Precambrian Research 255 (2014) 847–864

Contents lists available at ScienceDirect

Precambrian Research

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

Syn-collisional lower continental crust anatexis in the Neoproterozoic Socorro-Guaxupé Nappe System, southern Brasília Orogen, Brazil: Constraints from zircon U–Pb dating, Sr–Nd–Hf signatures and whole-rock geochemistry

Claudio Alejandro Salazar Mora*, Mario da Costa Campos Neto, Miguel Angelo Stipp Basei

Geosciences Institute, São Paulo University, Rua do Lago, 562, CEP 05508-080. São Paulo, Brazil

ARTICLE INFO

Article history:
Received 15 January 2014
Received in revised form 20 October 2014
Accepted 21 October 2014
Available online 31 October 2014

Keywords:
LA-MC-ICP-MS
TIMS
Zircon
Sr–Nd–Hf isotopes
High-T granulites
Brasília Orogen

ABSTRACT

The southern Brasília Orogen occurs along the southernmost border of the São Francisco Craton. This Orogen is structured as a pile of Ediacaran syn-metamorphic thicked-skinned nappes that diachronically migrate toward the cratonic margin. A magmatic arc environment is represented by the Socorro-Guaxupé Nappe (SGN), which is a thick segment of partially molten lower to middle continental crust. The SGN comprises three main units: a lower granulitic, an intermediate diatexitic and an upper metatexitic. High-temperature metamorphic peak was reached at ~625 Ma, when large volumes of high-K diatexitic rocks were formed. Charnockitic and mangeritic magmatic rocks (São José do Rio Pardo suite) and in situ leucosomes of mafic composition are inferred to have formed under hornblende-dehydration melting conditions (i.e. $T \geq 850\,^{\circ}$C). Granitic diatexites (Pinhal-type) were also formed, and zircon thermometry indicates $T \geq 850\,^{\circ}$C. Elemental and isotopic geochemistry indicate that these diatexites and in situ leucosomes derived from melting of lower to middle continental crust. TIMS zircon U–Pb ages are presented for the lower and middle units. U–Pb dating coupled to Lu–Hf analysis (LA-MC-ICP-MS) was performed on charno-enderbitic in situ leucosomes from metatexitic rocks that also resulted from hornblende-dehydration melting. Two different zircon typologies were recognized. The first comprises bipyramidal-prismatic grains with oscillatory zoning and high luminescence, sometimes preserving low-luminescence 670 Ma cores. The high-luminescence grains show 19 concordant ages at 621 ± 16 Ma. The second typology comprises isometric or soccer-ball-type grains. These grains show sector zoning and a concordia age of 608 ± 4 Ma. Th/U ratios from soccer-ball grains vary from 1.253 to 2.107, whereas prismatic grains vary from 0.118 to 1.774. Initial εHf signatures between −13 and −21 in both typologies provide evidence of a reworked crustal reservoir. The older prismatic grains may be related to the onset of metamorphic peak (~625 Ma), whereas the isometric ones provide evidence of long-lived high-T conditions until ~610 Ma.

1. Introduction

Accretionary orogens are thought to have played an important role in Earth's crustal history since at least the Archean, when horizontal lithospheric plate motion became prevalent. Subduction-related accretionary orogens are reckoned to be sites of continental growth, whereas collisional orogens are envisaged as sites of crustal reworking (Cawood et al., 2009 and references therein). Whilst the latter evolve during short periods of time, subduction-related orogens admit long-lived convergent activity, such as 185 Ma in the Andean Orogen (Ramos and Aleman, 2000; Dalziel, 1997; Rivers and Corrigan, 2000) and 650–700 Ma for the Trans-North China Orogen (Zhao et al., 2007, 2008a,b, 2012), which is in contrast to 80 Ma of Himalayan magmatic arcs migration (Sengör, 1990).

During collision, the thickened crust is heated and evolves according to clock-wise P-T paths (Brown, 1993), where *liquidus* temperatures are reached and partial melting takes place

* Corresponding author. Tel.: +55 11 30913937.
E-mail address: claudio.mora@usp.br (C.A. Salazar Mora).

http://dx.doi.org/10.1016/j.precamres.2014.10.017

(Brown, 2001). Current and ancient orogens comprise exposed migmatitic terranes, where high-temperature and low-pressure conditions permitted partial melting of both lower and upper crust, leading to recycling of pre-collisional accreted continental crust. Some debates have been made concerning the source of the heat necessary to melt the continental crust, particularly for more mafic and lower crust. Crustal thickening was thought to reach maximum temperatures around 750–800 °C (Thompson and Connolly, 1995), but recent studies have shown that radioactive decay in thickened and K–U–Th enriched crust is an important heat source (Vanderhaeghe, 2012). Mantle-derived heat is also advocated in the evolution of granulite-facies metamorphism in collisional orogens. Asthenospheric upwelling may result from gravity-driven delamination of eclogitised roots from thick orogens or slab break-off (Davis and von Blanchenburg, 1993). U–Pb geochronology in zircon grains has proven to be useful for linking P-T paths with time during orogenic collision. It is specially the case of the so-called 'hot orogens' (e.g. Collins, 2002; Beaumont et al., 2006; Schulmann et al., 2008) where zircon may survive from precursor rocks, recrystallize or grow anew (Harley et al., 2007). The combined use of U–Pb and Lu–Hf systematics in zircon leads to important petrogenetic constraints that may be slightly different from Sm–Nd whole-rock geochemistry. According to Nebel et al. (2007), whole-rock neodymium model ages actually represent average ages of crustal residence due to mixing of juvenile and reworked materials in a rock. Hafnium model ages in zircon, on the other hand, can be calculated to accurate U–Pb ages (which are more likely to represent an actual geological event), where initial hafnium compositions are calculated. With the initial hafnium composition, a two-stage model age can be calculated with respect to a depleted mantle evolution curve, which in turn, represents the crustal formation age of the zircon's host. Zircon has low ^{176}Lu/^{177}Hf ratio, thus the present-day ^{176}Hf/^{177}Hf ratio in zircon corresponds closely to the isotopic composition of the surrounding environment (i.e. host rock) at the time of zircon growth (Nebel et al., 2007; Scherer et al., 2007).

In southeast Brazil, the Ediacaran Southern Brasília Orogen occurs along the southernmost border of the São Francisco Craton and records subduction and collisional events that resulted from the convergence of the passive São Francisco Plate and the active Paranapanema Plate during western Gondwana amalgamation. The Orogen's Socorro-Guaxupé Nappe System (SGN) is thought to represent a magmatic arc environment. In this paper we present new geochronological, isotopic and elemental geochemistry constraints from the northern SGN that attest pre-collisional magmatism and granulite-facies syn-collisional anatexis.

2. Geological setting

2.1. The southern Brasília Orogen

The Brasiliano Orogenic Collage (Brito Neves et al., 1999) comprises significant orogenic events that led to the western Gondwana amalgamation during the Neoproterozoic time. The Brasília Orogen (Dardenne, 2000) is part of the collage-derived Tocantins Province and records an Ediacaran collision between the passive São Francisco Plate and the active Paranapanema Plate (Fig. 1). Along the southern São Francisco Craton, a pile of syn-metamorphic nappes constructs the Southern Brasília Orogen, which diachronically migrates laterally over the cratonic margin.

Different tectonic settings and orogenic stages are recorded in the three main thicked-skinned nappe systems of the Southern Brasília Orogen (Campos Neto and Caby, 2000; Trouw et al., 2000; Campos Neto, 2000; Campos Neto et al., 2004, 2011). Comprising the base of the collisional pile in the east of the orogen (Fig. 2), the Carrancas and the Lima Duarte Nappes are the youngest allochtons with passive margin affinities. They are overthrusted by the Andrelândia Nappe System, which seems to represents a Cryogenian accrecionary prism. All of these nappe systems are in turn overthrusted by the older Socorro-Guaxupé Nappe System that exhibits affinities of a magmatic arc environment.

The three main nappe systems are interpreted to have evolved as a single orogenic event where the orogenic front, partially controlled by channel flow, migrated toward the cratonic domain (Campos Neto et al., 2011). The migration dynamics is observed by the different ages of metamorphic peak between the nappe systems that comprise the collisional pile. The lower Carrancas Nappe System reached peak metamorphism around 590–570 Ma, the middle Andrelândia Nappe System around 610–605 Ma and the upper Socorro-Guaxupé Nappe System about 625 Ma.

2.2. The Socorro-Guaxupé Nappe System

The Socorro-Guaxupé Nappe is divided into three units that represent a deep partially molten continental crust section (~10 km thick). The allochton is segmented into a northern and southern domain, which respectively, are the Guaxupé and Socorro Domains (Fig. 2), between which high-angle lateral ramps are developed (Campos Neto and Caby, 2000). A recumbent metamorphic foliation, gently SW-dipping, is the main nappe structure, to which stretching and mineral lineations are associated. The orientation of these lineations shifts from WNW to ENE, suggesting a thrust kinematics parallel to the southern border of the São Francisco Craton (Campos Neto et al., 2011).

The first lithological unit is the Granulitic Unit, which occurs at the base of the nappe. It basically comprises banded granulites that developed mineral assemblages of Grt-Cpx-Opx-Pl-Qtz in mafic rocks and re-equilibrated mineral assemblages of Grt-Sil-Crd-Spl-Bt-Pl-Qtz in metapelitic rocks. In situ charnockitic leucosomes form stromatic structures and are interpreted as products of anhydrous melting. Above the banded granulites, a Diatexitic Unit is developed, where pinkish (Hbl)-Bt granitic rocks are predominant (Pinhal-type diatexites). These rocks are mainly hipidiomorphic and coarse-grained, with compositions varying between granodiorites, monzogranites, sienogranites and syenites. Nebulitic and *schliere* diatexitic structures are often preserved as well as gneissic enclaves (probably representing the paleosome). Kinzigitic (Sil-Crd-Grt) metasedimentary enclaves also occur among these diatexites. Finally, the upper unit is a Metatexitic Unit. It comprises migmatitic Bt-Hbl gneisses with well-preserved pre-anatexis structures. Dark gray Hbl-Opx gneisses and amphibolite *boudins* are very frequent. This last unit also comprises metasedimentary rocks, such as quartz-rich gneisses, quartzites, muscovite-rich quartzites and calc-silicate rocks.

Besides the main lithological units, important calc-alkaline syn-orogenic magmatic suites also occur (Fig. 2). The granitic Socorro and Pinhal-Ipuiúna Batoliths and the mangeritic São José do Rio Pardo suite varies between 625 and 629 Ma (e.g. Töpfner, 1996; Ebert et al., 1996; Basei et al., 1995). There are also granitic suites interpreted as products of continental crust anatexis, such as the Pinhal-type Bt granites, which were formed around 625 ± 3 Ma (Janasi, 1999), the Nazaré Paulista Grt-Bt granites, dated at 624 ± 2 Ma (Janasi, 1999) and the recorded periodic stages of anatexis to at least ~610 Ma (Martins et al., 2009).

Late and post-orogenic magmatic activity is recorded in the 580–590 Ma Itú Province (Janasi et al., 2009) in the southern SGN and in the 610 Ma Capituva and Pedra Branca syenitic massifs in the northern SGN (Carvalho and Janasi, 2012).