THE CORE OF COLUMBIA FORMED BY LAURENTIA, BALTICA, AMAZONIA AND WEST AFRICA – A GEODYNAMIC MODEL OF AGGLUTINATION

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ABSTRACT

Recent paleomagnetic data establishes that the core of Columbia was formed at about 1.85 Ma by the docking of parts of Laurentia, Baltica, Amazonia and West Africa. In this model, West Africa was attached to proto-Amazonia in a configuration where the Guri (in Amazonia) and Sassandra (in West Africa) shear zones were aligned. Present north-northwestern Amazonia was linked to southern Baltica while the Eastern Greenland in Laurentia was linked with the Arctic margin of Baltica. Paleomagnetic and geochronological data for these cratonic blocks obtained along the last decades allowed us to propose a paleogeography at 2.0 Ga, which culminated with the formation of the core of Columbia at 1.85 Ma.

Keywords: Amazonia, Laurentia, Báltica, West Africa, Paleomagnetism, Columbia

RESUMO

Dados paleomagnéticos recentes estabeleceram que o núcleo do Columbia foi formado pela colisão de partes da Laurentia, Báltica, Amazônia e Oeste da África há cerca de 1.85 Ga atrás. Neste modelo, o Oeste da África estava unido ao Escudo das Guianas em uma configuração em que as zonas de cisalhamentos Guri (na Amazônia) e Sassandra (no Oeste da África) estavam alinhadas. A atual parte norte-noroeste do Cráton Amazônico estava unida à atual parte sul da Báltica, enquanto a parte leste da Groelândia, na Laurentia, estava unida com a margem Ártica da Báltica. Dados paleomagnéticos e geocronológicos para estas unidades cratônicas obtidos nas últimas décadas permitem propor uma paleogeografia há 2.0 Ga atrás, a qual culminou com a formação do núcleo do Columbia há 1.85 Ga.

Palavras Chave: Amazônia, Laurentia, Báltica, Oeste-África, Paleomagnetismo, Columbia

Introduction

To establish the paleogeography of continental blocks in the past is extremely important to understand the geological evolution of the Earth and the mechanisms that prevailed in the formation and rupture of supercontinents, a process which is called supercontinental cycle (Condie, 2002). Several paleogeographic reconstructions of a Paleoproterozoic supercontinent (1850-1800 Ma) have been proposed in the literature here named as Columbia (*e.g.*, Meert, 2012).

The Amazonian Craton, in the northwest of South America, indeed played a fundamental role in the Earth's geodynamic history and in the paleogeography of Columbia. In recent years, a significant amount of paleomagnetic data were obtained for this and other units, which have important implications to the formation of Columbia supercontinent. Here we discuss the participation of the Amazonian Craton in pre- Columbia times and how its nucleus was assembled.

The proto-Amazonian craton pre-Columbia

Definition of a crustal paleogeography for times prior to the Columbia formation is yet very speculative, since many continental blocks were still being assembled during this period, including the Amazonian Craton, Laurentia and Baltica. Well-dated paleomagnetic poles for the different fragments that were later assembled in these cratons are scarce, thus we can only speculate about the possible presence of Archean supercratons. In Amazonia, some authors advocate a link between the Guiana Shield and the West Africa Craton forming a single, large cratonic block (supercraton) at about 2.0 Ga ago (Onstott, Hargraves, 1981, Nomade *et al.*, 2003, Johansson, 2009, 2011, Bispo-Santos *et al.*, 2014a). Despite the general scarcity of Precambrian paleomagnetic data for the Amazonian Craton, the interval between 2070 and 1970 Ma is relatively well represented in the database as a result of studies carried out by two research groups at different times. These studies led to the construction of apparent polar wander paths (APW Paths) for the Amazonian Craton (Guiana Shield) and the West Africa Craton for Orosirian times (Nomade *et al.*, 2003, Théveniaut *et al.*, 2006). In the 80's, the Princeton group (led by Tullis C. Onstott) conducted a series of paleomagnetic and geochronological studies on intrusive rocks from Guiana Shield (Venezuela and Guyana) and West Africa Craton (Onstott, Hargraves, 1981; Onstott *et al.*, 1984a, 1984b). Based on the available paleomagnetic data, these authors argued that Guiana Shield was an extension of West Africa Craton, however, displaced in relation to the Pangaea reconstruction in such way that the Guri lineament in Guiana Shield and the Sassandra lineament in West Africa Craton were aligned (Onstott, Hargraves, 1981). This model was corroborated by Nomade *et al.* (2003) who studied granitic and metavolcanic rocks exposed in French Guiana, and also from West Africa Craton (Nomade *et al*., 2001, 2003).

Recently, new paleomagnetic data were obtained for felsic volcanic rocks from the Surumu Group (Guiana Shield), which are well dated at 1960 to 1980 Ma by the U-Pb method (Bispo-Santos *et al.*, 2014a). A robust paleomagnetic pole was obtained for these rocks, which helps to better define the APW Path traced by Théveniaut *et al.* (2006) between 2070 and 1970 Ma for the Guiana Shield. Bispo-Santos *et al.* (2014a) proposed a model in which West Africa was rotated to Guiana Shield using an Euler pole located at 43.3°N; 330.5° (rotation angle of -71.5°). In this model proto-Amazonian/West-African paleogeography (Fig. 1a) is similar to that proposed by Onstott, Hargraves, (1981), where the Guri (Guiana Shield) and Sassandra (West Africa) shear zones were part of the same tectonic lineament.

Paleogeography of the proto-Amazonian craton at 2.0 Ga

In general, the paleomagnetic poles from the Amazonian Craton are compared with poles from Laurentia and Baltica aiming supercontinental reconstructions. As already stressed, at times prior Columbia formation, however, any reconstruction must be considered very speculative since the major cratonic masses that would be assembled in Columbia were still not completely formed. For example, most of Laurentia was only assembled at *ca*. 1.85 Ga, after the following collisions: Archean Slave and Rae blocks at 1.97 Ga, the Slave/Rae and Hearne blocks at 1.92 Ga, and this block with the Superior Craton at 1.85 Ga (Mitchell *et al.*, 2014). Based on well-dated paleomagnetic poles from Slave and Superior cratons in the interval between 2.2 Ga and 2.0 Ga, Mitchell and colleagues (2014) demonstrate that these blocks were separated by a very large ocean (Manikewan ocean) at *ca*. 2.0 Ga (see their Fig. 2). In their reconstruction, the Slave block was rotated -79° around an Euler pole at 52° N, 356° E relative to the Superior block. Using this reconstruction we speculate a possible paleogeography at 2.0 Ga (Fig. 1b) which tentatively includes other three cratonic blocks of Laurentia (Hae, Hearne and Greenland), and also parts of Baltica, Amazonia, and West Africa, partly based on paleomagnetic poles as described below. The relative paleogeographic positions of Slave and Superior

Cratons (Mitchell *et al.*, 2014) is constrained using the 1998 Ma pole determined for the Minto dykes (pole at 30° N, 183° E, A95 = 13°) from the Superior Craton. The Hae and Hearne blocks were speculatively positioned between these cratonic blocks.

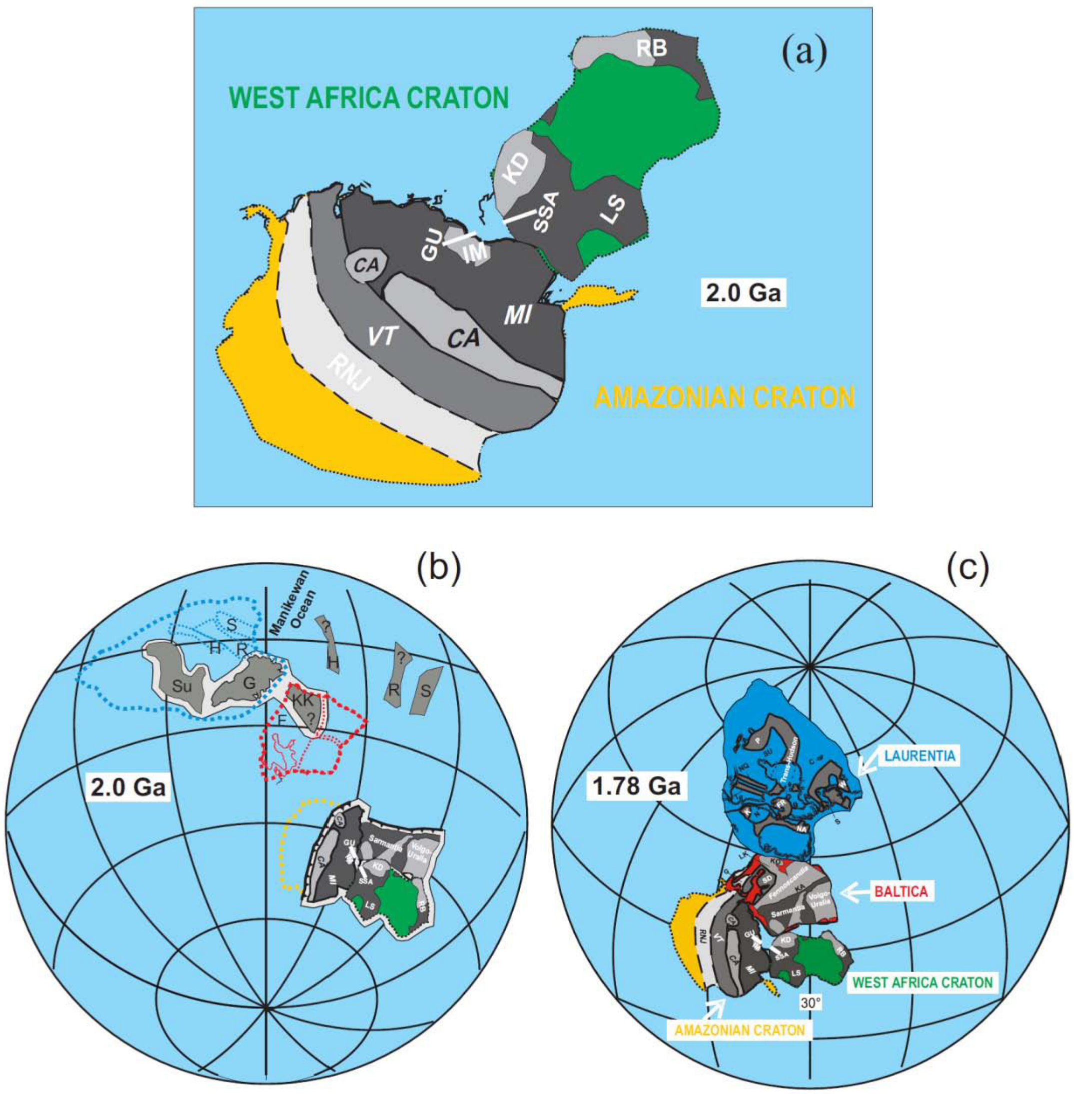

Figure 1. (**a**) Paleogeographic configuration showing the Amazonian Craton and West Africa Craton link at around 1970 Ma ago. Geotectonic provinces: Amazonia (CA – Central Amazonian, MI – Maroni-Itacaiúnas; VT – Ventuari-Tapajós; RNJ – Rio Negro-Juruena, GU – Guri lineament); West Africa (LS – Leo Shield, KD – Kenemanan Domain, RB – Requibat Shield, SSA – Sassandra lineament). (**b**) Reconstruction at 2.0 Ga partially based on paleomagnetic data. Proto-Amazonia was constrained using the OYA pole – Oyapok Granitoids (Nomade *et al.*, 2001). Superior Craton was constrained using the Minto dykes pole (Buchan *et al.*, 1998, Evans, Halls, 2010). Superior and Slave relative positions are the same proposed by Mitchell *et al.* (2014) based on paleomagnetic data. In this scenario, it is supposed that Superior (Su), Greenland (G) and Kola-Karelia (KK) formed a single cratonic mass. The same is proposed for proto-Amazonia, West Africa, Volgo-Uralia and Sarmatia. Rae (R) and Hearne (H) cratonic blocks were tentatively positioned between Superior and Slave Archean Cratons. CA, MI, GU, LS, KD, RB, SSA as in (a). See text for details. (**c**) Columbia Supercontinent at ~1790 Ma based on paleomagnetic data, after Bispo-Santos *et al.* (2014b). Abbreviations as in Bispo-Santos et al. (2014b). See details in the text.

At that time, Central Amazonia was already assembled with the collision of Archean blocks along the 2.25- 2.05 Ga Maroni-Itacaiúnas mobile belt (MIMB, Cordani, Teixeira, 2007). Since other Archean blocks collided with Central Amazonia along the MIMB during and after the assembly of Central Amazonia, it is very likely that the craton at the time was a larger landmass. Based mainly in geological/ geochronological evidence Johansson (2009) proposed the SAMBA model for Columbia, where West Africa and Sarmatia/Volgo-Uralia may be the components of this larger cratonic block. As discussed above, West Africa was linked to the Guiana Shield at least since 1.97-2.00 Ga in a position where the Guri (in Guiana Shield) and Sassandra (in West Africa) lineaments were aligned (Onstott, Hargraves, 1981, Nomade *et al.*, 2003, Bispo-Santos *et al.*, 2014a).

At 2.0 Ga ago, Baltica was not yet formed (see Bogdanova *et al.*, 2013). Collision between Sarmatia and Volgo-Uralia occurred between 2.1 and 2.0 Ga, forming the Volgo-Sarmatia block. So, we speculate here that a large landmass was already formed at 2.0 Ga composed by Volgo-Uralia, Sarmatia, Central Amazonia and West Africa, agglutinated along Paleoproterozoic mobile belts developed up to 2.0 Ga. The position of this landmass is constrained by the OYA pole (28° S, 346° E, A95 = 13.8°) obtained for the Oyapok granitoids with an Ar-Ar (amphibole) age of 2020 ±4 Ma (Nomade *et al.*, 2003, Théveviaut *et al.*, 2006). At that time, active subduction zones were in progress at the northern and western margins of Volgo-Sarmatia and Central Amazonia, respectively (Fig. 1b).

Between 1.83 and 1.80 Ga an oblique collision occurred between this large continental mass with Fennoscandian terrains along the NW part of Sarmatia (Bogdanova *et al.*, 2013). Here we speculate that Archean terrains from Baltica (Kola-Karelia) were part of Laurentia since 2.0 Ga ago (Fig. 1b). After oblique collision, Volgo/Sarmatia (together with Central Amazonia and West Africa in our model) performed a counterclockwise rotation which activated older strike-slip faults (Bogdanova *et al.*, 2013). These fault systems accommodated mafic dyke swarms with ages between 1.79 and 1.75 Ga in the Ukrainian Shield (northwestern Sarmatia). At the same time (1.79-1.78 Ga) profuse mafic intrusions occurred as dykes and sills at the Guiana Shield, spread over Venezuela, French Guiana and northern Brazil (Reis *et al.*, 2013, Bispo-Santos *et al.*, 2014b). After Columbia formation at 1.78 Ga (Fig. 1c) minor internal rotations occurred associated with 1.75 Ga mafic dykes at Ukrainian Shield (Bogdanova *et al.*, 2013).

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