



Fossil footprints from the Late Permian of Brazil: An example of hidden biodiversity

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ABSTRACT

Although Late Permian tetrapods are relatively common around the world, few taxa are known in rocks of this age in South America. So far, the study of the tetrapod paleofaunas in the Permian of Brazil has provided significant chronological data, though knowledge about them is still incipient. These studies generally take into account only body fossil records, but the ichnological record can provide new biostratigraphic elements for correlation. In Brazil, fossil tracks were first recorded in Rio do Rasto and Corumbataí Formations (Late Permian from Paraná Basin), but to date these tracks have not been studied in an ichnotaxonomic, morphofunctional, paleoenvironmental and chronological context. The study of these tracks became possible due to a considerable increase in the number of taxa from the Late Permian of Brazil, including *Chelichnus* isp. (Synapsida: Caseidae?), *Procolophonichnium* isp. (Procolophonoidea), *Rhynchosauroides gangresci* isp. nov. (basal Diapsida), *Dicynodontipus penugnu* isp. nov. (Dicynodontia) and *Incertae sedis* (Amphibia?). With the exception of Dicynodontia, the remaining recorded taxa are unknown through fossil skeletons, showing that the Brazilian Permian faunas were much more diverse than was previously reported and demonstrating the potential of South American fossil vertebrates for global correlations.

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1. Introduction

In Brazil, two kinds of tracks were preliminarily recorded in Rio do Rasto Formation (Late Permian from Paraná Basin) as *Rhynchosauroides* Maidwell, 1911 and cf. *Dicynodontipus* Rühle von Lilienstern, 1944 (Costa and Sedor, 2001; Leonardi et al., 2002), but to date these tracks have not been studied at the ichnospecific level. In Corumbataí Formation were previously recorded tracks assigned to Archosauria (Andreis and Carvalho, 2001). Although the imprints appear to be undertracks, the quality of preservation allows the study of morphological details.

This work deals with the more detailed ichnologic and morphofunctional study of these occurrences, considering the paleoenvironmental and chronological context, which can reveal new information to the understanding of the South American paleofaunas.

2. Material and methods

The studied material comes from two localities (Fig. 1). The first is the Pau Preto quarry (23° 28' 24.87" S and 49° 19' 59.55" W), operated by Mineração Gobbo, Municipality of Taguaí, São Paulo State. The second is an outcrop located in a section of the highway PR-090 (23° 47' 45.78" S and 50° 37' 30.82" W) in the Municipality of São Jerônimo da Serra, Paraná State. The Pau Preto quarry corresponds to rocks of Corumbataí Formation and the material consists solely of photographs, drawings and diagrams of the outcrop and the tracks – there are no collected specimens from this site. These tracks were previously studied by Andreis and Carvalho (2001) and consist of two associations with a total of 82 imprints. The photos were digitally processed with the use of filters for contrast, noise and contour, allowing a reevaluation of the material.

In São Jerônimo da Serra are outcrops of rocks from the Morro Pelado Member, Rio do Rasto Formation, and the studied material consists of eight samples with a total of 83 imprints. These specimens are deposited in the paleontological collection of the Museu de Ciências Naturais, Setor de Ciências Biológicas, Universidade Federal do Paraná (MCN-SCB-UFPR) in Curitiba, southern Brazil.

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Fig. 1. Location of the studied outcrops in Paraná and São Paulo states, Southern Brazil.

The morphometric parameters used to measure the footprints were based on Leonardi (1987). In the case of Corumbataí Formation, only the length and width of 65 of the 82 imprints were measured, as the nature of the material (photographs) did not allow the precise measurement of other parameters.

3. Geologic context

All the occurrences of tetrapod tracks from Late Permian of Brazil were recorded in the Passa Dois Group of the Paraná Basin, a large intracratonic depression that includes portions of Brazil, Paraguay, Argentina and Uruguay, and consists of sedimentary and igneous rocks deposited between the Late Ordovician and Cretaceous (Milani et al., 2007). The Passa Dois Group comprises Irati, Serra Alta, Teresina, Corumbataí and Rio do Rasto formations, and documents the transition from intracontinental marine to continental terrestrial environments, a process that led to the prevailing desertification during the Mesozoic in the basin.

The Corumbataí Formation is characterized by dark gray mudstones, siltstones and shales in the lower portions and purple to red fine sandstones, with intercalations of carbonate banks, in the upper portion (Schneider et al., 1974). The most common sedimentary structures are horizontal stratification, cross-bedding, flaser bedding, mud cracks and ripple marks. The fossil content includes molluscs, sponges, ostracods, fish, plants and palynomorphs. The Corumbataí Formation is stratigraphically equivalent to Serra Alta, Teresina and Rio do Rasto formations (Milani et al., 2007), documenting an extensive system of tidal plains.

The Rio do Rasto Formation is subdivided into Serrinha and Morro Pelado members (e.g. Gordon, 1947; Lavina, 1991; Schneider et al., 1974). The Morro Pelado Member is characterized by red, gray, green or purple mudstones and siltstones, with continuous or lenticular intercalations of green to red sandstones. The main sedimentary structures are horizontal stratification and trough cross-bedding (Schneider et al., 1974). In these strata occur fossils of conchostracans, ostracods, bivalve molluscs, fish, temnospondyl amphibians, therapsids and sphenophytes. The Morro Pelado members document the final phase of sedimentation in the basin and the consequent transition from delta front to delta top

environments (Gama, 1979; Lavina, 1991; Milani et al., 2007). The upper contact of the Rio do Rasto Formation is considered transitional with the eolian sandstones of the Pirambóia Formation, indicating the progradation of dune fields over the deltaic deposits (Riccomini et al., 1984; Rohn, 1994).

3.1. Age of Passa Dois group

Since the first studies on the Passa Dois Group, in the early twentieth century, Permian and Triassic ages have been suggested based on fossil content. In the 1960s the group was generally accepted to be Permian in age. According to Daemon and Quadros (1969), the Teresina-Rio do Rasto section would be Tatarian age. Later, Cunha and França (1994) argued that sedimentation rates of the group were very high in relation to the time lag, thus positioning the Teresina, Corumbataí and Rio do Rasto formations in the Triassic, which was also followed in a major syntheses of the basin (Milani et al., 1994).

A major chronostratigraphic problem of the Passa Dois Group was the estimated Kazanian age for the Irati Formation (e.g. Cunha and França, 1994; Milani et al., 1994; Schneider et al., 1974), based mainly on the work by Daemon and Quadros (1969). The Irati Formation is correlated to the Whitehill Formation of the Karoo Basin based on lithology and fossil content, mainly by the occurrence of mesosaurids, and is equivalent also to Mangrullo Formation in Uruguay and to the lower portion of the Chacabuco Formation, Chaco-Paraná Basin, Argentina (Lavina, 1991). However, the other formations were dated as Sakmarian (e.g. Lavina, 1991; Oelofsen and Araújo, 1987), unlike the Brazilian age. The Kazanian age adopted by Cunha and França (1994) for the Irati Formation led them to extend the Passa Dois Group to the Triassic. This problem was only solved with the work of Premaor et al. (2006) and Santos et al. (2006), who attributed the Artinskian age for the Irati Formation based on palynology and radiometric dating. Currently, it is accepted that the Rio do Rasto Formation was deposited in the Late Permian (Tatarian), possibly extending to the Triassic in their uppermost limits (e.g. Warren et al., 2008), although Milani et al. (2007) speculate that this unit can only reach the Early Triassic in the center of the basin, in sections not represented in outcrops.

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