Museu Nacional de História Natural e da Ciência: one hundred years of dinosaur ichnology in Portugal

Vanda Faria dos SANTOS

V.F. Santos, Museu Nacional de História Natural e da Ciência, Rua da Escola Politécnica 58, P-1250-102 Lisboa, Portugal; vsantos@museus.ul.pt

KEY WORDS - Dinosaur Ichnology, Geosite, Geoheritage, Geoconservation, Science Outreach, Portugal.

ABSTRACT - Jacinto Pedro Gomes (1844-1916) was a naturalist at the Mineralogical and Geological Museum of the former Polytechnic School of Lisbon (nowadays National Museum of Natural History and Science - Universidade de Lisboa). His interest in dinosaurs started when he began to study dinosaur tracks from Cabo Mondego (Figueira da Foz) at the end of the 19th century. The Cabo Mondego coalmine administration generously sponsored the campaign to remove the tracks from the outcrop close to the sea and transfer them to the museum in Lisbon. Gomes was a pioneer in studying dinosaur tracks in Portugal and with him the National Museum of Natural History and Science became an important player in the study of Portuguese dinosaur tracksites and their conservation. Indeed, besides the study of the dinosaur footprints from Cabo Mondego, Gomes recognized the importance of rescuing those footprints from ongoing marine erosion. Since Gomes’ pioneer work, many additional dinosaur tracksites were discovered and studied and in the 1990’s five dinosaur tracksites were designated as natural monuments thanks to the efforts of António Marcos Galopim de Carvalho (at the time Director of this Museum). At present, several important tracksites have been protected but they still need a better valorization to further promote the public’s interest for geological and palaeontological heritage. The Avelino tracksite was subject to a museological intervention in 2012, improving its accessibility and allowing autonomous public visits. The Galinha tracksite was protected and made accessible in 1996-1998 but it requires renovation to improve its geoconservation status and assure the in situ preservation of the dinosaur tracks. Also, it is worth keeping in mind that the Galinha tracksite was the first palaeontological site in Portugal, where a geoconservation strategy and unprecedented musealization was applied.


INTRODUCTION

One of the earliest allusions for dinosaur tracks can probably be found in Portugal. The cliffs with huge surfaces on the south side of Lagosteirios bay at Cabo Espichel, near Sesimbra, disclose impressions that caught the attention of fishermen as early as in the 13th century, who most probably assumed that they were the footprints of a “giant mule” that carried the Virgin Mary from the sea to the top of the cliffs (e.g., Mendes, 2014; Pereira, 2014). These footprints, that were only recognized as Late Jurassic sauropod footprints in 1971 (as reported by Antunes, 1976), are the main motif of this religious legend (Mendes, 2014), and where one of the Late Jurassic sauropod trackways of Cabo Espichel, originally recognized as the “giant mule” trackway, is pictured (Fig. 1).

The scientific study of dinosaur tracks in Portugal began one hundred years ago with the pioneer work of Jacinto Pedro Gomes (1844-1916) a Naturalist at the Mineralogical and Geological Museum of the Polytechnic School of Lisbon (nowadays Museu Nacional de História Natural e da Ciência, Universidade de Lisboa - National Museum of Natural History and Science). Gomes (1916) is the first ever study on dinosaur tracks from Cabo Mondego (Figueira da Foz) and constitutes the base and starting point of the important role of this Museum in the study of dinosaur tracksites and their geoconservation. Antunes (1976, 1981, 1990) contributions were the first studies on the dinosaur fauna from Cabo Espichel and the Sesimbra region and the last work presents an illustration by Fátima
Antunes (Antunes, 1990, fig. 3) that is considered the first illustration of a sauropod and its footprints that was produced in Portugal (Santos et al., 2015a).

The research carried out in this area after Antunes was promoted by Galopim de Carvalho, at the time Director of what is today the National Museum of Natural History and Science, who obtained financial support from institutions like Fundação Calouste Gulbenkian and Fundação para a Ciência e a Tecnologia to study dinosaur tracks and for public outreach. The Instituto da Conservação da Natureza e das Florestas (the national institute responsible for the management of protected areas) also supported the initial study of the Galinha tracksite. The municipalities of Sesimbra (Câmara Municipal de Sesimbra) and Ourém (Câmara Municipal de Ourém) were also engaged in public outreach. The public outreach activities were crucial to improve public awareness of the palaeontological and geological heritage and to obtain recognition and the support and commitment of local authorities and governmental departments, to preserve and protect relevant tracksites (e.g., Brilha, 2005; Reis et al., 2014). The contribution of journalists to promote geoheritage and geoconservation issues has also been of fundamental importance.

This new stage of research on dinosaur ichnology began in 1990 and has allowed for the emergence of several scientific publications and a PhD Thesis (e.g., Lockley et al., 1992, 1994a; Lockley & Santos, 1993; Fantas et al., 1994; Meyer et al., 1994; Santos, 2003; Santos et al., 1992) and publications for the public (e.g., Galopim de Carvalho & Santos, 1992; Galopim de Carvalho, 1994; Santos, 2008). All this scientific and public outreach activity on Portuguese dinosaur tracksites coincided in time with the so-called “dinosaur footprint renaissance” (Lockley & Gillette, 1987) and Portugal was a main contributor.

Despite the low financial support over the last ten years to perform scientific research at the Portuguese dinosaur tracksites, they have been the subject of several scientific studies thanks to the collaborative efforts of palaeontologists from different national and international institutions allowing the production of a substantial scientific background that are the fundament for their scientific and educational relevance (e.g., Castanera et al., 2014, 2016; D’Orazi Porchetti et al., 2016; Razzolini et al., 2016; Santos, 2016a, b; Santos et al., 2013, 2015b, 2016a, b).

Accordingly, the purpose of the paper is to be an overview of the vertebrate ichnology that began one hundred years ago in what is today the National Museum of Natural History and Science with the pioneer work of Jacinto Pedro Gomes.

THE BEGINNING OF VERTEBRATE ICHNOLOGY IN PORTUGAL

Jacinto Pedro Gomes, after being informed in 1884 about the discovery of “large and very curious fossils” by miners from the Cabo Mondego coalmine in an outcrop close to the sea (Figueira da Foz), undertook the study of this new discovery and he soon recognized that they were natural casts of tridactyl footprints. In the late 19th century, after correspondence with the European palaeontologists of his time, he came to the conclusion that the tridactyl footprints were produced by dinosaurs. Gomes (1916), a posthumous publication, is considered the first scientific study on dinosaur footprints from Portugal, and one of the earliest works with international recognition (Fig. 2) (e.g., Antunes, 1999; Santos, 2003). He was also a pioneer in geoconservation issues wisely suggesting the safeguard through recovery of these dinosaur footprints from their inevitable destruction by ongoing marine erosion. He...
accepted the generous offer from the Cabo Mondego coalmine administration of sponsoring the campaign to remove the tracks and transfer them to the museum in Lisbon. These tracks still exist in the collections of the National Museum of Natural History and Science. This procedure may be considered one of the first geoconservation actions in Europe.

Later, other dinosaur footprints were discovered in the same Late Jurassic sedimentary sequence from Cabo Mondego (Lapparent et al., 1951; Lapparent & Zbyszewsky, 1957). Some of these dinosaur footprints are in display in the Museu Geológico (Lisboa).

DINOSAUR TRACKSITES AND THE NATIONAL MUSEUM OF NATURAL HISTORY AND SCIENCE

More contemporary work on dinosaur ichnology in Portugal is represented by the emblematic scientific works published by Antunes (1976), Madeira & Dias (1983) and Ramalho (1988) and by several studies that have been performed on the Jurassic and Cretaceous of Portugal that generated an extraordinary amount of information (e.g., Antunes & Mateus, 2003; Mateus & Antunes, 2003; Milán et al., 2005; Mateus et al., 2006; Mateus & Milán, 2010a, b; Mateus et al., 2011). Additionally to the dinosaur track record there is also an emergent field on the study of Pleistocene vertebrate tracks that allowed the recognition of bird footprints as well as small and large mammal footprints (Neto de Carvalho, 2009, 2011; Neto de Carvalho et al., 2016). Notwithstanding, systematic fieldwork and ichnological studies on dinosaur tracksites have also been carried out since 1990 by the National Museum of Natural History and Science and it is worth to mention its contribution to the conservation and enhancement of the Portuguese palaeontological heritage. Thus, since Gomes (1916), the last one hundred years can be considered a long walk that culminated with the systematic research on dinosaur ichnology developed in the Lusitanian Basin and Algarve Basin. The Museum’s work also enhanced public consciousness about geoheritage and its intrinsic exceptional value.

It is fully recognized that Portuguese Middle Jurassic through Late Cretaceous dinosaur tracksites has been disclosing important and novel information about the palaeobiology and palaeoecology of dinosaurs. Middle Jurassic dinosaur tracksites

The Galinha tracksite known as Monumento Natural das Pegadas de Dinossáurios de Ourem - Torres Novas (Bairro, Portugal) belongs to the Lower Bathonian Serra de Aire Formation. It exhibits exceptionally long wide-gauge sauropod trackways (Fig. 3) (Santos, 2003; Santos et al., 1994; Azeredo et al., 1995; Azeredo, 2007; Santos et al., 2009; Santos, 2016b). Ten of the best trackways were depicted in a map showing a random orientation pattern. Gregarious behaviour has not been identified, even though the Galinha tracksite has a huge track level area of about 40,000 m² (Santos et al. 2009, fig. 3; Castanera et al., 2014).

Santos et al. (2009) proposed a new ichnogenus and ichnospecies based on distinctive characteristics of the sauropod tracks (Polyonyx gomesi), an unequivocal evidence of wide-gauge sauropod trackways produced by
non-titanosauriform dinosaurs, an important information on dinosaurs that is not available from the osteological record of this time period. These authors described a new manus track morphology that yields information about the arrangement of the metacarpals and suggests an intermediate stage of manus structure between the non-tubular primitive sauropod manus and a tubular metacarpal distribution characteristic of more derived sauropods. The best-preserved manus track reveals a large digit I impression oriented in a medial direction, a large triangular claw mark I (ungula) impression posteriorly oriented, and digits II-V impressions with a slightly bent disposition. This configuration represents a unique morphology among sauropod manus impressions recently named speech-bubble-shaped (Castanera et al., 2016). The best-preserved pes track reveals four claw marks, whereas claws I-II are oriented in an anterior direction and claws III-IV oriented laterally (Santos et al., 2009).

Fig. 3 - The Middle Jurassic Galinha tracksite known as Monumento Natural das Pegadas de Dinossáurios de Ourém - Torres Novas (Bairro, Portugal) and a wide-gauge sauropod trackway (trackway G1) produced by a non-titanosauriform dinosaur.
The Vale de Meios tracksite (Alcanede, Santarém) that belongs to the Bathonian Serra de Aire Formation, reveals hundreds of theropod footprints (Fig. 4), several organized in subparallel trackways, and at least two sauropod trackways (Santos, 2003, 2008; Azeredo, 2007). Despite a scarce Middle Jurassic dinosaur ichnological record, the Vale de Meios tracksite only recently was subject to a full investigation thanks to a scientific collaboration between the National Museum of Natural History and Science (Universidade de Lisboa) and international institutions (Institut Català de Paleontologia “Miquel Crusafont”, Universitat Autònoma de Barcelona and Museu de la Conca Della from Spain, and Ludwig-Maximilians-Universität from Germany). Razolini et al. (2016) is one outcome of this cooperation, and these authors formally described the Vale de Meios tracksite as one of the largest theropod tracksites from the Middle Jurassic described worldwide and it is a crucial and unique reference for understanding the behavior of the Middle Jurassic theropod fauna. Hundreds of large tridactyl, elongated and asymmetric footprints are organized in, at least, 80 unidirectional trackways arranged in a bimodal orientation pattern (W/NW and E/SE). These Middle Jurassic theropod footprints were described and assigned to the Megalosauripus ichnogenus that, until now, was only known from the Late Jurassic-Early Cretaceous (Razzolini et al., 2016). Accordingly, the Vale de Meios tracksite reveals the earliest occurrence of this ichnotaxon.

Razolini et al. (2016) have notably concluded that Vale de Meios tracksite: 1) yields some of the largest theropod tracks ever reported; 2) was an ancient intertidal flat located at the margin of a coastal barrier crossed by large theropods of the Megalosauridae family, the dominant tetanuran clade during this age in Europe; 3) is the first tracksite in which Megalosauripus is in a probable coincident correlation with megalosauroids, and yields the unique palaeoethological evidence of megalosauroid moving towards a lagoon, most likely during low tide and probably for feeding purposes on fish, invertebrates and other vertebrates exposed on the intertidal surface.

Late Jurassic dinosaur tracksites

The cliffs at Cabo Mondego (Figueira da Foz) yield a sedimentary sequence with international stratigraphic relevance given by the establishment of two stratotypes: the Global Boundary Stratotype Section and Point (GSSP) for the Bajocian Stage and the Auxiliary Stratotype Section and Point (ASSP) for the Bathonian Stage (e.g., Henriques, 2008; Rocha et al., 2014). It is on the outcrops along these cliffs where, in Middle Oxfordian layers, the first dinosaur tracks ever founded were identified and studied in Portugal (Gomes, 1916). Based on the exceptional quality of the geological record, on its international relevance and on its high scientific and educational value, this area was designated in 2007 as Natural Monument (e.g., Rocha et al., 2014).

Six well preserved theropod footprints collected by Jacinto Pedro Gomes in the late years of the 19th century are housed in the National Museum of Natural History and Science - Universidade de Lisboa. Lockley et al. (2000) described the holotype of Eutynichnium lusitanicum (Nopsca, 1923) on the basis of one of these natural casts. Until now the Upper Jurassic sequence visible along the Cabo Mondego coast-line yielded at least eight track levels with several isolated theropod tracks preserved as natural casts (e.g., Santos, 2003, 2008).

The coastline between Cabo Espichel and Lagosteirios bay as well as the area of Zambujal (Sesimbra) yielded several levels with dinosaur trackways and the majority of the sauropod trackways from the Late Jurassic of Portugal.

The Avelino tracksite (Kimmeridgian) reveals five narrow-gauge sauropod trackways of different size and there is evidence of a sauropod with a hip-height of 1.2 m and another of almost 4 m (Lockley & Santos, 1993; Santos, 2003; Santos et al., 2015a, 2016a; Caetano et al., 2016). A multidirectional trackway orientation pattern is interpreted as milling or/and solitary behaviour (e.g., Castanera et al., 2014).

The Pedra da Mua tracksite (Tithonian) reveals eight track levels with well-preserved sauropod footprints preserved as true tracks (Brontopodus pes prints showing four claw marks) and parallel trackways interpreted as evidence of gregarious behaviour amongst sauropods (Lockley et al., 1994a, c; Meyer et al., 1994; Castanera et al., 2014; Santos et al., 2016a).

One level displays 11 sauropod trackways and ten of these trackways have been interpreted as an age-segregated herd of seven small and three larger sauropods which passed afterwards (Lockley et al., 1994a; Santos, 2003, 2008; Castanera et al., 2014). In another track level five sauropod trackways with different movement directions have also been described and most probably one of them was the one assumed as the trackway of a “giant mule” that carried the Virgin Mary to the top of the cliffs (e.g., Antunes, 1976; Galopim de Carvalho & Santos, 1992; Meyer et al., 1994; Santos, 2008; Pereira, 2014). On the eight track levels at Cabo Espichel, 38 wide-gauge sauropod trackways (several are incomplete) and two theropod trackways were identified, and a limping gait was inferred from both a theropod and a sauropod trackway (Dantas et al., 1994; Lockley et al., 1994c).

Until now only one Late Jurassic dinosaur tracksite was documented in the Algarve Basin in a small bay just west of Praia da Figueira (Vila do Bispo, southwest Algarve). At the Tithonian Foia do Carro tracksite, two track levels were identified and the general morphology of the footprints, their disposition along one trackway and the trackway width, allow us to assign them to sauropods and to the ichnogenus Brontopodus (Santos, 2003, 2016a). The upper level reveals a surface with moderate trampling, according to the dinoturbation index proposed by Lockley & Conrad (1989). These sauropod trackways are similar to those from Pedra da Mua tracksite (Upper Jurassic, Cabo Espichel, Sesimbra) regarding track morphology and trackway type (Santos, 2003, 2016a).

Early Cretaceous dinosaur tracksites

Lagosteirios A, from the Berriasian, and Lagosteirios B from the Hauterivian (Caspais) and Olhos de Água (Óbidos) from the Aptian-Albian, are all Early Cretaceous dinosaur tracksites that were described from the Lusitanian Basin yielding sauropod, theropod and ornithopod tracks. In Lagosteirios Bay (north of Cabo Espichel, Sesimbra), dinoturbation and dinosaur tracks of probable theropod
origin were discovered at Lagosteiros A in Berriasian sediments that overlie Late Jurassic (Tithonian) limestones (Santos, 2003). Lagosteiros B is situated on the north cliff of Lagosteiros Bay and this tracksite of Hauterivian age reveals theropod footprints and a sequence of very aligned subcircular footprints without morphological features (Antunes, 1976). The measures of the pace angulation in this sequence suggest a probable ornithopod trackway (Santos et al., 1992, 2013). A trackway suggesting a theropod moving at a speed of about 14 km/h is the most interesting feature of this tracksite (e.g., Santos, 2008).

The Early Aptian tracksite at Praia Grande (Sintra) shows a lower level with dinoturbation and an upper level with sauropod, theropod and ornithopod tracks (Madeira & Dias, 1983; Lockley et al., 1994b; Santos, 2003, 2008). At the early Late Albian Parede tracksite (Cascais, Portugal) at least two sauropod trackways were identified on a horizontal slab with moderate trampling (Santos et al., 2015b). This tracksite (Fig. 5) is not always available for public outreach activities because often and mostly unpredictable, the site is covered by beach sand. From a time period with a scarce sauropod record, the Parede tracksite reveals the youngest evidence of sauropods in the Portuguese dinosaur record, and one narrow-gauge trackway, which is the only narrow-gauge sauropod trackway in the Albian of the Iberian Peninsula (Santos et

Fig. 4 - The Middle Jurassic Vale de Meios tracksite (Alcanede, Santarém) with theropod footprints.
al., 2015b). At Olhos de Água (Óbidos) an Aptian-Albian tracksite with theropod and ornithopod footprints was described by Mateus & Antunes (2003).

Three Early Cretaceous dinosaur tracksites are known in the Algarve Basin: 1) Praia dos Arrifes tracksite from the Valanginian (Albufeira, southeast Algarve), 2) Praia da Salema and 3) Praia Santa tracksites from the Early Barremian (Vila do Bispo, southwest Algarve) (Santos et al., 2013, 2016b; Santos, 2016a).

Praia dos Arrifes tracksite yields the first evidence of Early Cretaceous sauropods in the Algarve Basin and an ongoing study may provide more palaeobiogeographical information of sauropods in the Iberian Peninsula (Santos et al., 2016b).

The cliffs in the eastern sector of Salema beach revealed a slab with seven small tridactyl footprints with a theropod morphology (Santos, 2003; Santos et al., 2013). Nowadays this slab is poorly preserved due to marine erosion.

In the western sector of Salema beach, a sequence of aligned footprints (Fig. 6) with a pace angulation of about 170º occurs (Santos et al., 2013). Some of these footprints are sub circular and others are tridactyl with the characteristic morphology of ornithopod footprints, which made it possible to understand how erosion may change a typical ornithopod track morphology into a subcircular impression that could potentially be interpreted as of sauropod origin (Santos et al., 2013; Santos, 2016a).

At Praia Santa tracksite the ichnogenus *Iguanodontipus* was identified (Santos et al., 2013; Santos, 2016a) though subsequent studies have assigned this tracks to *Caririchnium* (Díaz-Martínez et al., 2015). The discovery of these tracks suggests that this dinosaur group was well-represented in the Iberian Peninsula and southwestern Europe during the Early Cretaceous and allowed to improve the palaeobiogeographical data available for the distribution of Early Cretaceous iguanodontids (Santos et al., 2013).

The sedimentary sequence that can be followed along the shoreline near Praia Santa presents track levels with small surfaces, where an isolated impression has the typical kidney shape of a sauropod manus print, yet it is not possible to assign these isolated tracks to sauropods with confidence. However, such occurrences indicate a high probability to discover sauropod tracks in this area (Santos et al., 2013; Santos, 2016a).

**Late Cretaceous dinosaur tracksites**

The only Late Cretaceous dinosaur tracksite known in Portugal is the Cenomanian Carenque - Pego Longo tracksite, situated near Sintra, is also a natural monument. This tracksite exhibits small tridactyl footprints of theropod affinity and a long sequence of aligned, circular and oval shaped footprints with a pace angulation of about 170º, much similar to those described from the Praia da Salema and Lagosteirós B tracksites and therefore assigned to an ornithopod, likely iguanodontid trackmaker (Santos et al., 1992, 2013).

**DINOSAUR TRACKSITES AS GEOHERITAGE**

Besides their intrinsic scientific interest, dinosaur tracksites are also a tool to enhance public awareness about geological heritage (Fig. 7), as they are privileged places where it is possible to learn geosciences and comprehend the significance of natural heritage (e.g. Marty et al. 2004; Reis et al., 2014).

Portuguese politicians and the public became more aware about dinosaur tracksites as early as 1992 and five Portuguese dinosaur tracksites became designated as Natural Monument in the years of 1996 and 1997. Carenque tracksite, now renamed Pego Longo, was designated as Natural Monument in 1997 (Decreto nº 19/97, of 5th May) and became a classic case of a successful campaign to preserve Portuguese palaeontological heritage (Galopim de Carvalho, 1994). The Portuguese Government voted unanimously to preserve the Pego Longo tracksite and a road tunnel was built beneath it (instead of the road being built over it). Unfortunately, ever since, nothing else happened, the site is not accessible to the public and is subject to erosion. Nonetheless, all joint efforts allowed changing the perception of natural heritage within the Portuguese society.

Although discovered later, the Galinha tracksite was designated as Natural Monument before Pego Longo. The Decree n.º 12/96 of October 22nd 1996 declared the importance of this dinosaur tracksite and designated the site as Monumento Natural das Pegadas de Dinossáurios de Ourém - Torres Novas, With political support from Minister Elisa Ferreira, ICN’s President, Teresa Andresen, and the Director of the Parque Natural das Serras de Aire e Candeeiros, Maria João Botelho, began the transformation of the former quarry in a geosite that was protected and made accessible in 1996-1998. Consequently, the former quarry was adapted and transformed into a visitor centre with the scientific support of the Science Faculty and the National Museum of Natural History (Universidade de Lisboa). To allow self-guided visits, an educational pathway with interpretation panels was installed. To accomplish this task an intervention program was established, coordinated by José Manuel Alho with support from José Pedro Martins Barata, António

![Fig. 5 - Early Cretaceous Parede tracksite (Cascais, Portugal): at least two sauropod trackways were identified on a horizontal slab with moderate trampling. Note the erosion of the tracks due to wave action. This tracksite is often covered by beach sand.](image-url)
Marcos Galopim de Carvalho, Vanda Faria dos Santos and Viriato Soromenho Marques with contributions from Fernando Catarino and his team of the Botanical Garden (Universidade de Lisboa).

This geosite is quite unique to study Middle Jurassic sauropods as there is only a small number of tracksites from this period worldwide. Even though much has been accomplished, difficulties to promote and enhance the Galinha tracksite still persist. Unfortunately, new data from several recent scientific studies (e.g., Santos et al., 2009; Castanera et al., 2014, 2016) have so far not yet been included in public outreach or educational activities at the natural monument. The Galinha tracksite was the target of a comprehensive geoconservation strategy and unprecedented musealization in Portugal.

Notwithstanding the exceptional scientific value of the Vale de Meios tracksite this place is oddly overlooked. This impressive site with theropod trackways has an outdoor interpretation panel that contain information to allow self-guided visits and it is a legacy of the IDPI (Dinosaur Ichnites of the Iberian Peninsula) World Heritage Candidacy (FCPTD, 2009).

The Decree nº 20/97, of 7th May 1997 also designated three dinosaur tracksites in the Sesimbra area as Natural Monuments: Lagosteiros Natural Monument, Pedra da Mua Natural Monument and Avelino Quarry Natural Monument. These geosites are an important and well known component of the Sesimbra GEOcircuit that aims to catalogue, characterize, interpret and promote the geological heritage of Sesimbra (Caetano et al., 2016; Santos et al., 2015a, 2016a).

Pedra da Mua and Lagosteiros tracksites benefit from outdoor interpretation panels that contain information to allow self-guided visits; Avelino Quarry was subject to a museological intervention in 2012 as a consequence of the interest of the Sesimbra municipality to enhance and promote these three natural monuments for educational purposes. The Sesimbra municipality submitted an application to ADREPES (a regional development funding association) with the project for the musealization of Avelino Quarry. Thus, the dinosaur tracksite and the quarry were rehabilitated becoming an excellent example of geoconservation, enhancement and management of the natural heritage of Sesimbra (Caetano et al., 2016; Santos et al., 2015a, 2016a). A cooperation agreement was established between the Sesimbra municipality and researchers from two Lisbon universities: the Faculty of Sciences and Technology from Universidade Nova de Lisboa and the Faculty of Sciences from Universidade de Lisboa.

Fig. 6 - An ornithopod trackway at the Early Cretaceous Salema tracksite (Vila do Bispo, southwest Algarve).

Fig. 7 - Visitor platform with educational panel at the Late Jurassic Avelino Quarry Natural Monument. This site exhibits five narrow-gauge sauropod trackways of different size and with a multidirectional trackway orientation pattern.
CONCLUSIONS

The pioneer work of Jacinto Pedro Gomes (Gomes, 1916) constitutes the base of the important role of the National Museum of Natural History and Science in the study of dinosaur tracksites and their geoconservation. In the last 25 years several tracksites were discovered and yielded important and novel information about dinosaur palaeobiology and palaeoecology. Thanks to the cooperation with palaeontologists from different national and international institutions (Germany, Italy, Spain, Switzerland, United Kingdom, U.S.A.), the National Museum of Natural History and Science has contributed with an extended scientific and outreach work. This activity allows to achieve recognition and the support and commitment of local authorities and governmental departments, to preserve and protect relevant tracksites. In Portugal, dinosaur tracksites declared as natural monuments are under the management of Instituto da Conservação da Natureza e das Florestas but a comprehensive strategy for geoconservation does not exist as yet. Creating the appropriate legislation is an urgent and necessary step, but it is not enough. Of course, the potential of dinosaur tracksites to enhance Earth Sciences Literacy should not be overlooked as they arouse public interest for geological and palaeontological heritage and are much appreciated for public outreach activities. Initiatives like the Sesimbra municipal project to rehabilitate the Avelino Quarry Natural Monument intend to accomplish these goals.

ACKNOWLEDGEMENTS

This work is a contribution to the call for papers arising from the Fourth International Congress on Ichnology “Ichnia 2016 - Ichnology for the 21st century: (palaeo)biological traces towards sustainable development”, held in Idanha-a-Nova (Portugal), 6-9 May 2016.

I am especially indebted to Guadalupe Jácome, Luis Quinta and Paulo Sá Caetano for their support to this work. I would like to thank Andrea Baucon and Carlos Neto de Carvalho for editing this special volume and the reviewers Daniel Marty and Diego Castanera for their helpful and important constructive comments which actually improved the manuscript.

REFERENCES


Manuscript received 9 March 2017
Revised manuscript accepted 16 July 2017
Published online 18 September 2017
Guest Editors Andrea Baucon & Carlos Neto de Carvalho