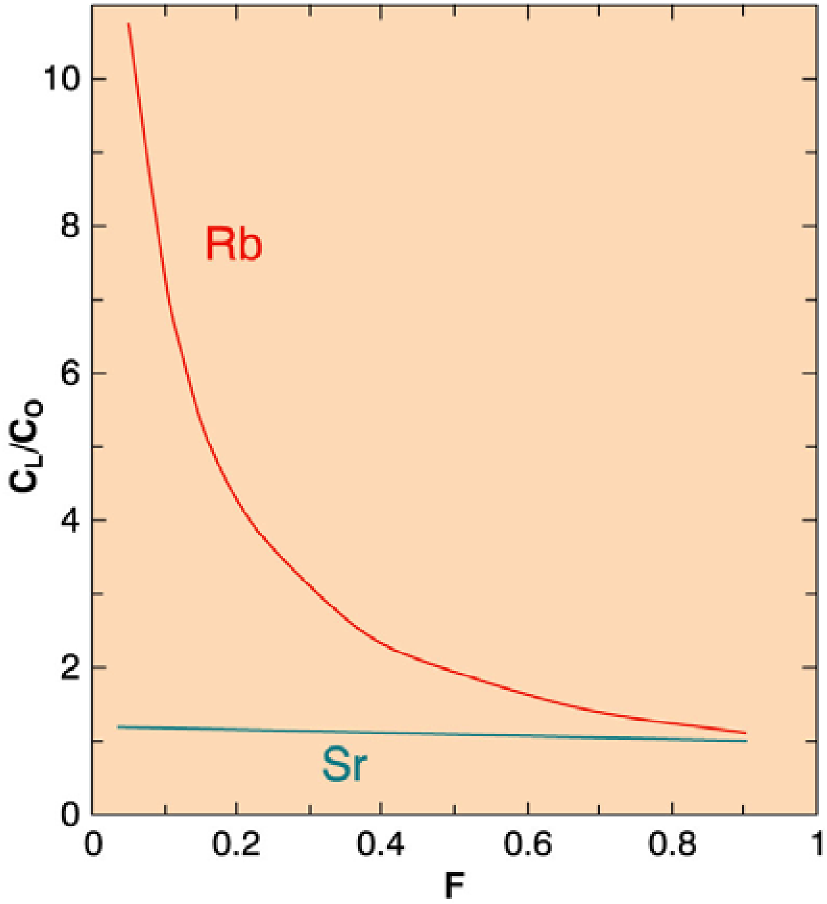
Announcements

Be on time for Field Trip: 9:45 AM on Friday

Rayleigh Fractionation



$$\frac{C_L}{C_o} = F^{(D-1)}$$

C_L = concentration in melt

C_O = concentration in total original assemblage

F = fraction of melt remaining

D = bulk distribution coefficient = $X_1K_1 + X_2K_2 + \ldots$

Relevant to… perfect fractional crystallization!!!!!!

Rayleigh fractionation in petrology I

- Application: fractional crystallization of a melt
- Trace elements will partition preferentially into a melt or a mineral during this process (chemical fractionation)

Example: Eu

Initial concentration: 2 ppm

K_{Dplag} = 4

When have 20 wt% fractional crystallization

What is concentration of Eu in melt?

C_L = 1 ppm

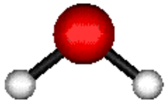
Stable Isotopes

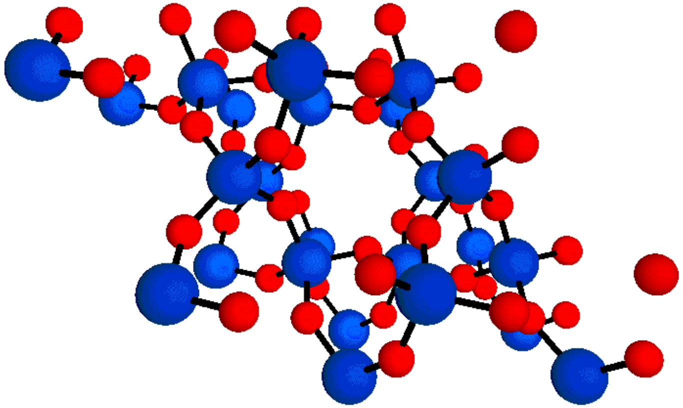
- Stable: last ~ forever
- Chemical fractionation is (impossible)
- Mass fractionation is the only type possible

Oxygen isotopes

- Terrestrial abundances: $^{16}O=99.76/^{17}O=0.04/^{18}O=0.20$
- $\delta^{18}O = 1000 * \left(\frac{^{18}O/^{16}O_{sample} - ^{18}O/^{16}O_{std}}{^{18}O/^{16}O_{std}}\right)$

Std = Standard Mean Ocean Water (SMOW)

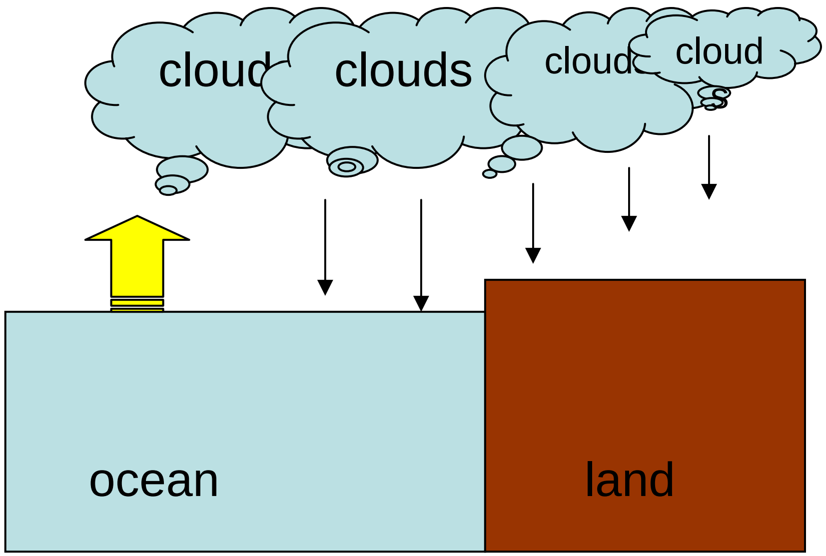


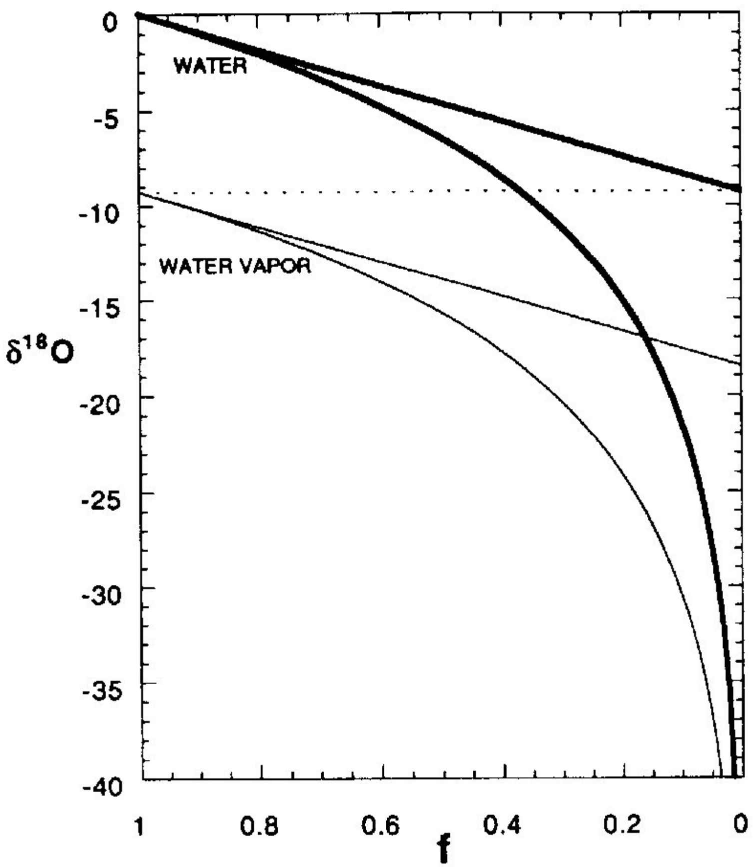


Mass-dependent fractionation

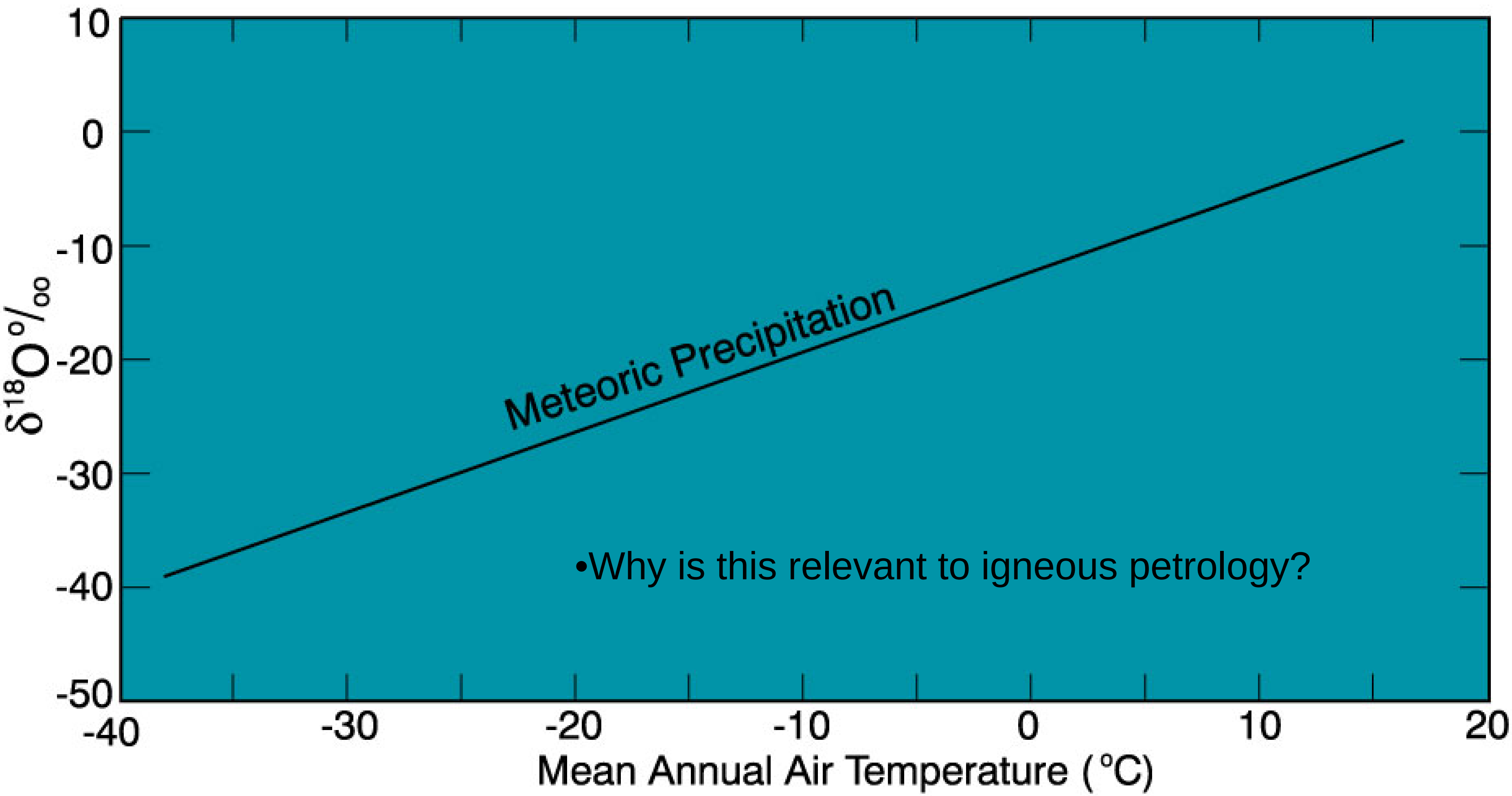
Rayleigh fractionation in petrology II

- Oxygen isotopes are fractionated during evaporation and rain cycles





Fraction of water vapor remaining

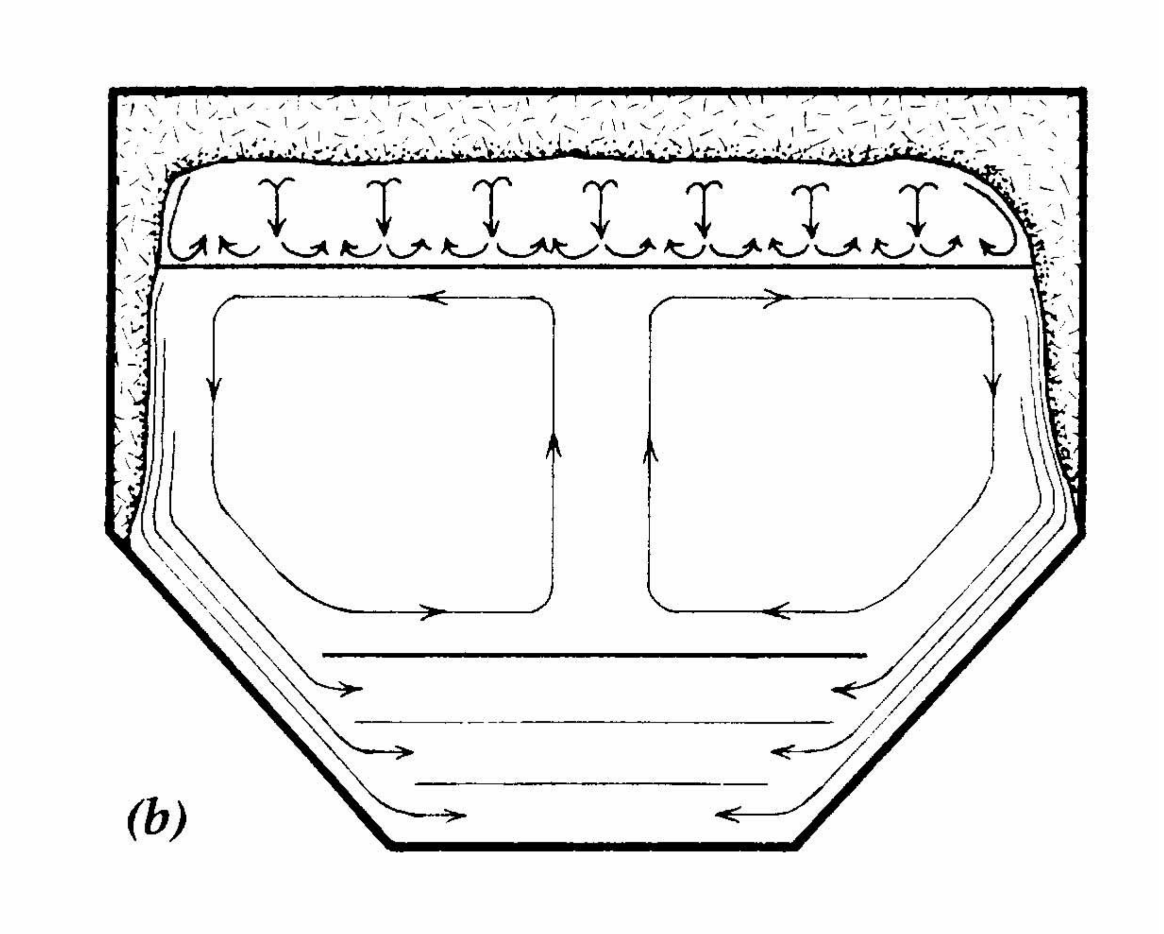


- Why is this relevant to igneous petrology?

Figure 9-9. Relationship between d($^{18}O/^{16}O$) and mean annual temperature for meteoric precipitation, after Dansgaard (1964). *Tellus*, **16**, 436-468.

Cooling of an intrusive body

- Magma convection
- Fractional crystallization results in solidification from bottom up (and top down)



Cooling of an intrusion

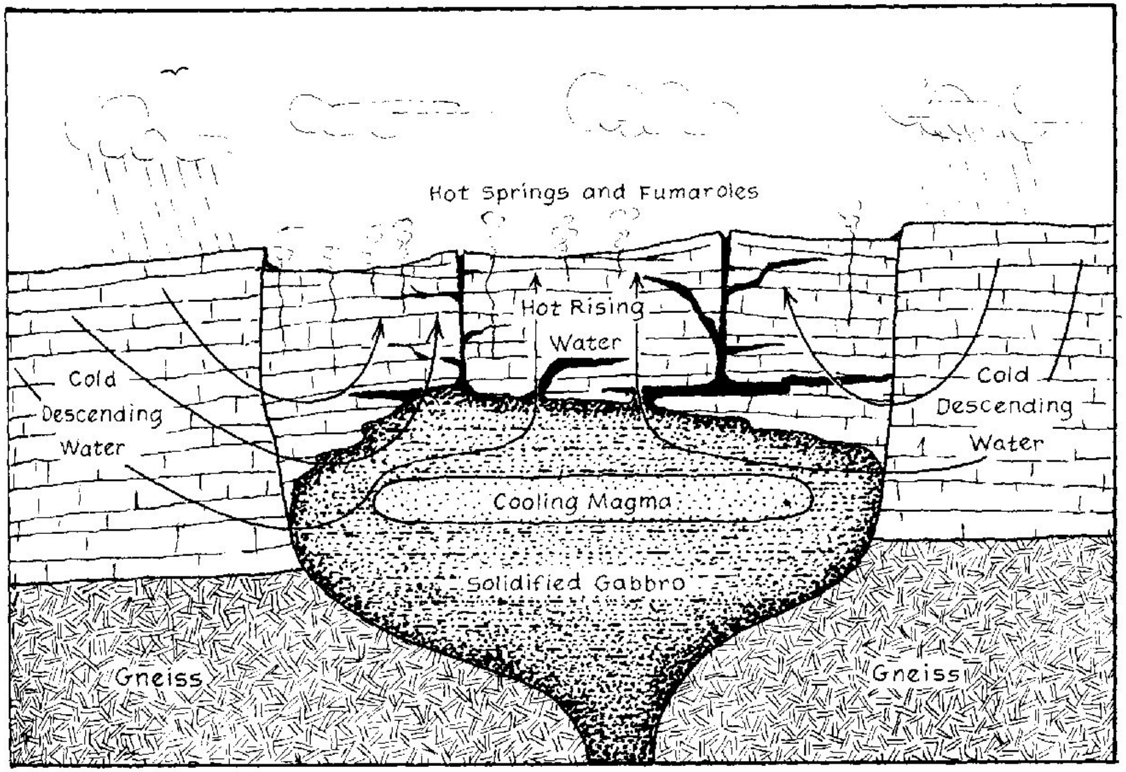
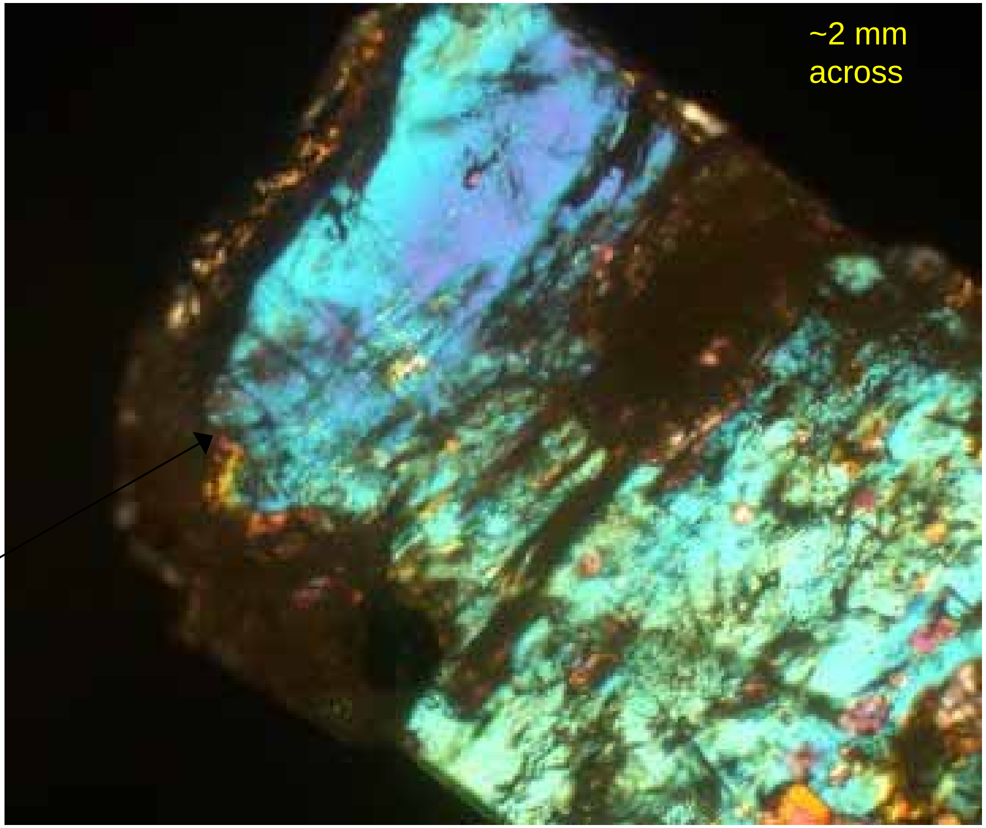


Figure 6–34 The Skaergaard intrusion set up a large hydrothermal system in which meteoric water heated by the cooling gabbro convected through the permeable basaltic rocks of the roof and upper walls. (After H. P. Taylor and R. W. Forester, 1979, *Jour. Petr.* 20:355–419).

Groundwater or meteoric water:
from precipitation

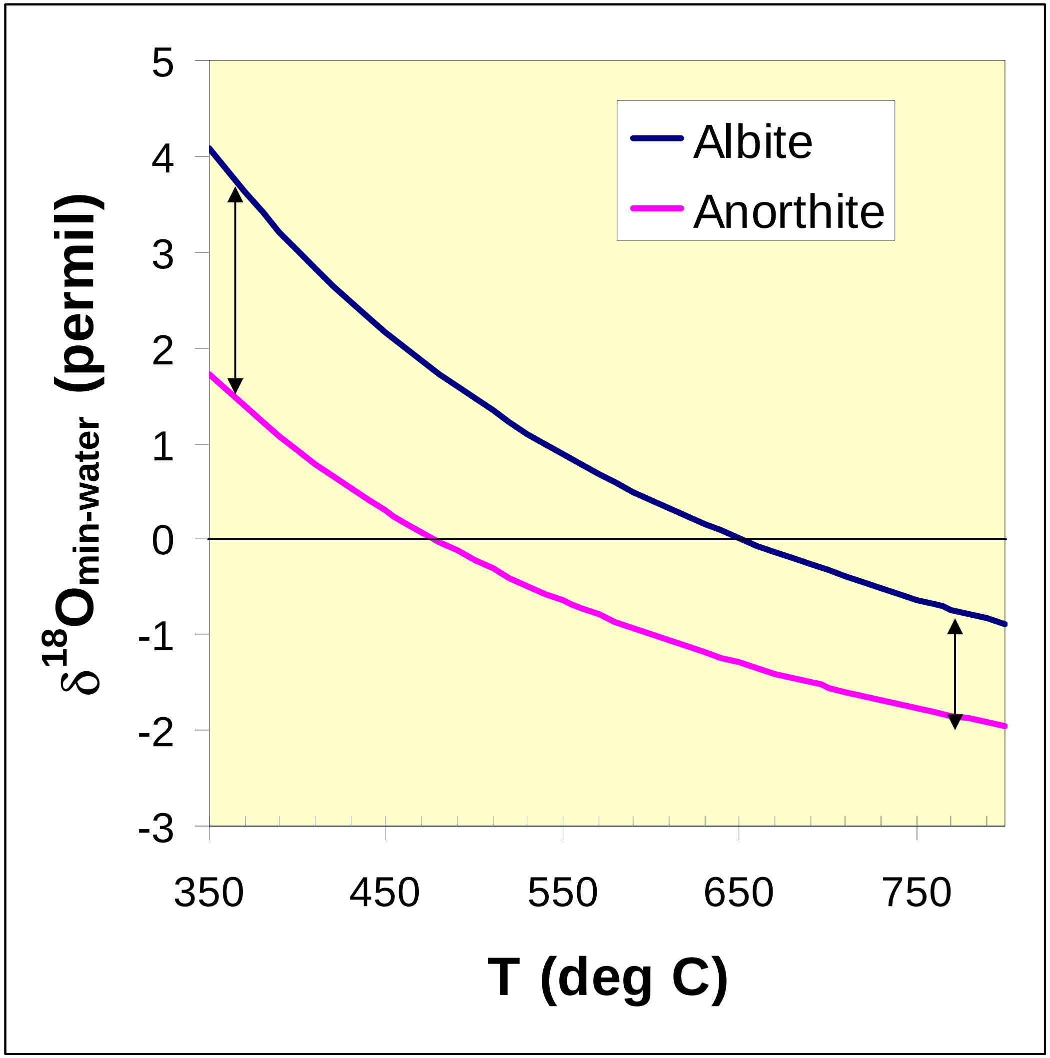
Hydrothermal exchange of minerals

"…every part of the crystal must have had to 'swim' across the 'river' in solution in order to reach the other side." – O'Neil and Taylor, 1967



Solution and redeposition in fluid film at interface between exchanged and unexchanged feldspar.

Temperature dependence of $\delta^{18}O$ in feldspar



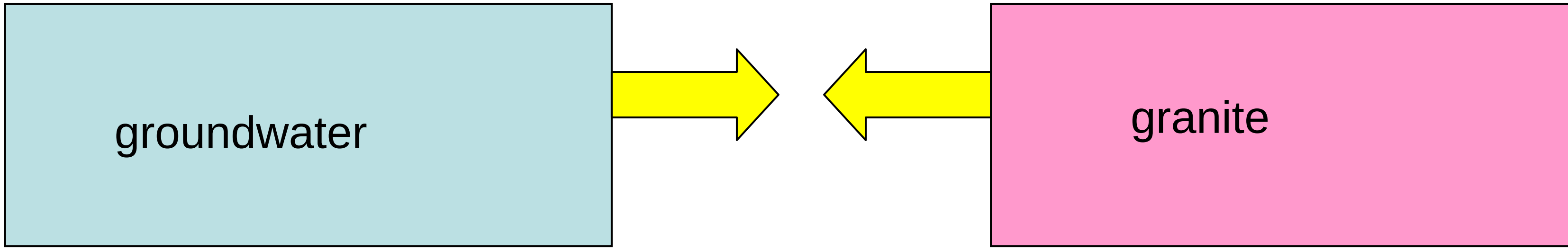
Larger fractionation between two minerals at a LOWER temperature

HOT hydrothermal activity >450 °C will tend to draw down mineral $\delta^{18}O$ to lower values

What is effect of large scale circulation and exchange of water with crystallized but hot intrusion?

Groundwater: -5 to -25 ‰ in temperate areas

Whole rock granite $\delta^{18}O$~ feldspar ~ +6 to +13 ‰



> 450°C; $\delta^{18}O_{min\text{-}water}$ is negative

Cooling of an intrusion: model

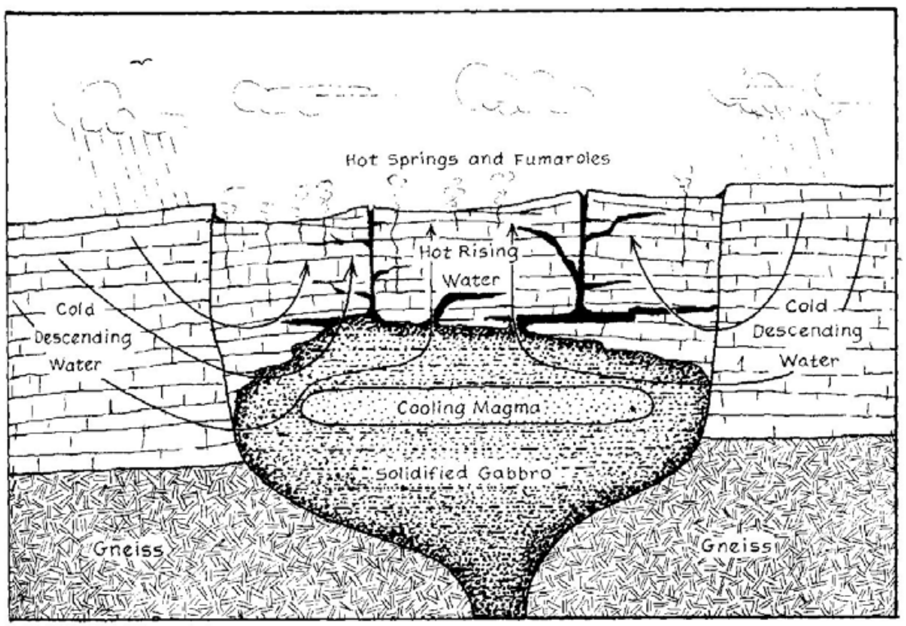
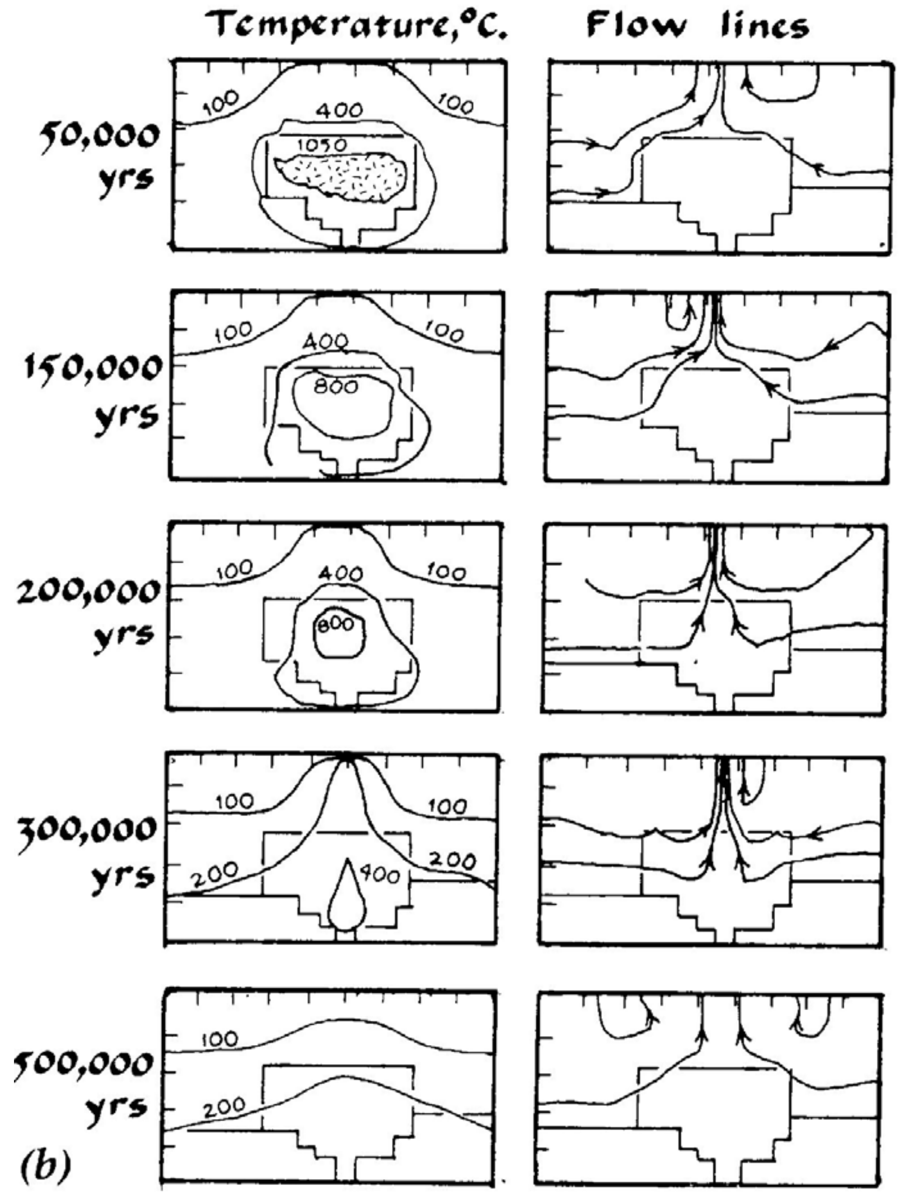
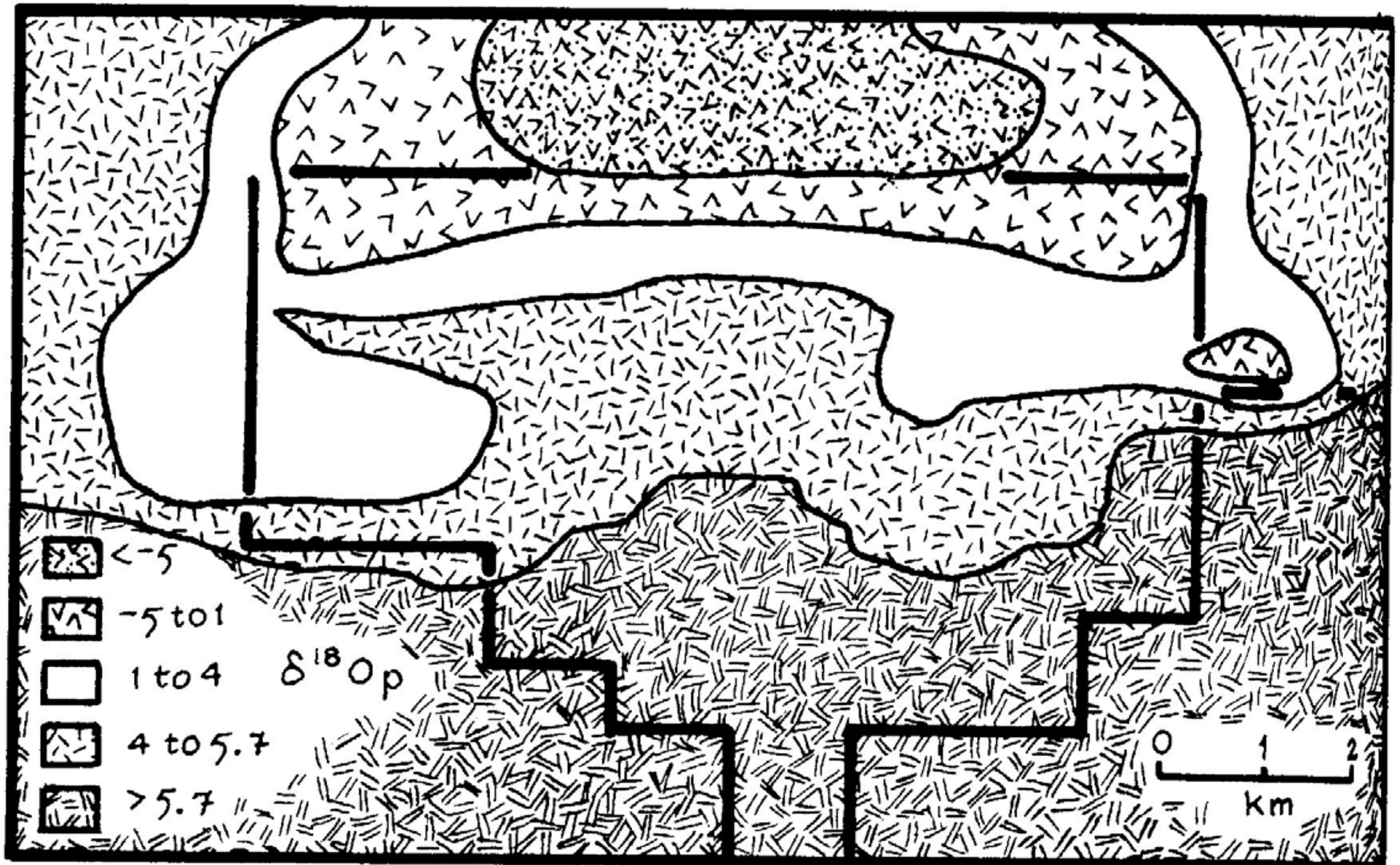


Figure 6–34 The Skaergaard intrusion set up a large hydrothermal system in which meteoric water heated by the cooling gabbro convected through the permeable basaltic rocks of the roof and upper walls. (After H. P. Taylor and R. W. Forester, 1979, *Jour. Petr.* 20:355–419).

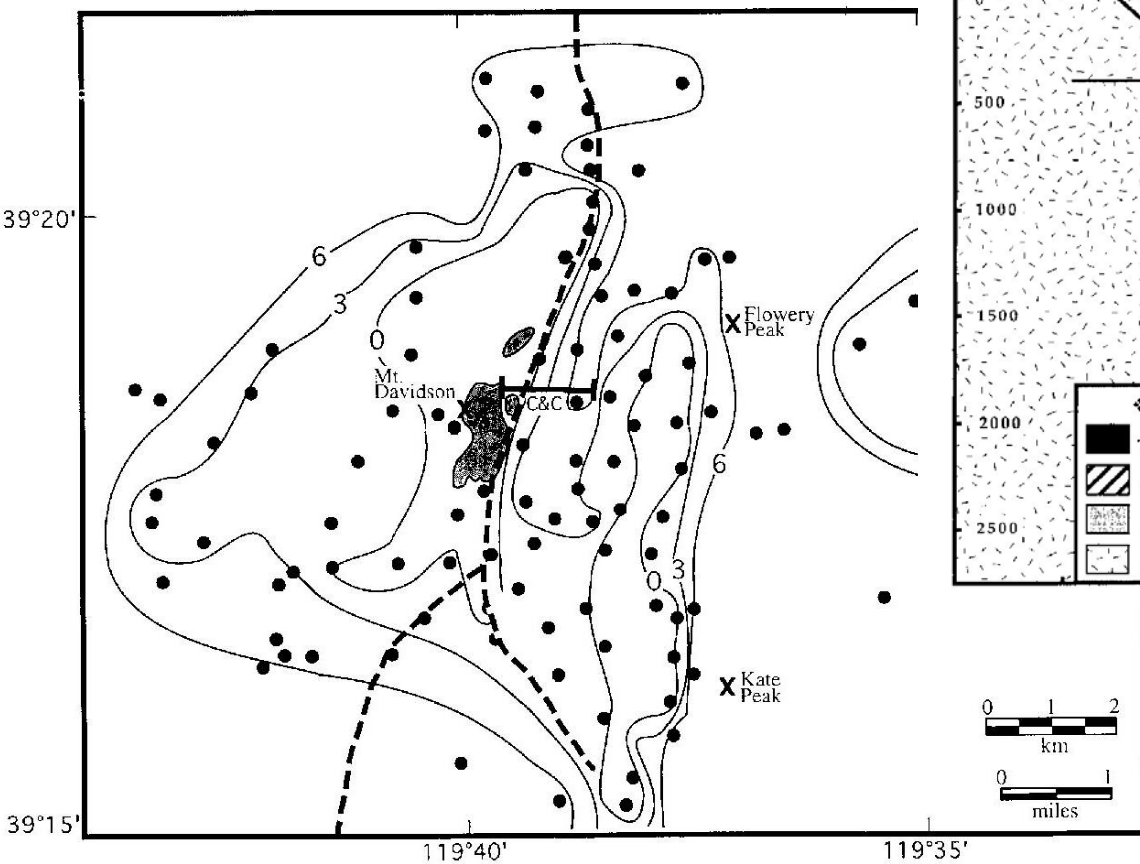


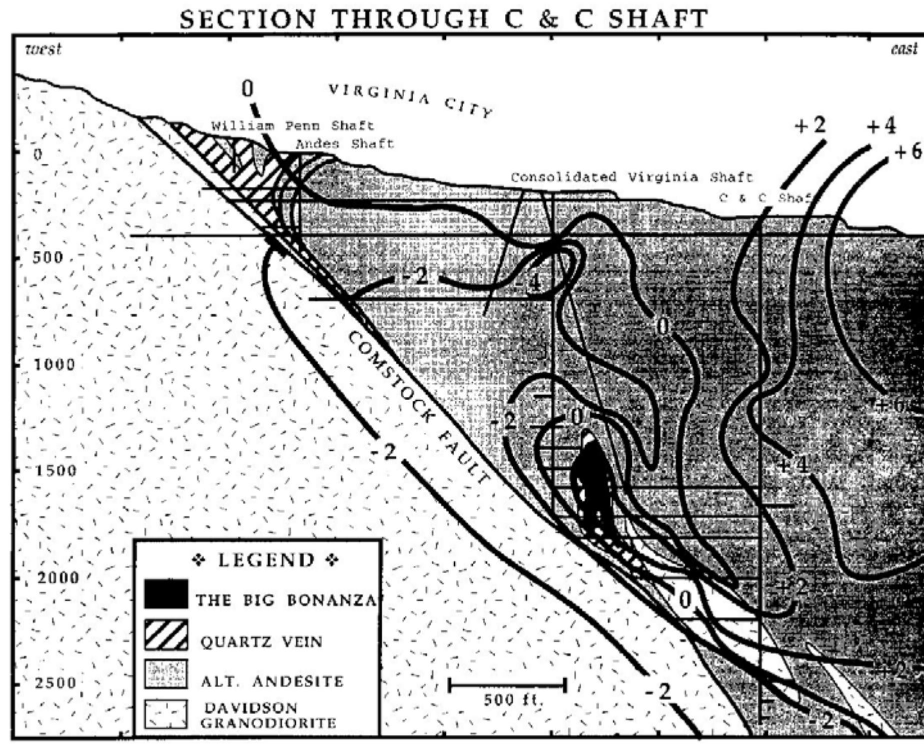
Cooling and hydrothermal exchange



In map view? Would fractional xtallization produce this picture?

Famous example: Comstock





Hydrothermal systems and trace elements

Fumaroles

- Glass exchanges oxygen with water faster than the feldspar phenocrysts

- In small hydrothermal system = low total water

- Glass oxygen isotopes change while the feldspar $\delta^{18}O$ stays pretty much the same.