Weathering and Soils
Chapter 5

Essentials of Geology, 8e
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Earth’s external processes

- **Weathering** – the physical breakdown (disintegration) and chemical alteration (decomposition) of rock at or near Earth’s surface

- **Mass wasting** – the transfer of rock and soil downslope under the influence of gravity
Earth’s external processes

- **Erosion** – the physical removal of material by mobile agents such as water, wind, ice, or gravity
Weathering

- Two types of weathering
  - **Mechanical weathering** – breaking of rocks into smaller pieces
  - **Four types of mechanical weathering**
    - **Frost wedging** – alternate freezing and thawing of water in fractures and cracks promotes the disintegration of rocks
Frost wedging

[Diagram showing the process of frost wedging]
Increase in surface area by mechanical weathering

4 square units \times 6 \text{ sides} \times 1 \text{ cube} = \frac{24 \text{ square units}}{}

1 \text{ square unit} \times 6 \text{ sides} \times 8 \text{ cubes} = \frac{48 \text{ square units}}{}

.25 \text{ square unit} \times 6 \text{ sides} \times 64 \text{ cubes} = \frac{96 \text{ square units}}{}}
Weathering

- **Mechanical Weathering continued**
  - **Unloading** – exfoliation of igneous and metamorphic rocks at the Earth’s surface due to a reduction in confining pressure
  - **Thermal expansion** – alternate expansion and contraction due to heating and cooling
  - **Biological activity** – disintegration resulting from plants and animals
Exfoliation of igneous rocks
Joint-controlled weathering in igneous rocks
Weathering along joints in sedimentary rocks, Bryce Canyon, Utah
Weathering

- Chemical Weathering
  - Breaks down rock components and the internal structures of minerals
  - Most important agent involved in chemical weathering is water (responsible for transport of ions and molecules involved in chemical processes)
Weathering

- Major processes of chemical weathering
  - **Dissolution**
    - Aided by small amounts of acid in the water
    - Soluble ions are retained in the underground water supply
  - **Oxidation**
    - Any chemical reaction in which a compound or radical loses electrons
Weathering

- **Major processes of chemical weathering**
  - **Oxidation** continued
    - Important in decomposing ferromagnesian minerals
  - **Hydrolysis**
    - The reaction of any substance with water
    - Hydrogen ion attacks and replaces other positive ions
### Table 5.1 Products of weathering.

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Residual Products</th>
<th>Material in Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>Quartz grains</td>
<td>Silica</td>
</tr>
<tr>
<td>Feldspars</td>
<td>Clay minerals</td>
<td>Silica, K(^+), Na(^+), Ca(^{2+})</td>
</tr>
<tr>
<td>Amphibole (hornblende)</td>
<td>Clay minerals</td>
<td>Silica, Ca(^{2+}), Mg(^{2+})</td>
</tr>
<tr>
<td>Olivine</td>
<td>Limonite, Hematite</td>
<td>Silica, Mg(^{2+})</td>
</tr>
</tbody>
</table>
Weathering

- Alterations caused by chemical weathering
  - Decomposition of unstable minerals
  - Generation or retention of materials that are stable
  - Physical changes such as the rounding of corners or edges
Weathering

- Rates of weathering
  - Advanced mechanical weathering aids chemical weathering by increasing the surface area
- Others factors affecting weathering
  - Rock characteristics
    - Rocks containing calcite (marble and limestone) readily dissolve in weakly acidic solutions
Weathering

- Others factors affecting weathering
  - Rock characteristics continued
    - Silicate minerals weather in the same order as their order of crystallization
  - Climate
    - Temperature and moisture are the most crucial factors
    - Chemical weathering is most effective in areas of warm, moist climates
Weathering

- Differential weathering
  - Masses of rock do not weather uniformly due to regional and local factors
  - Results in many unusual and spectacular rock formations and landforms
Soil

- Soil is a combination of mineral and organic matter, water, and air
- That portion of the regolith (rock and mineral fragments produced by weathering) that supports the growth of plants
Typical components in a soil that yield good plant growth:

- 25% air
- 25% water
- 5% organic matter
- 45% mineral matter
Soil

- Factors controlling soil formation
  - **Parent material**
    - Residual soil – parent material is the underlying bedrock
    - Transported soil – forms in place on parent material that has been carried from elsewhere and deposited
Soil

- Factors controlling soil formation

  - **Time**
    - Important in all geologic processes
    - Amount of time for soil formation varies for different soils depending on geologic and climatic conditions

  - **Climate**
    - Most influential control of soil formation
    - Key factors are temperature and precipitation
Soil

Factors controlling soil formation

- **Plants and animals**
  - Organisms influence the soil’s physical and chemical properties
  - Also furnish organic matter to the soil

- **Slope**
  - Steep slopes often have poorly developed soils
  - Optimum terrain is a flat-to-undulating upland surface
Variations in soil development due to topography
Soil

- The *soil profile*

  - Soil forming processes operate from the surface downward
  - Vertical differences are called *horizons* – zones or layers of soil
Soil

- The soil profile
  - O horizon – organic matter
  - A horizon – organic and mineral matter
    - High biological activity
    - Together the O and A horizons make up the topsoil
  - E horizon – little organic matter
    - Zone of eluviation and leaching
Soil

- The soil profile
  - B horizon – zone of accumulation
  - C horizon – partially altered parent material
- The O, A, E, and B horizons together are called the solum, or “true soil”
An idealized soil profile

- **O horizon**: Loose and partly decayed organic matter
- **A horizon**: Mineral matter mixed with some humus
- **E horizon**: Light colored mineral particles. Zone of eluviation and leaching
- **B horizon**: Accumulation of clay transported from above
- **C horizon**: Partially altered parent material
- **Unweathered parent material**
A soil profile showing different horizons
Soil types

- The characteristics of each soil type primarily depend on the prevailing climatic conditions

Three very generic soil types

- Pedalfer
  - Accumulation of iron oxides and Al-rich clays in the B horizon
Soil

- Three very generic soil types
  - **Pedalfer** continued
    - Best developed under forest vegetation
  - **Pedocal**
    - High accumulations of calcium carbonate
    - Associated with dry grasslands and brush vegetation
Soil

- Three very generic soil types
  - Laterite
    - Hot and wet tropical climates
    - Intense chemical weathering
<table>
<thead>
<tr>
<th>Climate</th>
<th>Temperate humid (&gt;63 cm rainfall)</th>
<th>Temperate dry (&lt;63 cm rainfall)</th>
<th>Tropical (heavy rainfall)</th>
<th>Extreme arctic or desert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation</td>
<td>Forest</td>
<td>Grass and brush</td>
<td>Grass and trees</td>
<td>Almost none, so no humus develops</td>
</tr>
<tr>
<td>Typical Area</td>
<td>Eastern U.S.</td>
<td>Western U.S.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil Type</td>
<td>Pedalfer</td>
<td>Pedocal</td>
<td></td>
<td>Laterite</td>
</tr>
<tr>
<td>Topsoil</td>
<td>Sandy, light-colored; acid</td>
<td>Commonly enriched in calcite; whitish color</td>
<td>Enriched in iron (and aluminium) brick-red color</td>
<td>No real soil forms, because there is no organic material. Chemical weathering is very slow.</td>
</tr>
<tr>
<td>Subsoil</td>
<td>Enriched in aluminum, iron and clay; brown color</td>
<td>Enriched in calcite; whitish color</td>
<td>All other elements removed by leaching</td>
<td></td>
</tr>
<tr>
<td>Remarks</td>
<td>Extreme development in conifer forests, because abundant humus makes groundwater very acidic. Produces light gray soil because of removal of iron.</td>
<td>Caliche is name applied to the accumulation of calcite.</td>
<td>Apparently bacteria destroy humus, so no acid is available to remove iron.</td>
<td></td>
</tr>
</tbody>
</table>
Soil

- Soil erosion
  - Recycling of Earth materials
  - Natural rates of soil erosion depend on
    - Soil characteristics
    - Climate
    - Slope
    - Type of vegetation
Soil

- Soil erosion
  - In many regions the rate of soil erosion is significantly greater than the rate of soil formation

- Sedimentation and chemical pollution
  - Related to excessive soil erosion
  - Occasionally soil particles are contaminated with pesticides