3.4 MINERAL CHANGES DUE TO PRESSURE

Mineral densities can change in several ways in response to pressure:

a) self-compression - remember that the bulk modulus gives the charge in volume due to pressure charges

$$\frac{dv}{v} = \frac{-dP}{K} \text{ (No structural change} - \text{just squishing)}$$

So for a depth of 300 km (P = 100 kbar)

$$\frac{dv}{v} \sim \frac{100 \text{ x } 10^3 \text{ x } 10^5}{5 \text{ x } 10^{11}} \sim 0.02$$

This is a slow continuous change with depth

b) solid materials can go through *isochemical* phase changes to denser structures (polymorphs).

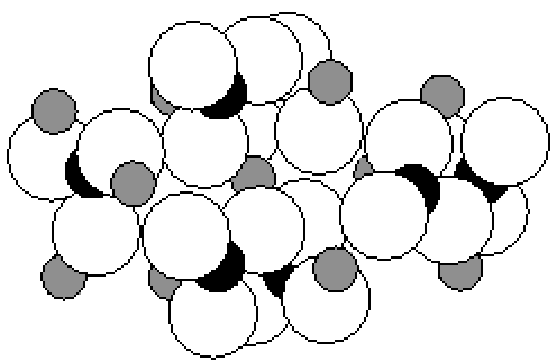
$$Mg_2SiO_4 \text{ (Forsterite)} \rightarrow \text{spinel structure}$$

8% volume change at approximately 120 kbar ~400 km (gives rise to 400 km discontinuity)

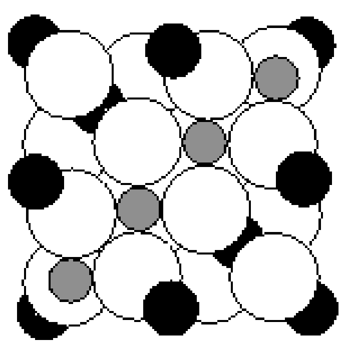
c) minerals can form new minerals, *eutectoids*. For example, at depths below which olivine has changed to spinel structure

$$Mg_2SiO_4 \text{ (spinel structure)} \rightarrow MgSiO_3 \text{ (perovskite structure)} + MgO \text{ (rock salt structure)}$$

OLIVINE

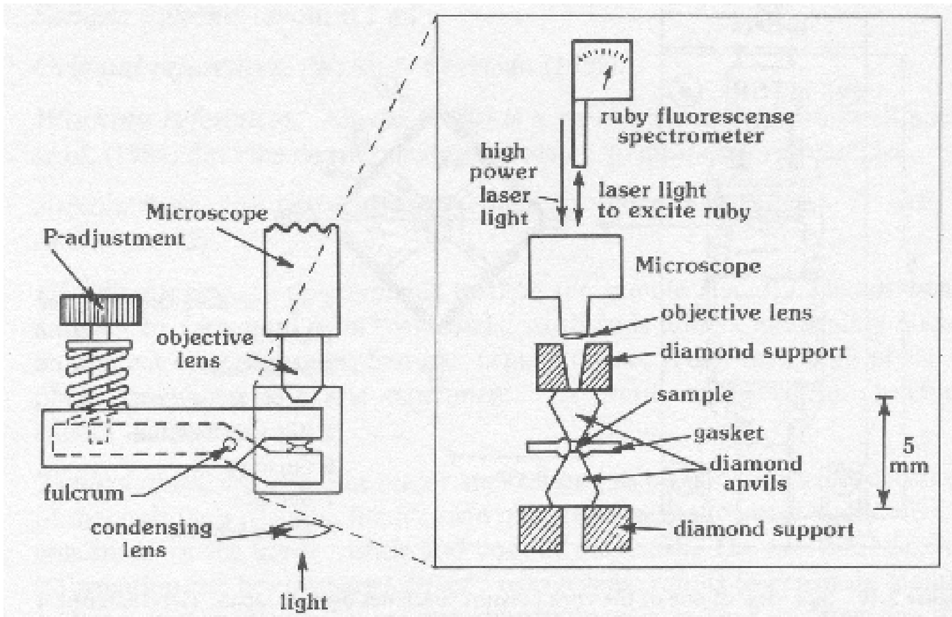


SPINEL STRUCTURE



at about 200 kbars, this change gives rise to 660 km discontinuity.

These phase charges are studied in high pressure laboratories by experimental mineralogists and petrologists (lab tour)



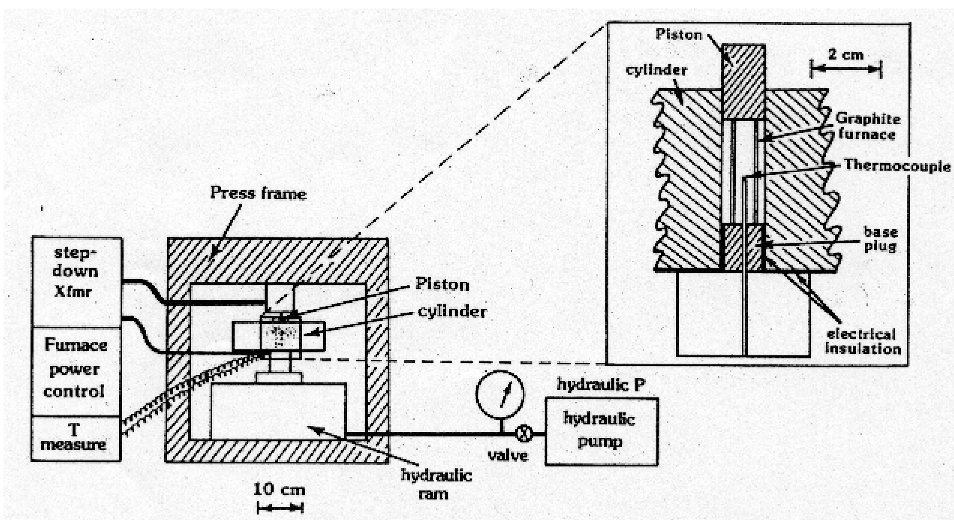
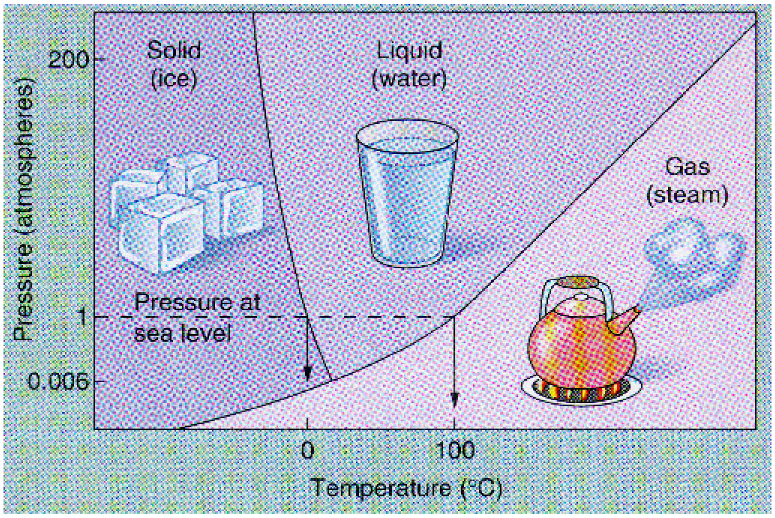


Figure 3.7 Piston-cylinder high pressure system. Detail at right shows the pressure chamber in cross-section.

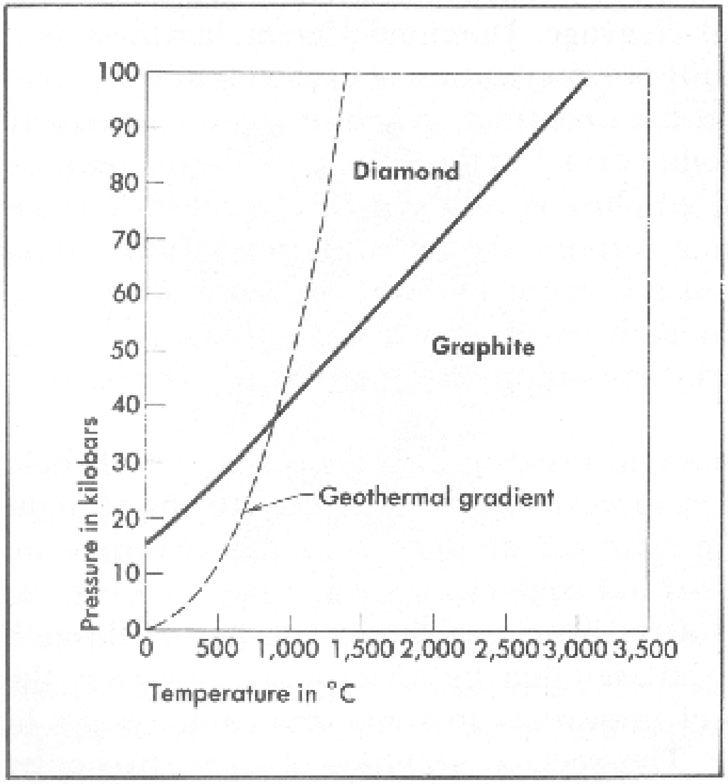
3.5 PHASE DIAGRAMS

Polymorphs are different structures for the same mineral (different phases).
Simplest examples:
ice-water-steam (H_2O system)



Phase diagram - shows which phase is stable in P vs. T space. This depends on pressure and temperature. *Phase changes* occur when we move from one phase to another.

carbon - another simple example
diamond - graphite



Strictly speaking diamonds are unstable (metastable) at the earth‘s surface. They are not "forever"!

The phase change results from putting the atoms into a denser crystal structure

graphite $\rho = 2.2$ g/cm^3

diamond $\rho = 3.5$ g/cm^3

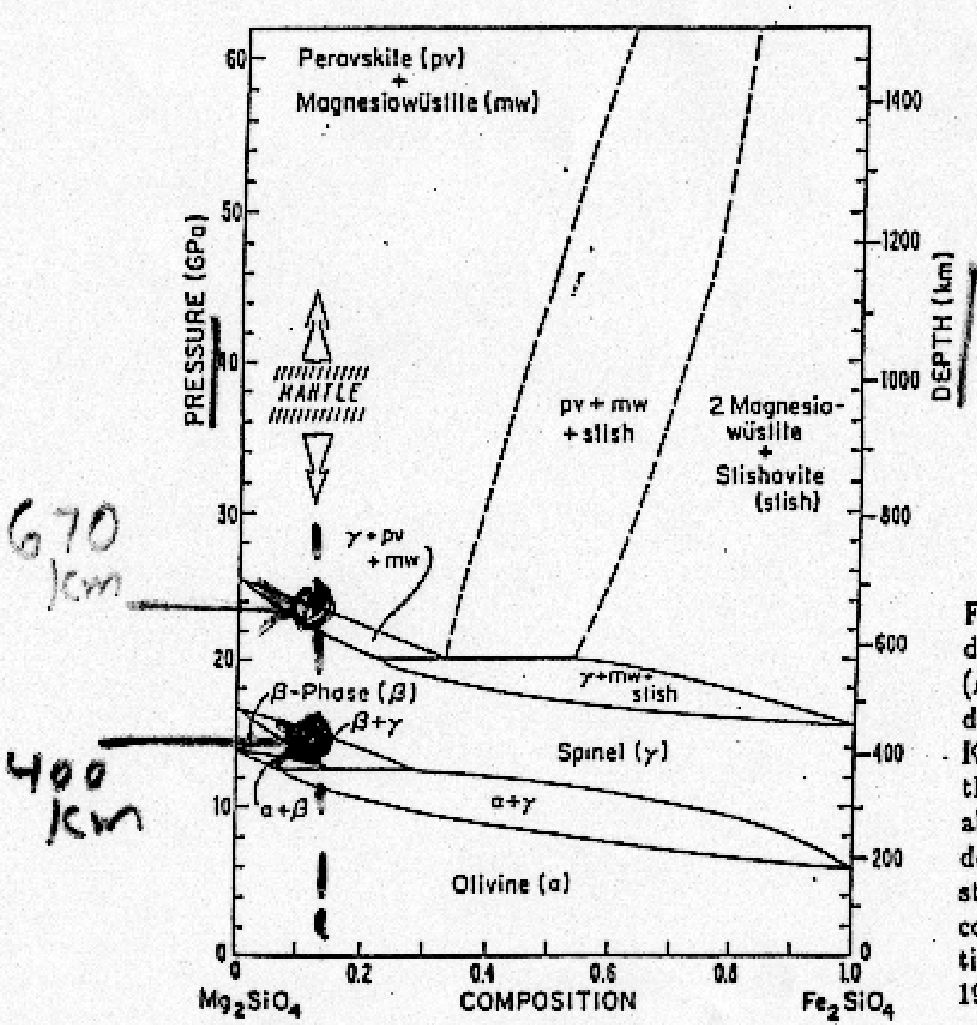
So increased pressure always favors the denser phase - while increased temperature usually favors the less dense phase (contrast to H_2O)

olivine-spinel

A very important phase change thought to occur in the mantle transition zone is olivine $\longrightarrow$ spinel structure

an 8% volume change occurs at about 120 kbar ~400 km!

This depth is very tempting!



OLIVINE

Figure 26: Isothermal phase diagram (1000° C) for the system $(Mg,Fe)_2SiO_4$, as a function of depth and pressure (1 GPa equals 10 Kbars). For the mantle composition, the olivine - spinel transformation at about 140 Kbar corresponds to a depth of about 400 km. The spinel stucture breaks down at depths corresponding to the 670 km discontinuity. [Jeanloz and Thompson, 1983].