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New tracksites reported from the Zizhou area elucidate the nature of the Early-Middle Jurassic dinosaurian ichnofaunas in Shaanxi Province. The assemblage is composed of footprints and trackways of medium- to large-sized theropods that show similarities with both the ichnogenera *Kayentapus* and *Eubrontes* and of small bipedal ornithischians that are referred to AS *Anomoepus* isp. Additionally tracks of a quadruped are present and assigned to *Deltapodus* isp. that may be related to a stegosaurian. *Anomoepus* isp. is similar to the holotype of *Shensipus tungchuanensis* which is, although apparently lost, reassigned here and considered to be a subjective junior synonym of *Anomoepus*. It is therefore placed in new combination as *Anomoepus tungchuanensis* comb. nov. Identical tracks have been reported from well-preserved trackways both in the Zizhou and Shenmu areas, where they also co-occur with theropod tracks (*Kayentapus* and *Grallator*) and tracks of quadrupedal ornithischians (*Shenmuichnus* and *Deltapodus*). Thus, it appears that the carbonaceous (coal-bearing) facies of the region reveal ichnofaunas with both relatively abundant saurischian (theropod) and ornithischian tracks. This is in contrast with many areas where the ichnofaunas are heavily or exclusively saurischian (theropod) dominated.

Keywords Shaanxi, Ordos Basin, Dinosaur tracks, *Kayentapus*, *Shensipus*, *Anomoepus*

INTRODUCTION

Northern Shaanxi Province is important for dinosaur ichnology research in China. The first dinosaur tracks ever reported in China were described by C. C. Young and P. Teilhard de Chardin, in 1929 at Shenmu County, Yulin City, Shaanxi Province. These early tracks were later used to erect the new ichnogenus *Sinoichnites* (Kuhn, 1958). Young (1966) has described and named the theropod tracks *Shensipus tungchuanensis* based only two tridactyl footprints from the Jiaoping tracksite. Li et al. (2012) discovered multiple, well-preserved trackways of the apparently rare quadrupedal ornithischian ichnogenus *Shenmuichnus* in Lower Jurassic deposit of the Shenmu area, which was the first discovery of *Moyenosauripus*-type tracks in Asia. Li et al. (2012) also reported theropod (*Grallator*) and ornithopod (*Anomoepus*) tracks in the Shenmu area. In 2011–2012, Middle Jurassic dinosaur tracks were discovered in Zizhou County, approximately 150 km southwest of Shenmu County (Figs. 1A, 1B, 2). These tracks are dominated by theropod footprints and also include thyreophoran footprints.

Remarkably, prior to the scientific identification of the tracks, local villagers had long been collecting sandstone slabs with dinosaur footprints. Currently, footprints are commonly displayed in the village's stone walls and pathways, and within villager's homes and farm houses, where dinosaur footprints are incorporated into the simple masonry of furniture, mangers, and stone grinders. The local villagers believe that these footprints were left by "Heavenly Chickens," identifiable by possessing a tridactyl morphology and distinct claw impressions. Obviously, the dinosaur tracks have contributed to the origin of local folk legends (e.g., Xing et al., 2011).

Institutional Abbreviations

CI = Cun (village) collections, Shaanxi, China; CUGB = China University of Geosciences, Beijing, China; HT = Huo tracksite, Shaanxi, China; I = Isolated track; IVPP = Institute of Vertebrate Paleontology and Paleoanthropology, Beijing, China; NT = Nianpan (stone grinder) collections, Shaanxi, China; T = Trackway; WT = Wang tracksite, Shaanxi, China.

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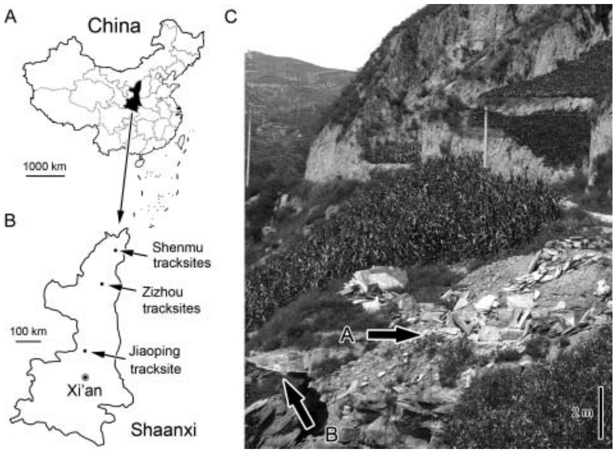

FIG. 1. Geographic map indicating the location of the dinosaur footprint localities in Shaanxi Province, P.R. China (A, B) and Photograph of the Wang tracksite location. **A**. outcrop of Wang tracksite; **B**. outcrop of thyreophoran tracks.

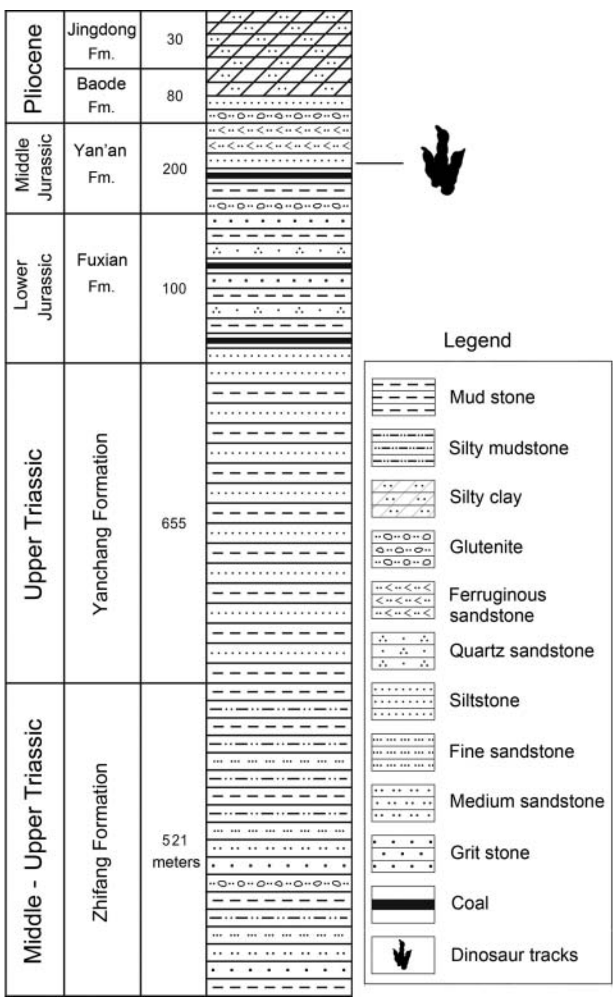

FIG. 2. Stratigraphic section of the Mesozoic sedimentary sequences in the Zizhou area with the position of the footprint level.

METHODOLOGY

All tracks were outlined on transparency film, scaled and re-drawn with a vector-based computer software. Measurements were taken following the standard procedures of Leonardi, 1987 and Lockley and Hunt, 1995. Bivariate analysis based on footprint length/width ratio vs. AT (anterior triangle length-width ratio *sensu* Weems, 1992) was applied to different theropod and ornithopod tracks. For speed calculations (v) from theropod tracks we used the formula of Alexander (1976): $v = 0.25g^{0.5}.\ SL^{1.67}.\ h^{-1.17}$, where g = gravitational acceleration in m/sec, SL = stride length, and h = hip height – estimated as 4.5 times foot length (FL), using the ratio for small theropods proposed by Thulborn (1990).

RESEARCH HISTORY

In 2011, the villagers at Wang Village, Zizhou County, Yulin City found numerous strange and densely crowded tridactyl impressions on sandstone slabs when they were collecting stones adjacent to a road. In March 2012, the local villager Jun Wang discovered similar impressions at a quarry north of Longweimao Village, which is close to Wang Village. The tracksite is herein referred to as the Wang tracksite (GPS: N37°39′0.65″, E109°48′16.44″) (Fig. 1C). In June 2012, Jun Wang brought the track specimens that he had collected to Northwest University for identification. Leping Yue and Yongxiang Li identified them as dinosaur tracks. In July and August 2012, Yongxiang Li went on a field expedition to Zizhou. Specimens from the Wang tracksite were collected and are still undergoing research at Northwest University. In September 2012, the first author of this paper was invited by the Yulin Association of Collectors and by the Zizhou County Yellow Land Culture Research Society to investigate the Wang tracksite. This investigation discovered another tracksite level six meters beneath the Wang tracksite and containing thyreophoran tracks.

In May 2013, Junmin Gao and Shurong Dong, from the Yellow Land Culture Research Society of Zizhou County, discovered another tracksite 150 meters opposite the Wang tracksite. This tracksite is owned by the villager Dengcheng Huo of Wang Village and has been named the Huo tracksite (GPS: N37°39’6.30”, E109°48’8.80”) (Fig. 3). Later, the Zizhou County Bureau of Land and Resources, financed excavation of the site, and more dinosaur tracks were exposed.

An important track discovery has come from the base of a stone mill of the home of the villager Qiteng Huo. These tracks have been named the Nianpan (= stone grinder) collection (Fig. 4). An additional track collection, named the Cun (= village) collection (Fig. 5), has come from stone slabs that formerly lined the lateral side of the manger of the home of the village head Dengfeng Huo. These slabs were originally collected 250 meters northeast of the Huo tracksite (N 37°39′12.21″, E 109°48′15.69″). During 2013–2014, one of the authors, Y. G Tang from the Institute of Geology and

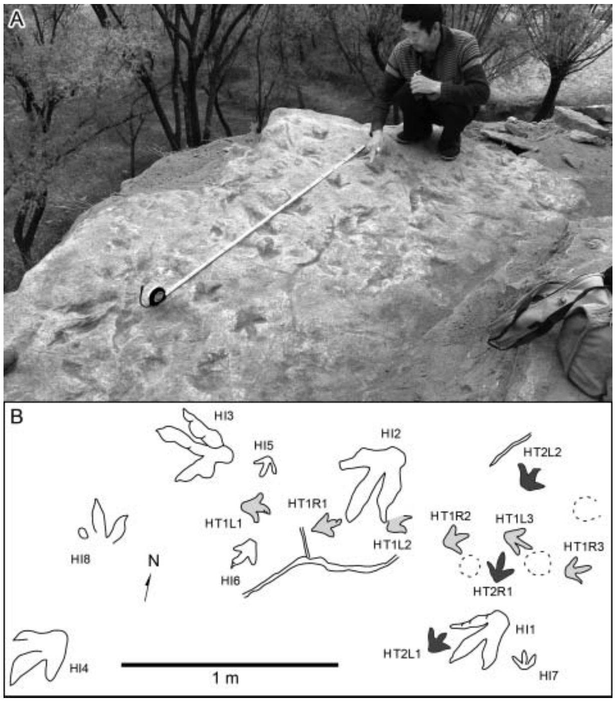

FIG. 3. Distribution of footprints at Huo tracksite. **A.** Photographs (Photo by Suiqin Zhao); **B**. Outline drawing.

Palaeontology, Linyi University, investigated all these tracksites. Herein, the thyreophoran tracksite and the Huo tracksite are described.

GEOLOGICAL SETTING

The Zizhou tracksites are situated between Longweimao Village and Wang Village, Zizhou County, Shaanxi Province, within the range of the eastern Ordos Basin. The tracks are found in a layer of feldspathic quartz sandstone underlying a layer of red clay that is exposed on both sides of the Wang River. Based on the local geologic survey conducted by the Bureau of Geology and Mineral Resources of Shaanxi Province in 1989 (Bureau of Geology and Mineral Resources of Shaanxi Province, 1989) and on geologic maps produced by the Geological Hazards Investigation and Zonation of Zizhou County, Shaanxi Province (internal reporting, http://gtzl.mlr.gov.cn/) (No. 908 Team of Hydrogeology and Engineering Geology, Shaanxi Province Bureau of Geology and Mineral Resources, 2009), the tracksite is assigned to the greyish, grey-yellow sandstones of the lower portion of the early Middle Jurassic Yan'an Formation (Fig. 2). Fragmentary petrified wood fossils were observed in the layer containing the tracks. Abundant bedding plane structures, including ripple marks, mud cracks, and invertebrate traces, were also observed. The paleoenvironment of the Early–Middle Jurassic Ordos Basin was characterized by warm and moist climate, and therefore a favorable environment for coal forming (Zhang et al., 2008).

ICHNOTAXONOMY

Kayentapus-Eubrontes-type Tracks

Material. Five natural molds of large (34–41 cm in length) tridactyl footprints of bipedal dinosaurs from the Huo tracksite have been cataloged as HI1, 2, 3, 4 and 18 (Fig. 3, 5; Table 1). All these tracks are isolated and are not part of any discernible trackways. There are twenty five natural molds of middle-sized (18–29.5 cm in length) tridactyl footprints of bipedal dinosaurs from the Nianpan collections, cataloged as NT1L1–R1, NT2R1–R2, NI1–20 (Figs. 4, 5). Among which NT1L1-R1 and NT2R1-R2 are consecutive tracks. CI1 and 2 from the Cun collections are also isolated bipedal tracks (Fig. 5). None of these tracks have been collected and, at the time of writing, all remain in the field. However, as shown in Figs. 3–5 tracings of the track outlines have been recorded, and are stored at CUGB.

Locality and horizon. Yanan (Yan'an) Formation, Middle Jurassic. Huo tracksite and Nianpan (stone grinder) collections, Zizhou County, Shaanxi Province, China.

`***Description.*** The best preserved footprint from Huo tracksite is HI3 which is a left imprint (Fig. 5). It is mesaxonic with digit III projecting the farthest anteriorly, followed by digits II and IV. The phalangeal pad formula is x-2-3-4-x (IV includes metatarsophalangeal pad IV). The second and the third pads of digit IV are slightly deformed. Claw marks are sharp. The pronounced and circular metatarsophalangeal pad of digit IV is positioned in line with the axis of digit III. The divarication angle II–IV is wide (67°), that between digits III and IV being much larger (41°) than between digits II and III (26°).

NT1L1-R1 constitute a single pace. Track NT1L1 is representative of the morphology of the medium-sized tracks. Digit III projects the farthest anteriorly, followed by digits II and IV. The phalangeal pad formula is x-2-3-4-x (including MT pad IV). Claw impressions are sharp. The metatarsophalangeal pad of digit IV lies nearly in line with the axis of digit III. The divarication angle II–IV is wide (77°). The footprints forming trackway NT2 are consistent with NT1L1-R1 in morphology. NT2 is narrow with a pace angulation of 143°.

The Nianpan medium-sized tracks vary in morphology. For example, NT1R1 is shallower than NT1L1, the three digits are separated NI15 and NI18 lack the metatarsophalangeal pad of digit IV, which makes the apparent divarication angle enlarged.

Discussion

Kayentapus is the ichnogenus name applied to relatively large (pes length ~35 cm) tridactyl tracks of a slender-toed bipedal theropod dinosaur that was originally described by Samuel Welles in 1971. Welles' description was based on a trackway with long steps from the Lower Jurassic Kayenta Formation of Arizona (Lockley et al., 2011). *Kayentapus hopii* is characterized by the absence of a hallux impression and the

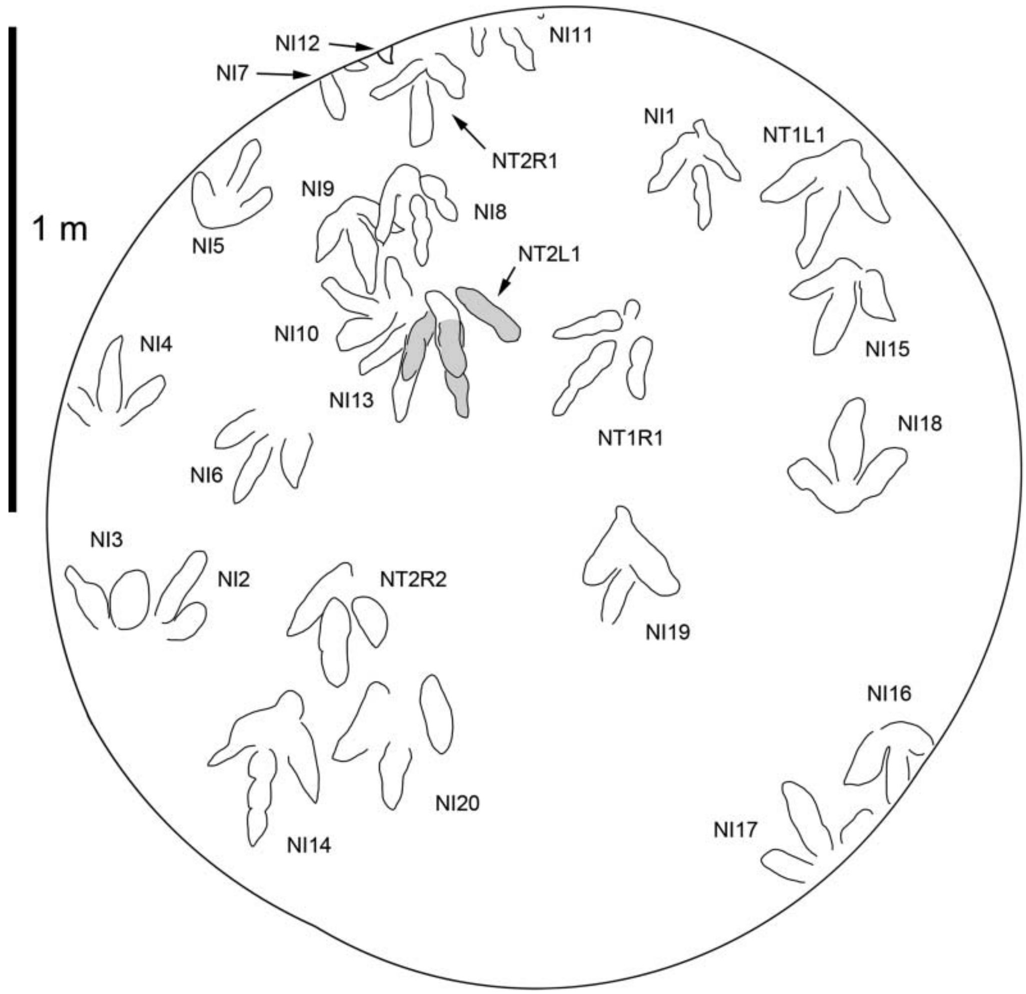

FIG. 4. Distribution map of footprints at Nianpan collections.

preservation of the metatarsophalangeal pad of digit IV well separated from the rest of the digit impressions (Welles, 1971; Lockley et al., 2011). In addition, compared to *Eubrontes*, *Kayentapus* is gracile, with a wider digit divarication (60–75° between digits II and IV of *K. hopii*), and also differs in the anterior and posterior triangle configurations (Lockley, 2009; Lockley et al., 2011).

All large- and medium-sized tracks from Zizhou differ from *Eubrontes* in having a wide digit divarication (Olsen et al., 1998), and relatively slender digit traces. Although the large-sized tracks have a pronounced metatarsophalangeal pad, the digit proportions with II>IV are different from typical *Changpeipus* (Xing et al., in press a). Among well-preserved large Zizhou tracks, the divarication angle between digit III and digit IV is significantly larger than that between digit II and digit III, as noted for *Kayentapus* and *Kayentapus* like tracks from the USA (Lockley et al., 2011: fig. 7), especially the unnamed tracks from the Navajo Formation of Utah (Lockley et al., 2011) and *Kayentapus minor* (Lull, 1953; Weems, 1992). The medium-sized tracks from Zizhou lack this feature. However, both divarication angle (digits II–IV) and anterior triangle length/width ratio of Zizhou medium-sized tracks are close to those of the large tracks, which might indicate different ontogenetic stages. Bivariate analysis of the Zizhou theropod tracks and other tridactyl theropod ichnotaxa (Lockley, 2009; see above) revealed that there is no discernable morphological difference between medium-sized and large tracks (Fig. 6). The middle and large-sized theropod tracks from Zizhou are similar to the type specimens of *Eubrontes* (Weems, 1992) and *Kayentapus* (Lockley et al., 2011), Early Jurassic *Eubrontes* from the Glen Canyon Group, Utah (Lockley, 2009) and *Eubrontes* and *Kayentapus*-type tracks from China (Lockley, 2009; Lockley et al., 2013).

However, due to suboptimal preservation resulting from both original substrate conditions and subsequent weathering, the tracks lack sufficient morphological details to be assigned to either *Kayentapus* or *Eubrontes* with confidence.

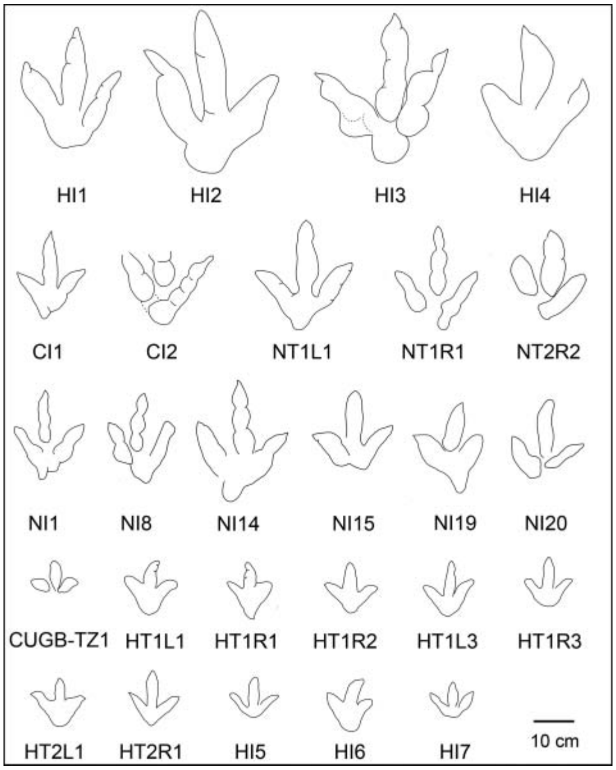

FIG. 5. Outline drawings of Zizhou theropod and ornithopod footprints.

Anomoepus–type Tracks

Ichnogenus *Anomoepus* Hitchcock 1848
Anomoepus isp.

Material. There are approximately 12 natural molds of tridactyl footprints of a small biped at the Huo tracksite (Fig. 3, 5; Table 1). Of these, nine tracks belong to two distinct trackways (HT1 and HT2). All other tracks are isolated and not part of discernible trackways. None of these tracks have been collected, all remain in the field. CUGB-TZ1 is an isolated track from the Wang tracksite, housed at China University of Geosciences, Beijing.

Description. Trackway HT1 consists of 6 pes imprints and HT2 of 3 pes imprints that are rotated toward the midline (along digit III). They are small (12.0–14.5 cm in length) and tridactyl. Manus and tail traces are absent. The length/width ratios of these tracks range from 1.0 to 1.2. Track HT1R2 is the best representative of the track morphology. Digit III projects the farthest anteriorly. Some digit impressions reveal indistinct pad impressions. Each terminal digit trace is deep, probably because the sediments were soft during track formation and the claws sank into the substrate. The proximal region of digits II and IV forms an indistinct U-shaped metatarsophalangeal region that lies in line with the axis of digit III. The footprints of trackway HT1 have wide divarication angles (63–88°), show weak mesaxony, and have an anterior triangle length-width ratio of 0.45. Trackway HT1 is narrow (pace angulation about 161°) and characterized by comparatively short stride lengths (61 cm on average), given a mean footprint length of 12.8 cm.

Other small tracks are generally similar to HT1R2 in morphology. For partial tracks such as HT1R1, digit III has three phalangeal pads. CUGB-TZ1 lacks a digit IV metatarsophalangeal pad, which makes the apparent divarication angle enlarged to 127°.

Discussion

The shape of the small tridactyl tracks from Zizhou strongly resembles that of the ichnogenus *Shensipus* from the Middle Jurassic Zhiluo Group of Shaanxi Province which is revised here and considered as a junior synonym of *Anomoepus* (see below), that is, similar size, wide divarication angles, weak mesaxony, U-shaped metatarsophalangeal region. Thus we assign the Zizhou tracks to *Anomoepus* isp. Based on the bivariate analysis (Fig. 6), it is clear that the morphology of these small Zizhou tracks is distinct from those of typical theropods such as *Grallator*. It is more close to that of transverse weakly mesaxonic forms such as *Anomoepus* (Lockley, 2009).

Speed of Trackmakers

The well-preserved Zizhou theropod trackway allows us to calculate speed (v) using the formula of Alexander (1976). $v = 0.25g^{0.5}.\ SL^{1.67}.\ h^{-1.17}$, where g = gravitational acceleration in m/sec, SL = stride length, and h = hip height—estimated as 4.5 times foot length (FL), using the ratio for small theropods proposed by Thulborn (1990). Based on measurements of the trackways, we estimate a speed of ~0.65 m/sec or ~2.34 km/hr (trackway HT1); ~1.13 m/sec or ~4.07 km/hr (trackway HT2); and ~0.88 m/sec or ~3.17 km/hr (trackway NT2).

The speed of the trackmaker of the *Kayentapus*-type trackway NT2 is slower than that of the type trackway of *Kayentapus hopii* (~14.51 km/hr, Lockley et al., 2011) and the Middle Jurassic possible *Kayentapus* trackway from Sichuan, China (*Schizograllator*, Zhen et al., 1986) (~12.0 km/hr) (Lockley et al., 2011), while similar to that of the Middle Jurassic *Kayentapus* trackways from the Panxi region, China (~4.1– 5.1 km/hr) (Xing et al., 2013a).

The trackmaker of *Anomoepus* (*"Shensipus"*) trackways HT1 and HT2 are identified as walking at a slow speed. Although the type specimen of *Shensipus tungchuanensis* (= *A. tungchuanensis*) merely preserves a single pace, the stride was calculated multiplying the pace by two. However, this value has to be considered cautiously because there is a large variation of pace length within single trackways and this kind of extrapolations might falsify the correct speed. Using 2x pace = stride as a proxy, *S. tungchuanensis* IVPP V3229 was also walking at a slow speed, ~0.18 km/hr.

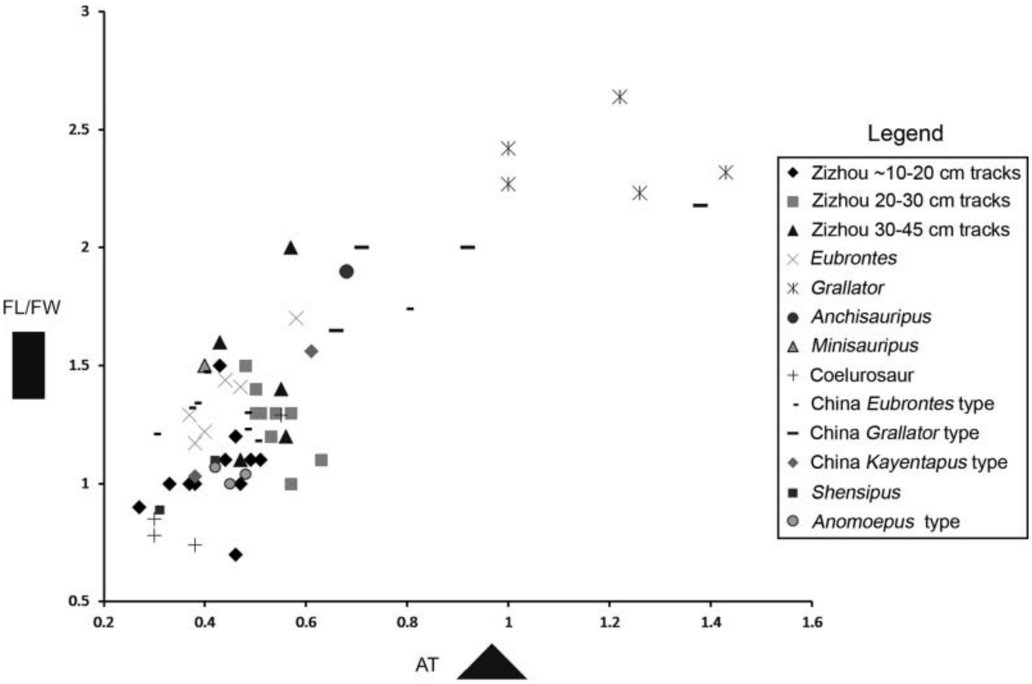

FIG. 6. Bivariate analysis of the length/width ratio vs. AT (anterior triangle length-width ratio) of Zizhou theropod tracks and other tridactyl theropod ichnotaxa (Lockley, 2009).

Re-assignment of *Shensipus tungchuanensis* Young 1966

Ichnogenus *Anomoepus* Hitchcock 1848

Anomoepus tungchuanensis (Young 1966) comb. nov.

Remarks. The type specimen of the Shaanxi tracks (IVPP V 3229) consists of only two preserved footprints collected from the northeastern slope of the Qianhe open-air mineral well of the Jiaoping Coal Mine, Tongchuan, Shaanxi, which pertains to the lower part of the Middle Jurassic Zhiluo Group (= Chiloo Group). The identifying characteristics described by Young (1966; p. 70) include "tridactylous with rather slender digits; digit II and digit IV considerably divergent; tip of the fingers with distinct pellet-like claw, heel small." The trackmakers represent small bipeds with a short step and the suggestion of inward rotation of the foot axis (digit III). Unfortunately, these tracks have evidently been lost, and the first and second authors were unable to find them in the IVPP collections in 2013. Here we present an outline of the tracks (Fig. 7; Table 2) and a new description based on Young 1966: plate I (and on an artificial mold of the tracks housed at the Fukui Prefectural Dinosaur Museum, Japan). We infer that the tracks belong to the ichnogenus *Anomoepus* as they closely resemble those reported by Li et al. (2012, fig. 12B), and others described here from the Huo tracksite. Here we consider *Shensipus tungchuanensis* a subjective junior synonym of *Anomoepus sensu lato* and therefore propose the new combination *Anomoepus tungchuanensis*.

Description

The two tracks represented by the holotype (IVPP V.3229) are relatively small, about 10 cm long and wide. Fills are strongly amalgamated with the surrounding rock, therefore tracks are less well defined, and a detailed morphology, such as phalangeal and metatarsophalangeal pads, are difficult to discern. However, the metatarsophalangeal region appears expanded and may indicate that the short hallux characteristic of *Anomoepus* might have been visibly registered if preservation in this region were clearer. IVPP V.3229-1 is considered a right footprint and IVPP V.3229-2 is a left footprint. They may constitute a single pace of about 20 cm length. Assuming this, a line between the tips of digits III on both tracks gives inward rotation values of about 30° for IVPP V.3229-1 and 20° for track IVPP V.3229-2. The average length/width ratio of the two footprints is 1.0, the anterior triangle length-width ratio is 0.37, and the average divarication angle is 86°. The terminations (claws) of digit II and digit III traces are sharp. The average divarication angle II–IV is wide (86°), that between digits III and IV being much larger than between digits II and III. The proximal region of digits II and IV forms an indistinct U-shaped metatarsophalangeal region that lies in line with the axis of digit III.

Discussion

All these characteristics, notably the wide digit divarication, length/width ratio, short step, and inward rotation, are

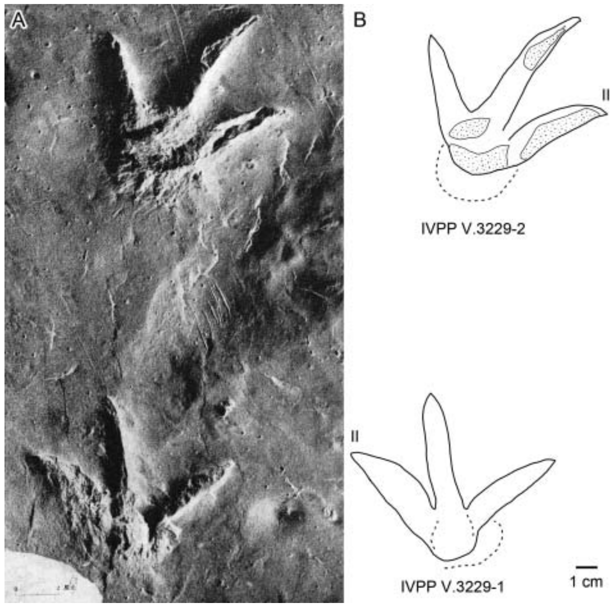

FIG. 7. *Shensipus tungchuanensis* lost holotype **A.** Photographs (after Young, 1966: plate I); **B**. Outline drawing.

characteristic of *Anomoepus* (Lockley and Gierliński, 2006). The short pace of *Anomoepus tungchuanensis* was explained by Zhen et al., (1989) as evidence that the trackmaker had paused. This speculation is less plausible than simply inferring a short step, as is typical of many *Anomoepus* trackways. Zhen et al. (1989) considered *Shensipus tungchuanensis* similar to *Talmontopus* (Lapparent and Montenat, 1967). *Talmontopus* was first considered an ornithopod track. This inference is consistent with the conclusion that *Shensipus* is a synonym of *Anomoepus*. Lockley and Meyer (2000) argued that the length of *Talmontopus* is larger than the width (27 cm and 23 cm, respectively) and that *Talmontopus* was therefore most probably a theropod track. Ferrusquiá-Villafranca et al. (2007) regarded the theropod morphotype A from the Middle Jurassic of Oaxaca of southeastern Mexico as similar to *Shensipus tungchuanensis*. However, the former is 25% larger than *Shensipus.* In short, previous comparisons between *Shensipus* and *Talmontopus*, or the Mexican tracks are tenuous.

Small Jurassic tridactyl tracks with a wide divarication angle are not rare in China. For example, *Anomoepu*s was first reported, in China, from the early Jurassic Jinlijing Village site in Sichuan Province by Lockley and Matsukawa (2009). *Grallator*-type tracks from the Lower Jurassic Ziliujing Formation of Zigong City, Sichuan, China, have divarication angles between digits II and IV that average 74° (Xing et al., in press b). However, *S. tungchuanensis* has weak mesaxony, which is different from other *Grallator*-type tracks, and more like *Anomoepus*. In general, due to the previously insufficient number and quality of *S. tungchuanensis* specimens, there appear to be no specific identifying characteristics. Also, the small tridactyl tracks discovered in recent years from northern Shaanxi (Li et al., 2012, fig. 12B) are likely assignable to *Anomoepus* (see below) and provide better information on the affinity of the tracks originally named *Shensipus* by Young (1966). Trackways HT1L1 to HT1R3, and HT2l1-HT2L2 from the Hou tracksite have all diagnostic characteristics of *Anomoepus* including small size (~13 cm) length = width, short step (~30 cm) and inward rotation.

Although Lockley and Matsukawa (2009) claimed that the Jilijing *Anomoepus* was the first example identified from China, which was a correct statement at that time, our present study, showing that *Shenshipus* is a junior synonym of *Anomoepus*, demonstrates that Chinese tracks representing this ichnogenus were illustrated by Young (1966), almost 50 years ago, before they were correctly identified.

Deltapodus-type Tracks

Ichnogenus *Deltapodus* Whyte and Romano 1994
Deltapodus isp.

Materials. WTM1- WTP1 (M = manus; P = pes), WTM2- WTP2, WTP3, and WTM4- WTP4, manus-pes impression sets remain at the lower layer of the Wang tracksite, Shaanxi, China (Fig. 8; Table 3). Except for WTM4-WTP4, which are natural molds, the rest of the specimens are natural casts. The original specimens remain in the field under the protection of the Zizhou County Bureau of Land and Resources.

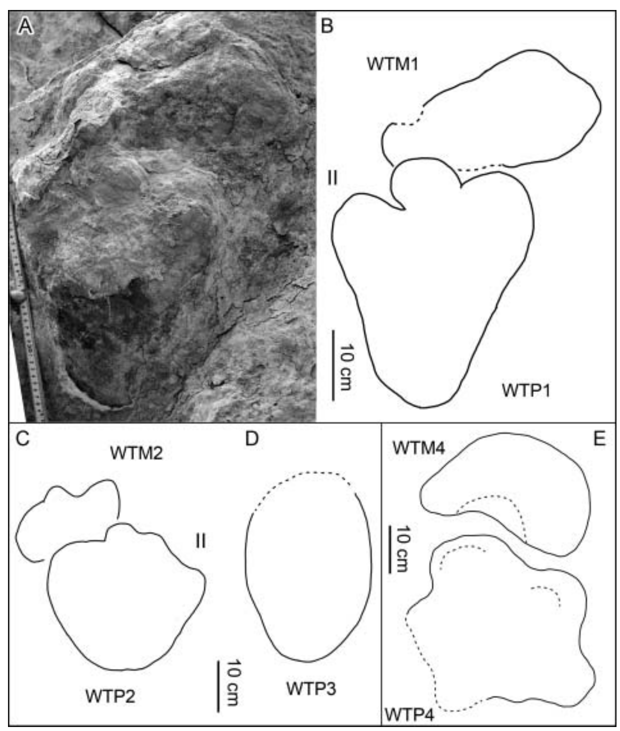

FIG. 8. *Deltapodus* at Wang tracksite. **A**. Photograph; **B–E.** Outline drawings.

TABLE 1
Measurements (in cm) of the theropod and ornithopod tracks from Zizhou tracksites

Number	PL	PW	D	II	III	IV	II–III	III–IV	II–IV	SL	PL	PA	AT	L/W
HT1L1	13.0	12.5	2.2	7.0	9.0	9.5	34°	42°	76°	65.5	33.0	166°	0.37	1.0
HT1R1	13.0	11.0	3.2	7.0	9.5	9.0	30°	33°	63°	60.5	33.0	155°	0.46	1.2
HT1L2	12.0	—	2.3	6.5	9.5	—	—	—	—	58.5	29.0	159°	—	—
HT1R2	12.5	12.5	2.5	7.5	10	9.0	39°	49°	88°	59.5	30.5	165°	0.47	1.0
HT1L3	13.5	12.5	2.2	8.0	10.5	10	33°	42°	75°	—	29.5	—	0.44	1.1
HT1R3	13.0	11.5	1.1	6.5	10.5	9.0	41°	42°	83°	—	—	—	0.49	1.1
Mean	12.8	12.0	2.3	7.1	9.8	9.3	35°	42°	77°	61.0	31.0	161	0.45	1.1
HT2L1	12.5	13.5	2.1	6.5	8.5	10.5	40°	40°	80°	88.0	45.5	150°	0.33	1.0
HT2R1	14.5	13.5	2.2	7.5	10.5	11.0	34°	44°	78°	—	45.5	—	0.51	1.1
HT2L2	—	16.0	2.4	7.0	—	11.5	—	—	—	—	—	—	—	—
Mean	13.5	14.3	2.2	7.0	9.5	11.0	37°	42°	79°	88.0	45.5	150°	0.42	1.1
HI1	39.0	24.0	4.0	18.0	30.5	31.0	31°	32°	63°	—	—	—	0.43	1.6
HI2	41.0	33.5	3.3	25.0	32.0	31.0	25°	39°	64°	—	—	—	0.56	1.2
HI3	38.0	34.0	4.1	24.5	28.0	31.0	26°	41°	67°	—	—	—	0.47	1.1
HI4	34.5	25.0	2.4	12.0	24.0	24.0	29°	36°	65°	—	—	—	0.55	1.4
HI5	11.0	11.5	1.5	6.5	8.5	8.0	48°	47°	95°	—	—	—	0.38	1.0
HI6	17.5	11.5	3.2	6.0	12.5	12.0	45°	22°	67°	—	—	—	0.43	1.5
HI7	9.5	11.0	1.3	6.5	7.5	8.5	40°	41°	81°	—	—	—	0.27	0.9
HI8	—	22.5	1.8	15.0	19.0	—	—	—	—	—	—	—	—	—
HI9	26.0	19.0	4.0	15.0	—	19.0	—	—	—	—	—	—	—	1.4
NT1L1	28.0	24.0	1.7	13.5	20.0	18.5	35°	42°	77°	—	54.0	—	0.53	1.2
NT1R1	27.0	21.5	1.5	12.5	18.0	14.0	37°	34°	71°	—	—	—	0.57	1.3
Mean	27.5	22.8	1.6	13.0	19.0	16.3	36°	38°	74°	—	54.0	—	0.55	1.3
NT2R1	21.0	19.0	1.4	12.0	15.0	14.0	48°	46°	94°	107.5	57.5	143°	0.63	1.1
NT2L1	23.0	20.0	1.1	13.0	18.0	17.0	—	—	—	—	56.0	—	—	1.2
NT2R2	22.5	17.5	1.1	11.0	16.0	16.0	24°	34°	58°	—	—	—	0.51	1.3
Mean	22.2	18.8	1.2	12.0	16.3	15.7	36°	40°	76°	107.5	56.8	143°	0.57	1.2
NI1	22.5	17.5	2.1	10.5	16.0	16.0	36°	29°	65°	—	—	—	0.50	1.3
NI2	21.0	16.5	1.8	10.0	16.5	12.0	—	—	—	—	—	—	—	1.3
NI3	18.0	—	1.8	—	—	—	—	—	—	—	—	—	—	—
NI4	20.0	19.5	2.0	11.0	16.5	15.0	—	—	—	—	—	—	—	1.0
NI5	20.0	17.0	2.1	10.0	16.0	12.5	40°	40°	80°	—	—	—	—	1.2
NI6	19.0	17.0	1.3	—	—	—	—	—	—	—	—	—	—	1.1
NI8	22.5	15.5	1.6	12	15	16.5	31°	24°	55°	—	—	—	0.48	1.5
NI9	21.0	18.0	1.4	10.5	16.5	15.5	—	—	—	—	—	—	—	1.2
NI10	18.5	19.0	1.1	10.0	14.0	12.5	—	—	—	—	—	—	—	1.0
NI11	—	—	—	—	—	—	—	—	—	—	—	—	—	—
NI12	—	—	—	—	—	—	—	—	—	—	—	—	—	—
NI13	27.0	19.5	1.2	13.0	21.5	19.0	—	—	—	—	—	—	—	1.4
NI14	29.5	22.0	0.8	15.0	18.5	18.0	26°	36°	62°	—	—	—	0.54	1.3
NI15	20.5	20.5	1.6	11.0	16.0	14.0	54°	44°	98°	—	—	—	0.57	1.0
NI16	—	—	—	—	—	—	—	—	—	—	—	—	—	—
NI17	—	20.0	1.7	—	—	—	—	—	—	—	—	—	—	—
NI18	21.5	20.0	1.3	10.0	16.0	16.5	59°	38°	97°	—	—	—	—	1.1
NI19	25.0	17.5	1.0	10.5	13.5	16.5	19°	41°	60°	—	—	—	0.50	1.4
NI20	27.0	19.5	1.7	14.0	18.0	19.5	42°	45°	87°	—	—	—	—	1.4
CI1	34.8	17.7	2.0	14.0	16.0	15.8	36°	35°	71°	—	—	—	0.57	2.0
CI2	—	—	2.2	—	—	23.0	—	—	—	—	—	—	—	—
CUGB-TZ1	8.5	12.3	0.9	5.8	8.0	5.6	67°	60°	127°	—	—	—	0.46	0.7

ML: maximum length; MW: maximum width measured between the tips of digits II and IV; II: length of digit II; III: length of digit III; IV: length of digit IV; II-III: angle between digits II and III; III-IV: angle between digits III and IV; SL: stride length; PL: pace length; L/W: ratio of maximum length/maximum width.
PA: pace angulation.
AT: anterior triangle length-width ratio.

TABLE 2
Measurements (in cm) of the *Shensipus* tracks from Jiaoping tracksite*

Number	PL	PW	II	III	IV	II–III	III–IV	II–IV	PL	AT	L/W
IVPP V.3229-1	9.8	8.9	3.7	6.1	4.0	36°	54°	90°	9.7	0.42	1.1
IVPP V.3229-2	8.1	9.1	4.1	5.5	4.4	31°	51°	82°	—	0.31	0.9
Mean	9.0	9.0	3.9	5.8	4.2	34°	53°	86°	—	0.37	1.0

*the date of PL, PW, II, III, IV, and PL are from Young (1966).

Description. The average length of all manus and pes prints is 32.3 cm and 26.3 cm, respectively. The average length/width ratio is 1.3 and 0.6, respectively. WTM1- WTP1 and WTM2- WTP2 constitute a single pace that is 71 cm long. The distance between the manus track and the trackway midline exceeds the distance between the pes track and the trackway midline. Taking the best-preserved WTM1- WTP1 as representative, each digit of WTM1 lacks distinct impressions; WTP2 has three developed wide blunt digits, and digit III is slightly longer than digits II and IV. WTP4 is seriously deformed. While WTM4 is well-preserved, it exhibits an U−shaped manus print like sauropods.

Comparisons and Discussion

The type of *Deltapodus* (Whyte and Romano, 1994) is characterized by an elongate tridactyl pes with very blunt wide digits that are not separated by well-developed hypices (Lockley et al., 2008). Pedal digit III is only slightly longer than digits II and IV, thus mesaxony is weak (Lockley, 2009). Zizhou tetrapod tracks coincide with the morphological characteristics of *Deltapodus*. As noted by Li et al. (2012), *Deltapodus*-like tracks co-occur with *Shenmuichnus* and both have diagnostic ornithischian characteristics.

Presently, the global distribution of tracks attributed to stegosaurians includes Africa, Europe and North America (Milàn and Chiappe, 2009). These tracks mostly pertain to *Deltapodus* and *Stegopodus*, but also include several unattributed specimens. *Deltapodus* was originally described from the Middle Jurassic of Yorkshire, England (Whyte and Romano, 1994). The ichnospecies *D. brodricki* was successively attributed to a sauropod (Whyte and Romano, 1994), ankylosaurian or stegosaurian (Lockley and Meyer, 2000), ankylosaurian (Gierliński and Sabath, 2008), and stegosaurian (Whyte and Romano, 2001) trackmakers.

This ichnotaxon is abundant in Western Europe in the Middle-Late Jurassic and ranges into the earliest Cretaceous (such as Whyte et al., 2007; Garcia-Ramos et al., 2006; Lockley et al., 2008; Mateus and Milàn, 2008). Outside Europe, discoveries include specimens from the Late Jurassic of Utah (Milàn and Chiappe, 2009; Gierliński et al., 2010), the Late Jurassic of Iouaridène, Morocco (Belvedere and Mietto, 2010), and the Early Cretaceous boundary of China (Xing et al., 2013b).

Although *Deltapodus* has been widely accepted as a distinct and relatively widespread ichnogenus, details of its morphology are still poorly known. Cretaceous *Deltapodus curriei* exhibits a well-preserved manus and pes track. Digit I of the manus track is developed, while other digits are indistinct (Xing et al., 2013b).

Zizhou *Deltapodus* tracks WTM1- WTP1 and WTM2-WTP2 show an unusual feature with the posterior manus track being overlapped by the pes track, that might caused by the varied speed of the trackmaker. Furthermore, WTM1 and WTP1 have low heteropody, that is different from the high heteropody of *Deltapodus brodricki* (Whyte and Romano, 1994), while similar to *Deltapodus* isp. from the Tereñes Formation (Upper Jurassic) of Spain (Gierliński and Sabath (2008). Due to the small sample size, it is difficult to discern systematic features, and thus the material is referred to *Deltapodus* isp.

Li et al. (2012) demonstrated that the tracks (*Shenmuichnus*) of an early Mesozoic (probably Late Triassic-Early Jurassic), quadrupedal ornithischian (?thyreophoran) appear as well-defined, tridactyl pes prints and pentadacyl manus prints when shallow and well-preserved, but may, in contrast, be more *Deltapodus*-like when the prints are deeply impressed and the individual digits are poorly defined. Zizhou *Deltapodus* tracks are not ideally well-preserved. Thus, a closer relation with *Shenmuichnus* is also inferred.

TABLE 3
Measurements (in cm) of the quadrupedal trackways from the Zizhou tracksite. Abbreviations: PL: pes length; PW: pes width; ML: manus length; MW: manus width

Number	PL	PW	PL/PW	ML	MW	ML/MW
WTM1	—	—	—	13.0	21.0	0.6
WTP1	32.5	24.0	1.4	—	—	—
WTM2	—	—	—	10.2	20.0	0.5
WTP2	27.0	25.0	1.1	—	—	—
WTP3	31.7	21.1	1.5	—	—	—
WTM4	—	—	—	21.0	31.5	0.7
WTP4	38.0	35.0	1.1	—	—	—
Mean	32.3	26.3	1.3	14.7	24.2	0.6

DISCUSSION

Lockley and others suggested a distinction between humid, clastic, coastal plain, coal-bearing facies dominated by ornithopods (*Caririchnium* ichnofacies; Lockley et al., 1994) and ankylosaurs (*Tetrapodosaurus* ichnofacies; McCrea et al., 2001, 2014) and semi-arid carbonate facies dominated by sauropods (Lockley et al., 1994). The discovery of Zizhou *Deltapodus* tracks supports this view.

Two tracksites were discovered at the Shenmu area of northern Shaanxi, which is located at Bamengou Village (the Early Jurassic Fuxian Formation), Lijiananwa Village (the Middle Jurassic Yan'an Formation) (Zhang et al., 2012; Li et al., 2012). The sites were dominated by theropod and early ornithischian tracks, with abundant *Anomoepus*, *Grallator*, *Deltapodus*, and *Shenmuichnus*. The theropod tracks remain the subject of further analysis. Both the Shenmu area and Zizhou tracksite are situated at the eastern Ordos Basin and share a similar geologic background. The Zizhou *Kayentapus*–*Anomoepus* assemblage with *Deltapodus* tracks are similar to those in the Shenmu area. It indicates that similar dinosaur faunas roamed the Early-Middle Jurassic in northern Shaanxi and the eastern Ordos Basin. Many Early and Middle Jurassic ichnofaunas in China, North America, Europe, and southern Africa are saurischian-dominated. Some include relatively small numbers of ornithischian tracks (*Anomoepus* and *Moyenisauropus*). Other ornithischian tracks such as *Shenmuichnus* and *Deltapodus* are also uncommon or unknown. While the current sample from Shaanxi is too small to make confident generalizations, it appears that the ornithischian component in the region is well represented.

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