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Crystal-mush remobilization timescales in the Snæfellsnes volcanic zone (W-Iceland): Insights from olivine Fe-Mg diffusion chronometry

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Efforts to understand pre-eruptive magma storage and transfer in Iceland's neovolcanic zones have largely focused on on-rift systems, leaving off-rift volcanic flank zones like the Snæfellsnes Volcanic Zone (SNVZ) poorly constrained. Elevated seismicity detected in the Grjótárvatn area of the Ljósufjöll volcanic system (SNVZ), starting in 2021, has intensified since August 2024, including the largest earthquakes on 18 December 2024 (M 3.1) and 25 January 2025 (M 3.3) (https://en.vedur.is/about-imo/news/seismic-activity-in-grjotarvatn-has-increased-in-the-last-months). This has fuelled speculation about a potential reawakening of SNVZ eruptive activity, akin to the Reykjanes Peninsula in 2021. We present a quantitative petrological approach combining clinopyroxene-melt, clinopyroxene-only, and Raman-based fluid inclusion barometry with olivine Fe-Mg diffusion chronometry to constrain magma storage depths and timescales associated with mush disaggregation and magma mobilization leading up to the Holocene Búðahraun (~5.0–8.0 ka) and Berserkjahraun eruptions (~4.0 ka) in the SNVZ. Olivine-hosted fluid inclusions (n=109) record entrapment pressures of 1.5–5.1 kbar, with medians of 3.6 (Búðahraun) and 3.7 kbar (Berserkjahraun), corresponding to median depths of ~12–13 km. Clinopyroxene cores return similar median pressures of ~3.6–4.0 kbar, translating to storage depths of 13–14 km.

Overlapping olivine fluid inclusion and clinopyroxene-core barometry suggests a primary magma storage zone at ~13–14 km, coinciding with the region from which most of the recently detected deep seismicity originates. Olivine diffusion timescales from Búðahraun lava and Berserkjahraun lava and scoria samples indicate timescales from 6 days to ~4.1 years, with median pre-eruptive magma mobilization timescales of 34 to 36 days. Notably, 81% (n=111) of the timescales are shorter than 3 months (~93 days). Olivine diffusion records emphasize the gradual erosion of crystal-mush-rich layers at mid-crustal levels starting ~4.1 and ~1.6 years prior to the Búðahraun and Berserkjahraun eruptions. The frequency of mush erosion and crystal-melt disequilibria recorded in olivine zoning increases one month before eruptions, suggesting magma ascent from the mid-crustal storage zone to the surface within a month or less. Given the sparse petrological documentation and monitoring infrastructure in the SNVZ, our integrated dataset provides critical insights into magma storage and mobilization in this underexplored volcanic region.