First dinosaur tracks from the Lower Cretaceous of the Western High Atlas (Morocco)

Primer yacimiento con huellas de dinosaurio del Cretácico Inferior del Alto Atlas Occidental (Marruecos)

Moussa Masrour[1], Félix Pérez-Lorente[2], Serge Ferry[3], Nourrisaid Içame[1] and Danièle Grosheny[4]

[1] Université Ibn Zohr, Faculté des Sciences, Dpt. de Gèologie, BP8106 Cité Dakhla, Agadir, Morocco. moussamasrour5@gmail.com, ns_icame@yahoo.fr
[2] Edificio CT, Universidad de La Rioja, c/ Madre de Dios 51-53, 26006 Logroño, Spain. felix.perez@unirioja.es
[3] Université de Lyon, 43 Bd du 11 Novembre. 69622. Villeurbanne cedex, France. serge.ferry@yahoo.fr
[4] Université de Strasbourg. EOST, IPGS, UMR 7516. 1 Rue Blessig. 67084 Strasbourg cedex. France. grosheny@unistra.fr

ABSTRACT

Eight vertebrate trackways were found near the Imi-n-Tanout village, in the proximity of the two Marrakesh-Agadir roads: three theropod, two sauropods trackways; and three of an unknown bipedal trackmaker. The outcrop is the first Early Cretaceous dinosaur tracksite found in Morocco and the second (Barremian-early Aptian) site of Africa. This preliminary report provides morphometric and biomorphic descriptions of the footprints and trackways, their classification, and an interpretation on the formation of the two "pes-only" sauropod trackways.

Key-words: *Footprints, dinosaurs, Early Cretaceous, High Atlas, Morocco.*

RESUMEN

Se han descubierto ocho rastrilladas de vertebrados cerca del pueblo de Imi-n-Tanout, en la vecindad de las dos carreteras que unen Marrakesh y Agadir. El contenido icnológico incluye: tres rastrilladas terópodas; dos de saurópodos; y tres de icnopoyetas bípedos no identificados. Es el primer yacimiento encontrado con huellas de dinosaurio del Cretácico Inferior de Marruecos y el segundo (Barremiense-Aptiense inferior) del continente africano. En el trabajo se proporcionan los datos morfométricos y biomórficos de las icnitas, su clasificación y una interpretación sobre la génesis de las dos rastrilladas saurópodas "solo de pies".

Palabras clave: *Icnitas, dinosaurios, Cretácico Inferior, Alto Atlas, Marruecos.*

Geogaceta, 53 (2013), 33-36.
ISSN (versión impresa): 0213-683X
ISSN (Internet): 2173-6545

Fecha de recepción: 10 de julio de 2012
Fecha de revisión: 25 de octubre de 2012
Fecha de aceptación: 30 de noviembre de 2012

Introduction

Since the first discovery of dinosaur footprints in Morocco (Plateau *et al.*, 1937), dinosaur tracks have attracted the interest of scientists. Some discoveries have undergone extensive paleontological studies (cf. Boutakiout *et al.*, 2010; Nouri *et al.*, 2011). Most of the dinosaur trackways hitherto known in Morocco are from Jurassic, and only two tracksites are Upper Cretaceous in age. (Ambroggi and Lapparent. 1954; Martill *et al.*, 2011).

The sediments of the Lower Cretaceous had not reveiled any footprints of dinosaurs so far. In Africa there is only one reference to dinosaur footprints from the Lower Cretaceous in Cameroon (Dejax *et al.*, 1989; Jacobs *et al.*, 1989)

The geological field works on Lower Cretaceous terrains of the region of Imi-n-Tanout led to the discovery, of the dinosaur tracks described in this work (Fig. 1). The track-bearing bed with the traces is attributed to the late Barremian- early Aptian age interval (Fig. 2).

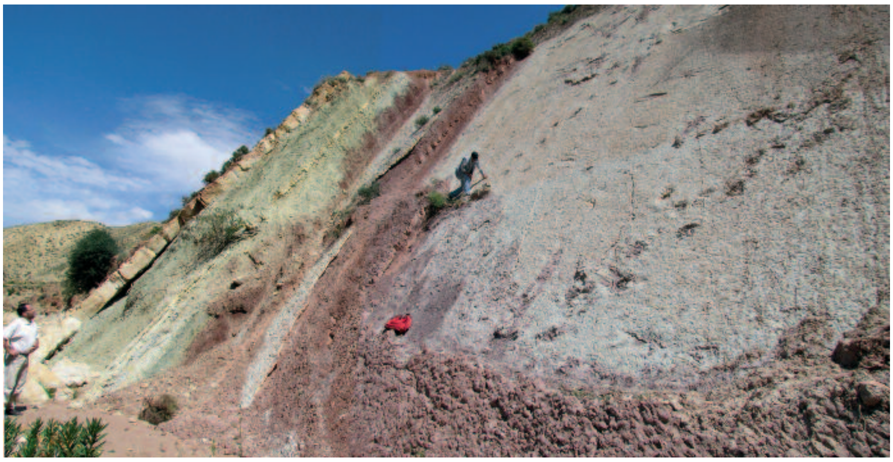

Fig. 1.- General view of the Talmest track surface. Dark beds are continental red clays.
Fig. 1.- Vista del yacimiento de Talmest. Los niveles oscuros son lutitas continentales.

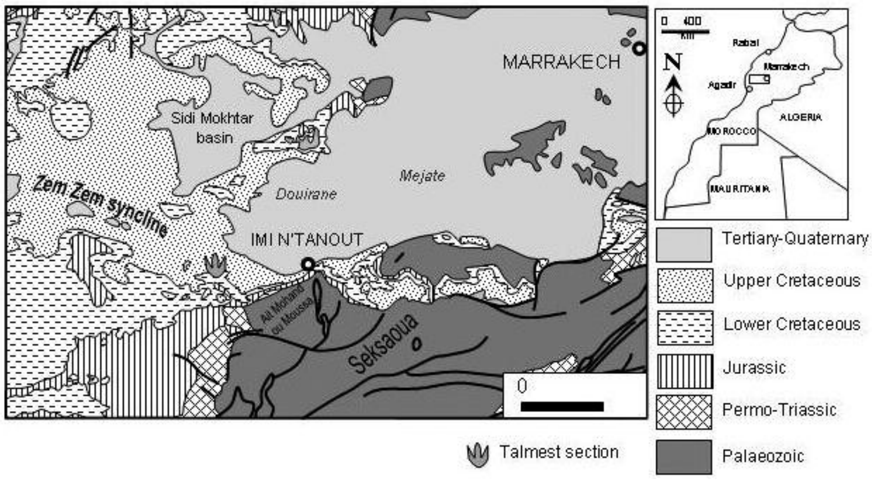

Fig. 2.- Geological location of the Talmest tracksite (Redrawn from Rey *et al.*, 1988).

Fig. 2.- Localización geológica del yacimiento de Talmest. (Dibujado de Rey et al.*, 1988).*

The purpose of this repport is to provide an overview, both in term of sedimentological and ichnological aspects of this outcrop, highlighting the importance of this discovery in the Lower Cretaceous sediments of Morocco.

Geological setting

The newly discovered dinosaur tracksite of Talmest has been found in a variegated interval, about ten metres thick, intercalated between lower Barremian, oyster-bearing, full marine deposits and (? upper) Aptien marls (Fig. 3). This variegated interval is reminiscent of the thick, reddish, mostly continental deposits of the upper Hauterivian Talmest Formation below. In the coastal Agadir basin, Nouidar and Chellaï (2001, 2002) described deposits interpreted as the result of two major regressions: a beach to shoreface sandstone body in the upper Barremian, and an unconformity-bounded incised valley fill in lower Aptian deposits. The interval of the Talmest locality is supposed to be the updip facies of the first regression (SB-1, Fig. 3). A second sequence boundary (SB-2, Fig. 3) is found higher up in the Talmest section, as an unconformity-bounded transgressive conglomerate, overlain by beach to shoreface sandstones, shows hummocky cross-stratification and wood debris. SB-2 is tentatively correlated to the second forced regression downdip in the Agadir basin.

The variegated interval between the two sequence boundaries is considered as transgressive interval above the sequence boundary SB-1. It is made of five small-scale parasequences in which marine green clays, greenish to yellowish dolomites and red clays alternate. The parasequences are interpreted as the result of small transgressive pulses followed by the progradation of distal fluvial facies in a flat coastal depositional environment. Green clays in the parasequences are interpreted as the deepest marine facies but probably they are still very shallow. The overlying greenish to yellowish dolomites are interpreted as a tidal flat facies, because they are often laminated in their upper part. The lower boundary of the red clays is interpreted as a continental aggradation surface (CAS). These small-scale sequences are thus all bounded by transgressive surfaces (TS). In some cases

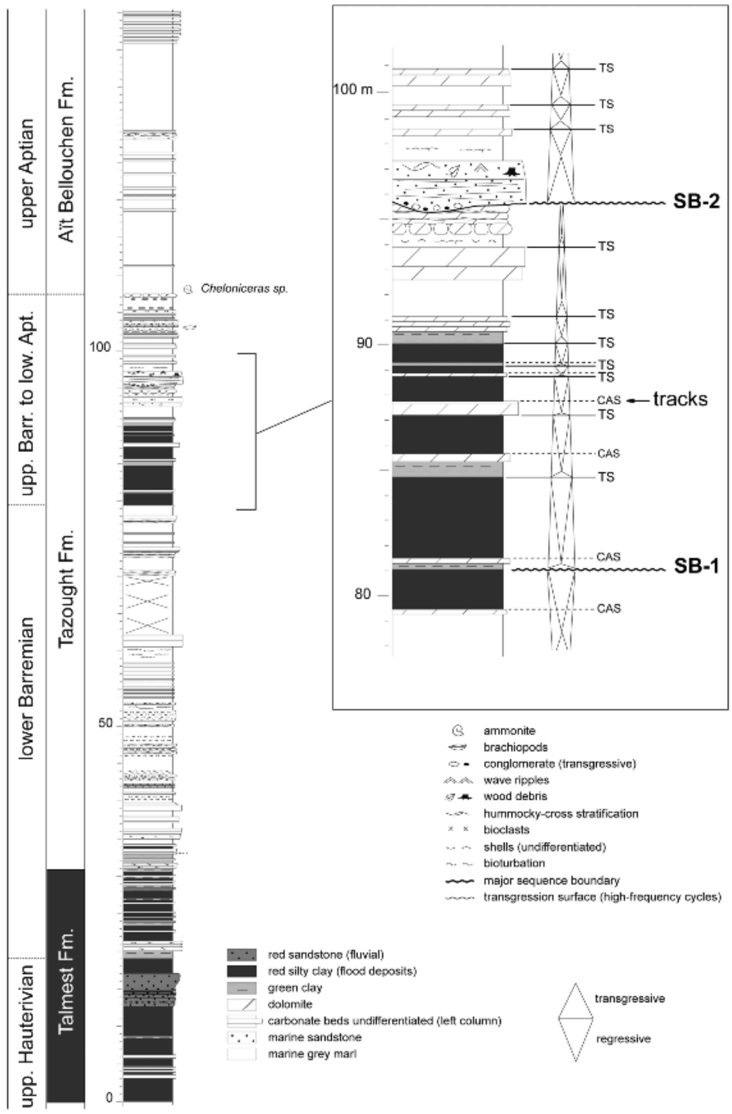

Fig. 3.- Stratigraphic position of the track-bearing level. The tracks are at the top of a laminated dolomitic bed interpreted as a tidal flat deposit. SB sequence boundary, TS transgression surface, CAS continental aggradation surface.

Fig. 3.- Posición estratigráfica de las huellas. El yacimiento está en el techo de un estrato dolomítico laminado en un medio de "tidal flat". SB límite de secuencia, TS superficie transgresiva, CAS superficie de agradación continental.

the basal green clays are lacking. So, the transgressive facies is only represented by the dolomite tidal flat facies intercalated in the red clays. The tracks have been found under the CAS of one of the parasequences. Their preservation was probably due to the wet character of the tidal flat deposits (Marty *et al*., 2009).

Ichnology

Sometimes the footprints and their outlines are difficult to distinghish. The stratification surface is not flat but rough so that its appearance is an irregular lumpy mosaic (Fig. 1). The surficial difference in relief is sometimes similar to the deepth os some digit prints. However, although the relief is sometimes the same, the diameters and shape of holows make the footprints easily distinguishables. Some of the trackways, especially those of large tracks show footprints with extruded mud (Figs. 4, 5).

Taking into account the ichnological characters, the following different trackway types can be distinguished.

i) trackways of large tridactyl footprints (TLM1 and TLM2);
ii) trackways of small tridactyl footprints (TLM8);
iii) quadrupedal trackways (TLM3 and TLM5) and
iv) trackways of small indeterminate footprints (TLM4, TLM6 and TLM7).

The total number of footprints belonging to the 8 trackways is 72. There are 30 structures (hollows) that could be isolated footprints (Fig. 4). The 8 trackways are attributed to biped and quadruped dinosaurs due to their shape, to the geological age and regularity of the sequences.

The measurements and their relationships (Table I), the morphotype identification and ichnotaxonomical characters used in this paper, are based on the proposal of several authors synthesized in Pérez-Lorente (2001) and Romero-Molina *et al*. (2003).

Large theropod trackways

These are the tridactyl footprints whith a length (Thulborn, 1990) exceedings 25 cm (29-39 cm). Both trackways TLM1 and TLM2 (Table I, Fig. 4) are characterized by three separated and relatively long toe traces, some of them with an acuminate form. The digital pads are not clearly visible. The trackways are of narrow gauge type, advancing at a moderate walking speed (Table I). The dinosaurs have relatively thin limbs. All these features are typical of large theropod dinosaurs

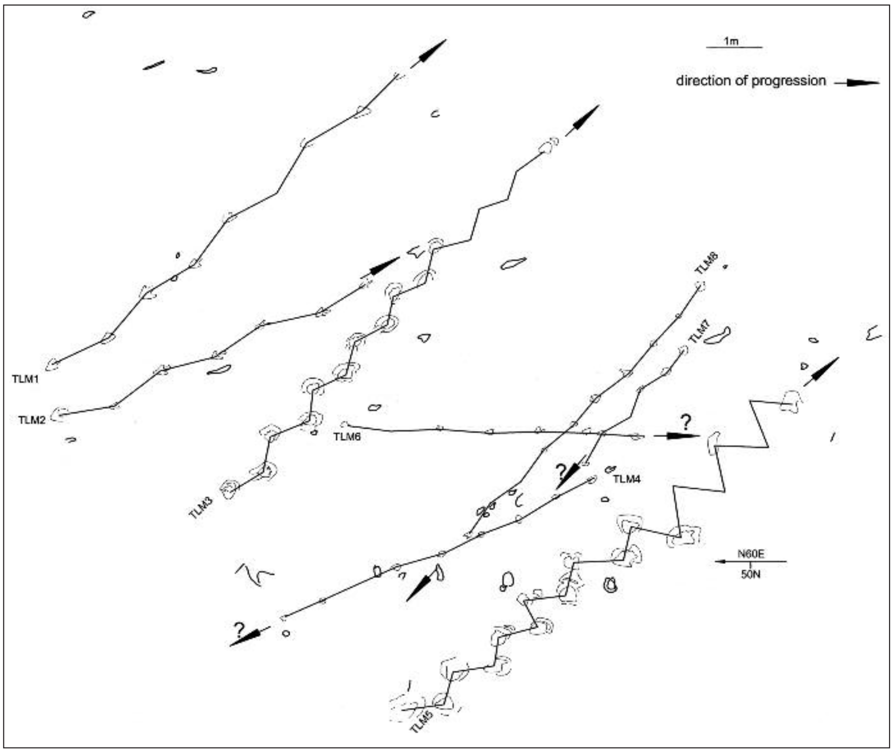

Fig. 4.- Map of the Talmest tracksite. Trackways are indicated by a broken line. Is also indicate the direction and dip of the bed.

Fig. 4.- Yacimiento de Talmest. Las rastrilladas están señaladas con líneas quebradas. Se indica también la dirección y buzamiento del estrato.

Small theropod Trackways

Only in TLM8, tridactyl footprints can be recognized. From the data of Table I it is suggested that a small dinosaur left the narrow gauge trackway TLM8. The digits are separated, relatively thin and pointly features of theropod footprints. The trackmaker was moving with a fast walking gait, has long and slender limbs (z/l).

We have also identified three sequences (trackways) of traces (TLM4, TLM6 and TLM7, Fig. 4) some with extruding mud rims, and yielding metric data (Table I) similar to TLM8. All trackways were biped with short (l) and narrow ([l-a]/a) footprints and very thin limbs (z/l). These characters are typical of theropod footprints. Therefore although neither the toes nor their shape is clearly distinguishable, they are assigned to the said ichnogroup.

Quadrupedal trackways

There are two (TLM3, TLM5) subparallel trackways indicating the same direction of progression. They consist of two different

trackway	l	a	Ar	P	z	Ap	h	z/h	v	(l-a)/a	Ar/a	z/l
TML1	29	20	10	105	203	159	144	1,4	5,1	0,5	0,5	7,0
TML2	30	18	10	102	202	158	160	1,3	5,0	0,6	0,6	6,7
TML3	24	19	14	63	113	129	101	1,1	3,3	0,3	0,7	4,7
TML4	16	11	3	77	155	172	73	2,1	5,4	0,5	0,2	10,0
TML5	30	26	20	70	103	101	109	1,0	2,7	0,2	0,8	3,5
TML6	18	11	1	88	172	178	72	2,2	6,2	0,4	0,1	9,5
TML7	16	13	5	56	104	159	72	1,4	3,9	0,4	0,4	6,5
TML8	16	13	3	68	137	173	72	1,9	5,7	0,2	0,2	8,5

l, footprint length (cm); P, pace length (cm); z/h, relative stride length
a, footprint width (cm); z, stride length (cm); v, speed (km/h)
(l-a)/a, relative pes length; Ap pace angle (degres); Ar/a, relative trackway with
h, acetabulum height (cm); Ar, trackway deviation (cm); z/l, limb thickness

Table I.- Mean data of the Talmest dinosaur footprints and trackways.

Tabla I.- Datos medios de las huellas y rastrilladas de Talmest.

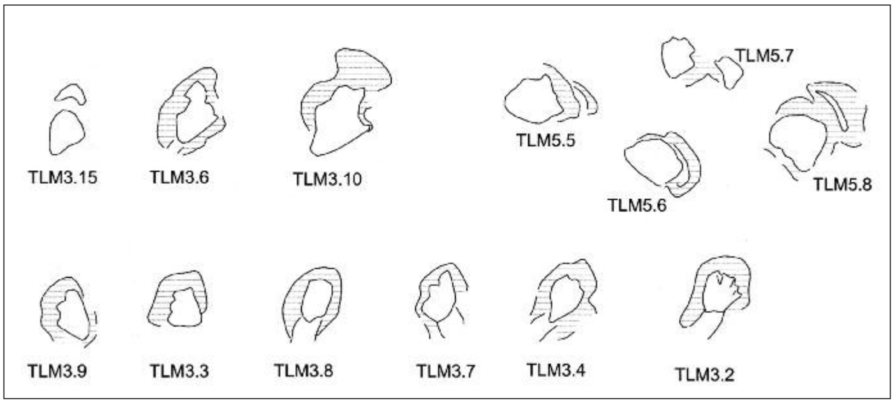

Fig. 5.- Some of the sauropod footprints of the Talmest tracksite. Rims are the hatched area.

Fig. 5.- Algunas huellas saurópodas del yacimiento de Talmest. El rayado son las rebabas.

footprint types: larger posterior (pes), and a smaller anterior (manus) print of various shapes (Fig. 5). The manus print depends mainly on the distortion produce by the pes print (Fig. 5). Separate manus traces (TLM3.15, TLM5.7) are anteriorly convex in to posteriorly concave towards (Fig. 5). The pes print is wide. The degree of overstepping of the pes on the manus is variable (Fig. 5, TLM5.8, TLM5.6, TLM5.5, TLM3.6) so that some manus prints are obliterated and its existence is deduced by the excessive length of the anteriorly-extruded mud (TLM3.10). It is inferred, in the rest of TLM3 and TLM5 footpirnts, that the overlapping pes completely overstepped the manus, as in some pes-only sauropod trackways (Casanovas *et al.,* 1995).

Manus prints show no signs of depth variation. The degree of overlap of pes on manus prints is variable in these trackways. It is therefore logical that these prints are related to the anatomical constitution and limb movements, i.e. related to relationships between the stride length, the type of gait (progression), the limb lenght, and the glenoacetabular distance.

The pes print outline (Fig. 5) is asymmetric (TLM3.15, TLM3.9, TLM3.6, TLM5.7), and on the inner side it is straight and subparallel to the midline. They have three distally located lateral projections interpreted as toe marks (Fig. 5,TLM3.9, TLM3.3). The rear toe mark is located in the middle lateral part of the ichnite producing a prominent projection outside in the centre of the footprint. The manus tracks, without anteriorly-projecting digit traces, are only reported for sauropod and stegosaur footprints. But the lateral placement of the toes in pes prints is only found in the tracks of sauropod dinosaurs.

The small to medium footprint size is not a diagnostic character in quadrupedal dinosaurs. The low value of the pace angle (Ap), the relative wide gauge (Ar/a) of the trackway, and the thick limbs, are typical of *Brontopodus* (Farlow, 1992). The walking gaits of the two trackways were very low.

Conclusions

The discovery of the Talmest dinosaur tracksite in important because dinosaur tracks have not formerly been found in the Lower Cretaceous of North Africa sediments. The present discovery is therefore an important addition to the global ichnological record because:

a) It is the first report of Early Cretaceous theropod footprints of Morocco and Africa.
b) It is the second case of dinosaur footprints discovered in the Lower Cretaceous in Africa.
c) It is one of few examples showing the transition between two patterns of sauropod trackways: those with impressions of manus and pes, and those "pes only" trackways. In the trackways we can see that the lack of manus tracks is not due to not being registered but to obliteration by the superposition pes prints.

Acknowledgements

This is a contribution to the cooperative programme Volubilis MA/09/208 of geological studies conducted jointly by the universities of Ibn Zohr (Agadir), Lyon 1, and Strasbourg.

References

Ambroggi, E. and Lapparent, A.F. (1954). *Notes du Service Géologique du Maroc*, 10, 43-57.

Boutakiout, M., Masrour, M., Ladel, L., Diaz-Martinez, I., and Perez-Lorente, F. (2010). *Geogaceta*, 48, 91-94.

Casanovas, M.L., Fernández, A., Pérez-Lorente, F., and Santafé, J.V. (1995). *Ciencias de laTierra*, 18, 33-44.

Dejax, J., Michard, J., Brunet, M., and Hell, J. (1989). *Neues jarhbuch für Geologie und Paläontologie Abhandlungen,* 178, 85-108

Farlow, J.O. (1992). *Zubía*, 10, 89-138

Jacobs, L., Flanagan, K., Brunet, M., Flin, L., Dejax, J., and Hell, J. (1989). In: *Dinosaur tracks and traces*. (D.D. Gillette and M.G. Lockley, Eds.) Cambridge University Press, 349-351.

Martill, D., Ibrahim, M., Brito, P., Baider, L., Zhouri, S., Naish, D., Loveridge, R., and Hing, R. (2011). *Cretaceous Research*, 32, 433-466.

Marty, D., Strasser, A., and Meyer, C.C. (2009). *Ichnos*, 16, 127-142.

Nouidar, M. and Chellaï, E.H. (2001). *Cretaceous Research*, 22, 93-104.

Nouidar, M. and Chellaï, E.H., (2002). *Sedimentary Geology*, 150, 375-384.

Nouri, J., Díaz-Martínez, I., and Pérez-Lorente, F. (2011). *PLoS ONE* 6(12): e.2682.doi:10.1371/journal.pone.0026882.

Pérez-Lorente, F. (2001). *Los dinosaurios y sus huellas en La Rioja. Paleoicnología*. Fundación Patrimonio Paleontológico, 227 p.

Plateau, H., Giboulet, G., and Roch, E. (1937). *Comptes rendues sommaires Séances Société Géologique de France,* 241-242.

Rey, J., Canerot, J., Peybernes, B., Taj-Eddine, K., and Thieuloy, J.P. (1988). *Cretaceous Research*, 9, 141-158.

Romero-Molina, M.M., Pérez-Lorente, F. and Rivas, P. (2003). In: *Dinosaurios y otros reptiles mesozoicos en España* (F. Pérez-Lorente, Coord.), *Ciencias de la Tierra*, 26, 13-32.

Thulborn, R.A. (1990). *Dinosaur Tracks*. Chapman and Hall, 410 p.