Tracking pre-eruptive degassing at Laki, Iceland, through diffusion modelling

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Information on the timescales of magma ascent, mixing and degassing in volcanic plumbing systems provides important constraints on the interpretation of seismic, geodetic and gas monitoring data prior to and during large fissure eruptions. The AD 1783 Laki eruption, southeast Iceland, produced over 15 km3 of basaltic lava and tephra, and led to three years of extreme climatic variability in Europe and North America. We quantify the timescales of degassing in the Laki magma system, and determine the potential flux of CO2 to the surface in the premonitory phases of the Laki eruption.

Olivine-hosted melt inclusions from Laki range from volatile-rich (5000 ppm CO2) to almost completely degassed (<50 ppm CO2). Volatile saturation models suggest that these melt inclusions were trapped at pressures from <0.1 to >7 kbar, and the melt inclusions preserve a record of concurrent degassing and crystallisation. The total CO2 mass release from the Laki magma is on the order of 370 Mt. Diffusion modelling techniques applied to compositional profiles across olivine and plagioclase phenocrysts enable the timescales of magmatic processes in the run up to the Laki eruption to be constrained.

Olivine crystals from rapidly-cooled tephra samples display up to three distinct compositional zones linked by diffusion profiles, indicative of crystallisation and storage in different magmatic environments. Preliminary modelling suggests that the diffusion profiles reflect timescales on the order of 100 days. These residence times apply to magma storage in a shallow reservoir immediately prior to eruption, thus providing a minimum bound on the timescale of melt inclusion entrapment.

Plagioclase macrocrysts from Laki often have high-anorthite (An84-89) cores surrounded by oscillatory-zoned (An74-80) mantles. The high-anorthite core compositions cannot be reproduced by fractional crystallisation modelling of the Laki carrier melt, and may have grown from depleted melts of the shallow mantle that were mixed into the Laki carrier liquid during the earliest stages of magmatic evolution. The growth of the zoned plagioclase mantles thus represents one of the earliest magmatic processes in the history of the Laki magma. Crystallisation of plagioclase mantles occurred concurrently with the crystallisation of the melt inclusion-bearing olivine macrocrysts. Diffusion of Mg and Sr between plagioclase cores and mantles is expected to provide information on the timescales of processes occurring early in Laki's magmatic history, including the deep degassing of CO2. Suitably-zoned plagioclase macrocrysts are used to obtain direct estimates for the timescales between crystal growth, melt inclusion entrapment and eruption. The timescale estimates are linked to the evolution of the Laki magma body by integrating the diffusion modelling results with the record of cooling and crystallisation preserved in the melt inclusion compositions.