Rare earth elements as indicators of hydrothermal processes within the East Scotia subduction system

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The East Scotia subduction zone, located in the Atlantic sector of the Southern Ocean, hosts a number of hydrothermal sites in both back-arc and island-arc settings. High temperature (> 353 °C) 'black smoker' vents have been sampled at three locations along segments E2 and E9 of the East Scotia back-arc spreading ridge, as well as 'white smoker' (< 212 °C) and diffuse (< 40 °C) hydrothermal fluids from within the caldera of the Kemp submarine volcano. The composition of the endmember fluids (Mg = 0 mM) is markedly different, with pH ranging from 0.8 to 3.4, [Cl^-] from 88 to 536 mM, [H_2S] from 6.7 – 200 mM, [F^-] from 35 to 1000 µM) and [Li] from 18 to 606 µM. All of the vent sites are basalt-hosted, providing an ideal opportunity for investigating the geochemical controls on rare earth element (REE) behaviour.

Hydrothermal fluids from E2 and E9 have total REE concentrations ranging from 7 – 127 nmol/kg, and chondrite-normalised fractionation patterns are either light REE-enriched (La_{CN}/Yb_{CN} = 12.9 – 30.0) with a positive europium anomaly (Eu_{CN}/Eu^*_{CN} = 3.51 – 59.4), or mid REE-enriched (La_{CN}/Nd_{CN} = 0.61) with a negative Eu anomaly (Eu_{CN}/Eu^*_{CN} = 0.59). By constrast, fluids from the Kemp Caldera have almost unfractionated REE patterns (La_{CN}/Yb_{CN} = 0.8 – 2.2; Eu_{CN}/Eu^*_{CN} = 1.0 – 2.2).

We will demonstrate that the REE geochemistry of fluids from the back-arc spreading ridge is variably influenced by ion exhange with host minerals, phase separation, competitive complexation with ligands, and anhydrite deposition, whereas fluids from the Kemp submarine volcano are also affected by the injection of magmatic volatiles which enhances the solubility of all the REEs. We will also show that the REE patterns of anhydrite deposits from Kemp differ from those of the present-day fluids, potentially providing critical information about the nature of hydrothermal activity in the past, where access to hydrothermal fluids is precluded.

Plutons are texturally modified primary igneous liquids, not cumulates

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Existing data support a model in which chemical patterns of both shallow plutonic rocks and volcanic rocks mainly reflect melt generation in the deep crust with minimal differentation in the upper crust. Field and petrologic features of shallow plutonic rocks reflect incremental assembly of evolving lower crustal melts, overprinted by significant textural modification. Homogeneous granodiorites reflect slow accumulation of compositionally uniform magmas that were likely feeding chemically similar, small (10^1 km^3) eruptions. Zoned intrusions reflect evolution of melt composition fed from the lower crust on time scales of 10^5 to 10^7a, with limited upper crustal differentiation. If so, plutonic rocks are as rich a source of information about chemical evolution of the crust as volcanic rocks, and plutonic rocks provide a more complete record than volcanic rocks because they are better preserved through geologic time.

In contrast to small eruptions, magmatism related to large ignimbrites (>500 km^3) may be scarcely represented in the plutonic rock record. The abnormally high magma flux necessary to generate an ignimbrite results in effective evacuation of the source. Comparable volumes of plutonic rocks that preserve such high fluxes remain unrecognized. In the Southern Rocky Mountain volcanic field, two examples are identified where the only intrusive rocks temporally equivalent to ignimbrites are dikes and ring dikes of roughly the same composition as the ignimbrite. We take this to indicate that the magmas were transported efficiently from deep sources to the surface without protracted storage in the upper crust.

Altogether, the data support a model for plutonic/volcanic rock connections in which both dominantly reflect melt generation processes with minimal overprinting by shallow crustal processes. Hypothetical links between plutonic and volcanic rocks that rely on significant shallow differentiation fail field, geophysical, geochemical and geochronological tests and should be reexamined.

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