Evidências Petrológicas e Termocronológicas para manutenção de elevado fluxo geotérmico na Faixa Ribeira, SE do Brasil

Petrological and Thermochronological evidences for long-term elevated geothermal gradient in the Ribeira Fold Belt, SE Brazil

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SUMÁRIO

A obtenção de uma série de novos dados geocronológicos U-Pb, Sm-Nd, Rb-Sr e K-Ar e sua integração com as respectivas temperaturas de fecho isotópico permitiu constatar a presença de taxas de exumação tão baixas quanto 3 ºC / Ma para a zona central da Faixa Ribeira. A manutenção das temperaturas regionais superiores a 650 ºC durante 60 a 100 Ma poderá ser uma nova explicação para a origem dos charnockitos da Faixa Ribeira.

Palavras-chave: Faixa Ribeira; geocronologia; termocronologia; taxa de arrefecimento; charnockito

SUMMARY

A series of new U-Pb, Sm-Nd, Rb-Sr and K-Ar geochronological results and integration at their respective isotopic closure temperature allowed to constrain cooling rates as low as 3 ºC / Ma for the central area of the Ribeira Fold Belt. Maintenance of regional temperatures over 650 ºC for 60 to 100 Ma is a new possible explanation for the origin of the Ribeira Belt charnockites.

Key-words: Ribeira Belt; geochronology; thermochronology; cooling rate; charnockite

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Introduction

Distinct geodynamic evolution models for Ribeira Fold Belt in SE Brazil have long been proposed by several authors (Cordani, 1971; Campos Neto & Figueiredo, 1995; Pedrosa Soares & Wiedmann-Leonardos, 2000), making it one of the best studied orogenic belts of Western Gondwana. However, some of the tectonometamorphic P-T conditions, as well as the sequence of burial, heating, cooling and uplift stages of this Neoproterozoic orogeny are yet unknown.

Geologic Setting and Field Observations

The studied São Fidelis – Santo António de Pádua (SFSAP) sector is located in the central-north Ribeira Belt (Cordani, 1971), SE Brazil (Fig. 1). The Ribeira Belt is a NE-SW to NNE-SSW trending Neoproterozoic mobile belt formed in the Braziliano Orogeny, as outcome of the collision between the São Francisco and West Congo cratons, from which resulted Western Gondwana at around 575 Ma ago (Heilbron & Machado, 2003). Various tectonic models for the geodynamic evolution of the Ribeira Belt, supported by U-Pb dating and structural analysis (Campos Neto & Figueiredo, 1995; Schmitt et al., 2004; Heilbron & Machado 2003), consider that Ribeira Belt included several terranes during Neoproterozoic to Eopaleozoic times. This led to the concept of a poly-orogenic Braziliano cycle, in which the older orogeny of the Ribeira Belt corresponds to the 630 – 610 Ma Rio Negro Orogeny (Tupinambá, 1999), followed by the 580 – 540 Ma Araçuaí Orogeny (Pedrosa Soares & Wiedmann-Leonardos, 2000) and the late ~

520 Ma Búzios Orogeny (Schmitt et al., 2004) in the Cabo Frio terrane.

Ribeira Fold Belt is a complex orogenic belt composed of several geological units, separated by deep dextral shears. The SFSAP sector is located immediately SE to one of this mega-shears, the Além Paraíba – Santo António de Pádua shear (APPS) that vigorously deformed the area rocks imposing a NE-SW trending transpressive shear deformation associated with high-grade metamorphism. From a structural point of view, the studied area underwent polyphase deformation: three main tectonometamorphic phases that globally correspond to three main geochronologic periods (see Fig. 2). The earliest deformation (D_1) corresponds to high-grade thrusts (250º, 55-70º NW) with a stretching lineation of 55-65º, 5-20º, that were mostly erased by the main D2 event. This corresponds to a dextral mega-shear zone (APPS: 50-65º, 70-85ºNW) with a sub horizontal stretching lineation (5-15º, 172-178º); finally, a event (D_3) is coeval with the reactivation of D_2 conjugate fault systems (290-320º, sub vertical) and with the intrusion of late granites. Granulite facies metamorphism was associated with D_1 (collisional phase) and produced generalized migmatization and partial melting. Different lithotypes outcroping in the studied area comprise migmatitic paragneisses (metatexites; sometimes, interlayered with marbles) diatexitic migmatites, massive charnockites (associated with orthogneisses and syn-metamorphic garnet-aplite intrusions), and blastomilonites that resulted from intense deformation (D_2) and retrogression in areas closer to the APPS. Xenoliths of flaser gabbros and pyroxenitic cumulates are locally observed representing dismembered fragments of early mantle derived from magma chambers.

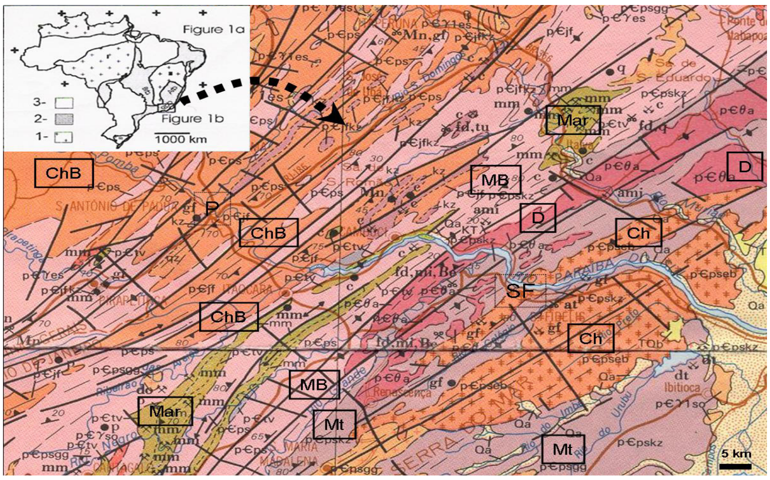

Fig. 1: Location of the SFSAP sector in Ribeira Belt, Brazil. Ch: Charnockites; Mt: Metatexites; D: Diatexites; Mar: Marbles; ChB: Charnockitic Blastomilonites; MB: Migmatitic Blastomilonites; SF: São Fidelis; P: Santo António de Pádua.

Geochronology and Thermochronology

SHRIMP U-Pb zircon age data range from 610 ± 13.0 Ma for an amphibolite to 555 ± 7.8 Ma for a diatexite. Charnockite and associated orthogneiss samples range from 560 ± 15.0 Ma to 575 ± 12.0 Ma, yielding identical ages (within error). Thus, peak regional metamorphic conditions (coeval with D_1) occurred at 572 ± 13 Ma, being simultaneous with the emplacement of garnet-aplites (561 ± 17 Ma) into charnockites. A D_3 granite was also dated yielding a SHRIMP U-Pb zircon age of 491 ± 7.1 Ma, which confirms its younger emplacement age.

Post-metamorphic peak cooling ages were also obtained. Garnet-whole rock Sm-Nd dating yielded the following ages: charnockites (541 ± 11 Ma to 472 Ma ± 17 Ma; retrogressed-biotite rich charnockite (biotitite) (491 ± 27 Ma), associated orthogneiss (502 ± 11 Ma), garnet-aplite (513.4 ± 4.5 Ma), metatexites (533.2 ± 7.7 Ma to 522.2 ± 3.8 Ma), diatexite (518.1 ± 7.8 Ma) and a blastomilonite (553 ± 4.0 Ma). Plagioclase-whole rock Rb-Sr dating results for charnockites, metatexites, diatexite and blastomilonite range from 526.2 ± 9.7 Ma to 474.3 ± 5.2 Ma, whereas most biotite-whole rock Rb-Sr ages range from 473 ± 4.0 Ma to 454.5 ± 4.4. Biotite K-Ar data were also obtained, but the results indicate that the ages are affected by excess ^{40}Ar, producing scattered results from 576 ± 10 Ma to 462 ± 9 Ma.

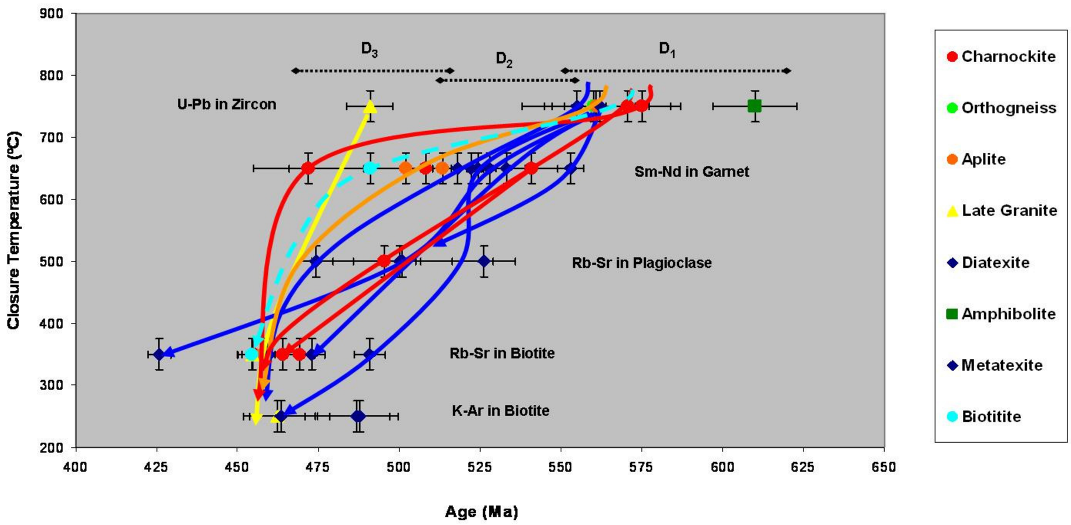

Fig.2: Geochronological cooling rates by integrating different closure temperatures (inferred deformation phases are displayed).

Geochronological Cooling Rates

Integration of the geochronological results and using characteristic closure temperatures for the different isotopic systems (Fig. 2) results in an overall 3 ºC / Ma cooling rate. This very low general cooling rate means that rocks sustained long-term high-temperature conditions and low initial exhumation rates. However, observation of Fig. 2 indicates that the studied rocks underwent distinct (complex) thermochronological paths: metatexites and two charnockite samples were cooled to ~ 650 ºC during 10 to 40 Ma after metamorphic peak, whereas most charnockites, orthogneisses and diatexites remained for at least 60 to 100 Ma above 650 ºC (until 510-480 Ma ago). Afterwards, T dropped abruptly (ΔT = 400 ºC) in a short period of time (15 to 60 Ma), implying increased cooling rates (~ 30 ºC / Ma), probably related to tectonically (D_3) induced exhumation. This period of fast cooling is coeval with late granite emplacement at 490 Ma.

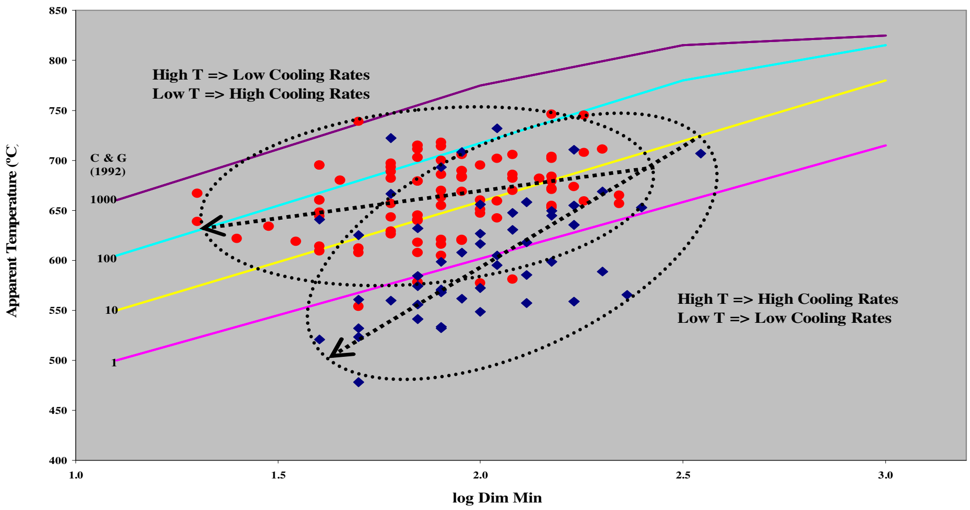

Fig. 3: Petrological Cooling Rates using Fe-Mg diffusion between garnet and inclusions of biotite. Symbols are as in Figure 2.

Petrological Cooling Rates

Theoretical and methodological problems to the use of mineral diffusion mechanisms in order to determine cooling rates can be found in the literature (Dodson, 1973; Spear & Parrish, 1996; Munhá et al., 2005). We employ the method proposed by Spear & Parrish (1996) that uses Fe-Mg exchange modeling between garnet and its biotite inclusions to infer cooling rates. Results for charnockites and migmatites are presented in Fig. 3. In this graph, migmatites show high cooling rates at high T and low cooling rates at low T, displaying a decrease in cooling rates with time, while charnockites show low cooling rates at high T (near peak conditions) and high cooling rates at low T. This means that the latter experienced high thermal stability after metamorphic peak,

followed by fast cooling exhumation, making these results generally compatible with the geochronological ones. However, these results show high dispersion and anomalous cooling rates (especially when compared with the geochronological results), ranging roughly from 400 ºC / Ma to 0.01 ºC / Ma for migmatites and from 1000 ºC / Ma to 0.6 ºC / Ma, for charnockites. This is probably due to the fact that the SFSAP sector rocks experienced high-deformation shearing that may have altered biotite diffusion mechanisms.

Discussion

The obtained thermochronological results are compatible with those reported for the S and N sectors of Ribeira Belt (Dias Neto, 2001; Munhá et al., 2005; Tassinari et al., 2006). Available structural, petrological and thermochronological data suggest that D_1 may be related to the early exhumation of metatexites, ≥10 Ma after peak metamorphism (572 ± 13 Ma), whereas most charnockites, orthgneisses and some diatexites remained for ≥60 Ma at lower crustal conditions. At ~ 520 - 490 Ma rocks were rapidly exhumed, probably related to D_3 tensional fault tectonics (D_3), coeval with the initial development of Paraná-type basins and sedimentary infilling.

The general tectonothermal evolution implies long-term elevated geotherms, followed by orogen collapse caused by thermal erosion and progressive thinning of the lithosphere. These features may have been partially driven by heating from the mantle (asthenospheric upwelling and magma underplating), as well as thermal insulation, sustaining the long-term thermal anomaly. These conditions promoted lower crustal melting and widespread charnockite development at different stages of the Ribeira Belt evolution. Crystallization of newly-formed zircon at different times could become possible in different areas, reflecting this lasting thermal anomaly. Thus, Ribeira Belt tectonics may be congruently envisaged from the perspective of a single long-term orogeny, removing unnecessary complexities inherent to previously proposed poly-orogenic scenarios.

Acknowledgements

Field and analytical procedures were financed by Fundação de Amparo a Pesquisa do Estado de São Paulo – FAPESP, POCA-PETROLOG (CEGUL, UI: 263; POCTI/FEDER), GEODYN (POCTI – ISFL – 5 – 32) and a scholarship from FCT (SFRH/BD/17014/2004).

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