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Trace element variations across olivine record the evolution of kimberlite melts: Case studies from the Kimberley kimberlites (South Africa)

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Olivine is the most abundant mineral in kimberlite rocks and its size, abundance and composition provide important insights into the diamond grade of kimberlite bodies [1]. In kimberlites, olivine occurs as macrocrysts (i.e. anhedral grains larger than 1 mm in size) and phenocrysts (i.e. (sub-)euhedral crystals commonly less than 1 mm in size) [2]. Both macrocrysts and phenocrysts commonly contain a xenocrystic core mantled by one or more rims of magmatic derivation [3, 4].

Olivine is the liquidus mineral in kimberlite melts [5] and olivine crystallisation can persist throughout most of the kimberlite crystallisation sequence [6, 7]. Previous work on kimberlite olivine has focussed on major (Mg, Fe) and minor element (Ni, Mn, Ca) compositions (e.g., [3, 4, 6, 7, 8, 9]) with only limited results for trace element concentrations [7]. These studies have revealed significant variations between cores, rims and internal zones (between cores and rims). Compositional variations across internal zones and rims probably reflect the progressive compositional evolution of kimberlite magmas, related to the interplay between wall rock assimilation, melt differentiation and changing oxygen fugacity conditions [6, 7].

Systematic measurements of the trace element compositions of different zones in olivine grains provide a more comprehensive delineation of kimberlite melt evolution, from the initiation of crystallisation because a large set of elements can be quantified simultaneously. We have studied compositional variations across olivine grains from the Kimberley kimberlites (samples from the Bultfontein, Wesselton and De Beers pipes and Wesselton Floor sills) using a combination of SEM back-scattered electron imaging, electron microprobe measurements (spot analyses, traverses and maps) and laser-ablation ICP-MS determinations (spot analyses and traverses).

Compositional traverses across olivine grains reveal an extreme decoupling between most of the elements that we have quantified (notable exceptions include Mg-Fe and Ni-Co). These traverses permit identification of specific events in the evolution of kimberlite melts, including their contamination due to wall rock assimilation, and the start (and cessation) of the crystallisation of olivine and other phases (e.g., spinel, ilmenite, apatite). Compositional variations across olivine due to the co-precipitation of other minerals are consistent with the crystallisation sequence inferred from petrographic examinations. This study reveals that olivine grains are a significant repository of detailed information on the evolution of kimberlite melts from the earliest stages of crystallisation.

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