

**A NEW CAENAGNATHID *OJORAPTOSAURUS BOEREI*, N. GEN., N. SP.  
(DINOSAURIA, OVIRAPTOROSAURIA), FROM THE UPPER CRETACEOUS OJO ALAMO  
FORMATION (NAASHOIBITO MEMBER), SAN JUAN BASIN, NEW MEXICO**

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**Abstract**—A nearly complete pair of pubes is identified as a new caenagnathid oviraptorosaur, *Ojoraptorsaurus boerei*, n. gen., n. sp., based on having a “spoon-shaped” depression on the anterior dorsal surface of the pubic boot, an elongated anterior process of the pubic boot, a recessed enclosed pubic fossa, the distal end of the pubic shaft convex anteriorly, and a sub-trapezoidal pubic peduncle articulation surface. *Ojoraptorsaurus boerei* is most similar to ROM 43250 (previously assigned to *Chirostenotes pergracilis* Gilmore) from the Horseshoe Canyon Formation (upper Campanian-lower Maastrichtian) of Alberta, Canada, but differs from it in having a pubic fossa that is lower on the shaft, a trapezoidal-shaped articulation surface of the pubes, a shorter shaft length and in being more robust. ROM 43250 is placed in a new genus and species, *Epichirostenotes curriei*, that is much younger than *Chirostenotes pergracilis (sensu stricto)*, which may include the holotype of *Macrophalangia canadensis* (CMN 8538) and a referred specimen TMP 79.20.1, all of which are from the Dinosaur Park Formation and predate *E. curriei* by nearly 3 million years. The holotype specimen of *Epichirostenotes curriei* (ROM 43250) differs morphologically from *Chirostenotes pergracilis (sensu stricto)*, based on TMP 79.20.1, in features of the ischium. We note minor differences in the morphology of the left manus of the holotype of *Chirostenotes pergracilis* (CMN 2367) compared to TMP 79.20.1, suggesting that these two may not be conspecific. *Ojoraptorsaurus boerei* is from the Naashoibito Member of the Ojo Alamo Formation, San Juan Basin, New Mexico, and is part of the Alamo Wash local fauna. This fauna is considered to be 69 Ma and thus is early Maastrichtian in age. *Ojoraptorsaurus boerei* represents the southern-most occurrence of a caenagnathid in North America. It is the first and only known caenagnathid from New Mexico and from the lower Maastrichtian of North America.

### INTRODUCTION

Since 1995, the State Museum of Pennsylvania has been actively engaged in systematically collecting micro- and macro-fossil vertebrates from the Upper Cretaceous Fruitland, Kirtland and Ojo Alamo formations, San Juan Basin, New Mexico. Of particular interest are the vertebrates from the upper Kirtland Formation (De-na-zin Member), Willow Wash local fauna (late Campanian) and the younger Ojo Alamo Formation (Naashoibito Member), Alamo Wash local fauna (early Maastrichtian). These two faunas are separated by 3.5 to 4 million years and were co-mingled, in part, by earlier collectors during the late 1970's and 1980's (Lucas et al., 2000; Sullivan et al., 2005a,b; Williamson and Weil, 2008), thus necessitating a rigorous reassessment of their respective faunal compositions.

While collecting in the Naashoibito Member (Ojo Alamo Formation) in the summer of 2002, Arjan C. Boere discovered a nearly complete pair of pubes that belong to a new caenagnathid dinosaur. Here we report on this new caenagnathid, the first to be recognized from New Mexico. This new caenagnathid, *Ojoraptorsaurus boerei*, n. gen., n. sp., not only increases the taxonomic diversity of the Alamo Wash local fauna, but further distinguishes the taxonomic composition of this local fauna at the generic and species level. Moreover, the presence of *O. boerei* further suggests that this is part of a pre-Lancian (late Maastrichtian) vertebrate fauna whose generic and specific composition differs from that of the classic Lance and Hell Creek vertebrate assemblages.

### INSTITUTIONAL ABBREVIATIONS

**AMNH** American Museum of Natural History, New York, NY.  
**BHM** Black Hills Museum of Natural History, Hill City, SD.  
**CM** Carnegie Museum of Natural History, Pittsburgh, PA.  
**CMN** Canadian Museum of Nature, Ottawa, ON, Canada.  
**GIN** Institute of Geology, Mongolian Academy of Sciences, Ulan Bator, Mongolia.

**MOR** Museum of the Rockies, Bozeman, MT.  
**ROM** Royal Ontario Museum, Toronto, ON, Canada.  
**SMP** The State Museum of Pennsylvania, Harrisburg, PA.  
**TMP** Royal Tyrrell Museum of Palaeontology, Drumheller, AB, Canada.

### SYSTEMATIC PALEONTOLOGY

**DINOSAURIA** Owen, 1842

**THEROPODA** Marsh, 1881

**COELUROSAURIA** Huene, 1914

**OVIRAPTOROSAURIA** Barsbold, 1976

**CAENAGNATHIDAE** Sternberg, 1940

*Ojoraptorsaurus*, new genus

**Etymology:** Derived from “*Ojo*” referring to the “Ojo Alamo Formation,” the stratum from which the specimen came; “*raptor*,” a plunderer; and “*saurus*,” meaning lizard.

**Type and only species:** *Ojoraptorsaurus boerei*, n. sp.

**Diagnosis:** As for the species.

*Ojoraptorsaurus boerei*, new species

**Figs. 1-5A**

**Etymology:** The species name honors Arjan C. Boere, who discovered and collected the specimen in 2002.

**Holotype:** SMP VP-1458. Nearly complete paired, fused pubes.

**Type locality, horizon and age:** SMP loc. 384b, (De-na-zin Microsite [south]), near Barrel Springs, San Juan Basin, NM. The holotype was collected from the Naashoibito Member of the Ojo Alamo Formation (*sensu* Bauer, 1916; Powell, 1973; Sullivan and Lucas, 2003, 2006). The age of the Naashoibito Member is “early” Maastrichtian, ~ 69 Ma.

**Diagnosis:** *Ojoraptorsaurus boerei* differs from all other

caenagnathids in possessing the following autapomorphies: 1) a “spoon-shaped” depression on the anterior dorsal surface of the pubic boot; 2) enclosed pubic fossa recessed at least one cm from the acetabular rim, positioned on the medial surface of the pubic shaft; 3) the distal portion of the pubic shaft above the pubic boot is slightly convex anteriorly; and 4) the iliac peduncle articular surface of the pubes is sub-trapezoidal in shape. Differs from the pubes of *Microvenator celer* (AMNH 3041) in having an enclosed, sub-oval to inverted teardrop-shaped pubic fossa. Differs from the pubes of *Epichirostenotes curriei*, n. gen., n. sp. (holotype ROM 43250; see Appendix) in being 20% smaller and relatively more robust, lacking a dorsal suture on the pubic boot, and having a significantly lower pubic apron/pubis length ratio. Differs from the pubes of *Nomingia gobiensis* (GIN 100/119) in having a spoon-shaped depression, lacking a suture on the dorsal surface of the pubic boot and being more gracile. Differs from CM 78001 in having the outline of the acetabular rim less constricted and smaller (approximately two-thirds the size).

**Description:** SMP VP-1458 (Figs. 1-5A) is an incomplete pair of pubes. The holotype was found broken, and most of the pieces that were recovered have been reassembled. Some proximal sections of both pubes are missing. There are some smaller fragments that cannot be reassembled. Nonetheless, a good part of the paired pubes has been restored, allowing for description.

Both the left and right shafts of the pubes are incomplete, and the distal part (Fig. 1) is partially intact, with the pair fused distally at the pubic boot. The left distal portion of the boot is better preserved and more complete than the right. The lower part of the right shaft is slightly curved (convex anteriorly); the left appears to be curved in the same manner, but it is slightly distorted, with the surface fractured and incomplete.

The broken surface of the pubic apron forms a prominent scar along the medial side of the right shaft, and is visible for its entire length (Fig. 1A, D). Immediately above the apron scar is a slightly raised ridge that extends for about 1.5 cm. The upper part of the right pubis is incomplete along the lateral side. The ventromedial lower part of the right shaft is crushed where it joins with the left shaft immediately above the pubic boot.

The pubic boot (Fig. 2) is incomplete, eroded along the ventral surface, and is broken posteriorly. Therefore, the full extent of the posterior process of the pubic boot cannot be determined with certainty, but it appears to have been shorter than the anterior part based on extrapolation of the posterior dorsal surface. The anterior dorsal surface of the boot is distinguished by a prominent “spoon-shaped” depression (Fig. 1B-C), which extends far forward. The long axis of this depression measures 5.7 cm, from the point where the two pubes join to the anterior-most portion of the pubic boot. The boot itself appears to have been strongly laterally compressed, and traces of the medioventral boot groove (Fig. 1D) are seen at both the anterior- and posterior-most parts of the boot (measuring 2.2 cm and 3.1 cm, respectively).

Laterally, the left side of the pubic boot is more complete than the corresponding right side. The dorsal lateral surface is smooth and “rim-like.” Three lateral impressions are visible on the left side (Fig. 2B) above the eroded region. Two of these correspond to similar depressions on the right lateral surface (Fig. 2A). These depressions are flanked by multiple hair-line fractures, strongly suggesting that they are postmortem features and thus are not morphologically significant. In addition, on the right side there is a prominent groove (Fig. 2A) that extends from the eroded surface along the laterodorsal surface for approximately 5.2 cm, terminating and tapering to a point above the symphysis of the pubes. The maximum thickness of this groove is 0.45 cm at its distal-most extent. The groove cuts through the hair-line fractures associated with the posterior-most depression on the right lateral surface, suggesting that this depression is a postmortem artifact.

There are three main fragments from the proximal end of the shafts (Fig. 3A-B), which include the terminal ends that articulate with

the pubic peduncle of the ilium. One, the left (Fig. 3B), includes a portion of the lower shaft with a segment of the pubic fossa. The two other fragments (Fig. 3A) are from the corresponding right side, but they are missing a section between the lower fragment and the terminal (proximal) end.

On the left proximal end, the articular surface that joins with the left pubic peduncle of the ilium is sub-trapezoidal in cross-section (Fig. 3D). The widest side faces posterior ventral, and the shortest side faces anterior dorsal. The posterior ventral side is a curved surface that participates in the acetabular opening. On the medial surface, directly below the articulation surface of the terminal (proximal) end, is a distinct groove (Figs. 3B, 4C, 5A). This groove measures 2.3 cm (maximum), and is visible on the right process (Fig. 3A). The right process is slightly crushed, whereas the left does not display any deformation, indicating that the groove is a natural feature.

The lower portion of the left fragment flares out posterior medial and is broken. Consequently, the ischial articulation surface of the pubis is missing. This portion of the pubis is distinguished by a prominent rim of the enclosed fossa (Figs. 3B, 4C, 5A) that is situated medially. The right lower fragment corresponds to that of the left, flaring out medially toward the proximal end, but it is broken along the posterior margin. The terminal end of the right pubis is crushed mediolaterally (Fig. 3C), with the lateral side showing stepwise semiconcentric crushing extending upward to the proximal articular surface.

## DISCUSSION AND COMPARISONS

The caenagnathids are a rare and somewhat enigmatic monophyletic group of oviraptorosaur dinosaurs from North America and Asia. There is also one problematic taxon, *Thecocoelurus daviesi*, reported from the Early Cretaceous of the Isle of Wight, considered to be an oviraptorosaur similar to *Chirostenotes* (Naish and Martill, 2002). This taxon has been regarded as a *nomen dubium* by Osmólska et al. (2004). Oviraptorosaurs have been reported from a few sites in North America (Alberta, Montana, South Dakota, and Utah) and Asia (Uzbekistan, Mongolia, and China) (Currie et al., 1993; Varricchio, 2001; Lü, 2002; Osmólska et al., 2004). The oviraptorid record is by far more complete in Asia than North America, whereas the caenagnathid record is better in North America. The majority of the fossil record of the Caenagnathidae consists of meager remains; including a fragmentary skull, a complete mandible and a few incomplete ones, and some isolated postcrania (Osmólska, 2004).

This fact was most recently and eloquently stated by Zanno and Sampson (2005), who were reluctant to accept the synonymy of *Chirostenotes* and *Caenagnathus* of Sues (1997). Along these lines, we doubt Sues' (1997) assessment that ROM 43250 is referable to *Chirostenotes pergracilis*. We note below that ROM 43250 is a distinct caenagnathid (see Appendix) recovered from the lower Horseshoe Canyon Formation, a unit that is much younger than the strata that yielded the holotype of *Chirostenotes pergracilis*. Moreover, the incomplete nature of the holotype of *Chirostenotes pergracilis*, plus the fact that ROM 43250 is 20%-30% larger than another specimen (TMP 79.20.1), also referred to *C. pergracilis* (Currie and Russell, 1988), strongly suggests that it is not the same taxon (genus and species). While such a conservative taxonomic assignment may be advocated by some in lieu of naming a new taxon, we regard extending the temporal and geographic range of a taxon without adequate morphological information to be misleading. We note, too, that our understanding of the precise biostratigraphic occurrence must be considered in assessing taxa. Fortunately, we now have a better understanding of the precise biostratigraphic occurrences of many holotypes from the “Judith River” and “Belly River” units (old terminology) in the area of Dinosaur Provincial Park, Alberta, largely due to the ongoing work of David Eberth and others. Indeed, taxonomic assignments based on undiagnostic material and imprecise stratigraphic data have frequently lead to inaccurate identifications and erroneous biostratigraphic distributions of taxa in groups such as the pachycephalosaurids (e.g., Sullivan, 2006).

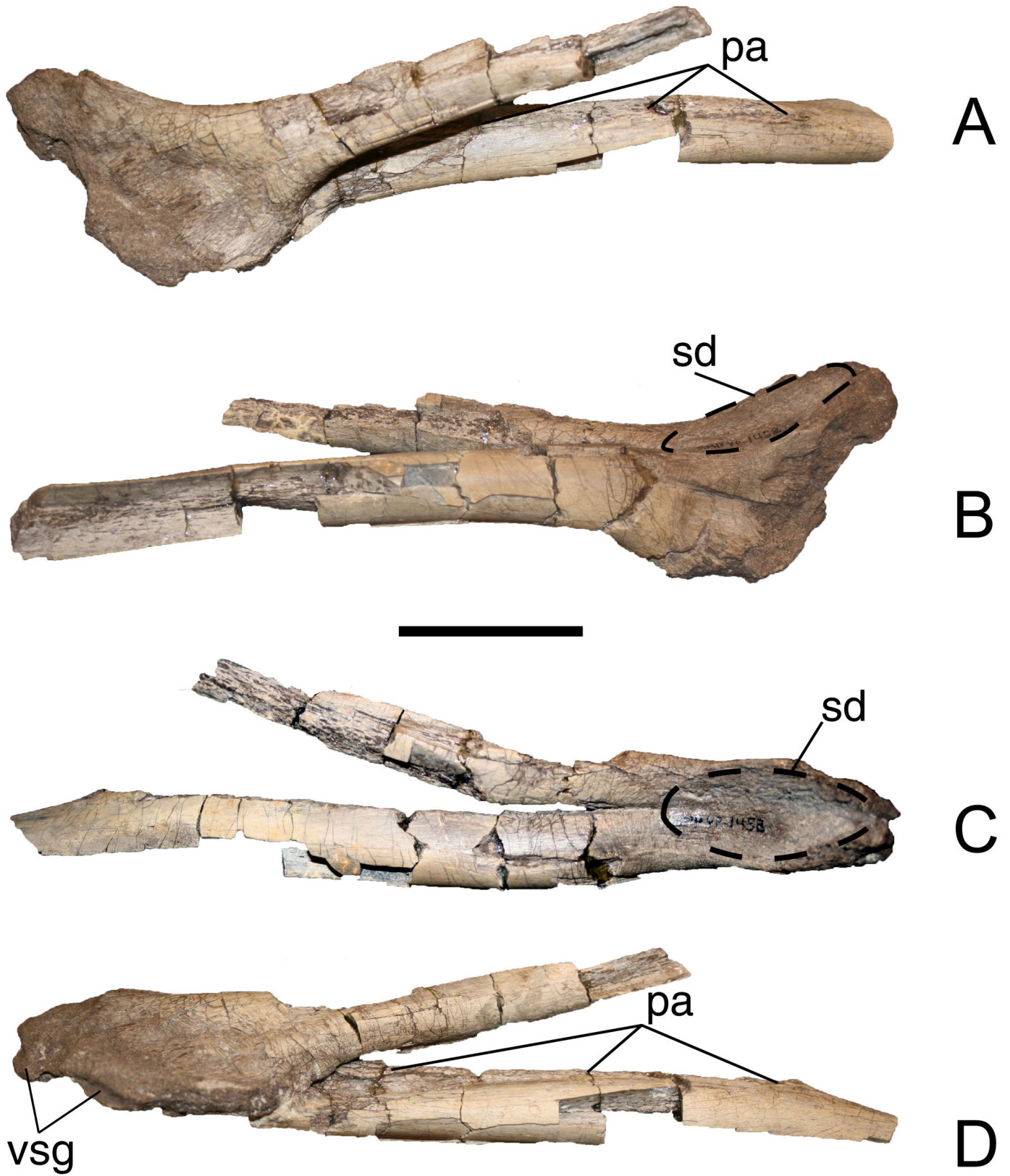


FIGURE 1. *Ojoraptorsaurus boerei*, n. gen., n. sp., SMP VP-1458, holotype, distal portion of nearly complete pubes in **A**, left lateral, **B**, right lateral, **C**, dorsal (superior) and **D**, ventral (inferior) views. **Abbreviations:** **pa**, pubic apron (scar); **sd**, spoon-shaped depression of pubic boot; **vsg**, groove along ventral surface of boot. Scale bar 5 cm.

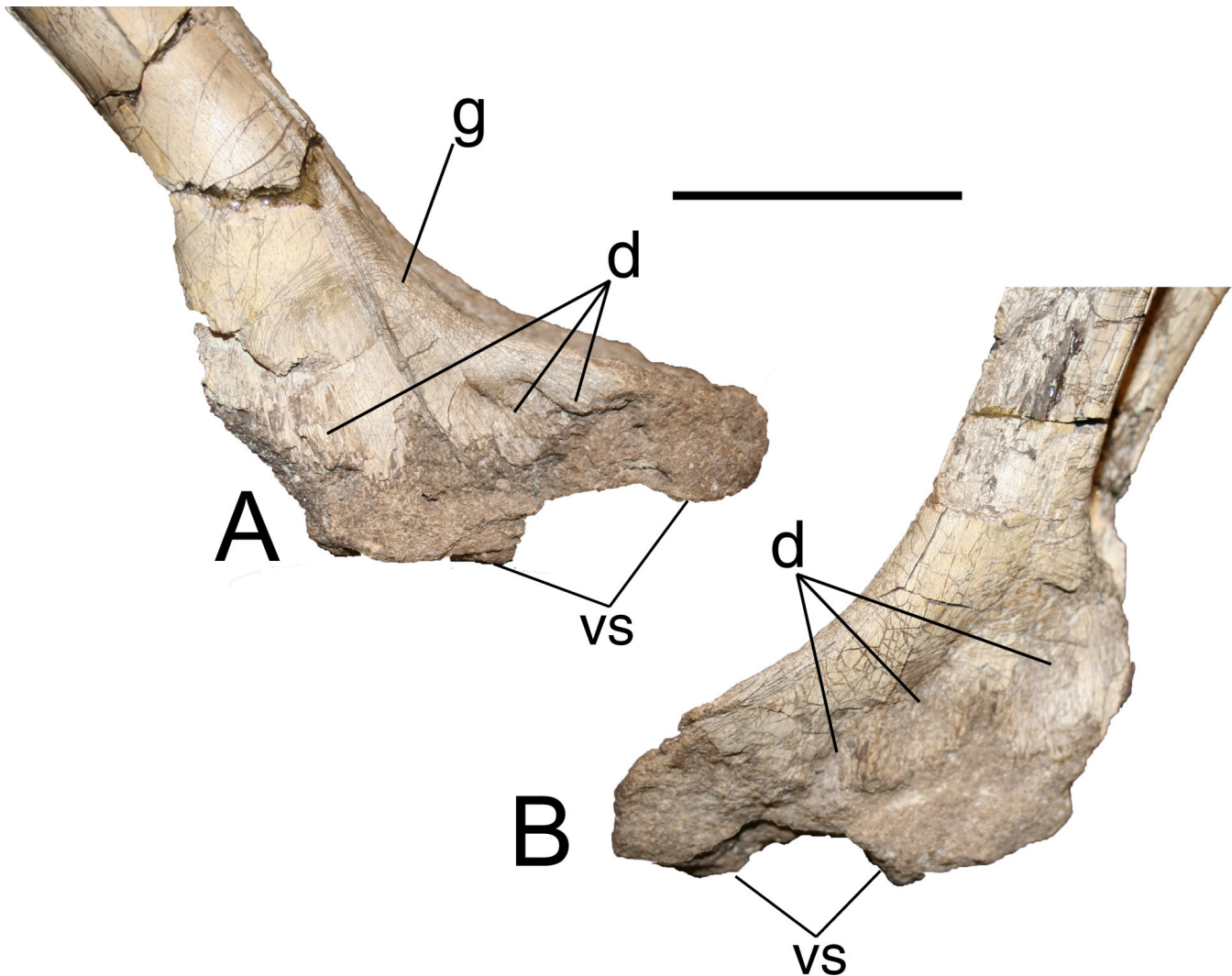


FIGURE 2. *Ojoraptorsaurus boerei*, n. gen., n. sp., SMP VP-1458, close up of pubic boot in **A**, right lateral and **B**, left lateral views. **Abbreviations:** **d**, depression(s); **g**, groove; **vs**, ventral surface of pubic boot. Scale bar 5 cm.

The oviraptorosaur *Hagryphus giganteus*, a taxon not assigned to any specific family, is known from a nearly complete left carpus and manus from the Kaiparowits Formation of Utah (Zanno and Sampson, 2005). *Hagryphus giganteus* is of a similar age to TMP 79.20.1, straddling the Judithian-Kirtlandian LVAs, approximately 76–74 Ma based on the correlation of this unit by Sullivan and Lucas (2006). Unfortunately, no pubes are known from *H. giganteus*.

While the pubes of *Citipati*, *Khaan*, and *Ingenia* are known, they remain largely undescribed. The pubes of the two former taxa are partly exposed in their respective holotype specimens, but the medial sides and morphology of the pubic boot and proximal ends are not known because they are not visible. The pubis of *Ingenia*, while figured as part of a line drawing of the pelvis (Barsbold et al., 1990; Osmólska et al., 2004), has not been described or photographed in the primary literature, so the morphology of the medial surfaces of the pubes are unknown. The pubes of the giant oviraptorid *Gigantoraptor erlianensis* (Xu et al., 2007) have not been described in detail, and photos of the holotype, kindly provided by Xing Xu, show that the proximal ends of both pubes are not preserved.

Our comparisons, therefore, are confined to the pubes of four specimens: the holotype of *Microvenator celer* (AMNH 3041); *Epichirostenotes curriei*, n. gen., n. sp. (ROM 43250), previously assigned to *Chirostenotes pergracilis*; the holotype of *Nomingia gobiensis*

(GIN 100/119); and an unnamed caenagnathid (CM 78001).

***Microvenator celer* (AMNH 3041):** *Microvenator celer* (Ostrom, 1970) was cited as a possible oviraptorosaur (Osmólska et al., 2004). The holotype (AMNH 3041) is an incomplete skeleton from the Lower Cretaceous Cloverly Formation (late Aptian-early Albian) of Montana and includes a complete pair of pubes coalesced at the pubic boot. In his description of this element, Ostrom (1970) noted that the pubis profile was concave anteriorly and that the distal extremities were only moderately expanded. He concluded that *Microvenator celer* was one of the smallest theropods known and that the holotype specimen was mature despite the presence of unfused neural arches and centra in some of the vertebrae. Also, Ostrom (1970) noted that the vertebral dimension/ratios and the “elongated, rod-like” form of the pubis set it apart from the dromaeosaurids. He assigned *Microvenator celer* to the Coeluridae.

Makovicky and Sues (1998) re-described the holotype of *Microvenator celer* and identified four autapomorphies. One of these (deep concavity on the proximomedial part of the pubis) warrants special attention, as this feature is similar to the enclosed pubic fossae seen in other caenagnathid taxa and might indicate caenagnathid affinities. However, our examination of this depression reveals that it differs significantly from all other caenagnathids, in that it is more proximal in position, widely expanded, not enclosed, sub-triangular in shape, and it extends to the margin of the acetabulum (Fig. 5C). In *Ojoraptorsaurus*

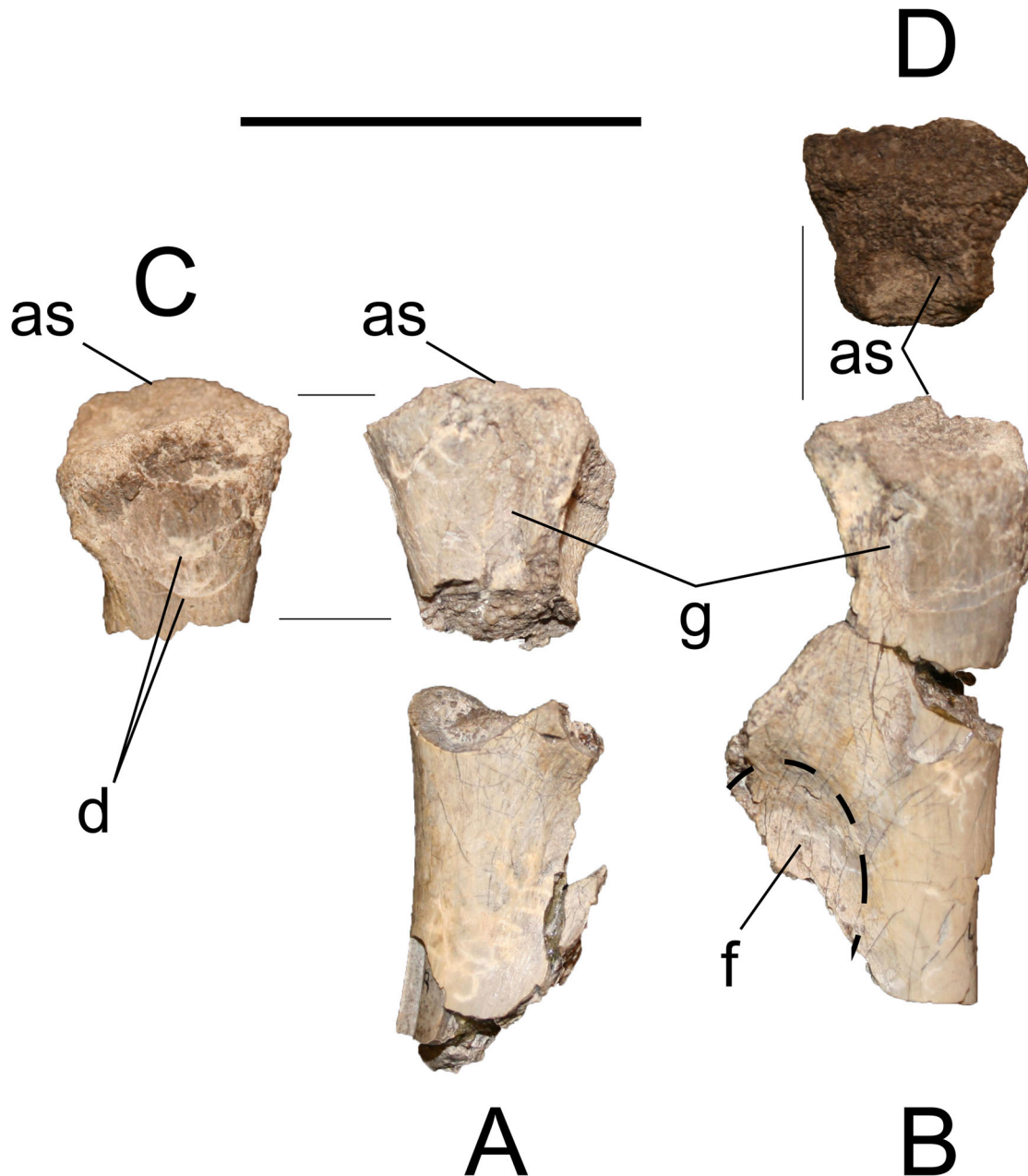


FIGURE 3. *Ojoraptorsaurus boerei*, n. gen., n. sp., SMP VP-1458, proximal portions of nearly complete pubes. **A**, Incomplete right proximal end and lower part of shaft (medial view). **B**, Incomplete left proximal end (oblique medial view). **C**, Right proximal end (lateral view). **D**, Articulation surface of left pubis in proximal view. **Abbreviations:** **d**, depression(s); **f**, fossa; **g**, groove. Scale bar 5 cm.

(SMP VP-1458), CM 78001, *Nomingia* (GIN 100/119) and *Epichirostenotes* (ROM 43250), the depression is enclosed and is located farther down on the medial side of the pubis, having a sub-oval to inverted, teardrop-shape form (Fig. 5A, B, D). *Microvenator celer* lacks this enclosed pubic fossa, which separates it from all known caenagnathids where the pubis is known. We interpret this feature, the enclosed pubic fossa, as a synapomorphy of the Caenagnathidae.

***Epichirostenotes curriei*, n. gen., n. sp. (ROM 43250, see Appendix):** Sues (1997) described an incomplete caenagnathid skull and skeleton (ROM 43250) that he referred to *Chirostenotes pergracilis*. Reference to this taxon was made based on TMP 79.20.1, a specimen described by Currie and Russell (1988) from the upper half of the Dinosaur Park Formation. TMP 79.20.1 only has some of the left manus elements in common with the holotype of *Chirostenotes pergracilis*

(CMN 2367); these are: metacarpal I, phalanx I-1 and I-2 (ungual); phalanx II-1, II-2 and II-3 (ungual); and phalanx III-3 (Gilmore, 1924; Currie and Russell, 1988). However, we note that in comparing the illustrations of the holotype (CMN 2367; see Gilmore, 1924, fig. 1) to that of TMP 79.20.1 (see Currie and Russell, 1988, fig. 4) that there are some minor morphological differences, including a broader curvature of unguis I and II, a deeper unguis (measured from the dorsal and plantar extremity of the articular facet as per Senter, 2007), and a shorter phalanx III-3. Whether this variation is significant is debatable; however, we note that there are differences. The observation further weakens the support for the notion that ROM 43250 is congeneric with *Chirostenotes*.

Despite the many similarities that Sues (1997) noted between TMP 79.20.1 and *Epichirostenotes curriei* (ROM 43250), there are also some compelling differences that suggest that the two specimens repre-

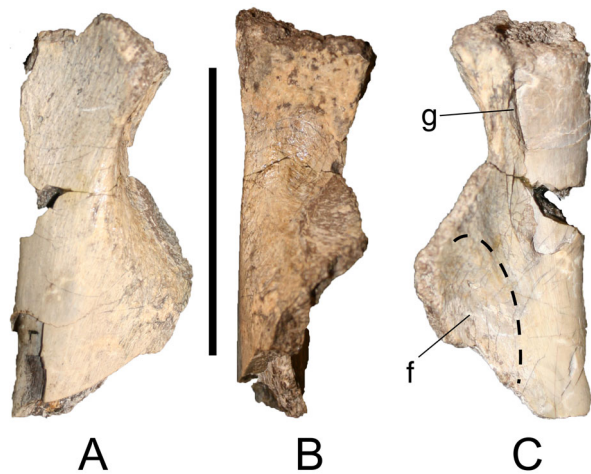


FIGURE 4. *Ojoraptorsaurus boerei*, n. gen., n. sp., SMP VP-1458, close-up of proximal left end of pubes in A, lateral, B, posterior (caudal) and C, medial views. **Abbreviations:** f, fossa; g, groove. Scale bar 5 cm.

sent different caenagnathids. The most striking differences are in the morphology of the right ischia as illustrated by Sues (1997, fig. 9). Aside from the difference in size between the two specimens (*Epichirostenotes curriei* is 20%-30% larger than TMP 79.20.1), the ischium of TMP 79.20.1 differs in: 1) being shorter, more abbreviated posteriorly; 2) being narrower behind the obturator process; 3) having a restricted obturator process; and 4) in lacking a prominent proximal anterior hook-like projection of the ischia. Based on these differences, we recognize *Epichirostenotes curriei* as distinct from TMP 79.20.1, which may, or may not, in fact be *Chirostenotes pergracilis* (see discussion above).

The pubes of *Epichirostenotes curriei* (ROM 43250) differ from those of *Ojoraptorsaurus boerei* in being larger and more gracile. Sues (1997) considered ROM 43250 to be a mature individual based on fusion of the neural arches to the centra of the vertebrae. Although *Ojoraptorsaurus boerei* is known solely by the pubes, we interpret the holotype (SMP VP-1458) to be of a mature individual based on the fusion of the pubic boot, which is supported by the absence of a distinct suture along the dorsal surface within the region of the “spoon-shaped” depression. Moreover, the pubes of *Epichirostenotes curriei* (ROM 43250) are crushed and, in part, distorted. The proximal process of the pubes most closely conforms to those of SMP VP-1458, but there are some differences. The proximal articulation surfaces of the pubes are sub-rectangular in shape compared to the sub-trapezoidal shape seen in *Ojoraptorsaurus*. Viewed medially, the acetabular rim of the left pubis is similar in size and outline to that of SMP VP-1458 (Fig. 5A, D). The proximal-most part of the pubic fossa lies adjacent to the acetabular rim, whereas in *Ojoraptorsaurus* it lies 1.0 cm below. The enclosed pubic fossa is complete and has an inverted “teardrop-shaped” form. It measures approximately 4.4 cm long and has a maximum width of 1.8 cm (Fig. 5D). There is a distinct groove located posteriorly on the medial surface of the proximal end directly below the articulation surface of the left pubis. The corresponding right pubis is crushed and does not preserve these features. Posteriorly, there is a distinct depression below the articulation surface and the medio-directed flange that forms the upper end of the left pubic fossa.

The profiles of the pubes are nearly straight as noted by Sues (1997). However, the distal end, near the pubic boot, is slightly concave anteriorly, which is the opposite of the condition found in *Ojoraptorsaurus boerei*. Toward the proximal end, the shaft appears to be convex anteriorly in *Epichirostenotes curriei* (ROM 43250), but we note that the specimen has been crushed and distorted. The profile of the shaft is uncertain in *Ojoraptorsaurus* due to breakage of both proximal ends.

The flange of the left pubic apron extends medially near the proxi-

mal-most region. The ratio between the length of the pubic apron to that of the pubis is 0.49, which is far from 0.38, the ratio for *Ojoraptorsaurus boerei* (Table 1).

As noted by Sues (1997), the pubic boot of *Epichirostenotes curriei* (ROM 43250) is crushed and incomplete. There is a hint of a depression on the dorsal-most part of the pubic boot. Also, there is a trace of a suture on its dorsal surface. Unfortunately the pubic boot is so crushed, distorted and incomplete, that no other informative comparisons can be made.

*Epichirostenotes curriei* shares a few features with *Ojoraptorsaurus boerei* including a similar-sized enclosed pubic fossa (on the left pubis) and the general morphology of the acetabular rim region (see Fig. 5A, D). It differs in having differently-shaped articulation surfaces of the pubes (with the pubic peduncle). The pubic fossa is slightly lower on the shaft in *Ojoraptorsaurus*, and the distal portion of the shaft, above the pubic boot, is slightly convex anteriorly. *Epichirostenotes curriei* (ROM 43250) is also approximately 20% larger, considering that they are both mature individuals.

***Nomingia gobiensis* GIN 100/119:** *Nomingia gobiensis* is known solely from an incomplete postcranial skeleton (GIN 100/119), including the tip of the tail that is fused to form a “dagger-like pygostyle,” from the Upper Cretaceous Nemegt Formation, Mongolia (Barsbold et al., 2000a, b). It was first thought to be a theropod of uncertain family affinities, then later it was considered to be a possible caenagnathid, closely related to “*Chirostenotes*,” based on ROM 43250 (Maryńska et al., 2002; Osmólska et al., 2004).

Despite some breakage, the coossified pubes (Fig. 6) of the holotype are nearly complete and virtually undistorted. In lateral view, the pubes are slightly concave anteriorly. The pubic boot is complete, and the anterior and posterior projections of the pubic boot are subequal, with the posterior projection slightly longer (Fig. 6). Anterior dorsally, there is no “spoon-shaped” depression as seen in *Ojoraptorsaurus*, rather there is a distinct deep suture that extends to the anterior tip of the pubic boot. The proximal end is distinctly curved anterior dorsally. Medially, there is an enclosed pubic fossa below the acetabular rim. Overall, the pubes of *Nomingia gobiensis* appear more robust than those of *Ojoraptorsaurus boerei* and *Epichirostenotes curriei* (ROM 43250). Based on the presence of the enclosed pubic fossa, we regard *Nomingia* to be a member of the Caenagnathidae (see below).

**CM 78001 (unnamed caenagnathid):** CM 78001 is an undescribed caenagnathid consisting of an incomplete skull and skeleton from the Hell Creek Formation of South Dakota. This specimen is currently being studied by Sues and Lamanna (in prep.) and will be thoroughly described elsewhere. The pubes of CM 78001 are nearly complete. In lateral view, the pubes are nearly straight, with the proximal ends slightly curved anterior dorsally. A well-defined enclosed pubic fossa is present on both pubes, and both fossae lie immediately below the acetabular rims (Fig. 5B). There is a groove above each fossa below the articular surface, as in *Epichirostenotes curriei* and *Ojoraptorsaurus boerei*. The outline of the acetabular rim is more constricted than that of *Epichirostenotes* and *Ojoraptorsaurus*. The pubic apron is intact toward the proximal end, and the distal half of the apron is broken on both pubes. The pubic boot is largely absent, and only the proximal surface is partly preserved. The ventral surface is either severely eroded, or it is pathologic. Both the anterior and the posterior projections of the pubic boot are missing. The pubes of CM 78001 are the largest and the most massive of all the pubes we have examined for this study. The pubes of *Ojoraptorsaurus boerei* are approximately two-thirds the size of those of CM 78001. Based on this, we conclude that *Ojoraptorsaurus boerei* was a medium-sized caenagnathid, around 1.8 to 2.1 meters in length.

#### SYSTEMATIC POSITION

Makovicky and Sues (1998) presented a phylogenetic analysis that resulted in an apical trichotomy between *Microvenator*, the Oviraptoridae and the Caenagnathidae, with the Therizinosauroidae as

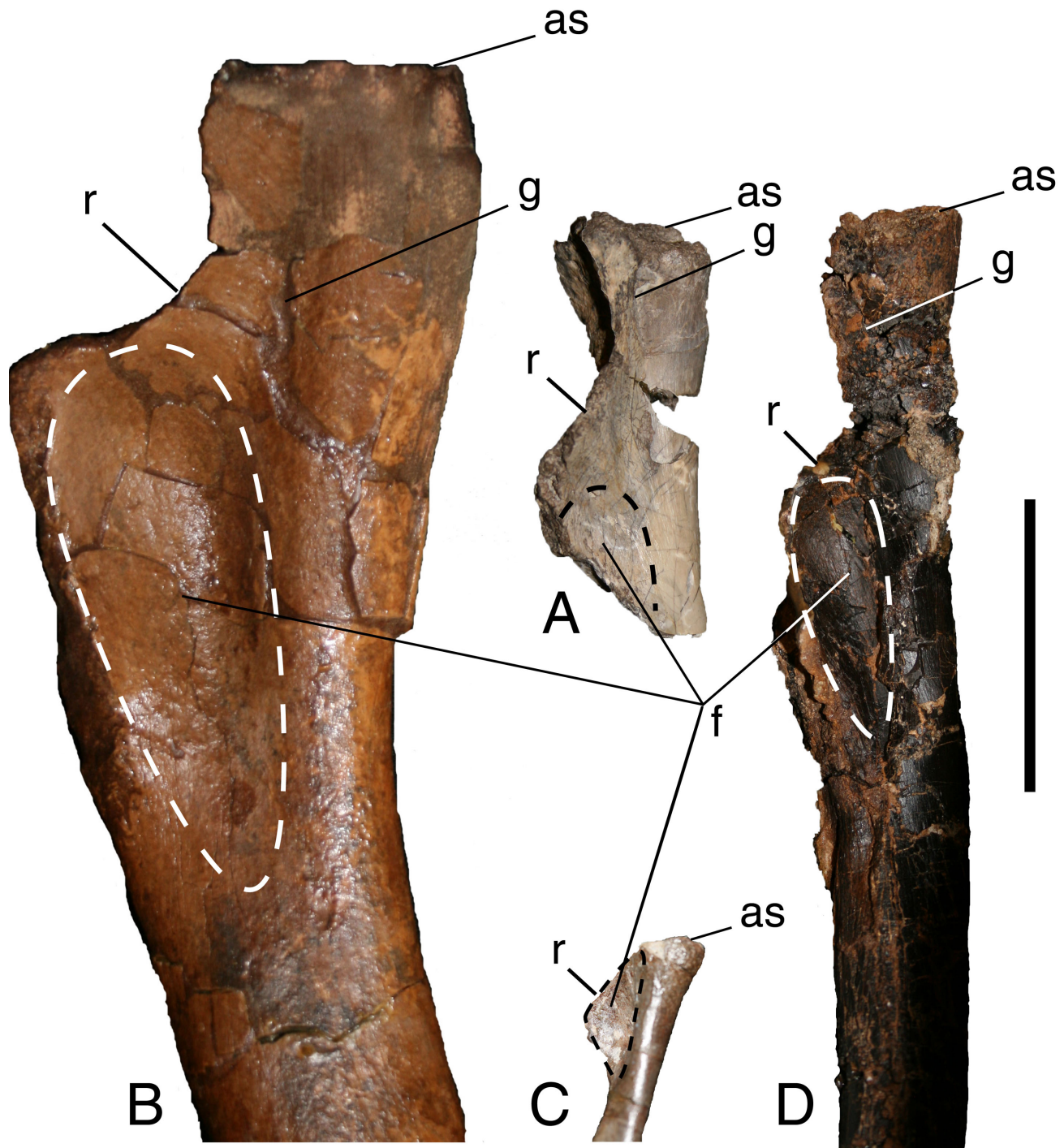


FIGURE 5. Comparison of the medial proximal regions of the left pubes of the North American caenagnathids. **A**, Holotype of *Ojoraptorsaurus boerei*, n. gen., n. sp. (SMP VP-1458). **B**, Unnamed caenagnathid (CM 78001). **C**, Holotype of *Microvenator celer* (AMNH 3041). **D**, ROM 43250 (formerly referred to *Chirostenotes pergracilis*). **Abbreviations:** as, articulation surface of pubis; f, fossa; g, groove; r, rim of acetabulum. Scale bar 5 cm.

the sister taxon. Based on our study of the pubes, *Ojoraptorsaurus boerei* shares some key features with *Epichirostenotes curriei*, *Nomingia gobiensis* and CM 78001, thus placing it within the Caenagnathidae.

Maryańska et al. (2002) noted that the clade Caenagnathidae is “poorly differentiated” and that much of the material is not well preserved. Moreover, we note here that their characterization of “*Chirostenotes pergracilis*” is based on ROM 43250, herein *Epichirostenotes curriei*, not to be confused with the holotype of the former taxon. Within the Caenagnathidae, Maryańska et al. (2002) recog-

nized that only two characters are shared by *Nomingia* and *Epichirostenotes curriei* (= “*Chirostenotes pergracilis*” *sensu lato*): 1) dorsal surface of the ilium arched along central portion of the blade; and 2) preacetabular process of the ilium longer than the postacetabular process. These characters been recognized as having utility in defining the Caenagnathidae. We here add a third synapomorphy, the enclosed pubic fossa that is seen in *Epichirostenotes*, *Ojoraptorsaurus*, *Nomingia* and CM 78001. Based on the lack of an enclosed pubic fossa, we exclude *Microvenator* from the Caenagnathidae.

TABLE 1. Measurements (in centimeters) of selected landmarks on the pubes of critical caenagnathid and other theropod specimens. **1**, Overall length of pubis. **2**, Pubic boot to maximum extent of pubic apron. **3**, Pubic boot to base of pubic apron. **4**, Pubic apron length. **5**, Maximum length of pubic fossa. **6**, Pubic apron/pubis length ratio.

Taxon	1	2	3	4	5	6
<i>Ornithomimus edmontonicus</i> (= <i>Dromiceiomimus breviterius</i> ) (AMNH 5201)	37.2	24.8	6.3	18.5	n/a	0.49
<i>Microvenator celer</i> (AMNH 3041, holotype)	10.8	5.7	1.3*	4.5	1.3	0.42
<i>Nomingia gobiensis</i> (GIN 100/119, holotype)	24.3	13.4**	6.2**	7.0**	3.5**	0.29
<i>Ojoraptorsaurus boerei</i> (SMP VP-1458, holotype)	34.4*	21.7	8.2	13.2	-?-	0.38
CM 78001 (unnamed caenagnathid)	47	27.5	11	16	7	0.34
<i>Epichirostenotes curriei</i> (ROM 43250, holotype)	41.7***	26.6***	6.7***	20.4	5.2****	0.49

**KEY**

\*estimated measurement

\*\*estimated measurement based on photograph(s)

\*\*\*incomplete (boot)

\*\*\*\*measurement from left pubic fossa

We measured the lengths of the pubic aprons of *Microvenator celer* and all the caenagnathid specimens, where pubes are known, as well as those from a specimen identified as *Dromiceiomimus breviterius*, now known as *Ornithomimus edmontonicus* (for outgroup purposes), and compared them to the overall length of the pubes (Table 1). The ratios obtained do not reveal any obvious relationships.

To summarize, *Ojoraptorsaurus boerei* appears to be closely allied to *Epichirostenotes curriei*, but differs from it in: 1) the shape of the proximal articulation surface of the pubes; 2) having the enclosed pubic fossa located 1.0 cm from the acetabular rim; 3) having the distal portion of the pubic shaft slightly convex anteriorly; 4) being somewhat more robust; 5) having a “spoon-shaped” depression on the anterior dorsal surface of the pubic boot; and 6) lacking an anterior dorsal boot suture. Given that both the holotypes of *Epichirostenotes curriei* (ROM 43250) and *Ojoraptorsaurus boerei* (SMP VP-1458) represent mature individuals, we regard these morphological differences as being taxonomically significant.

#### STRATIGRAPHY AND AGE OF *OJORAPTOSAURUS BOEREI*

The holotype of *Ojoraptorsaurus boerei* (SMP VP-1458) was recovered from the Naashoibito Member of the Ojo Alamo Formation at Barrel Springs, San Juan Basin, New Mexico. The stratigraphy and age of the Naashoibito Member have been in dispute for some time. Sullivan and Lucas (2003, 2006) included this unit in the Ojo Alamo Formation (formerly Ojo Alamo Sandstone), following the work of Bauer (1916) and Powell (1973), based on lithologic character and sedimentologic source, which differ from the underlying Kirtland Formation.

The age of the Naashoibito Member, and its contained fauna (the Alamo Wash local fauna; see Lehman, 1981), has also been contentious. Fassett (2005, 2009) and Fassett et al. (2000, 2002) have argued for a Paleocene age based on some key palynomorphs, an argument that has been rejected by many (Sullivan et al., 2002, 2003, 2005b; Sullivan and Lucas, 2003, 2006; Fastovsky and Sheehan, 2005; McKenna and Lillegraven, 2005; McKenna, 2007). Sullivan and Lucas (2003) correlated the Naashoibito Member to the base of the Maastrichtian, and in subsequent papers, assigned a numerical age of 69 Ma using the occurrence of *Alamosaurus sanjuanensis* as the primary datum (Sullivan et al., 2005a, b; Sullivan and Lucas, 2006), rejecting the interpretation that the fauna is Lancian age, most recently published by Williamson and Weil



FIGURE 6. *Nomingia gobiensis* GIN 100/119 (holotype), a well-documented caenagnathid oviraptorosaur. Lateral view of left pubis showing major axis bisecting the shaft of the pubis and the corresponding anterior posterior lengths of the pubic boot. **A** to **B**, anterior boot length = 45% of total boot length; **B** to **C**, posterior boot length = 55% of total boot length. This ratio invalidates the character (synapomorphy) for the Oviraptorosauria cited by Osmólska et al. (2004) as “the cranial process on the pubic foot longer than the caudal process.” This specimen clearly shows the opposite relationship.

(2008). Therefore, the Alamo Wash local fauna, including *Ojoraptorsaurus boerei*, is considered to be “late Edmontonian,” “pre-Lancian,” or early Maastrichtian in age (Sullivan and Lucas, 2006).

#### BIOSTRATIGRAPHY OF NORTH AMERICAN CAENAGNATHIDS

**Dinosaur Park Formation:** The holotype of *Chirostenotes pergracilis* (CMN 2367), which consists solely of phalanges of both the right and left manus (Gilmore, 1924; Currie et al., 1990), was probably recovered from the lower half of the Dinosaur Park Formation, within magnetochron 33n, 4n, which is no older than 76.5 Ma (Eberth, pers. comm. to RMS, 2008). The holotype of *Macrophalangia canadensis* (CMN 8538) is also known from the lower half of the Dinosaur Park Formation and was synonymized with *Chirostenotes pergracilis* by Currie and Russell (1988). This synonymy was based on elements of the pes belonging to TMP 79.20.1, which in turn was considered to be *Chirostenotes pergracilis* based on elements of the manus.

TMP 79.20.1 comes from the upper half of the Dinosaur Park Formation, placing it in magnetochron 33n, 3n, at 75.3 Ma (Eberth, 2005).

The holotype of *Caenagnathus collinsi*, which was synonymized with *Chirostenotes pergracilis* by Sues (1997), came from the Dinosaur Park Formation. We note here that Varicchio (2001) did not formally recognize all the synonymies of Sues (1997), but Osmólska et al. (2004) accepted them.

The holotype of *Caenagnathus sternbergi*, also from the Dino-



saur Park Formation, was synonymized with *Chirostenotes elegans* (Sues, 1997; Osmólska et al., 2004). We note that these two taxa are based on holotypes that have no elements in common (the former is a lower jaw and the latter is an incomplete foot). This synonymy was rationalized on the basis of both specimens being “gracile” in form.

The holotype of “*O.*” *elegans* (= *Chirostenotes elegans sensu* Sues, 1997) is from the Dinosaur Park Formation (D. Eberth, pers. comm. to RMS, 2009). The assignment of the holotype of “*O.*” *elegans* to *Chirostenotes* is tenuous, because of assumptions regarding the gracile morphology, which is seen in both taxa (“*O.*” *elegans* and *Caenagnathus sternbergi*). Strata of the Dinosaur Park Formation range from 76.5 to approximately 75 Ma (Eberth, 2005).

**Horseshoe Canyon Formation:** *Epichirostenotes curriei* (ROM 43250) was recovered from the lower part of the Horseshoe Canyon Formation, in coal swarm #8, just below the Drumheller Marine Tongue, placing it in magnetochron 32n, 3n (Eberth, pers. comm. to RMS, 2008). This would place it at about 72 Ma based on the correlation provided by Lerbekmo and Braman (2002).

**Ojo Alamo Formation (Naashoibito Member):** *Ojoraptorsaurus boerei* is from the Naashoibito Member of the Ojo Alamo Formation, which has been correlated to magnetochron 31r. This stratum is considered to be ~ 69 Ma (Sullivan and Lucas, 2006).

**Hell Creek Formation:** Currie et al. (1993) and Varricchio (2001) assigned BHM 2033, a left articular-surangular-coronoid complex, to *Caenagnathus sp.* from the Hell Creek Formation of South Dakota. Varricchio (2001) assigned another specimen (MOR 752), a partial left foot from the Hell Creek Formation of Montana, to *Elmisaurus* (= “*Chirostenotes*”) *elegans*. This taxonomic referral is based solely on a partial left metatarsal II, which we consider insufficient for assigning the specimen to either *Chirostenotes* or *Elmisaurus* (*sensu* Varricchio, 2001) based on the type material (i.e., “*O.*” *elegans*). Lastly, CM 78001 is an undescribed partial skeleton and skull and is the most complete caenagnathid known from North America. It is from the Hell Creek Formation of South Dakota and is currently under study by Sues and Lamanna. All Hell Creek specimens are of Lancian age (65.58 – 67.61 Ma, *sensu* Cifelli et al., 2004).

**Comments:** We regard the biostratigraphic distribution of North American caenagnathids presented by Osmólska et al. (2004) to be incorrect, based on our analysis of the holotypes and key specimens of North American taxa. *Chirostenotes* (*sensu stricto*) is restricted to the Dinosaur Park Formation. The taxa *C. pergracilis*, *Macrophalangia canadensis*, *Caenagnathus collinsi*, *Caenagnathus sternbergi*, and “*O.*” *elegans* are also restricted to this formation. All of these taxa are Judithian age. *Epichirostenotes curriei* is known only from the lower Horseshoe Canyon Formation and is considered to be of post-Kirtlandian (early “Edmontonian”) age. *Ojoraptorsaurus boerei* is known only from the Ojo Alamo Formation (Naashoibito Member), which is of late “Edmontonian” (pre-Lancian *sensu stricto*) age. All the Lancian (*sensu stricto*) caenagnathids from the Hell Creek (BHM 2033, CM 78001, MOR 752) are probably unnamed, new taxa. They are distinct from the previously mentioned taxa and thus cannot, based on current material, be assigned to any of them with certainty. Thus, *Chirostenotes* is not known from any stratigraphic unit younger than 75 Ma.

## CONCLUSIONS

*Ojoraptorsaurus boerei*, n. gen., n. sp., is a new caenagnathid oviraptorosaur that differs from both Asian and North American taxa based on the morphology of the pubes. We consider the holotype of *O. boerei* to represent a mature individual based on the fusion of the pubes at the pubic boot. *O. boerei* is most similar to *Epichirostenotes curriei*, n. gen., n. sp. (holotype ROM 43250), which we have removed from *Chirostenotes pergracilis*, but it differs in a number of respects, including the subtrapezoidal-shaped pubic articular surfaces, pubic fossa positioned lower on the shaft of the pubis, distal portion of the pubic shaft slightly convex anteriorly, being more robust, having a distinct “spoon-shaped” depression on the anterior dorsal surface of the pubic boot and lacking an anterior dorsal pubic boot suture. *O. boerei* is 20% smaller than *E. curriei* (ROM 43250), a specimen that is also considered mature (Sues, 1997). The ratio of the length of the pubic apron to the length of the pubis is 0.49 for *E. curriei* compared to 0.38 for *O. boerei*. Based on comparison with CM 78001, another unnamed caenagnathid, we estimate the length of *O. boerei* to be 1.8 to 2.1 meters.

*Ojoraptorsaurus boerei* is from the Naashoibito Member (Ojo Alamo Formation), which is considered to be 69 Ma (“early” Maastrichtian) or “late Edmontonian.” It predates CM 78001, and the other Hell Creek Formation specimens (“late” Maastrichtian), by 2.5 million years and is approximately 3 million years younger (i.e., late Campanian) than *E. curriei* (ROM 43250) from the lower part of the Horseshoe Canyon Formation (approximately 72 Ma). Thus, *O. boerei* occupies a distinct temporal position.

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## SYSTEMATIC PALEONTOLOGY

## DINOSAURIA

## THEROPODA

## OVIRAPTOROSAURIA Barsbold, 1976

## CAENAGNATHIDAE R.M. Sternberg, 1940

*EPICHIROSTENOTES*, new genus

*Chirostenotes* Gilmore, 1924 (in part).

**Type and only species:** *Epichirostenotes curriei*, n. sp.

**Included species:** Type and only species.

**Etymology:** From the Greek word “*epi*” meaning after; “*Chirostenotes*,” the caenagnathid to which the holotype was originally referred.

**Diagnosis:** Same as for species.

**Comments:** See below.

*EPICHIROSTENOTES CURRIEI*, new species

*Chirostenotes pergracilis* Gilmore (in part) Sues, 1997, p. 69.

**Holotype:** ROM 43250, incomplete skeleton (see Sues, 1997, p. 699 for complete list of elements).

**Etymology:** The species honors Philip J. Currie for his scholarly work concerning Late Cretaceous theropod dinosaurs.

**Distribution:** Horseshoe Canyon Formation, Dinosaur Provincial Park, Alberta, Canada.

**Age:** late Campanian (early “Edmontonian”), approximately 72 Ma.

**Other referred material:** none.

**Diagnosis (in part extracted from Sues, 1997; from his diagnosis of *Chirostenotes pergracilis* as per ROM 43250):** Braincase much deeper than long, with distinctly verticalized basicranial region. Otic region with deep, but anteroposteriorly narrow, lateral depression.

Synsacrum composed of six co-ossified vertebrae and pneumatic foramina. Ischium long and expanded posteriorly; broad behind obturator process; obturator process expanded and triangular; and having a prominent anterior proximal hook-like projection.

**Comments:** Sues (1997) provided a revised diagnosis for *Chirostenotes pergracilis* based in part on the inclusion of ROM 43250. Sues (1997, p. 708) referred the smaller morph of *Chirostenotes* (TMP 79.20.1) to *C. elegans* (= “*Ornithomimus*” *elegans* Parks), a specimen that previously was considered to be *C. pergracilis* (Currie and Russell, 1988). We consider Sues’ assignment of ROM 43250 to *Chirostenotes pergracilis* to be unlikely. We agree with Sues that the differences between TMP 79.20.1 and ROM 43250 are taxonomically significant, but at the generic level. Moreover, these taxonomic differences are further supported by a significant temporal hiatus between the two specimens. We are not convinced that TMP 79.20.1 is referable to “*C.*” *elegans*. There are no manus and/or pes elements (phalanges, carpals, metacarpals, metatarsals) in common that would allow us to compare *Epichirostenotes curriei* to the holotypes of *Chirostenotes pergracilis* and/or “*Ornithomimus*” *elegans* (= *Chirostenotes?* *elegans*). We also note that ROM 43250 and TMP 79.20.1 have sacral vertebrae 1-6 in common and only fragments of the ilium were noted by Sues (1997) for ROM 43250, but we are unable to assess any differences based on the published descriptions and illustrations by either Currie and Russell (1988) or Sues (1997). The ilia of TMP 79.20.1 to *Nomingia gobiensis* GIN 100/119, are vastly different. *Nomingia* has a broader, more open cuppedicus fossa compared to TMP 79.20.1. The postacetabular blade of the terminus of the ilium is procumbent U-shaped in *Nomingia*, whereas that of TMP 79.20.1 is tapered. The differences in the morphology of the iliac blades among two genera considered within the Caenagnathidae are unexpected. Given that TMP 79.20.1 was originally assigned to *Chirostenotes pergracilis* on the basis in similarities of some of the manus elements, this taxonomic assignment can be considered tenuous at best.