

# Variations in the Th/U ratio and Th isotope composition of Mauna Loa tholeiites

A.S. Cohen  
R.K. O'Nions

Department of Earth Sciences, University of Cambridge,  
Downing Street, Cambridge CB2 3EQ, UK.

## Introduction

The evolution of Hawaiian volcanoes is accompanied by systematic and coherent changes in the geochemical characteristics of the lavas erupted. Most of the material produced during the shield-building phase, estimated at over 95% of the total magma production, is olivine-bearing tholeiite. Significant changes are found in the isotopic and trace element compositions of tholeiitic lavas not only from separate shields but also from within individual volcanoes (Frey and Rhodes, 1993; Kurz and Kammer, 1991; West *et al.*, 1987). In general, however, the compositions of the erupted lavas are not reproduced by simple mixing models involving two discrete end members. Either the involvement of other components is required or further complexities, such as chromatographic effects resulting from melt/matrix interaction, must be entertained.

In the present study the Th/U ratios, and thorium and uranium isotope compositions of a suite of lavas from Mauna Loa have been investigated. The samples come from lava flows which range in age from ~60 a to ~200 ka; ages which are not known directly from historical records are  $^{14}\text{C}$  ages. The He, Sr and Pb isotope compositions of most of these samples have been determined previously (Kurz and Kammer, 1991) and they show marked changes on timescales of a few ka. Analytical techniques for thorium and uranium are described by Cohen and O'Nions (1993), and in references therein.

## Results and discussion

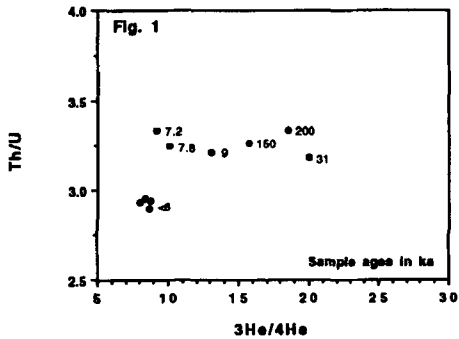
The results of this study are displayed graphically in Figs. 1–3. The changes in Th/U ratio and in He isotope composition are shown in Fig. 1. The youngest samples (those < 6 ka in age) possess the lowest Th/U ratios at ~2.96, together with MORB-like R/Ra values which are between 8.0 and 8.7 (Kurz and Kammer, 1991). Samples older than 7 ka all have distinctly higher Th/U ratios, from 3.18–3.33, together with R/Ra ratios which increase with age towards higher values characteristic of a less depleted source. The limited data

suggest a covariation between Th/U ratios and He isotope compositions.

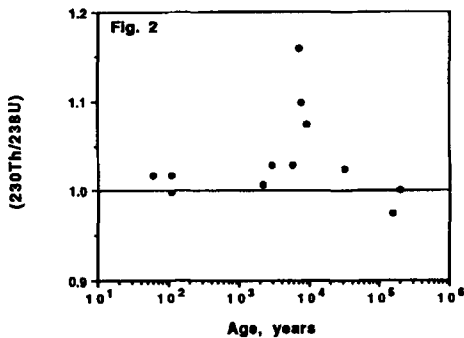
In Fig. 2, the ( $^{230}\text{Th}/^{238}\text{U}$ ) activity ratios of the samples are shown as a function of their eruption age. Most of the samples have ( $^{230}\text{Th}/^{238}\text{U}$ ) activity ratios close to or greater than the secular equilibrium value of unity. One datapoint has a ( $^{230}\text{Th}/^{238}\text{U}$ ) activity ratio of  $0.975 \pm 0.01$ ; it is noteworthy that this sample is relatively old (at ~150 ka) and is the only one for which  $^{234}\text{U}$  is not in radioactive equilibrium with its parent  $^{238}\text{U}$  ( $(^{234}\text{U}/^{238}\text{U}) = 0.975 \pm 0.005$ ). More importantly, however, three samples which range in age from 7–9 ka possess ( $^{230}\text{Th}/^{238}\text{U}$ ) activity ratios which are significantly > 1.0. The data are also presented on a conventional Th isochron diagram (Fig. 3) and all samples plot on or to the left of the equiline, with the single exception of the sample (of ~150 ka) discussed above. The dotted line in Fig. 3 follows those samples which fall significantly above the equiline, and it can be seen to follow a trajectory of decreasing sample age.

The Th isotope data and Th/U ratios presented here for the samples from Mauna Loa which are younger than ~6 ka, are very similar to those reported for samples from both Kilauea and Mauna Loa in the recent studies of Cohen and O'Nions (1993) and Hemond *et al.* (1994). These authors concluded that the observed disequilibria, with small  $^{230}\text{Th}$  and  $^{226}\text{Ra}$  excesses of ~2% and ~15% respectively, are consistent with a model of dynamic melting involving high melting rates relative to those for MORB, small melt fractions and rapid melt transport. However, the observation made in the present study that the three samples of 7–9 ka possess relatively large  $^{230}\text{Th}$  excesses is important. It indicates that the Th and U in these samples were fractionated, either during melting or subsequently, to a much greater extent than in those samples with ( $^{230}\text{Th}/^{238}\text{U}$ ) activity ratios close to unity. One possibility is that the  $^{230}\text{Th}$  excesses in the 7–9 ka samples result from the loss of U during weathering. Although this cannot be discounted at present, it is noteworthy that the ( $^{234}\text{U}/^{238}\text{U}$ ) activity ratios of these samples are within 1% of unity, and that the Sr isotope compositions of these samples show no

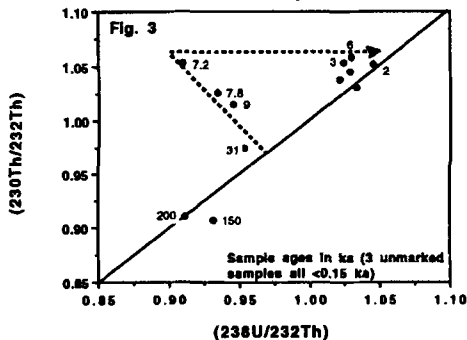
Th/U ratio vs.  $3\text{He}/4\text{He}$  ratio, for Mauna Loa samples (He data from Kurz and Kammer, 1991)



$(^{230}\text{Th}/^{238}\text{U})$  vs. age for Mauna Loa samples



$(^{230}\text{Th}/^{232}\text{Th})$  vs.  $(^{238}\text{U}/^{232}\text{Th})$  for Mauna Loa samples



significant differences to those of other samples of similar age (Kurz and Kammer, 1991). Alternatively, if the disequilibrium arose during melting, then the maximum observed  $^{230}\text{Th}$  excess of  $\sim 16\%$  would reflect a large decrease in melting rate of around an order of magnitude, which seems unlikely. A final possibility, supported by the coherent temporal changes in their  $(^{230}\text{Th}/^{238}\text{U})$  activity ratios, is that Th-U fractionation in the 7–9 ka samples has resulted from chromatographic effects caused by the interaction of melt with matrix.

### References

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