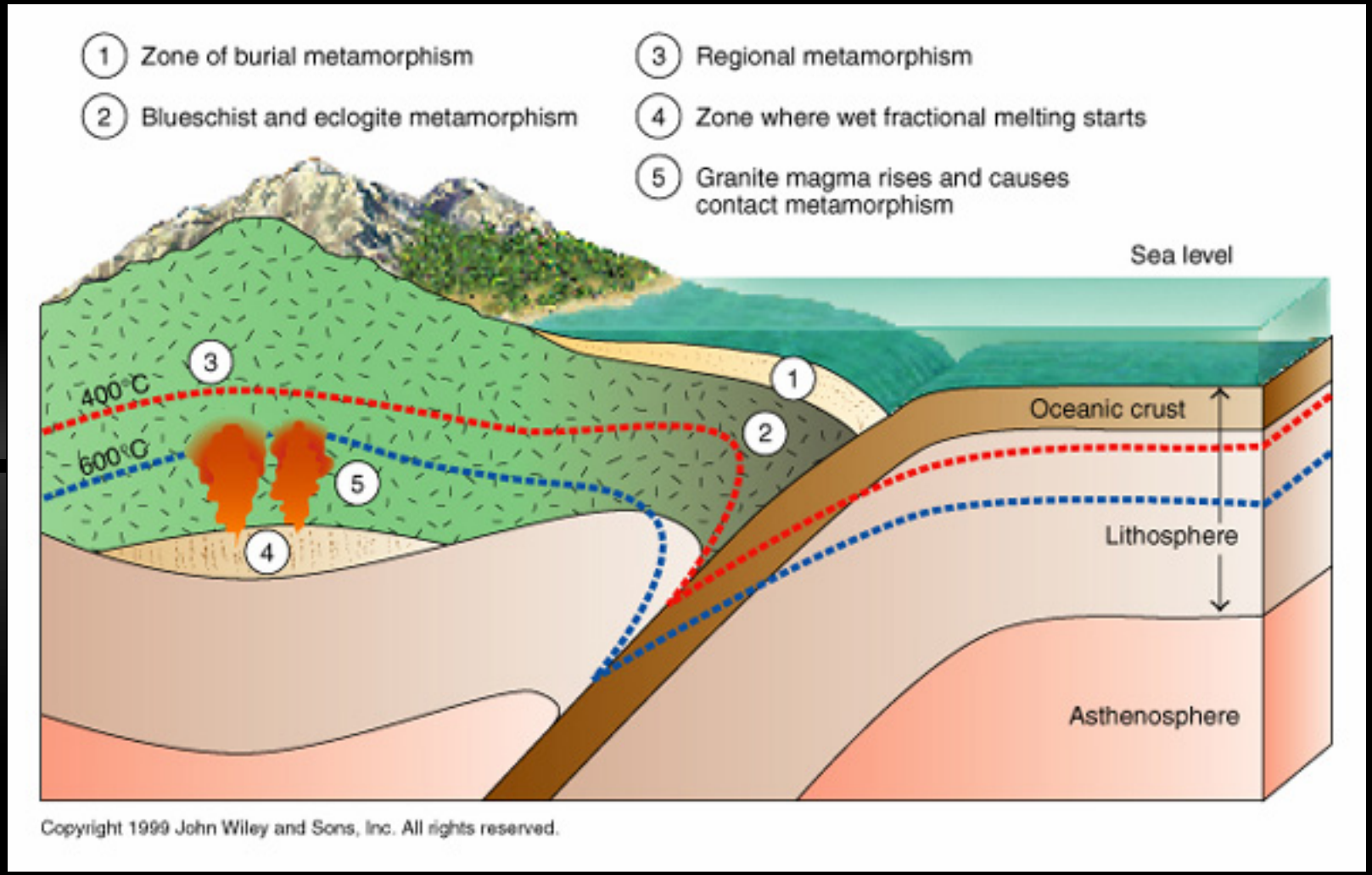
Types of Metamorphism



The Types of Metamorphism

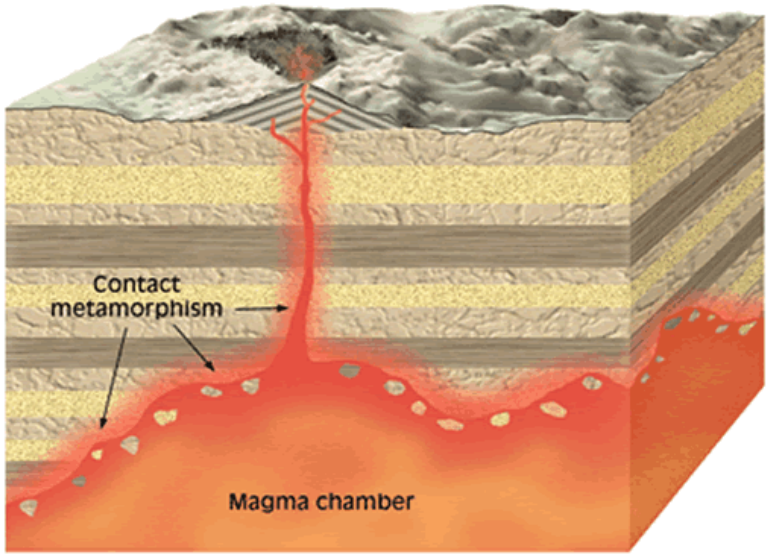
2 different approaches to classification

1. Based on principal process or agent
   - Dynamic Metamorphism
   - Thermal Metamorphism
   - Dynamo-thermal Metamorphism

The Types of Metamorphism

2. Based on setting
   1) Contact Metamorphism
   2) Regional Metamorphism
      Orogenic Metamorphism, Burial Metamorphism, Ocean Floor Metamorphism
   3) Fault-Zone Metamorphism
   4) Impact or Shock Metamorphism

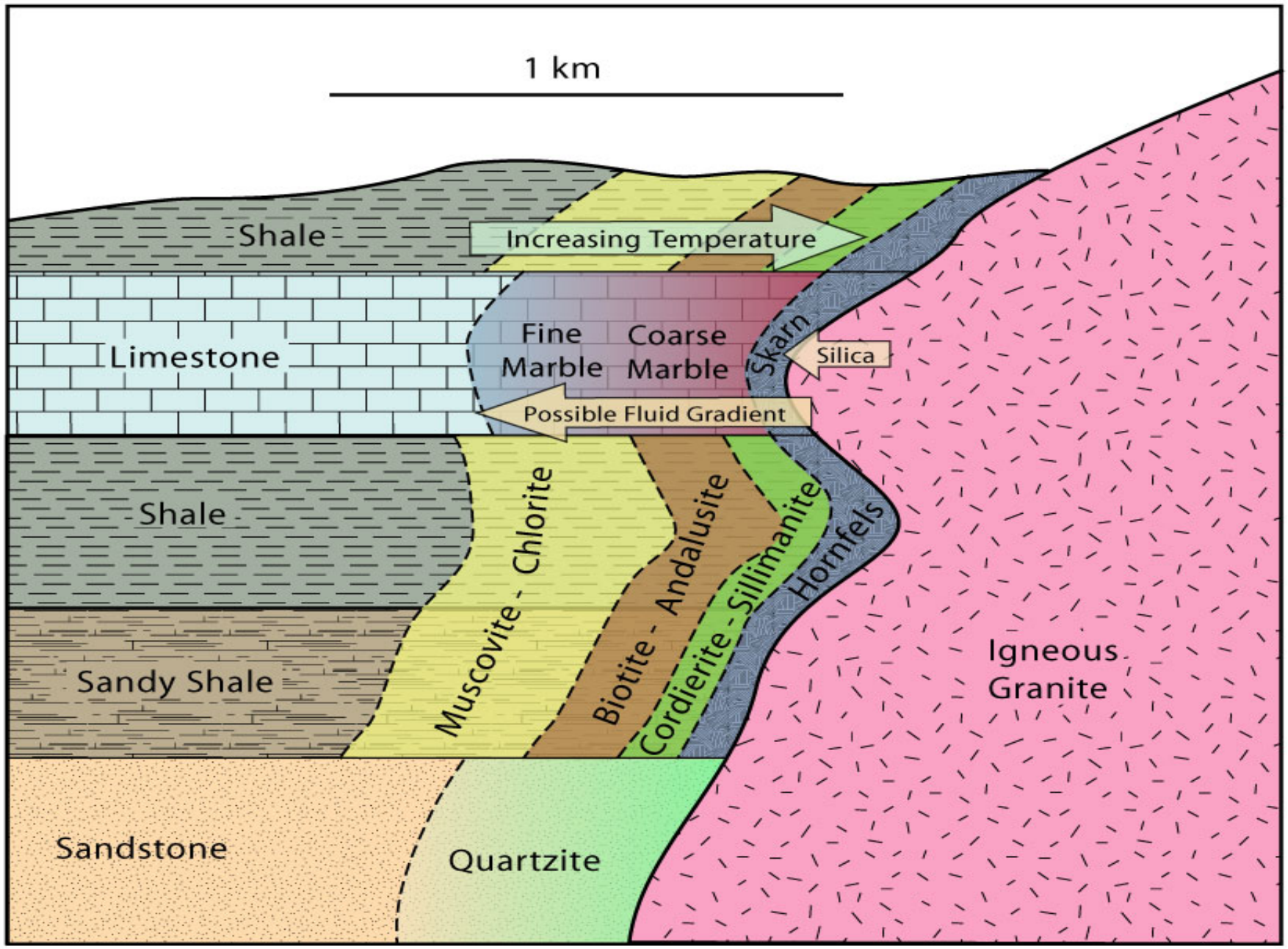
1. Contact Metamorphism



Adjacent to igneous intrusions (forms a contact aureole)

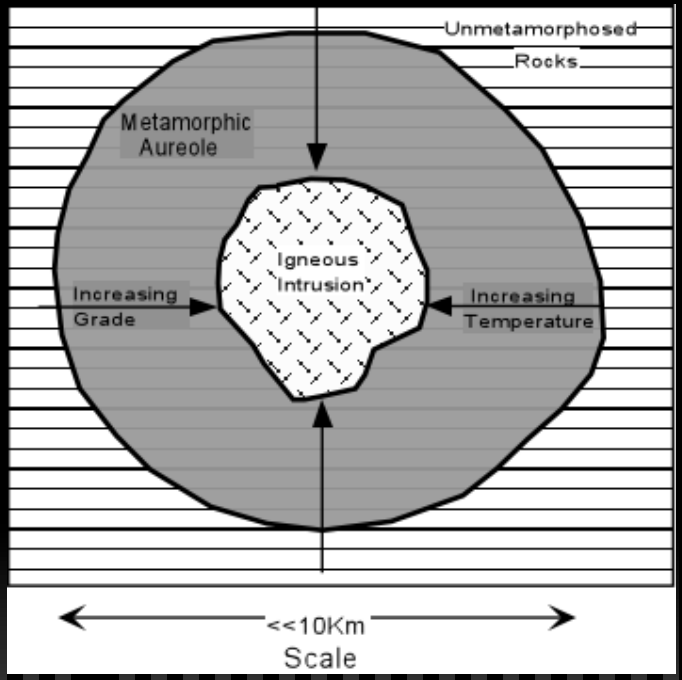
Thermal (± metasomatic) effects of hot magma intruding cooler shallow rocks

Occurs over a wide range of pressures, including **very low**


1 km
Shale
Increasing Temperature
Limestone
Fine Marble
Coarse Marble
Skarn
Silica
Possible Fluid Gradient
Shale
Muscovite - Chlorite
Biotite - Andalusite
Cordierite - Sillimanite
Hornfels
Sandy Shale
Igneous Granite
Sandstone
Quartzite

Contact aureole

View over the Race Track valley to the quartz-monzonitic Ubehebe Peak intrusion and its contact aureole. Ubehebe Peak belongs to a series of alkaline intrusions which formed the Hunter Mountain Batholith. The field area is located in the Death Valley National Park, CA (USA).



Hornfels

2. Regional Metamorphism

Metamorphism that affects a large body of rock, and thus covers a great lateral extent

Three principal types:

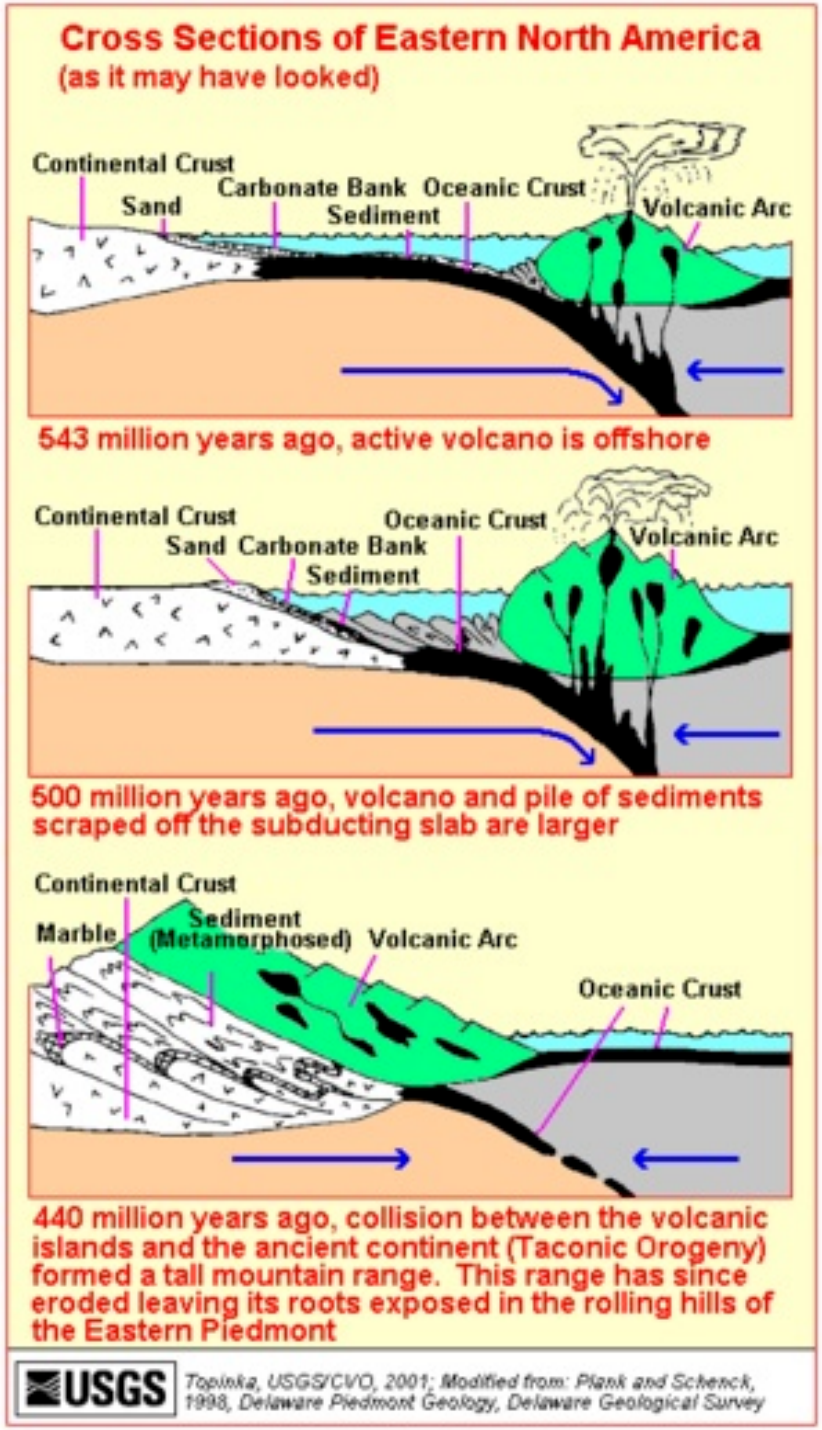
- Orogenic metamorphism
- Burial metamorphism
- Ocean-floor metamorphism

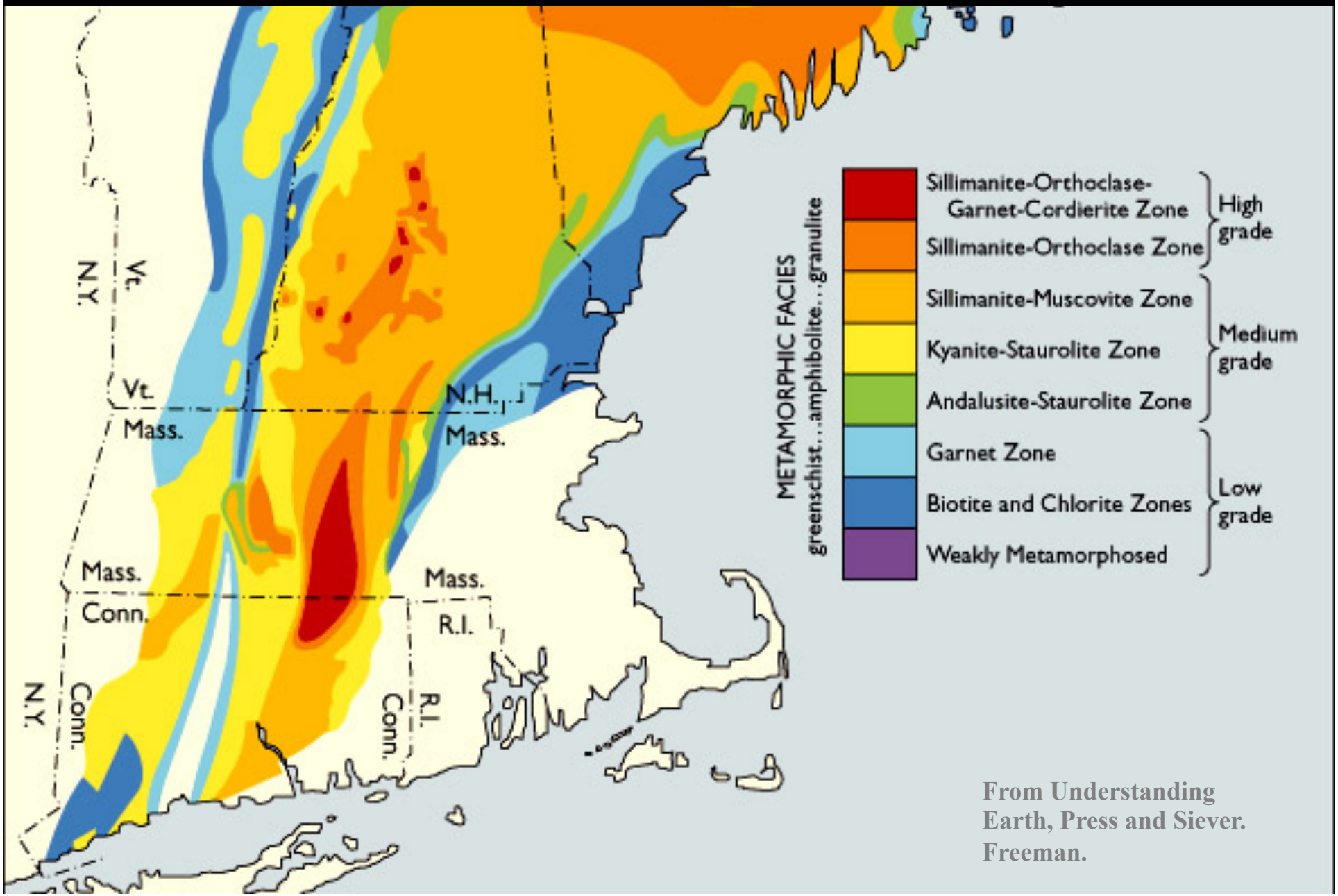
2a. Orogenic Metamorphism

Type of metamorphism associated with convergent plate margins

Dynamo-thermal: one or more episodes of orogeny with combined elevated geothermal gradients and deformation (deviatoric stress)

Orogenic Metamorphism





From Understanding Earth, Press and Siever. Freeman.

2b. Burial metamorphism

Occurs in areas that have not experienced significant deformation or orogeny

Restricted to large, relatively undisturbed sedimentary piles away from active plate margins

The Gulf of Mexico

Bengal Fan: sedimentary pile > 22 km, Extrap. → 250-300^{o}C at the base (P ~ 0.6 GPa)

2c. Ocean-Floor Metamorphism

Affects the oceanic crust at ocean ridge spreading centers

Considerable metasomatic alteration, notably loss of Ca and Si and gain of Mg and Na

Highly altered chlorite-quartz rocks- distinctive high-Mg, low-Ca composition

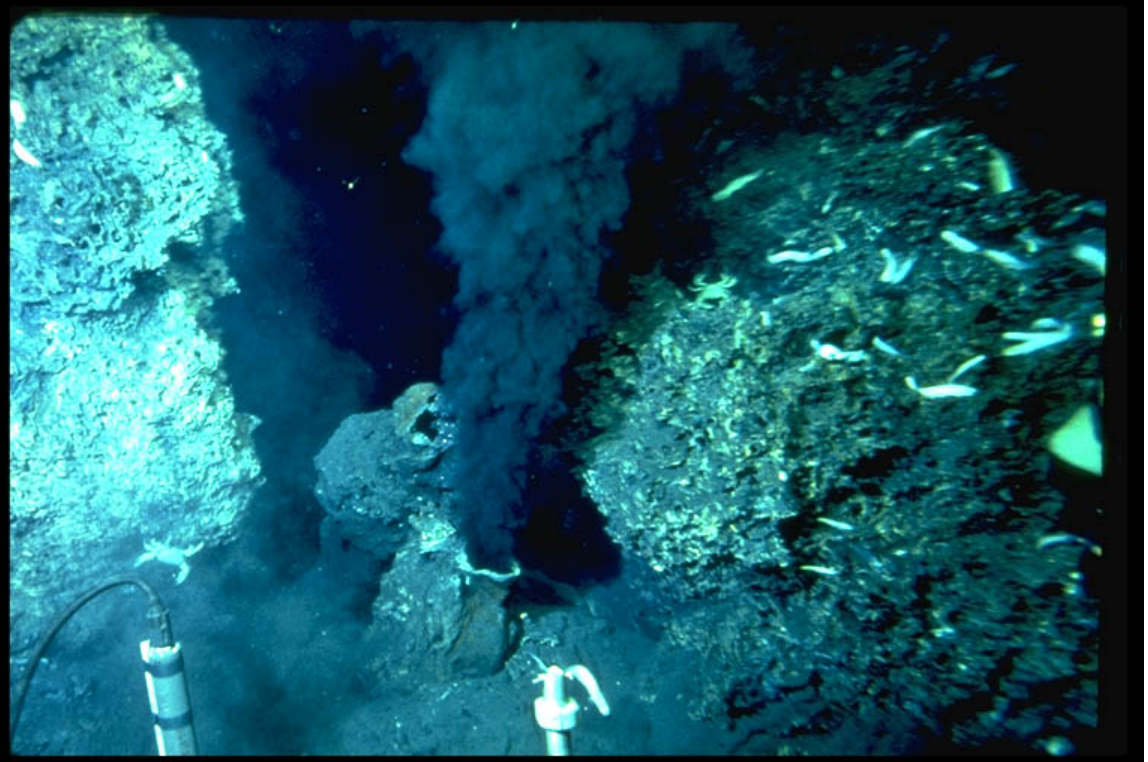
Exchange between basalt and hot seawater

Example of hydrothermal metamorphism

Ocean-Floor Metamorphism

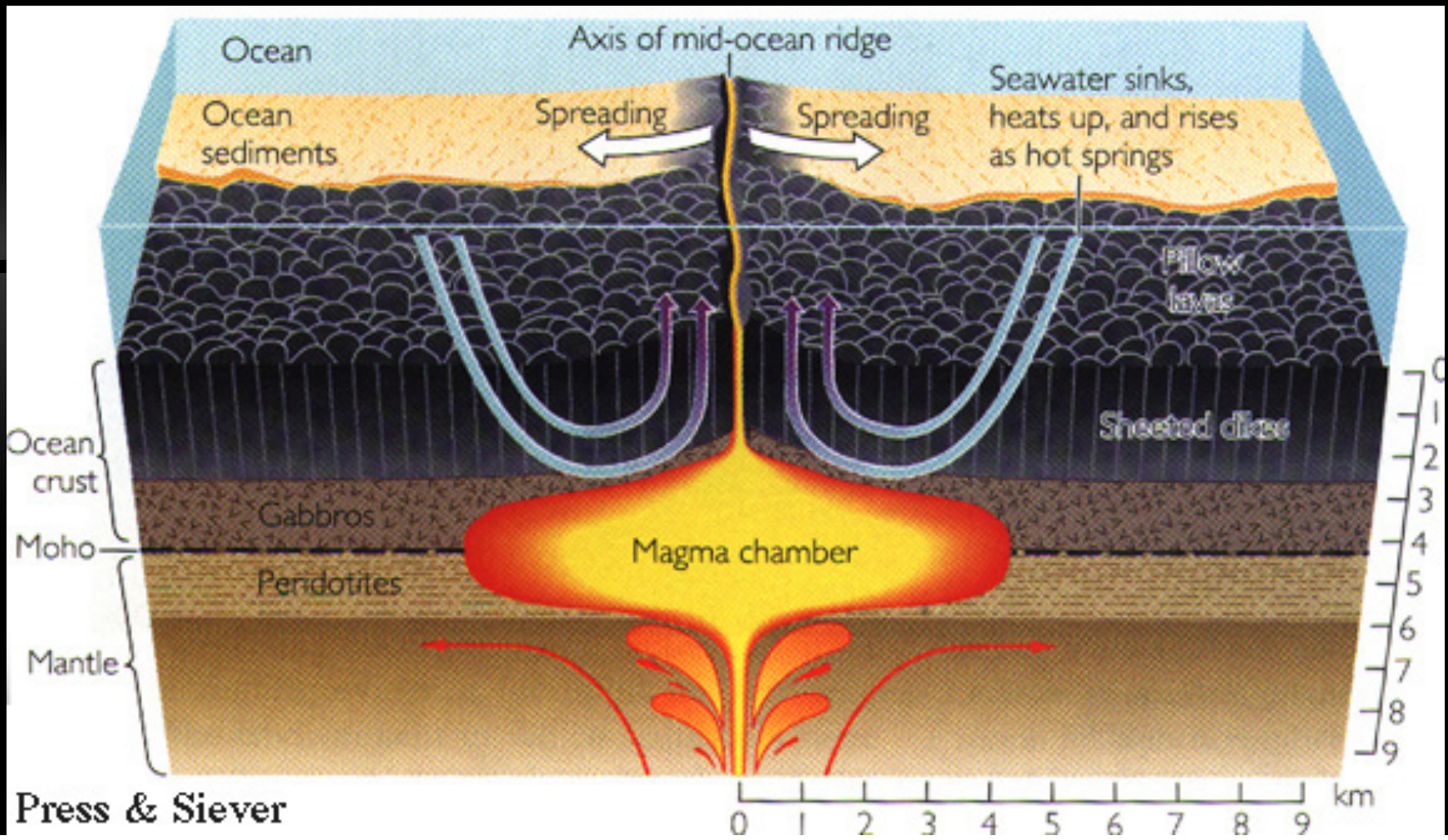
Hydrothermal metamorphism

Hot H_2O-rich fluids



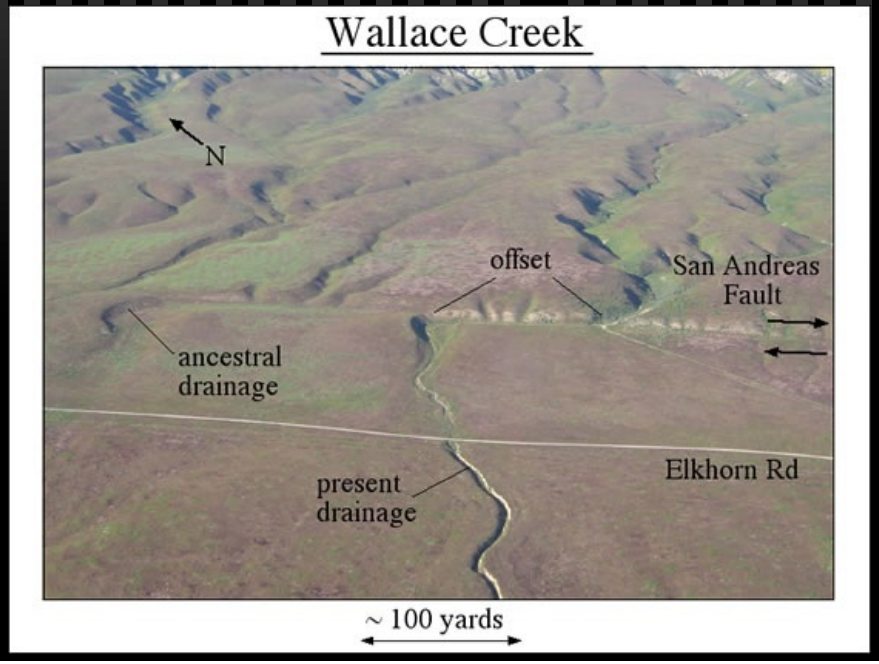
http://www.youtube.com/watch?v=EK9riJ-GpNU
http://www.youtube.com/watch?v=bCWsQ9OAc24&feature=related

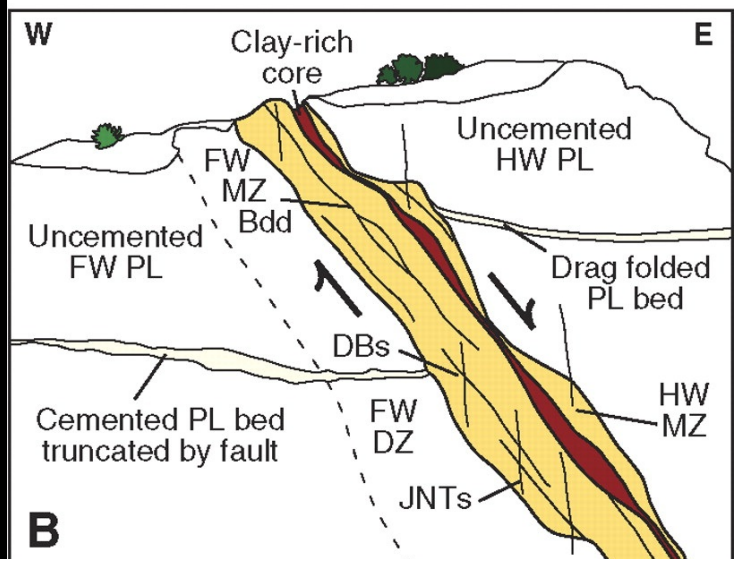
Mid Ocean Ridges



3. Fault-Zone metamorphism

High rates of deformation and strain with only minor recrystallization





(a) Shallow fault zone with fault breccia

(b) Slightly deeper fault zone (exposed by erosion) with some ductile flow and fault mylonite

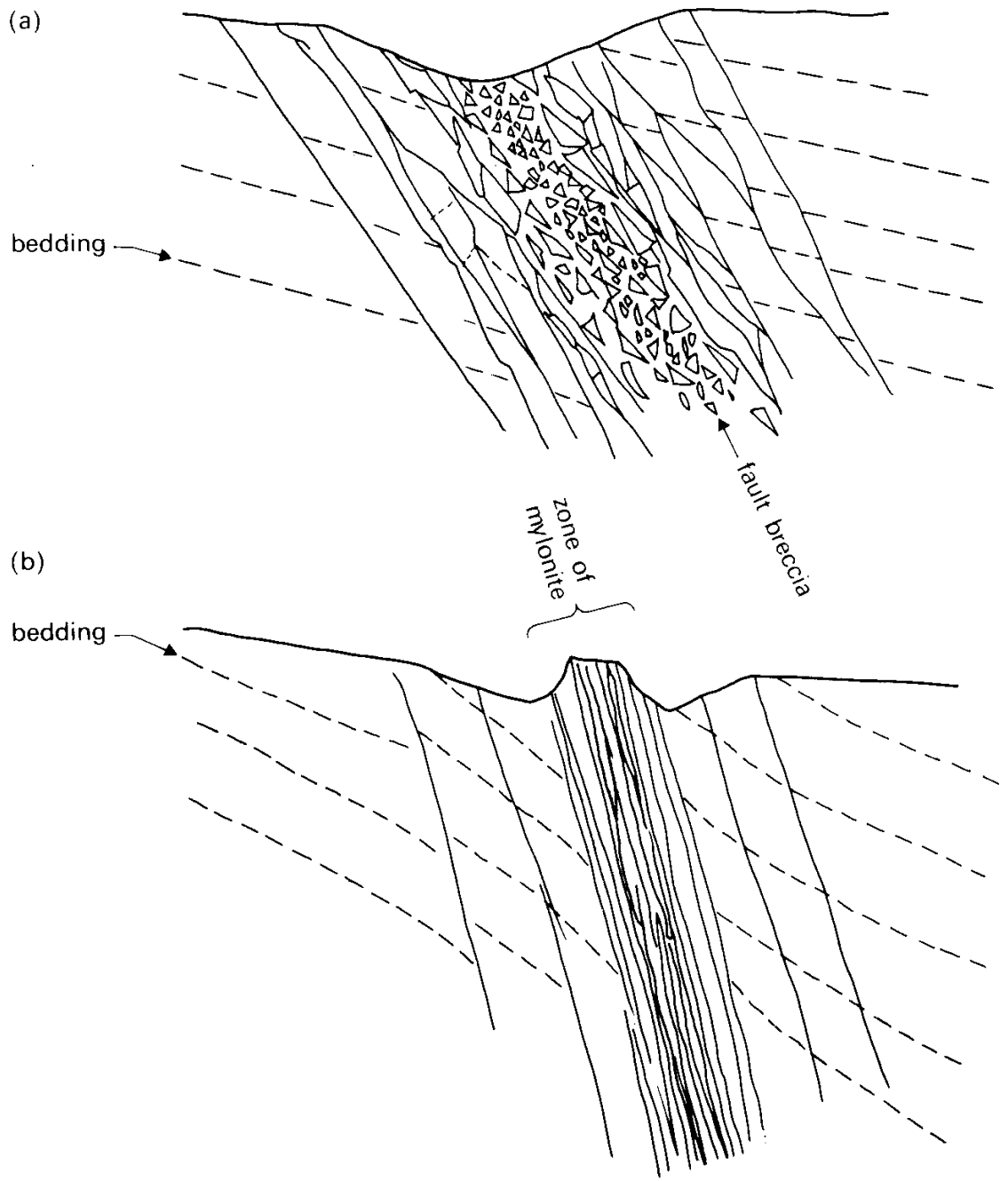


Figure 21-7. Schematic cross section across fault zones. After Mason (1978) *Petrology of the Metamorphic Rocks*. George Allen & Unwin. London.

4. Impact Metamorphism

Impact metamorphism at meteorite (or other bolide) impact craters

Dynamic metamorphism

(Aerial image by D. Roddy and K.Zeller, USGS)

The Progressive Nature of Metamorphism

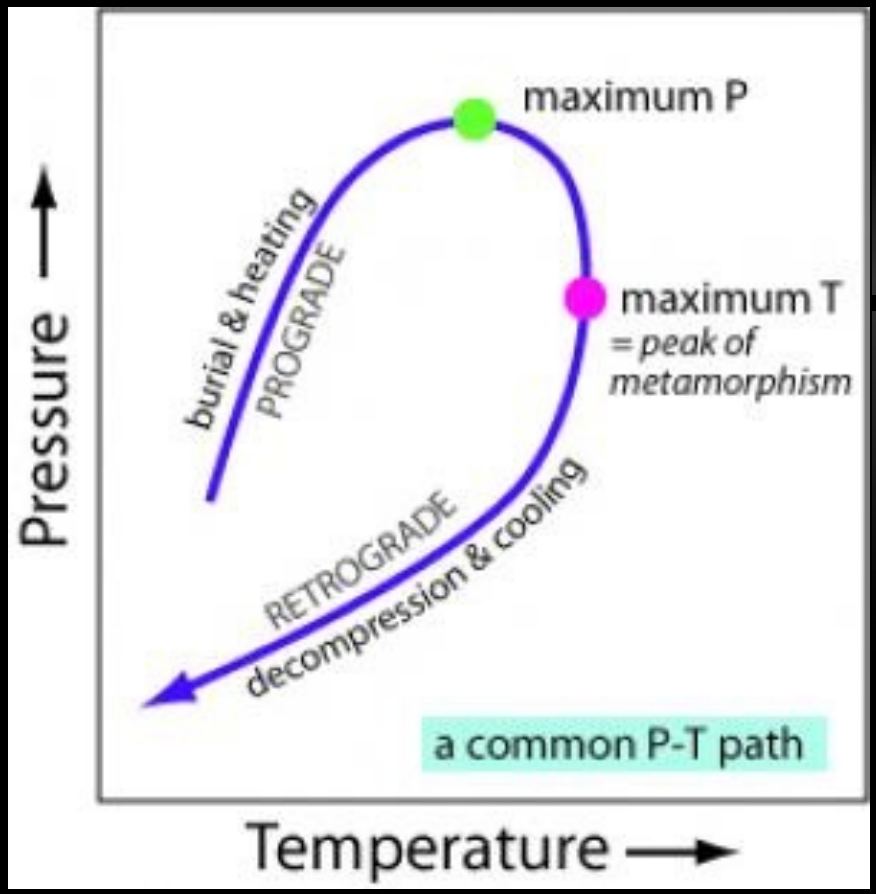
A rock at a high metamorphic grade **progressed** through a sequence of mineral assemblages rather than hopping directly from an unmetamorphosed rock to the metamorphic rock that we find today

Age of metamorphism??

Prograde and retrograde metamorphism

Prograde: increase in metamorphic grade with time as a rock is subjected to gradually more severe conditions

Retrograde: decreasing grade as rock cools and recovers from a metamorphic



Retrograde metamorphism typically of minor significance

Geothermometry indicates that the mineral compositions commonly preserve the maximum temperature

Why?

1. Prograde reactions are endothermic and easily driven by increasing T
2. Devolatilization reactions are easier than reintroducing the volatiles

Types of Protolith

Lump the common types of sedimentary and igneous rocks into six chemically based-groups

1. Ultramafic - very high Mg, Fe, Ni, Cr
2. Mafic - high Fe, Mg, and Ca
3. Shales (pelitic) - high Al, K, Si
4. Carbonates- high Ca, Mg, CO_2
5. Quartz - nearly pure SiO_2.
6. Quartzo-feldspathic - high Si, Na, K, Al