**Rocks: Materials of the Solid Earth**


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**Rock Cycle**

- Shows the interrelationships among the three rock types
- Earth as a system: The *rock cycle*
  - Magma
    - Crystallization
  - Igneous rock
    - Weathering, transportation, and deposition

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**Rock Cycle**

- Earth as a system: The *rock cycle*
  - Sediment
    - Lithification
  - Sedimentary rock
    - Metamorphism
  - Metamorphic rock
    - Melting
  - Magma
**Rock Cycle**

- **Earth as a system: The rock cycle**
  - Full cycle does not always take place due to "shortcuts" or interruptions
    - e.g., sedimentary rock melts
    - e.g., igneous rock is metamorphosed
    - e.g., sedimentary rock is weathered
    - e.g., metamorphic rock weathers

**The Rock Cycle**

![Figure 2.2](Image)

**Igneous Rocks**

- Form as magma cools and crystallizes
  - Rocks formed inside Earth are called *plutonic* or *intrusive* rocks
  - Rocks formed on the surface
    - Formed from *lava* (a material similar to magma, but without gas)
    - Called *volcanic* or *extrusive* rocks
**Igneous Rocks**

- Crystallization of magma
  - Ions are arranged into orderly patterns
  - Crystal size is determined by the rate of cooling
    - Slow rate forms large crystals
    - Fast rate forms microscopic crystals
    - Very fast rate forms glass

**Igneous Rocks**

- Classification is based on the rock’s texture and mineral constituents
  - Texture
    - Size and arrangement of crystals
    - Types
      - *Fine-grained*—fast rate of cooling
      - *Coarse-grained*—slow rate of cooling
      - *Porphyritic* (two crystal sizes)—two rates of cooling
      - *Glassy*—very fast rate of cooling

**Fine-Grained Igneous Texture**

Figure 2.4 A
Coarse-Grained Igneous Texture

B. Figure 2.4 B

Porphyritic Igneous Texture

Figure 2.6

Obsidian Exhibits a Glassy Texture

A Figure 2.7 A
**Igneous Compositions**

- Composed mainly of silicate minerals
- Two major groups
  - Dark silicates = rich in iron and/or magnesium
  - Light silicates = greater amounts of potassium, sodium, and calcium

**Igneous Compositions**

- Granitic rocks
  - Composed almost entirely of light-colored silicates—quartz and feldspar
  - Also referred to as *felsic*: feldspar and *silica* (quartz)
  - High silica content (about 70 percent)
  - Common rock is *granite*

**Igneous Compositions**

- Basaltic rocks
  - Contain substantial dark silicate minerals and calcium-rich plagioclase feldspar
  - Also referred to as *mafic*: magnesium and *ferrum* (iron)
  - Common rock is *basalt*
Igneous Compositions

- Other compositional groups
  - **Andesitic** (or intermediate)
    - Common volcanic rock is andesite
  - **Ultramafic**
    - Peridotite

Classification of Igneous Rocks

Figure 2.8
**How Different Igneous Rocks Form**

- Bowen’s reaction series
  - Magma crystallizes over a temperature range of several hundred degrees
  - Therefore, minerals crystallize in a predictable order
  - Last minerals to crystallize are very different in composition from the earlier formed minerals

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**Bowen’s Reaction Series**

![Figure 2.9](image)

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**How Different Igneous Rocks Form**

- Magmatic differentiation
  - Differentiation refers to the formation of one or more secondary magmas from a single parent magma
  - One example of this is crystal settling
    - Earlier-formed minerals are denser than the liquid portion and sink to the bottom of the magma chamber
weathering of rocks

- **mechanical weathering** is the physical breaking apart of earth materials
  - frost wedging = splitting of rocks due to alternate freezing and thawing of water in cracks or voids
  - unloading = slabs of rock "peel" away due to a reduction in pressure when overlying rock is eroded away

weathering of rocks

- mechanical weathering
  - biological activity = activities of plants and burrowing animals
  - *chemical weathering* alters the internal structure of minerals by removing and/or adding elements

weathering of rocks

- chemical weathering
  - water is the most important agent of chemical weathering
  - reactions such as oxidation or dissolution by acids serve to decompose rocks
  - clay minerals are the most abundant and stable product of chemical weathering
**Sedimentary Rocks**

- Form from *sediment* (weathered products)
- About 75% of all rock outcrops on the continents
- Used to reconstruct much of Earth’s history
  - Clues to past environments
  - Provide information about sediment transport
  - Rocks often contain fossils

**Sedimentary Rocks**

- Economic importance
  - Coal
  - Petroleum and natural gas
  - Sources of iron and aluminum

**Sedimentary Rocks**

- Classifying sedimentary rocks
  - Two groups based on the source of the material
    - *Detrital rocks*
      - Material is solid particles
      - Classified by particle size
      - Common rocks include
        - *Shale* (most abundant)
        - *Sandstone*
        - *Conglomerate*
Classification of Sedimentary Rocks

<table>
<thead>
<tr>
<th>Sedimentary Rocks</th>
<th>Chemical Sedimentary Rocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>arkose</td>
<td>conglomerate</td>
</tr>
<tr>
<td>chert</td>
<td>siltstone</td>
</tr>
<tr>
<td>siltstone</td>
<td>sandstone</td>
</tr>
<tr>
<td>shale</td>
<td>limestone</td>
</tr>
<tr>
<td>mud</td>
<td>dolomite</td>
</tr>
<tr>
<td>clay</td>
<td>marble</td>
</tr>
</tbody>
</table>

Figure 2.16

Shale with Plant Fossils

Figure 2.17 D

Sandstone

Figure 2.17 C
**Conglomerate**

A Figure 2.17 A

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**Sedimentary Rocks**

- **Classifying sedimentary rocks**
  - Two groups based on the source of the material
    - **Chemical rocks**
      - Derived from material that was once in solution, which precipitated to form sediment
      - Directly precipitated as the result of physical processes, or
      - Through life processes (biochemical origin)

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**Sedimentary Rocks**

- **Classifying sedimentary rocks**
  - **Chemical rocks**
    - *Limestone*—The most abundant chemical rock
    - Microcrystalline quartz (precipitated quartz) known as chert, flint, jasper, or agate
    - Evaporites such as rock salt or gypsum
    - Coal

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Sedimentary Rocks

- Sedimentary rocks are produced through *lithification*
  - Loose sediments are transformed into solid rock
- Lithification processes
  - Compaction
  - Cementation by
    - Calcite
    - Silica
    - Iron Oxide

Fossiliferous Limestone

Rock Salt
**Sedimentary Rocks**

- Features of sedimentary rocks
  - *Strata*, or beds (most characteristic)
  - *Bedding planes* separate strata
  - *Fossils*
    - Traces or remains of prehistoric life
    - Are the most important inclusions
    - Help determine past environments
    - Used as time indicators
    - Used for matching rocks from different places

**Metamorphic Rocks**

- "Changed form" rocks
- Produced from preexisting
  - Igneous rocks
  - Sedimentary rocks
  - Other metamorphic rocks

**Metamorphic Rocks**

- Metamorphism
  - Takes place where preexisting rock is subjected to temperatures and pressures unlike those in which it formed
  - Degrees of metamorphism
    - Exhibited by rock texture and mineralogy
    - *Low-grade* (e.g., shale becomes slate)
    - *High-grade* (obliteration of original features)
Metamorphic Rocks

- Metamorphic settings
  - Contact, or thermal, metamorphism
    - Occurs near a body of magma
    - Changes are driven by a rise in temperature
  - Regional metamorphism
    - Directed pressures and high temperatures during mountain building
    - Produces the greatest volume of metamorphic rock

Metamorphic Rocks

- Metamorphic agents
  - Heat
  - Pressure (stress)
    - From burial (confining pressure)
    - From differential stress during mountain building
  - Chemically active fluids
    - Mainly water and other volatiles
    - Promote recrystallization by enhancing ion migration

Origin of Pressure in Metamorphism

Figure 2.24
Metamorphic Rocks

- Metamorphic textures
  - Foliated texture
    - Minerals are in a parallel alignment
    - Minerals are perpendicular to the compressional force
  - Nonfoliated texture
    - Contain equidimensional crystals
    - Resembles a coarse-grained igneous rock

Development of Foliation

Figure 2.26

Metamorphic Rocks

- Common metamorphic rocks
  - Foliated rocks
    - Slate
      - Fine-grained
      - Splits easily
    - Schist
      - Strongly foliated
      - "Platy"
      - Types based on composition (e.g., mica schist)
Classification of Metamorphic Rocks

<table>
<thead>
<tr>
<th>Rock Name</th>
<th>Texture</th>
<th>Grain Size</th>
<th>Comments</th>
<th>Parent Rock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slate</td>
<td>Fine</td>
<td>Very fine</td>
<td>Excellent rock cleavage, smooth dull surfaces</td>
<td>Slate, mudstone, or dolostone</td>
</tr>
<tr>
<td>Phyllite</td>
<td>Fine</td>
<td>Medium to coarse</td>
<td>Micaceous minerals, dominant, slaty foliation</td>
<td>Phyllite</td>
</tr>
<tr>
<td>Schist</td>
<td>Coarse</td>
<td>Medium to coarse</td>
<td>Compositional banding due to segregation of minerals</td>
<td>Slate, granite, or volcanic rocks</td>
</tr>
<tr>
<td>Gneiss</td>
<td>Coarse</td>
<td>Medium to coarse</td>
<td>&quot;Banded&quot; texture</td>
<td>Gneiss</td>
</tr>
<tr>
<td>Marble</td>
<td>Coarse</td>
<td>Medium to coarse</td>
<td>Interlocking calcite or dolomite grains</td>
<td>Limestone, dolostone</td>
</tr>
<tr>
<td>Quartzite</td>
<td>Coarse</td>
<td>Medium to coarse</td>
<td>Fused quartz grains, fine to very fine</td>
<td>Quartz sandstone</td>
</tr>
<tr>
<td>Anthracite</td>
<td>Fine</td>
<td>Fine</td>
<td>Strong black organic rock that may exhibit conchoidal fracture</td>
<td>Anthracite coal</td>
</tr>
</tbody>
</table>

Figure 2.27

Metamorphic Rocks

- Common metamorphic rocks
  - Foliated rocks
    - Gneiss
      - Strong segregation of silicate minerals
      - "Banded" texture
  - Nonfoliated rocks
    - Marble
      - Parent rock is limestone
      - Large, interlocking calcite crystals

Metamorphic Rocks

- Common metamorphic rocks
  - Nonfoliated rocks
    - Marble
      - Used as a building stone
      - Variety of colors
    - Quartzite
      - Parent rock—Quartz sandstone
      - Quartz grains are fused
Marble—A Nonfoliated Metamorphic Rock