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Rapid growth of phosphorus-rich olivine in mantle xenolith from Middle Atlas Mountains (Morocco, Africa)

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Phosphorus(P)-rich zones in olivine may reflect incorporation of P in excess of equilibrium partitioning during rapid growth (e.g. Milman-Barris *et al*. 2008). We investigated a mantle xenolith from Middle Atlas Mountains (Morocco) by optical microscopy and electron microprobe. It contains spinel-bearing lherzolite and orthopyroxenite layers, cross-cut by veins dominated by glass and secondary phases including P-rich olivines. The host lava, presumed to be alkali basalt (El Messbahi et al. 2015), is present on the margins of the hand sample but not included in our thin section.

The studied melt veins (MV) generally contain Ol+Gl+Cpx+Pl+Spl±Ap. ***Olivines*** in the MV have ($Fo_{72.1-83.4}$) with 0.02-0.3 wt.% P_2O_5; olivines with P_2O_5 >0.1 wt.% are $Fo_{75.3-82.8}$. Some olivine grains are inclusion-free; others contain rounded glass inclusions or subhedral spinel or ilmenite inclusions. Olivines is generally found in contact with plagioclase and glass. ***Glass*** (5-15 vol%) has variable composition with P_2O_5 up to 1.52 wt.%, K_2O 1.65-2.37 wt%, CaO 6.39-9.55 wt%, Na_2O 0.78-6.70 wt% and SiO_2 45.2-49.6 wt%. Where glass is in contact with matrix olivine, Fe-rich outer rims on olivine indicate mineral-melt reaction. In MgO variation diagrams, glass compositions display a coherent single trend for all oxides, with the exception of a discrete low-Na group. ***Clinopyroxene*** is present both as isolated subhedral to euhedral crystals within the MV and as replacive rims on matrix minerals. Very fine-grained dendritic clinopyroxene quench crystals up to 10 μm long are also present. ***Plagioclase*** occurs as prismatic, flow-oriented crystals parallel or sub-parallel to the layering. ***Spinel*** shows anhedral and euhedral shapes and occurs both as inclusions in olivine and as discrete grains associated with plagioclase and glass. Spinel in contact with glass shows a spongy outer rim and normal zonation towards Fe-rich rim compositions. ***Apatite*** is found mostly as very small crystals embedded in glass.

High-resolution X-ray mapping of P in olivine reveals narrow P-rich bands parallel to crystal facets. P correlates negatively with Si^{4+}, poorly with divalent cations (Mg+Fe+Ca), and positively with Al^{3+}, suggesting a substitution $2\,{}^{IV}Si^{4+} = {}^{IV}P^{5+} + {}^{IV}R^{3+}$. Furthermore, P is concentrated mainly at the rim of the olivine, in contact with surrounding glass.

$D_P^{ol/melt}$ has a wide range (0.02 to 1.6), with the lowest numbers thought to represent equilibrium and higher numbers non-equilibrium partitioning via solute trapping during rapid growth (e.g. Watson et al. 2015). The imperfect correlation between P and Al in our data implies either diffusive relaxation of Al gradients or, judging by dynamic experiments (Grant & Kohn, 2013), cooling rates ∼1-10°C/h that generate disequilibrium P solute trapping but near-equilibrium Al incorporation. Early-crystallized olivine grew slowly enough to incorporate P by equilibrium partitioning, suggesting that no P-rich boundary layer developed despite slow diffusion of P in melts. Olivine rim crystallization, though was rapid enough to over-enrich P, by more than can be associated with concentration of P into a decreasing mass of residual melt (Shea et al. 2015). The apparent partition coefficient between olivine rims and adjacent melt suggests $D_P^{ol/melt}$ in the range 0.13-0.19.

References

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