

Cation diffusion in magmatic olivine and the 'melt problem'

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Diffusion chronometry has become a commonplace petrological tool to extract timescale information (e.g. magma mixing-to-eruption, ascent, long term storage, mush reactivation). Its success is partly owed its simplicity: concentration gradients in chemical elements are leveraged to solve for time using experimentally-derived element diffusivities. Experimental studies that measure element diffusivities mainly rely on solid-solid couples (mineral- or powder-mineral, thin film-mineral) because the setup allows for interface-position control and helps circumvent interface reactions that could affect calculated values. Melt-mineral couples are seldom utilized due to interface reaction problems, despite their capacity to better simulate crystal-melt configurations extant in natural magmas. The few existing mineral-melt studies found that diffusivities in some major, minor and trace elements were higher than those derived from melt-free solid couples [1] [2]. We completed a series of 10 experiments to investigate diffusion of major (Fe-Mg) and minor (Mn, Ni, Ca) elements in olivine surrounded by basalt melt at 1-atm, fO_2 at QFM-1. Natural olivine seeds crystals from Kālauea and San Carlos were mixed in basalt powder and heated to 1290°C for 8-24 hrs, cooled to 1200-1287°, and held for an additional 6-88 hrs. After quenching, concentration gradients were analyzed by electron microprobe and used to solve for diffusivities. Diffusivities are about an order of magnitude higher in our melt-bearing experiments than in studies that utilized solid-solid couples, but maintain similar degrees of anisotropy between different crystallographic directions (e.g. Fe-Mg diffusivity along c is ~6 times the diffusivity along other directions). We used TEM to investigate whether interface reaction during the experiments (dissolution/growth) created planar and/or tube defects that could act as fast diffusion pathways [3]. Features consistent with this hypothesis were not observed. We note potential experimental caveats but conclude that interface reaction or geometric effects cannot account for the large differences observed. We discuss the potential influence of hydrogen and other trace elements on major and minor element diffusivities.

[1] Jurewicz & Watson (1988), *CMP* 99, 186-201

[2] Spandler & O'Neill (2010), *CMP* 159, 791-818

[3] Burgess & Cooper (2012), *CMP* 166, 1223-1233

