LECTURE Sixteen: Introduction to Metamorphism

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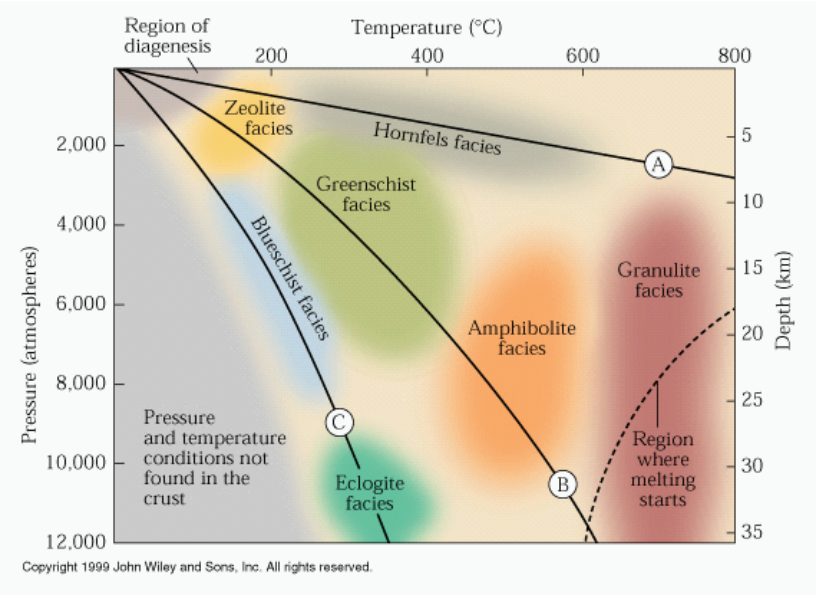
DEFINITION OF METAMORPHISM

Metamorphism is a subsolidus process leading to changes in mineralogy and/or texture (for example grain size) and often in chemical composition in a rock. These changes are due to physical and/or chemical conditions that differ from those normally occurring at the surface of planets and in zones of cementation and diagenesis below this surface. They may coexist with partial melting."

LIMITS OF METAMORPHISM

Low temperature grades into diagenesis
High temperature grades into zoe of melting and thus region of igneous rocks
Boundaries in both cases can be fairly arbitrary



AGENTS OF METAMORPHIC CHANGE

- **Temperature**
- **Pressure**
- **Stress and Strain**
- **Fluids**

TEMPERATURE: typically the most important factor in metamorphism. Increasing temperature has several effects

1. Promotes recrystallization leading to increased grain size
2. Drive reactions that consume unstable mineral(s) and produces new minerals that are stable under the new conditions
3. Overcomes kinetic barriers that might otherwise preclude the attainment of equilibrium

PRESSURE: Normal gradients may be perturbed in several ways. The two main examples are:

1. High T/P geotherms in areas of plutonic activity or rifting
2. Low T/P geotherms in subduction zones

STRESS and STRAIN

- Stress is an applied force acting on a rock (over a particular cross-sectional area)
- Strain is the response of the rock to an applied stress (= yielding or deformation)
- Deviatoric stress affects the textures and structures, but not the equilibrium mineral assemblage
- Strain energy may overcome kinetic barriers to reactions

METAMORPHIC FLUIDS

Evidence for the existence of a metamorphic fluid comes from fluid inclusions, the existence of hydrous or carbonate phases, and reactions that involve volatiles
P_{fluid} indicates the total fluid pressure, which is the sum of the partial pressures of each component ($P_{fluid} = p_{H_2O} + p_{CO_2} + \ldots$)

May also consider the mole fractions of the components, which must sum to 1.0 ($X_{H_2O} + X_{CO_2} + \ldots = 1.0$)

METAMORPHIC GRADE

A general increase in degree of metamorphism without specifying the exact relationship between temperature and pressure, although generally both temperature and pressure increase

- Low Grade
- Medium Grade
- High Grade

PROGRADE: increase in metamorphic grade with time as a rock is subjected to gradually more severe conditions
Prograde metamorphism: changes in a rock that accompany increasing metamorphic grade

RETROGRADE: decreasing grade as rock cools and recovers from a metamorphic or igneous event
Retrograde metamorphism: any changes that accompany decreasing metamorphic grade

How do we see metamorphic change?
1. Mineral assemblage and grainsize can be used to estimate metamorphic grade; 2. Gradients in T, P, Xfluid across an area; 3. Zonation in the mineral assemblages

CLASSIFICATION OF METAMORPHIC ROCKS: 1.Based on setting: Contact Metamorphism (Pyrometamorphism) and Regional Metamorphism (Orogenic Metamorphism, Burial Metamorphism, Ocean Floor Metamorphism)

Contact Metamorphism: Adjacent to igneous intrusions as a result of thermal (and possibly metasomatic – involvement of fluids) effects of hot magma intruding cooler shallow rocks, usually leads to the formation of a contact aureole around the pluton. The size and shape of an aureole is controlled by: 1. The nature of the pluton (Size, Shape, Orientation, Composition, Temperature) and the nature of the country rocks (Composition, Depth and metamorphic grade prior to intrusion, Permeability)

Regional Metamorphism: metamorphism that affects a large body of rock, and thus covers a great lateral extent. Type of metamorphism 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