Lecture Outlines
PowerPoint

Chapter 3
Earth Science, 12e
Tarbuck/Lutgens

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Earth Science, 12e
Rocks: Materials of the Solid Earth
Chapter 3
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
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
Figure 3.2

The rock cycle
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

A. Fine-grained
Coarse-grained igneous texture

B. Coarse-grained

Figure 3.5 B
Porphyritic igneous texture

D. Porphyritic

Figure 3.5 D
Obsidian exhibits a glassy texture.
Igneous rocks

- Classification is based on the rock’s texture and mineral constituents
  - Mineral composition
    - Explained by Bowen’s reaction series which shows the order of mineral crystallization
    - Influenced by crystal settling in the magma
## Classification of Igneous Rocks

**Chemical Composition**
- Granitic (Felsic)
- Andesitic (Intermediate)
- Basaltic (Mafic)
- Ultramafic
- Dominant Minerals
  - Quartz
  - Potassium feldspar
  - Sodium-rich plagioclase feldspar
  - Amphibole
  - Sodium- and calcium-rich plagioclase feldspar
  - Pyroxene
  - Calcium-rich plagioclase feldspar
- Olivine
- Pyroxene

**Texture**
- Coarse-grained
  - Granite
  - Diorite
  - Gabbro
- Fine-grained
  - Rhyolite
  - Andesite
  - Basalt
- Porphyritic
  - “Porphyritic” precedes any of the above names whenever there are appreciable phenocrysts
- Glassy
  - Obsidian (compact glass)
  - Pumice (frothy glass)

**Rock Color**
(based on % of dark minerals)
- 0% to 25%
- 25% to 45%
- 45% to 85%
- 85% to 100%

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*Figure 3.9*
# Bowen’s reaction series

![Bowen’s reaction series diagram](image)

<table>
<thead>
<tr>
<th>Temperature Regimes</th>
<th>Bowen’s Reaction Series</th>
<th>Igneous Rock Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>High temperature (~1200°C)</td>
<td>Olivine</td>
<td>Ultramafic</td>
</tr>
<tr>
<td>Low temperature (~750°C)</td>
<td>Pyroxene</td>
<td>Basaltic (Mafic)</td>
</tr>
<tr>
<td></td>
<td>Amphibole</td>
<td>Andesitic (Intermediate)</td>
</tr>
<tr>
<td></td>
<td>Biotite mica</td>
<td>Granitic (Felsic)</td>
</tr>
</tbody>
</table>

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Igneous rocks

Naming igneous rocks

- **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*
Granite

Figure 3.11
Igneous rocks

-Naming igneous rocks
  - 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
Basalt

Figure 3.11
Igneous rocks

- Naming igneous rocks
  - Other compositional groups
    - Andesitic (or intermediate)
    - Ultramafic
Sedimentary rocks

- Form from sediment (weathered products)
- About 75 percent 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>Detrital Sedimentary Rocks</th>
<th>Chemical Sedimentary Rocks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Texture (particle size)</strong></td>
<td><strong>Composition</strong></td>
</tr>
<tr>
<td>Coarse (over 2 mm)</td>
<td>Calcite, CaCO₃</td>
</tr>
<tr>
<td>Gravel (Rounded particles)</td>
<td></td>
</tr>
<tr>
<td>Gravel (Angular particles)</td>
<td></td>
</tr>
<tr>
<td>Medium (1/16 to 2 mm)</td>
<td>Various size shells and shell fragments cemented with calcite cement</td>
</tr>
<tr>
<td>Sand (If abundant feldspar is present the rock is called Arkose)</td>
<td>Microscopic shells and clay</td>
</tr>
<tr>
<td>Fine (1/16 to 1/256 mm)</td>
<td>Quartz, SiO₂</td>
</tr>
<tr>
<td>Mud</td>
<td>Gypsum CaSO₄·2H₂O</td>
</tr>
<tr>
<td>Siltstone</td>
<td>Halite, NaCl</td>
</tr>
<tr>
<td>Very fine (less than 1/256 mm)</td>
<td>Altered plant fragments</td>
</tr>
</tbody>
</table>

**Figure 3.16**
Shale with plant fossils
Sandstone

Figure 3.18

Close up

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Conglomerate
Sedimentary rocks

Classifying sedimentary rocks

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

Classifying sedimentary rocks

- Two groups based on the source of the material
  - 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
Fossiliferous limestone
Sedimentary rocks

- Sedimentary rocks are produced through **lithification**
  - Loose sediments are transformed into solid rock
  - Lithification processes
    - Compaction
    - Cementation by
      - Calcite
      - Silica
      - Iron oxide
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 3.27
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 due to directed pressure

Figure 3.29
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>Foliated</td>
<td>Very fine</td>
<td>Excellent rock cleavage, smooth dull surfaces</td>
<td>Shale, mudstone, or siltstone</td>
</tr>
<tr>
<td>Phyllite</td>
<td>Fine</td>
<td></td>
<td>Breaks along wavy surfaces, glossy sheen</td>
<td>Slate</td>
</tr>
<tr>
<td>Schist</td>
<td>Medium to Coarse</td>
<td>Micas dominate, scaly foliation</td>
<td>Phyllite</td>
<td></td>
</tr>
<tr>
<td>Gneiss</td>
<td>Medium to Coarse</td>
<td>Compositional banding due to segregation of minerals</td>
<td>Schist, granite, or volcanic rocks</td>
<td></td>
</tr>
<tr>
<td>Marble</td>
<td>Medium to coarse</td>
<td>Interlocking calcite or dolomite grains</td>
<td>Limestone, dolostone</td>
<td></td>
</tr>
<tr>
<td>Quartzite</td>
<td>Medium to coarse</td>
<td>Fused quartz grains, massive, very hard</td>
<td>Quartz sandstone</td>
<td></td>
</tr>
<tr>
<td>Anthracite</td>
<td>Fine</td>
<td></td>
<td>Shiny black organic rock that may exhibit conchoidal fracture</td>
<td>Bituminous coal</td>
</tr>
</tbody>
</table>

Figure 3.30
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
Gneiss typically displays a banded appearance.
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

Figure 3.31
Resources from rocks and minerals

- Metallic mineral resources
  - Gold, silver, copper, mercury, lead, etc.
  - Concentrations of desirable materials are produced by
    - Igneous processes
    - Metamorphic processes
Resources from rocks and minerals

- Metallic mineral resources
  - Most important ore deposits are generated from hydrothermal (hot-water) solutions
    - Hot
    - Contain metal-rich fluids
    - Associated with cooling magma bodies
    - Types of deposits include
      - **Vein deposits** in fractures or bedding planes, and
      - **Disseminated deposits** which are distributed throughout the rock
Resources from rocks and minerals

❖ Nonmetallic mineral resources
  • Make use of the material’s
    • Nonmetallic elements
    • Physical or chemical properties
  • Two broad groups
    • Building materials (e.g., limestone, gypsum)
    • Industrial minerals (e.g., fluorite, corundum, sylvite)
Mineral Resources

Figure 3.C
End of Chapter 3