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The role of volatile transport by diffusion and dispersion in driving biotite-forming reactions during regional metamorphism of the Gile Mountain Formation, Vermont

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ABSTRACT

Infiltration-driven decarbonation reactions produced biotite in pelites and psammites but not in micaceous carbonate rocks in the biotite zone during metamorphism. In one large exposure, the amount of biotite varies greatly in rocks that retain reactants of biotite-forming reactions (0.01–1.10 mol/L in pelites; 0.15–0.53 mol/L in psammites; 0 in carbonates). Conventionally, the variations are interpreted as reactive fluid flow in chemically isolated channels that correspond to individual metasedimentary layers. Measured values of $\ln Q_s$ for the equilibria: $KAl_3Si_3O_{10}(OH)_2 + 3\ CaMg(CO_3)_2 + 2\ SiO_2 = KMg_3AlSi_3O_{10}(OH)_2 + CaAl_2Si_2O_8 + 2\ CaCO_3 + 4\ CO_2$ and $3\ KAl_3Si_3O_{10}(OH)_2 + Mg_5Al_2Si_3O_{10}(OH)_8 + 4\ CaMg(CO_3)_2 + 5\ SiO_2 = 3\ KMg_3AlSi_3O_{10}(OH)_2 + 4\ CaAl_2Si_2O_8 + 8\ CO_2 + 4\ H_2O$ are uniform within error of measurement in all analyzed samples (–1.67 ± 0.08, MSWD = 0.89, and –4.17 ± 0.26, MSWD = 0.52, respectively). The uniformity in Q_s values is explained by homogenization of the activities of CO_2 and H_2O by diffusion and dispersion over a distance >70 m across layering during metamorphism. The uniformity in Q_s is inconsistent with the conventional interpretation of differences in the abundance of biotite. The differences are better explained in terms of layer-by-layer variations in the amounts and compositions of minerals prior to reaction. Measured progress of the biotite-forming reactions is reproduced by mass-balance calculations that consider different initial amounts and compositions of reactant minerals in different samples but the same or nearly the same value of Q_s at the end of reaction. Mass transport of volatiles both by advection and by diffusion and dispersion are essential controls on the progress of infiltration-driven reactions.

Keywords: Fluid flow, diffusion, dispersion, biotite, regional metamorphism, Gile Mountain Formation, Vermont, reaction progress