Goldschmidt 2024 Abstract
https://doi.org/10.46427/gold2024.24699

Diffusion with recrystallization – a challenge for diffusion chronometry

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A common situation in volcanic systems is the input of hotter, more primitive magma into an existing magma reservoir or mush zone. This is simultaneously a thermal (hotter material is introduced), chemical (compositional mixing occurs) and mechanical (volume changes / strain are involved) perturbation. Minerals respond by simultaneous dissolution, precipitation (new grains or overgrowth on older ones) and diffusion in the crystalline grains as well as in the melt phase surrounding mineral grains. Diffusion chronometry is based on the premise that diffusion in the zoned mineral grain of interest is the slowest rate limiting step as the system approaches equilibrium. However, this is valid only for a set of kinetic processes that occur in series. When several processes occur in parallel, as in the example above, it is essential to evaluate carefully the significance of timescales obtained by modeling a diffusion profile.

Theoretical calculations show that if compositional jumps exceed a threshold, the resulting strain in the lattice produces dislocations, and it is known from structural geology and mineral physics that when the concentration of such dislocations exceed a critical value, recrystallization / new grain growth occurs. This aspect can now be be quantified. The process has been observed experimentally in different systems (e.g. Beyer and Chakraborty, 2021). The occurrence of the process depends on, among other factors, the grain size of the material. Experiments with pyroxenes will be used to illustrate how the compositional evolution in such systems occurs in alternating steps of new grain growth and diffusion. Timescales obtained from modeling the diffusion profiles in such grains are short and relate to the duration between the last stage of growth and final freezing. It is necessary to exercise caution to recognize and interpret suitably the timescales obtained from such profiles in natural samples. Modeling tools such as phase field methods are providing options for quantifying such processes and may become commonplace in the future.

Beyer, C. and Chakraborty, S. (2021) *Internal stress-induced recrystallization and diffusive transport in $CaTiO_3$-$PbTiO_3$ solid solutions: A new transport mechanism in geomaterials and its implications for thermobarometry, geochronology and geospeedometry. Amer. Mineral. 106: 1940-1949.*