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New constraints on kimberlite melt compositions using bulk and groundmass compositions

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Kimberlites are low-volume igneous rocks that are rich in volatiles and derived from low-degree melting of the upper asthenosphere below the thick continental lithosphere. These magmas contain the deepest known mantle xenoliths and are the primary host to diamonds constituting the prime window into the deep Earth. Determining the composition of kimberlite melts at depth remains a challenging task, primarily due to the substantial modification of the primary kimberlite melts before, during and after their emplacement, including entrainment and assimilation of mantle and crustal fragments, volatile (CO_2 and H_2O) degassing, magmatic differentiation, and syn-/post-magmatic alteration (i.e., serpentinization).

To better approach the composition of primary kimberlite melts, we applied two distinct techniques to fresh sub-volcanic kimberlite samples from representative localities in South Africa, Botswana, Canada and Greenland. The first approach entails analysis of bulk groundmass composition where areas of the groundmass devoid of macrocrysts were extracted from thick sections, milled and measured by EPMA and LA-ICP-MS. This groundmass composition, devoid of entrained xenocrystic material, is considered to approach the kimberlite melt composition at the surface. In a complementary approach, we combined detailed modal analysis with estimating magmatic mineral compositions by EPMA. Combining both methods allows us to address the effect of serpentinization on bulk groundmass composition and include the magmatic contributions from the rims of larger olivine grains.

Initial findings suggest that bulk groundmass compositions display higher CaO and lower SiO_2, FeO_T, and Mg# concentrations than the corresponding bulk rock composition. These results are consistent with contributions to bulk rock compositions by the olivine xenocrysts, which ubiquitously form the cores of olivine grains. Comparison between samples shows variations representing the variable mineralogy across examined locations, e.g., Diavik is low in mica and bulk-groundmass K_2O compared to Gahcho Kué (both in Canada). Variations between kimberlite clusters can be explained by differing mantle source compositions, partial melting regimes, and modifications en route to the surface (crystal fractionation, assimilation, and volatile loss). These reconstructed melt compositions are compared to previously proposed primitive kimberlite melts and high P-T experimental melts of carbonate-bearing peridotites to get a better understanding of the primary melt composition of kimberlites.