Element re-equilibration of high-T melt inclusions via diffusion through the host crystals

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Diffusive re-equilibration of incompatible trace elements between olivine- or chromite-hosted melt inclusions and an external magma is widely regarded to be insignificant due to the low partition coefficients for these elements in chromite or olivine [1]. However, diffusive re-equilibration of melt inclusions depends not only on partitioning but also on diffusion through the crystal lattice [2]. At present there are no data on diffusion coefficients for most trace elements in olivine or chromite.

We have conducted diffusion experiments at 1300-1450ºC to determine both partition and diffusion coefficients for a wide range of trace elements in forsteritic olivine and chromite. Experiments were conducted at 1 atm under controlled fO_2 for up to 25 days using trace element-doped synthetic melts that were designed to be in equilibrium with olivine or chromite at run conditions. Diffusion profiles were measured across sections of the crystal/melt boundary by laser-ablation ICP-MS by traversing a thin laser slit oriented parallel to the crystal/melt interface. Element concentrations were fitted to the diffusion equation to obtain both diffusion coefficients and concentrations at the crystal/melt interface, and hence partition coefficients. Calculated diffusivities for many trace elements (REE, Y, Sc, V, Be, Ni, Co) are relatively fast ($D = 10^{-15}$ to 10^{-14} m^2/s at 1300ºC). Applying our diffusion and partition coefficients to the equations of Qin et al. [2], we calculate that the trace element compositions of olivine- or chromite-hosted melt inclusions in the mantle will completely re-equilibrate with external magma in years to decades. These timescales are significantly shorter than the times estimated for the production and extraction of magma from the mantle, whether from U-series disequilibria or geophysical modelling, implying anomalous melt inclusions cannot preserve a record of melting of mantle heterogeneities. Instead, anomalous melt inclusions formation is likely to be linked to crustal assimilation shortly before eruption [3] and so may be useful monitors of such processes.

References

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