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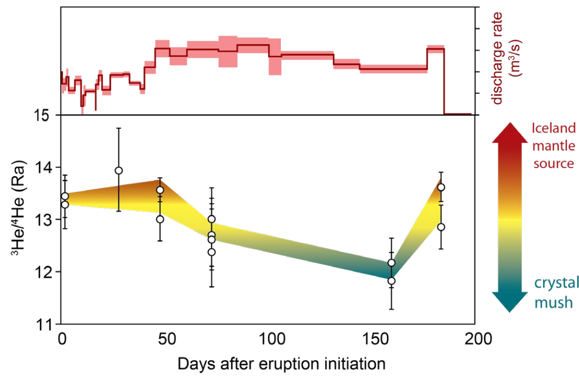
Rapid $^3He/^4He$ changes in Fagradalsfjall (Iceland) 2021 lavas

FORREST HORTON[1], EDWARD W. MARSHALL[2], SAEMUNDUR A HALLDORSSON[2], PETER H BARRY[1], JOSHUA CURTICE[1] AND MARK D KURZ[1]

[1]Woods Hole Oceanographic Institution

[2]Nordic Volcanological Center, Institute of Earth Sciences, University of Iceland

Presenting Author: fhorton@whoi.edu



Nebular helium preserved since planetary accretion is unevenly distributed throughout the terrestrial mantle. $^3He/^4He$ differences among mantle-derived lavas—and Iceland lavas in particular—inform our understanding of planetary accretion and long-term mantle evolution. Here we report $^3He/^4He$ variability on monthly timescales during the 2021 eruption of the Fagradalsfjall volcano (March 19th–September 18th). Olivine crushing experiments for lavas erupted on days 2–183 yielded average $^3He/^4He$ of 13.0 ± 0.6 Ra (s.d., n=14), where Ra is the atmospheric ratio of 1.384×10^{-6}. This is indistinguishable from average $^3He/^4He$ measured in nearby Reykjanes peninsula geothermal fluids, mafic crystals, and subglacial glass (13.2 ± 1.7 Ra, n=63, longitude west of 21.5° W [1]). Olivines erupted during the first 50 days and at the end of the eruption had $^3He/^4He$ of 13.4 ± 0.4 Ra. Mid-eruption, $^3He/^4He$ decreased to 12.0 ± 0.2 by day 60. If olivine $^3He/^4He$ reliably tracks mantle source compositions, an opposite trend might be expected over the course of the eruption because Fagradalsfjall magmas tapped mantle domains that were progressively more enriched in incompatible trace elements [2], which are associated with higher $^3He/^4He$ on this part of the island [3]. Instead, olivine $^3He/^4He$ may be partially inherited from crystal mushes [4] near the Moho that predate magma recharge leading up to the 2021 eruption. If so, Fagradalsfjall lavas contain variable proportions of mantle source (>14 Ra) and mush (<12 Ra) helium. These data suggest that mush decompaction and xenocryst entrainment were most efficient mid-eruption, when discharge rates were highest [5]. We suggest that transient mushes moderate magmatic $^3He/^4He$ changes and thereby mask mantle source heterogeneity.

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[2] Halldórsson et al. (2022) *Nature* 609, 529–534.
[3] Harðardóttir et al. (2022) *Chem. Geo.* 604: 120930.
[4] Maclennan (2019) *Phil. Trans. R. Soc.* A 377: 20180021.
[5] Pedersen et al. (2022) *Geo. Res. Lett.* 49, e2021GL097125.