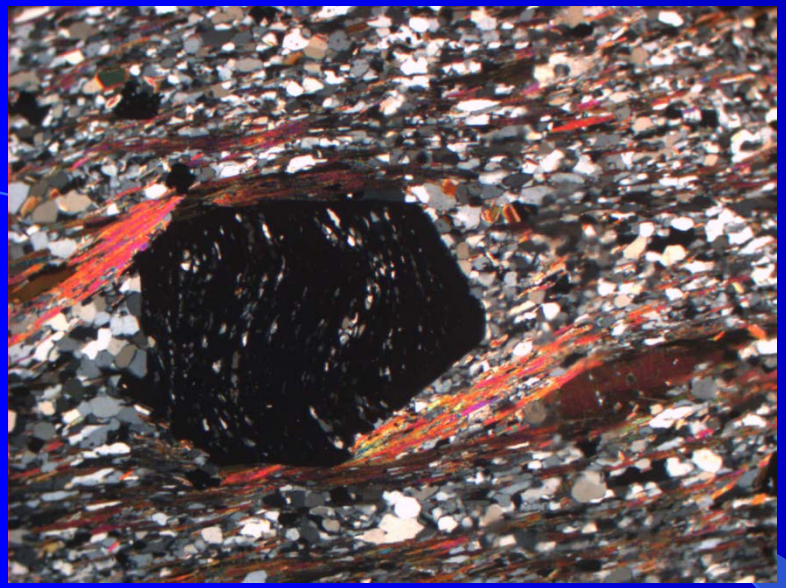
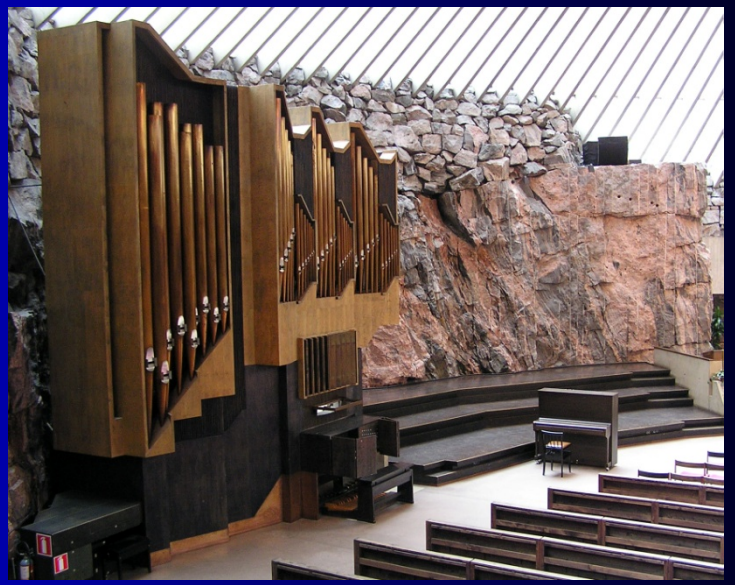
Metamorphic Rocks





Metamorphic rocks undergo changes in texture, mineralogy, or both while in the solid state

- Low-grade: 150˚C–550˚C and low pressure
- High-grade: above 550˚C and high pressure

Other factors also play an important role in metamorphism: fluids, time, and stress

Fluids trapped in the pores between rock grains heat up during metamorphism and can speed up chemical reactions

When there are abundant pore fluids involved in metamorphism, it is called metasomatism

The processes that result from changing temperature and pressure are either mechanical deformation or chemical recrystallization or both

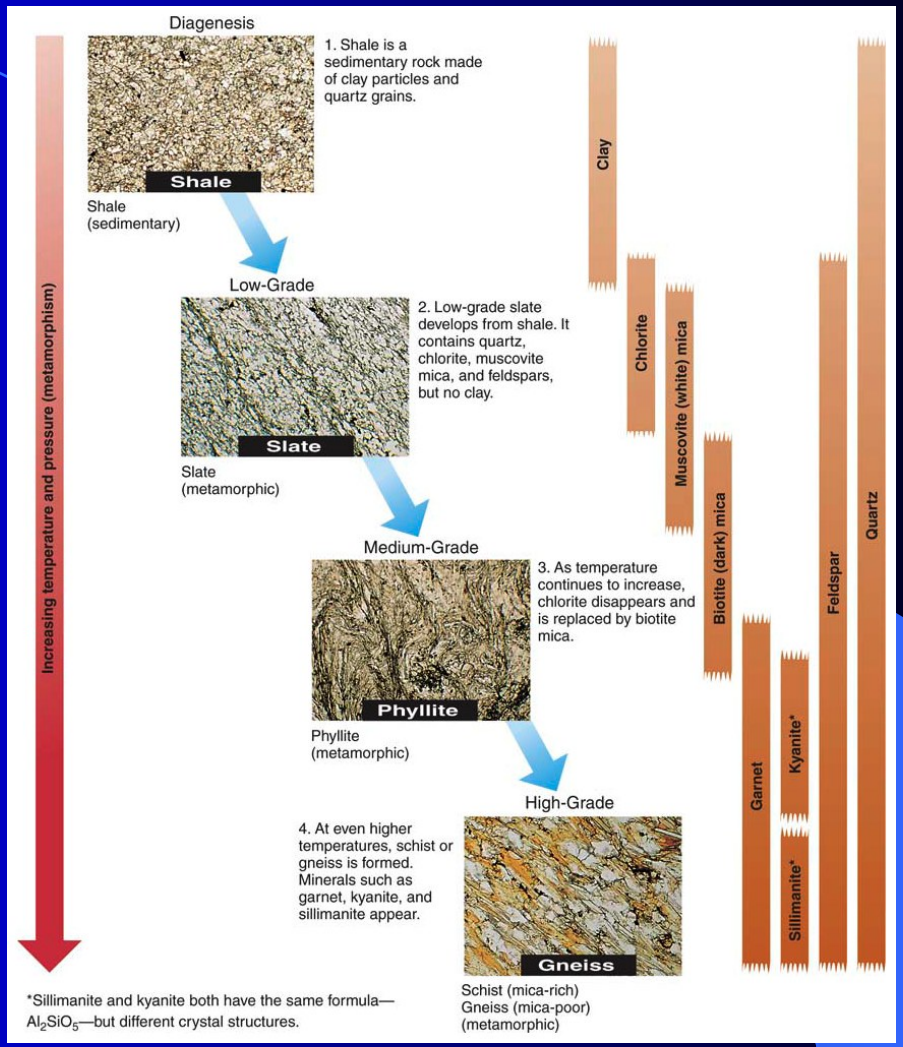
Different kinds of metamorphism reflect the importance of the two processes

Contact metamorphism
Burial metamorphism
Regional metamorphism

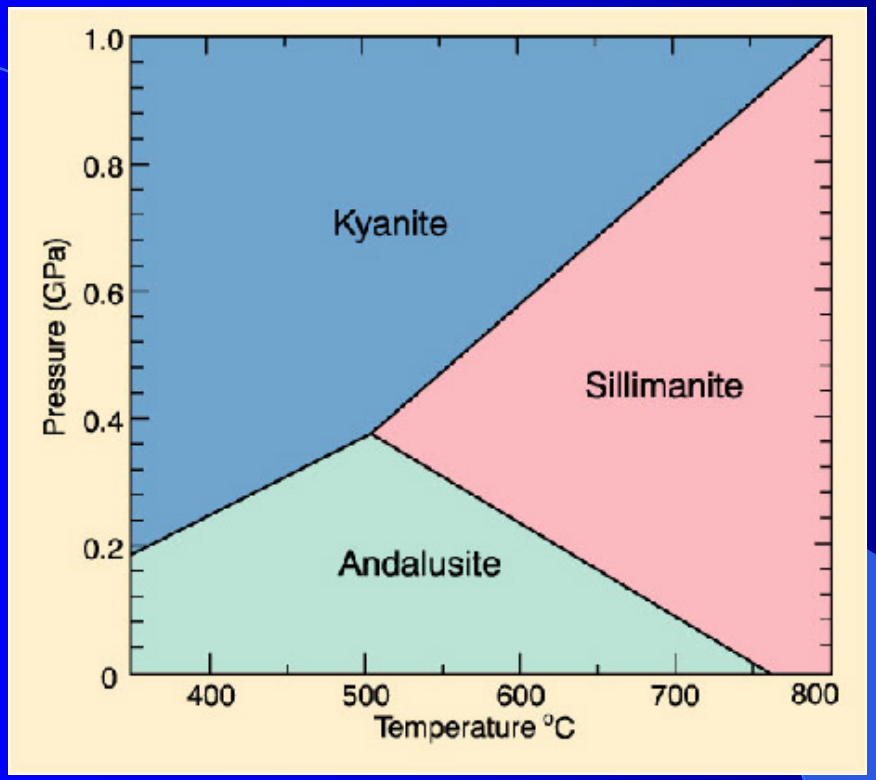
- Rock can be heated by burial, exposure to igneous intrusions, or collision
- Each of these can be associated with different pressures so metamorphism can rarely be due only to temperature
- The term stress implies direction, and is a more useful term than pressure, especially since metamorphic rocks record differential stress in their textures
- Differential stress is stress that is not equal in all directions
- Commonly this produces the parallel alignment of certain minerals that gives the rock a stripey pattern (gneiss) or a planar fabric (foliation)
- Metamorphism also produces new mineral assemblages that are stable at the new pressure and temperature


(A)


(B)

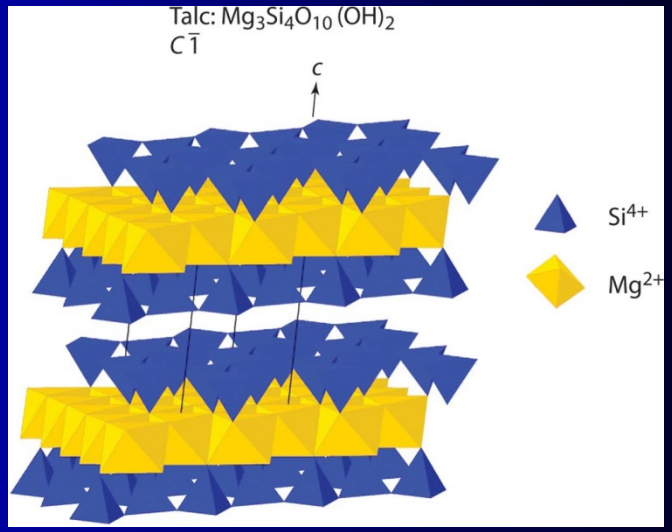

Diagenesis
1. Shale is a sedimentary rock made of clay particles and quartz grains.
Shale
Shale (sedimentary)
Low-Grade
2. Low-grade slate develops from shale. It contains quartz, chlorite, muscovite mica, and feldspars, but no clay.
Slate
Slate (metamorphic)
Medium-Grade
3. As temperature continues to increase, chlorite disappears and is replaced by biotite mica.
Phyllite
Phyllite (metamorphic)
High-Grade
4. At even higher temperatures, schist or gneiss is formed. Minerals such as garnet, kyanite, and sillimanite appear.
Gneiss
Schist (mica-rich)
Gneiss (mica-poor)
(metamorphic)
Increasing temperature and pressure (metamorphism)
Clay
Chlorite
Muscovite (white) mica
Biotite (dark) mica
Garnet
Kyanite*
Sillimanite*
Feldspar
Quartz
*Sillimanite and kyanite both have the same formula—Al_2SiO_5—but different crystal structures.

Al_2SiO_5 Polymorphs

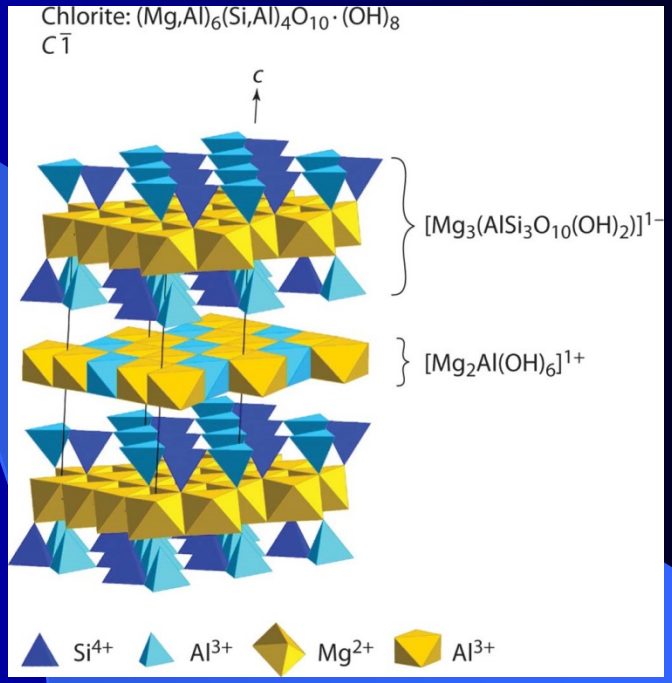


Staurolite ($Fe_{3-4}Al_{18}Si_8O_{48}H_{2-4}$)

Talc – forms in Mg-rich rocks through the alteration of magnesium silicates



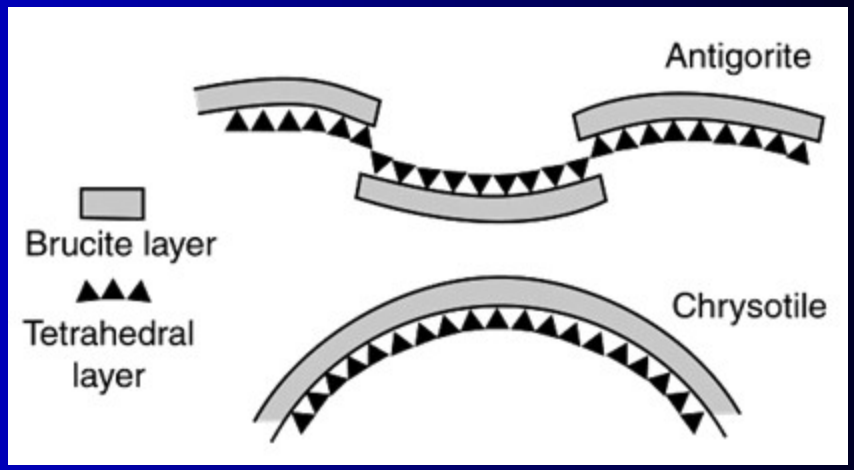
Chlorite – common mineral in greenschist facies rocks.



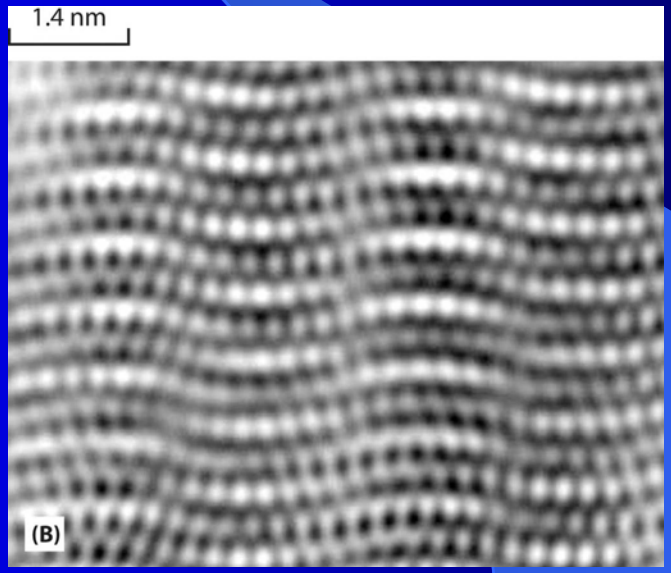
Serpentine minerals – antigorite, chrysotile, and lizardite

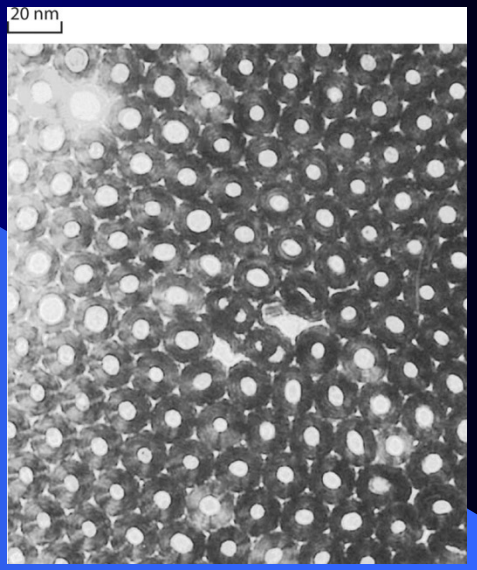
All are polymorphs of $Mg_3Si_2O_5(OH)_2$

Antigorite



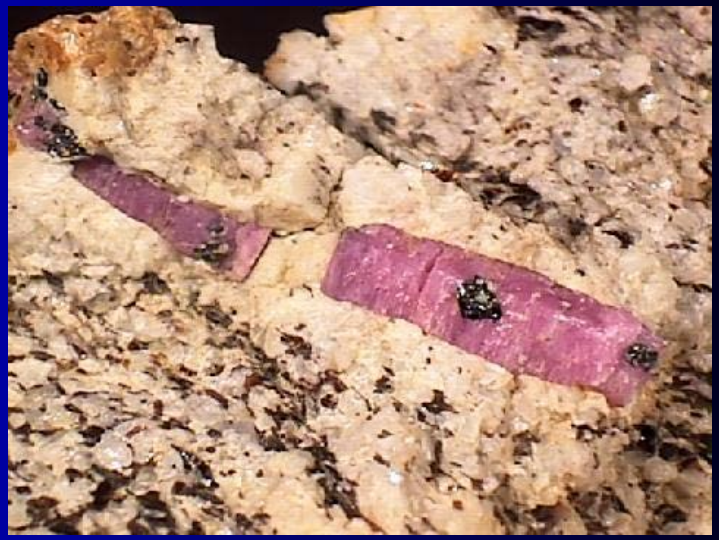
Chrysotile





Corundum

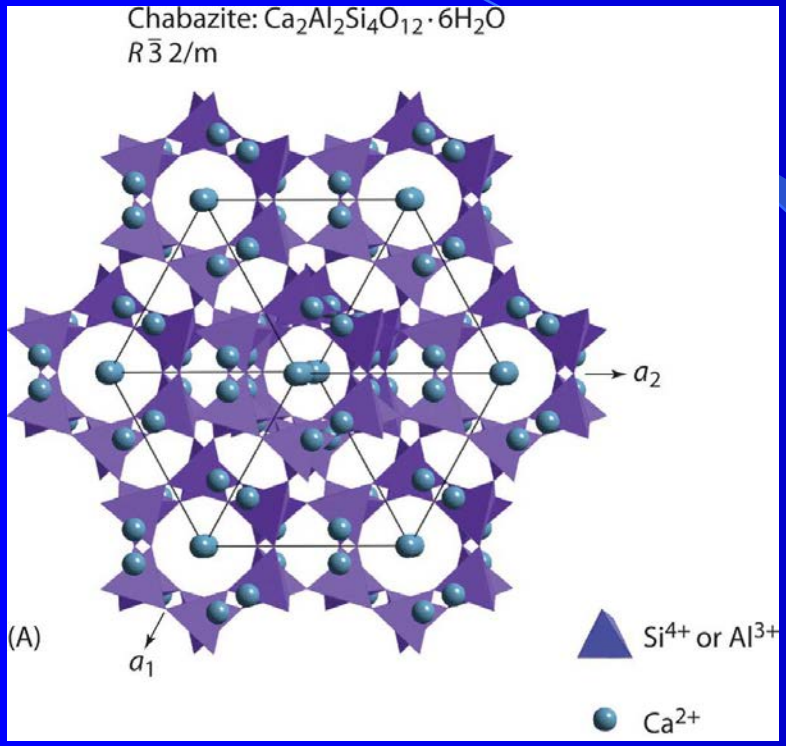
Extremely high-grade contact metamorphism of aluminous (pelitic) rocks.



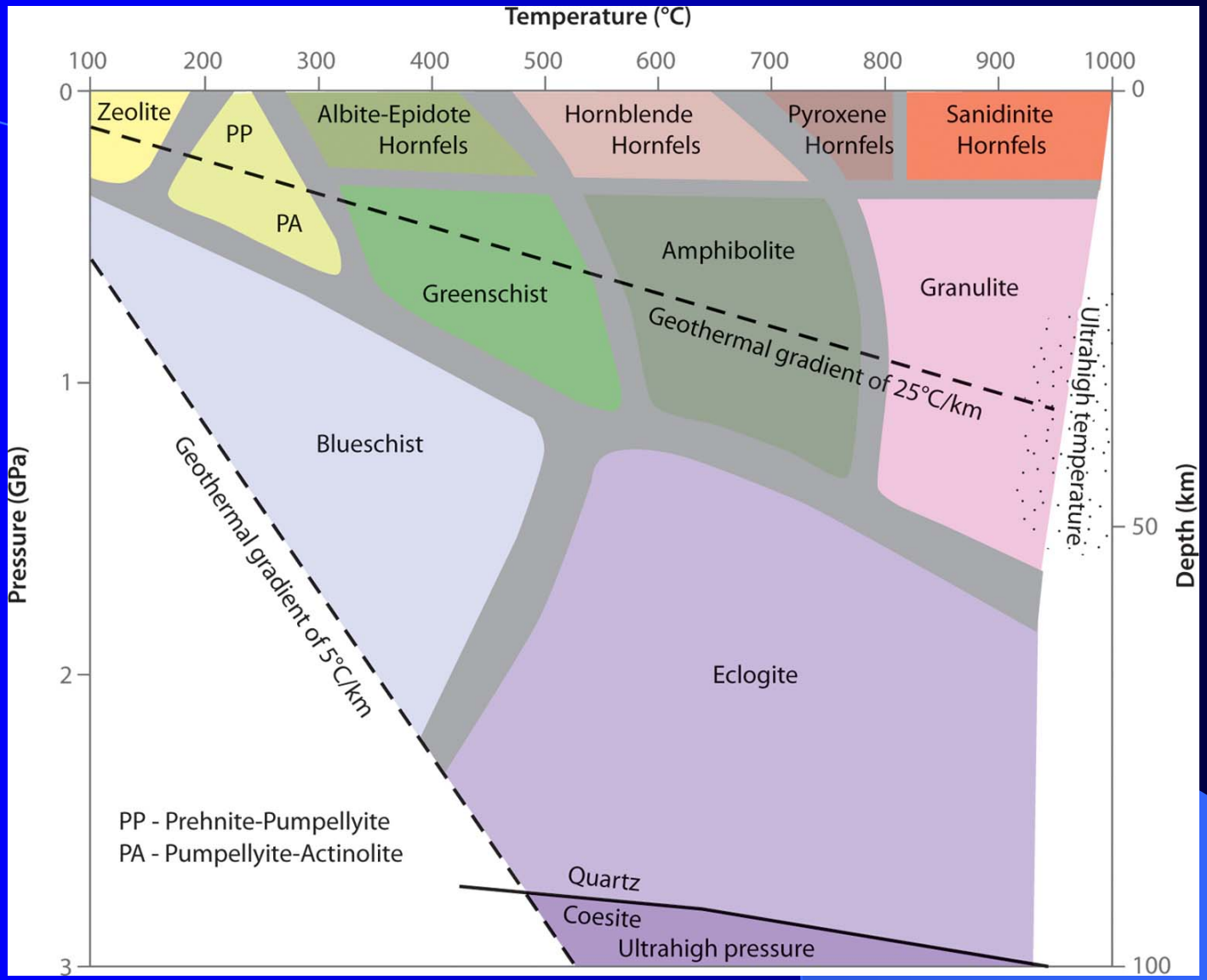
Chabazite

Result of low temperature hydrothermal alteration and/or metamorphism in the zeolite facies.

Other zeolite minerals – are analcime, clinoptilolite, heulandite, natrolite, phillipsite, and stilbite.

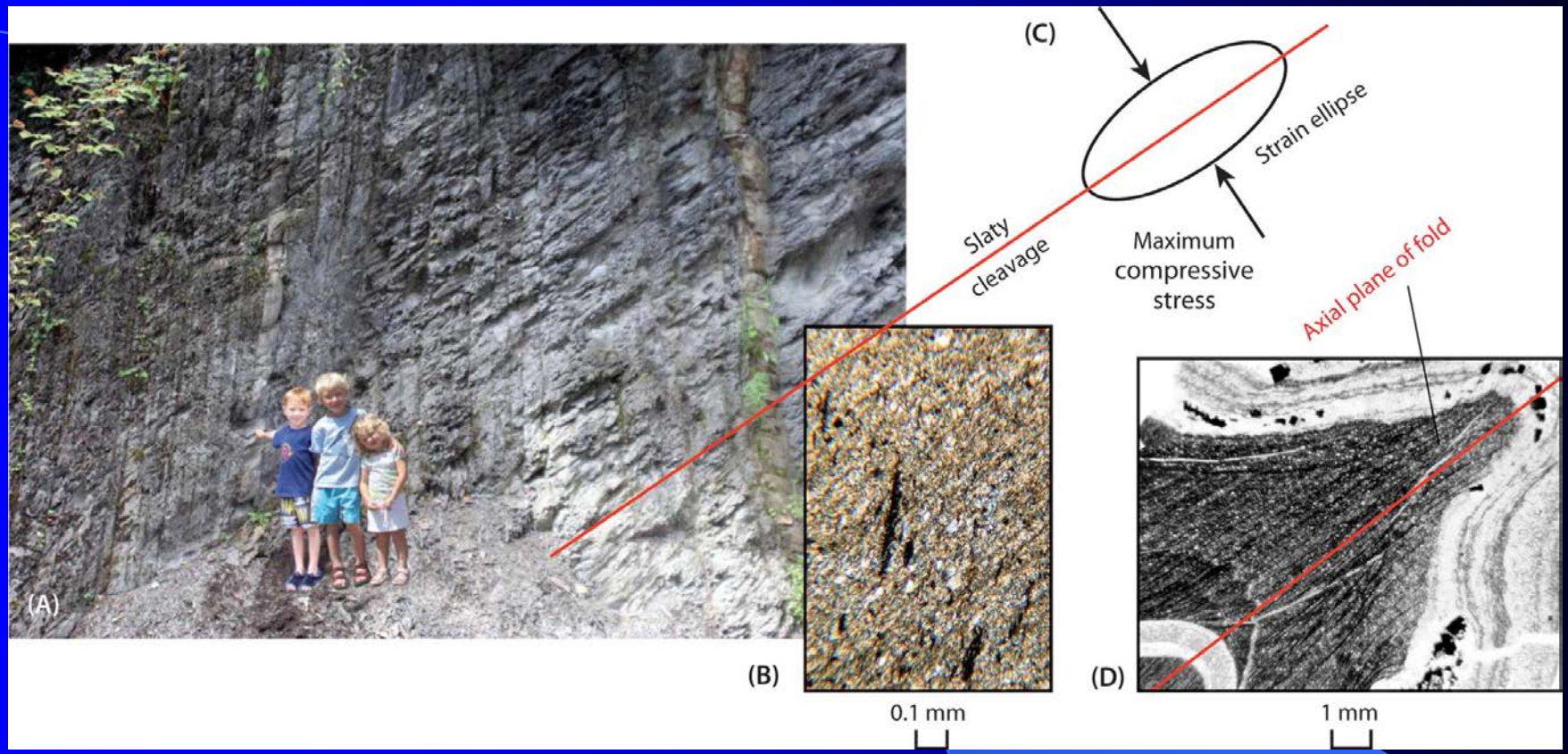


The concept of metamorphic facies states that for a given range of temperature and pressure and for a given rock composition, the assemblage of minerals formed during metamorphism is always the same

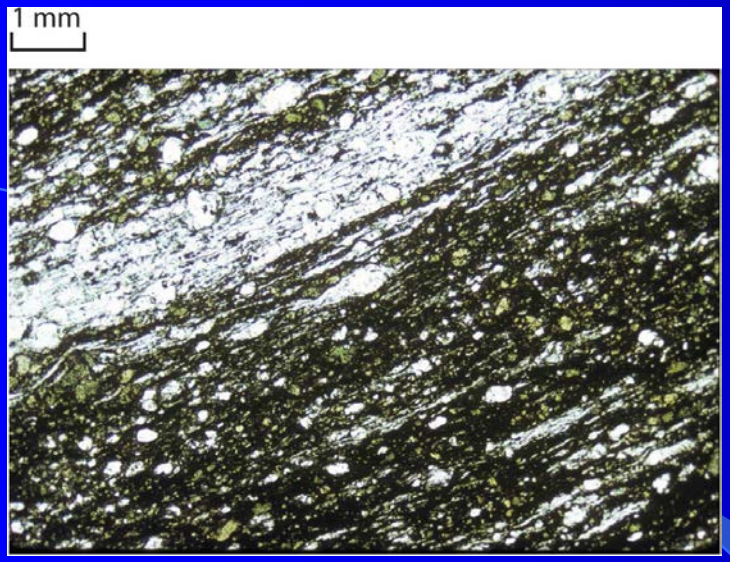


Deformation and textures of regional metamorphic rocks

Slaty cleavage dips to the left. Bedding near vertical.

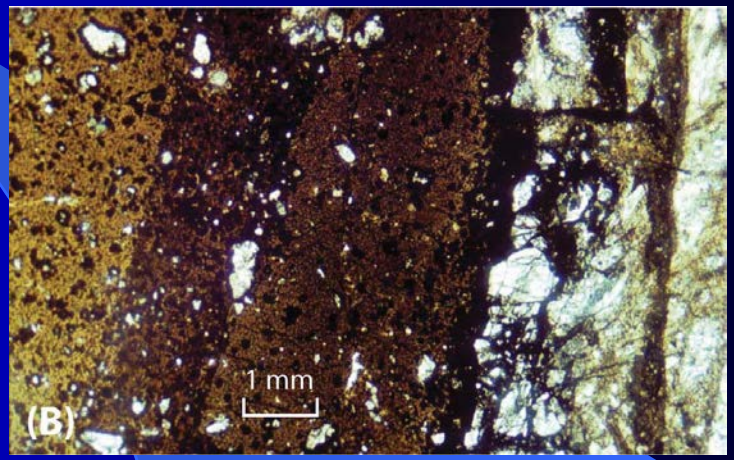


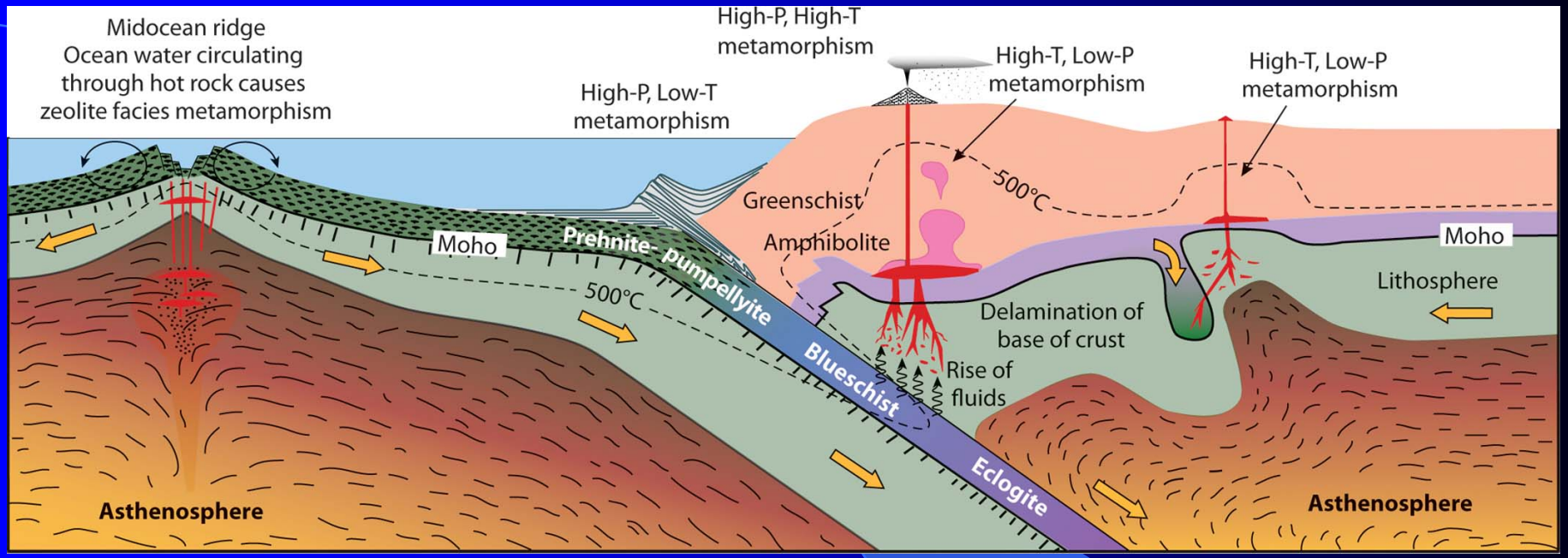
Boudinage



Plagioclase-hornblende mylonite

Black veins of pseudotachylite




Midocean ridge
Ocean water circulating
through hot rock causes
zeolite facies metamorphism
High-P, Low-T
metamorphism
High-P, High-T
metamorphism
High-T, Low-P
metamorphism
High-T, Low-P
metamorphism
Greenschist
Amphibolite
500°C
Moho
Prehnite-pumpellyite
Blueschist
Eclogite
500°C
Moho
Lithosphere
Delamination of
base of crust
Rise of
fluids
Asthenosphere
Asthenosphere