Dinosaur track sites from Portugal: Scientific and cultural significance

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ABSTRACT - Dinosaur tracks in Portugal are known from Bajocian-Bathonian (Jurassic) through middle Cenomanian (Cretaceous) rocks. The Portuguese track record includes two outstanding Middle Jurassic track sites both in Central W Portugal: the Vale de Meios track site, showing dozens of parallel theropod trackways, and the Galinha site, where several long sauropod trackways can be seen. There are two other major areas with important dinosaur track sites: SW Algarve (S Portugal), Lower Cretaceous, and the Sesimbra region (Central W Portugal), Upper Jurassic-Lower Cretaceous. Huge track sites such as the Vale de Meios and Galinha sites can not be excavated and removed into museums; therefore, they must be preserved *in situ*, to be studied and visited in their original geological context. Track sites such as these are important not only for their scientific, ichnological, significance; they are also valuable for science popularization and to stimulate public interest for the preservation of the geological/palaeontological heritage. In Portugal, in 1996 and 1997, five dinosaur track sites have been declared natural monuments. In such sites it is possible to teach and show Palaeontology, as well as other aspects of Earth sciences in their original geological context, to children from different school levels and to a broad public with different scientific backgrounds. Educational programmes for school children and the general public are paramount in order to elucidate them about dinosaurs and their tracks, but also to improve their attitude towards the scientific and cultural value of this palaeontological ichnoheritage. Educational activities are essential to the success of geoconservation. They boost public awareness, which, in turn, is fundamental for the protection and valorisation of the geological and palaeontological heritage. When local communities are conscious of the scientific and cultural value of the natural heritage in their home region they become proud of it and this fact dramatically increases the odds of its effective protection. Nevertheless, up until now the Galinha track site is the only Portuguese track site prepared to receive visitors and to offer them palaeontological educational programmes.

Keywords: *Dinosaur, track sites, geoconservation, palaeontological ichnoheritage, exomuseum, educational centre, Portugal.*

INTRODUCTION

The oldest known scientific reference to dinosaur tracks in Portugal goes back to Gomes (1915-16). In this posthumous publication, Gomes reported the discovery, in 1884, of an Upper Jurassic bed containing dinosaur footprints at Pedra da Nau beach, Cabo Mondego (Cape Mondego) area, 2 km north of Buarcos (Figueira da Foz, Central Portugal) (fig. 1). This early report is one of the first references to the excavation and the study of dinosaur tracks in the world. The remarkable Cabo Mondego Upper Jurassic sequence encompasses the Aalenian-Bajocian stage boundary, making it a geosite of global significance, part of the World Geological Heritage (e.g. Pavia & Enay, 1997; Rodrigues et al., 2002).

Currently, in Portugal, dinosaur footprints are known from no less than twenty Middle Jurassic through Upper Cretaceous track sites. Many of these sites show several track levels, and their study yielded relevant data to the understanding of dinosaur palaeobiology. The Portuguese ichnological record includes some of the longest and best preserved sauropod trackways known worldwide, showing exceptionally preserved manus and pes impressions. One track site – Pedra da Mua, Upper Jurassic, Sesimbra region – yielded a compelling evidence of sauropod herding behaviour, including an example of herding among juvenile sauropod dinosaurs; other track sites – in the same location – revealed evidences of limping behaviour in dinosaurs; yet another – Vale de Meios track site – shows dozens of theropod tracks in a single track level, most of them belonging to animals travelling in the same direction (e.g. Dantas et al., 1994; Lockley & Santos, 1993; Lockley et al., 1994; Santos et al., 1994b, 2000a).

In addition to their outstanding scientific importance, some of these occurrences are privileged sites for geoscience popularization, having the potential to become exceptional geological and palaeontological education centres. Indeed, five of these sites have already been declared Natural Monuments under Portuguese law (namely Galinha, Carenque, Lagosteiros, Pedra da Mua and Avelino track

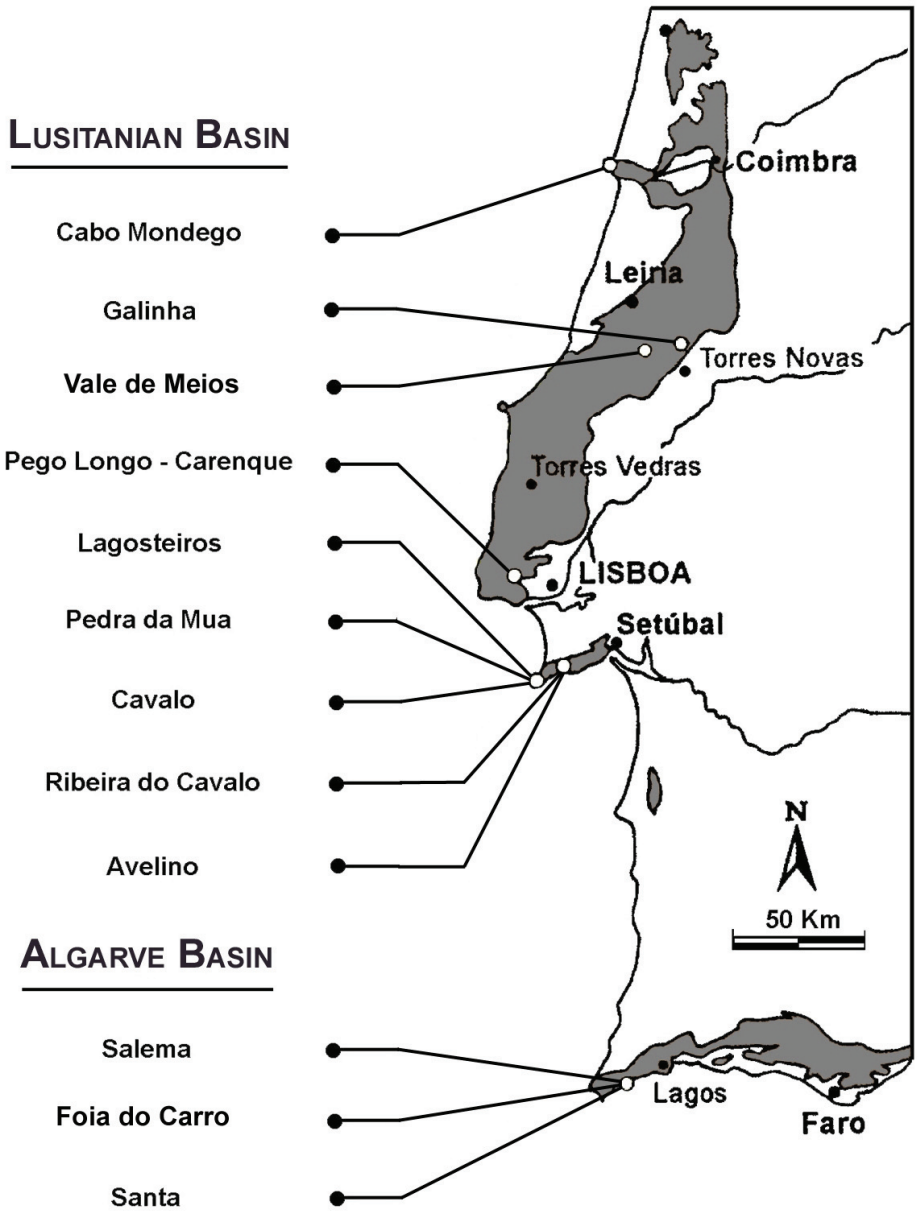


Figure 1 – Location of the main Portuguese tracksites in the Lusitanian (West Portugal) and Algarve Mesozoic basins (South Portugal).

sites) clearly reflecting their scientific, educational and cultural relevance. Nevertheless, so far, only the Galinha track site boasts operating educational programs and facilities capable of receiving and orientating visitors.

Fossils, the fossils of dinosaurs in particular, have always captured the public's interest. This characteristic of fossils may and should be used to enthral public attention and to focus it, also, on general geological aspects and on geoconservation issues. The Palaeontological Heritage is, therefore, a powerful driving force for geoconservation (Cachão et al., 1999). The pride of local populations in their ichnoheritage fuels geoawereness and boosts their interest for geoconservation. This is crucial for effective site protection. Geoconservation-wise, this "geocultural identification" factor is more effective for the protection of the sites than the mere knowledge of their abstract scientific importance.

RELEVANT PORTUGUESE DINOSAUR TRACK SITES

Portuguese dinosaur track sites are mainly located in the Lusitanian basin (Western Portugal), and only three in the SW tip of the Algarve basin (S Portugal) (fig. 1). The Middle Jurassic track record is represented by Galinha and Vale de Meios track sites. Upper Jurassic dinosaur tracks are well documented at Figueira da Foz (Cabo Mondego track site), Sesimbra (Avelino and Ribeira do Cavalo track sites) and Cabo Espichel (Cavalo and Pedra da Mua track sites). In the Algarve basin it is known one Upper Jurassic track site at Foia do Carro bay, near Vila do Bispo village. Lower Cretaceous track sites are also known on the top of the cliff that borders the northern side of the small bay of Lagosteiros at Cabo Espichel (Lagosteiros track site) and near Óbidos

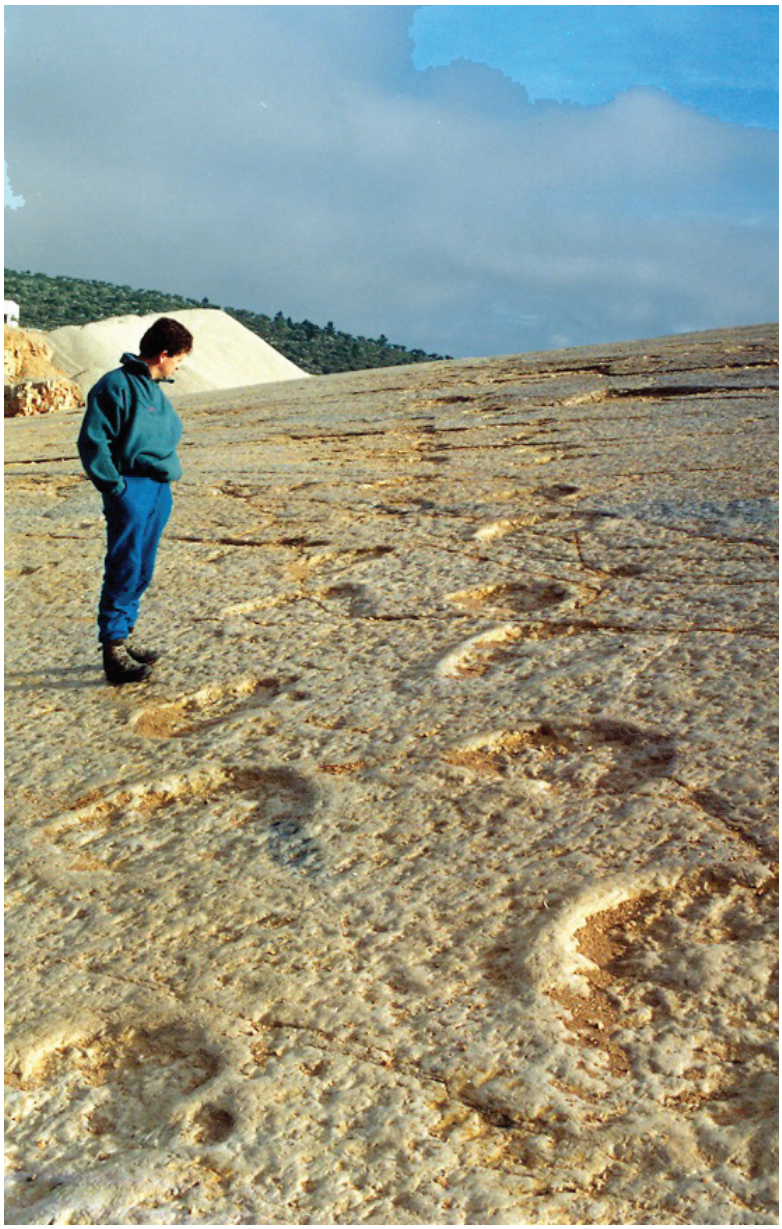


Figure 2 – Wide-gauge sauropod trackway at Galinha track site (Bajocian-Bathonian, Ourém - Torres Novas, Portugal).

(Olhos de Água track site, Mateus & Antunes, 2003) and in the Algarve: Salema and Santa track sites (Vila do Bispo). The Upper Cretaceous dinosaur track record is represented by the Carenque track site.

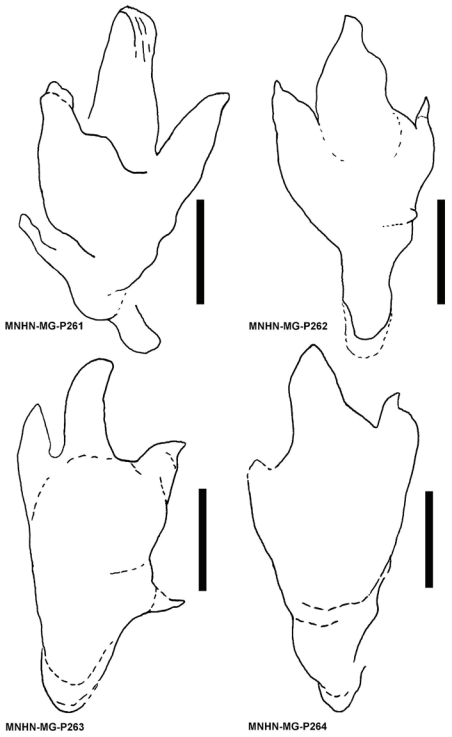
The Galinha track site

The Galinha track site is situated at a former limestone quarry near Fátima, on the eastern side of Serra d'Aire (West-Central Portugal), 120 km north of Lisbon. Several long sauropod trackways were discovered in the Galinha site in 1994 by João Carvalho, of the Torres Novas Speleological and Arqueological Society.

The tracks are located on 40.000 m^2 bedding surface, especially cleaned for their study with the cooperation of the former quarry owner Rui Galinha and the collaboration of the natural park Parque Natural das Serras d'Aire e Candeeiros (PNSAC). The site can be accessed without difficulty. The track level is located on a sub-horizontal bedding plane and displays long and visually spectacular wide-gauge sauropod trackways composed of sauropod pes and manus prints quite deeply impressed (Fig. 2) that can be easily observed from the high ground surrounding the former extracting area of the quarry. The wide-gauge long sauropod trackways are preserved on Middle Jurassic (Bajocian-Bathonian) limestones (Azeredo *et al*., 1995) and some consist of manus impressions only. In this track site are noticeable very well preserved sauropod manus and pes print morphologies (Santos *et al*., 1994b). Manus impressions reveal clear traces of digit I. The manus/pes area ratio is 1/2 and is different from ratios ranging up to 1/3 or 1/5 in other sauropod tracks suggesting a unique type of footprint (Santos et al., 1994b).

Figure 3 (left) – Theropod footprints at Vale de Meios track sites (Bathonian, Santarém, Portugal). Photograph by Luis Quinta.

Figure 4 (below) – Tetradactyl theropod footprints at Cabo Mondego track site (Oxfordian, Figueira da Foz, Portugal) (Lockley et al., 1996).



Since the Middle Jurassic dinosaur track record, and especially the sauropod track record, are poorly known (e.g. Clark et al., 2005; Clark & Barco Rodriguez, 1998; Day et al., 2004; Kvale et al., 2004; Lockley et al., 2007), the Galinha track site represents a considerable source of information on the Middle Jurassic sauropod palaeobiology.

The Vale de Meios track site

In 1998 several theropod dinosaur trackways were identified at Vale de Meios by Maria da Glória Araújo, Luís António Ferreira and António Frazão of the natural park Parque Natural das Serras d'Aire e Candeeiros (e.g. Santos *et al*., 2000a; Santos, 2003; Santos & Rodrigues, 2003). This site, situated near Alcanede village (Santarém, Central Portugal), is located in a working quarry extracting limestone of Bathonian age from the Maciço Calcário Estremenho (Estremenho Calcareous Massif) sedimentary formations. This track site, with an area of about 10.000 m^2, shows dozens of trackways (fig. 3), several of them displaying parallel displacement directions (Santos et al., 2000a; Santos, 2003; Santos & Rodrigues, 2003).

The Vale de Meios track site is presently under study. The ichnological survey is under way and the surface map of the site is currently being drawn in order to support its paleobiological and paleoecological interpretation. Preliminary research at Vale de Meios showed that it contains the most significant example of Middle Jurassic theropod footprints and trackways in Portugal. These trackways provide key evidence of theropod foot structure, locomotion and behaviour.

Theropod trackway-wise, the Middle Jurassic is a poorly known episode of geological history; therefore new discoveries are particularly important. The research at Vale de Meios track site will provide an important contribution to the knowledge of Middle Jurassic dinosaur communities and, therefore, its future preservation is crucial.

This site has good natural conditions to receive school children and the general public with little investment in basic infrastructures. The track site is easily accessible, and the tracks are located on a horizontal bedding surface.

The Cabo Mondego track site

This dinosaur track site is situated at Cabo Mondego, close to Figueira da Foz city. This was the first dinosaur

track site discovered and studied in Portugal. At Cabo Mondego, Gomes (1915-1916) described large theropod tetradactyl footprints preserved as natural casts in Upper Jurassic deposits (Oxfordian). The morphology exhibited by these tracks is characterized by a long digit I mark and a metatarsal impression (fig. 4). These theropod tracks were attributed to the ichnospecies *Megalosauripus lusitanicum* (Lockley et al., 1996, 1998). At this track site, at least eight stratigraphic levels with theropod tracks were identified (Santos, 2003).

The Sesimbra - Espichel Region track sites

Between the locality of Sesimbra and the Cabo Espichel (cape Espichel) region, near Setúbal, five dinosaur track sites, comprising at least twenty different track levels, have been identified (fig. 1). These sites are: the Avelino and the Ribeira do Cavalo quarries, at Zambujal village, near Sesimbra, and the Cavalo, Pedra da Mua, and Lagosteiros sites in the Cabo Espichel area. Avelino, Pedra da Mua and Lagosteiros track sites were declared natural monuments on the basis of their scientific value, the exceptional natural scenery surrounding them and the potential to host educational programmes and pedestrian tours to visit dinosaur tracks.

At the Avelino track site, on Kimmeridgian limestones, narrow-gauge sauropod trackways were described (fig. 5), and assigned to *Parabrontopodus* isp. (Lockley & Santos, 1993). These trackways reveal the passage of five different sized sauropod trackmakers (pes prints length ranging from 30 to 100 cm) travelling separately in different directions.

Until the discovery of Vale de Meios track site, in 1998, well preserved theropod trackways where known only from the Ribeira do Cavalo quarry on a vertical bedding surface of Oxfordian-Kimmeridgian age (Lockley et al., 1992). Here, a manus dominated sauropod trackway with digit impressions was also described and a manus replica was made (Lockley et al., 1992). The site collapsed in 1995, due to lack of protection, destroying all the track records existing there (Santos et al., 1995).

In the coastal cliffs between Cabo Espichel and Lagosteiros bay (SW Setúbal) there are several dinosaur track levels in a stratigraphic sequence of Portlandian age (Upper Jurassic).

The Praia do Cavalo (Cavalo beach) is a track site located immediately to the South of Lagosteiros bay. In this site a trackway of a large theropod has been recorded and it was recognized a limping gait (Dantas et al., 1994).

At Lagosteiros bay, the cliff beneath the Sanctuary of Cabo Espichel, known as the Pedra da Mua track site, reveals at least eight levels with 38 sauropod trackways and two theropod trackways (Lockley et al., 1994). Sauropod trackways are all wide-gauge (*Brontopodus* type) and show well-preserved Upper Jurassic *Brontopodus* footprint specimens, showing four claw marks (Meyer et al., 1994). In one of the Pedra da Mua track levels, seven parallel sauropod trackways, showing the same travel direction, were recognized and described. These trackways are composed of footprints having similar sizes and depths (footprint length ranging from 38 to 46 cm). The analysis of these parallel trackways revealed that their producers were travelling at similar speeds (Lockley et al., 1994). Along these trackways three other trackways of larger animals, with footprint length ranging from 70 to 73 cm, progressing in the same direction may be observed (Lockley et al., 1994). This record represents the first compelling evidence of sauropod gregarious behaviour in the European track record and an interesting example of herd behaviour among young sauropods (Lockley et al., 1994). At Pedra da Mua track site there is a sauropod trackway with irregular pace length which is another example of a limping gait revealed in a dinosaur trackway (Dantas et al., 1994; Meyer et al., 1994).

The Lower Cretaceous (Hauterivian) Lagosteiros track site was discovered in 1971 on the top of the cliff north of Lagosteiros bay (Antunes, 1976). The most prominent feature of this track site is a long sequence of poorly preserved subcircular impressions, with similar size and depth, attributed to a bipedal animal, probably an ornithopod (e.g. Santos et al., 1992a; Santos, 2003). The site also shows several tridactyl impressions of small theropods, but only one short trackway is identifiable. In this theropod trackway it is possible to estimate a displacement speed value of about 14 km/h. This is the sole evidence of a fast moving dinosaur in the Portuguese track record (Santos, 2003).

Portuguese Lower Cretaceous track sites are also known from the coastal area of Óbidos (Central-West Portugal), 80 km north of Lisbon. Several theropod and ornithopod dinosaur trackways have been described from this site. For further information and location map see Mateus & Antunes (2003).

The Algarve Region track sites

In 1992 and 1995 the first dinosaur osteological and ichnological remains were found in the Algarve Mesozoic Basin at the Praia de Porto de Mós (Porto de Mós beach, Lagos), and at Praia da Salema (Salema beach), close to Vila do Bispo, respectively (Santos et al., 2000b,c; Santos, 2003). Since then, two more algarvian track sites were identified and documented.

At Porto de Mós beach, in a layer of Aptian age (Gargasian/Clansayesian, according to Rey 1983) dinosaur teeth and longitudinal sections of vertebras were recognized (Santos et al., 2000b).

At the Salema track site two track levels were recognized on beds of Barremian age (e.g. Santos, 2003). The western track level reveals an ornithopod trackway. The best preserved footprint in this trackway displays the characteristic morphology of iguanodontid footprints. To the East of this slab, another track level was found with seven isolated theropod footprints.

Other Lower Cretaceous dinosaur track levels were found at Praia Santa (Santa beach), to the West of Salema

Figure 5 – Narrow-gauge sauropod trackway at Avelino track site (Upper Kimmeridgian, Sesimbra, Portugal). Photograph by Luis Quinta.

beach (Santos *et al*., 2000c). The main level revealed at least four bipedal trackways and isolated footprints. The well preserved prints in Santa track site reveal the characteristic iguanodontid morphology and their similarity with the prints attributed to *Iguanodontipus* isp. allows their assignment to this ichnogenus (Santos, 2003; Santos et al., 2000c). Until now, it was recognized the presence of iguanodontid and small unidentified theropods in the Lower Cretaceous of the Mesozoic Algarve basin (Santos et al., 2000b,c).

Sauropod trackways were also identified in two Upper Jurassic levels at Foia do Carro track site, close to Vila do Bispo village (e.g. Santos, 2003; Santos et al., 2000b).

The Carenque track site

The most recent dinosaur track site in Portugal is situated at Pego Longo (also known as Carenque), approximately 12 km NW of Lisbon, and it is Cenomanian in age (Upper Cretaceous). It was discovered in 1985 (Coke & Monteiro, 1986) and reveals theropod trackways and a single long trackway of a large bipedal animal. When first described, this trackway - with a total length of 127 m - was deemed the world's longest dinosaur trackway known (Santos et al., 1991, 1992a, b). This long bipedal dinosaur trackway is the main ichnological feature of the Carenque track

site. The trackway is composed of a sequence of subcircular impressions without morphological details. It displays some unusual features of preservation, making it difficult to identify the trackmaker, however the pace angulation criterion suggests the attribution of this trackway to a bipedal dinosaur (Santos et al., 1992a).

PORTUGUESE DINOSAUR ICHNOHERITAGE

Pioneer campaign to preserve the ichonological heritage

The study of a long dinosaur trackway at Carenque (Pego Longo) track site initiated the pioneer task of protecting the Portuguese ichnoheritage (e.g. Cachão et al., 1998; 1999; Galopim de Carvalho, 1989; 1994; 1998; Galopim de Carvalho & Santos, 1992a,b; Galopim de Carvalho et al., 1996; 1998; Santos et al., 1991; 1992a,b; 1994a; Silva et al., 1998). The Carenque site was located exactly in the path of a motorway construction project and, therefore, destined to be destroyed. This circumstance started, in 1992, the so-called Battle of Carenque (Galopim de Carvalho, 1994). The scientific community started a joint effort to promote public awareness, to inform the public of the dinosaur footprints scientific and ichnoheritage potential. In the end, the involvement of the population and the local authorities was crucial for the geoconservation of this site.

In response to the overwhelming public interest on this site, the Portuguese Government was compelled to take action in order to protect the site from destruction. President Mário Soares, first, and the Portuguese Government, later, voted unanimously to preserve the site from destruction, by building a tunnel beneath it. In order to build the tunnel under the site, in 1993, the main Carenque trackway, as a protection measure, was covered. After the spur of the moment, unfortunately, the trackway remained covered and, therefore, unavailable for researchers and for the general public. The Carenque site, after all these years, still awaits a recovery programme.

In 1994 the discovery of Galinha track site was announced and its scientific importance and spectacular setting within a Natural Park gave it immediate international significance. Though having been discovered later, the Galinha track site was declared Natural Monument even before the classification of the Carenque site, in 1996. The Carenque site, now renamed Pego Longo track site, was declared Natural Monument in 1997 and became an international reference of a campaign to preserve Portuguese palaeontological heritage (Galopim de Carvalho, 1994).

In 1997, three track sites from the Sesimbra – Cabo Espichel region were also declared Natural Monuments: Pedra da Mua, Lagosteiros and Avelino sites. However, until now, the Galinha track site is the sole site prepared to receive visitors interested in learning about dinosaur footprints in Portugal.

The Galinha track site - an example of an educational centre

Since 1996, when the Galinha track site was classified as a Natural Monument, a geological, palaeontological and environmental education centre has been developed there. Indeed, to endorse and to protect the natural geoheritage it is necessary to create appropriate legislation but, more important, to promote educational programs for school children and the general public, in order to promote their geoawareness and improve their attitude towards the scientific and cultural values of this heritage (Santos et al., 2001; Cachão et al., 1999). The Galinha track site is equipped to receive visitors and in the last year alone nearly 50,000 people visited the site and took part in the site's educational activities. Visitors include school children, national tourists as well as tourists from all over the world, and national and international geosciences congresses participants. In the site, several educational activities are offered to the public that do not exist in other track sites, such as following a dinosaur trackway, measuring it, deducing the mode of displacement of the trackmaker - bipedal or quadruped - and calculating its size and speed.

The facilities and activities available on the site to receive visitors include a hall with a video room for the viewing of educational videos, guided tours and autonomous pedestrian trails with outdoor informative panels through out the entire track site perimeter (fig. 6), restrooms, picnic area, children playground, as well a dinoshop with educational products and publications on dinosaur tracks and nature issues.

Scientific data obtained from the study of the Galinha track site is periodically integrated in palaeontology popularization publications, making new scientific developments in dinosaur ichnology available for the general public. A natural size sauropod model is on display on the site, allowing the visitors to actually see how the presumed trackmakers looked like. A "Jurassic" botanical garden has been created, using plants of botanical groups known to having lived in Jurassic times, and a huge mural of the history of life on earth was painted there.

In addition to the sauropod trackways, in the Galinha site, several geological elements and structures may also be witnessed: e.g., limestones, stratification, faults, karst, minerals (calcite and pyrite) and invertebrate somatofossils (i.e., body fossils).

Dinosaurs have always fascinated young people. The track site may be used as an open air "class room" where dinosaurs and their tracks can be used to show how Geology, Physics, Chemistry, Biology, Ecology and even Mathematics may and should be used to analyse and understand palaeobiological issues. In the site it is possible to teach Palaeontology, as well as other geological disciplines, for different school and scientific levels. Several concepts can be combined in a single guided visit: earth history; palaeoenvironments; different types of geological structures and how they

Figure 6 – Autonomous pedestrian trails are supported by outdoor informative panels throughout the entire Galinha track site perimeter.

were formed; karst; sedimentary rocks (limestones) and their origin; environmental impact of human activities; possible ways of dealing with the negative impact of quarrying activities in the landscape.

The quantity and the quality of the dinosaur tracks preserved here allow us to understand life in past geological Eras and turn this site into a place of rare interest for environmental education, for promoting educational actions which may contribute to instil respect for nature and the natural heritage. All the aspects stated above, combined with an easy access to the track site, and a mild climate, give this place a high potential for tourism, and make it possible to use it as an open air museum, an "exomuseum".

Other sites and other activities

Several other dinosaur track sites in Portugal have high educational and tourist potential but, up until now, none of them is prepared to receive visitors and to be enjoyed by the general public all year round autonomously, as it is possible to do at the Galinha educational centre. However, public institutions such as the National Natural History Museum of Lisbon University as well as independent science associations regularly organize fieldtrips to these sites.

Another strategy that allows the general public to visit places where they can observe geological and paleontological features, namely dinosaur track sites such as those in the Algarve, is the programme "Geology in the summer". This programme is part of a national campaign which takes place every year during the summer period, from July until September, promoted by Agência Ciência Viva (Live Science Agency), the Portuguese national agency for scientific and technological culture. The activities of Ciência Viva are the contribution of the Portuguese Ministry of Science and Technology to the promotion of scientific culture among the Portuguese population.

The programme "Geology in the summer" started in 1998 and includes, every year, dozens of different geological activities, promoted by Portuguese universities, museums and independent science associations. Concerning Palaeontology, these activities comprise indoor activities in museums but mostly outdoor visits to fossiliferous sites guided by trained palaeontologists and geologists, nature walks to observe fossils and geological features *in situ*, and even city walks, e.g., the activity "Fossils on your door step" (Silva & Cachão, 1998), to observe and interpret fossils trapped in building material in Lisbon – fossils of rudists, corals, gastropods, invertebrate ichnofossils, etc., literally entombed within the stone used in buildings – and small outcrops still preserved within city limits. Another Geology in the Summer activity – GPS_Geologia por Satélite (GPS_Geology and Satelites) – encourages autonomous visits to track sites

in the Sesimbra-Cabo Espichel region by giving the participants – in a specifically created web site (Silva, 2007) – the geographic coordinates of the track sites to be found with the aide of a personal GPS in a virtual geocache (or earthcache) mode. The web site also provides additional information about the outcrops and how to behave adequately in the field, in order to warrant a safe and meaningful visit and to promote geoawareness, ensuring the long term preservation of the track sites. The participants are asked to provide proof of their visit to the sites (by means of a digital photo taken on the spot) and receive, as a prize for their successful participation, additional information and educational materials produced by the National Natural History Museum and the Geology Department of the University of Lisbon.

In other European countries there are many track sites where the general public can observe dinosaur tracks and trackways in their geologic context.

Some of them are easily accessible places located along the shoreline, where the visitors may find dinosaur tracks as natural casts lying loose on the beach or preserved *in situ* on the bedding surfaces of cliffs, such as the sites along the south coast of the Isle of Wight in the UK (e.g. Martill, 2000).

The Ardley quarry, for example, in Oxfordshire in the UK, displays hundreds of dinosaur footprints but does not have public access and permission is required before visiting the site (Powell, 2003).

Other dinosaur track sites are linked to local museums. In these sites there are organized walking trails and interpretative panels that allow visitors to enlighten themselves about aspects of local geology and paleontology. This is the case of track sites such as Lavini di Marco in Italy (e.g. Avanzini, 2002), Asturias coastline and La Rioja province in Spain (e.g. García-Ramos *et al*., 2000; Moratalla *et al*., 1997), Isle of Skye in Scotland, UK (e.g. Clark *et al*., 2005).

An European dinosaur track site with a project similar to the Galinha exomuseum may be found at Münchehagen, near Hannover, in Germany (Dinosaurierpark Münchehagen). In this site dinosaur tracks are protected and are integrated in the museum as an outdoor museum.

Sites like the Courtedoux track site in northwestern Switzerland and the Coisia track site (eastern France; e.g. Le Loeuff et al., 2006) also have scientific, educational and tourist potential to become outdoor museums.

Geoconservation – effective protection of the ichnoheritage at the Galinha exomuseum

Public interest on dinosaur track sites is high, as demonstrated by the high number of visitors to the Galinha site every year, therefore the impact of such natural occurrences is of paramount importance for geoeducation and for the local economy. The potential of the dinosaur track sites for educational tourism purposes represents an important economical resource to be used with the necessary precautions in order to prevent possible damages due to overexploitation and overexposure of the site.

Indeed, the potential of the Galinha site to attract high numbers of tourists, being located in close proximity to a popular destination for thousands of pilgrims and religious tourists (The Fátima Sanctuary), has already been demonstrated. This circumstance poses real management problems when dealing with an overwhelming number of visitors. In addition we must also consider the effects of the natural erosion of the track surface exposed to weather conditions.

The advantages of scientifically and culturally enjoying such an important natural occurrence imply, therefore, a responsible management capable of preserving the site. Indeed, the management of large track sites, especially regarding the preservation of track surfaces, presents several challenging geotechnical problems. Constructive geoconservation decisions have been made and measures will have to be taken soon to ensure that these track sites will be developed and managed as study sites for scientists, university and school students, and as attractive destinations for the general public from Portugal and from all over the world.

The Galinha track site and other dinosaur track sites have the potential to become a valuable asset to boost public awareness and scientific culture, places where local citizens and authorities bond with their local ichnoheritage, thus ensuring its real protection and adequate management. Indeed, to preserve and to value natural heritage in general it is required more than just protective legislation, it is necessary that the general public (including national politics and local authorities) understands its actual importance and long term implications. This way the fossil record may give an effective and essential contribution to environmental conservation.

FUTURE PERSPECTIVES

In normal circumstances, to observe dinosaur tracks in Portugal with scientific and educational support it is imperative to go to Galinha track site. This geoturistic destination has become so popular that schools and even private travel agencies regularly organize one day excursions, and some of them requiring travelling more than ten hours by bus, to go there and back, to visit the site. Such long travels have obvious inconveniences, especially for young children; therefore it would be useful to have other track sites in the country equipped – at least – with basic infrastructures to receive visitors.

For example, at Vale de Meios track site, 20-25 km SW of the Galinha quarry, deeply impressed tridactyl footprints can be easily followed on a horizontal bedding surface providing an unexpected and exciting opportunity to track Middle Jurassic theropods.

It would be equally useful to promote the accessibility to dinosaur track areas in different Portuguese regions such as the Sesimbra – Cabo Espichel and the SW Algarve area. As an immediate action, it would be of great public and

educational service if local authorities and independent science associations could provide and maintain road and trekking signs to direct visitors to the track sites and the publication of educational material to support autonomous visitors.

Such a multiplication of ichnoturistic destinations would have several beneficial aspects to it, both economical and conservational. It would, for instance, boost local economy and geoawereness in other localities and, by providing alternative destinations, it would help prevent the overexploitation of Galinha track site.

However, even considering the possibility of adding new track sites to the Portuguese visitable sites list in the foreseeable future, on the short term it is essential to undertake direct actions – such as the periodical removal of gravel from the track surface along the visitors trail, in order to minimize erosion, and the overall consolidation of the track surface, namely by filling the existing cracks – for the future preservation of the Galinha track surface.

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