



## Current situation of the ichnological locality of São Domingos from the Corda Formation (Lower Cretaceous), northern Tocantins state, Brazil



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### ABSTRACT

In the 80's, Leonardi treated the presence of a vertebrate ichnological locality from the Barremian Corda Formation, Parnaíba Basin, on the left bank of the Tocantins river, near of the São Domingos town, Itaguatins, State of Tocantins, Brazil. Originally, the record was composed of at least seven *in situ* trackways, accounting for fifty six tracks. Since 2011, the Hydroelectric Power Plant do Estreito has begun to work, causing the development of a water reservoir 160 km upstream to the ichnological site, causing periodic and highly energetic floods over the footprints-bearing level and altering it. The imprints are poorly to moderate preserved, but it is possible to distinguish the general morphology and the spatial arrangement of the footprints. The specimens are represented by pes imprints, mostly circular to subcircular, with no digital and claw impressions. No distinguishable manus imprints are present. The trackways are relative narrow with respect to the size of the tracks, so they are considered into the *Parabrontopodus*-like category. The São Domingos tracks have been originally assigned to iguanodontid dinosaurs, and posteriorly related to a sauropodian origin. This idea is herein accepted, particularly to a basal sauropod, basal macronarians, or diplodocoids. Up to date, the tracks from the São Domingos locality are the only vertebrate fossil record from the Corda Formation, meaning an important contribution to the Cretaceous ichnofauna from South America.

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### 1. Introduction

The first record of dinosaur footprints from Brazil were achieved at the end of the nineteenth century (e.g., Moraes, 1924; Huene, 1931; Leonardi, 1994; Leonardi and Carvalho, 2002). These tracks were from the Lower Cretaceous Sousa and Uiraúna-Brejo das Freiras basins, from the Sousa region, Paraíba State, Northeast Brazil, and are represented by isolated footprints and trackways assigned to both small and large theropod, sauropod, ornithopod, and quadrupedal ornithischian footprints, besides some indetermined specimens (Moraes, 1924; Leonardi, 1994; Leonardi and

Carvalho, 2002; Leonardi and dos Santos, 2004). At present, this ichnofossiliferous area is one of the most important of the Cretaceous North Gondwana, and pertains to the Monumento Estadual do Vale dos Dinossauros [State Monument Dinosaur Valley], in the municipality of Sousa. Since then, ichnological expeditions to different sites of Brazil have been carried out by several researchers, increasing the known ichnolocalities and the track records from Brazil (e.g., Leonardi, 1981, 1994; Costa da Silva et al., 2007, 2012; Fernandes and Carvalho, 2005, 2008).

Leonardi (1980a) presented a vertebrate ichnological locality from the Lower Cretaceous Corda Formation, Parnaíba Basin, on the left bank of the Tocantins river, near of the São Domingos town, municipality of Itaguatins, State of Tocantins, northern Brazil (Fig. 1). Originally, the record was composed of at least seven *in situ* trackways accounting for fifty six footprints (Fig. 2), named informally with the code ITSD 1 to 7 (Itaguatins, Tocantins, São

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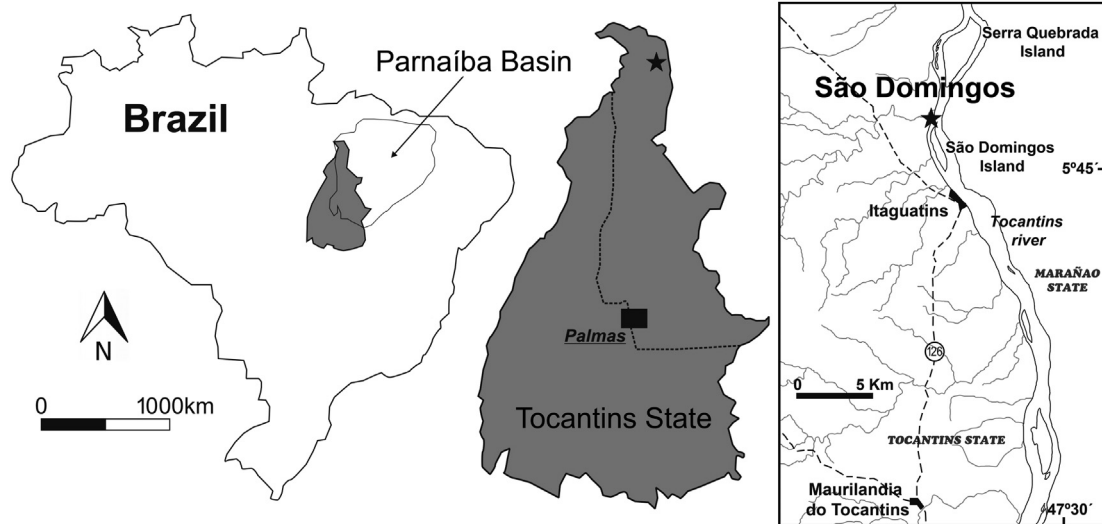


Fig. 1. Location map of the São Domingos site, State of Tocantins, Brazil. The star indicates the ichnofossiliferous locality.

Domingos). Firstly, these tracks had been assigned to iguanodontid dinosaurs (Leonardi, 1980a), but posteriorly, and with no further explanations, they were re-assigned to sauropods (Leonardi, 1994; de Valais et al., 2012; de Valais and Tavares, 2013).

A reptilian track fossils from the banks of the Igarapé Braço Seco, sub-tributary of the Guamá river, near Iritúia, Mãe do Rio district, Brazil, has been mentioned as coming tentatively from the Corda Formation (Ferreira et al., 1979; Leonardi, 1980b, 1994:62), but no further details are available to be confident about these data. So, up to date, and given that no other kind of corporeal fossils (e.g., teeth, bones) have been preserved in the unit, these tracks from the São Domingos locality are the only vertebrate fossil evidence from the Corda Formation.

A disturbing situation is that, since 2011, the Usina Hidrelétrica do Estreito (meaning Hydroelectric Power Plant) has begun to work, causing the development of a water reservoir 160 km upstream to the ichnological site. Its activity causes periodic and highly energetic floods over the footprints-bearing level, altering its stability by eroding artificially and covering with current sediments the ichnological surface (Tavares et al., in press).

The aim of this contribution is to update the knowledge of the condition of the São Domingos ichnological tracksite, northern Brazil, as well as describing and analyzing its vertebrate footprints.

## 2. Geological setting

The Corda Formation, Parnaíba Basin, outcrops in the central part of the basin in the north of Brazil, at west near to the Araguaia river mouth, and at east near to the right margin of the Parnaíba river (Aguiar, 1971). The Corda Formation overlies the Pastos Bons Formation in concordance (conforming a continental cycle), and discordantly to the basaltic Mosquito Formation, and is overlain with the basaltic Sardhina Formation (Aguiar, 1971). Together these four geological units comprise the Mearim Group (Lisboa, 1914; Aguiar, 1971; Pedreira et al., 2003).

The lithology of the unit is composed of sandstones white, pink, purple to gray cross bedding sandstones with predominance of moderate to well sorted sandstones, and rare conglomerates (Aguiar, 1971).

The sedimentation of the Corda Formation occurred in an environment of desert, under dry and warm weather conditions, and inland high energy fluvial, deposited in the distal portion of a

braided fluvial system, where the preservation of the fossils is a rare event (Santos and Carvalho, 2009).

The unit has been dated as Lower Cretaceous (Barremian, 130 m.a.; Barbosa et al., 1966; Leonardi, 1994; Lima and Leite, 1978; Santos and Carvalho, 2009) on the basis of the presence of the conchostracean *Macrolimnadiopsis paulo Beurlen, 1954 (sensu Lima and Leite, 1978)*. The rest of the fossils are represented by the conchostracean *Lioestheria* and the ostracod *Candona*, besides some palynomorphs as plant cuticles and tracheids (Lima and Leite, 1978).

As regards vertebrate remains, the exception is the dinosaur track record in the ichnological locality described in the present contribution, situated on the left bank of the Tocantins river, near of the São Domingos town, municipality of Itaguatins, State of Tocantins, northern Brazil (5°42'58"S, 47°29'48"O; Fig. 1). The tracks-bearing level is in the Corda Formation, almost horizontal and partially overlain with current sediments from the high-energy floods of the Tocantins river. The stratum includes reddish and gray sediments, fine to medium grained, lacking clasts, with desiccation cracks and root traces (Fig. 3). Sometime the footprint infilling displays a higher concentration of iron oxides, in contrast to the clear red sandstone; usually, the smaller structures are more superficial than larger ones.

## 3. Description of São Domingos vertebrate tracks

At present, just at least twenty footprints of four original trackways are preserved (Fig. 2). The imprints are poorly to moderate preserved, with eroded margins and displacement, and even it is probably that some of the tracks are undertracks. Nevertheless, it is possible to distinguish the general morphology and the spatial arrangement of the footprints (Fig. 4).

The specimens are represented by pes imprints, mostly circular to subcircular, and a few tracks with a subtriangular sole, probably due to erosion, which can be inferred given that they belong to trackways composed of other subcircular footprints. All of them lack digital and claw impressions. The footprints are slightly longer than wide; they range from 59 cm to 80 cm wide, with an average of 66 cm, and from 66 cm to 82 cm long, with an average of 70 cm. No distinguishable manus imprints are present.

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

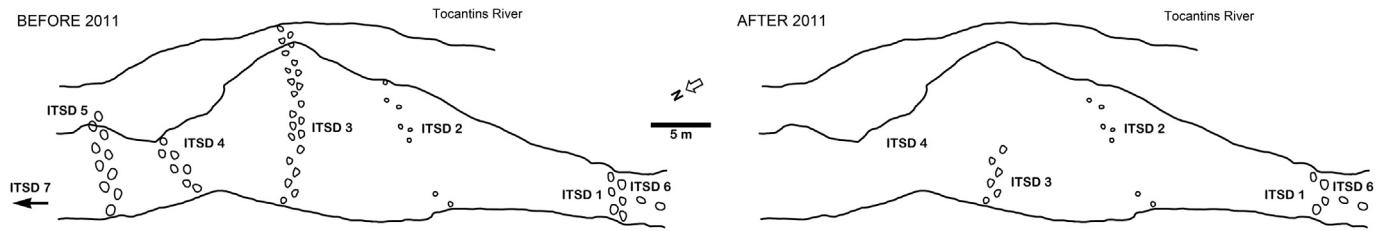


Fig. 2. Line drawing of the São Domingos site, on the Tocantins river left bank, State of Tocantins, showing distribution of trackways ITSD 1 to 7. Left, situation before 2011. Right, situation after 2011. Modified from Leonardi, 1980a. Scale: 5 m.

#### 4. Discussion

The São Domingos dinosaur tracks, on the Tocantins river floodplain, 0.5 km to the homonymous village, have been greatly reduced both in quantity and quality, due to both natural and artificial erosion on the area. This ichnological site, which in the 1980s contained at least seven trackways accounting for fifty six tracks, is partially lost, and currently, just one third of the original footprints is preserved (Fig. 2).

The São Domingos tracks have been originally assigned to iguanodontid dinosaurs (Leonardi, 1980a), and posteriorly related to a sauropodian origin (Leonardi, 1994; de Valais et al., 2012; de Valais and Tavares, 2013). Although no distinguishable manus imprints are present, this may be due to the preservation or taphonomic conditions, or that to the pes imprints are overlapping the hand prints. Because of the morphology and spatial distribution of

the tracks (i.e., circular to semicircular footprints overlapping the hand prints, disposed in relative narrow trackways), plus the regional paleofaunistic record, it is herein accepted as a sauropodian ichnotaxon.

Furthermore, on the basis of the evidence of narrow hips, the trackmaker could be a basal sauropod, basal macronarians, or diplodocoids (e.g., Day et al., 2002; Gallina and Apesteguía, 2005).

The sauropodian paleofauna from the Early Cretaceous of the North Gondwana is commonly recorded in outcrops of North both Brazil and Africa (Candeiro et al., 2011). This assemblage is characterized by the co-existence of diplodocoidean and titanosauriform sauropods, represented by the rebbachisaurids *Amazonasaurus maranhensis* Carvalho et al., 2003 from Brazil, *Rebbachisaurus garasbae* Lavocat, 1954 from Morocco, *Nigersaurus taqueti* Sereno et al., 1999 from Niger Republic, *Tataouinea hannibalis* Fanti et al., 2012 from Tunisia, cf. *Limaysaurus* from Brazil (Medeiros et al., 2014), titanosauriforms *Aegyptosaurus baharijensis* Stromer, 1932 and *Paralititan stromeri* Smith et al., 2001 from Egypt, and other records of Dicraeosauridae, Diplodocoidea, Lithostrotia, Somphosponyli, and Titanosauria, all of them indetermined (see Cavin et al., 2010; Candeiro et al., 2011; Mannion and Barret, 2013).

Regarding to the ichnotaxonomic analysis, the lack of morphological details of the tracks precludes a confident ichnotaxonomic assignment. However, some remarks and comparisons can be done.

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

Sauropod trackways from the pre-Aptian Sousa and Antenor Navarro formations, Rio do Peixe Basin, Brazil, were presented by Leonardi (1989). Posteriorly these tracks were briefly described, and mentioned as related to the dicraosaurids, rebbachisaurids or basal titanosaurs (*sensu* Leonardi and Carvalho, 2002). Nevertheless, there are no available data to determine whether the trackways are wide or narrow-gauge to make an assignment with confidence.

Souza et al. (2010) have mentioned at least fifteen tracks ascribed to a wide-gauge sauropod trackways from the Mata da Corda Formation (Late Aptian-Early Albian), Parnaíba Basin, Tocantins. The difference in the width of the trackway is the main distinction between the ichnofossils from this unit and from the Corda Formation.

Some sauropod tracks have been mentioned from the Arca-buco Formation (Early Cretaceous, probably pre-Valangianian), from Boyacá, Colombia (Moreno-Sánchez et al., 2011). However, maybe they are even not sauropod footprint (Moreno-Sánchez and Gómez Cruz, 2013), and the lack of proper descriptions and illustrations makes the comparisons with other footprints difficult.

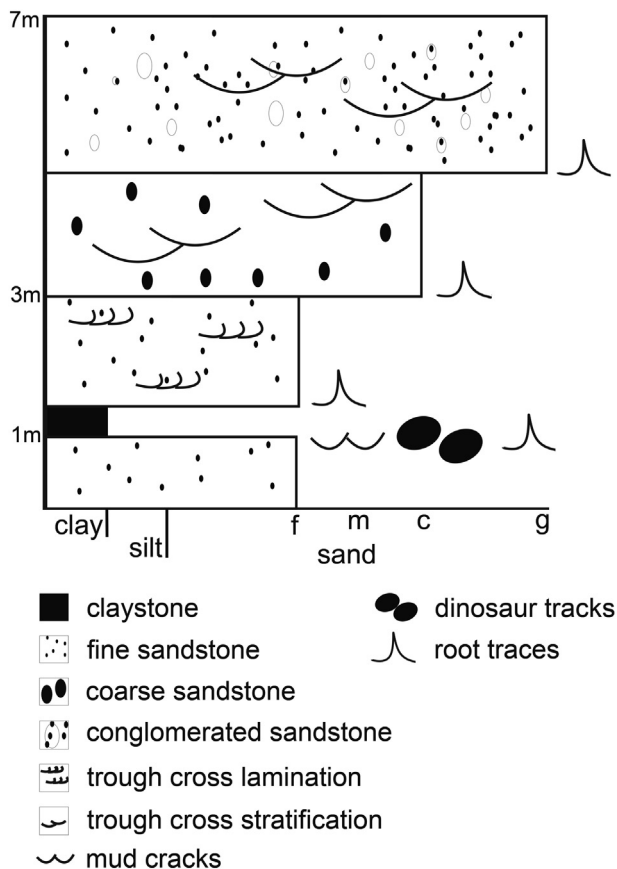
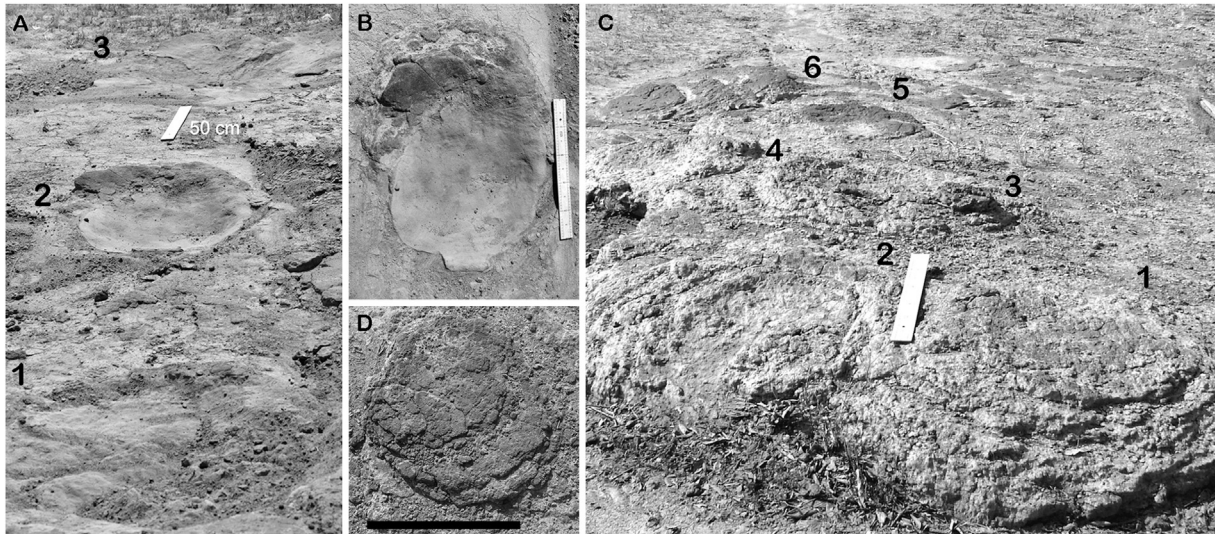


Fig. 3. Stratigraphic column of the São Domingos site, Corda Formation, showing the sauropod tracks bearing surface.





**Fig. 4.** Field photographs of specimens of the sauropod tracks. A, three tracks, indicated as 1 to 3, probably corresponding to ITSD 2. B, detail of the second footprint of the trackway of A. C, six tracks, indicated as 1 to 6, probably corresponding to ITSD 3. D, detail of the fourth footprint of the trackway of C. Scale: 50 cm.

The ichnogenus *Iguanodonichnus* Casamiquela and Fasola, 1968, from Baño del Flaco Formation, near San Fernando, IV Region, Chile, was originally assigned to ornithischian and then re-interpreted as narrow-gauge sauropod tracks (Moreno and Pino, 2002; Moreno and Benton, 2005). *Iguanodonichnus* differs from the São Domingos footprints in that it displays a triangular, elongated pes imprint, with clear digit and claw imprints.

*Sauropodichnus* Calvo, 1991, from the Cenomanian Candeleros Formation, southern Neuquén province, corresponds to wide-gauge sauropod tracks, main features that distinguish it from the São Domingos tracks.

## 5. Conclusion

The ichnological record from the Corda Formation, Northern Brazil, is an important contribution to the Cretaceous ichnofauna from South America, seeing that, if it is confirmed that these specimens are related to basal macronarians or diplodocoids, they would be the oldest for the Early Cretaceous North Gondwana. Particularly for this geological unit, the São Domingos footprints are up till now the unique evidence of vertebrate remains from the Corda Formation (e.g., Alves, 2010a,b; Santos and de Carvalho, 2009).

These tracks, belonging to the narrow-gauge sauropod trackway category, are an interesting record, while also informative about the Gondwana Cretaceous vertebrate paleofauna, aspect on which further work is needed.

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