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U-Pb AND Rb-Sr DATING AND ISOTOPIC SIGNATURE OF THE CHARNOCKITIC ROCKS FROM VÁRZEA ALEGRE INTRUSIVE COMPLEX, ESPÍRITO SANTO, BRAZIL

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INTRODUCTION

Hydrous and anhydrous magmatic rock associations have been studied by many authors around the world (e.g. Petersen, 1980; Hubbard & Whittley, 1979; Kaiyi et al., 1985; Janasi, 1992; Jordt-Evangelista, 1996). Many intrusive bodies containing charnockites, closely associated with rocks presenting an hydrous primary paragenesis occur in the central portion of the Espírito Santo State, SE Brazil (Ped rosa Soares & Wiedemann-Leonardos, 2000). A typical example is the Várzea Alegre Intrusive Complex (VAIC), related to the late- to post-tectonic Brasiliano magmatism in this region. The pluton has an almost circular shape with a gabbroic center surrounded by diorites and granite. An irregular charnockitic ring involves the inner structure. This paper highlights unpublished geochronological Rb-Sr and Sm-Nd isotopic data of the VAIC charnockitic rocks.

GEOLOGICAL SETTING

The Espírito Santo State is located in the northern portion of the Ribeira Belt, which is the continuation of the Neoproterozoic Araçuaí orogen (Pedrosa Soares & Wiedemann-Leonardos, 2000). In a late orogenic stage of the Brasiliano Cycle (535 - 490 Ma.), several complexly zoned plutons cut the enclosing high-grade gneisses, highlighting the post-collisional magmatism of this region (Wiedemann et al., 2002). According to Pedrosa Soares & Wiedemann-Leonardos (2000), the VAIC is included in the G5 suite, which is characterized by several diapirs with compositions varying from opx-gabbro to granite and corresponds to the latest magmatic event of the orogen. This suite comprises mataluminous, high-K calc-alkaline, I-type granitoids originated in the lowermost continental crust with important mantle contributions. The VAIC outcropps area of 150 km^2 and had geology, petrography and geochemistry studied (Mendes et al., 1997, 2001).

THE GEOLOGY OF THE VAIC

The Várzea Alegre pluton has an inversely zoned structure, with gabbros at the eroded center of the intrusion surrounded by diorites/quartz-diorites-monzodiorites and megaporphyritic granites. All these rocks are involved by a large ring of charnockitic rocks: opdalites, jotunites, opx-quartz diorites and quartz mangerites (Medeiros et al., 2000). The contact between the megaporphyritic granite and the gabbros/diorites is a mixed zone where contrasting lithotypes interfinger with each other. The charnockitic rocks have dark green color and megaporphyritic texture. Along the contacts with the enclosing rocks its foliation is well marked. Away from this region the rock becomes almost isotropic. When observed, the contacts with the enclosing rocks are sharp and parallel to the foliation. The border foliation and the schistosity of the gneisses are generally dipping toward the pluton. The contacts between the charnockitic outer ring and the magmatites of the inner domain are mainly interfingered, giving rise to locally intense mechanical mixing.

PETROGRAPHY AND GEOCHEMISTRY OF THE CHARNOCKITIC ROCKS

The charnockitic rocks consist essentially of plagioclase (An_{32-40}), perthitic ortoclase/mesoperthite, orthopyroxene, biotite, amphibole, ilmenite, magnetite, pyrite, apatite, zircon, rare allanite and hematite. Megacrysts of alkali feldspar and plagioclase, up to 6 cm, define a porphyritic texture. The matrix is medium to coarse grained and it may be finer-grained when compressed against and partially recrystallized around the megacrysts. Features of weak ductile deformation are observed in quartz and feldspar grains, as well as curved biotite and twining lamella of plagioclase. Opx may be partially replaced by biotite, amphibole and opaque minerals and is altered to chlorite and a brown secondary phase. Alkali felsdspar replaces plagioclase and the concentration of the perthitic lamella is very variable. Apatite and zircon appear as inclusions, single cristals or associated with mafic minerals.

The chemical composition of these rocks indicates SiO_2 values ranging from 54% to 65%. They are enriched in Ti, P, Zr, Ba and REE, relatively rich in K and Fe and they have low Mg, Al and V contents, when compared to granitoid rocks of similar silica contents (Mendes et al., 1997). A marked compatible behaviour is observed for Ca, Fe, Mg, Ti, P, Sr and V, in contrast to the incompatible behaviour of K, Na, Rb and Ba (Mendes et al., 1997); very high Al, Ca, Sr, K and Ba concentrations in some samples have been pointed by the authors as indicative of possible feldspar accumulation.

Table 1. Rb-Sr isotopic analytical results for the VAIC charnockitic rocks.

Sample	Rb (ppm)	Sr (ppm)	$(^{87}Sr/^{86}Sr)_0$	$^{87}Rb/^{86}Sr$	$(^{87}Sr/^{86}Sr)i$	ε (0)	ε (0.5 Ga)
VA-04	55.25	610.87	0.71074	0.2618	0.708875	88.57346	70.51839
VA-257	59.79	665.12	0.71074	0.2602	0.708886	88.57346	70.68035
VA-249B	54.20	675.20	0.71026	0.2324	0.708604	81.76011	66.67533
VA-249C	75.61	674.14	0.71198	0.3262	0.709656	106.1746	81.61543
VA-90	64.00	579.00	0.71080	0.3199	0.708521	89.42512	65.48923
VA-125	91.00	518.00	0.71223	0.5085	0.708607	109.7232	66.71384
VA-261	36.00	677.00	0.70963	0.1539	0.708534	72.81760	65.67343
VV-1751	82.70	591.90	0.71160	0.4000	0.708750	100.7807	68.74669
VV-1752	41.90	514.30	0.70980	0.2400	0.708090	75.23066	59.37111
VV-1756	54.90	545.40	0.71060	0.2900	0.708534	86.58623	65.67498
VV-1759	47.60	552.60	0.70960	0.2500	0.707819	72.39177	55.51760

Table 2. Sm-Nd isotopic results for the VAIC charnockitic rocks.

Samples	$(^{143}Nd/^{144}Nd)i$	$(^{143}Nd/^{144}Nd)_0$	$^{147}Sm/^{144}Nd$	T_{DM} (Ga)	ε (0)	ε (0.5 Ga)
VA-90	0.511565	0.511922	0.1091	1.631	-13.967	-8.3805
VA-125	0.511539	0.511897	0.1094	1.672	-14.454	-8.8880
VA-261	0.511477	0.511839	0.1106	1.778	-15.586	-10.098
VA-257	0.511533	0.511889	0.1088	1.675	-14.611	-9.0059
VA-249	0.511621	0.511971	0.1068	1.527	-13.011	-7.2764
VA-04	0.511628	0.511955	0.0997	1.455	-13.323	-7.1347

Therefore, the charnockitic rocks from Várzea Alegre show metaluminous and high-K calc-alkalic character, with conspicous enrichment in LIL and HFS elements. These features indicate a mantle contribution associated to crustal melts in the genesis of the rocks. The geochemical behaviour suggests fractional crystallization and magma mixing as the main differentiation process during the evolution of the charnockitic suite (Mendes et al., 1997).

GEOCHRONOLOGICAL AND ISOTOPIC DATA

The Rb-Sr and Sm-Nd whole-rock isotopic data of the VAIC charnockitic rocks are presented in the tables 1 and 2. The analysis were carried out at the Laboratory of Geochronology of the University of São Paulo. Using the isotope dilution tecnique, single zircon U-Pb determinations for the charnockitic ring were obtained at the Laboratory of Geochronology of the University of Brasília.

The geochronological U-Pb in zircon method provided a concordia age of 498.6 ± 4.9 Ma for four zircon grains of the VAIC charnockitic rocks. This age interval agrees with the obtained result for the charnockites from the Aimorés Intrusive Massif , ca. 50 km west of Várzea Alegre (Melo, 2000).

The Rb-Sr data show high $^{87}Sr/^{86}Sr$ initial ratios and $\varepsilon_{Sr(0)}$ for the charnockitic lithotypes. Despite the observed variations in the total Sr contents, the similar calculated initial ratios values for the analyzed samples points to an homogeneous isotopic distribution during the evolution of the sequence. Such high $^{87}Sr/^{86}Sr$ initial ratios were preliminarly interpreted by Mendes et al. (1997) as a response to crustal contamination.

Such as verified to the Rb-Sr isotopes, the six samples ivestigated for Sm-Nd isotopes indicate a very similar $^{143}Nd/^{144}Nd$ ratios, as well as $\varepsilon_{Nd(0)}$. The low $\varepsilon_{Nd(0)}$ values, around -14.00, are in accordance with the high $^{87}Sr/^{86}Sr$ initial ratios. The T_{DM} model ages for the VAIC charnockitic rocks range from 1.5 to 1.77 Ga. The average T_{CHUR} for these rocks is ca. 1.1 Ga. Medeiros et al. (2000) have considered such age interval as the most appopriate for the extraction of the parental magma from the mantle. As pointed by Mendes et al. (1997), the geochemical signature of the VAIC charnockitic rocks indicates participation of crustal and enriched mantle magmas for the generation of the rocks here studied. Having in mind such hypothesis, the T_{CHUR} age could be more realistic. Considering the crystallization age of ca. 500 Ma, a long lived crustal residence may be infered for the parental magma.

Plotting the analyzed samples in the 1/Sr x $^{87}Sr/^{86}Sr$ (0.5 Ga) diagram (Fig. 1), two groups can be separated. One of these could be related to samples evolved essentially by fractional crystallization, and the other may reflect mixing between a more radiogenic component with a less radiogenic one. The behaviour of the samples in the ε_{Nd}(0.5 Ga) x $^{87}Sr/^{86}Sr$ (0.5) diagram (Fig. 2) confirms this premise. An isochronic Rb-Sr age of 500 ± 12 Ma (Ri=0.70855) is indicated with selected samples from the mentioned diagrams.

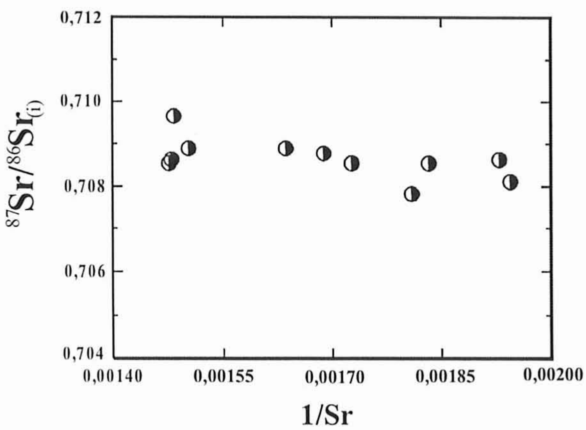

Figure 1. 1/Sr *versus* $^{87}Sr/^{86}Sr$ (0.5 Ga) diagram for the VAIC charnockitic rocks.

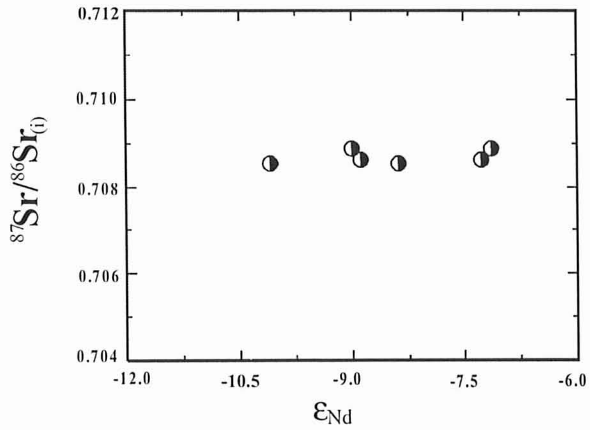

Figure 2. ε_{Nd} (0.5 Ga) *versus* $^{87}Sr/^{86}Sr$ (0.5 Ga) diagram for the VAIC charnockitic rocks.

DISCUSSION AND CONCLUSIONS

Mello (2000) found a lower concordia intercept age of 498.6 ±3 5.6Ma by conventional multigrain U-Pb zircon analysis, and U-Th-Pb ages in monazite between 562 and 468Ma for the Aimorés (MG) charnockite intrusion. High $(^{87}Sr/^{86}Sr)_i$ values at 500Ma associated with variable negative ε_{Nd} values attest either to an enriched mantle source or to a strong crustal influence on the petrogenesis of this intrusion.

The VAIC charnockitic rocks radiometric ages, U-Pb in zircons and whole rock Rb-Sr, of 498 ± 4.9 Ma and 500± 12 Ma respectivelly, can be surely considered as the crystallization age. This age is related to the post-tectonic magmatic activity in the central-north Ribeira Belt (Wiedemann et al., 2002). Mendes et al. (1997) pointed out the absence of solid state deformation in the VAIC charnockitic rocks. The young age obtained also corroborates this idea.

A whole rock Rb-Sr isochron age of 508 ± 12 Ma (Ri=0.7084) was obtained for the VAIC megaporphyritic granite (Medeiros et al., 2000). Therefore, the hypothesis of an early emplacement of the charnockitic outer shell (cf. Medeiros et al., 2000) is not accepted due to the age concordance between the lithotypes. This evidence indicates a possible simultaneous emplacement of the different magmas.

Possible combination of fractional crystallization and magma mixing process for the generation of the VAIC charnockitic rocks was suggested by Mendes et al. (1977). The Rb-Sr and Sm-Nd isotope interpretation described above agrees with this assumption.

Based on high $^{87}Sr/^{86}Sr$ initial ratios and incompatible elements anomalies detected in Brasiliano basic rocks, a sublithospheric enriched mantle has been proposed for this region (Ludka, 1998; Gimenez Filho et al., 2000). In spite of high $^{87}Sr/^{86}Sr$ initial ratios or $\varepsilon_{Sr(0)}$ and low $\varepsilon_{Nd(0)}$ values point to an exclusively crustal origin, the VAIC charnockitic rocks have conspicous enrichment in LIL and HFS elements which could indicate that the same enriched mantle contributed to the petrogenesis by interations with crustal melts (Mendes et al., 1999).

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