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Thermochronology of central Ribeira Fold Belt, SE Brazil: Petrological and geochronological evidence for long-term high temperature maintenance during Western Gondwana amalgamation

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ABSTRACT

The studied sector of the central Ribeira Fold Belt (SE Brazil) comprises metatexites, diatexites, charnockites and blastomylonites. This study integrates petrological and thermochronological data in order to constrain the thermotectonic and geodynamic evolution of this Neoproterozoic–Ordovician mobile belt during Western Gondwana amalgamation.

New data indicate that after an earlier collision stage at ∼610 Ma (zircon, U–Pb age), peak metamorphism and lower crust partial melting, coeval with the main regional high grade D_1 thrust deformation, occurred at 572–562 Ma (zircon, U–Pb ages). The overall average cooling rate was low (<5 °C/Ma) from 750 to 250 °C (at ∼455 Ma; biotite–WR Rb–Sr age), but disparate cooling paths indicate differential uplift between distinct lithotypes: (a) metatexites and blastomylonites show a overall stable 3–5 °C/Ma cooling rate; (b) charnockites and associated rocks remained at $T > 650$ °C during sub-horizontal D_2 shearing until ∼510–470 Ma (garnet–WR Sm–Nd ages) (1–2 °C/Ma), being then rapidly exhumed/cooled (8–30 °C/Ma) during post-orogenic D_3 deformation with late granite emplacement at ∼490 Ma (zircon, U–Pb age). Cooling rates based on garnet–biotite Fe–Mg diffusion are broadly consistent with the geochronological cooling rates: (a) metatexites were cooled faster at high temperatures (6 °C/Ma) and slowly at low temperatures (0.1 °C/Ma), decreasing cooling rates with time; (b) charnockites show low cooling rates (2 °C/Ma) near metamorphic peak conditions and high cooling rates (120 °C/Ma) at lower temperatures, increasing cooling rates during retrogression.

The charnockite thermal evolution and the extensive production of granitoid melts in the area imply that high geothermal gradients were sustained for a long period of time (50–90 Ma). This thermal anomaly most likely reflects upwelling of asthenospheric mantle and magma underplating coupled with long-term generation of high HPE (heat producing elements) granitoids. These factors must have sustained elevated crustal geotherms for ∼100 Ma, promoting widespread charnockite generation at middle to lower crustal levels.

1. Introduction

Experimental petrology and thermal modelling data have shown that different isotopic systems have different isotopic closure temperatures (e.g. Dodson, 1973; Mezger et al., 1992). Therefore, for the same rock, different isotopic systems will provide distinct geochronological results that can be used to obtain a *T*–*t* evolution (thermochronology) and, ultimately, the cooling rates of that rock.

Several authors have tried to determine thermochronological evolutions and cooling rates, mainly based on low temperature fission track (e.g. Lim and Lee, 2005; Lee et al., 2006) and Ar–Ar thermochronology (e.g. Glassmacher et al., 1999; Gray et al., 2006). However, the thermochronological data, cooling rates and the thermal evolution record of granulite belts from high temperatures (∼800 °C) to low temperatures (∼250 °C) is still very incomplete, worldwide. This has severely hampered the ability to constrain the processes involved in exhuming granulites from the middle/lower crust and the geodynamic evolution of the studied granulite belts themselves.

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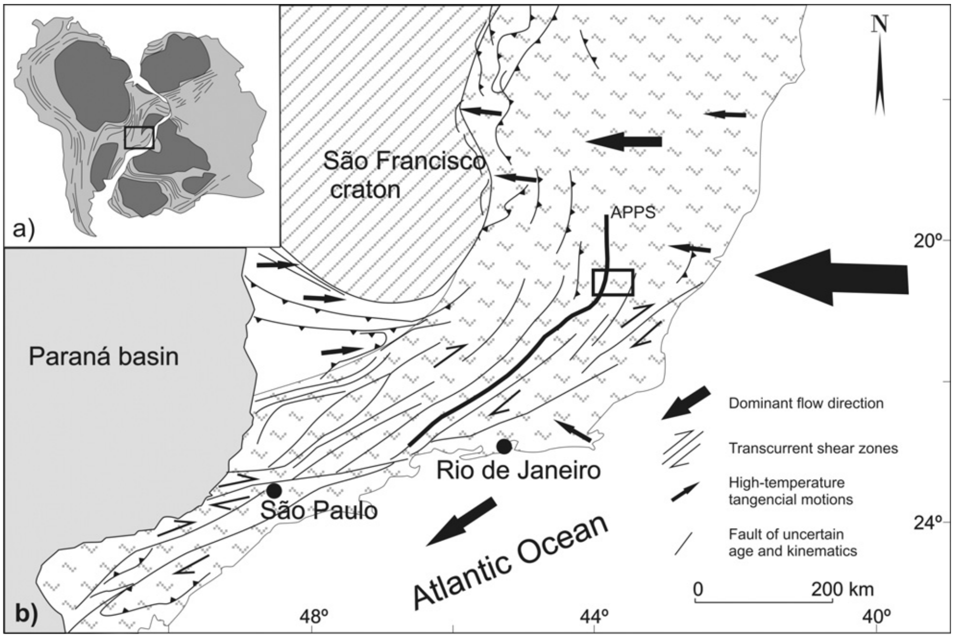

Fig. 1. (a) Central Ribeira Fold Belt (square) in the Western Gondwana amalgamation context (modified from Trouw et al., 2000); (b) Central Ribeira Fold Belt and the Além Paraíba–Pádua Shear (APPS) system main regional structures (Modified from Vauchez et al., 1994). APPS main shear zone is marked in bold. Box locates the studied area.

Zircon, due to its very low isotopic diffusivity, closes the U–Pb isotopic system at very high temperatures, close to the metamorphic peak (Heaman and Parrish, 1991; Cherniak et al., 1997; Tirone et al., 2005), whereas the Sm–Nd isotopic system in garnet only closes at $T < 650 \pm 30\,^{\circ}\mathrm{C}$ (Mezger et al., 1992; Tirone et al., 2005) and Rb–Sr in biotite at $T \sim 350\,^{\circ}\mathrm{C}$ (Harrison and MacDougall, 1980). Integration of these and other different geochronological results for the same sample or group of samples can be used for obtaining the retrograde evolution from high temperature (U–Pb in zircon and Sm–Nd in garnet) to medium–low temperature (for instance Rb–Sr in biotite) (Spear and Parrish, 1996). Such a comprehensive approach in a granulite belt may help constrain the thermal evolution (*T*–*t*), the metamorphic processes involved and the cooling/exhumation rates of the studied granulites.

Different geodynamic models proposed for the Ribeira Fold Belt (RFB), SE Brazil (e.g. Cordani et al., 1973; Campos Neto and Figueiredo, 1995; Machado et al., 1996; Pedrosa-Soares et al., 2001; Heilbron and Machado, 2003; Schmitt et al., 2008; see below), have made it one of the best studied orogenic belts of the Western Gondwana Supercontinent. However, because of contradicting data and interpretations, some basic questions still remain unexplained about the tectonometamorphic evolution of this Neoproterozoic–Early Paleozoic belt. For instance, was the RFB formed by successive orogenic events (as proposed by Campos Neto and Figueiredo, 1995; Heilbron and Machado, 2003) during the Brasiliano cycle or is the RFB the result of a single Brasiliano orogenic event? What were the duration and rates of the Brasiliano Orogeny geodynamic and metamorphic processes?

This work presents new petrological and geochronological data (SHRIMP U–Pb, Sm–Nd, Rb–Sr and K–Ar geochronological results) on granulites (s.l.) from the São Fidelis–Santo Antônio de Pádua sector (central-north RFB) with the purpose of contributing to a better understanding of the thermochronological (*T*–*t*) and geodynamic evolution of the RFB. It will allow depicting the thermochronology of burial, heating, cooling and uplift and, in this way, to constrain the duration and rates of the Brasiliano Orogeny geodynamic and metamorphic processes.

2. Geological setting

The studied area, the São Fidelis–Santo Antônio de Pádua (SFSAP) sector, is located in the central-north RFB (Cordani, 1971), northern Rio de Janeiro State, SE Brazil (Figs. 1 and 2). The RFB extends along the SE Brazilian coast, over 1500 km from southern Bahia State to Uruguay, through Espírito Santo, Rio de Janeiro, Minas Gerais, São Paulo and Paraná States (Cordani et al., 1973). This elongated belt is a NE–SW trending (south and central sectors) and NNE–SSW trending (northern sector) Neoproterozoic mobile belt (Cordani, 1971) formed during the Brasiliano (Pan-African) Orogeny by the collision between the São Francisco and West Congo cratons, and amalgamation of Western Gondwana at around 670–480 Ma ago (Trouw et al., 2000; Schmitt et al., 2008) (Fig. 1a).

The central RFB is a very complex orogenic zone composed of several geological units, commonly separated by deep dextral shear zones. The studied SFSAP sector is located immediately SE of one of these megashears, the Além Paraíba–Santo Antônio de Pádua Shear (APPS) (Fig. 1b and Fig. 2). This megashear vigorously deformed the rocks imposing a NE trending transpressive shear deformation associated with long-term HT/LP metamorphism (Bento dos Santos et al., 2007; Fonseca et al., 2008).

According to Trouw et al. (2000), the RFB can be divided in four major lithologic associations: (a) reworked Archean to Paleoproterozoic basement rocks composed of metavolcanic-sedimentary sequences, granodioritic orthogneisses and intermediate granulites; (b) a deformed meta-sedimentary sequence composed of pelitic schists and high grade migmatitic paragneisses with quartzite, calc-silicate and amphibolite intercalations; (c) molassic sedimentary basins; and (d) widespread granitoid intrusive bodies representing different tectonic settings, from pre- to post-collisional stages of the Brasiliano orogenic system (Campos Neto and Figueiredo, 1995; Trouw et al., 2000; Pedrosa-Soares and Wiedemann-Leonardos, 2000).

A common feature of the central RFB is the widespread occurrence of Neoproterozoic charnockites (Tassinari et al., 2006). These occur as massive metamorphic charnockites and variable sized patches and veins of incipient metamorphic charnockites related to