Lecture 7 - Simple Eutectic Systems

Wednesday, February 9th, 2005

2-C Eutectic Systems

Example: Diopside - Anorthite

No solid solution between Diopside and Anorthite

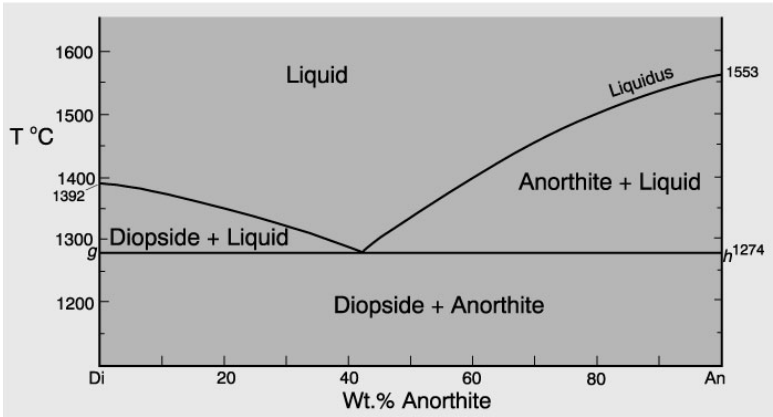
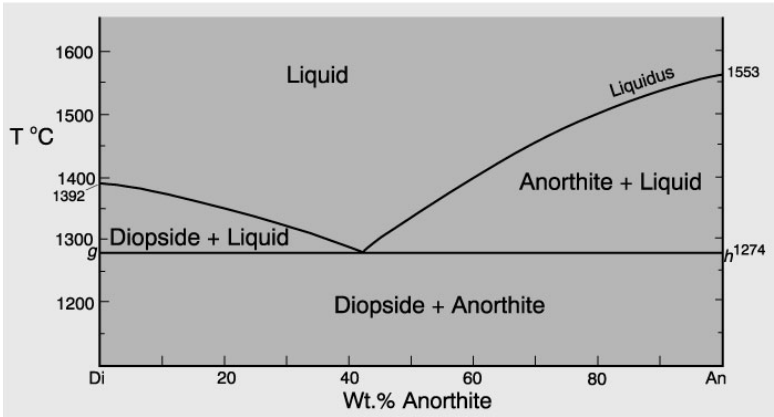
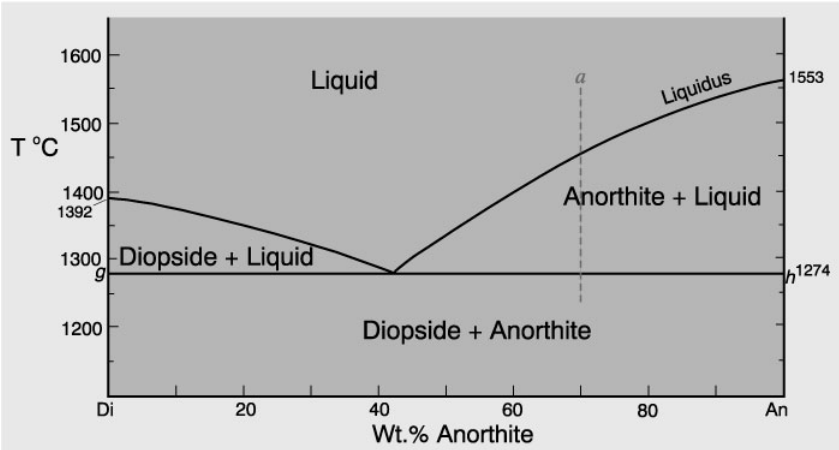


Fig. 6-11. Isobaric T-X phase diagram at atmospheric pressure. After Bowen (1915), Amer. J. Sci. 40, 161-185.

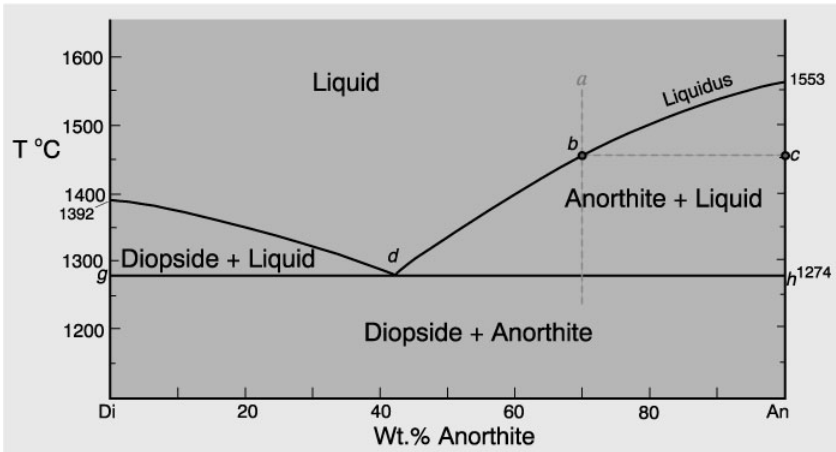
This simple system is analogous to a basaltic magma crystallizing pyroxene and plagioclase.
Note the low point at 1274^{0}C on the liquidus. This is known as a eutectic



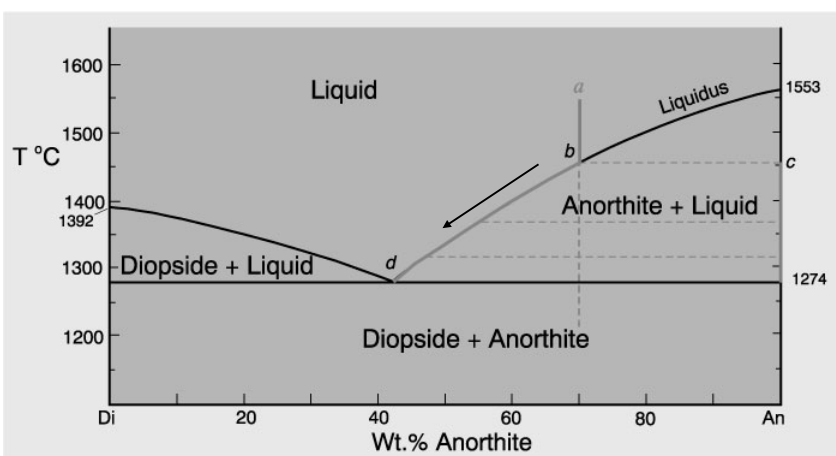
Cool composition a:
bulk composition = An:Di = 70:30



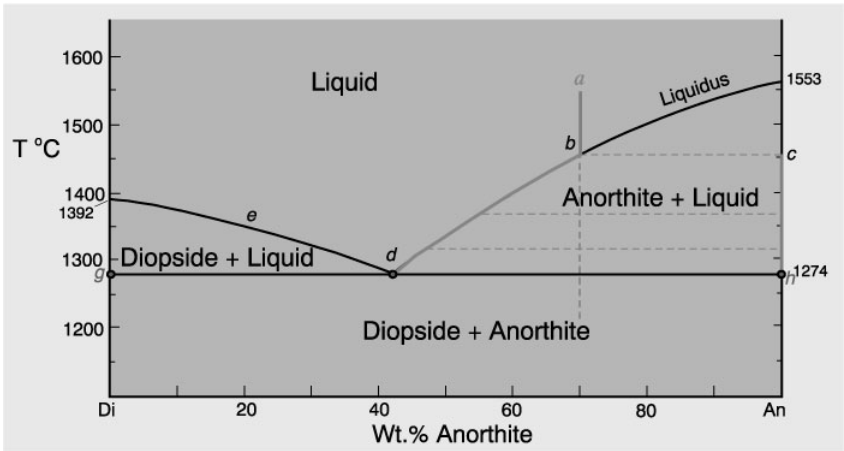
Liquid cools to 1455°C (point b)
At which point pure anorthite (An) crystallizes (point c)



- Continue cooling as X_{liq} varies along the liquidus
- Continuous reaction: $liq_A \rightarrow$ anorthite + liq_B

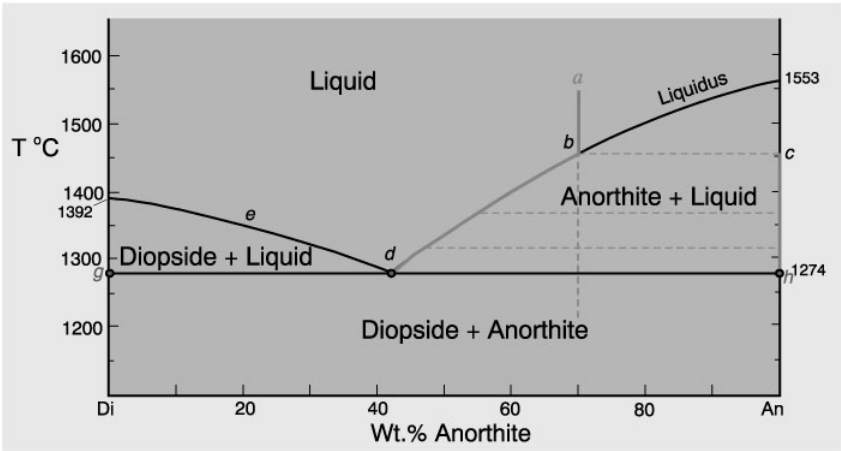


At point d (1274^0C) diopside (point g) begins to crystallize along with anorthite (point h)

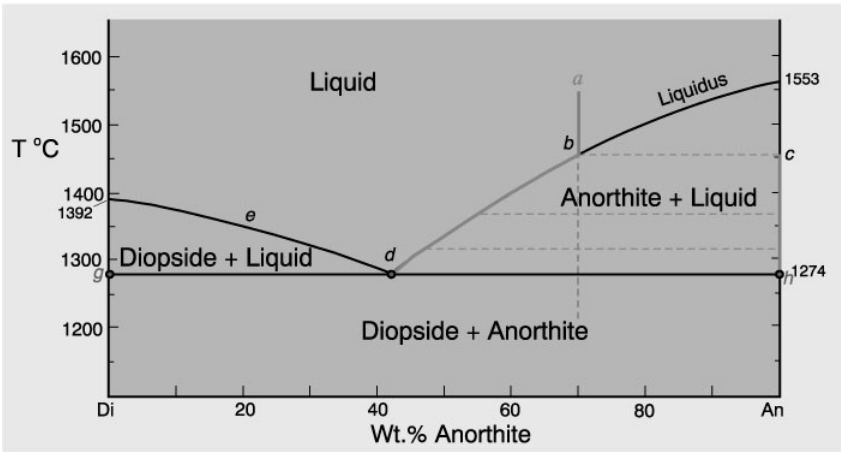


at 1274^oC $\phi = 3$ so $F = 2 - 3 + 1 = 0$ invariant

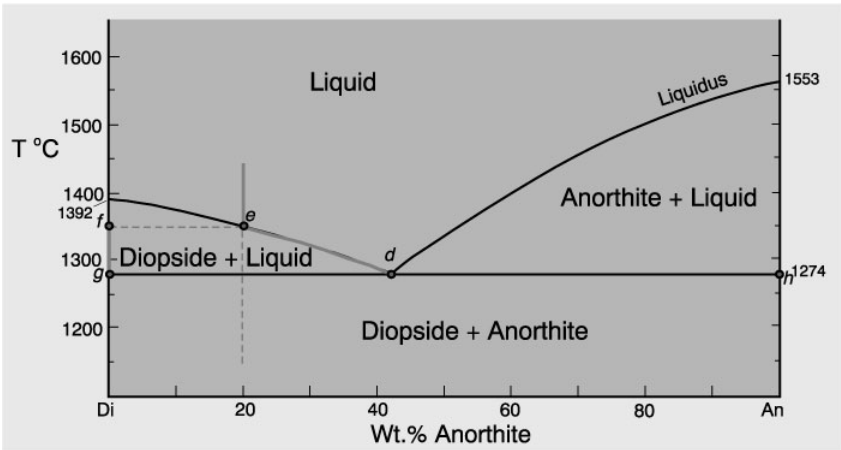
- (P) T and the composition of all phases are fixed
- Must remain at 1274^oC as a discontinuous reaction proceeds until a phase is lost (which one?)



Using the lever rule the ratio of anorthite to diopside crystallizing at the eutectic is given by:-
dg/dh = 42/58



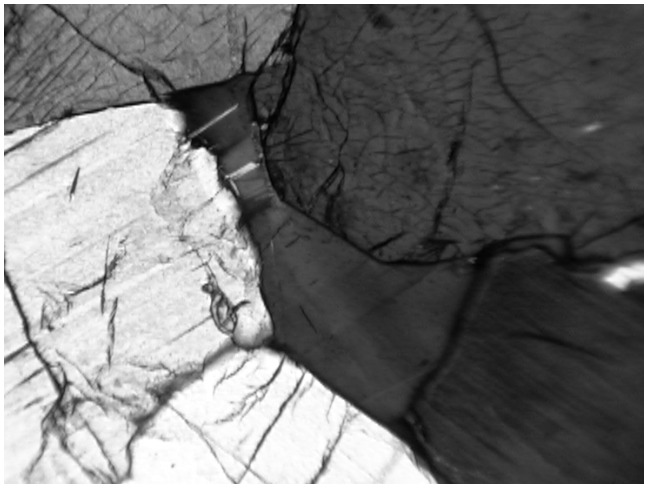
Left of the eutectic we get a similar situation Diopside (g) crystallizes first, then at point d it is joined by anorthite (h).



What this tells us about the crystallization behavior of melts

1. Cooling melts crystallize from a liquid to a solid over a range of temperatures (and pressures)
2. Several minerals crystallize over this Temp. range, and the number of minerals increases as Temp. decreases
3. The minerals that form do so sequentially, with considerable overlap
4. Minerals that involve solid solution change composition as cooling progresses
5. The melt composition also changes during crystallization
6. The minerals that crystallize (as well as the sequence) depend on T and composition (X) of the melt
7. Pressure can affect the types of minerals that form and the sequence
8. The nature and pressure of the volatiles can also affect the minerals and their sequence

Augite forms before plagioclase



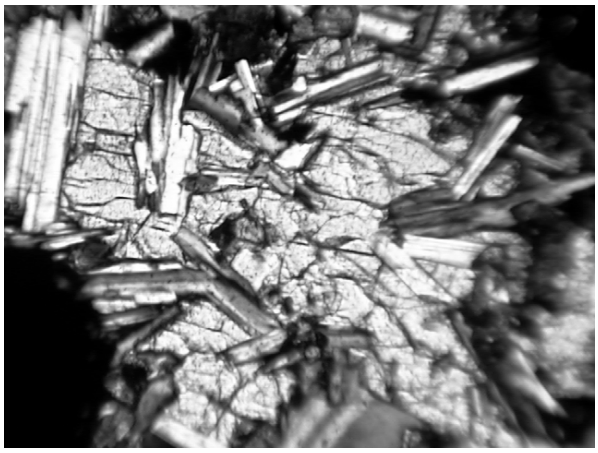
Gabbro of the Stillwater Complex, Montana

This forms on the left side of the eutectic

Plagioclase forms before augite

Ophitic texture

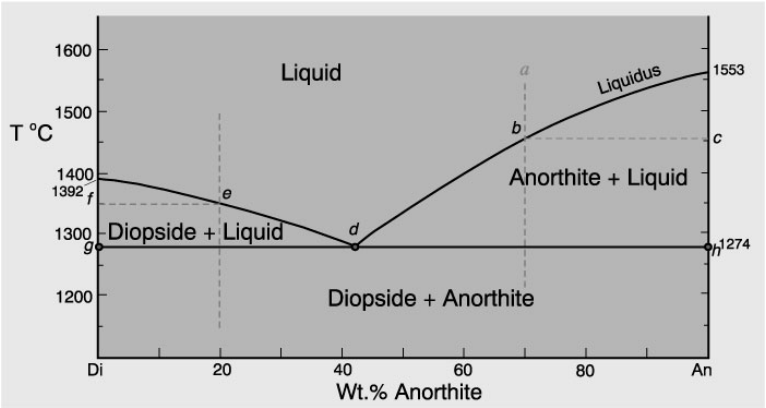
Diabase dike



This forms on the right side of the eutectic

Also note:

- The last melt to crystallize in any binary eutectic mixture is the eutectic composition
- Equilibrium melting is the opposite of equilibrium crystallization
  - Thus the first melt of any mixture of Di and An must be the eutectic composition as well



Fractional crystallization:

Does not change the situation. The path followed is that of equilibrium crystallization. However, the final rock composition will be that of the eutectic, NOT the bulk composition.

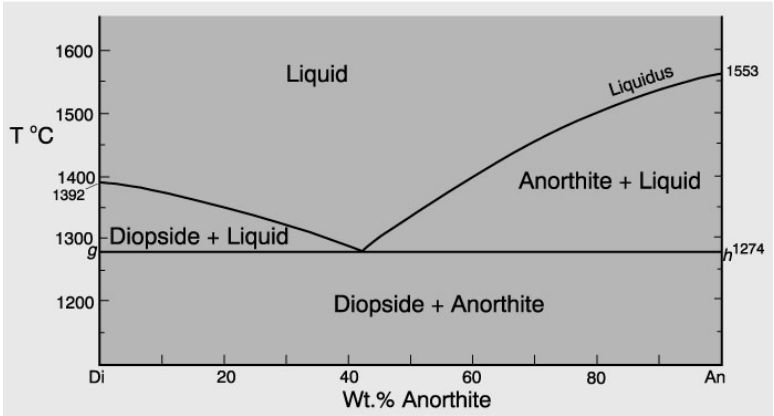
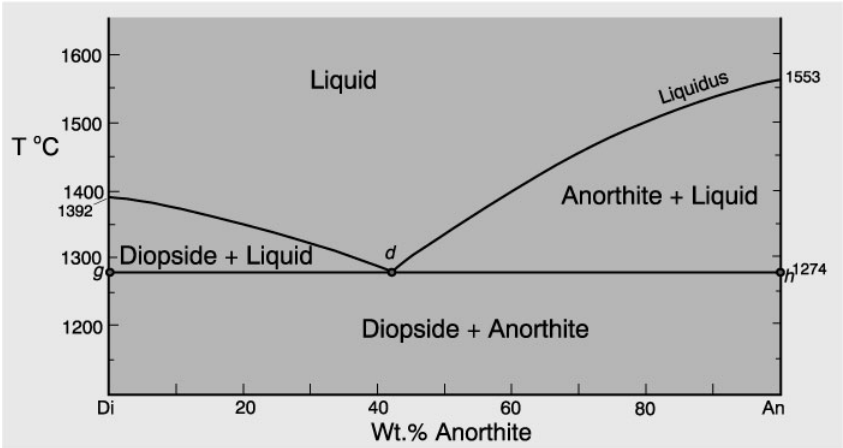


Fig. 6-11. Isobaric T-X phase diagram at atmospheric pressure. After Bowen (1915), Amer. J. Sci. 40, 161-185.

Partial Melting:

- The first melt formed will have composition d (the eutectic composition)
- With continued melting the melt composition remains at point d until either diopside or anorthite are exhausted
- At this point the residue consists of either pure anorthite or diopside
- No further melting will occur until the temperature exceeds the melting point of diopside (1392^{0}C) or anorthite (1553^{0}C)



This has profound implications - consider mantle melting

- Melting would produce a magma that differed substantially from the source
- Continued melting would produce the same magma composition
- Exhaustion of one of the phases would cut off melt production until much higher temperatures were achieved.