

## Timescales of crystal mush mobilization in the Bárðarbunga-Veiðivötn volcanic system based on olivine diffusion chronometry

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### ABSTRACT

The timescales of magmatic processes within a volcanic system may be variable over a volcano's geological history. Crystals reflect environmental perturbations under which they grew, and compositional gradients quenched inside crystals on eruption can be exploited to extract timescales of magmatic processes. Here, we use multi-element diffusion chronometry in olivine macrocrysts to recover their residence time in a melt that ultimately erupted at the surface. The macrocrysts were mobilized by the carrier melt from mushy layers in the magma reservoir, and diffusion timescales likely reflect the time interval between mush disaggregation, ascent, and eruption. To unravel the evolution of mush disaggregation timescales with time, we target early-Holocene, middle-Holocene, and historical magmatic units erupted in the Bárðarbunga-Veiðivötn volcanic system in Iceland's Eastern Volcanic Zone. Macrocryst contents vary between samples; early-Holocene samples are highly phyric (10–45 vol% macrocrysts) and contain gabbroic nodules, whereas middle-Holocene (5–15 vol%) and historical units (5–10 vol%) tend to be generally less phyric. Early-Holocene olivine macrocrysts have core compositions in the range  $Fo_{84-87}$ , while middle-Holocene and historical samples record a wider range in core compositions from  $Fo_{80}$  to  $Fo_{86.5}$ . Olivine rims are in chemical equilibrium with their carrier liquid and are slightly more evolved in early-Holocene units ( $Fo_{76-81}$ ) compared to middle-Holocene ( $Fo_{78-80}$ ) and historical ( $Fo_{81-83}$ ) units. Diffusion chronometry reveals that the timescale between mush disaggregation and eruption has changed over time, with timescales getting shorter approaching recent times. Early-Holocene olivine macrocrysts dominantly record Fe-Mg diffusion timescales between 200–400 days, while middle-Holocene and historical units typically record timescales of about 70 and 60 days, respectively. Barometric studies suggest that melts and crystals are likely stored and gradually transferred throughout an interconnected multi-tiered system that ultimately culminates in a mid-crustal reservoir(s) at about 6.8–7.5 ± 2.5 km depth, where final disaggregation by the carrier liquid took place. We argue that, as a result of extensional processes enhanced by rifting events, well-mixed melts got drawn into mid-crustal reservoir(s), causing crystal mush loosening and mobilization. In addition, we propose that more energy in the form of heat and/or melt supply was required in the early-Holocene to break up the dense mush fabric and convert it into an eruptible magma. Conversely, as evidenced by the diverse macrocryst content of the historical units and by the lack of gabbroic nodules, the system has become characterized by a less compact mush fabric since at least the middle-Holocene, such that fresh injection of melt would easily loosen and mobilize the mush, resulting in an eruption within a couple of months. This study provides evidence that along axial rift settings, rifting-related processes can help to “pull the mush apart” with no requirement for primitive magma injection as an eruption trigger. Furthermore, we provide evidence that in the Bárðarbunga-Veiðivötn volcanic system specifically, the time between mush disaggregation and eruption has decreased considerably with time, indicating shorter warning times before imminent eruptions.

**Keywords:** Iceland, crystal mush, diffusion chronometry, Bárðarbunga, timescales, olivine, Bárðarbunga-Veiðivötn, Igneous petrology