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Diffusion in Plagioclase

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The common occurrence of zoned plagioclase as phenocrysts in magmas makes this phase attractive as a recorder of the timescales of volcanic processes (e.g., [1]). In this regard, it would be valuable to make use of the different rates of diffusion available by studying a wide a range of elements. While the diffusivities of a few elements have been experimentally determined, there are several other minor and trace elements now analysable in plagioclase phenocryst whose diffusivities remain poorly constrained. Here we report the results of two series of experiments to determine the diffusivities of Be, Na, Mg, K, Mn, Fe, Sr and the REEs including Eu in natural plagioclase crystals of different composition at different activities of silica and alumina.

In the first series, diffusion couples were set up between polished cubes of natural An_{95} and An_{70} and polyphase mixtures of synthetic doped plagioclase with other phases in the system CaO-Al_2O_3-SiO_2, to control silica and alumina activities. These plagioclase crystals were hung in a 1-atm. gas mixing furnace at 1290°C at QFM oxygen fugacity for 691 hours. The second series used silicate melt as the diffusant source, with plagioclase crystals crafted into crucibles [2] and filled with melt compositions modified from the USGS standards AGV (andesite) and BIR (basalt) to be in equilibrium with the An_{70} and An_{60} crystals. These experiments were run at 1190°C and QFM for 777 hours. The long length and high temperature of these experiments allows most diffusion profiles to be measured by LA-ICP-MS and the shorter profiles to be measured by the nanoSIMS.

Preliminary results for diffusivities of Sr, Mg and K are similar to published data. The partition coefficients at the interface for all elements is in good agreement with plagioclase partitioning experiments. Eu^{2+} is highly compatible in plagioclase and large concentrations can diffuse into the crystal at a similar rate to the other divalent cations.

There is evidence for several diffusion pathways from the results of this study: diffusivities of 1+ and 2+ cations on the large cation site are generally fastest, while mechanisms associated with the tetrahedral site are slower. In addition very small amounts of REE^{3+}, perhaps charge-balanced by vacancies, diffuse even faster than the 1+ and 2+ cations.

[1] Cooper KM & Kent AJ (2014) Nature, 506, 480-483.

[2] Spandler C & O'Neill, HSC (2010) Contrib Mineral Petrol 159, 791-818.