



# A Middle Jurassic sauropod tracksite in the Argana Basin, Western High Atlas, Morocco: an example of paleoichnological heritage for sustainable geotourism



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## ARTICLE INFO

### Article history:

Received 13 June 2013

Received in revised form 17 September 2013

Accepted 25 September 2013

Available online 21 October 2013

### Keywords:

Geoheritage  
Dinosaur footprints  
Geotourism  
Middle Jurassic  
Morocco

## ABSTRACT

A Middle Jurassic site at Tafaytour area (Argana Basin, Morocco) with trackways of six large sauropod dinosaurs is regarded as having high scientific and touristic value. The new dinosaur track site is extremely vulnerable, and suffers from continuous degradation caused by weathering and human activity. Documentation and protection of this tracksite is still a necessity for its integration into local geotourism activities, where it may have a socio-economic impact on the local population. Taking into consideration many similar tracksites, and strata of great paleontological interest in Morocco, including the Tafaytour tracksite, the implementation of legislation for the protection of Morocco's geological heritage, especially the paleoichnological heritage, to protect against destruction, is strongly recommended. This is necessary to cement geoheritage impact, both for scientific reasons and to value add to the socio-economic activities of the local people.

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## 1. Introduction

Morocco is known for its rich natural heritage and its geological, structural and paleontological diversity. The country is rich in a large variety of fossils: trace fossils to body fossils, invertebrates to vertebrates, foraminifera to dinosaurs. It is also extremely rich in mineral resources, from precious metals such as gold and silver to its immense phosphate-rich basins. This geodiversity stems from its fortuitous geographical position on the northwestern edge of the West African Craton, to the northwestern extremity of the African continent, and on the edge of two African and Eurasian plates (Michard et al., 2008). For the last 250 million years, Morocco's history has been influenced by the Tethys Sea and latterly, since 180 ma, by the opening of the Atlantic Ocean (e.g. Hsü, 1971).

In recent years Morocco has witnessed several discoveries of trace fossils from extensive outcrops of Permian, Triassic, Jurassic and cretaceous strata (Klein et al., 2010, 2011; Voigt et al., 2010, 2011a,b; Lagnaoui et al., 2012a,b; Masrour et al., 2013), all adding considerably to the wealth of paleontological data provided by Morocco's abundant body fossils.

The record of African dinosaur tracksites is sparse in comparison to the numerous occurrences in North America and Europe. Since the first discovery of dinosaur footprints in Morocco (Plateau et al., 1937), dinosaur tracks have attracted the interest of scientists. Some discoveries have under-gone 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). In Morocco, a few dinosaur tracksites have been reported since the 1930s located in the western part of the Iouaridène Valley near Taghbalout village in the Central High Atlas Mountains, around 120 km E of Marrakech (Plateau et al., 1937). Jenny et al. (1981) reported the occurrence of dinosaur tracks from Middle Jurassic red beds in the Tafaytour area, which is situated approximately 14 km WSW from Imi-N-Tanoute town, in Western High Atlas Mountains. Dinosaur footprints were reported from the Jurassic of Midelt by Monbaron et al. (1985) in the 1980. Year after that is Sereno et al. (1996) reported dinosaur footprints from the Cretaceous Kem Kem beds, and taxonomically studied by Belvedere et al. (2013). More recently, the first dinosaur tracks from the Early Cretaceous strata in Morocco and the second in Africa was described by Masrour et al. (2013), in Western High Atlas near Imi-N-Tanout village.

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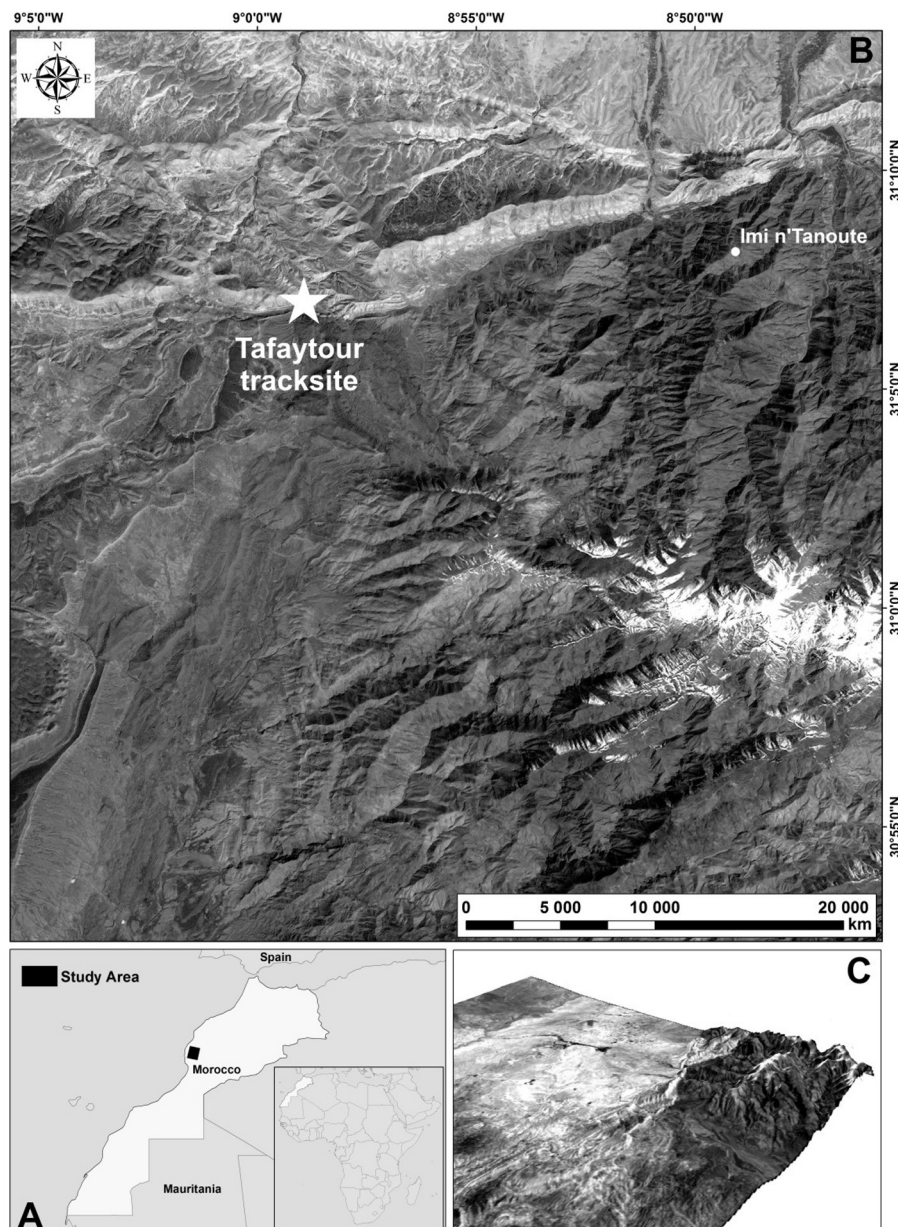
More and more paleontological and geological sites are now identified and afforded protection under conservations schemes such as Geoparks and Paleoparks (Lipps, 2009). There is an increasing use of fossil sites in educational tourism with an overwhelming popularity of dinosaurs in the media (TV, movies, novels, etc., e.g. Haste, 1993; Torrens, 1993). Paleontological and geoheritage sites continue to attract considerable attention, for instance, in North America, Europe and China, with more than 100 paleontological sites preserved and made accessible for visits (Lipps, 2009). Whereas research and studies on the evaluation of dinosaur tracksites in Morocco still in its infancy, recently, one study has highlighted the importance and vulnerability of a paleoichnological site heritage in the Central High Atlas (Díaz-Martínez et al., 2010). Sustainable geotourism is becoming more and more an important component in the world socio-economy including that based on paleoichnological heritage. Geotourism demonstrably generates revenue and jobs for local and indigenous populations, often including some of the poorest members of those societies, as well as

conserving natural, geological and cultural heritage. The use of geological heritage, especially vertebrate paleoichnological heritage as touristic and didactic sites, everywhere is a benefit for the local people and promotes scientific knowledge and education.

In the present study, we highlight one of the dinosaur paleoichnological heritage sites in Morocco that has contributed significantly to education and the development of geotourism. Furthermore, we recommend several actions to protect and preserve this Dinosaur tracksite, which should be an example for all other vertebrate paleoichnological sites in Morocco.

## 2. Geological setting

The Argana Basin is situated between Marrakech and Agadir at the southwestern edge of the High Atlas mountain range in central Morocco (Fig. 1). The basin is about 20 km wide and 70 km long, defining a NNE–SSW trending area of excellently exposed Permian, Triassic and Jurassic continental deposits (Tixeront, 1973). The



**Fig. 1.** Location and geomorphological overview of the sauropod tracksite of the Tafaytour area, Morocco (extract from Landsat ETM+ image). (A) Location of the studied area. (B) Position of the described Tracksites in the Argana Basin (31°07'00" N, 08°58'57" W). (C) 3D geomorphological overview of the studied area.

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