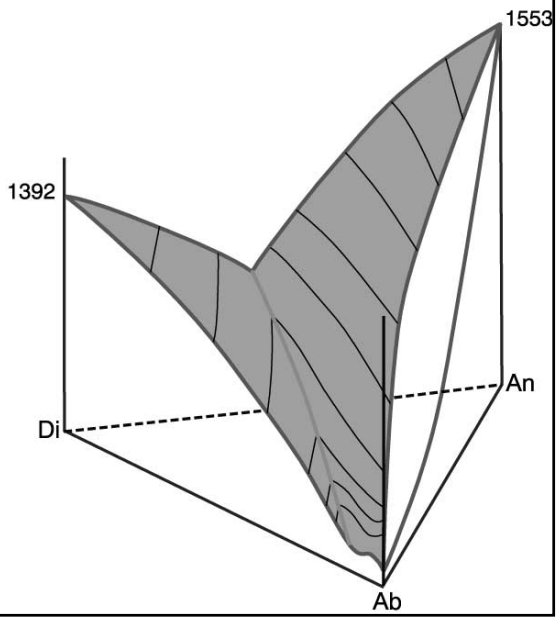
More Complex Systems

Wednesday, February 16th, 2005

Diopside-Albite-Anorthite

Figure 7-5. Isobaric diagram illustrating the liquidus temperatures in the system diopside-anorthite-albite at atmospheric pressure (0.1 MPa). After Morse (1994), Basalts and Phase Diagrams. Krieger Publushers



Di - An Eutectic
Di - Ab Eutectic
Ab - An solid solution

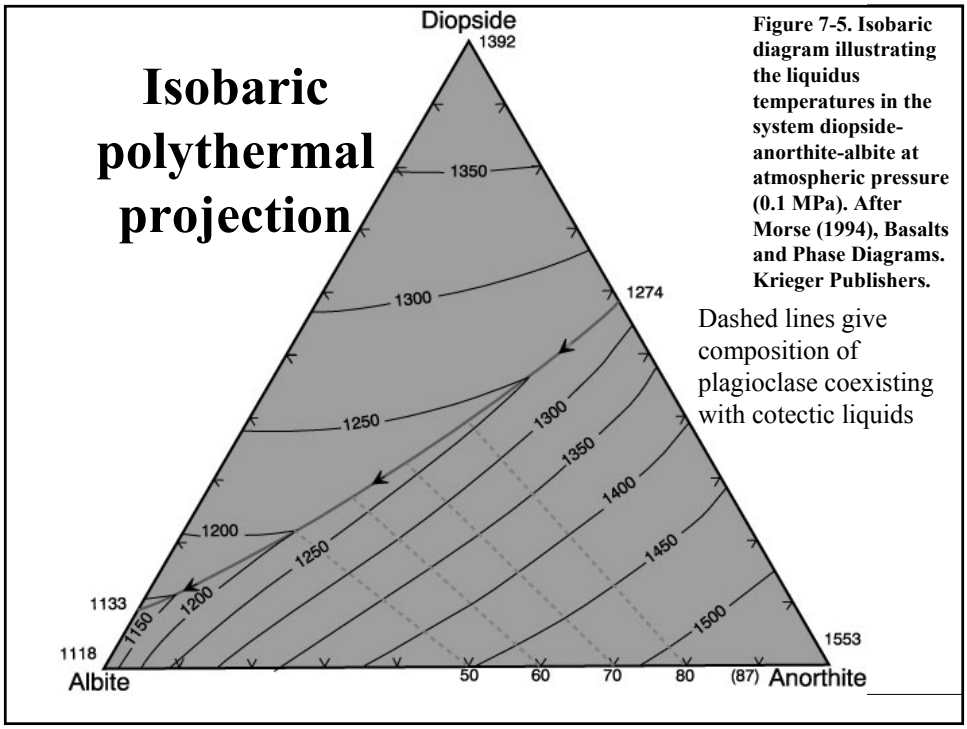
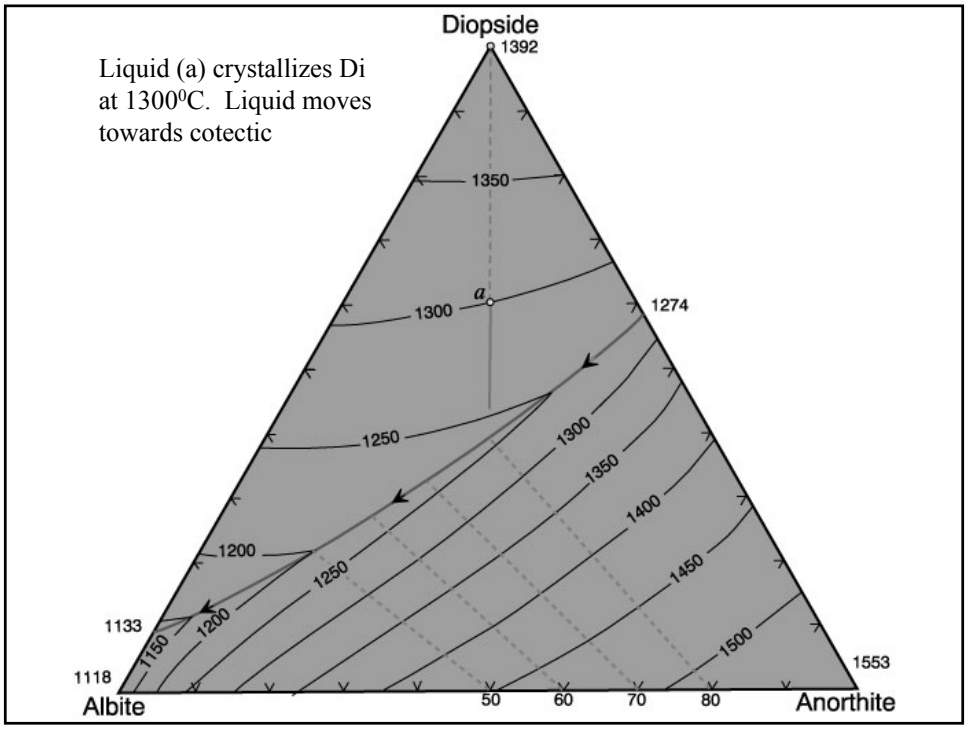
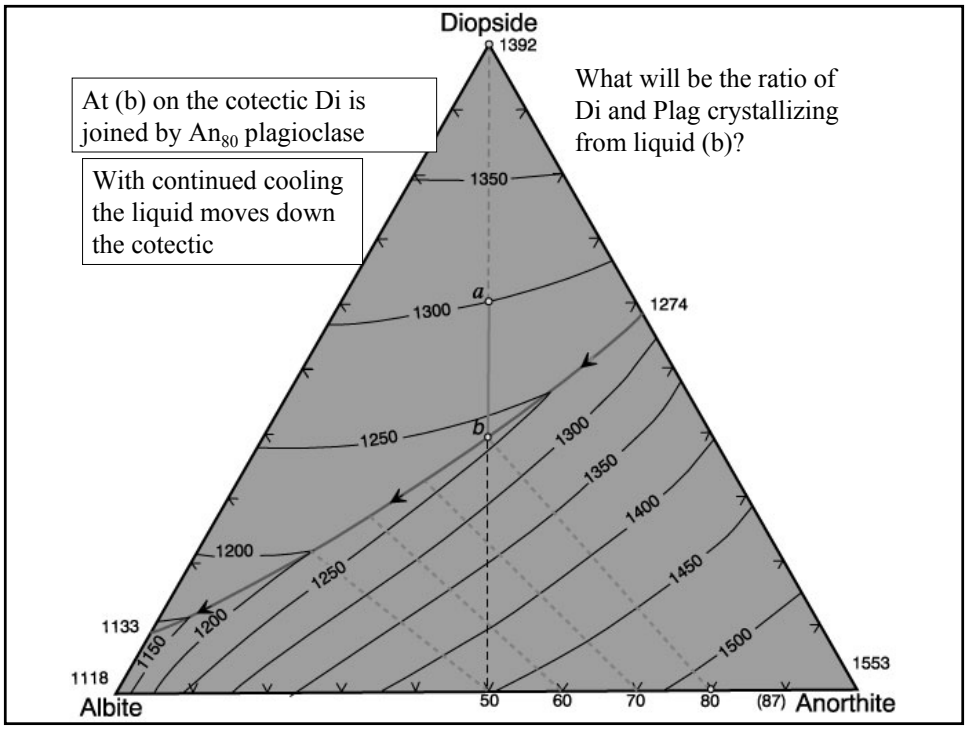
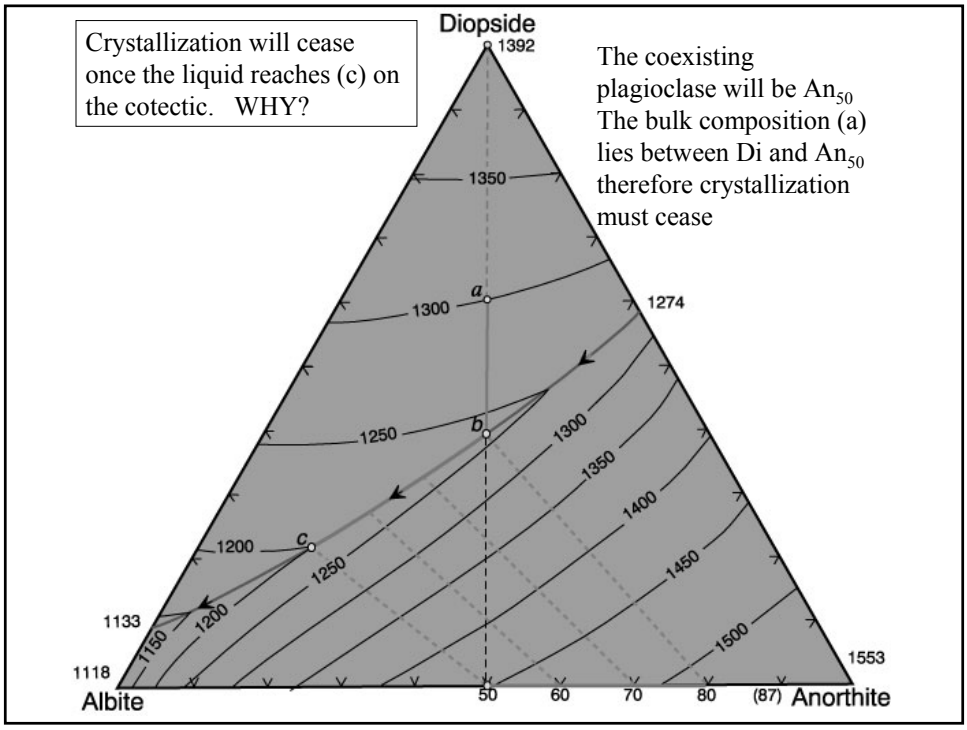
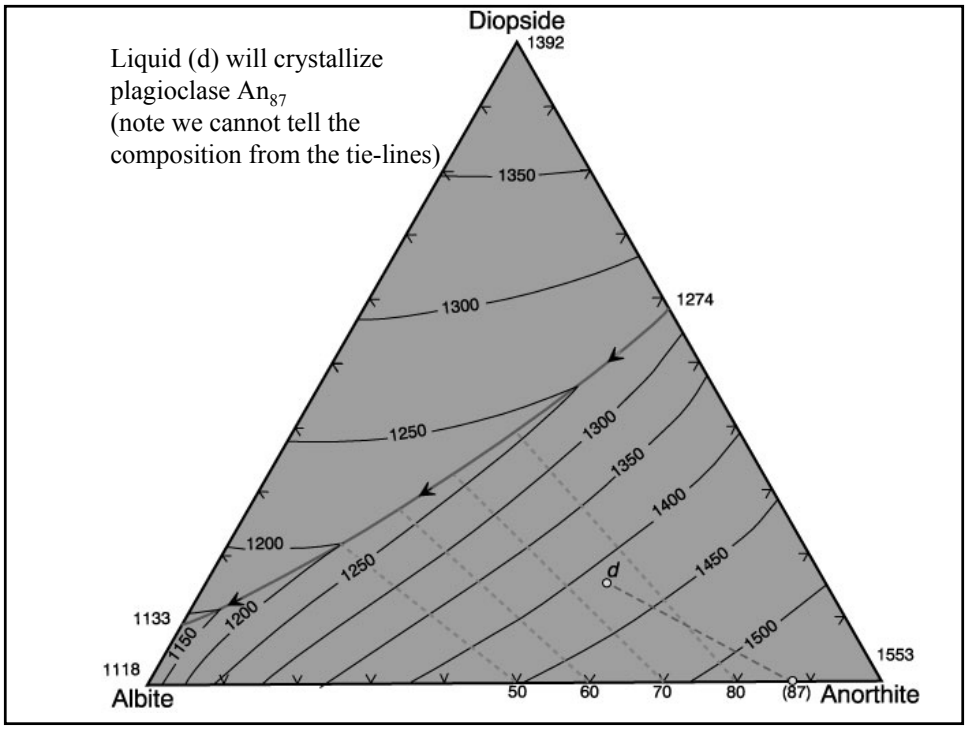


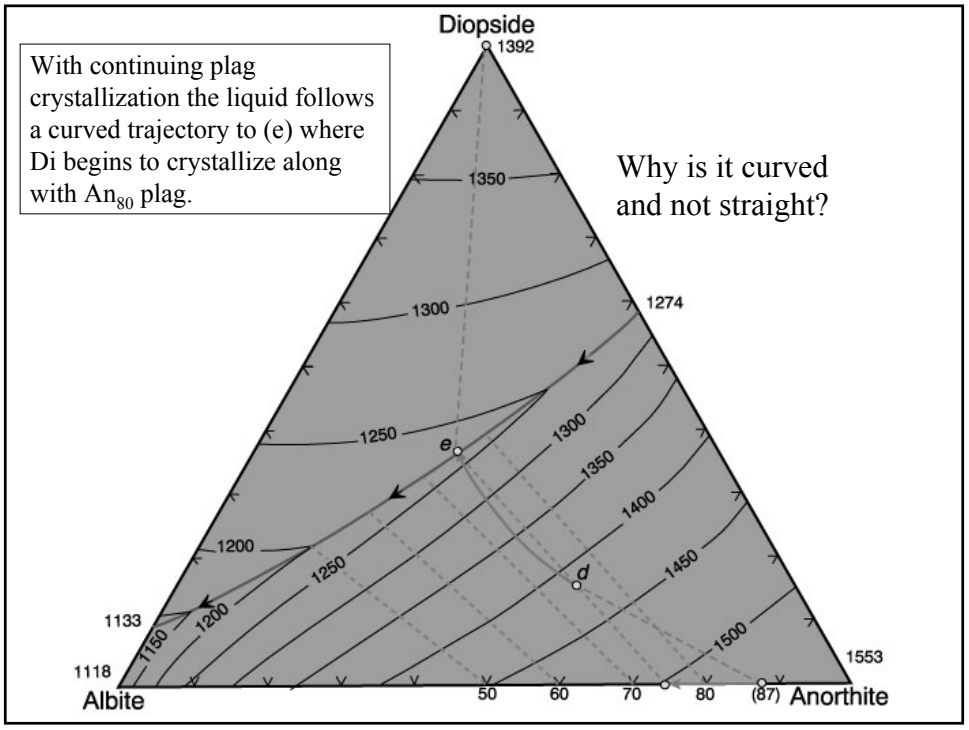
Figure 7-5. Isobaric diagram illustrating the liquidus temperatures in the system diopside-anorthite-albite at atmospheric pressure (0.1 MPa). After Morse (1994), Basalts and Phase Diagrams. Krieger Publishers.

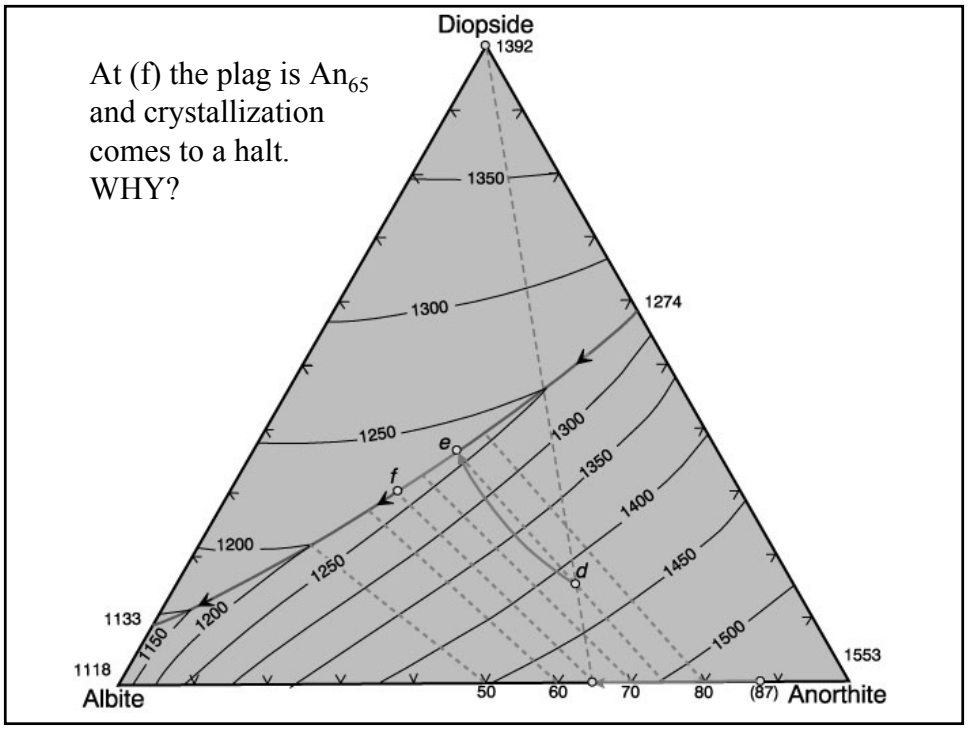



Diopside
1392
At (b) on the cotectic Di is joined by An_{80} plagioclase
With continued cooling the liquid moves down the cotectic
What will be the ratio of Di and Plag crystallizing from liquid (b)?
1350
a
1300
1274
1250
b
1300
1350
1400
1200
1250
1450
1133
1200
1150
1500
1118
1553
Albite
50
60
70
80
(87)
Anorthite

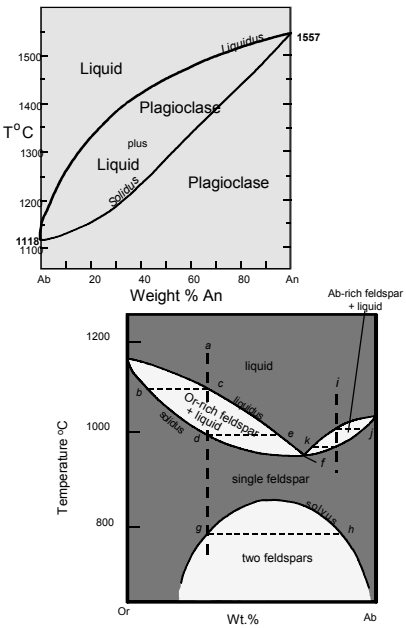

Diopside
1392
Crystallization will cease once the liquid reaches (c) on the cotectic. WHY?
The coexisting plagioclase will be An_{50} The bulk composition (a) lies between Di and An_{50} therefore crystallization must cease
1350
a
1300
1274
1250
b
1300
1350
1400
1200
c
1250
1450
1133
1200
1150
1500
1118
1553
Albite
50
60
70
80
(87)
Anorthite


Liquid (d) will crystallize plagioclase An_{87}
(note we cannot tell the composition from the tie-lines)
Diopside
1392
1350
1300
1274
1250
1300
1350
1400
1200
1250
1450
d
1133
1150
1200
1500
1118
1553
Albite
50
60
70
80
(87)
Anorthite


With continuing plag crystallization the liquid follows a curved trajectory to (e) where Di begins to crystallize along with An_{80} plag.
Why is it curved and not straight?
Diopside
1392
1350
1300
1274
1250
e
1300
1350
1400
1200
1250
d
1450
1133
1150
1200
1500
1118
1553
Albite
50
60
70
80
(87)
Anorthite



Ternary Feldspars



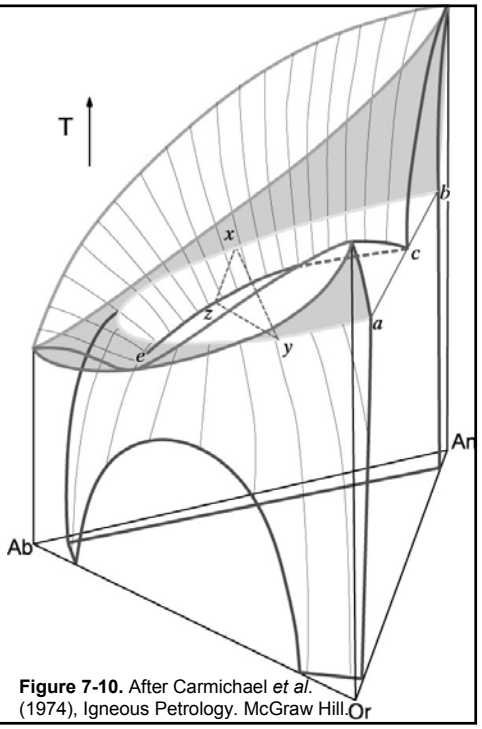


Figure 7-10. After Carmichael *et al.* (1974), Igneous Petrology. McGraw Hill.

Ternary Feldspars

Trace of solvus at three temperature intervals

Triangle shows coexisting feldspars and liquid at 900°C

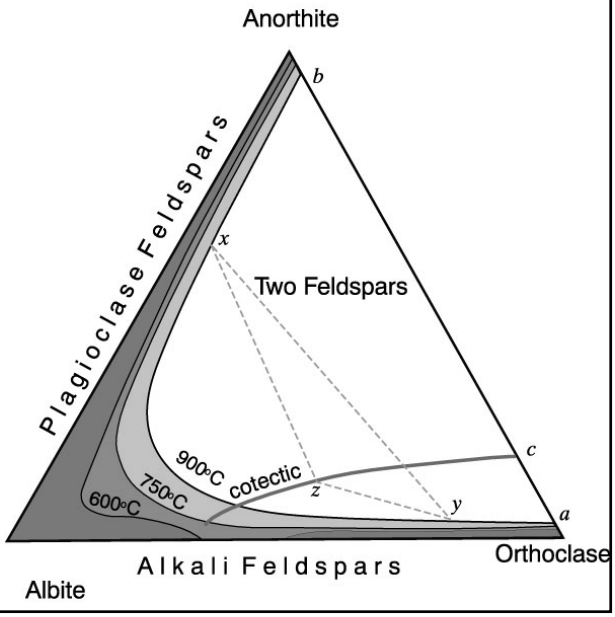
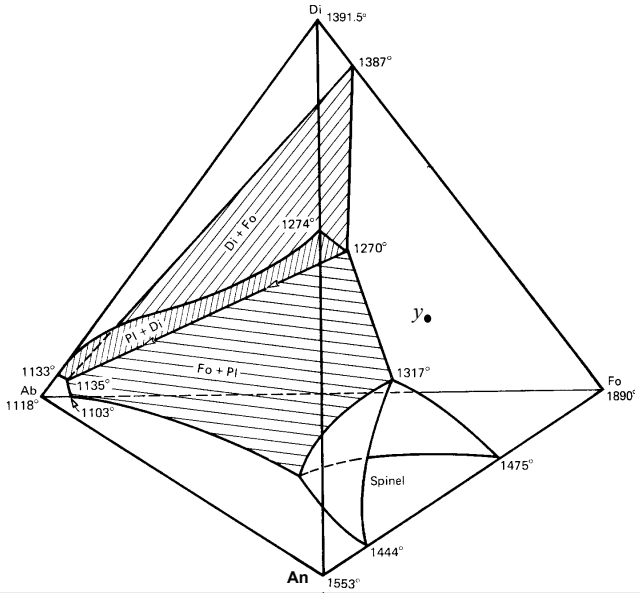


Figure 7-11. Winter (2001) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.

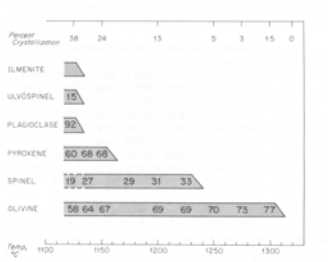
4 - Component Diagrams



The basalt system

Figure 7-12. The system diopside-anorthite-albite-forsterite. After Yoder and Tilley (1962). J. Petrol.

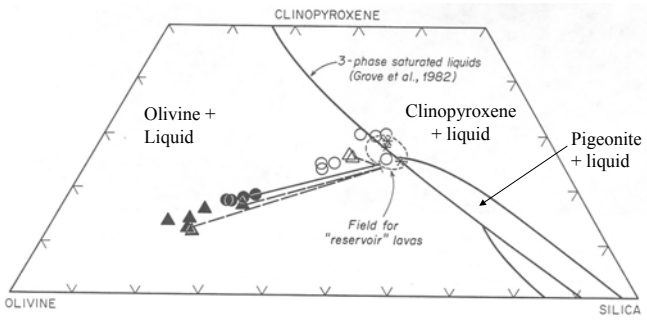
Experiments on Natural Multi-Component Systems



Melting Experiments on an Apollo 12 Lunar Basalt
Rhodes et al., 1979

- Note sequence and temperature range of crystallizing minerals
- Minerals change composition with decreasing temperature

Natural System Olivine – Clinopyroxene – Silica projected from Plagioclase

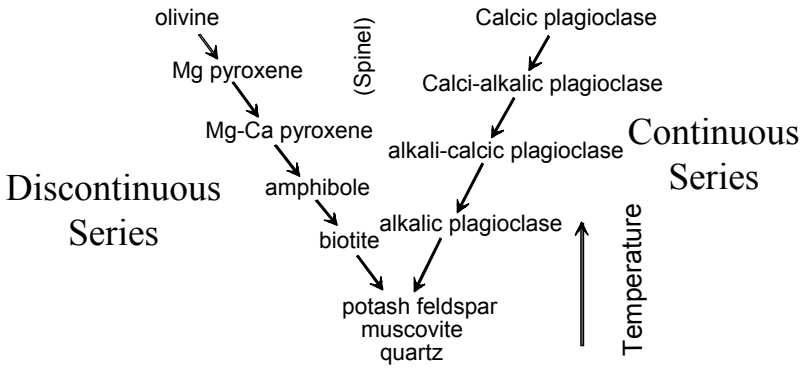


This system fairly accurately predicts the crystallization sequence and liquid lines of descent of natural basaltic magmas. The example is from Mauna Loa (where else!) Rhodes, 1988.

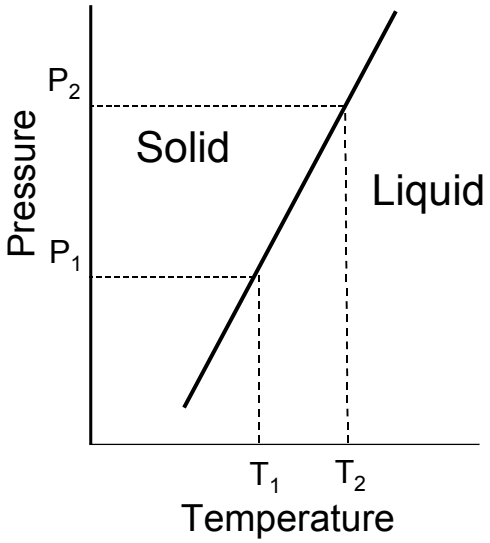
Some fundamental observations

- With decreasing Temp liquids become enriched in SiO_2 and Na_2O and FeO.
- With decreasing Temp liquids become depleted in MgO and CaO.
- There is a sequence of mafic minerals with decreasing Temp (Ol – En/Di).
- Plagioclase becomes more Albitic.

Bowen's Reaction Series



The Effect of Pressure



Eutectic system

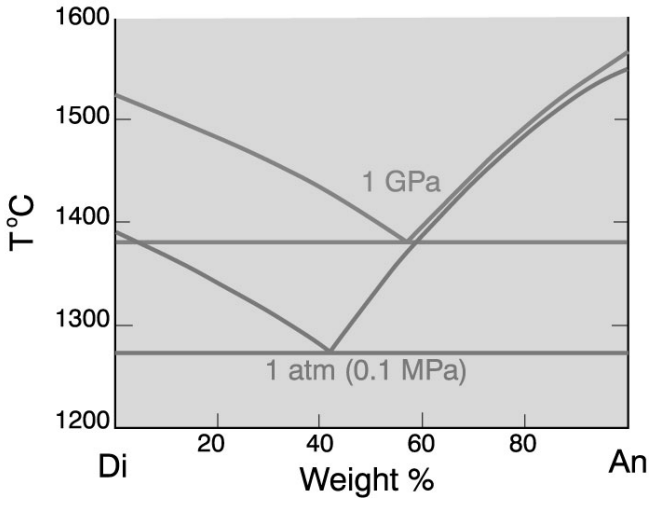


Figure 7-16. Effect of lithostatic pressure on the liquidus and eutectic composition in the diopside-anorthite system. 1 GPa data from Presnall *et al.* (1978). Contr. Min. Pet., 66, 203-220.

> 4 Components

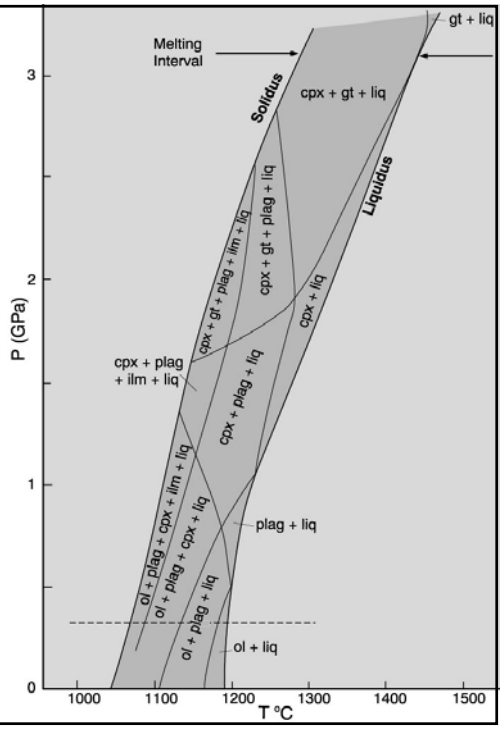


Figure 7-13. Pressure-temperature phase diagram for the melting of a Snake River (Idaho, USA) tholeiitic basalt under anhydrous conditions. After Thompson (1972). Carnegie Inst. Wash Yb. 71

The Effect of Water on Melting

Dry melting: solid → liquid

Add water- water enters the melt

Reaction becomes:

solid + water = $liq_{(aq)}$

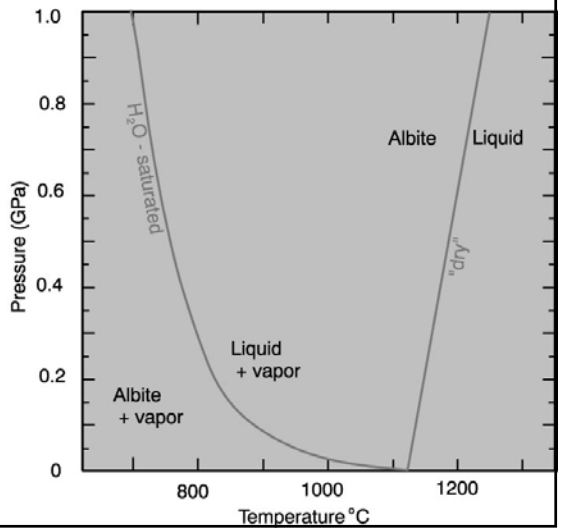


Figure 7-19. The effect of H_2O saturation on the melting of albite, from the experiments by Burnham and Davis (1974). A J Sci 274, 902-940. The "dry" melting curve is from Boyd and England (1963). JGR 68, 311-323.

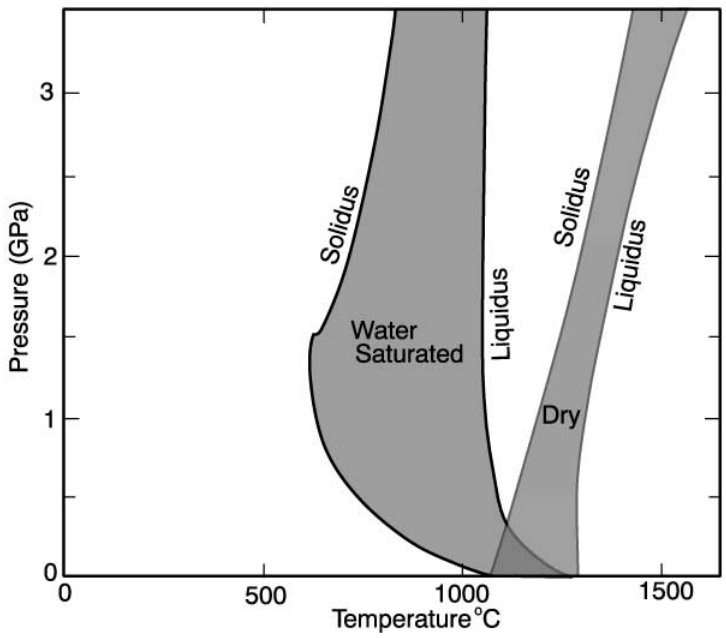


Figure 7-20. Experimentally determined melting intervals of gabbro under H_2O-free ("dry"), and H_2O-saturated conditions. After Lambert and Wyllie (1972). J. Geol., 80, 693-708.

Dry and water-saturated solidi for some common rock types

The more mafic the rock the higher the melting point

All solidi are greatly lowered by water

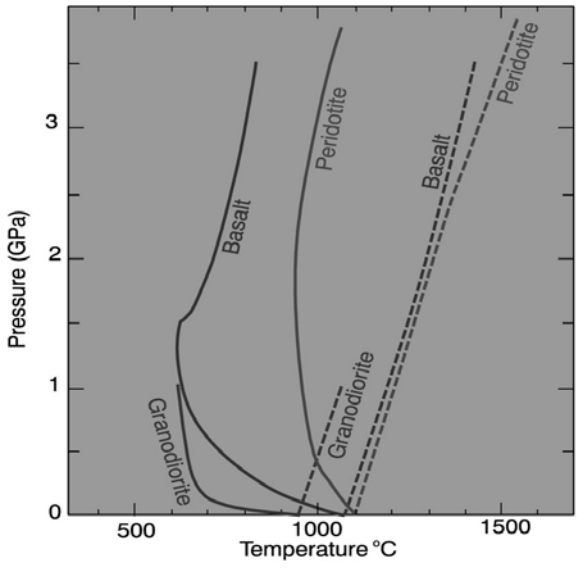
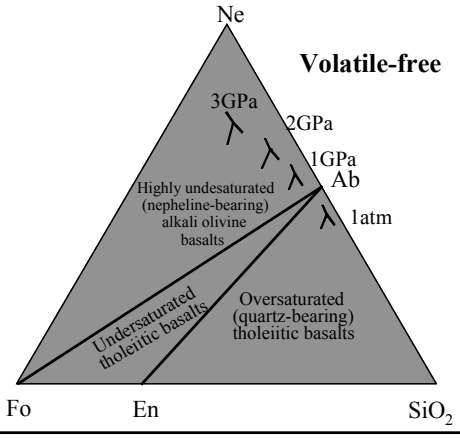
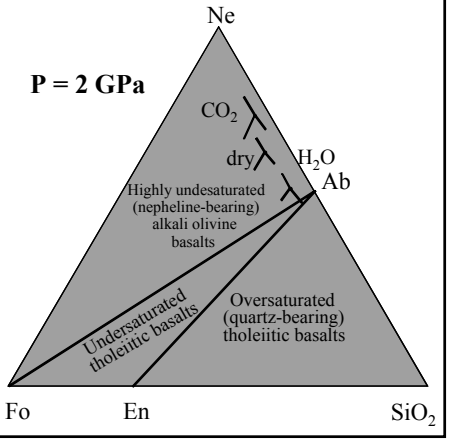


Figure 7-21. H_2O-saturated (solid) and H_2O-free (dashed) solidi (beginning of melting) for granodiorite (Robertson and Wyllie, 1971), gabbro (Lambert and Wyllie, 1972) and peridotite (H_2O-saturated: Kushiro *et al.*, 1968; dry: Ito and Kennedy, 1967).

Effect of Pressure, Water, and CO_2 on the position of the eutectic in the basalt system

Increased pressure moves the ternary eutectic (first melt) from silica-saturated to highly undersat. alkaline basalts



Water moves the (2 Gpa) eutectic toward higher silica, while CO_2 moves it to more alkaline types