Zootaxa 3884 (3): 253–266
www.mapress.com/zootaxa/

Article

ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)

http://dx.doi.org/10.11646/zootaxa.3884.3.4
http://zoobank.org/urn:lsid:zoobank.org:pub:4B0EA72D-A7B8-4A9E-9B3A-47DDE7D384AE

An advanced, new long-legged bird from the Early Cretaceous of the Jehol Group (northeastern China): insights into the temporal divergence of modern birds

DI LIU[1], LUIS M. CHIAPPE[2], YUGUANG ZHANG[1], ALYSSA BELL[2], QINGJIN MENG[1], QIANG JI[3] & XURI WANG[3,4]

[1]*Beijing Museum of Natural History, Beijing 100050, China*
[2]*The Dinosaur Institute, Natural History Museum of Los Angeles County, 900 Exposition Boulevard, Los Angeles, CA 90007, USA*
[3]*Institute of Geology, Chinese Academy of Geological Sciences, Beijing 100037, China*
[4]*Corresponding author. E-mail: wang198109@163.com*

Abstract

We describe a new ornithuromorph bird species, *Gansus zheni* from the Lower Cretaceous lacustrine deposits of the Jiufotang Formation (Jehol Group), Liaoning Province, China. A cladistic analysis resolves *Gansus zheni* as the sister taxon of the roughly contemporaneous *Gansus yumenensis* (Xiagou Formation, Gansu Province), and together as the most immediate outgroup to Ornithurae. *Gansus zheni* is the most advanced bird known today for the Jehol Biota. Its discovery provides the best-documented case of inter-basinal correlations (Jehol and Changma basins of Liaoning and Gansu provinces, respectively) using low-taxonomic clades of fossil birds. The existence of close relatives of Ornithurae in deposits formed at about 120 million years ago helps to mitigate the long-standing controversy between molecular and paleontological evidence for the temporal divergence of modern birds (Neornithes).

Key words: Early Cretaceous, Neornithes, birds, anatomy

Introduction

The remarkable Jehol Lagerstatte has yielded thousands of fossil birds representing multiple species spread over a vast portion of the phylogenetic tree of early avians. While enantiornithine birds dominate in taxonomic diversity, a growing number of fossils are revealing that a large diversity of basal ornithuromorphs (Zhou *et al.* 2009, 2012), the group that includes all living birds, is also characteristic of the Jehol Biota. Research on those early ornithuromorphs has revealed important ecological differences between these birds and their enantiornithine contemporaries. Evidence for niche partitioning is apparent from the fossil record of Jehol enantiornithines, which primarily represent forest, or arboreal birds, and the Jehol ornithuromorphs representing either land or semiaquatic birds (Wang *et al.* 2013). With the exception of the small hongshanornithids (Zhou & Zhang 2005; Chiappe *et al.* 2014), all other basal ornithuromorphs from the Jehol Biota lack clear specializations for wading. Here we report on a new fossil taxon, much larger than the hongshanornithids, and with definitive semiaquatic specializations. The new taxon shows close similarities with the roughly coeval *Gansus yumenensis* Hou & Liu 1984 (see You *et al.* 2006) from the Lower Aptian Xiagou Formation (Suarez *et al.* 2013) of Gansu Province's Changma Basin, thus providing a well-documented case of inter-basinal correlation based on Early Cretaceous birds.

Systematic Paleontology

Aves Linnaeus, 1758

Accepted by T. Worthy: 21 Oct. 2014; published: 14 Nov. 2014

FIGURE 7. Strict consensus tree resulting from the cladistic analysis of 31 Mesozoic and modern avian taxa (A) and two alternative most parsimonious tree topologies for Ornithurae (B, C). The strict consensus has a consistency index (CI) of 0.497 and a retention index (RI) of 0.814. The following unambiguous synapomorphies(character numbers correspond to Wang *et al.*, 2014) unite the lettered nodes: A) sacral vertebrae, number ankylosed (synsacrum): 11 or more (character 64); ilium/ischium, distal co-ossification to completely enclose the ilioischiadic fenestra (character 179); ischium, caudal demarcation of the obturator foramen developed as a small flange or raised scar contacting/fused with pubis and demarcating the obturator foramen distally (character 190); extensor canal on tibiotarsus present as groove bridged by an ossified supratendinal bridge (character 214); tarsometatarsus, projected surface and/or grooves on proximocaudal surface (associated with the passage of tendons of the pes flexors in Aves; hypotarsus) developed as caudal projection at least one groove enclosed by bone caudally (character 229). B) symphysial portion of dentaries fused (character 36); sternum, caudal margin, number of paired caudal trabecula: none (character 111); costal facets of the sternum present (character 116); ulnare: U-shaped to V-shaped, well-developed rami (character 152); intermetacarpal process or tubercle on metacarpal II present as scar (character 163); ungual phalanx of major digit (II) absent (character 172); ischium more than two-thirds the length of the pubis (character 188); pubic apron absent (absence of symphysis) (character 197); tibia/tarsal-formed condyles: no tapering of either condyle (character 217); metatarsal I: the distal half of the metatarsal I is laterally deflected so that the laterodistal surface is concave (character 232). C) supracoracoidal nerve foramen of coracoid displaced so that its nerve no longer passes through the coracoid (absent) (character 92); coracoid, sternolateral process present and with a distinct omal projection (hooked) (character 95); intermetacarpal space terminates distal to end of metacarpal I (character 165); intermembral index = (length of humerus + ulna)/(length of femur + tibiotarsus) between 0.9 and 1.1 (character 177); metatarsal II, distal extent of metatarsal II relative to metatarsal IV: metatarsal II shorter than metatarsal IV, reaching distally only as far as base of metatarsal IV trochlea (character 236); sternum, outermost trabecula: mainly parallel to the long axis of the sternum (character 246). D) dorsal (ascending) ramus of the maxilla: ramus absent (character 8); cervical vertebrae: heterocoelous cranial (i.e., mediolaterally concave, dorsoventrally convex) and caudal (i.e., mediolaterally convex, dorsoventrally concave) surfaces (character 51); sacral vertebrae, number ankylosed (synsacrum): 10 (character 64); carpometacarpus, proximal ventral surface: pisiform process forming a distinct peg-like projection (character 156); orientation of proximal portion of pubis: more or less parallel to the ilium and ischium (character 193); extensor canal on tibiotarsus present as an emarginate groove (character 214); metatarsal IV, distal extension of the metatarsal IV relative to the metatarsal III: shorter but reaching distally further than the proximal margin of the trochleae III (character 255); the ratio (tibiotarsus length/tarsometatarsus length) between 2 and 1.6 (character 257). E) ulnar shaft, radial-shaft/ulnar-shaft ratio: larger than 0.70 (character 145); ischium with a proximodorsal (or proximocaudal) process: absent (character 191); the ratio (tibiotarsus length/tarsometatarsus length): 2 or larger (character 257).

Acknowledgments

We are grateful to Maureen Walsh and Stephanie Abramowicz for the preparation and illustration of the specimen, respectively. We also thank Hai-Lu You, Ya-Ming Wang, and two anonymous reviewers for constructive comments to the original manuscript, and to Trevor Worthy for his comments and editorial handling of the manuscript. Partial funding for this study was granted by donations from Doreen and Glenn Gee, and Carl and Lynn Cooper to the Dinosaur Institute of the Natural History Museum of Los Angeles County. This research was also funded by the Study on Morphology and Systematics of the Jehol Biota Projects (IG201101C2) of China and Building of Innovative Team Plan of the Beijing Natural History Museum.

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APPENDIX I. Scoring of *Gansus zheni* used in the cladistic analysis.

Character matrix taken from Wang *et al.* 2014.

????10?3?0?????????????11????????0?000?1010101?????110??011?2??[24]0???24????1??01?01?11?0010?20?320??????210
02302?11??????11001??0102[23]0?1???01???11?00??0??31210011?00110210101112210??1111?101001210000?0[12]????0
1?1??2?11101?1120??1?0??102?02?1?0?11??001?1011010100001