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Xinghaiornis lini (Aves: Ornithothoraces) from the Early Cretaceous of Liaoning: An Example of Evolutionary Mosaic in Early Birds

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Abstract: We describe a new species of Early Cretaceous bird from the Yixian Formation of Liaoning Province. *Xinghaiornis lini* gen. et sp. nov. is relatively large and characterized by a long, toothless rostrum and an elevated pedal digit I. The design of the skull and feet suggests that this bird was likely a mud-prober. This discovery provides strong support indicating that this avian trophic specialization originated at least 125 million years ago.

Key words: Early Cretaceous, *Xinghaiornis lini*, Yixian Formation, avian trophic specialization

1 Introduction

In the last two decades dozens of new species of birds have been named from the Early Cretaceous Jehol Group of western Liaoning (Chiappe, 1995, 2001; Zhou, 2004; Zhou and Zhang, 2004, 2007; Chiappe et al., 2007; Wang et al., 2010; Hu et al., 2011; Wang and Zhou, 2011). Many of these birds correspond to the two well-diagnosed, major groups of ornithothoracine birds: the Enantiornithes (all taxa closer to *Sinornis* than to Neornithes; Chiappe, 2002; Chiappe and Walker, 2002; O'Connor et al., 2011a; Li et all, 2012) and the Ornithuromorpha (common ancestor of *Patagopteryx* and Ornithurae plus all its descendants; Chiappe, 2002; Zhou and Zhang, 2005; O'Connor et al., 2011b; Zhou et al., 2012). However, to date there is limited evidence of birds that are morphologically intermediate between these major groups. Here we report on a new fossil bird from the Early Cretaceous Yixian Formation of Liaoning Province that exhibits characters typical of both enantiornithines and ornithuromorphs (Fig. 1). The new fossil represents a previously unrecognized clade of basal ornithothoracine birds, with a unique cranial morphology. This new discovery expands our understanding of the ecological specializations of the Early Cretaceous birds from China and provides a glimpse into the morphology of avians very close to the split between Enantiornithes and Ornithuromorpha.

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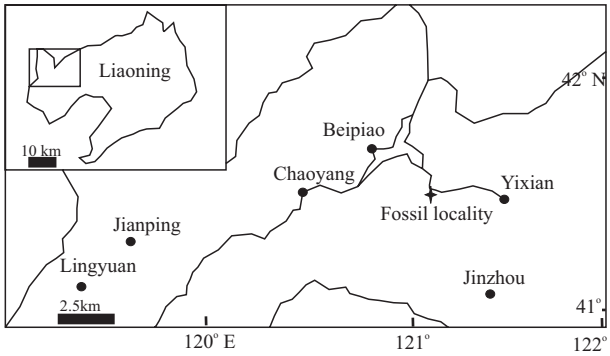

Fig. 1. Map showing the locality of XHPM 1121 in western Liaoning, China (Modified after Li et al., 2012).

2 Systematic Paleontology

Aves Linnaeus, 1758
Pygostylia Chiappe, 2001
Ornithothoraces Chiappe, 1995
Xinghaiornis lini, gen. et sp. nov.

Holotype. XHPM 1121 (Xinghai Paleontological Museum of Dalian, Dalian, Liaoning Province, China), a nearly complete and articulated adult individual preserved in tuff and with feather impressions concentrated around the neck and forelimbs (Fig. 2).

Etymology. The genus name is derived from the Xinghai Square in Dalian, China, and the Xinghai Paleontological Museum where the holotype is housed. The species name honors Mr. Lin Zhihong for his

Fig. 2. Photograph of XHPM 1121.
Anatomical abbreviations: ce, cervical vertebra; co, coracoid; fe, femur; fi, fibula; fu, furcula; hu, humerus; il, ilium; mc, metacarpal; mt, metatarsal; ra, radius; sa, sacral vertebra; sc, scapula; ti, tibiotarsus; ul, ulna; I, II, III, IV, digit I, II, III, IV.

contribution towards this investigation.

Locality and horizon. Sihetun, Shangyuan Town, Beipiao City, Liaoning Province, China; Yixian Formation, Lower Cretaceous.

Diagnosis. A basal ornithothoracine bird distinguishable from other Mesozoic avians by the following unique combination of characters: rostrum long and slim; edentulous upper and lower jaws; dentary with elongated grooves; slender and Y-shaped furcula; humerus with large robust deltopectoral crest; intermembral index (humerus + radius/femur + tibiotarsus) approximately 1.2; articulation of metatarsal I close to the mid-shaft of metatarsal II; trochlea of metatarsal I much more proximally located than those of the other metatarsals.

3 Descriptions

The skull (~ 81 mm long) is complete and exposed in left lateral view. The rostrum is long, approximately 2/3 the total length of the skull, and toothless. The external nares are long and oval in shape. The prenarial region is also long and shallow. The antorbital fenestra appears to be subtriangular. The lower jaw is slender, tapering towards the rostral end. Ventrally, the margin of the lower jaw forms a gentle concavity (Fig. 3).

The vertebral column is poorly preserved and the precise number of cervical and thoracic vertebrae cannot be determined.

The thoracic girdle is preserved nearly in its entirety. The scapula (~ 62 mm long) is long and robust, and it is much longer than the coracoid. The scapular blade is slightly curved and it tapers caudally. The scapula has a prominent glenoid facet, which faces dorsolaterally. The left coracoid is partly covered by the left humerus, but nonetheless, it is evidently a short, strut-like bone. The furcula is Y-shaped, with a long hypocleidium. The sternum is partly covered by a series of other bones, but long lateral trabeculae are visible. The distal ends of these processes are only slightly expanded.

The humerus is long (~ 75 mm) and robust, with a large deltoid crest, which extends for more than a third of the length of the bone. The proximal end has a prominent, dome-like head. The ulna and radius have almost the same length as the humerus. The ulna is slightly bowed proximally and the radius is straight. The mid-shaft width of the ulna is almost twice that of the radius. The right carpometacarpus—the only one preserved—is damaged and partially overlapped proximally by the right ulna and radius. The metacarpals appear to be only partially fused to one another. The major metacarpal is straight, robust, and rectangular-like. The minor metacarpal is not preserved completely but judging from the preserved proximal portion, it is much thinner than the major metacarpal and it extends distally beyond the distal end of the latter. The major digit is long, almost of the same length as the major metacarpal and bears a small ungual phalanx.

The left and right pelvic girdles are exposed dorsomedially and dorsolaterally, respectively. The ilium has a long preacetabular process and a short postacetabular process. The morphology of the ischium and pubis is not

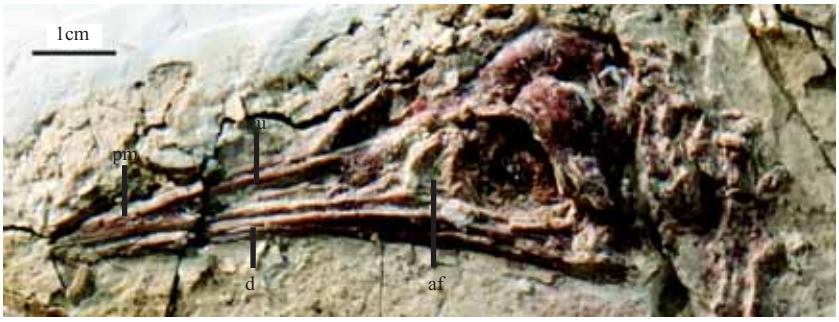

Fig. 3. Detail of the skull of XHPM 1121 in left lateral view.
Anatomical abbreviations: af,antorbital fossa; en, external nares; d, dentary; f, frontal; o, orbit; pm, premaxillary.

clear.

The femur (~ 52 mm long) is longer than the tarsometatarsus but much shorter than the tibiotarsus. The femoral shaft is slightly curved craniocaudally. The tibiotarsus is long (~ 72 mm) and robust. This bone has twice the length of the tarsometarsus (~ 34 mm long). The prominent fibular crest extends nearly to the middle of the tibiotarsal shaft. The distal condyles are fused completely to the shaft and extend laterally. The fibula is slender and short, nearly half the length of the tibiotarsus. The proximal portion is slightly broad and tapering distally from the middle shaft. The metatarsals Ⅱ and Ⅳ are not completely fused along their shafts. Digit I is located high above the others, near the mid-shaft of the metatarsus. The proximal phalanges of digits Ⅱ and Ⅳ are similar in size and shape; they have a sub-symmetrical, ginglymous distal articulation. Digit Ⅲ is the longest. All the pedal claws are small, subequal in size, and weakly recurved.

4 Discussion and Conclusions

Xinghaiornis lini exhibits characters that are typical of either group within Enantiornithes (e.g., slender and Y-shaped furcula, minor metacarpal projecting more distally than major metacarpal) or within Ornithuromorpha (e.g., ball-shaped humeral head, reduced pedal claws, elevated hallux). Such a character combination suggests that this new species is likely close to the phylogenetic split between these two major clades but whether it should be assigned to Enantiornithes or Ornithuromorpha needs to be determined on the basis of a comprehensive cladistic analysis, which is beyond the scope of this brief communication.

Based on the morphology of the rostrum—the long and edentulous jaws—and the structure of the feet, we hypothesized that *Xinghaiornis* was most likely a mud-prober, with feeding strategies comparable to those of living sandpipers and snipes that typically forage along the shore of bodies of water picking out small invertebrates from the soft substrate (Fig. 4). Such ecology has been proposed for some longipterygid enantiornithines (Hou et al., 2004) but the fact that the feet of these birds are typical of perching birds raises some questions about such an interpretation. The discovery of *Xinghaiornis lini* provides strong support to the idea that by the Early Cretaceous basal ornithothoracine birds had already evolved ecologies approaching those of living mud-probers.

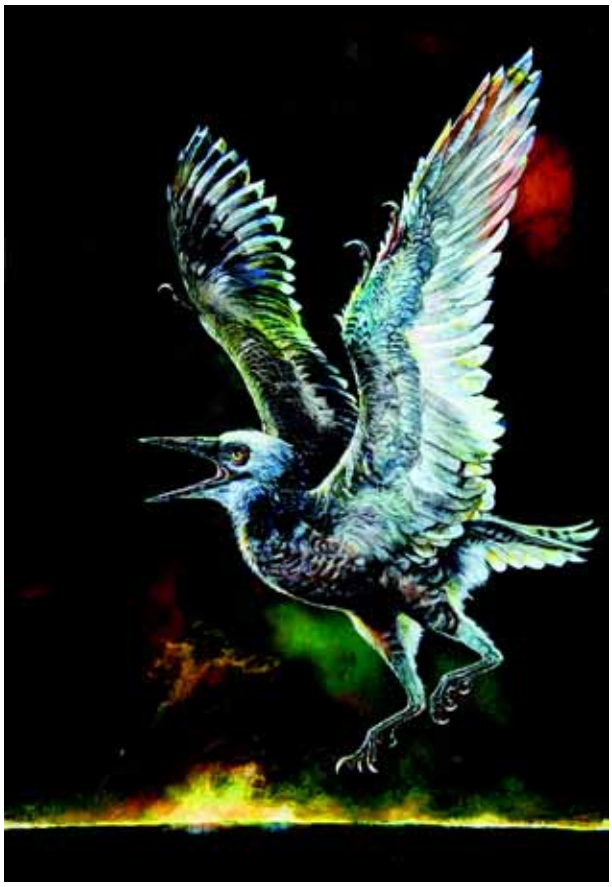

Fig. 4. Life reconstruction of XHPM1121

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