Petrographic and geochemical variations in the Kaavi-Kuopio kimberlite field, Finland: The role of mantle assimilation

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Kimberlites are silica-poor, volatile-rich (CO_2 ± H_2O), volcanic rocks that are often described as 'hybrid', because their parental magmas include abundant xenocrystic (crust- and mantle-derived) components. Unravelling the influence of mantle assimilation on kimberlite melt compositions represents an outstanding question of kimberlite petrology. To address this issue, we have carried out a comprehensive geochemical and petrographic investigation of nine kimberlites from the Kaavi-Kuopio field in Finland, that were emplaced on the southern margin of the Karelian Craton in the Neo-proterozoic (~550-600 Ma).

Olivine is the dominant mineral phase in kimberlites (~50 vol.%) with cores mainly derived from the disaggregation of mantle peridotite. In contrast, olivine rims crystallise directly from the kimberlitic melt and their Mg# (Mg/(Mg+Fe)) typically show remarkable homogeneity within and between kimberlites of a single cluster and field (e.g., Lac de Gras).

The Kaavi-Kuopio kimberlites appear to represent a unique case where there is a (statistically) significant difference between the average Mg# of olivine rims in different pipes (89.9 ± 0.2 to 88.5 ± 0.3). Importantly, the Mg# of olivine rims exhibit a strong correlation with the Mg# of olivine cores. Furthermore, the compositions of olivine cores (and rims) exhibit a strong correlation with those of spinel (e.g., Mg#, TiO_2 contents). These geochemical variations correlate with the modal mineralogy of the kimberlites: for example, higher abundances of monticellite and lower abundances of ilmenite are associated with higher Mg# olivine. The robust relationship between entrained and assimilated lithospheric mantle material (i.e. olivine cores) and magmatic components (i.e. olivine rims, spinel, and other groundmass minerals) suggests that assimilation of lithospheric mantle has impacted the compositions of kimberlitic melts to a greater extent than previously recognised. These new data also suggest significant variations in the composition of the mantle lithosphere beneath the Kaavi-Kuopio kimberlites, which are spaced less than 10 km apart.