



A new species of Velociraptor (Dinosauria: Dromaeosauridae) from the Upper Cretaceous of northern China

Pascal Godefroit , Philip J. Currie , Li Hong , Shang Chang Yong & Dong Zhi-Ming

To cite this article: Pascal Godefroit , Philip J. Currie , Li Hong , Shang Chang Yong & Dong Zhi-Ming (2008) A new species of Velociraptor (Dinosauria: Dromaeosauridae) from the Upper Cretaceous of northern China, *Journal of Vertebrate Paleontology*, 28:2, 432-438, DOI: [10.1671/0272-4634\(2008\)28\[432:ANSOVD\]2.0.CO;2](https://doi.org/10.1671/0272-4634(2008)28[432:ANSOVD]2.0.CO;2)

To link to this article: [http://dx.doi.org/10.1671/0272-4634\(2008\)28\[432:ANSOVD\]2.0.CO;2](http://dx.doi.org/10.1671/0272-4634(2008)28[432:ANSOVD]2.0.CO;2)



Published online: 02 Aug 2010.



Submit your article to this journal [↗](#)



Article views: 163



View related articles [↗](#)



Citing articles: 7 View citing articles [↗](#)

A NEW SPECIES OF *VELOCIRAPTOR* (DINOSAURIA: DROMAEOSAURIDAE) FROM THE UPPER CRETACEOUS OF NORTHERN CHINA

PASCAL GODEFROIT,^{*1} PHILIP J. CURRIE,² LI HONG,³ SHANG CHANG YONG,³ and DONG ZHI-MING⁴

¹Department of Palaeontology, Royal Belgian Institute of Natural Sciences, rue Vautier 29, 1000 Bruxelles, Belgium, Pascal.Godefroit@naturalsciences.be;

²Department of Biological Sciences, University of Alberta, Edmonton, Alberta T6G 2E9, Canada, philip.currie@ualberta.ca;

³Inner Mongolia Museum, Xinhua Street 2, Hohhot 010020, P. R. China;

⁴Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, P.O. Box 643, Beijing 100044, P. R. China.

ABSTRACT—A new dromaeosaurid dinosaur—*Velociraptor osmolskae* n. sp.—is described on the basis of associated paired maxillae and a left lacrimal discovered in Campanian (Upper Cretaceous) deposits at Bayan Mandahu (Inner Mongolia, P. R. China). The maxilla of this new taxon is characterized by its long rostral plate and its enlarged, teardrop-shaped promaxillary fenestra, which is as large as the maxillary fenestra. The teeth are robust and the serrations are weakly developed on their distal carinae. This new taxon appears more closely related to *Velociraptor mongoliensis*, from the Campanian Djadokhta Formation in Mongolia, than to other dromaeosaurids described to date. The identification of the Bayan Mandahu *Velociraptor* as a distinct species is in keeping with the taxonomic distinction of the entire dinosaur fauna of this locality. Minor regional differences among Djadokhta-like localities in regards to their dinosaur faunas may reflect either some kind of geographic isolation, or small differences in their age or in their paleoenvironment.

INTRODUCTION

Dromaeosaurids were highly specialized, small to medium-sized, agile theropods characterized by a second pedal digit with a raptorial sickle claw and caudal vertebral adaptations for balance control. Recently, the scientific interest in dromaeosaurid dinosaurs was greatly increased by the discovery of feathered forms from the Lower Cretaceous of China—*Sinornithosaurus millenii* (Xu et al., 1999), *Microraptor zhaoianus* (Xu et al., 2000; Hwang et al., 2002), and *Microraptor gui* (Xu et al., 2003). According to the authors who described these taxa, dromaeosaurids are the closest relatives to Aves.

Dromaeosaurids were widely distributed, particularly on northern landmasses, throughout the Cretaceous. The stratigraphic range of reasonably well-documented skeletal material displaying diagnostic characters extends from the Barremian (Canudo et al., 1997; Swisher et al., 1999; Sweetman, 2004) to the Maastrichtian (Weishampel and Jianu, 1996; López-Martínez et al., 2001; Codrea et al., 2002). Dromaeosaurids also had a large geographic distribution: western North America (*Atrociraptor*, *Bambiraptor*, *Deinonychus*, *Dromaeosaurus*, *Saurornitholestes*, *Utahraptor*), Europe (*Pyroraptor*, *Variraptor*, and indeterminate material from England, Portugal, Romania and Spain), Mongolia (*Achillobator*, *Adasaurus*, *Velociraptor*), northern China (*Microraptor*, *Sinornithosaurus*), possibly Africa (Rauhut and Werner, 1995), and Argentina (*Buitreraptor*, *Unenlagia*).

The Bayan Mandahu Formation of Inner Mongolia is exposed about 50 km northwest of the Lang Shan Mountains that separate the southern part of the Mongolian plateau and Gobi Basin from the Yellow River alluvial plain (Fig. 1). The fossiliferous deposits are exposed along the Ni Qi Daba Gorge that cuts the

badlands of Bayan Mandahu. This gorge is approximately 45 km long, 1 to 5 km wide and 24 to 32 m deep (Dong and Cheng, 1996). The Bayan Mandahu Formation was explored in 1988 and 1990 by Sino-Canadian expeditions (Dong, 1993) and subsequently by Sino-Belgian expeditions in 1995, 1996, and 1999. The vertebrate fauna of Bayan Mandahu includes a variety of squamates (Gao and Hou, 1996; Wu et al., 1996), the turtle *Zangerlia neimongolensis* (Brinkman and Peng, 1996), multituberculate mammals (Smith et al., 2001), and a dinosaur fauna largely dominated by basal ceratopsians. Dong and Currie (1993) referred embryonic remains to both *Protoceratops andrewsi* and cf. *Bagaceratops* sp., and Jerzykiewicz et al. (1993) also suggested the presence of the larger *Udanoceratops*. Lambert et al. (2001) studied the protoceratopsid material collected at Bayan Mandahu by the Sino-Belgian Dinosaur Expeditions and described the new species *Protoceratops hellenikorhinus*. You and Dong (2003) described an almost complete protoceratopsid skull discovered at Bayan Mandahu by the Sino-Canadian Dinosaur Project as *Magnirostris dodsoni*. Ankylosaurs are also well represented at Bayan Mandahu by juvenile and adult specimens of *Pinacosaurus mephistocephalus* (Jerzykiewicz et al., 1993; Godefroit et al., 1999). Theropods are rare: Dong and Currie (1996) described a partial skeleton of *Oviraptor philoceratops* lying on top of a nest of eggs, and Currie and Peng (1993) referred a hind limb to the troodontid *Saurornithoides mongoliensis*. Jerzykiewicz et al. (1993) reported the presence of the dromaeosaurid *Velociraptor mongoliensis* in this locality, but this material is not prepared yet. Bohlin (1953) also tentatively referred some isolated bones and teeth, discovered in the neighboring Ulan-Tsonch locality, to cf. *Velociraptor mongoliensis*.

In 1999, the Sino-Belgian Dinosaur Expeditions discovered at Bayan Mandahu a pair of theropod maxillae and an associated left lacrimal, which display several autapomorphies indicating that they belong to a new taxon.

*Corresponding author.

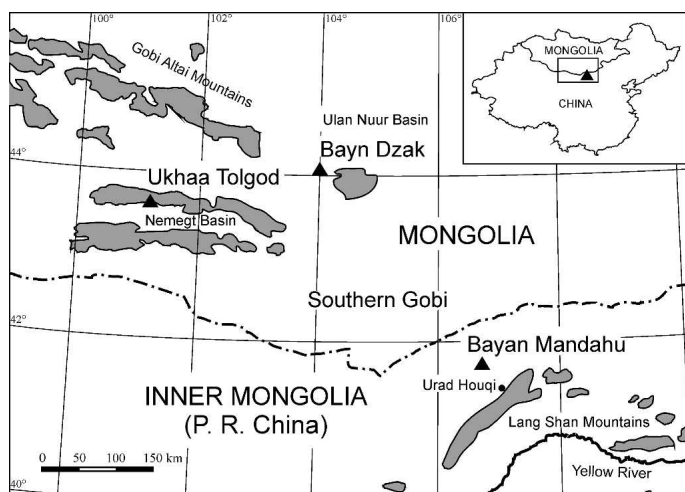


FIGURE 1. Map of the Gobi Basin, showing Bayan Mandahu (Inner Mongolia, P. R. China), Bayn Dzak, and Ukhaa Tolgod (Djadokhta Formation, Mongolia) dinosaur localities (solid triangles). Mountain ranges are in grey.

Institutional Abbreviations—AMNH, American Museum of Natural History, New York, USA; IGM, Institute of Geology, Mongolian Academy of Sciences, Ulaan Baatar, Mongolia; IMM, Inner Mongolia Museum, Hohhot, P. R. China; IVPP, Institute of Vertebrate Paleontology and Paleoanthropology, Beijing, P. R. China; MNUFR, Mongolia National University, Ulaan Baatar, Mongolia; MOR, Museum of the Rockies, Bozeman, USA; MPC, Paleontological Center of the Mongolian Academy of Sciences, Ulaan Baatar, Mongolia; TMP, Royal Tyrrell Museum of Palaeontology, Drumheller, Canada; YPM, Yale Peabody Museum, New Haven, USA.

SYSTEMATIC PALEONTOLOGY

DINOSAURIA Owen, 1842

THEROPODA Marsh, 1881

DROMAEOSAURIDAE Matthew and Brown, 1922

VELOCIRAPTOR Osborn, 1924

VELOCIRAPTOR OSMOLSKAE sp. nov.

Figs. 2, 3

Holotype—IMM 99NM-BYM-3/3 (A–C), paired maxillae and left lacrimal.

Etymology—Named in honor of Halszka Osmólska, for her contributions toward understanding of Asian theropods.

Locality and Horizon—15 km north of Bayan Mandahu Village, quarry SBDE 99BM-III (N 41° 47' 17.3", E 106° 43' 26.1"), Urad Houqi, Bayan Nor League, Inner Mongolia Province, P. R. China (Fig. 1). Bayan Mandahu Formation, correlated with the Djadokhta Formation in Mongolia, Campanian, Late Cretaceous.

Diagnosis—Long rostral plate of maxilla, with elongation index (L/H ratio) = 1.38. Promaxillary fenestra subequal in size to the maxillary fenestra and teardrop-shaped; long axis of the promaxillary fenestra perpendicular to the dorsal border of the maxilla; long axis of maxillary fenestra parallel to this border. Ten maxillary teeth with short unserrated carina on the apical end of the mesial edge and with incipient serrations on the distal carina.

DESCRIPTION

Maxilla—The maxilla is long, low, and triangular in lateral view (Table 1; Fig. 2A, B). Its dorsal and ventral borders form an angle of about 30°. Consequently, the rostral plate of the maxilla,

in front of the antorbital fossa, is proportionally long, with a L/H ratio = 1.38. In lateral view, the ventral margin is slightly convex. Numerous vascular foramina are aligned in a distinct row on the lateral side of the maxilla, which contains ten alveoli. The antorbital fossa forms a large and well-defined semi-elliptical depressed area on the lateral side of the maxilla. It is limited rostrally and ventrally by a distinct rim. It is pierced by two teardrop-shaped accessory antorbital fenestrae that are nearly the same size. The promaxillary fenestra is positioned in the rostral corner of the antorbital fossa. The long axis of the promaxillary fenestra is roughly perpendicular to the dorsal border of the maxilla. The maxillary fenestra is caudodorsal to the promaxillary fenestra and is recessed within a shallow, caudally-open fossa. Its long axis lies parallel to the dorsal margin of the maxilla. Because of the relatively large sizes of the promaxillary and maxillary fenestrae, the pila promaxillaris is particularly narrow, with its long axis more or less perpendicular to the dorsal margin of the maxilla. On the other hand, the pila interfenestralis is robust. The antorbital fossa is deeply notched by the rostral margin of the internal antorbital fenestra, which is incomplete. This fenestra forms a deep rostral sinus that excavates the caudal wall of the pila interfenestralis. It is also observed in *Deinonychus antirrhopus* and corresponds to the caudal antral fenestra observed in several other theropods (Witmer, 1997). In medial view, a deeply excavated cavity invades the dorsal half of the maxilla (Fig. 2C, D). This cavity corresponds to the promaxillary recess and maxillary antrum, which communicate with the promaxillary and maxillary fenestrae, respectively. Because the rostral wall of the maxillary antrum is not developed at all, the promaxillary recess and the maxillary antrum form a virtually continuous depression. The pila postantralis is poorly developed and is excavated by a small and shallow epiantral recess. Medially, a well-developed horizontal shelf separates the dorsal region with the maxillary recesses from the ventral alveolar part. A similar shelf was described in *Deinonychus antirrhopus* as the lateral portion of the secondary palate (Ostrom, 1969). A small and thin bony lamina ascends from the caudal part of this shelf, limiting the caudoventral portion of the maxillary antrum. Individual interdental plates are not visible on the lingual side of the maxilla. However, the labial and lingual margin of the tooth sockets are nearly equal in height, suggesting the presence of fused interdental plates, as previously described in *Dromaeosaurus* (Currie, 1995). The fused interdental plates form a continuous, thin lingual parapet. A series of small, circular damaged pits form a horizontal line at mid-height of the lingual parapet. This line probably corresponds to the junction between the interdental plates and the margin of the dentary. At this level in most dromaeosaurids, there are a series of foramina, through which branches of the dental artery passed (Currie, 1995). The caudal end of the ascending ramus is bifid and its medial side has an elongate and deep contact facet for the lacrimal. The jugal ramus is preserved on the right maxilla. It is particularly slender and its dorsomedial side has a groove for contact with the jugal.

There are ten maxillary teeth. Each tooth is robust, laterally compressed, recurved, and sharply tapered (Fig. 2). The mesial edge is well rounded along the greatest part of its height. Only close to the apex is there a short, unserrated carina. The distal edge is sharper in section and bears some incipient serrations close to its apical end. The labial side of the crown is slightly more convex than the lingual side.

Lacrimal—The left lacrimal is partially preserved (Fig. 3). Its rostral ramus is missing, but its caudal ramus appears relatively well developed, indicating that the complete bone was probably T-shaped. The medial side of the caudal ramus is flat, whereas its lateral surface is convex and rugose (Fig. 3B). Its dorsal surface is flat and inclined rostrally and laterally. The lacrimal shaft is thin, rostrocaudally compressed, and curved gently caudoventrally. The rostral side of the lacrimal has a deep elliptical de-

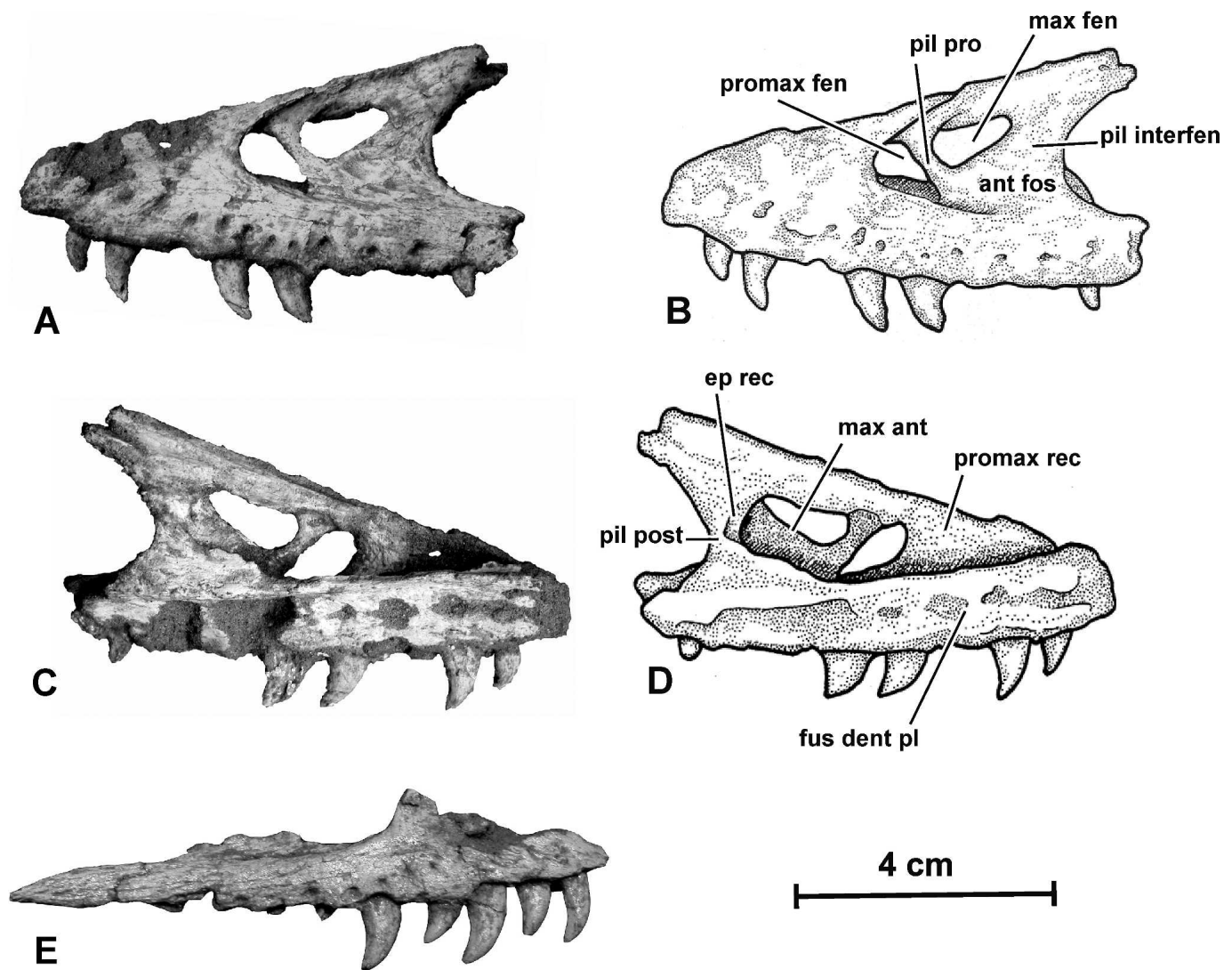


FIGURE 2. *Velociraptor osmolskai*, from the Bayan Mandahu Formation (Campanian; Inner Mongolia, P. R. China). A–D, left maxilla (IMM 99NM-BYM-3/3A) in lateral (A–B) and medial (C–D) views; E, right maxilla in lateral view. **Abbreviations:** ant fos, antorbital fossa; ep rec, epiantral recess; fus dent pl, fused dental plates; max ant, maxillary antrum; max fen, maxillary fenestra; pil interferen, pila interfenestralis; pil post, pila postantralis; pil pro, pila promaxillaris; promax fen, promaxillary fenestra; promax rec, promaxillary recess.

pression, just below the dorsal edge of the bone (Fig. 3A). This area corresponds to the lacrimal recess, a pneumatopore often found in the caudodorsal corner of the antorbital fossa in theropods (Witmer, 1997). Below this area, a large lacrimal duct communicates with a deep depression on the caudal side of the bone, connecting the antorbital fenestra with the orbital cavity.

COMPARISONS AND IDENTIFICATION

The suspected presence of fused interdental plates in *Velociraptor osmolskai* and the T-shaped lacrimal may be interpreted as dromaeosaurid synapomorphies (Currie, 1987, 1995). The proportions and distribution of the teeth are consistent with this identification. On the other hand, the elongated rostral plate of the maxilla and the large maxillary fenestra suggest troodontid affinities. However, all currently known troodontids have a large number of close-packed teeth (Makovicky et al., 2003): 30 maxillary teeth in *Byronosaurus jaffei*, 18 in *Sinornithoides youngi*, around 20 in *Saurornithoides mongoliensis*. Advanced troodontid teeth are usually distinctive with their much larger serrations and constrictions between crowns and roots (Currie, 1987; Currie

and Dong, 2001). However, this is not the case in all troodontids: *Byronosaurus jaffei*, from the Djadokhta Formation of Mongolia, for example, has unserrated teeth. With the exception of the basal form *Sinovenator dongi*, the promaxillary fenestra is not present in troodontids (Xu et al., 2002). In *Byronosaurus jaffei*, the maxillary fenestra is backed medially by an osseous wall and communicates with the antorbital fenestra by a canal that perforates the pila interfenestralis (Makovicky et al., 2003). In *Saurornithoides mongoliensis*, another troodontid discovered in the Djadokhta and Bayan Mandahu formations, the pila interfenestralis is distinctly inset in the antorbital fossa.

Within dromaeosaurids, *V. osmolskai* closely resembles *Velociraptor mongoliensis*, from the Djadokhta Formation of Mongolia, in the great elongation of the rostral plate of the maxilla, in the presence of a single row of neurovascular foramina on the lateral side of the maxilla, and in the teardrop-shaped maxillary fenestra (Fig. 4D). As in the holotype of *Velociraptor mongoliensis* (AMNH 6515), there are ten maxillary teeth in *V. osmolskai*. However, most specimens of *Velociraptor mongoliensis* have 11 or more (Table 1). However, important differences exist

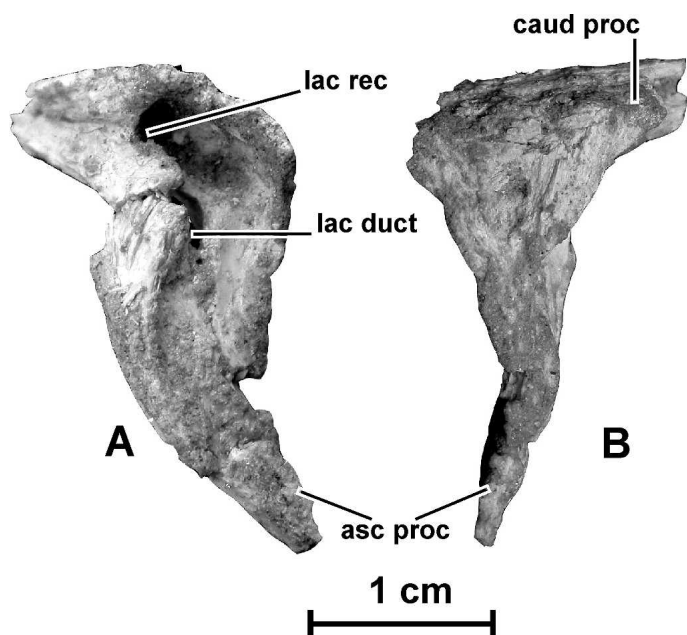


FIGURE 3. Left lacrimal of *Velociraptor osmolskae*, from the Bayan Mandahu Formation (Campanian; Inner Mongolia, P. R. China). **A**, medial view; **B**, lateral view. **Abbreviations:** asc proc, ascending process; caud proc, caudal process; lac duct, lacrimal duct; lac rec, lacrimal recess.

between these taxa. Although the maxillary fenestra is similar in shape and position, it seems much smaller in *V. mongoliensis*. But the development of the maxillary fenestra appears highly variable in at least *V. mongoliensis*. Relatively round in AMNH 6515, it is distinctly more constricted in MPC 100/25. On the other hand, the promaxillary fenestra is always very reduced in *V. mongoliensis*. It is developed either as a slit-like opening (AMNH 6515), or as two small, rostrally directed openings (MPC 100/25). Barsbold and Osmólska (1999) mention the presence of a low, longitudinal ridge extending between the alveolar border and the row of neurovascular foramina on the lateral side of the maxilla in *V. mongoliensis*. Such ridge has not been observed in *V. osmolskae*. The denticles are always more distinct on the maxillary teeth of *V. mongoliensis*. The ascending process of the lacrimal appears straighter in *V. mongoliensis* than in IMM 99NM-BYM-3/3 (Barsbold and Osmólska, 1999: fig. 4).

Tsaagan mangas has recently been described from the Djado-khta Formation of Ukhaa Tolgod, Mongolia (Norell et al., 2006). As in *V. osmolskae*, the maxillary fenestra is large, but it lies more rostrally (Fig. 4I), near the terminus of the fossa. In *Tsaagan*, the osseous floor of the antorbital fossa is much shorter than in IMM 99NM-BYM-3/3, and the promaxillary fenestra forms a

TABLE 1. Measurements of the holotypic maxilla of *Velociraptor osmolskae* (IMM 99NM-BYM-3/3).

Length of rostral plate of maxilla (tip of maxilla—most rostral point of antorbital fossa)	40 mm
Height of the rostral plate of the maxilla (at the level of most rostral point of antorbital fossa)	29 mm
Distance between most rostral points of antorbital fossa and of antorbital fenestra	34 mm
Height of antorbital fossa (at the level of most rostral point of antorbital fenestra)	31 mm
Length of promaxillary fenestra (long axis)	15 mm
Width of promaxillary fenestra (perpendicular to long axis)	8 mm
Length of maxillary fenestra (long axis)	16 mm
Width of maxillary fenestra (perpendicular to long axis)	8 mm

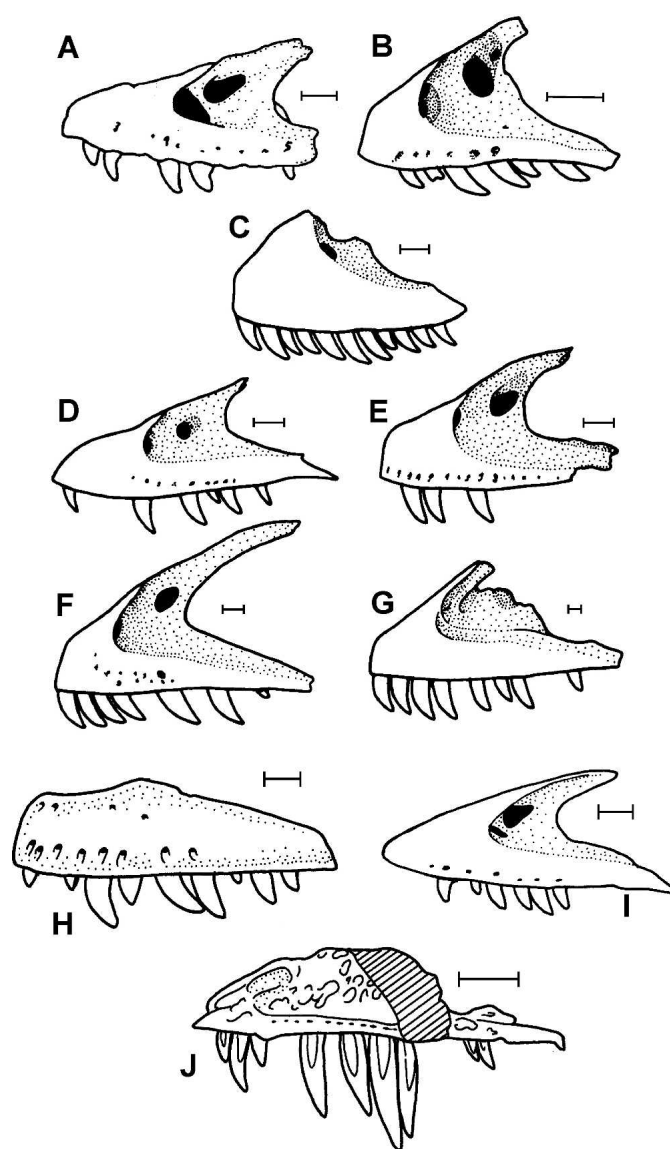


FIGURE 4. Left lateral views of dromaeosaurid maxillae. **A**, *Velociraptor osmolskae*; **B**, *Bambiraptor feinbergi*; **C**, *Atrociraptor marchalli*; **D**, *Velociraptor mongoliensis*; **E**, *Saurornitholestes langstoni*; **F**, *Deinonychus antirrhopus*; **G**, *Achillobator giganticus*; **H**, *Dromaeosaurus albertensis*; **I**, *Tsaagan mangas*; **J**, *Sinornithosaurus millenii*. Scale bars equal 1 cm. B–G modified after Currie and Varricchio (2004); H modified after Currie (1995); I modified after Norell et al. (2006); J modified after Xu and Wu (2001).

small slit, separated from the maxillary fenestra by a very thin promaxillary pila. The teeth of *Tsaagan* show the enlarged distal denticles characteristic of most dromaeosaurids.

In all other dromaeosaurids in which this bone is known, the rostral ramus of the maxilla is proportionally shorter, with an elongation index (L/H ratio) <1 (Table 2). This character is apparently not significantly affected by ontogeny: all the currently known *Velociraptor* specimens are characterized by an elongated rostral plate, whereas shortened plates can be found in both large (*Achillobator*) and small (*Sinornithosaurus*, *Bambiraptor*) dromaeosaurids. The maxilla of *V. osmolskae* resembles that of *Saurornitholestes langstoni*, from the Dinosaur Park Formation (late Campanian) of Alberta (Fig. 4E) in the presence of a single row of neurovascular foramina and its large teardrop-shaped maxillary fenestra, the long axis of which is parallel to the

TABLE 2. Maxillary tooth counts and elongation indices (L/H ratio) of the rostral plate in dromaeosaurids.

Species, Specimen #	Maxillary tooth positions	L/H ratio
<i>Achillobator giganticus</i> , MNUFR 15	11	0.69
<i>Atrociraptor marshalli</i> , TMP 95.166.1	11	<0.7
<i>Bambiraptor feinbergi</i> , AMNH 30556	12	0.62
<i>Bambiraptor feinbergi</i> , MOR 553S-7.30.91.274	12	0.75
<i>Deinonychus antirrhopus</i> , YPM 5232	15	0.9
<i>Dromaeosaurus albertensis</i> , AMNH 5356	9	—
Dromaeosaurid, MPC 100/23	11	—
<i>Saurornitholestes langstoni</i> , TMP 88.121.39	12	0.8
<i>Sinornithosaurus millenii</i> , IVPP V12811	11	—
<i>Tsaagan mangas</i> , IGM 100/1015	13	1.12
<i>Velociraptor mongoliensis</i> , AMNH 6515	10	1.3
<i>Velociraptor mongoliensis</i> , MPC 100/24, 100/25	11	1.34
<i>Velociraptor osmolskae</i> , IMM 99NM-BYM-3/3	10	1.38

dorsal border of the maxilla. In contrast, the promaxillary fenestra of *Saurornitholestes* is much smaller, its maxillary fenestra is positioned more caudally (above the rostral margin of the antorbital fenestra), and the rostral border of its maxilla is truncated (Currie and Varricchio, 2004).

In *Deinonychus antirrhopus*, from the Aptian–Albian of Montana, Wyoming, and Oklahoma, the promaxillary fenestra (Ostrom, 1969: fig. 6) is slit-like, and the maxillary fenestra is much smaller, semicircular with a straight dorsal margin, and more dorsocaudally set than in *V. osmolskae* (Fig. 4F). The neurovascular foramina are more numerous, but more irregularly spaced on the lateral side of the maxilla. The rostral margin of the internal antorbital fenestra is subtriangular in *D. antirrhopus*, whereas it is broadly rounded rostrally in *V. osmolskae*. In *D. antirrhopus*, the maxillary teeth are numerous (15) and, consequently, mesiodistally shorter. They are strongly inclined toward the throat. The denticles are particularly well developed on the distal carina of the maxillary teeth (Brinkman et al., 1998, figs. 4–5). The lacrimal shaft appears straighter in *D. antirrhopus* (Ostrom, 1969, fig. 7) than in *V. osmolskae*.

The maxillae are incompletely preserved in *Dromaeosaurus albertensis*, from the Campanian to early Maastrichtian of Alberta, Canada (Fig. 4H). The neurovascular foramina are more numerous and more irregularly spaced. Not far from the tip, the mesial carina of each maxillary tooth twists towards the lingual side. Both the mesial and distal carinae bear distinct denticles that are subequal in size (Currie, 1995).

The early dromaeosaurid *Sinornithosaurus millenii*, from the Early Cretaceous of Liaoning Province, northeastern China, is characterized by numerous pits and ridges on the anterolateral surface of its antorbital fossa (Fig. 4J). Both the promaxillary and maxillary fenestrae are distinctly smaller and more dorsally positioned than in *V. osmolskae*. The maxillary fenestra has a straight ventral border. The ventral rim of the antorbital fossa is better developed and forms a strong longitudinal ridge. The maxillary teeth are particularly narrow mesiodistally (Xu and Wu, 2001: figs. 2–4). In the tiny dromaeosaurid *Microraptor zhaoianus*, from the same locality as *S. millenii*, the teeth are closely packed and there is a basal constriction between crown and root on the posterior teeth (Xu et al., 2000).

In *Achillobator giganticus*, from the Bayan Shireh Formation of Mongolia, the rostral ramus of the maxilla appears particularly deep (Fig. 4G). There is no trace of maxillary or promaxillary fenestrae, but instead there is a set of fossae and ridges. The neurovascular foramina are more numerous and more irregularly spaced than they are in *V. osmolskae*. The maxillary teeth appear to be mesiodistally narrower and serrations are well developed, the mesial serrations being slightly smaller than the distal serrations (Perle et al., 1999, fig. 2 and pl. 1).

In *Bambiraptor feinbergi*, the rostral ramus of the maxilla is short and bluntly squared-off where it contacts the premaxilla (Burnham, 2004: fig. 3.5; Fig. 4B.). The maxillary teeth are strongly inclined towards the throat. As in *V. osmolskae*, the maxillary fenestra is large and teardrop-shaped, but its long axis is perpendicular to the dorsal border of the maxilla, whereas it is parallel in *V. osmolskae*.

The maxilla of *Atrociraptor marshalli*, from the Horseshoe Canyon Formation (late Campanian–early Maastrichtian) of Alberta (Canada) is characterized by the shortness of its antorbital fossa and of its rostral ramus, and by its large maxillary fenestra positioned directly above the promaxillary fenestra (Currie and Varricchio, 2004; Fig. 4C). As in *V. osmolskae*, the promaxillary fenestra is relatively narrow. Moreover, the neurovascular foramina are more numerous and more dispersed on the lateral side of the maxilla, and the teeth are strongly inclined towards the throat.

From these comparisons, it appears that the maxilla is a very diagnostic bone in dromaeosaurids. It is also clear that IMM 99NM-BYM-3/3 does not belong to any dromaeosaurid described to date. However, this specimen appears more closely related to *Velociraptor mongoliensis* than to any other taxon, even though it shows individual characters that are closer to other dromaeosaurid specimens. Because of the larger size of its promaxillary and maxillary fenestrae, it can be argued that IMM 99NM-BYM-3/3 might represent a juvenile specimen of *V. mongoliensis*. But the Bayan Mandahu maxilla is about the same size, and is indeed even slightly larger than typical *V. mongoliensis* maxillae with smaller fenestrae. Therefore, the enlarged sizes of the promaxillary and maxillary fenestrae in IMM 99NM-BYM-3/3 cannot be adequately explained as ontogenetic features within the species *V. mongoliensis*. Although the specimen sample is small, differences appear to be important enough to justify the creation of a new species, *Velociraptor osmolskae*. Whether or not this new species really belongs to the genus *Velociraptor* must be confirmed by the discovery of more complete specimens at Bayan Mandahu.

PALEOGEOGRAPHICAL OR STRATIGRAPHIC SIGNIFICANCE

Jerzykiewicz et al. (1993) and Eberth (1993) correlated the Bayan Mandahu Formation of Inner Mongolia with the Djado-khta Formation of Mongolia. The type section of the Djado-khta Formation is located at Bayn Dzak, in the Ulan Nuur Basin, approximately 350 km northwest of Bayan Mandahu. Djado-khta-facies sediments are in fact widely distributed in southern Mongolia and Djado-khta-like vertebrate faunas have been discovered in numerous localities (Jerzykiewicz and Russell, 1991). The Ukhaa Tolgod site in the Nemegt Basin, approximately 470 km northwest of Bayan Mandahu, is one of the most spectacular fossil localities in the Djado-khta Formation. It has yielded hundreds of vertebrate skeletons, including complete specimens (Dashzeveg et al., 1995; Norell, 1997; Norell et al., 2006). Dashzeveg et al. (2005) suggested that the Djado-khta sediments may have been deposited during the rapid sequence of polarity change in the late part of the Campanian between about 75 to 71 Ma.

The biostratigraphic correlation between the Bayan Mandahu and Djado-khta formations is not only based on the presence of common vertebrate species, but also on similarities in the relative abundance of several taxa in both areas. Gao and Hou (1996) recognized 10 common squamate species at Bayan Mandahu and Bayn Dzak; in both localities, the scincomorph teiid *Adamisaurus* is most abundant. The middle-sized multituberculate *Kryptobaatar* is the most abundant mammal in the Djado-khta Formation (Wible and Rougier, 2000) and at Bayan Mandahu (Smith et al., 2001). However, this genus is represented by different species: *K. dashzevegi* at Bayan Dzak and *K. mandahuensis* at Bayan Mandahu.

The Bayan Mandahu and Djadokhta formations are characterized by a low diversity of herbivorous dinosaurs. Protoceratopsids are abundant in both formations and are mainly represented by the genus *Protoceratops*: *P. andrewsi* at Bayn Dzak and in the other Djadokhta localities, *P. hellenikorhinus* at Bayan Mandahu (Lambert et al., 2001). The second most common dinosaur in the Bayan Mandahu and Djadokhta formations is the middle-sized ankylosaur *Pinacosaurus*. Again, this genus is represented by two different species: *P. grangeri* in the Djadokhta Formation and *P. mephistocephalus* at Bayan Mandahu (Godefroit et al., 1999).

Theropods are rare and represented by scarce material at Bayan Mandahu. The following two species have been found both in the Bayan Mandahu and in the Djadokhta faunas: the troodontid *Saurornithoides mongoliensis* (Currie and Peng, 1993) and the oviraptorid *Oviraptor philoceratops* (Dong and Currie, 1996). The dromaeosaurid *Velociraptor mongoliensis* is represented by more than eight partial postcrania and skulls in the Djadokhta Formation (Norell and Makovicky, 1999). Jerzykiewicz et al. (1993) mentioned the presence of this species at Bayan Mandahu, but these undescribed specimens could not be found in the IVPP collections. In any case, *Velociraptor mongoliensis* and *Velociraptor osmolskae* are closely related and occupied the same ecological niche as small, fast, and agile predators.

Besides the close resemblance of the faunas, the similarities of the lithofacies in the Bayan Mandahu and Djadokhta Formations apparently indicate a consistency in climate and depositional processes throughout the Gobi Basin during Campanian times (Eberth, 1993). The relatively short distance between the two sites, when considered with the lithological similarities, may also suggest that the two sites are synchronous. But lithological similarities are not convincing evidences of lateral equivalence, since they are closely tied to environments and can be time transgressive (Gao and Norell, 2000). The low diversity of the vertebrate assemblages and the small to medium sizes of the dinosaurs are evidence of a stressed paleoenvironment for the Bayan Mandahu and Djadokhta faunas. The poses of some complete dinosaur skeletons in the structureless sandstones suggest that the animals died in the process of attempting to free themselves from sandstorm deposits during storm events (Jerzykiewicz et al., 1993). Depositional environments of some modern arid and semi-arid basins in central Asia are regarded as excellent analogues for the Campanian Gobi Basin (Eberth, 1993). With such palaeoecological conditions, a geographical barrier, such as a desert, might have limited the migrations of vertebrate populations in the Campanian Gobi Basin. Therefore, the small differences in the composition of the Bayan Mandahu and Djadokhta faunas could result from local speciation processes between geographically isolated populations. However, this interpretation is intuitively in contradiction with the simple observation that many lizards, which presumably cannot disperse as effectively as much larger dinosaurs, could be conspecific between Bayan Mandahu and Djadokhta-like localities in Mongolia. Kielan-Jaworowska et al. (2003) cautiously suggested that the differences in the composition of the mammal faunas between the typical Djadokhta Formations and the Ukhaa Tolgod beds might reflect slight age differences. In the Campanian Dinosaur Park Formation (Alberta, Canada), it has been shown that specific differences in the composition of the dinosaur faunas reflect small age differences of the localities (Ryan and Evans, 2005; Evans and Reisz, 2007). Dashzeveg et al. (2005) recently studied key and newly discovered sections in the Djadokhta Formation along the southern margin of the Ulan Nur Basin. On the basis of lithology, they distinguished two members within the Djadokhta Formation: a lower Bayn Dzak Member and an upper Tugrugyin Member. Like in Bayan Mandahu, vertebrate fossils occur almost exclusively in the structureless sandstones of both members. It is worth noting that specific differences in the dino-

saur composition are apparently absent between the Bayn Dzak and the Tugrugyin members, even though they show substantial age and facies differences (Dashzeveg et al., 2005).

It may therefore be concluded that the identification of the Bayan Mandahu *Velociraptor* as a distinct species is in keeping with the taxonomic distinction of its entire dinosaur fauna. It confirms that there were minor regional differences among Djadokhta-like localities in regards to their dinosaur faunas (Norell et al., 2006). In the current state of our knowledge, it is still impossible to determine whether those differences reflect geographic isolation of the localities, or differences in the age or in the paleoenvironment of the different sites.

ACKNOWLEDGMENTS

This paper is part of the project S&T BL/36/C22–R12 ‘Cretaceous dinosaurs from Far Eastern Asia (eastern Asia and Inner Mongolia)’, supported by the Belgian State, Federal Scientific Policy. We should like to express our gratitude to all the participants to the excavations at Bayan Mandahu in the scope of the Sino-Belgian Dinosaur Expeditions in Inner Mongolia (1995–1999). A. Wauters drew the figures of this paper. P. J. Makovicky and D. J. Varricchio kindly reviewed the manuscript and made many helpful comments.

LITERATURE CITED

- Barsbold, R., and H. Osmólska. 1999. The skull of *Velociraptor* (Theropoda) from the Late Cretaceous of Mongolia. *Acta Palaeontologica Polonica* 44:189–219.
- Bohlin, B. 1953. Fossil reptiles from Mongolia and Kansu. Sino-Swedish Expedition Publication 37:1–105.
- Brinkman, D. L., R. L. Cifelli, and N. J. Szaplewski. 1998. First occurrence of *Deinonychus antirrhopus* (Dinosauria: Theropoda) from the Antlers Formation (Lower Cretaceous: Aptian–Albian) of Oklahoma. *Oklahoma Geological Survey Bulletin* 146:1–27.
- Brinkman, D. L., and J.-H. Peng. 1996. A new species of *Zangerlia* (Testudines: Nanhsiungchelyidae) from the Upper Cretaceous redbeds at Bayan Mandahu, Inner Mongolia, and the relationships of the genus. *Canadian Journal of Earth Sciences* 33:526–554.
- Burnham, D. A. 2004. New information on *Bambiraptor feinbergi* (Theropoda: Dromaeosauridae) from the Late Cretaceous of Montana; pp. 67–111 in P. J. Currie, E. B. Koppelhus, M. A. Shugar, and J. L. Wright (eds.), *Feathered Dragons*. Indiana University Press, Bloomington and Indianapolis.
- Canudo, J. I., G. Cuenca-Bescós, and J. I. Ruiz-Omeñaca. 1997. Dinosaurios dromeosáuridos (Saurischia: Theropoda) en el Barremiense Superior (Cretácico Inferior) de Castellote, Teruel. *Geogaceta* 22: 39–42.
- Codrea, V., T. Smith, P. Dica, A. Folie, G. Garcia, P. Godefroit, and J. Van Itterbeek. 2002. Dinosaur egg nests, mammals and other vertebrates from a new Maastrichtian site of the Hațeg Basin (Romania). *Comptes Rendus Palévol* 1:173–180.
- Currie, P. J. 1987. Bird-like characteristics of the jaws and teeth of troodontid theropods (Dinosauria, Saurischia). *Journal of Vertebrate Paleontology* 7:72–81.
- Currie, P. J. 1995. New information on the anatomy and relationships of *Dromaeosaurus albertensis* (Dinosauria: Theropoda). *Journal of Vertebrate Paleontology* 15:579–591.
- Currie, P. J., and Z.-M. Dong. 2001. New information on Cretaceous troodontids (Dinosauria: Theropoda) from The People’s Republic of China. *Canadian Journal of Earth Sciences* 38:1753–1766.
- Currie, P. J., and J.-H. Peng. 1993. A juvenile specimen of *Saurornithoides mongoliensis* from the Upper Cretaceous of northern China. *Canadian Journal of Earth Sciences* 30:2224–2230.
- Currie, P. J., and D. J. Varricchio. 2004. A new dromaeosaurid from the Horseshoe Canyon Formation (Upper Cretaceous) of Alberta, Canada; pp. 112–132 in P. J. Currie, E. B. Koppelhus, M. A. Shugar, and J. L. Wright (eds.), *Feathered Dragons*. Indiana University Press, Bloomington and Indianapolis.
- Dashzeveg, D., L. Dingus, D. B. Loope, C. C. Swisher III, T. Dulam, and M. R. Sweeney. 2005. New stratigraphic subdivision, depositional environment, and age estimate for the Upper Cretaceous Djadokhta

- Formation, Southern Ulan Nur Basin, Mongolia. *American Museum Novitates* 3498:1–31.
- Dashzeveg, D., M. J. Novacek, M. A. Norell, J. M. Clark, L. M. Chiappe, A. Davidson, M. C. McKenna, L. Dingus, C. Swisher, and A. Perle. 1995. Unusual preservation in a new vertebrate assemblage from the Late Cretaceous of Mongolia. *Nature* 374:446–449.
- Dong, Z.-M. 1993. The field activities of the Sino-Canadian Dinosaur Project in China, 1987–1990. *Canadian Journal of Earth Sciences* 30:1997–2001.
- Dong, Z.-M., and Y.-N. Cheng. 1996. The land of the dragon. The varied dinosaurs from China and Mongolia. *Paleontology Research Space*, Taichung, Taiwan, 215 pp.
- Dong, Z.-M., and P. J. Currie. 1993. Protoceratopsian embryos from Inner Mongolia, People's Republic of China. *Canadian Journal of Earth Sciences* 30:2248–2254.
- Dong, Z.-M., and P. J. Currie. 1996. On the discovery of an oviraptorid skeleton on a nest of eggs at Bayan Mandahu, Inner Mongolia, People's Republic of China. *Canadian Journal of Earth Sciences* 33:631–636.
- Eberth, D. A. 1993. Depositional environments and facies transitions of dinosaur-bearing Upper Cretaceous redbeds at Bayan Mandahu (Inner Mongolia, People's Republic of China). *Canadian Journal of Earth Sciences* 30:2196–2213.
- Evans, D. C., and R. R. Reisz. 2007. Anatomy and relationships of *Lambeosaurus magnicristatus*, a crested hadrosaurid dinosaur (Ornithischia) from the Dinosaur Park Formation, Alberta. *Journal of Vertebrate Paleontology* 27:373–393.
- Gao, K., and L. Hou. 1996. Systematics and taxonomic diversity of squamates from the Upper Cretaceous Djadochta Formation, Bayan Mandahu, Gobi Desert, People's Republic of China. *Canadian Journal of Earth Sciences* 33:578–598.
- Gao, K., and M. Norell. 2000. Taxonomic composition and systematics of Late Cretaceous assemblages from Ukhaa Tolgod and adjacent localities, Mongolian Gobi Desert. *Bulletin of the American Museum of Natural History* 249:1–118.
- Godefroit, P., X. Pereda-Suberbiola, H. Li, and Z.-M. Dong. 1999. A new species of the ankylosaurid dinosaur *Pinacosaurus* from the Late Cretaceous of Inner Mongolia (P. R. China). *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre* 69 (supplément):17–36.
- Hwang, S. H., M. A. Norell, Q. Ji, and K.-Q. Gao. 2002. New Specimens of *Microraptor zhaoianus* (Theropoda: Dromaeosauridae) from northeastern China. *American Museum Novitates* 3381:1–44.
- Jerzykiewicz, T., and D. A. Russell. 1991. Late Mesozoic stratigraphy and vertebrates of the Gobi Basin. *Cretaceous Research* 12:345–377.
- Jerzykiewicz, T., P. J. Currie, D. A. Eberth, P. A. Johnston, E. H. Koster, and J.-J. Zheng. 1993. Djadochta Formation correlative strata in Chinese Inner Mongolia: an overview of the stratigraphy, sedimentary geology, and paleontology and comparisons with the type locality in the pre-Altai Gobi. *Canadian Journal of Earth Sciences* 30:2180–2195.
- Kielan-Jaworowska, Z., J. H. Hurum, and D. Badamgarav. 2003. An extended range of multituberculata *Kryptobaatar* and distribution of mammals in the Upper Cretaceous of the Gobi Desert. *Acta Palaeontologica Polonica* 48:273–278.
- Lambert, O., P. Godefroit, H. Li, C.-Y. Shang, and Z.-M. Dong. 2001. A new species of *Protoceratops* (Dinosauria, Neoceratopsia) from the Late Cretaceous of Inner Mongolia (P. R. China). *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre* 71 (supplément):5–28.
- López-Martínez, N., J. I. Canudo, L. Ardèvol, X. Pereda Suberbiola, X. Orue-Etxebarria, G. Cuenca-Bescós, J. I. Ruiz-Omeñaca, X. Murelaga, and M. Feist. 2001. New dinosaur sites correlated with Upper Maastrichtian pelagic deposits in the Spanish Pyrenees: implications for the dinosaur extinction pattern in Europe. *Cretaceous Research* 22:41–61.
- Makovicky, P. J., M. A. Norell, J. M. Clark, and T. Rowe. 2003. Osteology and relationships of *Byronosaurus jaffei* (Theropoda: Troodontidae). *American Museum Novitates* 3402:1–32.
- Marsh, O. C. 1881. Classification of the Dinosauria. *American Journal of Science* (series 3) 23:81–86.
- Matthew, W. D., and B. Brown. 1922. The family Deinodontidae, with notice of a new genus from the Cretaceous of Alberta. *Bulletin of the American Museum of Natural History* 46:367–385.
- Norell, M. A. 1997. Central Asiatic expeditions; pp. 100–104 in P. J. Currie and K. Padian (eds.), *Encyclopedia of dinosaurs*. Academic Press, San Diego.
- Norell, M. A., and P. J. Makovicky. 1999. Important features of the dromaeosaurid skeleton II: information from newly collected specimens of *Velociraptor mongoliensis*. *American Museum Novitates* 3282:1–45.
- Norell, M. A., J. M. Clark, A. H. Turner, P. J. Makovicky, R. Barsbold, and T. Rowe. 2006. A new dromaeosaurid theropod from Ukhaa Tolgod (Ömnögovi, Mongolia). *American Museum Novitates* 3545:1–51.
- Osborn, H. F. 1924. Three new Theropoda, *Protoceratops* zone, central Mongolia. *American Museum Novitates* 144:1–12.
- Ostrom, J. H. 1969. Osteology of *Deinonychus antirrhopus*, an unusual theropod from the Lower Cretaceous of Montana. *Bulletin of the Peabody Museum* 30:1–165.
- Owen, R. 1842. Report on British fossil reptiles. Part II. Report of the British Association for the Advancement of Science 11:60–204.
- Perle, A., M. A. Norell, and J. M. Clark. 1999. A new maniraptoran theropod—*Achillobator giganticus* (Dromaeosauridae)—from the Upper Cretaceous of Burkhan, Mongolia. *National University of Mongolia, Geology and Mineralogy, Ulan Bataar*, 105 pp.
- Rauhut, O. W., and C. Werner. 1995. First record of the family Dromaeosauridae (Dinosauria: Theropoda) in the Cretaceous of Gondwana (Wadi Milk Formation, Northern Sudan). *Paläontologische Zeitschrift* 69:475–489.
- Ryan, M. J., and D. C. Evans. 2005. Ornithischian dinosaurs; pp. 312–348 in P. J. Currie and E. B. Koppelhus (eds.), *Dinosaur Provincial Park. A spectacular ancient ecosystem revealed*. Indiana University Press, Bloomington and Indianapolis.
- Smith, T., D.-Y. Guo, and Y. Sun. 2001. A new species of *Kryptobaatar* (Multituberculata): the first Late Cretaceous mammal from Inner Mongolia (P. R. Mongolia). *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre* 71 (supplément):29–50.
- Sweetman, S. C. 2004. The first record of velociraptorine dinosaurs (Saurischia, Theropoda) from the Wealden (Early Cretaceous, Barremian) of southern England. *Cretaceous Research* 25:353–364.
- Swisher III, C. C., Y.-Q. Wang, X.-L. Wang, X. Xu, and Y. Wang. 1999. Cretaceous age for the feathered dinosaurs of Liaoning, China. *Nature* 400:58–61.
- Weishampel, D. B., and C.-M. Jianu. 1996. New theropod material from the Hateg Basin. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen* 200:387–404.
- Wible, J. R., and G. W. Rougier. 2000. Cranial anatomy of *Kryptobaatar dashzevegi* (Mammalia, Multituberculata), and its bearing on the evolution of mammalian characters. *Bulletin of the American Museum of Natural History* 247:1–124.
- Witmer, L. M. 1997. The evolution of the antorbital cavity of archosaurs: a study in soft-tissue reconstruction in the fossil record with an analysis of the function of pneumaticity. *Society of Vertebrate Paleontology Memoir* 3:1–73.
- Wu, X. C., D. B. Brinkman, and A. P. Russell. 1996. *Sineoamphisbaena hexatabularis*, an amphisbaenian (Diapsida: Squamata) from the Upper Cretaceous redbeds at Bayan Mandahu (Inner Mongolia, People's Republic of China), and comments on the phylogenetic relationships of the Amphisbaenia. *Canadian Journal of Earth Sciences* 33:541–577.
- Xu, X., X.-L. Wang, and X.-C. Wu. 1999. A dromaeosaurid dinosaur with a filamentous integument from the Yixian Formation of China. *Nature* 401:262–266.
- Xu, X., Z. Zhou, and X. Wang. 2000. The smallest known non-avian theropod dinosaur. *Nature* 408:705–708.
- Xu, X., and X.-C. Wu. 2001. Cranial morphology of *Sinornithosaurus millenii* Xu et al. 1999 (Dinosauria: Theropoda: Dromaeosauridae) from the Yixian Formation of Liaoning, China. *Canadian Journal of Earth Sciences* 38:1739–1752.
- Xu, X., M. A. Norell, X.-L. Wang, P. J. Makovicky, and X.-C. Wu. 2002. A basal troodontid from the Early Cretaceous of China. *Nature* 415:780–784.
- Xu, X., Z. Zhou, X. Wang, W. Kuang, F. Zhang, and X. Du. 2003. Four-winged dinosaurs from China. *Nature* 41:335–340.
- You, H., and Z.-M. Dong. 2003. A new protoceratopsid (Dinosauria: Neoceratopsia) from the Late Cretaceous of Inner Mongolia, China. *Acta Geologica Sinica* 77:299–303.

Submitted October 5, 2007; accepted November 25, 2007.