Brazilian Geographical Journal: Geosciences and Humanities research medium, Uberlândia, v. 1, n. 2, p. 372-386, jul./dec. 2010

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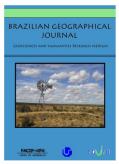
Brazilian Geographical Journal: Geosciences and Humanities research medium



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Report on the Upper Permian and Lower Cretaceous fossiliferous localities vertebrates-bearing in the central-north of Tocantins State, Brazil

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ARTICLE HISTORY

KEY WORDS:
Tocantins
Pedra de Fogo Formation
Corda Formation
Fossil Vertebrates

Received: 09 December 2010
Accepeted: 24 December 2010

ABSTRACT

Since the second half of the last century, fossils of vertebrates have been encountered in the Balsas and Mearim group in the center north area of the State of Tocantins, Parnaiba Basin. The Pedra de Fogo and Corda formations compose these unities respectively and their respective ages are dated as Upper Permian and Lower Cretaceous in age. Upper Permian and Lower Cretaceous vertebrates were recovered in the municipalities of Filadélfia (1), Barra do Ouro, Filadélfia (2), Guaraí and Itaguatins. This fauna consists essentially of fragments (scales, spines, teeth, etc.) of paleonisciforms, elasmobranches, coelacantids and one sauropod dinosaur ichnofossil. All, with the exception of the sauropod and the municipality of Itaguatins, are outercroppings of the Trisidela Member (Pedra de Fogo Formation).

PALAVRAS CHAVE:
Tocantins
Formação Pedra de Fogo
Formação Corda
Vertebrados fósseis

RESUMO – NOTA SOBRE AS LOCALIDADES FOSSILÍFERAS PORTADORAS DE VERTEBRADOS DO PERMIANO SUPERIOR E CRETÁCEO INFERIOR DA REGIÃO CENTRO-NORTE DO ESTADO DO TOCANTINS, BRASIL. Desde a segunda metade do século passado, fósseis de vertebrados têm sido encontradas em rochas dos grupos Balsas e Mearim, porção centro norte do estado do Tocantins, Bacia do Parnaíba. As formações

Pedra de Fogo e Corda compõem os referidos grupos, respectivamente, sendo suas respectivas idades datadas no Permiano Superior e Cretáceo Inferior. As ocorrências de vertebrados do Permiano Superior e Cretáceo Inferior são encontradas nos municípios de Filadélfia 1, Barra do Ouro, Filadélfia 2, Guaraí e Itaguatins. Esta fauna consiste essencialmente de fragmentos (escamas, espinhos, dentes e etc.) de paleonisciformes, elasmobranquios, celacantídeos e um icnofóssil Sauropoda. Todos, com exceção do dinossauro sauropoda e o município de Itaguatins, são aflorantes na Formação Pedra de Fogo, Membro Trisidela.

1. Introduction

In the State of Tocantins the most recent and relevant vertebrate fossils were found in the Upper Permian of the Pedra de Fogo Formation and Lower Cretaceous of the Corda Formation. The history of the findings has revealed paleofauna consisted predominantly by fish, basal tetrapods, petrified wood in the Pedra de Fogo Formation and footprints of sauropod dinosaurs in the Corda Formation (ALVES, 2009).

This contribution aims to characterize the fossiliferous localities of the Upper Permian and Lower Cretaceous, with representation of vertebrates found in the Parnaíba Basin in the State of Tocantins, as well as briefly commenting and reporting the taxa mentioned. The area under study is in the Southern region of the Parnaíba Basin, whose physical space is located in the center and north region of the State of Tocantins embracing an area of approximately 80.000 km².

It is to be known that, after future prospects and mappings of the State of Tocantins, new fossiliferous vertebrate deposits may be encountered thereby necessitating up date of this information.

2. Methodology

The method applied is based on:

1. Detailed field survey since 2007 to 2010 in the localities here presented.

2. Bibliographical survey based on articles, dissertations, monographs, field reports and thesis existing in the library of the Laboratório de Paleobiologia, Porto National *Campus* of the Federal University of Tocantins, and the National Department of Mineral Production, Rio de Janeiro.
3. Location of the fossiliferous localities on maps obtained from IBGE (Brazilian Institute of Geography and Statistics) in the 1:100.000 scale and the data base of Santos; Carvalho (2009)
4. The illustrations of this study were obtained by scanning of images and edition on design program (Corel Drawn X4).

3. Geology of the Parnaíba Basin contaning vertebrates in the Tocantins State

The Parnaíba Basin includes practically the total area of the states of Piauí and Maranhão, and their limits reach the northeast of Pará, center north of Tocantins and west of Ceará, having a total surface of approximately 600,000 km² (BRITO, 1979).

Even though it is considered as a characteristically Paleozoic sedimentary basin, this unit also contains thin Mesozoic and Cenozoic deposits which covers large portions of the area. The base of this basin is Proterozoic, Neoproterozoic and Cambrian-Ordovician metamorphic rocks, and its sedimentary composition is divided into five sequences: Silurian, Devonian, Carboniferous-Triassic, Jurassic, and Cretaceous. (GOÉS; FEIJÓ, 1994).

The Permian Sequence corresponds to the Balsas Group which is composed of the Piauí, Pedra de Fogo, Motuca, and Sambaíba formations and has an expressive fossiliferous content, especially in the Pedra de Fogo Formation where the greatest amount of vertebrate fossils in the whole Parnaíba Basin can be found. The Cretaceous Sequence corresponds to the Mearim Group, which includes the Mosquito, Pastos Bons, Corda and Sardinha formations.

Pedra de Fogo Formation

The Pedra de Fogo Formation was described by Plummer et al (1948) and was recognized in the states of Maranhão, Piauí, and center north of

Tocantins. Its maximum thickness on the surface is 189 meters, which has been determined by sub-surface investigations (PETRI; FÚLFARO, 1988).

Lithologically, this formation is characterized by the presence of gray, brown and purple shales, intercalated with dolomitic layers and siliceous concretions (FARIA JR; TRUCKENDRODT, 1980a), sandstones and siltstones, extending above to the intercalations of shales with chert, containing intra-formational breccia. The deposit environment for this formation is an epicontinental restricted shallow marine paleoenvironment, which progressed to deltaic and estuarine (FARIA JR; TRUNCKENDRODT, 1980 b). *Psaronius* trunks, varied remains of pecopterideans and gymnosperms, are associated with chert horizons (DIAS-BRITO et al, 2007).

The fossil vertebrates are found in a horizon composed of a thin layer of breccia with limonitic cement, which contains small fragments of bones, teeth, fin spines and scales. Many remains are abraded and fragmented, indicating pre-depositional transport. This paleofauna include different groups of Chondrichthyes (Sphenacanthidae, Xenacanthidae, Agassizodontidae and Petalodontidae), Osteichthyes (Palaeonisciformes, Dipnoiformes, Coelacanthiformes), in addition to the labyrinthodont amphibian (Archegosauridae) and some spiral coprolites (PRICE, 1948; SANTOS, 1990, 1994; COX; HUTCHINSON, 1991; TOLEDO; BERTINI, 2005; SCHWANKE; SOUTO, 2007; ALVES, 2009).

Faria Jr.; Truckenbrodt (1980a, 1980b) proposed a subdivision of the Pedra de Fogo formation into three members: Silex Basal, Medium and Trisidela members. The Silex Basal Member, widely distributed alternates siltistones and dolomitic banks with abundant concentrations and horizontal silex. The Medium Member is made up of layers of fine sand with crossed stratifications which alternate siltistones, shales and carbonate banks with small siliceous concretions. The fossiliferous Trisidela Member is composed of fine sand, siltistones, shales and carbonate bank. In the higher beds of the Trisidela Member is where fossilized woods are found besides the occurrence of an assembly of vertebrates.

The fossiliferous early Late Permian deposits of Tocantins State are mainly located in the municipalities of Guaraí, Barra do Ouro, and Filadélfia. These

areas contain a fossil record typical of the Pedra de Fogo formation. A new locality in Guaraí has yielded abundant finspines of sharks ascribed to two possible new ctenacanthid morphotypes. There are also abundant scales and skeletal material of sarcopterigyan and actinopterigyan fishes. Together with this diverse fish assemblage, large pieces of petrified wood of the fossil plant Pteridophytes have been found (ALVES, 2009). At Filadélfia1 a petrified florest is also preserved, where *Psaronius* and unidentified gymnosperms are found dispersed, together with fragmentary bones, scales and spine of fishes (DIAS-BRITO et al, 2007). In Barra do Ouro, the xenacanthids teeth possibly ctenacanthids spines, paleoniscids scales are found too (see results) (SANTOS; CARVALHO, 2009).

The establishment of age is still under constant debate by various authors (e.g. PRICE, 1948; MESNER; WORLDRIDGE, 1964; BARBERENA, 1972), however we follow the proposals influenced by Cox; Hutchinson (1991) and Dino; Antonioli; Braz, (2002) with Upper Permian for the layers of this formation in the state of Tocantins.

Corda Formation

The Corda Formation is characterized by having a sedimentation of high energy desert and freshwater environments where preservation of fossils was very rare. This formation outcrops in the central part of the Parnaíba Basin, west border near the mouth of the Araguaia river to the east until the left margin of the Parnaíba river (SANTOS; CARVALHO, 2009).

Lithologically this unit is characterized essentially by red sandstones, with grain size which raging very fine to medium, good to regular selection of semi-fragile to semi-cohesives, rich in iron oxide and zeolites. When there is overlaying of whinstones there is abundant presence of fragments of this rock as a framework. Heavy cross bedding, crossed climbings and ripples, grain flow and other typical structures of wind dunes are common in this unit. Cross structures of low angle and channeled crosses also occur. From this complex of formation it can be deducted that this unit was deposited in a desert system. A contemporary relationship among the deposits in the Corda, Grajaú and Codó formations are proposed by Vaz et al. (2007).

According to Pinto; Pupper (1974) and Lima; Leite (1978), based on the occurrence of ostracodes, conchostraces and *Lepdotes piauhyensis* fish, this unit has been admitted to the Neo-Jurassic age, extending up to the Eocretaceous (SANTOS, 1945). Therefore we assume through this contribution a re-definition of the Corda Formation to Eocretaceous (neoaptian-eoalbian) proposed by Vaz et al. (2007).

In the extracts of the Corda Formation, reptile footprints are referred to a sauropod described by Leonardi (1988;1994) in sand layers situated at the margin of the Tocantins river, in Itaguatins and in the state of Tocantins. Concerning these footprints there were found seven trails identified with the initials ITSD. In this same study the author relates with doubts for the Corda Formation other icnofossils, represented by footprints and perforations of invertebrates.

These dinosaur trails reveal a biological event related to transit of animals on land. These elements indicate preservation by accumulation and with taxonomic process *in situ (*SANTOS; CARVALHO, 2009)

4. Results

Within the complex of outcroppings with the occurrence of macro-vertebrates in the Parnaíba Basin only five are located in the state of Tocantins: 1) West Margin of the Tocantins river near Filadélfia; 2) East and West margins of the Tocantins River near Barra do Ouro; 3) 67 km southeast of Filadélfia; 4) the three sites in the north of the Municipality of Guaraí; 5) Itaguatins (fig 01) (SANTOS; CARVALHO, 2009).

Within the Brazilian sedimentary basins that of Parnaíba is found to be in the most precarious situation regarding study and knowledge of fossil vertebrates (ALVES, 2009). Data concerning fossiliferous occurrences in the Permian and Cretaceous of the Parnaíba Basin in general are scarce and fragmentary.

The most of *taxa* have been identified by Lima; Leite (1978) and Richter (2008) during geological expeditions at Tocantins state. As the description of the specimens does not include illustrations, detailed information depend on

the type-material examination. More fieldworks will be realized to confirm the *taxa* here compiled (mainly the taxa of outcrops Filadélfia 1 and 2, and Barra do Ouro).

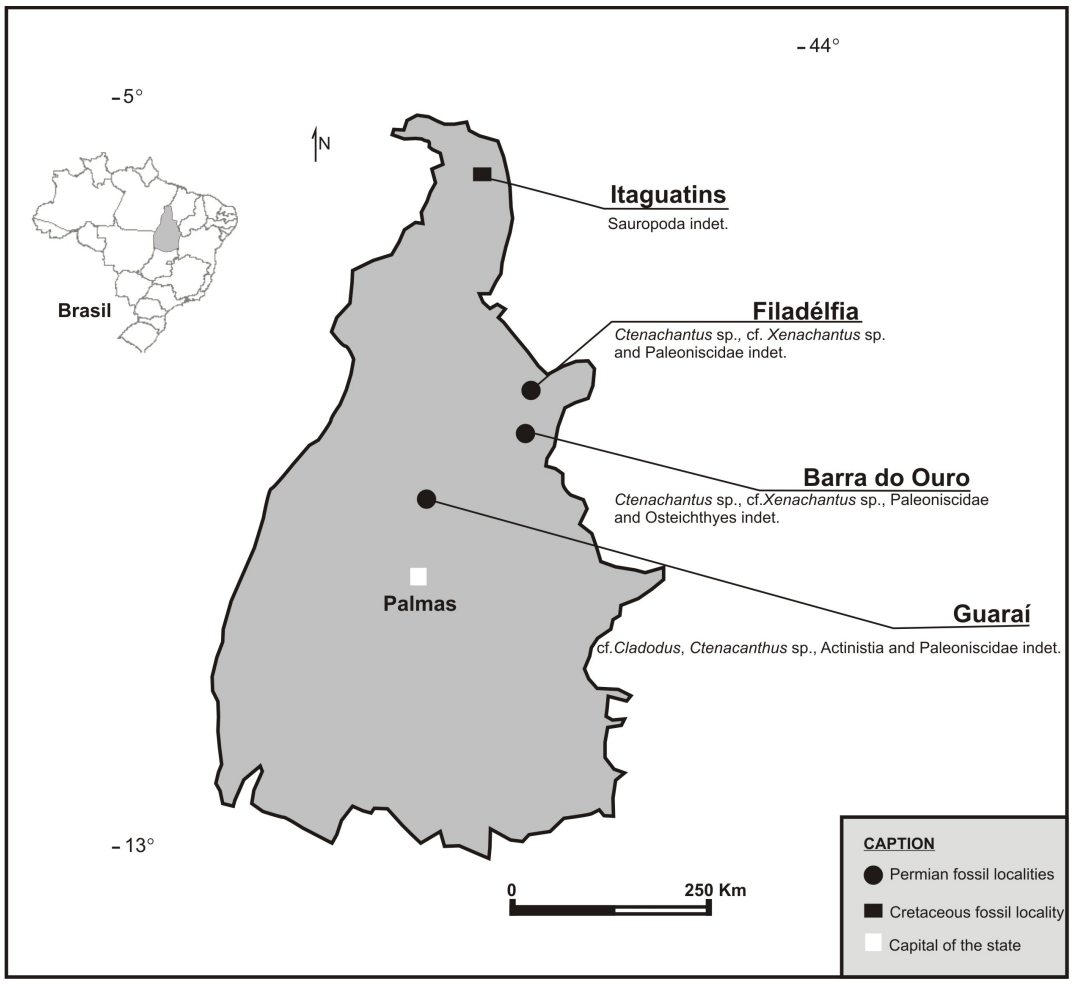

Figure 1. Distribution of Permian and Cretaceous strata of the Parnaíba Basin in central-north region of Tocantins State Brazil (Modified from SANTOS; CARVALHO, 2009).

5. Localities

1- Filadélfia 1

Locality 1. West margin of the Tocantins River, near Filadélfia municipality, Tocantins state.

Stratigraphical level. Pedra de Fogo Formation, Trisidela Member.

Age. Neopermian (neokungurian-eoufimian).

Geographical Position. 07°24´S-47°34´W.

Fossil records. Possible xenacanthids teeth, paleoniscids scales and bone remains.
Selected bibliography. Lima; Leite (1978).

2- Barra do Ouro

Locality 2. East and West margins of the Tocantins River, Barra do Ouro municipality, near Pirarucu Stream, Tocantins.
Stratigraphical level. Pedra de Fogo Formation, Trisidela Member.
Age. Neopermian (neokungurian-eoufimian).
Geographical Position. 07°28´S-47°36´W.
Fossil record. Ctenacanthids fin spines, paleoniscids scales, possible xenacanthids teeth and bone remains indet.
Selected reference. Lima; Leite (1978).

3- Filadélfia 2

Locality 3. Sixty seven km southeast of Filadélfia, road to Araguaína.
Stratigraphical level. Pedra de Fogo Formation, Trisidela Member.
Age. Neopermian (neokungurian-eoufimian).
Geographical Position. 07°28´S-47°56W.
Fossil record. xenacanthids teeth, ctenacanthids fin spines, paleoniscids scales and bones remains indet.
Selected bibliography. Lima; Leite (1978).

4- Guaraí

Locality 4. Three sites at the north of the Municipality of Guaraí.
Stratigraphical level. Pedra de Fogo Formation, Trisidela Member.
Age. Neopermian (neokungurian-eoufimian).
Geographical Position. 48°30´W-08°50´S.
Fossil record. *Cladodus* sp. teeth (Fig. 1B), fin spines (Fig. 1A) and segment of calcified cartilage of ctenacanthids, scales and fragmentary bones of Actinistia, paleoniscids scales and bones remains (Fig. 1D-E).
Selected bibliographies. Weiss; Oliveira (2006); Richter (2008); Alves, 2009.

5- Itaguatins

Locality 4. Left margin of Tocantins River, near of São Domingos village, TO, 22 km of Imperatriz city, Maranhão, and 7 km of Santo Antônio, Tocantins.
Stratigraphical level. Corda Formation.
Age. Lower Cretaceous (neoapitian-eoalbian).
Geographical Position. 05°46´S-47°31´W.
Fossil record. Sauropoda trackways.
Selected bibliographies. Barbosa et al. (1966); Leonardi (1980); Leonardi (1994).

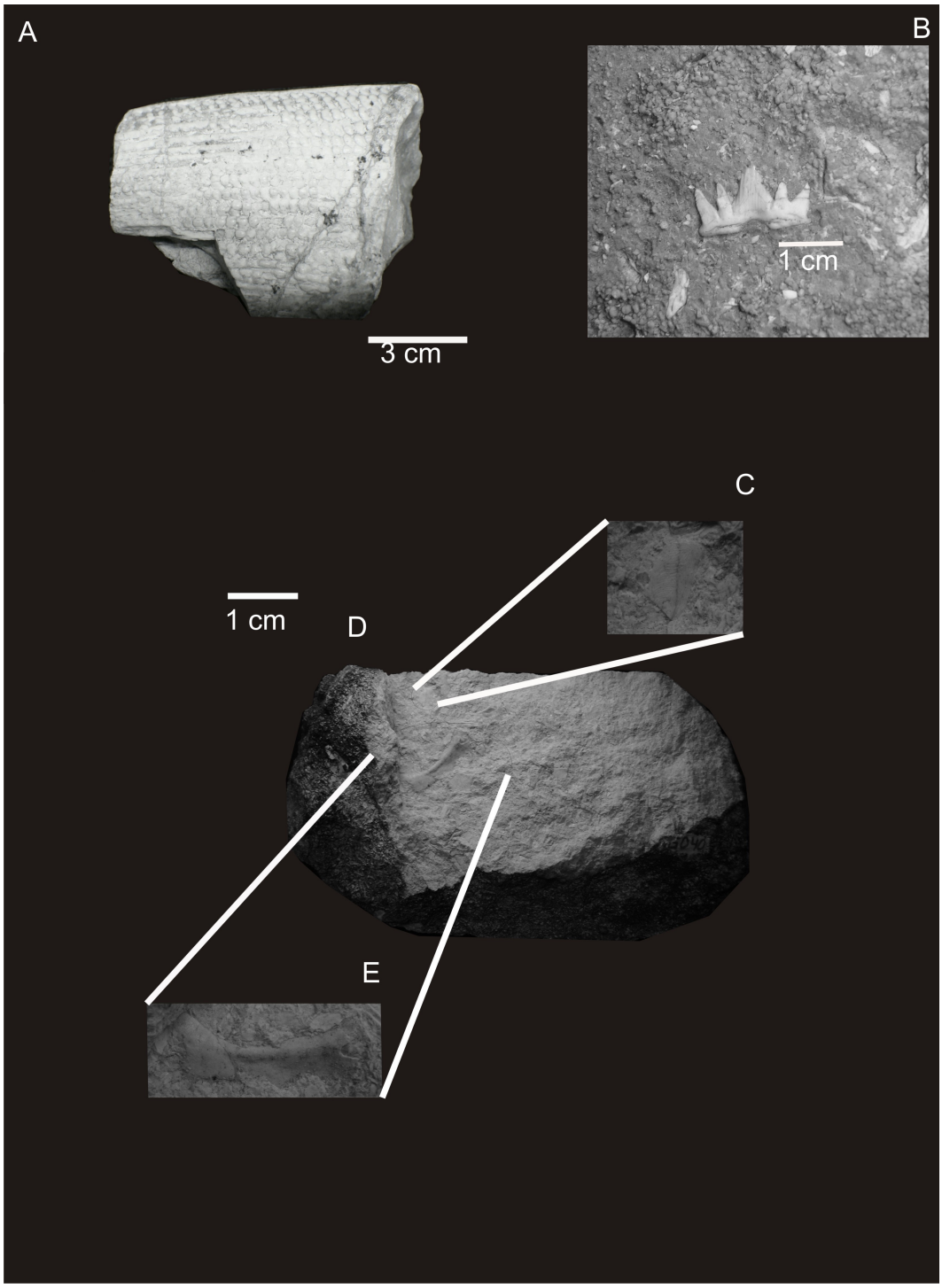

Figure 2. The fóssil vertebrates of Pedra de Fogo Formation, Guaraí municipality, Tocantins. A. The distal portion of fin spine of cf. *Ctenacanthus* sp. **B.** Pentacuspid teeth of cf. *Cladodus* sp. **C.** scale of Paleoniscidae. **E.** Bone remains indet.

6. Discussion and final considerations

The vertebrate fossils in the state of Tocantins are known on the scientific community since the middle of the last century, however few studies of

taxonomical description have been carried out, due principally to the fragmentary nature of most of the specimens encountered, which render a more refined description impossible. Except for the ichnofossils in the Corda Formation, all the occurrences related come from the Pedra de Fogo Formation, Trisidela Member.

In the extracts from the Upper Permian various fossil fragments of aquatic taxa were encountered, among which are remains of invertebrates, bone and cartilaginous fish, coprolites, basal amphibians and plants. Most noteworthy in this ensemble the paleoichtyofauna, especially the elasmobranchs, consider the most expressive group to be Ctenacanthidae and Xenacanthidae, all in the form of fin spines and teeth with up to five cuspids (cf.*Cladodus* sp.) (RITCHER, 2008; SANTOS; CARVALHO, 2009; ALVES, 2009).

In the paleoictiologic assembly of the state of Tocantins, the osteichthyes paleoniscideos, Actinistia indet. and other bones of undetermined nature have been recognized in the form of unarticulated scales or small bone groups, isolated teeth and fin rays.

Alves et al. (2008) bring especially to light the fossil diversity present in the Pedra de Fogo Formation, explaining as a consequence of the mixture of marine and freshwater depositary environments where this fauna is represented by both biota. This fossil diversity can be proved, through various fragmented materials encountered in the Municipalities of Filadélfia, Barra do Ouro, and Guaraí which render the formation of the Parnaíba Basin of great paleontological importance.

Leonardi (1988) reported sauropod dinosaur trails at the left margin of the Tocantins River, near the Municipality of Itaguatins. These are trails and large diameter circular footprints indicating the presence of large animals (Leonardi, 1994). These findings represent the first record of Sauropods in the Lower Cretaceous of the Parnaíba Basin. According to Souza; Harris; Candeiro (2010), a sauropod trackway shows a wide-gauge locomotion pattern and has round manus prints, suggesting that the track maker was a titanosauriform sauropod. We anticipate that ongoing collecting efforts will fing many new and significant dinosaur tracks from the Lower Cretaceous strata in Tocantins

State that will continue to improve understanding of dinosaur diversity and paleobiogeography in Gondwana.

The state of Tocantins has two geological formations in the Parnaíba Basin (Pedra de Fogo and Corda) with a paleontological potential for vertebrates. However it is necessary to carry out new studies because there is the possibility of new vertebrates forms being described with the discovery of new outcroppings (as the three sites in the Municipality of Guaraí) thereby furthermore amplifying present knowledge.

Acknowledgements

I wish to thank Thiago da Silva Marinho (Universidade Federal do Rio de Janeiro), Etiene Fabbrin Pires, Alberto Akama and Fernando Morais (Universidade Federal do Tocantins), for their support and their numerous discussions which resulted in good studies. I am also grateful to the anonymous referee, and to the editor committee of Brazilian Geographical Journal: Geosciences and Humanities research medium, who provided helpful critiques on the manuscript. Marise Salgado de Carvalho and Tania Freire (DNPM/CPRM-RJ) for the bibliographies supplied to us. To our collegues of Laboratório de Paleobiologia/ Universidade Federal do Tocantins for help in fieldworks: Francisco Edinardo Ferreira de Souza, Wagner Matos da Silva, José Rafael Wanderley Benicio, Katiuce Rodrigues da Silva and Lanuze Tavares.

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