Trace element diffusion during mixing of rhyolitic and shoshonitic magmas

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Knowledge of the diffusive behaviour of trace elements is of crucial importance in the understanding of several magmatic processes, among them the chemical exchange occurring in magma mixing events, in which diffusion has the potential to provide timescales for such events. We experimentally studied the diffusion of 34 trace elements from diffusion couple experiments at high-pressure (50-500 MPa), high temperature (1200ºC) and both dry and hydrous (1 wt.% and 2 wt.% H_2O) conditions. Experiments were run in an internally heated pressure vessel (IHPV). The experimental end members are natural compositions sampled in Vulcano island (Aeolian archipelago, Italy): a shoshonite (Vulcanello peninsula) and a high-K rhyolite (Pietre Cotte obsidian flow). Concentration-distance profiles were measured by LA-ICP-MS and water contents were characterized by Fourier Transform Infrared spectroscopy. For elements with Fickian behaviour, concentration-dependent diffusion coefficients were determined at four intermediate compositions by a Sauer & Freise method (modified Boltzmann-Matano).

Most trace elements show Fickian diffusion profiles, with the notable exception (among others) of trivalent REE. Water content is the main conditioning factor of diffusion in our experimental setup but a variable behaviour is observed between elemental groups. LIL elements display a moderate (Rb, Cs) to non-existent (Ba, Sr) compositional dependence and are greatly enhanced by water (up to 1.5 orders of magnitude increase at 2 wt. %). Transition elements (Ni, Co) have a moderate water and compositional dependence, and HFS elements (e.g. Eu, U, Th) have a moderate water dependence but show a strong compositional dependence. Uphill diffusion (diffusion against concentration gradient) is observed in elements such as Mn, Ga, Zr, Nb, Pb, Y and, most prominently, the trivalent REE (La to Sm and Gd to Lu). The apparent effect of uphill diffusion is greatest in the LREE and diminishes gradually towards the HREE.