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Lead Isotopic Evidence for Multiple Components in the Hawaiian Plume

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The Hawaiian plume has produced lavas whose large range of isotope compositions suggest the existence of two isotopically distinct trends, the so-called "Kea" and "Loa" trends. Models calling for the presence of two or three components in the source of the Hawaiian plume have been put forward. Here, we report high precision Pb isotopic data ($2\sigma_{ext}$ <100 ppm) obtained with a triple spike (TS), together with Sr and Nd isotopes, on over 100 samples from eight Hawaiian volcanoes. The purpose of re-analysing Pb isotopes in Hawaiian lavas at much higher precision is related to the intrinsic properties of this isotope system which provides us with three isotope ratios, allowing to distinguish between mixing involving two or three-components. The samples are shield tholeiites and come from Koolau, Lanai, Kahoolawe, Mauna Loa, and Loihi volcanoes, which belong to the "Loa" trend, and from Kilauea, Mauna Kea and Kohala from the "Kea" trend.

The results show that samples from each volcano exhibit a distinct linear array in both Pb isotope space, each array having a distinct slope. These arrays contrast with the "clouds" displayed by conventional data obtained on the same samples from individual volcanoes. Linear Pb isotopic arrays could reflect binary mixing lines, in which case, several isotopically distinct components would be required to explain the Pb isotope systematics displayed by the Hawaiian volcanoes considered here. On the other hand, covariations between conventional Pb isotope data and other radiogenic isotope systems in lavas from several Hawaiian volcanoes show binary mixing relationships (Bennett et al., 1996; Lassiter and Hauri, 1998; Blichert-Toft et al., 1999). However, if the Pb TS data are considered, the binary mixing relationships break down. In particular, the relationships between all three Pb isotope ratios and Nd isotopes suggest the presence of more than only two or three components. Thus, high precision Pb isotopes alone reveal far more details and source heterogeneities within the Hawaiian plume than covariations between Pb isotopes and other radiogenic isotope systems. This may partly be related to the limited analytical resolution of those systems relative to their total variation in Hawaiian lavas and illustrates the higher resolution provided by the high precision Pb TS data.

In $^{207}Pb/^{204}Pb$ vs. $^{206}Pb/^{204}Pb$, linear arrays can be interpreted as either isochrons or mixing lines. In the isochron case, the $^{207}Pb/^{204}Pb$-$^{206}Pb/^{204}Pb$ slopes of Loihi, Mauna Kea and Kohala yield consistent ages of ~ 2 Ga, while the Kilauea slope indicates a younger age of 0.7 Ga. Exceptions are Koolau and Lanai samples, which show a nearly horizontal line with $^{207}Pb/^{204}Pb$ ratios clustered around 15.44, Mauna Loa data which display some scatter, while Kahoolawe yields zero age. A test for the isochron interpretation can be made using $^{208}Pb/^{204}Pb$-$^{206}Pb/^{204}Pb$ systematics. Calculated κ (=$^{232}Th/^{238}U$) values from the $^{208}Pb/^{204}Pb$-$^{206}Pb/^{204}Pb$ slopes are inconsistent with those inferred from Th and U concentrations measured in the lavas themselves, suggesting that the $^{207}Pb/^{204}Pb$-$^{206}Pb/^{204}Pb$ slopes have no age significance. If, on the other hand, the Pb isotopic arrays are interpreted as binary mixing lines, then the observed Pb isotope systematics require far more than three components in the Hawaiian plume source. However, in each volcano it seems that only two of these components are tapped - a high $^{206}Pb/^{204}Pb$ and a low $^{206}Pb/^{204}Pb$ component - resulting in a well-defined binary mixing line. Furthermore, stratigraphic Pb isotopic fluctuations observed within individual volcanoes (Mauna Kea, Mauna Loa, Koolau and Kahoolawe) suggest that tapping of each pair of components by the melts vary over the lifetime of a given volcano. A comparison of the Hawaiian Pb isotopic data with those of East Pacific Rise MORB glasses obtained using the TS technique (Galer et al., 1999) further shows that none of the mixing components contributing to the lavas studied here has the characteristics of present-day EPR type oceanic lithosphere.

The Pb isotopic anatomy of the Hawaiian plume, which suggests the presence of several discrete mantle components in the source, clearly contradicts currently proposed models. The high degree of Pb isotopic heterogeneity exhibited by Hawaiian lavas at the scale of an individual volcano as well as on the scale of the whole Hawaiian chain implies complex mechanisms of melt extraction and transport and mixing processes within the Hawaiian plume.

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