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Caenagnathasia sp. (Theropoda: Oviraptorosauria) from the Iren Dabasu Formation (Upper Cretaceous: Campanian) of Erenhot, Nei Mongol, China

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Abstract The oviraptorosaurian theropod *Caenagnathasia* was first described from the Late Cretaceous (Turonian) vertebrate assemblage from the Bissekty Formation of the Kyzylkum Desert, Uzbekistan. Here we report a partial pair of oviraptorosaurian fused lower jaws, comprising the symphysial region, from the Upper Cretaceous (Campanian) Iren Dabasu Formation of Nei Mongol, China. This mandibular fragment can be referred to *Caenagnathasia* based on the following shared characters: dentaries fully fused, symphysial portion of dentary not downturned, anterior part of dorsal margin of dentary broadly concave in lateral view, lingual ridge present at margin of occlusal surface on each dentary, lingual ridge bears apical projection, vascular grooves and associated foramina do not extend to dorsal surface of symphysis, and anterior occlusal groove present. This new specimen extends the temporal and geographic range of *Caenagnathasia* to the Campanian of China.

Key words Erlian Basin, Nei Mongol; Late Cretaceous; Iren Dabasu Formation; Theropoda, Caenagnathidae, *Caenagnathasia*

1 Introduction

Oviraptorosaurs are a group of highly specialized theropods generally characterized by a short, deep skull with robust mandibles, a relatively short tail, and long hindlimbs (Osmólska et al., 2004). Their geographic distribution is restricted to Asia (China, Mongolia, Uzbekistan, and Kazakhstan) and North America (Currie et al., 1994; Osmólska et al., 2004), though some putative oviraptorosaur fragments have been reported from the southern hemisphere (Frankfurt and Chiappe, 1999). The Caenagnathidae is an oviraptorosaurian group mostly represented by fragmentary fossils from North America. The only reported Asian caenagnathids are *Gigantoraptor erlianensis* from China, the largest known oviraptorosaurian (Xu et al., 2007; Lamanna et al., 2014), *Elmisaurus rarus* from Mongolia, and *Caenagnathasia martinsoni*

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from central Asia (Osmólska, 1981; Currie et al., 1994). Currie et al. (1994) first reported *C. martinsoni* from the Bissekty Formation (Upper Cretaceous: Turonian) of Uzbekistan based on a pair of partial fused dentaries CCMGE 401/12457 (holotype) and an additional partial right dentary CCMGE 402/12457. Recently Sues and Averianov (2015) assigned to *C. martinsoni* a third dentary specimen (ZIN PH 2354/16) and some dissociated postcranial bones from the same geographic area and horizon. An unnamed specimen from the Bostobe Formation (probably Santonian) of Kazakhstan described by Nessov and Khisarova (1988) might also belong to *Caenagnathasia* (Currie et al., 1994).

The Erlian Basin, located in the north-central part of Nei Mongol, is among the richest sources of dinosaur fossils in China (Itterbeeck et al., 2005; Xing et al., 2012). The Late Cretaceous dinosaur fauna of the Erlian Basin includes two documented oviraptorosaurian taxa, *Avimimus portentosus* and *Gigantoraptor erlianensis*, from the Iren Dabasu Formation (Ryan and Russell, 2001; Osmólska et al., 2004; Xu et al., 2007). This region was explored first by the Central Asiatic Expeditions of the American Museum of Natural History led by Roy Chapman Andrews in the 1920s, and subsequently by the Sino-Soviet Expedition in 1959 (Berkey and Morris, 1927; Rozhdestvensky, 1977). Over the last few decades, the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences together with the Long Hao Institute of Geology and Paleontology has organized several expeditions with the objective of uncovering more dinosaurian fossils in the formation, and that fieldwork has produced several new taxa (e.g., Zhang et al., 2001; Xu et al., 2002, 2006, 2007). Among the recent discoveries is a lower jaw fragment (IVPP V 20377) consisting of the symphysial region of a pair of fused mandibles. This specimen was collected during the 2012 IVPP expedition, and is referable to *Caenagnathasia*. It represents the youngest *Caenagnathasia* specimen by about 10 Ma, and the first record of this taxon in China.

Abbreviations CCMGE, Chernyshev's Central Museum of Geological Exploration, Saint Petersburg, Russia; IVPP, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, China; ZIN PH, Paleoherpetological Collection, Zoological Institute, Russian Academy of Sciences, Saint Petersburg, Russia.

2 Systematic paleontology

Theropoda Marsh, 1881

Oviraptorosauria Barsbold, 1976

Caenagnathidae Sternberg, 1940

***Caenagnathasia* Currie et al., 1994**

***Caenagnathasia* sp.**

Material IVPP V 20377, fused symphysial region of paired mandibles.

Locality and horizon This fossil derives from a rare microvertebrate locality within the Iren Dabasu Formation, about 16 km northeast of Erenhot City (see Xing et al., 2012: fig 3 for details). The deposit is less than 30 cm thick, approximately 2 to 3 meters wide, and

approximately 10 meters in lateral extent. The poorly consolidated sandy sediment produced a very large number of small unarticulated bones and teeth, including fossils of fishes, turtles and dinosaurs (ornithomimids, tyrannosauroids, hadrosauroids, and dromaeosaurids). Most fossil localities in the formation only produce isolated bones or individual articulated partial skeletons, not high-density microvertebrate remains. The Iren Dabasu Formation is thought to be Middle to Late Campanian (Late Cretaceous) in age (Xing et al., 2012).

3 Description

IVPP V 20377 consists of the symphysial region of a pair of fused dentaries, with most of the ramus of each dentary broken away. It is a small specimen with a minimum symphysial length of 8.0 mm, and a height of 5.3 mm immediately posterior to the symphysis (Table 1). In dorsal view, the dentaries curve anteriorly toward the midline to form a U-shaped symphysis (Fig. 1A), as in other oviraptorosaurs (Osmólska et al., 2004). Each dentary is fully fused to the other, with no trace of an intervening suture anteriorly. The contact between them is anteroposteriorly extensive, strengthening the symphysis (Fig. 1A). The dorsal surface of the symphysis is generally smooth and trough-like, but bears a shallow longitudinal midline groove (Fig. 1A,E) as in the holotype of *Caenagnathasia martinsoni* (Currie et al., 1994; Sues and Averianov, 2015). The groove appears to be absent, or at best weakly defined, in the smaller *C. martinsoni* specimen ZIN PH 2354/16 (Sues and Averianov, 2015: fig. 3A).

Table 1 *Caenagnathasia* jaw measurements (mm)

Specimen	MSL	BSH	BSW
CCMGE 401/12457 (Currie et al., 1994)	11.2	8.3	15+
CCMGE 402/12457 (Currie et al., 1994)	–	9	–
ZIN PH 2354/16 (Sues and Averianov, 2015)	7.5	4.7	–
IVPP V 20377	8.0	5.3	15.6

Note: MSL. minimum symphysial length; BSH. height behind symphysis; BSW. width behind symphysis. For IVPP V 20377, BSH corresponds to the height of the posterior surface of the symphysis and BSW corresponds to the transverse width of the paired mandibles along the posterior border of the symphysis; these may not correspond precisely to measurements taken by previous authors.

Anteriorly, the shallow midline groove leads into a large, deep anterior occlusal groove, which is approximately subcircular in outline (Fig. 1A,E). The right wall of the anterior occlusal groove bears two vascular foramina, situated close together, while the left wall bears a single foramen. The anterior portion of the occlusal edge is damaged in this specimen. Laterally, the dorsal surface of the symphysis is bordered by robust anteromedially trending lingual ridges. Each ridge bears two small nutrient foramina, one located anterior to the other. Beyond the foramina, each lingual ridge bends abruptly through an obtuse angle so that its most anterior portion extends almost straight anteriorly and forms one lateral margin of the anterior occlusal groove (Fig. 1A,E). At the inflection point, each lingual ridge bears a slight prominence, the apical projection. The left lingual ridge bears a third, very small nutrient foramen lateral to the apical projection.

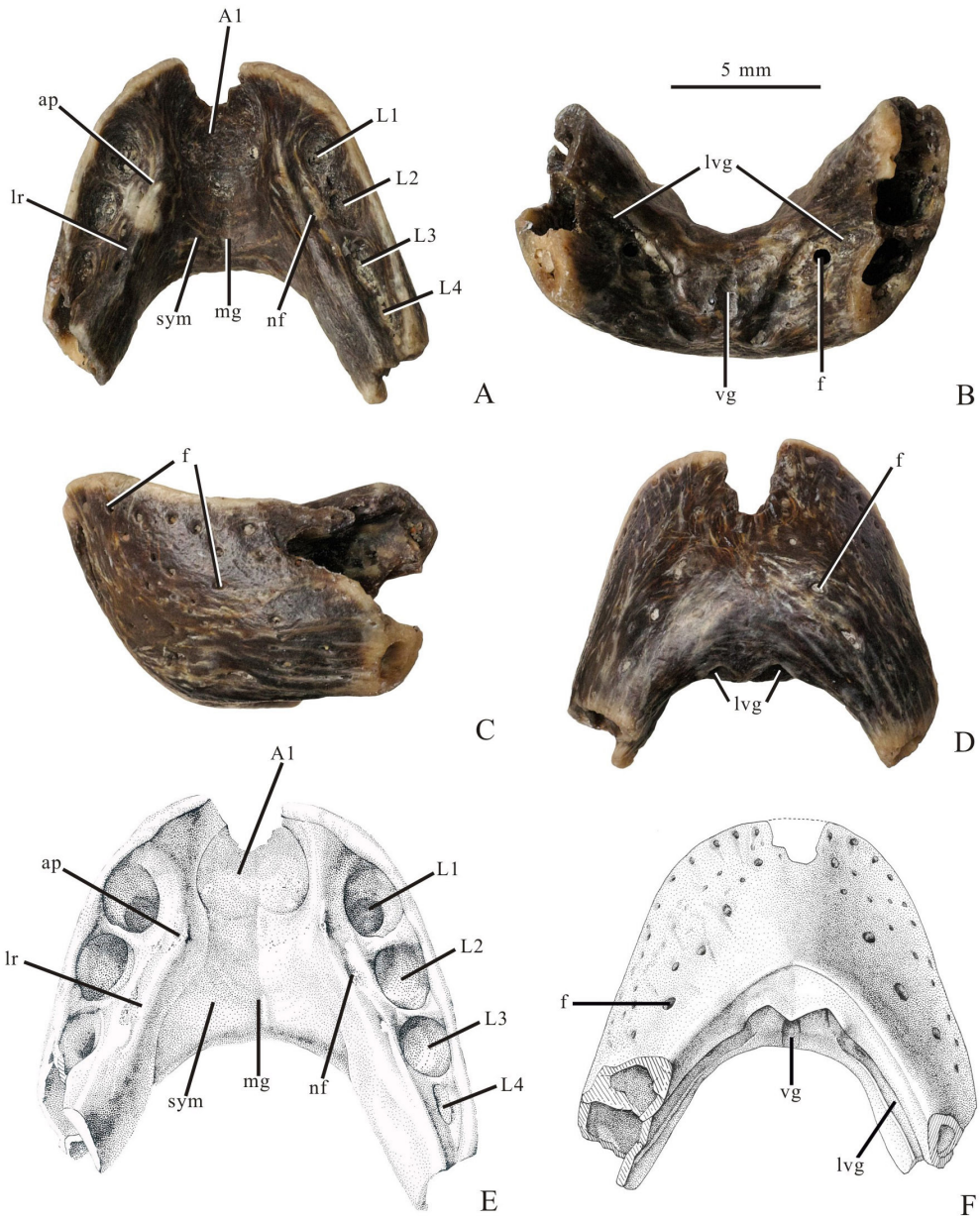

Fig. 1 Referred specimen of *Caenagnathasia*, IVPP V 20377
A. dorsal view; B. posterior view; C. left lateral view; D. ventral view;
E. line drawing in dorsal view; F. line drawing in posteroventral view
Abbreviations: A1. anterior occlusal groove; ap. apical projection; f. foramen;
L1−L4. lateral occlusal grooves; lr. lingual ridge; lvg. lateral vascular grooves; mg. midline groove;
nf. nutrient foramen; sym. symphysis; vg. vertical groove

Close to the lateral edge, the dorsal surface of each dentary bears an anteroposteriorly elongate trough which contains a series of transverse bony partitions, forming individual depressions that bear a superficial resemblance to alveoli but clearly represent the “lateral

occlusal grooves" of previous authors (Currie et al., 1994; Sues and Averianov, 2015). Three grooves are preserved in the left dentary, and five in the right dentary (Fig. 1A,E). The first lateral groove on each side is subcircular and pit-like, whereas the second and third are anteroposteriorly elongate and have labial walls that slope lingually as they descend. The lingual walls of the second and third grooves are excavated, so that their lingual margins are shelf-like. The fourth lateral groove is also elongate, but very small, and the fifth is tiny. The lateral grooves are floored by bone, separating them from the large, more ventrally situated space occupying most of the interior of each dentary. The bony floors appear to be pierced by foramina, but some of these openings may be the result of damage. The dentary rami posterior to the symphysial region diverge at an angle of approximately 55° in dorsal view (Fig. 1A,E). There is a short, shallow dorsoventrally trending groove in the middle of the posterior surface of the symphysis, extending upward from the ventral margin. Meckelian grooves appear to be absent, but deep, sinuous, slit-like vascular grooves extend dorsally and laterally from the vicinity of the middle part of the ventral edge of the posterior surface of the symphysis. The ventral ends of the vascular grooves flank that of the median dorsoventral groove, and deepen into small fossae with sharp ventral margins (Fig. 1B,D). The right fossa contains a small foramen. Each vascular groove bends sharply as it approaches the dorsal margin of the dentary, continuing posteriorly along the lingual face of the ramus below the prominent lingual ridge. The vascular groove is deepest in the region of the bend, and a conspicuous foramen pierces the surface of the dentary just posterior, ventral and lateral to the bend in the groove (Fig. 1B). Because the dentary rami are broken posteriorly, it is possible to see that the interior of the dentary is hollow below the bone flooring the lateral occlusal grooves, as in *Caenagnathasia martinsoni* and at least some other caenagnathids (Currie et al., 1994).

The ventral surface of V 20377 is smooth and flat, and there is no sign of an hourglass-shaped or dumbbell-shaped depression on the ventral surface as in *Caenagnathus collinsi*, *C. sternbergi* or *Caenagnathasia martinsoni* CCMGE 401/12457 (Currie et al., 1994). In lateral view, the dorsal margin of the dentary is broadly concave, the most anterior portion of this margin projecting dorsally (Fig. 1C). The ventral margin is nearly straight, and there is no indication of a prominent chin-like eminence of the kind present in one small specimen of *C. martinsoni* (ZIN PH 2354/16; Sues and Averianov, 2015). This eminence is likewise absent in larger specimens of *C. martinsoni* (Currie et al., 1994; Sues and Averianov, 2015). The anterior aspect of the symphysis is slightly convex anteriorly, and curves smoothly into the ventral surface. The lateral and anterior surfaces of the mandibles bear a large number of nutrient foramina, indicating that this region was probably covered by a horny beak in life.

4 Discussion

IVPP V 20377 is referable to the Caenagnathidae on the basis of the following suite of synapomorphies: anteroposteriorly extended symphysis; dentaries fully fused; symphysial

portion of dentary not downturned; anterior part of dorsal margin of dentary broadly concave in lateral view; lingual ridge present at margin of occlusal surface on each dentary; and dentary pneumatized (Lamanna et al., 2014). V 20377 does not have a prominent flange or shelf arising from the lateral surface of dentary as in *Anzu wyliei* (Lamanna et al., 2014), or a posteroventral depression in the symphysial region as in *Caenagnathus* (Longrich et al., 2013). V 20377 shares with *Caenagnathasia martinsoni* the following unique features (Currie et al., 1994; Sues and Averianov, 2015): apical projection on lingual ridge; vascular grooves and associated foramina do not extend onto dorsal surface of symphysis; anterior occlusal groove present; and midline groove present. Based on these features, a case could be made for referring V 20377 to *C. martinsoni*. However, the fragmentary nature of the material and the large temporal separation between V 20377 and all previously described examples of *C. martinsoni*, in addition to some differences of morphological detail between V 20377 and previously described *C. martinsoni* specimens (see below), lead us to adopt the more conservative course of referring the material to *Caenagnathasia* sp.

One feature deserves special note. In both *Caenagnathasia martinsoni* and V 20377, an anteroposterior row of fossae that superficially resemble the dental alveoli of other dinosaurs is present on the dorsal surface of the anterior portion of the dentary. However, these fossae differ from the alveoli of other theropods in that the bony partitions between them are poorly developed and there is no indication of dental tissues. They are probably homologous to the occlusal grooves seen in some other caenagnathids, such as *Caenagnathus*. However, the lateral occlusal grooves in *Caenagnathus* are separated only by bony prominences that protrude a short distance lingually from the labial margin of the dorsal surface of the dentary (Currie et al., 1994: fig. 1C), rather than by complete transverse bony partitions as in *Caenagnathasia*. This morphological distinction may suggest a difference in feeding strategy between these two taxa, but it is also possible that the lateral “occlusal” grooves were entirely obscured by the keratinous beak in both cases. Specimens that reveal the morphology of the upper jaw will be needed in order to understand how the jaws interacted during feeding.

Also noteworthy are several morphological variations present among the four known dentary specimens of *Caenagnathasia* (Table 2). V 20377 is more different from the other *Caenagnathasia* specimens, which are all from the Bissekty Formation (Upper Cretaceous: Turonian) of Uzbekistan and have all been assigned to *C. martinsoni* (Currie et al., 1994; Sues and Averianov, 2015), than the Bissekty specimens are from each other. Furthermore, V 20377 is approximately 10 million years younger than other *Caenagnathasia* specimens, further suggesting that V 20377 is more likely to represent a new species of *Caenagnathasia* than to be referable to *C. martinsoni*. Given the limited nature of the material, however, we refrain from formally erecting a new species and instead assign V 20377 to *Caenagnathasia* sp., pending the discovery of more complete specimens that may shed light on the taxonomic position of V 20377. Nevertheless, the discovery of V 20377 demonstrates that the genus *Caenagnathasia* lasted for a minimum of about 10 million years in the Late Cretaceous of Asia, representing

one of the longest-lived theropod genera.

Table 2 Summary of differences among the specimens of *Caenagnathasia*

Osteological feature	ZIN PH 2354/16	CCMGE 401/12457	CCMGE 402/12457	IVPP V 20377
1. Posterior surface of symphysis	with tubercle	smooth with foramina	?	with shallow vertical groove
2. Chin-like eminence between anterior and ventral surfaces in lateral view	present	absent	absent	absent
3. Dorsal surface of symphysis	midline groove weak or absent	with midline groove	?	with midline groove
4. Paired second anterior occlusal grooves flanking first anterior occlusal groove	present	absent	?	absent
5. Apical projections on lingual ridges	absent	present	?	present
6. Pneumatic foramen in front of mandibular fenestra on lateral surface of dentary	absent	?	present	?
7. Depression on posteroventral margin of symphysis	absent	present	?	absent
8. Foramen for inferior alveolar nerve and internal mandibular artery	present	?	present	?

Two oviraptorosaurian taxa, namely *Avimimus* (Ryan and Russell, 2001) and *Gigantoraptor* (Xu et al., 2007), were previously recovered from the Upper Cretaceous Iren Dabasu Formation. V 20377 represents the third oviraptorosaur known to exist in the Erlian Basin. Both *Caenagnathasia* and *Gigantoraptor* were assigned to Caenagnathidae in a recent phylogenetic analysis (Lamanna et al., 2014), while *Avimimus* was classified in a more basal position, as the sister group of Caenagnathoidea (including both Caenagnathidae and Oviraptoridae). The oviraptorosaurian fauna of the Erlian Basin shows a large range of body size, from the large ~8 m *Gigantoraptor* to the small *Caenagnathasia* (probably under 1 m in body length). By contrast, the largest North American caenagnathid is *Anzu wyliei*, with an estimated total length of about 3.5 m (Lamanna et al., 2014), so caenagnathids appear to have been restricted to smaller body sizes in North America. Neither the Erlian Basin fauna nor the North American fauna includes oviraptorids, whereas the oviraptorosaurian fauna from Mongolia (Osmólska et al., 2004), consists mostly of oviraptorids and exhibits even less size variation than the North American fauna and the Erlian fauna.

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内蒙古二连盆地二连组亚洲近颌龙(兽脚类：窃蛋龙类)一未定种

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摘要：亚洲近颌龙属(*Caenagnathasia*)首次报道于乌兹别克斯坦的晚白垩世Bissekty组，时代为土伦阶(Turonian)。报道了发现于内蒙古二连盆地晚白垩世二连大巴苏组的一件下颌联合部分，根据以下特征将这件标本归为亚洲近颌龙属：齿骨完全愈合，齿骨愈合部分未向下倾斜，齿骨背侧边缘的前部侧面观略凹，侧面的咬合面具有舌嵴，舌嵴上具有尖状突起，血管槽和相关的孔未延伸到齿骨愈合部分的背面，具有前部的咬合槽。新的标本将亚洲近颌龙的生存时代和地理分布延伸到了中国的坎潘阶(Campanian)。

关键词：内蒙古二连盆地，晚白垩世，二连组，兽脚类，近颌龙科，亚洲近颌龙属

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