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Tracking early melt differentiation in Ugandan potassic rocks using trace elements in olivine phenocrysts

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Olivine is commonly the earliest abundant crystallizing phase in mafic igneous rocks, and therefore has the potential to record information about melts closer to the original, unfractionated compositions than other, better studied, phenocryst phases such as clinopyroxene. Here, the trace element abundances in olivine phenocrysts in ugandite from the Toro Ankole volcanic field and leucite basanite from the Virunga volcanic field in the western branch of the East African Rift are reported for up to 34 trace elements by Laser-ICP-MS with detection limits as low as 1ppb. The ugandites contain abundant olivine phenocrysts of varying sizes, prompting the suspicion that many olivines may be xenocrystic. In the leucite basanites, olivine phenocrysts are less common than clinopyroxene.

To investigate the best method of analysis of trace elements in olivine, analyses were compared from cylindrical ablation holes ("point analyses") with varying ablation crater diameters (40-140μm) and from line scans peformed by automatically moving the sample stage beneath a rectangular 100 x 10μm laser beam. Both methods allow identification of subtle zonations from core to rim, whereas the line scan analyses potentially allow characterization of larger crystals and the chemical effects of contamination along cracks. Results show that line scan analyses are contaminated in several elements (Al, Ca, Cu, Ga, Sr, Zr, Nb, La and Ce) that are also concentrated in microcracks between subgrains. This indicates that contamination is due to smearing out of material contained along subgrain boundaries during polishing, and is not due to the choice of polishing agent itself. These tests demonstrate that large diameter large spot analyses produce the best results for trace elements in olivine.

In the ugandites, trace element concentrations are remarkably uniform between large and small phenocrysts that show a small range in Mg# (91.8-86.4). Zonation is seen in elements with cation charges from 5+ to 2+ (P, Ti, Zr, Cr, Al, Sc, V, Cu, Mn, Ni) and show correlation between Ti and Al, but not P. Zonation patterns do not conform simply to those identified in basaltic rocks, and also not to a simple increase in diffusion rates with decreasing cation charge. Early phenocryst cores with slightly higher Li or Ni, lower Mn, or enrichments in many trace elements can be identified, whereas the very rare xenocrysts have exceptionally low Na, Cr, Ti, V and Co. Partition coefficients for Ni are 31-35, less than in lamproites, with which they demonstrate an approximately linear correlation between D(Ni) and K2O content, K2O/Al2O3 and K2O/Na2O of the melt, but no correlation with SiO2 content or Mg#. D-values for Cr, Mn and Co overlap with those of basalts, whereas those for Sc (0.011-0.018), Zn (0.44-0.49) and Ga (0.006-0.007) are lower. D(V) of various potassic rocks (0.015 in the Ugandan rocks) confirms the dependence on fO2 calibrated by the Fe3+/(Fe3++Fe2+) of spinels. The V/Sc ratios of the ugandites indicate log fO2 of the source slightly above the FMQ buffer.

Leucite basanites have olivines with a greater range of Mg# (92.6 to 70.5) and consequently more variability in trace elements. The more fractionated lecuite basanites (Mg# 59) have less fractionated LREE/HREE than MgO-rich ugandites (Mg# 75-80).