Trace element anomalies and correlations in Indian Ocean MORB

M. Rehkäper
A.W. Hofmann
Max-Planck-Institut für Chemie, Postfach 3060, 55020 Mainz, Germany.

Introduction

Isotopic studies have established the distinct geochemical character of the Indian Ocean MORB mantle in comparison with the Atlantic and Pacific. In particular Indian MORB is characterized by low $^{206}Pb/^{204}Pb$ and high $^{87}Sr/^{86}Sr$ values (e.g. Dupré and Allègre, 1983, Mahoney *et al.*, 1989). The trace element geochemistry which may correlate with these isotopic differences has not until now been comprehensively studied. Low Ti/Zr (Mahoney *et al.*, 1989) and particularly Ce/Pb (Loock *et al.*, 1993) ratios have been reported for Indian Ocean MORB glasses. Here we report new data on highly incompatible elements and their correlations with Sr isotope ratios in an effort to characterize the nature of the anomalous mantle component.

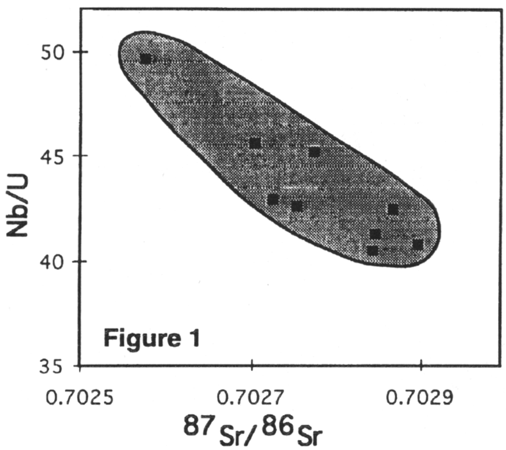
Samples and analytical methods

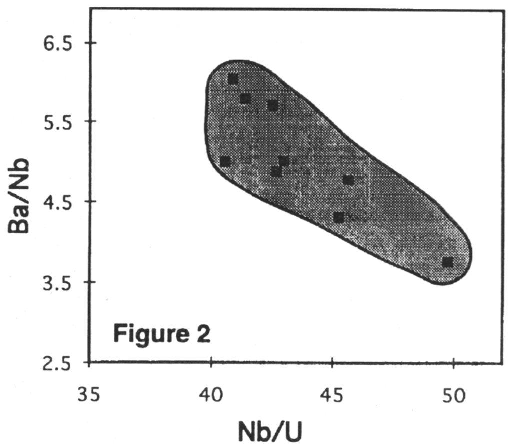
The samples were collected by the RV Sonne in 1983 (cruise SO-28) on the Carlsberg and Central Indian Ridge. Nine glasses from different dredge hauls at four dredge sites (Site A, 1 sample, 6.2°N, 60.9°E; Site B, 4 samples, 1.4°S, 67.6°E; Site CD, 1 sample, 5.4°S, 68.5°E and Site EX, 3 samples, 21.4°S, 68.8°E) were selected for analysis. The analyses of major elements, Zr and Y had been performed previously on whole rock powders using XRF (Herzig *et al.*, 1985). For the present study, glass rims were manually separated from the basalts, hand-crushed in an agate mortar, and carefully hand-picked under a binocular microscope to avoid phenocrysts and alteration. Prior to analyses samples were washed briefly in cold 0.5 M HCl and distilled water. The concentrations of K, Rb, Ba, Sr, Nd, Sm and Sr, Nd isotopic compositions were analyzed by (isotope dilution-) thermal ionization mass spectrometry using standard procedures. Rare earth elements, Nb, Th and U concentrations were measured by HPLC (high performance liquid chromatography). The determination of these elements by HPLC is based upon highly sensitive, recently developed methods (Rehkämper, 1994a and 1994b). This study represents the first geochemical application of these techniques.

Results and Discussion

Nd isotopic compositions show a very limited variation ($^{143}Nd/^{144}Nd$ = 0.51305-0.51309) and fall within the range of values determined by previous studies. $^{87}Sr/^{86}Sr$ values are more variable and systematic variations along the length of the Carlsberg/Central Indian Ridge are apparent. The most radiogenic $^{87}Sr/^{86}Sr$ ratios ($^{87}Sr/^{86}Sr$ = 0.70277-0.70290) are attained by the samples collected in the vicinity of 1.4°S. The glasses from 21.4°S are less radiogenic ($^{87}Sr/^{86}Sr$ = 0.70270-0.70275) and show no significant signature of the isotopic anomaly associated with the Réunion hotspot. In comparison with previous studies the new $^{87}Sr/^{86}Sr$ data are generally lower for a given value of $^{143}Nd/^{144}Nd$. The sample from Carlsberg Ridge (Site A) displays the least radiogenic Sr isotopic composition ($^{87}Sr/^{86}Sr$ = 0.702574).

The trace element geochemistry of the samples is characterized by a general depletion in highly incompatible and *LREE* with a mean (La/Sm)N = 0.61 ± 0.06, classifying them as N-MORB. The average Ba/Rb value (11.5 ± 0.8) is indistinguishable from the global mantle average (Hofmann, 1988). All samples display low Ti/Zr (75 ± 5) in good agreement with previous studies of Indian MORB, but lower than found in other oceanic regimes (Ti/Zr $\sim$95, Mahoney *et al.*, 1989). The K/U (mean = 17500 ± 1100) and K/Nb (mean = 405 ± 39) ratios of the glasses are significantly higher than the mean Atlantic-Pacific values of 12700 and $\sim$250 (Hofmann, 1988), indicating an enrichment of K relative to U and Nb. Positive Nb anomalies are apparent in the trace element patterns of all samples. The mean Nb/U and Nb/Th ratios of the glasses (43.5 ± 2.8 and 13.9 ± 0.9), however, are somewhat lower in comparison to the global MORB averages of 47 ± 10 and $\sim$19, respectively (Hofmann, 1988). Loock and Goldstein (1993) found Ce/Pb ratios in Indian MORB (range 13-18) to be significantly lower than in Atlantic and Pacific samples (mean = 25 ± 5; Hofmann, 1988). They also reported a correlation of Ce/Pb with $^{87}Sr/^{86}Sr$ and $^{207}Pb/^{204}Pb$. The present results show trace element ratios such as Ba/Nb and Nb/U to be





significantly correlated with Sr isotopic composition (e.g. Figure 1). Good correlations are also obtained when such element ratios are plotted against each other (e.g. Figure 2). Taken together, this evidence strengthens the case for an Indian Ocean MORB mantle that is geochemically distinct and heterogeneous in its trace element composition. Its geochemical signature is the result of a large-scale mixing event involving ordinary depleted MORB mantle and a component characterized by e.g. high $^{87}Sr/^{86}Sr$, Ba/Nb and low Nb/U, Ba/Rb. The correlations are explained by variable mixing of these components, which were not completely homogenized by convective stirring of the mantle. The origin of the contaminant has previously been assigned to ancient recycled sediments or delaminated subcontinental lithosphere (e.g. Dupré and Allègre, 1983; Mahoney *et al.*, 1989). All trace element and isotopic correlations are internally consistent and can be accounted for by a mixture of small amounts (< 0.5%) of average continental material (e.g. Galer *et al.*, 1989) or abyssal sediments (Ben Othman *et al.*, 1989) with depleted upper mantle.

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