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The influence of textural inheritance and general kinetics in the development of porphyroblasts during metamorphism

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Metamorphic rocks record attempts to reach an equilibrium chemical configuration by modifying mineralogy and microtexture in response to changing P-T-X conditions. Of all of the possible rate-limiting processes that control metamorphic (i.e. essentially solid-state) equilibration, inter- and intra-crystalline diffusion have previously been shown to be particularly crucial. Here we forward model the metamorphic evolution of several initial rock configurations (reflecting protolith chemistry and texture) by imposing specific P-T-X-t paths and by varying diffusional constraints. In this, we consider rocks to be composed of one or several kinds of porphyroblast phase surrounded by an effectively homogenous matrix $\pm$ a fluid phase on grain boundaries. We assess the local 'goal assemblage' at each time-step for several positions in the 2D model using free energy minimization, diffusing material through the model with diffusivities extrapolated from available literature constraints (e.g. Carlson 2002; 2006; 2010). This allows us to quantify the physico-chemical relations between the kinetics of metamorphic reactions and the development of subsequent microtextures in metapelitic rocks. We particularly seek to characterize controls on the size, spacing, shape, and zoning of one or several commonly porphyroblastic minerals. We track their spatial association with each other and available fluids. Key to this is careful tracking of the most appropriate diffusing species (chiefly Al, Si, Fe, Mg, Ca, and H2O) during each model run. At the end of each numerical simulation, zoning profiles of grown porphyroblasts can be related to both P-T condition (through equilibrium thermodynamics) and initial disposition, using diffusivities of key 'porphyroblast forming' cations. In addition to initial configuration, the resultant modeled textures depend most strongly on absolute temperature, duration above a "closure temperature", rate of heating or cooling, matrix grain size, and the presence or absence of a transient fluid phase.