Phosphorus-rich olivines in a composite xenolith from Morocco: implications for growth processes

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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 (by optical microscopy and electron microprobe) a composite mantle xenolith from the Middle Atlas Mountains (Morocco) containing two lithologies, wehrlite and harzburgite, in direct contact. The host alkali basalt (El Messbahi et al. 2015) is present on the margins of the hand sample but not included in our thin section. Both lithologies display porphyroclastic texture and contain interstitial devitrified glass. Large primary matrix olivine in both wehrlite and harzburgite has P\textsubscript{2}O\textsubscript{5} concentrations \(\leq 0.09\) wt.\% and nearly constant composition, Fo\textsubscript{90}, except for Fe-rich reaction rims in contact with the interstitial devitrified glass. The P-rich interstitial spaces between these primary matrix olivines consist of devitrified glass, secondary olivine, clinopyroxene, spinel, andapatite. The secondary olivine ranges between Fo\textsubscript{86-93} and is obviously enriched in P\textsubscript{2}O\textsubscript{5}, with concentrations from 0.36-1.98 wt.\%. Whereas matrix clinopyroxene in the wehrlite forms isolated subhedral to euhedral crystals, the interstitial regions contain elongated and dendritic clinopyroxene up to 10 \(\mu\)m long as well as replacive clinopyroxene rims on matrix minerals. Spinel occurs as tiny discrete grains associated with the devitrified glass. Apatite is found only as very small crystals embedded in devitrified glass.

High-resolution X-ray mapping of P in olivine reveals both alternating P-rich bands parallel to crystal elongation and patchy zoning. P\textsuperscript{5+} correlates negatively with Si\textsuperscript{4+} (\(R = -0.90\)) and positively with Na\textsuperscript{+} (\(R = +0.73\)). Correlation with total divalent cations (Mg\textsuperscript{2+}+Mn\textsuperscript{2+}+Fe\textsuperscript{2+}+Ca\textsuperscript{2+}+Ni\textsuperscript{2+}) is weakly negative (\(R = -0.44\)). Although correlation of P\textsuperscript{5+} and Al\textsuperscript{3+} is weak (\(R = -0.42\)), the combination P\textsuperscript{5+}+Al\textsuperscript{3+} displays a better anticorrelation with Si\textsuperscript{4+} (\(R = -0.92\)). Overall, the observed correlations suggest the predominant substitution mechanism is 2 \(^{IV}\)Si\textsuperscript{4+} \(\leftrightarrow\) \(^{IV}\)P\textsuperscript{5+} + \(^{IV}\)R\textsuperscript{3+}, with some additional accommodation by \(^{IV}\)Si\textsuperscript{4+} + \(^{VI}\)M\textsuperscript{2+} \(\leftrightarrow\) \(^{IV}\)P\textsuperscript{5+} + \(^{VI}\)Na\textsuperscript{+}.

Because no glass was observed, the apparent olivine/melt partition coefficient could not be directly measured. However, using the maximum P\textsubscript{2}O\textsubscript{5} contents (1.05, 1.18 and 2.31 wt\%)
measured in glass in melt veins from other xenoliths from the a nearby Moroccan volcanic flow (Baziotis et al. 2019) and the P-rich olivines from the present study, we infer a $D_{\text{ol/melt}}$ range 0.85-1.88. The most probable value is greater than unity, despite P being incompatible in olivine during equilibrium growth. Such an apparent partitioning suggests that olivine crystallization was rapid enough, ~1-10 K/hour, to develop a P-rich diffusive boundary layer from which the growing olivine incorporated P in excess of equilibrium partitioning with the bulk melt pocket (Grant & Kohn, 2013).

We consider several scenarios for the formation of the interstitial pockets, including partial melting of the xenolith, intrusion of a metasomatic melt in an event earlier than eruption, and reaction with the host lava during ascent.

References


Milman-Barris et al. 2008. Contributions to Mineralogy and Petrology 155, 739-765.