Chapter 6: Weathering, Erosion, and Soil

Chapter Outline

6.1 Introduction
6.2 Alteration of Minerals and Rocks
6.3 Mechanical Weathering—Disaggregation of Earth Materials
6.4 Chemical Weathering—Decomposition of Earth Materials
6.5 Soil and its Origin
GEO-FOCUS 6.1: Industrialization and Acid Rain
GEO-INSIGHT 6.1: Arches National Park, Utah
6.6 Expansive Soils and Soil Degradation
6.7 Weathering and Resources
Key Concepts Review

Learning Objectives

Upon completion of this material, the student should understand the following.

• Weathering yields the raw materials for both soils and sedimentary rocks.
• Some weathering processes bring about physical changes in Earth materials with no change in composition.
• Some weathering processes cause a change in the chemical composition of the parent material.
• A variety of factors are important in the origin and evolution of soils. These include climate, the parent material being weathered, the amount of organic material, and slope among others.
• Soil degradation involves any loss of soil productivity that results from erosion, chemical pollution, or compaction.

Chapter Summary

• Mechanical and chemical weathering disintegrate and decompose parent material so that it is more nearly in equilibrium with new physical and chemical conditions.
• The products of weathering include rock fragments and minerals liberated from parent material as well as soluble compounds and ions in solution.
• Weathering yields materials that may become soil or sedimentary rock.
• Mechanical weathering processes include frost action, pressure release, thermal expansion and contraction, salt crystal growth, and the activities of organisms. The particles yielded retain the composition of the parent material.
• Chemical weathering by solution, hydrolysis, and oxidation results in a chemical change in parent material and proceeds most rapidly in hot, wet environments.
• Mechanical weathering contributes to chemical weathering by breaking parent material into smaller pieces, thereby exposing more surface area.
• Soils possess horizons designated, in descending order, as O, A, E, B, and C, which differ from one another in texture, composition, structure and color.
• The important factors controlling soil formation are climate, parent material, organic activity, relief and slope, and time.
• Soils in humid regions are darker and more fertile than those of semiarid regions. Laterite is soil that forms in the tropics where chemical weathering is intense.
• Soil degradation results from erosion as well as from physical and chemical deterioration. Human activities such as construction, agriculture, deforestation, waste disposal, and chemical spills, contribute to soil degradation.
• Chemical weathering is responsible for the origin of some mineral deposits such as residual concentrations of iron, lead, manganese, and clay.

Enrichment Topics

**Topic 1. Soils and a Positive Feedback Mechanism for Global Warming.** Soils are rich with carbon, which microbes eat. Warmer temperatures are causing microbes to decompose soil carbon faster and release it into the atmosphere. This increases atmospheric CO$_2$, which increases global temperatures and increases the rate at which microbes decompose soil carbon. This is called a positive feedback mechanism for global warming. There are ways to increase the storage of carbon in the soil, but the effect would be small compared to the potential effect of the release of carbon from soil due to warmer temperatures. The only way to reduce the loss of soil carbon is to reduce greenhouse gas emissions into the atmosphere.


**Topic 2. Soil Erosion and Coral Reefs.** Corals cannot exist in muddy water because sediment clogs their feeding apparatus and inhibits oxygen diffusion. Extensive deforestation in tropical areas is resulting in dramatic increases in the rates of soil erosion. This, in turn, is threatening the health and diversity of coral reefs, which exhibit incredible biodiversity and are nurseries for important commercial fish species. In Guam, a soil scientist has planted Vetiver grass on shorelines to keep soil from entering the coastal waters so readily. Different strategies are used in other regions of the world to protect reefs.


**Topic 3. Philippine Logging Ban.** The Philippine government has taken a drastic step to reducing soil erosion. Over the past decade, the Philippine government has enacted stricter regulations of logging because soil erosion on deforested slopes bring about massive landslides that kill hundreds or thousands of people during storms. In February 2006, for example, a massive landslide killed more than 1,000 people and buried portions of the town of Guinsaugon. In 2011, President Aquino ordered a logging moratorium after 70 people were killed. So many slopes have been deforested that it will be a long while before landslides are reduced in number and severity.

Common Misconceptions

**Misconception 1:** Modern agricultural practices, including intensive farming, have been universally good by allowing many more people to live on the planet than would otherwise be possible.

**Fact:** The Green Revolution has kept alive about 1 billion people who would not otherwise have been able to be fed. However, the costs in pollution and topsoil erosion, among many other things, will eventually need to be paid. Allowing 1 billion more people contributes to overpopulation, which causes many more problems.

**Misconception 2:** Granite and marble are for eternity—what do you want on your tombstone?

**Fact:** No rock will retain an inscription and last as a monument forever. All rocks exposed at the surface undergo weathering. The type and rate of weathering depend on several factors, with climate being most important. The acid content of the rainwater is also an important factor. Perusing headstones in old cemeteries is very informative along this line.

Lecture Suggestions

1. Point out the importance of soils to everyday activities. For example, if a student has a hamburger for lunch, everything which he/she eats depended on a soil: the lettuce, tomato, and wheat for the bun were grown in soils, and the beef cattle had to eat plants grown in soil. If the hamburger was wrapped in aluminum foil, the aluminum came from bauxite.

2. Stress the distinction between weathering and erosion.

3. Since the Industrial Revolution, acid rain has taken a tremendous toll on some of the great architectural works and outdoor sculptures of the past two millennia. For example, compare the 1853 photo of a gargoyle at Notre Dame Cathedral in Paris (http://en.wikipedia.org/wiki/File:Henri_Le_Secq_near_a_Gargoyle.jpg) with a modern one (http://en.wikipedia.org/wiki/File:Notre_dame-paris-view.jpg). The modern gargoyle is pitted and sharp edges are rounded.

4. Discuss the economic causes of soil erosion. In the article “High Prices Sow Seeds of Erosion” from the New York Times, farmers are afraid that erosion will increase now that marginal lands are being farmed due to high prices for corn and soy beans. http://www.nytimes.com/2011/04/13/business/13erosion.html?scp=1&sq=soil%20erosion&st=cse

5. Many techniques are used to prevent soil erosion. Conservation of cropland is aided by crop rotation, and planting cover crops and windbreaks. Contour farming and terracing and contour tillage are also used on farmland. Logs may be placed perpendicular to a steep slope. Soil conservation requires measures that reduce salination of soils.
Consider This

1. The ecosystem encompasses the interactions among the lithosphere, hydrosphere, atmosphere, and biosphere. Soils are very different in different ecosystems. What role do they play in deserts, forests, tundra, and other ecosystems?

2. How did the rates of weathering and erosion change after the evolution of land plants?

3. What are some of the ways in which the rate of soil erosion can be reduced?

4. Should gossans and other mineral resource-rich laterite soils in tropical regions be mined? Why or why not?

5. Is soil a renewable or nonrenewable resource?

6. What effect might increased soil erosion have on global warming?

Important Terms

- chemical weathering
- differential weathering
- erosion
- exfoliation dome
- expansive soil
- frost action
- hydrolysis
- laterite
- mechanical weathering
- oxidation
- parent material
- pressure release
- regolith
- salt crystal growth
- sheet joins
- soil
- soil degradation
- soil horizon
- solution
- spheroidal weathering
- talus
- thermal expansion and contraction
- weathering

Internet Sites, Videos, Software, and Demonstration Aids

Internet Sites

1. Natural Resources Conservation Data, U.S. Department of Agriculture
   http://soils.usda.gov/

   http://geomaps.wr.usgs.gov/parks/rxmin/rock2.html

3. U.S. National Geophysical Data Center, Sediment Thickness of the World’s Oceans
   http://www.ngdc.noaa.gov/mgg/sedthick/sedthick.html
Videos

   The rock cycle, the main types of rocks and how fossil fuels are used.

2. From Rock to Sand to Muck: All the Dirt on Soils. Insight Media DVD (1996, 63 mins.)
   The breakdown of rock into sediments and their decomposition into soils; soil types.

3. The Once Good Earth: Understanding Soil. Insight Media DVD (2005, 46 mins.)
   The chemical and ecological features of soil.

   • #15: Weathering and Soils. A comparison of weathering in a city versus a remote desert.

Slides and Demonstration Aids

   Erosion, Slides and Surface Features

2. National Geographic – images of erosion and weathering

Answers to Figure-Related Critical Thinking Questions

☐ ☐ Critical Thinking Question Figure 6.4

* Barely visible in the left foreground is a highway. Why do you think these sheet joints might be a problem for highway maintenance crews? *

One form of exfoliation, removal of loose surface rock, in rock bodies influenced by pressure release, is mass wasting. The joints are inclined toward the road. When the sheets break off they will slide toward the road.

☐ ☐ Critical Thinking Question Figure 6.6

* Does vegetation, especially trees, have a detrimental effect on rocklike substances such as foundations and sidewalks? *

“Darn maple tree keeps popping up the sidewalk slabs. City says to replace it at $300 a slab! Still, taking down the maple tree would be much more expensive.”

☐ ☐ Critical Thinking Question Figure 6.7

* Which do you think would dissolve fastest, rock salt or table salt? Explain. *

Rock salt, table salt, halite, NaCl…all the same?
OK: Table salt is closest to “pure” NaCl as it is formed from solution extraction and evaporation. Rock salt is usually the physically mined product (Detroit Salt Company) from the original marine precipitate while ocean basins still contained ocean water! This strata of salt also contains
other “impurities” from shale to CaSO4; “impurities” that would slow down the dissolving process.

**Critical Thinking Question** Figure 6.9

*If you placed some rectangular ice cubes in the sun, how do you think their shape would change as they melted?*

Those ice cubes would look like the shape progression documented in Figure 6.9 in this new Chapter 6: check those cubes out in your drink glass!

**Critical Thinking Question** Figure 6.11

*Why does soil extend to much greater depths in the tropics compared to deserts?*

Weathering and the depth of soil formation are both increased by climate factors of longer seasonal warmth and greater precipitation. Even if temperatures are comparable, then water is the difference. In the tropics, it rains, a lot more than in any desert community (no desert crosses the Equator!).

**Critical Thinking Question** Figure 6.14

*Laterite supports lush vegetation but is not very good for agriculture. Why?*

In the tropics where laterite soil forms, nutrients are immediately recycled into the vegetation. Because of this process, very little of these nutrients are stored in the soil. Any of the important ions that would contribute to good agricultural soil is intensely weathered into the deep B horizon and the ground water (I prefer 2 words, as a professional hydrogeologist).

**Suggested Answer to Selected Short Answer Question**

*(Answers to question 8 and question 9 provided in the appendix to the text)*

7. How do parent material, particle size, and climate control the rate of chemical weathering?

**Suggested Answer:**

Chemical weathering is the decomposition of rocks and minerals through chemical processes such as oxidation, hydrolysis and dissolution. The rate of chemical weathering is affected by various criteria. The effect of parent material on a soil include such feature as soil texture, pH and mineral constituents. Small particle size of rocks accelerate chemical weathering by providing more surface area for chemical reactions. Climatic factors, especially temperature and moisture, have a strong effect on the rate of weathering. Generally, the warmer the temperature and the higher the humidity, promote chemical weathering.