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Determination of hydrogen diffusivity in Ca-rich plagioclase

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Introduction: Compared to studies on hydrogen diffusivity in olivine and pyroxenes, studies on hydrogen diffusivity in feldspars are very few. Plagioclase is one of the most common nominally anhydrous minerals in arc basaltic rocks, and hydrogen diffusivity in volcanic plagioclase can be applied as an useful indicator of degassing from arc basaltic magmas. Here, we performed preliminary experiments to determine hydrogen diffusivity in Ca-rich plagioclase. We also combined the obtained experimental results and analytical results of plagioclase from the 1986 summit eruption of Izu-Oshima volcano to estimate magma ascent rate.

Experimental: Hydrothermal annealing experiments of Ca-rich plagioclase were carried out at 300 MPa using an internally-heated pressure vessel to constrain hydrogen diffusivity in plagioclase. Experiments were performed at temperature ranging from 1000 to 1200 degree C and at fO_2 close to NNO buffer. Experiments were quenched after run duration of 1 to 10 hours depending on temperature. For diffusion experiments, only the relative change of hydrogen concentration is necessary and no independent calibration is required. Thus, we did not quantify hydrogen concentration in plagioclase using polarized infrared spectroscopy (Johnson and Rossman, 2003, *Am. Mineral.*) and instead we measured infrared absorption area per unit thickness using unpolarized infrared beam.

Results: The profile of infrared absorption area per unit thickness across the plagioclase crystal was converted to hydrogen diffusivities, which ranged from about 10^{-11} m^2/s at 1200 degree C to about 10^{-12} m^2/s at 1000 m^2/s. These results are consistent with extrapolated hydrogen extraction diffusivity determined at 1 atm under N^2 gas (Johnson, 2003).

Application: The hydrogen concentration in Ca-rich plagioclase (about An_{90}) from the 1986 summit eruption of Izu-Oshima volcano shows variation ranging from $<$ 50 wt. ppm H_2O through 300 wt. ppm H_2O as a result of polybaric degassing (Hamada et al., 2011, *EPSL*). Hydrogen concentration in each plagioclase is almost uniform across the crystal. The hydrogen diffusivity at eruptive temperature (about 1100 degree C) is about 10^{-12} m^2/s, which gives that plagioclase with high hydrogen concentration (300 wt. ppm H_2O) was brought from magma chamber to surface within a few hours to keep hydrogen at the core and to lose minimal amount of hydrogen at the rim. In agreement with this estimation, estimated magma ascent rate at the onset of the 1986 eruption was of the order of 10^3 m/h based on the discharge rate of magma at that time ($>$ 2x10^5 m^3/h). As demonstrated here, hydrogen diffusivity in plagioclase can be useful as an ascent rate meter of hydrous arc basaltic magmas during explosive eruption.

Keywords: Water in nominally anhydrous minerals, plagioclase, Hydrogen diffusivity