



# Paleontologia: Cenários de Vida



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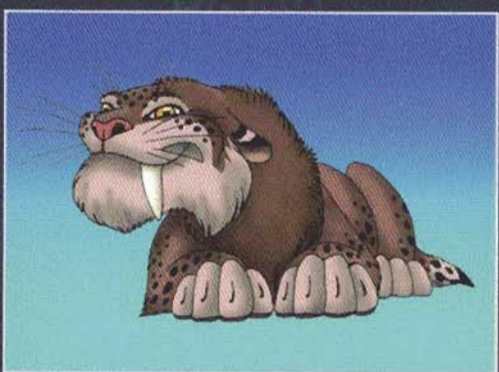
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## Volume 1



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# DINOSAUR ICHNOCOENOSIS FROM SOUSA AND UIRAÚNA-BREJO DAS FREIRAS BASINS, NORTHEAST BRAZIL

Giuseppe Leonardi<sup>1</sup> & Ismar de Souza Carvalho<sup>2</sup>

<sup>1</sup>7, Av. Chemin de la Forêt, Place Commerciale Ma Campagne, Kinshasa/Ngaliema - République Démocratique du Congo

<sup>2</sup>Universidade Federal do Rio de Janeiro, Instituto de Geociências - CCMN - Dept<sup>o</sup> de Geologia, 21949-900, Cidade Universitária - Ilha do Fundão - Rio de Janeiro-RJ - Brasil

E-mail: gi-leonardi@simbatel.com, ismar@geologia.ufrj.br

## ABSTRACT

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Sousa and Uiraúna-Brejo das Freiras are two Cretaceous basins located on the west of Paraíba State, Northeast Brazil, and their origin are related to fault movements of the basement, during South Atlantic Ocean opening. Among the clastic continental sediments of these basins, dinosaur footprints are the most abundant paleobiological evidence. The main tetrapod ichnofauna comprises isolate footprints and trackways of large and small theropods, besides ornithopods. Sousa and Uiraúna-Brejo das Freiras basins comprise 32 ichnofossiliferous sites with at least 90 ichnofossiliferous levels. The dinosaurian ichnofaunas of these basins have the same stratigraphic-time-paleogeographical context, and represent parts of a widespread megatracksite. Altogether, the classified dinosaurian is more than 491 individuals. The environmental setting at that time (Berriasian to lower Barremian) was influenced by the initial development of the equatorial Atlantic seaway, with an endemic biota living nearby ephemeral rivers and shallow lakes under hot climatic conditions.

**Key-words:** dinosaur footprints, Sousa and Uiraúna-Brejo das Freiras basins, Early Cretaceous

## RESUMO

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Sousa e Uiraúna-Brejo das Freiras são duas bacias cretáceas localizadas na porção oeste do Estado da Paraíba e leste do Estado do Ceará, Nordeste do Brasil. A origem destas bacias relaciona-se aos movimentos de zonas de falhas do embasamento, durante a abertura do Oceano Atlântico. Nos sedimentos clásticos destas bacias, as pegadas de dinossauros são a evidência paleobiológica mais abundante. As principais icnofaunas de tetrápodes compreendem pegadas isoladas e pistas de grandes e pequenos terópodes, além de ornitópodes. As bacias de Sousa e Uiraúna-Brejo das Freiras apresentam 32 localidades icnofossilíferas, com pelo menos 90 níveis contendo icnofósseis. As icnofaunas de dinossauros destas bacias estão em um mesmo contexto estratigráfico-temporal-paleogeográfico, e representam partes de um amplo *megatracksite*. Ao todo já foram classificados mais de 491 indivíduos dinossaurianos. O contexto ambiental neste tempo (Berriasiano a Barremiano inferior) foi influenciado pelo desenvolvimento inicial do Atlântico, com uma biota endêmica vivendo próximo à rios efêmeros e lagos rasos, em condições climáticas quentes.

**Palavras-chave:** pegadas de dinossauros, bacias de Sousa e Uiraúna-Brejo das Freiras, Cretáceo Inferior

## 1. INTRODUCTION

Sousa and Uiraúna-Brejo das Freiras basins are located at the west of Paraíba State, in the municipalities of Sousa, São João do Rio do Peixe, Poço, Brejo das Freiras, Triunfo, Santa Helena and Pombal (Figure 1). They comprise an abundant tetrapod ichnofauna, consisting of tracks of theropods, sauropods, ornithopods, one ankylosaur, and of some representatives of the reptilian mesofauna. Invertebrate ichnofossils, such as tracks and burrows produced by arthropods and annelids are also common (Fernandes & Carvalho, 2001). Despite the strong reddish color, typical of subaerial environments, there are some levels of greenish shales, mudstones and siltstones where fossils are present. In Sousa Basin there is also an oil occurrence (Mendonça Filho *et al.*, 2006). There are ostracods, conchostraceans, plant fragments, palynomorphs, fish scales and crocodylomorph bone fragments.

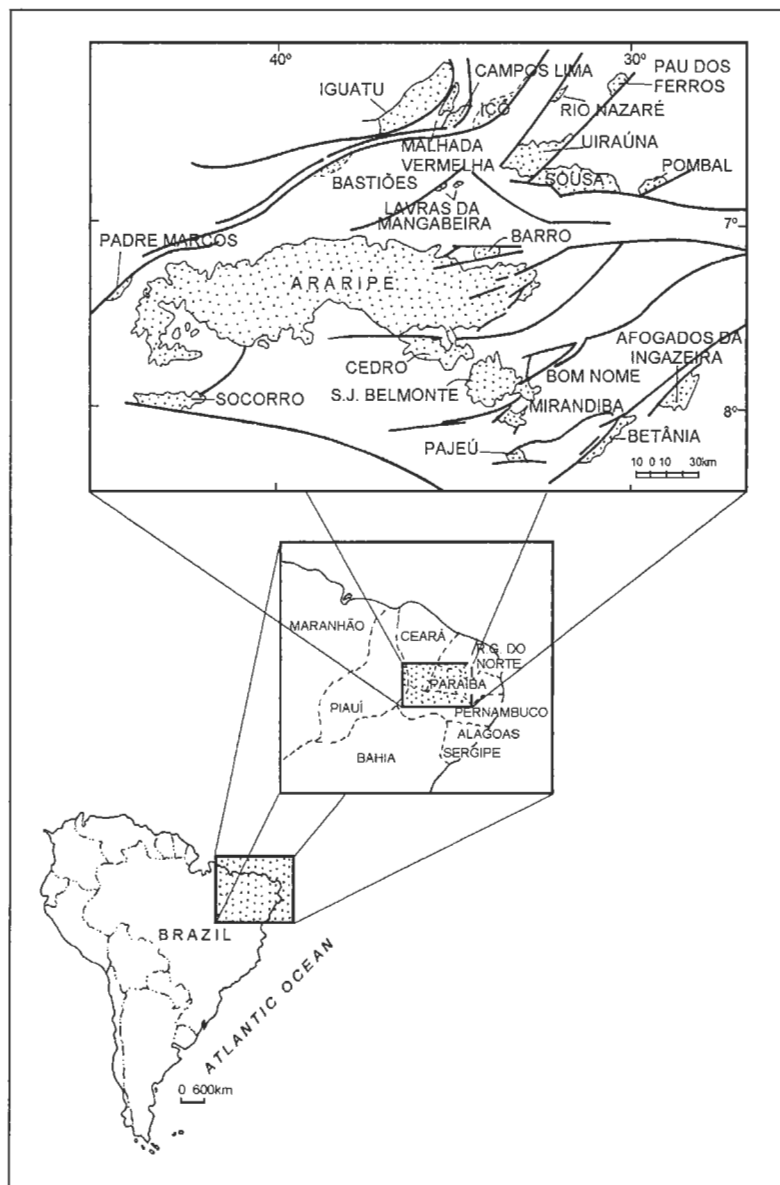


Fig. 1: Map of the intracontinental basins of the Brazilian Northeast.



The sedimentation in these basins was controlled by regional tectonic processes (Lima Filho, 1991). During Dom João time (Purbeckian Stage) due to crustal extension, sigmoidal basins developed at the inflection of the northwest-southwest and east-west faults. During the Rio da Serra time (Berriasian to Hauterivian) under the same tectonic stress pattern, the basinal areas increased and its shapes became rhomboidal. In the last stage, probably at the end of the Aratu time (Lower Barremian Stage), there was a change in the tectonic pattern and the sediment accumulation began to decline.

Dinosaur footprints are the most frequent paleobiological traces in these basins. The best preserved ichnologic material comes from the Lower Cretaceous (Neocomian) of Sousa and Uiraúna basins also collectively known in the literature as Rio do Peixe basins. The study of all these Early Cretaceous footprints demonstrates that the dinosaur faunas of Brazil were abundant and diverse, in spite of the paucity of skeletal remains. Their study also permits us to draw inferences about the paleoenvironment, in which these dinosaurian faunas of northeast Brazil lived during the initial formation of the South Atlantic.

## 2. GEOLOGY OF THE SOUSA AND UIRAÚNA-BREJO DAS FREIRAS BASINS

Sousa and Uiraúna-Brejo das Freiras are intracratonic basins of northeast Brazil, that developed along preexisting structural trends of the basement, during South Atlantic Ocean opening. The age of its deposits, based on palynological material, is characteristic of Rio da Serra (Berriasian to Hauterivian) and Aratu (lower Barremian) local stages (Lima & Coelho, 1987; Regali, 1990).

The intracratonic basins of northeast Brazil are sites of Cretaceous sedimentation, whose origin and evolution were controlled by reactivation of preexisting tectonic structures in the basement (Precambrian rocks), during the Jurassic and Cretaceous periods. This reactivation was closely related to the South Atlantic Ocean opening. Normal and transcurrent faults are the main structural style for the opening of grabens and half grabens at the central region of northeast Brazil during the Early Cretaceous.

During the early Mesozoic, a hot and arid climate was typical in the southern hemisphere. This climatic condition is well recognized throughout the widespread aeolian deposits along the Brazilian and African intracratonic basins. The connection of South America and Africa as a single, large continental block, did not permit a higher humidity in what was (at that time) the continental interior.

With the breakup of this continent and the establishment of a lacustrine and fluvial system among the new rift basins, the climate gradually became more humid. These environmental changes may have been linked to the same tectonic events that drove the separation of South America and Africa and led to the origin of the equatorial Atlantic Ocean (Carvalho, 2000a).

The dinosaurian ichnofaunas of these basins all have the same stratigraphic-time-paleogeographical context, and represent parts of a widespread megatracksite (Figure 2). Similarities in the lithofacies among the deposits where the footprints occur reflect the same tectonic, climatic and sedimentary processes. The environmental setting at that time was influenced by the initial development of the equatorial Atlantic seaway, with an endemic biota living nearby in ephemeral rivers and shallow lakes, under hot climatic conditions (Carvalho, 2000 a, b).

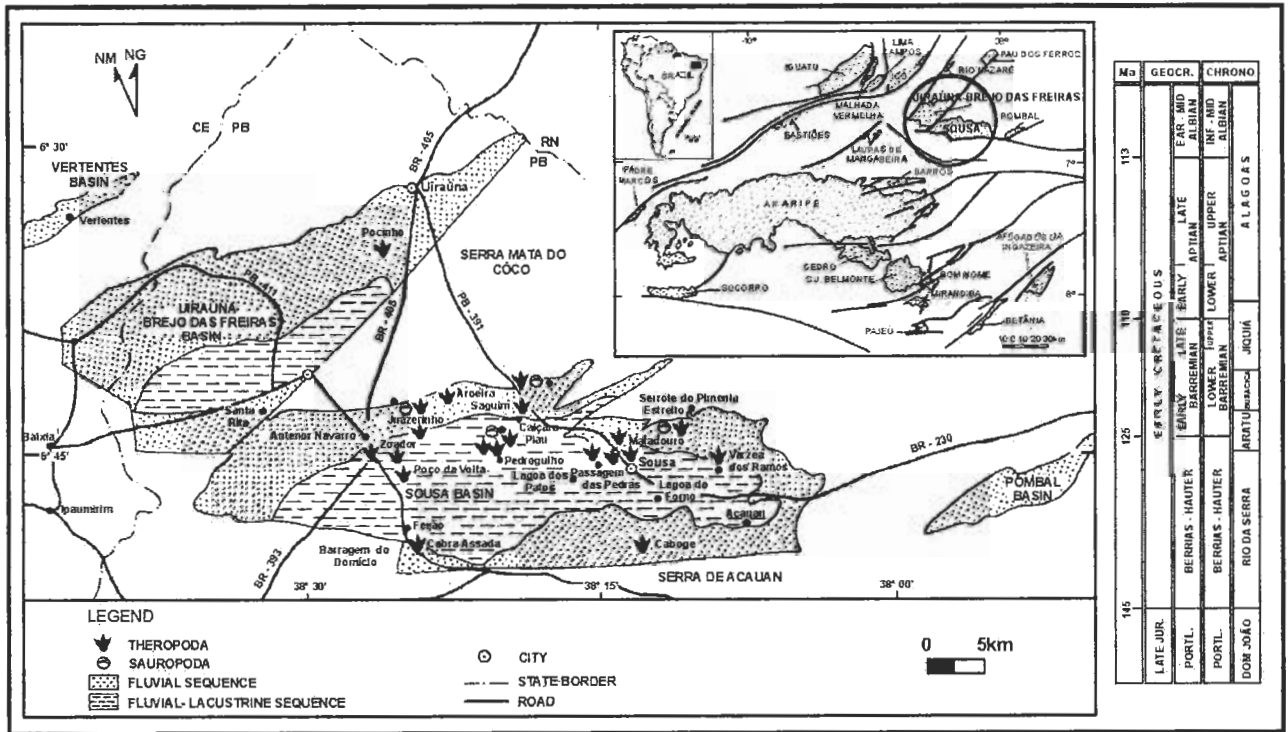


Fig. 2: Distribution map of the main ichnofossiliferous sites in Sousa and Uiraúna-Brejo das Freiras basins.

The Sousa Basin comprises an area of 1,250 km<sup>2</sup>. The Uiraúna-Brejo das Freiras is a smaller basin with 480 km<sup>2</sup>. They are located at the west part of Paraíba State, Brazil. The basement of these basins is composed of highly metamorphosed Precambrian rocks (aligned structurally in a northwest-southwest or east-west direction). The predominant rocks are migmatites, granites, gabbros and amphibolites.

A formal lithostratigraphic subdivision of the Cretaceous in the Sousa Basin, and the neighbouring Uiraúna-Brejo das Freiras Basin, was erected by Mabesoone (1972) and Mabesoone & Campanha (1973/1974). These authors designated the Rio do Peixe Group with a total thickness of 2,870 meters, subdivided into the Antenor Navarro, Sousa and Piranhas formations. The Antenor Navarro and Piranhas formations are composed of immature sediments, including breccias and conglomerates, with pebbles of metamorphic and magmatic rocks in a coarse arkose matrix. These lithologic types are located near the faulted borders of the basins. Toward the basin depocenter, there are conglomeratic and fine sandstones, sometimes interbedded with siltstones and shales. The Sousa Formation is composed of reddish sandstones, siltstones, mudstones and carbonate nodules; marls also may occur. The deposits in these basins reflect a direct control of the sedimentation by tectonic activity. Along the faulted borders of the basins, deposition consisted of alluvial fans, changing to an anastomosing fluvial system more distally. In the central region of the basins, a meandering fluvial system with a wide floodplain was established, where perennial and temporary lakes were developed (Carvalho, 2000a).

### 3. THE ICHNOCOENOSIS

#### 3.1 SOUSA FORMATION

In the Sousa Formation the lithologies are sandstones, shales and mudstones, whose finer grain size was more susceptible for footprint preservation. This essentially microclastic sequence points to lacustrine, swampy and meandering-braided fluvial paleoenvironments (Figure 3). The first two trackways were discovered by L.J. de Moraes before 1924; the others tracks reported herein were discovered and studied in more than 30 expeditions in the period 1975-2005 (Leonardi, 1994; Leonardi & Santos, 2006). A large monograph on them is well in progress.

Altogether, the 18 sites from the Sousa Formation, in at least 66 levels, include approximately the following ichnofauna: 245 large theropods; 30 small theropods that were classically attributed to Coelurosauria; 14 sauropods; 16 graviportal ornithopods; 1 small quadrupedal ornithischian; a number of unclassifiable or uncertain dinosaurian tracks; one batrachopodid set and one crocodilomorph trackway; and a large number of small chelonian tracks. Altogether, the recorded dinosaurian comprises a number of more than 306 individuals.

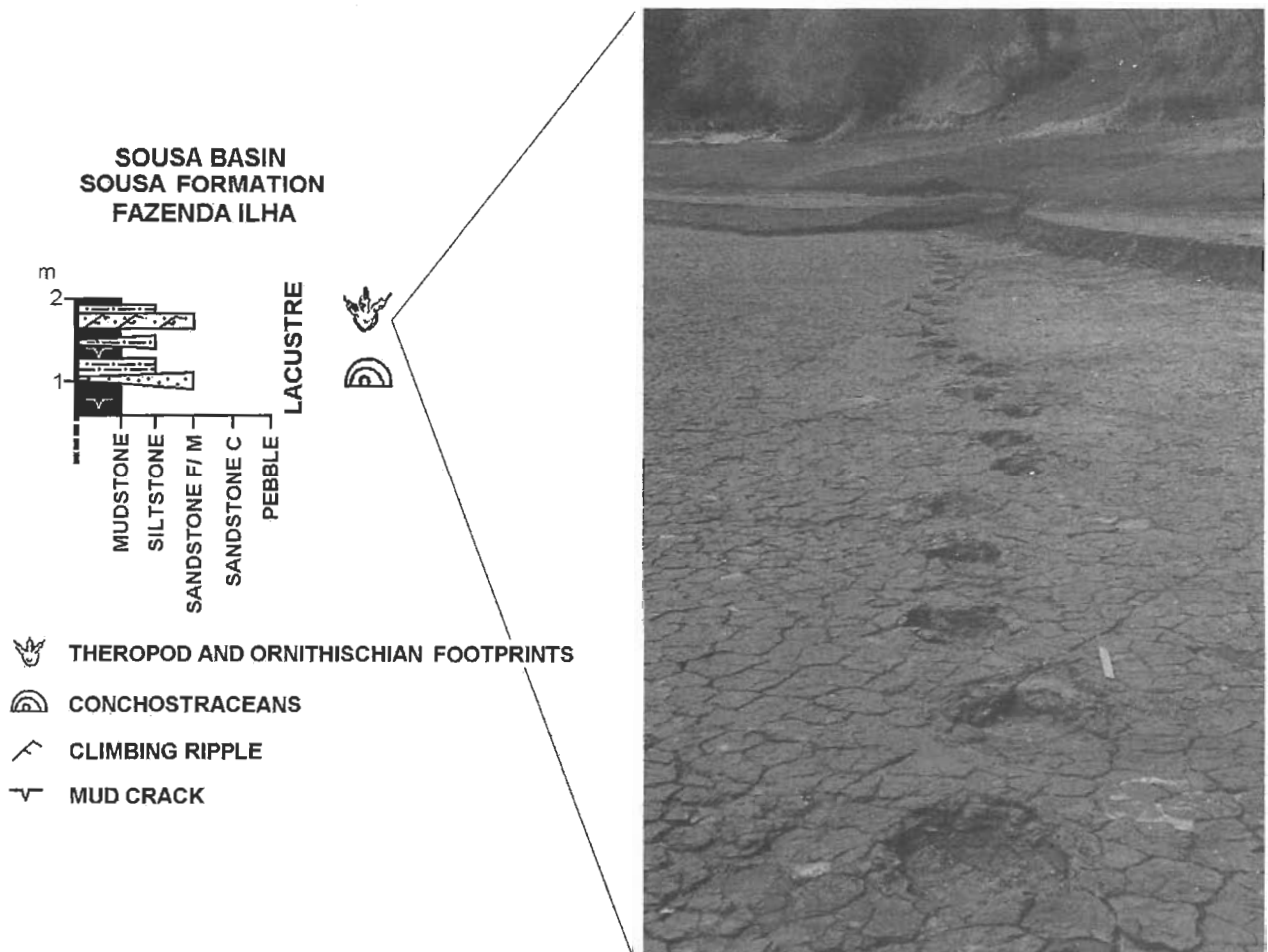


Fig. 3: Stratigraphical profile from the Sousa Basin, Sousa Formation, Fazenda Ilha.

### **3.1.1 ABREU (SOAB)**

At least one large theropod track with bent digits.

### **3.1.2 ARAÇÁ DE CIMA (ANAC)**

At least one theropod track on a greenish surface.

### **3.1.3 BARRAGEM DO DOMÍCIO (ANBD)**

Three trackways (undertracks) imprinted in different levels, so there is not a true association. The trackmakers were large theropods, all of the tracks tend towards the north.

### **3.1.4 ENGENHO NOVO (ANEN)**

26 tracks attributable to several different forms (large and very small) of Theropoda; one hand-foot set attributable to the Sauropoda; one large trackway probably attributable to the Sauropoda (with complete overlapping).

### **3.1.5 JUAZEIRINHO (ANJU)**

All the dinosaurs of this small ichnofauna of 4 individuals, scattered in three levels, were theropods of medium to large dimensions. No associative behaviour is recorded.

### **3.1.6 MATADOURO (SOMA)**

A small ichno-association of bipedal dinosaurs, all of them large theropods; three of the four trackways are directed approximately N-S. The tracks are most likely of four isolated theropod individuals, belonging to different ichnogenera, with no gregarious behaviour.

### **3.1.7 PEDREGULHO (SOPE)**

A very large theropod track, worn by the river, and a smaller theropodian footprint.

### **3.1.8 PIAU-CAIÇARA (SOCA)**

This is a very interesting locality, because in such a restricted area it has at least 25 levels with dinosaurian ichno-associations. To date, a total of almost 200 individual dinosaurian trackways and isolated footprints have been uncovered, along with hundreds of footprints of very small reptiles, probably turtles that appear to be half-swimming. A study of the ichnofauna reveals: a great predominance of theropodian tracks (170 individuals), among which 129 were made by large predators, 27 by small predators; 9 trackways or isolated footprints of ornithopods, almost all Iguanodontidae; a set of very large roundish subtracks, attributed to sauropods, seven of them probably in a herd and three other

sauropodian individuals; one crocodyloid hand-foot set, attributable to the Batrachopodidae. With the exception of the sauropods, the tracks are not, indicative of social behaviour. The directions of the trackways were specifically studied. At the SOCA4 to SOCA13/6 levels, a predominant NE-SW direction was recorded, with traffic in both ways. On SOCA 16 level however, which is the older, and includes 40 individuals (half-swimming tracks) the main direction is NNW-SSE. These directions do correspond in general to the wave ripple crest orientation and the dinosaurs probably walked or swam in preferential directions parallel to the beach lines (freshwater lakes). Reasons were presented to suggest that the local landscape was not the only element to influence the movements of the populations. Indeed, the local paleogeography was influenced by the regional tectonic context (Godoy & Leonardi, 1985; Leonardi, 1989).

### 3.1.9 PIEDADE (SOPI)

This is a varied ichnofauna, with predominantly large theropods. It includes one short trackway and some isolated prints attributed to the ichnogenus *Eubrontes* E. Hitchcock, 1845 and isolated footprints of Iguanodontidae. The individuals proceeded in both ways, along a "corridor" with approximate direction NNE-SSW.

### 3.1.10 THE BED OF THE PEIXE RIVER BETWEEN PASSAGEM DAS PEDRAS (SOPP) AND POÇO DO MOTOR (SOPM)

One kilometer of rocky bed of Peixe river, containing 10 levels with fossil tracks. Passagem das Pedras is the locality discovered by Moraes (1924). The main pavement includes the large iguanodontid trackway *Sousaichnium pricei* Leonardi, 1979, the iguanodontid trackway *Staurichnium diogenis* Leonardi, 1979 and five trackways of a population of long heeled theropods *Moraesichnium barberenae* Leonardi, 1979. Some of these are running tracks (~25 km/h). It is possible that three *Moraesichnium*-trackmakers (SOPP2,3,4) were in a pack, as they belonged to the same ichnospecies. However, one was walking (SOPP2) and two were running (SOPP3 and 4). There are in the other levels trackways and isolated footprints of eight large predators, one "coelurosaurian" footprint, one ornithopod track and a trackway (undertrack) of a small quadruped that is difficult to identify. The directions of all the dinosaur tracks of the bed of the river between Passagem das Pedras and Poço do Motor in the deeper levels lie mainly in the II and III quadrants, with some trend to rotate toward E through W-wards, rising through the levels; however, upstream of the large pavement of Passagem das Pedras the trend is to pass to the IV and I quadrants (Leonardi 1979 a,b). The overall distribution of the SOPM-SOPP site is almost random. However, some concentrations do exist (10 tracks or 29.4% in the sector 135° -199° (17.7%).

Currently, at Passagem das Pedras main level the excavated part of the trackway *Sousaichnium pricei* Leonardi, 1979 (holotype) SOPP 1, formerly SOPP A, includes 52 footprints (and 25 hand-prints, but of the right side), and is 48 m in length. The paratype of *Moraesichnium barberenae* Leonardi, 1979 (SOPP 5, formerly SOPP E) consists of 34 excavated footprints on the right side of the river and a further 13 footprints on the left side. The total excavated length of the trackway is now 56 meters.



### **3.1.11 PIAU II (SOPU)**

Two half-swimming footprints attributable to theropods were found on a flagstone-fence.

### **3.1.12 POÇO DA VOLTA (ANPV)**

A short theropod trackway (ANPV1). There is also an unclassifiable roundish footprint, with displacement rim, without morphological details (ANPV2).

### **3.1.13 SÍTIO SAGUIM (SOSA)**

Five isolated footprints on one narrowly outcropping layer. It is a small ichnoassociation of five footprints, representing an association of four large theropods (three adults and one young), of at least two different forms, and one Iguanodontidae. The distribution of the trackway directions is apparently random.

### **3.1.14 TAPERA (APTA)**

A large outcropping rocky surface with ripple marks, mud cracks showing an ichnofauna including (at first sight) three or four forms attributable to theropods (one of them very small), one or two forms of sauropoda, perhaps one ornithopod track; there are also some long, bent furrow that could perhaps be tail impressions. One crocodylomorph trackway was also reported (Campos, 2005).

### **3.1.15 VÁRZEA DOS RAMOS I (SOVR)**

More than 60 footprints (SOVR1-63), aside from many other incomplete prints. A few of them are in a short trackway, the other are isolated footprints: altogether the tracks of almost sixty bipedal dinosaurs. Almost all are attributable to theropods (mainly large sized), except a big footprint (65 x 57 cm) without morphological details and with a strong displacement rim, which could perhaps be attributed to a sauropod.

### **3.1.16 VÁRZEA DOS RAMOS II AND III (SOVR II AND III)**

At the site Várzea dos Ramos II, a theropodian trackway was discovered, along with small theropod isolated tracks.

At the site named Várzea dos Ramos III, on a rippled red surface, six small isolated theropodian footprints were found, and four half-swimming theropodian tracks are seen.

### **3.1.17 ZOADOR (ANZO)**

In this place there is an isolated footprint (ANZO1) left side, tetradactylous, mesaxonic, poor quality and infilled by the sediment of the upper contiguous layer.

### 3.2 ANTENOR NAVARRO FORMATION

In the Antenor Navarro and Piranhas formations, the footprints are rare. The lithologies of these lithostratigraphic units are conglomerates, coarse sandstones and sandstones interbedded with siltstones. The lithofacies, sedimentary structures and geometry of the beds point to a sedimentation in fan-delta, alluvial fan and anastomosing fluvial environments. Footprints were preserved in fine sediments of subaerial sandy bars in alluvial fans and anastomosing rivers (Figure 4).

Altogether the eight sites from the Antenor Navarro Formation, in at least 16 levels, include approximately the following ichnofauna: 63 large theropods; about 51 sauropods; 8 graviportal ornithopods, one or perhaps two of them quadrupedal; 1 quadrupedal ornithischian, probably an ankylosaur; a lacertoid footprint; and a small number of unclassifiable or uncertain tracks. Altogether the recorded dinosaurian is more than 123 individuals.

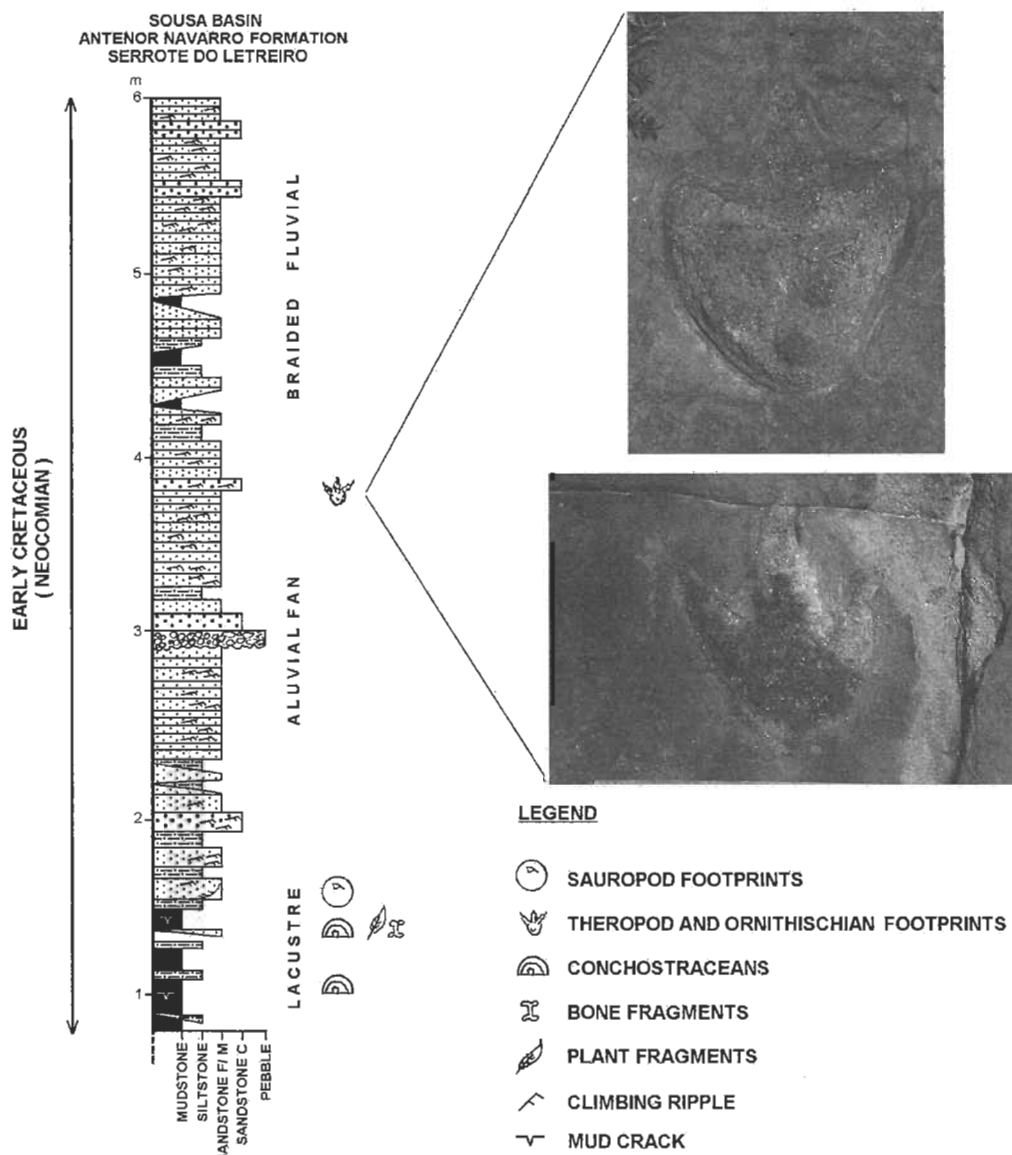


Fig. 4: Stratigraphical profile from the Sousa Basin, Antenor Navarro Formation, Serrote do Letreiro locality.

### 3.2.1 AROEIRA (ANAR)

A short trackway of three or four large footprints is associated with some small unclassifiable dinosaurian footprints. The main trackway shows large, roundish footprints with high displacement rims, very similar to those attributed to sauropods at the Serrote do Letreiro. The trackway seems to be a bipedal one, but it can be quadrupedal with complete overlapping and is probably attributable to a sauropod.

### 3.2.2 BALEIA (UIBA)

At Baleia farm, in the municipality of Uiraúna, two doubtful, very shallow theropodian footprints were found.

### 3.2.3 FLORESTA DOS BORBA (SOFL)

Three very large theropod isolated tracks. SOFL 1-3 that are among the larger theropod footprints of the Rio do Peixe basins. There are other theropod tracks and trackways in the area. A great number of sauropod tracks in a herd, many of them large, deep and with a high displacement rim; among them there are some good hand-foot sets. Some rare and well preserved ornithopod footprints. Among them, there is a well imprinted tridactylous footprint with a wide III toe hoof and small hooves in the II and IV toes. This print is most likely attributable to *Staurichnium diogenis* Leonardi, 1979, (SOFL 4); and a large, tridactylous footprint, attributable to *Caririchnium magnificum* Leonardi, 1984 (SOFL 5). The locality is not yet completely explored nor studied.

### 3.2.4 POCINHO (UIPO)

This is the only site (Figure 5) so far discovered in the Brejo das Freiras basin (Carvalho, 1996). Five badly eroded footprints or short trackways attributable to theropods. The toes are broad and knobbed, with broad claws.

### 3.2.5 RIACHO DO CAZÊ (SORC)

Four uncertain large footprints, with wide and high displacement rim, similar to the tracks attributed to sauropoda at Serrote do Letreiro and some bad quality theropod tracks.

### 3.2.6 RIACHÃO DO OLIVEIRA (SORO)

One surface along the Riacho de Santa Rosa show a probably shallow ornithopods footprint.

### 3.2.7 SERROTE DO LETREIRO (SOSL)

A cluster of footprints and trackways, representing about 36 individuals of a population of the same form of theropod (group SOSL4-49996 and SOSL5) and, downhill, the tracks SOSL9 and SOSL10, attributed to *Grallator* E. Hitchcock, 1845. Two footprints in a trackway are attributed to *Iguanodon*

Mantell, 1825 (SOSL8); and the short trackways and isolated footprints of a herd of a sixteen sauropods (Carvalho, 1989; Carvalho, 2000b). The tracks are associated with ancient indian rock engravings (Leonardi, 1979b).

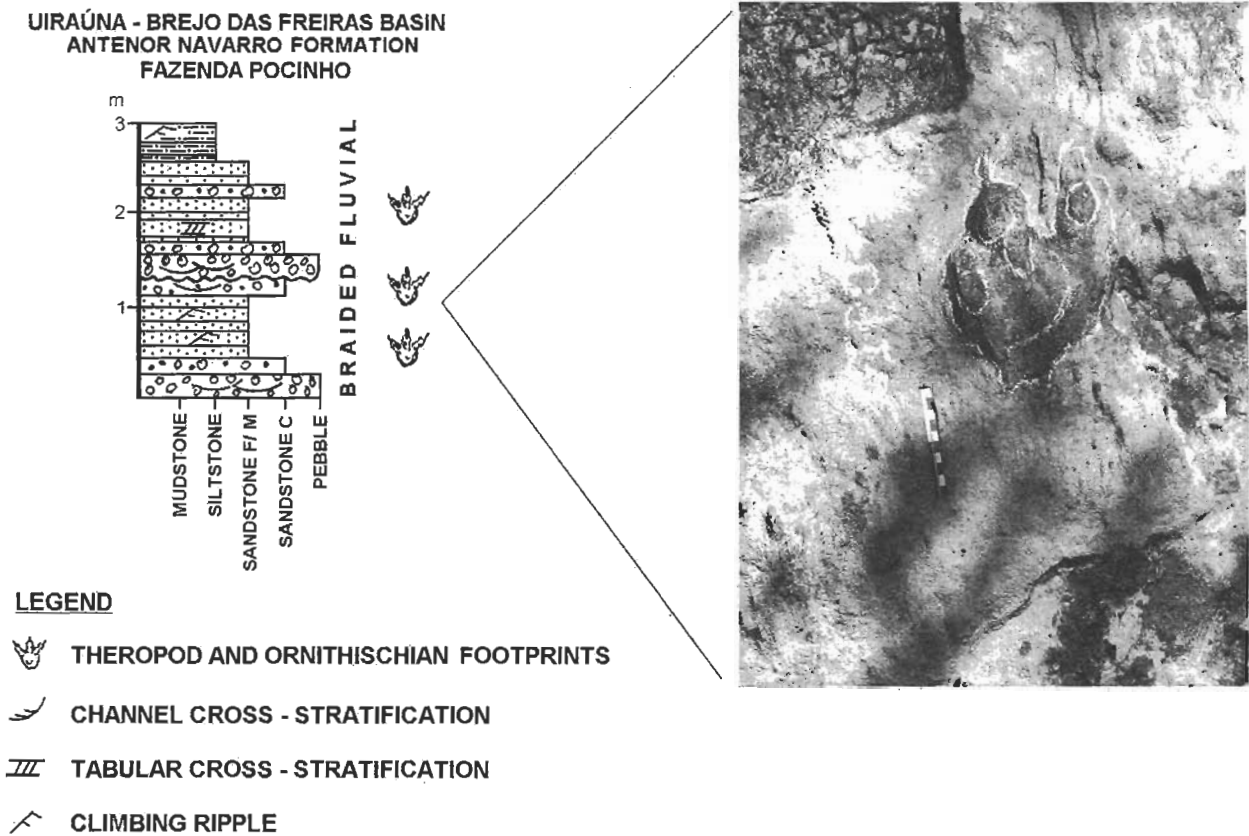


Fig. 5: Stratigraphical profile from the Uiraúna-Brejo das Freiras Basin, Antenor Navarro Formation, Fazenda Pocinho.

### 3.2.8 SERROTE DO PIMENTA - ESTREITO (SOES)

This ichnofauna, covering a wide area in three levels, includes: 8 subparallel trackways attributable to a herd of sauropods; three trackways of large theropods of three different forms and a short incomplete trackway of a quadrupedal dinosaur, probably an ankylosaur. A large pavement contains the trackways and isolated footprints of about 30 large predators, a quadrupedal iguanodontid trackway (and two isolated footprints) *Caririchnium magnificentum* Leonardi, 1984 and a rare lacertoid footprint. Altogether, the site contains the tracks of 45 individuals: 33 large theropods, 3 Iguanodontidae, 8 Sauropoda and 1 *incertae sedis*.

### 3.3 PIRANHAS FORMATION

Altogether the 6 sites from the Piranhas Formation include at least 8 levels with approximately the following ichnofauna: 41 large theropods; 9 sauropods; 2 small ornithopods; 9 graviportal ornithopods,



one of them quadrupedal; and a number of unclassifiable or uncertain tracks. Altogether the recorded dinosaurian individuals numbered in excess of 61.

### **3.3.1 CABRA ASSADA (ANCA)**

The footprints were found in stone fences inside the village. The flagstones of these fences were procured from an outcrop near the village, in a tributary stream of the Peixe river, where a small quarry had been dug. This is an ichnofauna of 13 bipedal dinosaurian individuals, which probably lived in the same place in not too different times, engraving their tracks in different but near layers. Of these trackmakers, 7 were large theropods, two were ornithopod iguanodontids and 4 can be attributed alternatively to either one or other of these two groups. The theropodian footprints are sometimes rather typical and easy to classify; other times, as they are undertracks and/or poorly impressed and preserved, they are deformed and their toes are broad. Attribution to the theropods in this case is done principally on the basis of the presence of claws, as we have no trackway parameters. The theropods represent 54% of the sample, the iguanodontids 15% and the uncertain footprints are 31%. Among the theropods we have at least four different forms with two of them among the iguanodontids.

### **3.3.2 CURRAL VELHO (SOCV)**

Twelve isolated, poor quality, medium to large sized footprints of bipedal, tridactylous dinosaurs. The prints are infilled by the reverse prints and one can observe of little but the outline. In some cases, as the infilling material is coarser than that of the track-bearing layer, there is inversion of the relief. The ichnological material can be divided into different forms of large theropods and of ornithopods, forming a varied ichnoassociation in a so small a sample. There are seven large theropods, with a rather high degree of variability, with at least three different forms; three iguanodontids, probably of the same form; and two probable small ornithopods. We have here dinosaurs of both suborders (Saurischia, Ornithischia) and probably of four families, with at least five different forms. All prints are of bipedal dinosaurs, as is common in the Sousa Formation, and their dimensions are quite varied.

### **3.3.3 LAGOA DO FORNO (SOLF I AND II)**

In this farm, very probably at the border between the Sousa and Piranhas Formations, on the dirt roadbed, almost completely erased by the road bulldozers, there are at least six poor quality sauropods, four theropod footprints and a partial theropodian footprint left by a swimming animal. Another isolated very large theropod footprint is imprinted on the road bed, on the tracksite Lagoa do Forno II.

### **3.3.4 MÃE D'ÁGUA (SOMD)**

The footprints here are infilled and eroded, so that they are observable only as outlines. The tracks are comprised of a short trackway and a dozen of isolated footprints. This is a varied ichnofauna, with at least five different forms: about 7 tracks and a trackway of a large theropod, one sauropod with two individuals, one Iguanodontidae and two other individuals, which probably belong also to the Iguanodontidae.

### 3.3.5 FAZENDA PARAÍSO (SOFP)

The main site, aside the tracks of the railway Fortaleza-João Pessoa, contains a fine trackway of a large theropod individual (SOFP 1). The animal was heading for N45°E. There are also eight isolated footprints, probably all of them attributable to theropods (SOFP 2-9). And a different trackway (SOFP 10), probably a large theropodian undertrack. Some of the theropodian individuals (*e. g.* SOFP 1, 2, 5, 9, 10) are very large, and their footprints are among the largest of this basin. More isolated, poor quality footprints are scattered in the thorny bush of the farm around a small reservoir, on the north of the main pavement. They are attributed to a sauropod (SOFP 11) and to theropods (SOFP 12, 13).

## 4. THE ICHNOFAUNA OF RIO DO PEIXE BASINS: A SYNTHESIS

Altogether, the 32 sites of the Rio do Peixe basins (Sousa and Uiraúna-Brejo das Freiras basins) include at least 90 levels with approximately the following ichnofauna: 349 large theropods; 30 small theropods; 74 sauropods; 2 small ornithopods; 35 graviportal ornithopods, three of them quadrupedal; one (perhaps two) ankylosaurian individual tracks; and a number of unclassifiable or uncertain tracks. Altogether, the recorded dinosaurian individuals numbered in excess of 491. One can add the mesofauna: a batrachopodid set and one crocodylomorph trackway; a lacertoid footprint; and a large number of small chelonian tracks.

### 4.1 THE TRACKMAKERS

It is not always easy to attribute the track to a trackmaker. However, the tracks described above can be attributed, with some probability, to the following groups: the large theropodian tracks pertain very probably, in the Cretaceous of South America, to large predators of the family Abelisauridae Bonaparte & Novas, 1985 and then probably to the Ceratosauria; the small theropod tracks with the III digit substantially longer than the II and IV, which were classically attributed to the Coelurosauria may probably be referred to some south American theropodian families which assumed in that continent the ecological niche occupied by the Coelurosauria in Laurasia (*e.g.* Noasauridae Bonaparte & Powell, 1980); the sauropod tracks were perhaps impressed by Dicraeosauridae, Rebbachisauridae or, more probably, by early titanosaurs.

The short quadrupedal trackway of Serrote do Pimenta can very probably belong to an ankylosaur, most likely a nodosaurid, like for example the little *Minmi* Molnar, 1980 of Queensland. The quadrupedal trackway (undertrack) from Passagem das Pedras could also, perhaps, belong to this group. Ankylosaur trackways are known from Bolivia (Leonardi, 1984) and posteriorly (1998) recorded in the field by Christian Meyer, Martin Lockley and G. Leonardi and await publication. The large bipedal or quadrupedal tracks with three roundish hooves are attributable to graviportal iguanodontids similar, for example, to *Ouranosaurus* Taquet, 1976; some rare small ornithopodoid tracks may belong to young iguanodontids or better to some form of small-sized ornithopod, perhaps dryosaurids, already known in South America (Coria & Salgado, 1996).

The existence of an abundant ichnofauna of vertebrates, consisting of several forms of dinosaur footprints and trackways, is one of the Sousa basin's leading characteristics. Invertebrate ichnofossils, such as tracks and burrows produced by arthropods and annelids, are also common.

Despite the strong reddish color, typical of subaerial environments, there are some levels of greenish shales, mudstones and siltstones where fossils are common. There are ostracods, conchostraceans, plant fragments, palynomorphs and fish scales.

In the Uiraúna-Brejo das Freiras basin occur conchostraceans, bone fragments, and both invertebrate and vertebrate ichnofossils. Except for the dinosaur footprints, located close to the north border, the other fossiliferous occurrences are distributed in the central-south region of the basin.

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