Evidence from trace elements and H_2O for regionally distinctive sources of depleted MORB: implications for evolution of the depleted mantle

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Sources of depleted mid-ocean ridge basalts (N-MORB) worldwide are regionally distinctive. H_2O/Ce ratios in MORB are fairly constant for depleted N-MORB through enriched E-MORB within a region, but there are significant differences between regions. These observations can be explained by open system mantle evolution in which the sources of virtually all MORB have been influenced by regionally distinctive plume material that has been variably depleted by small extents of melting during OIB formation or during earlier episodes of MORB formation. The depleted residue of this process bears the trace element signature (H_2O/Ce) of the plume material and could serve as a component in the source of N-MORB. Mixing of this residue with newly-input plume material can explain much of the spectrum of MORB trace element compositions. Variations in H_2O/Ce in plumes (and therefore MORB) may arise from differences in the amount of juvenile volatiles or, more likely, differences in the amount and nature of recycled subducted components in their sources.

Introduction

It is widely accepted that isotopic and trace element ratios of E-MORB are strongly influenced by enriched material from mantle plumes (Schilling, 1973). The extent to which the sources of N-MORB have been influenced by plume material is less certain, but isotopic studies (Hamelin & Allègre, 1985) have shown that the sources of N-MORB are regionally distinctive, possibly because of plume influence. In this paper, regional differences in H_2O/Ce of MORB are examined. H_2O and Ce have similar bulk solid/liquid partition coefficients during oceanic basalt formation (Michael, 1988), so H_2O/Ce is characteristic of the source. H_2O/Ce ratios are used to provide unique information about the nature of the MORB source and about the influence of plumes on N-MORB.

Results

Total H_2O contents determined by FTIR spectroscopy range from 0.05% to nearly 1.5%. With increasing source enrichment (i.e., increasing Nb/Zr or La/Sm), H_2O/Ce is roughly constant (Figure 1) while K_2O/H_2O and H_2O/Nd increase and H_2O/La decreases. This suggests that H_2O and Ce have similar incompatibility in magmatic processes that influence the MORB source, and that the H_2O/Ce ratio is not sensitive to basalt genesis from the mantle.

There are significant differences in H_2O/Ce between different regions (Figure 1). N-MORB through E-MORB from the American-Antarctic Ridge, Southwest Indian Ridge , southern Mid-Atlantic Ridge, Pacific-Nazca Ridge 27°–34°S, East Pacific Rise 10°–12°N, Explorer Ridge, Mid-Cayman Rise Spreading Center and Galapagos Spreading Center, as well as basalts from Loihi Seamount have H_2O/Ce ratios that average from 155 to 213 (40 for each region). Notably, enriched *and depleted* MORB from the northern Mid Atlantic Ridge have *significantly higher* H_2O/Ce ratios than the other regions. Their means range from 280 north of Iceland to 239 in the region from 45°–62° N. Higher H_2O/Ce ratios are characteristic of the most depleted through the most enriched MORB of northern MAR.

Discussion

Distinctive H_2O/Ce ratios cannot be imparted to depleted sources by simple binary mixing with enriched components without causing the source to appear *enriched* in terms of ratios of highly incompatible elements such as Rb/K. The fact that even the most depleted MORB (Rb/K 0.001) of a region share the regional H_2O/Ce ratio suggests that the depleted source component also had that ratio.

An alternative to *simple* mixing of enriched and depleted components is an open system model of mantle evolution (Galer & O'Nions, 1985), in which the concentrations and ratios of incompatible elements in the depleted mantle are

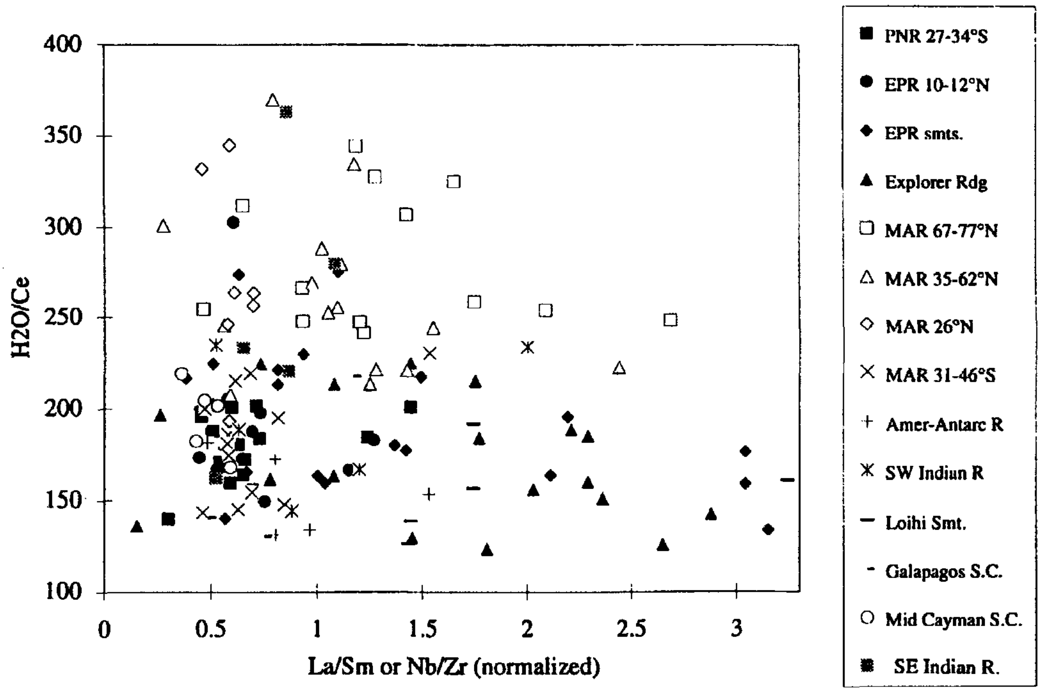

FIG. 1.

determined by fluxes into and out of the reservoir, not by long-standing heterogeneities. In our model, plumes provide the flux of incompatible elements into the depleted mantle, and H_2O and Ce have similar short residence times in the upper mantle. Plume material may be melted to form OIB. Or it may be diverted to a nearby mid-ocean ridge (Schilling, 1973) and form E-MORB. During melting, a small volume of mantle undergoes large extents of melting, while a much larger volume of mantle undergoes small extents of melting, supplying most of the incompatible elements and H_2O to the pooled melts (Galer & O'Nions, 1985). E-MORB and OIB produced in this way have the plume's distinctive H_2O/Ce signature. A further product of these melting processes is the large volume of plume-related residue that has undergone small extents of melting The residues may still generate basaltic magma, but they have a variably *depleted* signature. Notably, the residues retain the distinctive H_2O/Ce (and isotopic) characteristics of the plume, since these species are not fractionated during melting. The variably depleted residue may mix at a later time with itself or with new inputs of plume material having similar H_2O/Ce ratios, giving rise to a spectrum of depleted through enriched MORB sources, all having the plume's H_2O/Ce ratio. Binary mixing trends in trace element and isotopic ratios would be apparent. In this way, both enriched and highly depleted MORB from a region can have the same distinctive H_2O/Ce ratios: ratios that are determined by the long-term regional plume inputs.

In this model, H_2O/Ce variations in MORB originate by the same mechanisms as these variations in OIB and their sources. This may include differences in the amount of juvenile volatiles or, more likely, differences in the amount and nature of recycled subducted components in plumes.

References

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