Experimental Determination of Cation Diffusivities in Ilmenite

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Ilmenite ($FeTiO_3$) in volcanic rocks occurs with solid solutions of Mg^{2+}, Mn^{2+}, and Fe^{3+}. Ilmenite and coexisting oxides are often used to estimate pre-eruptive temperatures and oxygen fugacities. However, these methods are only reliable when coexisting phases are in equilibrium. Evidence for ilmenite disequilibria exists in rapidly cooled volcanic rocks as both ilmenite-titanomagnetite disequilibria and compositional zoning in ilmenite grains. The diffusion rates of Mg and Mn in ilmenite at high-temperature conditions are key to understanding the ilmenite disequilibria preserved in volcanic rocks.

We conducted diffusion-annealing experiments in a 0.5” piston cylinder apparatus to investigate the diffusivity of Fe^{2+}, Mg^{2+}, and Mn^{2+} in ilmenite solid solutions between 800°C and 1100°C. Synthetic polycrystalline ilmenite was juxtaposed against either an oriented, synthetic geikielite ($MgTiO_3$) crystal, or a synthetic polycrystalline Mn-bearing ilmenite, in a “diffusion-couple” geometry. Geikielite single crystals were oriented to control the diffusion direction (either perpendicular or parallel to the crystallographic c-axis). Electron microprobe analyses were obtained perpendicularly across the diffusion interface for each experiment. Our experimental diffusion profiles create smooth curves that, when fit with an error function, define Fe-Mg and Fe-Mn interdiffusion coefficients in ilmenite. We apply our diffusion coefficients to constrain the timescales of rapid volcanic processes.