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POLYGENETIC MONAZITE FROM THE SÃO JOSÉ DO CAMPESTRE MASSIF, BORBOREMA PROVINCE, NE BRAZIL: INSIGHTS FROM EPMA CHEMICAL AND DATING STUDIES.

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INTRODUCTION

Unravelling and dating the main episodes of the evolution path of polygenetic rocks is a major challenge in geochronology. In some circumstances, the use of geochronometers with well-defined properties provides a good help, but the ultimate solutions come from microbeam methods. Only such high resolution techniques are able to unravel contrasted chemical and isotopic intra-grain domains related to inheritance or generated by late partial substitutions, overgrowths, and in-fillings within minerals suitable for dating. In such cases, conventional methods based on “whole” grain fractions or single crystals should yield mixed results, the weighted averages of the sampled domains, often without any geological meaning.

Chemical studies and dating with the microprobe can give useful insights concerning the behavior of the monazite geochronometer in polygenetic rock, depicting the main micro-structures and chemical characteristics of contrasted inter- and intra-grain domains formed in different geological periods. This allows a better comprehensive view of the operating geological phenomena and must be taking into account in any detailed geochronological study in such terranes.

A systematic electron microprobe (EPMA) study and dating of monazite from an Archean gneiss from NE Brazil showing U-Pb isotopic discordance was made in order to understand the reasons for such a pattern.

GEOLOGICAL SETTING AND SAMPLE DESCRIPTION

The studied sample (CE-118) came from the São José do Campestre Massif, an older Archean nuclei within the Borborema Province, Northeastern Brazil (Fig. 1). The typical rock cropping out is a fine-

grained trondhjemitic biotite-gneiss presenting a NW trending banding with a low angle fabric, cut by discreet medium-grained garnet-bearing leucosome veins with a granitic composition. Primary monazite occurs in both the host gneiss and the veins as euhedral to round and somewhat corroded grains up to 0.4 mm. In the veins, it appears as isolated grains and inclusions within garnet; contact relationships indicate that it grew mainly in equilibrium with garnet and biotite.

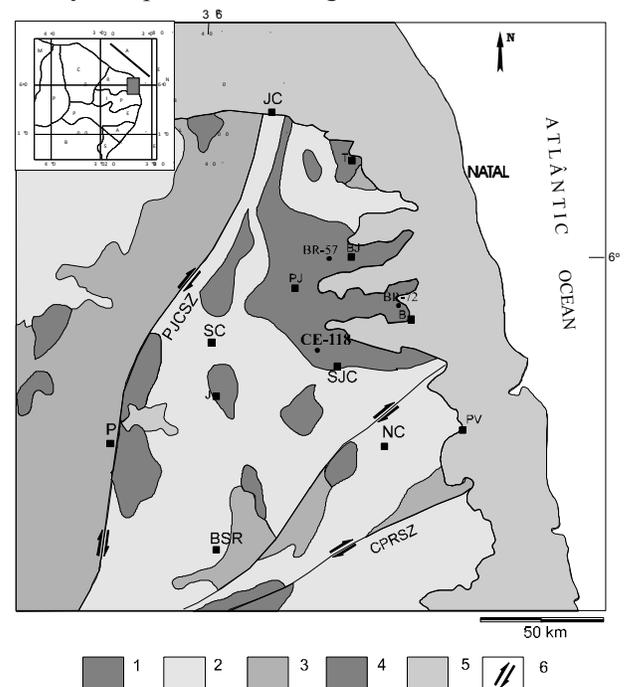


Figure 1. Simplified geological map of the São José do Campestre Massif, Borborema Province, NE Brazil. Archean block (1), Paleoproterozoic (2) and Neoproterozoic (3) units. Neoproterozoic granite massifs (4) and Phanerozoic cover (5). Main ductile-brittle shear zones (6): PJCSZ: Pícuí-João Camara, CPRSZ: Caerengo-Poçinho-Remígio. CE-118: location of the studied sample.

Conventional U-Pb isotopic data in zircon and monazite is already available for the studied sample (Dantas *et al.*, 1999). The first episode, the crystallization of the trondhjemitic host, appears to be well-constrained by U-Pb data in zircon, which gave *ca.* 3.25 Ga. Monazite grains picked from the veins yield a discordia line with lower and upper intercepts at *ca.* 0.60 and 3.03 Ga, respectively and high MSWD values. Two grains gave concordant or slightly reverse discordant ages (*ca.* 0.57 Ga), one grain is concordant at *ca.* 0.67 Ga and another is highly discordant (Fig. 2). According to authors, the older age is related to the main metamorphic episode and melt-forming vein crystallization; the younger reflects an important Neoproterozoic thermal peak in that region.

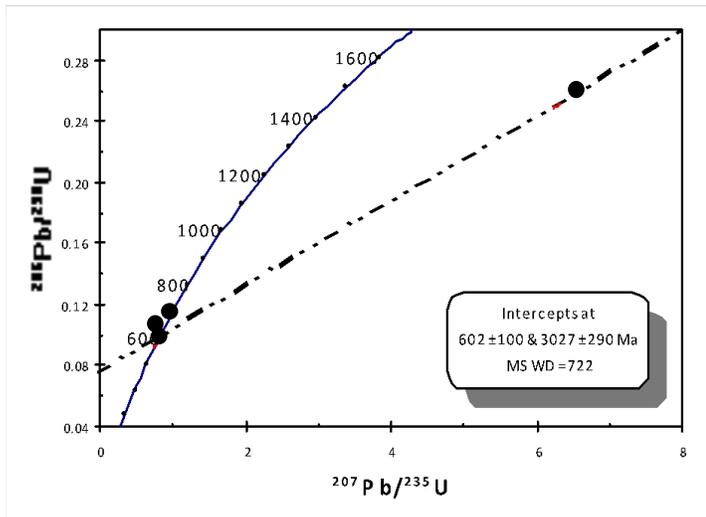


Figure 2. Concordia diagram for monazite from sample CE-118. Represented analytical points are enlarged well beyond real errors for clarity.

MICROPROBE ANALYTICAL AND DATING PROCEDURES

EPMA work was done at the microprobe laboratory in the Geoscience Institute of the University of São Paulo with a JEOL-8600 superprobe. Operating conditions were 15 kV, 300 nA, and 2-4 μm for the electronic beam accelerating voltage, current, and diameter, respectively.

Vlach and Gualda (2000) describe procedures and instrumental settings for monazite quantitative analysis, well as Th, U, and Pb detection limits and

data treatment. Qualitative WD x-ray dot maps were obtained simultaneously for Th ($M\alpha$), U ($M\beta$), Y ($L\alpha$), and Pb ($M\beta$) under 20 kV, 150 nA, and a minimum beam diameter. Five frames were integrated into an image, each of them acquired with a resolution of 256x256 and a dwell time of 1s. We did not make any effort in correct the influence of the K $K\alpha$ line over U $M\beta$ intensities, thus some brightest areas in the U map, outside monazite, correspond to alkali-feldspars or biotite (*cf.* Fig. 3).

Isochron Th*-Pb (*cf.* Vlach and Gualda, 2000) calculations were made with the IsoPlot software (Ludwig, 1998), with best fits drawn to origin. Results are presented with a 95 % confidence level.

RESULTS

Three isolated monazite grains and three inclusions in garnet were studied. Over 45 complete analyses were obtained along grain traverses and areas with high contrast in electron backscattered images (BEI). X-ray distribution dot maps were obtained for two isolated grains. The chosen grains, with a special reference to the isolated ones, have always some kind of normal, complex and/or sectorial zoning, as revealed in BEI and X-ray images. Compositional variations are mainly due to the coupled substitution $[(\text{Th,U})\text{Ca}](\text{REE+Y})_2$.

Qualitative elemental x-ray maps for one grain are reproduced in Fig. 3. Two main well-marked features are enhanced in them. The first one is a normal zoning evidenced by both Th and Pb, whose concentrations are highly correlated, representing a primary pattern. The second and more remarkable is depicted by irregular in-fillings with lower Th and higher U and Y contents. These in-fillings also present contrasted REE patterns, being poorer in some LREEs and richer in HREEs (Fig. 4).

Seven analytical spots over the main crystal (see Fig. 4) gave chemical ages in the range between 2.91-3.03, with an average of 3.0 Ga. Similar values were obtained for all spots located in monazite inclusions in garnet and over one of the two other isolated crystals. Most results align very well in the Th*-Pb chemical cationic diagram; the fitted isochron line gives *ca.* 2.99 ± 0.05 Ga (Fig. 4), in close agreement with upper concordia intercept showed in Fig. 2. This value should correspond to the main metamorphic episode and crystallization of granite veins as mentioned above.

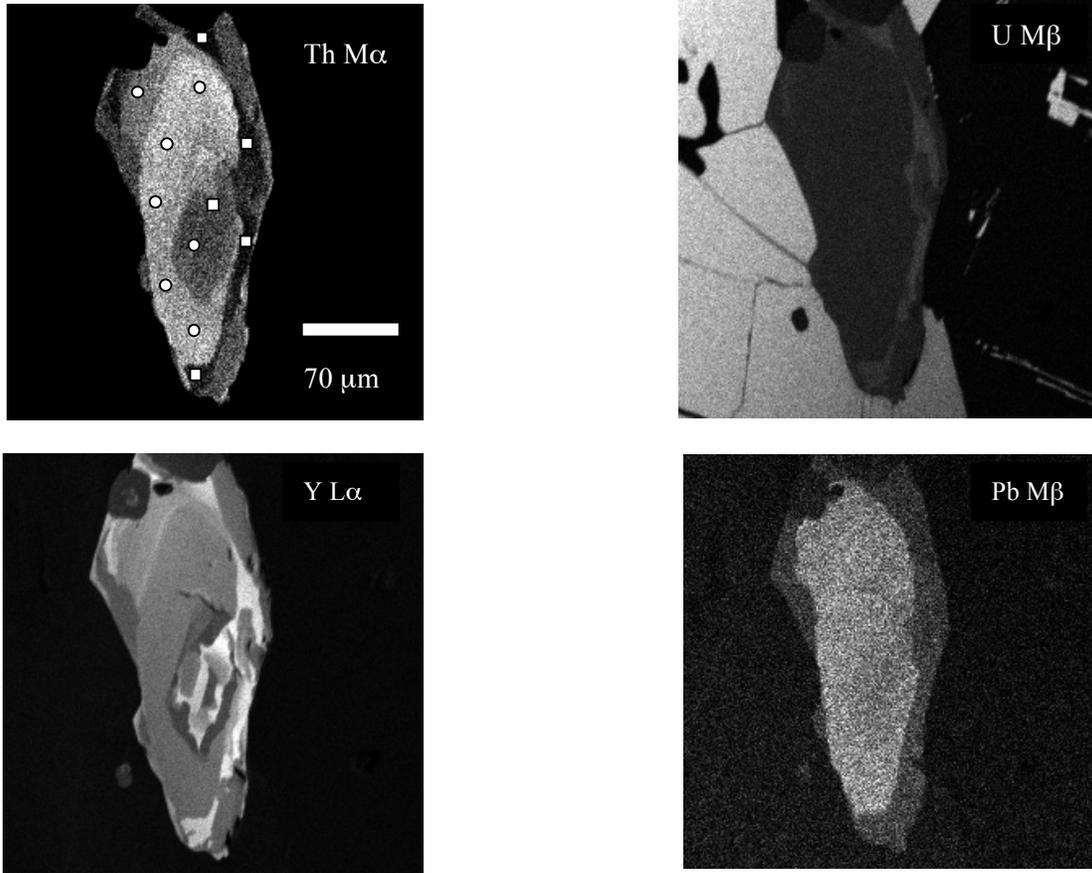


Figure 3. Th, U, Y, and Pb X-ray dot maps (WD) for monazite (sample CE-118, grain 2). Brightest areas correspond to the highest elemental intensities. Late monazite in-fillings are depicted by lower Th, and higher Y and U contents. WDS analytical spots drawn in white: circles: 2.91-3.03 Ga; squares: 0.56-0.60 Ga.

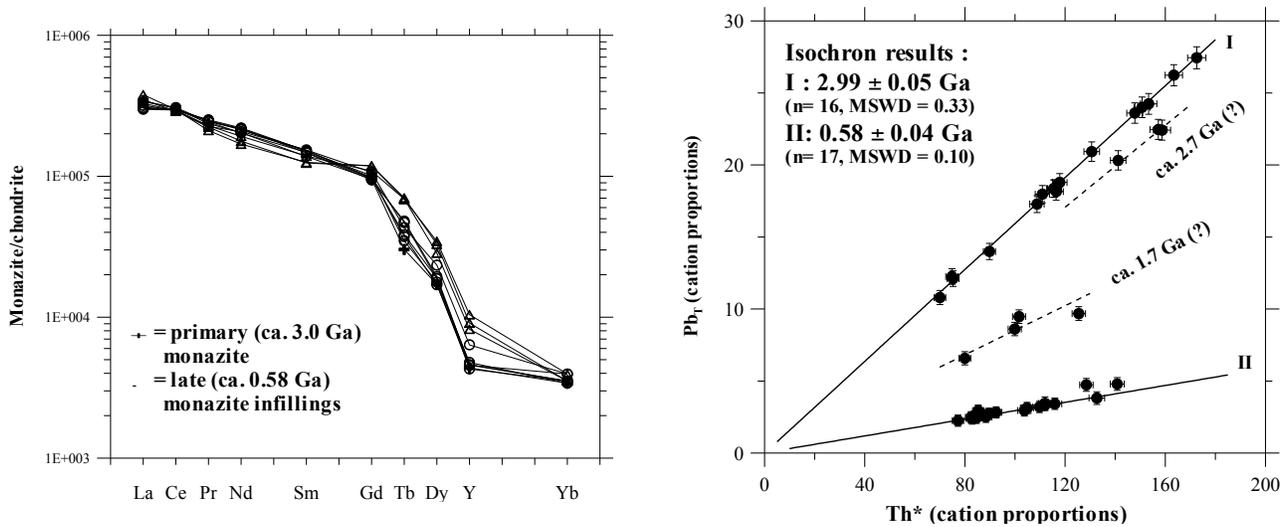


Figure 4. Left: elemental RRE patterns for monazite grain 2 (Fig. 3) from sample CE-118, showing the LRRE (Pr-Sm)-poor and (HREE+Y)-rich character of the late in-fillings. Right: chemical (cationic) isochron diagram. Computations (I and II) were made after model I of Ludwig (1998), with the best fits drawn to origin

On the other hand, ages of five spots located in the in-fillings (see Fig. 3) are much younger, between 0.56 and 0.60, averaging 0.58 Ga. The same values were obtained for similar in-fillings within the second isolated grain and in all points of the third small isolated crystal analyzed. Isochron computations for all data furnish an age of 0.58 Ga (Fig. 4). This matches with the concordant to slight reversely discordant isotopic results obtained for three monazite grains, as shown in Fig. 2. This age is related to the main Brasiliano imprint in the area.

Rock texture, elemental x-ray distributions and REE patterns clearly demonstrate that the late monazite partially substituted the primary one and also formed minor isolated grain within the veins. This monazite undoubtedly grew under the influence of percolating fluids and contains contrasted concentrations of some REEs (Pr-Sm), HREEs, Y, and U contents.

Some analytical spots in two of the isolated monazite grains gave intermediate ages (see Fig. 4) about *ca.* 2.7 Ga and 1.7 Ga, respectively. Events with similar ages were recognized in the Borborema province already (*e.g.*, Van Schmus *et al.*, 1995) but their meaning is not well understood yet. We suspect that they represent discrete periods of partial monazite resetting, but even considering the high spatial resolution of our analysis, they should reflect mixing of the main Archean and Brasiliano domains and complementary data are needed to verify if they have a concrete geological meaning.

FINAL REMARKS

Our study on polygenetic monazite from an Archean rock reveals at least two main periods of monazite development and explain the monazite discordant behavior depicted by conventional isotopic data. In the studied case discordance is due to mixing between two generations during distinct geologic episodes, with contrasted textural and chemical features.

The main episode of monazite growth occurs during regional medium- to high-grade metamorphism and related granite melt generation in Archean times (*ca.* 3.0 Ga.) Later on, a thermal

imprinting and related metamorphism and magmatism during the Brasiliano orogeny (*ca.* 0.58 Ga) allowed fluid circulation and partial dissolution of the older monazite and precipitation of a new generation in in-fillings and also as discrete small crystals. Such fluids had relatively high LREE (Pr-Sm) and low HREE, Y, and U solubilities.

Some discrete results suggest resetting of the monazite clock about *ca.* 2.7 and 1.7 Ga. In spite of the coincidence of these values with important geological events in NE Brazil, they should be taken with some caution, until more geochronological data become available.

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