Explanatory notes for the problem set "Constructing metamorphic phase diagrams using phase equilibria and the Clausius-Clapeyron equation"

Mark Brandriss, Smith College

Purposes of the assignment:

This assignment is designed to guide students through the process of constructing a metamorphic P-T phase diagram based on thermodynamic data and experimental phase equilibria. The aluminosilicate polymorphs are used as an example. The assignment proceeds step-by-step, with extensive instructions, so that all students can complete the exercise successfully and hopefully learn something along the way. Because many of the concepts and ways of thinking are difficult and intimidating for undergraduate geologists (especially those without a good background in chemistry), I've intentionally avoided making the assignment too challenging — my goal is to help students see how thermodynamics can be applied to real geologic problems and I want them to become enlightened rather than frustrated.

Specific pedagogic goals include:

- Illustrating how phase diagrams are made, and what kinds of data are involved.
- Examining how (and why) mineral assemblages vary with temperature and pressure.
- Showing how thermodynamic data can be used to solve real geologic problems.
- Illustrating the meaning and utility of the Clausius-Clapeyron equation.
- Providing an example of the usefulness of XRD for addressing problems beyond mineral identification.
- Providing some practice with quantitative methodology, including manipulation of numerical data, use of appropriate units, graphing of data, etc.

Expected results:

In addition to reproducing the familiar aluminosilicate phase diagram, and learning about the Clausius-Clapeyron equation, students will:

- Deal with uncertainty and ambiguity. This will be most obvious when trying to determine the positions of univariant curves and the triple point.
- Students should also find that their calculated Clapeyron slope for the andalusite-sillimanite reaction is not quite as steep as the phase equilibrium experiments require, thus necessitating consideration of analytical uncertainties and/or faulty assumptions (i.e. constancy of ΔV and ΔS of reaction; question 6).
- Results of phase equilibrium experiments for the kyanite-sillimanite reaction are not provided, so students must locate this univariant curve solely on the basis of topology and the Clapeyron slope.