Lithos 174 (2013) 157–174

Contents lists available at SciVerse ScienceDirect

Lithos

journal homepage: www.elsevier.com/locate/lithos

U–Pb (ID-TIMS) baddeleyite ages and paleomagnetism of 1.79 and 1.59 Ga tholeiitic dyke swarms, and position of the Rio de la Plata Craton within the Columbia supercontinent

Wilson Teixeira [a,*], Manoel S. D'Agrella-Filho [b], Mike A. Hamilton [e,1], Richard E. Ernst [c,d], Vicente A.V. Girardi [a], Maurizio Mazzucchelli [f], Jorge S. Bettencourt [a]

[a] Instituto de Geociências, Universidade de São Paulo, USP, Rua do Lago 562, Cidade Universitária, São Paulo, SP 05508-080, Brazil
[b] Instituto de Astronomia, Geofísica e Ciências Atmosféricas, IAG, Departamento de Geofísica, Universidade de São Paulo, USP, Rua do Matão 1226, Cidade Universitária, São Paulo, SP 05508-090, Brazil
[c] Ernst Geosciences, 43 Margrave Avenue, Ottawa, Canada K1T 3Y2
[d] Department of Earth Sciences, Carleton University, Ottawa, Canada K1S 5B6
[e] Jack Satterly Geochronology Laboratory, Department of Geology, University of Toronto, 22 Russell St. Toronto, Canada ON M5S 3B1
[f] Università degli Studi di Modena e Reggio Emilia, Dipartimento di Scienze della Terra, P. Sta Eufemia, 49, I-41100 Modena, Italy

A R T I C L E I N F O

Article history:
Received 25 May 2012
Accepted 20 September 2012
Available online 27 September 2012

Keywords:
U–Pb geochronology
Paleomagnetism
Mafic dyke swarms
Rio de la Plata Craton
LIPs

A B S T R A C T

The Tandilia Terrane (southernmost fringe of the Rio de la Plata Craton) is an igneous and metamorphic complex produced by an accretionary orogeny (2.25–2.02 Ga). Calc-alkaline acidic dykes with E–W strike and a major shear zone with similar orientation are related with the late orogeny stage, as supported by field relations. In a previous study the acid dykes gave ^{40}Ar–^{39}Ar ages of 2007 ± 24 Ma to 2020 ± 24 Ma. A N and NW trending tholeiitic dyke swarm (Tandil swarm) is also present in the Tandilia Terrane. One sample from the NW-trending subset previously gave a U–Pb (ID-TIMS) baddeleyite age of 1588 ± 11 Ma. New precise U–Pb (ID-TIMS) baddeleyite dating of both N- and NW-trending Tandil dykes yielded crystallization ages of 1589 ± 3 Ma, 1588 ± 3 Ma and 1588 ± 3 Ma. Significantly older tholeiitic dykes known as the Florida swarm occur in the Northern Rio de la Plata Craton, for which a U–Pb (ID-TIMS) baddeleyite age of 1790 ± 5 Ma was previously reported. Consequently intermittent rifting (1.79, 1.59 Ga) took place after tectonic stabilization of the late Paleoproterozoic lithosphere (proto-Rio de la Plata Craton). The available geochemical data for the 1.59 Ga Tandil dykes define low- and high-TiO_2 trends, although, only the low-TiO_2 subgroup is firmly dated. Both the Tandil and Florida dykes have geochemical and Nd–Sr characteristics consistent with derivation from heterogeneous mantle sources that underwent metasomatic effects.

The Tandil dykes may be linked with the 1.57 ± 0.02 Ga Capivarita anorthosite which occurs to the east of the northern part of the craton. Correlatives on other crustal blocks may include those in Baltica such as bimodal rock association (including the Breven-Hällefors and Åland-Åboland diabase dykes) and in the reconstructed Gawler Craton/NW Laurentia dolerites, bimodal magmatism and IOCG deposits. Contemporary within-plate bimodal associations are also present in the SW Amazonian Craton.

Paleomagnetic data for the 1790 Ma Florida dykes allows three possible reconstruction scenarios for the position of Rio de la Plata Craton: *i*) in the southern hemisphere linked to the Pampia terrane, and the Amazonia + Rio Apa landmass as close as they are in present day; *ii*) in the northern hemisphere, as a nearest neighbor to the reconstructed NW Laurentia and Gawler blocks (proto-Australia); or *iii*) in the northern hemisphere near the boundary of Amazonia (proto-Amazonian Craton) and Baltica. Positions 2 and 3 are consistent with all three criteria: paleomagnetic poles and proximity to matching ca. 1790 Ma and 1590 Ma mafic magmatism. Our data are consistent with the idea that the Columbia supercontinent started major break up at 1.59 Ga.

* Corresponding author. Tel.: +55 11 30913906; fax: +55 11 30913993.
E-mail addresses: wteixeir@usp.br (W. Teixeira), dagrella@iag.usp.br (M.S. D'Agrella-Filho), mahamilton@geology.utoronto.ca (M.A. Hamilton), Richard.Ernst@ErnstGeosciences.com (R.E. Ernst), girardi@usp.br (V.A.V. Girardi), Maurizio.Mazzucchelli@unimore.it (M. Mazzucchelli), jsbetten@usp.br (J.S. Bettencourt).
[1] Tel. 1 416-946-7424.

0024-4937/$ – see front matter
http://dx.doi.org/10.1016/j.lithos.2012.09.006

1. Introduction

Late Paleoproterozoic orogenic belts are widespread worldwide, as portrayed in South America and West Africa, Laurentia and Baltica, Siberia and Central Australia and North China and India (e.g., Windley, 1998). The cratonization of these orogenic belts formed during a broadly contemporaneous collage marks the "birth" of the Columbia (also called Nuna), as supported by the geologically based models and paleomagnetism of correlatable units. However , the configuration of Columbia is still a matter of debate (e.g., Bispo-Santos et al., 2008, 2012; Cordani et al., 2009; D'Agrella-Filho et al., 2012; Ernst et al., 2008; Evans and Mitchell, 2011; Hou et al., 2008; Meert, 2012; Pesonen et al., 2003; Pisarevsky and Bylund, 2010; Pisarevsky et al., 2013; Rogers and Santosh, 2002, 2009; Zhang et al., 2012; Zhao et al., 2004, 2006). Most of the landmasses of Columbia contain a huge volume of bimodal rock associations [anorthosite–mangerite–charnockite–granite (AMCG type)] starting emplacement mostly at ~1.6 Ga, and along with fault related basins with diachronous sedimentary rocks and volcanic rocks, and layered mafic intrusions reflect intermittent, aborted rifting phenomena. Particularly, large scale radiating mafic dyke swarms mark prominent extensional structures and are useful for paleogeographic reconstruction of past supercontinents related to mantle plumes (e.g., Bleeker and Ernst, 2006; Ernst and Buchan 2001a,b; Halls and Fahrig, 1987).

This paper deals with two prominent mafic dyke swarms in the Rio de la Plata Craton (RPC) in order to potentially use these swarms to constrain the location of this craton in the Columbia supercontinent.

We present new U–Pb (ID-TIMS) dating of baddeleyite from the Tandil tholeiitic dyke swarm which occurs in the Tandilia Terrane (southernmost edge of the RPC). We also present a paleomagnetic pole for the Florida dyke swarm (northern part of the Craton) for which a U–Pb (ID-TIMS) 1790 ± 5 Ma baddeleyite age and earlier paleomagnetic work was previously reported (Halls et al., 2001). The available geochemical and isotopic signatures highlight the nature of mantle source from which the Tandil and Florida dykes derived. The paleomagnetic results from the Florida dykes are also used to test possible geometric fits with NW Laurentia and Gawler cratons (reconstructed as per Hamilton and Buchan, 2010), or with the Amazonian Craton and Baltica — in the context of the Columbia supercontinent. For each of these fits we also consider the presence/absence of matching 1790 Ma and 1590 Ma events.

2. Geologic outline of the Rio de la Plata Craton and the Nico Pérez Terrane

The RPC is one of the major nuclei of Western Gondwana, surrounded by late Neoproterozoic–Cambrian orogenic belts (e.g., Almeida et al., 2000; Cingolani, 2010; Rapela et al., 2011 and references therein). These belts contain internal suture zones that mark the disappearance of large-scale intervening oceans (e.g., Goianides, Clymene), preceding the assembly of nearby continental masses, such as Amazonia and proto-RPC (Cordani et al., 2009; Tohver et al., 2012; Trindade et al., 2006). The RPC occurs in southern South America, mainly exposed in the Uruguayan shield and in a restricted area in eastern Argentina (known as the Tandilia Terrane); elsewhere it is obscured by the extensive Phanerozoic cover (Fig. 1).

Two tectono-stratigraphic terranes crop out in the Uruguayan Shield, separated by strike-slip faults, shear zones and associated mylonites (e.g., Bossi and Cingolani, 2009; Rapela et al., 2007 and references therein): *i*) the Piedra Alta Terrane of RPC (PA in Fig. 1), composed of Paleoproterozoic igneous and meta-igneous complexes located to the west of the Sarandí del Yí megashear; *ii*) the Nico Pérez (NP) polycyclic Terrane (to the east of the megashear), with continuation into northern Uruguay and southern Brazil (the Rivera (R) and Tacuarembó (T) blocks in Fig. 1). The southernmost edge of the RPC is the Tandilia Terrane, located in the Buenos Aires Province (Argentina). The age differences together with contrasting geophysical signatures support the interpretation that the RPC comprises only the Piedra Alta and Tandilia terranes, whereas the Sarandí del Yí megashear (transcurrent structure) marks the eastern border of the RPC with the Nico Pérez Terrane (Oyhantçabal et al., 2010 and references therein).

2.1. Piedra Alta Terrane

Paleoproterozoic crust makes up the bulk of the Piedra Alta Terrane which comprises mainly juvenile granitic to tonalitic gneisses, although a few Sm–Nd T_{DM} ages (2.9–2.3 Ga) suggest derivation from Archean protoliths. Subordinate low-grade metamorphic volcanic–sedimentary belts and plutonic suites of TTG affinity (2220–2020 Ma) are also present in the terrane (Bossi and Cingolani, 2009; Rapela et al., 2007). The Piedra Alta Terrane is intruded by late- to post-kinematic K-rich granitoid rocks and gabbros (2060–2070 Ma) (e.g., Hartmann et al., 2000; Oyhantçabal et al., 2010; Preciozzi et al., 1999).

2.2. Nico Pérez Terrane

The Nico Pérez Terrane has been the focus of detailed geochronological work, particularly in the Uruguayan Shield, which records several Archean to Proterozoic events (Bossi and Cingolani, 2009; Bossi and Gaucher, 2004; Hartmann et al., 2001, 2002; Oyhantçabal et al., 2010). Intrusive rapakivi granites and associated rocks (AMCG type) typical of extensional settings are also present. One of these intrusions, the 1777 ± 60 Ma Illescas batholith (star #1 in Fig. 1), is cut by the Sarandí del Yí megashear that also deformed the eastern portion of the Florida dyke swarm (Teixeira et al., 1999). Another correlated unit is the Carapé Granite that formed at 1754 ± 7 Ma (Mallmann et al., 2007). The Nico Pérez Terrane in Uruguay includes an allochthonous block (named Chuchilla-Dionisio Terrane by Bossi and Gaucher, 2004) — which was juxtaposed by lateral accretion along the Sierra Ballena shear zone (SBSZ; Fig. 1). It comprises the Lavalleja, Parque UTE, Mina Verdún groups (1.49–1.43 Ga), deformed and metamorphosed between 1.25 and 1.20 Ga. These units were intruded by collisional granites (680 to 550 Ma) which are related to the Neoproterozoic Pampean orogenic belt (Gaucher et al., 2011; Rapela et al., 2011).

The northernmost outcrops of the Nico Pérez Terrane form the well known Rivera (northern Uruguay) and Tacuarembó (Brazil) blocks (Fig. 1). The former is made up of Paleoproterozoic high grade metamorphic basement intruded by granitoid rocks (600–550 Ma). In the Tacuarembó block the rocks which are correlatable with the Rivera ones known as the Santa Maria Chico complex were metamorphosed within the time interval 2.2–2.0 Ga but have U–Pb protolith ages between 2.4 and 2.5 Ga (Hartmann et al., 2008 and references therein).

Juvenile Neoproterozoic rocks comprising the São Gabriel arc (880–670 Ma) are restricted to the east of the Tacuarembó block (Fig. 1). They are tectonically imbricated with Paleoproterozoic gneisses of the Encantadas block (not shown) (Babinski et al., 1996; Saalmann et al., 1996). The Porongos/Lavalleja supracrustal belt to the east is correlative with the Cuchilla-Dionísio Terrane (see above). This belt comprises greenschist to amphibolite facies metavolcanic and metasedimentary rocks, and shares the same basement with the Neoproterozoic Dom Feliciano belt (see Fig. 1), while intruded by several generations of granites and alkaline rocks dated between 660 and 540 Ma (Babinski et al., 1997; Basei et al., 2000, 2008; Saalmann et al., 1996). Within the Dom Feliciano belt the Capivarita anorthosite (star #2 in Fig. 1) crops out as roof pendants within the 595 Ma granites (Babinski et al., 1997), and yields a magmatic zircon age of 1573 ± 21 Ma (Chemale et al., 2011). The Lu–Hf model ages for this anorthosite cluster between 1.81–2.03 Ga ($\varepsilon_{Hf(t)} = +2.2$ to $+6.4$) and 2.55–2.62 Ga($\varepsilon_{Hf(t)} = -4.6$ to -5.6), and point to an intraplate precursor setting for the emplacement (see below).

The Nico Pérez Terrane was juxtaposed to the RPC along the Sarandí del Yí megashear zone during late Mesoproterozoic times (Bossi et al., 1993; Gaucher et al., 2009, 2011; Oyhantçabal et al., 2005), as suggested