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Anza palaeoichnological site. Late Cretaceous. Morocco. Part I. The first African pterosaur trackway (manus only)

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ABSTRACT

Cretaceous pterosaurs tracksites are very rare worldwide. Until now,only one African Cretaceous site withtracks of (*Agadirichnus elegans* and *Pteraichnus*) was known. This makes the discovery of a new outcrop in the Upper Cretaceous of Anza (Morocco) the third manifestation of this type of footprint in Africa, extending the existence of such traces from the Coniacian-Santonian to the Maastrichtian. The site contains only manus tracks, which can be explained as a result of erosion of pes prints. The lack of pes prints and the morphometric characteristics of the manus prints only allow us to relate these prints to *Agadirichnus*, *Pteraichnus* or maybe to a new ichnogenus. It is possible that the trackmakers are related to Ornithocheiroidea or Azhdarchoidea superfamilies whose fossil bones have been found from the Late Cretaceous in Morocco.

1. Introduction

Among all fossil reptile footprints, if we exclude those of dinosaurs, the most common are those of pterosaurs. Since their first identification (Stokes, 1957), their number has been steadily increasing in almost every continent. Today there are pterosaur footprint sites in North and South America, Europe, Asia and Africa (Lockley et al., 2008). Their age ranges at least from the Middle Jurassic (Whyte and Romano, 2014) until the end of the Upper Cretaceous (Lockley et al., 2008). The largest deposits are located in Upper Jurassic and Lower Cretaceous strata, while the Upper Cretaceous findings are scarcer (Ambroggi and Lapparent, 1954; Currie, 1989; Parker and Balsley, 1989; Lockley et al., 1997, 2008; Lockley, 1999; Calvo and Lockley, 2001; Hwang et al., 2002; Cheng et al., 2013; Rodriguez de la Rosa, 2003; Fiorillo et al., 2009 . Bell et al., 2013 . Masrour et al., in press).

Although in Morocco the number of ichnological dinosaur sites is considerable, only two sites were known with pterosaur footprints: one in the Jurassic (Gierlinski et al., 2013), and the other in the Maastrichtian of Agadir (Billon-Bruyat and Mazin, 2003). Billon-Bruyat and Mazin (2003) considered that the Cretaceous traces defined as "*Agadirichnus elegans*" Ambroggi and Lapparent, 1954, are made by pterosaurs and not by lacertids, or mammals (Lockley and Foster, 2003). Although Ambroggi and Lapparent (1954) describe only pes prints made by small reptile/pterosaur and birds, Brillon-Bruyat and Mazin (op.cit.) point to the possibility that some of the trackswere pterosaur manus prints. Because of the absence of the original material and the lack of any relationship between manus and pes prints, it was considered "*nomen dubium*" (Sánchez-Hernández et al., 2009). The rediscovery of the original site (Masrour et al., in press.) has allowed us to maintain this ichnogenus and ichnospecies, and reaffirm that they constitute the first footprints of pterosaurs ever described (Billon-Bruyat and Mazin, 2003) three years before the report of Stokes (1957) from the western USA. It is possible that there is another site (Kem-Kem, Cenomanian/Turonian) with pterosaur footprints, cited by

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Belvedere et al. (2013).

After many years without discoveries of pterosaur footprints, we found several of these animal tracks among the dinosaur ichnites of the Anza site. This is the third confirmed discovery of pterosaur tracks in Morocco. The morphological characters of the Kem-Kem pterosaur prints are similar to those of the turtle footprints that were also described by Belvedere et al. (2013) from the same site. This exceptional circumstance and the fact that they are the first ones found from the Coniacian-Santonian age, make us consider it appropriate to publish, describe and relate them with those already known, both from the Upper Cretaceous age and those of earlier times. At the same time we will try to give an explanation for the singular fact of the existence at the site of manus only prints and a hypothesis about possible trackmakers.

2. Material and methods

At the Anza site (ANZ), there are at least two types of archosaur footprints: pterosaur and dinosaur footprints (Masrour and Perez-Lorente, 2015), and striae, probably imprinted by dinosaur claw dragging.

For the study of Anza pterosaur footprints a 30 × 30 cm square mesh with chalk was made, one of whose lines is parallel to the strike of the sedimentary bed. On this mesh an alphanumeric reference system was established and photographs were taken of each ichnite. We have mapped the outcrop from photographs restored with Adobe Photoshop. The images are translated on a scaled plane using an AutoCAD program. The measurement and orientation data are made directly on the outcrop and on the AutoCAD representation. For 3D treatment of the images Adobe Photoshop, Photosynt, SynthExport, MeshLab and Paraview programs have been used.

The ichnological analysis of Anza pterosaur ichnites has been based on their morphologic characters and metric values. The same criteria were used to compare these ichnites with other defined ichnotaxa.

3. Geographical and geological situation

Anza is a small industrial town roughly 5 km north of the city of Agadir. Geologically, Anza is on the northwest flank of the anticline of the Kasbah of Agadir, which forms the last relief of the southern chain of the western High Atlas (Fig. 1). The current structure of the intra-Continental chain is due to compression movements of Tertiary and Pliocene-Quaternary ages (Medina and Cherkaoui, 1988).

Anza Beach, the site with dinosaur and pterosaur footprints, consists of monoclinal layers shallowly dipping (5–12°) to the south-west. The age of the layers is Coniacian-Santonian and they are located on the NW flank of the Kasbah of Agadir anticline according to the geological map (1:50 000 Ambroggi, 1955). In the outcrop no other fossils are cited. We have not found either macro- or microfossils. The coordinates of the site are 29R, 436590E, 3368315N (Google Earth).

The footprints studied here are from six centimetric levels of calcareous sandstone from a stratigraphic section not exceeding 10 m of total thickness. (Fig. 2). Some layers show oscillation ripples at their surface, which indicates the movement of waves (Fig. 3A). One can also observe stromatolitic crust surfaces (the result ofmicrobial activity of photosynthetic cyanobacteria). Some layers are bioturbated by vertical burrows (*Skolithos*) and U morphotypes (*Arenicolites*) (Fig. 3B) characteristic of beach environments.

The presence of storm wave ripples and hummocky cross stratification (Fig. 3C) in beach facies *s.l.* may indicate a tidal beach. Ripples and hummocky structures are generated by high tide waves. Dinosaurs probably walked on the beach at low tide.

4. Ichnology

4.1. Description

The Anza tracksite (ANZ) contains several layers separated into three groups (1ANZ, 2ANZ, 3ANZ) with dinosaur and pterosaur footprints (Fig. 4A). Theropod footprints are the most abundant. The pterosaur tracks have been detected in a single layer (in the 2ANZ group). They form a complete manus only trackway (2.1ANZ3) and two isolated footprints (2.1ANZ1 and 2.1ANZ2) or possibly one incomplete trackway lacking two intermediate prints (2.1ANZ4) (Fig. 4B). Near them, theropod semiplantigrade footprints can be seen.

The pterosaur trackway contains seven manus prints, without any of the pes prints having been found so far. The trackway is nearly straight, showing a slight turn to the left. The footprint depth decreases in the direction opposite to travel, probably due to recent marine wave erosion. The manus prints are longer than wide (average length is slightly less than 9 cm, and average width is4.7 cm; Table 1), asymmetric and tridactyl with unequal length of digit impressions (lI < lII < lIII) (Fig. 5). Digit I is the shortest (about 4.5 cm) and oriented anterolaterally regarding the midline of the trackway; an ichnite shows a short I nail. Digit II is slightly longer (lII = 5.8 cm) and oriented laterally and outwardly; it is not well marked, so we have not been able to observe signs of nails. Digit III is the longest (lIII = 7.8 cm) and backward, nearly parallel to the midline of the trackway; it is possible that it ends up in a nail not clearly distinguished, but arranged perpendicular to the floor. The

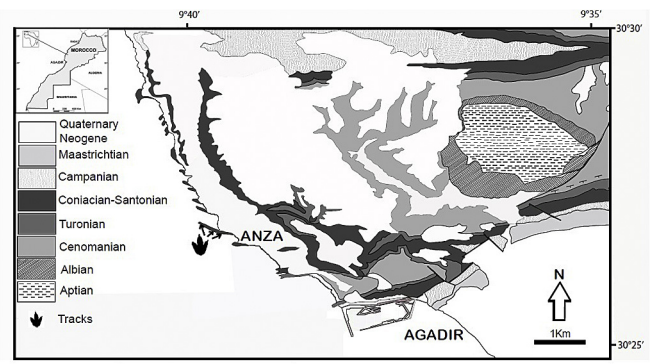

Fig. 1. Geological map of the Anza zone Redrawn from Ambroggi, (1955).

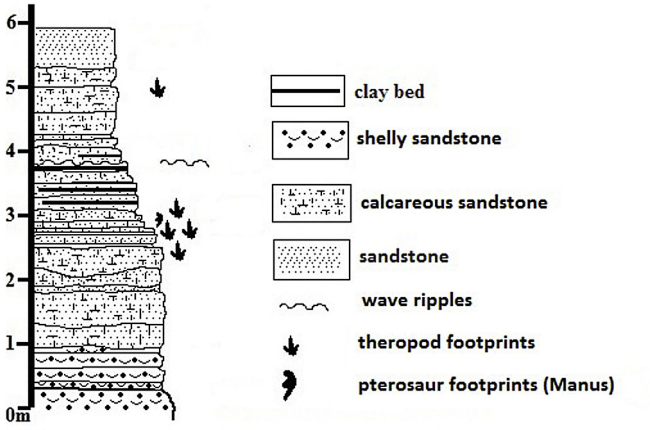

Fig. 2. Stratigraphic log.