ELSEVIER

Cretaceous Research 27 (2006) 56–69

CRETACEOUS RESEARCH

www.elsevier.com/locate/CretRes

The oldest record of webbed bird and pterosaur tracks from South Korea (Cretaceous Haman Formation, Changseon and Sinsu Islands): More evidence of high avian diversity in East Asia

Jeong Yul Kim [a], Sam Hyang Kim [a], Kyung Soo Kim [a], Martin Lockley [b,*]

[a] *Department of Earth Science Education, Korea National University of Education, Cheongwon, Chungbuk 363-791, Korea*
[b] *Geology Department, University of Colorado at Denver, Dinosaur Tracks Museum, PO Box 173364, Campus Box 172, Denver, CO 80217-3364, USA*

Received 12 January 2004; accepted in revised form 20 October 2005
Available online 8 February 2006

Abstract

Tracks of web-footed birds and pterosaurs from the Lower Cretaceous (Aptian-Albian) Haman Formation of Changseon and Sinsu Islands, respectively (southern coast of Korea), represent the oldest records for these footprint types in Asia. The morphology of the bird tracks, with prominent posteriorly directed hallux impression, semi-palmate web, and small ratio of length to width is similar to *Hwangsanipes choughi* from the Upper Cretaceous (Cenomanian) Uhangri Formation. However, they about 20–25% smaller, and therefore much closer to the size of North American *Ignotornis* (size difference less than 10%). The development of the web appears intermediate in size between *Hwangsanipes* and *Ignotornis*. This leads us to infer a new ichnotaxon herein named *Ignotornis yangi*. This is the first Asian report of a named bird track similar to the type material of *Ignotornis* from North America.

Pterosaur tracks consist predominantly of clear impressions of tridactyl mani (length 9–13 cm) characterized by strongly asymmetric digit impressions that outnumber less-clear elongated pes traces by a ratio of about 10 to 1. Clusters of short digit impressions or parallel to subparallel scrape marks indicate incomplete pes traces probably made by swimming animals. The pterosaur tracks, here provisionally identified as *Pteraichnus*, represent the first record of this ichnogenus from Korea. The track maker represents a species quite different from the giant track maker represented by the ichnogenus *Haenamichnus* from the Cenomanian Uhangri Formation, but it is similar to recent reports of *Pteraichnus*-like forms from the Lower Cretaceous of China.

These new records shed light on patterns of bird-track diversity and abundance in the ''mid'' Cretaceous of Korea (Aptian-Cenomanian) and show that at least two quite distinct pterosaurian species existed during this time span with at least six distinct species of track-making birds. When combined with additional reports of bird track ichnotaxa from China, the picture emerges of a remarkably diverse Lower Cretaceous avifauna. Such diversity is consistent with the skeletal record for this region, though the types of birds represented by tracks are ''shorebird-like'' and therefore distinct from the skeletal avifauna, which consist of birds of the perching type.

The ability of tracks to record whole foot morphology including details of web and hallux configuration allows for fine discrimination of foot morphology and comparison with web-footed tracks from other regions and geologic time periods. As is the case with modern shore birds, Cretaceous tracks were probably mostly made by adults whose foot size as well as shape is probably indicative of the identity of the track maker at low taxonomic levels.

Keywords: Webbed bird tracks; Pterosaur tracks; Cretaceous; Haman Formation; Korea

* Corresponding author.
E-mail address: Martin.Lockley@cudenver.edu (M. Lockley).

0195-6671/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cretres.2005.10.005

1. Introduction

In recent years there has been an exponential increase in the discovery of bird and pterosaur tracks. The track record can be particularly instructive in adding information that is not otherwise available from the realm of body fossils. Especially in Korea there has been a significant increase in the rate of discovery of Cretaceous bird tracks with many additional reports from the Cretaceous of other regions including China, Japan, Israel, Spain, Canada, USA, and Argentina (Mehl, 1931; Avnimelech, 1966; Kim, 1969; Currie, 1981; Zhen et al., 1987; Lockley et al., 1992; Yang et al., 1995; Vidarte, 1996; Baek and Yang, 1997; Lockley and Matsukawa, 1998; Lim et al., 2000; Azuma et al., 2002; Coria et al., 2002). However, only a few webbed bird tracks including ten named and six unnamed ichnospecies have been previously reported from Cretaceous through Neogene strata (Table 1).

The purpose of this paper is to describe the new Changseon site in the Haman Formation (Fig. 1), from which 11 well-preserved trackways (comprising 80 footprints) of web-footed birds have been reported, and to provide a discussion of where these tracks fit into the morphological and ichnotaxonomic record of a rapidly expanding database of bird tracks from East Asia. We also describe the first *Pteraichnus*-like tracks (comprising at least three trackways and about 30 partial and complete tracks) from the Haman Formation of Sinsu Island (Fig. 1), and compare them with other pterosaur tracks from the Cretaceous of Korea and China.

2. Tracks of web-footed birds

Cretaceous web-footed bird tracks are known from at least seven separate geographical areas, four of which are found in Korea. The general localities of the Korean sites, in order of discovery are: western Goseong County (Lockley et al., 1992; this paper), Hwangsan Basin (Yang et al., 1995, 1997, 2003), Kyungnam (Baek and Yang, 1997; Yang et al., 1997) and the Changseon site described herein. There are two North American sites described from Colorado (Mehl, 1931) and Wyoming (Lockley et al., 2004), and one described from Argentina (Coria et al., 2002).

The ichnotaxa considered to represent web-footed birds are as follows: *Ignotornis mcconnelli* (Mehl, 1931) from Colorado, cf. *Ignotornis* Mehl, 1931 from Argentina (Coria et al., 2002) and *Sarjeantopodus semipalmatus* (Lockley et al., 2004) from Wyoming (Table 1). *Uhangrichnus chuni* and *Hwangsanipes choughi* (Yang et al., 1995) are known from the Uhangri Formation of the Hwangsan Basin in southwestern Korea, and the former ichnotaxon (*U. chuni*) is reported from the Kyungnam site (Baek and Yang, 1997). In this study we report well-preserved and extensive trackways of a new morphotype similar to the type material of *Ignotornis* from

Table 1
Record of webbed bird tracks

Age	Formation	Locality	Name	Reference
Pliocene	Bidahochi Fm	Arizona, USA	goose or goose-like tracks	Breed, 1973
Early Pliocene		California, USA	goose footprints	Miller and Ashley, 1934
Miocene (late Messinian)	Caños Fm	Almería, Spain	*Roepichnus grahami*	Doyle et al., 2000
Late Miocene	Copper Canyon Fm	California, USA	*Avipeda* ichnosp.	Scrivner and Bottjer, 1986
Miocene	Miocene fm	Rumania	*Anatipeda anas*	Panin and Avram, 1962
Oligocene	Lower Oligocene fm	Navarra and Zaragoza, Spain	heron-like or stork-like wading bird tracks	de Raaf et al., 1965
Late Eocene	Eocene fm	Trans-Pecos Texas, USA	*Charadriipeda becassi*	Sarjeant and Langston, 1994
Early Eocene	Green River Fm	Utah, USA	bird tracks	Moussa, 1968
Early Eocene	Green River Fm	Utah, USA	*Presbyorniformipes feduccii*	Yang et al., 1995
Paleocene	Fort Union Fm	Wyoming, USA	bird tracks	Johnson, 1986
Late Cretaceous (Maastrichtian)	Lance Formation	Wyoming, USA	*Sarjeantopodus semipalmatus*	Lockley et al., 2004
Late Cretaceous (Campanian)	Anacleto Fm	Neuquén, Argentina	cf. *Ignotornis*	Coria et al., 2002
Late Cretaceous (Cenomanian)	Dakota Sandstone	Golden, Colorado	*Ignotornis mcconnelli*	Mehl, 1931
Late Cretaceous (Cenomanian)	Uhangri Fm	Haenam, South Korea	*Uhangrichnus chuni* *Hwangsanipes choughi*	Yang et al., 1995
Early Cretaceous (Albian)	Jindong Fm	Goseong-Donghae, South Korea	*Uhangrichnus chuni*	Baek and Seo, 1998
Early Cretaceous (Aptian-Albian)	Haman Fm Haman Fm Haman Fm	Jinju, South Korea Jinju, South Korea Namhae, South Korea	tracks of web-footed birds *Uhangrichnus chuni* *Ignotornis yangi*	Lim et al., 2000 Baek and Yang, 1997 This study