Li and B diffusivity in hydrated silicate melts: an experimental study

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Magmatic volatiles play a major role in controlling magma dynamics, such as ascent characteristics and eruption style. In order to fully understand their influence in magmatic systems, it is crucial to examine their behaviour within silicate melts. Although numerous studies have been conducted on volatile solubility, exsolution and degassing, some aspects of magma degassing such as bubble formation, bubble growth and the effect on the distribution of fluid-mobile elements are poorly understood. For instance, magma degassing is likely to affect the abundance and dispersion of fluid-mobile elements, such as Li and B, in the magma. Thus, this study focuses on the diffusivity of Li and B in hydrated silicate melt as a proxy for degassing processes.

Lithium and boron are particularly suitable as geochemical tracers of degassing processes because they are light elements, present in natural volcanic systems in low concentrations, and have similar characteristics: both elements are fluid-mobile and each has two stable isotopes with different transport behaviours due to their atomic weights, which can lead to isotope fractionation. In order to successfully model their behaviour during magmatic ascent, their diffusivities in silicate melts have to be well constrained.

Diffusion data in hydrous settings are missing or underrepresented: very little studies have been conducted on boron diffusivity, the literature gives contradictory diffusion coefficients for lithium. In this study, we focus on elemental diffusion and isotopic fractionation of lithium and boron in hydrated silica-rich melts, in order to better understand B diffusivity and solve the discrepancies about Li data.

Sets of diffusion-couple experiments on synthetic water-bearing rhyolitic glasses have been performed, using an internally heated pressure vessel, at a constant pressure of 300 MPa and temperatures of 700°, 800° and 1000° C, with durations of 0 seconds, 30 minutes, 2 hours and 4 hours. Lithium and boron elemental concentrations have been measured by LA-ICP-MS, resulting in 600 μm long profiles, while isotopic ratios are being evaluated by SIMS analysis.

The zero-hour experiment indicates that lithium diffuses very rapidly, potentially already at
temperatures below 700° C (during the heating process), while boron diffusion is generally slower, hence the necessity of higher temperatures and longer experimental run durations. Overall, our experimental results confirm previous literature findings that Li diffuses faster in water-bearing melts, and give first constraints on boron diffusivity in hydrated silicate melts, whereas previous studies only considered anhydrous samples. The determination of diffusion coefficients of the two elements gives us a better understanding of the diffusion timescales. This information allows us to interpret additional decompression experiments, simulating a wide range of magma ascent rates, and to correlate the elemental and isotopic behaviour of lithium and boron with decompression-induced bubble formation processes.