Thermal and chemical structure of on- and off-craton lithosphere in central Africa from kimberlite indicator minerals

P.E. Janney1, F. Luzolo-Ndongani1, B.J. Nkere1*, D. Demaiffe2, T. De Putter3§, S. Hashibi1, G.H. Howarth1, M.C.J. de Wit4, R. Price5

1Department of Geological Sciences, University of Cape Town, South Africa. phil.janney@uct.ac.za; 2Université Libre de Bruxelles, Brussels B 1050, Belgium; 3Royal Museum for Central Africa, Tervuren 3080 Belgium; 4Stellenbosch University, Matieland 7602, South Africa; 5Lucapa Diamond Company, Perth WA, Australia. *Now at Département de Géologie, Université officielle de Bukavu, Karhale, DRC; §Now at Belgium Science Policy Office, Brussels 1000, Belgium.

Introduction

In the kimberlites of central Africa (including DR Congo and Angola), mantle xenoliths are exceedingly rare and difficult to obtain for study. Therefore, an understanding of the thermal and chemical structure of the regional lithosphere must be based primarily on the study of kimberlite indicator minerals (KIM). We have assembled a data set of major and trace elements for garnet, ilmenite and clinopyroxene KIM from kimberlites in the Mbuji-Mayi, Kundelungu and Bas-Congo kimberlite fields of the southern DRC and the Lunda Norte kimberlite field, northeastern Angola (Fig. 1). These range in age from mid-Cretaceous (Lunda Norte field) to Late Cretaceous (Mbuji-Mayi field) to Palaeogene (Kundelungu).

Results

Garnet geochemistry and thermobarometry: The Mbuji-Mayi, Tshibwe, Mulenda and Matabala kimberlites from the Mbuji-Mayi kimberlite field, on the eastern Kasai Craton in south central DRC, have peridotitic garnet KIM populations containing 15 to 40% G10 garnets, whereas the off-craton Kundelungu and Bas-Congo kimberlite fields, both located on Proterozoic lithosphere, have few, if any G10s (<1%, this study and Batumike et al., 2009). Peridotitic KIM garnets from the Lunda Norte field on the southern Kasai Craton also have a very low percentage of G10 garnets (≈2%; Fig. 2). Consistent with this, G10 garnets from the Mbuji-Mayi field have sinusoidal rare earth element (REE) patterns, whereas G9 garnets have normal LREE-depleted patterns with relatively flat MREE and HREE abundances. Garnets from the Kundelungu kimberlites have normal LREE-depleted patterns and trace element measurements of garnets from Kimpangu and Lulo field kimberlites are in progress. Single mineral garnet barometry is problematic and requires assumption of equilibration of garnet with Cr-spinel. Following Hashibi et al (this meeting)
we present T and P values for garnets using Ni in garnet thermometry (Sudholz et al., 2021) and P_{Cr} barometry (Ryan et al., 1996) but only for garnets falling near or above the “graphite-diamond constraint” line of Grütter et al. (2006; i.e., with Cr_{2}O_{3} ≥ 0.94*CaO + 4). Even with this filtering, there is significant scatter and no clear separation of garnets from on-craton (Mbuji-Mayi, Tshibwe) and off-craton localities (Kundelungu). Average garnet temperatures from Mbuji-Mayi, Tshibwe and Kundelungu are similar (all \approx 1000°C ± 125; Fig 2.) but the Kundelungu garnets have a markedly bimodal distribution with a secondary peak at \approx 1200°C. Peridotitic garnets from all localities include significant proportions (>30% for DRC, >50% for Lunda Norte) with TiO_{2} contents in excess of 0.5 wt.%, likely indicating megacrystic paragenesis.

Figure 2. CaO vs. Cr_{2}O_{3} plots for garnets from (a) the Mbuji-Mayi field (Kasaï craton), (b) the Kundelungu and Bas-Congo fields (off-craton) and (c) the Lunda Norte kimberlite field (Kasaï craton) and (d) temperature (Ni in garnet, Sudholz et al., 2021) versus pressure (P_{Cr}, Ryan et al., 1996) thermobarometry plot for Cr-rich garnets from Mbuji Mayi, Tshibwe and Kundelungu kimberlites. Data are from this study, Batumike et al. (2009) and Pivin et al (2009). Angolan literature data are from numerous sources.

Ilmenite geochemistry: Ilmenite from on- and off-craton kimberlites can be distinguished on the basis of MgO, Cr_{2}O_{3} and Fe_{2}O_{3} contents, with those from on-craton having higher average MgO and Cr_{2}O_{3} contents (Fig. 3) and lower Fe_{2}O_{3} (<15 wt% for Mbuji-Mayi and <25 wt.% for Lunda Norte), whereas those from off-craton localities display lower and more variable MgO (though Lunda Norte is also variable in MgO) lower Cr_{2}O_{3} (Fig. 3a) and extend to higher Fe_{2}O_{3} values.

Clinopyroxene geochemistry and thermobarometry: Clinopyroxene (cpx) comprises a relatively small proportion of the KIM assemblage. Clinopyroxenes from the Mbuji-Mayi, Kundelungu and Lunda Norte fields extend from subcalcic to calcic varieties (100*Ca/[Ca+Mg] = 32 to 53). Cpx single mineral thermobarometry shows a clear difference between KIM from the on-craton Mbuji-Mayi field (mainly falling between the 35 & 40 mW/m² geotherms) and the off-craton Kundelungu field (mainly falling around
the 45 mW/m² geotherm; Fig. 3b). However Lunda Norte KIM mainly record an even steeper thermal gradient, although with a subset of cpx overlapping the Mbuji-Mayi data almost entirely.

**Discussion and Conclusions**

The KIM mineral data suggest that the kimberlites of the Mbuji-Mayi field sampled a region of fairly typical Archean cratonic lithosphere with most of the grains representing minerals disaggregated from ancient melt-depleted garnet harzburgite and lherzolite. Kimberlites of the Kundelungu and Bas-Congo fields yielded peridotitic KIM that, in contrast, were derived almost entirely from garnet lherzolite that experienced only moderate degrees of melt extraction, typical of Proterozoic mantle lithosphere. At all localities, there is evidence that grains of megacrystic paragenesis (crystallization products of melt-lithosphere interaction) make up a major proportion of the KIM assemblage. Moreover, these appear to make up an unusually large proportion from Lunda Norte. It is likely that interaction with deep protokimberlitic melts had a significant effect on the bulk composition of the lithosphere sampled by central African kimberlites, and may be responsible for extensive chemical and thermal modification (heating, refertilization) of the lithosphere beneath northeastern Angola, as well as the relatively low ratio of lithospheric to sublithospheric diamonds from this region.

**References**


