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Late Paleozoic paleofjord in the southernmost Parana Basin (Brazil): Geomorphology and sedimentary fill

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ABSTRACT

In the southernmost part of the Parana Basin, records of the late Paleozoic glaciation occur in a discontinuous form preserved in paleovalley systems excavated in the crystalline basement. This paper addresses one of these paleovalleys, the Mariana Pimentel, which extends over 60 km with NW-SE valley direction and a constant width of 2.5 km. With the objective of demonstrating that the paleovalley worked as a fjord during the glaciation period, its origin as well as sedimentary fill and morphology were analyzed. The paleovalley morphology was obtained through electrical resistivity (electrical sounding and lateral mapping) and mathematical modeling in four transverse sections. The morphology of the paleovalley documented by the U-shape, steady width, and high depth reaching up to 400 m are typical features of modern glacial valleys. The sedimentary facies that fill the base of the paleovalley, such as rhythmites and dropstones with thickness up to 70 m and diamictites with faceted pebbles (up to 5 m thick) are signs of its glacial origin. During the glaciation period, the paleovalley had a connection to the epicontinental sea located to the northwest, extended toward Namibia, and was excavated by glaciers from the highlands of this region. Thus, the evidence attests that the Mariana Pimentel paleovalley was a fjord during the late Paleozoic glaciation. The duration of the late Paleozoic glaciation (which is longer than the Quaternary glaciation), the apatite fission track that suggests erosion up to 4 km thick in the study area, and the lack of preserved hanging valleys in the Mariana Pimentel indicate that the paleovalley once featured a higher dimension. Furthermore, the existence of paleofjords excavated in the border of the basement corroborates the idea of small ice centers controlled by topography during the late Paleozoic glaciation.

1. Introduction

During the late Paleozoic, the south of the Gondwana supercontinent experienced severe glaciation. Records from this period were preserved in the sedimentary basins of many continents (Crowell, 1983). Several paleovalleys were developed during this period in western Argentina (e.g., Kneller et al., 2004; Dykstra et al., 2006, 2007; Limarino et al., 2010, 2014; Aquino et al., 2014; Enkelmann et al., 2014), western Namibia (Martin, 1975; Miller, 1992), and southern Brazil (Lopes et al., 1986; Lavina and Lopes, 1987; Dias, 1993; Machado, 1994; Santos et al., 1996; Holz et al., 2000; Silveira, 2000), preserving glacial deposits inside them.

In the southernmost part of the Paraná Basin, paleovalleys were excavated in the Proterozoic rocks of the basement. Seven paleovalleys were identified in the southeastern border of the basin by Holz et al. (2000), among them the Mariana Pimentel paleovalley. Studies suggest that sediments were brought from Africa to the Paraná Basin through glaciers that moved toward the NW (Frakes and Crowell, 1969, 1970; Visser, 1987, 1993; Santos et al., 1996; Vesely et al., 2015).

Evidence of glaciation in the Paraná Basin paleovalleys is supported by the occurrence of rhythmite with dropstones and rain out, in addition to diamictites facies with polished and faceted pebbles (Guerra-Sommer, 1989). The presence of algae (which indicate low temperatures: Guerra-Sommer, 1989) and fresh/brackish water during glacial melting of the Itararé Group (Dias, 1993), asserts the cold climatic conditions and the connection to the sea. Studies suggest that the Mariana Pimentel paleovalley is potentially a paleofjord (Paim et al., 1983; Holz et al., 2000; Silveira, 2000); however, such studies did not detail the geomorphological aspects and geological evolution of the paleovalley. The existence of paleofjords excavated in the border of basement in the southernmost Brazil corroborates the idea of small ice centers controlled by topography during the late Paleozoic glaciation, proposed by Isbell et al. (2003); Isbell et al., 2012; contrary to the hypothesis of a continuous ice cap, e.g., Veevers and Powell, 1987; Ziegler et al., 1997; Blakey, 2008; Buggisch et al., 2011). Therefore, the main objective

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of this paper is to analyze the origin, morphology, and sedimentary fill of the Mariana Pimentel paleovalley, with the aim of presenting data that validates the hypothesis of this paleovalley to be a paleofjord.

2. Regional geology/Mariana Pimentel paleovalley

The Paraná Basin is an intracratonic basin filled mainly with sedimentary and magmatic rocks between the Silurian and the Late Cretaceous (Milani et al., 2007). It spreads throughout southern Brazil, northern Uruguay, northeastern Argentina, and eastern Paraguay (Zalán et al., 1990). Through regional discordances, it is divided into six depositional supersequences (Milani, 1997). The section under this study is located in the Gondwana I Supersequence (Carboniferous to Early Triassic), preserved in the Mariana Pimentel paleovalley by the sedimentary rocks of the Itararé and Guatá groups.

The Mariana Pimentel paleovalley is located in the southern border of the Paraná Basin, and in the east-central of the Rio Grande do Sul state (Brazil) (Fig. 1). It is a valley of Carboniferous age (Lavina and Lopes, 1987), excavated on metamorphic and intrusive granitic rocks of the crystalline basement (Philipp et al., 2000). It extends for over 60 km toward the NW, with an average width of 2.5 km, which varies between 0.5 km wide at its head and 6.5 km wide near its mouth.

Between the end of the late Carboniferous and the beginning of the early Permian, the Mariana Pimentel paleovalley was filled with glacial (Itararé Group) and post-glacial sediments (Guatá Group; Lavina and Lopes, 1987). Most of the glacial deposits of the paleovalley are subsurface; outcropping sections are not well exposed because of weathering and dense vegetation covering. The best outcrops in the study area are the Morro do Papaléo kaolin quarry (Paim et al., 1983; Lavina et al., 1992; Iannuzzi et al., 2003a, 2003b; Smaniotto et al., 2006) and the Faxinal coal mine (Guerra-Sommer, 1988; Guerra-Sommer and Cazzulo-Klepzig, 1993; Cazzulo-Klepzig et al., 2007).

The sediments of the Itararé Group were deposited in glacially influenced environments during the late Paleozoic glaciation discontinuously, filling small basins interpreted as paleofjords (D'Elboux and Paiva, 1980; Piccoli and Bortoluzzi, 1981; Paim et al., 1983; Santos et al., 1996; Holz et al., 2000; Silveira, 2000). Fjords are defined as deep estuaries in coastal environments excavated by ice that, during interglacial periods, are occupied by the sea (Syvitski et al., 1987; Syvitski and Shaw, 1995; Aarseth, 1997). The Rio Bonito Formation (base of Guatá Group) occurs overlying the Itararé Group and records transitional environments, such as deltas, lagoons, and estuaries, with predominantly sandy and muddy packages (Lavina et al., 1985). Superimposed on the Rio Bonito Formation and preserved only outside the paleovalley is the Palermo Formation (top of Guatá Group), interpreted as marine transgressive deposits (Lavina et al., 1985; Lavina and Lopes, 1987). The Itararé and Guatá groups represent the transgressive part of the transgressive-regressive cycle of the Gondwana I Supersequence (Lopes and Lavina, 2001).

3. Methodology

For this study, we used the electrical resistivity geophysical method, through vertical electrical sounding (VES) and lateral mapping (LM), to obtain the paleovalley basement depth. The geophysics study was conducted in the proximal area (near the paleovalley head), transversal to the paleovalley with N–S direction. The equipment used was Terrameter SAS 4000, with an electrical current of 200 and 500 mA and a frequency of 60 Hz.

The geoelectrical arrangement used in the VES was Wenner. In this configuration, the four electrodes are moved away from a central point in the survey profile. The larger the distance between two electrodes, the greater the depth reached. The electrical current is injected through two external electrodes (A and B), and the electrical potential difference is measured by two other internal electrodes (M and N).

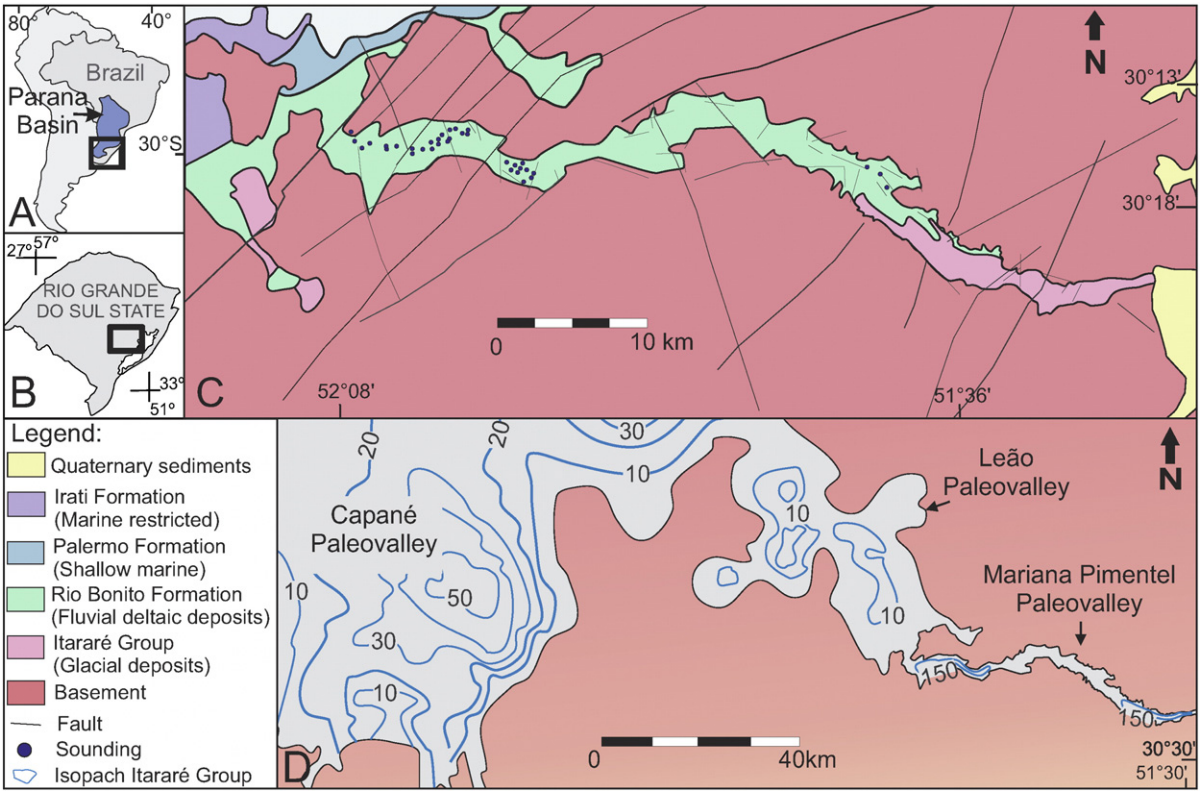

Fig. 1. A) and B) Localization of the study are in South America and the Rio Grande do Sul state (Brazil). C) Geological map of the Mariana Pimentel paleovalley. D) Map with the isopach of the Itararé Group, showing the paleo-relief during the glaciation period (modified from Lopes, 1995). The Mariana Pimentel paleovalley was connected to the sea by the wide Leão paleovalley.