THE NAZARÉ PAULISTA-TYPE ANATECTIC GRANITE: MIXED SOURCES INFERRED BY ELEMENTAL GEOCHEMISTRY AND Sr-Nd ISOTOPES

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INTRODUCTION

Research on the generation, extraction and migration of granitic melts in the continental crust has gained renewed interest in the geological literature in recent years, mostly with the introduction of new methodologies which allow a more precise determination of intensive and extensive parameters such P, T, t, fluid activities etc. More stimulating results have been obtained in studies in which the source areas of the granitic magmas are well characterized, either in anatectic terranes, where magmas and sources are directly associated (Watt & Harley, 1993; Barbero et al., 1995), or in regions such as the Himalayas, where continued studies over the last decades allowed the sources of the collisional leucogranites to be very well constrained (Harris et al., 1995).

The source identification typically makes use of a geochemical approach, with major and trace elements and radiogenic isotopes (especially Sr, Nd and Pb) yielding fundamental and complementary information (Inger & Harris, 1993; Harris et al., 1995) that can be confronted with experimental results (cf. Patiño Douce & Harris, 1998; Castro et al., 1999).

Crustal granites directly associated to migmatite terranes are abundant in extensive areas of the crystalline basement in Brazil. In the southernmost portion of the Socorro-Guaxupé Nappe (SGN) east of Atibaia (SP) (Fig. 1), three main types of anatectic granites closely associated to migmatites occur. In order of decreasing abundance, they are: the garnet-biotite Nazaré Paulista (NP) granite; the pink or grey biotite Quatro Cantos (QC) granite and white two-mica (2M) leucogranites.

This work uses elemental and isotope geochemistry as tools to identify the role of the main regional metamorphic units as potential sources for the different types of anatectic granites occurring in the Atibaia area.

THE COUNTRY ROCKS

Shown in Figure 1 is the southernmost portion of the SGN, a high-grade metamorphic terrane allochtonous over the SW portion of the São Francisco Craton in SE Brazil. The metamorphic units belong to the Piracaia Metamorphic Complex (Campos Neto et al., 1983), and locally three main units ar e recognized, from "base" to "top": (1) granitic to tonalitic biotite (± hornblende) gneisses; (2) banded garnet-biotite gneisses with centimeter to decimeter layers and variations towards more aluminous (sillimanite-bearing), and more calcic (with hornblende and andesine-labradorite plagioclase) gneisses, and frequent intercalations of hornblende gneisses, calc-silicate rocks wiht amphibolites, and (3) (± sillimanite)-garnet-muscovite-biotite schists (often with quartzite and quartz schist bands), that occasionaly grade into thin packages of micaceous quartzite (cf. Fig. 1).

On the basis of their chemistry, rocks from units 2 and 3 are identified as of dominantly metasedimentary origin. The sillimanite-bearing schists are invariably weathered, so it is hard to obtain samples suitable for chemical analysis; their derivation from pelite sediments is however undoubtful. The garnet-biotite gneisses are metagreywackes with different propotions of a pelitic component and possibly some contribution from associated basic volcanics now appearing as amphibolite layers. Rocks from unit 1 are of doubtful origin, and could include orthogneisses (from basement sequences or as early bodies locally intrusive into units 2 and 3) or strongly immature sediments. A peculiar feature of unit 1 gneisses are their strongly fractionated REE patterns and high Sr contents, reminescent of Archean TTG sequences.

THE ANATECTIC GRANITES

Under the name "Nazaré Paulista (NP) granite" are grouped several types of garnet-biotite granites, the most abundant product of crustal anatexis in the Atibaia region. Two main facies are present, both occurring as small bodies, no more than a hundred meters wide, sometimes crosscutting each other in the same outcrop. The grey facies is an equigranular garnet-biotite granite with M (mafic index)=5-8 strongly veined by a white, usually slightly coarser-grained, garnet leucogranite (M<4). The white facies is texturally similar to the latter veins, but forms independent bodies with pegmatitic pockets, and is chemically distinct. Monazite U-Pb dating of the grey facies resulted in an age of 624 ± 2 Ma (Janasi, 1999).

The QC anatectic biotite granites occur mostly to the north of the Nazaré Paulista granites, usually directly associated to the biotite gneisses from unit 1. The 2M leucogranites appear as small bodies southwest of the NP granites, surrounding the younger Atibaia granite (Figure 1), and mostly associated to the upper schist unit.

Compared to the experimental products of melting of crustal protoliths, the NP granites have an excess of quartz, plagioclase and mafic minerals, which appear to reflect a restite component. Melting temperatures, as inferred from zircon and monazite saturation thermometry, are within the range of muscovite dehydration-melting (~700-750 °C) for the NP granites and the 2M granites; the lower values are shown by the NP garnet leucogranites. Higher temperatures, already within the biotite dehydration-melting field (>820 °C), are obtained in the QC granites.

Relative to typical products of crustal anatexis such as the Himalayan leucogranites (Harris et al., 1995), the NP granites have lower Rb/Sr, higher La/Yb and lower phosphorous content. The QC granites have even higher Sr and La/Yb and can be modelled as products of melting of unit 1 biotite gneisses, which is suggestive that the latter could also be an important component in the Nazaré Paulista granites. Flatter REE patterns and low Sr contents thought to be typical of crustal leucogranites are only shown by the NP garnet leucogranites.

Sr-Nd ISOTOPE GEOCHEMISTRY

The $^{87}Sr/^{86}Sr_{625}$ of the anatectic granites are widely varied and increase from QC (0.7122-0.7128) to grey NP (0.7134-0.7187) to NP garnet leucogranite (0.7237-0.7245; data from Ragatki, 1998) to 2M granite (0.7327), pointing to sources with increasingly higher Rb/Sr ratios in this sequence (Fig. 2).

The εNd_{625} are strongly negative and less varied, and appear to reflect the geographic position of the samples rather than the petrographic type. Samples intrusive into the easternmost portion of the Piracaia Metamorphic Complex, near the Nazaré Paulista town (outcrops 41 and 51; cf. Figure 1) have $\varepsilon Nd_{625} = -12$ to -13, while those collected further west (outcrops 40 and 50) are more negative ($\varepsilon Nd_{625} \sim -16$). It is remarkable that the NP granite samples from the latter two outcrops show the lowest $^{87}Sr/^{86}Sr_{625}$, suggesting a (unusual) positive correlation between the Sr and Nd isotopes.

Also shown in Figure 2 are the fields of regional granulites and metasediments (from Janasi, 1999), and the Sr-Nd isotope compositions of metamorphic rocks from units 1 and 2 of the Piracaia Complex. The spread in $^{87}Sr/^{86}Sr_{625}$ is similar to that shown by the anatectic granites (0.7132-0.7275); the lowest value is shown by the unit 1 biotite gneiss. The εNd_{625} are on average less negative than in the granites (–8 to –13). Interestingly, samples spatially associated with granites showing $\varepsilon Nd_{625} \sim -13$ are the least negative (# 41 and 53), whereas samples with εNd_{625} overlapping those of the latter granites occur westwards, suggesting greater contribution from old sources in this direction.

IDENTIFICATION OF THE SOURCES

Elemental and isotope geochemistry data are consistent with the QC biotite granites deriving from unit 1 biotite gneisses, from which they must have inherited their high Sr and La/Yb and relatively low $^{87}Sr/^{86}Sr_{625}$. The NP garnet leucogranites and probably also the 2M leucogranites can derive mostly from the regional metasediment, as shown by the overlap in their Sr-Nd radiogenic signature, the high Rb/Sr and lower REE fractionation. The grey garnet-biotite NP granites cannot be derived solely from either of these sources; their chemical and isotopic character is intermediate between the QC biotite granites and the leucogranites, which is consistent with a mixed source involving a metasedimentary component similar to the regional garnet-biotite gneisses and a high-Sr, high-LREE component. Their εNd_{625}, which seem to become more negative westwards and are more negative than the country garnet-biotite gneisses in a given location, are suggestive that the latter component is or mostly derived from the erosion of old basement.

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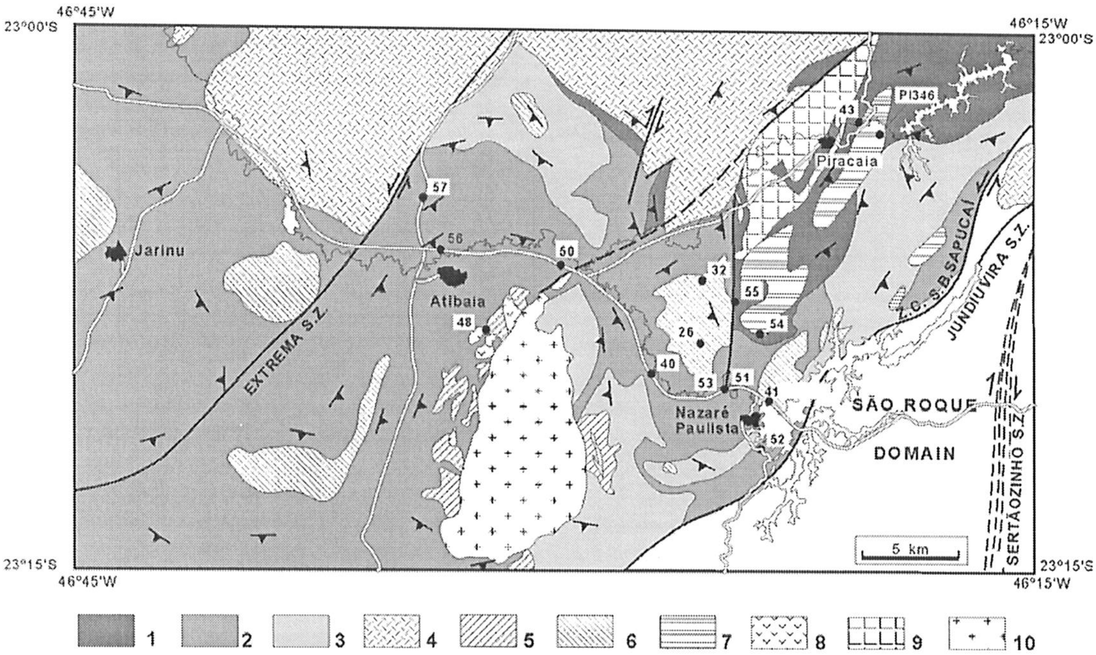

Figure 1. Simplified geologic map of the Atibaia region. 1, 2, 3 = Piracaia Metamorphic Complex (1= Bt gneiss; 2 = Grt-Bt gneiss; 3= (Sil)-Grt-Bt-schist); 4 = high-K calc-alkaline granite; 5 = Ms-Bt (2M) leucogranite; 6 = Nazaré Paulista (NP) Grt-Bt granite ; 7 = Quatro Cantos Bt granite; 8 = Porphyritic tonalite-granodiorite; 9 = Piracaia monzodiorite; 10 = Atibaia granite. Numbers refer to sampling sites.

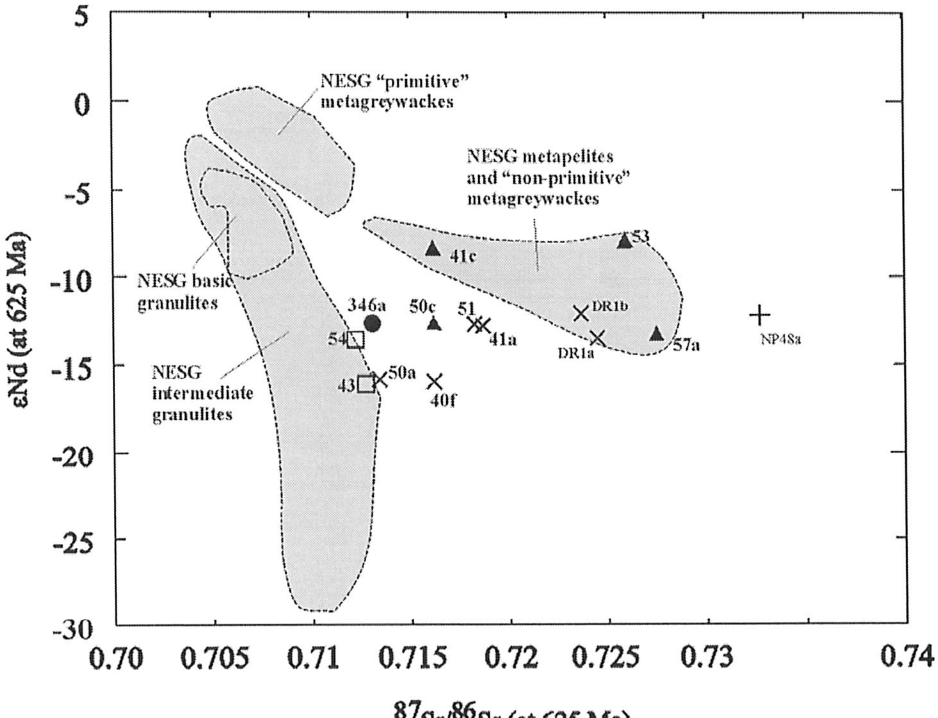

Figure 2. εNd x $^{87}Sr/^{86}Sr$ (calculated at 625 Ma) for crustal granites and metamorphic rocks from the Atibaia region. The fields of SGN granulites, metagreywackes and metapelites (from Janasi, 1999a) are also shown. Numbers refer to sampling sites (cf. Fig. 1).
Symbols: closed triangles, Grt-Bt gneiss (sample 50c is a calc-silicate rock); closed circle, Bt orthogneiss; open squares, QC bt granite; "x", NP Grt-Bt granite (samples DR1a, DR1b are Grt leucogranites analysed by Ragatki, 1998); "+", Ms-Bt granite.