TYPES OF METAMORPHISM

Reading:

Winter Chapter 21.3 – 21.6

Types of Metamorphism

Based on principal process or agent

- Dynamic Metamorphism
- Thermal Metamorphism
- Dynamo-thermal Metamorphism

Setting Based Classification

- Contact Metamorphism
  - Pyrometamorphism
- Regional Metamorphism
  - Orogenic Metamorphism
  - Burial Metamorphism
- Ocean Floor Metamorphism
  - Hydrothermal Metamorphism
- Fault-Zone Metamorphism
- Impact or Shock Metamorphism

Contact Metamorphism

- Adjacent to igneous intrusions
- Result of thermal (and possibly metasomatic) effects of hot magma intruding cooler shallow rocks
- Occur over a wide range of pressures, including very low
- Contact aureole

Contact Metamorphism

The size and shape of an aureole is controlled by:

The nature of the pluton

Size
Shape
Orientation
Temperature
Composition

The nature of the country rocks

Composition
Depth and metamorphic grade prior to intrusion
Permeability

Contact Metamorphism

Most easily recognized where a pluton is introduced into shallow rocks in a static environment

– The rocks near the pluton are often high-grade rocks with an isotropic fabric: hornfelses (or granofelses) in which relict textures and structures are common

Contact Metamorphism

Polymetamorphic rocks are common, usually representing an orogenic event followed by a contact one

- Spotted phyllite (or slate)
- Overprint may be due to:
  - Lag time between the creation of the magma at depth during T maximum, and its migration to the lower grade rocks above
  - Plutonism may reflect a separate phase of post-orogenic collapse magmatism

Contact Metamorphism

Pyrometamorphism

Very high temperatures at very low pressures, generated by a volcanic or subvolcanic body

Also developed in xenoliths

Regional Metamorphism

sensu lato: metamorphism that affects a large body of rock, and thus covers a great lateral extent

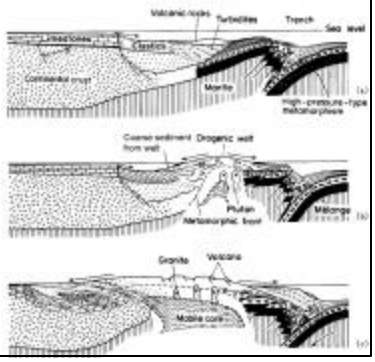
Three principal types:

- Orogenic metamorphism
- Burial metamorphism
- Ocean-floor metamorphism

Orogenic Metamorphism

- This type of metamorphism is associated with convergent plate margins
- Dynamo-thermal, involving one or more episodes of orogeny with combined elevated geothermal gradients and deformation (deviatoric stress)
- Foliated rocks are a characteristic product

Orogenic Metamorphism



Schematic model for the sequential (a ® c) development of a "Cordilleran-type" or active continental margin orogen. The dashed and black layers on the right represent the basaltic and gabbroic layers of the oceanic crust. From Dewey and Bird (1970) *J. Geophys. Res.*, 75, 2625-2647; and Miyashiro *et al*. (1979) *Orogeny*. John Wiley & Sons.

Orogenic Metamorphism

- Uplift and erosion
- Metamorphism often continues after major deformation ceases
  - Metamorphic pattern is simpler than the structural one
- Pattern of increasing metamorphic grade from both directions toward the core area

Orogenic Metamorphism

- Most orogenic belts have several episodes of deformation and metamorphism, creating a more complex polymetamorphic pattern
- Continental collision

Orogenic Metamorphism

- Batholiths are usually present in the highest grade areas
- If plentiful and closely spaced, may be called regional contact metamorphism

Burial Metamorphism

- Low -grade metamorphism in sedimentary basins
- Mild deformation and no igneous intrusions discovered
- Fine-grained, high-temperature phases, glassy ash: very susceptible to metamorphic alteration
- Metamorphic effects attributed to increased pressure and temperature due to burial
- Range from diagenesis to the formation of zeolites, prehnite, pumpellyite, laumontite, etc.

Hydrothermal Metamorphism

- Caused by hot H_2O-rich fluids and usually involving metasomatism Coombs (1961)
- Difficult type of metamorphism to constrain, since hydrothermal effects often play some role in most of the other types of metamorphism

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?

Bengal Fan Example

- The sedimentary pile > 22 km
- Extrapolating $\rightarrow$ 250-300^{o}C at the base (P ~ 0.6 GPa)
- Well into the metamorphic range and the weight of the overlying sediments sufficient to impart a foliation at depth
- Passive margins often become active
- Areas of burial metamorphism may thus become areas of orogenic metamorphism

Ocean-Floor Metamorphism

- Affects the oceanic crust at ridge spreading centers
- Wide range of temperatures at relatively low pressure
- Metamorphic rocks exhibit considerable metasomatic alteration, notably loss of Ca and Si and gain of Mg and Na
- These changes can be correlated with exchange between basalt and hot seawater

Ocean-Floor Metamorphism

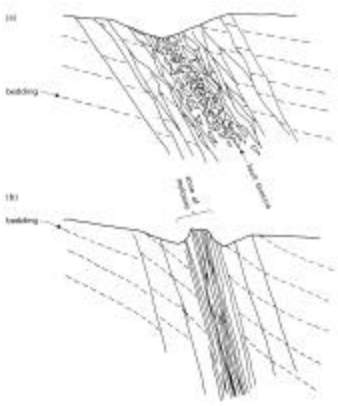
- May be considered another example of hydrothermal metamorphism
- Highly altered chlorite-quartz rocks-distinctive high-Mg, low-Ca composition

Fault-Zone and Impact Metamorphism

- Occurs in areas experiencing relatively high rates of deformation and strain with only minor recrystallization
- Impact metamorphism ("shock metamorphism") occurs at meteorite (or other bolide) impact craters
- Both fault-zone and impact metamorphism correlate with dynamic metamorphism, based on process

(a) Shallow fault zone with fault breccia

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



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