ISOTOPE GEOCHEMISTRY OF MONTE DE TRIGO ISLAND ALKALINE SUITE: MANTLE SOURCE CHARACTERIZATION

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INTRODUCTION

Monte de Trigo Island, a Late Cretaceous alkaline complex (86.5 Ma, Ar/Ar) located in southeastern Brazilian coastline, is part of a wide Meso-Cenozoic continental alkaline/carbonatite magmatism that occurs surrounding the Paraná Basin (Fig. 1; Comin-Chiaramonti & Gomes, 2005).

The geology of the Monte de Trigo Island is composed of a SiO_2-undersaturated syenitic-gabbroic association where three main magmatic phases are recognized (Enrich, 2005). The first one includes a cumulate body of melatheralites, olivine melagabbros, clinopyroxenites and nepheline monzosyenites, in addition to synplutonic microtheralite and microessexite dykes and a magmatic breccia pipe. The second one includes a miaskitic hipersolvus stock of nepheline syenite and nepheline-bearing alkali feldspar syenites, covering over more than 90% of the island, together with synplutonic nepheline microsyenite dykes. The last phase is a dyke series with aphanitic matrix, which varies from lamprophyres, tephrites, phonotephrites, tephriphonolites to phonolites, cross cutting the other lithologies.

This short paper presents Sr and Nd isotope analyses from representative lithologies of the Monte de Trigo Island Alkaline Suite. These data are discussed within the isotope regional context, from a mantle enrichment point of view.

ANALYTICAL RESULTS

$^{87}Sr/^{86}Sr$ and $^{147}Nd/^{144}Nd$ isotope ratios were analyzed at the Geochronological Research Center of the Instituto de Geociências, Universidade de São Paulo, in different lithologies from the cumulate mafic/ultramafic body, nepheline syenite stock and dyke suite (lamprophyres to phonolites) of the Monte de Trigo Island. The $(^{87}Sr/^{86}Sr)_i$ and $(^{147}Nd/^{144}Nd)_i$ initial ratios were calculated assuming an age of 86.5 Ma (Enrich, 2005). Lamprophyre dykes data from Thompson *et al.* (1998; samples 94SOB14, 94SOB17 e 94SOB20) are also included.

$^{87}Sr/^{86}Sr_{(86.5Ma)}$ values range between 0.70374 and 0.70424 for olivine clinopyroxenite, olivine gabbro and nepheline-bearing olivine gabbro. The nepheline monzosyenite shows a higher value than the latter ones (0.70466). In the nepheline syenite stock, $^{87}Sr/^{86}Sr_{(86.5Ma)}$ ratios from different facies vary between 0.70463 and 0.70504, being somewhat higher than the nepheline monzosyenite ratio. The dyke suite has $^{87}Sr/^{86}Sr_{(86.5Ma)}$ ratios between 0.70387 and 0.70451, similar to the other lithologies of the Monte de Trigo Island, also showing a discrete increasing trend of $^{87}Sr/^{86}Sr_{(86.5Ma)}$ ratio in more felsic lithologies.

$^{87}Sr/^{86}Sr_i$ values are generally within the variation range observed for Brazilian alkaline rocks (Morbidelli *et al.*, 1995; Gibson *et al.*, 1995; Thompson *et al.*, 1998), with small differences between more felsic and more mafic lithologies. This variation suggests diffentiated enriched mantle sources (Morbidelli *et al.*, 1995). It should be noted that low $^{87}Sr/^{86}Sr_i$ ratios even in more felsic lithologies (*i.e.*, nepheline syenites) of the Monte de Trigo Island suggest low or negligible crustal contamination.

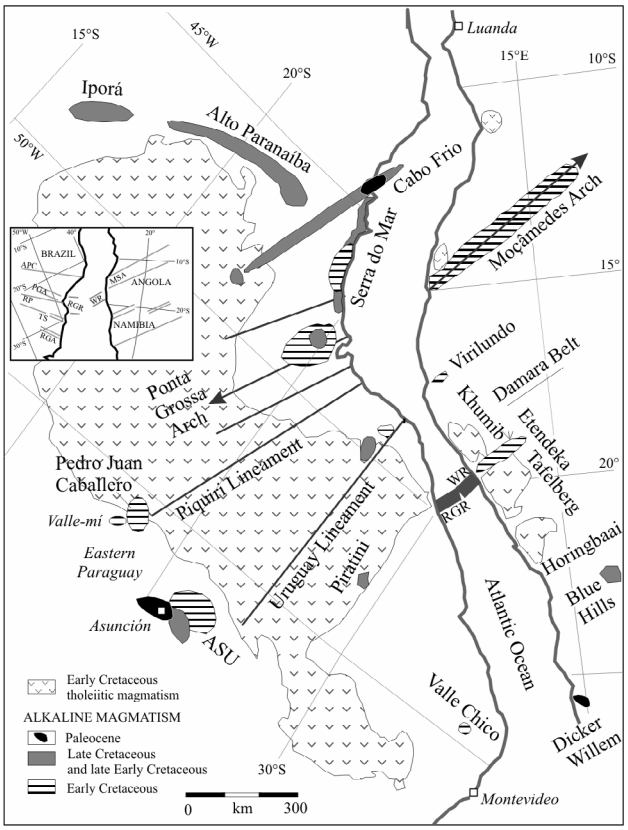

Figure 1. Distribution of the alkaline and tholeiitic magmatism in the Paraná-Angola-Etenkeda Province (Comin-Chiaramonti et al., 2002).

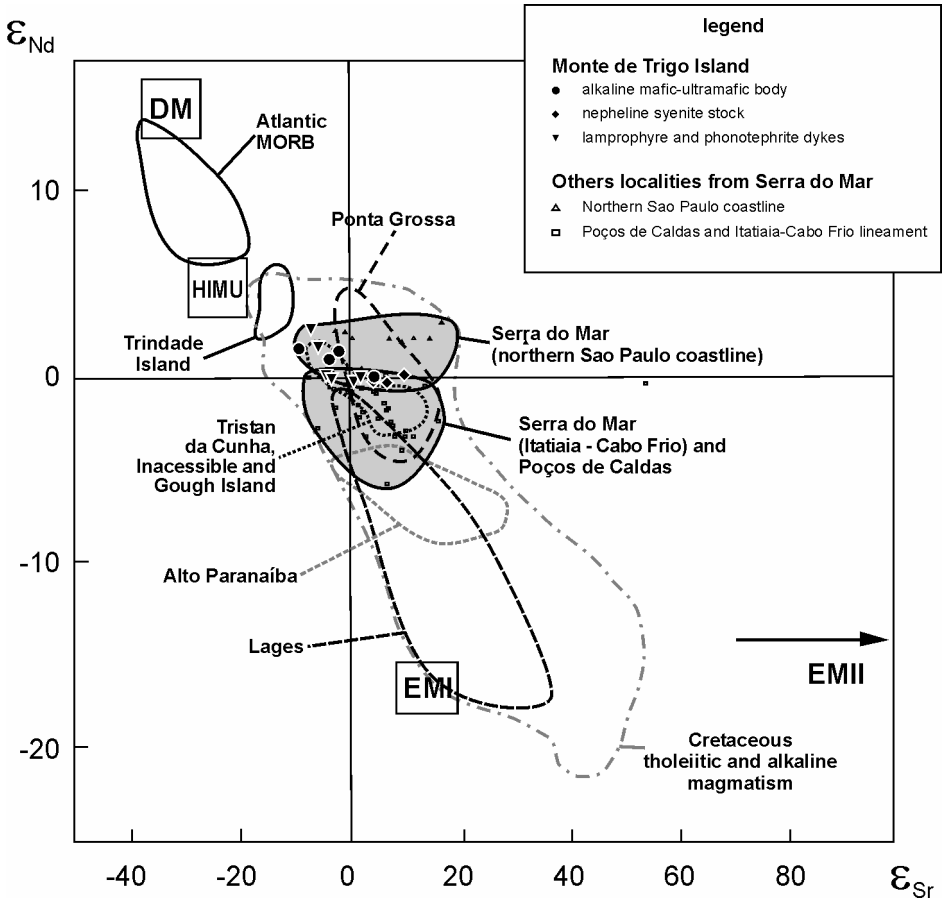

Figure 2. Time-integrated, ε notations, $^{87}Sr/^{86}Sr$ (εSr) *vs* $^{144}Nd/^{143}Nd$ (εNd) diagram of alkaline rocks from the Monte de Trigo Island, together with fields of the Serra do Mar Alkaline Province, nearby provinces and the overall Early to Late Cretaceous magmatism from Paraná-Angola-Etenkeda Province. According to Enrich (2005) and references therein.

ε_{Nd} values vary between 1.05 and 1.62 for olivine clinopyroxenite, nepheline-bearing olivine gabbro and olivine gabbro, while associated nepheline monzosyenite has an ε_{Nd} of 0.15. The nepheline syenitic stock has ε_{Nd} between -0.56 and 0.12, somewhat lower than those of mafic/ultramafic body. The dyke suite presents a limited variation of ε_{Nd}, with values between -0.11 and 0.13, except for two mafic dykes presented by Thompson *et al.* (1998) whose values are 1.72 and 2.69.

DISCUSSION

ε_{Sr} *vs.* ε_{Nd} diagram

The Cretaceous tholeiitic and alkaline magmatism of South American platform follows a well-defined Sr-Nd isotopic trend (Fig. 2), comprising EMI and HIMU mantle components (Comin-Chiaramonti *et al.*, 2005 and references therein). This isotopic signature has been interpreted as originated from a heterogeneous subcontinental lithospheric mantle, with different enrichment degrees (Gibson *et al.,* 1995; Comin-Chiaramonti *et al.,* 1997, 1999; Thompson *et al.,* 1998; Alberti *et al.,* 1999). As pointed out by Comin-Chiaramonti *et al.* (2005), Pb isotopes also support these considerations. On the other hand, Garda *et al.* (1995) and Thompson *et al.* (1998) also suggest the influence of asthenospheric mantle melts in the genesis of some occurrences of the Serra do Mar Alkaline Province that have Sr-Nd isotopic compositions near the *Bulk Earth* component, or even in depleted quadrant (toward DM).

Serra do Mar Alkaline Province isotopic data (Fig. 2) presents an intermediate Sr and Nd isotopic signature between EMI and HIMU (or EMI and DM), close to the *Bulk Earth* composition. As compared with nearby alkaline provinces, this one shows a great similarity with the Ponta Grossa Arch signature, and more depleted than those of the Alto Paranaíba and Lages.

It should also be pointed out that most of Serra do Mar occurrences show isotopic variations similar to those of the Tristan da Cunha, Gough and Inacessible islands. However, when compared to the Trindade Island, they have more enriched characteristics.

Moreover, there is a clear distinction in ε_{Nd} between occurrences along the Itatiaia-Cabo Frio lineament (including Poços de Caldas massif) and those from northern São Paulo coastline, plotting in enriched and depleted quadrant, respectively. This difference could be associated with a heterogeneous lithospheric mantle in regional scale.

The Monte de Trigo Island isotopic Sr-Nd signature is coherent with the variation observed in other alkaline

bodies from northern São Paulo state coastline (Fig. 2), with greater variation in ε_{Sr} than in ε_{Nd}.

The mafic lithologies of the island (olivine gabbro, nepheline-bearing olivine gabbro, olivine clinopyroxenite and lamprophyres) occupy the depleted quadrant in Figure 2, while more felsic varieties (nepheline monzosyenite, nepheline-bearing syenite, nepheline syenite and phonolite) present near-zero ε_{Nd} and positive ε_{Sr}.

Incompatible elements ratios in Monte de Trigo Island also indicate a heterogeneous character of the mantle source and confirm the signature between EMI e HIMU components (Enrich, 2005). The hypothesis of an asthenospheric component such as depleted mantle (DM), as suggested by Garda *et al.* (1995) and Thompson *et al.* (1998) based on initial Sr and Nd isotopic data, is not supported by these ratios.

Nd model ages (T_{DM})

Nd model ages (T_{DM}) for the Meso-Cenozoic Paraná-Etedenka toleiitic magmatism and surrounding alkaline magmatism range from 550 to 1600 Ma (Gibson *et al.,* 1995; Comin-Chiaramonti *et al.,* 1997, 1999, 2005; Alberti *et al.,* 1999; Ruberti *et al.*, 2005). These ages are interpreted as representative of the period of metassomatic mantle enrichment events. The nature of these events, as pointed out by Ruberti *et al.* (2005), could be related either to subduction processes, or to small fractions of asthenospheric fusions enriched in volatiles phases, setting up veins in the upper lithospheric mantle at different depths. It should be noted that the preservation of these events only occurs in the lithospheric mantle, where they are protected from asthenospheric convection (Fitton and Upton, 1987).

T_{DM} calculated from the Monte de Trigo Island Nd data ranges from 480 to 830 Ma, with mean value and standard deviation of 650±100 Ma. These T_{DM} are comparable with those of Poços de Caldas Massif (Ulbrich *et al.*, 2003) and São Sebastião Island (Enrich *et al.*, 2005) and somewhat younger than other Serra do Mar Alkaline Province occurrences (800±50 Ma, Brotzu *et al.*, 2005; Enrich *et al.*, 2005).

However, the above model age is strongly correlated with the $f_{Sm/Nd}$ (difference of Sm/Nd ratio as compared with chondrite ratio), varying between -0.28 and -0.58, which suggests a heterogeneous lithospheric mantle as magma source. De Paolo (1988) points out that subcontinental lithospheric mantle shares various genetic characteristics with the crust, but differs from the last one by more variable Sm/Nd ratios. He considers that the lithosphere structure could be (1) similar to the crust, with ε_{Nd} values much more negatives and proportional to the age, or (2) could vary between a positive value and a lower limit near the mean value of the upper crust.

Monte de Trigo Island T_{DM} variation range, like the other Serra do Mar Alkaline Province occurrences, is correlated with Neoproterozoic events of their host rocks. In this region, the evolution of continental crust over the lithospheric mantle that originated the alkaline magmas, *i.e.* Província Mantiqueira, is characterized according to Heilbron *et al.* (2004) by: (1) *rift* basins evolving to a passive continental margin between 930 and 880 Ma; (2) oceanic opening between 840 and 800 Ma; (3) generation of intra-oceanic magmatic arcs and active continental margin arcs between 790 and 585 Ma; (4) and collisional orogenetic events between 630 and 520 Ma.

FINAL REMARKS

The model age obtained from the Monte de Trigo Island Alkaline Suite data associated with the evolution of the upper crust in this region suggests the existence of a mantle metassomatism linked to Neoproterozoic subduction events (magmatic arcs). This way, EMI and HIMU isotopic signatures are interpreted as resulting from dehydratation residues (through the formation of calc-alkaline magmas) of a subducted and recycled oceanic crust, either with or without the addition of pelagic marine sediments, respectively (Weaver, 1991; Holfmann, 1997).

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RESUMO

Dados isotópicos de Sr e Nd foram determinados para as rochas da suite alcalina da Ilha Monte de Trigo, um centro intrusivo Cretaceo pertencente à Província Alcalina Serra do Mar, no sudeste do Brasil. Os dados $^{87}Sr/^{86}Sr$ e $^{143}Nd/^{144}Nd$ indicam uma assinatura do manto litosférico do tipo EMI-HIMU. Esta assinatura é consistente com as demais ocorrências da mesma província. As idades modelo de Nd para o manto empobrecido (T_{DM}) de aproximadamente 650 Ma para as rochas da Ilha Monte de Trigo indicam um manto enriquecido metassomaticamente durante eventos registrados no embasamento Neoproterozóico.