Olivine, kimberlites and the modification of carbonated melts in the deep Earth

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Olivine in kimberlite rocks is typically zoned regardless of shape and size. The rims contain primary inclusions of groundmass phases (e.g., chromite, ilmenite), and exhibit homogeneous Mg# composition coupled with decreasing Ni and increasing Ca and Mn concentrations. These features are consistent with a magmatic origin for the rims. Conversely, the olivine cores may host inclusions of mantle phases (e.g., clinopyroxene, garnet) unstable in kimberlite magmas. The cores show widely variable compositions extending from those of olivine in mantle peridotites (i.e. Mg# ~ 90-94) to compositions richer in Fe, and derive from disaggregation of mantle wall rocks. The magmatic rims of olivine can threfore be employed as proxies of the composition of kimberlite melts, whereas the xenocrystic cores can provide constraints on the composition of the lithospheric mantle traversed by kimberlite magmas.

To understand the role, if any, of assimilation of lithospheric mantle material in the origin of kimberlites and other carbonate-rich magmas, we have examined major-element compositions of olivine in kimberlites and orangeites from South Africa, Botswana, Lesotho, Canada, Brazil, Russia and Greenland. Different kimberlite pipes from individual clusters (e.g., Kimberley in South Africa, Ekati in Canada) contain olivine with very similar compositional features (e.g., restricted range of rim Mg#). However, large compositional variations are evident for olivine grains from kimberlite clusters on the same craton and worldwide. The most remarkable finding of this study is the statistically significant (R^2 = 0.8) linear correlation between the Mg# of olivine cores and rims in kimberlites worldwide, which extends to South African orangeites and rocks from Brazil and Greenland with transitional features between kimberlites and ultramafic lamprophyres. The correlation between Mg# of (xenocrystic) cores and magmatic rims suggests that the composition of wall rocks along the magma conduit exerts a fundamental control on the composition of the olivine rims and, therefore, kimberlite magmas. This process also applies to other mantle-derived carbonate-rich magmas (e.g., orangeites) and might potentially affect the composition of any carbonated melt in the deep Earth.