Lecture 12: Metamorphism Oct. 18, 2006

How do we know P/T conditions? part I - stress conditions

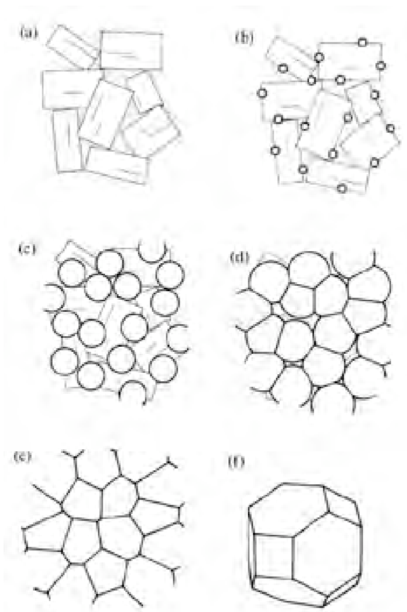
met rx contain history of P,T,X variations
stress condition and orientation of dominant stress field
how can we tell the stress condition?

Recrystallization

in either regional or contact metamorphism, grains will recrystallize
- a) growth of new phases from old phases
- b) recrystallization (growth) of old phases if still stable

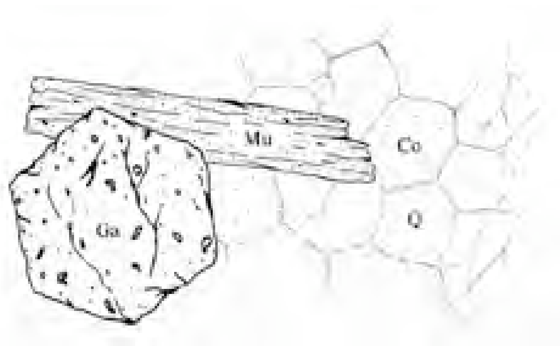
lithostatic conditions

increase in grain size and interlocking
monomineralic: quartzite, marble, glacial ice



in the case above A+B > C

polymineralic: grains with strong surface energy anisotropy >> euhedra
- high: sphene, garnet, staurolite
- int.: micas
- low: calcite, plag, Q
- *porphyroblast*



nonlithostatic conditions:

recrystallization or grain growth >> preferred orientation (perp. to σ1)

foliation = planar texture and/or compositional banding

lineation = long axes may also be aligned

relationship to preexisting (sedimentary) structures

metamorphic paths

(re)crystallization may continue after directed pressure ceases

expectation in this case would be non-foliated texture overprints foliated one

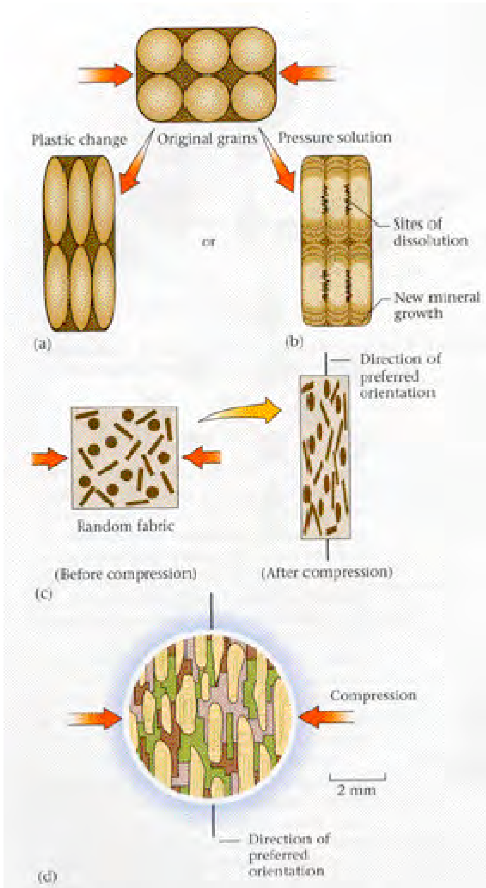
Mechanisms of foliation development

1) plastic deformation (uniaxial)
   - refresher on stress and strain
   - typical deformation in rocks
     - elastic
     - ductile
     - failure

2) pressure solution
   - stress concentration leads to dissolution
   - preferential recrystallization perp to max stress
   - allow recrystallization of micas
   - possible influence in generating mineralogical banding
     - stress higher in Q than mica, so Q preferentially dissolves

3) rotation of anisotropic grains (ductile)

4) growth of anisotropic grains
   - lower energy state elongate perp. to max stress

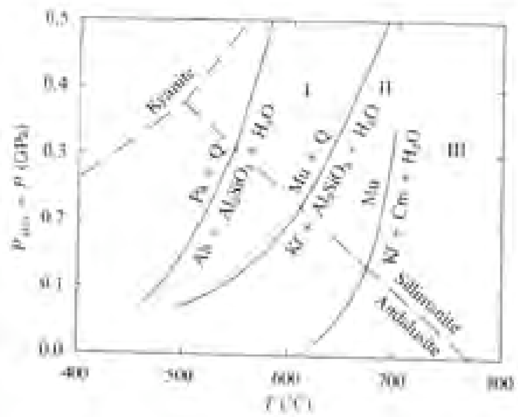


How do we know P/T conditions? part II (calibrating P/T)

mineral assemblage gives clues to the P/T conditions
specific assemblages from various rock types
equilibrium assemblages
evidence in uniform compositions

Experimental Approach

series of metamorphic reactions defined by lab expts (note loss of water)



$KAl_2(AlSi_3O_{10})(OH)_2 + SiO_2 <--> KAlSi_3O_8 + Al_2SiO_5 + H_2O$
muscovite quartz orthoclase sillimanite

Thermodynamic Approach

example for aluminosilicate polymorphs (important for micaceous rocks)

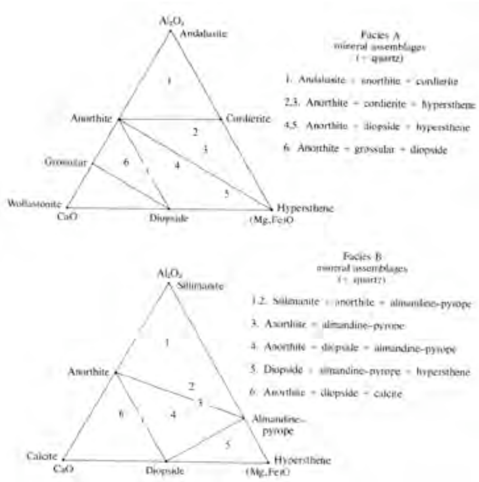
molar volumes - high P favors phase with lower partial volume
entropy of reaction - higher entropy phase favored by high T
entropy (measure of disorder)

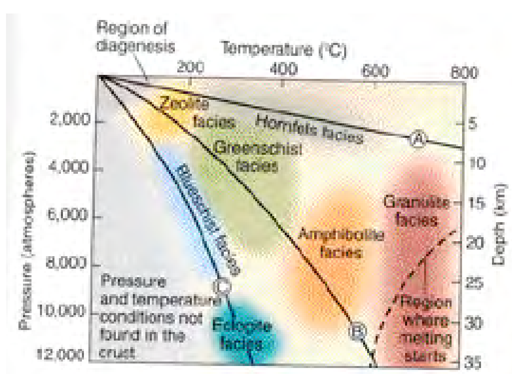
How do we determine metamorphic history in field?

mapping reveals sequence of minerals (*index minerals*)
isograd = surface connecting points of first appearance of index mineral

compositional dependence
clay rich rocks: chlorite, biotite, garnet, staurolite, sillamanite
mafic rocks:

metamorphic facies = all rocks which have originated under T & P conditions so similar that a definite chemical composition has resulted in the same set of minerals regardless of the crystallization manner.





whiteschist facies metamorphism (time permitting)

Why don't mineral assemblages revert to original state?

1. most metamorphic reactions produce water, CO_2 as byproduct

    fluids escape and are not available for reaction on cooling

2. deformation accompanying metamorphism produces defects that speed rxn significantly

Tectonic setting of metamorphic facies

links to geothermal gradient from above figure