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Th/U and other geochemical evidence for the Réunion plume sampling a less differentiated mantle domain

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Abstract

Like Mid-Ocean Ridge Basalts (MORB), most Ocean Island Basalts (OIB) record a Th/U decrease during the history of their source. Notable exceptions are lavas sampling EM1 mantle end-member, which have super-chondritic time-integrated Th/U ($[Th/U]_{Pb}$). An intermediate situation is observed for the Réunion plume, where both present-day [Th/U] and $[Th/U]_{Pb}$ are similar to the bulk Earth value (weight ratio ~3.9). If [Th/U] measured in basalts reliably reflects the source ratio, then the Réunion plume source could have evolved in closed system with respect to Th/U. Th/U decrease in the mantle has been ascribed either to early continental crust extraction, or to preferential recycling of U over Th since oxidizing conditions appeared at the surface of the planet (~2.2 Ga). The primitive-like Th/U signature of Réunion is best explained by the absence of subduction influence since at least the Archean. This possibility is consistent with the $^{187}Os/^{186}Os$ signature, which is the less radiogenic of ocean island shield basalts. In addition, the difference in $^{3}He/^{4}He$ between Réunion (R/R_A ~12.5) and high-$^{3}He/^{4}He$ plumes (Hawaii, Iceland) most likely reflects a Réunion source less depleted in U and Th, rather than more degassed. In Sr–Nd–Pb–Os–He isotope space, Réunion signature plots in the region where OIB arrays converge, suggesting that the Réunion plume samples a component common to OIB, which is neither the source of MORB, nor the region where subducted plates are stored. It is suggested that the Réunion plume taps an early-depleted mantle domain subsequently influenced little, or not at all by recycling processes.

Keywords: Réunion; thorium/uranium ratio; primitive mantle; differentiation

1. Introduction

Geochemical models initially divided the mantle into a lower primitive layer and an upper layer whose composition has been depleted in incompatible elements during continental crust formation. Isotopic variations

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seen in oceanic basalts were thus interpreted as reflecting mixing between these two reservoirs. This model, and in particular the existence of a primitive deep reservoir sampled by hotspot volcanism, has been questioned for the last thirty years. Hofmann and White [1] pointed out that most Ocean Island Basalts (OIB) have positive εNd, which is indicative of long-term depletion of the source, whereas the concentration of trace elements in their mantle source must be higher than primitive. They proposed that recycling of oceanic crust accounts for this observation, and also solves the lead paradox (the unexpected U/Pb increase in the mantle) raised by Allègre [2]. Although the un-degassed isotopic signature of many OIB suggests their source has been less processed than that of Mid-Ocean Ridge Basalts (MORB), Hofmann and White's recycling model became widely accepted. Moreover, it appeared later that recycling of underlying lithosphere and overlying sediments is required to explain the composition and great isotopic diversity of OIB. The debate about the survival of a less differentiated reservoir was reactivated when Hart et al. [3] and Farley et al. [4] showed that the isotopic signatures of individual islands (or island groups) converge towards a common composition, a feature that possibly reflects lower mantle entrained into plumes [3,5].

The volcanic chain linking Deccan trapps to Réunion island displays geophysical and geochemical

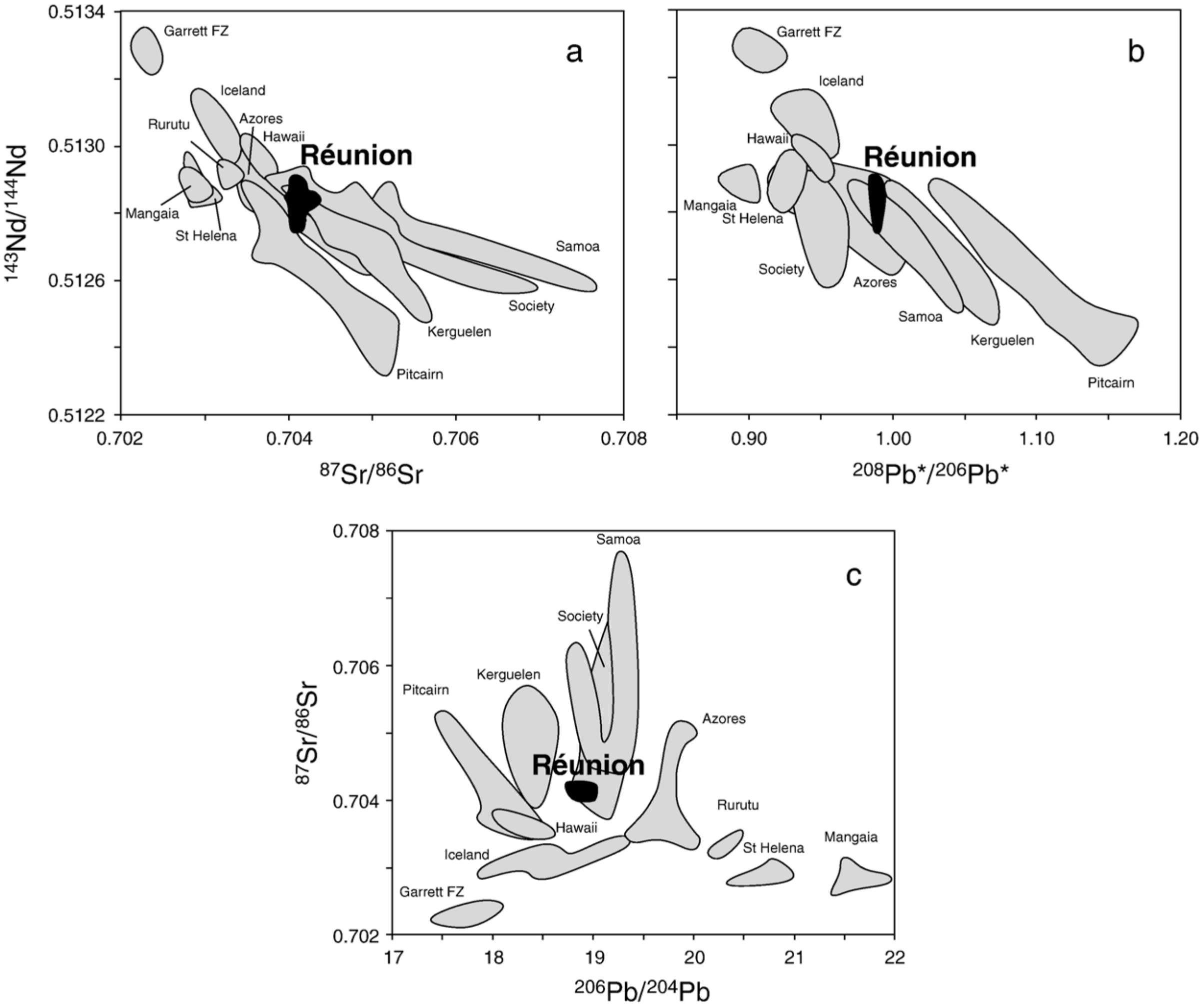

Fig. 1. Sr–Nd–Pb isotope signature of the Réunion plume. The Réunion isotopic field is inferred from the signature of the lavas erupted at Piton de la Fournaise since 0.53 Ma ([13,22] and unpublished data from D. Bosch). The signature of the depleted mantle, major plumes, and plumes sampling mantle end-components are shown for comparison. Samples whose compositions are used to represent the depleted mantle are from the Garrett fracture zone (East Pacific Rise, 13°28′S) [75]. Plumes isotopic fields have been drawn using most recently published data (references available on request). Data were compiled with the help of the GEOROC [76] and PETDB [77] databases.