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The Neoproterozoic–Cambrian Paraguay Belt, central Brazil: Part I — New structural data and a new approach on the regional implications

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ABSTRACT

Together with the Araguaia and Brasília belts, the Paraguay belt forms in central Brazil, the Tocantins Province that is one of the largest orogens of western Gondwana. The Corumbá area occupies the site where the northern and southern parts of the Paraguay belt form, together with the Chiquitos-Tucavaca aulacogen (stretching E–W in the adjacent Bolivian territory) an R-R-R basin system opened-filled in the ~700/650–540 Ma interval within the Amazon-Rio Apa paleo-continent. The sedimentary (volcanic) rocks of the Jacadigo and Corumbá Groups found around the Corumbá city record part of the Neoproterozoic–Cambrian passive margin precursor of the Paraguay belt. Our pioneer structural analysis reveals that these rocks experienced progressive deformation (phases D_1–D_2–D_3) and low-grade metamorphism during the Brasiliano Cycle (540–513 Ma). The crystalline basement was also involved, according to structural data and K–Ar ages in the literature. The paleo-passive margin was thickened during the D_1–D_2 deformation and was lately shortened (D_3) in two orthogonal directions, SE–NW (D_{3P}) and SW–NE (D_{3T}). Developed co-axially and verging to NW, D_1–D_2–D_{3P} structures record the closure of the basin precursor of the Paraguay belt, whereas D_{3T} structures seem related to the inversion of the aulacogen. Although the tectonic transport to NW, as observed in the Corumbá area, matches the reported transport of Paraguay belt's supracrustal rocks towards the eastern margin of the Rio Apa block and Araguaia belt's rocks towards the Amazon craton, the transport direction is opposite in other parts of the Paraguay belt. Our comprehensive discussion of these facts brings to light profound regional implications.

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1. Introduction

In the surroundings of Corumbá (Fig. 1), a large city on the western banks of the Paraguay River, central Brazil, the substratum includes Neoproterozoic–Cambrian (meta)sedimentary/volcanic rocks (Jacadigo and Corumbá Groups) plus metamorphic/igneous rocks of the crystalline basement (Jones, 1985; Walde, 1988). According to these authors and many others (e.g. Ruiz, 2005; Cordani et al., 2010) from Corumbá the Neoproterozoic-Cambrian rocks stretch into three belts which record the arms of an ancient R-R-R rift basin and the amalgamation of western Gondwana in central Brazil. The NNE-trending northern Paraguay belt stretches towards the city of Cuiabá; the southern Paraguay belt stretches SSE towards the city of Bonito, following along the eastern margin of the Rio Apa block (where is the Bodoquena Range); and the WNW-trending Chiquitos-Tucacava (or Tucavaca) aulacogen stretches WNW of Puerto Suarez, into the Bolivian territory (Fig. 1b).

Such template points to the basin precursor of the Paraguay belt as established along the Amazon–Rio Apa passive continental margin (Ruiz, 2005; and references therein).

The Corumbá area, famous worldwide for the swamp named Pantanal, is geologically relevant because: (1) — the large reserves of Fe–Mn ore contained in Jacadigo Group rocks; (2) — the Paraguay belt and the R-R-R system integrate, together with the Araguaia and Brasilia belts, the Tocantins Province (Almeida et al., 1981), the large collisional orogen which originated during the Brasiliano Cycle orogeny (Fig. 1a; Trompette, 1994); (3) — because the Paraguay belt was the last to form, its evolution must be linked to a series of events responsible for the Brasília and Araguaia belts, therefore a better geological understanding of the Corumbá area should help unraveling the final moments of amalgamation of western Gondwana in central Brazil; and (4) — the Corumbá Group carbonate platform corresponds laterally to the Araras Group platform mapped further North, in the Cuiabá area of the Paraguay belt, and these are age- and lateral-equivalent to the 540 Ma-old carbonate platform (Tocantins Group) that occurs obducted by the ~750 Ma-old Quatipuru ophiolite in the westernmost part of the Araguaia belt, indicating the continuation of the Quatipuru Ocean to the south, into the basin precursor of the Paraguay belt (Paixão et al., 2008).

Nevertheless, despite of its importance, and after the pioneer regional-scale work by Dorr (1944), the Corumbá area has been the

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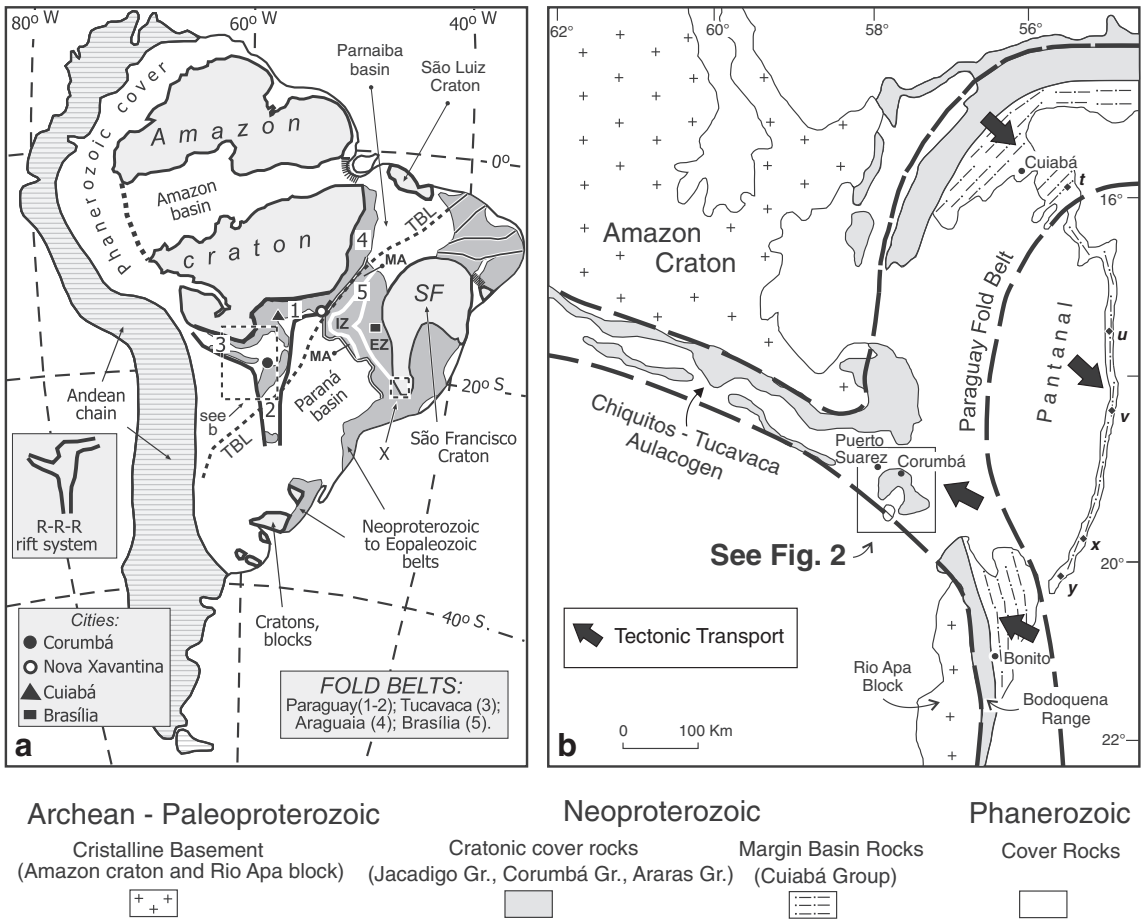

Fig. 1. a–b: Lithotectonic setting. (a) — Simplified map displaying the main lithotectonic units in South America, emphasizing the cratons and fold belts of the Tocantins Province, central Brazil. In the Brasília belt: MA = Goiás Magmatic Arc; IZ = Internal Zone; and EZ = External Zone. The trace of the Transbrasiliano Lineament (TBL) is in agreement with Curto et al. (2015). (b) — Simplified map of the area surrounding the southern corner of the Amazon Craton, emphasizing the main lithostratigraphy units across the Paraguay belt and Chiquitos-Tucavaca Aulacogen (based on Jones, 1985). Five of the seven granite intrusions studied by Godoy et al. (2010) are indicated: *t*, *u*, *v*, *x*, and *y* respectively stand for the São Vicente, Sonora, Coxim, Rio Negro, and Taboco granites. The Laginha and Araguaiana granites occur outside this map, in the Nova Xavantina area (Fig. 1a). See text for the directions of tectonic transport.

focus of studies devoted basically to the detailed description of the lithostratigraphy units and the fossil record (Walde, 1988; Trompette et al., 1998; Walde et al., 2015) or to sedimentology and geochronology details (e.g., Boggiani et al., 2010; Piacentini et al., 2013) therefore leaving open an entire field for detailed structural/tectonic analysis.

This paper results from the detailed structural study carried out upon the Jacadigo and Corumbá rocks of the Corumbá area, and is particularly necessary should the style of deformation/metamorphism of the rocks along the Amazon–Rio Apa paleo-continental margin be understood. It presents a large amount of structural data collected (2012–2013) in tens of outcrops situated inside the VETRIA Mine (one of the private properties in which the local Fe–Mn reserves are divided) and in outcrops of Corumbá Group rocks, the most relevant of which are being localized in Fig. 2. The structures and their mutual relationships are clear enough for a simple and straightforward interpretation. Our studies unravel the post-sedimentation evolution of the rocks in the Jacadigo and Corumbá Groups according to a poly-phase (D_1–D_2–D_3) contraction deformation associated to a very low-grade metamorphism, and were accompanied in the last stage by additional studies (Angerer et al., 2015) focusing specifically on the microscopic aspects of deformation and the role of fluids for the Fe mineralization in the Santa Cruz deposit (VETRIA Mine).

Our structural data and others' geology/geochronology data indicate evolution late in the Brasiliano Cycle orogeny, 540-518/513 Ma ago.

However, different to other structural studies (comments and references in Section 4.2) our results require a detailed discussion on the tectonic evolution of the Tocantins Province. This new approach starts with a comprehensive discussion of our and others' structural data across the Paraguay belt and the regional implications of such data (Part I; this paper) and ends with a detailed discussion on the origin of the Paraguay basin and on how it might have been positively inverted (Part II; companion paper).

2. Regional setting

2.1. Few words on the Tocantins Province

The Tocantins Province derives from the tectonic interaction of the Amazon (Amazon-Rio Apa) and São Francisco paleo-continents with participation of the Parnaíba and Paraná continental blocks and underlying lithospheric mantle shown to exist respectively under the Parnaíba basin (Ussami and Molina, 1999; Castro et al., 2014) and Paraná basin (Mantovani and Brito Neves, 2005; Fig. 1a).

According to Fuck et al. (1994, 2006) the Brasília belt is commonly divided in three domains parallel to western margin of the São Francisco craton (Fig. 1a): the Goiás Magmatic Arc, the Internal Zone, and the External Zone. The arc comprises oceanic island rocks derived from the 900–650/640 Ma consumption of the Goiás Ocean plus sediments of back-arc basins adjacent to the western margin of the São Francisco paleo-continent (Pimentel et al., 2000). The Internal Zone encloses slices of granulite facies tectonites within (amphibolite-)greenschist facies supracrustal rocks (garnet-mica schist) of napes derived from the back-arc basin and, locally, a mélange of M–Um rocks. The part of the Internal Zone salient to the west (about the latitude of Brasília; Fig.1a)

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