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Title:

Short magma residence times for Kilauea Volcano based on high-precision Pb isotope ratios

Abstract:

We present new high-precision Pb isotopic analyses of 46 historical Kilauea summit lavas (1823-2008). These data are used here to investigate the architecture of Kilauea's summit magma storage reservoir and the characteristics of the volcano's mantle source region. These lavas exhibit a temporal trend characterized by low $^{206}Pb/^{204}Pb$ ratios in 1823, a gradual increase to a maximum in 1921, an abrupt drop to relatively constant intermediate values from 1923 to 1959, and a rapid decrease to 2008. These variations indicate that Kilauea's summit reservoir is being supplied by rapidly changing parental magma compositions derived from a mantle source that is heterogeneous on a small scale. At least three components are required to explain two distinct mixing arrays on a plot of $^{206}Pb/^{204}Pb$ vs. $^{208}Pb/^{204}Pb$, where the 19th century lavas have a low $^{206}Pb/^{204}Pb$ at a given $^{208}Pb/^{204}Pb$ compared to the 20th century lavas. Analyses of multiple lavas from several individual eruptions reveal small but significant differences in $^{206}Pb/^{204}Pb$ ratios (~0.01-0.03). For example, the extra-caldera lavas from Aug. 1971 and Jul. 1974 display significantly lower Pb isotope ratios and higher MgO contents (10 wt. %) than the intra-caldera lavas (MgO ~7-8 wt. %) from the same eruption. These distinctions appear to be spatially delineated by the rim of the volcano's summit caldera. From 1971 to 1982, the $^{206}Pb/^{204}Pb$ ratios of the lavas define two separate decreasing temporal trends. Intra-caldera lavas from 1971, 1974, 1975, Apr. 1982 and the lower MgO lavas from Sep. 1982 have consistently higher $^{206}Pb/^{204}Pb$ ratios at a given time (compared to the extra-caldera lavas and the higher MgO lavas from Sep. 1982). Magma residence-time modeling of the high $^{206}Pb/^{204}Pb$ (low MgO) and low $^{206}Pb/^{204}Pb$ (high MgO) trends suggest that the intra- and extra-caldera lavas are being supplied from two distinct magma bodies, each with a volume of ~0.2 km3. This volume estimate is more precise and much smaller than previous estimates of a single, ~2-3 km3 magma body based on trace element ratios. Overall, these observations suggest that Kilauea's summit reservoir has a small volume that efficiently transfers the changing compositional signals of the mantle-derived parental magmas.