Minerals and Rocks

Chapter 20
Hey Emily, the seashore is the perfect place to see interactions of the geosphere, hydrosphere, and atmosphere!

You're right, Megan, it is the perfect place. We are standing on the solid geosphere, but all the while, the hydrosphere and atmosphere are at work weathering the rock we stand on. The hydrosphere is where life on Earth began, and the atmosphere provides the oxygen animals need and the carbon dioxide plants need. Plus the atmosphere shields us from harmful UV rays. Our planet is unique in our solar system. It is our home and we need to learn more about it to be able to preserve it.
Earth System Science

- Interconnected
- Rocks and minerals
- Interior processes
- Erosion and deposition
- Water and air
Elements of Earth by weight

- Made of atoms
- Earth is mostly iron, by weight

- Iron 33.3%
- Oxygen 29.8%
- Silicon 15.6%
- Magnesium 13.9%
- Aluminum 1.5%
- Calcium 1.8%
- Sodium 0.2%
- Nickel 2.0%
- Others 1.9%
Crust Elements, by weight

- Made of atoms
- Earth is mostly iron, by weight
- Surface is mostly oxygen, by weight
Minerals

- Naturally occurring
- Not composed of ‘organic’ molecules
- Crystalline solid
- Specific chemical composition
Halite crystals
NaCl
Crystals

- Amethyst quartz
- Pyrite

Shape reflects internal arrangement of atoms

- Rhodochrosite
- Asbestos
Mineral Classification

- Crust is mostly oxygen and silicon
- Silicon always bonded to oxygen
- ‘SILICATES’
- 92% of minerals of crust
Silicate Minerals

• Silica bonded to metals
• Aluminum, sodium, potassium, calcium
  – Feldspar: Most abundant mineral
  – ‘felsic minerals’
  – Pale, less dense than ferromags
• Examples of felsic minerals
  – Feldspar
  – Quartz
  – Muscovite mica
Silicate Minerals

- Silica bonded to metals
- Iron, magnesium
  - Ferromagnesian silicates: ‘ferromags’
  - Dense, dark
- Examples of ferromags
  - Amphibole
  - Pyroxene
  - Biotite mica
  - Olivine
<table>
<thead>
<tr>
<th>Mineral</th>
<th>Idealized Formula</th>
<th>Cleavage</th>
<th>Silicate Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olivine</td>
<td>(Mg, Fe)_2SiO_4</td>
<td>None</td>
<td>Single tetrahedron</td>
</tr>
<tr>
<td><strong>Pyroxene group</strong></td>
<td>(Mg, Fe)SiO_3</td>
<td>Two planes at right angles</td>
<td><strong>Single chains</strong></td>
</tr>
<tr>
<td>(Augite)</td>
<td></td>
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<tr>
<td><strong>Amphibole group</strong></td>
<td>Ca_2(Fe,Mg)_5Si_8O_22(OH)_2</td>
<td>Two planes at 60° and 120°</td>
<td><strong>Double chains</strong></td>
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<tr>
<td>(Hornblende)</td>
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<tr>
<td><strong>Micas</strong></td>
<td></td>
<td>One plane</td>
<td><strong>Sheets</strong></td>
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<tr>
<td>Biotite</td>
<td>K(Mg, Fe)_3AlSi_3O_10(OH)_2</td>
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<tr>
<td><strong>Feldspars</strong></td>
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<td><strong>Three-dimensional networks</strong></td>
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<tr>
<td>Orthoclase (Potassium</td>
<td>KAlSi_3O_6</td>
<td>Two planes at 90°</td>
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<tr>
<td>feldspar)</td>
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<tr>
<td>Plagioclase</td>
<td>(Ca, Na)AlSi_3O_8</td>
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<td></td>
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<tr>
<td>Quartz</td>
<td>SiO_2</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>
Hardness

• Resistance to scratching
• Compare to glass/steel, penny, fingernail
Breaking minerals

• Strength of bonds within crystals
• Cleavage
  – Some planes with weak bonding
  – Break along these
Breaking minerals

• Strength of bonds within crystals
• Fracture
  – No planar arrangement of weak bonds
  – Conchoidal or irregular
Non-silicates

- Carbonates
  - Calcite: CaCO$_3$

- Oxides
  - Fe$_2$O$_3$, Fe$_3$O$_4$
  - tin, chromium, uranium

- Sulfides
  - Zinc, lead, mercury
  - Pyrite: FeS$_2$

- Native elements: Au, Cu
Minerals crystallize

• From liquid (usually) or gas (occasionally)
• Magma: molten rock
• Watery solutions
Crystallization of Magma

- Cools, atoms attracted to one another
- Arrange in orderly crystalline structures
- When very hot, low-silica forms
- Cooler, greater amounts of silica in them
- Composition of magma changes as crystallization proceeds
Crystallize from watery solutions

• Change solubility by changing physical or chemical conditions in magmatic water left
  – pH, other ion content
  – Temperature, pressure

• Chemical sedimentary rock
  – Carbonates: made by organisms, mostly
  – Increase concentration by evaporation: evaporites
Rock Types

- Igneous
- Sedimentary
- Metamorphic
The rock cycle is a continuous process that describes the formation and transformation of rocks. It involves the following stages:

1. **Magma forms when rock melts deep beneath Earth's surface.**
2. **Melted rock (magma) rises to the surface and becomes lava.**
3. **When lava cools and solidifies, it forms igneous rock.**
4. **Igneous rock can be exposed to heat and pressure, causing it to transform into metamorphic rock.**
5. **Metamorphic rock can be weathered and weathering can cause it to break down into sediment.**
6. **Sediment is compacted and cemented to form sedimentary rock.**
7. **Sedimentary rock can be uplifted and eroded, leading to the formation of sediment again.**
8. **Weathering and erosion break down the sediment into smaller particles.**
9. **Sediment can be transported and deposited, leading to the formation of new sedimentary rock.**
10. **Lithification occurs when sediment is compacted and cemented.**

This cycle is ongoing and helps to explain the evolution of Earth's crust over time.
Sedimentary rocks

• Cover 2/3 of Earth’s surface
• Record conditions at time of deposition
• Include remains of organisms preserved as fossils
Sedimentary rocks

Sediment is derived from weathering
Carried by fluid
Formed at Earth’s surface
Important to reconstruct much of Earth's history
Sedimentary rocks

Features of sedimentary rocks

• Strata, or beds (most characteristic)
• Bedding planes separate strata
  May have important characteristics
• Size, shape and distribution of grain sizes
• Fossils
Sedimentary rocks

Two main types

• Rocks formed by deposition of sediment—**Clastic**

• Rocks formed by precipitation from water—**Chemical** (includes rocks formed by organisms)
Clastic Sediment Grains

- Particle loosened from pre-existing rock
- Transported to place of deposition
- Shape, size, and sorting of grains can tell about the environment of deposition
Lithification

Process of becoming stone

- Burial and compaction
- Precipitation of cement
- Each reduces ‘pore space’
Cement

- Brought in by water
- Mineral material between grains
- Fills in pore spaces
- Commonly calcite, silica, and sometimes iron oxide
Bedding and bedding planes

Types of Clastic Rocks

- Shale (most abundant)
- Sandstone
- Conglomerate
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
Shale with plant fossils
Shale

- Composed of very fine grained sediment
- Shows obvious tendency to split along planes (fissile)
- Usually gray
- Most common type of sedimentary outcrop
Sandstone
Sandstone

• Composed of sand-size particles
  – Between 1/16 mm and 2 mm diameter
  – Particles may be individual mineral grains or rock fragments
  – Quartz most common type of grain

• Environments include
  • Beach,
  • river,
  • shallow sea,
  • sand dunes
Conglomerate
Conglomerate

- Composed of particles larger than 2 mm
- Usually particles are rock fragments
Clastic rocks

- **Shale** is the most common one
- Made from solid particles
- Classified by particle size
Chemical rocks

Material was once in solution and precipitates to form sediment

- Directly precipitated as the result of physical processes, or
- Through life processes (biochemical origin)
Chemical rocks

Limestone

- Composed of the mineral calcite (calcium carbonate)
- Much of this calcite was precipitated by organisms
- Considered an ‘organic chemical sediment’ if from organisms
- Most common type of chemical rock—
- Second most common type of sedimentary rock
Fossiliferous limestone
Coquina
Chemical rocks

Direct mineral precipitation from water

- Evaporites such as rock salt or gypsum
- Microcrystalline quartz (precipitated quartz) known as chert, flint, jasper, opal or agate
- Travertine (calcite) and sinter (silica) from hotspring deposits
Travertine

- http://njminerals.org/travertine.html
Evaporites

- http://www.img.uni-karlsruhe.de/925.php
- http://www.paintersflat.net/saltflat.html
- http://www.bonnevillehealeyclub.org/
- http://www.nv.blm.gov/Winnemucca/blackrock/BRHR_Planning.htm
- http://www.flickr.com/photos/snogun/1917329886/
Rock salt
Chert

- http://homestake.sdsmt.edu/Photos/Surface_geology_photos.htm
## Classification of Sedimentary Rocks

<table>
<thead>
<tr>
<th>Detrital Sedimentary Rocks</th>
<th>Chemical Sedimentary Rocks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Texture (grain size)</strong></td>
<td><strong>Composition</strong></td>
</tr>
<tr>
<td>Coarse (over 2 mm)</td>
<td>Calcite, CaCO₃</td>
</tr>
<tr>
<td></td>
<td>Very fine crystalline</td>
</tr>
<tr>
<td>Medium (1/16 to 2 mm)</td>
<td>Fine to coarse crystalline</td>
</tr>
<tr>
<td>Fine (1/16 to 1/256 mm)</td>
<td>Visible shells and shell fragments loosely cemented</td>
</tr>
<tr>
<td>Very fine (less than 1/256 mm)</td>
<td>Microscopic shells and clay</td>
</tr>
</tbody>
</table>

### Detrital Sedimentary Rocks
- **Gravel (Rounded fragments)**: Conglomerate
- **Gravel (Angular fragments)**: Breccia
- **Sand** (If abundant feldspar is present the rock is called **Arkose**): Sandstone
- **Mud**: Siltstone
- **Mud**: Shale

### Chemical Sedimentary Rocks
- **Crystalline Limestone**
- **Travertine**
- **Coquina**
- **Fossiliferous Limestone**
- **Chalk**
- **Chert (light colored)**
- **Rock Gypsum**
- **Rock Salt**
- **Bituminous Coal**
Features of sedimentary rocks

- Porosity
- Permeability
Sedimentary rocks

Economic importance

- Coal
- Petroleum and natural gas
- Precipitation of iron and aluminum
- Deposition of gold and tin
- Sand, gravel, clay