Os isotopic results from rift and flood basalts of Ethiopia and Djibouti

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The Afar triple junction and the surrounding region provide a classic example of continental rifting preceeded by the impingement of a mantle plume. Volcanism began in the Oligocene with the emplacement of a massive flood basalt pile in Ethiopia and Yemen, and continues to the present day in the Red Sea and Gulf of Aden oceanic spreading centers and the East African continental rift. This volcanism is currently the subject of a collaborative French-Ethiopian project aimed at understanding the relationship between plume impingement and continental break-up. In the context of this project, we have undertaken an Os isotopic study of rift and flood basalts from Ethiopia and Djibouti.

Because of the strong isotopic contrast between the mantle and the crust, Os isotopes are especially useful for constraining processes of crustal contamination. In particular, they allow assimilation of crustal material by basaltic magma to be distinguished from direct melting of metasomatized mantle lithosphere. Os isotopic ratios of rift and flood basalts are plotted as a function of 1/[Os] in Fig. 1. It is evident that very few of the rift basalts have Os isotopic values compatible with direct mantle derivation. There is a rough correlation between $^{187}Os/^{188}Os$ and 1/[Os]. That is, rocks with lower Os concentrations (2 ppt, in the most extreme case), resulting from higher degrees of differentiation, are most sensitive to the effects of crustal contamination.

Further information concerning crustal assimilation can be obtained by comparing Os and He isotopic data. Helium, though geochemically very different from Os, is also a highly sensitive indicator of crustal addition. He is also the only isotopic tracer capable of clearly indicating the presence of a deep, less degassed, mantle component. A direct comparison of Os and He isotopes in the rift basalts yields no correlation. This is because the $^{187}Os/^{188}Os$ ratio is controlled by the Os concentration of the rock as well as by the total amount of contamination. On the other hand, a negative correlation (Fig. 2) is observed between the proportions of crustal assimilation required to explain the Os isotopic compositions, given the measured Os concentrations, and the $^{3}He/^{4}He$ ratios of the rift samples. (Decreasing $^{3}He/^{4}He$ implies increasing crustal contamination.) These crustal proportions were calculated assuming simple binary mixing between basalt and crust with $^{187}Os/^{188}Os = 0.6$ and [Os] = 50 ppt, the average Os composition of the upper continental crust (Esser and Turekian, 1993). These calculated proportions will probably change when Os measurements of locally derived crustal rocks are obtained. However the sense of the trend in Fig. 2 will not change. Thus He and Os apparently provide coherent information about crustal contamination, despite their markedly different geochemical behaviour.

We currently have Os isotopic data for two Oligocene flood basalts from the Northwestern Ethiopian Plateau. These samples were chosen to represent the most primitive end-members of two basaltic suites identified on the basis of major and trace element characteristics (Pik, 1997): 1) A low-Ti suite similar to those frequently observed in other flood basalt provinces, often thought to display lithosphere-derived features; and 2) A high-Ti suite with OIB isotopic and trace element characteristics, notably high $^{3}He/^{4}He$ ratios suggestive of derivation from the deep mantle (Marty *et al.*, 1996). (A third suite of intermediate character is currently being analysed.) The low-Ti sample, though relatively primitive (Mg# = 63.2), has a low Os concentration (13 ppt). Its initial $^{187}Os/^{188}Os$ ratio (0.151) has

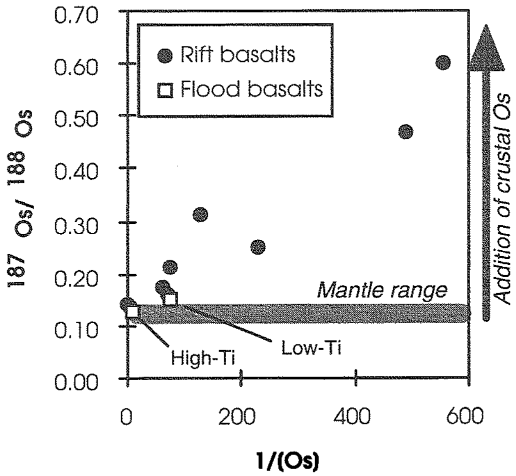

FIG. 1. $^{187}Os/^{188}Os$ *vs* 1/[Os] in rift and flood basalts from Ethiopia and Djibouti. [Os] in ppb.

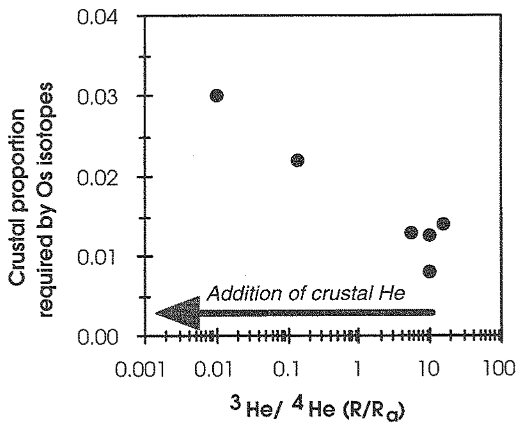

FIG. 2. Calculated crustal proportion required to explain Os isotopic ratios and concentrations of contaminated rift basalts, plotted against R/R_a (R_a = $^3He/^4He$ of the atmosphere). Mixing parameters given in text. He isotopes from Marty *et al.* (1996).

apparently been affected by crustal assimilation, though to a lesser extent than those of rift basalts of similar Os concentration. The high-Ti sample is rich in Os (147 ppt) and shows no sign of crustal contamination. It has a He isotopic ratio (R/R_a = 12.6) suggestive of an important deep mantle component. Its initial $^{187}Os/^{188}Os$ ratio (0.127) is equal to that theoretically expected for the primitive mantle. Interestingly, this ratio is lower than almost all those actually measured in OIBs (e.g. Bennett *et al.*, 1996; Roy-Barman and Allègre, 1995). These high measured ratios have led to repeated proposals that the lower mantle has a radiogenic Os isotopic composition (e.g. Martin, 1991) and to intensive debate about the origin of this signature. If the non-radiogenic character of the high-Ti, ^3He-rich samples is confirmed by further analyses, it may suggest that the Os isotopic ratio of the deep mantle is in fact not very radiogenic.

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