A conceptual model of kinetically controlled isotope fractionation during diffusion-controlled magmatic mineral growth

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The crystallization history of magmatic mineral grains is recorded in its chemical and isotopic composition, which is commonly used to constrain parental magma compositions and temperature of crystal formation. While this approach inherently implies that crystal growth took place under equilibrium conditions, an increasing number of studies find evidence indicating non-equilibium crystal growth.

We present a conceptual model of kinetically controlled element uptake and isotope fractionation during diffusion-controlled mineral growth. The multi-component and multi-dimensional numerical modelling approach assumes a spherical grain growing under the assumption of local equilibrium on its surface in a spherical matrix of given size and composition. It is shown that the time-dependent ratio between mineral growth and near-surface diffusion in the matrix controls the uptake of an element into the crystal lattice. Modeling results reveal that under conditions of fast mineral growth highly compatible or uncompatible elements will be depleted or accumulated near the growing mineral surface forming an compositional boundary layer in apparent disequlibrium with the matrix. Equilibration of the boundary layer and the reservoir will depend on the diffusivity of an element if the effect of free and forced convection can be assumed to be sufficiently small. As a result, significant isotope fracionation is predicted to occur during progressive mineral growth since diffusion rates of isotopes of the same element depend on their masses. Consequently, this fractionation is then "recorded" in the resulting isotope profile of the crystal.

The maximum amount of fractionation and the shape of the resulting isotope profile are shown to be sensitive to the applied growth and diffusion rates as well as the effect of free and forced convection on the size of the boundary layer. Thus, application of this model potentially provides an additional key tool to decipher crystallization histories of magmatic mineral grains.

Magmatic history of the Ice River Alkaline Complex, British Columbia (Canada)

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The 368±4 Ma [1] Ice River Alkaline complex of southern BC is hosted in Cambro-Ordovician limestones and shales. The intrusion is exposed over an area of 29 km^2, and comprises three major units, an early ferrocarbonatite phase located near the centre of an older layered alkaline mafic complex, and a younger zoned syenite complex. The feldspar-poor, mafic complex comprises rhythmically layered urtite, ijolite, and jacupirangite; the feldspar-rich, zoned nepheline syenite complex has a range of lithologies that grade from leuco- to melanocratic nepheline syenite, natrolite- and sodalite-rich syenite. Two phases of late carbonatite veins crosscut the syenite complex. One is highly enriched in Ba-Sr-REE (>140000 ppm Ba), whereas the other has Ba contents of <3000 ppm. A 2-3 m wide, coarse-grained alkaline lamprophyre occurs between the limestone of the Ottertail Formation and a nepheline syenite dyke. This lamprophyre is unrelated to the finer-grained lamprophyres that are present through out the intrusion. Several generations of fine-grained to pegmatitic, nepheline syenite dykes cut both the nepheline syenite and layered mafic alkaline complexes and their associated rocks. These dykes are interpreted to be the result of periodic tapping of a deep-seated fractionating magma chamber. One of the most REE-enriched dykes gives an EPMA U-Pb monazite age of 155±17 Ma, suggesting that at least some of the dykes may be from a magmatic event that is temporally distinct from the 368±4 Ma Ice River Intrusion.

[1] Parrish *et al*. (1987) *GSC paper* **87**, 33-37.