epiparietal contacts on parietal fragments that were recovered with the specimen. From this, we infer that *Xenoceratops* had elongate, robust postorbital horncores similar to the similarly aged basal centrosaurines *Albertaceratops* and *Diabloceratops*.

Although fragmentary, the preserved nasal fragment suggests that *Xenoceratops* may have had an elongate, low nasal ornamentation

similar to that of *Medusaceratops* and that which has been reconstructed for *Albertaceratops* (Ryan 2007).

The recognition of *Xenoceratops foremostensis* is a significant addition to the dinosaurian faunal record for the lower portion of the Belly River Group. With the exception of the pachycephalosaur, *Colepiocephale lambei* (Schott et al. 2011), all other dinosaur taxa from the Foremost Formation have been erected based on teeth collected primarily from microvertebrate fossil localities. The relative lack of diagnosable skeletal material is related to the limited amount of exposures in the near-shore terrestrial sequence that constitutes the top of the formation. However, the data from these dinosaurs and the microvertebrate localities indicate that the dinosaurs in the formation are similar at the family level to those in both the overlying Oldman and Dinosaur Park formations (Baszio 1997; Brinkman et al. 2004; Frampton 2007), albeit representing more basal members of these clades. Future work on the tempo and mode of dinosaurian evolution in the Belly River Group will require the recovery and description of more taxa from the regressive lower half of the Belly River Group (Oldman and Foremost formations), where the dinosaur faunas remain poorly known.

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## APPENDIX A

### Systematic paleontology

- Order Ornithischia Seeley, 1888  
 Suborder Ceratopsia Marsh, 1890  
 Neoceratopsia Sereno, 1986  
 Family Ceratopsidae Marsh, 1888  
 Subfamily Centrosaurinae Lambe, 1915  
 Genus *Coronosaurus* gen. nov. previously *Centrosaurus brinkmani* (Ryan and Russell 2005)

**ETYMOLOGY:** *Coronosaurus* refers to *corona* (Latin), for crown, and *saurus* (Latinized Greek), meaning “lizard”, in reference to the multiple occurrences of extra epiparietals that cover the posterior margin of the parietal, giving it a crown-like appearance.

**TYPE SPECIES:** *Coronosaurus brinkmani* (Ryan and Russell 2005).

**HOLOTYPE:** TMP 2002.68.1.

**REFERRED SPECIMENS:** Unless otherwise noted in Ryan and Russell (2005), all the ceratopsid material from BB 138 in Dinosaur Provincial Park, Alberta, and the Milk River Ridge bone bed (MRR BB) near Warner, Alberta, is referred to

*Coronosaurus brinkmani*. Material is listed in Ryan (2003), a copy of which is on file with the Royal Tyrrell Museum of Palaeontology. Significant representatives of the parietal, postorbital, and supraorbitals include TMP 2002.68.3 (Ryan and Russell 2005, fig. 3a), TMP 2002.68.10 (Ryan and Russell 2005, figs. 3d, 3e), and TMP 2002.68.5 (Ryan and Russell 2005, fig. 3f), respectively.

**TYPE LOCALITY:** Bone bed 138, Dinosaur Provincial Park, approximately 50 km from Brooks, Alberta, Canada (12 463090E, 5621680N (WGS 84)), Oldman Formation, 14.6 m below the contact with the Dinosaur Park Formation (645 m above sea level), referable to the Comrey sandstone (Eberth 2005). Additional referred specimens from the MRR BB near Warner, Alberta, approximately 180 km southwest of BB 138, are also from the Oldman Formation. Exact locality information of this bone bed is on file with the TMP.

**DISTRIBUTION:** As for the type and referred localities.

**DIAGNOSIS:** Adult-sized supraorbital horn cores are inflated (but not elongated as in *Zuniceratops*, chasmosaurines, *Albertaceratops*, and *Diabloceratops*) and project laterally over the orbit; sub-adult-sized postorbital horn cores have an attenuated pyramidal shape with a slight lateral inflection of the distal one half; posterior parietal bar has a number of accessory epiparietal ossifications that fuse to the posterior and dorsal surfaces and through ontogeny develop as short spines that may fuse along their adjacent margins into larger, irregular masses. They contribute to the substance of P1 and, through fusion, form the composite epiparietal at the P2 loci. The P3 epiparietal is variably developed as a short tongue-like hook or tapered spike that is dorsolaterally oriented.

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