Understanding Overstepped Metamorphic Reactions via Changes in the Chemical Potential of Thermodynamic Components

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Overstepped reactions can result in the first recorded nucleation and growth of a mineral at pressure (P) and/or temperature (T) conditions far beyond its theoretical initial stability. This can have potentially important implications for the tectono-metamorphic interpretation of many terranes. Here, we examine the energetic consequences of a system in which garnet fails to grow at the *P-T* of initial thermodynamic equilibrium. Specifically, we calculate differences in the chemical potential (μ) of thermodynamic components between distinct phase equilibria (one containing garnet, one prohibiting garnet stability). This reveals the evolution of μ for each component upon reaction overstepping, relative to the true equilibrium state (i.e. $\Delta\mu_{component}$). Components are expressed as oxide units (MgO, FeO, etc).

In multiple examples, the interval between the 'garnet-in' reaction and the inferred *PT* at which first garnet stability is recorded in a natural sample is associated with substantial $\Delta\mu$ between the true equilibrium state and the metastable overstepped state for most but not all components. Natural garnet crystals almost always appear to record initial growth at a *PT* coinciding with $\Delta\mu \neq 0$ for every garnet-forming component. Al_2O_3 is always the final component to experience a difference in μ from the true equilibrium state, typically at the *P-T* associated with preserved garnet compositions. This suggests that the calculated μ of thermodynamic components might be utilized to approximately predict the amount of reaction overstepping in metamorphic rocks.