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The 1420 Ma Indiavaí Mafic Intrusion (SW Amazonian Craton): Paleomagnetic results and implications for the Columbia supercontinent

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ABSTRACT

The configuration and the timing of assembly and break-up of Columbia are still matter of debate. In order to improve our knowledge about the Mesoproterozoic evolution of Columbia, a paleomagnetic study was carried out on the 1420 Ma Indiavaí mafic intrusive rocks that crosscut the polycyclic Proterozoic basement of the SW Amazonian Craton, in southwestern Mato Grosso State (Brazil). Alternating field and thermal demagnetization revealed south/southwest ChRM directions with downward inclinations for sixteen analyzed sites. These directions are probably carried by SD/PSD magnetite with high coercivities and high unblocking temperatures as indicated by additional rock magnetic tests, including thermomagnetic data, hysteresis data and the progressive acquisition of isothermal remanent magnetization. Different stable magnetization components isolated in host rocks from the basement 10 km NW away to the Indiavaí intrusion, further support the primary origin of the ChRM. A mean of the site mean directions was calculated at Dm = 209.8°, Im = 50.7° (α_{95} = 8.0°, K = 22.1), which yielded a paleomagnetic pole located at 249.7°E, 57.0°S (A_{95} = 8.6°). The similarity of this pole with the recently published 1420 Ma pole from the Nova Guarita dykes in northern Mato Grosso State suggests a similar tectonic framework for these two sites located 600 km apart, implying the bulk rigidity of the Rondonian-San Ignacio crust at that time. Furthermore these data provide new insights on the tectonic significance of the 1100–1000 Ma Nova Brasilândia belt—a major EW feature that cuts across the basement rocks of this province, which can now be interpreted as intracratonic, in contrast to previous interpretation. From a global perspective, a new Mesoproterozoic paleogeography of Columbia has been proposed based on comparison of these 1420 Ma poles and a 1780 Ma pole from Amazonia with other paleomagnetic poles of similar age from Baltica and Laurentia, a reconstruction in agreement with geological correlations.

1. Introduction

The existence of a Paleo- to Mesoproterozoic supercontinent has been postulated by various authors, although its configuration is still a matter of debate, partly due to the scarcity of paleomagnetic data (Rogers, 1996; Meert, 2002; Rogers and Santosh, 2002; Zhao et al., 2002, 2004, 2006; Pesonen et al., 2003; Kusky et al., 2007; Bispo-Santos et al., 2008; Hou et al., 2008; Johansson, 2009; Evans and Mitchell, 2011). Several names are attributed to this supercontinent—Nena, Nuna, Paleopangea, Columbia, among others (Gower et al., 1990; Hoffman, 1997; Piper, 2000; Rogers and Santosh, 2002). Following the reasoning of Meert (2012) we call this supercontinent as Columbia.

In the present work we focus on some of the building blocks of Columbia, namely Baltica, Laurentia, Amazonia, North China and West Africa. Two different configurations for the Laurentia–Baltica connection have been proposed in Columbia supercontinent, one of which juxtaposes southeastern Greenland to western Baltica (Zhao et al., 2002, 2004; Hou et al., 2008; Johansson, 2009), and the other one places eastern Greenland next to northern Baltica (Hoffman, 1988; Buchan et al., 2000; Karlstrom et al., 2001; Pesonen et al., 2003; Zhao et al., 2006; Salminen and Pesonen, 2007; Bispo-Santos et al., 2008; Lubnina et al., 2010; Pisarevsky and Bylund, 2010; Evans and Mitchell, 2011). Paleomagnetic data favor the latter model, suggesting Laurentia and Baltica drifted together since 1800 Ma up to at least 1270 Ma ago (Salminen and Pesonen, 2007; Lubnina et al., 2010; Pisarevsky and Bylund, 2010; Evans and Mitchell,

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2011). Geologic and geochronologic similarities in the Mesoproterozoic evolution of Laurentia and Baltica with that of the Amazonian Craton led several authors to propose a possible link between the north-northeastern Amazonian Craton and southwestern Baltica (e.g., Sadowski and Bettencourt, 1996; Geraldes et al., 2001; Zhao et al., 2002, 2004, 2006; Hou et al., 2008; Johansson, 2009). Both cratons show subduction-related accretionary belts, which evolved throughout the Mesoproterozoic marginally to such contiguous cratonic nuclei. However, paleomagnetic tests of this configuration for Paleoproterozoic times (Pesonen et al., 2003; Bispo-Santos et al., 2008) indicate that these cratons were not linked. Instead, a well-dated 1789 ± 7 Ma (SHRIMP U–Pb in zircon) paleomagnetic pole from the Amazonian Craton (the Colider intrusive suite) suggested a latitudinal gap between this craton and the Laurentia–Baltica block, which could have been occupied by another large landmass, such as the North China Craton (Bispo-Santos et al., 2008). The position of North China between Baltica and Amazonia is supported by the models of Kusky et al. (2007) and Yakubchuk (2010), which were based on the continuity of Archean and Paleoproterozoic provinces along those four different cratons.

Recently, Bispo-Santos et al. (2012) reported new paleomagnetic and ^{40}Ar–^{39}Ar results for the 1418.5 ± 3.5 Ma Nova Guarita dyke swarm from northern Mato Grosso State (southwestern Amazonian Craton). These new data provided a test for the longevity of the previously proposed Columbia paleogeography. The mismatch between Laurentia–Baltica and Amazonian poles led the authors to suggest that break-up of Columbia must have taken place before 1420 Ma, although a paleogeography where Amazonian Craton was closer to Baltica in the Mesoproterozoic is also allowed by the paleomagnetic data. In the present study, we report new paleomagnetic data from the recently dated (1415.9 ± 6.9; Teixeira et al., 2011) Indiavai mafic intrusion sampled in southwestern Mato Grosso State, ca. 600 km away from the Nova Guarita region. We use the new paleomagnetic data to test different paleogeographic configurations of Columbia for the Mesoproterozoic (and also Paleoproterozoic) times, and speculate on the viability of the different paleogeographic configurations proposed so far, given the present paleomagnetic and geological evidence.

2. Geological setting

The Amazonian Craton is one of the largest tectonically stable areas of Precambrian rocks in the world. The northeastern part of the craton consists of two Archean blocks with granite-greenstone terranes and high-grade metamorphic rocks exposed in the Central Amazonian Province (Fig. 1a). These Archean blocks collided along the Maroni-Itacaiunas belt, between 2250 and 2050 Ma ago (e.g., Ledru et al., 1994; Santos et al., 2000; Fraga et al., 2009). The basement rocks are covered by undeformed volcano-sedimentary successions dated between 1900 and 1400 Ma, and are bordered by progressively younger accretionary belts towards the southwest (Tassinari et al., 2000; Cordani and Teixeira, 2007; Cordani et al., 2009; Bettencourt et al., 2010; Teixeira et al., 2010) (Fig. 1a): the 1980–1810 Ma Ventuari-Tapajós Province, the 1780–1600 Ma Rio Negro-Juruena Province, the 1600–1300 Ma Rondonian-San Ignacio Province, and the 1200–950 Ma Sunsás-Aguapeí Province. The latter includes the Nova Brasilândia high grade belt (see afterward).

The southwestern border of the Amazonian Craton has experienced a complex geological history involving the Neoproterozoic Sunsás, Aguapeí and Nova Brasilândia belts and the Paleo to Mesoproterozoic Paraguá Terrane (Fig. 1b)—see Teixeira et al. (2010) for a review. The Sunsás belt, which marks the southwestern border of the Craton, has long been considered the counterpart of the collisional Grenville belt in Rodinia reconstructions (e.g., Dalziel, 1991; Hoffman, 1991; Sadowski and Bettencourt, 1996). The intracratonic Aguapeí basin (Fig. 1b) is interpreted as an aborted rift (Saes and Fragoso-Cesar, 1994), being separated from the Sunsás belt sensu strictu by the Paraguá Terrane, a Paleo and Mesoproterozoic basement block not affected by the Sunsás orogeny. According to Teixeira et al. (2010) the Aguapeí belt (or aulacogen) may be a late tectonic offshoot of the Sunsás collision over the Jauru granite-greenstone terrane. The northern limit of the Paraguá Terrane, is defined by the E–W 1100–1000 Ma Nova Brasilândia metasedimentary belt (Fig. 1b), which has been interpreted as the Meso- to Neoproterozoic suture zone between this Terrane and the Amazonian Craton basement to the north (Tohver et al., 2004, 2005a). However, this interpretation is disputed by Teixeira et al. (2006), Cordani and Teixeira (2007), and Cordani et al. (2009) who argue that deformation along the Nova Brasilândia belt rather represents intracratonic tectonic reactivation as result from the Sunsás collisional orogeny.

The focus of this work is an area situated to the southeast of the Nova Brasilândia belt (C rectangle in Fig. 1b), within the Jauru Terrane (1780–1420 Ga), which is interpreted by Bettencourt et al. (2010) as a SE extension of the Rio Negro-Juruena Province, whilst reworked by the mobile belts (Cachoeirinha, Santa Helena, Rio Alegre—see below) that built up the Rondonian-San Ignacio Province. In brief, the NW-trending Jauru Terrane (Fig. 1c) is represented by: (i) Paleoproterozoic basement rocks (1790–1720 Ma) comprising the Alto Jauru Group (metasedimentary–metavolcanic assemblages; 1760–1720 Ma), the Alto Guaporé Metamorphic Complex (mainly granite-gneisses; 1790–1740 Ma), and the Cabaçal Tonalite (1780 Ma) (Fig. 1); (ii) rocks from the Cachoeirinha accretionary orogen (1560–1520 Ma; Santa Cruz and Alvorada Intrusive Suites), composed of tonalites, granodiorites and granites; and (iii) younger intrusive associations (Rio Branco, Pindaituba, Santa Helena, and Água Clara), comprising tonalites, granites and mafic rocks making up the Santa Helena orogen (1.48–1.42 Ga, Bettencourt et al., 2010).

The Jauru Terrane is limited to the west by the Rio Alegre Terrane (1510–1380 Ma), (Saes and Fragoso Cesar, 1996). After uplift and cooling, these rocks were probably sources to the younger sedimentary rocks that formed the Sunsás-Aguapeí province (1200–950 Ma, Teixeira et al., 2010). Detrital zircon U–Pb ages from sedimentary rocks of the Fortuna Formation (lowest unit of the Aguapeí Group) are between 1500 Ma and 1230 Ma (Santos et al., 2001; Leite and Saes, 2003). This indicates a maximum age of 1230 Ma for deposition of the Fortuna Formation, whose possible sources are derived from the Rio Alegre Terrane and the granitoid suites that crosscut the Jauru Terrane (Leite and Saes, 2003).

The Figueira Branca Intrusive Suite (FBIS) consists of differentiated, disrupted mafic–ultramafic lithotypes comprising dunites, anorthosites, troctolites, norites, and gabbros. The latter rocks represent the upper part of one stratiform complex. From the petrographic point of view the gabbros may exhibit adcumulatic and cumulatic textures. The FBIS (Fig. 1c) is formed by several bodies mainly intruded into the Orosirian granite-gneisses and the metavolcano-sedimentary rocks of the Alto Jauru Group (Lacerda-Filho et al., 2004). One of the mafic lithotypes (rectangle #2 in Fig. 1c), the Indiavaí mafic intrusion crops out in the vicinity of the Indiavaí town, and another occurs along the Jauru River, in the Figueira Branca farm (rectangle #1 in Fig. 1c). The Indiavaí Intrusion represents a nearly elliptical pluton trending N20–30W (Fig. 2). It intrudes meta-volcanosedimentary rocks of the Alto Jauru Group, it is composed of melanocratic and mesocratic, medium-grained gabbroic rocks with intergranular, cumulate texture, and it presents a discrete tectonic orientation parallel to the main trend (N20–30W) of the pluton. In the studied area, it appears in close association with granitoid stocks, plugs and plutons (Pindaituba Intrusive Suite; 1462–1423 Ma), and show a similar tectonic strike (Ruiz, 2005).

Recently, Teixeira et al. (2011) reported ^{40}Ar–^{39}Ar and U–Pb (SHRIMP) geochronological data for gabbros from both intrusive occurrences. U–Pb (SHRIMP) zircon ages of 1415.9 ± 6.9 Ma and 1425.5 ± 8.0 Ma, from the Indiavaí and Figueira Branca intrusions, respectively, were interpreted as crystallization ages. The analytical concordance between these two sets of results indicates that they reflect a single magmatic event. Nevertheless, the ^{40}Ar–^{39}Ar dating