U-Series isotope studies of Atlantic OIB: links between inferred rates and degrees of partial melting, and the influence of (lithospheric) source composition

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Partial melting processes beneath ocean islands are arguably less well understood than those beneath mid-ocean ridges (MOR), not least because the source composition variations are demonstrably greater, and the thickness of the lithospheric lid influences the depth at which melting ceases. For MORB the average degrees and depths of melting increase with increasing temperature and decreasing ridge depth (Klein and Langmuir, 1987). The degree of ^{230}Th-^{238}U disequilibrium also appears to be greater in MORB from shallower ridge depths, and this has been attributed to more of the melt zone being within the garnet stability field in areas of higher mantle temperatures (Bourdon *et al*, 1996). By contrast, in OIB, the degree of ^{230}Th-^{238}U disequilibrium tends to be less, and the melt fraction lower, in those OIB associated with high buoyancy flux, i.e. high mantle potential temperature (Chabaux and Allègre, 1994; Sims *et al.*, 1995). Thus, the controls on ^{230}Th-^{238}U disequilibrium appear to be different in MORB and OIB. In intraplate settings partial melting should start deeper in regions of high buoyancy (i.e. high Tp), and the height of the melt zone is controlled by the thickness of the overlying lithosphere, which in turn limits the total amounts of melting in any area. However, in general links between the inferred rates and degrees of partial melting are not well established, and this contribution reviews the results of a number of detailed studies on Atlantic Ocean OIB.

U-Th isotope analyses of young volcanic rocks from the Azores (Turner *et al.*, 1997), the Canary Islands, and the Cape Verde Islands, indicate that the majority are out of ^{230}Th-^{238}U equilibrium with (^{230}Th/^{238}U) in the range 1.08?1.35. All are associated with relatively low buoyancy mantle plumes, and in contrast to the results from Hawaii (Sims *et al.*, 1995) there is no simple link between the degree of ^{230}Th-^{238}U disequilibria and degree of silica saturation (Fig. 1), although the range in (^{230}Th/^{238}U) is greater in the silica undersaturated rocks. The Hawaiian data suggests that there may be a negative correlation between the degree of partial melting and the amount of U-Th disequilibria (Sims *et al.*, 1995). However, there are no obvious negative trends within OIB from the central Atlantic region, despite variations in lithospheric thickness from 20 to 125 km and lithospheric age from 7 to 175 Ma. In detail, the inferred degrees of melting on Lanzarote, for example, range from 1 to 4% and yet there is no correlated change in the degree of ^{230}Th-^{238}U disequilibria.

Overall, the Canary Islands, Cape Verdes and Azores plumes have similar buoyancy fluxes (1.0, 1.6 and 1.1 Mg s^{-1} respectively) and exhibit large ^{230}Th-^{238}U isotope disequilibria consistent with the argument that low buoyancy plumes result in magmas with significant U-Th disequilibria. These plumes also appear to have similar low melt production rates of 0.02, 0.03 and 0.01 km^3 y^{-1} respectively, despite the location of the Azores close to the axis of the mid-Atlantic ridge. Plumes may rise beneath lithosphere of any age, and so the rates of melt production, and hence ^{230}Th-^{238}U disequilibria, appear largely independent of lithosphere thickness. In contrast, there is a broad negative correlation between lithosphere thickness and the integrated degrees of melting (Haase, 1996). It follows that there should be no link between the ^{230}Th-^{238}U disequilibria, and hence the inferred rates of melt generation, and the integrated degrees of melting, and that is what is can be observed in the Atlantic OIB

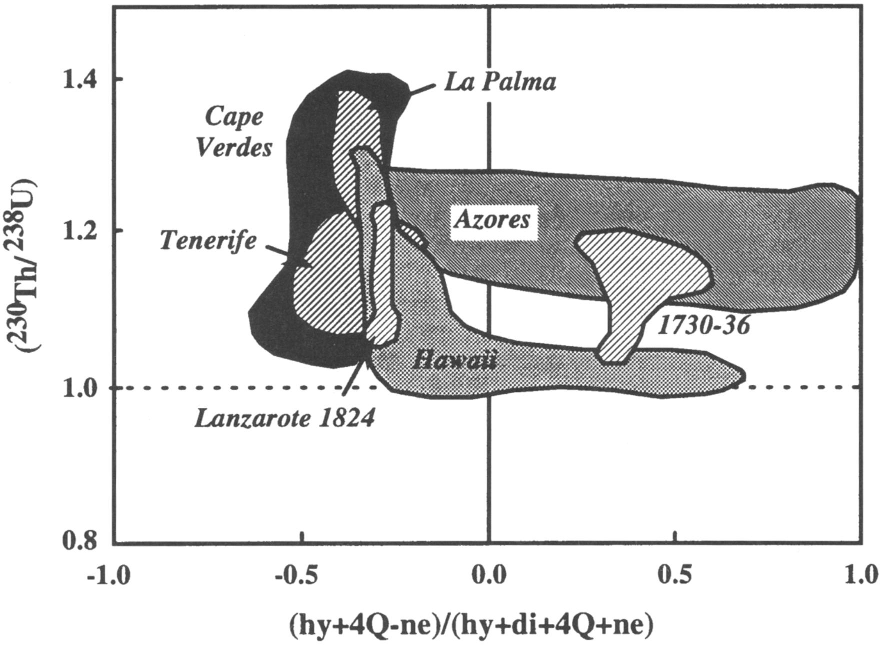

FIG. 1. Silica saturation index (Sims *et al.*, 1995) *vs* U-Th isotope disequilibria for La Palma.

considered here. The rates of melt generation reflect the deep seated controls on the buoyancy flux of individual mantle plumes, whereas the integrated degrees of melting depend largely on the thickness of the overlying lithosphere. For OIB it is the rate at which material upwells through its solidus which controls U-Th disequilibria. In contrast, for MORB the upwelling rate is more or less constant and the amount of the melt column within the garnet zone is much smaller. Consequently, the time spent in equilibrium with garnet, during which ^{230}Th - ingrowth may occur, is dependant on the length of this part of the melting column rather than the rate at which mantle material upwells (Bourdon *et al.*, 1996).

A number of authors have noted that the average OIB compositions vary with the thickness of the lithospheric lid (e.g. Haase, 1996). Thus, average Tb/Yb from different ocean islands increases with both decreasing SiO_2 and the age of the underlying lithosphere, consistent with a general link between the mean depth and amount of melting. However, individual islands, such as Lanzarote, can preserve a wide range in SiO_2 (42?51%) and *REE* ratios in primitive, fractionation-corrected compositions. Moreover, many of the volcanics on the Canaries, Cape Verde and the Azores have been attributed to melting of relatively shallow trace element enriched source regions, often within the mantle lithosphere. Thus, there is increasing evidence for a contribution from the lithospheric mantle to OIB (e.g. Class and Goldstein, 1997), and source composition may play a far more important role in controlling partial melting processes beneath ocean islands than that inferred for mid-ocean ridges (cf. Bourdon *et al.*, 1996).

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