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The thermal and chemical litho-stratigraphy beneath the Hawaiian Islands

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To understand overall variations of Hawaiian mantle xenoliths, we examined mineral chemistry and whole-rock Os isotopes from six peridotite xenoliths from Kaua'i Island. The average equilibrium temperature of Kaua’i peridotites is 934°C and lower than that of other localities in the Hawaiian Islands (Pali and Ka’au: 997°C, Salt Lake Carter: 1034°C, Ka’ula: 1101°C). Whole-rock $^{187}Os/^{188}Os$ ratios in Kaua’i Island range from 0.1211 to 0.1258. Our data indicate that Kaua’i peridotites are dominated by fertile peridotites as well as Pali, and Ka’au peridotites from O’ahu. In contrast, Ka’ula and SLC peridotites are distinct regarding the abundant occurrence of refractory peridotites and garnet-bearing pyroxenites. Since the variations in xenoliths equilibrium temperatures are unrelated to island age (Ka'ula >4.0 Ma; Kaua’i >3.6 Ma; O’ahu >2.1 Ma), the observed difference does not reflect the temporal changes of the Hawaiian plume activity, but spatial variations of the thermo-chemical structure of lithosphere modified by upwelling plume. The most enigmatic but interesting question raised from the variations in Hawaiian mantle xenoliths is why the refractory peridotites from Ka’ula and SLC record high equilibrium temperatures. One possibility is that they represent the re-melting products in the basal Pacific lithospheres triggered by the impingement of the Hawaiian plume [1]. However, unradiogenic $^{187}Os/^{188}Os$ compositions dominate the refractory peridotites. They are also distinct from low-temperature Kaua’i, Pali, and Ka’au peridotites. Since the metasomatic effect caused by the percolation of Hawaiian magma could increase the $^{187}Os/^{188}Os$ ratios of the lithosphere, the refractory peridotites may not be a part of the Pacific lithosphere. The other is that they represent the heterogeneous plume containing ancient refractory materials [2]. However, these peridotites derive from moderate depths in the lithosphere, similar to the argument for garnet pyroxenites [3]. It needs the erosion and replacement of the Pacific lithosphere by a plume than previously thought. Whichever it is, these observations suggest the modification of the basal Pacific lithosphere due to the Hawaiian plume.

[1] Sen (1988), Contrib. to Mineral. Petrol. 100, 61-91

[2] Bizimis, Griselin, Lassiter, Salters & Sen (2007), EPSL 257, 259-273

[3] Guest, Ito, Garcia & Hellebrand (2022), Geochem Geophys 21, e2020GC009359.

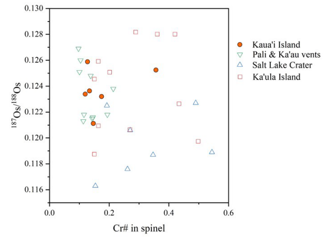

Figure 1. Cr# in spinel versus whole-rock $^{187}Os/^{188}Os$ ratios. Data source is from Bizimis et al., 2007 (Salt Lake Crater and Pali and Ka’au vents).

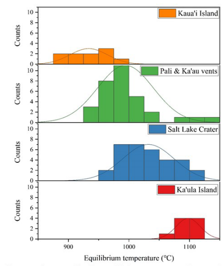

Figure 2. Histogram showing equilibrium temperature for Hawaiian xenoliths calculated with two-px thermometer (Putirka et al., 2008). Published data is from Tommasi et al. (2020), Sen (1988), and Bizimis et al. (2007).