Petrologic insights from graphical analysis of two-component systems

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Mike O'Hara bridged the petrological divide between natural systems and simplified ones amenable to treatment with phase diagrams. He understood the importance of using a phase diagram in the right model system, with the right independent variables, to understand a problem. Our paper with Mike on solidus "cusps" and isentropic decompression [1] was a prime example, where one-component entropy-pressure (*S*-*P*) and two-component entropy-composition (*S*-*X*) diagrams showed that results from the MELTS model [2] were reasonable and explained the underlying principles.

Thermodynamic constraints other than fixed temperature (*T*), *P*, and bulk composition are in fact common in petrology. During adiabatic decompression, *S* (or, arguably, a modified from of enthalpy, *H* [3]) rather than *T* is conserved and *H* is minimized at equilibrium. Nearly all assimilation, mixing, and recharge problems are best treated using *H* conservation to infer the evolution of *T* [5], as *S* is maximized at equilibrium. Reactions in in rigid containers such as melt or fluid inclusions (and diamond anvil cells) are properly treated using volume (*V*) as a constraint [5], with phase equilibria determining the evolution of *P*, as Helmholtz free energy is minimized at equilibrium. Sometimes an activity or fugacity is imposed rather than a closed system. Although the thermodynamic models and equations of state needed to realize such constraints in natural systems are complex and uncertain, in each case suitable phase diagrams can reveal the systematic underlying principles. When processes are visualized in the right space, they become simple and the results are apparent by inspection.

Extending our treatment of one-component systems [6], we will look at cases where static or animated phase diagrams of two-component systems with appropriate choice of axes matching the independent variables reveal the range of outcomes of significant petrological processes.

[1] Asimow, Hirschmann, Ghiorso, O'Hara & Stolper (1995) *GCA* **59**(21):4489-4506. [2] Ghiorso & Sack (1995) *CMP* **119**:197-212. [3] Ganguly (2005) *GRL* **32**(6):L06312. [4] Zhang (1998) *EPSL* **157**:209-222. [5] Glazner (2007) *Geology* **35**: 319-322. [6] Stolper & Asimow (2007) *AJS* **307**:1051-1139.