Skin impressions associated with dinosaur tracks from the Upper Jurassic of Veguillas de la Sierra (Villar del Arzobispo Fm., Teruel)

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Introduction

Dinosaur skin impressions associated with tracks are rare in the Iberian Peninsula, being only found in a few tracksites. These records include impressions attributed to sauropods (e.g. García Ramos *et al.*, 2000), stegosaurs (e.g. Guillaume *et al.*, 2022), theropods (e.g. Pascual-Arribas & Hernández-Medrano, 2011), and ornithopods (e.g. Cobos *et al.*, 2016; García-Cobeña *et al.*, 2024).

The Iberian Basin (north and eastern region of the Iberian Peninsula) stands out for its Upper Jurassic–Lower Cretaceous continental to transitional sedimentary record, which favored the preservation of both osteological and ichnological dinosaur fossils.

In particular, the South-Iberian Basin (provinces of Teruel and Valencia, Spain) contains a high number of dinosaur fossil sites from the Upper Jurassic (Kimmeridgian–Tithonian) Villar del Arzobispo Formation (Campos-Soto *et al.*, 2019), mainly osteological fossils of several taxa, including huge sauropods, stegosaurs, ornithopods and theropods (see Sánchez-Fenollosa *et al.*, 2024 and references therein). Among the ichnological record fewer tracksites have been reported. However, tracks attributed to several groups have been described, those attributed to theropods and ornithopods being the most abundant (e.g.: Santisteban *et al.*, 2003).

In this work, an *ex-situ* block containing skin impressions associated with dinosaur ichnites is described and analyzed in order to understand the relationship between the scale impressions and the tracks. The block was found in a field located in levels from the Villar del Arzobispo Formation in the municipality of Veguillas de la Sierra (southwestern province of Teruel).

Results

MAP-8444 is a sandstone block that exhibits two tridactyl tracks associated with skin impressions. These tracks (VS2-1R-1 and VS2-1R-2) are tridactyl. The block contains four areas with skin impressions, two of them associated with the ichnite VS2-1R-2 and two isolated (VS2-1R-3 and VS2-1R-4).

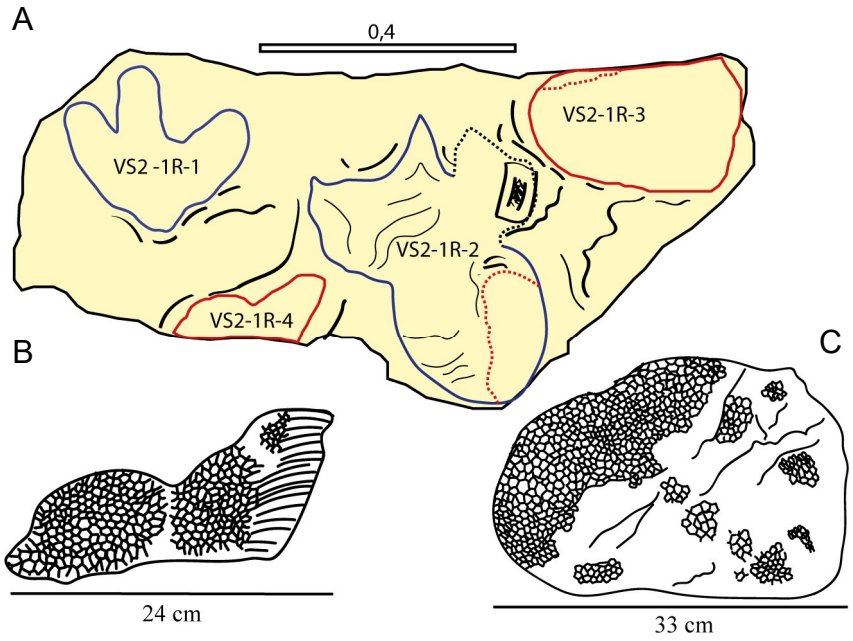

Figure 1. A) Inferred outlines of the tracks (in blue) and skin impression areas (in red) at the block from Veguillas de la Sierra (Teruel). B, C) Detailed drawings of the skin impressions VS2-1R-4 (B) and VS2-1R-3 (C).

The tracks are medium-sized (FL ~ 25 cm) and display different morphologies. VS2-1R-2 is a deep cast of a tridactyl track characterized by having acuminated digits and a large metatarsal impression with associated skin impressions. VS2-1R-1 is also a tridactyl track, but shallower, and exhibits wide digits with rounded distal ends, without associated skin impressions. Both tracks have similar morphometric data (e.g.: low mesaxony, similar length/width ratio), despite the observed differences that are possibly a consequence of deformation processes linked to the state of the substrate.

The skin impressions are characterized by impressions of small scales (4-7 mm diameter) of hexagonal to pentagonal contours, tuberculated and sometimes bounded by movement longitudinal striae. Of the four areas of skin impressions distinguished in the block, two are directly associated with the metatarsal impression and the other two (VS2-1R-3 and VS2-1R-4) are separated from the ichnites, with no direct association.

Discussion

The well-defined tracks (VS2-1R-1 and VS2-1R-2) are natural casts exhibiting a tridactyl morphology. The identification of tridactyl ornithopod and theropod tracks from the Upper Jurassic is complex due to their similarity (e.g.: Castanera *et al.*, 2013). However, VS2-1R-1 shows features (e.g.: subsymmetrical pes tracks that are as wide as or wider than long; digit pads longer than wide; notches in the proximal part of the digit II and IV) that allow its classification within the ichnofamily Iguanodontipodidae (Díaz-Martínez *et al.*, 2015).

Several hypotheses are proposed to explain the distribution and preservation of tracks associated with concrete areas that preserve skin impressions. Firstly, some specimens of the ornithischian ichnotaxa *Anomoepus* and *Moyenisauropus* are associated to some concrete areas with skin impressions, which are explained as consequence of a resting behavior of their trackmakers (Ellenberger, 1974; Lallensack *et al.*, 2022). It consists of a resting posture in which the trackmaker lies part of its body on the ground, leaving a distribution of skin impressions close to their pes and manus tracks. This kind of behavior may explain the subparallel position of the pes tracks, the large metatarsal

impression in VS2-1R-2 and the distribution of some of the skin impressions, and the similarity among the preserved scales. Nonetheless, it is hard to explain the different preservation of the two tracks (despite the similar morphometric data) and the rather far location of the VS2-1R-3.

Alternatively, due to the observed differences in the preservation across the block, another hypothesis involves multiple track-making events. Instead of attributing all the tracks to a single trackmaker, a second hypothesis include two tridactyl trackmakers passing through the area at different times, in the same direction, but under varying substrate conditions. This hypothesis would suggest a resting posture just by the tridactyl individual who left track VS2-1R-2 and the associated skin impressions, and an ornithopod passed later, leaving only a single footprint (VS2-1R-1). A third hypothesis proposes that a tridactyl trackmaker firstly produced a resting trace, including track VS2-1R-2 and a parallel footprint currently not well identified in the block, and that a second individual stepped later producing VS2-1R-1.

Skin impressions pose an additional challenge since scale patterns and morphologies within major dinosaur groups are highly variable and may appear similar or identical depending on the body region to which they belong (Hendricks *et al.*, 2022). Therefore, a global compilation of skin impressions from the Upper Jurassic–Lower Cretaceous interval has been conducted to compare them with those found on block MAP-8444, aiding in the identification of the trackmaker. Thus, the scales are very similar to those of ornithopods (e.g. Bell, 2012; Guillaume *et al.*, 2022). Further work is needed to properly understand which of the three hypotheses is most robust, but the ornithopod affinities of both the tracks (at least VS2-1R-1) and the skin impressions are noteworthy.

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