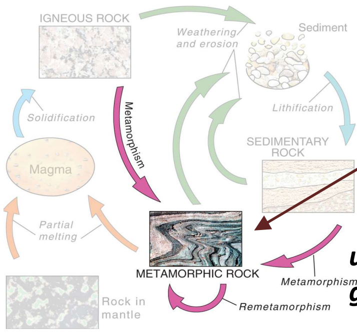
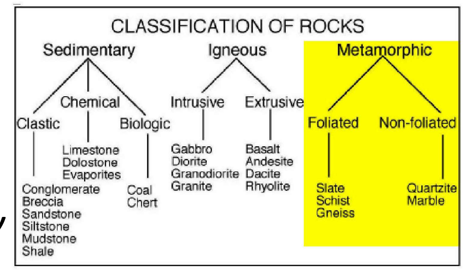


Metamorphic rocks in the Rock Cycle

Chapter Outlines

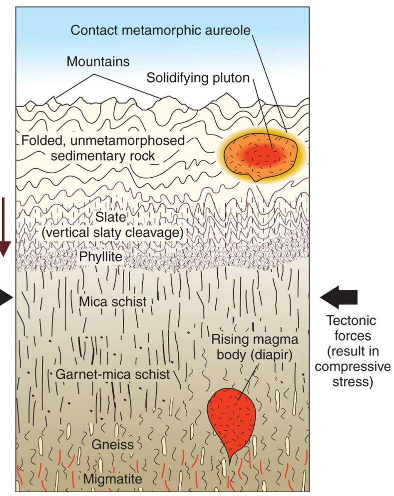
NOTE: This is intended to help students 'organize' their understanding of each topic. It is not a comprehensive study guide for quizzes or midterms, i.e. study your text!



Metamorphic Rocks

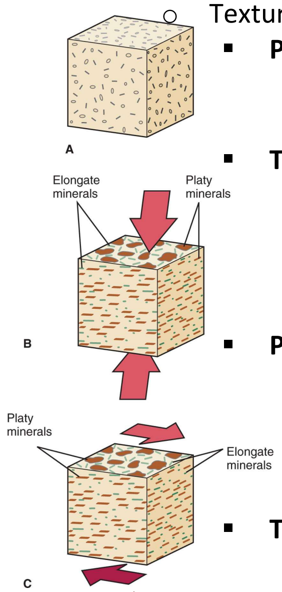
When rocks are subjected to deep burial, tectonic forces such as folding, high pressures, and high temperatures, the textures and mineral compositions begin to change. This process, called **metamorphism**, is the solid-state transformation *(no melting)* of a rock mass into a rock of generally the same chemistry but with different textures and minerals.

Grades of metamorphism increase with depth (higher t° and pressure)



Factors Controlling Metamorphic Rock Characteristics

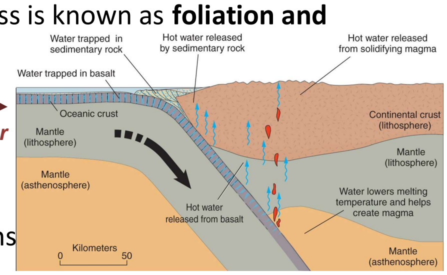
- In general, metamorphism causes:
  - Growth of new minerals
  - Deformation and rotation of mineral grains
  - Recrystallization of minerals as larger grains
  - Production of strong brittle rock
- Texture and mineral content of metamorphic rocks depend on:
  - **Parent rock composition**
    - usually no new material is added to rock during metamorphism
    - resulting metamorphic rock will have similar composition to parent rock
  - **Temperature**
    - heat for metamorphism comes from **Earth's deep interior**
    - all minerals are stable over a **finite temperature range**
    - if this range is exceeded, **new minerals** result
    - if temperature gets high enough metamorphism ends as **melting occurs**
  - **Pressure**
    - **confining pressure** is stress applied equally in all directions
    - pressure is directly proportional to **depth** within the Earth
      - increases ~1 kilobar/3.3 km *(1 bar ≈14.5psi)*
    - the resulting high-pressure minerals are **more compact/more dense**
  - **Tectonic forces**
    - often lead to stresses that are not equal in all directions ***(differential stress)***
    - **compressive stress** causes flattening of grains perpendicular to stress
    - **shearing** causes flattening by sliding parallel to stress
    - planar rock texture of aligned minerals produced by differential stress is known as **foliation and banding**
    - these effects increase with pressure and time



Differential stress causing alignment of minerals & grains

- **Fluids**
  - hot water *(often as vapor)* is most important
  - rising temperature causes water to be released from unstable minerals
  - hot water is very reactive; acts as a rapid transport agent for mobile ions

Available water for metamorphism



- **Time**
  - metamorphism, particularly from high pressures, may take millions of years
  - longer times allow newly stable minerals to grow larger and increase foliation

Metamorphic Rock Classification

- **Rock texture**
  - **foliated** *(layered)* vs. **non-foliated** *(non-layered)*

Gneiss (foliated)

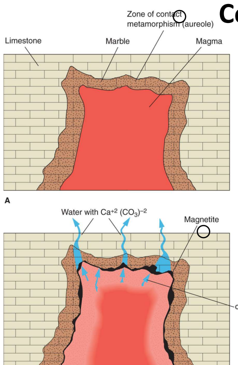
Quartzite (non-foliated)

        - foliated rocks *(including banded appearance)* are named based on type of foliation (slaty, schistose, gneissic)
        - **migmatic** – results from partial melting *(see illustration further below)*
        - non-foliated rocks are named based on composition

    - There are a limited number of common metamorphic rock names including:

ROCK NAME	TEXTURE	PARENT ROCK	CHARACTERISTICS
SLATE	foliated	shales and muds	prominent splitting surfaces
SCHIST	foliated	fine grained rocks	mica minerals, often crinkled or wavy
GNEISS	foliated	coarse grained rocks	dark and light bands or layers of aligned minerals
QUARTZITE	non-foliated	sandstone	interlocking almost fused quartz grains, little or no porosity
MARBLE	non-foliated	limestone	interlocking, often coarse, calcite crystals, little or no porosity

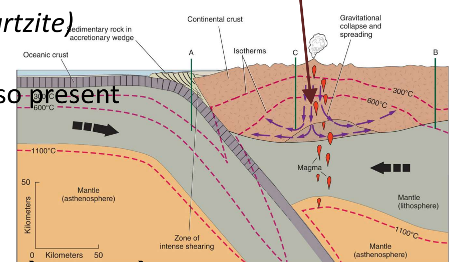
Types of Metamorphism



Contact Metamorphism, resulting from magma intrusion

- **Contact metamorphism**
    - **high temperature** is dominant factor
    - produces **non-foliated** rocks
    - occurs adjacent to magma bodies intruding cooler country rock
    - occurs in narrow zone *(~1-100 m wide)* known as contact **aureole**
    - rocks may be fine- *(e.g., hornfels)* or coarse-grained *(e.g., marble, quartzite)*

Large area of regional metamorphism



- **Regional metamorphism**
    - **high pressure** is dominant factor, but with increased temperatures also present
    - results in rocks with **foliated** textures
    - prevalent in the roots of intensely deformed mountain ranges
    - may occur over a wide temperature range
    - **Higher t° and pressure** will produce **higher grades** of metamorphism
    - One example – Shale will progress as follows: shale → slate → phyllite → schist → gneiss
- **Partial melting** during metamorphism produces **migmatites**
    - **migmatites** exhibit both intrusive igneous and foliated metamorphic textures
- **Shock metamorphism** is produced by rapid application of extreme pressure
    - meteor impacts produce this…shocked rocks are found around and beneath impact craters

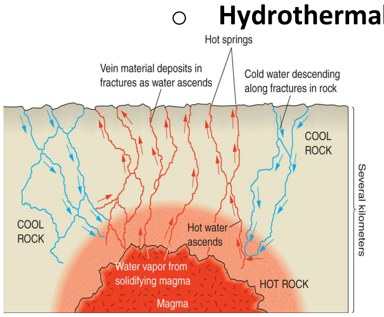
Plate Tectonics and Metamorphism

- Regional metamorphism is normally associated with **convergent plate boundaries**
    - Increased pressure due to colliding tectonic plates
    - temperature varies laterally at convergent boundaries
        - **isotherms** bow down in sinking oceanic plate and bow up where magma rises
    - wide variety of **metamorphic facies** are produced


Migmatite, result of partial melting

Hydrothermal Processes

- **Hydrothermal** – rocks precipitated from, or altered by, hot water
- **Hydrothermal processes**
    - Metamorphism – as stated earlier, water transmits pre-existing ions between grains
    - **Metasomatism** – water adds new ions to the rock *(from surrounding area)*
    - **Hydrothermal veins** - Occurs in the cracks of the country rock surrounding a magmatic intrusion when hot water precipitates materials that crystallize into minerals. M**etallic ore deposits** often form this way *(California's 'Mother Lode' gold)*
    - Precipitation from groundwater – occurs in many areas, including divergent boundaries as precipitated rocks on the ocean floor *(black smokers)*
    - Disseminated metal deposits can occur this way *(Utah's Kennecott copper mine)*



Hydrothermal processes near a magma intrusion