Otozoum trackway in Issil-n-Aït Arbi (Lower Jurassic, Central High Atlas, Morocco)

Rastrillada de Otozoum *en Issil-n-Aït Arbi (Jurásico Inferior, Alto Atlas Central, Marruecos)*

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ABSTRACT

A new site has been found in the Central High Atlas, in the Issil-n-Aït Arbi near the Dadés Gorges. This paper is the first study presented of this locality, with the description of a quadruped trackway of pentadactyl pes and tridactyl manus, which we have attributed to Otozoum. The characters of these prints and trackway are described, compared, and analyzed in the text and they are attributed to a prosauropod trackmaker. Some anatomical considerations are deduced from this type of trackway. It is the first track of this ichnogenus cited in north of Africa, though it is possible other similar ones exist in Lesotho.

Key-words: Otozoum*, Lower Jurassic, Dinosaur, High Atlas, Morocco.*

RESUMEN

Se ha encontrado un nuevo yacimiento en el Alto Atlas en Issil-n-Aït Arbí muy próximo a las gargantas del Dadés. Este trabajo es el primero de los estudios que se presenta de esta localidad. con la descripción de una rastrillada cuarúpeda de pies pentadáctilos y manos tridáctilas que hemos atribuido a Otozoum. En el texto se describen comparan y analizan los caracteres de estas pisadas y los de la rastrillada y se atribuyen a un icnopoyeta prosaurópodo de cuya forma de caminar se deducen algunas consideraciones anatómicas. Es el primer rastro de este icnogénero que se cita en el Norte de África aunque es posible que otros similares se encuentren en Lesotho.

Palabras clave: Otozoum*, Jurásico Inferior,dinosaurio, Alto Atlas, Marruecos.*

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Introduction

In the Oued Ait Arbi, a site has recently been found with several outcrops with dinosaur footprints (Fig. 1). After getting in contact with the discoverer, a team of Moroccan and Spanish researchers have begun to study them all. The site has been called AAR, which is an acronym for Aït Arbi; the outcrop, called 1AAR, is the easternmost, and the described trackway is1AAR1.

The footprints are assigned to *Otozoum* Hitchcock 1847, on the basis of their shape. Traces of *Otozoum* mentioned to date, are in Lower Jurassic basins (Smith and Farlow, 2000) that were in contact with Morocco before the continental drifting ("northern Newark Supergroup rift basins" Rainforth, 2003, her fig. 1A). The climate that is recognized in the basins (North America and Morocco) at this time is the same (dry and warm) detected by evaporite sediments. The nearest footprints of this ichnogenus on this side of the Atlantic Ocean that have been cited are in France (Gand *et al.*, 2000, 2007).

The authors who have most recently worked with them assume that they were made by prosauropods (cf. Rainforth, 2003, pp. 818-819). Except in France (Triassic), the age of the others is Lower Jurassic. It is the first record of this type of footprints in North Africa.

Location

The trackway is located in the Central High Atlas in the zone 30R, (coordinates X = 221238 Y = 3484954 obtained from Google Earth). The ravine is a tributary of the Dades River, located to the west of Ouarzazate between the Valley of the Roses and the gorges of the Dades.

The level bearing traces (Fig. 2) strikes N 075° E and dips 65° to the South. It is a brown coloured limestone possibly of the Aganane Formation, Lower Jurassic in age (Pliensbachian). This Formation is rich in footprint sites and the nearest studied are those of Adrar-n-Ougladal (Monbaron *et al.*, 1985), of Aghbalu-n-Kerdous and Taoudaat (Hadri *et al.*, 2007)

Facies of the Aganane Formation are dominated by limestone and dolomite with mud cracks, and varicoloured clay. The sedimentology (Ettaki *et al.*, 2007) showed that these sediments were deposited in the middle of temporary lagoon environments.

Ichnologic description

1AAR1 is a trackway made up of 14 pairs of pes-manus prints, which are fairly well preserved (Fig. 3). The outcrop is in an

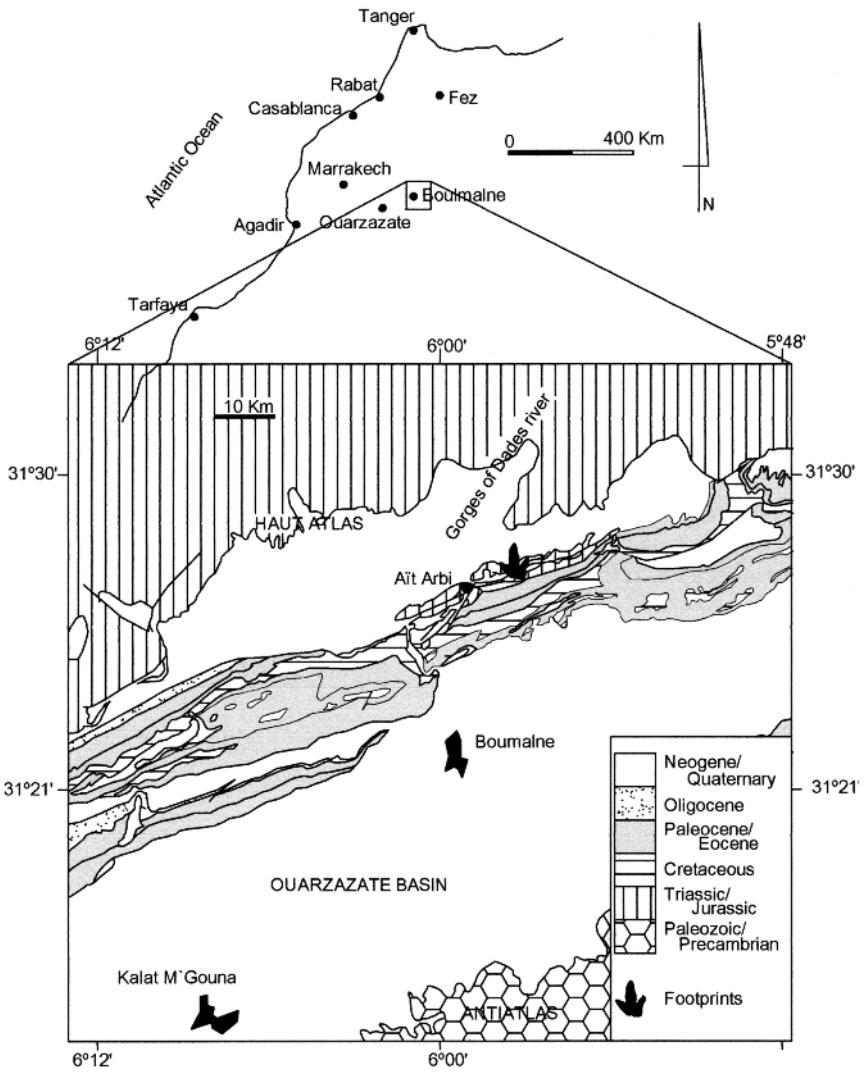

Fig. 1.- Geographic and geologic location (redrawn from Hindermeyer *et al.*, 1977)

Fig. 1.- Situación geográfica y geológica (tomado de Hindermeyer* et al.*, 1977).

almost vertical wall of very difficult and dangerous access, so that direct contact has only been made with the first five pairs from which the measurements and observations described were did. The trackway has been done by reconstruction from photographs taken with telephoto lens and retouching with Photoshop and AutoCAD

Pes prints

The pes prints (Figs. 4 and 5) are relatively large and narrow (length = 46 cm, wide = 30 cm). They consist of a probably tarsometatarsal pad placed in the rear, relatively wide and certainly not elongated. In front of it are placed, firstly a wide protruding pad corresponding to digit V, and secondly a series of three or four (I-IV) metatarsal-phalangeal pads. It is unclear if there is a repeated pattern of coalescence between these pads in the footprints of this trackway. In the anteriorly-directed four digits (I-IV), slightly mesaxonic, pad marks are visible. The "phalangeal" pad numbers appear to be I (2-3), II (3-4), III (4), IV (3), V (1), these data are not certain. The metatarsal-phalangeal pads (except V?) are not included in these data.

The axes of the anteriorly-directed digits are subparallel. The distal end of digits I-IV is a round hole, usually deeper than the rest of the digit. It may be comprised of an ungular pad and the claw itself, which would leave no other mark. In front of digit V in footprints 1AAR1.9p and 1AAR1.8p there is a small hole that is perhaps the mark of the V nail.

The digits (I-IV) are relatively straight. Pad V is a small protrusion in the rear part of proximal digit IV. It consists of a pad adjacent to the metatarso-phalangeal IV and tarso-metatarsal pads.

The metatarsal-phalangeal pads are a proper part of the foot, i.e. they are part of the sole, and not of the digits. They form an elongated depression whose major axis is transverse to the axis of the elongation of the foot. Unlike *O. moodii* no coalescence of the metatarsal-phalangeal III- IV pads is appreciated, but it appears that coalescence takes place between pads II-III.

The posterior pad (tarso-metatarsal) is large and adjacent to the metatarsal-phalangeal digits I-IV, and the V digital pad. It is deeper than all the previous ones and the separation from them is very clear.

The trackway left by pes prints describes a low amplitude wave. In the initial portion the footprints step on the midline and would be considered a very narrow trackway. The average data (cf. Pérez-Lorente, 2001) are: step = 81 cm, stride = 158 cm, pace angle=150º, and orientation = 12°.

Manus prints

The manus prints are wider (26 cm) than long (16 cm). Their shape is concavo-convex or plano-convex, like the segment of an orange, the concavity pointing medially, and the deepest part (distal) outwardly in the trackway. All manus prints have in the distal part, three round or somewhat radially elongated holes. One of the footprints 1AAR1.4m has five holes two of which are probably due to breakage and erosion of rock.

The manus prints leave a trackway whose parameters are: step = 84 cm, stride = 163 cm, pace angle = 150°. The orientation of the manus prints or angle between their anteroposterior axis with the midline is 60 ° to the left and 25 ° to the right.

The midline of the manus trackway is displaced to the left side of that of the pes. This finding is consistent with the asymmetric positioning of the manus and pes prints relative to the trackway. In it, the sequence of two manus prints and two pes prints, standing on a straight line oblique to the midline, is repeated. The manus and pes prints are aligned as follows: right pes, right manus, left pes, left manus.

The right pes and left manus, are the more external trackway prints.

Ichnosystematic

We have compared this ichnite with others from the Upper Triassic and Lower Juras-

Fig. 2.- Trackway 1AAR1.
Fig. 2.- Rastrillada 1AAR1.

sic, characterized by having the pes marks with more than three digits directed forward, without a significant digit V and pentadactyl manus. The footprints that are these characters are *Navahopus* Baird, 1980, *Otozoum* Hitchcock, 1847, and (in Lesotho) *Kalosauropus* Ellenberger, 1972, *Pseudotetrasauropus* Ellenberger, 1972, and *Tetrasauropus* Ellenberger, 1970. These ichnogenera were reexamined by Rainforth (2003) who regroups and redefines *Otozoum,* removing *Pseudotetrasauropus*, *Tetrasauropus* and *Navahopus*. According to Rainforth (2003) *Otozoum* is Lower Jurassic in age.

The footprints of 1AAR1 satisfy the conditions to be pentadactyl, probably mesaxonic, with digits I- IV subparallel to the elongation of the foot, but digit V oblique (1AAR1.6, 1AAR1.8, 1AAR1.9, 1AAR1.11). The difference in I to IV digit lengths is small. The longest are III and II, followed by IV and I. Digit V is residual. The phalangeal and metatarsal-phalangeal pads of the four digits are printed. The proximal phalanges of digits I- IV start from the same straight line, which means that the metatarsals I- IV should also end on a straight transversal line to the pes. The claw marks are rounded and sometimes somewhat separated from the last digital pads, probably preungeals. The metatarsal-phalangeal pads, like in *Otozoum* prints, are integrated in the sole of the foot. The manus prints, apparently tridactyl, are small footprints with three short rounded marks of digits. The position and placement of the lateral- medial axis of the manus, more parallel than perpendicular to the middle line, is similar to the *Otozoum* manus position.

The characters of the footprint (size, shape and arrangement of the pads, claw marks, number of digits and shape of the claws), are similar to the ichnogenus *Otozoum*. When compared to those of the three ichnoespecies recognized by Rainforth (2003), the 1AAR1 footprints are closer to *Otozoum moodii* than the other two (*O. pollex, O. minus*). *O. moodii* has been defined on a print of a trackway with three pes prints in which two of them are not complete. In 1AAR1 direct access has only been made to a well-preserved ichnite, so that the foot characters cannot be strictly defined. The same applies to the marks of the manus, of which only two *O. moodii* manus prints are known, very close to the pes prints and probably, as some authors suppose, deformed by them.

Trackway type and discussion

The posterior part of the pes print has a large pad placed under the proximal end of the metatarsals (Rainforth, 2003, her fig. 7). According to the latter author, the metatarsal would be inclined with respect to the ground, so that the footprint tends to be semiplantigrade.

The pes have positive orientation that is normal in quadrupedal gait. The manus prints are very open (high angle of orienta-

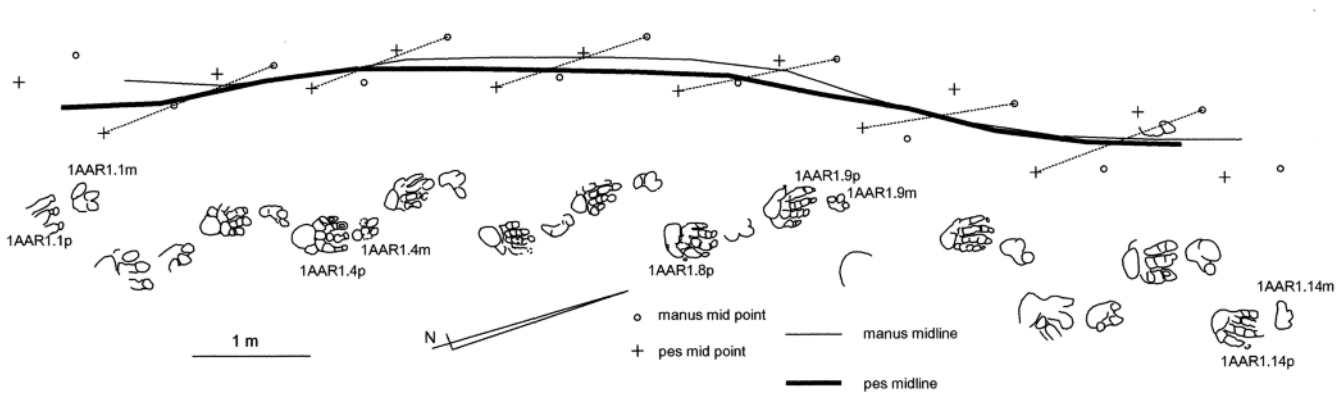

Fig. 3.- 1AAR1 trackway. Orientation of prints in relation to manus and pes midlines.
Fig. 3.- Rastrillada 1AAR1.Colocación de las huellas en relación con la línea media de las huellas.

Fig. 4.- Photograph of 1AAR1.4p, 1AAR1.4m, 1AAR1.5p, and partially of 1AAR1,3m.

Fig. 4.- Fotografía de 1AAR1.4p, 1AAR1.4m, 1AAR1.5p y parcialmente de 1AAR1.3m.

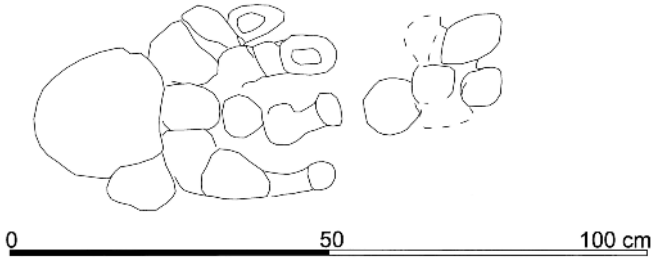

Fig. 5.- Diagram of the 1AAR1.4 right pair.

Fig. 5.- Dibujo esquemático del par derecho

tion) respect to the midline. It is noted that the left manus form an angle greater than the right with respect to that line. The prints of trackway 1AAR1 show no sign of slipping or more support on the heel or nails, so it follows that the animal was walking or calmly trotting.

The position of the footprints (manus and pes) obliquely aligned to the midline is found in both animals who are knuckle walking like chimpanzees (Schmidt, 2010), and in animals trotting (diagonal trot of some dogs, pers. observ.) or galloping like otters (Richarz, 2007). This mechanism is used so that the forelimbs do not stumble or interfere with the hindlimbs. The animals that walk or trot leaving this sequence of prints have at least one pair of long limbs in relation to the glenoacetabular distance. Furthermore, the separation between manus and pes, perpendicular to the midline (trackway deviation), while should be the same or very similar for the aforementioned interference to occur. Perhaps, as in some dogs, the axial body plane is slightly transverse to the running direction, so that the midline of the manus prints is slightly offset to one side with respect to the midline of the pes prints. They are prosauropods whose hands mark from time to time the ground (Gand *et al.*, 2000).

Probably the Mallison (2011) model of a *Plateosaurus* with flexed hind limbs can be a suitable model for quadrupedal running posture.

Conclusions

The *Otozoum* ichnogenus is described in the Issil-n-Aït Arbi sites. It is the first time that is mentioned in scientific literature. The trackmaker was probably a prosauropod dinosaur.

Previously it was described in USA, France and Lesotho. All authors attributed these footprints to quadrupedal-bipedal Prosauropods. These trackmakers are known by skeletons in Triassic and lower Jurassic. In Morocco not have found skeletons of these animals in Jurassic sediments.

The ichnogenus is from a quadrupedal trackway, printed by an animal that moved with a moderate gait, which provide information about the posture during walking.

Acknowledgements

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