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FIRST DINOSAUR TRACK SITE FROM THE LOWER CRETACEOUS OF YUNNAN PROVINCE, CHINA

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ABSTRACT

A new dinosaur track site is reported from the Puchanghe Formation (Lower Cretaceous), Hemenkou, Chuxiong Yi Ethnogenesis Autonomous Prefecture, Yunnan Province, China. Five theropod, fifteen sauropod, and seven poorly preserved tridactyl tracks are observed in an area approximately 20 m long and 6 m wide on the bedding surface. One theropod trackway and one poorly preserved tridactyl trackway can be recognized. The Hemenkou site is the first track site from the Lower Cretaceous in Yunnan Province.

Key words: dinosaur tracks, theropod, sauropod, Puchanghe Formation, Lower Cretaceous, Yunnan

藤田将人・王　増清・東　洋一・柴田正輝・董　枝明（2008）中国雲南省の下部白亜系から初めて発見された恐竜足跡化石産地．福井県立恐竜博物館紀要 7：33–43.

中国雲南省楚雄彝族自治州の河門口の下部白亜系 Puchanghe 層から新しい恐竜の足跡化石産地を報告した．5 つの獣脚類，15 の竜脚類，7 つの保存不良の三指性の足跡化石が長さ約 20 m，幅約 6 m の地層面上に確認された．1 つの獣脚類の行跡と 1 つの保存不良の三指性の行跡が認められた．河門口の恐竜足跡化石産出地は白亜紀前期の足跡化石としては雲南省で最初の例である．

INTRODUCTION

Abundant dinosaur remains have been reported from the Lower and Middle Jurassic in Yunnan Province (e.g., Young, 1941, 1951; Zhang and Yang, 1995; Dong, 2001; Lü et al., 2006b; Lü et al., 2007). By contrast, dinosaur remains are barren in the Lower Cretaceous in Yunnan, except for tyrannosaurid teeth found in the western part of Yunnan (Ye, 1975). On the other hand, dinosaur tracks such as *Grallator limnosus, Schizograllator xiaohebaensis, Paracoelurosaurichnus monax, Eubrontes platypus,* and *Youngichnus xiyangensis* were reported from the Lower Jurassic Fengjiahe Formation of Jinnin, central Yunnan (Zhen et al., 1986). The Upper Cretaceous of Chuxiong Prefecture yields sauropod tracks *Brontopdus changlingensis* and poorly preserved theropod tracks (Lockley et al., 2002). Recently, a large sized theropod track *Lufengopus dongi* was found from the Middle Jurassic of Lufeng (Lü et al., 2006a). Thus, several dinosaur tracks have been reported from the Lower and Middle Jurassic, and the Upper Cretaceous in Yunnan Province. However, the Lower Cretaceous in Yunnan has not yielded dinosaur tracks so far.

The dinosaur track site reported in this paper is located at Hemenkou approximately 70 km south to the Chuxiong, (24˚22’54.7”N; 101˚40’05.2”E) (Fig. 1A, B), and the Sino-Japanese expedition team worked at the Hemenkou track site in November, 2006. The aim of this paper is to describe the Hemenkou dinosaur tracks.

GEOLOGICAL SETTING

The Lower Cretaceous sediments in central Yunnan subregion are divided into the Gaofengsi, Puchanghe, and Matoushan formations in ascending order (Compilation Committee of Geological Atlas of China, 2002), and the dinosaur tracks were found from the Puchanghe Formation. The dinosaur track site of Hemenkou is composed of alternating beds of sandstone and mudstone (Fig. 2). The medium- to coarse-grained gray sandstones range from 1 to 10 meters in thickness with erosive bases. The sandstone contains rip-up clasts in the base and indicates trough cross lamination occasionally. Reddish brown fine-grained sandstone, siltstone, and mudstone often include drab-halo root traces and calcareous nodules (Figs. 2 and 3). The gray-colored, medium- to coarse-grained sandstones with erosive bases might be channel deposits or crevasse spray deposits

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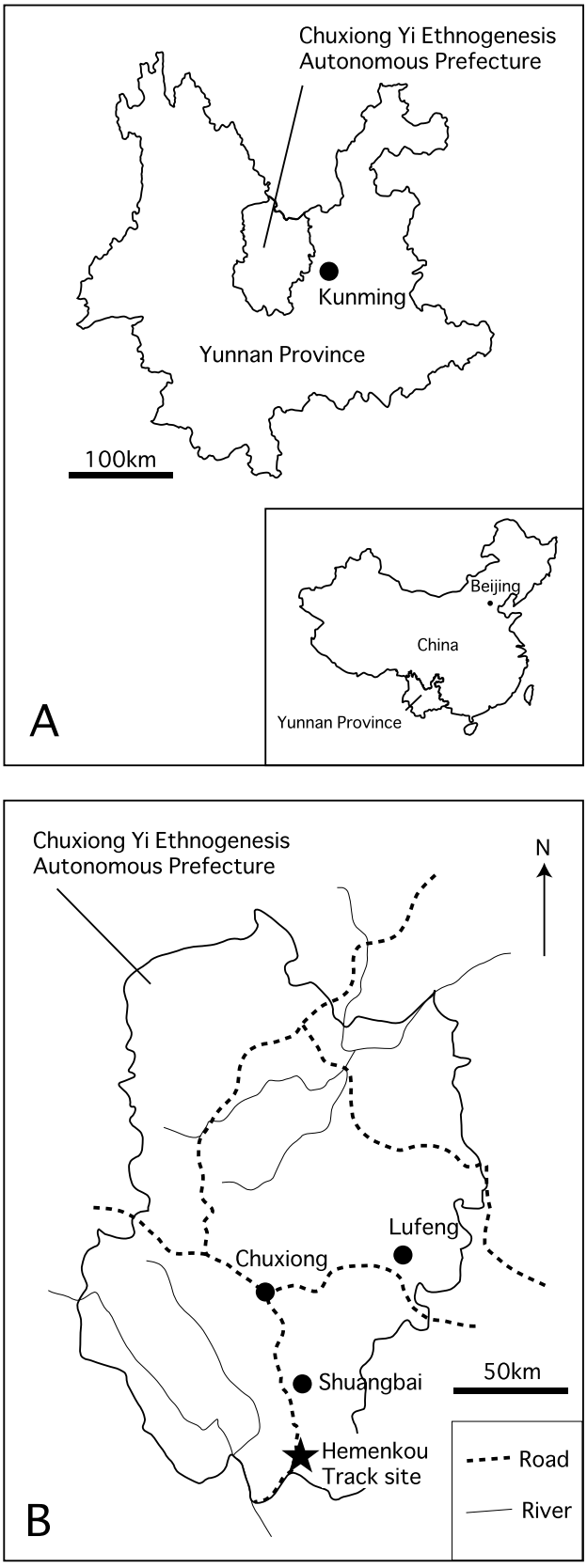


FIGURE 1. **A**, Map showing locality of Chuxiong Yi Ethnogenesis Autonomous Prefecture; **B**, Map showing locality of the dinosaur track site.

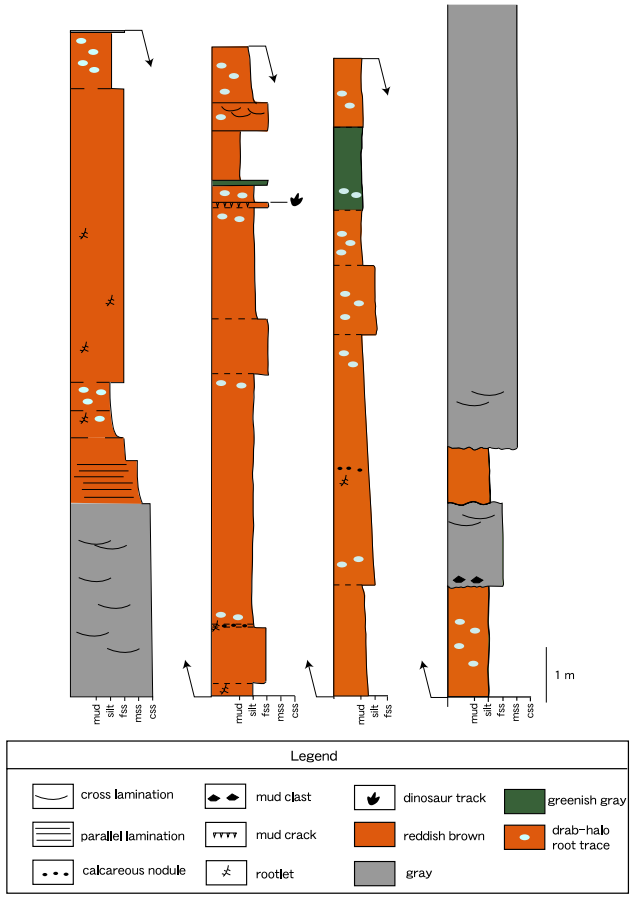


FIGURE 2. Columnar section of the Hemenkou track site.

FIGURE 3. Drab-halo root trace in the reddish brown fine-grained sandstone.

of fluvial sediments. Drab-halo root traces were formed by chemical reduction during anaerobic decomposition of organic matter remaining after burial of the paleosol (Retallack, 1997). Therefore, the reddish brown colored, fine-grained sandstone and mudstone that include calcareous nodules and drab-halo root traces would be paleosol in the fluvial sedimentary systems.

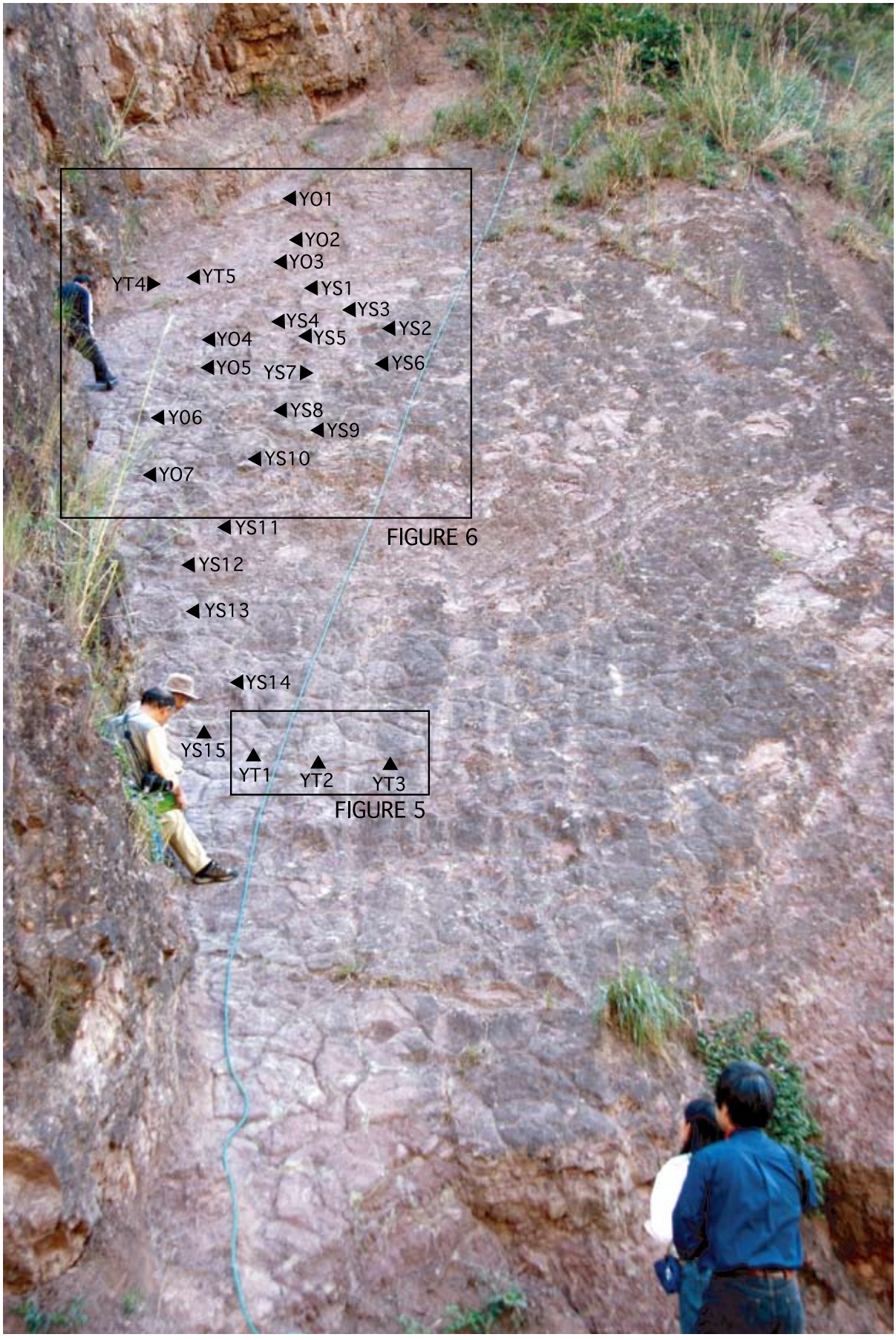


FIGURE 4. Photograph of the Hemenkou track site.

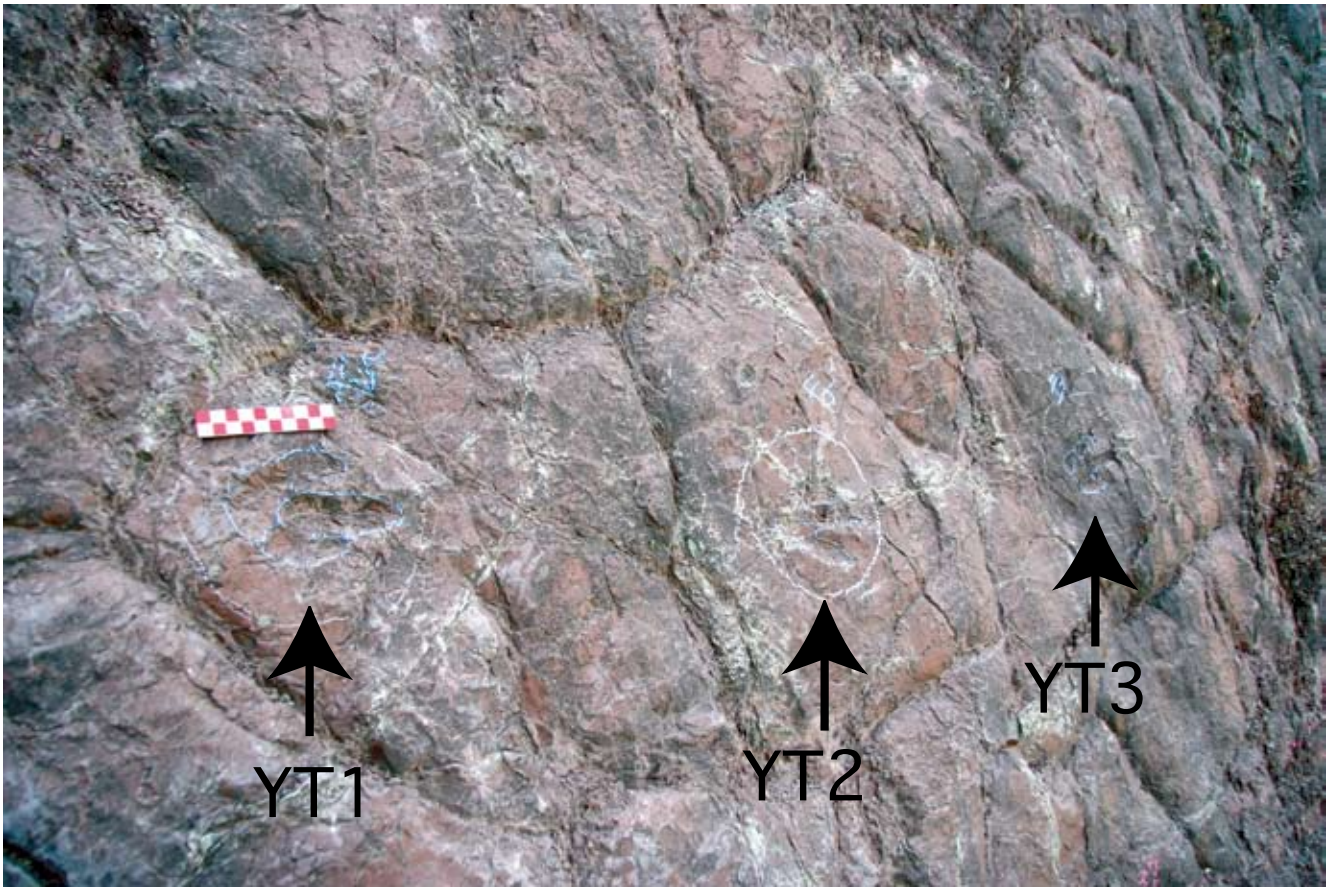


FIGURE 5. Trackway of theropod track YT1–3. Scale bar equals 10 cm.

DESCRIPTION

The dinosaur tracks were discovered on the bedding surface of the reddish brown fine-grained sandstone, on which numerous mud cracks are present in the Hemenkou track site (Figs. 2 and 4). There are twenty-seven dinosaur tracks in an area approximately 20 m long and 6 m wide on the bedding surface (Fig. 4). More than sixteen probable dinosaur tracks are present on the northern part of the bedding surface as dents, but their taxonomic identifications are obscure because of their poor preservation. The bed strikes N28˚W and dips 50˚N. The authors could not draw up the map of the tracks, due to the steep dip of the bedding surface. Silicon rubber moulds were made of tracks YT1, YT2, YT3, YT4, and YT5.

I. Theropod tracks

One trackway (YT1, YT2, and YT3) and two isolated tracks (YT4 and YT5) of theropod were recognized on the same bedding surface in the Hemenkou track site (Figs. 5 and 6).

Theropod trackway.—One trackway consists of tracks YT1, YT2, and YT3 (Fig. 5). The average length of pace is 509 mm and the stride length is 1020 mm (Table 1). The pace angulation is 165˚. The tracks of the trackway are small sized tridactyl pes prints with no hallux impressions (Fig. 7). Three digits are slender with digital pad impressions, which have 2-3-3 formula.

YT1: Digit III is the longest and digit IV is slightly longer than the digit II. Sharp claw impressions are preserved on the end of all digits. The claw mark of the digit IV is rotated somewhat outward from the midline of the track. The distinctive elliptic metatarso-phalangeal pad impressions are preserved behind the digits II and III. The digital axis of digit II is subparallel to that of the digit III. The footprint length and width of the track YT1 are 132 mm and 70 mm, respectively (Table 1), and the ratio of footprint length to footprint width is 1.9. For further measurements, see Table 1.

YT2: The impression of digit III is the longest, which taper anteriorly. Digit IV is longer than digit II. Sharp claw impressions are preserved on the end of all digits. The claw mark of the digit IV is rotated somewhat outward from the midline of the track. The distinctive circular metatarso-phalangeal pad impressions are preserved behind digits II and III. The digital axis of digit II is subparallel to that of the digit III. The footprint length and width of the track YT2 are 114 mm and 71 mm, respectively (Table 1), and the ratio of footprint length to footprint width is 1.6. For further measurements, see Table 1.

YT3: The proximal digital pad impression of digit III is rather obscure. The digit III is the longest, and the digit IV is longer than the digit II. Sharp claw impressions are preserved on the end of all digits. The claw mark of the digit IV is rotated somewhat outward from the midline of the track. The

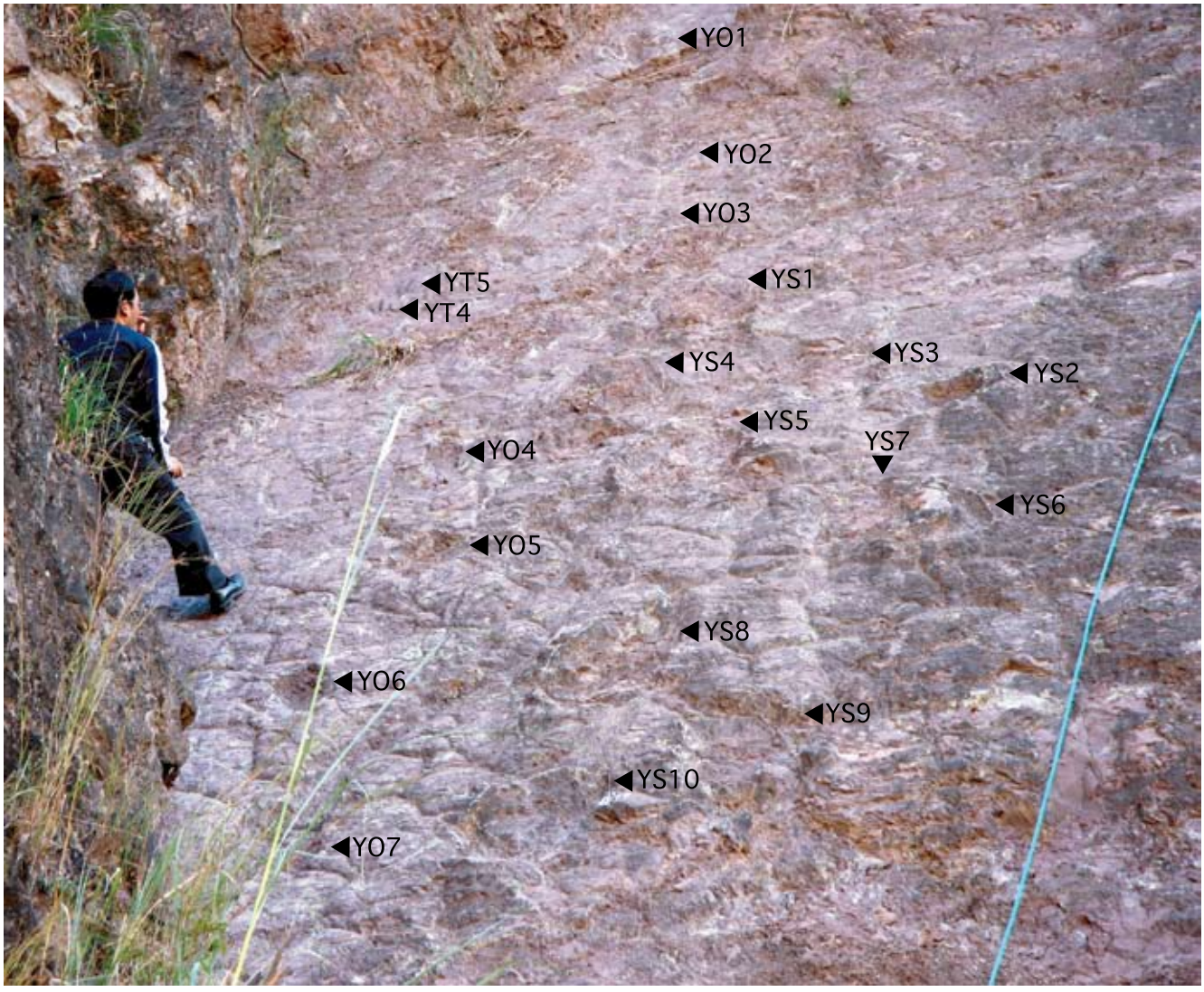


FIGURE 6. Photograph of the upper part of the Hemenkou track site.

TABLE 1. Distribution of left and right tracks and measurements of each theropod track (YT1–3) from the Hemenkou track site.

No.	FL	FW	R/L	DL II	DLIII	DLIV	DWII	DWIII	DWIV	DII-III	DIII-IV	DII-IV	Pace	Stride
YT1	132	70	L	56	94	60	23	26	18	21	15	36		
YT2	114	71	R	38	83	75	19	23	19	11	22	33	493	
YT3	120	69	L	49	89	63	15	19	19	8	22	30	524	1020
AV	122	70		48	89	66	19	23	19	13	20	33	509	1020

No: track number
FL: track length (mm)
FW: track width (mm)
R/L: right/left
DL II: digital length of digit II (mm)
DL III: digital length of digit III (mm)
DL IV: digital length of digit IV (mm)
DWII: maximum digital width of digit II (mm)
DWIII: maximum digital width of digit III (mm)
DWIV: maximum digital width of digit IV (mm)
DII-III: divarication angle between digits II and III (°)
DIII-IV: divarication angle between digits III and IV (°)
DII-IV: divarication angle between digits II and IV (°)
Pace: pace length of trackway (mm)
Stride: stride length of trackway (mm)
AV: average

TABLE 2. Distribution of left and right tracks and measurements of each theropod track (YT4 and 5) from the Hemenkou track site.

No.	FL	FW	R/L	DL II	DLIII	DLIV	DWII	DWIII	DWIV	DII-III	DIII-IV	DII-IV
YT4	170	103	L	69	107	73	17	23	20	29	20	49
YT5	188	100	L	63	124	88	29	29	25	19	14	33

No: track number
FL: track length (mm)
FW: track width (mm)
R/L: right/left
DL II: digital length of digit II (mm)
DL III: digital length of digit III (mm)
DL IV: digital length of digit IV (mm)
DWII: maximum digital width of digit II (mm)
DWIII: maximum digital width of digit III (mm)
DWIV: maximum digital width of digit IV (mm)
DII-III: divarication angle between digits II and III (°)
DIII-IV: divarication angle between digits III and IV (°)
DII-IV: divarication angle between digits II and IV (°)

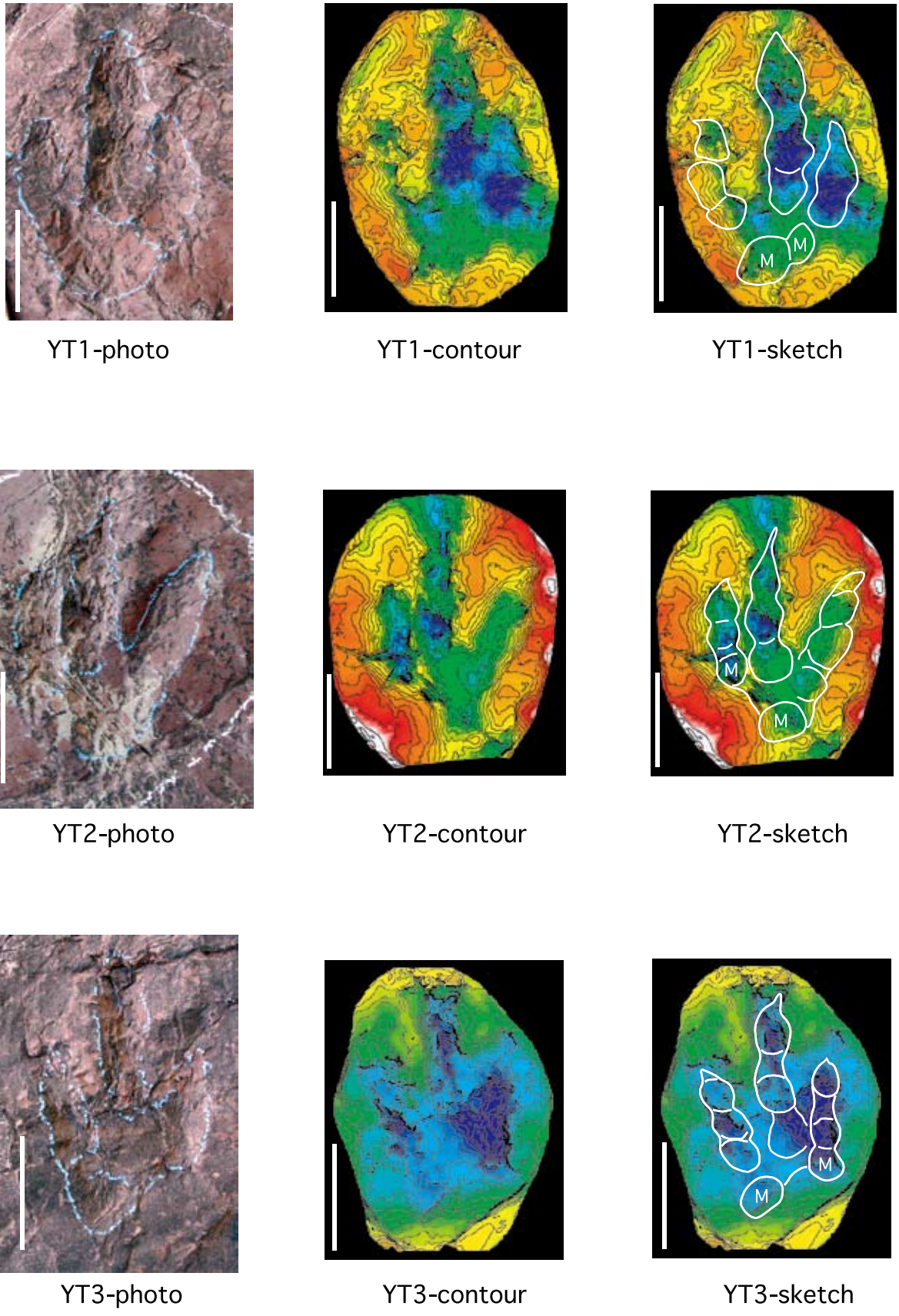


FIGURE 7. Theropod tracks (YT1–3) of the Hemenkou track site. Photographs, topographic images, and topographic images with superimposed outline. Topographic images are produced by the non-contact three-dimensional digitizer (VIVID700) and the software (3D-Rugle), following the procedure of Arakawa et al. (2002). All topographic images were obtained from plaster moulds. All scales = 5 cm. Contour intervals equal 0.4 mm. (M) Trace of metatarso-phalangeal pads.

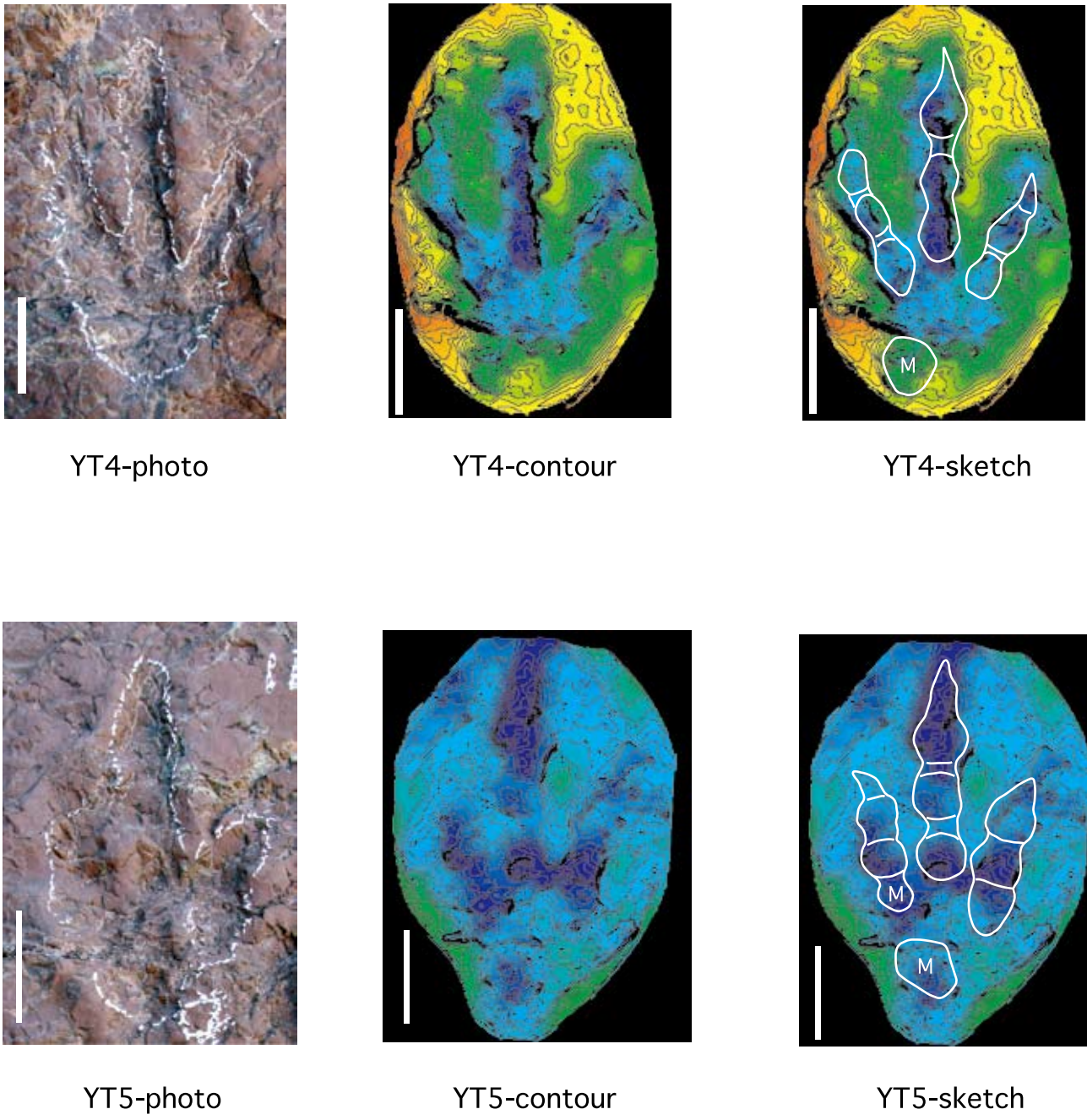


FIGURE 8. Theropod tracks (YT4–5) of the Hemenkou track site. Photographs, topographic images, and topographic images with superimposed outline. Other explanations are same as Fig. 7.

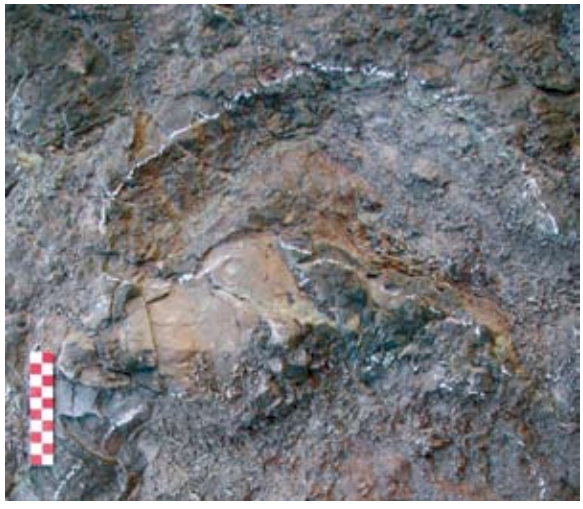
distinctive circular metatarso-phalangeal pad impressions are preserved behind digits II and IV. The digital axis of digit II is subparallel to that of the digit III. The footprint length and width of the track YT3 are 120 mm and 69 mm, respectively (Table 1), and the ratio of footprint length to footprint width is 1.7. For further measurements, see Table 1.

Isolated theropod tracks.—Two isolated theropod tracks (YT4 and YT5) were found on the same bedding surface of the theropod trackway (YT1, YT2, and YT3). The isolated theropod tracks YT4 and YT5 are medium sized tridactyl pes prints with no evidence of hallux impressions (Fig. 8). Three digits are slender with digital pad impressions, which have 2-3-3 formula. The digit III is the longest and the digit IV is longer than digit II.

YT4: Sharp claw impressions of the track YT4 are preserved on the end of digit II and III. The claw marks of the digit II and III point forward. The rather distinctive elliptic metatarso-phalangeal pad impression is preserved behind the digit III. The footprint length and width of YT4 are 170 mm and 103 mm, respectively (Table 2), and the ratio of footprint length to footprint width is 1.7. For further measurements, see Table 2.

YT5: The claw marks of the digits II and IV are rotated somewhat outward from the midline. The distinctive elliptic

A



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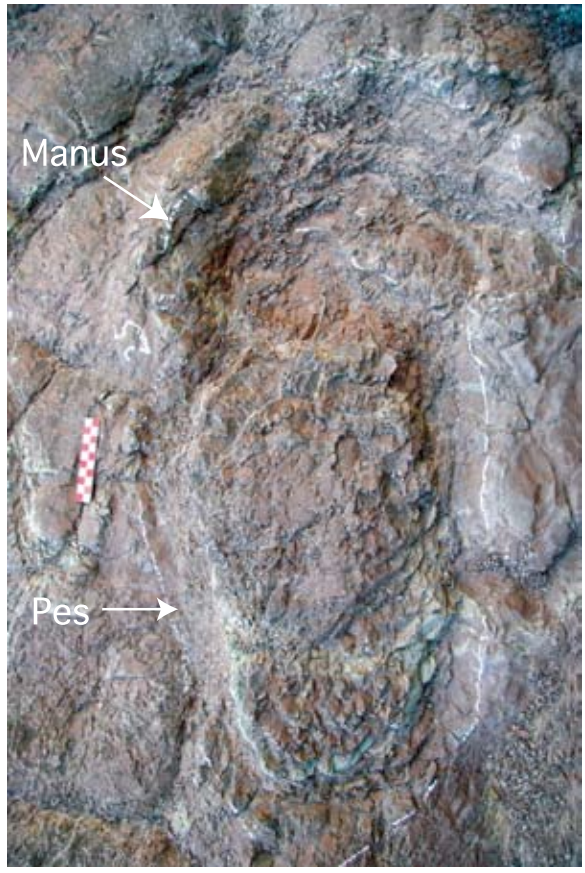

C

FIGURE 9. Poorly preserved tridactyl and sauropod tracks in the Hemenkou track site. **A**, poorly preserved tridactyl track of YO1; **B**, sauropod manus track of YS6; **C**, sauropod manus (YS15) and pes (YS14) tracks. Scale bar equals 10 cm.

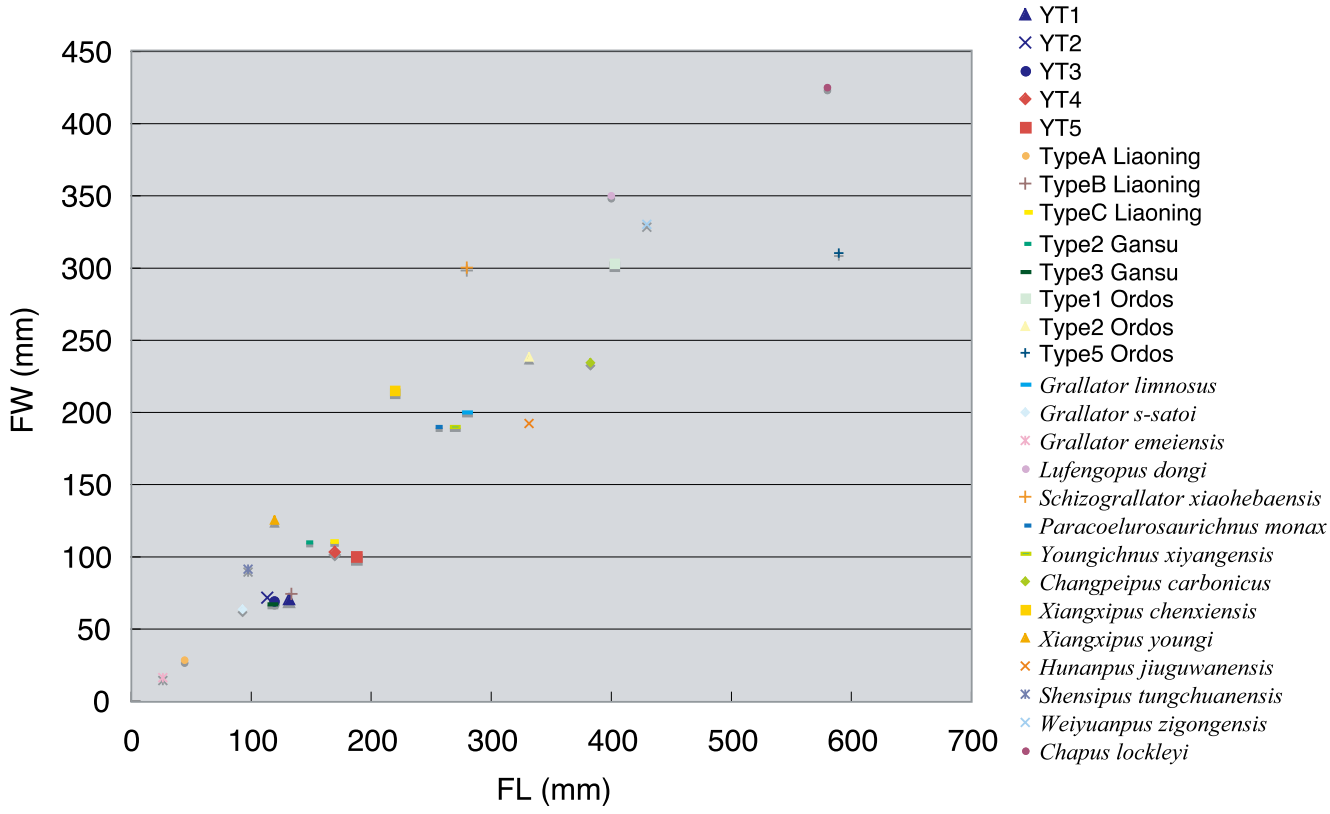

FIGURE 10. The scatter diagram of width to length of the theropod tracks in China. The references are given below.
Type A–C Liaoning: Fujita et al., 2007, Type 2–3 Gansu: Li, D. et al., 2006, Type 1, 2, 5 Ordos: Azuma et al., 2006, *Grallator limunosus*: Zhen et al., 1986, *Grallator s-satoi*: Yabe et al., 1940, *Grallator emeiensis*: Zhen et al., 1994, *Lufengopus dongi*: Lü et al., 2006a, *Schizograllator xiaohebaensis*: Zhen et al., 1986, *Paracoelurosaurichnus monax*: Zhen et al., 1986, *Youngichnus xiyangensis*: Zhen et al., 1986, *Changpeipus carbonicus*: Young, 1960, *Xiangxipus chenxiensis*: Zhen et al., 1989, *Xiangxipus youngi*: Zhen et al., 1989, *Hunanpus jiuguwanensis*: Zhen et al., 1989, *Shensipus tungchuanensis*: Zhen et al., 1989, *Weiyuanpus zigongensis*: Gao, 2007, *Chapus lockleyi*: Li, J. et al., 2006.

metatarso-phalangeal pad impressions are preserved behind the digits II and III. The digital axis of digit II is subparallel to that of the digit III. The footprint length and width of YT5 are 188 mm and 100 mm, respectively (Table 2), and the ratio of footprint length to footprint width is 1.9. For further measurements, see Table 2.

II. Poorly preserved tridactyl and sauropod tracks

Seven poorly preserved tridactyl and fifteen sauropod tracks were observed on the same bedding surface of the theropod tracks (Figs. 4 and 6). A brief description with the best-preserved tracks are given below, because almost all the tracks are very poorly preserved.

Poorly preserved tridactyl tracks.—One trackway consists of the seven tracks of YO1, YO2, YO3, YO4, YO5, YO6, and YO7. The track YO1, which is the best preserved one among the seven tracks, has broad three digits with round ends (Fig. 9A). The length and width of the track YO1 are 37.4 cm and 28.6 cm respectively. The divarication angle between digits II and IV is 55°. Pace length along the trackway averages 108.5 cm and the stride 287.8 cm. The trackmaker of the tridactyl tracks might be ornithopod because of the broad three digits with round ends and the trackway is the zigzag arrangement of their tracks (Fig. 6). However, we can't deny the possibility that the trackmaker is theropod since the rear margins of the tracks are slightly narrow.

Sauropod tracks.—Five manus (YS2, YS3, YS5, YS6, and YS15) and ten pes prints (YS1, YS4, YS7, YS8, YS9, YS10, YS11, YS12, YS13, and YS14) were recognized (Figs. 4 and 6). Manus prints are crescent-shaped and have no claw impressions, all of which are positioned in front of the corresponding pes prints (Fig. 9C). The best-preserved manus print (YS6) has 36.7 cm in length and 16.7 cm in width (Fig. 9B). The pes prints are oval in outline with lack of claw marks. The best-preserved pes print (YS14) has 75.0 cm in length and 40.4 cm in width. Some pes prints are filled with overlying mudstone (Fig. 9C). The trackmaker of these footprints might be sauropod judging from their shape and the positional relationship between manus and pes prints.

DISCUSSION

Several dinosaur tracks, such as *Grallator limnosus* (Zhen et al., 1986), *Schizograllator xiaohebaensis* (Zhen et al., 1986), *Paracoelurosaurichnus monax* (Zhen et al., 1986), *Youngichnus xiyangensis* (Zhen et al., 1986), and *Lufengopus dongi* (Lü et al., 2006a), have been reported from the Lower and Middle Jurassic, and the Upper Cretaceous in Yunnan Province. These

ichnospecies are much larger than the theropod tracks of the Hemenkou site (Fig. 10). The theropod tracks YT1–3 plot most closely to the point of the Type B from the Upper Jurassic in Liaoning Province (Fujita et al., 2007) among the theropod tracks in China (Fig. 10). However, metatarso-phalangeal pad impressions are preserved behind the digit II of the tracks YT1-3, while they are not preserved on the Type B of the Upper Jurassic in Liaoning (Fig. 7). The average of the ratio of footprint length to footprint width of the tracks YT1–3 is 1.7, while that of Type B of Liaoning is 1.8. The average digital length II-III ratio of YT1–3 is 0.54, while that of Type B of Liaoning is 0.62. The shape and measurements of the theropod tracks YT4 and 5 are very similar to those of the theropod track Type C from the Upper Jurassic in Liaoning (Fujita et al., 2007) (Figs. 8 and 10). However, a metatarso-phalangeal pad impression preserved behind the digit II of the track YT5, while it is not preserved on the track of the Type C of the Upper Jurassic in Liaoning (Fig. 8). Ichnospecies *Anchisauripus tuberosus, A. parallelus, A. minusculus, Eubrontes giganteus, E. divericantus* from the Lower Jurassic in North America have a metatarso-phalangeal pad impression behind their digit II (Lull, 1953). Ichnogenus *Anchisauripus* has a hallux impression, but no impression of hallux is preserved on the tracks YT1–5. *Eubrontes giganteus* and *E. divericantus* are large sized tracks, which are more than 30 cm in length, but the footprint length of the tracks YT1–5 are less than 20 cm. As mentioned above, the known ichnites differ from the theropod tracks of the Hemenkou site in their size and morphological character. Therefore, it is reasonable to expect that the theropod tracks would be new ichnogenus. We will compare in detail the theropod tracks of the Hemenkou site with the known ichnites, and discuss about the ichnogenus.

Although the Lower and Middle Jurassic and the Upper Cretaceous yield dinosaur tracks in Yunnan Province (Zhen et al., 1986; Chen and Huang, 1993; Lockley et al., 2002; Lü et al., 2006a), dinosaur tracks have not been discovered from the Lower Cretaceous. Thus, the Hemenkou site is the first track site from the Lower Cretaceous in Yunnan Province. Tyrannosaurid teeth were discovered from the Lower Cretaceous in Yunnan Province (Ye, 1975), but not small theropod and sauropod body fossils yet. The tracks from the Hemenkou site indicate the existence of small theropod and sauropod dinosaurs in early Cretaceous in Yunnan Province. We expect that small theropod and sauropod skeletons would be found from the Lower Cretaceous in Yunnan Province in future.

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* : in Chinese

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