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Oxygen Isotope Variations in Recent Magnesian Lavas from Iceland's Northern Neovolcanic Zone

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Geochemical variations of Icelandic lavas reflect both differences in the compositions and conditions and extents of melting of their sources (e.g., Thirlwall, 1994) and magmatic differentiation and crustal contamination (e.g., Gee et al., 1996). Discriminating between these two processes is key to constructing models of the composition and dynamics of the Iceland plume. Recent efforts to do so have focused on relatively magnesian lavas from the northern and western neovolcanic zones; Theistareykir volcano has been of particular importance for this work because of its abundance of magnesian lavas, the absence of a well-developed central volcanic complex, and the fact that it's lavas include the 'depleted' extreme to the array of compositional variations in Icelandic lavas generally (e.g., Elliott et al., 1991). We report here a study of oxygen-isotope variations in phenocrysts from recent Theistareykir lavas, conducted to search for evidence for both crustal contamination and oxygen isotope variations in the sub-Icelandic mantle.

Phenocrysts from Theistareykir basalts and picrites span a narrow range in $\delta^{18}O_{SMOW}$ (e.g., olivines vary from 4.7 to 4.2‰), consistently below the range typical of those minerals in upper-mantle peridotites and terrestrial basalts, and are correlated with trace-element indices and radiogenic-isotope compositions; the sense of these correlations is that decreasing $\delta^{18}O$ is associated with increasing 'enrichment'. We consider that such trends could reflect one of two phenomena: (1) sampling of a low-$\delta^{18}O$, enriched component in the Iceland plume, or (2) contamination of primitive Theistareykir lavas by low-$\delta^{18}O$ rocks in the Iceland crust. The latter of these two processes may be unexpected because it requires contaminants to be systematically more enriched than lavas. However, the most magnesian recent Thestareykir lavas are notable for being the most depleted Icelandic lavas generally and therefore their contamination by rocks more typical of the Icelandic crust will produce systematic changes in their incompatible-element and radiogenic-isotope abundances toward more enriched compositions.

Evidence discriminating between these two alternatives is found in correlations among $\delta^{18}O$, indices of 'enrichment', and major-element abundances. Decreasing $\delta^{18}O$ (and increasingly 'enriched' geochemical signatures) are associated with decreasing CaO and Mg# and increasing Na_2O, TiO_2, and FeO. The major-element variations underlying these trends fit the predictions of low-pressure crystallization differentiation of the most magnesian Theistareykir lavas; furthermore, these trends resemble previously-observed correlations between $\delta^{18}O$ and major element variations in highly evolved and contaminated Icelandic lavas (e.g., Nicholson et al., 1991). These trends can be accurately modeled either as mixing between primitive, depleted magmas having approximately 'normal' $\delta^{18}O$ and low-$\delta^{18}O$, evolved magmas similar to Icelandic quartz tholeiites, or as evolution of the most magnesian Theistareykir lavas by AFC processes. Therefore, we suggest that geochemical variations in recent Theistareykir lavas reflect contamination of relatively depleted primary magmas by systematically more 'enriched', hydrothermally altered rocks in the Icelandic crust (or partial melts of such rocks). The alternative hypothesis-that low-$\delta^{18}O$ lavas preferentially sample a low-$\delta^{18}O$ mantle component- cannot be strictly disproved but requires a fortuitous correspondence between the major-element compositions of putative plume melts and low-Mg# (~55) differentiates of magnesian Icelandic lavas.

If Theistareykir magmas have undergone crustal contamination as we infer, then their intra-lava geochemical variations provide only an indirect measure of the sources and dynamics of the Iceland plume (i.e., because the extraction from the mantle of 'depleted' primary lavas and 'enriched' crustal rocks are separated in time and the details of their mixing reflect crustal rather than mantle processes). Extrapolation of correlations between $\delta^{18}O$ and other geochemical indices for Theistareykir lavas to an oxygen-isotope composition within the range typical of mantle derived basalts suggests that melts parental to recent Theistareykir lavas are remarkably depleted in incompatible-elements when compared to NMORB (e.g., the La_N/Sm_N ratio of this end member is projected to be ~0.2±0.1). Given the MORB-like radiogenic isotope compositions of the most magnesian Theistareykir lavas, this may reflect unusually high integrated extents of melting of a portion of the upper mantle entrained within or heated by the Iceland plume or of a broadly 'MORB-like' component of the plume itself.

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