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Structure of the Hawaiian Plume from the Isotopic Trail of Senescence of the Mauna Loa and Mauna Kea Volcanoes

Julia G. Bryce (jbryce@uclink4.berkeley.edu)[1], **David L. Shuster** (dshuster@lbl.gov)[2], **Allen Dodson** (dodson@socrates.berkeley.edu)[2], **Donald J. DePaolo** (depaolo@socrates.berkeley.edu)[1] & **B. Mack Kennedy** (bmkennedy@lbl.gov)[2]

[1] Berkeley Center for Isotope Geochemistry, Dept. Geology & Geophysics, MC 4767 University of California, Berkeley CA 94720-4767, USA
[2] Berkeley Center for Isotope Geochemistry, Earth Sciences Division- LBNL MS: 70A-3363, Berkeley CA 94720, USA

The Mauna Loa volcano is generally regarded as the most important representative of Hawaiian volcanism by virtue of its location near the axis of the Hawaiian Ridge and its relatively primitive isotopic ratios. Studies of Mauna Loa (ML) lavas have mainly been restricted to subaerial outcrops and submarine dredges. The Pilot Hole of the Hawaii Scientific Drilling Project (HSDP) provided the first ordered sequence of lava samples that spanned most of the last 100kyr of ML eruptive history (Stolper et al., 1996). We have measured Sr-Nd-Pb-He-Ar isotopic values for ML lavas from the HSDP Pilot Hole to complete coverage of the sampled section. These new data, in combination with those existing for ML and Mauna Kea (MK), provide two "continuous" ~200 kyr records of the isotopic evolution of Hawaii's two largest volcanoes. These records allow us to evaluate the structure of the Hawaiian plume as sampled by volcanoes both on and off the Hawaiian Ridge axis.

The samples measured are taken from the 1993 HSDP core at Hilo and represent lava recovered from drilling depths of 105 to ~240m, filling in a gap between the 0 - 30ka and ~150ka data available in the literature (Kurz et al., 1995). The >30ka samples used in our compilation are stratigraphically controlled, and sample ages have been estimated based on geochronology and the lava accumulation rate models of DePaolo and Stolper (1996).

The He isotopic data (Figure 1a) show that the R/Ra values for ML gradually decrease from values ~16-20 at ~200ka to values of 8-12 over the past 20kyr, with a pronounced excursion to high values at 30-40ka. A similar, but less noisy trend is found for MK: R/Ra decreases from 10-12 at 400ka to 6-8 at 300ka. These trends suggest that the plume has a well defined radial structure, at least on its northwest side. The large fluctuations in the ML record indicate either that the plume is grossly heterogeneous or that the magma delivered to ML over a period of 20 to 60kyr comes from a variety of different radial positions in the plume. Other isotopic systems demonstrate more complex non-monotonic trends, and do not show analogous behavior for the two volcanoes. For ML, $^{87}Sr/^{86}Sr$ values (these data, Kurz et al., 1995, Lassiter et al., 1996) increase with time but are noisy, whereas for MK the values decrease with time. For Nd, ML products show wide variations, with excursions over several ε units over relatively short time frames (< 10 ky); the MK data are nearly noise free and show a small systematic increase in ε_{Nd} with time. For $^{206}Pb/^{204}Pb$ values, there is a drift toward lower values with time in both volcanoes, but the values are offset when comparing similar evolutionary stages of each volcano. For MK, MORB-like R/Ra values were reached before the end of shield building (ca. 340ka), which indicates that the plume has an "outer core" with MORB-like He. The high -R/Ra "inner core" of the plume may be less than 40km in radius.

The noble gas abundance data from the ML sequence show some interesting features that have not previously been reported. F^4He values [$F^4He = (^4He/^{36}Ar)_{sample}/(^4He/^{36}Ar)_{air}$] vary dramatically by nearly three orders of magnitude between consecutive flows at 200m depth in the core (Figure 1B). Considering the inverse correlation between F^4He and $^3He/^4He$ (over a range of 15 to 10 R/Ra), the systematic increase of F^4He values in lavas between 250 and 200m can not be ascribed to or dominantly controlled by varying degree of an atmospheric contribution (e.g., Farley and Craig, 1994). The inverse correlation between F^4He and [$1/^{36}Ar$] in these samples further supports this argument. These data must therefore reflect changes in the inventory of noble gases sampled by the olivine fluid inclusions of these magmas, and may be explained by incorporation of entrained mantle or lithospheric fluids/melts or oceanic crust into the magma supply. The dramatic and abrupt transition in F^4He and a shift in Ar isotopic compositions, both observed at 200 m depth, could be due to local effects such as physical modification of the magma transport structures or sudden changes in the volatile composition of the source material.

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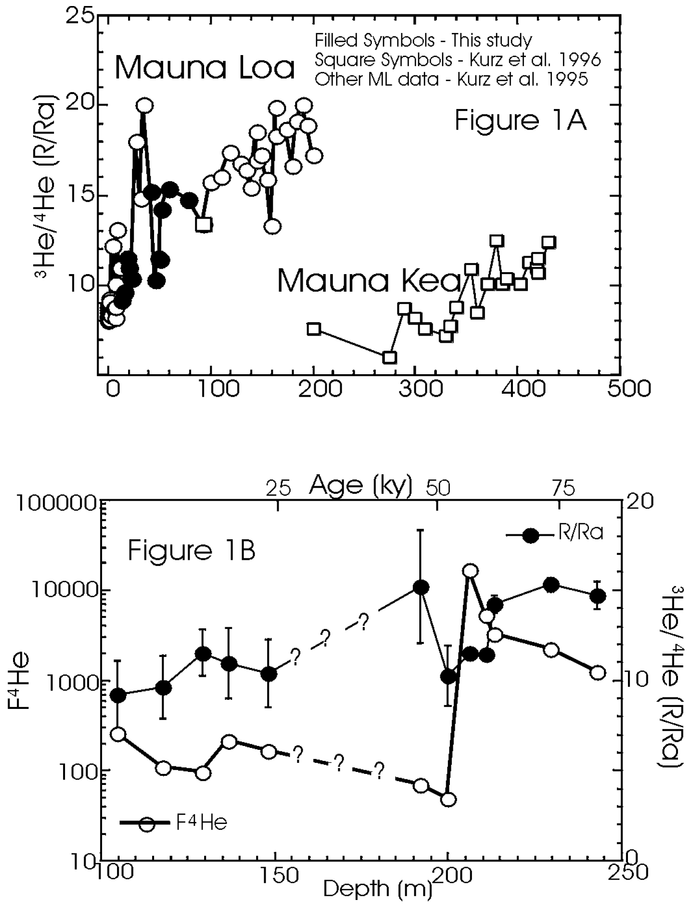

Figure 1A,1B Noble Gas Isotopic Data for Mauna Loa and Mauna Kea (see text for discussion)

Figure 1A, 1B (1A): He isotopic evolution in Hawaiian volcanoes; F^4He and R/Ra variations in Mauna Loa samples from the HSDP Pilot Core.

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