

On the kinetics of surface-controlled crystallization

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Summary

The fundamental assumption inherent in conventional geothermobarometry is that metamorphic reactions take place close to equilibrium. This equilibrium approach has been proven successful for a variety of metamorphic reactions and it is widely used to derive parameters such as geothermal gradient or depth of subduction that are vital for geodynamic interpretations. However, there are numerous examples where equilibrium thermodynamics fails to predict the mineral content and the chemical composition of minerals in rocks. This phenomenon is observed in a variety of rocks that were exposed to metamorphism ranging from low to high-grade conditions (e.g., Jamtveit and Andersen, 1992; Keller et al., 2006; Wilbur and Ague, 2006; Pattison and Tinkham, 2009). In particular, the equilibrium approach cannot be used to predict the texture of a rock. In order to overcome these limitations we developed a more realistic approach that drops the assumption of chemical equilibrium during metamorphic crystallization. Instead, it accounts for the departure from equilibrium required for surface-controlled crystallization - an end-member in the kinetics of metamorphic crystallization (e.g., Carlson, 1989; Kretz, 1974; Spear and Daniel, 1998). Based on classical nucleation and reaction rate theory (Becker and Doering, 1935; Turnbull and Fisher, 1949; Kelton et al., 1983) and Gibbs free energy dissipation (Thompson and Spaepen, 1983) we simulate the reactions by which nuclei and crystals of the product of a metamorphic reaction form. First results will be presented that compare predictions from numerical experiments on garnet crystallization to analytical data obtained through XR-CT and EPMA. We will show that this approach may allow information to be inferred on two of the most important thermophysical properties that impact on rock texture formation: atomic mobility at the surface of growing particles and effective interfacial energy.

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