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Research Advances

First Report of Avian Tracks from the Cretaceous of Tibet, China

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Objective

Despite a large number of bird fossils in the Jehol Biota, Mesozoic bird records from other parts of China are dominated by tracks. Late Cretaceous bird tracks are rarely found in China. Reliable reports so far include a *Dongyangornipes* and *Koreanaornis* assemblage of early Late Cretaceous age from Dongyang City, Zhejiang Province, China (Azuma et al., 2013). Buckley et al. (2016) consider *Dongyangornipes sinensis* a subjective junior synonym of *Uhangrichnus chuni*. Type *Uhangrichnus chuni* (Yang et al. 1995; Lockley et al., 2012) from the Uhangri Formation, Hwangsan Basin of South Korea is Late Cretaceous in age, and the trackmaker was a web−footed avian.

In 1972, the Tibet Geology Bureau discovered a series of Late Cretaceous dinosaur tracks at the Dongga coal mine. But they were subsequently considered to be Cenozoic large bird footprints (Xing et al., 2013). Bird footprints were also reported from Late Cretaceous deposits in the Gupei Basin in Anhui Province (Jin and Yan, 1994), but then re-interpreted as an Early Cretaceous record (Xing et al., 2018).

In July 2017, a team from China University of Geosciences (Beijing) found some invertebrate traces and vertebrate tracks on a hill (GPS: 31°13'53.35"N, 95°57'18.95"E, altitude 3739 m) east of Jue'en Township, Dingqing County, Changdu City, Tibet Autonomous Region. According to the 1:250000 scale geologic mapping of Dingqingfu area (No. H46C001004), the Jue'en site belongs to the Upper Cretaceous Bada Formation, consisting of interbedded purple red siltstone, fine-grain lithic quartz sandstone, micrite and dolomicrite in variable thickness, and has yielded abundant gastropod fossils (Wang et al., 2013).

Results

Koreanaornipodidae Lockley et al., 2006

Koreanaornis Kim, 1969

Type ichnospecies. *Koreanaornis hamanensis* Kim, 1969, Lockley et al., 1992 emend.

Diagnosis. Small, tetradactyl bird tracks with small hallux impressions occasionally present. Digit traces typically separate (i.e., not connected proximally). Claw traces variably present, slender, and obscure. Trackways exhibit inward (positive) rotation of the tracks. Tracks wider than long, with widths ranging from 2.5–4.4 cm. Divarication between digits II and IV averaging about 120° (Lockley et al., 1992).

Material. Two natural molds cataloged as JE-B1-1L and 1R, from the Jue'en track site (Fig. 1) and stored in China University of Geosciences (Beijing).

Description. Small, tridactyl bird tracks lacking hallux impressions. JE-B1-1L lacks digit IV trace. JE-B1-1R is well-preserved. Digit III trace is the longest; digit II trace is the widest, and digit IV trace only preserves its distal end. Digital pad impressions are absent. The digit II trace is broader than those representing digits III and IV. The maximum length of JE-B1-1L is 2.7 cm and maximum width is 2.7 cm. The length:width ratio is 1.0. The average divarication angle between digits II and IV is 92°. The divarication angles between digits II and III (56°) are larger than those between digits III and IV (36°). The pace

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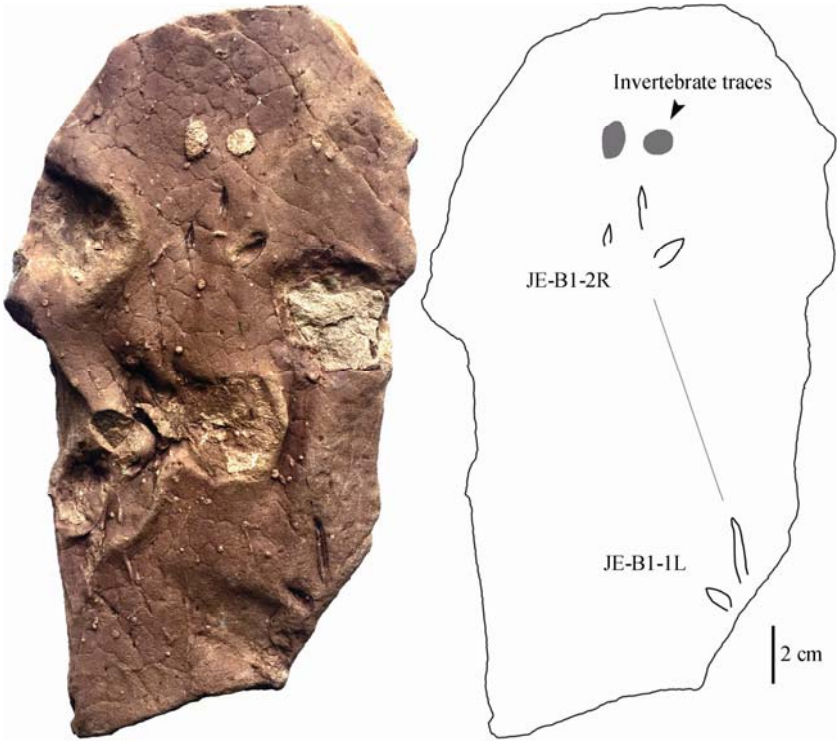

Fig. 1. Photograph and outline drawing of bird tracks JE-B1-1L and 1R from the Jue'en track site.

length is 11.8 cm. Tracks in the trackway exhibit slight positive (inward) rotation. The maximum length of JE-B1-1R is 2.9 cm.

Digit III of JE-B1-1L and digits III and IV of JE-B1-1R are relatively shallow, evidently shallower and narrower than digit II in each specimen, possibly due to preservation condition or medially located center of gravity of the track maker.

Discussion

Most characteristics of JE-B1 match those of Koreanaornipodidae (Kim, 1969; Lockley et al., 2006), such as small, wide, sub-symmetric, functionally tridactyl tracks with slender digit impressions and wide divarication angles between digits II and IV. Koreanaornipodidae trackways also exhibit positive rotation (Lockley et al., 2006). Based on these characteristics, the JE-B1 tracks are provisionally referred to *Koreanaornis*. However, the divarication angles between digits II and IV of the tracks are markedly smaller than the 120° of *Koreanaornis hamanensis*; and similar with the 87° of *Koreanaornis dodsoni* (Xing et al., 2011). Due to the small sample size, it is difficult to discern systematic features, and thus the material is referred to *Koreanaornis* isp.

The Tibetan Scientific Expedition Team of Chinese Academy of Sciences discovered a large quantity of Early and Middle Jurassic dinosaur fossils in Changdu (Qamdo) Prefecture in the 1970s (Zhao X-J unpublished data), but these specimens have never been published. These records are similar to Early Jurassic lufengosaur fauna and Middle Jurassic *Shunosaurus* fauna from Sichuan Basin. Xing et al. (2011) described Early-Middle Jurassic sauropod tracks from the Changdu area. Cretaceous marine strata in Tibet are well developed without any dinosaur fossil so far. Bird tracks from the Jue'en site are the only Cretaceous vertebrate records in Tibet.

Conclusion

Although Cretaceous bird tracks are now well known from East Asia, especially in China and Korea, none have previously been reported from Tibet. Likewise although vertebrate body fossils are known from the Jurassic of Tibet none have been reported from the Cretaceous. Thus, the discovery of Cretaceous bird tracks in Tibet, is a significant addition to the Mesozoic vertebrate record in this region.

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