Hafnium and strontium isotope measurements in high-MgO basalts from Theistareykir, northern Iceland

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We report Hf and Sr isotope compositions from 31 samples from Theistareykir volcano, northern Iceland. The samples are high-MgO olivine tholeiites and picrites with the majority having MgO contents higher than 9 wt.%. The total range of MgO contents is from 5.5 to 22 wt.%. All samples are younger than 10,000 years and were collected from different post-glacial lava flows of the Theistareykir volcano in the northern Icelandic rift zone.

Hf and Sr isotope results

Hf isotope ratios were obtained by multi-collector plasma-source mass spectrometry on the Fisons Instruments Plasma 54 in Lyon. $_{176}Hf/_{177}Hf$ ratios are reported relative to $_{176}Hf/_{177}Hf = 0.28216 \pm 1$ of the JMC-475 Hf standard. Average in-run precision is better than 40 ppm ($2\sigma_m$). $_{176}Hf/_{177}Hf$ ratios range from 0.283170 to 0.283294 (corresponding to ε_{Hf} of +14 to +18.5). This is in good agreement with the range of $_{176}Hf/_{177}Hf$ ratios for Icelandic basalts reported in the literature ($_{176}Hf/_{177}Hf$ = 0.283180 to 0.283400).

Sr isotope ratios were measured by thermal ionization mass spectrometry (TIMS) on a Finnigan MAT 262RPQ mass spectrometer at the NHMFL. Repeated measurements (n = 13) of the E&A $SrCO_3$ standard averaged 0.708008 ± 16 (2σ); all replicate sample analyses agreed to better than this estimate for the in-run precision. $_{87}Sr/_{86}Sr$ ratios were measured on leached sample powders and vary between 0.702847 and 0.703208. They are similar to $_{87}Sr/_{86}Sr$ ratios previously reported from this volcano (Elliott *et al.*, 1991; Hémond *et al.*, 1993), and cover the full range of $_{87}Sr/_{86}Sr$ ratios reported from olivine tholeiites and picrites from other localities in Iceland (e.g. $_{87}Sr/_{86}Sr$ = 0.702859–0.703207, Hémond *et al.*, 1993).

Discussion

The range of Hf and Sr isotope ratios is relatively large in view of the temporally and spatially restricted sample suite suggest the close spatial association of isotopic heterogeneities within the Icelandic source. There is an excellent anti-correlation between $_{176}Hf/_{177}Hf$ and $_{87}Sr/_{86}Sr$ isotope ratios (Fig.1). Moreover, Hf and Sr isotope ratios are correlated with major and trace element concentrations and ratios, including MgO (Mg#), K_2O/TiO_2, and La/Sm, suggesting that the variable isotopic characteristics are closely related to the melting process. The most MgO-rich samples are also the most depleted isotopically; that is, they have the highest $_{176}Hf/_{177}Hf$ ratios and the lowest $_{87}Sr/_{86}Sr$ ratios (Fig. 2). These isotopically depleted samples also have the lowest concentrations of incompatible elements (e.g. TiO_2 and Na_2O) and the lowest La/Sm and K_2O/TiO_2 ratios (Fig. 3).

The required isotopically heterogeneous source

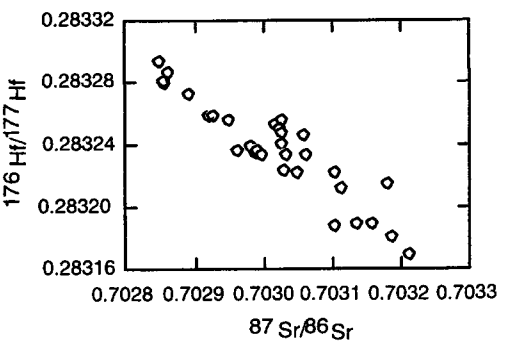

FIG. 1. $^{176}Hf/^{177}Hf$ *vs* $^{87}Sr/^{86}Sr$.

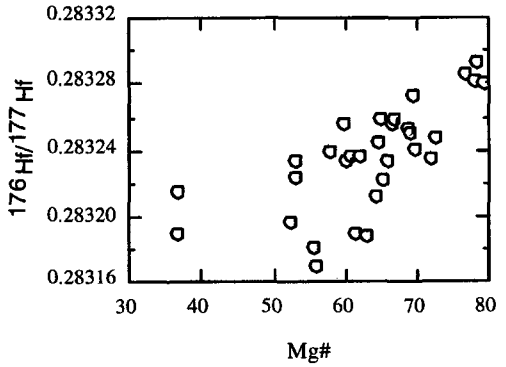

FIG. 2. $^{176}Hf/^{177}Hf$ *vs* Mg#.

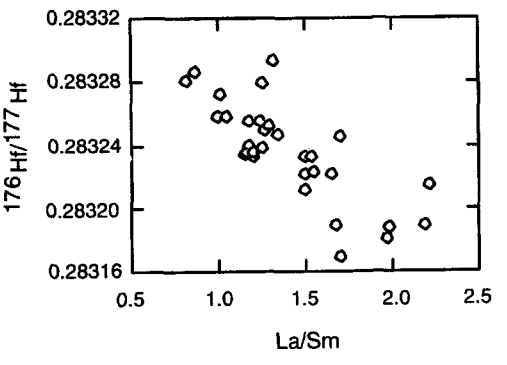

FIG. 3. $^{176}Hf/^{177}Hf$ *vs* La/Sm.

may be produced in a variety of ways, each of which leads to a different conceptual view of the source itself (see, e.g. Zindler *et al.*, 1979). This source may be produced by the migration (or redistribution) of a small melt fraction within an essentially homogeneous peridotite some time in the distant past (probably predating the most recent opening of the Atlantic). Isotopic heterogeneities would then evolve within this source and, on melting, show the observed relationships to trace element ratios. Some dependence of solidus temperature on trace element character, due to the melt migration, would have to be invoked for this source in order to account for the observed relationship between Hf and Sr isotope ratios and Mg#.

Alternatively, the required source could result from the incorporation of ancient subduction-processed mafic material within ambient depleted mantle, or, semi-equivalently, from the entrainment of ambient depleted mantle in a plume that originates within a boundary layer containing ancient subducted material. In either case, isotopic and trace element signatures in derivative melts will be correlated, and the observed relationships between isotopic and trace element parameters and Mg# can again result, at least in part, from variable solidus temperatures for the two components. Conceptually, we can also imagine a model intermediate between these two where invading small-degree melts originate from a mantle segment which is chemically distinct from the proto-Icelandic source, whether or not this segment contains recycled crustal material.

In any case, the principal distinguishing feature of Iceland among other plume-fed ocean islands is its location on the MAR, and our data once again demonstrate that depleted Icelandic basalts can, in very many respects, be virtually indistinguishable from nearby MORBs (e.g. Reykjanes Ridge, Schilling refs.). Any model constructed to explain the observed trace element and isotopic variations must, therefore, include an important role for depleted source material very similar to that which ascends beneath normal mid-ocean ridges. Measurement of U-Th disequilibrium in the samples discussed here is currently underway and we hope that these results will help to distinguish between possible models for the origin of the Icelandic mantle source.

References

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