Highly explosive basaltic eruptions: magma fragmentation induced by rapid crystallisation

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The low viscosity of basaltic magmas generally favours effusive and mildly explosive volcanic activity. Highly explosive basaltic eruptions occur less frequently and their eruption mechanism still remains subject to debate, with implications for the significant hazard associated with explosive basaltic volcanism. Particularly, highly explosive eruptions require magma fragmentation, yet it is unclear how basaltic magmas can reach the fragmentation threshold.

The crystallisation kinetics of an ascending magma are driven by degassing and cooling. So far, the crystallisation kinetics have been estimated through *ex situ* experiments. However, this experimental approach induces underestimation of crystallization kinetics in silicate melts. The crystallization experiments reported in this study were performed *in situ* at Diamond Light Source (experiment EE12392 at the I12 beamline), Harwell, UK, using basalt from the 2001 Etna eruption as the starting material. We combined a bespoke high-temperature environmental cell with fast synchrotron X-ray microtomography to image the evolution of crystallization in real time. After 4 hours at sub-liquidus conditions the system was perturbed through a rapid cooling (0.4 °C/s), inducing a sudden increase of undercooling. Our study reports the first *in situ* observation of exceptionally rapid plagioclase and pyroxene crystallisation in basaltic magmas. We combine these constraints on crystal kinetics and viscosity evolution with a numerical conduit model to show that exceptionally rapid syn-eruptive crystallisation is the fundamental process required to trigger basaltic magma fragmentation under high strain rates.

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