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SHORT COMMUNICATION

A preliminary report on dinosaur track assemblages from the Middle Jurassic of the Imilchil area, Morocco

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Dinosaur tracks are reported from three new localities near Imilchil, in the Central High Atlas of Morocco. New dinosaur track assemblages are recognized in Bathonian and Bajocian beds. The Bathonian track assemblage comprises theropod, sauropod and ornithopod footprints. The Bajocian deposits contain a sauropod-thyreophoran track assemblage.

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INTRODUCTION

The sites reported are located to the west of Imilchil, in the Central High Atlas of Morocco (Fig. 1). The first dinosaur tracksite (site A) near Imilchil was discovered by one of us (PM), in October 2008. In April 2009, a join expedition of the JuraPark Explorer Team and the Polish Geological Institute-National Research Institute found two more sites in that area. The sites are located along the road from Imilchil to Tabanast. Over a few days, we collected as much data as was possible, including casts of the ichnites discovered. Resin replicas of those specimens have been stored in the JuraPark collection in Bałtów, Poland, where they are available for the future study.

The Tethyan Atlas system comprises two distinct branches — the High and Middle Atlas — which were tectonically active areas during Early Jurassic times. The High Atlas in central Morocco rises in the west at the Atlantic coast and stretches eastwards to the Moroccan-Algerian border (Michard *et al*., 2008). The High Atlas Trough was formed during the early rifting of Africa and North America (Evans *et al*., 1974). Sedimentological evidence indicates that subsidence of the trough was not accompanied by intense crustal deformation. A continental rift opened in the Late Triassic, accumulating redbeds, evaporites and basalts. Marine carbonate sedimentation commenced in Hettangian–Sinemurian (earliest Jurassic) and continued until the Middle Jurassic, when the basin ceased to subside and became once more continental (Evans *et al*., 1974). The stratigraphy of the Atlas redbeds is based on vertebrate, ostracod and charophyte fossils. The numerous tectonic features associated with the Jurassic sedimentary rocks of this area probably developed at a later, post-Jurassic stage. Post-Jurassic uplift and tectonic inversion created the superb exposures of the modern Central and Eastern High Atlas (Warme, 1988).

DESCRIPTIONS OF TRACKSITES

SITE A

The site is located at the northern side of road 1903, near the village of Ait Ali Ou Ikkou. According to Fadile (2003), the exposed dolomites are Bajocian in age. The main track-bearing surface, located at the GPS coordinates N 32°09.088’ and W 005°34,742’, comprises medium-sized theropod footprints and a two-step sauropod trackway (Fig. 2). The tracks are preserved

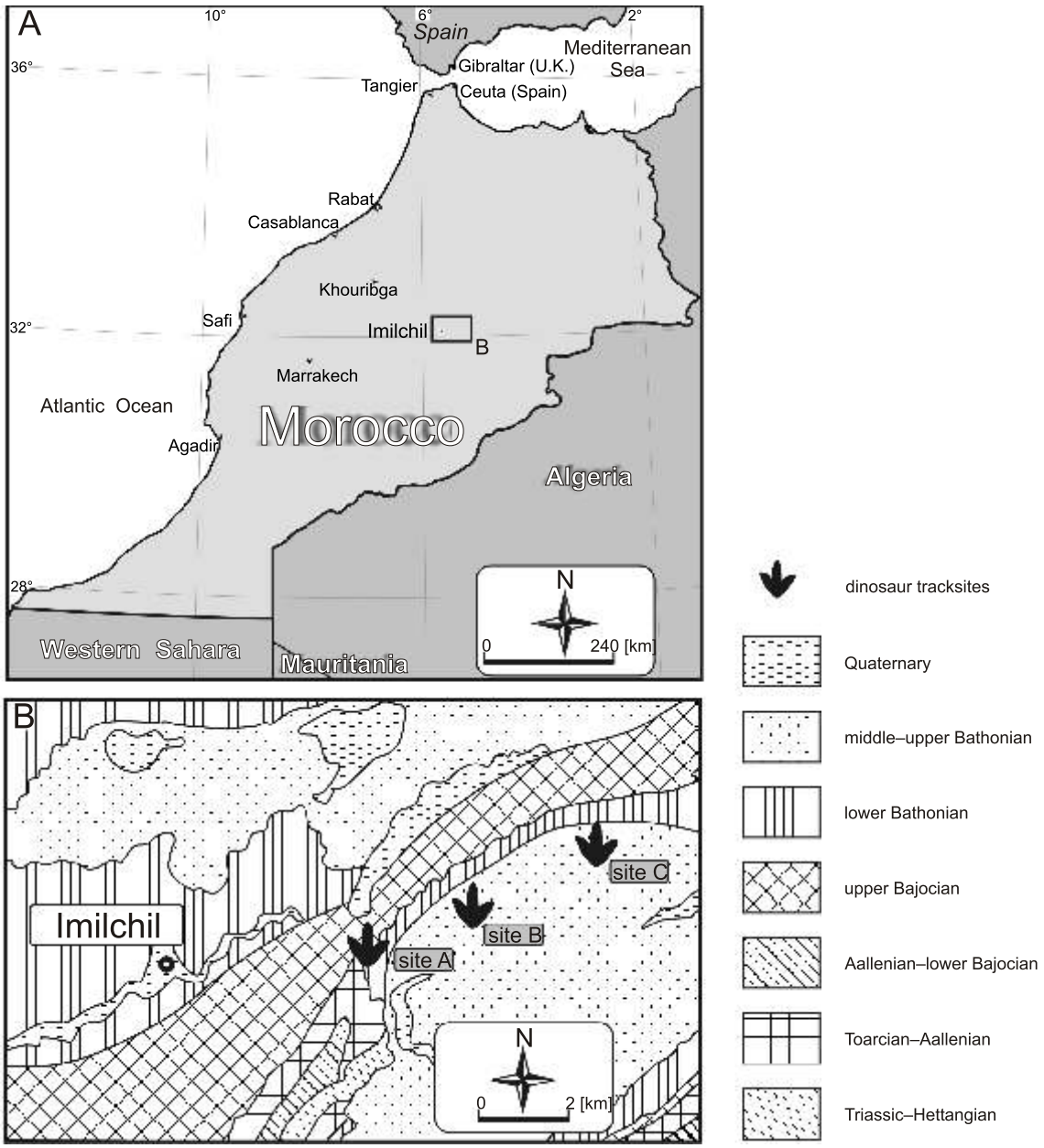

Fig. 1. Location of the new dinosaur tracksites in the Central High Atlas of Morocco

A — map of Morocco; **B** — geological map of the Imilchil area, after Fadile (2003)

as natural moulds on the layer, which dips to the south-east at an average of 60°.

The theropod footprints (Fig. 2B) are randomly oriented and look like diminutive versions of *Megalosauripus sensu* Lockley *et al*. (1996, 1998*b*). Their size (pes length 36 cm) fits the size range of *Therangospodus* Lockley *et al*., 1998*a*. However, they differ from *Therangospodus* by a more projected third toe and defined phalangeal pads. *Changpeipus* Young, 1960, seems to be the best match for those footprints. *Changpeipus* was originally described by Young (1960) from the Middle Jurassic of China, but recently was also reported from the Lower Jurassic of China (Xing *et al*., 2009).

There is also a narrow-gauge sauropod trackway directed eastwards (Fig. 2A). The pedal print length is 40 cm and its width is 29 cm, while the manual print is 11 cm long and 24 cm wide. Following the sauropod track designation concept of Lockley, Farlow et Meyer (1994), our specimen corresponds with the narrow-gauge trackway morphotype named *Parabrontopodus* Lockley, Farlow et Meyer, 1994.

Above the main surface, there are another track-bearing horizons. The upper part of the site revealed a few theropod footprints and one ornithopod ichnite (Fig. 3). The smallest theropod footprint (cast JuraPark J386) is only 2 cm long (Fig. 3A) and was found at GPS coordinates N 32°09.120', W 005°34.752'. This footprint resembles the diminutive ichnites *Wildeichnus*

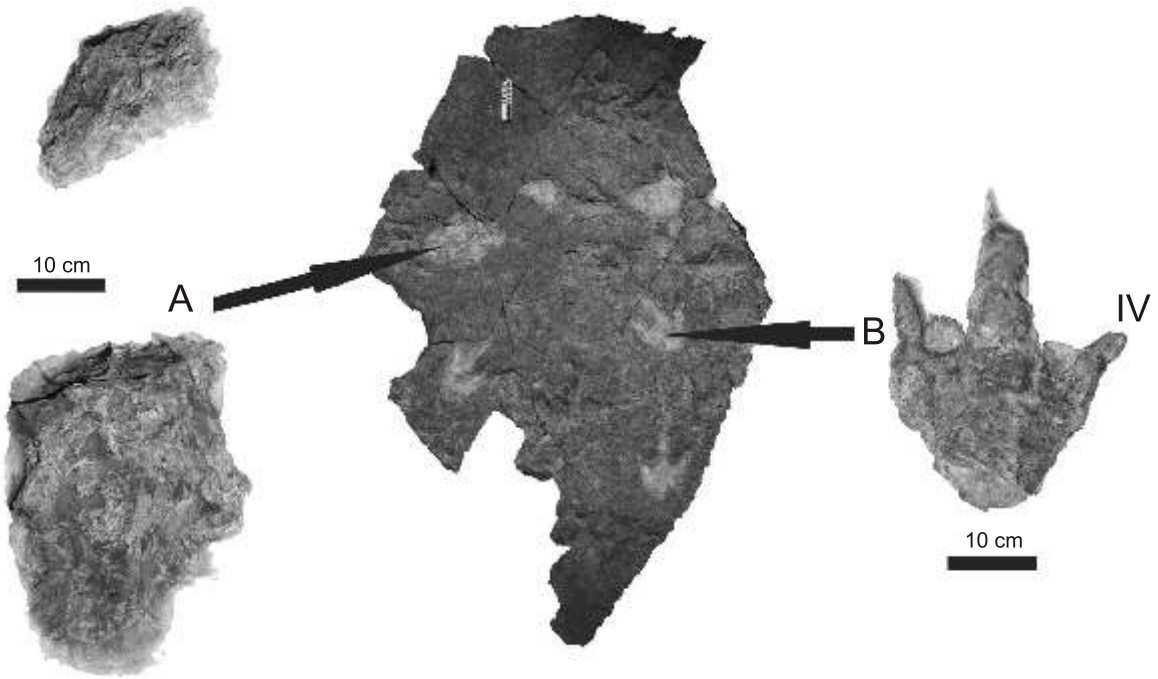

Fig. 2. The main track-bearing surface at site "A", Bajocian of the Imilchil area, Morocco

A — *Parabrontopodus* sp. (specimen cast: JuraPark J523); **B** — *Changpeipus* sp. (specimen cast: JuraPark J383)

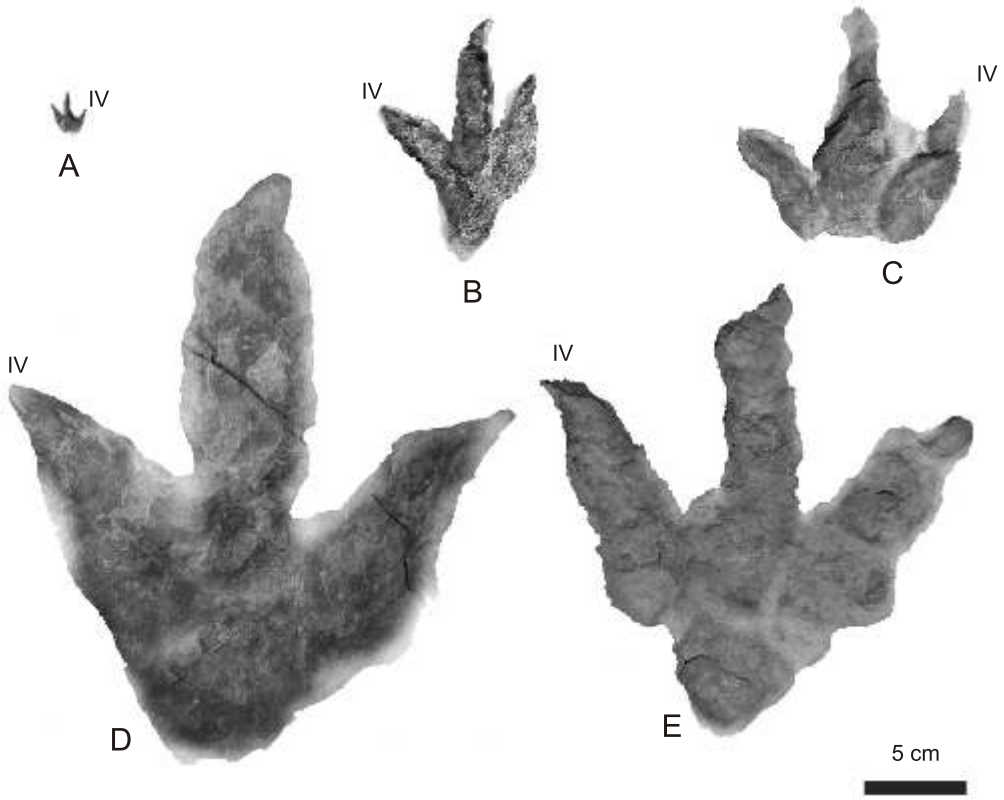

Fig. 3. Isolated footprints found above the main surface at site "A", Bajocian of the Imilchil area, Morocco

A — *Wildeichnus* sp. (specimen cast: JuraPark J386); **B** — *Jialingpus* sp. (specimen cast: JuraPark J387);
C — *Carmelopodus* (specimen cast: JuraPark J385); **D** — *Therangospodus* sp.;
E — cf. *Dinehichnus* sp. (specimen cast: JuraPark J384)

Casamiquela, 1964, known from the Middle Jurassic of Argentina and Utah, USA (Leonardi, 1994; Lockley *et al*., 2007), and the Upper Jurassic of Poland (Gierliński *et al*., 2009).

The other small theropod track (cast JuraPark J387) was found at GPS coordinates: N 32°09.124', W 005°34.748'. The footprint is 12 cm long and characterized by the large elongate metatarsophalangeal pad of digit IV which markedly extends posteriorly from the proximal (metatarsophalangeal) area of the footprint (see, Fig. 3B). It corresponds with the ichnogenus *Jialingpus* Zhen, Li et Zhen, 1983, described from the Upper Jurassic of China and Poland (e.g., Zhen *et al*., 1989; Gierliński *et al*., 2009).

A natural cast of a small theropod footprint (12 cm long), was found on an isolated slab, at GPS coordinates N 32°09.114' and W 005°34.750'. This is the only specimen (cast JuraPark J385) described in this paper that is preserved as convex hyporelief. The pedal digits clearly lack their proximal pads (Fig. 3C). Similar footprints from the Middle Jurassic of North America were labeled as *Carmelopodus* Lockley *et al*., 1998. The possible presence of *Carmelopodus* in the Middle Jurassic of Morocco has been previously suggested by Meyer and Monbaron (2002). Several *Carmelopodus* tracks were also found more recently, in the Bathonian beds close to Imilchil.

A medium-sized (29 cm long) theropod track (Fig. 3D) with coalesced phalangeal pads was found at GPS coordinates N 32°09.131' and W 005°34.747'. Its morphology strongly resembles that of *Therangospodus*, an ichnogenus known from the Middle Jurassic of North America, the Upper Jurassic and Lower Cretaceous of Europe, and the Upper Jurassic of Central Asia (Lockley *et al*., 1998*a*; Gierliński, 2009).

The most intriguing specimen in the reported assemblage is a well-preserved footprint (cast JuraPark J384; Fig. 3E) discovered at coordinates N 32°09.122' and W 005°34.753'. In contrast to above-mentioned theropod ichnites, this is a tridactyl track with the middle toe highly projected and being the longest digit, the digits other being relatively shorter and subequal in length and arranged in the ornithischian track fashion. The similar footprint (except for the hallux presence) has been described from the Upper Jurassic of Poland as a supposed camptosaurid track (Gierliński *et al*., 2001, 2009). The footprint is nearly as long as wide (22 cm long and 23 cm width), with cigar-shaped, highly and equally divericated digits, and the discrete, oval proximal pad located almost centrally below the middle toe. Its morphology resembles the ichnogenus *Dinehichnus* Lockley, Santos, Meyer and Hunt, 1998, originally described from the Upper Jurassic of North America and later reported also from the Upper Jurassic of Europe (Gierliński, 2009; Gierliński *et al*., 2009).

SITE B

Site B is the top of a layer, dipping some 30° to the south, trampled by sauropods. Several sauropod trackways directed to the east have been distinguished. The site is located at the northern side of road 3425, at GPS coordinates: N 32°09.739' and W 005°32.724'. Many trackways are shallowly impressed, but some are deep and well preserved, such as the one illustrated on Figure 4. The trackways clearly show a narrow-gauge *Parabrontopodus* pattern. The tracks are much larger than the

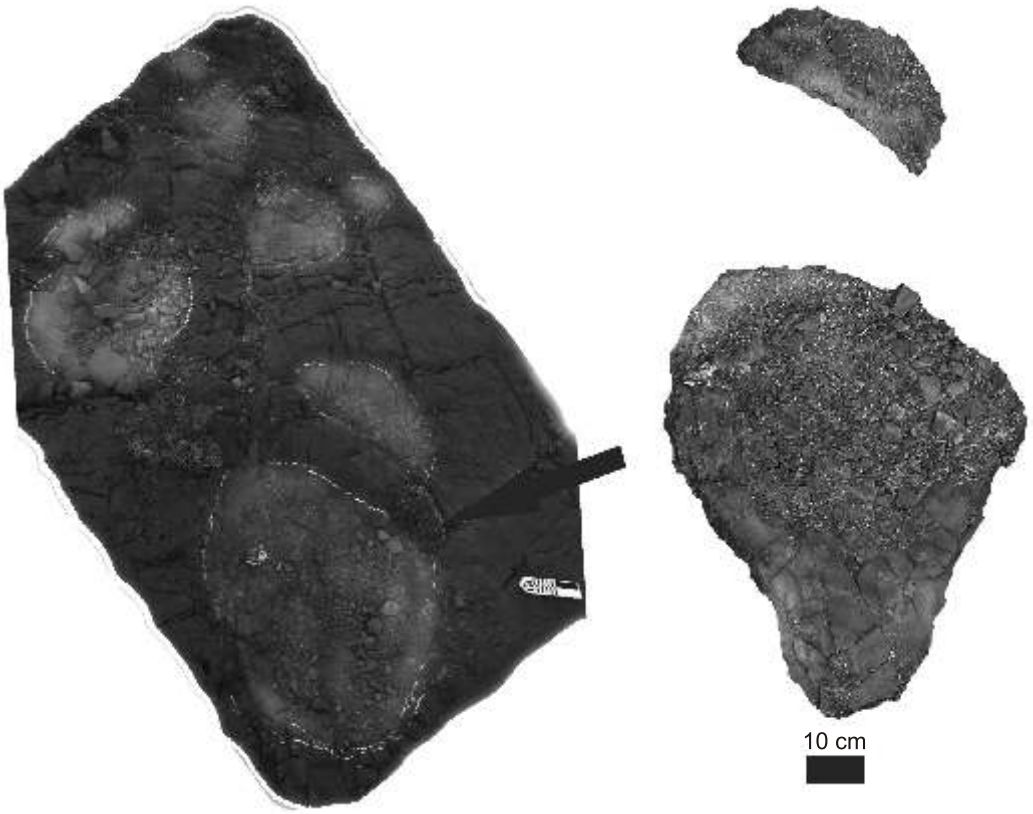

Fig. 4. ***Parabrontopodus*** **sp. (no casts made) from site "B" Bathonian of the Imilchil area, Morocco**

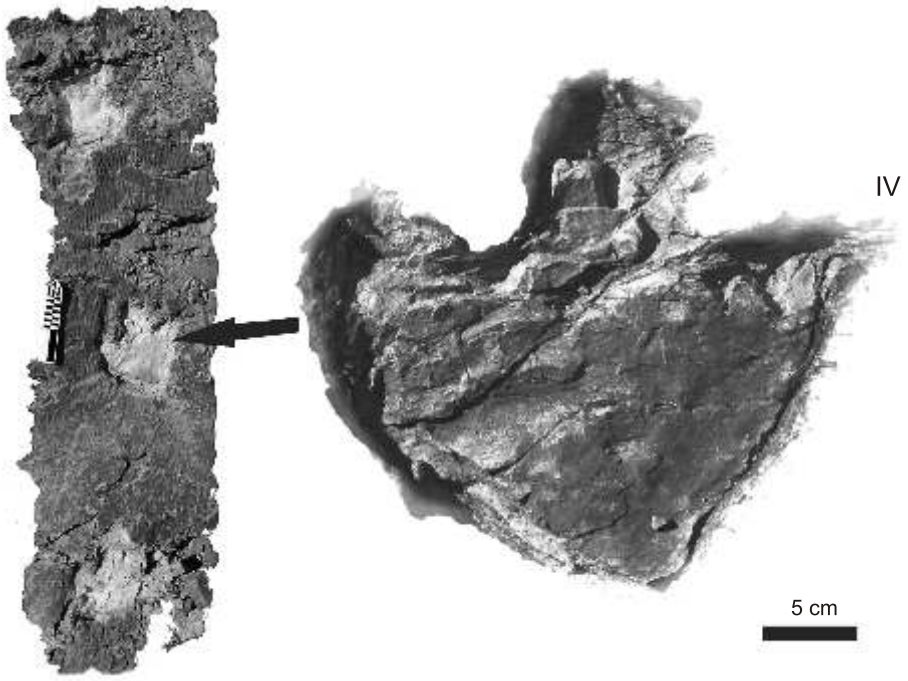

Fig. 5. cf. *Stegopodus* sp. (specimen cast: JuraPark J388) from site "C", Bathonian of the Imilchil area, Morocco

Bajocian sauropod tracks described at site A. The pedal prints are approximately 80 cm long and 60 cm wide, while the manual prints are 20 cm long and 40 cm wide. According to Fadile (2003), the exposed strata are Bathonian in age.

SITE C

This is another Bathonian outcrop (GPS coordinates: N 32°10.387', W 005°29.956') located at the northern side of road 3425, close to the village of Tabanast. The site comprises an ornithischian bipedal trackway directed northwards (Fig. 5) preserved on a surface dipping at *ca*.10° to the south. The footprint (cast JuraPark J388) is relatively large, slightly wider than long (27 cm long and 29 cm wide), tridactyl and blunt-toed. Digits are very short, broad, widely divaricated and barely project beyond the hypex. Pes is asymmetrical, with the proximal pad located posterolaterally. All these distinctive features fit the diagnostic traits of *Stegopodus sensu* Gierliński and Sabath (2008).

CONCLUSIONS

The ichnofauna briefly reported herein, with *Changpeipus* sp., *Wildeichnus* sp., *Carmelopodus* and *Therangospodus* sp., supports the Middle Jurassic age of these dinosaur track assemblages. Moreover, the range of distinctive ichnites of *Carmelopodus* seems to be indicative of a Bajocian–Bathonian age worldwide (Lockley *et al*., 1998; Lockley and Meyer, 2000; Adams and Breithaupt, 2003; Gierliński and Nowacki, 2008). This ichnogenus is known from the Carmel Formation (Bajocian–Bathonian) of Utah, the Sundance Formation (Bathonian) of Wyoming, the Forest Marble (Bathonian) of England and the Kościelisko Beds (Bajocian) of Poland (the Polish specimen is stored in the JuraPark collection as J483).

In contrast to *Changpeipus* sp., *Wildeichnus* sp., *Carmelopodus* and *Therangospodus* sp., the medium ornithopod ichnite cf. *Dinehichnus* sp., the small theropod footprint *Jialingpus* sp. and the stegosaurian track cf. *Stegopodus* sp. have hitherto been recorded in Late Jurassic deposits only. It is also noteworthy that *Wildeichnus* sp., *Jialingpus* sp., *Therangospodus* sp., *Changpeipus* sp., cf. *Dinehichnus* sp. and cf. *Stegopodus* sp. are recognized for the first time in the Jurassic strata of Africa.

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