Determining magma ascent rates from diffusive D/H fractionation in olivine-hosted melt inclusions

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The depths at which magmas are stored, their pre-eruptive volatile concentrations, and the rates at which they ascend to the surface are important controls on the dynamics of volcanic eruptions. Magma ascent rates are particularly difficult to quantify, however, due to a dearth of geospeedometers applicable to processes occurring on timescales ranging from hours to days. We developed a new approach to determining ascent rates on the basis of D/H fractionation associated with diffusive H_2O loss from olivine-hosted melt inclusions (MIs). During ascent, the host magma degasses which, in turn, drives diffusive loss of H from MIs. Preferential loss of H – relative to the more slowly diffusing D – leads to increasing D/H (or δD_{VSMOW}) with decreasing H_2O concentration in the MI. The slope of the negative correlation between H_2O and δD_{VSMOW} is a reflection of ascent time, which can be determined from diffusion modeling. The utility of this approach was demonstrated on olivine-hosted MIs from hyaloclastite at Hut Point Peninsula, Antarctica. All inclusions are glassy and contain vapor bubbles. Total CO_2 was determined by summing CO_2 in the included glass and in the vapor bubble (VB). The volumes of MIs and VBs were determined by X-ray microtomography, and the density of CO_2 within each VB was determined using Raman spectroscopy. The included glass was analyzed for volatiles and δD_{VSMOW} by secondary ion mass spectrometry. Entrapment pressures calculated on the basis of total CO_2 and maximum H_2O using the MagmaSat solubility model [1] indicate a depth of origin of ~24 km – in good agreement with the seismically determined depth of the Moho beneath Ross Island [2]. An ascent rate of ~0.1 m/s was determined using a finite difference model for melt inclusion dehydration during magma ascent.

[1] Ghiorso and Gualda (2015) *Cont Miner Pet* **169**; [2] Finotello et al. (2011) *Geophys J Int* **185**, 85-92.