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ENRICHED-MANTLE CONTRIBUTIONS TO THE ITU GRANITOID BELT, SOUTHEASTERN BRAZIL: EVIDENCE FROM K-RICH DIORITES AND SYENITES

Valdecir de A. Janasi, Silvio R. F. Vlach & Horstpeter H.G.J. Ulbrich
Instituto de Geociências, Universidade de São Paulo, C.P. 20899, CEP 01498-970, São Paulo-SP

Basic to intermediate rocks in the late Brasiliano (620-580 Ma) Itu granitoid belt appear as scarce individual occurrences (Piracaia monzodioritic-monzonitic massif, Pedra Branca and Capituva syenitic massifs) and as a series of small dioritic bodies, synplutonic dikes and enclaves present in the different granitoid associations (Vlach et al., 1990), mostly those of calc-alkaline affinities. Important similarities (e.g., K- and LILE-rich character) and differences (e.g. elemental ratios, initial Sr isotope ratios) between these rocks are revealed by the available data, and allow some preliminary constraints to be placed on the nature and origin of the mantle contributions to the Itu belt magmatism.

The Capituva and Pedra Branca massifs are the northeasternmost occurrences of the Itu belt, intruding migmatites and syn-tectonic granitoids of the allochthonous Guaxupé Domain. The predominant facies in both massifs are medium- to coarse-grained, laminated K-rich syenites (color indices 20-25). Fine-grained syenites found in the Capituva massif are chemically similar to those facies, indicating that the most important chemical features of these rocks reflect the nature of the parent magmas and cannot be attributed to cumulative processes (Janasi, 1993). More basic rocks are restricted to deeply weathered biotite-rich mela-syenites (color indices over 35) present in the core of the Capituva massif; these share most of the chemical fingerprint of the predominant facies, but seem not to be related to them through simple crystal fractionation processes (Janasi, 1993). The oxidized nature (above the NNO buffer) of the syenites from both massifs is revealed by the occurrence of hematite-rich ilmenite as the sole opaque oxide, and by Mg-rich biotite and diopside. A particular facies association present in the Pedra Branca massif crystallized under even higher fO_2 (near the HM buffer) and bears a mafic assemblage of (soda)-diopside, phlogopite, titano-hematite, magnetite and sphene. Rb-Sr isotope data available for the Pedra Branca massif (Winters, 1981) give good indications of the $(^{87}Sr/^{86}Sr)_{600}$ ratios, which vary in the range 0.706-0.708 (Janasi, 1992).

The Piracaia massif is an oval-shaped, northeast-striking pluton intruding high-grade metasedimentary and metaigneous rocks of the Jundiaí allochthonous Domain. In spite of its small size, the massif exhibits a remarkable variety of facies which defines an almost continuous modal trend, from early monzodiorites and monzonites (concentrated at the core of the massif) to late quartz syenites (as sparse bodies at the borders) (Janasi & Ulbrich, 1987). Elemental data (Janasi, 1986, and unpublished data) show that most of the variation can be modelled by *in situ* crystal fractionation, which was in part strengthened by synplutonic movements along a major shear zone. Recalculation of the available Rb-Sr isotope data (Janasi, 1986) point to an emplacement age of 600 ± 13 Ma; Sr initial ratios calculated at this age are in the range 0.704-0.705 for all facies, emphasizing their consanguineous nature.

In the Morungaba region, dioritic rocks appear as small irregular bodies of medium- to coarse-grained quartz diorites and quartz monzodiorites, constituting a contrasted association with the predominant coeval granites. Their parental basic-intermediate magmas intruded in a transtensional regime, and their evolution combined processes of (largely *in situ*) fractional crystallization and mixing with granitic magmas/mushes during ascension and final emplacement (Vlach, 1985; 1993). Diopside-rich clinopyroxene (**mg#** ca. 0.8), actinolitic and magnesian amphibole, magne-

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sian biotite, sphene and magnetite make up the mafic mineralogy of the rocks, and point to crystallization under oxidizing conditions, near the TMQAI buffer. Sr and Nd isotopic data testify their fairly evolved character ($(^{87}Sr/^{87}Sr)_{600}$=0.706-0.708; $^{143}Nd/^{144}Nd)_{600}$= ca. 0.51165 (Vlach,1993).

Mantle-normalized incompatible-element patterns for a Capituva fine-grained syenite, a Piracaia monzodiorite, and a Morungaba K-diorite are presented in Figures 1 and 2. REE data are not available for rocks of the Piracaia massif, but the incompatible-element patterns shown in Figure 2 suggest that the monzodiorites from this massif are very similar to those from Morungaba, with only a slight enrichment in almost all elements. Some important differences are, however, apparent in the enrichment pattern for the Capituva syenite, the more remarkable one being the deeper trough in Nb and the absence of a negative Sr anomaly. Moreover, the pattern for the syenite is more fractionated (less enriched in elements more compatible than Ti; Figure 1), a feature also evident in normalized REE patterns.

Elemental data suggest that none of these occurrences could represent magmas from primary mantle sources. That is particularly evident for the less differentiated rocks from the Piracaia massif, whose Ni (<40 ppm) and Cr (<10 ppm) contents and **mg** numbers are extremely low, and could not have been in equilibrium with acceptable mantle (olivine-bearing) rocks. The Capituva syenites and the Morungaba K-diorites have higher values (Ni <70 ppm; Cr < 90 ppm; **mg#** around 50), which are however lower than those accepted even for magmas generated from olivine-free (phlo-gopite-clinopyroxenite) mantle sources (e.g. Foley, 1992). The interpretation of the incompatible-element patterns must therefore distinguish, as far as possible, those features inherited from the source and those which result from fractionation.

The contrast in Sr contents between the Capituva syenite and the two K-diorites clearly results from different histories of crystallization. The Sr troughs in the K-diorite patterns can easily be attributed to plagioclase fractionation, which indeed is expected from the abundance of plagioclase phenocrysts in some of these rocks. In contrast, plagioclase was <u>not</u> a primary magmatic phase in the Capituva syenites; the absence of Sr troughs suggests that only mafic mineral phases participated in the previous fractionation history of these magmas, pointing to the very peculiar nature of the primitive mantle magmas (depleted in "basaltic" components; ultrapotassic?).

The differences in the size of the Nb anomalies between the syenite and the K-diorites (La/Nb= 6.5 in the first and ca. 2 in the Morungaba K-diorite) is almost certainly a primary feature. A few other LILE/HFSE ratios that appear to be unaffected by fractionation point to systematically higher values in the syenites; one example is Rb/Nb, which is in the 8-10 range in the Capituva syenites and (normally) 2.5-3.5 in Piracaia (where both behave as incompatible elements over most of the compositional range). The low Ti contents of the Capituva syenites when compared to those of the K-diorites (Figures 1 and 2) could also reflect the HFSE-poorer nature of these magmas, although in this case the influence of opaque mineral fractionation is difficult to evaluate. It is of interest to note that syenites from the more oxidized facies of the Pedra Branca massif, which are overall LILE-richer than the Capituva syenites (Janasi, 1992), show even larger LILE/HFSE ratios (La/Nb >11; Rb/Nb >12).

A major conclusion to be advanced from the geochemical data is that at least two fundamentally different mantle-derived magmas, both enriched in LILE, occur in the Itu granitoid belt. The K-rich syenites derive from strongly oxidized magmas, poor in a "basalt" component, and with very high LILE/HFSE ratios. The K-dioritic magmas present in the Piracaia and Morungaba occurrences have some shoshonitic affinities and less pronounced, although still remarkable, LILE/HFSE and fO_2.

A significant contribution from crustal materials to the Capituva and Pedra Branca syenites seems not to be plausible, since they are LILE-richer than any known potential contaminants (Janasi, 1993). In fact, many authors envisage the origin of very K-rich magmas in the subcontinental lithospheric mantle (more precisely in the mechanical boundary layer), where "metasomatic" horizons (formed by the percolation of "small-fraction melts" ascending from the convecting mantle or by fluids and/or melts released from subducting slabs) can be preserved and become isotopically evolved over geologic time.

A major issue, however, is the extent to which the "cold" lithospheric mantle can be melted when reactivated by rifting or plume activity. Some geophysical evidences suggest that the temperatures usually attained under these circumstances would only allow the partial melting of the enriched veins (possibly of phlogopite-clinopyroxenite composition), giving rise to K-rich magmas poor in a "basalt component". In this case, "basaltic" magmas enriched in LILE and radiogenic isotopes could represent asthenospheric magmas which incorporated a lithosphere-derived component upon ascent; some calculations suggest that ca. 10% of this very enriched component would be sufficient to dominate the incompatible-element and isotope characteristics of the magmas (Thompson et al., 1993). Some authors, however, admit that extensive melting of the lithospheric mantle can occur under special circumstances (e.g. where it is hydrated), and attribute the generation of the high K/Ti basalts of continental flood provinces to essentially lithospheric sources (e.g. Hergt et al., 1991; Bradshaw et al., 1993). An alternative model for the incorporation of a "basalt component" to lithospheric mantle magmas is offered by the "vein-plus-wall-rock melting" model (Foley, 1992) which admits that solid-solution reactions in the veins and wall-rock dissolution allow material from the wall-rock peridotites to be progressively incorporated into the initial low-fraction, vein-derived magmas.

The available data for the mantle-derived magmas of the Itu belt do not yield elements to decide whether the "basalt component" present in the K-diorites is derived from the convecting mantle or from the mechanical boundary layer. Whatever the case, an old, possibly Proterozoic "subcontinental lithospheric mantle" component dominates the elemental and isotopic (Sr and Nd) patterns of these magmas (Vlach, 1993), and purely asthenospheric magmas are absent or rare.

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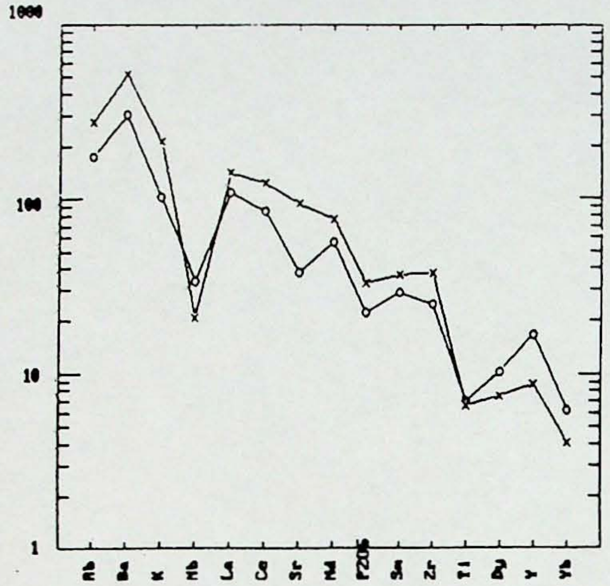

Figure 1 - Mantle-normalized incompatible-element patterns for K-diorites and syenites from the Itu belt. Open circles, K-diorite from the Morungaba region (sample A-515b; Vlach, 1993); "x", fine-grained syenite from the Capituva massif (sample CA-28b; Janasi, 1992). Normalization factors: depleted mantle from Sun & McDonough (1989).

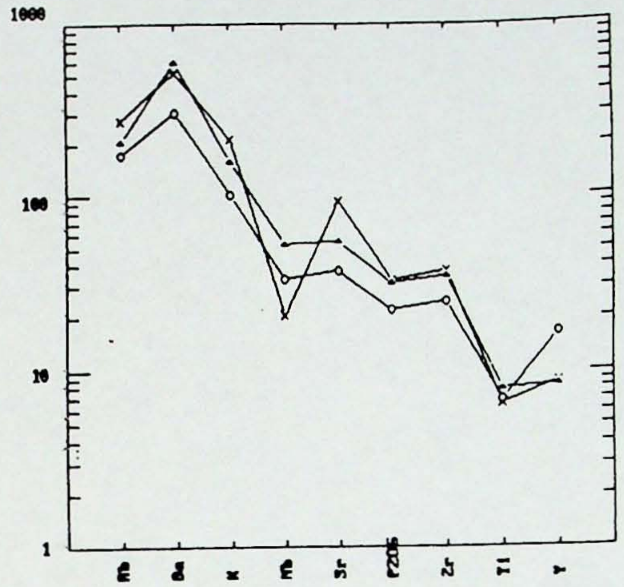

Figure 2 - Partial mantle-normalized incompatible-element patterns for K-diorites and syenites from the Itu belt. Symbols and normalization factors are the same used in Figure 1; open tringle, monzodiorite from the Piracaia massif (Janasi, 1986).