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Geochemical Variability in a Single Flow from NE Iceland

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The composition of magma erupted at the Earth's surface can be used to investigate the processes which generate melt. It is often necessary to assume that the composition of a small number of rock samples is representative of the melt generated in the mantle. However, a wide range of melt compositions may be produced in the melting region and if these melts are not well mixed then this assumption will not hold. Therefore it is important to gain an understanding of the processes which mix mantle melts. Studies of the high MgO basalts and picrites of the Theistareykir volcanic system in NE Iceland have found a wide range in trace element concentrations in both whole rock samples and olivine-hosted melt inclusions (Elliott et al, 1991; Slater, 1996). The aim of the present study is investigate magma mixing by examining the magnitude and spatial distribution of geochemical variability present in a single lava flow from Theistareykir. The Borgarhraun flow was chosen for this purpose because it is thought to have undergone relatively little fractionation (MgO contents of 10.5-13.3 wt%) and has a surface area of 35 km^3, almost all of which is easily accessible. Over 70 samples were collected from Borgarhraun and the average sample spacing was about 300 m. The major and trace element compositions of the whole rock samples and 40 olivine-hosted melt inclusions were determined and almost all elements show variability greater than the estimated analytical noise. The signal to noise ratio is >2 for 20 of the 36 elements measured on the whole-rock samples, including both major elements and incompatible trace elements (e.g. MgO, Nd). The poor correlation between major and incompatible element concentrations suggests that incompatible element variability is not a result of fractional crystallisation/crystal accumulation processes.

The REE variation in whole rock samples and melt inclusions can be produced by incomplete mixing of fractional melts from a melting model which matches the estimated composition of the average magma from Theistareykir. This melting model also reproduces the observed crustal thickness under the southern part of Theistareykir ~20 km. The melt inclusion compositions are more variable than the whole rock compositions and a simple mixing model shows that the magnitude of variability of the whole rock samples can be matched if each hand specimen is made of magma that was formed by mixing of ~30 batches of melt with the compositional variability of the inclusions. The variability in major elements can be explained by addition/removal of the olivine, clinopyroxene and plagioclase crystals found in the magma. Thermobarometry shows that the olivine and clinopyroxene compositions were in equilibrium with the whole rock composition at about 1300°C and depths close to ~30 km. Hence, the major element trends can be explained by fractional crystallisation and assimilation of cumulates in sub-Moho magma chambers.

Analysis of the distribution of geochemistry in Borgarhraun shows that the spatial distribution of the concentrations of moderately incompatible elements (e.g. Nd) is not random, so that samples with a separation of less than 4 km have more similar concentrations than expected from a random distribution of geochemistry. This separation distance corresponds to a lava volume of ~0.1 km^3. This volume may be controlled by magma mixing in a sub-Moho chamber, so that each time the magma chamber supplies melt for eruption, it provides a volume of about 0.1 km^3. The concentration variations of compatible elements with position cannot be distinguished from random variation. It is likely that the crystal removal and addition processes that control major element variability operate to cause this variability on short length-scales, below the resolution of this study.

Elliott TR, Hawkesworth CJ & Gronvold K, *Nature*, **351**, 201-206, (1991).
Slater L, *PhD Thesis*, *University of Cambridge*, (1996).