Source origin of the ultrapotassic lavas from the Leucite Hills, Wyoming: Hf isotope constraints

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The Leucite Hills of SW Wyoming consist of 22 volcanic outcrops that occur over an area of ~ 2,500 km^2. The lavas consist of 3 types of lamproite, basic to ultramafic madupite (M), and more silicic wyomingite and orendite (W/O), characterized by phlogopite phenocrysts in a groundmass of leucite, diopside, apatite, ±sanidine, ±glass. Volcanism spanned 3.0-0.89 Ma. 84% of the <0.7 km^3 of magma was erupted between 0.94 and 0.89 Ma. The lamproites cross-cut the NE flank of the Late Cretaceous Rock Springs Uplift and are underlain by the Archean Wyoming craton, stabilized at 3.2-2.5 Ga. The Wyoming subcontinental lithospheric mantle (SCLM) was enriched metasomatically >1.0 Ga by ancient subduction of carbonate-bearing sediments.

Previous radiogenic isotope studies indicate that M, and W/O have distinct Nd isotopic compositions, but overlap in Pb and Sr isotope space. In general, M is more radiogenic in Pb and Nd, but less in Sr than W/O. New Hf isotope ranges are similar, but the M are more radiogenic on average. εHf ranges from -13.1 to -15.9 for M and from -13.5 to -17.1 for W/O. In the εNd-εHf diagram the M fall about the mantle array with ΔεHf varying from -4.0 to +1.1. In contrast, W/O plots above the mantle array, at more negative εNd, with ΔεHf varying from -0.8 to +5.7. The isotopic character of the M and W/O reqiure discrete mantle sources.

Outstanding questions are: (1) what caused the sources to melt; and (2) are the sources located in the SCLM or in the asthenosphere? A possible solution involves delamination of dense eclogitized SCLM. Delamination and sinking of the heterogeneous SCLM could cause asthenosphere to rise, melt, and heat and interact with the lithosphere. Sinking delaminated SCML may devolatize, contributing to further melting of the asthenosphere, and/or sinking material. In this model, the M forms first, followed by the W/O. The positive ΔεHf of the W/O suggests that its mantle source was previously depleted and contained residual garnet and/or was recently metasomatised by carbonate-rich fluid. This could have taken place a few million years prior to the formation of the lavas, perhaps during the eruption of the M lavas.

References

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Geochemistry of post-shield lavas from paired Loa- and Kea-trend Hawaiian volcanoes

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Late-stage lavas formed by small degrees of melting can be used as high-resolution tracers of source components and heterogeneities in the Hawaiian mantle plume. This study presents high-precision isotopic ratios (Sr, Nd, Hf, Pb) and trace element concentrations of late- and post-shield lavas from four Hawaiian volcanoes: Mauna Kea and Kohala on the Kea-trend and their counterparts Hualalai and Mahukona on the Loa-trend.

Mauna Kea and Hualalai demonstrate a systematic shift to distinctly less radiogenic Pb and Sr isotopic compositions as they evolve from the shield to post-shield stage. Post-shield lavas from both volcanoes deviate from the mixing trends (Sr-Pb, Nd-Pb, Hf-Pb) defined by Hawaiian shield-stage lavas, reflecting involvement of a more depleted source component similar to that sampled by rejuvenated lavas from other Hawaiian volcanoes. Interaction with oceanic crust and lithosphere (low $^{87}Sr/^{86}Sr$, high $^{206}Pb/^{204}Pb$) beneath Hawaii cannot explain the observed compositions of Hualalai post-shield lavas, which have some of the least radiogenic Pb isotopic compositions ($^{206}Pb/^{204}Pb$ = 17.888-18.011) of recent Hawaiian volcanoes. In contrast, Kohala and Mahukona become more radiogenic with respect to Pb during the waning stages of volcanism. Post-shield lavas from these volcanoes remain within the Loa-Kea mixing hyperbola, but are shifted to more depleted Sr, Nd, and Hf isotopic compositions.

Despite their contrasting Pb isotope systematics, post-shield lavas from all four volcanoes preserve the striking Loa-Kea Pb bilateral asymmetry inferred for the Hawaiian plume over the past ~1.5 Myr [1]. However, post-shield lavas and tholeiites from Kohala form a Pb-Pb linear array that crosses the Loa-Kea isotopic division. The sampling of Loa-type heterogeneities has been observed at other Kea-trend volcanoes [e.g. 2] and may be related to structure within the plume conduit. The coupled isotopic systematics of both volcanic pairs indicates the successive sampling of isotopically distinct material intrinsic to the Hawaiian plume. The enriched trace element signatures of the post-shield lavas ($(La/Yb)_N$ = 6.0-16.3) further suggests that this material is not related to MORB. The isotopic similarities between the post-shield and rejuvenated lavas imply continuity of these heterogeneities on a million year timescale and have implications for models of Hawaiian plume structure.

References

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