Crocodyliform footprints from “les couches rouges” of the Middle Jurassic of Msemrir, High Atlas, Morocco

Icnitas cocodriliformes de las “couches rouges” del Jurásico Medio de Msemrir, Alto Atlas, Marruecos

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ABSTRACT

Two Crocodyliform footprints from "les couches rouges" of the Middle Jurassic of the High Atlas are described. We highlight it for its scarcity in the global record. Footprints cannot be compared with other known ichnogenus. The pes print is incomplete. We assume that it is a continental crocodyliform because the footprints are in fluvial deposits. Finally there follows, although with wide margins of uncertainty, the size that we assume for the trackmaker.

Key-words: *Footprints, Crocodyliforms, Middle-Upper Jurassic, High Atlas, Morocco.*

RESUMEN

Se describen dos huellas crocodyliformes de “les couches rouges” del Jurásico Medio del Alto Atlas de las que se destaca su importancia por su escasez en el registro mundial. Las huellas no son comparables con los icnogéneros descritos hasta ahora. La huella del pie es incompleta. Suponemos que es un crocodiliforme continental porque el ambiente sedimentario en el que están las icnitas es fluvial. Finalmente se indica, aunque con unos márgenes de inseguridad amplios, el orden de tamaño que suponemos para el autor de las pisadas.

Palabras clave: *Icnitas, Crocodyliformes, Jurásico Medio-Superior, Alto Atlas, Marruecos.*

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Introduction

In 2007 three researchers (from the universities of Rabat and La Rioja) prospected the surroundings of Msemrir (Fig. 1) searching for dinosaur footprints. They found several footprint sites in rocks of the Middle and Upper Jurassic. The first (site of IfGH, Bajocian) is already studied (Boutakiout *et al*., 2008). The second is a slab with two “crocodile” footprints (MSR site, Bathonian), described in this paper. The 2007 survey also found tridactyl footprints attributable to theropods and some traces still unidentified. The site has been called MSR, the abbreviation of Msemrir, and the described tracks MSR1m and MSR1p. In the vicinity of Msemrir there are other published sites: one with footprints of birds of the same age as MSR (Belvedere *et al*., 2011), two with dinosaur tracks (Issil-n-Aït Arbi) of Pliensbachian age (Masrour and Pérez-Lorente, 2014; Masrour *et al*., 2015).

Although in Africa crocodyliform footprints and trackways have been cited (Ellenberger, 1970, 1972), all of which have been reassigned to other vertebrates (cf. D’Orazi and Nicosia, 2006; Klein and Lucas, 2010; Olsen and Galton, 1984; Rainforth, 2003). Currently only marks of a rock fragment also from the Upper Cretaceous of Morocco (Belvedere *et al*., 2013) are attributed to a crocodile.

The MSR crocodyliform footprints are in a loose and isolated fragment of red sandstone in the Getioua Formation formerly included in the “couches rouges” sedimentary group. The tracks are very shallow and natural contrast is very small. To show their characters (including variation in depth) photographs have been treated with: AutoCAD, Adobe Photoshop, Photosynt, SynthExport, MeshLab and Paraview 4.0.0-RC.2. The fragment of rock with the footprints (Fig. 2) shall be deposited in the University of Rabat after the publication of this article.

Location

The MSR site is in the Central High Atlas, at the point 30R X= 234446E, Y=3512711N, about 1800 meters north of the town of Msemrir.

The fragment of rock with footprints is a red shaly fine-grained sandstone of the Guetioua Formation (Milhi, 1997). The sedimentary sequences are sandstone and shale alternations of very intense red-brown color. The site is located on the SE flank of a syncline verging approximately in a SE direction.

The Guetioua Formation extends throughout the High Atlas and is characterized by its composition of red sandstones,

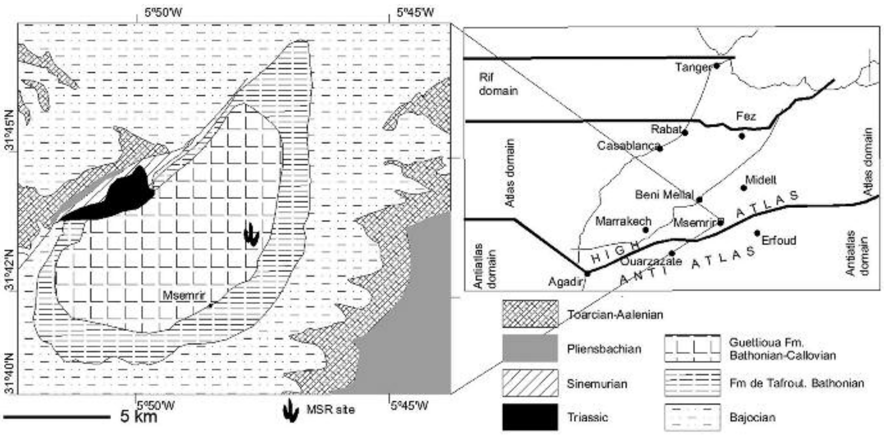

Fig. 1.- Geographical and geological location (based on Milhi, 1997).

Fig. 1.- Localización geográfica y geológica (de Milhi, 1997).

silts and clays and because it contains direct and indirect fossil remains of vertebrates. According to Milhi (1997) it is of Bathonian age, which is adopted in this work. Kohring (1992) also gave for this Formation in the Msemrir area a Bathonian age and fluvial origin.

Ichnology

In the MSR (Fig. 2) fragment there are two footprints: a complete manus print which we call MSR1m, and another incomplete pes print (MSR1p) forming a right manus-pes pair (Fig. 3).

Fig. 2.- Slab with the footprints. The color change (brown-black) is the edge of the rock. Bar is 5 cm.

Fig. 2- Forma de la laja con las icnitas. El cambio de color (marrón-negro) es el borde la la muestra de mano. Escala, 5 cm.

Manus (MSR1m)

MSR1m is the mark of a right manus that is wider (64 mm) than long (52 mm), pentadactyl and digitigrade (Fig. 3). The digits measured (from I to V) are 23-35-35-34-27 mm and interdigital angles (in the same order) 13°-52°-79°, I^IV = 180°. I and V are opposite and are likely to be subparallel to the midline of the trackway. Some digital pad marks are seen. The proximal parts of the digits are together in a lower common area. The high divarication value is not abnormal (greater than 180° in *Crocodylopodus meijidei* [Fuentes Vidarte and Meijide Calvo 2001], *Paleosuchus trigonata* [cf. Kubo, 2010], *Alligator mississippiensis* and Valdelavilla footprints [cf. Pascual Arribas *et al*., 2005]) The tip of the digits is acuminate or rounded (Fig. 3), attributable to relatively long, thin nails. These claw marks are on every digit. The nails point radially, i.e. non-directed to the side or toward the medial ichnite sector (Fig. 3). The depressed areas between the manus digits I-II-III-IV might correspond to interdigital webbing, which would not reach the tip of the digits. It is not clear whether there was a similar area between IV-V digits because this space has been modified by the III pes digit. Apparently, the manus is placed in front and slightly spaced from the axis of the foot, turned outward from the trackway.

Pes (MSR1p)

MSR1p is a right foot. The footprint is not complete and not measurable, but is probably tetradactyl and larger than the manus print (Figs. 2 and 3). The tendency of the tips of digits I to III to be positioned progressively further away is observed. There are several phalangeal and possibly metatarsophalangeal pad marks. The tips of all toes are acuminate. The marks of the nails (Figs. 3 and 4) are bent toward the outside of the footprint. There are interdigital depressions between I-II-III digits.

Size

Deducing the size of a crocodile by the length or width of the manus print is problematic. In *Crocodilopodus,* Fuentes Vidarte and Meijide Calvo (2001) deduce the

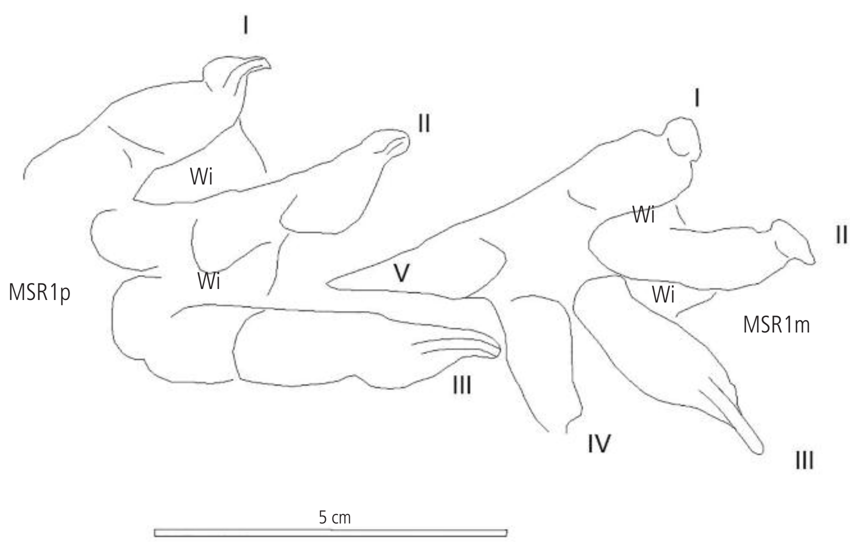

Fig. 3.- MSR. Drawing of the footprint outlines, pads, and claw marks. Wi depressions are possible interdigital webbing.

Fig. 3.- Dibujo de la línea de contorno, marcas de almohadillas y marcas de las uñas. Wi son- depresiones de posibles membranas interdigitales.

glenoacetabular distance from the footprints of trackways (primitive alternate pace). Fuentes Vidarte and Meijide Calvo (2001) calculated the length of the animal between 1.5 to 2 m. Kubo (2010) overlaps the figure of a *Paleosuchus* on its trail. If the average (manus length/animal length) of the measurement obtained by the two progressive approaches is made, the MSR1 animal could be between a minumum of 1 meter and a maximum of 3 meters long.

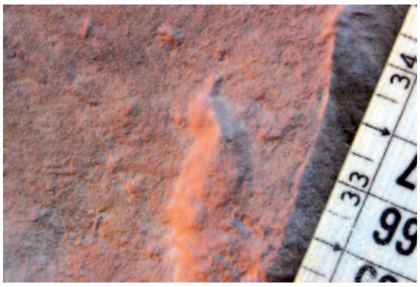

Fig. 4.- Mark of the distal part of toe I. The mark of the claw and last digital pad is observed.

Fig. 4.- Parte distal del dedo I del pie. Se observa la marca de la uña y de la última almohadilla dactilar.

Other features

The contour line of the footprints is clear in many line segments. It is easy to point to contact between the tracking surface and the wall of the footprint (Figs. 4 and 5). In one case (II pes digit) the edge around the digit is falling inward. At the medial edge of digit III of the manus print, the raising of a very narrow extrusion rim is observed. There are narrow grooves of parallel edges on the distal part of the digits, consistent with the elongated shape of "alligator nails" (Farlow and Elsey, 2010) and

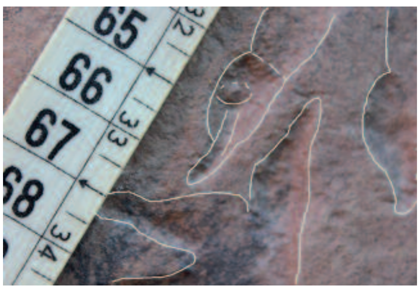

Fig. 5.- Striation left by claws of toe III dregging, and mud piled behind it.

Fig. 5.- Estría dejada por deslizamiento de la uña del dedo III del pie, y barro arrastrado por ella.

slide marks. In III toe (Fig. 5), the mound of mud left in the back of the nail groove for the K phase (Thulborn and Wade, 1989) is preserved. The structures shown are incongruent with a flexible floor, so it is likely that the interdigital depressions are markings of webbing and not indirect structures induced by the sinking of the digits (Manning, 2004). If so, the trackmaker probably has webbing in all interdigital spaces.

The depth (Fig. 6) of the manus print is between 3 and 5 mm, and the pes print between 5 and 6 mm. The difference in depth between the two footprints is not significant because we do not know if the whole surface is the tracking surface; a part of the rock may have been eliminated by erosion. Since there are points where the clay extrusion structures, possible interdigital webbing depressions, and collapse structures are preserved, it can be assumed that the original depth of the footprints was of the order of 5 mm.

Ichnotaxonomy

The number of manus digits (5), their position and the atrophy of toe V of the foot is typical of crocodylomorphs. Other characters are: pointed digit marks, deltoid pes outline, quadrupedal trackways, digitigrade manus and plantigrade pes. Although the MSR1p pes print does not show more than three toes (Fig. 3), it is likely that the IV mark is not there because the specimen is broken (Fig. 2).

If the recommendations of Lockley *et al.* (2010) are followed, the taxonomic group of crocodilian trackmakers should be specified better than has generally been done so far. The MSR fossil footprints are similar to those of today's crocodiles because they have very divergent pentadactyl manus (cf. Pascual *et al.*, 2005) and less open tetradactyl pes (cf. Farlow and Elsey, 2010; Kumagai and Farlow, 2010). The scarcity of fossil footprints, make it difficult to establish the possible identification characters. Not enough Jurassic crocodyliform ichnotypes are described to discuss their allocation to any trackmaker. In this case, which is Middle Jurassic age (not Cretaceous) and a river environment, the footprints should be attributed to terrestrial Crocodylomorpha, non- Mesoeucrocodylia, with the exception of Thalattosuchia and primitive Notosuchia (cf. Pol *et al.*, 2014).

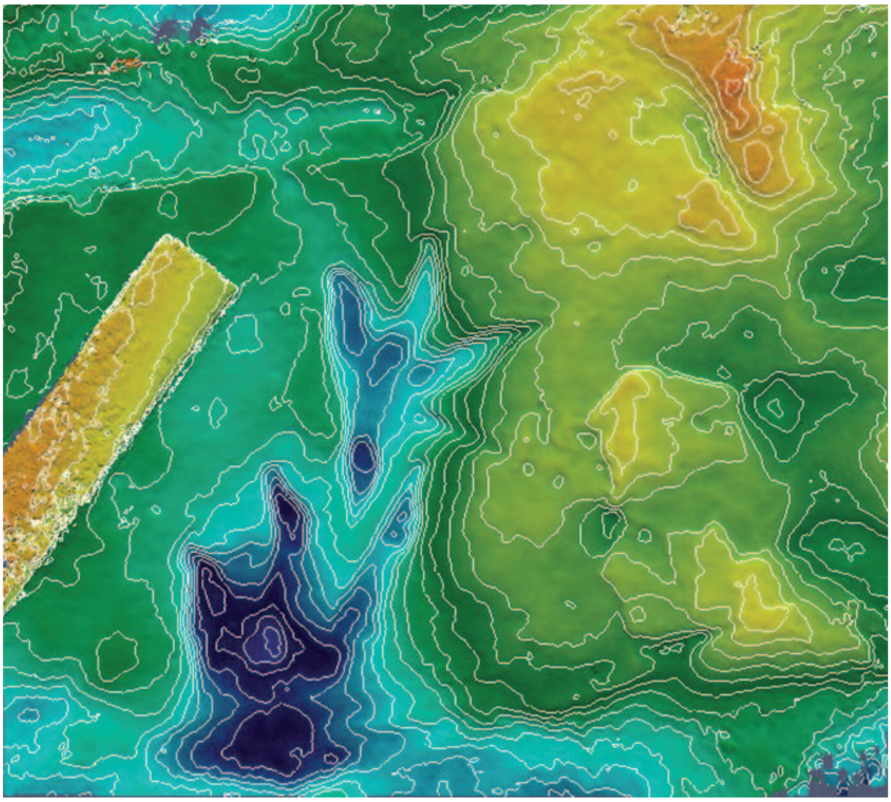

Fig. 6.- Variation of the surface of the slab study shown with different colors. Equidistance of the contour lines is 0.5 mm. Yellow bar width is 20 mm.

Fig. 6.- Imagen en color de la variación de altura de la laja. Equidistancia de las curvas de nivel, 0,5 mm. Anchura de la barra amarilla, 20 mm.

Traces of crocodilians from this age have been described worldwide, some of which are marks of swimming or sliding (cf. Lockley *et al*., 2010) of the feet in the mud. The names that have been given to these ichnites (ichnogenus and ichnospecies) do not serve for identification or comparison of MSR1. The citations of the above authors did not include all the existing swimming marks of crocodilans (e.g., Ezquerra and Pérez-Lorente, 2003; Pérez-Lorente and Ortega, 2003). The only described footprints of a relatively near time interval (Upper Jurassic-Lower Cretaceous) that retain the digit prints and have closed or nearly complete contour lines, are classified in ichnogenus *Crocodylopodus* (Fuentes and Meijide Calvo, 2001) (see also Avanzini *et al*., 2010b), and footprints of "a medium sized crocodile probably from the Goniopholidae family" (Pascual *et al*., 2005)

Discussion

MSR1p is not a complete footprint because the piece of rock in which the heel and toe IV should be printed is missing. The manus print must also be modified because toe III of MSR1p is in the interdigital space of MSR1mIV-V. Furthermore, MSR toes are thicker and have more pronounced nails that *Crocodylopodus.* It is possible that MSR1p and MSR1m also have interdigital webbing. We think MSR1m and MSR1p are exclusive characters but we cannot define a new ichnotype with one incomplete manus-pes pair of footprints.

The age and location of most of the Moroccan crocodyliforms (Albian to Paleogene, regions of Kem Kem [Antiatlasic Domain and Khourigba [Moroccan Meseta]) are not used for correlation with MSR footprints because they come from different geological environments and ages. Up to now we have not been able associate the tracks with other Crocodyliforms cited in Morocco (eg. Lapparent, 1955).

Footprints of other reptiles are excluded due to distinctive crocodilian manus morphology which has five digits with a I^V divarication of about 180° (Avanzini *et al*., 2010a)

Conclusions

The discovery of the MSR site in Msemrir provides evidence on new crocodyliform footprints in Morocco. The record is of interest because crocodyliform footprints are rarely documented, although in this country (Morocco) there are many fossils referenced and described, especially from the Upper Cretaceous and Paleogene. This is the second time that traces of these reptiles are described, not only in Morocco but in the African continent, and the only one in which a complete print of one of the autopods is preserved.

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