November 15, 2005

Bulk composition variations (continued)

Metamorphosed mudstones or shales – pelites
SiO_2 – Al_2O_3 – K_2O – MgO – FeO system, abundant in tectonically active areas
CaO and Na_2O are not as abundant as these five because they are carried away in solution during surface weathering.
In weathering, plagioclase is the first phase to dissolve from a pelite, through seracitic alteration

Calc-silicates
Less abundant, but more attractive are calcareous pelites ($CaCO_3$ + SiO_2) or muddy limestones. When metamorphosed, these become calcareous schists (in Europe, called "marl").

Siliceous Dolomites (siliceous carbonates)

Kaapval craton – 3.1 Billion years ago platform carbonates – stromatolites grow there, might be older stuff but lost since pT.

Only one way to make subduction zones: make pluton-sized granites/rhyoliutes or hydro-alter ocean floor basalts and remelt oceans for a long time
We can't see back that far in the rock record

Meta-basic rocks – metamorphosed mafic volcanics
Ultramafic – serpentinites
Peridotite protoliths
MgO-SiO_2-H_2O

Iron formations – sedimentary rocks, SiO_2-FeO-Fe_2O_3-H_2O
BIFs

Metamorphic facies + isograds

1. Isograds

Barrow – mapped metamorphic rocks in Scotland, recognized zones of progressive metamorphism – based on pressure of index minerals
Boundaries between zones marked by the appearance of each index mineral

Pelite sequence: chlorite → biotite → garnet → staurolite → kyanite → sillimanite
See in field: Chlorite zone | Biotite zone, etc.

Boundaries marking the appearance or disappearance of minerals between zones were called isograds.
Isograd – "equal grade" – intersection of a surface of equal P&T with the ground topography

Appearance depends on P, T, fluids, and the bulk composition of a rock

Barrovian metamorphism – classic example of middle P-T conditions (usually in orogenic or tectonic setting)

2. Facies

Eskola (1910-20, later than Barrow) – recognized a distinct set of mineral assemblages that were characteristic of a set of P-T conditions – metamorphic facies

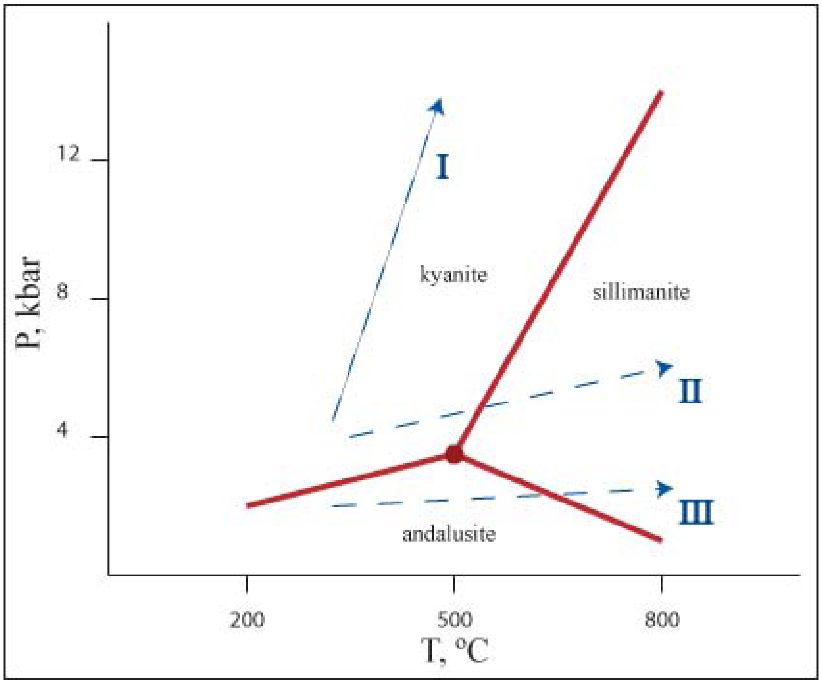
This got complicated because of the large number of named facies. Fortunately, people stopped naming new facies. In common use now:

Barrow's zones	**Mafic rock facies**	**Calc-silicate rock facies**
Biotite	Greenschist	Talc-phlogopite
Garnet	Epidote-amphibolite	Tremolite-actinolite-epidote-zoisite
Staurolite		
Staurolite-kyanite	Amphibolite	Diopside-grossular-scapolite
Sillimanite	Pyroxene granulite	Forsterite
K-feldspar		

Plate Tectonics + Metamorphism

Miyashiro – worked in Japan in 1950s, most famous Ryoke belt – discovered new types of metamorphic rocks
Metamorphic belts were recognized that recorded contrasting P-T conditions

Al_2SiO_5 triple point @ 3.5 kbars, 500ºC
1 kbar ≈ 3 km in mantle, 4 km in crust
10^5 Pa = 1 atm

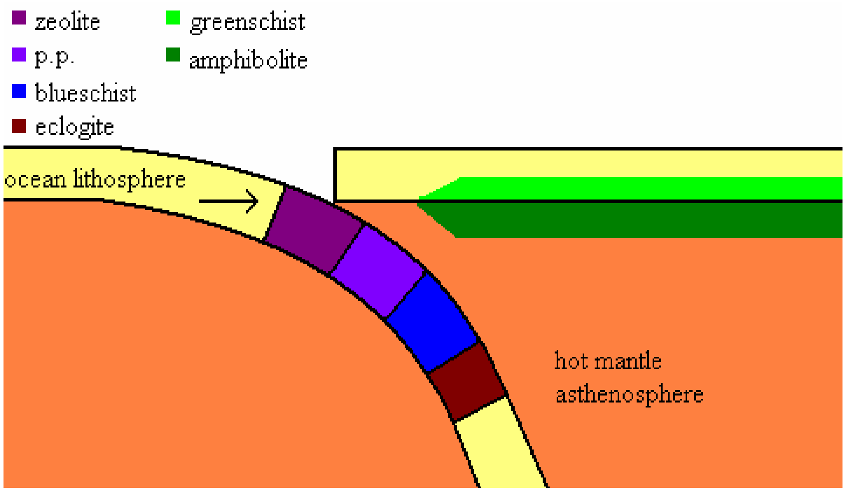


Types

I. Zeolite → prehnite-pumpellyite → blueschist → eclogite
II. Barrovian
III. Low P, high T sequence – andalusite → sillimanite → greenschist → amphibolite

In the 60s when plate tectonics were recognized, it became clear that these zones represented different parts of the subduction environment
I – characteristic of subducted oceanic lithosphere
III – characteristic of the active volcanic arc

Interpretation



3. how do isograds and mineral assemblages record changes in P and T?

system – CaO – Al_2O_3 – SiO_2, 3 components, phase rule $F = c + 2 - \varphi$
F = # degrees of freedom
c = # components
2 = T and P
φ = # phases
so $F = 5 - \varphi$

if F = 0 (no degrees of freedom, invariant point), 5 phases coexist
at aluminosilicate triple point, 3 of those phases are the three isomers of Al_2SiO_5