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The Role of Magmatic Versus Subsolidus Processes in Determining Mineral-Scale Isotopic Characteristics of the Rum Intrusive Complex

Frank J. Tepley III (tepley@ess.ucla.edu)[1], **Jon P. Davidson** (davidson@ess.ucla.edu)[1] & **Zenon Palacz**[2]

[1] Dept. of Earth and Space Sciences, University of California, Los Angeles, Los Angeles, CA 90095-1567, USA
[2] Micromass UK, Floats Road, Wythenshawe, Manchester, M23 9LZ, UK

Cumulate rocks of the Eastern Layered Series (ELS) of the Rum intrusion in northwest Scotland exhibit large isotopic variations of bulk rock samples within and between single macrorhythmic units. These variations have been attributed to recharge events of parental magma and concomitant crustal contamination of more radiogenic country rock (Palacz and Tait, 1985). Isotope compositions may vary among and within phases as they crystallize from magma undergoing contamination and/or recharge. The bulk-rock isotopic composition of each cumulate layer is controlled by the modal mineral abundance weighted by elemental concentration. We have therefore examined the character of the interaction between magma and crust in detail via bulk-rock isotopic analyses, single-crystal isotopic analyses, and *in situ* laser ablation multi-collector ICP-MS isotopic analyses.

Initially, we evaluated the isotopic heterogeneity of plagioclase feldspar crystals within 2.5-3.0 cm-sized samples from the base and top of unit 10 in which there exists a large upsection change in bulk-rock $^{87}Sr/^{86}Sr$ ratios (~0.7038 to ~0.7065) (Palacz (1985), and verified by our whole-rock isotopic analyses). We first employed the *in situ* laser ablation multi-collector ICP-MS method of analysis because of its ability to characterize large numbers of crystals in a speedy fashion using either spot or raster transect analyses. Plagioclase feldspar is an ideal candidate for evaluation of $^{87}Sr/^{86}Sr$ analyses through this analytical method because of its ubiquity and protracted growth history in the Rum rocks, and extremely low Rb/Sr ratios. Isotopic transects were performed on individual crystals from the down-section side of the samples upsection, analyzing grains every ~2-5 mm to the top of the sections. The results show negligible $^{87}Sr/^{86}Sr$ variations within individual grains or among different grains, and they agree with whole-rock isotopic ratios. However, the laser ablation method typically returns 2σ precisions of ±250 ppm so that any real variations that might exist at that level cannot be confidently resolved. Therefore, mineral separates (olivine, clinopyroxene and plagioclase) in rocks from the top of unit 9 and the base of unit 10, where bulk-rock $^{87}Sr/^{86}Sr$ ratios again show a range in values (~0.7048 to ~0.7038), were examined through the more precise, traditional single grain TIMS analysis. Results from this method also produce values nearly identical with the bulk-rock isotopic values indicating that on the order of hand sampled-sized rocks (~20-30 cm), isotopic variability did not exist in the original magma or that isotopic equilibration has occurred through solid-state diffusion. Given that large isotopic variability does exist within and between layers, it is possible that sub-solidus diffusion has played an important role in the present chemical state of these rocks. This is consistent with the lack of textural features, such as zoning, indicative of sustained growth during large-scale open-system behavior.

To estimate the potential length scale of interaction, we modeled the interplay between two layers as simple linear solid-state diffusion, using whole-rock isotopic values between layers as end-members in the model and diffusion coefficients from the literature (e.g., Giletti & Casserly (1994) and Cherniak & Watson (1994)). It is stressed that this is a simplified calculation not taking into account potential diffusion along grain boundaries. Our results show that for T ~950 ºC and time ~1-10 Ma, diffusion length scales are on the order of few to several cm. This length scale can and will be tested with detailed single-crystal and within-crystal isotopic analyses from samples just below and above the sharp petrologic unit 9-unit 10 boundary to determine the length scale of isotopic heterogeneity (Figure 1).

To date, our findings suggest that interlayer isotopic variations in the ELS of the Rum intrusive body are the result of either both rapid and efficient crystallization and accumulation of mineral phases from a homogenous melt at that time, or post-cumulus isotopic re-equilibration of mineral phases.

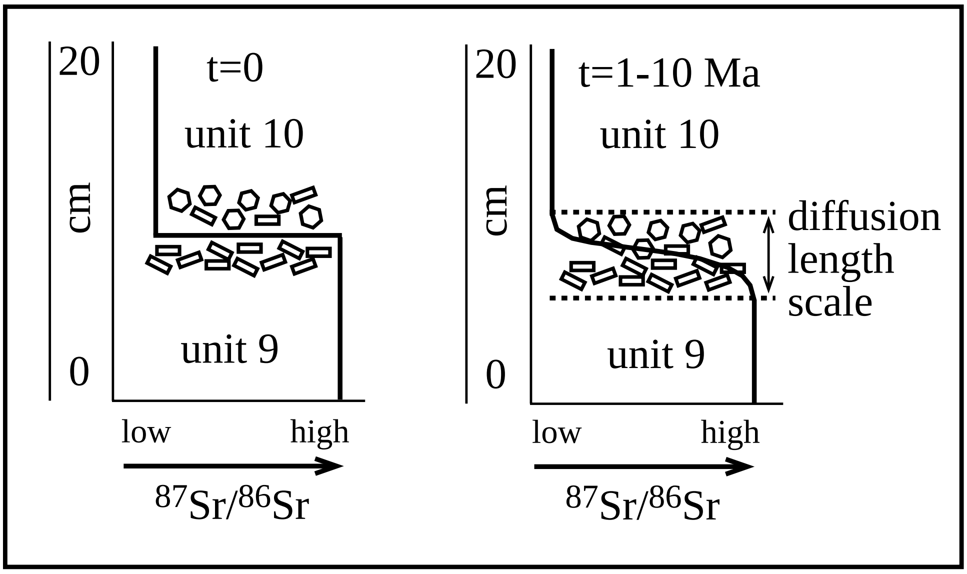

Figure 1: Schematic illustration demonstrating the sharp isotopic contrast across the petrologic boundary of unit 9-unit 10 at time t=0 when crystals first settled, and the relaxation of that isotopic boundary and possible diffusion length scale at t=1-10 Ma

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