Metamorphism & Metamorphic Rocks

(adapted from Brunkel, 2012)
Metamorphic Rocks

- Changed rocks - with heat and pressure
  - But not melted
  - Change in the solid state
- Textural changes (always)
- Mineralogy changes (usually)
Metamorphism

- The mineral changes that transform a parent rock into a new metamorphic rock by exposure to heat, stress, and fluids unlike those in which the parent rock formed.
Geothermal gradient

- Subsiding basin
- Shallow crustal rocks are metamorphosed by rising magma bodies
- Deeply buried sedimentary strata are metamorphosed
- Subducting sediments are metamorphosed by increase in pressure and temperature
- Idealized geothermal gradient
- Subducting oceanic lithosphere
- 100 km
- 200 km

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Types of Metamorphism

- **Contact** metamorphism -
  - Happens in wall rock next to intrusions
  - HEAT is main metamorphic agent
Contact metamorphism
Contact Metamorphism

- Local: Usually a zone only a few meters wide
- Heat from plutons intruded into “cooler” country rock
- Usually forms nonfoliated rocks
Types of Metamorphism

- **Hydrothermal** metamorphism -
  - Happens along fracture conduits
  - **HOT FLUIDS** are main metamorphic agent
Types of Metamorphism

- **Regional** metamorphism -
  - Happens during mountain building
  - Most significant type
  - **STRESS** associated with plate convergence &
  - **HEAT** associated with burial
  (geothermal gradient) are main metamorphic agents
- **Contact metamorphism**
- **Hydrothermal metamorphism**
- **Regional metamorphism**

- Wide range of pressure and temperature conditions across a large area
Regional metamorphism
Other types of Metamorphism

- Burial
- Fault zones
- Impact metamorphism

Tektites
Metamorphism and Plate Tectonics

- Fault zone metamorphism
- Mélange - chaotic mixture of materials that have been crumpled together
Stress (pressure)

- From burial beneath younger sediments (lithostatic stress -equal in all directions)

- From tectonic stress at convergent margins (differential stress -different in all directions)
Metamorphic textures

- **Texture** refers to the size, shape, and arrangement of grains within a rock.

- **Foliation** - any planar arrangement of mineral grains or structural features within a rock.

  - **Examples of foliation**
    - Parallel alignment of platy and/or elongated minerals.
Stress

Before metamorphism

After metamorphism

Stress

Stress

Stress

Stress
Direction of compressive forces

Preferred orientation

Direction of compressive forces
Recrystallization
Of minerals in the direction of preferred orientation

Change of shape
equidimensional grains changed into elongated shapes that are aligned
**Metamorphic Rock Names: 2 Types:**

1. **FOLIATED** Metamorphic Rocks
   - Named mainly from their foliation type
   - **NAME** | **FOLIATION TYPE**
     - Slate
     - (Phyllite)
     - Schist
     - Gneiss
     - Slaty texture
     - Schistocity
     - Gneissic Texture

2. **NON-FOLIATED** metamorphic rocks
Foliated Metamorphic Textures

- Slaty texture (Phyllite)
- Schistosity
- Gneissic texture

Increasing Metamorphic Grade for same parent rock (Note increase in size of crystals)
- Slaty texture
  - Closely spaced planar surfaces along which rocks split
  - Formed by alignment of microscopic mica through rotation, recrystallization, and change in shape.

- **Rock Name:** Slate  **Parent:** Shale
Slate and Phyllite
- **Schistosity**
  - Foliation formed mainly by visible platy minerals (muscovite, biotite)

- **Rock Name: Schist**
  - with modifier for dominant mineral: **biotite schist, muscovite schist**

- **Parent: Slate**
- **Gneissic Texture**
  - Foliation due to segregation of minerals into:
    - *light bands* of nonferromagnesian silicates (quartz, feldspar, muscovite)
    - *dark bands* of ferromagnesian silicates (biotite, amphibole, pyroxene)
- **Gneissic Texture**
  - Highest grade of metamorphic rock (most heat & stress)
- **Rock Name:** Gneiss - with modifier for dominant dark mineral: biotite gneiss, hornblende gneiss
Metamorphic grade in foliated rocks

- For same parent rock (i.e., shale), transitions from slate to gneiss indicate increasing depth of burial inside a mountain belt along a convergent plate boundary.
Metamorphic grade in foliated rocks

- For same parent rock (shale), transitions from slate to gneiss also display change in metamorphic minerals.
Metamorphic Rock Names: 2 Types

1. FOLIATED Metamorphic Rocks - layered or banded

2. NON-FOLIATED metamorphic rocks
   - Named mainly from the mineralogy inherited from their parent rock

<table>
<thead>
<tr>
<th>NAME</th>
<th>MINERAL</th>
<th>PARENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marble</td>
<td>Calcite</td>
<td>Limestone</td>
</tr>
<tr>
<td>Quartzite</td>
<td>Quartz</td>
<td>Quartz Sandstone</td>
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</tbody>
</table>
Nonfoliated metamorphic rocks

Quartzite – formed from quartz-rich sandstones, often have a “sugary” surface
Nonfoliated metamorphic rocks

Marble – metamorphosed limestones and dolomites, texture is inter-grown calcite x-tals
Engineering with Metamorphic

- Jointing
- Foliation sheets - anisotropy
- Weathering products
- Discontinuity infilling
- Grade variability