# TRACE ELEMENT PARTITIONING IN NATURAL PHLOGOPITE- AND K-RICHTERITE-BEARING XENOLITHS FROM SOUTHERN AFRICAN KIMBERLITES

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Mica- and amphibole-bearing rock types make up only a very small number of the xenoliths found in kimberlites, but have received a great deal of attention out of proportion to their abundance. Reasons for this are that they represent at least one type of metasomatic agent causing progressive change to the chemistry of the cratonic mantle, and that, because of their hydrous mineralogy, they can be expected to be early-melting components in an otherwise strongly refractory cratonic lithosphere. The attention of researchers has concentrated on the MARID nodules, which have been subjected to a number of geochemical studies (e.g. Waters 1987, Dawson 1987) and to experimental studies aimed at both explaining their origin and investigating the composition of melts which may result from reheating of a MARID-bearing mantle (Sweeney et al., 1993; van der Laan & Foley, 1994, Foley et al., this volume)

In this contribution, we extend the geochemical study of natural xenoliths to trace elements in order to provide a background of trace element abundance and partitioning data on these unusual mantle rocks. The two samples studied were a MARID nodule (BD70 from Boshof Dumps, South Africa) containing phlogopite (PHL), diopside (CPX), K-richterite (KR) and ilmenite (ILM), and a bimineralic phlogopite + amphibole rock (JKW-1 from Wesselton, South Africa) in which the amphibole is calcic (magnesio-hornblende; CAM). JKW-1 otherwise contains only minor amounts of perovskite on grain boundaries, presumably resulting from infiltrating kimberlite magma. The K-richterites in BD70 have smaller sums of Si+Al+Ti (< 8 cations) than is usual for MARID amphiboles, but have "normal" contents of Ca, Al, Na and K.

Trace element abundances were measured by Laser Ablation Microprobe-ICP-MS (LAM) at the Memorial University of Newfoundland. This instrument consists of a Q-switched Nd:YAG laser coupled to a SCIEX ELAN 250 ICP-MS. The laser beam is steered through a conventional petrographic microscope onto a thin section sample which stands under a continuous argon stream during analysis. Detection limits are between 0.1 and 1 ppm for the analytical conditions employed in this study. Further details of the LAM analytical system are given by Jackson et al. (1992). An analysis is obtained by time-integration of the signal, so that mineral zonation can be recognised and quantified as shown in Fig.1. The limits of the two zones are somewhat arbitrary, but are chosen to allow for any delay in the transport of ablated particles, and effectively show the magnitude of zonation.

Results of LAM analyses are listed as averages in Table 1. PHL, KR and CPX in the MARID nodule show LREE>HREE when normalised to primitive mantle. The alkaline amphibole KR shows mild enrichment in "strongly incompatible" elements, but to a much lesser extent than PHL, resulting in high $D_{PHL/KR}$ (Cs = 5; Rb = 14; Ba = 4.7; Th 5.8). Nb and Ta are also enriched in PHL relative to KR ($D_{PHL/KR}$ : Nb = 2.3; Ta = 2.2), whereas Zr and Hf are enriched in KR ($D_{PHL/KR}$ : Zr = 0.39; Hf = 0.53). KR also shows a positive Sr anomaly (Fig.2) resulting in $D_{PHL/KR}$ of 0.02 and $D_{KR/CPX}$ of 1.09.

**Figure 1.** Signal intensity vs. time for a MARID clinopyroxene showing zonation in trace elements. The segment marked "background" monitors the plasma before the laser is switched on. Zone 1 was analysed for about 30 seconds from the polished surface and thus repesents the crystal core analysis. Zone 2 is the crystal rim reached deeper in the ablation pit. Rims show higher abundances of HFSE and REE.

### LAM analysis of zoned crystals
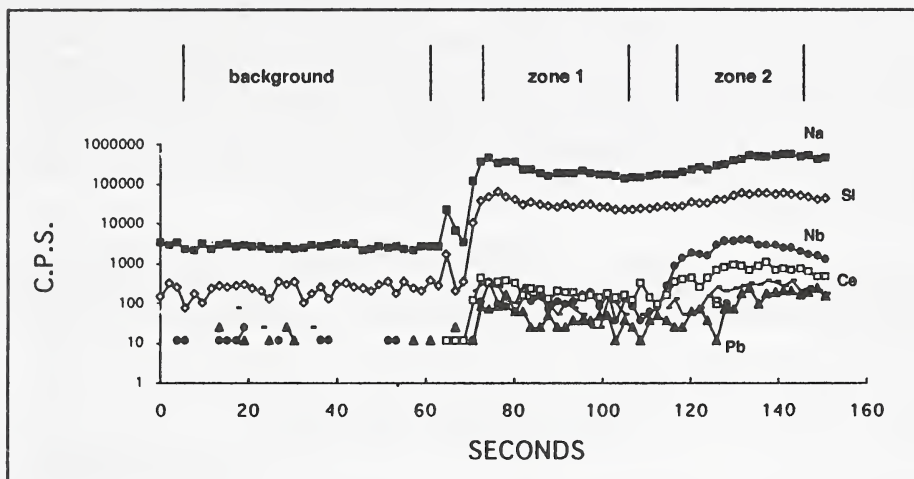


**Table 1**: Mean trace element abundances (ppm) by Laser Ablation Microprobe for minerals in MARID nodule BD-70 and bimineralic Ca-amphibole+phlogopite nodule JKW-1.

|     | BD70 Phl | BD70 K-Rch | BD70 Cpx | BD70 Ilm | JKW-1 Phl | JKW-1 Amph |
|-----|-----|-----|-----|-----|-----|-----|
| V   | 31   | 48    | 188   | 2342 | 85   | 129  |
| Rb  | 529  | 38    | 9     | 13   | 1929 | 221  |
| Sr  | 10   | 472   | 433   | 38   | 4.0  | 117  |
| Y   | 0.4  | 0.7   | 4.5   | 1.7  | 0.21 | 8.0  |
| Zr  | 10   | 27    | 52    | 417  | 0.7  | 8.7  |
| Nb  | 13   | 5.4   | 7.6   | 7625 | 36   | 3.2  |
| Cs  | 3.7  | 0.7   | <0.5  | 0.7  | 64   | 5.9  |
| Ba  | 153  | 32    | 51    | 25   | 452  | 40   |
| La  | 1.0  | 2.5   | 8.5   | 1.8  | 0.13 | 0.65 |
| Ce  | 1.7  | 6.6   | 30    | 3.9  | 0.19 | 2.7  |
| Nd  | 1.0  | 2.7   | 24    | 2.0  | 0.31 | 1.5  |
| Sm  | 0.6  | 0.7   | 2.9   | 7.2  | 0.26 | 0.33 |
| Er  | <0.2 | <0.24 | 0.4   |      |      | 0.67 |
| Yb  | <0.7 | 1.1   | 0.5   | 13.6 |      | 0.82 |
| Hf  | <0.8 | 1.4   | 1.2   | 6.5  | 0.29 | 0.26 |
| Ta  | 0.6  | 0.26  | 0.5   | 358  | 1.9  | 0.16 |
| Th  | 3.0  | 0.52  | 0.48  |      | 0.27 |      |
| U   | <0.3 | 0.27  | 0.26  |      |      |      |

The two nodules studied may have greatly differing origins: a composite MARID-plus-peridotite nodule has been described by Waters et al. (1989), showing that MARID nodules have a mantle origin, whereas crystallisation of JKW-1 at a significantly different depth, even in the crust, cannot be discounted. Trace element abundances in PHL and CAM in JKW-1 are generally lower than for the BD70 minerals, but with the significant exceptions of Cs, Rb and V, plus Nb and Ta for PHL. The differences in $D_{PHL/CAM}$ (Cs = 10.7; Rb = 8.7; Ba = 11.2; Nb = 11.3, Ta = 11.8) presumably are caused principally by differing partitioning behaviour of KR and CAM.

Figure 2 illustrates the trace element patterns of amphiboles from BD70 and JKW-1, which show the somewhat counterintuitive feature of less enrichment of Cs and Rb in the alkaline amphibole than in the calcic amphibole. Fig. 2 also compares the present data with Laser-ICP-MS analyses of amphiboles (kaersutites) from Kakanui, New Zealand, which occur in clinopyroxenite xenoliths and as megacrysts (Zack, 1995). The amphiboles in South African kimberlite nodules have lower contents of most trace elements plotted, but higher contents of alkalies. The marked negative anomaly for U and Th in the Kakanui samples is missing from the South African xenoliths. The results shown in Fig.2 show that a great variety of partitioning behaviour can be expected in amphiboles crystallising in different parageneses or under different conditions, so that care should be exercised in the application of current amphibole partitioning data.

**Figure 2:** Trace element abundances of amphiboles from nodules BD70 and JKW-1 compared to those of kaersutitic amphiboles from clinopyroxenite xenoliths and megacrysts from Kakanui, New Zealand. Data were all acquired with the Laser-ICP-MS facility at Memorial University of Newfoundland.



Alkali vs. Calcic Amphiboles

Legend: K-richterite (MARID); JKW-1 Ca-Amphibole; Kakanui megacrysts; Kakanui pyroxenites
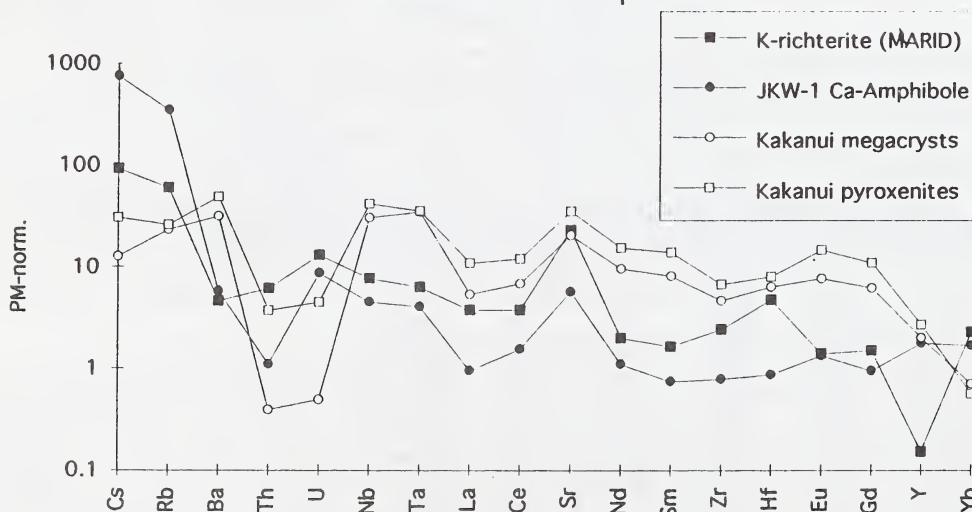
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