



Ichnology of deglaciation deposits from the Upper Carboniferous Rio do Sul Formation (Itararé Group, Paraná Basin) at central-east Santa Catarina State (southern Brazil)



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ARTICLE INFO

Article history:

Received 11 March 2015

Received in revised form

7 July 2015

Accepted 8 July 2015

Available online 15 July 2015

Keywords:

Trace fossil

Ichnotaxonomy

Arthropod

Marginal marine

Glacial

ABSTRACT

Trace fossil assemblages dominated by arthropod trackways are common in sediments deposited during the Late Paleozoic Ice Age. Ichnofaunas preserved in glacially-influenced sedimentary successions were previously reported from Paraná Basin in southern Brazil. The ichnofauna of the Rio do Sul Formation preserved in the rhythmites exposed in Trombudo Central quarries (Santa Catarina State, southern Brazil) is revised in this paper. *Cruziana problematica*, *Diplichnites gouldi*, *Diplopodichnus bififormis*, *Glaciichnium liebegastensis*, *Gluckstadtella elongata* isp. nov., *Helminthoidichnites tenuis*, *Mermia carickensis*, *Protovirgularia dichotoma*, *Treptichnus pollardi* and *Umfolozia sinuosa* were recorded. Two trace fossil suites were recognized. The undermat miners suite is dominated by *H. tenuis*, indicating the presence of surface grazers (insect larvae, isopods and amphipods). *C. problematica*, *D. gouldi* and *U. sinuosa* dominate the overmat grazers suite, as result of displacement of terrestrial and aquatic arthropods. The integrated sedimentological and ichnological data from Trombudo Central region suggests colonization of ephemeral, shallow water bodies filled by freshwater from glacier melting. The deposition of the rhythmites took place in a glaciolacustrine context represented by shallow ponds in marginal marine settings.

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1. Introduction

The glacial deposits of the Itararé Group (Upper Carboniferous) are among the most important records formed during the third Ice House Age in the western Gondwana (e.g. Eyles et al., 1993; Isbell et al., 2003; Rocha-Campos et al., 2008). Trace fossils are common records in the Itararé Group and their presence is mentioned since the pioneering studies of the basin, although called “fringed trails” or “worm tubes” (e.g. Maury, 1927; Lange, 1952). In most of the trace fossil assemblages, arthropod trackways and shallow invertebrate burrows are dominant. This is considered an ichnological signature in rhythmite facies of glacial origin, since this pattern is observed in Upper Paleozoic deposits of

many gondwanic basins (Buatois et al., 2006, 2010; Netto et al., 2012).

The most extensive studies on the ichnofauna from the Upper Carboniferous deposits of the Paraná Basin in Santa Catarina State (SC), southern Brazil, were carried out in Mafra, Bela Vista do Sul and Dr. Pedrinho regions (northern SC). These studies emphasize the occurrence of distinctive suites representative of the *Mermia*, *Scoyenia*, *Glossifungites* and *Cruziana* ichnofacies, most of them impoverished both in diversity and in amount of trace fossils, in the fine-grained rhythmites of the Mafra (Balistieri et al., 2002, 2003) and Rio do Sul formations (Balistieri and Netto, 2002; Gandini et al., 2007). Balistieri and Netto (2002) registered a *Glossifungites* suite, composed for *Thalassinoides*, *Diplocraterion*, *Palaeophycus*, *?Rhizocorallium* and *Gyrolithes*-like burrows. Balistieri et al. (2002) described an ichnofauna composed for ten ichnogenera of shallow endobenthic burrows and 3 ichnogenera of arthropod trackways, but with dominance in amount of specimens of the latter. Balistieri et al. (2003) recorded an impoverished *Cruziana* assemblage with *Cruziana* isp., *Diplichnites gouldi* (the dominant

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form), *Diplopodichnus biformis* and *Protichnites* isp. Gandini et al. (2007) recognized 3 suites, the freshwater one, containing *Cochlichnus*, *Gluckstadtela*, *Hormosiroidea* and *Treptichnus*, the euhaline one, composed by *Umfolozia*, *Protovirgularia* and *Maculichna* and the terrestrial one, containing *Diplichnites* and *Diplopodichnus*.

Despite showing abundant trace fossils, the rhythmites of the Itararé Group exposed in quarries from the Trombudo Central region (central SC) were poorly studied in terms of ichnology until now. The few detailed studies were carried out in Itaú-Itaúna quarry by Marques-Toigo et al. (1989) and Nogueira and Netto (2001a, b), who provided some ichnotaxonomic classifications and a preliminary palaeoecological, palaeoenvironmental and stratigraphic approach. Marques-Toigo et al. (1989) recorded an ichnofauna composed chiefly of *Umfolozia*, *Isopodichnus* and *Gyrochorte*, with subordinate *Gordia*, *Kouphichnium* and undetermined resting and escape traces preserved in siltstone/claystone rhythmites from the top of Rio do Sul Formation. This trace fossil assemblage was interpreted by these authors as produced in a shallow, freshwater, glacial lake. In the same quarry, 2 trace fossil suites were posteriorly recognized by Nogueira and Netto (2001a), one dominated by arthropod trackways and containing the ichnogenera *Umfolozia*, *Diplopodichnus*, *Diplichnites*, *Rusophycus* and *Cruziana* and another dominated by grazing trails and resting traces represented for *Helminthoidichnites*, *Hormosiroidea?*, *Neonerites* and *Gluckstadtela*.

In the last decades, the knowledge on the ichnology of ancient and recent glacial environments considerably increased, providing new information about trace fossil distribution in glaciomarine, glaciolacustrine and glacially influenced fluvial environments (Netto et al., 2012 and references therein). Furthermore, the proposition of better criteria for morphological description of burrows (Bromley, 1996), trails and trackways (e.g. Trewin, 1994; Minter et al., 2007a) and the definition of an uniform approach for ichnotaxonomy (Bertling et al., 2006) enabled the trace fossil assignment and led to several studies revising many ichnotaxa, including some of those previously described in Rio do Sul Formation deposits. A more accurate analysis of the palaeoecology of these deposits and the palaeoenvironment in which they were formed depends on a detailed ichnotaxonomic study. Thus, the objectives of this paper are as follows: (1) to describe and review the ichnofauna of the Upper Carboniferous deposits exposed at Trombudo Central region; (2) to analyze their occurrence pattern throughout the succession; (3) to provide detailed information to future studies on palaeoecology and palaeoenvironment of the Rio do Sul Formation.

2. Materials and methods

The ichnotaxonomic descriptions that are the base of this study were carried out using the specimens studied and photographed in quarries. New collected samples were joined to those housed at the trace fossils collection of the Laboratório de História da Vida e da Terra (LaViGea) at Universidade do Vale do Rio dos Sinos (UNISINOS), under the numbers UMVT-10707 to UMVT-10721 and ULVG-11550 to ULVG-11577. The samples described originally by Marques-Toigo et al. (1989), housed at the fossils collection of the Laboratório de Geociências from Universidade Federal do Rio Grande do Sul (UFRGS), under the numbers IC-038a, IC-040, IC-042a, IC-043, IC-045, IC-047a, IC-051, IC-052, IC-054a, IC-054b, IC-055, IC-056, IC-056a, IC-056b, IC-057b, IC-057c, IC-059a, IC-060a, IC-060b, IC-065a, IC-065b, IC-065c, IC-065d, IC-066a, IC-066b and IC-067a, were also revised. The burrows were described following the ichnotaxobases proposed by Bromley (1996) and the ichnotaxonomic approach of Bertling et al. (2006). The trail and trackway terminology and methods of measurements were based

on Trewin (1994) and Minter et al. (2007a). The concepts by Seilacher (1964) were used for the stratigraphic classifications.

3. Geological setting

The Rio do Sul Formation deposits result from the Gondwana deglaciation and characterizes the uppermost lithostratigraphic unit of Itararé Group, which represents the glacial deposits of the Paraná Basin (e.g. Rocha-Campos, 1967; Schneider et al., 1974; Eyles et al., 1993; dos Santos et al., 1996). The typical facies observed in Rio do Sul Formation are dark gray to black shales, dominantly thin-bedded laminated rhythmites and mudstones, siltic-argillaceous matrix diamictites and fine-grained sandstones (Fig. 1), representing sedimentation in coastal to shallow marine environments (e.g. Schneider et al., 1974; dos Santos et al., 1996; Nogueira and Netto, 2001a).

Palynologic zonations suggest that the glacial succession were deposited between the Early Pennsylvanian and Early Cisuralian (Souza, 2006). In turn, fossil insects found in deposits of the Itararé Group in Santa Catarina state have been attributed to the Carboniferous (Pinto, 1990; Pinto and Sedor, 2000). Cagliari et al. (2014) collected tonstein samples in deposits of the superimposed Rio Bonito Formation in Cachoeira do Sul region, central Rio Grande do Sul state, southernmost Brazil. After the U–Pb radiometric analyze, the authors assumed the tonstein horizon as Sakmarian in age (290.6 ± 2.8 Ma), which is Early Permian. Thus, Cagliari et al. (2014) assumed that the deposition of the rocks of the Itararé Group occurred during the Early Pennsylvanian (Fig. 1), corresponding to

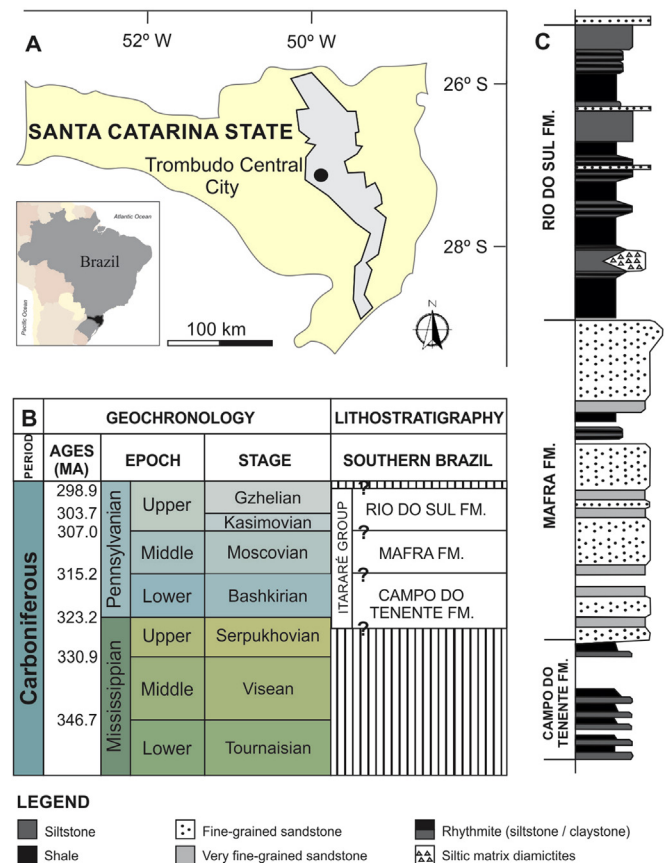


Fig. 1. A, Location map of the study area with the outcropping area of the Itararé Group deposits. B, Late Paleozoic geochronology chart of the Paraná Basin (after Cagliari et al., 2014). C, General log of the Itararé Group sedimentary succession (modified from Schneider et al., 1974).

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