

MAGMA EVOLUTION: THE ROLE OF DIFFERENTIAL MOBILITY OF MAJOR, MINOR AND TRACE ELEMENTS

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ABSTRACT: Differentiation processes in magmatic systems generate compositional gradients at different length scales. Some examples are: i) interaction between magmas produced by different sources; ii) crystallization along the walls of magma chambers; iii) differential assimilation of country rocks. Once compositional gradients or layers are generated, convection can be driven by local chemical gradients, leading to diffusion along the layers(1). At this point, both density and temperature differences are triggers for convection. The system evolves further, through the interplay between convection and diffusion(2 and 3).

All these processes inevitably lead to mixing among compositionally different melts. As a result, mixing may take place at any stage of the life span of a magmatic system. Therefore, the ability of chemical elements to diffuse in silicate melts is a process of utmost importance in igneous petrology. It controls the rate of homogenization of compositional gradients generated in the system and the crystallization kinetics.

What are the main parameters controlling the mixing process in natural silicate melts? What is the role of the local geometry (e.g. magma chamber, fracture/channel networks, volcanic and plutonic conduits) on the fluid-dynamic style and intensity of the process? In order to answer these questions, detailed analyses of natural examples at different scales (from the description of thin sections to the mapping of magma chambers) must be coupled with reliable experiments performed with natural melts.

Analyses of natural structures and fabrics, recent experimental work and numerical modeling have shed new light into the complexity of the mixing phenomenon. Magma mixing produces a fractal (scale-invariant) distribution of element concentrations. As a consequence, the classical conceptual model, that mixing should produce linear inter-elemental plots, is not always valid. This is due to the onset of a recently recognized process: the diffusive fractionation of chemical elements in silicate melts(3, 4 and 5). Differential mobility, especially of trace elements, along chaotic flow fields, may produce highly uncorrelated plots on geochemical diagrams(2 and 4).

Our experimental results demonstrate that mixing can be a very efficient process in producing compositional variability in igneous systems. Experimental results also show that different elements reach their respective hybrid composition at different times, depending not only on their diffusivities, but also on the fluid dynamics governing the mixing system(3).

Our main goal is to contribute to unraveling the complexity of magma mixing, by combining the principles of fluid dynamics with the chemical evolution of the system in time (6). By merging results from experiments performed with natural melts and constrained by geochemical data from natural rocks, a new approach towards understanding the intricacy of igneous systems is envisaged.

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