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Mapping Chemical Heterogeneity and Melt Fraction within Mantle Plumes with Machine Learning

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Mantle plumes allow us to investigate evolution of the deep mantle; machine Learning (ML) approaches that have been used to examine compositional relationships between mantle plumes (Stracke et al., 2022; White et al., 2025) can also used to examine heterogeneity within individual mantle plumes. ML identifies the Loa and Kea parallel compositional tracks of the Hawaiian plume as well as previously identified regional components in the Galapagos and Azores plumes. While ML identifies distinct components in the Society and Marquesas plumes, these do not resolve into distinct geographic tracks as had been previously suggested.

White et al. (2025) showed that much of the variation in parent-daughter isotope ratios (e.g., $^{176}Lu/^{177}Hf$) in plume-produced basalts could be predicted by multiple regression against their respective isotope ratio (e.g., $^{176}Hf/^{177}Hf$), plume flux, and lithospheric thickness. This suggests that deviations of parent-daughter ratios from their correlation with their respective daughter isotope ratios can be used as a qualitative measure of melt fraction. These are quantified by ΔLu/Hf and ΔSm/Nd, the deviations from values expected from a simple two-stage evolution model. In the Galapagos, ΔSm/Nd increases southward away from the Galapagos Spreading Center, indicative of thickening lithosphere suppressing melt fraction. In Iceland, ΔLu/Hf and ΔSm/Nd indicate that the greatest melt fractions occur along the northern and southern volcanic zones, with smaller melt fraction in the interior and the margins, suggesting thick crust and lithosphere suppress melting. In contrast, the highest melt fractions in the Azores occur in the center and east of the archipelago rather than close to the MAR, with distinctly lower melt fractions in Corvo and Flores west of the MAR. In Hawaii and Samoa, both ΔLu/Hf and ΔSm/Nd are consistent with post-shield phase lavas being generally produced by smaller melt fractions than shield-stage ones. These parameters also suggest that some of the oldest Mauna Kea lavas recovered by the HSDP are also produced by small melt fractions, despite their strongly tholeiitic character, perhaps due their source consisting of more refractory, less fusible mantle.

Stracke, A. et al. *G*^{3} **(**2022), doi:10.1029/2022GC010606

White, W., et al. *G*^{3} (2025). doi:10.1029/2024GC011870