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

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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).

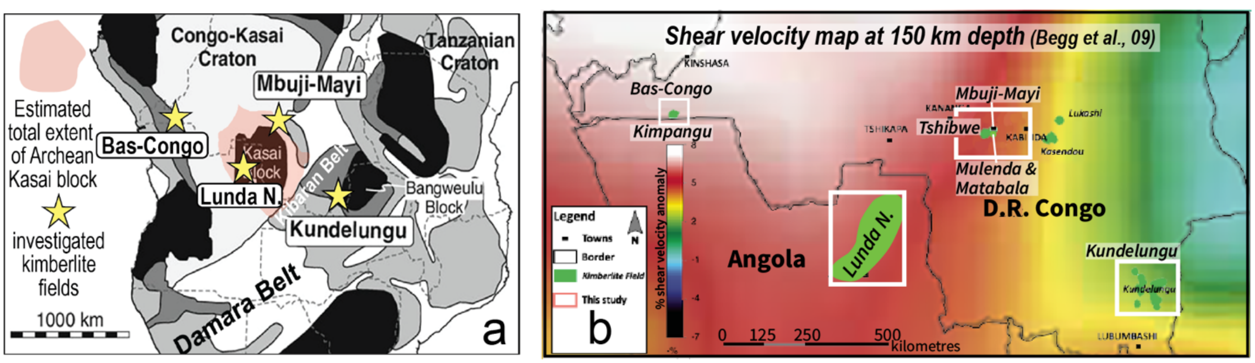

__Figure 1__. (a) Geology of southern central Africa and (b) Seismic velocity map (modified from Begg et al., 2009), both showing the four kimberlite fields investigated in this study.

Results

Garnet geochemistry and thermobarometry: The Mbuji-Mayi, Tshibwe, Mulenda and Matabala kimberlites from the Mbuji-Mayi kimberlite field, on the eastern Kasaï 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 Kasaï 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 $Cr_2O_3 \geq 0.94*CaO + 4$). 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 ≈1000°C ± 125; Fig 2.) but the Kundelungu garnets have a markedly bimodal distribution with a secondary peak at ≈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.

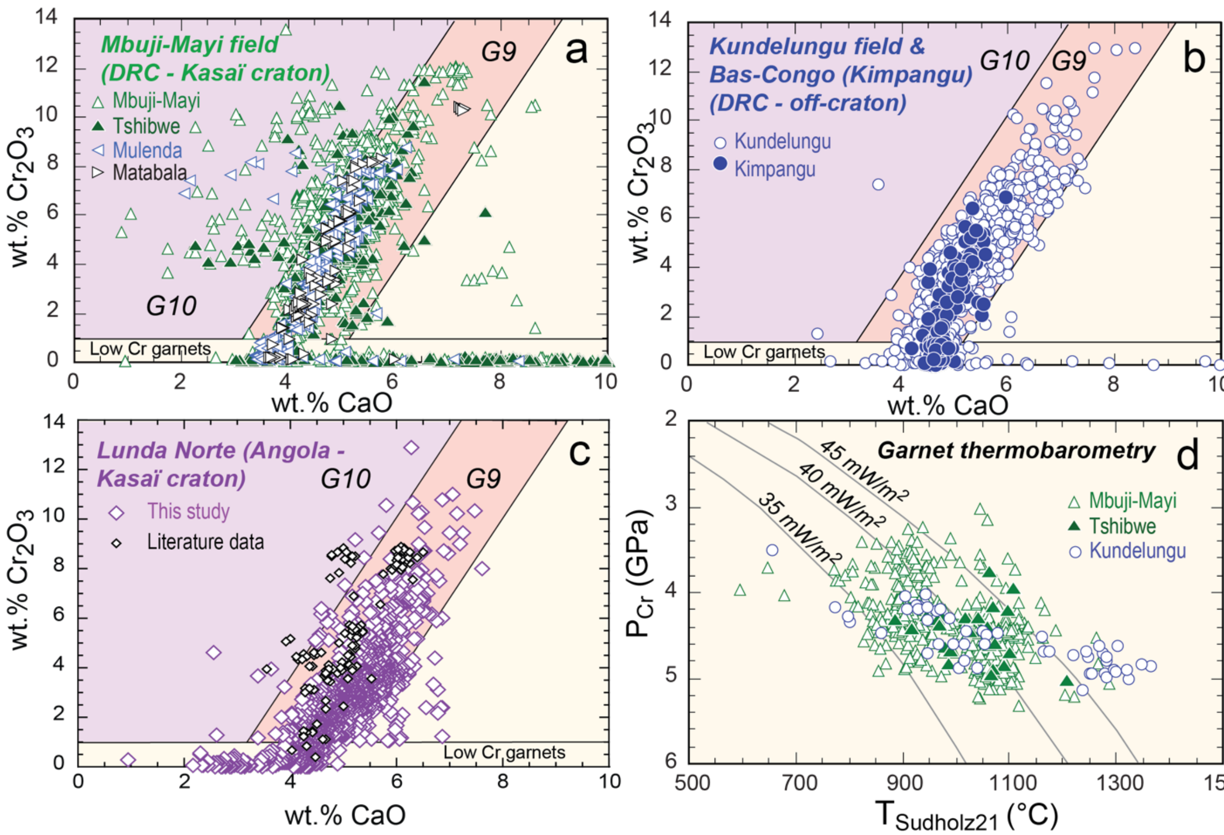

Figure 2. CaO vs. Cr_2O_3 plots for garnets from (a) the Mbuji-Mayi field (Kasaï craton), (b) the Kundelungu and Bas-Congo fields (off-craton) and (c) the Lunda Norte kimberlite field (Kasaï craton) and (d) temperature (Ni in garnet, Sudholz et al., 2021) versus pressure (P_{Cr}, Ryan et al., 1996) thermobarometry 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_2O_3 and Fe_2O_3 contents, with those from on-craton having higher average MgO and Cr_2O_3 contents (Fig. 3) and lower Fe_2O_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_2O_3 (Fig. 3a) and extend to higher Fe_2O_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/m^2 geotherms) and the off-craton Kundelungu field (mainly falling around the 45 mW/m^2 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.

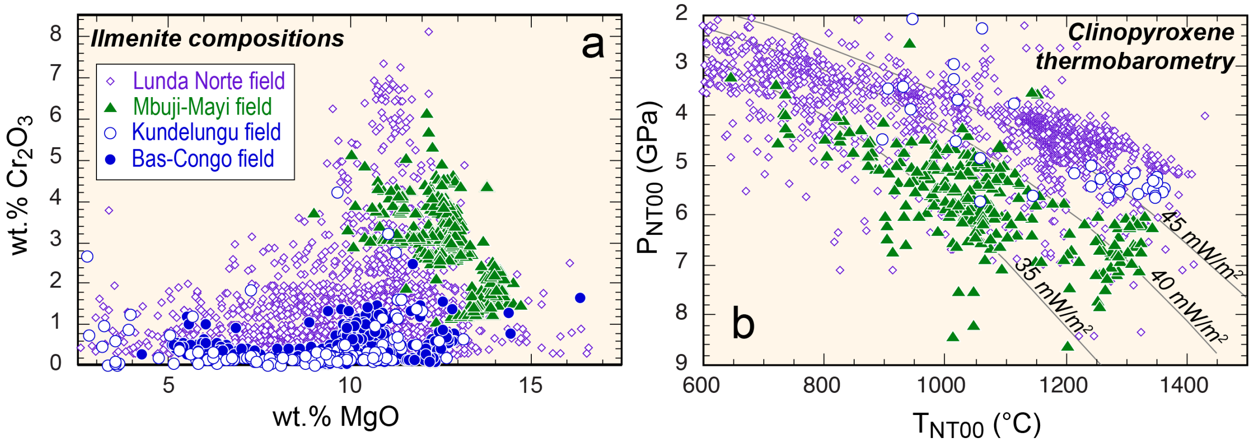

Figure 3. (a) wt.% MgO versus Cr_2O_3 contents of Central African KIM ilmenites, (b) single mineral cpx thermobarometry (Nimis & Taylor, 2000) for central African KIM. Vast majority of data is from this study.

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.

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