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Sedimentological and provenance response to Cambrian closure of the Clymene ocean: The upper Alto Paraguai Group, Paraguay belt, Brazil

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ABSTRACT

Final Gondwana amalgamation was marked by the closure of the Neoproterozoic Clymene ocean between the Amazonia craton and central Gondwana. The events which occurred in the last stage of this closure were recorded in the upper Alto Paraguai Group in the foreland of the Paraguay orogen. Outcrop-based facies analysis of the siliciclastic rocks of upper Alto Paraguai Group, composed of the Sepotuba and Diamantino Formations, was carried out in the Diamantino region, within the eastern part of the Barra dos Bugres basin, Mato Grosso state, central-western Brazil. The Sepotuba Formation is composed of sandy shales with planar to wave lamination interbedded with fine-grained sandstone with climbing ripple cross-lamination, planar lamination, swaley cross-stratification and tangential to sigmoidal cross-bedding with mud drapes, related to marine offshore deposits. The lower Diamantino Formation is composed of a monotonous, laterally continuous for hundreds of metres, interbedded siltstone and fine-grained sandstone succession with regular parallel lamination, climbing ripple cross-lamination and ripple-bedding interpreted as distal turbidites. The upper part of this formation consists of fine to medium-grained sandstones with sigmoidal cross-bedding, planar lamination, climbing ripple cross-lamination, symmetrical to asymmetrical and linguoid ripple marks arranged in lobate sand bodies. These facies are interbedded with thick siltstone in coarsening upward large-scale cycles related to a delta system. The Sepotuba Formation characterises the last transgressive deposits of the Paraguay basin representing the final stage of a marine incursion of the Clymene ocean. The progression of orogenesis in the hinterland resulted in the confinement of the Sepotuba sea as a foredeep sub-basin against the edge of the Amazon craton. Turbidites were generated during the deepening of the basin. The successive filling of the basin was associated with progradation of deltaic lobes from the southeast, in a wide lake or a restricted sea that formed after 541 ± 7 Ma. Southeastern to east dominant Neoproterozoic source regions were confirmed by zircon grains that yielded ages around 600 to 540 Ma, that are interpreted to be from granites in the Paraguay orogen. This overall regressive succession recorded in the Alto Paraguai Group represents the filling up of a foredeep basin after the final amalgamation of western Gondwana in the earliest Phanerozoic.

1. Introduction

The amalgamation of Gondwana in the Neoproterozoic–Cambrian was coeval with important environmental changes that involved several episodes of extreme climatic conditions marked by widespread low-latitude glaciations (e.g., Harland, 1964; Hoffman et al., 1998; Evans, 2000; Hoffman and Schrag, 2002; Meert et al., 2011). The same time period saw dramatic biological innovation (Knoll, 2000; Meert and Lieberman, 2008) and the fast migration of tectonic plates, which resulted in a dynamic palaeogeography (Kirschvink et al., 1997; Evans, 1998; Collins and Pisarevsky, 2005; Tohver et al., 2006; Trindade and Macouin, 2007).

Continents in the late Neoproterozoic were relatively small (Australia-sized) and dispersed (e.g. Collins and Pisarevsky, 2005). They only came together through a series of collisions that took more than 150 million years to form the supercontinent Gondwana (Meert and Lieberman, 2008; Pisarevsky et al., 2008). Amongst the last of these Gondwana-forming orogens was the Cambrian collision between Amazonia (and its probable southern extension in the Rio Apa) and the central and western Gondwana Neoproterozoic continents (now found in Africa and eastern South America) along the Paraguay belt in central South America (Tohver et al., 2006, 2010, 2011; Cordani et al., 2010). Palaeomagnetic and geologic data suggest that Amazonia was attached to the Laurentian remnant of Rodinia until late Ediacaran times, whereas the São Francisco–Congo, Kalahari, and the Rio de la Plata continents were separated from each other by the Clymene ocean

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(Tohver et al., 2006, 2010, 2011; Trindade et al., 2006). The closure of this Neoproterozoic–Cambrian ocean completed the assembly of western Gondwana. This paper looks at the surface response of loading caused by orogenesis in the Paraguay belt, until now, a largely overlooked, but vital component of understanding the timing and geographical evolution of the region.

The Paraguay belt, in central South America, represents an inverted passive-margin to foreland-basin succession, where many of the anomalous events of the Neoproterozoic have been recorded in the Ediacaran carbonates rocks of the Araras Group (Nogueira et al., 2003, 2007; Alvarenga et al., 2008; Dantas et al., 2009). These carbonate rocks are overlain, unconformably, by siliciclastic rocks of the Raizama Formation that are followed by the Sepotuba and Diamantino Formations here informally grouped together as the upper Alto Paraguai Group (Almeida, 1964; Nogueira et al., 2007).

In one of the few provenance studies that has been conducted in the Paraguay belt, Dantas et al. (2009) obtained Nd isotope data from sedimentary rocks from the upper part of the sequence (Raizama and Diamantino Formations). These workers concluded that these sediments were derived from a young source that may be either related to the Neoproterozoic Goiás Magmatic Arc, or found elsewhere in the Brasília belt. Previous works on these siliciclastic formations concentrated on their lithostratigraphy, with little sedimentological description. In addition, a total lack of age constraints has hindered an appreciation of the evolution of the basin and its link with the development of the adjacent orogen.

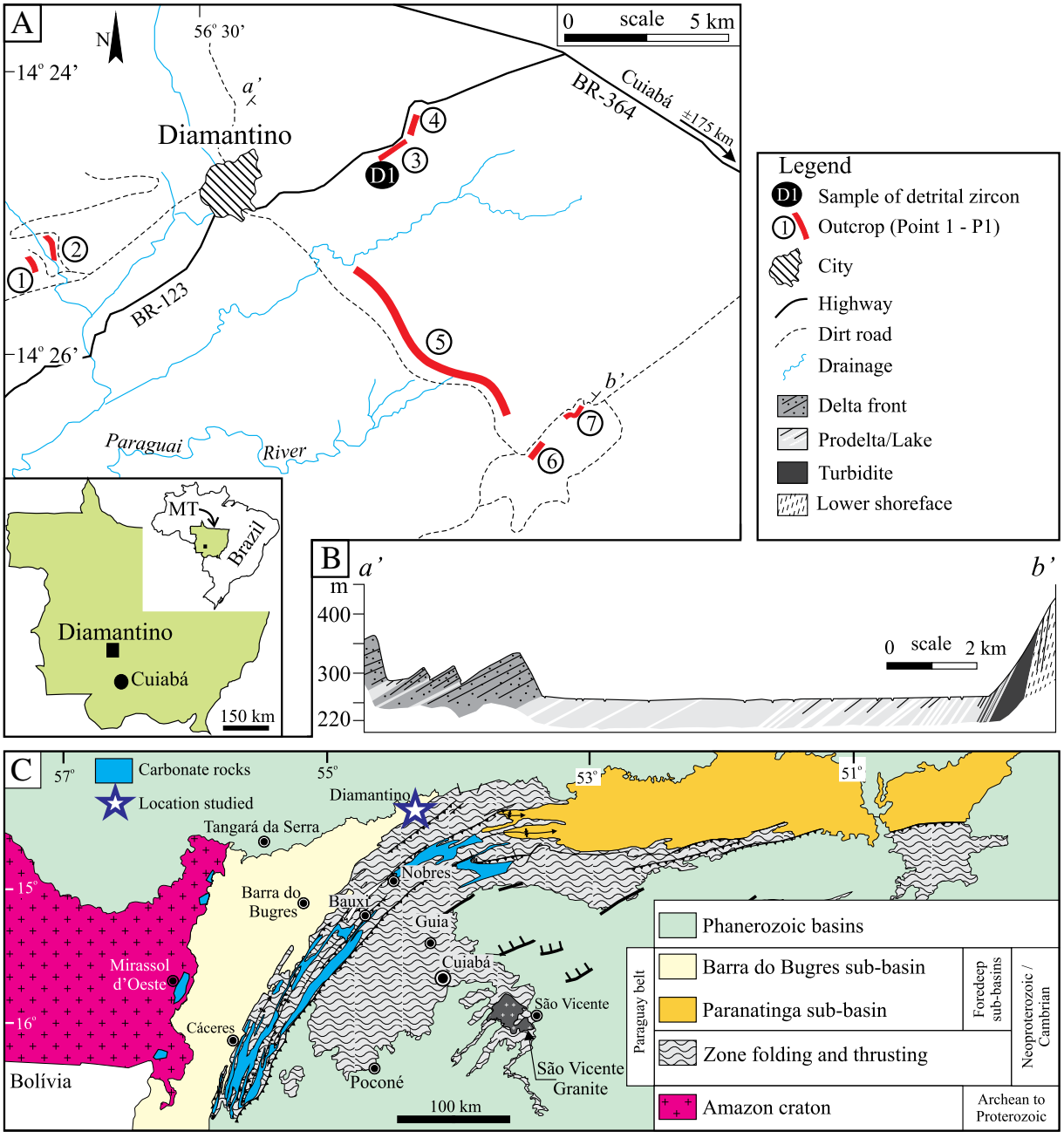

Fig. 1. Location map of the studied area. A) Area of the Diamantino city and points studied. B) Horizontal profile of the study area. C) Lithological and tectonic structure of the Paraguay Belt, according Alkmim and Martins-Neto (2001).