Chapter 6

Weathering, Erosion and Soils

Introduction

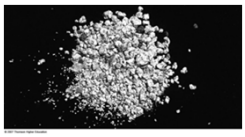
- Rocks and minerals are disintegrated and decomposed by the processes of mechanical and chemical weathering.

Introduction

- Weathering is the mechanical and chemical alteration of Earth materials at or near the surface
- Erosion involves removing weathered materials from their place of origin-by running water or wind, for example.

How Are Earth Materials Altered?

- The products of weathering include soluble salts, ions in solution, and solid particles. These products of weathering can be eroded and become sedimentary rock or modified in place to become soils.



How Are Earth Materials Altered?

- Weathering and erosion take place at different rates depending on the composition of the material – called differential erosion.

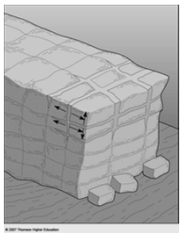
How Are Earth Materials Altered?

- Mechanical Weathering is a set of processes that result in materials that are chemically the same as the parent materials.
  - Frost action
  - Pressure release
  - Thermal expansion
  - Crystal growth
  - Activities of organisms.

How Are Earth Materials Altered?

- Mechanical Weathering - **Frost Action**

- Many years of freezing and thawing of water in fractures causes pressure which breaks rocks apart.
- Blocks gather at the base of the slope as talus.



How Are Earth Materials Altered?

- Mechanical Weathering – **Presure Release**
  - Sheet joints are fractures that are more or less parallel exposed rock surfaces.
  - These joints form in response to pressure release; that is, when the rocks formed, they contained energy that is released by outward expansion.
  - Leads to exfoliation domes.

How Are Earth Materials Altered?

- Mechanical Weathering – **Thermal Expansion**

- Volume changes in rocks and minerals with temperature changes.
- Outside expands faster than inside and/or dark minerals expand faster than lighter-colored minerals.

How Are Earth Materials Altered?

- Mechanical Weathering – **Salt Crystal Growth**

- Salt crystals form in fractures, exerting pressure as they grow.
- Coastal areas and regions where salt is used on roads are susceptible.

How Are Earth Materials Altered?

- Mechanical Weathering – **Organisms**

- Any organic activity such as tree roots growing in cracks contributes to mechanical weathering
- Organic acids and the tendrils of mosses and lichens aid in the chemical alteration of parent material.

How Are Earth Materials Altered?

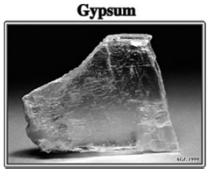
- Chemical weathering
  - Hydration
  - Solution
  - Oxidation
  - Hydrolysis

- Hot and wet environments accelerate chemical weathering.
- Chemical weathering occurs in all environments, except, possibly, permanently frozen polar regions.
- The parent material is transformed chemically into products including ions in solution, soluble salts and clay minerals.

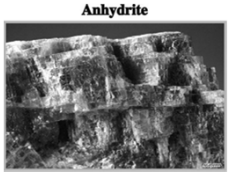
How Are Earth Materials Altered?

- Chemical Weathering – **Hydration**
  - ***Anhydrite and Gypsum are close "cousins"***
  - Anhydrite ($CaSO_4$) has a hardness of 3.5 and density of 3.0 g/cm³.
  - Gypsum ($CaSO_4 \cdot 2H_2O$) has a hardness of only 2.0 and a density of only 2.3 g/cm³. Gypsum is softer, less dense and easier to weather.

Gypsum



Anhydrite



How Are Earth Materials Altered?

- Chemical Weathering – **Solution**

- Rocks such as limestone (carbonate rocks) are nearly insoluble in neutral or alkaline solutions, but they rapidly dissolve in acidic solutions.
- Other minerals, such as halite and gypsum (evaporites), readily go into solution.

How Are Earth Materials Altered?

- Chemical Weathering – **Oxidation**

- Rocks such as sandstone may contain iron minerals that will breakdown when exposed to the atmosphere
- Rocks containing mafic minerals will also alter to oxide and hydroxide minerals
- The atoms making up the minerals dissociate, that is, they separate as the rock rusts away

How Are Earth Materials Altered?

- Chemical Weathering – **Hydrolysis** (see p.145)
  - During hydrolysis hydrogen ions react with and replace positive ions in potassium feldspar
  - The result is clay minerals and substances in solution such as potassium and silica.

K-spar

Hydrolysis Reaction

Kaolinite

http://www.mindat.org/photo-46933.html

How Are Earth Materials Altered?

- Chemical Weathering – **Hydrolysis**

Chemical Change:

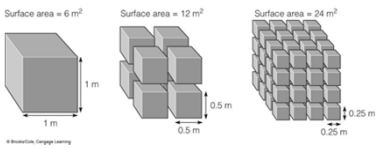
$2KAlSi_3O_8 + 2H^+ + 2HCO_3^- + H_2O \rightarrow$
orthoclase hydrogen bicarbonate ion water

$Al_2Si_2O_5(OH)_4 + 2K^+ + 2HCO_3^- + 4SiO_2$
clay (kaolinite) potassium ion bicarbonate ion silica

How Are Earth Materials Altered?

- Factors That Control the Rate of Chemical Weathering

Mechanical weathering enhances chemical weathering by breaking material into smaller pieces, thereby increasing the surface area for chemical reactions. ***Because chemical weathering is a surface process, the more surface exposed, the faster the weathering.***



How Are Earth Materials Altered?

- Factors That Control the Rate of Chemical Weathering
  - All chemical weathering processes are enhanced by the presence of water. ***Climates that have more rainfall are more likely to produce faster weathering rates.***

How Are Earth Materials Altered?

- Factors That Control the Rate of Chemical Weathering
  - The type of material is very important, since certain minerals weather faster at the Earth's surface than others.
  - Silicate minerals that form at lower temperatures, such as quartz, are more stable than higher temperature minerals such as olivine. Also, the products of weathering – clay minerals and oxides – are more stable. Highly soluble minerals – such as halite and gypsum – are highly unstable.
  - ***Therefore, the mineral content of the rock helps determine the rate of weathering.***

How Are Earth Materials Altered?

TABLE 6.1 Stability of Silicate Minerals

Ferromagnesian Silicates	Nonferromagnesian Silicates
Olivine	Calcium plagioclase
Pyroxene	
Amphibole	Sodium plagioclase
Biotite	Potassium feldspar
	Muscovite
	Quartz

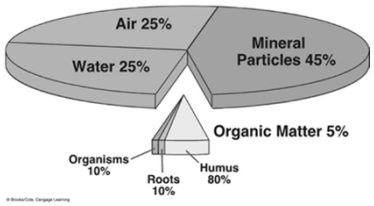
Increasing Stability ↓

Soils

- Definitions
- According to soil scientists, a soil is a mixture of weathered materials, air, water and organic matter capable of supporting plant growth.
- According to an engineer, a soil is any loose material at the Earth's surface removable without blasting.
- *Regolith* is a term geologists use for any unconsolidated material.

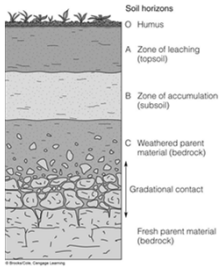
How Does Soil Form and Deteriorate?

- Soil Composition – Soils consist of weathered materials, air, water, humus and also the plants which they support.



How Does Soil Form and Deteriorate?

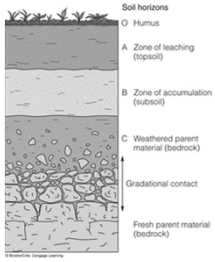
- The Soil Profile



- Soil formation produces horizons that are known in descending order as O, A, B, and C.

How Does Soil Form and Deteriorate?

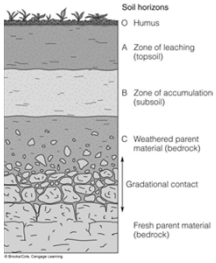
- The Soil Profile



- O horizon – Thin layer of humus and partially decayed plants

How Does Soil Form and Deteriorate?

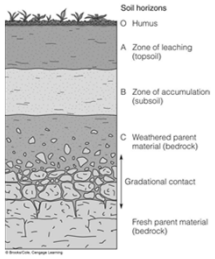
- The Soil Profile



- A horizon - Zone of leaching
  - Most important layer for plant growth
  - More organically rich than underlying horizons
  - Top soil, thick in fertile soils

How Does Soil Form and Deteriorate?

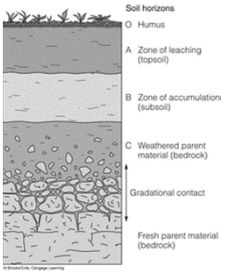
- The Soil Profile



- B horizon – Subsoil
  - Zone of Accumulation, especially of clays and iron oxides

How Does Soil Form and Deteriorate?

- The Soil Profile



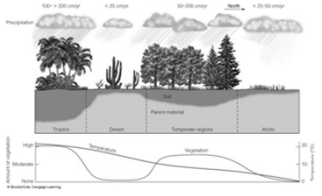
- C horizon – weathered parent material
- Partially weathered in-place bedrock
- Other horizons, such as the E, are less common

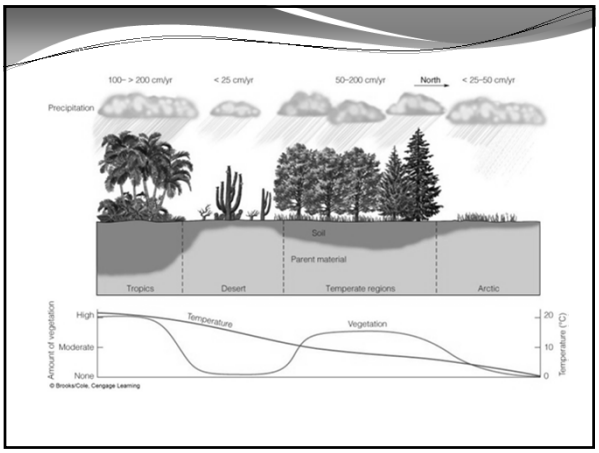
Soil Production

- Soil is produced at a rate of 2.5 cm per century, *Therefore, soil is a non-renewable resource.*
- We can improve the soil with fertilizer, but the upper portion, the *topsoil*, is critically important.

Soil Production

- Factors That Control Soil Formation
  - Climate - the most important factor in soil formation because chemical processes operate faster where it is warm and wet





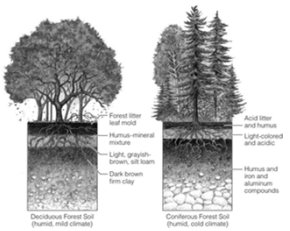
Soil Production

Other Factors That Control Soil Formation

- Parent material
- Organic activity
- Relief and slope
- Time

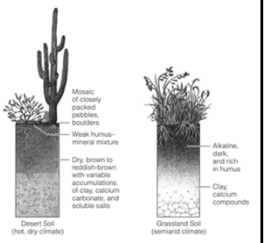
Types of Soils

- Humid Forest
  - Forest soils develop in humid climates such as the eastern United States and much of Canada.
  - Feature a well-developed A horizon and an iron- and aluminum-rich B horizon



Types of Soils

- Types of soils: Hot desert
  - Hot desert soils have thin O and A horizons because of the lack of plant growth
  - B horizon often contains irregular masses of calcite, called caliche
  - Desert soils are often alkaline (low pH)



Types of Soils

- Laterites
  - Red tropical soils
  - Severe chemical weathering

Types of Soils

- Soils can be divided into Residual and Transported soils.
- Residual Soils form in place directly on bedrock; the resulting soil is greatly influenced by the parent bedrock.
- Transported Soils form on materials that have been transported to their destination via various agents of transportation, such as gravity, wind or water.

Types of Soils

- Residual Soils depend on rock type and climate:
- Granite –mixture of sand and clays; deep in humid regions and thin in arid regions.
- Other igneous and metamorphic rocks – composition depends on parent material – could contain more clays or oxides than quartz.
- Sandstone – thin, sandy soils.
- Shale – thicker, clay-rich soils. Some clays are *expansive*, and this can lead to major problems with building foundations.
- Limestone – leftover materials after calcite dissolution (chert, sand, clay) gives thicker (humid) or thinner soils (arid).

Types of Soils

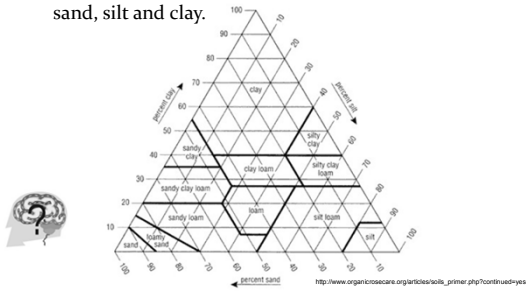
- Transported Soil types depend on material, which depends on agent of transportation:
- Colluvial soils are formed on the remnants of material moved downslope by gravity.
- Alluvial soils are formed on all sediment deposited by streams (flowing water) and are good mixture of sand, silt, clay and organic matter.
- Glacial soils are formed on sediment deposited by ice; soil quality depends on deposited material.

Types of Soils

- Transported Soil (cont.):
- Lacustrine and marine soils are those formed on sediment deposited in lakes or the oceans. Deep water deposits tend to be very clay-rich, whereas nearshore deposits are sandier.
- Eolian soils are formed on sediment deposited by wind. Fine silt and clay transported by wind (*loess*) makes some of the world's best and most fertile soils.

Types of Soils

- Soils can also be classified by grain size using percent sand, silt and clay.



Types of Soils

- Apply what you've just learned: Use your triangular diagram to determine the soil type for the following soils:

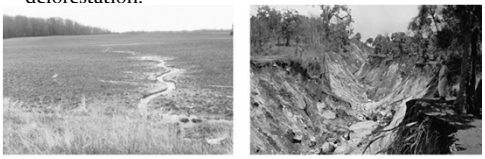
a. Sand = 40%, Silt = 40%, Clay = 20%
b. Sand = 98%, Silt = 1%, Clay = 1 %
c. Sand = 60%, Silt = 30%, Clay = 10%
d. Sand = 30%, Silt = 35%, Clay = 35%

How Does Soil Form and Deteriorate?

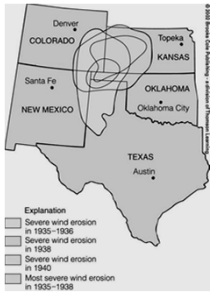
- Soil Degradation - Any soil losses, physical changes, or chemical alteration is called soil degradation, and all lead to reduced soil productivity.
  - Causes include erosion, compaction, and any kind of chemical pollution that inhibits plant growth.

How Does Soil Form and Deteriorate?

- Soil Degradation
  - Soil erosion is caused mostly by sheet and rill erosion.
  - Accelerated by human activities such as construction, agriculture, ranching, and deforestation.



The Dust Bowl – An American Tragedy



How Does Soil Form and Deteriorate?

- Soil Degradation due to nutrient depletion – a loss of nutrients caused by land overuse.
- Improper disposal of chemicals and concentrations of insecticides can also destroy soil.

Weathering and Resources

- Intense chemical weathering causes the concentration of valuable mineral resources
- Residual concentrations – bauxite and other valuable minerals are concentrated by selective removal of soluble substances during chemical weathering
  - **Bauxite**, which forms in lateritic soils in the tropics, occurs in areas where chemical weathering is so intense that only the most insoluble compounds accumulate in the soil.
  - Laterites are the primary source of aluminum oxide, called bauxite. It is the main source of aluminum ore.
- Gossans - hydrated iron oxides formed on the earth's surface by oxidation of iron. Sulfide minerals leach out and concentrate as deposits of iron ore, copper ore, lead and zinc ore beneath the gossan.