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A comparison of the geochemistry of megacrysts from Group I and Group II southern African kimberlites: Evidence for a cognate origin

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Controversy surrounds the relationship between megacrysts and their host kimberlites. Garnet and clinopyroxene (cpx) megacrysts from four Cambrian to Late Cretaceous southern African kimberlites representative of Group I and Group II varieties have been selected for a comparative study aimed at characterizing their geochemistry and petrogenesis. Megacrysts have been analysed for their major and trace element compositions from the Bellsbank and Kalkput kimberlites (both Group II) located on the Kaapvaal craton, and the Orapa and Colossus kimberlites (Group I) located on the Zimbabwe craton. Over 500 clinopyroxene, garnet and ilmenite megacrysts from these kimberlites have been analysed. Major element variations reveal some systematic differences between megacrysts from Group 1 and Group 2 kimberlites. For clinopyroxenes, those from Group I tend to have lower Ca-numbers than those from Group II kimberlites. The Group II cpx megacrysts from Kalkput are Cr-poor whereas those from Bellsbank are dominantly Cr-rich however, both suites extend to more Na- and Ti-rich compositions than the Group 1 cpx megacrysts studied. Additionally, Group I cpx megacrysts extend to more Ni-rich compositions, whereas Group II cpx megacrysts have higher and much more variable Zr/Hf values ranging from 15 to 35 compared to Zr/Hf ratios of ≈16 for group I. Both Group I and Group II cpx megacrysts show a decrease in Lu/Hf ratio with increasing Ca/[Ca+Mg] (i.e., with decreasing crystallization temperature) but this decrease appears to occur at significantly lower temperatures in the Group II cpx suites. For garnet megacrysts, no significant, systematic geochemical differences between Group I and Group II kimberlites have been identified.

Chondrite-normalised REE patterns of Group I clinopyroxene megacrysts are coherent and mostly subparallel. Most of the Group 1 clinopyroxenes show a moderate LREE enrichment. The patterns displayed by the Group II cpx megacrysts are more variable. Kalkput cpx shows patterns similar to the group 1 cpx megacrysts, but the Bellsbank cpx are both more LREE-enriched and HREE-depleted, suggesting interaction of their parental melts with metasomatised peridotite, consistent with their Cr-rich compositions. For garnets, group I kimberlite megacrysts have higher Ni and Zr contents; group II garnets have higher Sc contents (130-200 ppm). Chondrite-normalised REE patterns of group I garnet megacrysts have extremely coherent, subparallel, strongly LREE depleted and HREE enriched REE patterns. On the other hand, group 2 garnet megacrysts from Bellsbank show both sinusoidal and normal patterns, suggesting that some of the large garnets analysed are of peridotitic origin rather than true megacrysts. The overall differences, particularly in cpx composition, between megacrysts from Group I and Group II kimberlites correspond in many respects to the main differences between Group I and Group II kimberlite bulk composition and suggest that the parental magma to these megacrysts are genetically related to kimberlites of the type that transported the megacrysts to the surface. Furthermore, the fact that enrichment in incompatible elements (e.g., increase in LREE/HREE and decrease in Lu/Hf) observed in Group II cpx kimberlite megacrysts appears to occur at lower temperatures than in Group I cpx, is consistent with the idea that Group II kimberlites have dominantly sampled a highly volatile- and incompatible element-enriched SCLM with a lower melting temperature,

whereas Group I kimberlites were generated from melting of more normal peridotitic mantle in the lithosphere or asthenosphere.