Introduction to Metamorphism

Reading:
Winter Chapter 21, p. 410-414

Chemical Systems

- An assemblage of coexisting phases (thermodynamic equilibrium and the phase rule)
- A basaltic composition can be either:
  - Melt
  - Cpx + plag (± olivine, ilmenite…)
  - Or any combination of melt + minerals along the liquid line of descent
  - If uplifted and eroded → surface, will weather → a combinations of clays, oxides…

Definition of Metamorphism

"Metamorphism is a subsolidus process leading to changes in mineralogy and/or texture (for example grain size) and often in chemical composition in a rock. These changes are due to physical and/or chemical conditions that differ from those normally occurring at the surface of planets and in zones of cementation and diagenesis below this surface. They may coexist with partial melting."

Lower Limit of Metamorphism

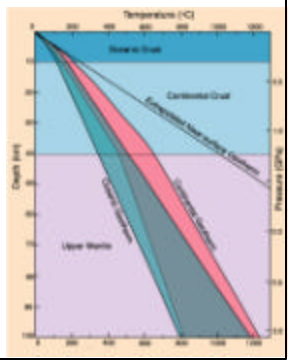
- Low-temperature limit
  - Grades into diagenesis
  - The boundary is somewhat arbitrary
    - Diagenetic/weathering processes are indistinguishable from metamorphic
    - Metamorphism begins in the range of 100-150°C for the more unstable types of protolith
    - Some zeolites are considered diagenetic and others metamorphic – pretty arbitrary

Upper Limit of Metamorphism

- High-temperature limit grades into melting
- Over the melting range solids and liquids coexist
- If we heat a metamorphic rock until it melts, at what point in the melting process does it become "igneous"?
- Xenoliths, restites, and other enclaves are considered part of the igneous realm because melt is dominant
- Migmatites ("mixed rocks") are gradational

Metamorphic Agents & Changes

Temperature: typically the most important factor in metamorphism



Estimated ranges of oceanic and continental steadystate geotherms to a depth of 100 km using upper and lower limits based on heat flows measured near the surface. After Sclater *et al*. (1980), Earth. Rev. Geophys. Space Sci., 18, 269-311.

Increased Temperature

- Promotes recrystallization which increases grain size
- Larger surface/volume ratio of a mineral has lower stability
- Increasing temperature eventually overcomes kinetic barriers to recrystallization, and fine aggregates coalesce to larger grains

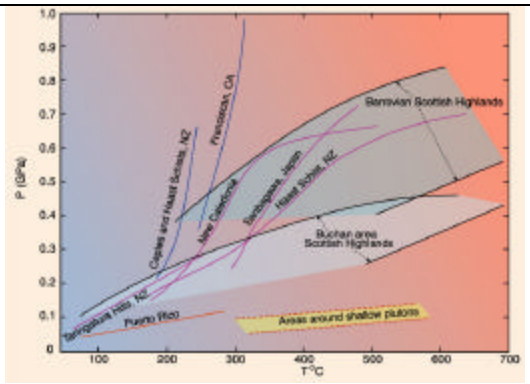
High Temperature Effects

- Reactions occur that consume unstable mineral(s) and produces new minerals that are stable under the new conditions
- Overcomes kinetic barriers that might otherwise preclude the attainment of equilibrium

Effect of Pressure

"Normal" gradients may be perturbed in several ways, typically:

- High T/P geotherms in areas of plutonic activity or rifting
- Low T/P geotherms in subduction zones



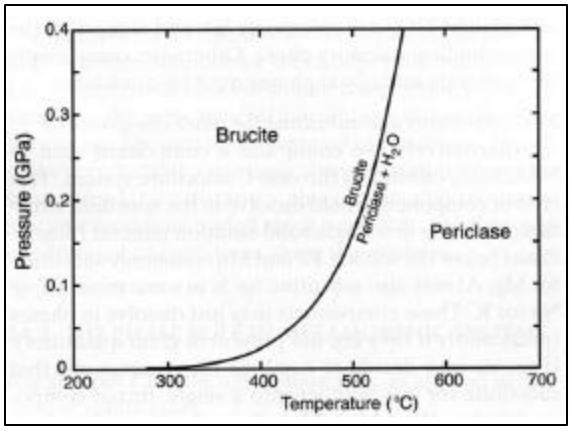
Metamorphic field gradients (estimated P-T conditions along surface traverses directly up metamorphic grade) for several metamorphic areas. After Turner (1981). *Metamorphic Petrology: Mineralogical, Field, and Tectonic Aspects*. McGraw-Hill.

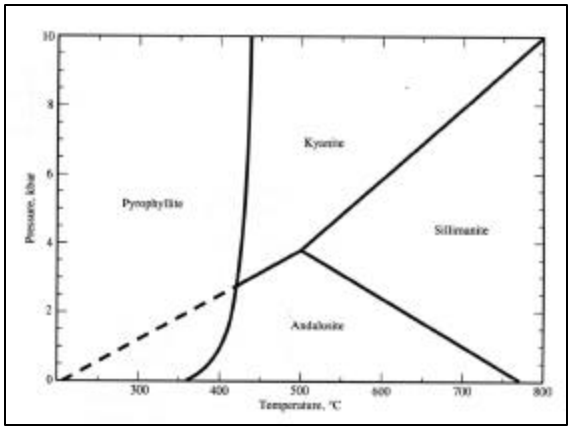
Metamorphic Grade

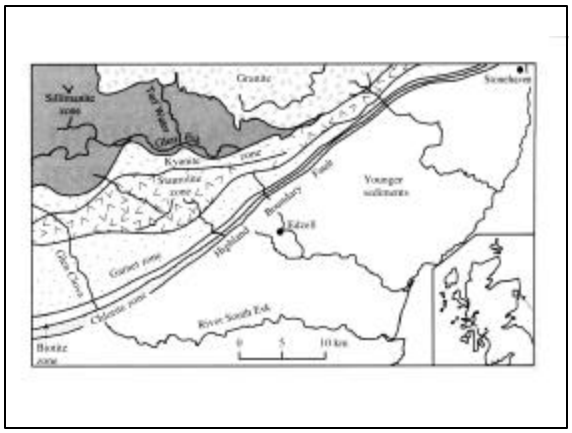
A general increase in degree of metamorphism without specifying the exact relationship between temperature and pressure

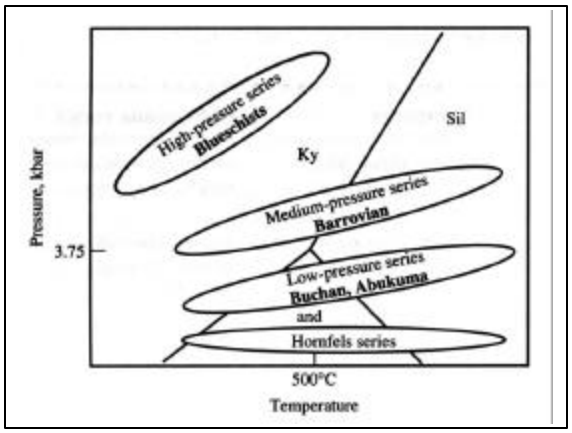
Main Concepts

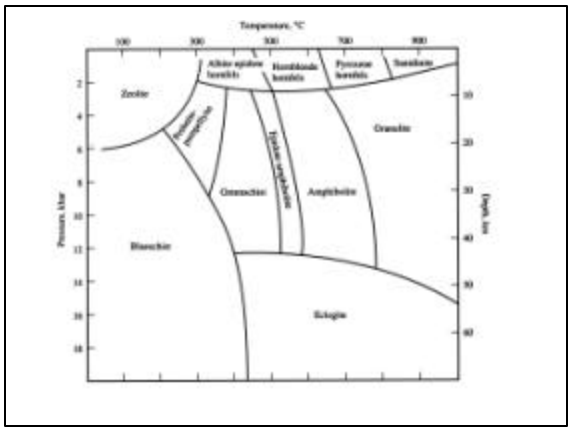
- Devolatilization reactions
- P-T grids with stable mineral fields
- Progressive mapable changes in minerals
- Determination of geothermal gradients
- Metamorphic facies on a P-T grid
- Stable assemblages on Chemographic diagrams

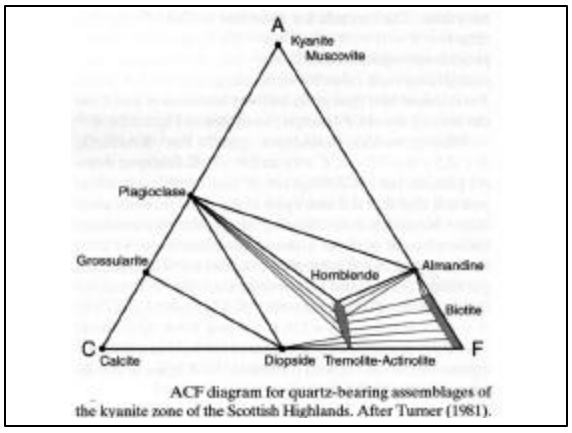












ACF diagram for quartz-bearing assemblages of the kyanite zone of the Scottish Highlands. After Turner (1981).