

Amazonian Lower Cretaceous North Tocantins State (Brazil) dinosaur track site: conservation significance

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Abstract On the left bank of the Tocantins River, near São Domingos, State of Tocantins, northern Brazil, there are at least six vertebrate trackways from the Barremian Corda Formation (Parnaíba Basin) first reported by Leonardi (Buenos Aires 1:215–222, 1980) and assigned to iguanodontid dinosaurs. Later, these trackways were reassigned as belonging to sauropods. Until 2011, this locality was subject to river floods during seasonal rain cycles. Since then, the amount of water on the flatstones was substantially modified due the implantation of the “Usina Hidroeletrica de Estreito”, which has a dam 160 km upstream from the trackways locality. Recent fieldwork in the area has revealed that only a part of four original trackways is still preserved. The specimens, with poor to moderate preservation, are represented by large

semicircular pes imprints lacking digital impressions mostly overlapping the hand print, which supports a sauropodian origin. Here, the authors consider and suggest geotourism as an important tool to protect and preserve the São Domingos’ footprints.

Keywords Conservation · Dinosaur track site · Tocantins State · Brazil

Introduction

The first discovery of dinosaur footprints in Brazil was reported at the end of the nineteenth century (sensu Leonardi 1994). These dinosaur tracks come from the Cretaceous Sousa and Uiraúna-Brejo das Freiras basins, in the Sousa region, State of Paraíba, northeastern Brazil. According to Leonardi and Carvalho (2002), these ichnofossil records are composed of isolated footprints of small and large theropod and ornithopod dinosaurs. At present, the area where these ichnofossils were found belongs to the Monumento Estadual do Vale dos Dinossauros, in the municipality of Sousa. This conservation area arose as an initiative for preservation of the fossil site, and to increase the economic and geotouristic potential of the area by attracting researchers and tourists from all countries to observe and learn more about its importance.

Leonardi (1980) mentioned the presence of a vertebrate ichnological locality from the Barremian Corda Formation, Parnaíba Basin, in the left bank of the Tocantins River, in the village of São Domingos, municipality of Itaguatins, State of Tocantins, northern Brazil (Fig. 1). The tracks have been originally assigned to iguanodontid dinosaurs, but were later reassigned to sauropod tracks (Leonardi 1994; de Valais et al. 2012, 2014; de Valais and Tavares

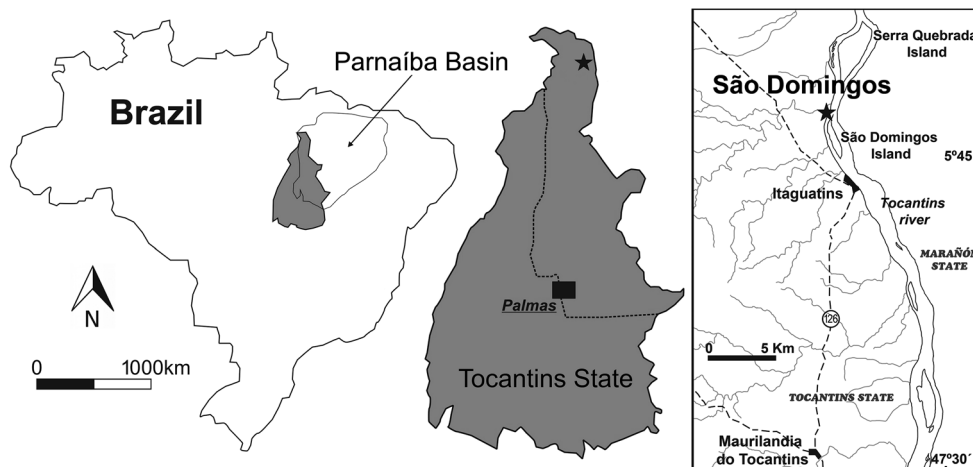
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Fig. 1 The São Domingos track site locality in North Tocantins State Amazonian regions



2013). These ichnological records are one of the few known in the Cretaceous of Brazil.

Since 2011 the Usina Hidroelétrica de Estreito (a Hydroelectric Power Plant) started its activities, including the catchment to a dam located 160 km upstream from the ichnological site. Those activities cause periodic and highly energetic floods over the coastal plains of the Tocantins River, affecting the stability of the terrain containing the footprints.

Therefore, the aims of this contribution are: (1) to describe the present condition of the ichnological surface of the São Domingos dinosaur track site; and (2) to evidence the scientific, educational, and cultural importance of this region in northern Brazil to the local population, as well as the touristic potential of the area by stimulating its geo-observation.

Supported by grants from funding agencies in the Conselho Nacional de Desenvolvimento Científico e Tecnológico and Curso de Pós-Graduação de Ecologia de Ecótonos da Universidade Federal do Tocantins/Porto Nacional, a team of South American scientists was assembled to document the present condition of the São Domingos dinosaur track site. Until now, the dinosaur footprints in the São Domingos region have never been studied with a geo-conservative objective.

São Domingos ichnological site

Description of the tracks

The vertebrate ichnological locality is situated on the left bank of the Tocantins River, in the village of São Domingos, municipality of Itaguatins, State of Tocantins, northern Brazil (Fig. 1). The track-bearing level is a very fine- to medium-grained red sandstone, rich in iron oxide and zeolites, which belongs to the Barremian (Lower

Cretaceous) Corda Formation, Parnaíba Basin (Santos and Carvalho 2009; Alves 2010a, b).

At present, just a part of four original trackways is preserved, having a total of at least twenty tracks. Most imprints are poorly to moderately preserved, but it is still possible to distinguish their morphology and spatial arrangement (Fig. 2).

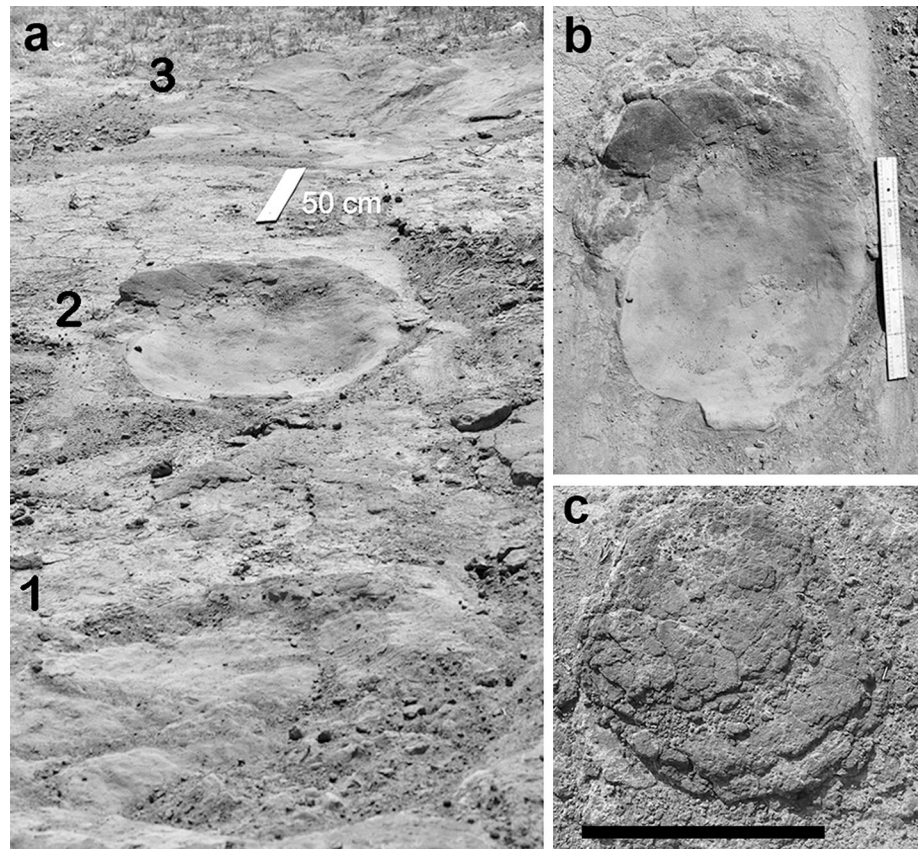
The specimens are mostly represented by circular to subcircular pes imprints, and a few tracks with a subtriangular sole, probably due to erosion. All tracks lack digital and claw impressions. The footprints are slightly longer than wide; range from 59 to 80 cm wide, with an average of 66 cm wide, and from 66 to 82 cm long, with an average of 70 cm long. No distinguishable manus imprints are present, probably due to their state of preservation or taphonomic condition, or because the pes imprints are overlapping the hand prints.

The trackways are relatively narrow with respect to the size of the tracks, with a width equivalent to about a footprint and a half. The average of stride length and pace angulation is 3 m and 140°, respectively.

Remarks

The tracks from São Domingos are the unique evidence of vertebrate remains from the Corda Formation (Alves 2010a, b; Santos and Carvalho 2009). Originally, this fossil site was composed of at least seven trackways accounting for fifty-six footprints assigned to iguanodontid dinosaurs (Leonardi 1980). Subsequently, they were reassigned to sauropod tracks (Leonardi 1994; de Valais et al. 2012; de Valais and Tavares 2013), particularly to basal sauropod, basal macronarians, or diplodocoids (de Valais et al. 2014). Based on the morphology and spatial distribution of the tracks, and on the known paleofauna of the region, we agree with this later inference.

Fig. 2 Photographs of in situ tracks from the São Domingos track site, in Brazil. **a** A three-footprint trackway; the nearest track is covered by modern sediments, **(b)** and **c** moderately preserved footprints. Scale bars 50 cm



It is usually accepted that sauropod footprints are divided into two main categories based on the width of the trackways, namely wide- and narrow-gauge trackways, i.e., *Brontopodus* or like and *Parabrontopodus* or like, respectively (Lockley et al. 1994). On the basis of the distinction, the footprints from São Domingos have been considered into the narrow-gauge or *Parabrontopodus*-like group (sensu de Valais et al. 2014).

Discussion preservation proposal

The ichnological site of São Domingos was subject to flooding during seasonal rainfalls until 2011. However, when the hydropower plant “Usina Hidroelétrica de Estreito” was implanted with a dam 160 km upstream from the locality, the amount of water getting to the flatstones containing the footprints was substantially modified. Recent fieldwork in the area aimed to educate the local population of Itaguatins about the scientific and cultural importance of these dinosaur footprints, especially for the region (Souza et al. 2010; Alves 2010a, b; Candeiro et al. 2011).

There are several sites from other regions of the world where dinosaur footprints can also be observed in their

geological context (Martill 2000; Powell 2003; Silva 2010). Some localities are of easy access along the coast where visitors can observe dinosaur tracks preserved in situ as natural unattached moulds on beaches. For example, there are dinosaur trackways along the coast of the island of Wight (Martill 2000) and in Ardley Quarry, in Oxfordshire, both located in Great Britain. However, public access requires previous authorization from responsible authorities to visit each fossil site (Powell 2003).

As previously mentioned in the literature (Leonardi and Carvalho 2002; Ribeiro and Carvalho 2007; Silva 2010; Santos and Carvalho 2011), geotourism is an important tool for the protection and conservation of the Itaguatins footprint site. The introduction of this potentially popular activity in the area would attract scholar and touristic excursions to observe and learn about the footprints. On the guided visits, the general public can learn about evolution, geology, the local paleofauna, and the peculiarities of the native dinosaurs that produced those trackways.

The Monumento Estadual Vale dos Dinossauros, located in the municipality of Sousa, state of Paraíba, is an excellent example of a Brazilian paleontological site which is not only a preservation area but also a tourist destination that promotes the popularization of science (Silva 2010;

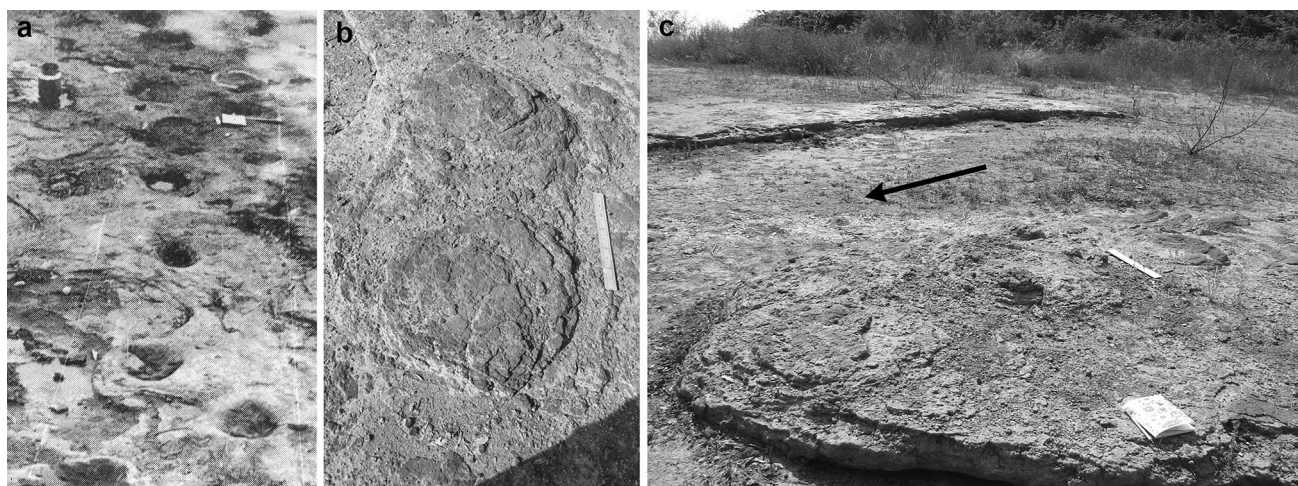


Fig. 3 **a** Photographs of one of the trackways from the São Domingos track site, northern Brazil, taken from Leonardi (1994), **b** two associated footprints, preserved at an apparent positive

epichnia, **c** the *arrow* indicates the direction of the water drainage through the channel. *Scale bars* in **(b)** and **(c)**: 50 cm

Santos and Carvalho 2010; Siqueira et al. 2011). Also, the geotourism is economically important to this region as it increases the number of tourists.

The São Domingos dinosaur tracks, on the Tocantins river floodplain, nearby the homonymous village, have been greatly reduced both in quantity and quality (Fig. 3). The accelerated erosion caused by anthropological activities have abraded or destroyed many footprints in the area. This ichnological site, which in the 1980s contained at least seven sauropod trackways accounting for sixty-six tracks, is nowadays partially destroyed. Leonardi (1980) shows a picture with some sauropod tracks preserved as natural casts, in deep concave epirelief (Fig. 3a). Recent pictures of the same area allow the recognition of the present condition of preservation of the footprints. The specimens are preserved at the uppermost level with respect to the surface ground, and it is possible to observe the degree of erosion in the track-bearing layer (Fig. 3b). The tracks were preserved in the surface because of the compression pressure caused by the animal's weight on the sediments, making it more erosion-resistant. It is also possible to observe drainage channels in some sectors of the beach, which drain the water from floods caused by the presence of the dam (Fig. 3c). This results in marked erosion on the sandstones.

Our interpretation that there is an increase in vulnerability of the Itaguatins Geosite was based on the following criteria: (1) the Tocantins River has high energy transportation to the Estreito Hydropower dam both during the rainy season and spillway operations. The stream transports sediments of different size, as well as rock fragments, causing the abrasion of the sandstone slabs where the dinosaur footprints are preserved; (2) because large ungulates living in the area may cause trampling damage to the

sandstones, their easy access to the ichnological area increases the vulnerability of the trackways; (3) the São Domingos community is not fully aware of the importance of preserving the dinosaur footprints of the region, causing indifference towards the paleontological site.

As presented here, the São Domingos ichnological site is nowadays under risk. Therefore, the ongoing erosion of the footprints evidences the importance of our proposal to create a comprehensive and updated database about these ichnofossils. In order to preserve the São Domingos ichnofossils, the following actions are suggested: to carry out an updated, detailed and systematic study of the tracks in order to identify all footprint records from the area; to facilitate and support the studies of geologists and paleontologists by placing signposts in the Geosite that inform visitors about the prohibition to remove any material from the site; to institutionalize educational programs for the São Domingos community; to prohibit the entrance of domesticated large animals in the Geosite area; to request via the Superintendence of the Departamento Nacional de Produção Mineral in Tocantins the permission of the Public Prosecutor's Office to make those preservation actions official with the Itaguatins City Hall; and finally, to place signs containing information about the fossil records and its present preservation status in the Geosite.

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