I. Objectives

1. Apply Bowen's reaction series to explain mineral crystallization from a magma.
2. Plot cooling trajectories for simple binary mineral system.
3. Determine mineral phase fractions and compositions from a phase diagram.

II. Introduction

Different minerals have different melting points, which also mean that they start to crystallize at different temperatures. The primary textural element of intrusive rocks is their course crystalline textures. Close examination of these granitic textures reveals a complex assemblage of different minerals, with the minerals with the lowest melting/crystallization temperatures typically making up the final interlocking matrix of the rock. The general order in which minerals crystallize is called the Bowen Reaction series as shown in the diagram below.

Bowen determined that specific minerals form at specific temperatures as magma cools. At the higher temperatures associated with mafic and intermediate magmas, the general progression can be separated into two branches. The continuous branch describes the evolution of the plagioclase feldspars as they evolve from being calcium-rich to more sodium-rich. The discontinuous branch describes the formation of the mafic minerals olivine, pyroxene, amphibole, and biotite mica. One of the more interesting illustrations of this behavior is exposed in the Skaergaard layered basic intrusion in Greenland, where distinct layers of crystals of systematically different composition rained out of solution as this pluton slowly cooled.

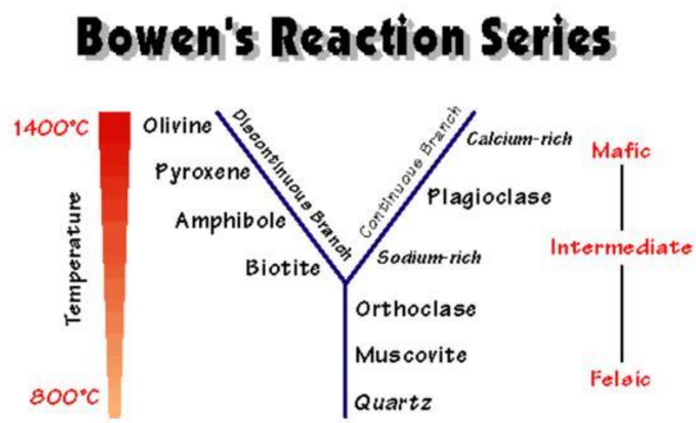

Figure 1: Bowen's Reaction Series (soilsci.wordpress.com)

Figure 2: Skaergaard LBI showing layering of with olivine-clinopyroxene grading upwards into plagioclase-rich rock (Kurt Hollocher, 2001)

Extensive laboratory experimentation has resulted in a rich collection of pressure-temperature (P-T) phase diagrams, which illustrate the crystallization behavior of various melt reaction series. The P-T phase diagram for water (below) may be the most familiar example of this. Notice how the phase diagram for the one component system Al_2SiO_5, is similar, although the axis scales are very different.

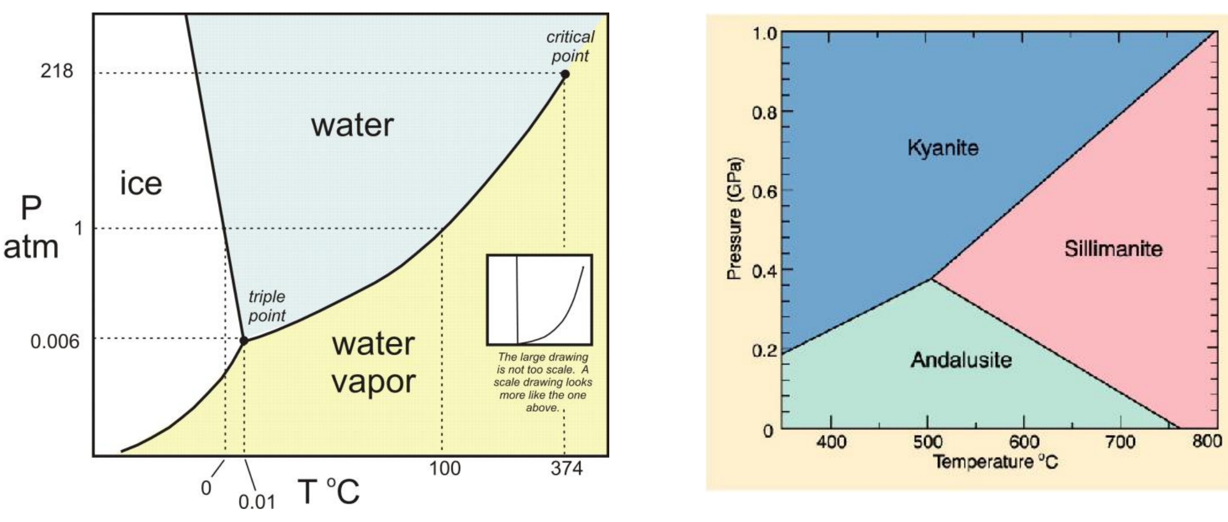

Figure 3: Phase Diagrams of Water and Al_2SiO_5 (SERC)

III. Materials

Calculator

IV. Prelab Definitions

1. phase diagram

2. solidus

3. liquidus

4. eutectic point

V. Lab Procedure

We will investigate the range of crystal compositions that might result from the reaction graphs given in Figures 4 and 5. Based on information provided in class or available on the web, use the curves below to trace the cooling histories and determine the percent composition of liquid or crystals formed from the specified initial compositions and temperatures.

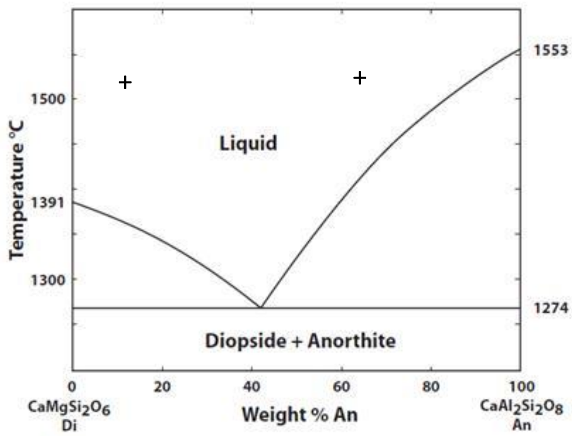

Figure 4: Diopside + Anorthite Phases (SERC)

Table 1: Di-An Liquid #1	
Temperature	%An
1500	20%
1350	
1300	
1250	

Table 2: Di-An Liquid #2	
Temperature	% An
1500	60%
1350	
1300	
1250	

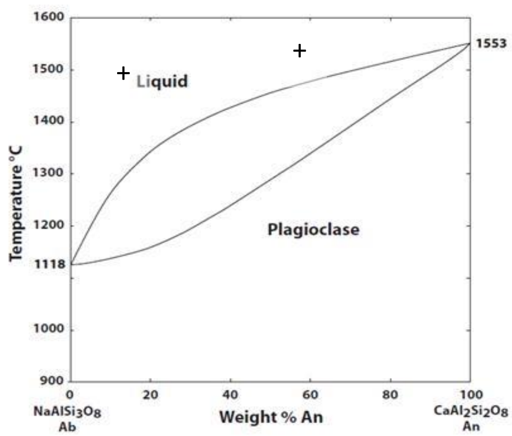

Figure 5: Albite + Anorthite Phases (SERC)

Table 3: Ab-An Solid #1	
Temperature	% An
1500	20%
1400	
1300	
1200	
1100	

Table 4: Ab-An Solid #2	
Temperature	% An
1500	60%
1400	
1300	
1200	

VI. Lab Discussion

1. Describe the equilibrium conditions shown in Figure 4.

2. What happens to the composition and relative fractions as a 100% melt is cooled from a starting composition of 20% An?

3. Describe the equilibrium conditions shown in Figure 5.

4. Describe what happens to the composition and relative fractions as a 100% melt is cooled from a starting composition of 20% An. Note that any crystals that have formed above 1200 ^{o}C are precipitated or otherwise lost from the system at that point.

Lab courtesy of Dr. Jim Washburne