Geochemical variation in the Tertiary basalts of Iceland

B.S. Harðarson
J.G. Fitton
Department of Geology & Geophysics, University of Edinburgh, West Mains Road, Edinburgh EH9 3JW, UK

Introduction

Most of what we know about the composition of the Iceland plume comes from studies on the neovolcanic zone, that is on basaltic rocks less than 0.7 million years old. The Icelandic Tertiary plateau basalts, however, have preserved a continuous 15 m.y. record of plume activity. We have sampled 1022 lavas from Tertiary and Lower Pleistocene profiles with an established palaeomagnetic stratigraphy which allows us to compare the different profiles chronologically.

Geochemical results

In Fig. 1 Zr/Nb (MgO > 5 wt%; 84% of the sample collection) is plotted against model age. This ratio is generally immune to the effects of alteration and is a good indicator of degree of melting and source depletion. Zr/Nb from the neovolcanic zone and the off-rift Snaefellsnes volcanic zone are included for comparison.

The plot shows that, for most of the 15 m.y. history of Iceland, the exposed lavas are remarkably constant in composition (MgO generally < 9 wt.%; Zr/Nb = 9±2). More

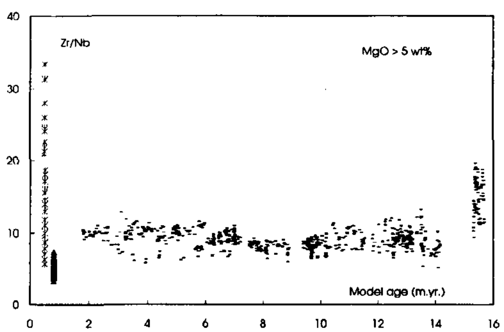

FIG. 1. Zr/Nb plotted against model palaeomagnetic age. Data for the neovolcanic zone (crosses) from Wood *et al.* (1979), Macdonald *et al.* (1990), Nicholson (1990) and Hemond *et al.* (1993). Data for Snaefellsnes (solid triangles) from Harðarson (1993).

diverse compositions, however, are found in the neovolcanic zone (Zr/Nb = 5–35) and in the oldest rocks in NW Iceland (Zr/Nb = 10–20). The latter occur beneath an unconformity and represent an extinct rift axis. The compositional diversity and generally more depleted character of the rift-zone lavas may be resolved through the application of Palmason's (1981) model for the crustal structure and accretion of Iceland. Lavas which are erupted near the ridge axis are rapidly buried and ultimately form the lower layers of the crust. Consequently, only lavas emplaced on the rift flanks will be preserved in the observable part of the Tertiary lava pile. Mowever, from the time that the Iceland rift system drifted west of the mantle plume (during Anomaly 7, 25 Ma) the rift axis has repeatedly been relocated to the east leaving behind fossil axial rift zones characterised by synclinal/anticlinal structures and unconformities. Lavas from beneath one of these unconformities, at Suðureyn in northwest Iceland, shows clear chemical differences from the rest of the sample collection. This section shows a continuous decrease in Zr/Nb from around 20 to around 7–8 at which level the ratio becomes constant. The trend is accompanied by an increase in $^{87}Sr/^{86}Sr$ (0.703087–0.703418115) and a decrease in $^{143}Nd/^{144}Nd$ (0.513159–0.51302718). The range in Zr/Nb in the section is not as great as that seen in the neovolcanic zone but the Sr and Nd isotopic range is of a similar magnitude. O'Nions and Pankhurst (1973) reported secular $^{87}Sr/^{86}Sr$ in Icelandic basalts from around 0.70345 at 15 Ma to about 0.70315 for Recent basalts, and this is apparently accompanied by a decline in *LREE* enrichment (Schilling *et al.*, 1982). We confirm that there is an overall decline in $^{87}Sr/^{86}Sr$ with time but we have insufficient data at present to see whether this is accompanied by an increase in $^{143/144}Nd$. Explanations for this variation include variable degrees of disequilibrium melting of a homogeneous mantle source, partial melting of a heterogeneous source, and mixing of two or more sources with the proportion of plume component decreasing since 15 Ma (e.g. ONions and Pankhurst, 1973, O'Nions *et al.*, 1976, Schilling *et al.*, 1982). Our data show that the decrease is

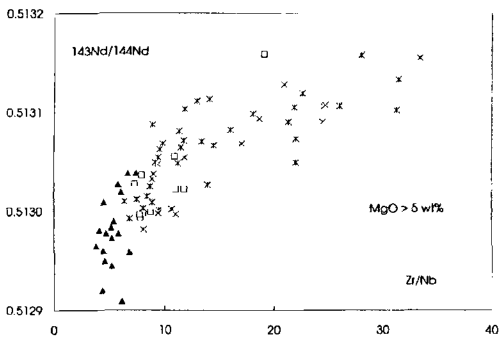

FIG. 2. $^{143}Nd/^{144}Nd$ plotted against Zr/Nb. This study (open boxes). Data for the neovolcanic zone (crosses) from Wood *et al.* (1979), Zindler *et al.* (1979), Nicholson (1990), Elliott *et al.* (1991) and Hemond *et al.* (1993). Snaefellsnes data (solid triangles) from Harðarson (1993).

not continuous but stepwise, and major irregularities in Sr and Nd isotopic ratios are seen across the Suðureyri unconformity. The compositional constancy of lavas emplaced distal to the spreading axis is remarkable and unexpected. It is also counter-intuitive in that one would expect the larger degrees of mantle melting beneath the axis (> 20%) to homogenise the melt products much more efficiently than the smaller degrees of mantle melting distal to the axis (5–10%). The chemical variation is reflected in isotopic variation since Zr/Nb shows a good positive correlation with $^{143}Nd/^{144}Nd$, and a weaker negative correlation is observed with $^{87}Sr/^{86}Sr$. This implies that the melting process directly beneath a spreading centre can sample the different components of a heterogeneous mantle source whereas magma generated a short distance away appears to favour the less depleted component. Alternatively, it may be that large flows from axial magma chambers are able to escape from the rift axis. Storage would effectively homogenise the magma and favour the eruption of less-magnesian lavas. This observation is important and has profound implications for the interpretation of the North Atlantic Tertiary province since this region is generally more closely analogous to the Icelandic Tertiary sequences than to the neovolcanic zone.

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