Multicomponent diffusion in silicate melts: SiO_2-TiO_2-Al_2O_3-MgO-CaO-Na_2O-K_2O system

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Multicomponent diffusion in natural silicate melts plays an essential role in mass transport, such as mixing and contamination of magmas, double-diffusive convection, and mineral growth or dissolution in a magma. The often-observed uphill diffusion profiles require a multicomponent diffusion treatment, which is not available yet. In this report, we investigate multicomponent diffusion in a haplobasaltic melt.

Ten successful diffusion couple experiments were conducted in a 7-component haplobasaltic melt SiO_2-TiO_2-Al_2O_3-MgO-CaO-Na_2O-K_2O (with average compositions SiO_2~50wt%, TiO_2~1.5wt%, Al_2O_3~15wt%, MgO~10wt%, CaO~19wt%, Na_2O~3wt%, K_2O~1.5%) at ~1500 °C and 1 GPa. In six experiments, the initial concentration gradients are in SiO_2 vs. every other component, plus four experiments with initial concentration gradients in TiO_2-MgO, Al_2O_3-MgO, MgO-CaO, and CaO-Na_2O. After each experiment, at least two traverses were measured for concentration profiles. Effective binary diffusion coefficients (EBDCs) were fit by an error function for components with monotonic profiles. It shows that the EBDCs are dependent on its counter-diffusing component. For example, the EBDC of SiO_2 varies from 15.7 $\mu m^2/s$ when diffusing with Al_2O_3, to 102.9 $\mu m^2/s$ when diffusing with K_2O. Multicomponent diffusion matrix was obtained by fitting simultaneously concentration profiles of all components in all ten experiments, as well as a subset of the experiments (six experiments). The resulting diffusion matrices are similar. Most features, for example the uphill diffusion profiles, are well captured by the fit, using a single diffusion matrix. The eigenvalues of the diffusion matrix range from 16.5 to 310 $\mu m^2/s$, and the eigenvectors of the diffusion matrix were examined when the dependent component is varied. The results show that the smallest eigenvalue is largely due to the exchange of Si and Al, and the largest eigenvalue is due to the exchange of Na with all other components. In order to test the validity of this diffusion matrix, an anorthite dissolution experiment was conducted in the same melt, and the calculated profiles in the melt match fairly well with the measured profiles.