Journal of Vertebrate Paleontology 23(3):695–698, September 2003

NOTE

A LARGE ORNITHOMIMID PES FROM THE LOWER CRETACEOUS OF THE MAZONGSHAN AREA, NORTHERN GANSU PROVINCE, PEOPLE'S REPUBLIC OF CHINA

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The Mazongshan Area of northern Gansu Province, People's Republic of China, has yielded a diverse tetrapod paleofauna that includes dinosaurs, crocodiles, mammals, and turtles (Dong, 1997). Based on palynomorph, invertebrate, and vertebrate fossil data, the dinosaur-bearing sediments in the ''Middle Grey unit'' of the Lower Cretaceous lower Xinminbao Group are most likely of Aptian–Albian age (Tang et al., 2001). In 1999, a partial skeleton of a large ornithomimid was recovered from these deposits by a joint expedition of the Carnegie Museum of Natural History, the University of Pennsylvania, and the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP). This new specimen has the largest known foot of any Early Cretaceous ornithomimid.

SYSTEMATIC PALEONTOLOGY

Suborder THEROPODA Marsh, 1881
cf. ORNITHOMIMIDAE Marsh, 1890

Comment—The new specimen is placed within Ornithomimidae (sensu Smith and Galton, 1990). Smith and Galton (1990) advocated revising Ornithomimidae to include *Harpymimus* (Harpymimidae), *Elaphrosaurus* (no longer considered an ornithomimid; Chure, 2001), *Archaeornithomimus*, and *Garudimimus* (Garudimimidae). This revision was based in part on the ''possible presence of teeth'' (Smith and Galton, 1990:264), which are known in *Harpymimus* and *Pelecanimimus*, and the presence of five or six sacral vertebrae. The resulting taxonomic reorganization synonymizes Ornithomimidae with Ornithomimosauria (Barsbold, 1976).

Material—IVPP V12756, a partial right foot (astragalus and calcaneum [Fig. 1A, B]; all three phalanges of digit II, first and second phalanges of digit III, third through fifth phalanges of digit IV [Fig. 1C, D]; second and third metatarsals [Fig. 1E, F]) and fragmentary phalanges of a left foot (distal ends of first and second phalanges of digit III, proximal end of first phalanx and partial ungual of digit IV; not figured or described).

Age and Provenance—''Middle Grey unit'' of the Xinminbao Group (Aptian–Albian) of the Mazongshan Area of northern Gansu Province, People's Republic of China (Dong, 1997; Tang et al., 2001).

Remarks—Features shared with Ornithomimidae (sensu Smith and Galton, 1990): pedal unguals pointed and subtriangular with flat flexor surface, semicircular depression on proximal flexor surface (Barsbold and Osmólska, 1990; Russell, 1972) [note: following Barsbold and Osmolska (1990), we refer to ''extensor'' and ''flexor'' surfaces of the foot rather than to ''dorsal'' and ''ventral,'' ''dorsal'' and ''plantar,'' or ''anterior'' and ''posterior'']; the two proximal phalanges of digit III lacking well-developed sagittal ridge (proximal articular surface) and sagittal sulcus (distal articular surface; Barsbold and Osmólska, 1990). Pedal unguals with sharp outer edges producing ''spurs'' at the proximal end (Osmólska et al., 1972; Barsbold and Osmólska, 1990). Phalanges of digit IV abbreviated (Russell, 1972). Feature possibly shared with *Garudimimus* and *Harpymimus*: metatarsal III narrows proximally and separates metatarsals II and IV along extensor surface of foot (Barsbold, 1981; Barsbold and Perle, 1984; Barsbold and Osmólska, 1990). Features shared with *Harpymimus*: proximal phalanges of second and third digits subequal in length (Barsbold and Osmólska, 1990); limb elements ''moderately massive'' (Barsbold and Perle, 1984:120).

DESCRIPTION

Tarsus

The astragalus-calcaneum complex (Fig. 1A, B) is not fused to the tibia. The astragalus, considerably larger than the slender calcaneum (Table 1), is shallowly concave along its distal articular surface as in other ornithomimids (Osmólska et al., 1972; Barsbold and Osmólska, 1990). The medial condyle is much larger than the lateral condyle. A deep depression characterizes the extensor side of the astragalus, and the flexor edge is gently concave. The lateral condyle is broadly notched on its distal aspect for articulation with the medial protuberance of the calcaneum. This articulation is similar to that of *Gallimimus* (Osmólska et al., 1972), but it extends further towards the flexor surface in IVPP V12756. The proximal portion of the lateral condyle (extensor side) also contributes to the medial wall of the fibular notch. The ascending process is broken proximally and medially; only a slender rectangular portion is preserved (Fig. 1B).

The calcaneum is mediolaterally reduced as in other ornithomimids. A broad medial protuberance emanates from its medial aspect and fits into a corresponding notch in the astragalus. The lateral surface is distinctly concave, unlike the corresponding flat surface in *Gallimimus* (Osmólska et al., 1972). The proximal surface of the calcaneum bears a deep notch for articulation with the distal end of the fibula.

Metatarsals

The second metatarsal (Fig. 1E, F) is essentially complete, missing only the lateral tip of the proximal articular surface. If this border were intact, the proximal articular surface would appear triangular or subtriangular in shape. A process extends from the proximal flexor surface of the metatarsal for insertion of the ankle flexor musculature. The proximal two-thirds of the diaphysis is straight, whereas the distal portion flares medially. The caput is rotated slightly medially so that the articular surface is directed distally and medially. The medial condyle is larger than the lateral and the two condyles are separated by a deep sulcus. The flexor-extensor depth of the diaphysis is greater than the medial-lateral width, except in the portion immediately proximal to the caput. The lateral aspect of the diaphysis contains an articulation with the third metatarsal. This articular surface is narrowest and slightly concave at the proximal end of the element and expands distally to form a broad, flat surface that extends nearly to the caput. The flexor edge of the bone bears two low ridges, approximately one cm apart, running longitudinally from mid-diaphysis to approximately two-thirds of the length of the diaphysis. The area bound by the ridges bears muscle scars from the intrinsic digital flexor muscles.

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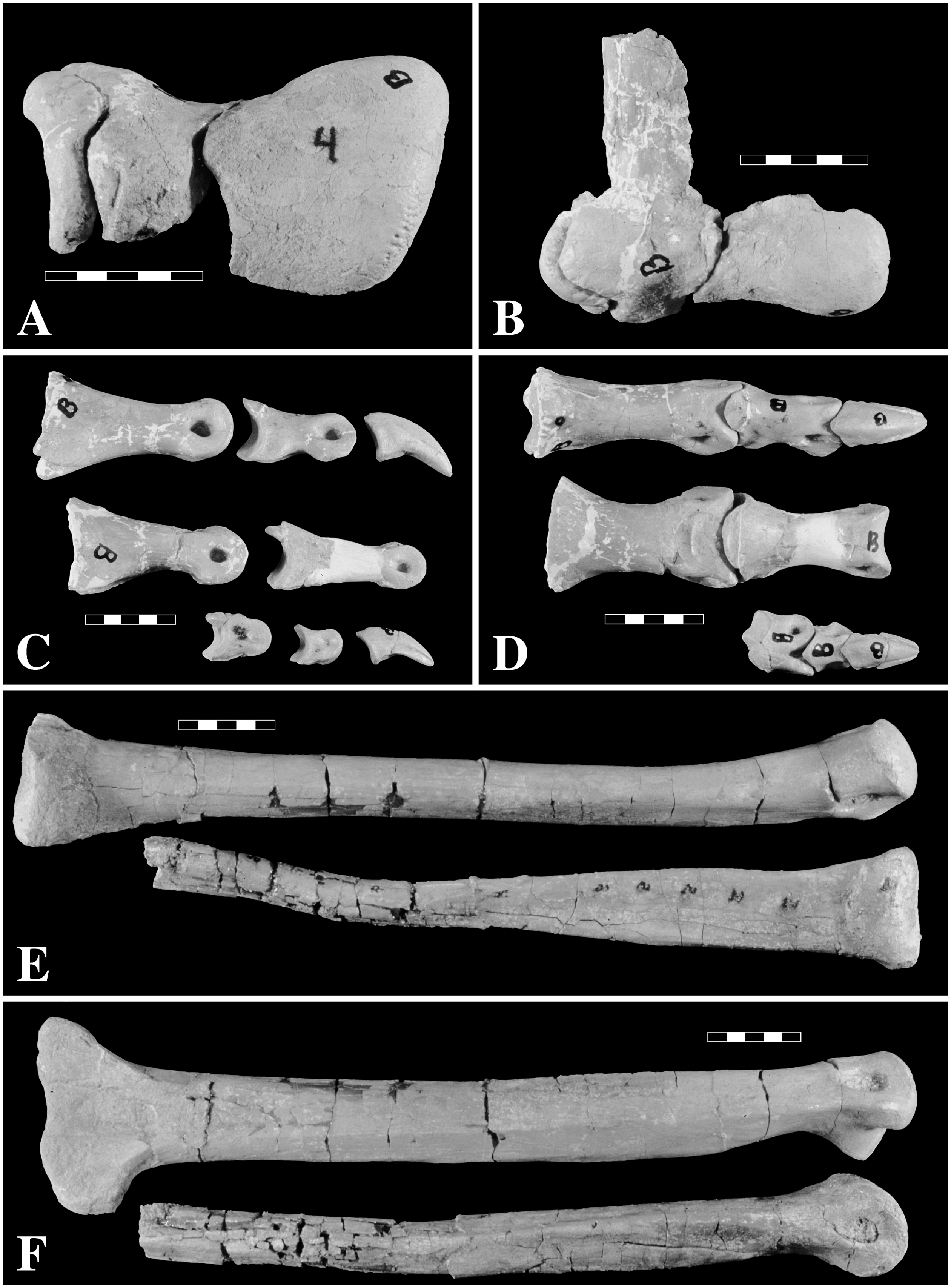

FIGURE 1. Cf. Ornithomimidae gen. et. sp. indet, IVPP V12756. **A**, **B**, right astragalus and calcaneum in (**A**) distal and (**B**) extensor views. Extensor side is at top in **A**. **C**, **D**, three phalanges of digit II (top row), first and second phalanges of digit III (middle row), and third through fifth phalanges of digit IV (bottom row) in (**C**) lateral and (**D**) extensor views. **E**, **F**, metatarsal II (top) and metatarsal III (bottom) in (**E**) extensor and (**F**) lateral views. Scale bars equal 5 cm.

TABLE 1. Measurements* (in mm) of tarsal and pedal elements of IVPP V12756; **MT**, metatarsal; **P**, phalanx.

Element	Length	Proximal medial-lateral width	Proximal flexor-extensor width	Distal medial-lateral width	Distal flexor-extensor width
Astragalus	—	—	—	126.85	76.54
Calcaneum	—	—	—	21.94	59.58
MT II	435	44.53	130	48.73	48.45
MT III	401	—	—	60.18	50.16
P II-1	100.23	45.43	46.00	38.12	32.29
P II-2	60.40	31.94	32.70	30.12	23.16
P II-3	53.83	23.49	27.00	—	—
P III-1	94.77	56.60	47.86	50.86	31.48
P III-2	84**	45.54	34.46	37.90	25.18
P IV-3	36.04	28.96	26.41	29.16	20.79
P IV-4	27.53	24.59	20.55	18.70	23.96
P IV-5	45.54	18.36	20.22	—	—

*To nearest 0.01 mm for lengths under 130 mm; to nearest mm for lengths 130 mm and above.
**Estimated length (element broken at mid-diaphysis and reconstructed).

The third metatarsal (Fig. 1E, F) is missing its proximal end. The entire diaphysis is triangular in cross section with a flat extensor surface. This surface is narrowest and the circumference smallest in the proximal third of the diaphysis. The surface gradually and symmetrically widens over the middle third, whereas the distal third is uniformly wide and only slightly narrower than the caput. The medial and lateral surfaces of the diaphysis are flattened for articulation with the second and fourth metatarsals, respectively. The medial distal condyle is slightly larger than the lateral, and the two are separated by a shallow sagittal depression, in marked contrast to the distinct sulcus of the second metatarsal.

Phalanges

The proximal phalanges of digits II (II-1) and III (III-1) are robust and bear pronounced ridges on their lateral and medial flexor surfaces (Fig. 1C, D). The flexor-extensor height of these ridges is greater in the second digit than in the third. The diaphysis of III-1 is more robust than that of II-1, which is slightly longer proximodistally. The articular surfaces of III-1 and III-2 lack sagittal ridges proximally and sagittal sulci distally, as is typical of other ornithomimids (Barsbold and Osmólska, 1990). Phalanges IV-3 and IV-4 are small, block-like, and highly ginglymoid.

The flexor sides of the two preserved unguals (digits II and IV) are flattened as in other ornithomimids (Osmólska et al., 1972; Russell, 1972). A horseshoe-shaped depression marks the flexor surface of the proximal half of the element and surrounds a low tubercle. The medial and lateral edges of the unguals are flared, forming small ''spurs'' (Fig. 1D; Osmólska et al., 1972; Smith and Galton, 1990).

DISCUSSION

Ornithomimids are known principally from the Upper Cretaceous of Laurasia (Barsbold and Osmólska, 1990), but records from the Lower Cretaceous are also known. Early Cretaceous forms, including *Harpymimus* (Barsbold and Perle, 1984) and *Pelecanimimus* (Pérez-Moreno et al., 1994), are also phylogenetically basal within Ornithomimidae (Norell et al., 2001), and so additional material from this time interval can improve our understanding of the early evolution and distribution of the group.

Derived ornithomimids are known from the Late Cretaceous and tend to have a more elongate pes than basal forms (Holtz, 2001). For example, the ''arctometatarsalian'' pedal morphology (Holtz, 1995) of Late Cretaceous ornithomimids, which may permit contact between metatarsals II and IV proximally and excludes metatarsal III from the ankle joint, is not as pronounced in phylogenetically basal ornithomimids such as *Harpymimus* and *Garudimimus*. Instead, in basal taxa, metatarsal III is wider proximally and thus separates metatarsals II and IV along the extensor surface of the foot.

On the basis of its age, provenance, and large size, IVPP V12756 resembles *Harpymimus* (known only from the Aptian–Albian of Mongolia). However, an important difference between *Harpymimus* and IVPP V12756 involves the morphology of metatarsal III. Based on published descriptions and figures, metatarsal III of *Harpymimus* (although deemed arctometatarsalian by Holtz, 1995) is weakly to moderately pinched at its proximal end (Barsbold and Perle, 1984; Barsbold and Osmólska, 1990; Holtz, 1995, 2001). Indeed, this proximal compression is subtle enough to not be highlighted in the figure that accompanies the original description (Barsbold and Perle, 1984). In IVPP V12756, the proximal diaphysis of metatarsal III is more strongly pinched, and the distal diaphysis is distinctly triangular in cross-section with flattened medial and lateral sides for articulation with metatarsals II and IV, respectively (Fig. 1E, F). Furthermore, the distal diaphysis of metatarsal III in IVPP V12756 has a uniform medial-lateral width on the extensor surface (Fig. 1E), whereas the distal diaphysis of metatarsal III in *Harpymimus* appears to taper uniformly from its distal end to the midshaft (Barsbold and Perle, 1984:fig. 1; to a lesser extent, as redrawn by Barsbold and Osmolska, 1990:fig. 8.6). Unfortunately, the proximal end of metatarsal III of IVPP V12756 was not recovered, and thus we cannot determine whether this bone forms part of the tarsometatarsal joint, as it does in *Harpymimus*.

If not referable to *Harpymimus*, IVPP V12756 may represent a heretofore unknown taxon, and may thus support an important prediction by Holtz (2001) regarding the evolution of the arctometatarsalian pes among ornithomimids. Holtz posits that *Harpymimus* and *Garudimimus* show reversal of the arctometatarsalian plan. That is, these genera do not have the elongate pedal morphology and strongly pinched metatarsal III characteristic of Late Cretaceous ornithomimids, but they may have descended from more strongly arctometatarsalian ancestors. Holtz predicts, therefore, that other early—and presumably phylogenetically basal—specimens will eventually be found with a more strongly arctometatarsalian pes than those of *Harpymimus* and *Garudimimus*. IVPP V12756 may represent such a specimen and may thus extend the derived arctometatarsalian condition as early as the Early Cretaceous.

IVPP V12756 is also remarkable for its large size. Metatarsal II, the best preserved long bone of the foot in the Mazongshan specimen, is nearly 40% larger than the corresponding bone of the holotype of *Harpymimus* (based on measurements from Barsbold and Perle [1984:fig. 1] and Holtz [1995]). IVPP V12756 thus has the largest foot of any known Early Cretaceous ornithomimid, and the largest of any ornithomimid with the exception of *Gallimimus bullatus* (for comparative material and measurements, see Osmólska et al., 1972; Barsbold and Osmólska, 1990; Holtz, 1995).

Acknowledgments—We thank L. Claessens and W. Joyce for comments; G. Erickson, D. Russell, and D. Smith for insightful reviews; Tang Zhilu, Tang Feng, and J. A. Georgi for assistance in the field; and Professor Dong Zhiming for advice. This project was supported by grants from the Research Foundation of the University of Pennsylvania (to N. H. S. and H.-L. Y.), and the National Science Foundation and Nettings and O'Neil funds of the Carnegie Museum (to Z.-x. L.).

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Received 19 November 2001; accepted 24 July 2002.