

12.109 Lecture Notes
September 22, 2005

Thermodynamics I
Intro to Phase Diagrams

Read: Hess Ch. 2

Handout: using phase diagrams

Phase diagrams are graphical representations that help us understand what happens in igneous systems as melts cool and crystallize.

With igneous rocks, liquids are the focus.

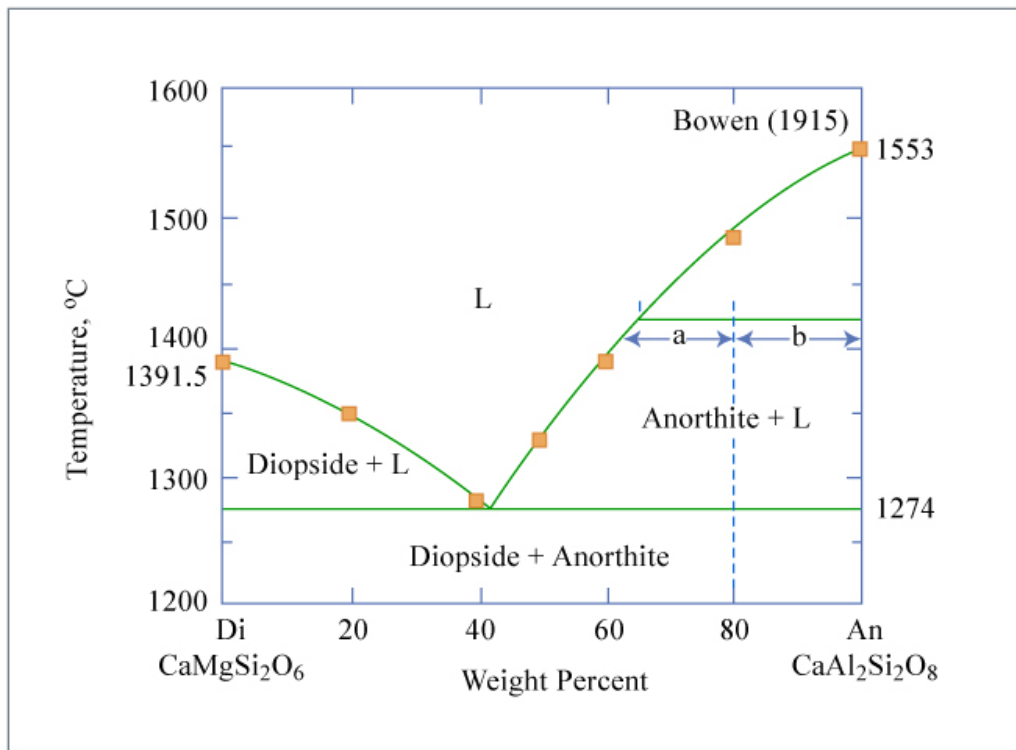
Terrestrial petrology – a lot of what we see at the surface of the earth is the result of melting and crystallization processes, look especially at basalts and granites → very diverse rocks!

inverse problem – we got this result, what are the conditions recorded by it?

Want to understand compositional diversity in igneous rocks

- 1) history of formation
- 2) physical conditions – P, T, volatiles

Diopside – Anorthite phase diagram



Example of a binary (two component) system with a eutectic
“eutectic” from the Greek, for “coexisting” or “occurring together”

In real rock systems there are 8-9 chemical components, usually:

SiO₂ MgO FeO CaO Al₂O₃ K₂O Na₂O TiO₂ Cr₂O₃

Binary systems – liquid first formed by melting a mixture of 2 pure substances which are insoluble in solid phase

Eutectic T = temp of 1st melting

At this T, T will remain constant until one of the solids is entirely melted out of the matrix

Steps to make a melt:

- 1) Heat to eutectic T
- 2) Di and some An melt → eutectic liquid
- 3) Di gets used up
- 4) Then T can go up, liquid composition moves along the liquidus with increasing T, melting of An

Use the lever rule to determine the percentage of the bulk in each phase.

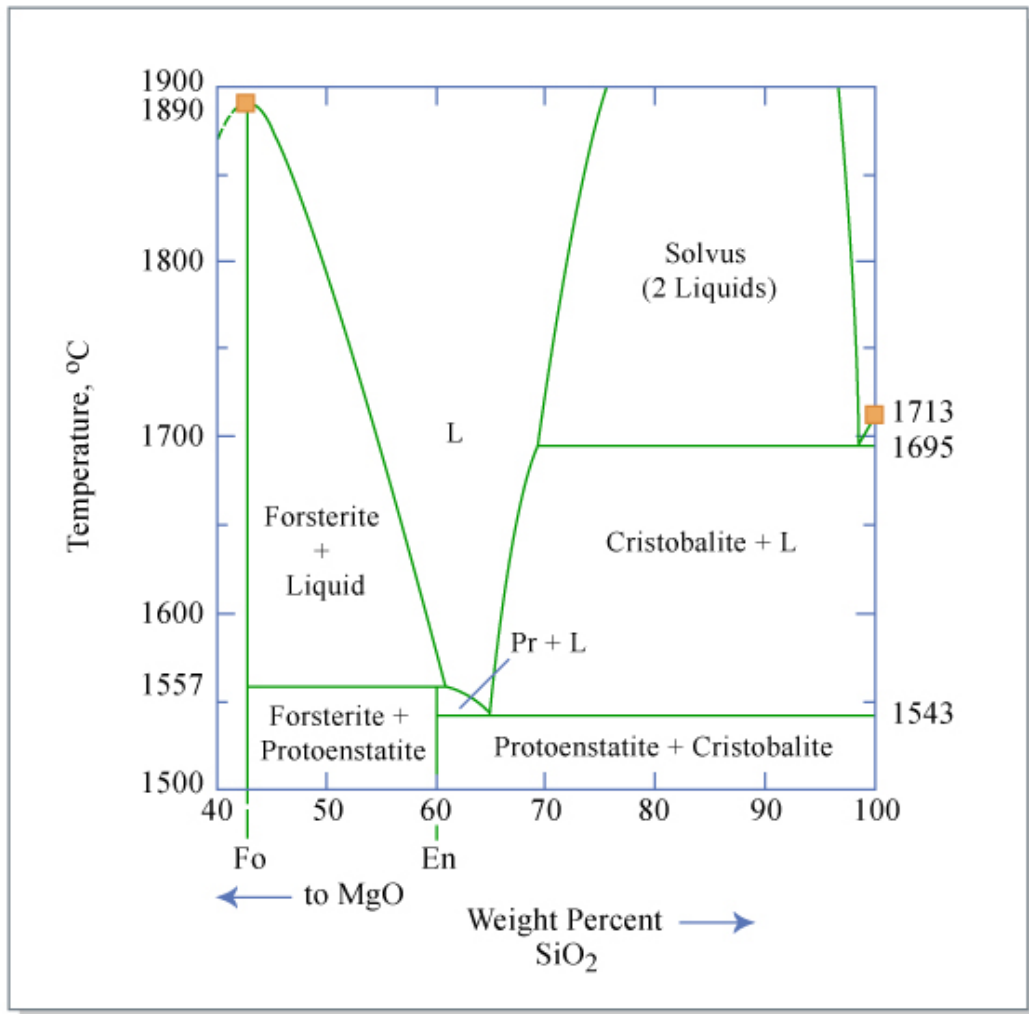
(see diopside-anorthite diagram)

$$\% \text{ liquid} = \frac{b}{a+b} \qquad \% \text{ An} = \frac{a}{a+b}$$

There is a special phenomenon if bulk composition is near the eutectic: eutectoidal precipitation. This is responsible for graphic granite, where the quartz and feldspar crystals grow concurrently and become aligned and intertwined.

Pure end member phases don't melt at the eutectic, they melt at the mineral melting point (same reason we add salt to ice in the winter, mixing lowers melting points).

Forsterite – Enstatite – SiO₂ phase diagram



Melting:

At 1557 °C, Fo and En react to form Fo and liquid

$\text{En} \rightarrow \text{Fo} + \text{liquid}$

When all En is used up, T can increase, Fo melts, and the amount of Fo decreases, % liquid increases, until liquidus T is achieved.

Freezing

1. 100% liquid, above liquidus
2. Fo crystallizes out and T drops
3. at 1557 °C, $\text{Fo} + \text{liquid} \rightarrow \text{En}$, all liquid goes away

if the bulk composition is at pure En, Fo and liquid react to 100% En

THIS IS ALL THE IDEAL CASE

It assumes we reach equilibrium at every reaction and change of T, but in the real world, sometimes equilibrium is Not achieved.

Fractional crystallization

What if the crystals are removed from the melt as they form?

--overgrowth reaction ← visible from rimmed/surrounded crystals, ex. rapakivi granite

--differential settling ← forms cumulates, concentration of settled/floated crystals

Removing the crystals effectively resets the bulk composition. This composition moves along the liquidus if all crystals removed.