

## Nd-Sr ISOTOPIC COMPOSITION OF MICROGRANULAR ENCLAVES OF THE BREJINHO BATHOLITH, ALTO PAJEÚ TERRANE, BORBOREMA PROVINCE, NE BRAZIL

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### INTRODUCTION

The microgranular enclaves of intermediate to mafic composition are common in granitoid rocks, especially in calc-alkaline suites, being considered, in general, as products of incomplete mixing between coeval magmas of acid and mafic composition from different origins. They can also be interpreted as: a - refractory residue of mafic rocks remnants of an igneous protolith which was partially melted to yield the host granitoid magma (restite model), or b -together with the granitoids, originated by differentiation of a parental mafic magma constituting the “autoliths”. In this case, these last two interpretations are less likely, in agreement with isotopic, petrographic, chemical and field constraints, so that the enclaves and the granitoids hosts are considered as representatives of two coexisting magmas, but with different composition and origin (Torres, 2001).

Among other investigation lines, the isotopic composition of mafic enclaves and granitoid hosts constitute one of the main tools for the interpretation of the genesis and evolution of granitoids plutons. It allows assessing the genetic relationships between the granitoids and the enclosed enclaves, making possible the understanding of the relative role of crustal and mantelic sources in the magmatism, and also the type(s) of source(s) involved.

Nevertheless, the study of the isotopic composition of these rocks not always lead to conclusive interpretations. So, frequently, the enclaves do not retain their primary isotopic signatures; being these, at least partially, acquired from the interaction with crustal melts in the lodging place, still in the lower crust, contamination with crustal rocks or mixing in the site of the emplacement, not representing original liquids.

Enclaves and the hosts granitoids originated from different magmas may show similar isotopic signature, if the mafic magma has been extracted from the enriched mantle or an almost complete isotopic equilibrium has been reached. In the case of the Brejinho batholith, the most prominent isotopic features are the overlap of the isotopic Nd values and the presence of Sr isotopic contrasts between the enclaves and the granitoids (all with negative  $\epsilon_{\text{Nd}}$  and positive  $\epsilon_{\text{Sr}}$ ).

Data for pristine mafic rocks are not available. Therefore, conflicting interpretations have been considered with relationship to type of mantle involved in the generation of the mafic magma (Guimarães & Da Silva Filho, 2000; Torres, 2001). The aim of this paper is

to demonstrate the limitation of the use of these data for the resolution of this problem.

Additionally, geochemical and Nd isotope data of the enclaves from several high-K calc-alkaline granitoids of the Borborema Province (BP) also related to the Brasiliano/Pan-African Cycle, have been used by some authors (Mariano et al., 2000) with the objective of contesting the widespread use of the tectonostratigraphic terrane model in this province, proposed by Santos (1996). The present work suggests that the characteristics of the mantle source of the mafics enclaves of the Brejinho granitoid (and of other granitoids also located in the Alto Pajeú Terrane; APT), they oppose to the great part of BP mantle, unequivocally enriched, according to those authors.

### GEOLOGICAL FRAMEWORK AND MAIN CHARACTERISTIC

The Brejinho batholith (also called Itapetim Granitoid Complex; Guimarães & Da Silva Filho, 2000) is located in the central northern sector of the State of Pernambuco. It is inserted in the APT (Santos, 1996) which is part of the Transversal Zone Domain (TZD) of the BP. It is of Neoproterozoic age ( $638 \pm 4.9$  Ma—concordia U-Pb in zircon - Guimarães & Da Silva Filho, 2000), therefore related to the Brasiliano/Pan-African Cycle, being treated as a syn-transcurrent body that intrude orthogneisses and metasediments of the Cariris Velhos Cycle (ca. 1.0 Ga). It is constituted by porphyritic monzogranites and granodiorites, and contains quartz-diorites/diorites enclaves and sin-plutonic dikes, specially in the central portion (Central Zone of Mixing and Mingling). All the types have similar mineralogical composition, with quartz, oligoclase,  $\pm$ KF, biotite,  $\pm$ amphibole and titanite, differing in the modal proportion. It is a metaluminous granitoid, with peraluminous tendency, magmatic epidote-bearing, belonging to the high-K calc-alkaline series, with  $\text{K}_2\text{O}/\text{Na}_2\text{O} < 1$ , some enrichment in Rb, K, and LREE (Torres, 2001).

The Nd isotope signature and the high MgO, CaO and compatible elements (Cr up to 300ppm) content regardless of the fractionation and the interaction with felsic melts indicate that the diorites are derived from a parental magma extracted from the upper mantle. To consider them as originated from a crustal source (Guimarães & Da Silva Filho, 2000), would demand high degree partial melt and extremely high temperature, and a smaller LREE/HREE ratio, not supported by the

patterns presented by these elements (Torres, 2001). The granitoids also present relatively high values of MgO, CaO, Cr (up to 216ppm) and  $\epsilon_{Nd}$  close to CHUR, suggesting an origin from basic crust with participation of mantle-derived material. The values of  $\delta^{18}O$ , the peraluminous tendency and correlation with experiments accomplished by Patiño Douce (1995) they indicate participation of sedimentary component in the source (Guimarães & Da Silva Filho, 2000; Torres, 2001).

#### Nd AND Sr ISOTOPE DATA

The Sm/Nd model ages ( $T_{DM}$ ) of granitoids are between 1.3 and 1.45Ga and  $\epsilon_{Nd 600}$  of  $-2.4$  to  $-6.4$ . The values for the enclaves are also between the above interval (Torres, 2001). One granitoid sample located close to the contact with the regional rocks, presents  $T_{DM}$  1.8Ga, interpreted as reflecting assimilation processes with these gneisses which display  $T_{DM}$  ca. 2.0Ga (Guimarães & Da Silva Filho, 2000) suggesting that these processes are restricted to the most external portion of the batholith.

The  $\epsilon_{Sr}$  values (data of Guimarães & Da Silva Filho, 2000) are variable: 68 for a dioritic enclave, 61 for a hybrid type, 74 for a granodiorite and 110 for a monzogranite.

#### DISCUSSION ON POSSIBLE SOURCES

The variation in the the isotopic  $Sr_i$  values points to the fact that the system must have caught a sufficiently fast cold, not allowing to attain a complete isotope equilibrium. This hypothesis is also supported by the small fraction of the mafic rocks (enclaves) and by size enclaves, almost always smaller than 1.5m, that could lead to the accomplishing of a thermal equilibria before the chemical equilibria (Pin, 1992). The trends of geochemical variation (Torres, 2001) corroborate this behavior, showing that the system has been developed from an incomplete mixture of different magmas (fact corroborated by petrographyc and field data, and by the suggestion of a  $\epsilon_{Nd}/\epsilon_{Sr}$  mixing trend, obtained by Guimarães & Da Silva Filho, 2000). The hybridization process was incipient and limited in volume, since the characteristics of each one of the suites are relatively well preserved (Torres, 2001). The time of coexistence between the felsic and mafic magma, besides the development of chilled margins in the enclaves (commingling evidence), they act as a strong barrier against isotopic and element equilibria (Fourcade & Javoy, 1992).

On the other hand, the overlap of Nd isotopic values between the enclaves and the granitoid differ clearly of the behavior presented by the Sr isotopes and geochemical variation diagrams, suggesting a near-complete equilibria. Experiments by Baker (1989) and Leshner (1990) indicate that isotopic homogenization through liquid-state diffusion (in spite of the diffusion, by itself, would not be enough to allow a complete mixing), is faster than the chemical equilibration, and that the velocity of Nd isotopes equilibrium are more slowly than the one of Sr, so that, it is very difficult that Nd isotopic

equilibrium should occur. These observations suggest that the Nd isotopic signature is primary, implicating that the mafic magma has been extracted from an enriched mantle (Torres, 2001) without great isotopic contrast with the crustal melts.

Besides, the apparent mixing trend obtained by Guimarães & Da Silva Filho (2000) very shallow and flat, is not consistent with a model involving a depleted mantle and old crust as final members (Pin & Duthou, 1990).

However, another hypothesis should be considered. A sedimentary component contributed to the formation of the granitic melt (probably metagreywackes-biotite gneiss; Guimarães & Da Silva Filho, 2000 and Torres, 2001). The Sr isotopic variation in the system, could be attributed to a more heterogeneous source in terms of Rb/Sr that Sm/Nd, as commonly observed in sediments, or to the great mobility of Sr during the anatexis, inhibiting the Sr isotopic homogenization (Pin & Duthou, 1990; Pin, 1992).

The presence of samples with lower  $\epsilon_{Sr}$  and higher  $\epsilon_{Nd}$ , they are, suggestive that some re-equilibrium process has operated. So, the primary Nd isotope signature in the enclaves, which could reflect a depleted mantle source (as proposed by Guimarães & Da Silva Filho, 2000) or CHUR, would have been erased through mixing (liquid-state diffusion) with the felsic magma.

Finally, the fact that the parental magma of the diorites is mantle-derived, and all the enclaves have Nd and Sr crustal isotopic signature, leads to two interpretations: (a) none of them was exempt of assimilation or equilibrium, even if in an incipient way, being derived from a depleted re-homogenized source or, (b) enriched-mantle source.

#### REGIONAL IMPLICATIONS

The subdivision of BP in tectono-stratigrafic terranes (Santos, 1996) was recently contested (Mariano et al., 2000), based in the study of diorites enclaves of the various high-K calc-alkaline associations which have a widespread distribution in this province. These authors argue that the very restricted isotopic and geochemical variation of the diorites, is not concordant with the Santos' model (1996) indicating that an enriched continental lithosphere (characterized by high LREE/HREE ratios, enrichment in LILE and  $\epsilon_{Nd600}$  between  $-7$  and  $-16$  and  $T_{DM}$  of 1.8 to 2.0 Ga) permeates great part of the province, since the Transamazonic Cycle.

On the other hand, the characteristics of the mantle involved in the generation of the mafic enclaves of the Brejinho batholith (isotopic signature of uncertain source,  $\epsilon_{Nd}$  with values less negative, smaller LREE/HREE ratios and smaller LILE enrichment) they suggest origin from a different source.  $T_{DM}$  also present significant differences, varying from 1.3 to 1.5 Ga in Brejinho and in the granitoids Riacho do Icó, Conceição das Creoulas e Tavares, all located in APT (see revision in Torres, 2001).

Additionally, two granitoids, included in Mariano et al. (2000) study, Serra da Lagoinha e Caruaru/Arcoverde, are inserted, respectively, in the Piancó/Alto Brígida and Rio Capibaribe terranes, both also belonging to TZD. The first one is juxtaposed to the APT by the NW side, and the second is separated from APT, at SE, by the Alto Moxotó terrane, in which, to the moment, Brazilian granitoids are scarce or not known.

These constraints suggest to the fact that these crustal segments do not have the same lithospheric mantle, pointing that they constitute different terranes in the TZD.

## CONCLUSIONS

The available isotopic data of the enclaves for the Brejinho batholith don't allow unequivocal conclusions concerning the type of mantle involved. It can be concluded that the source of the enclaves was the lithospheric mantle and they do not constitute residues of partial melt related to generation of felsic magmas, considered that the magma progenitor represents the magmatic end-member, juvenile, extracted from the mantle during the Brasiliano/Pan african event.

On the contrary to the enriched characteristics of the mantle considered as source of most enclaves of other high-K calc-alkaline associations of BP, the isotopic and geochemical data of the underlying mantle to APT, implies in considering this and other crustal segment of the TZD, as amalgamates terrains, testifying favorably to the model of Santos (1996), at least in this domain.

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