Intergranular diffusion rates in mineral aggregates: Where are we and where do we go from here?

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As noted by Carlson in his recent Presidental Address to the Mineralogical Society of America [1], "the kinetics of intergranular diffusion govern rates of metamorphic crystallization and chemical equilibration in many ordinary circumstances. Unfortunately, those rates remain largely unknown." While intergranular diffusion rates remain largely unknown, significant advances have been made over the past decade.

The results of experimental laboratory studies will be reviewed in light of applications to the kinetics of metamorphic processes. The important role of fluids and the equilibrium fluid distribution during metamorphism will be illustrated through the results of the experimental studies. In addition, the results of recent experiments on the bulk diffusion of Si in feldspar aggregates will be presented. The results of these experiments place valuable constraints on the rate-limiting diffusing species in mineral reactions involving feldspars.

References

[1] Carlson W.D., (2002), *Am. Min.* **87**, 185-204.

Can competitive porphyroblast growth lead to size-time correlation?

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Two types of evidence for intergranular diffusion being the rate-limiting process in metamorphic crystallization are spatial ordering of porphyroblasts and radius-rate relationships. However, these are to some extent mutually exclusive in any single situation, as the theoretical radius-rate relationship for thermally-accelerated diffusion is based on growth in isolation, whereas ordering implies competitive growth. However, they both are observed in quartzite schists from the Picuris Mountains of New Mexico.

This paradox provided part of the impetus for creation of a new computer model of metamorphic crystallization in which diffusion is directly quantified as a function of local concentration gradients in the intergranular medium brought about by dissolution of reactants and growth of products. This new treatment allows spatial variability in reactant distribution to be quantitatively taken into account, and its possible effects on final porphyroblast distribution to be studied. As with its predecessor (Carlson et al. 1995), this model successfully reproduces the spatial ordering and crystal size distributions measured in natural samples.

When intergranular diffusion is the only driving force for nutrient transport in these simulations, all growth is competitive. The growth rate of any given porphyroblast is highly dependent on the local nutrient supply and the number of nearby porphyroblasts competing for it. As a result, in the final result there is only a very broad correlation between porphyroblast size and time of nucleation. Conversely, in the Picuris study conducted by Chernoff and Carlson (1997), the correlation between size and time as inferred from central MnO content is relatively tight, a trend that apparently spans several outcrops. This result implies a fairly consistent growth rate that is not achievable in the models as originally posed.

Reproducing this observation requires re-examination of the assumptions behind nucleation and material transport. In particular, fluid advection, possibly driven by fluids produced during dewatering, may provide the missing mechanism.

References

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Chernoff C. B. and Carlson W. D., (1997), *J. Met. Geol.* **15**, 421-438.