Timescales of Contact-regional Metamorphic Events: Constraints from Heat and Mass-transport Modeling

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Abstract

Interpretation of the thermal and tectonic evolution of metamorphic terranes derives from a combination of field studies, chemical analyses, pressure-temperature (P-T) determinations and geochronologic studies. These data, supplemented by heat and mass-transport modeling, provide insights into the thermal and flow regimes that likely operate during metamorphism. Such calculations also provide timescales over which mineral transformations occur.

Computational heat and mass-transport modeling in 2D and 3D of a contact-regional metamorphic terrane with well-delineated heat sources, P-T conditions, and mineral textures constrains timescales for mineral growth. For 2-5 km thick granitic plutons emplaced into country rock with a 34^{o}C/km geotherm, the maximum temperatures attained in the aureole are about 675^{o}C immediately adjacent to the pluton and occur early in the thermal history of the contact aureole when geologically instantaneous emplacement is assumed. For a single intrusion, temperatures remain above 600^{o}C for about 250,000 yr, above 550^{o}C for ~600,000 yr for a low-flow (permeability (K) = 10^{-18} m^2) system but ~1.5 Ma for a regime with fluid flow (K = 10^{-16} m^2) and above 500^{o}C for ~1.35 Ma and ~1.9 Ma for low-flow and flow conditions, respectively. In contrast, when multiple intrusions take place within a time span of about 750,000 yr, rocks remain above 600^{o}C for 650,000 yr, above 550^{o}C for ~2.5 Ma and above 500^{o}C for ~2.7 Ma. Consequently, multiple pulses with the same total heat energy input maintain elevated thermal condition above 550^{o}C about 30% longer. However, for multiple intrusions to have a substantial thermal impact that is an additive component, they must be emplaced before the initial thermal pulse substantially dissipates. For metapelitic contact-regional terranes, the integrated time the rocks remain at elevated temperature limits the time available for growth of garnet, staurolite and alumino-silicate.

These data provide constraints on realistic parameters for kinetic equations of mineral nucleation and growth. Heat and mass-transport calculations suggest that minerals nucleate and grow in contact-regional terranes in hundreds of thousands of years to a few million years rather than tens of millions of years as has been suggested by some studies.

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