MANTLE XENOLITHS AND NEW CONSTRAINTS ON THE ORIGIN OF ALKALINE ULTRAPOTASSIC ROCKS FROM THE ALTO PARANAÍBA AND GOIÁS IGNEOUS PROVINCES, BRAZIL

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INTRODUCTION

The Alto Paranaíba and Goiás Alkaline Provinces, located in southern Brazil (**Figure 1**) are composed mainly by kamafugites (Danni & Gaspar 1994; Sgarbi et al. 1995; Gibson et al. 1995; Sgarbi 1998; Araujo et al. 2001a, 2001b). In the Alto Paranaíba Province the kamafugites are associated with kimberlites (Araujo et al. 2001a) and carbonatites (Brod et al. 2000).

The Alto Paranaíba Province magmas intruded the Neoproterozoic Brasília Mobile Belt, while the Goiás Province is located in the limit between the Brasília Belt and the Paraná Basin. Some recent works have proposed to group the two provinces under the designation of "Minas Gerais-Goiás Province", including all the respective alkaline occurrences. However, the nature and the relationship between the provinces have not been studied in enough detail yet. In this work, we present new geochemical and isotopic data that point to different lithospheric mantle sources and different evolution processes, arguing against the unification of the two provinces. Araujo et al. (2001a) identified, on the basis of Re-Os isotopic composition, different mantle sources for kimberlites and kamafugites of the Alto Paranaíba Province. The chemistry and thermobarometry of low-T spinel and garnet peridotite xenoliths from the Alto Paranaíba Province were initially studied by Carvalho (1997). Danni et al. (1994) presented thermobarometric data (ca. 850^{o}C, 14 kb) for the garnet spinel peridotites from the Paraúna area, in the Goiás Province.

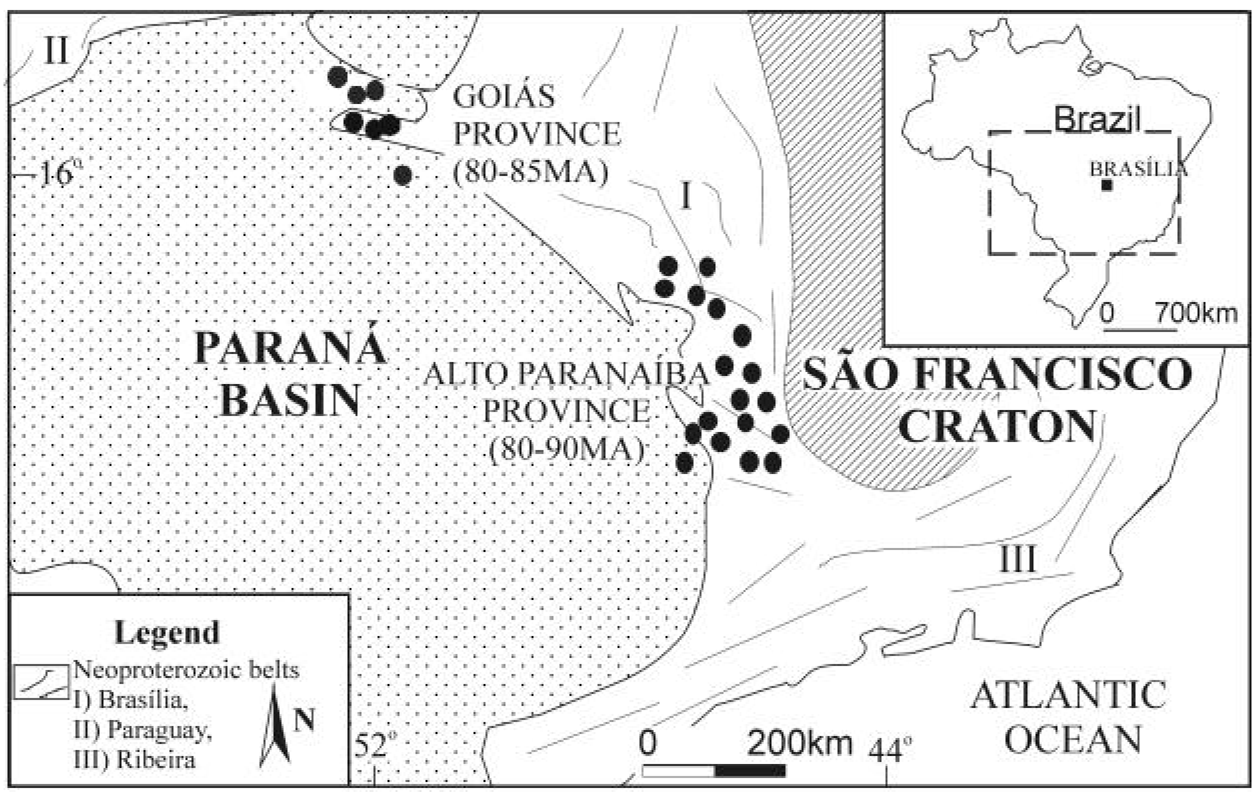

Fig. 1: Location of Alto Paranaíba and Goiás Province. Modified from Gibson *et al.* 1995.

The Alto Paranaíba garnet and spinel lherzolite xenoliths are small (4-6 cm), medium- to coarse-grained, and show a slightly strained texture. The Paraúna spinel lherzolite xenoliths are small (up to 7 cm), coarse-grained, and have polygonal texture. All samples correspond to low-temperature peridotites (Carvalho 1997; Danni et al. 1994).

ANALYTICAL PROCEDURES

The xenoliths were manually and carefully separated from the host rock (kimberlites and kamafugites) and crushed into an alumina vessel. Aliquots from the powdered sample were separated for major element analyses, carried out by ICP spectrometry, and for determination of the Re-Os isotopic composition, by negative thermal ionization mass spectrometry. Procedures for Re-Os separation follow Carlson et al. (1999). Rb, Sr, Sm, and Nd compositions of kamafugites were determined by MC-ICP-MS and TIMS as described by Araujo et al. (2001). All isotope analyses were carried out at the Carnegie Institution of Washington.

GEOCHEMISTRY

Table 1 shows some representative major and trace element analyses of the studied spinel and garnet peridotites.

MAJOR ELEMENTS

The Alto Paranaíba peridotite xenoliths exhibit high MgO content (mg# = 89-91) and low Al_2O_3, CaO and Na_2O, when compared with Paraúna peridotite xenoliths (**Figure 2**). In the Paraúna peridotite xenoliths (mg# roughly constant around 89), the very high Al, Ca, Na and Ti oxide contents could be indicative of metasomatic introduction of these elements. FeO and Cr contents are similar in both xenolith groups (ca. 8.0wt% and 2500ppm, respectively). The TiO_2 contents vary from 0.09-0.24wt% in the Alto Paranaíba xenoliths and from 0.15-3.17wt% in the Paraúna xenoliths.

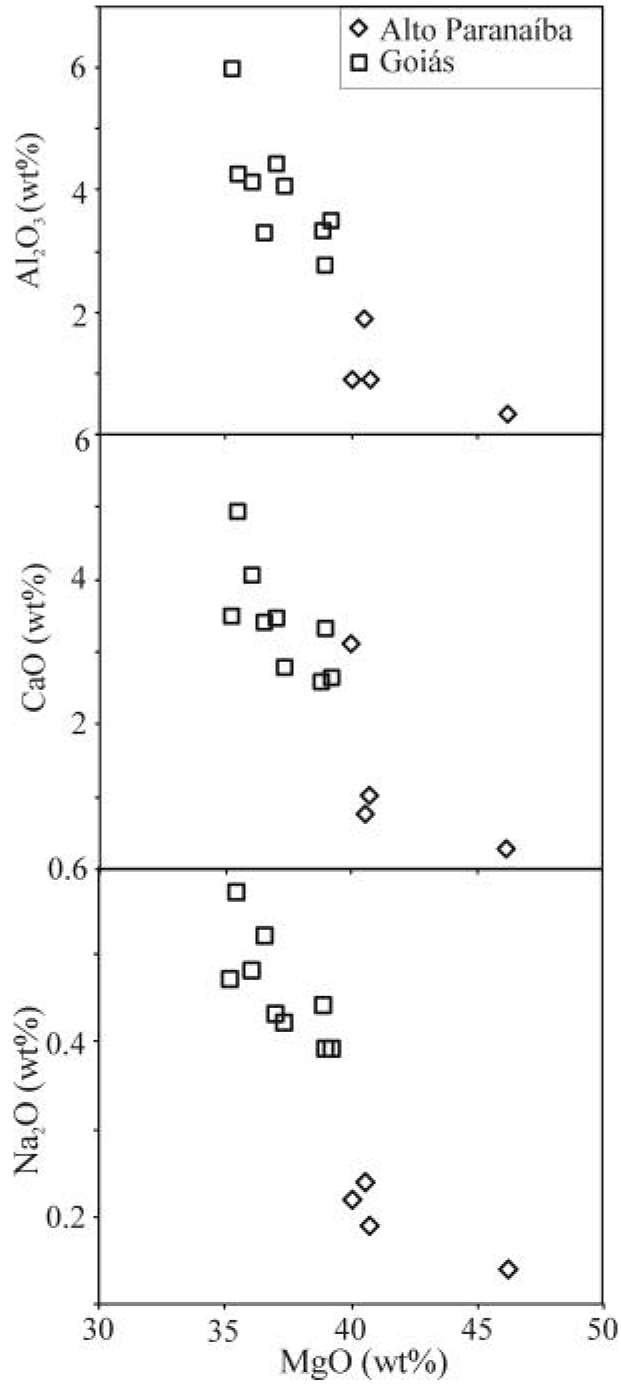

Figure 2: Major elements variation diagrams for the Alto Paranaíba and Goiás (Paraúna) peridotite xenolhits.

ISOTOPIC COMPOSITIONS

Re-Os isotopes in mantle xenoliths

Tables 1 and **2** summarize the isotopic data obtained in this work.

The Alto Paranaíba garnet and spinel lherzolite xenoliths have very low $^{188}Os/^{187}Os$ ratios (0.109 to 0.115, **Figure 3**), similar to those of ancient lithospheric peridotites from Kaapvaal, Wyoming and Siberian cratons (Carlson and Irvinig 1994; Pearson et al. 1995; Carlson et al. 1998), and yield Re-depletion model ages varying from 1.9 to 2.7 Ga. This indicates the presence of Paleoproterozoic/Archean lithosphere underneath the Neoproterozoic Brasília Mobile belt, where the kimberlites intruded. The spinel lherzolites from Goiás Province (Paraúna) show two different $^{188}Os/^{187}Os$ groups (**Figure 3**). One has $^{188}Os/^{187}Os$ between 0.121 and 0.122, with Re-depletion model ages ranging from 1.0 to 1.2 Ma. The second group has very high $^{188}Os/^{187}Os$ (between 0.126 and 0.129), similar to those observed in younger rift-related spinel peridotites (Meisel et al. 1996).

Isotopic composition of kamafugites and kimberlites

The Santo Antônio da Barra kamafugites, in the Goiás Province, have Sr and Nd isotope signatures which completely overlap those observed for the Tristan/ Walvis Ridge and for the high-Ti Paraná basalts (**Figure 4**). The Alto Paranaíba kamafugites have Pb isotopic signatures overlapping the Tristan/ Walvis Ridge basalts, but their Sr and Nd isotopic ratios are slightly more enriched (Araujo et al. 2001). The $^{188}Os/^{187}Os$ in kamafugites of the Goiás Province are higher (ca. 0.15) than those of the Alto Paranaíba kamafugites (ca. 0.13), probably indicating that their sources were subjected to different evolution process.

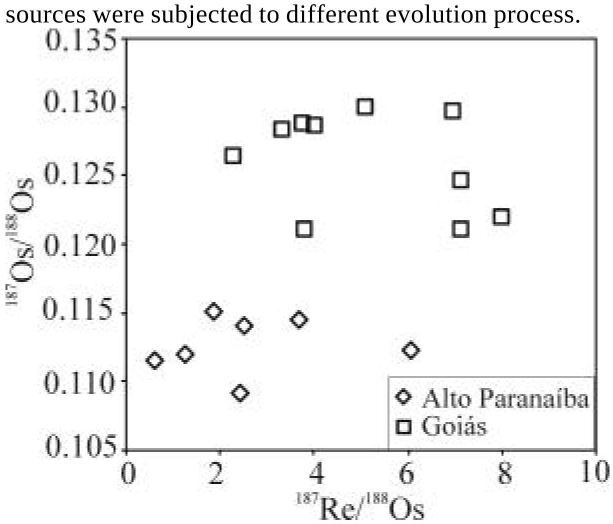

Figure 3: $^{187}Re/^{188}Os$ *versus* $^{187}Os/^{188}Os$ isotopic composition for the Alto Paranaíba and Goiás (Paraúna) peridotites

The Pb, Sr, and Nd signatures of kimberlites from the Alto Paranaíba Province are intermediate between the fields of South African kimberlites and orangeites, partially overlapping the former (Araujo et al. 2001).

DISCUSSION

In spite of their geographical proximity and lithologic similarities, the Alto Paranaíba and Goiás provinces, show isotopic differences that are difficult to reconcile with a single origin and evolution. The lithosphere under the Alto Paranaíba Province contains a Re-Os signature that is similar to ancient cratonic lithosphere, whereas the isotopic signature of peridotite xenoliths in the Goiás Province indicates a younger lithosphere. Furthermore, kamafugites from Alto Paranaíba and Goiás Provinces show differences in $^{187}Os/^{188}Os$, which could be indicating independent evolution of their respective mantle sources.

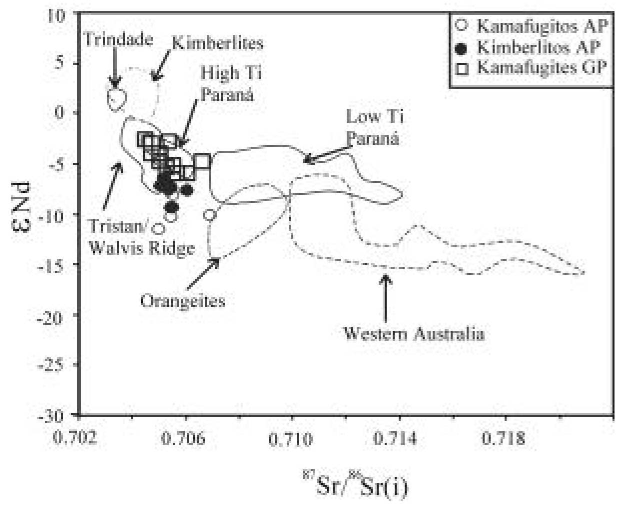

Figure 4 : ε_{Nd} *versus* $^{87}Sr/^{86}Sr$ variation diagram. Kamafugites and kimberlites from the Alto Paranaíba Alkaline Province from Araujo *et al*. (2001), Kimberlites and orangeites fields from Mitchell (1995), Paraná basalts from Hawkeswork *et al*. (1988), Mantovani *et al*. (1985), and Piccirillo *et al*. (1989), and Tristan da Cunha from O'Nions *et al*. (1977).

The occurrence of Paleoproterozoic to Archean Re-depletion model ages in peridotite xenoliths of the Alto Paranaíba Province indicates that at least some of the lithosphere underneath is composed of preserved remnants of the São Francisco Craton.

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Table 1: Major and Re-Os representative analyses of mantle xenoliths from Alto Paranaíba and Goiás Province (Paraúna region).

Location	Alto Paranaíba xenolhits				Paraúna xenoliths			
Type	gr-lherzoliths			Sp-lherz.	Sp-lherzolits			
Sample	AP-2	AP-3	AP-6	AP-8	IP-1	IP-2	IP-5	IP-9
SiO_2	43,23	38,89	41,03	39,75	44,18	43,54	43,07	43,98
TiO_2	0,09	0,12	0,2	0,24	0,18	0,19	0,15	0,2
Al_2O_3	1,88	0,34	0,9	0,91	4,4	2,74	3,49	4,1
Fe_2O_3	1,3	1,04	1,67	1,64	1,81	1,82	1,61	1,73
FeO	5,54	7,18	6,45	10,25	6,64	6,76	7,08	6,36
MnO	0,12	0,12	0,15	0,19	0,15	0,14	0,15	0,15
MgO	40,55	46,21	40,74	40	37,05	39	39,26	36,1
CaO	0,76	0,28	1,03	3,12	3,46	3,3	2,64	4,05
Na_2O	0,24	0,14	0,19	0,22	0,43	0,39	0,39	0,48
K_2O	1,19	0,13	0,89	0,13	0,07	0,15	0,17	0,16
P_2O_5	0,03	0,05	0,05	0,18	0,03	0,04	0,05	0,04
PF	4,23	4,94	5,82	2,67	1,23	1,87	1,87	2,4
Total	99,16	99,44	99,12	99,3	99,63	99,94	99,54	99,75
Ni	2390	3115	2545	2685	2295	2600	2365	2025
Cr	6200	202	2745	1445	2465	1470	1710	2405
#*Mg*	91	91	90	89	89	89	89	89
Re(ppt)	1005	3278	2060	1565	1038	3363	3077	3181
Os(ppt)	8126	2608	4087	2983	1241	2023	2076	3007
$^{187}Re/^{188}Os$	0,595	6,046	2,423	2,524	4,031	8,007	7,136	5,101
$^{187}Os/^{188}Os$	0,11157	0,11228	0,10915	0,11411	0,12866	0,12186	0,12097	0,12993
$^{187}Os/^{188}Os(i)$	0,11073	0,10371	0,10572	0,11053	0,12295	0,11051	0,11086	0,12270
$\gamma Os(i)$	-13,6	-19,0	-17,5	-13,7	-4,0	-13,7	-13,5	-4,2
T_{RD}(Ga)	2,4	2,3	2,7	2,0	-	1,0	1,1	-

Table 2: Isotopic representative analyses of kamafugites from Goiás Province

Location	Santo Antônio da Barra			Paraúna	
Sample	SAB-2	SAB-5	SAB-6	IPK-3	IPK-4
Rb(ppm)	239	39,71	106,7	58,68	68,90
Sr(ppm)	1136	1199	1429	1659	1353
$^{87}Rb/^{86}Sr$	0,6077	0,0958	0,2159	0,1023	0,1473
$^{87}Sr/^{86}Sr$	0,705526	0,704986	0,705406	0,705048	0,705039
$^{87}Sr/^{86}Sr(i)$	0,704792	0,704870	0,705145	0,704924	0,704861
Sm(ppm)	16,48	10,42	15,93	17,03	16,60
Nd(ppm)	82,49	68,16	100,39	105,61	102,89
$^{147}Sm/^{144}Nd$	0,1207	0,0924	0,0959	0,0975	0,0975
$^{143}Nd/^{144}Nd$0,512356	0,512443	0,512481	0,512420	0,512377	
$^{1433}Nd/^{144}Nd(i)$	0,512289	0,512392	0,512428	0,512366	0,512323
$\varepsilon_{Nd}(i)$	-5	-3	-2	-3	-4
T_{Dm}(Ga)	1,36	0,94	0,92	1,01	1,07
Re(ppt)	-	51	230	873	248
Os(ppt)	-	5713	3723	8696	12462
$^{187}Re/^{188}Os$	-	0,043	0,298	0,486	0,096
$^{187}Os/^{188}Os$	-	0,14523	0,14568	0,15875	0,14256
$^{187}Os/^{188}Os(i)$	-	0,14517	0,14526	0,15806	0,14242
$\gamma_{Os}(i)$	-	13,325793	13,394649	-	11,182862
T_{RD}(Ga)	-	-2,3762076	-2,3891907	-	-1,9735461