**Metamorphic Rocks**

- **METAMORPHISM:** a process that occurs typically at elevated temperature and pressure to produce changes in texture and assemblage of minerals present in the original, or parent rock.

- Includes **recrystallization:** making new minerals from original minerals, or changing the texture of the rock.

- Metamorphism is a solid state transformation.

**Factors of Metamorphism**

- **High temperature:** lower limit ~150°C (diagenesis) and upper limit ~ 700°C to 900°C (melting of granite or basalt)

- **High pressure:** commonly due to overlying rock or force applied during mountain building

- **Shear stress:** deformation of rock, typically in association with mountain building

- **Presence of fluids** (especially H2O): active in making and breaking chemical bonds

**Styles of Metamorphism**

- **Contact metamorphism**
  - Achieved as heat energy passes from a cooling body of magma into the enclosing (or host) rock
  - Occurs at **high temperature** and (typically) low pressure
  - Normally affects a small area.

- **Regional metamorphism**
  - Associated with mountain-building
  - **High temperature, high pressure and shear stress**
  - Affects a large area.

**Metamorphic Grade**

- **Low-grade (mild) metamorphism:** small changes in texture and/or mineralogy of parent rock (150-200°C)

- **High-grade (extreme) metamorphism:** radical changes in texture and/or mineral composition of the rock

**Metamorphic Texture**

- **Foliation:** Parallel alignment of platy or elongate mineral grains (mica/amphibole) in a rock caused by directed stress.

- Foliated textures:
  - **slaty cleavage:** parallel alignment of microscopic platy minerals (mainly mica). LOW-GRADE METAMORPHISM
  - **phyllic texture:** parallel, but wavy, foliation of fine-grained platy minerals (mainly mica and chlorite) exhibiting a shiny or glossy luster. LOW-GRADE METAMORPHISM
  - **schistosity:** parallel to sub-parallel foliation of medium to coarse-grained platy minerals. INTERMEDIATE TO HIGH-GRADE METAMORPHISM
  - **gneissic layering:** discontinuous light and dark layering due to mineral segregation. INTERMEDIATE TO HIGH-GRADE METAMORPHISM

- **Nonfoliated** texture:
  - absence of parallel layers of platy minerals
  - may exhibit stretched grains (ductile deformation)
  - normally composed of stubby, interlocking grains approximately the same size
Textural Changes

- Other changes that can occur during metamorphism:
  - Crystals grow in size.
  - Minerals can become segregated from one another to form compositional layering (as in gneiss).
  - Crystal shapes can become distorted (ductile deformation).
  - New minerals can form:
    - polymorphic transformation
    - reshuffling of atoms to form new minerals with no change in bulk chemical composition

Mineral Assemblages

- Depend upon:
  - chemical composition of parent rock
  - intensity of metamorphism (involving temperature, pressure, shear stress)

Mineral assemblage can change with no change in bulk chemical composition.

Shear Stress (directed stress)

- Distortion or deformation (change in shape or size, or both)
- Development of lineation: single, preferred orientation of elongated crystals (such as hornblende)
- Development of foliation: crystals with platy habit (such as mica) lining up parallel

Index Minerals

- Diagnostic minerals indicate restricted range of pressure-temperature conditions of metamorphism.
- General appearance with increasing metamorphism:
  - Low grade to high grade
  - Mica appears (clay disappears) garnet and staurolite appear; amphibole increases (mica disappears)
  - H₂O-rich to H₂O-absent

Increasing Metamorphic Grade

Mudstone/shale → slate → phyllite → schist → gneiss
(fine-grained) → (medium-coarse grained)

Bulk Composition

- Although a mineral assemblage may change with an increasing grade of metamorphism, the bulk chemical composition of the original parent rock commonly does not change (except for loss of water).
- Examples:
  - Quartz sandstone → quartzite
  - Limestone/dolomite → marble
  - Basalt → amphibolite
  - Granite → granite gneiss