The Daly gap: Low-pressure fractionation and heat-loss from a cooling magma chamber

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The Daly gap describes the paucity of magmas with intermediate SiO_2 content and the bimodal distribution of mafic and felsic compositions in igneous rock suites from various magmatic environments. Its origin was attributed to fusion of crustal rocks by intruding mafic magmas; discontinuous eruptions from a fractionating magma chamber due to varying magma properties, e.g., viscosity or crystallinity; variation in liquidus slopes or changes in the residence time of magma in the chamber.

In this study, the MELTS program was used to model the evolution of a suite of mafic to felsic (type A) magmas from the Amram Massif, southern Israel as the product of a fractionating crustal basaltic body. The calculated heat loss is used, in conjunction with a simple cooling model, to quantitatively constrain a relative time-scale for the process and to demonstrate that random sampling of such fractionating magma would produce a compositional gap.

The probability for sampling is calculated as the reciprocal of dX/dt, the rate of change of a compositional parameter with time (e.g. the SiO_2 content of the melt). Using the program output for melt volume (V), SiO_2 content (X) and released heat (H) at each melt temperature (Tm), the only free parameter is the wall rock temperature (T_0):

$$\left[\frac{dX}{dt}\right] \propto \left[\frac{dX}{dH}\right] * (T_m - T_0) * V^{2/3}$$

We suggest that the Daly gap reflects the relatively low sampling probability of intermediate compositions during the cooling and crystallization of magma chambers. Mafic compositions evolve slowly because of the small difference in silica content between the melt and the fractionating assemblage. The more felsic compositions evolve slowly because of their low cooling rate combined with the onset of K-feldspar crystallization. The fast evolution and low sampling probability through the intermediate stage reflects the combination of efficient cooling and large difference in silica content between fractionating crystals and the magma.

The hypothesis we present is similar, in some respects, to some earlier explanations for the formation of the Daly Gap. However, the MELTS program provides an independent, quantitative calculation of chemical composition and heat budget during fractionation and clearly demonstrates the important role of slow conductive cooling in enhancing the sampling probability of the felsic compositions.

Mineral/melt partitioning of Sm, Eu and Gd: implications for the redox state of the Martian mantle

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Introduction: Redox variations have recently been discovered among the shergottites [1,2,3]. [2] used the experimentally determined relationship of the Eu anomaly in pyroxenes with fO_2 to infer a range of fO_2 for the shergottites. [3] inferred fO_2 using equilibria between FeTi oxides. These two methodologies give different results. The problem is one of calibration, the Eu redox relationship used by [2] was determined for the LEW86010 angrite [4]. We have completed a set of experiments on the redox relationship of Eu partitioning relative to Sm and Gd for pyroxene and melt compositions more relevant to Martian meteorites.

Experimental: Augite/melt partitioning experiments were run in a gas-mixing DelTec furnace at fO_2 ranging from IW-2 to IW+4 (QFM+0.5). The starting materials were oxide mixtures doped with 1% each of Sm, Eu and Gd. Samples were suspended from a Re wire loop in the furnace. The samples were held at run temperature for up to 24 hrs and then quenched in water. Run products were analysed for all elements with the SX100 EMP at NASA/JSC.

Results: Glasses are homogeneous in all experimental run products. Augites are generally zoned with CaO from 19 to 13 wt% and MgO from 15 to 18 wt%. Mg# for the augites are fairly constant (0.54 to 0.56). D_{Sm}, D_{Eu} and D_{Gd} vary with CaO and MgO content of the augites for a given fO_2. More importantly, however, the RATIOS of the D values are constant with changes in CaO and MgO in the augites for a given fO_2. D ratios are plotted in the figure below. Compared with experimental angrite compositions [4], fO_2 for a given D_{Eu}/D_{Gd} for this study are shifted to higher values. This shift is greatest for high fO_2s. Consequently, fO_2 values for the shergottites determined from REE data of [2] and D data from this study are higher than those of [2] for the higher fO_2s and closer to those determined by [3]. The shergottites with the lower fO_2 values are approximately the same as those of [2].

References

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