Introduction and major element systematics

The composition of clinopyroxenes from heavy mineral concentrates of the diamondiferous Mbuji-Mayi and Tshibwe kimberlites in the DRC have been studied to constrain the thermal and compositional state of the lithospheric mantle underlying the northeastern section of the Archaean Kasai craton of central Africa. Clinopyroxenes from Mbuji-Mayi fall into two populations, a larger subcalcic group (group 1; with Ca# between 41 and 45) and a smaller calcic group (group 2; with Ca# between 45 and 47) with group 2 cpx showing overall lower Al$_2$O$_3$ values and a trend of decreasing Al$_2$O$_3$ with increasing Ca#. The group 1 cpx show an increase in Al$_2$O$_3$ contents with increasing Ca#. Both groups are relatively Cr-rich (Cr# ranging between 17.7 and 69.1) with group 1 having higher Cr content, but they both show a broad increase of Cr# with increasing Mg#, and both groups display a broad range of Mg# (from 88.5 to 94 with group 2 cpx having higher Mg# on average than group 1). Both groups have high Na$_2$O contents (ranging between 1.5 to 3.6 wt.% with group 1 extending to higher Na$_2$O contents. Contents of TiO$_2$ and Na$_2$O decrease with increasing Ca# in group 2 while no correlation is observed in group 1.

Clinopyroxenes from the Tshibwe kimberlite are very similar to the Mbuji-Mayi group 2 clinopyroxenes in terms of their major element compositions. However, they extend to slightly higher Ca# values (44 – 48) and lower Al$_2$O$_3$, lower TiO$_2$ (0.22 – 0.05 wt.%) and lower Na$_2$O (1.7 – 1.18 wt.%) than Mbuji-Mayi clinopyroxenes.

Trace element and Sr isotope systematics

Trace element patterns of Mbuji-Mayi group 1 and group 2 clinopyroxenes are similar. They show fairly uniform convex upward and LREE enriched REE patterns with group 1 cpx extending to greater extents of LREE enrichment than group 2 cpx ((Nd/Yb)$_N$ = 22.1 – 100.1 and 22.5 – 55.1 for group 1 and group 2, respectively). Both group 1 and 2 cpx show relative depletions in Ba, Pb, Zr and Ti relative to elements of similar incompatibility, but the depletions in Group 1 are stronger (Fig. 2c).

Trace element patterns of Tshibwe clinopyroxenes are very similar to Mbuji-Mayi group 2 clinopyroxenes, but with slightly less LREE-enrichment on average (most Tshibwe cpx have (Nd/Yb)$_N$ ratios between 30.5 and 38.7). However one Tshibwe cpx grains have anomalously high (Nd/Yb)$_N$ value of 150.5 with (Sc/V)$_N$ ratios lower than unity (0.87; Fig. 2a).

Clinopyroxenes from Mbuji-Mayi and Tshibwe span nearly identical ranges of measured $^{87}$Sr/$^{86}$Sr (with ranges of 0.7031 – 0.7052 and 0.7035 - 0.7053, respectively), falling within the range of Group 1 kimberlites (including Mbuji-Mayi; Weis & Demaiffe, 1985) and PIC rocks (as summarised by Grégoire, 2002).
Thermobarometry

The P–T equilibration conditions of peridotitic concentrate clinopyroxenes from the Mbuji-Mayi and Tshibwe kimberlites were estimated using the clinopyroxene thermobarometer of Nimis and Taylor (2000). Based on these P–T estimates, clinopyroxenes from Mbuji-Mayi and Tshibwe define a compositional and thermal profile through the northeastern Kasai craton to depths as great as 220 km, a depth consistent with previous thermobarometry and geophysical studies (Batumike et al., 2009; Crosby et al., 2010). The two kimberlites sampled and entrained clinopyroxenes from a pressure and temperature interval between 26 and 72 kbar and 967 to 1264 °C. However, the continental lithospheric mantle beneath Tshibwe, on average, was cooler (with an average thermal gradient of 20°C per kb) than at Mbuji-Mayi (with an average thermal gradient of 26°C per kb) (Fig. 2b).

Origin of clinopyroxenes

Clinopyroxenes from Mbuji-Mayi and Tshibwe show typical peridotitic major element compositions, with high Mg# and with Cr₂O₃ and Al₂O₃ concentrations that plot in the field associated with garnet-bearing lherzolites (Nimis, 1998). Moreover, the REE concentrations and profiles of Mbuji-Mayi and Tshibwe clinopyroxenes are also similar to those reported for diopsides from “type 1” metasomatised garnet lherzolites (Grégoire et al., 2003) from some Kaapvaal kimberlites.

Group 1 clinopyroxenes from Mbuji-Mayi have (Sc/V)N ratios lower than unity (0.41 – 0.99), typical of clinopyroxenes from garnet lherzolites (Glaser et al., 1999; Barth et al., 2001). Therefore, the group 1 clinopyroxenes likely originated from metasomatised garnet lherzolite. Group 2 cpx from Mbuji-Mayi and Tshibwe cpx have (Sc/V)N ratios greater than unity (with ranges of 1.01 – 2.19 and 1.14 – 2.56, respectively), suggesting derivation from a mantle lithology with little to no garnet present. This could indicate a highly infertile garnet lherzolitic or possibly a garnet-free peridotitic or pyroxenitic source.

Peridotitic garnets occur, though not abundantly, in the concentrate from these kimberlites. It is therefore likely that garnet lherzolite is the main lithology beneath the northeastern section of the Congo-Kasai Craton. The SCLM beneath Mbuji-Mayi appears to have a higher proportion of garnet lherzolite while the SCLM beneath Tshibwe appears to have a more garnet-depleted lithological character.

Metasomatism

Primitive mantle-normalised incompatible element patterns both in Tshibwe and Mbuji-Mayi clinopyroxenes show evidence of kimberlite-related metasomatism, which is supported by the large degree of Sr isotopic overlap between the clinopyroxenes and whole-rock ⁸⁷Sr/⁸⁶Sr values for Mbuji-Mayi kimberlites (Weis & Demaiffe, 1985). However, it appears that Mbuji-Mayi clinopyroxenes have undergone more extensive metasomatism (stronger LREE enrichment, higher overall incompatible element contents) than at Tshibwe. Therefore, the mantle sampled by the Mbuji-Mayi kimberlites appears to have been warmer and metasomatically more disturbed compared to the cooler and more depleted lithosphere sampled by the Tshibwe kimberlite cluster. The occurrence of different thermal and metasomatic states in mantle located in close proximity (within 35 km) suggests that the Tshibwe cluster kimberlites may have been emplaced prior to Mbuji-Mayi (70 Ma) (Schärer et al., 1997) and prior to major thermal and metasmotic disturbance of the SCLM.

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References


**Figure 2:** (a) (Nd/Yb)n vs (Sc/V)n plot. Note the distinct distribution of Mbuji-Mayi group 1 and Tshibwe/Mbuji-Mayi group 2 cpx; (b) P (kbar) vs T (°C) plot with values based on the Nimis and Taylor (2000) thermobarometer. 35 mW/m² geotherm is provided for reference; (c) Primitive-mantle-normalized trace element patterns of Mbuji-Mayi (BM group1 and group 2) and Tshibwe cpx (TB cpx). Normalizing values from McDonough and Sun (1995).