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Paleogeography of the Congo/São Francisco craton at 1.5 Ga: Expanding the core of Nuna supercontinent

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ABSTRACT

The Congo/São Francisco (C/SF) craton, one of the largest cratons in Proterozoic paleogeography, has been lacking reliable paleomagnetic data for the supercontinent Nuna interval (ca. 1600–1300 Ma). Here we provide a new paleomagnetic key pole for this craton from recently dated mafic dykes in the Curaçá (1506.7 ± 6.9 Ma) region of Brazil. The characteristic remanent magnetization (ChRM) direction $D = 070.6°$, $I = 54.0°$ ($k = 22.1$ and $\alpha_{95} = 13.1°$) corresponds with a paleomagnetic pole at 10.1°N, 009.6°E ($K = 15.6$, $A_{95} = 15.8°$), which places C/SF craton in moderate paleolatitudes at the time of remanence acquisition. Primary nature of the paleomagnetic remanence is supported by a baked-contact test. A similar ChRM direction was obtained for four Mesoproterozoic mafic intrusions in Chapada Diamantina region. The new pole, only from Curaçá, for C/SF allows us to reconstruct the extended core of the supercontinent Nuna at 1.5 Ga. Based on coeval 1.5 Ga and 1.38 Ga magmatism in Baltica, Siberia and C/SF, we favor the position where Southwest Congo is reconstructed against present South-Southeast (S-SE) Baltica. We explore two alternative 1.5 Ga reconstructions of Nuna's core. In both of them Baltica and Laurentia are shown in the well-defined NENA (Northern Europe North America) fit, together with Siberia in a tight fit to northern Laurentia. In reconstruction option A, more traditional fit of Amazonia with Baltica is shown, modified from the geologically based SAMBA (South AMerica BAltica) model to accommodate paleomagnetic data. In this option, however, West Africa must be extricated from SAMBA because C/SF has taken its place. For reconstruction option B, Amazonia is shifted to lie adjacent to NE Laurentia and West Baltica. In both options SW Congo is reconstructed against S-SE Baltica, but in option B there is a tighter fit between them, and there is a better match with our new paleomagnetic data for C/SF. In either option, separation of C/SF from Baltica and Siberia probably occurred at 1.38 Ga, the age of pronounced mafic magmatism throughout this sector of Nuna.

1. Introduction

The existence of the Paleoproterozoic supercontinent Nuna (a.k.a. Columbia, Hudsonland) has been proposed by many researchers (e.g., Williams et al., 1991; Hoffman, 1997; Meert, 2002; Rogers and Santosh, 2002; Zhao et al., 2004; Pesonen et al., 2003; Condie, 2004; Pisarevsky et al., 2014; Pehrsson et al., 2016). One of the main geological arguments used for the existence of Nuna is the presence of 2.1–1.8 Ga orogens in the majority of continents (e.g., Zhao et al., 2004), and it was suggested that some or all of these orogens resulted from the assembly of this supercontinent. Paleomagnetism is the only quantitative method to generate Precambrian paleogeographic reconstructions, and recent paleomagnetic data have appeared to support, within the analytical uncertainties, a single NENA juxtaposition (Northern Europe - North America; Gower et al., 1990) between Baltica and Laurentia at ca. 1750–1270 Ma (Buchan et al., 2000; Salminen and Pesonen, 2007; Evans and Pisarevsky, 2008; Lubnina et al., 2010; Pisarevsky and Bylund, 2010; Salminen et al., 2014), forming a core element of Nuna. Adding cratons around this core has been a major initiative among

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paleogeographers in recent years (e.g., Siberia, Evans and Mitchell, 2011; Evans et al., 2016a; North China, Zhang et al., 2012; Xu et al., 2014; India, Pisarevsky et al., 2013). The combined Congo/São Francisco (C/SF) craton has been placed adjacent to Baltica and Siberia based mainly on ages of mafic magmatism in the interval 1.5–1.38 Ga (Ernst et al., 2013), but paleomagnetic support for such a reconstruction was limited to an old result (Piper, 1974) that requires confirmation by more modern methods and field tests on the age of remanence acquisition.

Application of paleomagnetic data to the reconstructions requires not only a high reliability of the remanence directions, but also confidence in accurate dating of the rocks and their magnetic acquisitions. A reliable paleomagnetic pole generally fulfills at least three of the seven quality criteria of Van der Voo (1990). If two of these include adequately precise geochronological age and a positive paleomagnetic field test, the obtained paleomagnetic pole can be called a "key" pole (Buchan et al., 2000; Buchan, 2013). Paleomagnetic data from different continents allow comparison of lengths and shapes of apparent polar wander paths (APWPs) to test proposed long-lived proximities of the cratons. As long as these landmasses have traveled together they should have identical APWPs. In the absence of well-defined APWPs, pairs of coeval paleomagnetic poles from these cratons can be used for a rough test (e.g. Buchan et al., 2000; Evans and Pisarevsky, 2008). If the arc distance between two paleopoles with ages X and Y from one continent is the same as the arc distance between two paleopoles of the same ages from a second continent, then one can propose that those two continents traveled together (e.g. Evans and Pisarevsky, 2008; Pisarevsky et al., 2014). Moreover, these pairs of paleopoles should plot on top of each other within their error limits, after Euler rotation to the continents' correct relative configuration. Unfortunately, many cratons -such as C/SF, Kalahari, and West Africa – have been entirely lacking good-quality paleomagnetic data for the Nuna interval.

A complementary approach to suggest neighborhood of cratons in the geological past is to compare coeval large igneous province (LIP) events for each craton (e.g. Bleeker and Ernst, 2006; Ernst and Bleeker, 2010). Specifically, cratons that share a number of coeval LIP events can be argued to have been "nearest neighbors", whereas the lack of such matches suggests they were far away from each other during a given time period. Silveira et al. (2013) provided new U-Pb baddeleyite ages for the Chapada Diamantina and the Curaçá dykes in the SF craton (1501 ± 9 and 1506.7 ± 6.9 Ma, respectively), and the recent U-Pb baddeleyite age of 1502 ± 5 Ma (Ernst et al., 2013) for the Humpata sill in the Congo craton added a new Mesoproterozoic igneous event for C/SF craton. Another Mesoproterozoic igneous event of contemporaneous age for the combined C/SF craton is represented by the 1380 Ma Kunene Intrusive Complex in SW Angola (Drüppel et al., 2007; Ernst et al., 2008) and a nearly coeval mafic–ultramafic belt in the eastern portion of the Congo craton (Maier et al., 2007; Tack et al., 2010; Mäkitie et al., 2014), but is thus far not recognized in São Francisco. A Neoproterozoic igneous activity for the C/SF Craton is present on both blocks, the ca. 920 Ma Salvador dykes in the São Francisco Craton (Heaman, 1991; Evans et al., 2016b) and the contemporaneous Gangila/Mayumbian succession in the Congo craton (Tack et al., 2001). The 130 Ma basalts and sills from Paraná Basin of SF craton together with their counterpart in the southwest African territory, i.e. the Etendeka magmatic province, are a continental flood-basalt type LIP (Deckart et al., 1998;

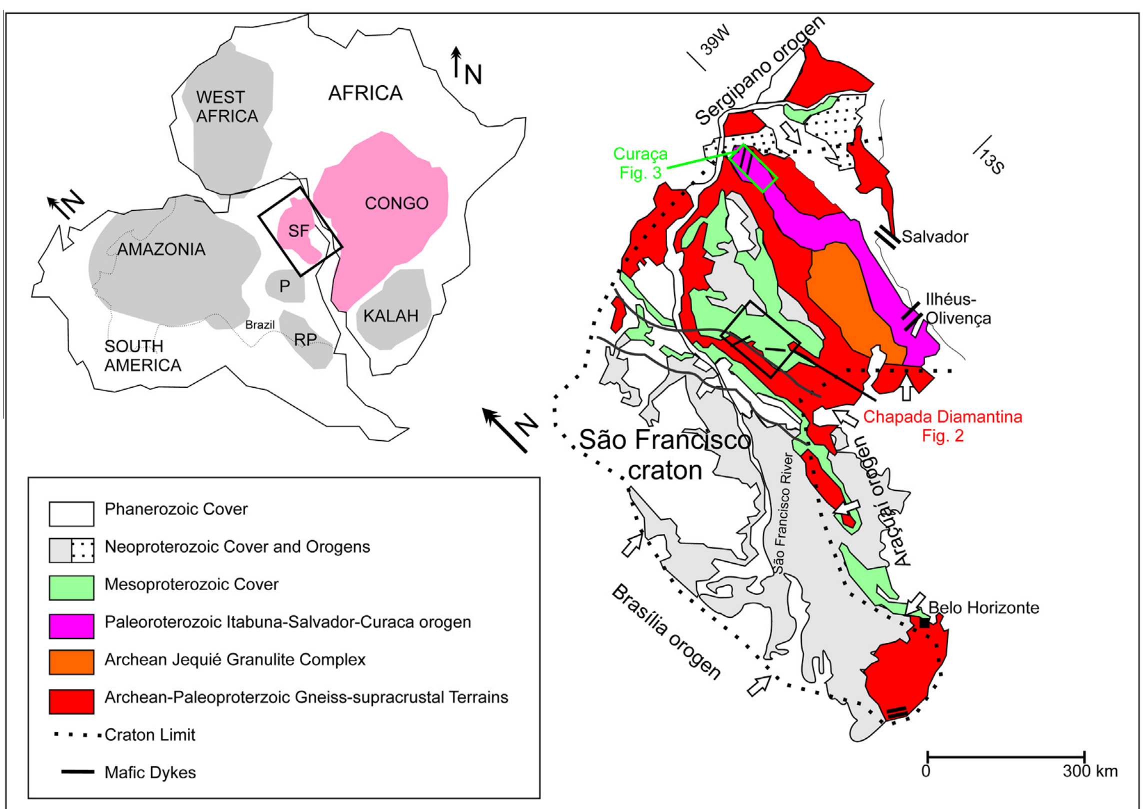

Fig. 1. Regional tectonic map of the Congo(C)/São Francisco(SF) craton after reconstruction of the South Atlantic Ocean (modified from Alkmim et al. (2006)). Cratons of western Gondwana-Land: Kalah – Kalahari, P – Paranapanema, RP – Rio de la Plata, SF – São Francisco. Inset, Simplified geological map of the São Francisco Craton (modified after Silveira et al., 2013). Sampling areas of Curaçá (green) and Chapada Diamantina (black) are indicated with rectangles. White arrows signify vergence in bounding orogens. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)