

U-series isotopic constraints on mantle upwelling on the periphery of the Hawaiian plume

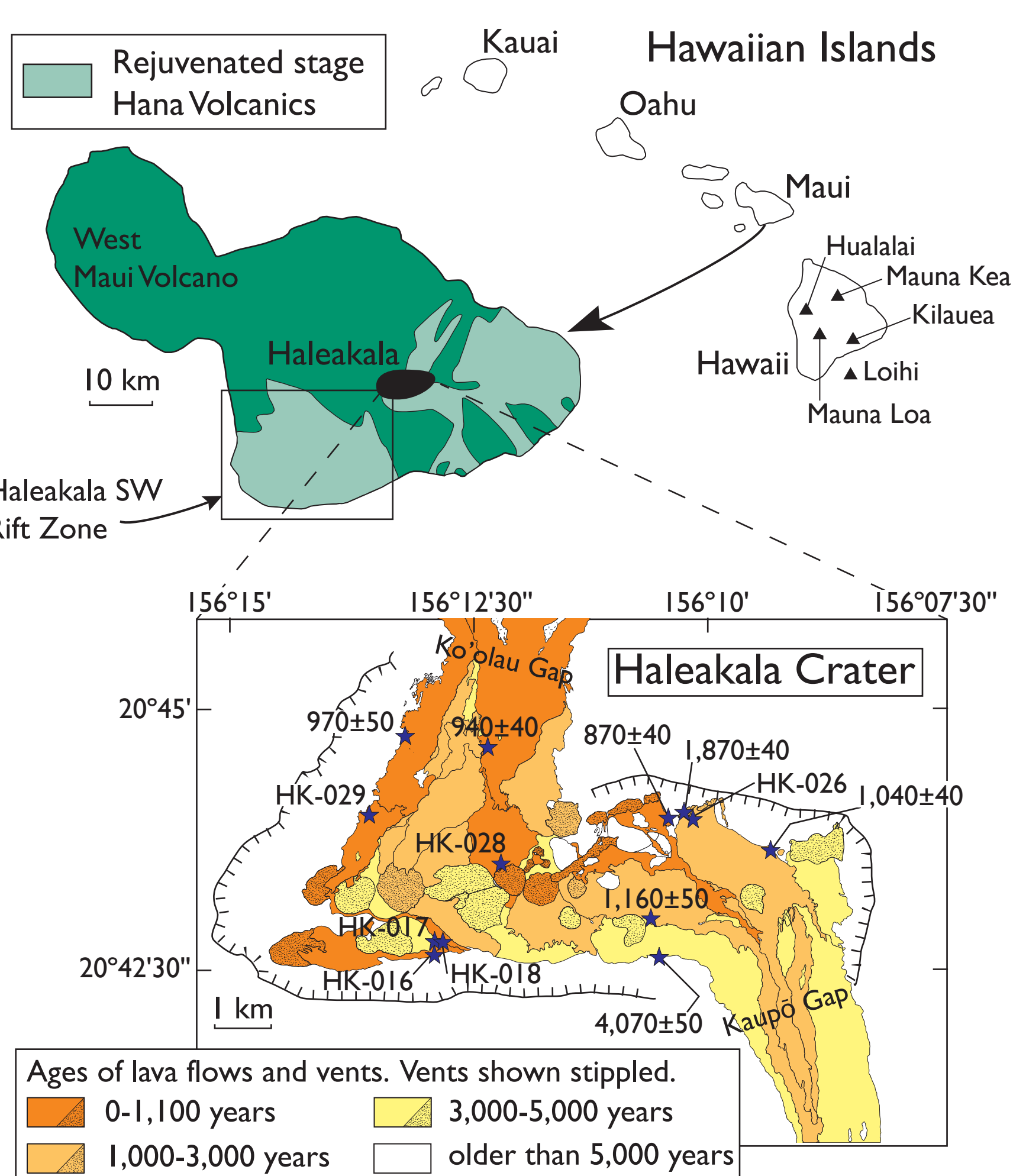
Isotope geochemistry of Haleakala crater basanites

Erin H. Phillips and Kenneth W.W. Sims, University of Wyoming, and Vincent J.M. Salters, Florida State University

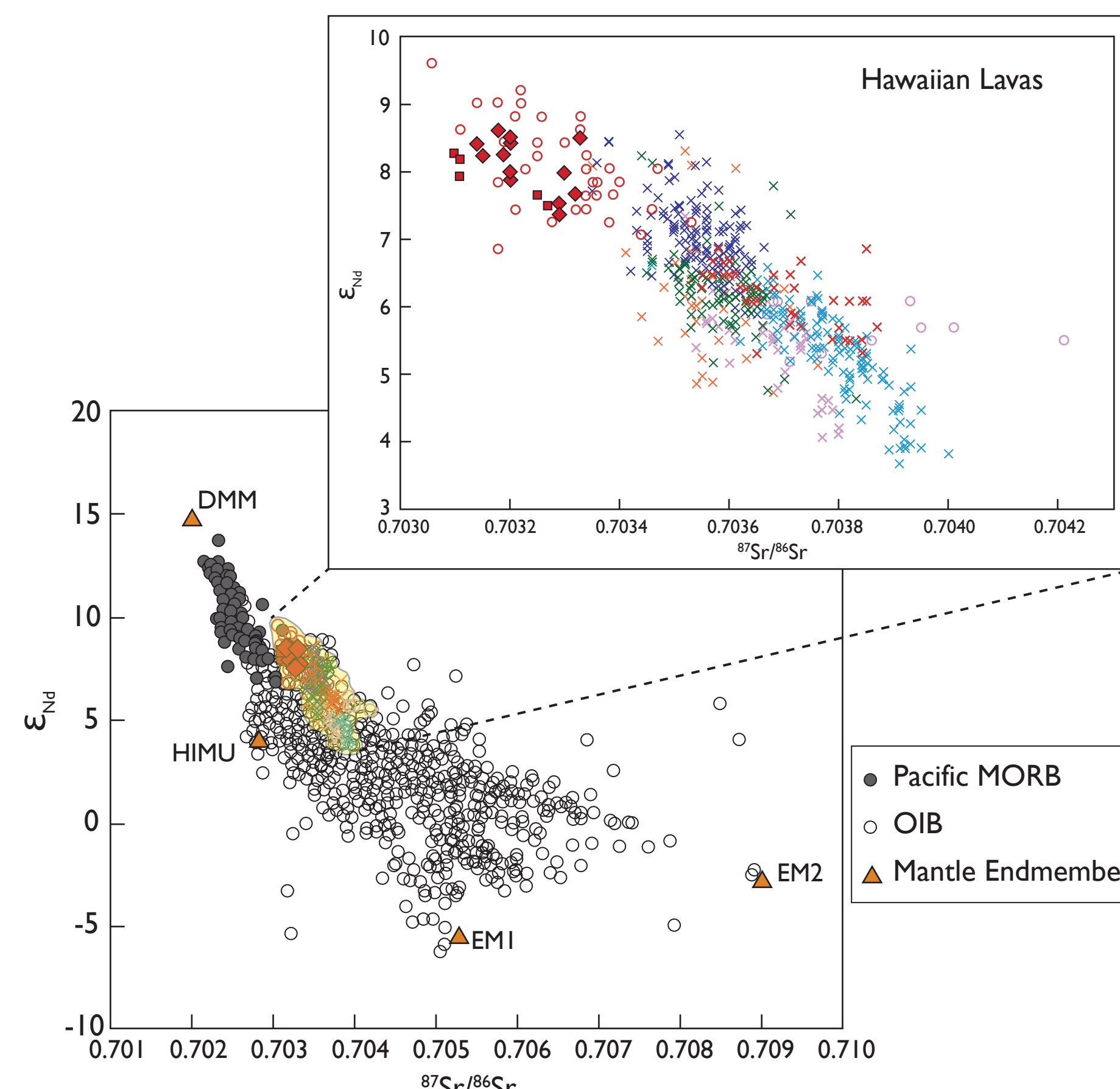
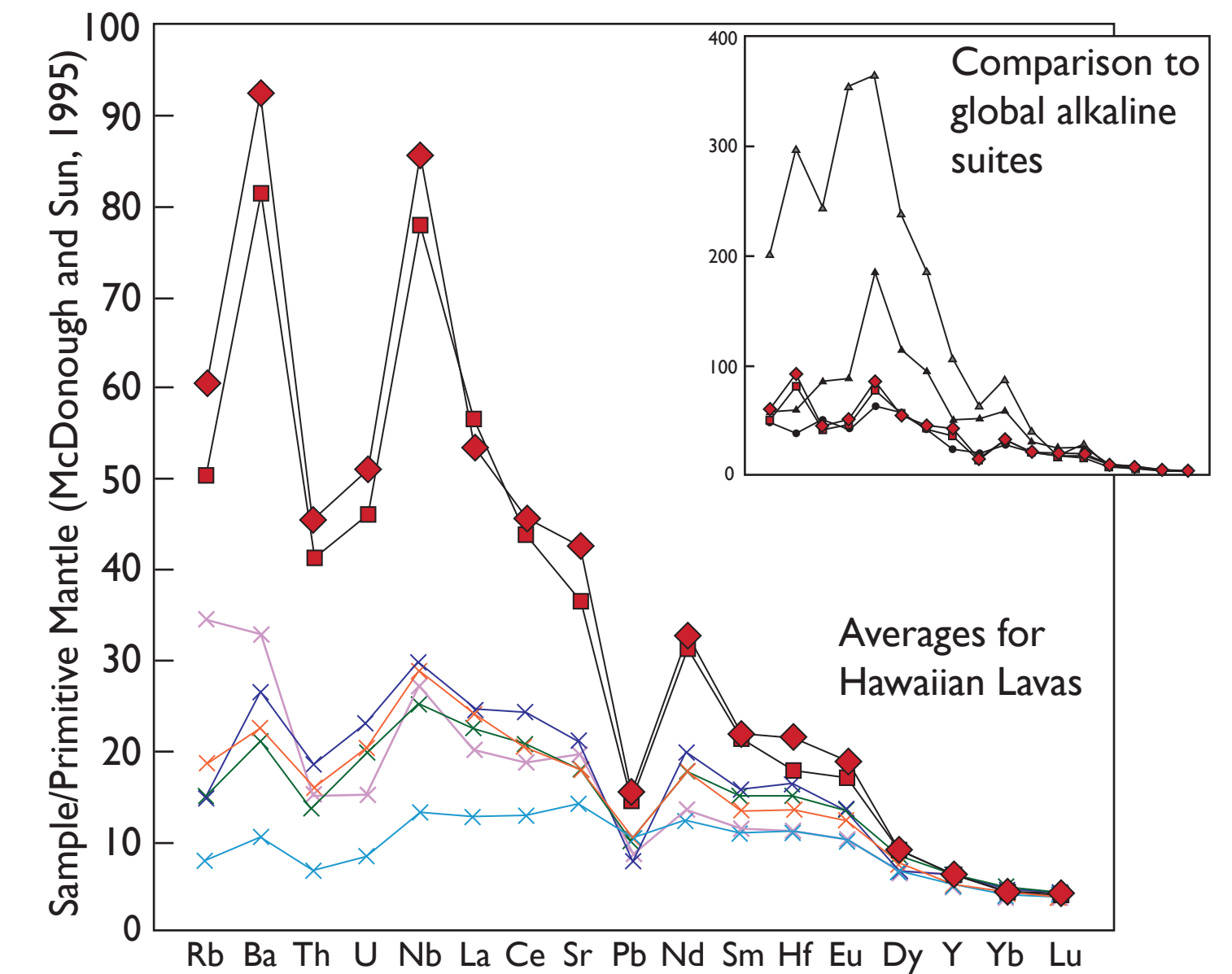
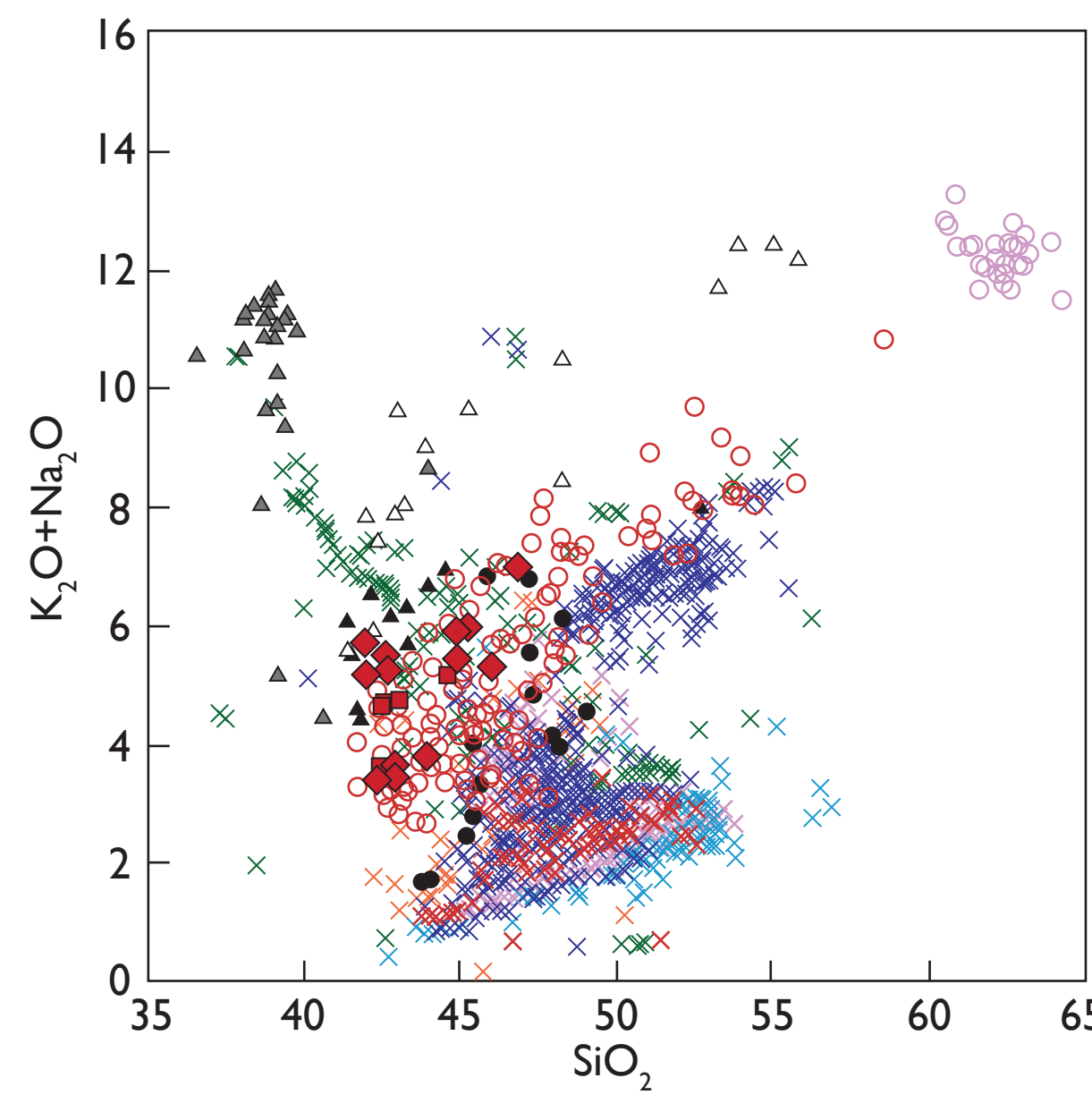
1. Introduction

• The Hawaiian islands are part of the age progressive series of volcanoes that form the Hawaiian-Emperor seamount chain. At Haleakala, on the island of Maui, basanitic lavas of the Hana Volcanics represent end-member rejuvenated stage alkaline magmatism (Clauge, 1987). Although shield-stage tholeiitic volcanism predominates in the Hawaiian islands, alkaline lavas erupted on the trailing edge of the Hawaiian plume present an important component to understanding mantle melting and solid mantle upwelling.

• We present geochemical data for 13 samples from Haleakala crater. ^{14}C ages for seven samples range from 870 ± 40 to 4070 ± 50 years (Sherrod and McGeehin, 1999). Preliminary data for 5 samples from the Haleakala southwest rift zone (Sims et al., 1999) are consistent with iso-viscous (Watson and McKenzie, 1991) and thermo-viscous (Hauri et al., 1994) fluid mechanical models of plume upwelling in which upwelling rates are slower on the periphery of plume.



2. Major and Trace Element Geochemistry and Long-lived Radiogenic Isotopes

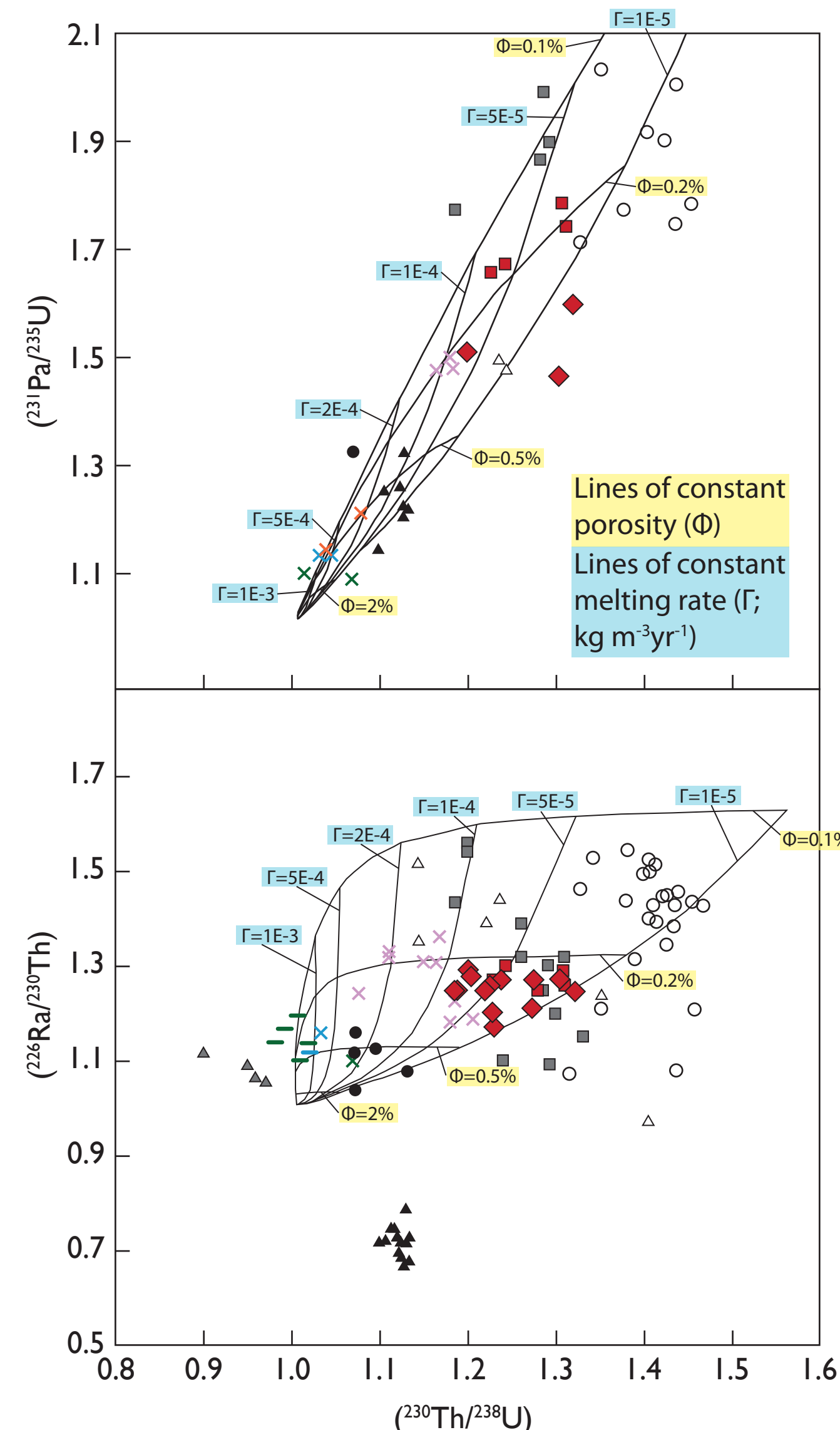
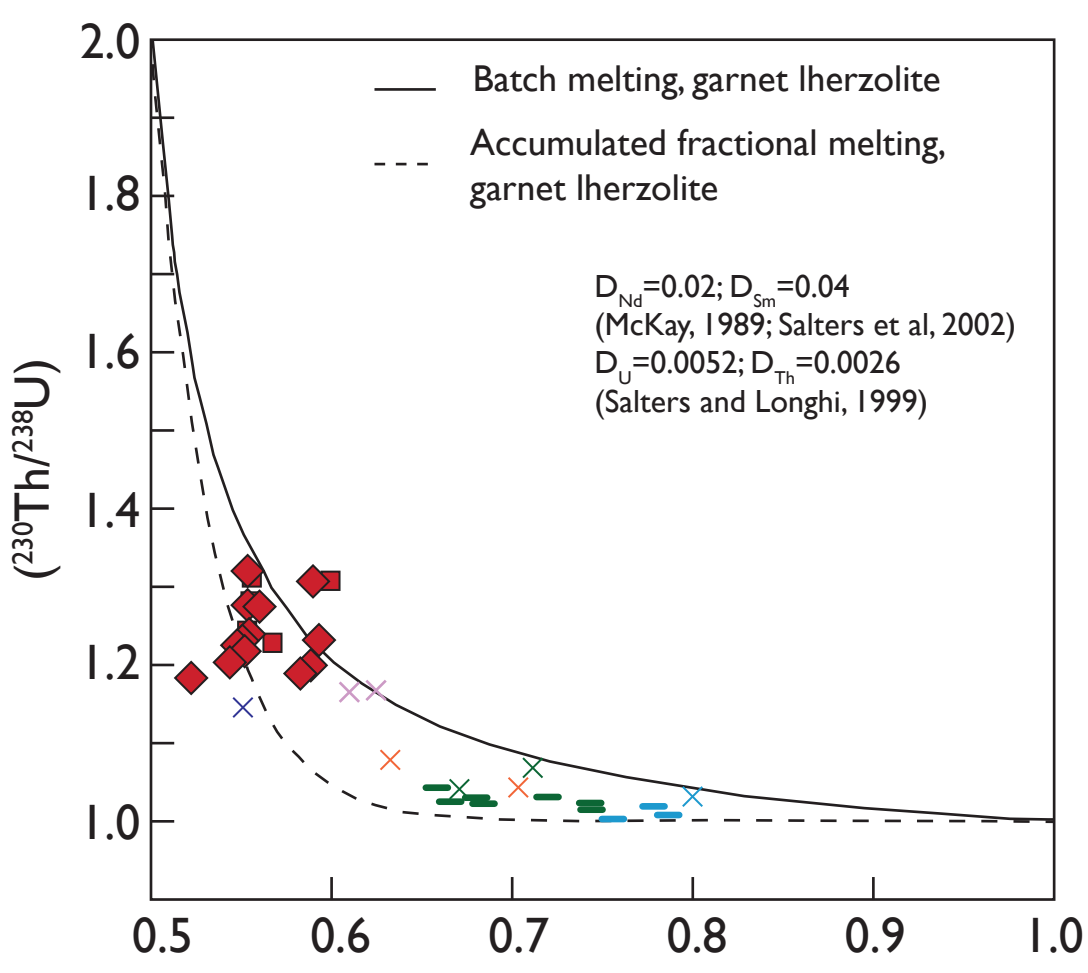


• Haleakala crater and SW rift zone basanites have lower SiO_2 and higher alkali contents and exhibit an enrichment in incompatible trace elements compared to other young Hawaiian lavas (above).

• Haleakala basanites fall within the global range of major and trace element compositions for alkaline volcanic rocks and do not define an extreme alkaline end member. For example, compare the trace element pattern for Haleakala basanites with Nyiragongo lavas (above).

• In comparison with other young Hawaiian lavas, Haleakala basanites exhibit higher ϵ_{Nd} (and ϵ_{Hf}) and lower $^{87}\text{Sr}/^{86}\text{Sr}$ values, implying a greater contribution from a depleted source in these late-stage alkaline magmas (left).

3. U-series Isotopes

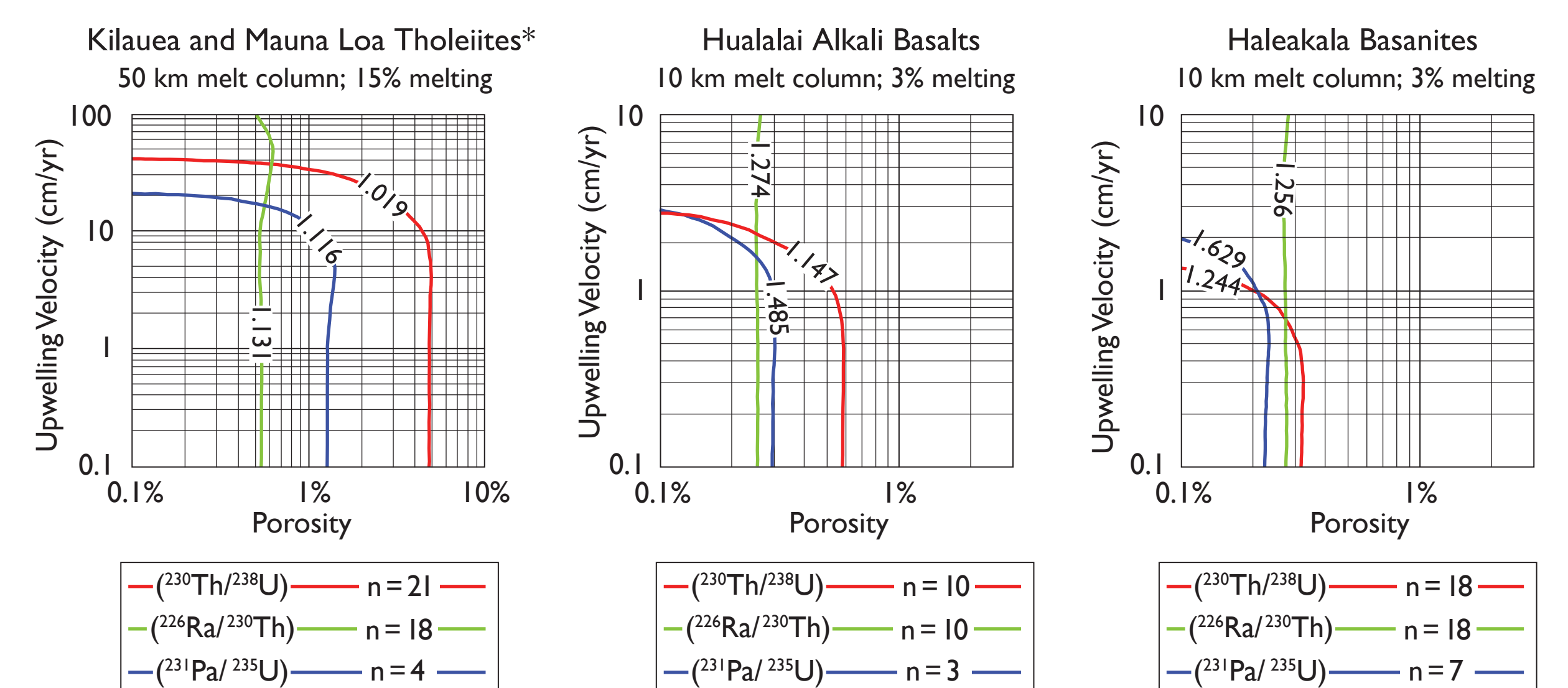


• Haleakala lavas exhibit higher $(^{230}\text{Th}/^{238}\text{U})$ than other Hawaiian lavas, implying that they are the manifestation of a small degree of partial melting from a source containing residual garnet (upper left).

• Haleakala basanites exhibit higher $(^{226}\text{Ra}/^{230}\text{Th})$ and $(^{231}\text{Pa}/^{235}\text{U})$ than shield stage tholeiites from Kilauea and Mauna Loa and fall within the global range of alkaline volcanics based on U-series isotopic composition (above right).

• Dynamic melting models (after McKenzie, 1985) show that melting rates for Haleakala basanites are between approximately 1×10^{-5} and $1 \times 10^{-4} \text{ kg m}^{-3} \text{ yr}^{-1}$ with melt-zone porosity from 0.2% to 0.5%, significantly lower than shield stage tholeiites (above right).

4. Upwelling Velocity and Porosity of the Melt Zone



* Includes data from Pietruszka et al. (2001), Cohen et al. (1996), and Cohen and O'Nions (1993).

	Sims et al., 1999 inverted D values (shown in models above)		
Maximum porosity	0.5-0.7%	0.2-0.3%	0.2-0.3%
Solid mantle upwelling velocity	20-40 cm/yr	approx. 2 cm/yr	0.7-0.9 cm/yr
	Salters and Longhi, 1999 D values		
Maximum porosity	2-3% (25% melting)	approx. 1%	approx. 1%
Solid mantle upwelling velocity	30-80 cm/yr (25% melting)	4-8 cm/yr	approx. 1 cm/yr
	Lundstrom et al., 1994 D values		
Maximum porosity	1-2%	approx. 0.6%	no convergence
Solid mantle upwelling velocity	20-50 cm/yr	approx. 2 cm/yr	no convergence

• Chromatographic porous flow modeling (Spiegelman, 2000) shows that solid mantle upwelling velocities and porosities on the periphery of the Hawaiian plume are lower than at the plume center.

• All models utilize D values for a garnet peridotite source. D values for a garnet pyroxenite source from Elkins et al. (2008) did not converge on a unique solution for any of the compositions.

5. Conclusions

• New data from Haleakala crater basanites reveal that these lavas result from a small degree of partial melting. Their depleted isotopic signature suggests that a MORB-like component mixed with plume source material to produce these alkaline lavas.

• U-series isotopes shed light on Hawaiian plume dynamics and show that solid mantle upwelling rates and porosities on the periphery of the plume, represented by Haleakala basanites, are much lower than at the center of the plume.

• Chromatographic porous flow modeling suggests that garnet peridotite is a more likely source for Hawaiian lavas than garnet pyroxenite. Previous interpretations preclude mafic lithologies in the source of Hawaiian lavas (Stracke et al., 1999), although this remains controversial (e.g., Wang and Gaetani, 2008; Sobolev et al., 2005).

• Haleakala crater basanites represent an end-member in the range of Hawaiian lavas, but fall within the global array of alkaline volcanism in the context of major and trace element geochemistry and isotopic signatures.

Acknowledgements and Further Information

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