



FLORESTA DOS BORBAS, A NEW LOCALITY WITH DINOSAUR TRACKS IN THE SOUSA BASIN, PARAÍBA, BRAZIL ⁽¹⁾

(With 6 figures)

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ABSTRACT: A new site with dinosaur tracks from the Sousa Basin, Lower Cretaceous of Northeast Brazil is presented. Floresta dos Borbas is the sixth dinosaur tracksite found in the Antenor Navarro Formation. Two theropod trackways are described as well as three sauropod tracks. The sauropod record in this region indicates a restriction to the northern portion of the basin, mostly found in the Antenor Navarro Formation and probably the basal portion of the Sousa Formation. A preliminary analysis indicates that the lower portion of the stratigraphic sequence that forms the Sousa Basin was deposited in a different paleoenvironmental condition than the upper part, being possibly more favorable for sauropods.

Key words: Dinosauria, ichnofossils, Antenor Navarro Formation, Lower Cretaceous, Sousa Basin, Paraíba, Brazil.

RESUMO: Floresta dos Borbas, uma nova localidade com pistas de dinossauros na Bacia de Sousa, Paraíba, Brasil. Uma nova localidade com pistas de dinossauros da Bacia de Sousa, parte do complexo de bacias do Rio do Peixe, Cretáceo Inferior do Nordeste do Brasil, é apresentada. A região, conhecida como Floresta dos Borbas, forma a sexta localidade com pistas e pegadas de dinossauros encontrada na Formação Antenor Navarro. Duas pistas de terópodes e três pegadas de saurópodes são descritas. O registro de pegadas de saurópodes está restrito à parte norte da bacia, procedente da Formação Antenor Navarro e possivelmente à base da Formação Sousa. Uma análise ainda bastante preliminar sugere a existência de diferentes condições paleoambientais na base da seqüência estratigráfica que forma esta bacia, possivelmente mais favorável ao desenvolvimento de uma comunidade de saurópodos do que a parte superior.

Palavras-chave: Dinosauria, icnofósseis, Formação Antenor Navarro, Cretáceo Inferior, Bacia de Sousa, Paraíba, Brasil.

INTRODUÇÃO

The Rio do Peixe basin complex is presently subdivided into four basins, called Sousa, Uiraúna-Brejo das Freiras, Pombal, and Vertentes (LEONARDI & CARVALHO, in press). The Sousa and Uiraúna-Brejo das Freiras basins contain the richest dinosaur ichnofauna from Brazil, which is considered one of the most important from South America. The first report of dinosaur tracks from this region was presented by L.J.Moraes in nineteenth-twenties (MORAES, 1924). Since that time, several authors have contributed to the knowledge of this ichnofauna (*e.g.*, AZEVEDO, 1993; CARVALHO, VIANA & LIMA FILHO, 1993) but most information was provided

by Giuseppe Leonardi, who has studied them systematically for several years (LEONARDI, 1979 a, b; 1980; 1987; 1994; LEONARDI, LIMA & LIMA, 1987a, b, c). Up to now, 22 tracksites have been identified in the Rio do Peixe basin: 13 at the Sousa Formation, 5 at the Antenor Navarro Formation, and 4 at the Piranhas Formation (LEONARDI & CARVALHO, in press).

During August 2001, a joint fieldtrip was made by the Museu Nacional (MNRJ), Rio de Janeiro; Universidade Regional do Cariri (URCA), Crato, Ceará; and the Geology and Paleontology Museum of the National University of Comahue, Neuquén, Argentina, to investigate a new locality with dinosaur tracks. This site, named Floresta dos Borbas (GPS: S 06°41'10"; W 038°20'34"), was

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discovered in 1998 by three members of the MOVISSAUROS (Movimento de Preservação do Vale dos Dinossauros, Sousa, Paraíba), Luiz Carlos da Silva Gomes, Robson de Araujo Marques, and Carlos Antonio Lima. The region is located in the Sousa Basin, close to the Sousa - Antenor Navarro road, and has shown several isolated dinosaur tracks (theropods and sauropods). Here we describe two theropod trackways (Figs.1-4) and three isolated sauropod tracks (Figs.5, 6) of this new locality, which demonstrate the large potential for new findings of this new site. They were identified with the following abbreviations: AN (for Antenor Navarro Formation), 23 (since this is the twenty-third locality with ichnofossils from this area) and capital letters for each trackway or isolated track.

GEOLOGICAL SETTING

The Sousa Basin is one of four small basins that compose the Rio do Peixe basin complex (LEONARDI & CARVALHO, in press). The sedimentary rocks of this tectonic feature were designated Rio do Peixe Group by MABESOONE (1972) and MABESOONE & CAMPANHA (1974), and were further subdivided into three formations, named, from base to top, Antenor Navarro, Sousa, and Piranhas. According to studies done on palynomorphs, those strata were deposited during the Lower Cretaceous, between the Berriasian and the Hauterivian (REGALI, 1990), extending possibly into the Lower Barremian (LIMA & COELHO, 1987).

Based on the geological data available, the tracks described here belong to the Antenor Navarro Formation (AN). The strata at the Floresta dos Borbas site are characterized by a succession of coarse yellowish sandstones, occasionally intercalated with conglomeratic lenses. The sandstones are formed predominantly by well-sorted grains of quartz. When weathered, the top surface shows a reddish color. Some sandstone layers show well-developed ripple marks, indicating that shallow waters at least occasionally covered parts of the area.

THEROPOD TRACKWAYS

Two theropod trackways were observed at the Floresta dos Borbas site. The first one (AN-23-A;

Figs.1-3), situated some 20m from the road Sousa - Antenor Navarro, is composed of 8 tracks, five of them well preserved. A conglomeratic layer overlies the last one, suggesting that this trackway is longer (Fig.1). The tracks were made by a medium sized theropod with an estimated height and length of about 2m and 4 to 5m, respectively. It was walking to the southwest (S 25 W) with an average pace of 74cm and a pace angle of 162°. All tracks are tridactyls, digitigrades and mesaxony with the digits terminating in sharp pointed ends (Figs.2,3). The average length and width is 29cm and 23cm, respectively. No impression of phalanx pads could be observed.

Digit II is poorly preserved in all tracks. It is the shortest of all three, being slightly shorter than digit IV (see Table 1). Digit III is the longest, about 50% longer than digits II and IV. All digits have an average width of 4cm becoming acute at the distal end. The divergence between digit II and III are 40° and the divergence between digits III and IV is 35°. The posterior border of the heel is more or less acute and small with respect to the length of the digit.

The second trackway (AN-23-B; Fig.4) is placed on a sandstone layer positioned about 28cm higher than the first one. It is situated directly on the road and is composed by 5 tracks, 3 of which are well marked. According to their displacement, there must have been one more (the second) which was destroyed. The trackmaker was walking toward northeast (N 60 E), with an average pace of 73cm and a pace angle of 160°. All tracks are tridactyl, digitigrades and mesaxony, with the digits ending in sharp points. The average length and width are 31cm and 23cm, respectively (Tab.2). The length of the digits are slightly larger than AN-23-A, but this could be an artifact of preservation (*e.g.*, different water content of substrate at the time the tracks were made) and not necessarily indicates that different taxa were responsible for the tracks. In average, digit II is 12cm long, while digit III and digit IV have, respectively, a length of 19cm and 10cm. The posterior border of the heel is rounder compared to AN-23-A, but the digit divergence is similar in the tracks of both. In AN-23-B only one track shows evidences of the digit pads (track 4), but no phalanx pads.

Since there are no substantial morphological differences between this and the previous

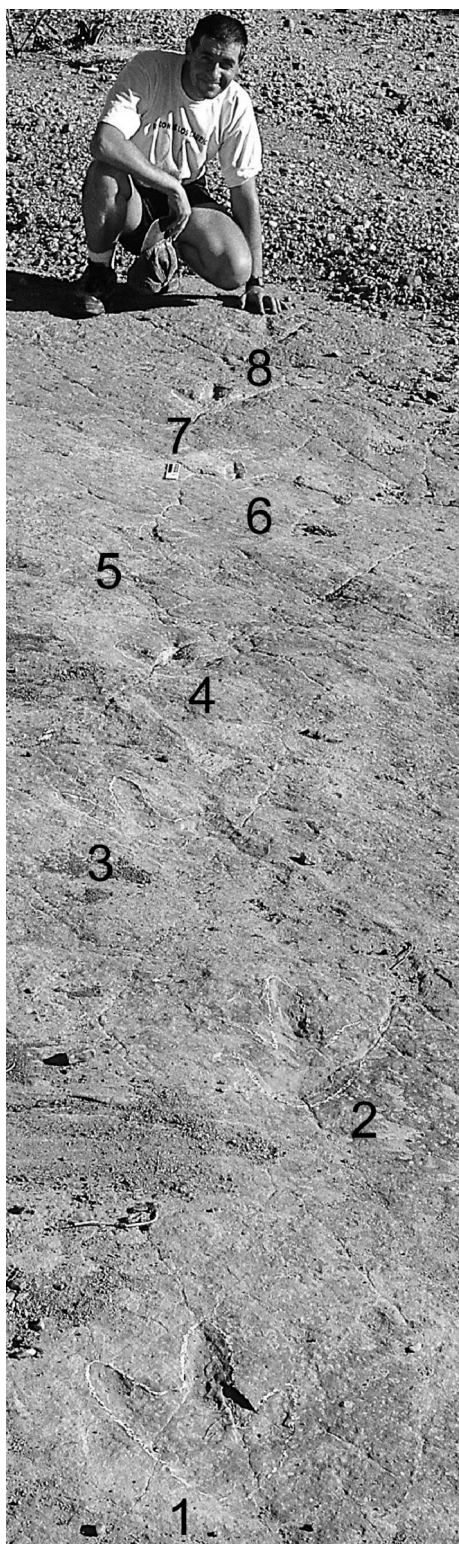


Fig.1- Theropod dinosaur trackway AN-23-A. Numbers indicate individual tracks.

TABLE1
Trackway AN-23-A

Track	Track's measurements (cm)		Digit length (cm)		
	length	width	II	III	IV
1	29	23	9	17	?
2	30	23	?	17	?
3	28	25	12	16	?
4	30	23	11	15	9
5	30	22	10	15	9
6	29	21	8	17	11
7	28	23	10	16	10
8	30	23	9	15	11

TABLE2
Trackway AN-23-B

Track	Track's measurements (cm)		Digit length (cm)		
	length	width	II	III	IV
1	30	23	12	19	9
4	31	23	13	20	11
5	31	23	12	20	11

trackways, they were likely made by similar trackmakers (in different times), both representing a medium-sized theropod. The ichnospecies could not be determined.

SAUROPOD TRACKS

The sauropod ichnofossils are positioned close to the same level as AN-23-B, about 50m west of it. These tracks were positioned directly on the road and were partially destroyed. There are at least two *pes* tracks and one *manus* track (respectively AN-23-C, D and E). Several more rounded depressions were observed at this site, but could not be identified as tracks and no sauropod trackway could be recognized.

Sauropod tracks AN-23-C and AN-23-D (Fig.5) are interpreted as belonging to the *pes*, both not well preserved. The shape of AN-23-C is suboval (0.90 x 0.75m) while AN-23-D tends to be subtriangular. The external dimensions of the latter are 1.20 x 1.00m, while the internal are 0.80 x 0.60m. Rather than being made by two distinct taxa (or animals of distinct



Fig.2- Theropod dinosaur track 8 of AN-23-A.

ontogenetic stage), we interpret the differences of the latter due to deformation and partial destruction that occurred after the track was made. Both sauropod *pes* are associated with a small suboval depression (0.30 x 0.20m) situated only a few centimeters away. So far, the known record indicates that the sauropod *manus* is smaller than the *pes* but not to the degree found in this outcrop. Therefore, those proportionally small depressions are either artifacts or *manus* tracks partially destroyed before burial.

It is interesting to note that the southern borders of these sauropod tracks are shallower than the others, some of which are missing. This suggests that the animal (or animals) were walking at a southward dipping surface. Since this portion of the site is inclined to the south, it is quite possible that the present inclination maintains the same or a similar relief as those tracks were made.

About 40m northeast from the previous sauropod tracks, an isolated *manus* track (AN-23-E; Fig.6) was found. Overall it has a reniform shape, similar to other sauropod *manus* tracks recorded in

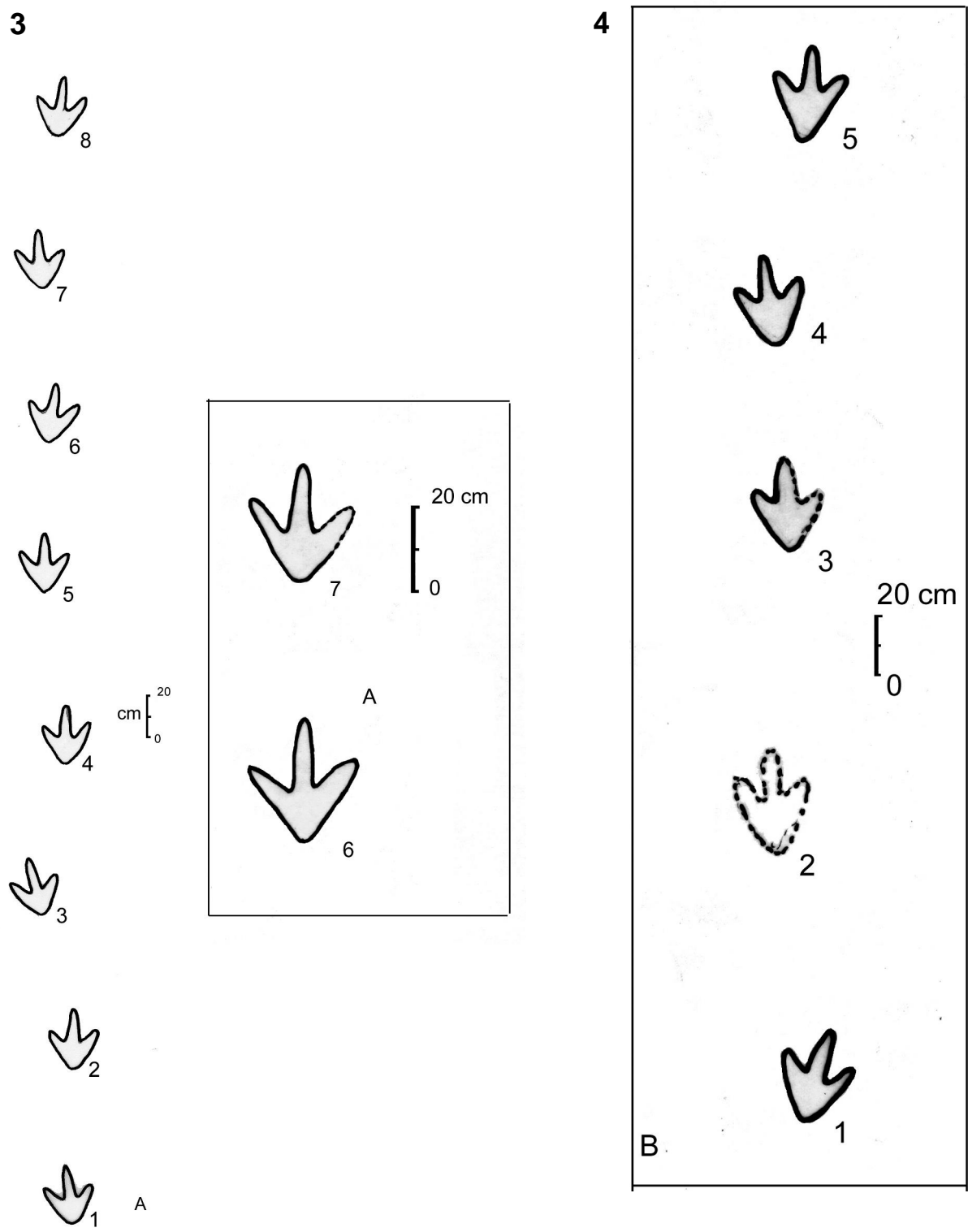


Fig.3- Drawing showing the theropod dinosaur trackway AN-23-A, showing in detail tracks 6 and 7; fig.4- drawing showing the theropod dinosaur trackway AN-23-B.

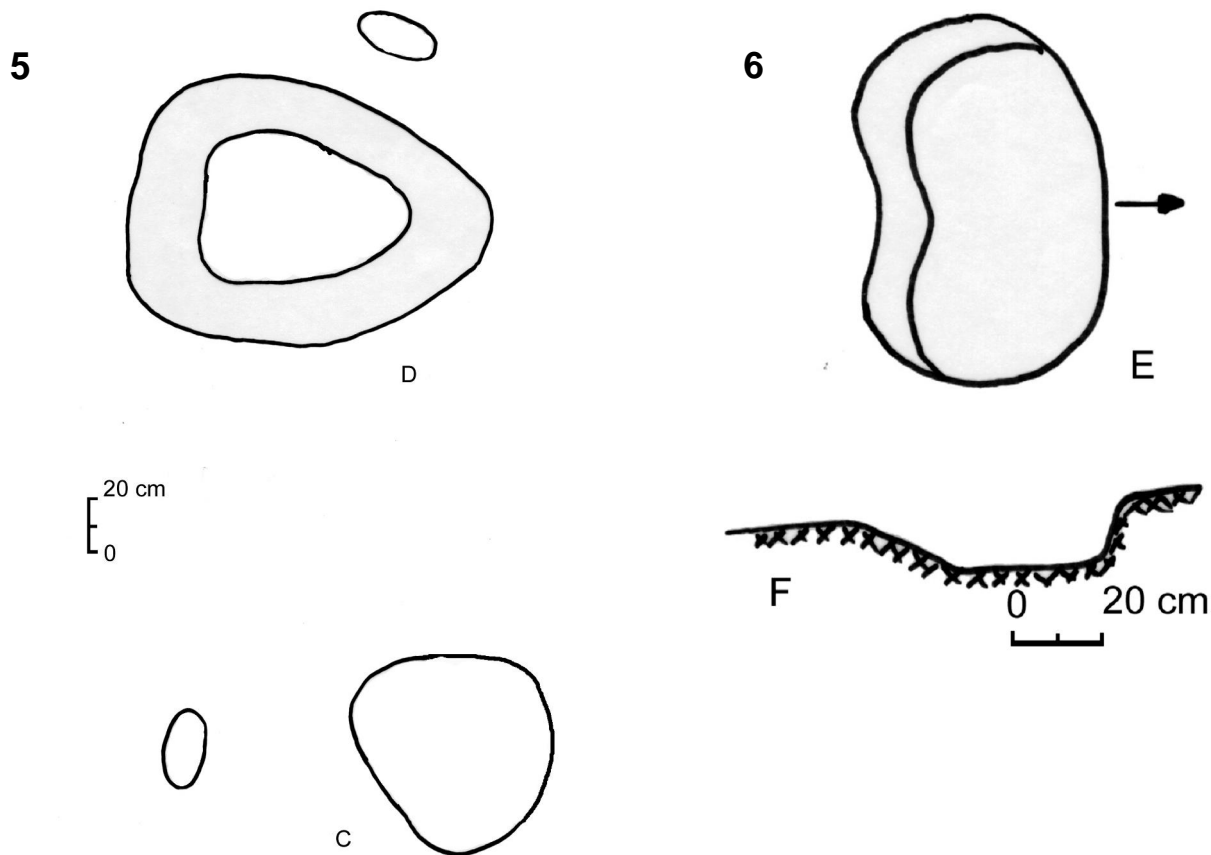


Fig.5- drawing showing isolated sauropod track (AN-23-C and AN-23-D), including a small depression next to it (see text for details); fig.6- drawing showing isolated sauropod track (AN-23-E), with a transversal section (antero-posteriorly).

Argentina (SANTOS & SANTOS 1987; CALVO, 1989, 1999). On the basis of shape of the *manus*, the trackmaker was walking towards the northeast (N 65 E). The anteroposterior external dimension is 55cm while the internal one is 45cm, with the transversal dimension reaching 70cm. The track does not show any impressions that could be referred to digits; overall it is deep with its anterior border convex and the posterior one concave. As the *pes* tracks described before, the posterior border (placed south) is also shallower than the anterior one, corroborating the suggestion that this animal was walking over an inclined (southward dipping) surface.

CONCLUSIONS

Floresta dos Borbas is the 6th dinosaur tracksite found in the Antenor Navarro Formation. Theropods and sauropods form the dinosaur fauna represented in this locality. The theropod

ichnofossils indicate animals of medium size with tracks 29cm long and 23cm wide, digits II and IV well divergent relative to digit III, and a pace length of around 73cm. The sauropod tracks belonged to large animals with rounded *pes* of about 80cm in diameter and a reniform shaped *manus* (70 x 45cm).

The sauropod tracks of the Sousa basin have been found at Serrote do Letreiro, Serrote do Pimenta, Aroeira (Antenor Navarro Formation), Piau-Caiçara and Engenho Novo (Sousa Formation) (see LEONARDI, 1994 and references therein). All the sauropod evidences, including the new locality reported here, were found at the northern portion of the basin. Although tentative, the present distribution of those tracks suggests that the Antenor Navarro Formation and the base of the Sousa Formation were deposited under paleoenvironmental condition that were favorable for the development of a sauropod community. However, since sauropod ichnofossils tend to

disappear toward the top of the sequence, those paleoenvironmental condition might have changed during the deposition of the remaining part of the Sousa and Piranhas formations.

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