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Thorium, Sr and Nd isotope ratios in basalts from the 2021-2022 Fagradalshraun, Iceland

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The composition of MgO-rich basalt produced during the six-months long 2021 eruption at Fagradalsfjall, Reykjanes Peninsula, varied from those with low K_2O/TiO_2 and incompatible element contents to basalt enriched in incompatible elements with high K_2O/TiO_2 over a timespan of a month, explained by binary mixing of different mantle melts (Halldórsson et al., 2022). For the rest of the eruption, the basalt composition varied in a periodic manner as illustrated by trace element ratios and long-lived radiogenic isotope ratios (see also Marshall, this meeting). For example, the periodicity of $^{87}Sr/^{86}Sr$ from early May to middle of September 2021 was 52 days, likely representing the time elapsed from the final melt mixing at depth (the moment of acquiring the measured isotope composition) until eruption at surface. Here we show that this rapid mantle-derived temporal variability also extends to ^{238}U-^{230}Th radioactive disequilibria.

Published Th isotope ratios on recent basalt lavas from the Reykjanes Peninsula yield uniform ($^{230}Th/^{232}Th$) of 1.15 (2SD=0.02; n=15; Pete et al. 2001; Kokfelt et al. 2003: Koornneef et al. 2012). Preliminary results on Th isotope ratios in the 2021 Fagradalshraun exceed this range with higher Th isotope ratios [($^{230}Th/^{232}Th$) = 1.30] in the first lava emitted (the low K_2O/TiO_2 basalt) relative to basalt erupted at the end of the eruption [($^{230}Th/^{232}Th$) = 1.18].

While this observation could be explained by slower mantle melting, excellent correlation between Th and Nd isotope ratios confirms the importance of binary mixing of melts from a depleted mantle source (with high Th and Nd isotope ratios) with melt(s) from enriched mantle lithology (having lower Th and Nd isotope ratios) before magma ascent and eruption. Consequently, mantle heterogeneity, melt aggregations and mixing dominate the Th isotope composition of the erupted basalt, rather than the duration of mantle melting. Correlation between Sr and Th isotope ratios is significantly more scattered, most likely reflecting the different nature of the two elements during the basalt formation and/or an additional process responsible for the scatter in Sr relative to Th. Interestingly, better correlation is observed between the eruption discharge rate and $^{87}Sr/^{86}Sr$ rather than with Nd and Th isotope ratios.