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Earliest records of dinosaur footprints in Xinjiang, China

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Abstract Although Xinjiang Uyghur Autonomous Region is a vast territory, its fossil tetropod track record is scant. In recent years, this situation has begun to change and a variety of Jurassic and Cretaceous tetrapod tracks have been reported and described from Xinjiang, including tracks attributable to birds, non-avian dinosaurs, and pterosaurs. Here we report on the first dinosaur track discovered from Lower Jurassic deposits in Xinjiang. The tracks are those of a small theropod and are oldest known dinosaur tracks in Northwest China. The tracks are provisionally assigned to cf. *Changpeipus* isp., which resembles well-known tracks in the *Grallator-Eubrontes* plexus, which dominate tetrapod ichnofaunas in the Early and Middle Jurassic both within China and globally.

Key words Xinjiang, Lower Jurassic, Badaowan Formation, theropod tracks, *Changpeipus*, paleogeography

1 Introduction

The Mesozoic vertebrate fauna of the Junggar Basin is dominated by crocodilians, dinosaurs, various small-bodied diapsids, turtles, and therapsids. The oldest records of dinosaur skeletons in the Junggar Basin came from the Middle Jurassic Toutunhe Formation and the Wucaiwan Formation. Dinosaur fossils from these formations include material from a variety of sauropods and basal ornithischians (Jia et al., 2009). However, until recently, tetrapod tracks have been unknown in Xinjiang. Dinosaur tracks have now been reported in the lower part of the Middle Jurassic Xishanyao Formation, but these reports have lacked detailed descriptions and figures (Jia et al., 2009). These Middle Jurassic dinosaur tracks include theropod tracks from the Shanshan area (Wing et al., 2007), which have been attributed to the ichnogenus *Changpeipus* (Xing et al., 2014).

In 1993, Wang Qifei from Nanjing Institute of Geology and Paleontology, Chinese Academy of Sciences, discovered two isolated small theropod tracks in the Lower Jurassic

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Badaowan Formation, at a site neighboring Wusu City of Xinjiang (Matsukawa et al., 2006). These tracks are presently the oldest dinosaur record in Xinjiang. In 2001, a replica of one of these tracks was made by one of the authors (Lockley MG) for comparative study. This replica now resides in the University of Colorado collections as UCM 178.13. However, these specimens were never illustrated or described in detail. In 2013, Xing Lida was invited by the Resources and Environment Institute of Mineral Exploration Department of the Bureau of Geology and Mineral Resources, Sichuan Province, to re-study the tracksites in the Wusu City area of Xinjiang, as part of a geologic heritage research project. However, no new track was discovered by the 2013 field expedition, and the descriptions herein are based on Wang Qifei's original 1993 discoveries.

Institutional abbreviations HIII, Henan Geological Museum, Zhengzhou, Henan, China; IVPP, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, China; NIGP, Nanjing Institute of Geology and Paleontology, Chinese Academy of Sciences, Nanjing, China; SS, Shanshan tracksite, Xinjiang, China; UCM, University of Colorado Museum of Natural History, USA; ZLJ-ZQK, the World Dinosaur Valley Park, Lufeng County, Yunnan Province, China.

2 Geological setting

The tracks were discovered at Wanminggou (risk-taking ditch) site (44°8'20"N, 84°22'49"E), Baiyanggou Town, Wusu City, Ili Kazak Autonomous County, China (Fig. 1). The site pertains to the lower part of the Badaowan Formation (Fig. 2). The Badaowan Formation is a series of interbedded sandstone, gravel-bearing sandstones and mudstone, and carbonaceous

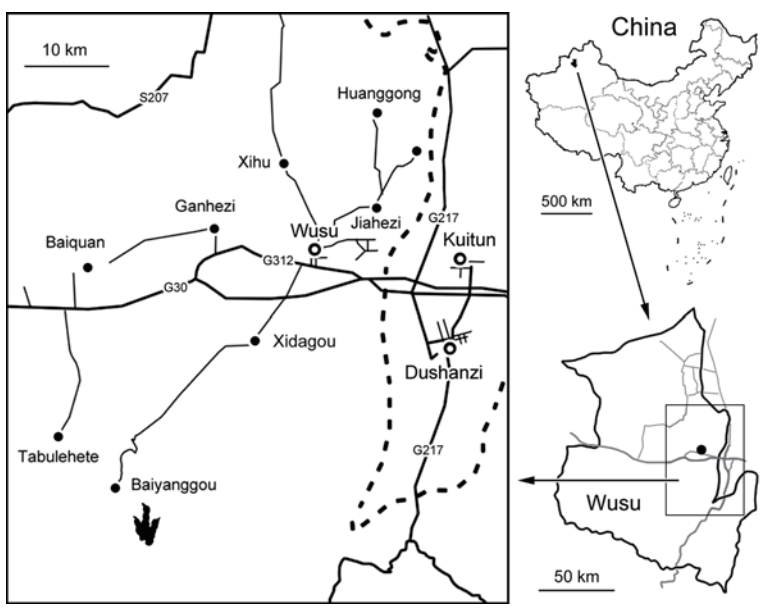

Fig. 1 Geographic position of the Wanminggou dinosaur footprint locality (footprint icon)

mudstones mixed with coal beds (Editorial Unit of Stratigraphic Chart of Xinjiang, 1981). The tracks were preserved in siltstone, along with abundant invertebrate traces).[1)]

Abundant plant (primarily ferns) (Wu and Zhou, 1986), bivalves, and conchostracan fossils were discovered in the Badaowan Formation. Pollen analysis reveals a gymnosperm dominance (Li and Shen, 1995). The plant stem fossils from the sandstone of the lower part of the Badaowan Formation indicate a moist and rainy climate, which is favorable for the growing of *Neocalamites*, *Desmiophyllum* and *Podozamites* etc (Wang et al., 2011). The upper part of the Badaowan Formation bears coal streaks and small coal seams, indicative of a swampy environment (Yang et al., 2010). Xiao et al. (2006) divided the Badaowan Formation into upper and lower segments. The lower segment is interpreted as a braided river delta plain facies. The upper segment is interpreted as a braided river delta front facies.

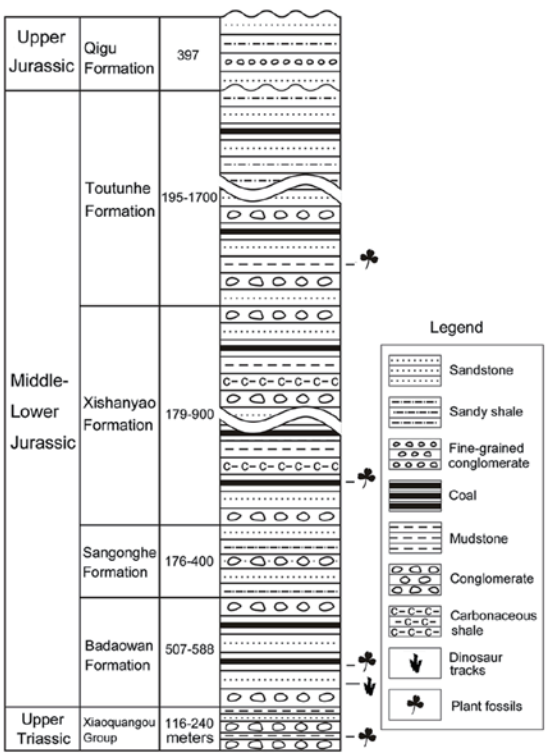

Fig. 2 Stratigraphic section of the Middle-Lower Jurassic of Wusu area
Emended from Geological Map of the People's Republic of China, Wusu Map Sheet 1:2000001)

The Triassic-Jurassic boundary is placed between the Haojiagou and Badaowan formations (Sha et al., 2011). The sequence of sedimentary succession is interpreted as terrestrial, with intermittent lake deposits yielding fresh water algae and bivalve fossils. However, the presence of the water algae *Tasmanites* and the marine-littoral bivalve *Waagenoperna* (both more typical of the Badaowan Formation) indicate that, during the Sinemurian, the Junggar Basin was influenced by sea water from transgressions of the northern Tethys (Chen and Zhang, 2000; Yang et al., 2010).

3 Systematic ichnology

Saurischia Seeley, 1887

Theropoda Marsh, 1881

1) Geological Survey Team, Geological Bureau, Xinjiang Uyghur Autonomous Region, 1977. Geological Map of the People's Republic of China, Wusu Map Sheet 1:200000 (L-45-XXXI)

***Changpeipus* Young, 1960**

cf. *Changpeipus* isp.

Material A natural cast on one slab is cataloged as NIGP MV11 (Fig. 3). A replica of the same specimen is held in Colorado as UCM 178.13, with corresponding tracing T-567.

Locality and horizon Badaowan Formation, Shuixigou Group, Lower Jurassic. Wusu tracksite, Xinjiang, China (Matsukawa et al., 2006).

Description Only one well-preserved dinosaur track was discovered. NIGP MV11 is a right tridactyl theropod footprint. Manus and tail traces are absent. The maximum length of the track is of 10.7 cm and its maximum width (measured as the distance between the tips of digits II and IV) is 9.1 cm. The length/width ratio of NIGP MV11 is 1.2, and the length/width ratio of the anterior triangle is 0.44. The length of digit II–IV impressions are 4.2, 7.5, 5.8 cm, respectively. The distal tips of digit II and III are partially damaged, but the borders are discernable. Digit III projects the farthest anteriorly, followed by digits IV and II. The phalangeal pad formula is x-2-3-4-x, which is common in theropod tracks. The claw marks of digit III and IV are sharp. The proximal region of the digits form an indistinct U-shaped metatarsophalangeal region that lies nearly in line with the axis of digit III. The footprint has wide divarication angles (69°, between digit II and IV). The divarication angle between digit II and III (40°) is larger than that between digit III and IV (29°).

In addition, a poorly-preserved track is visible anterior to digit III and IV of NIGP MV11. This track is 7.9 cm long and 5.2 cm wide, with two visible digit casts which are too poorly preserved to be useful for interpretation.

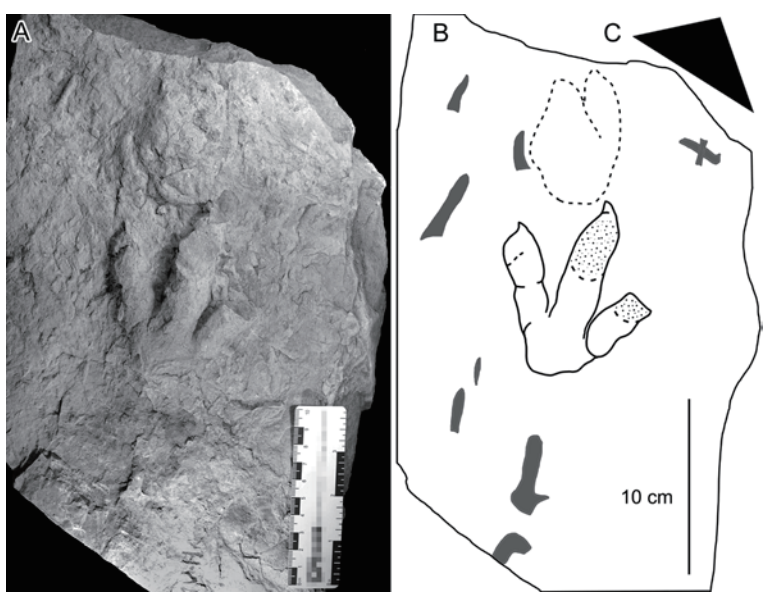

Fig. 3 NIGP MV11, theropod footprint from Wanminggou tracksite
A. photograph; B. outline drawing; C. anterior triangle, drawn between the tips of the distal ends of digits II, III and IV (sensu Weems, 1992; Lockley, 2009), indicating the degree of mesaxony

Comparison and discussion Early Jurassic theropod tracks in China generally coincide with classical *Grallator–Anchisauripus–Eubrontes* plexus from North America (Olsen, 1980) and primarily include *Changpeipus carbonicus* from North and Southwest China (Young, 1960; Xing et al., 2009, 2014) and *Grallator* type tracks from the Jinning region, Yunnan Province (Lockley et al., 2013). The latter includes *Grallator limnosus* and several ichnospecies based on poorly preserved tracks, such as *Paracoelurosaurichnus monax*, *Schizograllator xiaohebaensis*, and *Youngiehnus xiyangensis* (Zhen et al., 1986), all of which Lockley et al. (2013) assigned to better-known tracks with historical priority: i.e., the Yunnan tracks are considered junior subjective synonyms allowing assignment of *P. monax* and *Y. xiyangensis* to *Eubrontes*, while *S. xiaohebaensis* was attributed to *Kayentapus*. Recently tracks tentatively assigned to *Eubrontes glenrosensis*, *Kayentapus hailiutuensis*, and *Anomoepus intermedius* have also been reported from Wulatezhongqi site, Nei Mongol, China (Li et al., 2010).

NIGP MV11 differs from the other theropod tracks at the Jinning region in the L/W ratio of the anterior triangle (Table 1). Although the L/W ratios of the anterior triangle of the theropod tracks at the Wulatezhongqi site are similar to that of NIGP MV11 (Table 1), they are significantly different in morphology. The metatarsophalangeal pad of NIGP MV11 is more developed than that of *K. hailiutuensis*, whereas the phalangeal pad of NIGP MV11 is less developed than that of *E. glenrosensis*. In addition, Young (1966) reported *Shensipus tungchuanensis* from the Middle Jurassic of Shaanxi Province, which resembles NIGP MV11 in overall size (average 9.0 cm). However, the divarication angle of *Shensipus* is significantly large (90°) and the digits are more slender (Zhen et al., 1989).

Changpeipus (Young, 1960) is an ichnogenus known from reasonably well-preserved theropod track that exhibits numerous features, such as the digital pad formula, that allies it to the *Grallator–Eubrontes* plexus (sensu Olsen, 1980). Xing et al. (2014) reviewed all the *Changpeipus* ichnospecies from China, all the specimens suggest a monotypic ichnogenus *Changpeipus*, with the type species *C. carbonicus*. *Changpeipus* is known primarily from the Lower-Middle Jurassic of China (Young, 1960; Lü et al., 2007; Xing et al., 2009, 2014) with a few specimens discovered in Lower Cretaceous strata (Young, 1979).

Xing et al. (2014) proposed the following characteristics for *Changpeipus*: 1) medium-

Table 1 Comparison of NIGP MV11 with Lower Jurassic theropod tracks from Jinning and Wulatezhongqi sites, China

Ichnospecies	L/W ratio of the anterior triangle
NIGP MV11	0.44
Jinning site	
Grallator limnosus (Zhen et al., 1986)	0.69
Eubrontes monax (Lockley et al., 2013)	0.77
Eubrontes xiyangensis (Lockley et al., 2013)	0.60
Kayentapus xiaohebaensis (Lockley et al., 2013)	0.36
Wulatezhongqi site	
Eubrontes glenrosensis (Li et al., 2010)	0.46
Kayentapus hailiutuensis (Li et al., 2010)	0.50

sized tridactyl theropod track, 2) divarication angles between digits II-IV of 50°, 3) a metatarsophalangeal region located more or less directly posterior (or proximal) to digit III, and 4) digit IV projecting farther anteriorly (distally) than digit II and exceeding digit II in length (Young, 1960, 1979; Xing et al., 2009). NIGP MV11 is similar to *Changpeipus* with regards to 2), 3), and 4). NIGP MV11 is small, but small individuals are also known for *Changpeipus*, such as the 13 cm-long track IVPP V 2472.2a, which was discovered close to the holotype. A few 12 cm-long tracks were also discovered in Xinjiang. Furthermore, the L/W ratio of the anterior triangle of the holotype of *Changpeipus carbonicus* (IVPP V 2472.2) is 0.51. The L/W ratio of the best-preserved Xinjiang *C. carbonicus* specimen (SSIB59) is 0.50. The L/W ratio of the Yunnan specimen (ZLJ-ZQK2) is 0.50. The L/W ratio of NIGP MV11 is 0.44, which is close to that of all these specimens. The ratio of the Henan specimen (41HIII-0098) is 0.70, which is larger. Due to insufficient specimens, it is difficult to assign NIGP MV11 to *Changpeipus*. However, based on the similar morphology, NIGP MV11 is temporarily assigned to cf. *Changpeipus* isp.

4 Paleogeography

Dinosaur track assemblages have been reported from Upper Triassic to Lower Jurassic strata throughout the world, e.g. Jinning and Yaozhan, Yunnan, China (Zhen et al., 1989; Xing et al., 2009), Wulatezhongqi, Nei Mongol (Li et al., 2010), Massachusetts, Connecticut and Arizona in North America, Brazil in South America, Sweden and France in western Europe, Zimbabwe in southern Africa, and Kuruma in Japan (Matsukawa et al., 2005: fig. 16). Dinosaurs were evidently moving freely throughout these areas, before continental drift began fragmenting Pangea in the Middle Jurassic.

In the Lower Jurassic of China, theropod tracks are mostly known from the Chuandian (Sichuan-Yunnan) Basin in South China, including the Jinning site (Zhen et al., 1986) and the Yaozhan site (Xing et al., 2009). Theropod tracks are also known from the Ordos Basin (Li et al., 2010). The discovery of the Wanminggou site expands our knowledge of the distribution of Lower Jurassic theropod tracks. It shows that theropods roamed the border of the Lower Jurassic Junggar Basin. Furthermore, tracks with similar morphology have been discovered in the Middle Jurassic Shanshan Basin, suggesting that foot morphology of the Lower-Middle Jurassic theropods in Xinjiang was generally conserved.

In Asia, *Changpeipus* and *Grallator*-type tracks are closely related to classic ichnotaxa, such as *Eubrontes* and *Grallator* (Lockley et al., 2003). Based on the Wanminggou site evidence, the theropod ichnogenus is also distributed on the eastern periphery of the Asian continent. This supports the idea of Lucas (2007) and Lucas and Hunt (2004) that the Lower Jurassic theropod ichnofauna was globally distributed.

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新疆恐龙足迹的最早记录

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摘要：尽管新疆地域辽阔，但其四足动物足迹在不久前仍是寥寥。近几年，这种情况得以改变，来自侏罗纪和白垩纪的四足动物足迹陆续被报道和描述，其形态可归入鸟类、非鸟恐龙和翼龙足迹。这里报道了中国科学院南京地质古生物研究所保存的新疆下侏罗统地层发现的第一个恐龙足迹。该足迹是一个小型兽脚类足迹，也是中国西北目前已知的最古老的恐龙足迹。标本暂时归入似张北足迹未定种(cf. *Changpeipus* isp.), 它类似于常见的跷脚龙–实雷龙足迹丛(*Grallator-Eubrontes* plexus), 该种类的足迹主宰着早、中侏罗世的中国，乃至全球之四足动物足迹群。

关键词：新疆，下侏罗统，八道湾组，兽脚类足迹，张北足迹，古地理学
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消息

中国古脊椎动物学会第14次年会在贵州省黔西县召开

2014年4月18日至21日，中国古脊椎动物学会第14次学术年会、中国第四纪古人类—旧石器专业委员会第5次学术会议在贵州省黔西县顺利召开。会议由中国科学院古脊椎动物与古人类研究所和毕节市人民政府联合主办，黔西县人民政府和毕节市文化体育广播影视电视局承办。来自全国各科研院所、高校、文博系统90多家单位的近300位代表参加会议，交流研讨最新学术成果，为我国古脊椎动物学、古人类学和旧石器考古学的国际化发展献计献策。

本次大会共安排76场学术报告，并出版论文集。论文和报告从不同角度展示了古脊椎动物学、古人类学、旧石器考古学、生物地层学、分子生物学、第四纪测年、博物馆建设与科普传播等领域的最新研究成果和进展。20余名研究生参加了研究生报告专场，5位同学表现优异，获得“研究生优秀报告奖”。本届年会首次设立“杨钟健科学传播奖”，李建军、王原、齐芳三人获得奖励。为表彰上海睿宏文化传播有限公司在学科科学传播方面做出的突出贡献，授予其“中国古脊椎动物学会科普创作基地”称号。

本次年会，学会理事会完成了换届选举工作，召开了理事会和常务理事会会议，审议了下一届年会的承办申请，最终确定由大庆市文化广电新闻出版局和大庆市博物馆联合承办。

(刘庆国)