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EARLY CRETACEOUS TURTLE TRACKS AND SKELETONS FROM THE JUNGGAR BASIN, XINJIANG, CHINA

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ABSTRACT: **A high density of tracks resembling both the ichnogenera *Chelonipus* and *Emydhipus* occurs on surfaces of the Lower Cretaceous Tugulu Group at the Huangyangquan tracksite in Wuerhe district (Xinjiang Uyghur Autonomous Region, northwestern China). These ichnotaxa are especially known from Central Europe where they have been found in Triassic and Upper Jurassic–Lower Cretaceous deposits. Tracks are highly variable in morphology due to having been made while walking and swimming over soft substrates. Nevertheless they are diagnostic of turtle trackmakers and are readily distinguished from those of other aquatic vertebrates such as crocodilians and from those of pterosaurs. Abundant turtle body fossils occur in the region helping to provide strong support for this interpretation. The record enlarges our knowledge of turtles, their environment and distribution in the Early Cretaceous of China.**

INTRODUCTION

Relatively few turtle tracks have been reported from Mesozoic strata. In 1850, Schimper described a single tridactyl footprint from the Lower Triassic of the Vosges mountains (France) as *Chelonichnium vogesiacum*; it is the earliest report of a purported turtle track (Schimper, 1850). Other Mesozoic turtle tracks were described later, including *Chelonipus* and *Agostropus* from the Early–Middle Triassic (Rühle von Lilienstern 1939; Haubold 1971a, 1971b), *Anyropus* from the Early Jurassic (Hitchcock, 1858), *Emydichnium* and *Saltosauropus* from the Late Jurassic (Nopcsa 1923; Bernier et al. 1984; Gaillard et al. 2003), and *Chelonichnium* and *Emydhipus* from the Late Jurassic and Early Cretaceous, respectively (Bernier et al. 1982; Fuentes Vidarte et al. 2003). Haubold (1971a, 1971b) doubted a turtle origin of *Chelonichnium vogesiacum* and *Agostropus*. Generally, the ichnotaxonomy and interpretation of purported turtle tracks has been problematic (Moratalla et al. 1995) for a number of reasons, including confusion caused by major differences in the trackway configuration between tracks and trackways made by swimming and walking turtles and those made by small freshwater forms and large marine forms. Avanzini et al. (2005) considered only two turtle ichnogenera as valid: *Chelonipus* and *Emydhipus*. In that study, in order to simplify the complex ichnotaxonomy *Chelonichnium cerinense* was renamed as *Emydhipus cerinensis*.

Lockley et al. (2012) summarized three discoveries of turtle tracks in the Lower Cretaceous of China: (1) the Chabu tracksite in the Jingchuan Formation of Nei Mongol, (2) the Zhucheng tracksite in the Longwangzhuang Formation of Shandong Province, and (3) the Huangyangquan tracksite in the Tugulu Group of the Wuerhe district in the Xinjiang Uyghur Autonomous Region. Collectively, these represent the first reports of turtle tracks from the Mesozoic of China, but none of these discoveries have yet been described in any detail. Here we describe the turtle tracks from the Huangyangquan tracksite, in the Wuerhe district (Fig. 1).

Associated tracks in Wuerhe have been attributed to small non-avian theropods and birds. Bird footprints at the Huangyangquan tracksite include *Koreanaornis dodsoni*, *Goseongornipes* isp., *Aquatilavipes* isp., and *Moguiornipes robusta*; these shorebird-morph tracks have increased the known faunal diversity of the Lower Layer of the Tugulu Group. Non-avian dinosaur footprints at the same tracksite have been attributed to theropods tracks cf. *Jialingpus* isp., *Asianopodus* isp., and *Kayentapus* isp.; *Pteraichnus* isp. is the first pterosaur track in the Xinjiang area (Xing et al. 2011, 2013a; He et al. 2013), whereas *Deltapodus curriei* is the first record of stegosaurian tracks from the Early Cretaceous of China (Xing et al. 2013b). Numerous invertebrate traces are preserved as burrows referred to *Scoyenia* isp. All ichnofaunas are found on the same layer at the Huangyangquan tracksite in the Wuerhe district, providing evidence for the presence of a diverse animal community in a single ecosystem.

INSTITUTIONAL ABBREVIATION

MGCM = Moguicheng Dinosaur and Bizarre Stone Museum, Xinjiang, China

MATERIAL AND METHODS

All footprints were traced on transparency film at actual size, scaled down, and digitalized with a vector-based drawing software. Photographs

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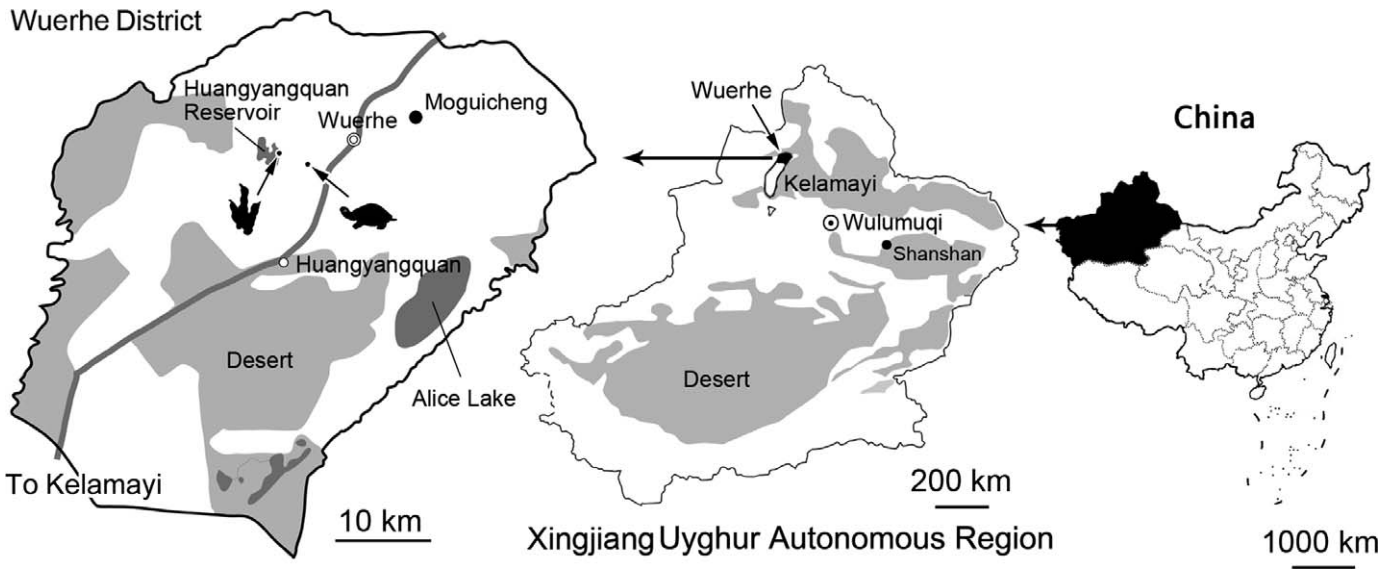

FIG. 1.—Location of the Huangyangquan track locality (indicated by the footprint icon) in Xinjiang, China.

were taken under natural light conditions. Measurements were made according to standard procedures in Haubold (1971a, 1971b).

GEOLOGICAL SETTING

The Huangyangquan tracksite is located in the Wuerhe district, approximately 110 km northeast of downtown Kelamayi City, Xinjiang Uygur Autonomous Region, China. The turtle tracks are preserved as natural casts on the underside of a light-gray fine-grained sandstone bed (~ 2 m in thickness) which is underlain by a 0.40-m-thick mudstone layer outcropping at the margin of the Huangyangquan Reservoir (46°4′26.65″N, 85°34′59.21″E, WGS 84). In most track-bearing sandstone a planar structure known as bedding is visible.

The Huangyangquan tracksite is in the Lower Layer of the Lower Cretaceous Tugulu Group (Fig. 2). Along the southern and eastern margins of the Junggar basin, the Tugulu Group can be divided, in ascending order, into the Qingshuihe, Hutubihe, Shengjinkou, and Lianmuqin formations. However, along the northwestern margin of the basin, including in the Wuerhe district, the Tugulu Group is difficult to divide into subunits. Presently, it can only be divided into Upper, Grey-green, and Lower layers, for which correlations with the four southern and eastern units are uncertain (Academy of Prospecting and Developing, Xinjiang Bureau of Petroleum 1977, 1996, 1997).

Rocks of the Tugulu Group around Urho consist of alternating beds of mudstone, shale, and fine sandstone of fluviolacustrine origin (Brinkman et al. 2001). This facies association corresponds to hot and seasonally arid climatic conditions with a preponderance of widespread floodplains and transient ponds (Eberth et al. 2001).

The Lower Layer of the Tugulu Group, which can be further subdivided into eight layers (Qi et al. 1995; Fig. 2), may correlate with the better-defined, stratigraphically low Qingshuihe and/or Hutubihe formations in the southern and eastern portions of the basin. Lower layer sediments, which are gray sandy mudstones and light green–gray sandstones, were deposited in deltaic and lakeshore to moderately-deep lake environments (Gu et al. 2003). The Huangyangquan tracksite has abundant vertebrate tracks including those of shorebirds, pterosaurs, and dinosaurs (theropods and stegosaurs) present alongside invertebrate traces associated with sedimentary structures of ripples and mudcracks, representing a lake shore environment under semiarid climate conditions (He et al. 2013).

SYSTEMATIC ICHNOLOGY

Material

40 complete natural casts on 15 slabs are cataloged as MGCM.G1–15 (Figs. 3, 4, Table 1). The specimens are housed in the Moguicheng Dinosaur and Bizarre Stone Museum.

Locality and Horizon

The Lower Layer of the Tugulu Group, Lower Cretaceous, Huangyangquan tracksite, Wuerhe District, Xinjiang, China

Description

These are tracks of a quadrupedal animal, consisting in some cases of distinct manus and pes impressions. All of the tracks exhibit tridactyl to pentadactyl footprints, with digit traces facing anteriorly and showing little interdigital divarication. The digit traces are mostly elongated into scratch marks and furrows that can be interpreted as claw impressions. Variable digit trace lengths are discussed below. All digits are connected by a posterior arched structure slightly less impressed into the substrate than the claw impressions. Unfortunately, the tracks lack an arrangement in a distinct trackway; only a few of them display identifiable paired pedal and manual impressions.

MGCM.G1 is well preserved; it includes one manus–pes set (RM2 and RP2) and three isolated manus impressions. The manus print RM2 is apparently digitigrade and shows three distinct claw marks, probably representing digits I–III. A small, short digit IV is probably present, but indistinctly preserved. Digits I–III are anteriorly oriented and nearly parallel; their lengths are 1.0, 1.5, and 1.1 cm, respectively. In the manual print, digit I and digit III are almost of the same length, whereas digit II is the longest one. The pes print RP2 is significantly smaller than the corresponding manus print, and is located anteromedially relative to the manus print. The manus print is digitigrade and has three claw marks. Digit ?III is the longest and is slightly curved, while the lateral digits ?II and ?IV are more or less straight and equal in length. Because all five tracks are oriented toward the midline, they are probably part of a single trackway. The pace angle between RM2, LM2, and ?RM3 is 40°. All the tracks on this slab lack elongated claw marks, suggesting a terrestrial walking turtle track.

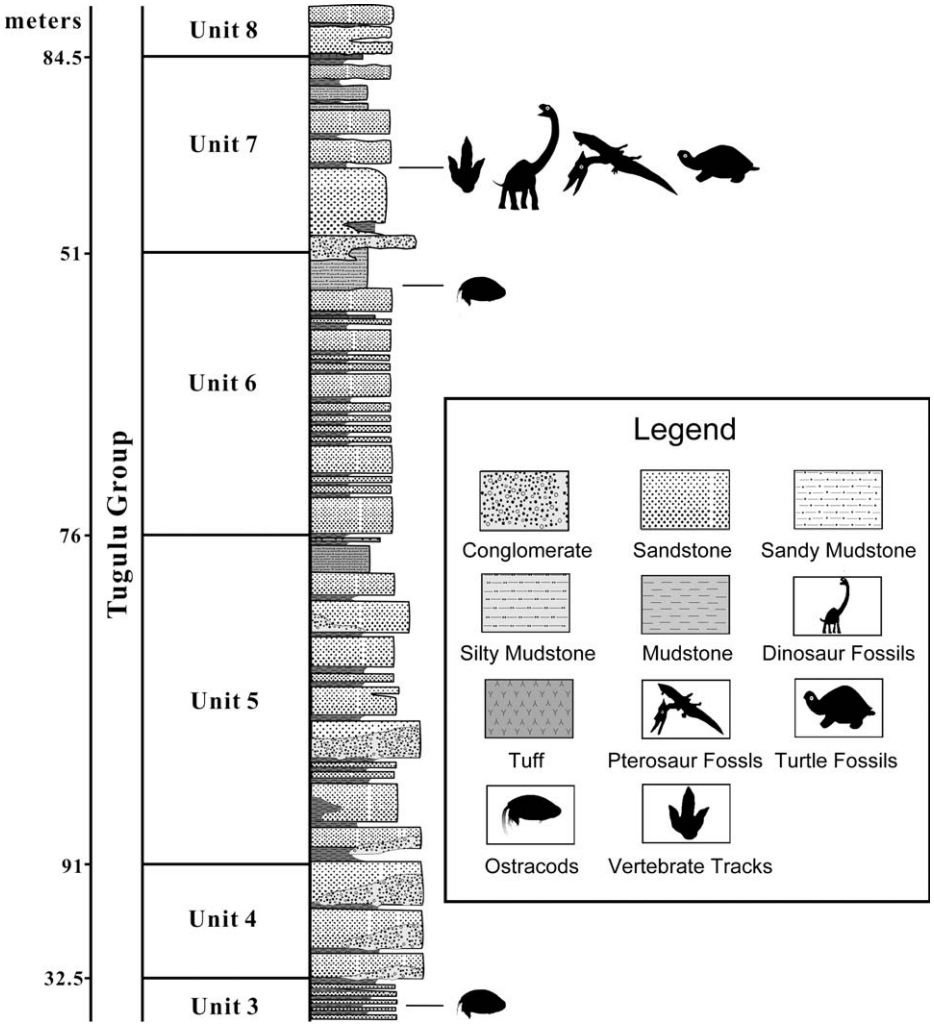

FIG. 2.—Stratigraphic section of the Lower Layer of the Tugulu Group at the Huangyangquan track locality (emended from Qi et al. 1995).

TABLE 1.—*Measurements (in cm) of the turtle tracks from the Huangyangquan tracksite. Abbreviations: ML: maximum length; MW: maximum width; L/W: Maximum length/ Maximum width. For the specimen number: R= right, L=left, I= isolation, M= manus, P= pes.*

Number. MGCM.	ML	MW	L/W	Number. MGCM.	ML	MW	L/W
G1.RM1	1.5	2.2	0.7	G10.IP1	1.2	2.1	0.6
G1.RM2	1.5	2.3	0.7	G10.IP2	1.3	2.1	0.6
G1.RP2	0.9	1.8	0.5	G11.IM1	5.1	2.4	2.2
G1.LM2	2.5	2.1	1.2	G12.IM1	5.3	3.0	1.8
G2.RM1	5.6	3.0	1.9	G12.IM2	2.2	3.3	0.7
G2.RP1	1.2	2.2	0.6	G12.IM3	1.3	3.6	0.4
G2.IP1	0.8	1.9	0.4	G12.IM4	10.8	2.8	3.9
G3.RM1	18.9	2.6	7.3	G12.IM5	1.6	3.1	0.5
G3.RP1	0.9	1.7	0.6	G13.IM1	3.2	2.0	1.6
G4.LM1	8.9	2.9	3.0	G13.IM2	2.4	2.5	1.0
G4.LP1	1.3	1.2	1.1	G13.IM3	1.4	2.5	0.6
G5.IM1	4.4	3.2	1.4	G14.IM1	3.2	1.9	1.7
G5.IM2	6.4	3.0	2.1	G14.IP1	1.4	2.0	0.7
G5.IM3	2.8	2.6	1.1	G14.IM2	6.2	2.4	2.6
G6.IM1	6.3	2.7	2.3	G14.IP2	1.2	2.2	0.6
G6.IM2	6.2	1.4	4.4	G14.IM3	1.9	1.9	1.0
G7.IM1	9.0	2.0	4.5	G15.IM1	3.3	3.4	1.0
G8.IM1	11.2	1.7	6.7	G15.IM2	8.2	3.1	2.7
G9.RM1	7.6	3.9	1.9	G15.IM3	3.7	1.4	2.6
G10.IM1	4.6	2.1	2.2	G15.IM4	1.7	2.2	0.8

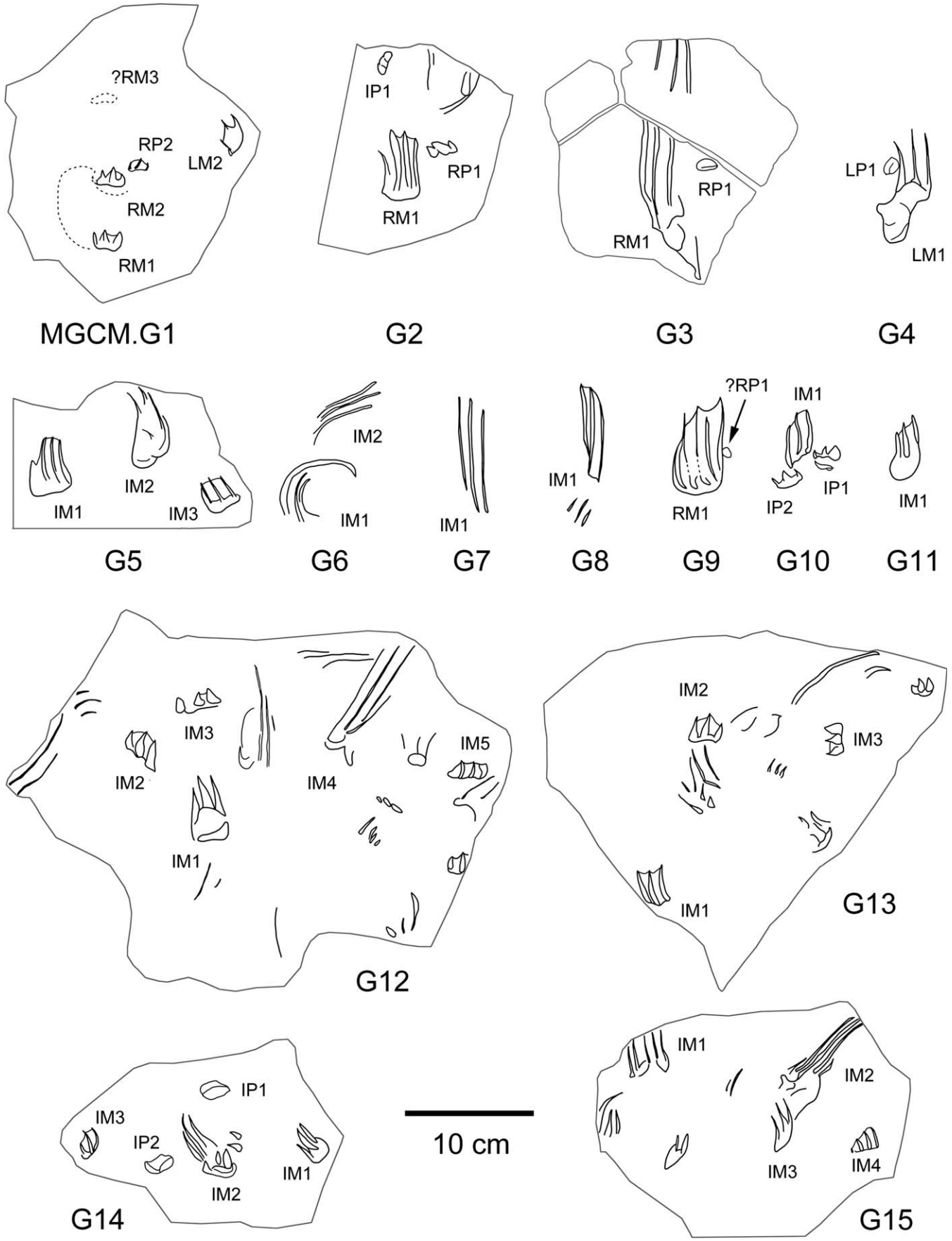

FIG. 3.—Turtle tracks from Huangyangquan tracksite, Xinjiang, China.

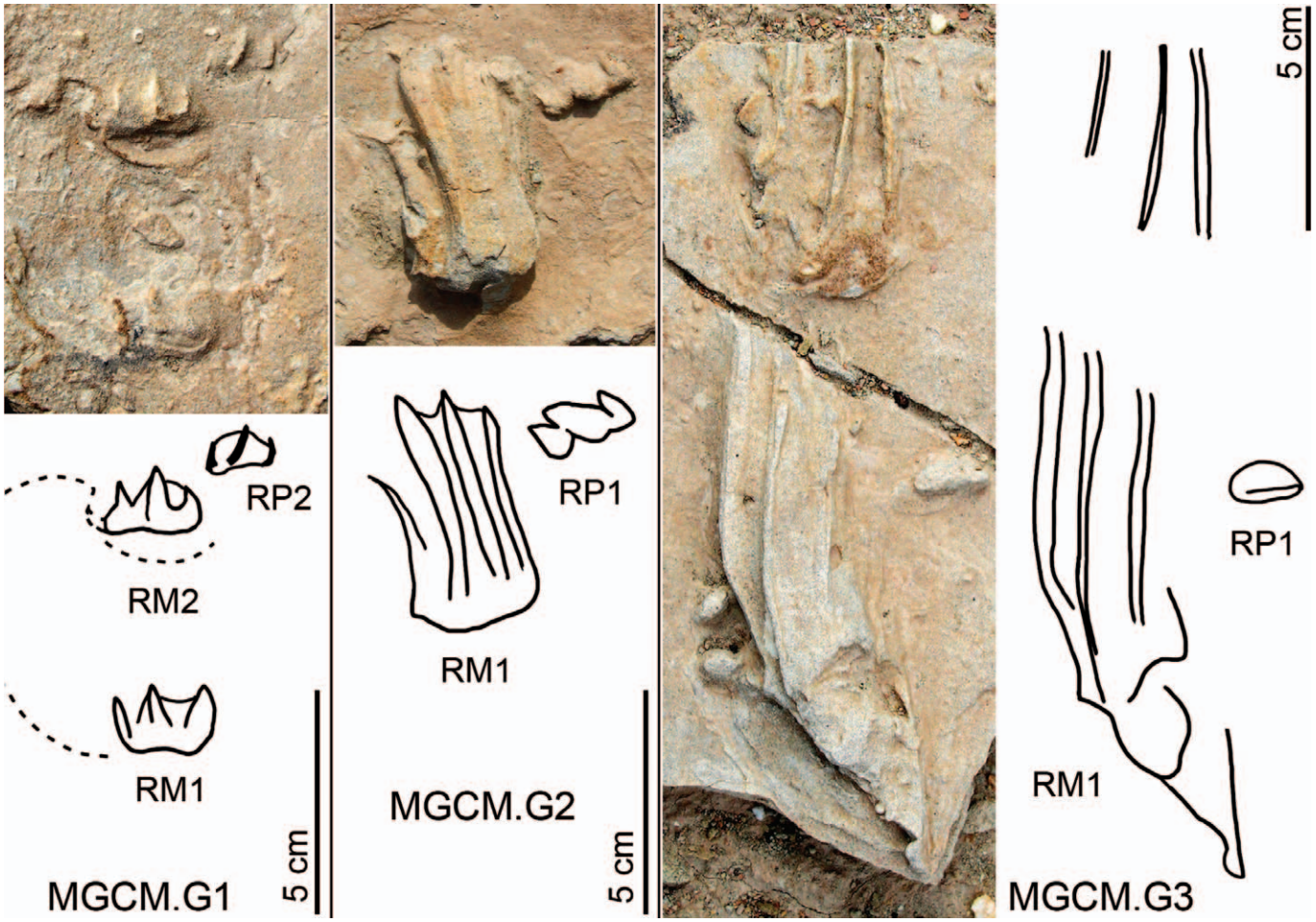

FIG. 4.—Photograph and outline drawing of well-preserved Turtle tracks MGCM. G1–G3 from Huangyangquan tracksite, Xinjiang, China.

MGCM.G12.IM3 and G13.IM3 are similar to G1. Most of the best-preserved tracks are represented by the MGCM.G2.RM1 and RP1 sets. The tracks are typically digitigrade, or semiplantigrade (especially G4.LM1) and have elongated ungual marks.

The manus print MGCM.G2.RM1 has four ungual marks; they are roughly parallel and face anteriorly. The middle ungual marks (digits II and III, 4.5 cm and 4.8 cm long, respectively) are longer than the lateral two (digits I and IV, 3.8 cm and 3.3 cm, respectively). The pes print RP1 has three shorter and more robust ungual marks; the middle digit, possibly digit III, is longest. The pes print is located anteromedially relative to the corresponding manus print.

In some instances, the claw impressions of digits extend into 3–5 parallel scratch marks that extend anteriorly up to several times the length of the footprint, for instance in MGCM.G3. This track represents a manus–pes set. The corresponding manus print RM1 has three thin scratch marks with irregular proximal impressions lacking the distal portion. The longest scratch mark is 14.8 cm long. The pes print RP1 is significantly smaller than the manus print, and is located medially relative to the manus print.

Most manus prints have three scratch marks, probably left by digits II–IV. In some well-preserved manus prints, such as G9.RM1, G15.IM1, and IM2, five distinct ungual marks were observed. G9.RM1 is wider than the other manus tracks, probably representing later ontogenetic stages.

DISCUSSION

The Huangyangquan turtle tracks probably represent both walking and swimming tracks. MGCM.G1.RM1 and RP1 and MGCM.G12.IM3 correspond to walking tracks, while the long parallel scratches of most tracks are interpreted as evidence of a partially to fully buoyant trackmaker that swam along the bottom of a water-filled channel (Milner et al. 2006; Mickelson et al. 2006; Lovelace and Lovelace 2012).

According to Avanzini et al. (2005), among the current ichnotaxa attributed to turtles, there are only two valid ichnogenera: *Chelonipus* (Triassic) and *Emydhipus* (Late Jurassic–Early Cretaceous). *Chelonichnium* is a *nomen dubium* and turtle footprints described as *C. cerinense* from the Late Jurassic (Demathieu and Gaillard in Bernier et al. 1982) were referred to the new combination *Emydhipus cerinensis* (Avanzini et al. 2005).

Chelonipus has been described from strata dating from the Early Triassic, the Late Triassic, and the Late Jurassic (Plieninger 1838; Meyer and Plieninger 1844; Rühle von Lilienstern 1939; Lockley and Foster 2006; Lovelace and Lovelace 2012). Haubold (1971b) diagnosed the ichnogenus *Chelonipus* as a digitigrade or semiplantigrade pes with three or four digits bearing thin claws, and a manus with four well defined digits that are shorter than those of the foot and connected by a fleshy, arched structure. Haubold (1971a) considered the original interpretation by Rühle von Lilienstern (1939) and identification of the pes imprint anterior to the manus imprint as incorrect, instead suggesting a reverse

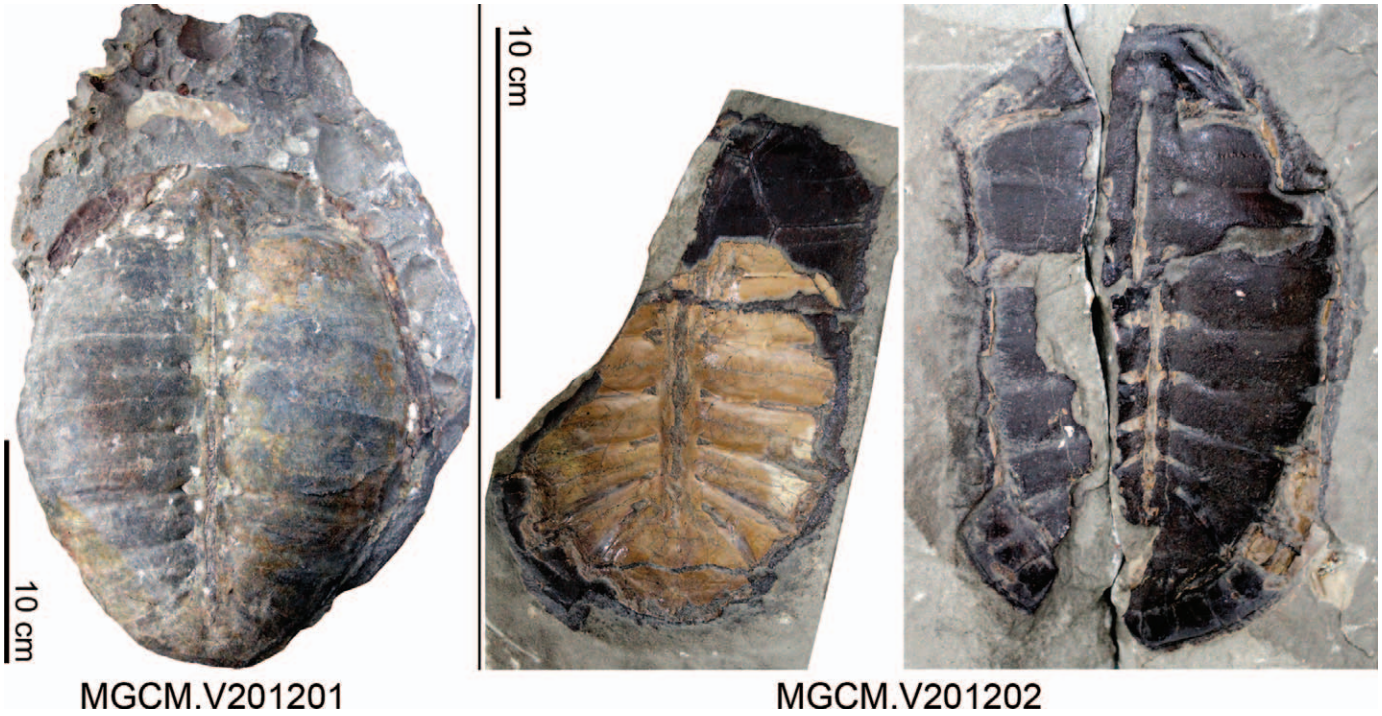

FIG. 5.—Photograph of Turtle specimens MGCM.V201201 and 201202 from Wuerhe district, Xinjiang, China.

relationship. Contrarily, Avanzini et al. (2005) supported the view of Rühle von Lilienstern (1939) based on experimental work with extant turtles.

Emydhipus is known from the Late Jurassic and Early Cretaceous (Fuentes Vidarte et al. 2003; Avanzini et al. 2005). This ichnogenus is characterized by a manual print with four elongated claw marks parallel to each other and to the midline of the trackway. The pedal print is plantigrade with four clawed digits and a short, rounded sole. Both manual and pedal prints lack rotation with respect to the trackway midline (Fuentes Vidarte et al. 2003; Avanzini et al. 2005). Avanzini et al. (2005) suggested that *Emydhipus* differs from *Chelonipus* by showing manual prints with evident and parallel ungual traces, slightly internal and apparently always away with respect to the pedal tracks, whereas in the latter the manus imprint is positioned external and posterior to the pedal tracks.

The Huanyangquan tracks are similar to *Chelonipus* in having parallel digits of comparable lengths in the manus prints, slight interdigital divarications in the pes prints, and digit traces from both manus and pes prints connected by a slightly arched structure. On the other hand the elongated scratch marks on the manus prints are very similar to those typical of *Emydipus*. Thus, it is possible to infer that the differences between *Chelonipus* and *Emydipus* are at least partially due to differences in the behavioral movement of the foot and limb of the trackmakers (see Avanzini et al. 2005). Thus tracks resembling both ichnogenera can be recognized.

Recent studies of the mid Cretaceous Dakota Group in the western United States have demonstrated the presence of turtle swim tracks found in some cases in close association with crocodilian and pterosaur swim tracks (Lockley et al. 2010, in press). These co-occurrences have raised the question of how easy it is to differentiate tetrapod swim tracks. As noted by Lockley et al. (in press), size, number of digits, length of digits, and presence or absence of web traces help to distinguish the tracks of these three groups, especially when tracks are relatively completely impressed. However, swim tracks are inherently variable and often incomplete making their identification problematic. However, as noted below, paleoenvironmental evidence, as well as other local body fossil evidence, may help make track identification easier.

Given these factors, the Huangyangquan turtle tracks could be provisionally assigned to the ichnogenus *Emydipus*, rather than *Chelonipus*. In any event, the incomplete preservation of manus–pes couples and the lack of a trackway make it impossible to give a definitive ichnotaxonomic assignment and we prefer to attempt a correlation with the turtle body fossils recovered in the same stratigraphic horizons.

TURTLE BODY FOSSILS

Turtle Body Fossils from Tugulu Group

The Tugulu Group has yielded numerous turtle body fossils. Matzke et al. (2004) recognized five turtle taxa from the Tugulu Group. Danilov and Sukhanov (2006) and Danilov and Parham (2007) revised the faunal list by adding two further taxa. In total, five species in four genera and one indeterminate taxon of turtles are known from the Tugulu Group: (1) *Dracochelys bicuspis* from the Lianmugin Formation (Gaffney and Ye 1992); (2) *Ordosemys brinkmania* from the Lianmugin Formation (Danilov and Parham 2007); (3) *Xinjiangchelys* sp. from the Lianmugin Formation (Danilov and Parham 2007); (4) *Wuguia hutubeiensis* from the Hutubei Formation (Matzke et al. 2004); (5) *Wuguia efremovi* comb. nov. (= *Dracochelys wimani*) from the Huatubei and Lianmugin formations (Danilov and Sukhanov 2006); (6) cf. *Pantryonichia* indet. from the Lianmugin Formation (Danilov and Parham 2007). This assemblage represents one of the most diverse Early Cretaceous turtle faunas from Asia (Danilov and Sukhanov 2006).

Turtle Body Fossils from Wuerhe District and Possible Trackmakers

Early Cretaceous turtle fossils are widely distributed in the Wuerhe district. In 2012, the senior author observed two turtle specimens at the Moguicheng Dinosaur and Bizarre Stone Museum, corresponding to specimens MGCM.V201201 and V201202 (Fig. 5). These specimens are

from the formation with the turtle tracks. The fossil site is situated about 5 kilometers east of the tracksite.

MGCM.V201201 (carapace length: 222 mm; carapace maximum width: 186 mm) consists of four left anterolateral peripherals and the impression of the ventral side of the carapace. The carapace is anteroposteriorly longer than transversely wide by 18% across its maximal width. The single, midline cervical scute is transversely wider than anteroposteriorly long. The nuchal plate has a weakly concave anterior margin. The lateral edges of the anterolateral peripherals are weakly upturned dorsally, resulting in a gutter along the anterolateral edge of the carapace. The impression of the ventral side shows a single preneural, nuchal, eight neurals, eight corresponding pleurals, and at least one suprapygal. There is no fontanelle in the carapace. The specimen corresponds to *Xinjiangchelys* sp. *Xinjiangchelys* is a genus previously known to occur in the Tugulu Group (Danilov and Parham 2007), and all morphological characters of the specimen are consistent with this assignment. In particular, the transversely wide cervical scute and the upturned lateral edge of the anterolateral peripherals are diagnostic of this genus (Matzke et al. 2004, 2005; Brinkman et al. 2008; Brinkman et al. 2012).

The smaller specimen, MGCM.V201202, is preserved in two slabs. The carapace is without fontanelle and approximately 1.5 times longer anteroposteriorly than wide transversely (carapace length: 140 mm; estimated maximum carapace width: 94 mm). The nuchal emargination is not preserved. Eight neurals and eight corresponding pleurals are present, whereas a preneural is absent. The nuchal plate is fused to the peripherals on both sides. These characters are all consistent with the referral of this specimen to *Wuguia* sp., possibly *Wuguia hutubeiensis*, which occurs in the Hutubei Formation of the Tugulu Group (Matzke et al. 2004; Danilov and Sukhanov 2006; Brinkman et al. 2008). This species is diagnosed partly based on the lack of a fontanelle in the carapace and the nuchal plate being fused to the peripherals.

The close proximity of turtle body fossils and ichnofossils in the same area and stratigraphic unit prompts speculations about the makers of the Huangyangquan tracks that could have been *Xinjiangchelys* sp. and/or *Wuguia* sp. However, there is no xinjiangchelyd specimen with well-preserved autopodia to test the correlation with precision. This even precludes a morphometric test about whether or not the turtle body fossils fall in the size range expected from dimensions of the footprints. All the turtle footprints from the Huangyangquan site are wider than 20 mm. *Wuguia* is a relatively small turtle that does not exceed the carapace length of 150 mm, whereas *Xinjiangchelys* may attain more than twice that size (Brinkman et al. 2008). Even though the manual and pedal morphology varies between clades of turtles, a hand or foot wider transversely at the wrist or ankle joint than one fifth of the carapace length is difficult to conceive for any terrestrial or semiaquatic turtle. Therefore, *Wuguia* is probably not responsible for the largest of the prints that exceeds 4 cm in width (e.g., MGCM.G9, Fig. 3).

CONCLUSIONS

Turtle tracks from the Lower Tugulu Group (Lower Cretaceous) of Wuerhe, Xinjiang show similarities with both the ichnogenera *Chelonipus* and *Emydhipus* well known from Triassic–Cretaceous deposits of Central Europe. A characteristic feature is the elongation of digit traces into scratchmarks in some imprints, indicating the presence of swim tracks of buoyant animals touching the bottom of water bodies. However, the incomplete preservation of the trackways prevents a concrete assignment. The record enlarges our knowledge of turtles in the Tugulu Group and in Xinjiang from where a rich fauna with turtle body fossils is also known. The proximity of ichno and body fossils in the same unit suggests a relationship of footprints and osteological taxa, however, no well-preserved autopodia are known thus far to prove this.

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