

Metamorphism and Metamorphic Rocks

1. Definitions
 - a. Metamorphism – mineralogical, chemical, and physical changes that occur in solid rocks.
Occurs at depths greater than that of lithification (Diagenesis).
 - b. Solid-state recrystallization – changes that occur without the rock melting (rocks that melt are igneous).
2. Factors influencing Metamorphism
 - a. Temperature
 - i. Below about 150°C, most minerals are stable (little or no metamorphism)
 - ii. Above 150°C, reaction rate increases as temperature increases, new minerals begin to form
 - iii. Above 600°C, some minerals begin to melt (transition to igneous rocks)
 - iv. Temperature a function of depth within the Earth and the presence of a magma
 - b. Pressure
 - i. As pressure increases, pore spaces reduced and density increases, pore fluids are expelled
 - ii. Minerals recrystallize and begin to realign
 - iii. Differential stress
 - iv. Pressure is greater in one direction than in another
 - v. Effects of Stress
 - vi. Differential Stress
 - vii. Foliation – a metamorphic rock texture due to alignment of minerals as a result of differential stress
 - viii. Slaty cleavage – foliation that develops at low temperature and pressure (metamorphosed shale)
 - c. Fluid
 - i. Pore fluids (water and carbon dioxide)
 - ii. As pressure increases, pore fluids are expelled
 - iii. Pore fluids increase the rate of metamorphic reactions by:
 - iv. Storing ions involved in reactions
 - v. Moving ions from one place to another
 - vi. Chemical Fluids from Magmas
 - vii. Carry ions from the melt
 - viii. Fluids increase the temperature in the rock
 - ix. Veins
 - x. Solutions are deposited in fractures and joints
 - d. Time
 - i. Solid state recrystallization is a slow process
 - ii. In general, size of minerals increases with time
 - e. a, b, & c are referred to as agents of metamorphism
3. Preferred Mineral Orientation (Not covered in lecture see book – p. 211)
 - a. Ductile (plastic) Deformation

- b. Pressure Solution
 - c. Grain Rotation
 - d. Growth in Preferred Orientation
4. Types of Metamorphism
- a. Burial Metamorphism
 - i. Most common type, occurs where crust is greater than 5 km thick
 - ii. Relatively low temperature and pressure (low grade metamorphism)
 - iii. Maximum stress vertical, foliation parallel to ground surface
 - b. Contact metamorphism
 - i. Occurs in rocks around a magma body
 - ii. High temperature (heat from magma) “bakes” the rock around the magma creating an alteration zone called an aureole
 - iii. High temperature & fluid primary agents, little to no pressure (occurs at shallow depths in the crust)
 - c. Regional metamorphism
 - i. Large scale – large volume of rock is affected
 - ii. Associated with convergent plate margins and mountain building
 - iii. Folding and faulting increase thickness of the crust
 - iv. Occurs over a range of temperatures and pressures
 - v. Fluids are also present
 - vi. Low grade to high-grade metamorphism
 - vii. Will have zones of contact metamorphism
5. Metamorphic Grade
- a. As pressure and/or temperature increases, the grade of metamorphism increases
 - b. Low Grade Metamorphism
 - i. Example: Slate
 - ii. Rocks become more dense and compact
 - iii. Forms at low temperature and pressure
 - iv. Microscopic crystals
 - v. Dull luster
 - vi. Clay and mica minerals
 - vii. Foliated
 - viii. Low Grade - Slate
 - c. Intermediate Grade Metamorphism
 - i. Example: Phyllite
 - ii. Intermediate temperature and pressure
 - iii. Small crystals
 - iv. Shiny luster
 - v. Mostly mica minerals
 - vi. Foliated
 - vii. Intermediate Grade – Phyllite
 - d. Intermediate-High Grade Metamorphism
 - i. Example: Schist
 - ii. High temperature and pressure

- iii. Large crystals
 - iv. Mica-rich
 - v. Foliated
 - e. High Grade Metamorphism
 - i. Example: Gneiss
 - ii. High temperature and pressure
 - iii. Large crystals
 - iv. Mica-poor
 - v. Foliated
 - vi. High Grade - Gneiss
- 6. Non-foliated Metamorphic Rocks
 - a. Granular texture
 - b. Interlocking grains
 - c. Composed primarily of one mineral
 - d. Uniform grain size
 - e. Nonfoliated - Marble
 - f. Nonfoliated - Quartzite
- 7. Metamorphic Facies
 - a. Different minerals form at different temperatures and pressures
 - b. Group of stable minerals define a facies
- 8. Metamorphism & Plate Tectonics