A new oviraptorosaur (Dinosauria, Theropoda) from Mongolia: The first dinosaur with a pygostyle

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A description of *Nomingia gobiensis* gen. et sp. n., the first known dinosaur with a pygostyle, the structure known so far only in birds, is presented. The specimen comes from the Late Cretaceous strata at Bugin Tsav, Trans-Altai Gobi, Mongolia. *N. gobiensis* is assigned within the Oviraptorosauria based on the following characters: pneumatized caudal vertebrae, posteriorly concave ischium, and deep cervicodorsal hypapophyses. This specimen has been previously partially described without being formally named (Barsbold *et al.* 2000).

Key words: Dinosauria, Theropoda, Oviraptorosauria, Late Cretaceous, Gobi Desert, Mongolia.

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Introduction

The present note is a description and formal erection of a new genus and species, *Nomingia gobiensis,* for a dinosaur, that earlier was referred to as either 'an oviraptorosaur from Mongolia' (Sloan 1999) or just by a field number (Barsbold *et al.* 2000).The specimen here described was found in 1994 by the Mongolian-Japanese Palaeontological Expedition. It is preserved in a bluish-white, fine sandstone layer which is interbedded with some dark red mudstone layers. This horizon is underlain by a hard,

fine sandstone layer with cross stratification (in-channel deposits). The specimen was preserved in point-bar deposits of a river.

The most striking character of *N. gobiensis* is its tail, which is shorter than the tails of most dinosaurs and ends in a dagger-like pygostyle (Barsbold *et al.* 2000). Up to now, this feature has been known only in birds. *N. gobiensis* exposes some oviraptorosaurian synapomorphies (pneumatized proximal caudals, prominent cervicodorsal hypapophyses, and a posteriorly concave ischium) and for this reason it has been assigned here to Oviraptorosauria Barsbold, 1976. Its relationship with the advanced oviraptorosaurs, Caenagnathidae and Oviraptoridae, has been implied by a cladistic analysis by Maryańska, Osmólska, and Wolsan, which is going to be published at a later date.

According to a recent cladistic analysis by Sereno (1999a: supplementary material), these oviraptorosaur families constitute a clade Oviraptoroidea (definition of this taxon is given in Sereno 1999a: p. 2147, position 88), later apparently renamed Caenagnathoidea (Sereno 1999b: fig. 1). Comparisons with Mongolian oviraptorids have been based upon recent observations by Barsbold, Maryańska, and Osmólska (unpublished) on the known, as well as new oviraptorid materials from the GIN and ZPAL collections.

Institutional abbreviations: GIN, Institute of Geology, Mongolian Academy of Sciences, Ulan Bator; ZPAL, Institute of Paleobiology, Polish Academy of Sciences, Warsaw.

Systematic palaeontology

Theropoda Marsh, 1881
Oviraptorosauria Barsbold, 1976
Family *incerte sedis*
Genus *Nomingia* nov.

Type species by monotypy: *Nomingia gobiensis* sp. n.

Diagnosis as for the species.

Derivation of the name: after Nomingiin Gobi, a part of the Gobi Desert close to the type locality.

Nomingia gobiensis sp. n.

Figs. 1–4.

Holotype: GIN 100/119 (referred to as GIN 940824 by Barsbold *et al.* 2000); incomplete postcranial skeleton.

Type horizon: Beds of Bugeen Tsav (equivalent of the Nemegt Formation) – ?upper Campanian and ?lower Maastrichtian (Gradziński *et al.* 1997); Nemegt Formation – ?mid-Maastrichtian (Jerzykiewicz & Russell 1991).

Type locality: Bugin Tsav, Bayankhongor Province, Gobi Desert, Mongolia (GPS coordinates of the site: latitude: 43-52-0101 N; longitude: 100-00-4247 E; altitude: 970 m).

Derivation of the name: Found in the Gobi Desert.

Material. — Only the holotype is known, including: a continuous series of vertebrae comprising 13 presacrals, 5 synsacrals, 24 caudals with most chevrons articulated, the complete pelvis, 10 fragmentary thoracic ribs, several disarticulated gastralia, left femur, and both tibiae and fibulae.

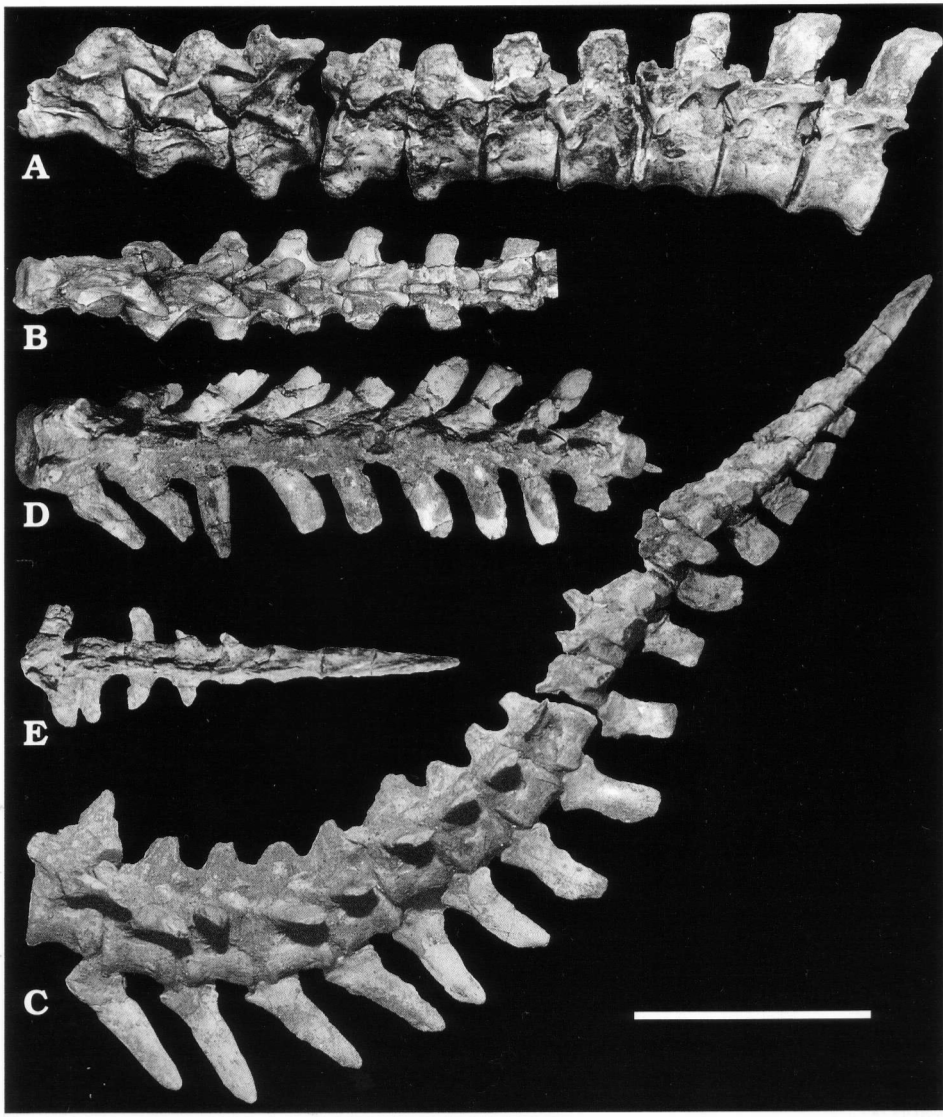

Fig. 1. *Nomingia gobiensis* gen. et sp. n. GIN 100/119. **A**. Ten most anterior vertebrae from the preserved presacral series, left lateral view. **B**. Six most anterior vertebrae from the preserved presacral series, dorsal view. **C**. Tail as preserved (second through twenty-fourth caudals), left lateral view. **D**. Proximal part of tail (second through tenth caudals), dorsal view. **E**. Distal part of tail (eleventh through twenty-fourth caudals), dorsal view. Scale bar 10 cm.

Diagnosis. — Differs from all other oviraptorosaurs in having the tail composed of only 24 vertebrae, the last five of which fused into a pygostyle; chevrons wide and dorsoventrally elongate on most caudals, except on pygostyle; pelvis weakly propubic, with pubic axis at angle of about 20° to vertical; dorsal margin of ilium convex along preacetabular process and horizontal along postacetabular process; preacetabular pro-

cess about 25% longer than postacetabular process; postacetabular process equally deep along its entire length; iliac process of pubis twice as long as respective process of ischium.

Description. — Number of presacrals unknown. Each preserved presacral centrum has a pleurocoel on either side (Fig.1A). Sutures between centra and arches are visible, and are open on the two most anterior vertebrae preserved. All the transverse processes are transversely short, wide and massive (Fig. 1B). In the three most anterior presacrals, they are subtriangular and slope lateroventrally, becoming right-angled and horizontal more posteriorly, and rising laterodorsally further down the series. At least two of the presacrals in the preserved series seem to represent cervical vertebrae. They differ from the succeeding presacrals in having longer centra, elongate postzygapophyses, and anteroposteriorly longer neural spines, with gently curved dorsal margins. The postzygapophyses are separated by deep V-shaped spaces, and have low, elongate epipophyses. The second of these vertebrae has a distinct ventral ridge along the anterior part of the centrum, whereas there are deep hypapophyses on the centra of the three succeeding presacrals. Beginning at the seventh preserved presacral, the centra gradually become spool-shaped, which is characteristic of the dorsals. Parapophyses are concave, cup-like, and located ventrally on centra in the first four preserved vertebrae, just below the arch in the fifth, and on the arches in the more posterior presacrals. Beginning at the third presacral, the neural spines become shorter anteroposteriorly. Their shape distinctly changes from subtriangular to rectangular between the fifth and sixth preserved presacrals, and from that point they become higher and more rectangular towards the sacrum. The last three dorsals lack the ventral ridge, which is present on the centra of the more anterior dorsals. The transverse process of the penultimate dorsal (twelfth preserved presacral) is bipartite: one part has a small surface for the rib tubercle, the other contacts the cranial margin of the preacetabular process of the ilium. The centrum of the last dorsal (thirteenth in the preserved presacral series) is tightly attached to the synsacrum, and the neural spine of this vertebra is in contact with the first sacral neural spine. However, the intercentral suture with the next (sacral) centrum is still visible (Fig. 2B), and the narrow transverse process (?rib) of this vertebra does not adhere to the ilium, but curves ventrally, extending parallel to the blade of the preacetabular process. For these reasons, this vertebra is considered here as an incompletely sacralised dorsal.

Table1. Measurements (in mm) of the pelvic and hindlimb elements in *N. gobiensis* (GIN 100/119).

length of ilium	252
max. length of pubis	243
length of ischium (along chord)	145
length of femur	285
length of tibia	355

The synsacrum comprises five vertebrae (but see above), which are fused both by their centra and arches; the sacral neural spines are not fused, at least dorsally, but contact each other (Fig. 2A, C). The second through fifth sacral centra are flat ventrally, and there is a medial groove along the second through fourth centra.

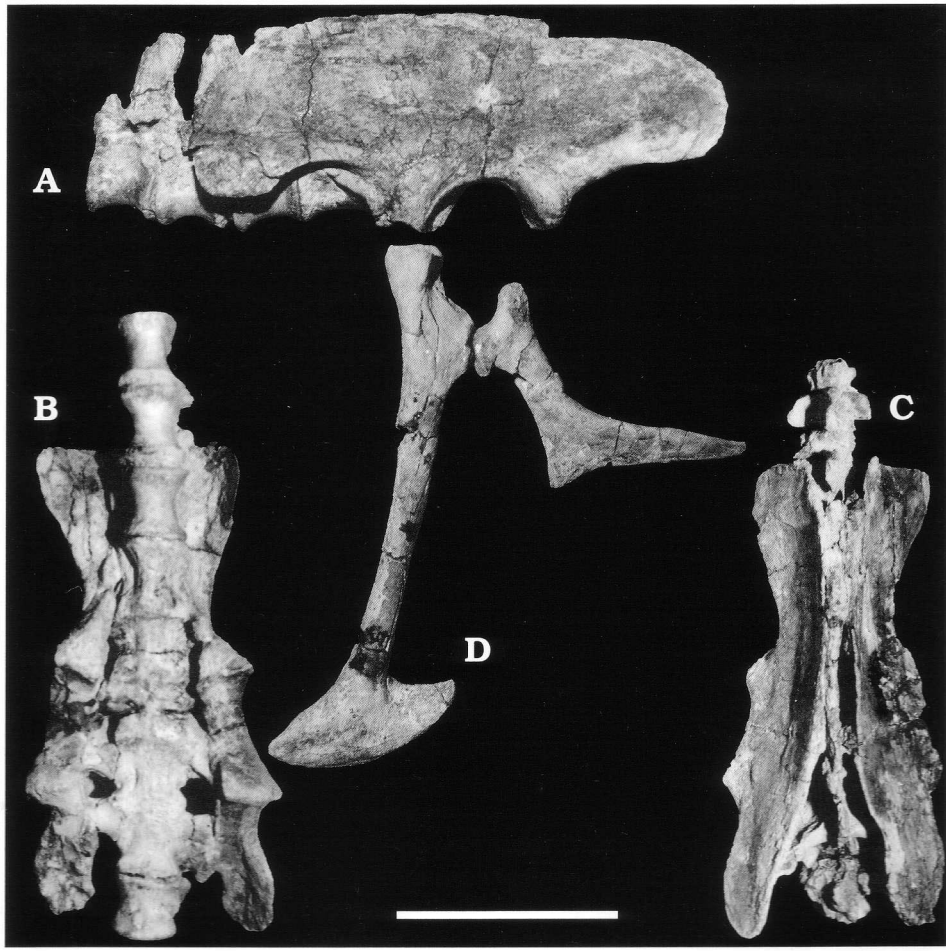

Fig. 2. *Nomingia gobiensis* gen. et sp. n. GIN 100/119. **A.** Left ilium with articulated three most posterior dorsals and sacrum, lateral view. **B.** The same, ventral view. **C.** The same, dorsal view. **D.** Right (reversed) articulated pubis and ischium, lateral view. Scale bar 10 cm.

The tail includes 24 vertebrae, the last five of which are fused into a dagger-like pygostyle (Barsbold *et al.* 2000). There are pleurocoels on the centra of the 10 proximal caudals (Fig. 1C). The first caudal is firmly joined with the synsacrum, but the intercentral suture is still well marked (Fig. 2D). All but the two most proximal, and the eleventh and twelfth distal caudal centra, each have a pair of parallel ridges bounding a median groove along the ventral surface. Throughout the first two-thirds of the tail, the depth and length of centra decrease progressively. More distally, the lengths of the centra do not change, until the last four caudals of the pygostyle. The neural spines become shallower distally, and the last is on the sixteenth caudal. The transverse processes are distinguishable up to the eighteenth caudal (Fig. 1D, E; compare also Barsbold *et al.* 2000: fig. 1a–g). The prezygapophyses are short, only slightly longer than the postzygapophyses, and have normal shapes up to the fourteenth or fifteenth caudal. Begin-

ning at about the fourteenth caudal, the postzygapophyses join to form a continuous crest. Initially, the crest is overlapped laterally by the prezygapophyses, but behind the eighteenth caudal, the prezygapophyses also participate in the formation of the median dorsal crest. In the last five fused caudals, the arches cannot be distinguished, and only the massive crest with a sharp dorsal margin projects above the centra.

Chevrons are present on 17 caudals, starting between the second and third and ending between the eighteenth and nineteenth (Fig. 1C). The chevrons are anteroposteriorly broad, but dorsoventrally elongate until the last three or four, which are equilateral rectangles. The proximal six or seven chevrons slightly narrow ventrally, and end in blunt points, whereas more distal chevrons are quadrangular.

Both pubes and ischia were found in articulation, but separate from the ilium, which makes the restoration of the pelvis tentative (Fig. 4B). It seems that the pelvis was weakly propubic, its axis being at no more than 20° to the vertical.

The ilium is longer than the synsacrum and covers eight vertebrae. It is relatively shallow, with the preacetabular process being about 25% longer than the postacetabular (Fig. 2A). The dorsal margin of the ilium is about horizontal along the postacetabular process but gently rises anteriorly above the middle of the acetabulum to the midpoint of the preacetabular process. More anteriorly, the dorsal margin slopes gently anteroventrally. The preacetabular process does not have a pointed anteroventral process, but extends into a slight, broadly rounded projection that does not attain the ventral level of the pubic peduncle. Anterior to the pubic peduncle, there is a shallow, elongate cuppedicus fossa at the ventral margin of the preacetabular process (Figs. 2A, 4A, B). The postacetabular process is almost equally deep along its entire length, and only slightly shallower than the preacetabular process. It is broadly rounded posteriorly. On its posterior margin there is a marked, flat rim that extends onto the posterodorsal margin. The brevis fossa is shallow and short, and is delimited medially by a low ridge that merges anteriorly with the flattened ventral border of the postacetabular process (Fig. 4A). The pubic and ischiadic peduncles are equally deep dorsoventrally, but the former is anteroposteriorly much longer. There is a low antitrochanter on the ischiadic peduncle.

The pubis is long, constituting 95% of the length of ilium (Fig. 2D). It has a long iliac process. The elongation of the iliac process of the pubis makes the ventral portion of the acetabulum deeper than the dorsal part. The pubic shaft is almost straight. The pubic foot comprises equally long anterior and posterior processes, which form a long symphysis. The pubic apron extends along the distal half of the pubis.

The ischium is short, and its maximum length is only half that of the pubis. It curves strongly posteriorly, so that the posterior margin of the distal end of the ischium is parallel to the ventral margin of postacetabular process of the ischium. The apex of the triangular obturator process is positioned slightly proximal to the midlength of the ischium. The iliac process of the ischium is less than half as long as the iliac process of the pubis.

The femur is about 13% longer than the ilium. It has a round head that faces mostly medially, and is supported by a weak neck (Fig. 3A, B). The craniocaudal curvature of the femoral shaft is pronounced. The greater trochanter is level with but clearly separated from the femoral head. The anterior (= lesser) trochanter is proximodistally long, but its dorsal extremity is not sufficiently well preserved to determine its precise relation to the greater trochanter. The cleft between the two trochanters, if any, could not have been

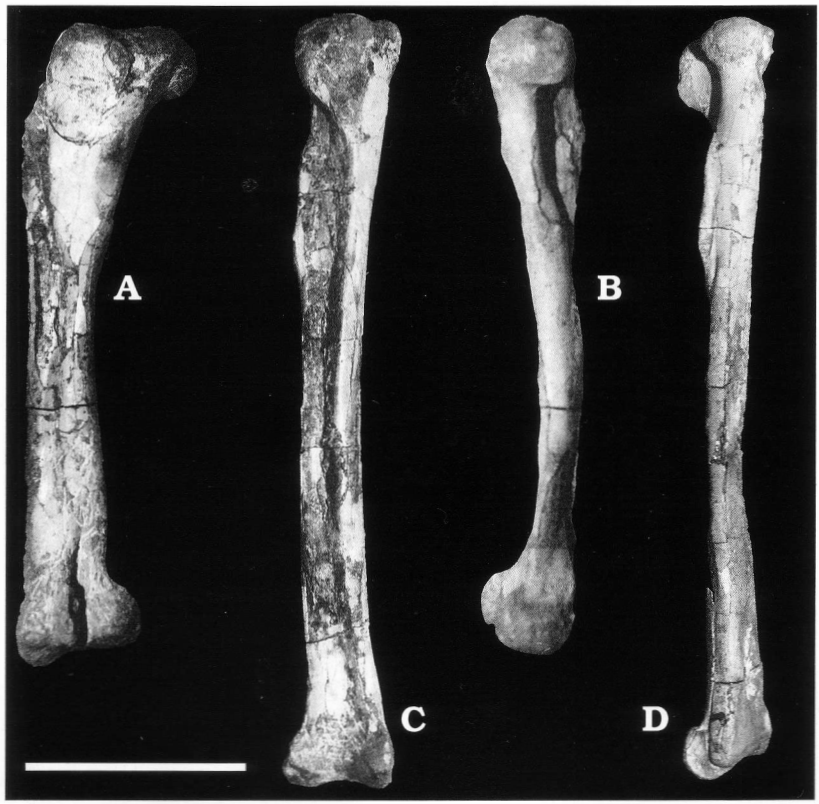

Fig. 3. *Nomingia gobiensis* gen. et sp. n. GIN 100/119. **A**. Left femur, caudolateral view. **B**. The same, medial view. **C**. Right tibiotarsus, anterior view. **D**. Left tibiotarsus, posterolateral view. Scale bar 10 cm.

very deep, however. On the distal end, the extensor groove is distinct, the lateral condyle extends downwards below the medial condyle, and there is a well demarcated tibiofibular crest. The medial condyle extends inwards beyond the medial margin of the shaft.

The tibia is 24% longer than the femur (Fig. 3C, D). The lateral cnemial crest is wide and anterolaterally directed. The fibula contacts the calcaneus. The fibular head is weakly concave medially. The tubercle for the tibiofibularis muscle is directed craniolaterally.

The astragalus and calcaneus are articulated and closely bound to each other and to the crus bones. The distal part of the lateral condyle is covered by the calcaneus. The ascending process of the astragalus is tall, and extends at least 20% of the length up the cranial surface of the tibia. The lateral surface of the disc-like calcaneus is concave (Fig. 3D).

Comparisons. — *Nomingia gobiensis* has at least four of the oviraptorosaurian, or oviraptorid, synapomorphies: three cervicodorsal vertebrae with deep hypapophyses, proximal caudals with pneumatized centra (vertebrae are not pneumatized in *Caudipteryx* Ji *et al.*, 1998; this genus has been interpreted as a basal oviraptorosaur by Sereno 1999a), tail relatively short, and ischium with its posterior profile concave.

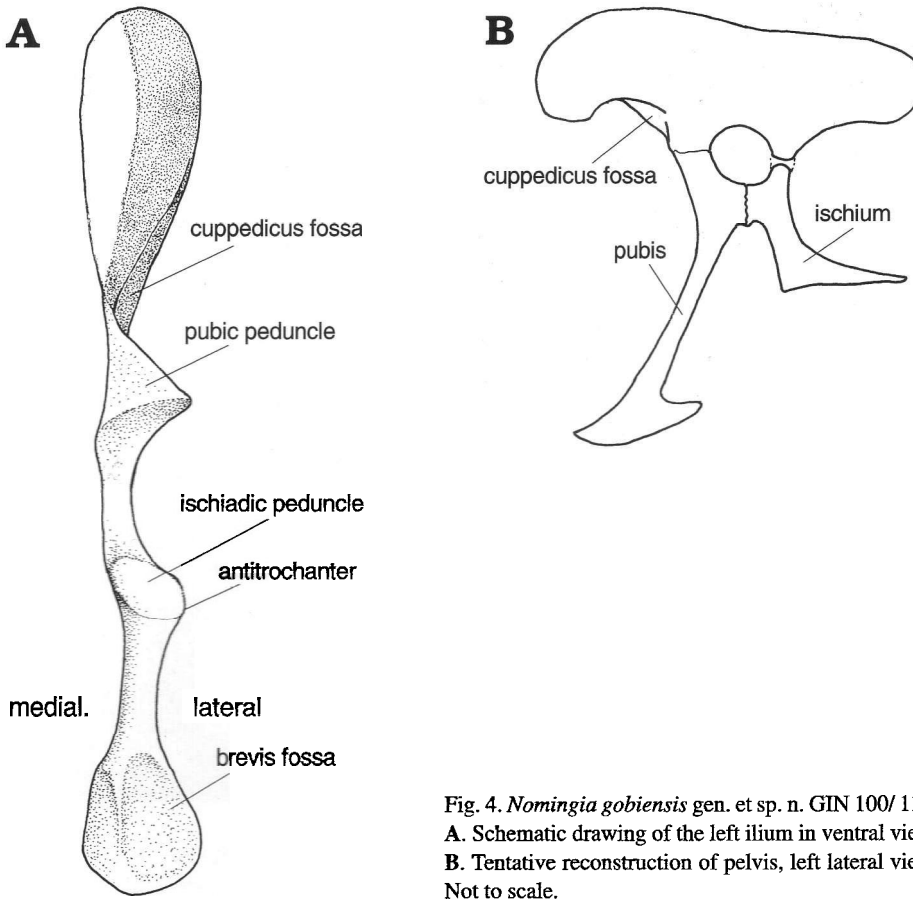

Fig. 4. *Nomingia gobiensis* gen. et sp. n. GIN 100/ 119. **A**. Schematic drawing of the left ilium in ventral view. **B**. Tentative reconstruction of pelvis, left lateral view. Not to scale.

A similarly deep hypapophysis is found on one of the vertebrae in *Mononykus olecranus* Perle *et al.*, 1993, but other hypapophyses are distinctly smaller in this species (Chiappe *et al.* 1996) than they are in the oviraptorids and *N. gobiensis*. Among theropods, pneumatized caudal vertebrae have been found only in oviraptorosaurs, and characterise representatives of their advanced groups, the Caenagnathidae and Oviraptoridae. The tail, which includes 35 or more caudals in other theropods, is shorter in oviraptorosaurs. Except in the caenagnathids and the holotype of *Oviraptor philoceratops* Osborn, 1924, complete tails are preserved in all oviraptorosaur species known. According to the present authors' personal observations, tails comprise at most 30 caudals in oviraptorids (contrary to Barsbold *et al.* 1990), with the possible exception of a juvenile specimen of *Conchoraptor gracilis* Barsbold, 1986 which seems to have 32 caudals. None of these tails ends with a pygostyle. The shortest are the tails in *Caudipteryx zoui* Ji *et al.*, 1998 which has 22 caudals, and *N. gobiensis*, described herein, which has 24 caudals (Barsbold *et al.* 2000).

Generally, oviraptorosaur ischia have concave posterior profiles. However, the curvature of the ischium in *N. gobiensis* is exceptionally strong, with the axes of the proximal and distal parts of the ischiadic shaft meeting at an angle of about 120°. Similarly

strong curvature is seen in the ischium of the caenagnathid *Chirostenotes pergracilis* Gilmore, 1924 (Currie & Russell 1988; Sues 1997).

In addition to its pygostylous tail, *N. gobiensis* differs from all known oviraptorosaurs in the shape of the ilium, and from the oviraptorids in having a straight pubic shaft. The dorsal outline of the ilium is rather straight in *Ingenia yanshini* Barsbold, 1981 (Barsbold *et al.* 1990: fig. 10.4f) and *Conchoraptor gracilis* (personal observation), and convex along the entire length of the ilium in *Caudipteryx zoui* Ji *et al.* (1998: fig. 5b), *'Rinchenia' mongoliensis* (Barsbold) 1986 (Barsbold *et al.* 1990: fig. 10.3c) and *Chirostenotes pergracilis* (Currie & Russell 1988: fig. 6). In *N. gobiensis*, the dorsal iliac margin is convex only along the preacetabular process. In most oviraptorosaurs, the preacetabular process of the ilium is either slightly longer or shorter (less than 10% each way) than the postacetabular process, but in *N. gobiensis*, the preacetabular process is about a quarter longer than the postacetabular process. The preacetabular process is about 50% longer than the postacetabular process in *Chirostenotes pergracilis*, thus it is even longer than the process in *N. gobiensis*, and the end of the postacetabular process is bluntly pointed, rather than broadly rounded as in *N. gobiensis*. The anteroposteriorly wide pubic peduncle of the ilium in *N. gobiensis* differs from the much narrower peduncles in *I. yanshini* and *Conchoraptor gracilis*, but seems comparable to the peduncles in *'Rinchenia' mongoliensis* and *Chirostenotes pergracilis*. The pubic peduncle is similarly widened in the dromaeosaurids *Deinonychus antirrhopus* Ostrom, 1969a (Ostrom 1969b) and *Velociraptor mongoliensis* Osborn, 1924 (Norell & Makovicky 1999). The pubic shaft is almost straight in *N. gobiensis* and *Chirostenotes pergracilis* (Sues 1997), but it is at least slightly concave anteriorly in known oviraptorids.

A family-level classification of *N. gobiensis* is impossible at the moment, although the elongate preacetabular process of the ilium, and the shapes of the pubis and ischium, suggest it may be closer to *Chirostenotes pergracilis* than to any other oviraptorosaur. Unfortunately, Caenagnathidae are poorly known, and species assigned to that taxon are based on incomplete specimens, which severely restricts any further comparisons of *N. gobiensis* with the caenagnathid taxa.

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Nowy owiraptorozaur (Dinosauria, Theropoda) z Mongolii: pierwszy dinozaur z pygostylem

RINCHEN BARSBOLD, HALSZKA OSMÓLSKA, MAHITO WATABE, PHILIP J. CURRIE i KHISHIGJAW TSOGTBAATAR

Streszczenie

Opisano nowego dinozaura z grupy terapodów, *Nomingia gobiensis* gen. et sp. n., z osadów wieku późnokredowego Mongolii w Bugin Caw na Gobi Zaałtajskiej. Niekompletny szkielet pozaczaszkowy tego dinozaura został znaleziony na pustyni Gobi, w Mongolii, przez mongolsko-japońską wyprawę paleontologiczną. Najbardziej charakterystyczną cechą *N. gobiensis* jest zakończony pygostylem i nieco skrócony ogon, liczący tylko 24 kręgi (Sloan 1999; Barsbold *et al.* 2000). Pygostyl nie był dotychczas znany u żadnego dinozaura i był uważany za cechę swoistą wyłącznie dla ptaków. *N. gobiensis* został uznany za przedstawiciela Oviraptorosauria o nieustalonej przynależności rodzinowej, wykazuje jednak pewne podobieństwa do słabo poznanego przedstawiciela rodziny Caenagnathidae, *Chirostenotes pergracilis* Gilmore, 1924.