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A new Cenomanian vertebrate tracksite at Tamajón (Guadalajara, Spain): Palaeoichnology and palaeoenvironmental implications

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ABSTRACT

A new Upper Cretaceous vertebrate tracksite has been discovered at Tamajón (Iberian Ranges, Guadalajara, Spain). The track level is a relatively smooth and slightly undulating sandy ferruginous crust, corresponding to an erosive surface at the base of a small meandering channel. It is incised into the underlying planar cross-bedded sandstones of coastal bars located at the middle-upper part of the Utrillas Formation (middle-upper Cenomanian). The site shows an extraordinary concentration of vertebrate tracks, among which numerous sets of two to five isolated digit impressions ("swim tracks") and, at least, two trackways referred to crocodyliforms, and a single tridactyl footprint probably produced by a theropod dinosaur can be recognized. There are also several long traces (epichnial grooves) revealing sharp direction changes (up to 90°) which seem to be fish fin traces (*Undichna unisulca*), although crocodyliforms (tail marks) and/or fish invertebrates cannot be rejected as possible trace-makers. Some crocodyliform tracks reveal a thin raised rim, due to the displacement of the sediment by the pressure produced by the feet. Several impressions are moderately deformed by small sediment slides, only preserving their deepest part (claw marks). This is clearly indicative of a soft substrate with a high degree of plasticity and water content at the time of the track registration. Nevertheless, the sediment was hard enough to preserve manus and pes print morphologies and also possible crocodyliform tail and/or fish fin traces. Small rhizoliths can also be recognized and may belong to herbaceous wetland vegetation. The morphology of the palaeochannel, the sedimentary context and the track preservation seem to indicate that the tracks were impressed in a shallow channel located near the coast, under wet conditions and in different moments of time. This discovery represents the first occurrence of vertebrate ichnites in the Utrillas Formation, a stratigraphic unit where osteological and ichnological remains are relatively scarce, and it confirms that some crocodyliforms lived in near coast channels during the deposition of this unit.

1. Introduction

Trace fossils in general, and vertebrate tracks in particular have a widely recognized importance for reconstruction of ancient sedimentary environments. An important key point, compared to body fossils, is their mode of preservation as they are exclusively autochthonous, thus allowing different research approaches to their taphonomy. Besides, vertebrate tracks provide an important source of information for the study of fossil faunal assemblages (Lockley, 1991; Thulborn, 1990). Even when the trackmakers are not identifiable, their tracks can provide precise information regarding palaeoenvironment and substrate consistency (e.g., Lockley, Houck, & Prince, 1986; Razzolini et al., 2014).

In Tamajón, the middle-upper Cenomanian Utrillas Formation consists of a sandy fluvial-coastal plain unit that is widely distributed in the Iberian Ranges (Central-Eastern Spain) (García-Hidalgo, Gil, Segura, & Domínguez, 2007). In spite of being a continental-coastal succession, the presence of tracks in this interval was

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until now unknown in the Iberian Ranges, in contrast to other Spanish Cretaceous units with similar facies, such as the well-known Lower Cretaceous sites in the Enciso and Oncala groups or the Villar del Arzobispo Formation (e.g., Castanera, Pascual, Canudo, Hernández, & Barco, 2012; Castanera, Pascual, et al., 2013; Castanera, Vila, et al., 2013; Moratalla & Hernán, 2010). Previously, the Utrillas Formation had not revealed any vertebrate tracks, and only the presence of rhizoliths had been mentioned in this unit (García-Hidalgo et al., 2007). The near absence of tracks in this unit, mainly composed of terrigenous sediments, is a striking point since it contains vertebrate remains as known at the Algora site (Guadalajara, Spain) (Torices, Barroso-Barcenilla, Cambra-Moo, Pérez-García, & Segura, 2012). Furthermore, the Cenomanian tracksites are really scarce in the Iberian Ranges (Pérez-Lorente, 2003) comparing to significant tracksites described in the Albian-Cenomanian of the USA (Lee, 1997; Lockley, Lucas, et al., 2010), Europe (Mezga & Bajraktarević, 1999) and Australia (Romilio & Salisbury, 2011).

Though dinosaur tracks are abundant during Mesozoic times, the tracks of other vertebrates such as crocodyliforms (Lockley, Fanelli, Honda, Houck, & Mathews, 2010; Lockley, Lucas, et al., 2010) or fishes are not so abundant (Minter & Braddy, 2006). Crocodyliform tracks, however, are not infrequent in the Jurassic and Lower Cretaceous, mainly of the Albian-Cenomanian Dakota Group of the USA (Kukihara & Lockley, 2012; Lockley, Lucas, et al., 2010), but they are especially scarce in the Upper Cretaceous. As yet, one isolated pes print from the Campanian of Utah, USA (Simpson et al., 2010), and different "swim tracks" and a pes print assigned to cf. *Crocodylopodus* from the Maastrichtian of the Pyrenees, Spain (Vila, Castanera, Marmi, Canudo, & Galobart, 2014), have been described. Fish trace fossils have been only described in the Cretaceous from some localities in Spain (Costeur & Ezquerra, 2009; Gibert et al., 1999) and Argentina (Melchor & Cardonatto, 1998), and have been assigned to the ichnogenus *Undichna*.

Here we present the preliminary description of the main vertebrate tracks (assigned to crocodyliforms, a probable theropod and fishes) identified in the Utrillas Formation of Tamajón, that represents the first occurrence of vertebrate ichnites in the middle-upper Cenomanian of Central-Eastern Spain. This work specially deals with the detailed analysis of the palaeoenvironmental conditions that permitted the preservation of the vertebrate tracks, being necessary a new excavation at the tracksite to get a larger exposure in order to obtain a wider perspective to interpret the relationships of the tracks.

2. Geographical and geological setting

This new vertebrate tracksite is located in the Tamajón municipality (Southeastern margin of the Central System, West of the Province of Guadalajara, Central-Eastern Spain). In this area, the Cretaceous crops out along the Eastern flank of a N–S trending syncline with very gentle dips (0–10°) to the W (Hernáiz et al., 2005; Sánchez-Serrano, Vicente-Muñoz, & de González-Casado, 1993) (Fig. 1A–B).

In Tamajón, the basal Cretaceous unit is the Utrillas Formation (Aguilar, Ramírez del Pozo, & Riba, 1971; *sensu* Gil, Carenas, Segura, García-Hidalgo, & García, 2004). It is a 25 m thick unit mainly composed of ochre conglomerates and whitish, kaoliniferous sandstones, with minor grey siltstones and mudstones (García, Segura, García-Hidalgo, & Carenas, 1993; Segura & Elorza, 2013). The Utrillas Formation rests unconformably on reddish sandstones and mudstones corresponding to the Triassic (Buntsandstein Facies), and it is conformably overlain by grey marls with cephalopods of the Picofrentes Formation (Floquet, Alonso, & Meléndez, 1982), whose biostratigraphy has been previously studied in detail in this area by Meléndez-Hevia (1984) and Barroso-Barcenilla, Goy, and Segura (2009) (Fig. 1B–C).

The studied interval corresponds to the middle-upper Cenomanian, because the Utrillas Formation grades laterally to different carbonate units, having orbitolines at their base (e.g., *Orbitolina* cf. *conica*: Segura, Carenas, & García, 1985, Segura, Carenas, García-Hidalgo, 1994), corresponding to middle (or even early) Cenomanian taxa. The same unit at the top contains cephalopods (e.g., *Eucalycoceras rowei*, *Neolobites vibrayeanus*, *Metoicoceras geslinianum*: Barroso-Barcenilla et al., 2009), well known as corresponding to the basal biozones of the upper Cenomanian (Fig. 1C). Thus, the presence of middle (or even early) Cenomanian orbitolines at its base and late Cenomanian cephalopods at its top, constrains this unit to the middle-upper Cenomanian, being probable that the middle-upper Cenomanian boundary is located at the middle or upper part of the Utrillas Formation, close to the stratigraphic interval studied here. Thus, the studied interval of Tamajón would be similar to that of the geographically and temporally close vertebrate site of Algora, currently under study, and where several middle-upper Cenomanian vertebrate remains have been found (e.g., *Stromerichthys* sp., cf. Eupleurodira indet., Solemydidae indet., Neosuchia indet., Carcharodontosauridae: Torices et al., 2012) (Fig. 1C).

3. Stratigraphy and sedimentology

The Utrillas Formation corresponds to the middle-upper Cenomanian 3rd order sequence (García-Hidalgo et al., 2007; Gil & García, 1996), composed of three 4th order parasequence sets (Fig. 1C). Each parasequence set presents a fining upwards trend with conglomerates or coarser sands at the base, and fine sands, silts and muds at the top. The conglomerates form three especially continuous and significant levels (Segura & Elorza, 2013), each representing the basal facies of each parasequence set. In addition, characteristic of this unit is the presence of several cm to mm thick ferruginous crusts with extensive lateral continuity, locally revealing bioturbation at their bases. These crusts are interpreted in relation to sedimentary discontinuities at the top of each parasequence set.

The Tamajón tracksite is located in the upper parasequence set, corresponding to the middle-upper part of the Utrillas Formation (Fig. 1C). It mainly consists of cross-bedded sandstones and conglomerates with minor siltstones and mudstones. Coarser-grained facies consist of either channelled or sheet sands. The channels are up to 3 m thick, of variable lateral extent (10–100 m in length), and are composed of poorly to well-sorted, medium to coarse grained or granule sandstones, showing some channels with lateral accretion surfaces. The sheet sands appear as massive to cross-laminated, mid to fine grained. They present bidirectional cross bedding (herringbone), minor mud-drapes and water-escape structures. The bases of this facies are locally mantled by clast lags, with quartzite clasts up to 10 cm long. Limonitic concretions or cementations are also common, whereas the tops of some group of beds are generally iron-cemented. The final infill of some abandoned channels consists of massive or laminated siltstones and mudstones (García-Hidalgo et al., 2007).

Channels with lateral accretion surfaces reveal meandering channels. The presence of herringbone and mud drapes suggests a tidal influenced coastal environment. The sheet-like sandstones interbedded with mudstones are interpreted as overbank crevasse-splay deposits, and water-escape structures suggest rapid sedimentation. Rhizolits (usually <1 cm diameter) are common at the tracksite and nearby areas, and have been interpreted as root traces horizons on the top of the sandstones, suggesting a shallow subtidal to intertidal setting for the deposition of sediments in the