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# Beyond the equilibrium paradigm: How consideration of kinetics enhances metamorphic interpretation

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## ABSTRACT

The equilibrium model of prograde metamorphism, in which rocks are regarded as departing only negligibly from equilibrium states as they recrystallize, has generated a wealth of petrologic insights. But mounting evidence from diverse approaches and observations over a range of scales has revealed that kinetic impediments to reaction may prevent metamorphic rocks from attaining rock-wide chemical equilibrium along their prograde crystallization paths. To illustrate the resulting potential for inaccurate interpretation if kinetic factors are disregarded, we briefly review several case studies, including: out-of-sequence, metastable, and displaced isograds in contact aureoles; paragenetic sequences documenting overstepped, disequilibrium reaction paths; patterns of compositional zoning in garnet demonstrating partial chemical equilibrium; petrologic incongruities between observation and thermodynamic prediction; and inhibited reaction progress revealed by petrologically constrained numerical simulations of garnet crystallization. While the equilibrium model provides an indispensable framework for the study of metamorphic systems, these examples emphasize that all reactions require departures from rock-wide equilibrium, so all rocks must traverse kinetically sensitive reaction paths during recrystallization. Mindfulness of the potential significance of kinetic influences opens new avenues for petrologic investigation, thereby enhancing both analysis and interpretation.

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