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The Trace Element Perspective on the Composition of Deep Mantle Heterogeneities in the Hawaiian Plume Source

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Hawaiian isotopic data define six statistically distinct groups [1], reflecting chemical (and geographical) differences along the Loa and Kea trends: Enriched Loa, Average Loa, Lō'ihi and Kea, Transitional Kea and Kohala. These compositional variations indicate the presence of multiscale heterogeneities in the underlying Hawaiian plume and its deep mantle source. We undertook a systematic study of a large dataset of 1000+ Hawaiian samples with published trace element data to better define the elemental compositions of Hawaiian basalts and test whether the six groups can be identified by trace element ratios. To ensure the data reflect primary magma compositions, the dataset underwent a thorough filtration procedure to reduce the influence of partial melting processes and alteration that affect trace element concentrations. Supervised machine learning classification models show that four (Average Loa, Enriched Loa, Lō'ihi, and Kea) of the six isotopically distinct groups are also statistically distinct in incompatible trace element ratios. This suggests that the chemical heterogeneities in the Hawaiian plume source are significantly different, both isotopically and elementally. Kea exhibits Nb/Nb* and Ce/Pb values characteristic of the average deep OIB mantle, supporting the interpretation that this group is sourced from the ambient deep Pacific mantle. Average Loa and Lō'ihi have relatively lower Ce/Pb than Kea, though Lō'ihi has the highest Nb/Nb* of all groups. Enriched Loa has low Nb/Nb*, low Ce/Pb, and high Sr/Nd. The variations in incompatible trace element ratios in the Average Loa, Enriched Loa, and Lō'ihi groups on the Loa trend could be explained by the presence of recycled surface material of varying compositions (e.g., oceanic crust, continental crust, ocean sediments) in their deep source. In particular, Enriched Loa exhibits geochemical characteristics reflecting the incorporation of recycled continental crust. The Loa trend, on the southwest side of Hawaii, is more heterogeneous and carries enriched signatures sourced in the Pacific large low shear velocity province that may have accumulated recycled surface and primordial material [2].

[1] Weis et al. (2020), Geochemistry, Geophysics, Geosystems.

[2] White and McNamara (2025), Treatise on Geochemistry.