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Origin of ‘enriched mantle I’ (EM-I) compositions in Hawai‘i: insights from Ko‘olau-Makapu‘u

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Several mantle plumes (Hawai‘i, Kerguelen, Pitcairn) produce ocean island basalt with enriched mantle I (EM-I) geochemical compositions. With the highest buoyancy flux, Hawai‘i is the most vigorous of these plumes. Hawai‘i’s isotopically enriched, EM-I-like compositions are limited to Ko‘olau, Lāna‘i, and Kaho‘olawe volcanoes, which define the Enriched Loa geochemical group. We undertook a systematic study on 28 new samples from three locations across the Ko‘olau volcano (on the island of O‘ahu) with the aim of characterizing their major element oxides, trace element concentrations, and Pb-Sr-Nd-Hf isotopic compositions. These new data are compared to literature data on Lāna‘i and Kaho‘olawe basalts to determine Enriched Loa compositions, and their longevity and spatial distribution along the Hawaiian chain. The Ko‘olau-Makapu‘u, Lāna‘i, and Kaho‘olawe volcanoes sample the Enriched Loa component over approximately 130 km and 1.4 Ma, which corresponds to a mantle heterogeneity of ~560 km in vertical length given a plume upwelling rate of 40 cm/year. The isotopic compositions of basalts from the three Enriched Loa volcanoes are statistically distinct, suggesting that the Enriched Loa component is chemically heterogeneous. We conclude that Enriched Loa consists of at least two separate mantle heterogeneities at a scale smaller than the ~50-150 km distance and ~1 Ma in time that separates the Enriched Loa volcanoes. The geochemical features of the Enriched Loa volcanoes are statistically different compared to all other Loa and Kea volcanoes and imply a distinct mantle source for Enriched Loa compositions. Compositions of the Ko‘olau-Makapu‘u stage, with high SiO_2, low CaO and TiO_2, low Ce/Pb, Ta and Nb depletions, and elevated radiogenic $^{208}Pb^*/^{206}Pb^*$ and $^{87}Sr/^{86}Sr$, likely reflect the incorporation of recycled continental materials in their deep mantle source, contained within the Pacific large low-shear-velocity province (LLSVP) and sampled by the Hawaiian plume. Compared to Kerguelen, the other large EM-I oceanic island complex, the Hawai‘i EM-I component is less radiogenic, indicating a younger age for the recycled material accumulated in the Pacific LLSVP compared to the African LLSVP.