Two populations of olivine cores in kimberlite - fellow travelers or distant relatives?

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Abstract

Kimberlites are ultrapotassic igneous rocks with complex and poorly understood origins. They form from mantle-derived magma and hence are important sources of information about mantle composition and processes, but kimberlites are also famous for their ability to bring diamonds to the surface. Hence petrologists and diamond prospectors alike are in pursuit of a better understanding of these rocks and the minerals that they contain. Olivine is one of the most abundant minerals in kimberlite, but its evolutionary history is not yet fully understood. The typical compositional range of olivine ranges from Fo_{80} to Fo_{99}, referred to as Fe-rich to Mg-rich endmembers, respectively. Three distinct populations of olivine crystals have been identified: (i) Mg-rich xenocrysts from disaggregated mantle xenoliths in which the crystals are unrelated to the kimberlite magma; (ii) Magmatic crystals and overgrowth rims of varying composition crystallized from the kimberlite magma; (iii) Fe-rich megacrysts, for which two different genetic models have been proposed: (i) the Fe-rich olivine was also derived from disaggregated mantle xenoliths unrelated to the kimberlite magma, with the higher Fe content explained by derivation from more enriched mantle at a greater depth; (ii) the Fe-rich olivine crystals are cognate phenocrysts, genetically related to a precursor melt and crystallized during or after formation of the magma.

The model for Fe-rich xenocrysts as disaggregated mantle xenoliths is supported by the textures of the cores, which have more rounded shapes as well as deformation structures consistent with high-pressure formation. They also have chemical similarities to xenocrysts of known mantle origin. Supporters of this origin typically divide olivine compositions into a melt trend and a mantle trend, based on, for example, Ni and Ca contents, and the Fe-rich olivine megacrysts appear to fall on the mantle trend. In the cognate phenocryst model, the Fe-rich olivine phenocrysts crystallized from the magma. Typically, their formation is attributed to metasomatic processes; one possible model involves melting caused by the influx of volatiles at depth and subsequent crystallization of Fe-rich olivine crystals which are then partially reabsorbed and abraded as the kimberlite magma moves upward through the mantle.