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 Publishers

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.
Figure 7.8. Oblique view illustrating an isothermal section through the diopside-albite-anorthite system. Figure 7.9. Isothermal section at 1250°C (and 0.1 MPa) in the system Di-An-Ab. Both from Morse (1994), Basalts and Phase Diagrams. Krieger Publishers.
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 (2010) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.
Figure 7.12. The system diopside-anorthite-albite-forsterite. After Yoder and Tilley (1962). J. Petrol.
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
Bowen’s Reaction Series

Discontinuous Series:
- olivine
- Mg pyroxene
- Mg-Ca pyroxene
- amphibole
- biotite
- potash feldspar
- muscovite
- quartz

Continuous Series:
- Calcic plagioclase
- Calci-alkaline plagioclase
- alkali-calcic plagioclase
- alkaline plagioclase

Temperature arrow pointing upwards.
The Effect of Pressure

The diagram illustrates the relationship between pressure and temperature for solid and liquid phases. The line indicates a phase transition point between solid and liquid states. The pressure axis is labeled as $P_1$ and $P_2$, and the temperature axis as $T_1$ and $T_2$. The solid phase is shown on the left side, transitioning into the liquid phase on the right side.
Eutectic system

The Effect of Water on Melting

Dry melting: solid → liquid
Add water- water enters the melt
Reaction becomes:

\[ \text{solid + water} = \text{liq}_{(aq)} \]

Figure 7.20. Experimentally determined melting intervals of gabbro under $\text{H}_2\text{O}$-free (“dry”), and $\text{H}_2\text{O}$-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$_2$O-saturated (solid) and H$_2$O-free (dashed) solidi (beginning of melting) for granodiorite (Robertson and Wyllie, 1971), gabbro (Lambert and Wyllie, 1972) and peridotite (H$_2$O-saturated: Kushiro et al., 1968; dry: Hirschman, 2000).
We know the behavior of water-free and water-saturated melting by experiments, which are easy to control by performing them in dry and wet sealed vessels.

What about real rocks?

Some may be dry, some saturated, but most are more likely to be in between these extremes.

- a fixed water content < saturation levels
- a fixed water activity
The Albite-Water System

Red curves = melting for a fixed mol % water in the melt ($X_w^m$)

Blue curves tell the water content of a water-saturated melt

Figure 7.22. From Burnham and Davis (1974). A J Sci., 274, 902-940.
Raise a melt with a ratio of albite:water = 1:1 ($X_{\text{water}}^{\text{melt}} = 0.5$) from point a at $925^\circ$C and 1 GPa pressure, toward the Earth’s surface under isothermal conditions.

Figure 7.22. From Burnham and Davis (1974). A J Sci., 274, 902-940.
Conclusions:

A rising magma with a fixed % water will progressively melt.

At shallower levels it will become saturated, and expel water into its surroundings.

It should completely solidify before reaching the surface.

Figure 7.22. From Burnham and Davis (1974). A J Sci., 274, 902-940.
Another example: isobaric heating of albite with 10 mol % water at 0.6 GPa.

Figure 7.22. From Burnham and Davis (1974). A J Sci., 274, 902-940.
Conclusion:

Although the addition of water can drastically reduce the melting point of rocks, the amount of melt produced at the lower temperature may be quite limited, depending on the amount of water available.

Figure 7.22. From Burnham and Davis (1974). A J Sci., 274, 902-940.
Melting of Albite with a fixed activity of $H_2O$

Fluid may be a $CO_2$-$H_2O$ mixture with $P_f = P_{Total}$

Figure 7.23. From Burnham and Davis (1974). AJ Sci., 274, 902-940.
Melting of Albite with a fixed activity of H₂O

Fluid may be a CO₂-H₂O mixture with $P_f = P_{\text{Total}}$

Figure 7.26. From Millhollen et al. (1974). J. Geol., 82, 575-587.
The solubility of water in a melt depends on the structure of the melt (which reflects the structure of the mineralogical equivalent).

**Figure 7.25.** The effect of $\text{H}_2\text{O}$ on the diopside-anorthite liquidus. Dry and 1 atm from Figure 7-16, $P_{\text{H}_2\text{O}} = P_{\text{total}}$ curve for 1 GPa from Yoder (1965). CIW Yb 64.
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.

P = 2 GPa