Journal of Geoscience and Environment Protection, 2021, 9, 84-96
https://www.scirp.org/journal/gep
ISSN Online: 2327-4344
ISSN Print: 2327-4336

New Dinosaur Tracks from the Lower Barremian of Portugal (Areia do Mastro Formation, Cape Espichel)

Silvério D. Figueiredo[1*], Carlos Neto de Carvalho[2], Pedro P. Cunha[3], Ismar de Sousa Carvalho[4]

[1]Instituto Politécnico de Tomar, CGeo-UC, Unidade Departamental de Arqueologia, Conservação e Restauro e Património, Quinta do Contador-Estrada da Serra, Tomar, Portugal
[2]Serviço de Geologia do Município de Idanha-a-Nova, Geopark Naturtejo Mundial da UNESCO, Avenida Joaquim Morão, Idanha-a-Nova, IDL, Instituto Dom Luiz, Faculdade de Ciências da Universidade de Lisboa, Campo Grande, Lisboa
[3]Universidade de Coimbra, MARE, Dep. Ciências da Terra, R. Sílvio Lima, Coimbra, Portugal
[4]Universidade Federal do Rio de Janeiro, Instituto de Geociências, CCMN Cidade Universitária, Ilha do Fundão, Rio de Janeiro, Brasil
Email: *Silverio.figueiredo@ipt.pt, carlos.praedichnia@gmail.com, pcunha@dct.uc.pt, ismar@geologia.ufrj.br

How to cite this paper: Figueiredo, S. D., De Carvalho, C. N., Cunha, P. P., & De Sousa Carvalho, I. (2021). New Dinosaur Tracks from the Lower Barremian of Portugal (Areia do Mastro Formation, Cape Espichel). *Journal of Geoscience and Environment Protection, 9,* 84-96.
https://doi.org/10.4236/gep.2021.91007

Received: November 30, 2020
Accepted: January 24, 2021
Published: January 27, 2021

Abstract

We present a new tracksite with multiple dinosaur tracks from the lowermost Barremian (Lower Cretaceous) of the Cape Espichel (Sesimbra, Portugal). The tracks are localized on three beds on the top carbonate beds of the Areia do Mastro Formation. Those bioclastic, nodular limestones were deposited in a very shallow subtidal-intertidal, restricted lagoon environment. The track surfaces are very dinoturbated, with a substantial number of tracks. Several tracks assign to sauropods, ornithopods and theropods dinosaurs were recorded. Due to heavy bioturbation and the preservation conditions, it is not possible to define trackways; some preliminary work done on the tracks could disclose some behaviours of their producers. Several species of carnivore and herbivore dinosaurs crossed that large area at different times. Herbivores may have used the lagoon margin as passage between feeding spots, while carnivores frequented the area to hunt in groups or individually.

Keywords

Trampled Surface, Dinosaurs, Locomotion Behavior, Lower Cretaceous, Cape Espichel, Portugal, Iberia

1. Introduction

The very first palaeontological investigations on Cape Espichel took place in the second half of the 19th century. The Portuguese Geological Survey (Sauvage, 1897-1898) reported dinosaur and crocodile teeth from the Papo-Seco Formation, at Boca do Chapim site. Later, Lapparent and Zbyszewski (1957) reported turtle remains and crocodile teeth and bones, as well as dinosaurian remains. Fragments of jaws found at Boca do Chapim by Sauvage (1897-1898) were identified as being from a crocodile (*Suchosaurus girardi*); they were later analysed by E. Buffetaut and classified as the spinosaurid *Baryonyx*, based on similarities with the holotype of *Baryonyx walkeri* from the English Barremian (Buffetaut, 2007). In 2011, O. Mateus and colleagues reported skull and postcranial bones attributed to *Baryonyx walkeri* (Mateus et al., 2011). In scope of the palaeontological research carried out by the Centro Português de Geo-História e Pré-História (CPGP) in the last 20 years new data on the vertebrate faunas of Cape Espichel has been reported: At Boca do Chapim site, a preliminary analysis of newly discovered material showed several bones of an ornithopod dinosaur (Figueiredo, 2010, 2014); At Praia do Areia do Mastro site, vertebrate bone fragments and teeth of fish (cf. *Lepidotus* sp.), crocodiles (cf. *Anteophtalmosuchus* sp.), turtles, pterosaurs (Ornithocheiridae indet. and Ctenochasmatoidea indet.), dinosaurs (*Baryonyx* sp, Iguanodonts and Sauropoda indet.) were described by Figueiredo et al. (2015, 2016); At Praia do Guincho site, a natural cast of an ornithopod dinosaur track was reported (Figueiredo et al., 2017). In addition to this ichnological finding, in the area of Cape Espichel dinosaur tracks have been reported at several sites, in Upper Jurassic and Lower Cretaceous formations: Praia do Cavalo showed theropod tracks; a trackway of large sauropod is protected at Pedreira do Avelino Natural Monument; from another protected site, Pedra da Mua, trackways of sauropods and theropods were described (Lockley et al., 1994; Santos, 2003, 2008). These three sites are comprised in the Upper Jurassic; Lagosteiros site (Hauterivian, Lower Cretaceous) shows trackways and tracks of theropods and ornithopods (Antunes, 1976, 1990; Carvalho & Santos, 1993; Santos, 2003, 2008).

Trace fossils are useful for palaeontologists because they enable to know more about the activity of ancient organisms. For example, the study of dinosaur tracks has contributed significantly to the understanding of dinosaur behaviour, because they record locomotion gaits and speed, besides daily activities in environments in which the trackmakers lived. Dinosaur herding or other behaviours such as locomotion styles, feet biomechanics and speed calculations have been inferred from several tracksites worldwide (e.g. Castanera et al., 2011; Lockley et al., 1994; Myers & Fiorillo, 2009; Ostrom, 1972). In fact, palaeontologists have learned much more about dinosaur behaviour from trace fossils than from their body fossils' functional anatomy. The purpose of this paper is to present new dinosaur tracks from Lower Cretaceous of Portugal and to discuss some preliminary data about the dinosaur behaviour represented by those tracks in successive trampled surfaces.

2. Geological, Stratigraphical and Paleoenvironmental Settings

The area of the new dinosaur tracksite is located between Boca do Chapim and Praia do Areia do Mastro sites. Those localities are situated at the coastal cliffs, about 2 km to the north of Cape Espichel (Figure 1), in the municipality of Sesimbra, SW of Setubal Peninsula, about 40 km south of Lisbon (Portugal, western Iberia).

The studied Lower Cretaceous sedimentary beds at Boca do Chapim and Praia do Areia do Mastro sites belong to the Lusitanian Basin, located on the Western Portuguese Margin and extending onshore from Aveiro to Sines (Figure 1). In the Lusitanian Basin, some Lower Cretaceous sedimentary successions present some ichnofossiliferous sites, which include dinosaur tracks.

The new tracksite is distributed in three limestone beds which outcrop at the upper part of the rocky beach, adjacent to a cliff about 60 m high. The cliff exposes a Lower Cretaceous (Barremian) sedimentary succession which includes limestones, marls, sandstones and thin conglomerate levels, deposited in shallow marine, lagoon and estuary environments. Three lithostratigraphic units were defined (from the bottom to top) (Figure 1 and Figure 2): the Areia do Mastro Formation, ascribed to the uppermost Hauterivian to lowermost Barremian; the Papo-Seco Formation, considered lower Barremian; and the Boca do Chapim Formation, dated as middle Barremian (e.g., Rey, 1972; Manupella et al., 1999; Aillud, 2001; Dinis et al., 2008; Rey et al., 2003; Figueiredo et al., 2020) (Figure 2).

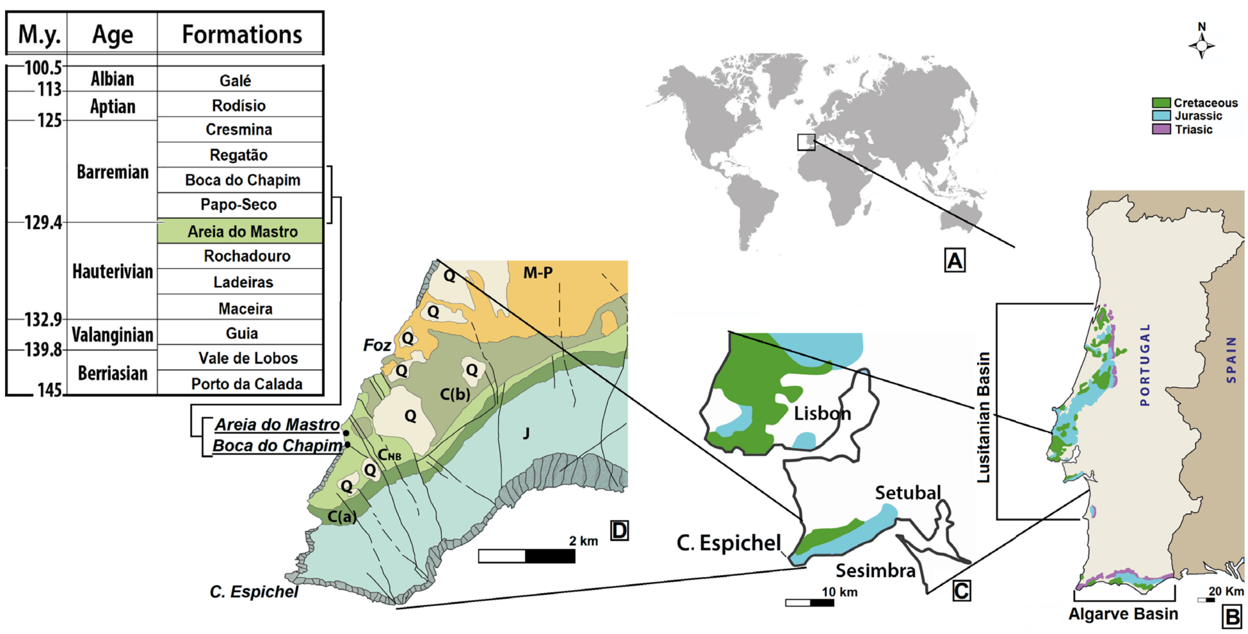

Figure 1. Location of the Boca do Chapim and Praia do Areia do Mastro sites and stratigraphy: A—Location of Portugal in the world; B—Distribution of the Mesozoic rocks in Portugal (Lusitanian Basin and Algarve Basin); C—Distribution of Mesozoic formations in Lisbon and Setúbal peninsulas; D—Distribution and age of the Cretaceous formations in the area of Cape Espichel (J—Jurassic; C—Cretaceous; M-P—Miocene and Pliocene; Q—Quaternary).

Figure 2. Distribution of the formations outcropping at the coastal cliff and location of the areas identified with dinosaur tracks. The white rectangle marks the drawing location of the stratigraphic column (modified from a Google Earth image).

The Areia do Mastro Formation comprises brackish-water estuarine sandstones and silty marls to marine carbonates (Rey, 1972, 1992; Manupella et al., 1999; Rey et al., 2003). The marine beds correspond to marly bioclastic limestones with a fauna consisting of invertebrates (echinoids, naticid gastropods and bivalves), dasycladacean alga and orbitolinid foraminifera (Rey, 1972, 1992; Manupella et al., 1999; Aillud, 2001), which document shallow marine and restricted lagoon environments.

The dinosaur tracks were found in three top beds of the Areia do Mastro Formation, which can be attributed to the lowermost Barremian (Rey, 1972; Manupella et al., 1999; Rey et al., 2003); remains of marine turtles and abundant large naticid gastropods were also found. The dinosaur trampled beds consist of bluish-grey limestones showing a nodular texture due to a high invertebrate bioturbation (mainly *Thalassinoides suevicus*) typical of an intertidal to subtidal lagoon environment (Neto de Carvalho et al., 2007), and that suggests that the dinosaurs crossed an intertidal environment (Figueiredo et al., 2017, 2020).

The penultimate bed of the Areia do Mastro Formation, which is 60 cm thick, consists of a sandy-limestone, with a macro fossiliferous content composed of fragments of turtle shell, fish teeth and internal moulds of naticid gastropods. The last beds of the Areia do Mastro Formation is a 2.1 m thick clay-limestone with fragments of bivalve shells, internal moulds of gastropods and rare fragments of turtle carapaces. The upper part of this bed shows convolute bedding (a probable palaeoseismites). Both beds are light grey in colour and very bioturbated, not only by dinosaurs (tracks), but also by worms and crustaceans (**Figure 3**). These beds are comprised between a bed of sandy-limestone below and a bed of yellow dolomitic sandstone, the latter already belonging to the Papo-Seco Formation.

3. Materials and Methods

This study consists in the analysis of three big sets of dinosaur tracks found in three different limestone beds located at the top of the Areia do Mastro Formation. Most of the work was carried out in the field, comprising the measurements, GIS location and orientation of each track. More detailed observations of sediment samples and the analysis of the data collected in the field were done in the laboratory.

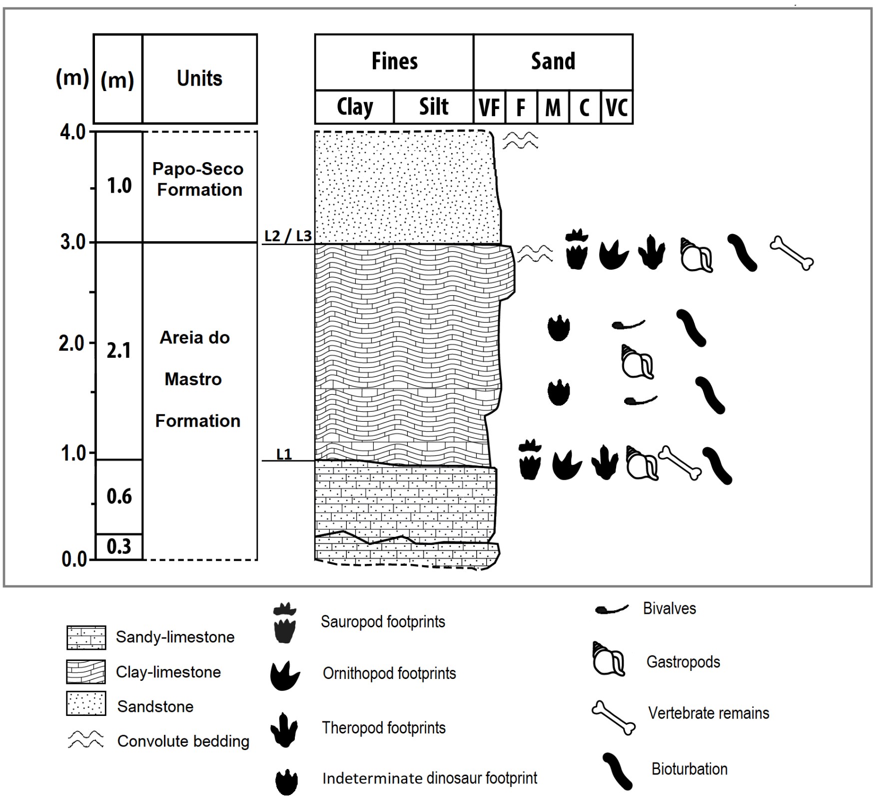

Figure 3. Stratigraphic column of the transition of the upper beds of the Areia do Mastro Formation to the first bed of the Papo-Seco Formation. L1, L2, L3—indication of the trampled surfaces, presented in this work.

4. Ichnological Description of the Tracksite

During the paleontological field work done in 2019, three trampled beds were identified at Praia do Areia do Mastro site, and at the base of the cliffs between Praia do Areia do Mastro and Boca do Chapim sites. The tracks presented in this work are located at the top of the last two beds of the Areia do Mastro Formation (Figure 3) and, in addition to these tracks, others were identified in the last beds of the Areia do Mastro Formation, but not studied. During the year 2020, field work was done to survey these tracks at these very dinoturbated stratigraphic surfaces. A total of 614 tracks were identified in an area summing about 1350 m^2 (Figure 4). Positive tracks and negative casts were found.

This set of tracks features a wide variety of producers. Tracks of three different groups of dinosaurs were identified (Figure 5): theropods (93 tracks); sauropods (324 tracks) and ornithopods (197 tracks). In terms of representation percentages, the carnivores are 15%, while herbivores are 85% (31% of ornithopods and 54% of sauropods) (Table 1). The ichnological record is not well preserved, because the intense dinoturbation and by the fact that tracks are exposed in very narrow outcrops at the costal cliff exposed to an intensive wave erosion. Due to preservational conditions, was not possible to clearly define trackways so far, but it was possible to identify the orientation of each one of the tracks. It was found that the tracks had a very varied orientation. The size of the tracks is also

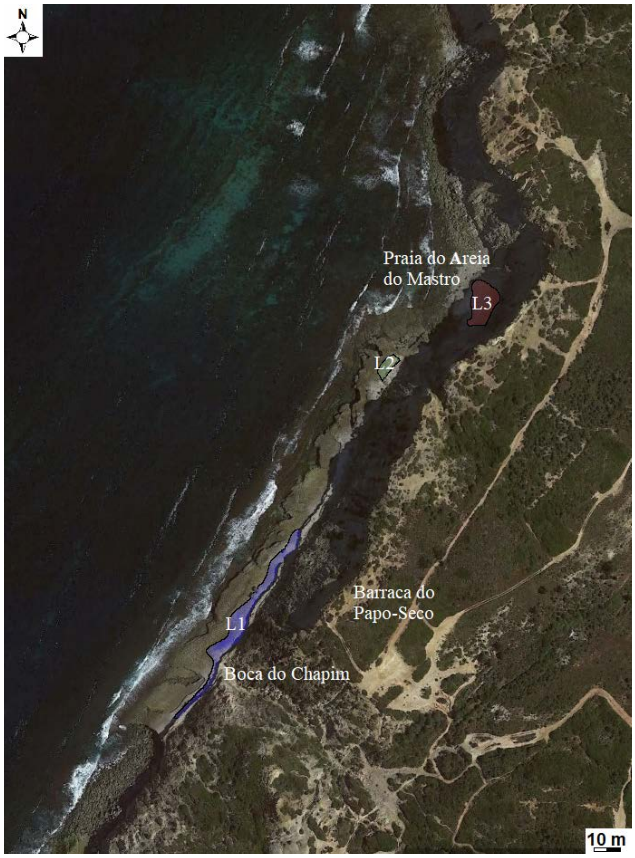

Figure 4. Location of the beds studied with dinosaur tracks (modified from a Google Earth image).

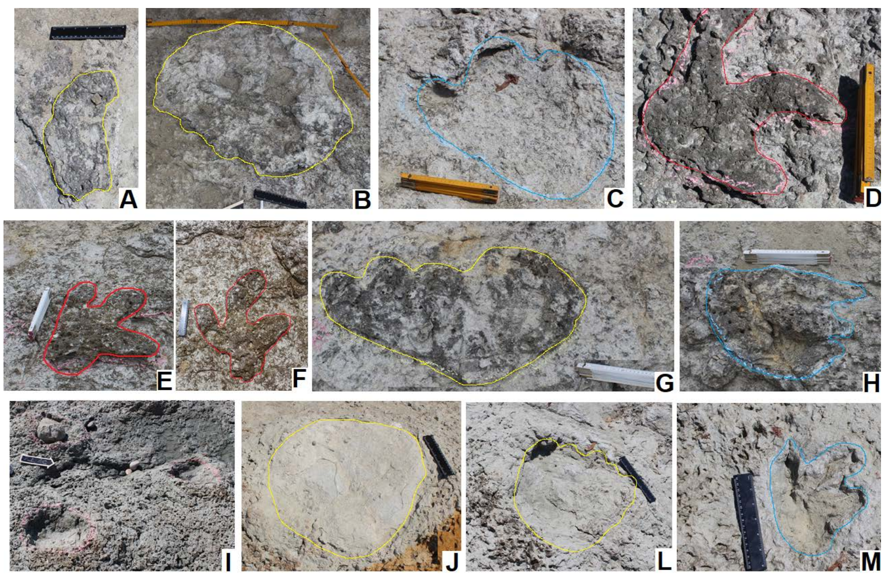

Figure 5. Some of the dinosaur tracks identified in the 3 beds: A-D Bed 1 (L1): A and B: sauropod tracks (A = *manus*; B = *pes*); C: ornithopod track (*pes*); D: Theropod track. E-H Bed 2 (L2): E and F: theropod track; G: sauropod track (*pes*); H: ornithopod track (*pes*). I-M Bed 3 (L3): I-L sauropod track (*pes*), In I (3 tracks) is possible to observe the sedimentary deformation resulting from the pressure of the foot; M: ornithopod track (*pes*). Scale: A, B, F, J, L, M = 15 cm; C, D, E, G and H = 20 cm; I = 25 cm.

Table 1. Number and percentage of the dinosaur's tracks from the Areia do Mastro Formation (L1, L2 and L3 = bed 1, 2 and 3, see **Figure 3**).

	L1		L2		L3		TOTAL	
	N	%	N	%	N	%	N	%
Sauropods	291	55	16	45	17	44	324	54
Theropods	81	15	12	34	0	0	93	15
Ornithopods	169	30	7	21	21	66	197	31
TOTAL	**541**		**35**		**38**		**614**	

very varied and the morphological differences between some tracks of the same group of dinosaurs suggests that these were produced by individuals of different species and different ages. They may also show preservation variants in substrates originally with different consistencies.

5. Animal Behaviour

Dinosaur tracksites data provide useful complementary constraints on the problem of population density and behaviour of large predators (e.g., Lockley & Hunt, 1995) and other groups of dinosaurs. Dinosaurs gregarious behaviour based on ichnological evidence has been described in several parts of the world and in different ages. Several dinosaur tracksites, especially sauropod tracks, indicate that those animals often formed social groups: an example of this gregarious behaviour are the parallel trackways of sauropods at the Pedra da Mua, in Cape Espichel, dated from the Tithonian, or Las Cerradicas, from the Berriasian of Spain (Lockley et al., 1994; Castanera et al., 2011). On the other hand, some accumulations of dinosaur skeletons with numerous individuals of the same species suggest the existence of very large herds or group gathering (Moreno et al., 2011).

Trackways are the closest thing that we have to motion pictures of the behaviour of fossil animals (Paul, 2010). Tracks, especially when they occur in large numbers, can also give indications about behaviour of fossil vertebrates. Some of dinosaur tracks or trackways have shown that some groups of dinosaurs traveled in groups or herds. Such behaviour has been described from sauropod tracks, at Oxfordshire, from Middle Jurassic of England (Day et al., 2004), at Pedra da Mua (Cape Espichel), from the Upper Jurassic of Portugal (Lockley et al., 1994) and Las Cerradicas (Teruel province), from the Lower Cretaceous of Spain (Castanera et al., 2011), as previously referred; ornithopod trackways at Tereñes (Asturias) from Upper Jurassic of Spain (Pinuela et al., 2016), or hadrosaurid dinosaur trackways at Denali National Park, from the Upper Cretaceous of Alaska (Fiorillo et al., 2014). Some tracksites have also revealed that some herds protected their young by keeping them in the centers of migrating groups (i.e. Malkani, 2007; Diedrich, 2011; Romano et al., 2018; Farlow et al., 2012; Thulborn & Wide, 1989). Other trackways show that dinosaurs did not drag their tails when they walked, which confirms the type of posture evidenced in the skeletons of dinosaurs (Paul, 2010). The study of trackways can estimate dinosaur's gait and speed and provide information about the way of locomotion of dinosaurs, by measuring the pace and stride, or determine the gregarious behaviour shown by some of these animals, when there are parallel trackways, approximately constant distances between those, same direction of movement, tracks with identical depth and preservation, as well an identical estimated speed (e.g., Ostrom, 1972; Lockley et al., 2002; Santos, 2003, 2008). In the case of the new tracksite described in this study, as it was not possible yet to identify trackways, the distance between eventual parallel trackways and speed estimation of the animals were not possible to measure; so, it is not possible to have conclusions about the form of displacement and gregarious behavior of dinosaurs that produced these tracks. In future, more detailed and in-depth studies of the data collected during the field work can give new insights about behavioural parameters. However, the data already analyzed, allow us to make some preliminary behavioural characterization of the dinosaurs that left these tracks.

6. Discussion

The presence of ornithopods, sauropods and theropods is documented in the body fossil record of Lower Cretaceous of Cape Espichel (Lapparent & Zbyszewski, 1957; Antunes, 1976; Mateus et al., 2011; Figueiredo et al., 2015, 2017). With specific regard to the occurrence of dinosaurs in the Barremian it is verified the occurrence of various remains of ornithopods, sauropods and theropods in the Papo-Seco Formation overlying the Areia do Mastro Formation, especially in basal beds of this formation and in the same sites of the tracks presented in this work. The ornithopod remains are comprised of bone elements and teeth of iguanodonts (Lapparent & Zbyszewski, 1957; Figueiredo, 2010, 2014; Figueiredo et al., 2015), and a track cast identified as *Iguanodontipus* (Figueiredo et al., 2017); the sauropods include a fragment of a caudal vertebra (Figueiredo et al., 2015) and the theropods are represented by bone elements and teeth of *Baryonyx* and *Megalosaurus* (Lapparent & Zbyszewski, 1957; Buffetaut, 2007; Figueiredo, 2010, 2014; Figueiredo et al., 2015; Mateus et al., 2011). Theropod teeth were recently discovered by the CPGP team, but still unpublished.

In addition to the tracksite described in this work, seven Lower Cretaceous tracksites are known in Portugal. Ornithopod tracks were described in Praia Santa and Praia de Salema, at Vila do Bispo (Algarve basin); from Lusitanian basin, Lagosteiros and Praia do Guincho, at Sesimbra, Praia Grande, at Sintra and Olhos de Água, at Óbidos (Antunes, 1976; Madeira & Dias, 1983; Santos et al., 2003; Santos, 2008; Mateus & Antunes, 2003; Santos, 2008; Figueiredo et al., 2017). Theropod tracks were described at Praia de Salema (Vila do Bispo), at the Algarve Basin, and Lagosteiros (Sesimbra) and Praia Grande (Sintra) sites, at the Lusitanian Basin (Antunes, 1976; Madeira & Dias, 1983; Santos, 2008). Sauropod footprints were described at Praia Grande (Sintra) and Parede (Cascais), both in the Lusitanian Basin (Madeira & Dias, 1983; Santos, 2008; Santos et al., 2015).

The tracks present in this work were found in a context of a carbonate tidal area. The large number of tracks in three different beds, their general orientation and the diversity of represented dinosaur groups suggest the existence of a coastal area intensely crossed during thousands of years by different species of dinosaurs, mainly herbivores which probably used the area as a passage to different pasture zones. Parallel tracks were not identified but the large number of tracks with similar depth and orientation, mainly of sauropods, could suggest the passage of groups of animals at the same time. The superposition of tracks indicates successive crossing moments. The smaller number of carnivore tracks (**Table 1**) suggests that theropods could have used that area as a hunting ground. The inferred frequency seems that the large theropods (few tracks identified) may have been solitary hunters with exclusive territorial behaviour, while the small theropods, which left a greater number of tracks there, might have hunted in groups. However, it is difficult to relate observed trackways to grouping behaviour of carnivores. Indeed, the tracks investigated here do not display typical patterns of gregariousness such as those observed for herds of herbivore dinosaurs.

Myers & Fiorillo (2009) stated that sauropods could be segregated in small herds, according to age: the juveniles could live in groups, and adults chosen to live alone. The set of tracks presented in this work shows that the majority of the sauropod footprints belongs to adult individuals. More studies can reveal that the sauropods passed at the same time, or at different times. If the sauropod passed in this place at different times, the hypothesis of Myers and Fiorillo (2009) can reenforce the idea of the sauropods that make those tracks passed alone in the margin of the lagoon.

The fluctuations of sea level in the tidal carbonate environments, with low hydrodynamics, recorded by the dinoturbated stratigraphic surfaces at the top of the Areia do Mastro Formation, likely facilitated the preservation of the dinosaur tracks and probably provided a preferential habitat for these animals, if merely transitional. In other Portuguese ichnofossil sites with occurrence of dinosaur tracks, sediments were deposited in very shallow marine, estuarine or deltaic environments (Santos et al., 2015; Santos, 2003, 2008; Figueiredo et al., 2017).

7. Conclusion

The paleontological sites of Boca do Chapim and Praia do Areia do Mastro have yielded important vertebrate remains, including skeletal fossils of dinosaurs from the Papo-Seco Formation, and new sauropod, ornithopod and theropod trampled surfaces at the top beds of the Areia do Mastro Formation. From the Areia do Mastro formation only, a few dinosaurs remains were known before: two ornithopod track casts (Figueiredo et al., submitted work in 2020).

Those tracksites represents a great increase in paleontological record, in particular the dinosaurs remains of Areia do Mastro Formation and they are relevant as a good evidence of a diverse dinosaur fauna throughout the Lower Cretaceous in the Lusitanian Basin. By the large number of tracks identified (the tracksite with the largest number of dinosaur footprints) and data obtained, that may offer an important contribution to the knowledge of the dinosaurs of the Lower Cretaceous, especially about conclusions that may be provided about the social behaviours of these animals. In the heavily dinoturbated surfaces, most of the contemporaneous sauropod tracks belong to adults which may be evidence for gregarious behaviour as previously highlighted for juveniles (e.g., Myers & Fiorillo, 2009). Both large number of sauropod and ornithopod tracks in shallow subtidal-to-lower intertidal environments, found in three different beds, allow considering that these large herbivores used the coastal flats to move between pastures, possibly related with close by alluvial plains, during a large period, contributing for trampling the ground, and for a period that can be measured by thousands of years. Also, the relatively small theropod tracks outnumber the larger tracks of the same group, enabling to identify the predominance of small carnivores in the tidal environments of Cape Espichel during the lowermost Barremian, and possibly chasing for prey in groups.

Acknowledgements

We would like to thank to all the team members who have collaborated in the fieldwork. This work was main financed by Centro Português de Geo-História e Pré-História, under the project PAL/2020/01, and by national funds through the Fundação para a Ciência e Tecnologia (FCT), under the projects UID/ Multi/00073/2021 (Centro de Geociências, Univ. Coimbra) and UIDB/MAR/ 04292/2021 (MARE—Marine and Environmental Sciences Centre); Ciência Viva—Agência Nacional para a Cultura Científica e Tecnológica, which has financially supported the field work through the program "Ocupação Científica dos Jovens nas Férias" (Scientific Occupation of Youngsters During Holidays), involving young people of the secondary school level.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Aillud, G. F. (2001). *Palaeoecology, Palaeoenvironmental Analysis and Their Application to Sequence Stratigraphy: Lower Cretaceous, Lusitanian Basin*. PhD Thesis, Plymouth: University of Plymouth.

Antunes, M. T. (1976). *Dinossáurios Eocretácicos de Lagosteiros; Ciências da Terra; Universidade Nova de Lisboa; Lisboa*.

Antunes, M. T. (1990). Dinossáurios em Sesimbra e Zambujal—Episódios de há cerca de 140 milhões de anos. *Sesimbra Cultural,* 12-14.

Buffetaut, E. (2007). The Spinosaurid Dinosaur *Baryonyx* (Saurischia, Theropoda) in the Early Cretaceous of Portugal. *Geological Magazine, 144,* 1021-1025. https://doi.org/10.1017/S0016756807003883

Carvalho, A. M. G., & Santos, V. F. (1993). Pegadas de Dinossáurios de Sesimbra. *Sesimbra Cultural, 3,* 10-14.

Castanera, D., Barco, J. L., Díaz-Martínez, I., Herrero Gascón, J., Pérez-Lorente, F., & Canudo, J. I. (2011). New Evidence of a Herd of Titanosauriform Sauropods from the Lower Berriasian of the Iberian Range (Spain). *Palaeogeography, Palaeoclimatology, Palaeoecology, 310,* 227-237. https://doi.org/10.1016/j.palaeo.2011.07.015

Day, J. J., Norman, D. B., Gale, A. S., Upchurch, P., & Powell, H. P. (2004). A Middle Jurassic Dinosaur Trackway Site from Oxfordshire, UK. *Palaeontology, 47,* 319-348. https://doi.org/10.1111/j.0031-0239.2004.00366.x

Diedrich, C. (2011). Upper Jurassic Tidal Flat Megatracksites of Germany—Coastal Dinosaur Migration Highways between European Islands, and a Review of the Dinosaur Footprints. *Palaeobiology and Palaeoenvironments, 91,* 129-155. https://doi.org/10.1007/s12549-010-0044-y

Dinis, J., Rey, J., Cunha, P. P., Callapez, P., & Pena dos Reis, R. (2008). Stratigraphy and Allogenic Controls of the Western Portugal Cretaceous: An Updated Synthesis. *Cretaceous Research, 29,* 772-780. https://doi.org/10.1016/j.cretres.2008.05.027

Farlow, J. O., O'Brien, M., Kuban, G. J., Dattilo, B. F., Bates, K. T., Falkingham, P. L., Piñuela, L., Rose, A., Freels, A., Kumagai, C., Libben, C., Smith, J., & Whitcraft, J. (2012). Dinosaur Tracksites of the Paluxy River Valley (Glen Rose Formation, Lower Cretaceous), Dinosaur Valley State Park, Somervell County, Texas. *Actas V Jornadas Internacionales sobre Paleontología de Dinosaurios y su Entorno, Salas de los Infantes,* Burgos, 2010, 41-69.

Figueiredo, S. D. (2010). Breve Notícia sobre a Descoberta de um Novo Dinossáurio Ornitópode no Cabo Espichel. *Bol Cen Port de Geo-Hist Pré-Hist, 3,* 7-15.

Figueiredo, S. D. (2014). *Os Dinossáurios em Território Português: As espécies, as jazidas e os fósseis* (232 p.). Lisboa: Chiado Editora.

Figueiredo, S. D., Dinis, P., Belo, J., Rosina, P., & Strantzali, I. (2017). A New Record of a Possible Ornithopod Footprint from the Lower Cretaceous of Cabo Espichel (Sesimbra, Portugal). *Bollettino della Societa Paleontologica Italiana, 56,* 217-231.

Figueiredo, S. D., Rosina, P., & Figuti, L. (2015). Dinosaurs and Other Vertebrates from the Papo-Seco Formation (Lower Cretaceous) of Southern Portugal. *Journal of Iberian Geology, 41,* 301-314. https://doi.org/10.5209/rev_JIGE.2015.v41.n3.47828

Figueiredo, S. D., Rosina, P., Strantzali, I., Antunes, V., & Figueiredo, S. (2020). Paleoenvironmental Changing Approach on the Lower Cretaceous Sequences of Areia do Mastro (Cabo Espichel, Southern Portugal). *Journal of Environmental Science and Engineering A, 9,* 66-71. https://doi.org/10.17265/2162-5298/2020.02.003

Figueiredo, S. D., Strantzali, I., Rosina, P., & Gomes, M. (2016). New Data about the Paleo Environment of the Papo-Seco Formation (Lower Cretaceous) of Southern Portugal. *Journal of Environmental Science and Engineering A, 5,* 463-470. https://doi.org/10.17265/2162-5298/2016.09.004

Fiorillo, A. R., Hasiotis, S. T., & Kobayashi, Y. (2014). Herd Structure in Late Cretaceous Polar Dinosaurs: A Remarkable New Dinosaur Tracksite, Denali National Park, Alaska, USA. *Geology, 42,* 719-722. https://doi.org/10.1130/G35740.1

Lapparent, A. F., & Zbyszewski, G. (1957). Les dinosauriens du Portugal. *Memórias dos-Serviços Geológicos de Portugal, Lisboa (N.S.), 2,* 63 p.

Lockley, M. G., & Hunt, A. P. (1995). *Dinosaur Tracks and Other Fossil Footprints of the Western United States* (338 p.). New York: Columbia University Press. https://doi.org/10.7312/lock90868

Lockley, M. G., Meyer, C. A., & dos Santos, V. F. (1994). Trackway Evidence for a Herd of Juvenile Sauropods from the Late Jurassic of Portugal. *Gaia, 10,* 27-35.

Lockley, M. G., Schulp, A. S., Meyer, C. A., Leonardi, G., & Kerumba, D. (2002). Titanosaurid Trackways from the Upper Cretaceous of Bolivia: Evidence for Large Manus, Wide-Gauge Locomotion and Gregarious Behaviour. *Cretaceous Research, 23,* 383-400. https://doi.org/10.1006/cres.2002.1006

Madeira, J., & Dias, R. (1983). Novas pistas de dinosáurios no Cretácico Inferior. *Comunicações dos Serviços Geológicos de Portugal, 69,* 147-158.

Malkani, M. S. (2007). Trackways Evidence of Sauropod Dinosaurs Confronted by a Theropod Found from Middle Jurassic Samana Suk Limestone of Pakistan. *Sindh University Research Journal, 39,* 1-14.

Manupella, G., Antunes, M. T., Pais, J., Ramalho, M. M., & Rey, J. (1999). *Notícia Explicativa da Carta Geológica de Setúbal; Serviços Geológicos de Portugal; Lisboa*.

Mateus, O., & Antunes, M. T. (2003). A New Dinosaur Tracksite in the Lower Cretaceous of Portugal. *Ciências da Terra (UNL), 15,* 253-262.

Mateus, O., Araúlo, R., Natário, C., & Castanhinha, R. (2011). A New Specimen of the Theropod Dinosaur *Baryonyx* from the Early Cretaceous of Portugal and Taxonomic Validity of *Suchosaurus*. *Zootaxa, 2827,* 54-68.
https://doi.org/10.11646/zootaxa.2827.1.3

Moreno, K., De Valais, S., Blanco, N., Tomlinson, A. J., Jacay, J., & Calvo, J. O. (2011). Large Theropod Dinosaur Footprint Associations in Western Gondwana: Behavioural and Palaeogeographic Implications. *Acta Palaeontologica Polonica, 57,* 73-83.
https://doi.org/10.4202/app.2010.0119

Myers, T. S., & Fiorillo, A. R. (2009). Evidence for Gregarious Behaviour and Age Segregation in Sauropods. *Palaeogeography, Palaeoclimatology, Palaeoecology, 274,* 96-104.
https://doi.org/10.1016/j.palaeo.2009.01.002

Neto de Carvalho, C., Viegas, P., & Cachão, M. (2007). Thalassinoides and Its Producer: Populations of Mecochirus Buried within Their Burrow Systems, Boca do Chapim Formation (Lower Cretaceous), Portugal. *Palaios, 22,* 107-112.
https://doi.org/10.2110/palo.2006.p06-011r

Ostrom, J. H. (1972). Were Some Dinosaurs Gregarious? *Palaeogeography, Palaeoclimatology, Palaeoecology, 11,* 287-301. https://doi.org/10.1016/0031-0182(72)90049-1

Paul, G. S. (2010). *Dinosaurs: A Field Guide* (320 p.). London: A & C Black.

Pinuela, L., García-Ramosa, Romano, J. M., & Ruiz-Omeñaca, J. I. (2016). First Record of Gregarious Behavior in Robust Medium-Sized Jurassic Ornithopods: Evidence from the Kimmeridgian Trackways of Asturias (N. Spain) and Some General Considerations on Other Medium-Large Ornithopod Tracks in the Mesozoic Record. *Ichnos, 23,* 298-311. https://doi.org/10.1080/10420940.2016.1178640

Rey, J. (1972). Recherches géologiques sur le Crétacé inférieur de l'Estremadura (Portugal). *Memórias dos Serviços Geológicos de Portugal, 21,* 477p.

Rey, J. (1992). Les unités lithostratigraphiques du Crétacé inférieur de la région de Lisbonne. *Comunicações Serviços Geológicos de Portugal, 78,* 103-124.

Rey, J., Graciansky, P. C., & Jacquin, T. (2003). Les séquences de dépôt dans le Crétacé inférieur du Bassin Lusitanien. *Comunicações do Instituto Geológico e Mineiro, Lisboa, 90,* 15-42.

Romano, M., Clark, N. D. L., & Brusatte, S. L. (2018). A Comparison of the Dinosaur Communities from the Middle Jurassic of the Cleveland (Yorkshire) and Hebrides

(Skye) Basins, Based on Their Ichnites. *Geosciences, 8,* 327-349. https://doi.org/10.20944/preprints201807.0610.v1

Santos, V. F. (2003). *Pistas de dinossáurio no Jurássico e Cretácico de Portugal. Considerações paleobiológicas e paleoecológicas* (365 p.). PhD Thesis, Fac. Ciências da Universidade Autonoma de Madrid.

Santos, V. F. (2008). *Pegadas de Dinossáurios de Portugal* (124 p.). Lisboa: Museu Nacional de História Natural.

Santos, V., Callapez, P., Castanera, D., Barroso-Barcenilla, F., Rodrigues, N., & Cupeto, C. (2015). Dinosaur Tracks from the Early Cretaceous (Albian) of Parede (Cascais, Portugal): New Contributions for the Sauropod Palaeobiology of the Iberian Peninsula. *Journal of Iberian Geology, 41,* 155-166. https://doi.org/10.5209/rev_JIGE.2015.v41.n1.48662

Sauvage, H. E. (1897-1898). *Vertébres fossils du Portugal. Contribuition à l'étude des Poisson et des Reptiles du Jurrassique et Crétacique*. Dir. Trab. Geol. Portugal.

Thulborn, R. A., & Wade, M. (1989). *Dinosaur Tracks and Traces.* Cambridge: Cambridge University Press.