Cretaceous Research 66 (2016) 141–154

Contents lists available at ScienceDirect

Cretaceous Research

journal homepage: www.elsevier.com/locate/CretRes

A new bird track, *Koreanaornis lii* ichnosp. nov., from the Lower Cretaceous Hekou Group in the Lanzhou-Minhe Basin, Gansu, Northwest China, and implications for Early Cretaceous avian diversity

Lida Xing [a], Lisa G. Buckley [b, *], Martin G. Lockley [c], Jianping Zhang [a], Daniel Marty [d], Yan Wang [e], Jianjun Li [f], Richard T. McCrea [b], Cuo Peng [g]

[a] School of the Earth Sciences and Resources, China University of Geosciences, Beijing 100083, China
[b] Peace Region Palaeontology Research Centre, 255 Murray Drive, Tumbler Ridge, British Columbia V0C 2W0, Canada
[c] Dinosaur Trackers Research Group, University of Colorado Denver, PO Box 173364, Denver, CO 80217, USA
[d] Naturhistorisches Museum Basel, Augustinergasse 2, CH-4001 Basel, Switzerland
[e] Institute of Geology and Paleontology, Linyi University, Linyi, Shandong 276000, China
[f] Department of Paleontology, Beijing Natural History Museum, Beijing 100050, China
[g] Geological Museum of Gansu, Lanzhou 730040, China

ARTICLE INFO

Article history:
Received 15 March 2016
Received in revised form
6 June 2016
Accepted in revised form 11 June 2016
Available online 18 June 2016

Keywords:
Early Cretaceous
Hekou Group
Lanzhou-Minhe Basin
Avian footprints
Ichnology
Koreanaornis lii
China

ABSTRACT

There are a growing number of Early Cretaceous avian tracks and trackways from around the world, with Asia (China and Korea) having the largest reported number and diversity of Mesozoic avian traces to date, and these new discoveries are increasing the Early Cretaceous avian ichnodivesrity of Laurasia. Here we report on a new Lower Cretaceous avian track locality in the Guanshan area, Yongjing County, Gansu Province, northwest China, and on a novel ichnospecies of *Koreanaornis*, *Koreanaornis lii* ichnosp. nov. *Koreanaornis lii* is distinct from other Koreanaornipodidae in that it possesses a consistently wider digit divarication than previously described tridactyl tracks, and possess a short, small, posteromedially oriented hallux that displays a different orientation than that seen in *Koreanaornis hamanensis*. The lack of linear and angular data reported for digit I traces of many avian ichnotaxa has the potential to give misleading results in multivariate statistical analyses. Also, the wide divarication of *Koreanaornis lii* causes the ichnotaxon to not group with other Koreanornipodidae in multivariate analyses, but with Ignotornidae. Despite the results of the analyses, *K. lii* is morphologically distinct from these ichnotaxa. The results demonstrate that relying solely on multivariate statistical analyses without careful examination of footprint morphology will result in erroneous ichnospecies groupings. While new vertebrate ichnotaxa discoveries from Asia may support the hypotheses of the presence of a unique and endemic Asian vertebrate ichnofauna during the Cretaceous, the recent discovery of skeletal remains interpreted to be of a volant wading bird from the Early Cretaceous, and recent reports of tracks from volant avians, could suggest that flighted avians of the shore- and wading bird ecotypes could have had a Laurasian-wide distribution during the Early Cretaceous. However, strong convergence in foot morphology of shore- and wading birds suggests that avian ichnotaxa found in both present-day Asia and North America may have been made by birds endemic to eastern and western Laurasia during the Early Cretaceous.

1. Introduction

The avian track record from the Early Cretaceous is fast growing. New reports of avian tracks from Australia (Martin et al., 2013), Utah, (Lockley et al., 2015), and British Columbia (McCrea et al., 2015) are beginning to flesh out the relative (and likely artificial) paucity of Early Cretaceous bird tracks from around the world. However, to date the greatest diversity of Early Cretaceous bird tracks is from the Lower Cretaceous deposits of Asia (China, Korea; Kim et al., 2012; Lockley et al., 2012c).

All bird tracks in northwestern China are distributed in Lower Cretaceous (?Aptian – Albian) strata, the majority of which

* Corresponding author. Tel.: +1 250 242 4051; fax: +1 250 242 4050.
E-mail address: lgbuckley@prprc.com (L.G. Buckley).

http://dx.doi.org/10.1016/j.cretres.2016.06.005
0195-6671/

occurring in the Lanzhou-Minhe Basin of Gansu (Li et al., 2002), Chabu of Inner Mongolia (Li et al., 2009; Lockley et al., 2012a), and Wuerhe of Xinjiang (Xing et al., 2011, 2013). The avian tracksites of the Wuerhe area preserve a highly diverse avian ichnofauna, with tracks attributed to *Aquatilavipes* ichnosp., *Goseongornipes* ichnosp., *Koreanaornis* ichnosp., and *Moguiornipes robusta* (Xing et al., 2011). *Tatarornipes chabuensis* occurs at the Chabu area, as well as *Aquatilavipes* ichnosp. and *Koreanaornis* ichnosp. (Lockley et al., 2012c). Lockley et al. (2012c) proposed that the abundance eastern Asian Cretaceous terrestrial vertebrate ichnofauna (specifically the dinosaurian ichnofauna) was due to local endemism. It remains to be seen if this endemism is supported by the avian track record, as several avian ichnotaxa are reported from China, Korea, and North America which indicates the existence of a prolific avian fauna in Laurasia during the Early Cretaceous.

Here we report a new avian tracksite containing a novel avian ichnotaxon of *Koreanaornis* from the Guanshan area, Yongjing County, Gansu Province. The Lanzhou-Minhe Basin is located on the boundary between the Gansu and Qinghai Provinces (Fig. 1) encompassing an area of 11,300 km^2, where abundant fossils of dinosaurs (e.g. You et al., 2005, 2006) and dinosaur-pterosaur tracks (Zhang et al., 2006; Xing et al., 2013) have been found. In the year 2000, collaborators from the Research Center of Paleontology of the Bureau of Geology and Resource Exploration of Gansu Province discovered a bird tracks exposed at Yanguoxia No.1 tracksite (the most representative tracksite at Yanguoxia area) from Yongjing County. At the same time, four additional bird footprints were found as well (Li et al., 2002). Subsequently more bird tracks were discovered at Shangpujia and Xiapujia Villages, Guanshan Township, Yongjing County (Fig. 1). However, these new tracks have not been scientifically described. In 2013, a research team led by the first author began a detailed study of these track sites. During this process, Xing LD, Lockley MG, Marty D and Peng C investigated the Xiapujia bird tracksite and documented the rest of the tracks (Fig. 2).

Li et al. (2002) originally reported the tracks from the Yanguoxia locality as similar to *Koreanaornis hamanensis* and *Aquatilavipes sinensis*. A detailed examination of these and additional specimens shows that the tracks, with slender digit traces, wide digit splay, and a small, posteromedially oriented hallux impression, are most similar in size and morphology to those ichnotaxa within Koreanaornipodidae.

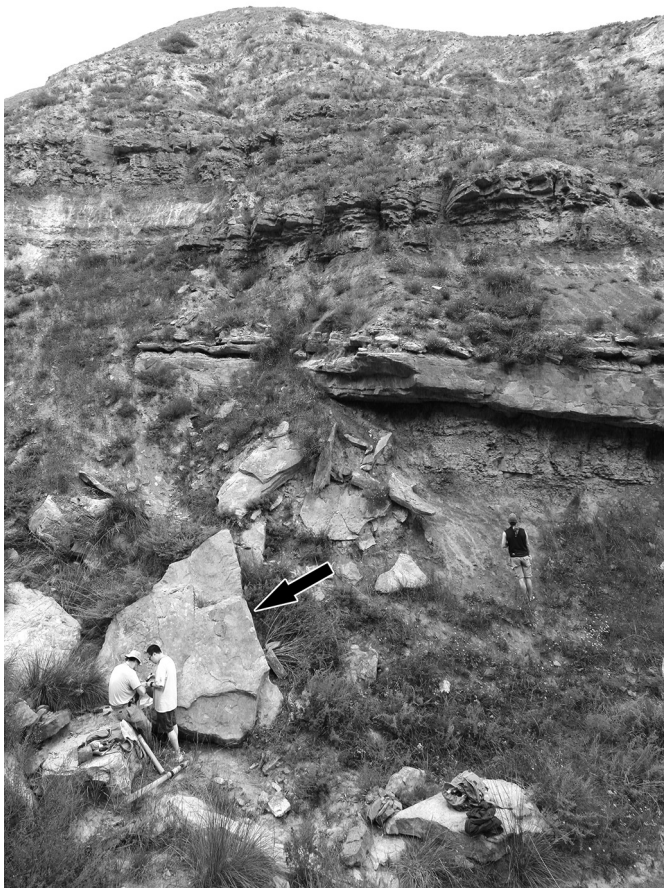

Fig. 2. Outcrop exposure of the Xiapujia bird tracksite in Gansu Province, central China Arrow indicates the ex-situ slab on which the bird tracks were preserved.

1.1. Koreanaornis *from Xiapujia and Shangpujia tracksites in the Gansu Province*

Koreanaornis hamanensis was the second avian ichnotaxon named from the Mesozoic (Kim, 1969; Lockley et al., 2012a). The

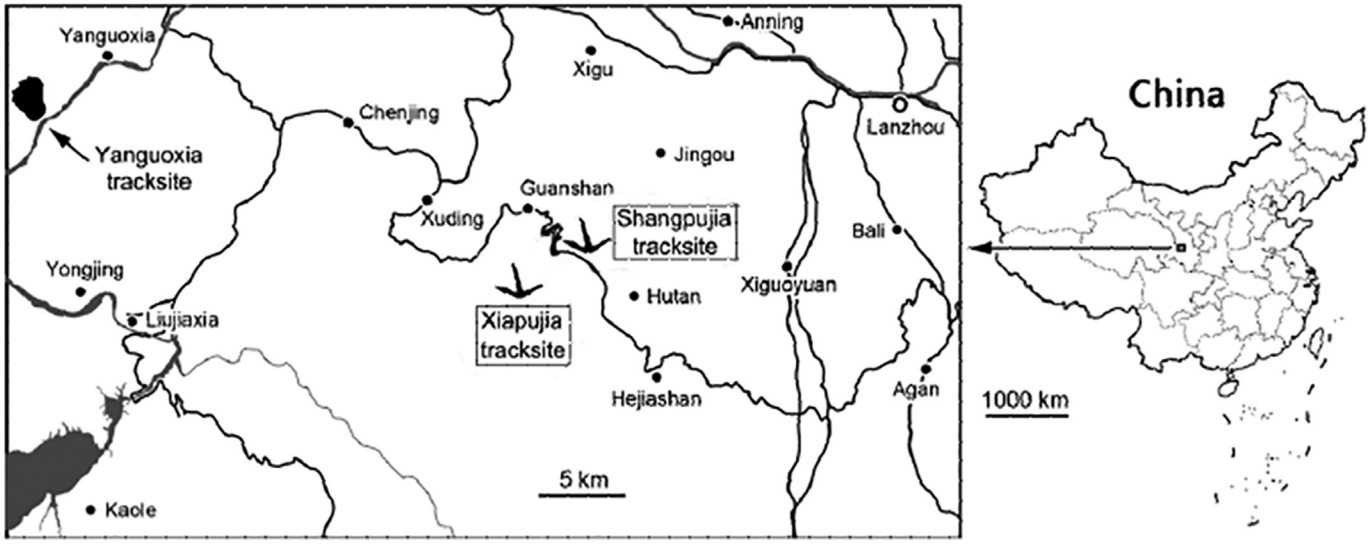

Fig. 1. Geographic location of location of the Xiapujia and Guanpujia bird tracksites from the Lower Cretaceous Hekou Group of Guanshan area, Yongjing County, Gansu Province.