Re-Os pattern of High-Ti Paraná flood Basalts, Brazil: preliminary inferences on their mantle sources

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Abstract
The Urubici, Pitanga and Paranapanema-types, high-Ti, flood basalts of the Paraná Basin, Brazil, represent some of the least contaminated groups in the region being appropriated for investigations about their mantle sources. Re-Os analysis of different fractions of the same whole rock powders from one sample representative of each type (HI-34, Urubici; KNJ-161, Pitanga, and PU-1098 Paranapanema) exhibits a spread in Re and Os concentrations as well as Re/Os ratios and indicate that HI-34 and KNJ-161 samples are of the same age and derived from the same source reservoir, within error. PU-1098, however exhibits elevated $^{187}Os/^{188}Os$ ratios for given values of Re/Os and while likely the same age as the other samples, may have been derived from a more enriched, crustally contaminated source. Together, HI-34 and KNJ-161 samples yield an age of approximately 131 Ma, consistent with other isotopic systems, and close to the age of maximum eruption rates within the Parana Basin. An initial $^{187}Os/^{188}Os$ ratio of approximately 0.133 for these two samples can be the result of a Sub-Continental Lithospheric Mantle (SCLM) or Medium Ocean Ridge Basalts (MORB) derived magma contaminated by less than 2% of a crustal component, or by direct derivation from an Ocean Island Basalt (OIB) mantle source.
Keywords: Re-Os, Flood basalt, Paraná Basin, Geochemistry, Geochronology

Resumo
Os basaltos de alto-Ti dos subgrupos Uribici, Pitanga e Paranapanema, correspondem aos termos menos contaminados da província do Paraná, no Brasil, sendo apropriados para estudos a propósito de suas fontes mantélicas. Análises Re-Os de diferentes frações dos mesmos pós de rocha total de preparados a partir de uma amostra representativa de cada tipo (HI-34, Urubici; KNJ-161, Pitanga, and PU-1098 Paranapanema) exibem distribuição nas concentrações de Re e Os, assim como razões Re/Os, que indicam a mesma idade e derivação a partir do mesmo reservatório para as amostras HI-34 e KNJ-161. Entretanto, os resultados para a amostra PU-1098, revelam razões $^{187}Os/^{188}Os$ mais elevadas para valores correspondentes de Re/Os. Embora sua distribuição em diagrama isocrônico indique idade equivalente às demais, elas podem ter se derivado de uma fonte mais enriquecida ou mais contaminada por componentes crustais. Juntas, as amostras HI-34 and KNJ-161 fornecem uma idade de 131 Ma, consistente com as indicadas por outros sistemas isotópicos e compatíveis com o período de maiores taxas de erupção dos basaltos da bacia. A razão inicial $^{187}Os/^{188}Os$ de aproximadamente 0.133 para essas duas amostras pode resultar de magmas derivados do Manto Sub-Litosférico Continental (SCLM) ou de fontes dos Basaltos das Dorsais Meso-Oceânicas (MORB), contaminados por menos de 2% de componente crustal, ou por derivação direta a partir de uma fonte mantélica compatível com a dos Basaltos de Ilhas Oceânicas (OIB).
Palavras-chave: Re-Os, Basalto continental, Bacia do Paraná, Geoquímica, Geocronologia

1. Geology

The Paraná-Etendeka continental flood basalt province is constituted in South America (PFB) by the Serra Geral formation and associated intrusive rocks (dikes and sills) that together cover approximately 75% of the superficial area of the Paraná Basin (~ 1.2 x 106 km^2) with a volume of ~$8x10^5$ Km^3. Its effusive basic magmatism of tholeitiic composition is the result of partial fusion of one or more mantle sources. The clear temporal correlation

between the formation of the PFB and the subsequent continental fragmentation has led researchers to try and establish causal relationships between the geodynamic processes involved, the related mantle sources, the emplacement of the province and the subsequent continental fragmentation.

$^{40}Ar/^{39}Ar$ radiometric ages reveal that volcanism occurred between 128-136 Ma (Renne et al., 1992; Ernesto et al., 1999 and Stewart et al., 1996), with a peak in magmatic output during ca. 3 Ma (134.8-131.5 Ma, Thiede e Vasconcelos, 2010; Janasi et al., 2011). On geochemical basis, Peate et al. (1992) divided these rocks into high- (ATi) and low-titanium (BTi) groups, with 2% marking an arbitrarily defined boundary. Based on other geochemical markers, these authors subdivided these two groups onto, respectively, the Urubici Pitanga and Paranapanema ATi subgroups, whereas the Gramado, Esmeralda and Ribeira, corresponds to the BTi subgroups (Fig. 1). According to Janasi et al. (2011), the main magmatic time interval for the older BTi bodies corresponds to 134.8-134.1Ma, while the younger ATi display peak ages between 133.6-131.5 Ma.

Picirillo et al. (1989) and Marques et al. (1999), among others, based on Sr, Nd and Pb isotope geochemistry, demonstrate that the BTI basalts better represented on the southern region of the PFB province were strongly affected by contamination processes, whereas the ATi subgroups, particularly, the Urubici lithotypes, also located within the south region, but restricted spatially, display Sr, Nd and Pb patterns that corresponds to the least contaminated basalts within the basin.

This work presents unpublished Re-Os results obtained on the high-Ti PFB which permit preliminary inferences about the nature of its mantle sources.

2. Methodology, Results and Discussion

The studied samples display massive structure, grain size varying between very fine to aphanitic (vitric, HI-34) and fine to medium grained (KNJ-161 and PU-1098) and have chemistry correspondent to Urubici, Pitanga and Paranapanema subgroups, respectively. All Re-Os analyses were performed at the Centro de Pesquisas Geocronológicas do Igc-USP (CPGeo), according to methodology reported by Correia et al., (2007).

The data (Tab. 1) demonstrate that all samples have $^{187}Re/^{188}Os$ ratios that vary significantly between aliquots analyzed, likely as a result of the aforementioned “nugget effect”. The resulting Re-Os isochron information indicates that both HI-34 and KNJ-161 samples are the same age and from the same source-reservoir within errors, resulting an isochron of 130.7±1.9 Ma (n=10, MSWD of 18), with an initial Os composition of $^{187}Os/^{188}Os$ of 0.1329±0.0037. The Paranapanema basalt PU-1098 sample in contrast does not lie on the above mentioned isochron trend, but rather parallel and at higher $^{187}Os/^{188}Os$ values for a

given $^{187}Re/^{188}Os$ ratio. While not an extreme displacement, the resulting difference in initial Os isotopic composition at 130 Ma is significant and may indicate a more crustal contamination or the contribution of a different mantle source.

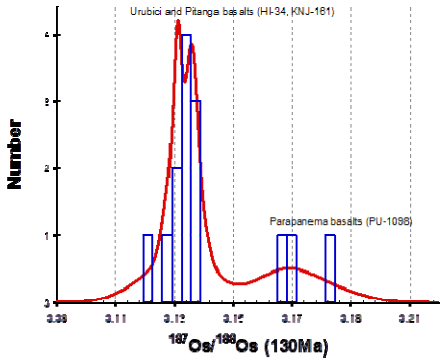

Figure 1 - Difference in initial Os isotopic composition at 130 Ma among the analyzed samples.

The initial $^{187}Os/^{188}Os$ of 0.1329±0.0037 at 131 Ma for the combined KNJ-161 and HI-34 isochron shows a strong correlation with average values of $^{187}Os/^{188}Os$ of non-crustaly contaminated basalts of the OIB-type (0.129-0.145, Widon, 1997) and are at the lower limit of the range of MORB-type Basalts (present day values: $^{187}Re/^{188}Os$ = 0.4353, and $^{187}Os/^{188}Os$ of 0.1296, Meisel et al., 2001).

As a result of extremely low Re/Os ratios, SCLM, and basalts derived solely from them, would likely have $^{187}Os/^{188}Os$ ratios significantly lower than the initial one here reported. Modeling using Meisel et al., 2001 values for the mantle Re/Os ratios of ~0, and assuming ages between 2.1 and 0.6 Ga, the SCLM in the vicinity of the Paraná Basin would likely have $^{187}Os/^{188}Os$ values between 0.114-0.125. Assuming contamination with contemporaneous early or late Proterozoic continental crust (~$^{187}Re/^{188}Os$=50, Os=50ppt, Esser and Turekian, 1993), an approximately 1-2% addition of continental material to a SCLM-derived basaltic magma at 131 Ma could produce the pattern of the ATi initial $^{187}Os/^{188}Os$ ratio of 0.1329 within errors.

Therefore, the presented Os data supports an origin of High-Ti Paraná flood Basalts by either an unmodified OIB like source or solely by SCLM or MORB derivation with subsequent modification by additions of small percentages of continental crust or OIB-source mantle.

In order to provide clearer insight into the nature of the source and/or the petrogenetic processes responsible for the reported Re/Os isotopic pattern and the observed heterogeneity related to the Paranapanema PU-1098 sample results, it will be necessary more data, including analyses of the BTi subgroups.

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Table 1 – Re-Os results for different aliquots of samples HI-34, KNJ-161, and PU-1098. All samples are whole rock analyses unless noted (* = whole rock with bulk of magnetite removed)

Sample	Location	Re (ppb)	Os (ppb)	Common Os (ppb)	$^{187}Re/^{188}Os$	$^{187}Os/^{188}Os$
HI-34	26.381^{0}S - 51.255^{0}W	0.556	0.0437	0.0429	63.33±0.63	0.2708±0.0029
Duplicate		0.529	0.0720	0.0711	35.82±0.36	0.2139±0.0006
Duplicate		0.529	0.0593	0.0585	43.57±0.44	0.2295±0.0011
Duplicate		0.529	0.0482	0.0474	53.75±0.54	0.2551±0.0024
Duplicate		0.530	0.0496	0.0488	52.30±0.52	0.2414±0.0010
Duplicate		0.532	0.0489	0.0482	53.31±0.53	0.2472±0.0013
Duplicate		0.532	0.1024	0.1017	25.23±0.25	0.1856±0.0005
KNJ-161	26.011^{0}S - 51.657^{0}W	0.732	0.0180	0.0170	208.5±2.1	0.5844±0.0031
Duplicate		0.733	0.0147	0.0136	260.1±2.6	0.7017±0.0018
Duplicate		0.734	0.0151	0.0141	251.9±2.5	0.6797±0.0031
*Duplicate		0.633	0.0145	0.0136	221.3±2.2	0.6022±0.0022
PU-1098	24.370^{0}S - 51.669^{0}W	0.885	0.0231	0.0218	195.9±2.0	0.5897±0.0021
Duplicate		0.873	0.0194	0.0180	233.3±2.3	0.6883±0.0010
Duplicate		0.875	0.0219	0.0205	205.4±2.1	06147±0.0009

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