

Phosphorous in Olivine from the Siqueiros Fracture Zone, East Pacific Rise and implications for dynamics of magma bodies

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Understanding the residence time of melts in crustal magma reservoirs is key to understanding how magmas are stored and transported to the Earth's surface. Of particular interest are the residence times and sizes of magma bodies in mid-ocean ridge systems. Here, we explore the possibility of using P, a slowly diffusing element, in olivine phenocrysts as a potential geospeedometer that tracks variations in crystal growth rates. P is highly incompatible in olivine, but under rapid, disequilibrium growth, P in olivine can become anomalously enriched relative to concentrations in the far field melt, owing to partitioning with respect to an enriched chemical boundary layer.

We analysed olivine crystals from the Siqueiros Fracture Zone in the East Pacific Rise. We find that olivine P₂O₅ contents vary from near detection limits at 0.0005 up to 0.04 wt%. Coexisting melts had P₂O₅ contents varying between 0.04-0.06 wt%. Using the ratios between melts and their associated olivines, we calculated apparent partition coefficients between 0.007-0.048. Experimental olivine/melt partition coefficients from the literature vary from 0.02 to 1.4. However, due to limitations in detection limits, it is highly likely that published partition coefficients are maximum bounds. We also compared MORB glass P₂O₅ contents with P contents of peridotites, which give a range of effective partition coefficients of 0.01 to 0.1. Given analytical limitations in historical data and the possibility of disequilibrium, which enhances apparent partition coefficients, we suggest that equilibrium olivine/melt P partitioning is likely less than 0.01.

Using 0.01 to estimate the P content of hypothetical olivines in equilibrium with MORBs, we find that the majority of the observed concentrations in olivines are significantly higher (up to 50-100 times) than equilibrium, manifested as high apparent partition coefficients. The extreme variability of apparent partitioning of P in olivine suggests P enrichment at the crystal/melt interface and rapid disequilibrium crystallization. Models are being developed to convert the level of P disequilibria in to crystal growth rates so that estimates of residence time in magma bodies can be quantified.