PERIDOTITE AND ECLOGITE XENOLITHS FROM THE JUÍNA KIMBERLITE PROVINCE, BRAZIL.

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ABSTRACT

The study of mantle xenoliths found in kimberlites (petrography, mineral chemistry and Sm-Nd data) showed that the mantle underneath the Juína Province is very heterogeneous and mainly composed of peridotite, piroxenite and eclogite. In many xenoliths the primary minerals are partially to completely replaced by secondary silica. Granular peridotites are the most abundant xenoliths but also the most altered to silica. Peridotites contain low-MgO clinopyroxene and low-Cr_2O_3 garnet compared to sheared peridotites. Granular peridotites present equilibration temperatures from 856 to 1237^oC and pressures from 56 to 67 kbar. Their ε_{Nd} values vary from -8.47 to -11.31 and model ages from 1884 to 1114 Ma. Sheared peridotites contain high-MgO garnets with low Al_2O_3 contents. Their equilibration temperatures and pressures vary, respectively, from 999 to 1361^oC and 51 to 59 kbar. One sheared peridotite presented ε_{Nd} = -3.24 and a model age of 1242 Ma. Eclogite xenoliths are less abundant and can be classified in three groups: 1) orthopyroxene - rutile eclogites, 2) bi-mineralic eclogites and 3) sanidine - coesite eclogites. It could be observed that from group 1 to group 3 there is an increase in modal garnet, grossular end-member content in garnet and Al_2O_3 in clinopyroxene. ε_{Nd} for eclogite xenoliths vary from +0,16 to -13,03 and one reference isochron age of ca. 1.6 Ga. The data suggest that granular peridotites and eclogites may represent portions of Precambrian subducted oceanic slabs.

INTRODUCTION

Peridotites, pyroxenites and eclogites are the main constituents of the continental mantle underneath Archean cratons and Proterozoic mobile belts. In the Juína kimberlites, nodules of peridotite, pyroxenite, eclogite, and M.A.R.I.D, as well as megacrysts and crustal xenoliths as basalts, gabbros, troctolites and metamorphosed granites and marbles were found (Costa & Gaspar, 2001).

The occurrence of diamond inclusions in the Juína Province (São Luiz river) indicating equilibration conditions characteristic of the Transition Zone and Lower Mantle (e.g. Hutchison, 1997) has drawn international attention to this province.

The present work deals with petrography, mineral chemistry and Sm-Nd isotopic analyses of the most important mantle xenoliths recovered from four drill hole cores completely dismantled for this purpose.

JUÍNA KIMBERLITES

The Juína Kimberlite Province (JPK) (~95 Ma) is located in the southwestern border of the Amazon Craton with the majority of intrusions emplaced into the Permo-Carboniferous sedimentary rocks of the Fazenda da Casa Branca Formation (Parecis Basin). Other kimberlites, however, intruded the regional granite-gneiss basement (Fig. 1), specifically the Rio Negro - Juruena belt (1.7 – 1.8Ga) (Tassinari & Macambira, 1999).

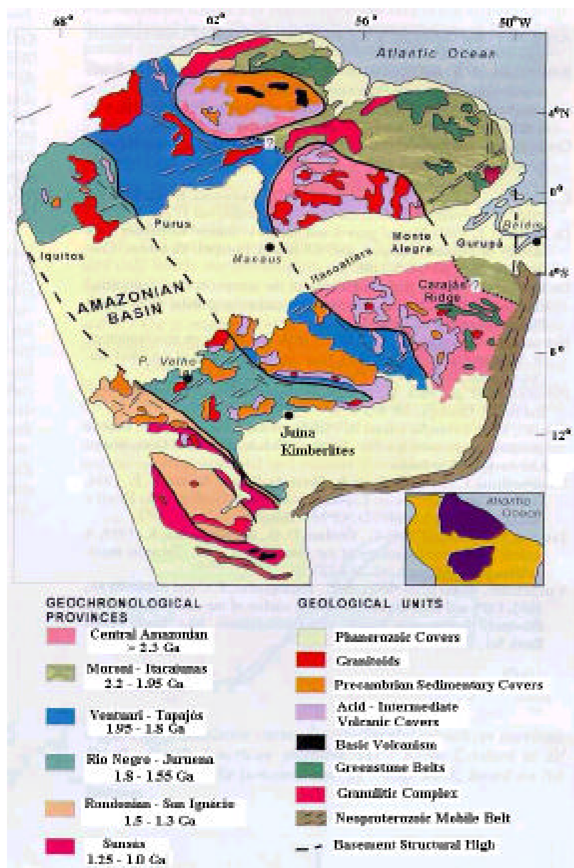

Figure 1: Schematic map showing the distribution of geochronological provinces and the main associated lithological units of the Amazon Craton (Tassinari & Macambira, 1999). See also the location of the Juína Kimberlite Provinve.

Twenty three maars were identified so far, which are mostly composed of pyroclastic rocks, hydroclastic tephras, volcaniclastic deposits and lens of sedimentary rocks containing some volcanogenic material (Teixeira *et al*. 1998). U-Pb dating on mantle zircons from the kimberlites by Heaman *et al*. (1998) gave a Cenomanian age between 91.6 to 94.6 Ma.

Analytical Procedures

Quantitative mineral analyses for major and minor elements were performed in a Cameca SX-50 electron microprobe at the Universidade de Brasília. Operating conditions for mosto of the analyses were 15kV and 25 nA and a general counting time of 10s for each element. Data were corrected by the PAP Cameca software.

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Nd isotopic analyses were carried out in static mode using a multicollector Finnigan MAT 262 mass spectrometer, at the Geochronology Laboratory of the University of Brasília. Chemical separation of Sm and Nd used conventional cation exchange techniques similar to those described by Richard *et al*.(1976), with separation of the REE as a group in a AG X12 column, followed by reverse phase chromatography for the purification of Sm and Nd.

$^{143}Nd/^{144}Nd$ ratios were normalized using $^{146}Nd/^{144}Nd$ = 0,7219 and the decay constant used is $6{,}54\times10^{-12}$ y^{-1}. Uncertainties are approximately 0.004% (2σ) for $^{143}Nd/^{144}Nd$ ratios and ca. 0.05% for $^{147}Sm/^{144}Nd$.

Petrography and Mineral Chemistry

The peridotites and ecologites are classified as:

i) Granular Peridotites: These are coarse grained (2 - 3mm) with some local banding and are usually intensively silicified. In the majority of these xenoliths both olivine and orthopyroxene were completely replaced by criptocystalline silica. Some samples contain garnet ± spinel and two clinopyroxene; one is gray and is associated with spinel while the second is emerald green and is associated with garnet. Modal data indicate a preponderance of lherzolites, which contain low-Cr_2O_3 garnet and low-MgO clinopyroxene compared to sheared peridotites (Fig. 2).

ii) Sheared Peridotites: They are lherzolites, harzburgites and orthopyroxenites. The rocks are fine grained (1 – 2mm), present porphyroclastic to mosaic textures and no silicification. One of these xenoliths contains two domains with a sharp contact; one domain is composed of garnet peridotite and the other by garnet pyroxenite. In some peridotites garnet crystals host two-phase inclusions composed of clino- and orthopyroxene. Variation of mineral compositions are: olivine (Fo $_{90,67-91,30}$),, orthopyroxene (En $_{88,49-92,45}$), clinopyroxene (En $_{55,99-57,64}$; Wo $_{37,47-39,09}$) and garnet (Py $_{56,52-58,55}$; Uv $_{16,34-18,17}$).

iii) Eclogites: they are coarse grained (1 – 6mm) and composed of approximately 59% clinopyroxene and 26 to 27% garnet. Accessory minerals are dark-green spinel and sulfide blebs. Some clinopyroxene crystals exhibit exolution lamelae, which are very similar to another clinopyroxene composition. CaO content in garnet and Al_2O_3 in clinopyroxene are intermediate between the two other eclogite types (**Figure 2**). According to the clinopyroxene composition and following the Taylor & Neal (1989) classification, these eclogites belong to the group A (**Figure 3**).

iv) Orthopyroxene – rutile eclogite: These are inequigranular and coarse grained (5 – 9mm) and composed of 42 to 53% garnet, 43 to 55% clinopyroxene, 0.5 to 1% orthopyroxene and 2.6 to 3.7% rutile. The latter occurs as exsolution lamellae in garnet and clinopyroxene. These eclogites are chemically similar to peridotites except for the lower Cr_2O_3 and CaO contents in garnet (**Figure 2**). Despite the fact that rutile needles are typical of group B eclogites the orthopyroxene-rutile eclogite is chemically classified as belonging to the group A (**Figure 3**).

v) Sanidine – Coesite eclogites: These were found as small (1 – 2cm) light-gray to greenish nodules. Their modal compositions vary from 41 to 72% garnet, 9 to 36% clinopyroxene, 1 to 10% quartz – coesite and 1 to 2% sanidine. These eclogites are inequigranular and fine grained (~1 mm), sometimes granoblastic and contain rare garnet and clinopyroxene porphyroclasts (2 – 2.5 mm). Coesite is surrounded by a rim of inverted polycrystalline quartz and is usually intergranular and fine grained (~1mm). The sanidine-coesite eclogites contain CaO-rich garnet and Al_2O_3-rich clinopyroxene (**Figure 2**) and can be classified as belonging to the group B according to texture and chemical composition (**Figure 3**).

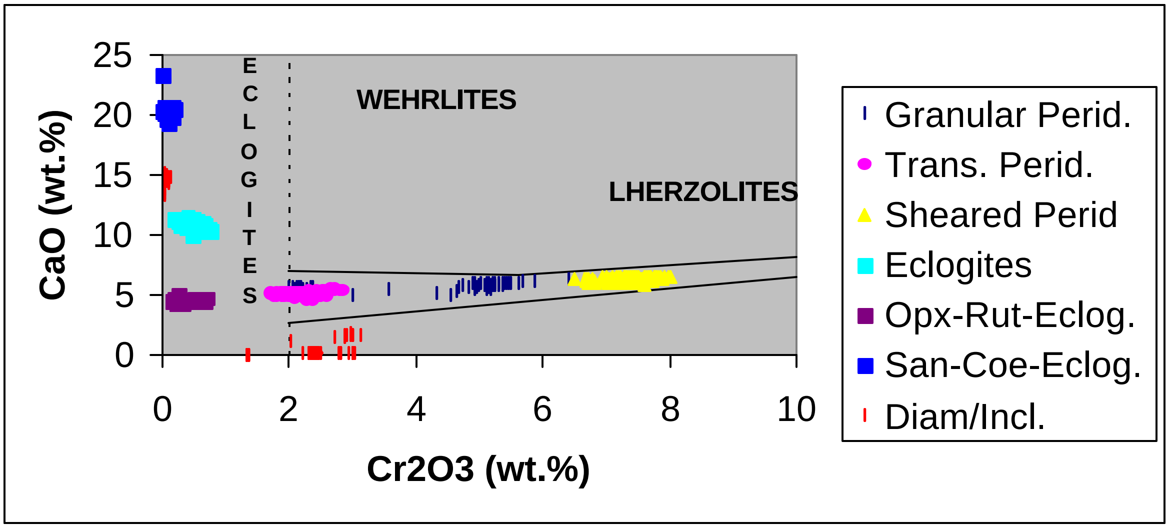

Figure 2 : CaO versus Cr_2O_3 in garnets from the Juína xenoliths. Granular Perid = granular peridotite; Trans. Perid. = transitional peridotite; Sheared Perid. = sheared peridotite; Eclogites; Opx-Rut-Eclog. = orthopyroxene – rutile eclogites; San-Coe-Eclog. = sanidine – coesite eclogites; Diam/Incl. = garnet included in diamond from Hutchison (1997).

Thermobarometry and Radiogenic Isotopes

The gothermometer of Ellis & Green (1979) and the geobarometer of Brey & Köhler (1990) were used in this work. For the granular peridotites calculated temperatures and pressures vary, respectively, from 856 to 1237°C and 56 to 67kbar. Their ε_{Nd} values are very negative ranging from –8.47 to –11.31, with Proterozoic model ages (T_{DM} from 1884 to 1114 Ma.). Sheared peridotites present equilibration temperatures from 999 to 1361°C and pressures from 51 to 59 kbar. ε_{Nd} for one sample is –3.24 and the T_{DM} is 1242 Ma. Eclogites gave 1182 to 1287°C as temperature interval, ε_{Nd} = –13.03 and a model age (T_{DM}) of 1593 Ma. Orthopyroxene – rutile eclogites present relatively low temperatures (712 – 941°C) and pressures between 47 and 50kbar. One whole rock isotopic composition gave ε_{Nd} = –0.10 and a T_{DM} age of 1648 Ma. Calculations for the sanidine – coesite eclogites resulted in high temperatures (1168 to 1428°C) and relatively low pressures (32 to 35 kbar). One xenolith presents ε_{Nd} of -4.47 and T_{DM} of 1166 Ma.

Discussion and Conclusions

Mantle xenoliths from the Juína Kimberlite Province are chemically and texturally similar to xenolith collections found in many other kimberlites elsewhere. Furthermore, they are similar to many rocks that occur in high-pressure metamorphic massives, as for example in Dora Maira (Alpes), among others. These massives are considered as fragments of oceanic or continental lithosphere subducted to depths greater than 100 km (Liou *et al*., 1998). The presence of sanidine – coesite eclogites, eclogite minerals with exsolution lamelae, garnet marble and sulfide dissemination in the rock matrix support a model involving the subduction of oceanic crust. The subduction of oceanic lithosphere during the Proterozoic (1,95 – 1,20 Ga) is admited as occurring in the evolution of some Amazon belts as the Venturari – Tapajós, Rio Negro – Juruena and Rondoniano – San Ignácio orogens, in successive magmatic arcs progressively younger to the west (Tassinari & Macambira, 1999).

A constant feature in the granular peridotites is the partial to complete replacement of their minerals by criptocrystalline quartz of unknown origin. We admit two possibilities:

i) Hydrothermal circulation in the final stages of the cooling history of the kimberlite magmas as described by Peltonen (1998) for some Finish kimberlites. The rock types and structures described by Teixeira *et al*. (1998) in the Juína kimberlite intrusions suggest the existence of lakes during the emplacement of these bodies, which supports the Peltonen (1998) model. According to this model, however, it is difficult to explain why not all xenolith types underwent alteration as well as the kimberlites themselves.

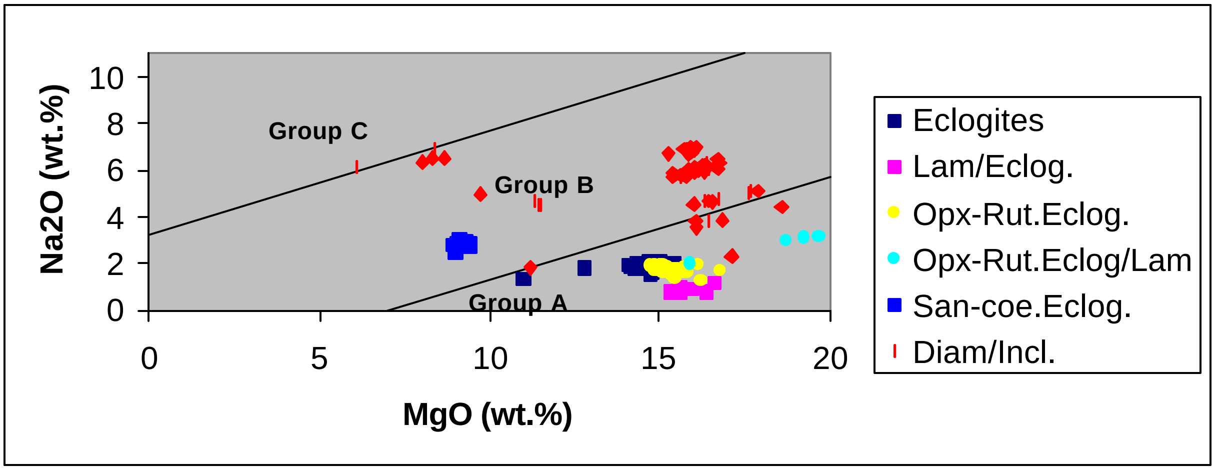

Figure 3 : MgO *versus* Na_2O in clinopyroxene eclogite xenoliths from the Juína Province. Eclogites: Lam/Eclog. = clinopyroxene lamellae from eclogite; Opx-Rut-Eclog. = orthopyroxene – rutile eclogites; Opx-Rut-Eclog/Lam. = clinopyroxene lamelae from orthopyroxene – rutile eclogites; San-Coe-Eclog. = sanidine – coesite eclogites; Diam/Incl. = clinopyroxene inclusions in diamonds from Hutchison (1997). Group limits are from Taylor & Neal (1989).

ii) The alteration process would have occurred during the subduction of the oceanic slab. In this model only the xenoliths belonging to the descending slab would have been silicified.

The negative values for ε_{Nd} and $f_{Sm/Nd}$, indicate that the mantle underneath the province was enriched in LREE, most likely during Proterozoic subduction events.
The reference isochron age of ca. 1.6 Ga for the eclogite and peridotite inclusions is roughly comparable with Mesoproterozoic ages of sialic rocks of the western part of the Amazon Craton, suggesting,, therefore, a Meso- or Paleoproterozoic age for the formation of the parental rocks of the xenoliths.
Mineral isochrons for two groups of eclogite indicated ages of 243±56 Ma and 219±19 Ma which should be interpreted as indicative of an uncertain thermo-tectonic event affecting the mantle during the Triassic, responsible for resetting the Sm-Nd isotopic system. One suggestion is that this event may be roughly correlated with the generation of the magmas which gave origin to the ca. 197 Ma-old tholeiitic basalts of the Anari and Tapirapuã formations, not far from the Juína Province.
Therefore, the peridotite, pyroxenite and eclogite xenoliths in the Juina kimberlites formed during the Mesoproterozoic (ca. 1.6-1.0 Ga) and had their Sm-Nd isotopic system reset during the Triassic.

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