

Chapter 14

Weathering and Erosion

Chapter Outline

1 Weathering Processes

Mechanical Weathering
Chemical Weathering

2 Rates of Weathering

Differential Weathering
Rock Composition
Amount of Exposure
Climate
Topography and Elevation
Human Activities
Plant and Animal Activities

3 Soil

Soil Characteristics
Soil Profile
Soil and Climate
Soil and Topography

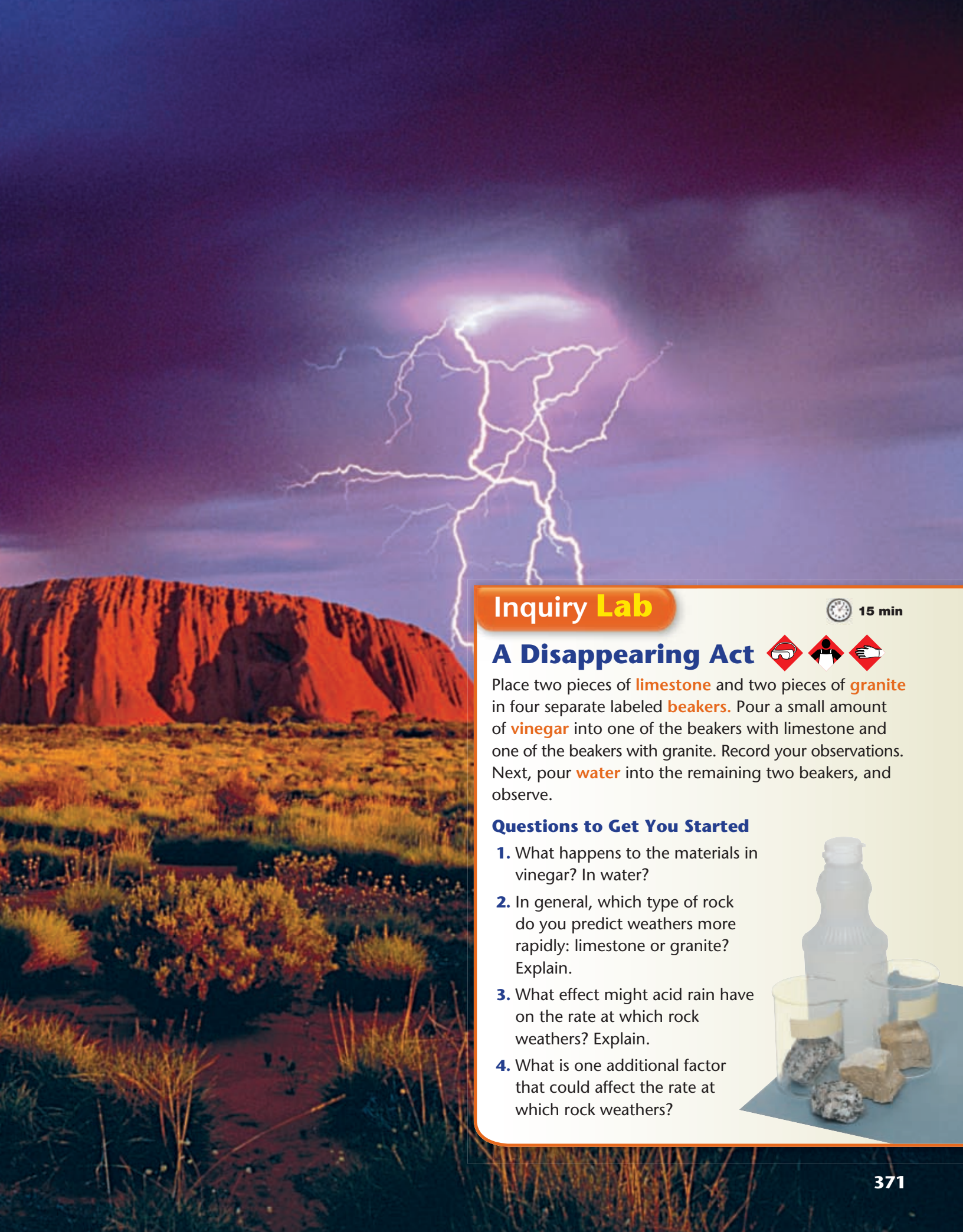
4 Erosion

Soil Erosion
Soil Conservation
Gravity and Erosion
Erosion and Landforms



Why It Matters

This red rock formation in Australia—like Earth's entire surface—is shaped by the processes of weathering and erosion. These processes are essential to the formation of soil, from which the food you eat grows.



Inquiry Lab

 15 min

A Disappearing Act

Place two pieces of **limestone** and two pieces of **granite** in four separate labeled **beakers**. Pour a small amount of **vinegar** into one of the beakers with limestone and one of the beakers with granite. Record your observations. Next, pour **water** into the remaining two beakers, and observe.

Questions to Get You Started

1. What happens to the materials in vinegar? In water?
2. In general, which type of rock do you predict weathers more rapidly: limestone or granite? Explain.
3. What effect might acid rain have on the rate at which rock weathers? Explain.
4. What is one additional factor that could affect the rate at which rock weathers?



Finding Examples

Examples of Mechanical

Weathering Examples can help you picture an idea or concept. Certain words or phrases can serve as signals that an example is about to be introduced. Such signals include

- *for example*
- *such as*
- *for instance*

Your Turn As you read Section 1, make a list of different types of mechanical weathering. See the sample list below to help you get started. Add examples for each type of mechanical weathering. If a word or phrase in the text signals the example, add that word or phrase.

| Types of mechanical weathering | Examples | Signal words |
|--------------------------------|-----------------------------------------------------|--------------|
| exfoliation | overlying rocks erode, granite expands; joints form | for example |
| ice wedging | | |
| abrasion | | |

FoldNotes

Tri-Fold A tri-fold can help you track your progress through the process of KWL. The letters KWL stand for “what I Know, what I Want to know, and what I Learned.” These notes help you relate new ideas to those you already know. This can help make new ideas easier to understand.

Your Turn Make a tri-fold FoldNote. In the left column, write what you already know about weathering and erosion. In the middle column, write what you want to know about weathering and erosion. In the right column, write what you learn as you read the chapter.

| Know | Want to Know | Learned |
|----------------------------------------------------|-------------------------------------------------|------------------------------------------------------------------------------|
| Weathering is an important part of soil formation. | What else makes up soil besides weathered rock? | Soil is a combination of weathered rock, water, gases, and organic material. |

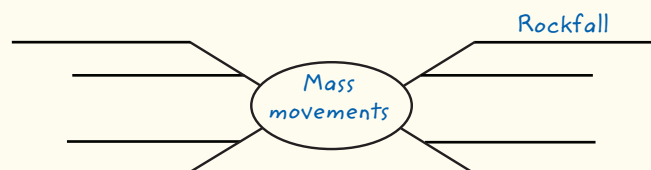
Graphic Organizers

Spider Maps A spider map divides a topic into ideas and details.

To make a spider map, follow these steps:

- 1 For your title, write the main topic. Draw an oval around it.
- 2 From the oval, draw legs. Each leg represents a category of the main topic.
- 3 From each leg, draw horizontal lines. Write details about each category on these lines.

Your Turn As you read Section 4, complete a spider map like the one started here to organize the ideas you learn about gravity and erosion.



For more information on how to use these and other tools, see **Appendix A**.

Weathering Processes

| Key Ideas | Key Terms | Why It Matters |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> ➤ Identify three agents of mechanical weathering. ➤ Compare mechanical and chemical weathering processes. ➤ Describe four chemical reactions that decompose rock. | <p>weathering</p> <p>mechanical weathering</p> <p>abrasion</p> <p>chemical weathering</p> <p>oxidation</p> <p>hydrolysis</p> <p>carbonation</p> <p>acid precipitation</p> | <p>Although we say that something that does not change is “like a rock,” rocks actually do change over time, through the processes of weathering. These processes also affect buildings, monuments, and other structures made of stone.</p> |

Most rocks deep within Earth’s crust formed under conditions of high temperature and pressure. When these rocks are uplifted to the surface, they are exposed to much lower temperature and pressure. Uplifted rock is also exposed to the gases and water in Earth’s atmosphere.

Because of these environmental factors, surface rocks undergo changes in their appearance and composition. The physical breakdown or chemical decomposition of rock materials exposed at Earth’s surface is called **weathering**. There are two main types of weathering: mechanical weathering and chemical weathering. Each type of weathering has different effects on rock.

Mechanical Weathering

The process by which rock is broken down into smaller pieces by physical means is **mechanical weathering**. Mechanical weathering is strictly a physical process and does not change the composition of the rock. Common agents of mechanical weathering are ice, plants and animals, gravity, running water, and wind.

Physical changes within the rock also affect mechanical weathering. For example, when overlying rocks are eroded, granite that formed deep beneath Earth’s surface can be exposed, decreasing the pressure on the granite. As a result of the decreasing pressure, the granite expands. Long, curved cracks, called *joints*, develop in the rock. When the joints are parallel to the surface of the rock, the rock breaks into curved sheets that peel away from the underlying rock in a process called *exfoliation*. One example of granite exfoliation is shown in **Figure 1**.

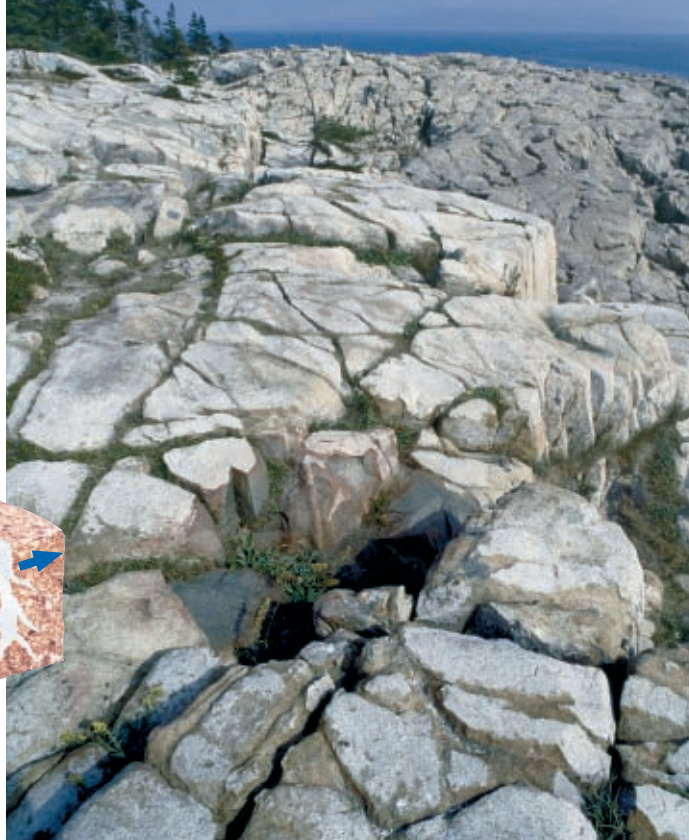
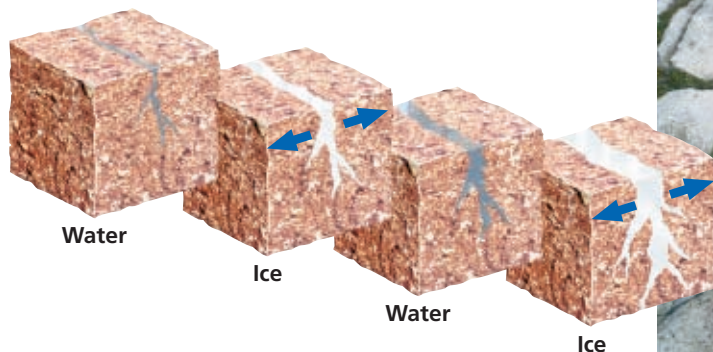
weathering the natural process by which atmospheric and environmental agents, such as wind, rain, and temperature changes, disintegrate and decompose rocks

mechanical weathering the process by which rocks break down into smaller pieces by physical means

Figure 1 This formation in Kings Canyon National Park is a dome of granite that is shedding large sheets of rock through the process of exfoliation.



Figure 2 Water flows into a crack in a rock's surface. When the water freezes, it expands and causes the crack to widen. Ice wedging is responsible for most of the cracks shown in this photo.




Ice Wedging

Another form of mechanical weathering is called *ice wedging*. Ice wedging occurs when water seeps into cracks in rock and then freezes. When the water freezes, its volume increases by about 10% and creates pressure on the surrounding rock. Every time the ice thaws and refreezes, cracks in the rock widen and deepen. This process eventually splits the rock apart, as shown in **Figure 2**. Ice wedging commonly occurs at high elevations and in cold climates. It also occurs in climates where the temperature regularly rises above and then falls below freezing, such as in the northern United States.

Abrasion

The collision of rocks that results in the breaking and wearing away of the rocks is a form of mechanical weathering called **abrasion**. Abrasion is caused by gravity, ice, running water, and wind. Gravity causes loose soil and rocks to move down the slope of a hill or mountain. Rocks break into smaller pieces as they fall and collide. Running water can carry sand or rock particles that scrape against each other and against stationary rocks. Thus, exposed surfaces are weathered by abrasion.

Wind is another agent of abrasion. When wind lifts and carries small particles, it can hurl them against surfaces, such as rock. As the airborne particles strike the rock, they wear away the surface in the same way that a sandblaster would.

 **Reading Check** Describe two forms of mechanical weathering. (See Appendix G for answers to Reading Checks.)

abrasion the grinding and wearing away of rock surfaces through the mechanical action of other rock or sand particles



Figure 3 This gray wolf (left) is burrowing into soil to make a den. Prairie dogs also dig into soil to form extensive burrows, where an entire prairie dog community may live.

Plant and Animal Activity

Plants and animals are important agents of mechanical weathering. As plants grow, their roots grow and expand, creating pressure that wedges rock apart. The roots of small plants cause small cracks to form in the rocks. Eventually, the roots of larger plants and trees can fit in the cracks and make the cracks bigger.

The digging activities of burrowing animals, shown in **Figure 3**, affect the rate of weathering. Common burrowing animals include ground squirrels, prairie dogs, ants, earthworms, coyotes, and rabbits. Earthworms and other animals that move soil expose new rock surfaces to both mechanical and chemical weathering. Animal activities and plants can increase the rate of weathering dramatically over a long period of time.

Academic Vocabulary

agent (AY juhnt) a substance or living organism that has an impact on an ecological process

Quick Lab Mechanical Weathering



 15 min

Procedure

- 1 Examine some **silicate rock chips** by using a **hand lens**. Observe the shape and surface texture.
- 2 Fill a **plastic container** that has a **tight-fitting lid** about half full of rock chips. Add **water** to just cover the chips.
- 3 Tighten the lid, and shake the container 100 times.
- 4 Hold a **strainer** over another container. Pour the water and rock chips into the strainer.
- 5 Move your finger around the inside of the empty container. Describe what you feel.
- 6 Use the hand lens to observe the rock chips.
- 7 Pour the water into a **glass jar**, and examine the water with the hand lens.
- 8 Put the rock chips and water back into the container that has the lid. Repeat steps 3 to 7.
- 9 Repeat step 8 two more times.



Analysis

1. Did the amount and particle size of the sediment that was left in the container change during your investigation? Explain your answer.
2. How did the appearance of the rock chips change? How did the appearance of the water change?
3. How does the transport of rock particles by water, such as in a river, affect the size and shape of the rock particles?

chemical weathering the process by which rocks break down as a result of chemical reactions

oxidation the process by which a metallic element combines with oxygen

Math Skills

Rates of Weathering

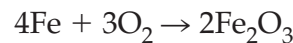
Limestone is dissolved by chemical weathering at a rate of 0.2 cm every 100 years. At this rate, after how many years would a layer of limestone 15 m thick completely dissolve?

Chemical Weathering

The process by which rock is broken down because of chemical interactions with the environment is **chemical weathering**. Chemical weathering, or decomposition, occurs when chemical reactions act on the minerals in rock. Chemical reactions commonly occur between rock, water, carbon dioxide, oxygen, and acids. Acids are substances that form *hydronium ions*, H_3O^+ , in water. Hydronium ions are electrically charged and can pull apart the chemical bonds of the minerals in rock. Bases can also chemically weather rock. Bases are substances that form *hydroxide ions*, OH^- , in water. Chemical reactions with either acids or bases can change the structure of minerals, which leads to the formation of new minerals. Chemical weathering changes both the chemical composition and physical appearance of rock.

Oxidation

The process by which elements combine with oxygen is called **oxidation**. Oxidation commonly occurs in rock that has iron-bearing minerals, such as hematite and magnetite. In this rock, iron, Fe, combines quickly with oxygen, O_2 , that is dissolved in water to form rust, or iron oxide, Fe_2O_3 :

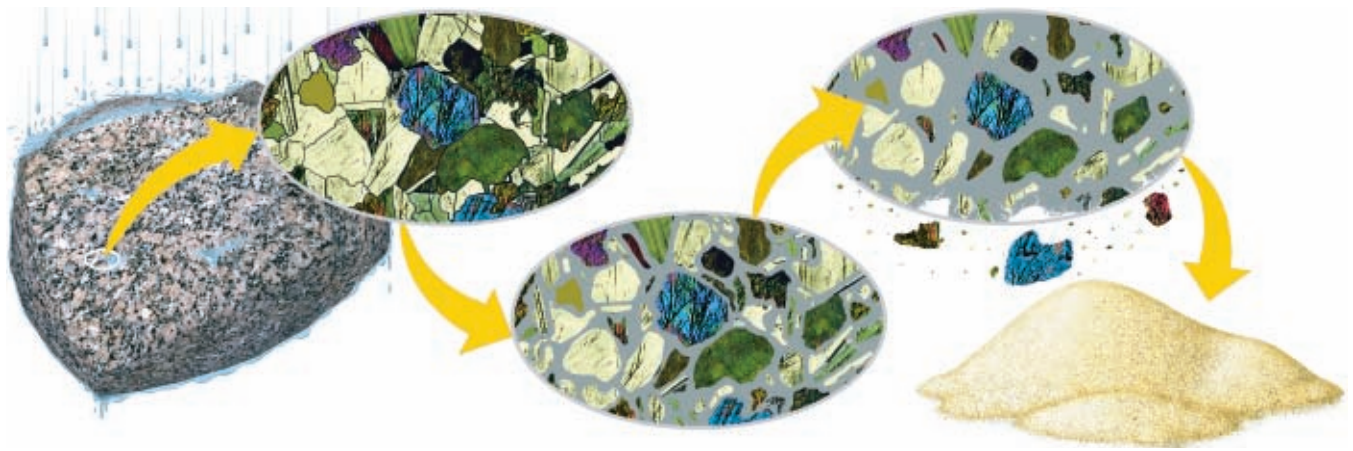


The red color of much of the soil in the southeastern United States, as shown in **Figure 4**, is mainly due to the presence of iron oxide produced by oxidation. Similarly, the color of many red-colored rocks is caused by oxidized, iron-rich minerals.

 **Reading Check** Describe two effects of chemical weathering.



Figure 4 The red color of the soil surrounding this farmhouse in Georgia is caused by the chemical interaction of iron-bearing minerals in the soil with oxygen in the atmosphere.



Rain, weak acids, and air chemically weather rock.

The bonds between mineral grains weaken as weathering proceeds.

Sediment forms from the weathered rock.

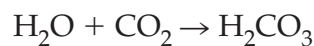
Hydrolysis

Water plays a crucial role in chemical weathering, as shown in **Figure 5**. The change in the composition of minerals when they react chemically with water is called **hydrolysis**. For example, a type of feldspar combines with water and produces a common clay called *kaolin*. In this reaction, hydronium ions displace the potassium and calcium atoms in the feldspar crystals, which changes the feldspar into clay.

Minerals that are affected by hydrolysis often dissolve in water. Water can then carry the dissolved minerals to lower layers of rock in a process called *leaching*. Ore deposits, such as bauxite, the aluminum ore, sometimes form when leaching causes a mineral to concentrate in a thin layer beneath Earth's surface.

Carbonation

When carbon dioxide, CO_2 , from the air dissolves in water, H_2O , a weak acid called *carbonic acid*, H_2CO_3 , forms:



Carbonic acid has a higher concentration of hydronium ions than pure water does, which speeds up the process of hydrolysis. When certain minerals come in contact with carbonic acid, they combine with the acid to form minerals called carbonates. The conversion of minerals into a carbonate is called **carbonation**.

One example of carbonation occurs when carbonic acid reacts with calcite, a major component of limestone, and converts the calcite into calcium bicarbonate. Calcium bicarbonate dissolves easily in water, so the limestone eventually weathers away.

Organic Acids

Acids are produced naturally by certain living organisms. Lichens and mosses grow on rocks and produce weak acids that can weather the surface of the rock. The acids seep into the rock and produce cracks that eventually cause the rock to break apart.

Figure 5 Thousands of years of chemical weathering processes, such as hydrolysis and carbonation, can turn even a hard rock into sediment.

hydrolysis a chemical reaction between water and another substance to form two or more new substances

carbonation the conversion of a compound into a carbonate

READING TOOLBOX

Finding Examples

As you read, find examples of each form of chemical weathering. Don't forget to use signal words as clues. Record the examples in a table. See the Reading Toolbox at the beginning of this chapter if you need help getting started.

Figure 6 This stone lion sits outside Leeds Town Hall in England. It was damaged by acid precipitation.



SCILINKS

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Topic: Acid Precipitation
Code: HQX1690

acid precipitation
precipitation, such as rain, sleet, or snow, that contains a high concentration of acids, often because of the pollution of the atmosphere

Acid Precipitation

✿ Natural rainwater is slightly acidic because it combines with small amounts of carbon dioxide. But when fossil fuels, especially coal, are burned, nitrogen oxides and sulfur dioxides are released into the air. These compounds combine with water in the atmosphere to produce nitric acid, nitrous acid, or sulfuric acid. When these acids fall to Earth, they are called **acid precipitation**.

Acid precipitation weathers some rock faster than ordinary precipitation does. In fact, many historical monuments and sculptures have been damaged by acid precipitation, as shown in **Figure 6**. Between 1940 and 1990, acid precipitation fell regularly in some cities in the United States. In 1990, the Acid Rain Control Program was added to the Clean Air Act of 1970. This program's regulations gave power plants 10 years to decrease sulfur dioxide emissions. The occurrence of acid precipitation has been greatly reduced since power plants have installed scrubbers that remove much of the sulfur dioxide before it can be released. ✿

Section 1 Review

Key Ideas

1. **Identify** three agents of mechanical weathering.
2. **Describe** how ice wedging weathers rock.
3. **Explain** how two activities of plants or animals help weather rocks or soil.
4. **Compare** mechanical and chemical weathering processes.
5. **Identify** and describe three chemical processes that weather rock.
6. **Compare** hydrolysis, carbonation, and oxidation.
7. **Summarize** how acid precipitation forms.

Critical Thinking

8. **Making Connections** Which two agents of weathering would be rare in a desert? Explain your reasoning.
9. **Understanding Relationships** Automobile exhaust contains nitrogen oxides. How might these pollutants affect chemical weathering processes?

Concept Mapping

10. Use the following terms to create a concept map: *weathering, oxidation, mechanical weathering, ice wedging, hydrolysis, abrasion, chemical weathering, carbonation, and acid precipitation.*

Rates of Weathering

Key Ideas

- Explain how rock composition affects the rate of weathering.
- Discuss how surface area affects the rate at which rock weathers.
- Describe the effects of climate and topography on the rate of weathering.

Key Terms

differential weathering

Why It Matters

Learning about the different factors that affect weathering can help you understand how your own activities may impact the environment.

The processes of mechanical and chemical weathering generally work very slowly. For example, carbonation dissolves limestone at an average rate of only about one-twentieth of a centimeter (0.05 cm) every 100 years. At this rate, it could take up to 30 million years to dissolve a layer of limestone that is 150 m thick.

The pinnacles in Nambung National Park in Australia are shown in **Figure 1**. Most of the limestone was weathered away by agents of both chemical and mechanical weathering until only the pinnacles remained. The rate at which rock weathers depends on a number of factors, including rock composition, climate, and topography.

Differential Weathering

The composition of rock greatly affects the rate at which rock weathers. The process by which softer, less weather-resistant rock wears away and leaves harder, more resistant rock behind is called **differential weathering**. When rocks that are rich in the mineral quartz are exposed on Earth's surface, they remain basically unchanged, even after all the surrounding rock has weathered away. They remain unchanged because the chemical composition and crystal structure of quartz make quartz resistant to chemical weathering. These characteristics also make quartz a very hard mineral, so it resists mechanical weathering.

Rock Composition

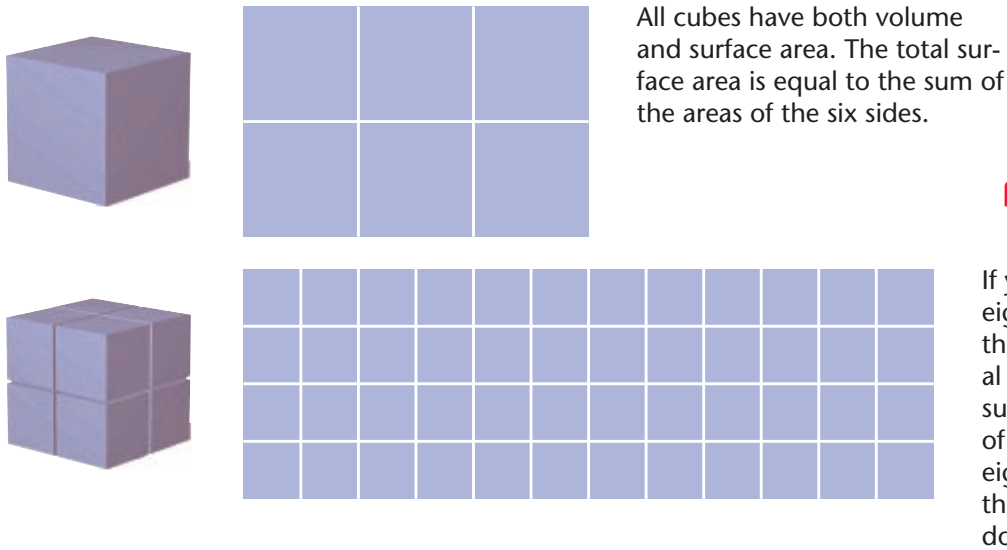
Limestone and other sedimentary rocks that contain calcite weather rapidly because they commonly undergo carbonation. Other sedimentary rocks are affected mainly by mechanical weathering processes. The rates at which these rocks weather depend mostly on the material that holds the sediment grains together. For example, shales and sandstones that are not firmly cemented gradually break up to become clay and sand particles. However, conglomerates and sandstones that are strongly cemented by silicates resist weathering longer than some igneous rocks do.

differential weathering the process by which softer, less weather-resistant rocks wear away at a faster rate than harder, more weather-resistant rocks do

Figure 1 Different rates of weathering formed these limestone pinnacles at Nambung National Park in Australia over millions of years.



Figure 2 The Ratio of Total Surface Area to Volume



All cubes have both volume and surface area. The total surface area is equal to the sum of the areas of the six sides.



If you split the first cube into eight smaller cubes, you have the same amount of material (volume), but double the surface area. If you split each of the eight small cubes into eight even smaller cubes, the original surface area is doubled again.

Academic Vocabulary

factor (FAK tuhr) a condition or event that brings about or contributes to a result

Quick Lab



10 min

Surface Areas



Procedure

- 1 Fill **two small containers** about half full with **water**.
- 2 Add **one sugar cube** to one container.
- 3 Add **1 tsp of granulated sugar** to the other container.
- 4 Use **two different spoons** to stir the water and sugar in each container at the same rate.
- 5 Use a **stopwatch** to measure how long the sugar in each container takes to dissolve.

Analysis

1. Did the sugar dissolve at the same rate in both containers?
2. Which do you think would wear away faster—a large rock or a small rock? Explain your answer.

Amount of Exposure

The more exposure to weathering agents that a rock receives, the faster the rock will weather. The amount of time that the rock is exposed and the amount of the rock's surface area that is available for weathering are important factors in determining the rate of weathering.

Surface Area

Both chemical and mechanical weathering may split rock into a number of smaller rocks. The part of a rock that is exposed to air, water, and other agents of weathering is called the rock's *surface area*. As a rock breaks into smaller pieces, the surface area that is exposed increases. For example, imagine a block of rock as a cube that has six sides exposed. Splitting the block into eight smaller blocks, as shown in **Figure 2**, doubles the total surface area available for weathering.

Fractures and Joints

Most rocks on Earth's surface contain natural fractures and joints. These fractures and joints are natural zones of weakness within the rock. They increase the surface area of a rock and allow weathering to take place more rapidly. They also form natural channels through which water flows. Water may penetrate the rock through these channels and break the rock by ice wedging. As water moves through these channels, it chemically weathers the rock that is exposed in the fracture or joint. The chemical weathering removes rock material and makes the jointed or fractured area weaker.

 **Reading Check** How do fractures and joints in a rock affect surface area?



Figure 3 The photo on the left shows Cleopatra's Needle before it was moved to New York City. The photograph on the right shows the 3,000-year-old carvings after only one century in New York City.

Climate

✦ In general, climates that have alternating periods of hot and cold weather allow the fastest rates of weathering. Freezing and thawing can cause the mechanical breakdown of rock by ice wedging. Chemical weathering can then act quickly on the fractured rock. When the temperature rises, the rate at which chemical reactions occur accelerates. In warm, humid climates, chemical weathering is also fairly rapid. The constant moisture is highly destructive to exposed surfaces.

The slowest rates of weathering occur in hot, dry climates. The lack of water limits many weathering processes, such as carbonation and ice wedging. Weathering is also slow in very cold climates.

The effects of climate on weathering rates can be seen on Cleopatra's Needle, which is shown in **Figure 3**. Cleopatra's needle is an obelisk that is made of granite. For 3,000 years, the obelisk remained in Egypt, where the hot, dry climate scarcely changed its surface. Then, in 1880, Cleopatra's Needle was moved to New York City. After only 130 years, the moisture, ice wedging, and pollution, such as acid precipitation, caused more weathering than was caused in the preceding 3,000 years in the Egyptian desert. ✦

Topography and Elevation

Topography, or the elevation and slope of the land surface, also influences the rate of weathering. Because temperatures are generally cold at high elevations, ice wedging is more common at high elevations than at low elevations. On steep slopes, such as mountainsides, weathered rock fragments are pulled downhill by gravity and washed out by heavy rains. As the rock fragments slide down the mountain or are carried away by mountain streams, they smash against each other and break apart. As a result of the removal of these surface rocks, new surfaces of the mountain are continually exposed to weathering.

SCILINKS

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Topic: Rates of Weathering

Code: HQX1269

READING TOOLBOX

Spider Map

Create a spider map and label the center oval "Factors that affect the rate of weathering." Then, fill in the map with at least four factors presented in this section.

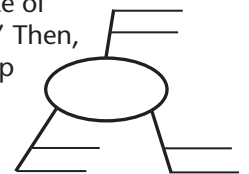




Figure 4 All-terrain vehicles and recreational activities can cause mechanical weathering of exposed rock. These activities may also expose new rock surfaces to chemical weathering.

Human Activities

Rock can be chemically and mechanically broken down by the action of humans. Mining and construction often expose rock surfaces to agents of weathering. Mining also exposes rock to strong acids and other chemical compounds that are used in mining processes. Construction often removes soil and exposes previously unexposed rock surfaces. Recreational activities, such as hiking and riding all-terrain vehicles, as shown in **Figure 4**, can also speed up weathering by exposing new rock surfaces. Rock that is disturbed or broken by human activities weathers more rapidly than undisturbed rock does.

Plant and Animal Activities

Rock that is disturbed or broken by plants or animals also weathers more rapidly than undisturbed rock does. The roots of plants and trees often break apart rock.

Burrowing animals dig holes, exposing new rock surfaces. Some biological wastes of animals can cause chemical weathering. For example, caves that have large populations of bats also have large amounts of bat guano on the cave floors. Bat guano attracts insects, such as millipedes and beetles. The presence of these insects speeds up mechanical weathering, and the presence of the guano increases the rate of certain chemical weathering processes.

Section 2 Review

Key Ideas

- 1. Explain** how rock composition affects the rate of weathering.
- 2. Discuss** how the surface area of a rock can affect the rate of weathering.
- 3. Identify** two ways that climate can affect the rate of weathering.
- 4. Describe** two ways that the topography of a region can affect the rate of weathering.
- 5. Summarize** three ways that human actions can affect the rate of weathering.
- 6. Explain** two ways that animals can affect the rate of weathering.

Critical Thinking

- 7. Applying Concepts** Imagine that there is an area of land where mechanical weathering has caused damage. Describe two ways to reduce the rate of mechanical weathering.
- 8. Identifying Relationships** How would Cleopatra's Needle probably have been affected if it had been in the cold, dry climate of Siberia for 130 years?

Concept Mapping

- 9.** Use the following terms to create a concept map: *composition, exposure, precipitation, surface area, climate, temperature, topography, weathering, elevation, and human activities.*

Key Ideas

- Summarize how soils form.
- Explain how the composition of parent rock affects soil composition.
- Describe the characteristic layers of mature residual soils.
- Predict the type of soil that will form in arctic and tropical climates.

Key Terms

soil
soil profile
horizon
humus

Why It Matters

Nearly all the food you eat was grown in soil. Earth scientists study the characteristics of soil to gain a better understanding of how to conserve and use this critical natural resource.

One result of weathering is the formation of *regolith*, the layer of weathered rock fragments that covers much of Earth's surface. *Bedrock* is the solid, unweathered rock that lies beneath the regolith. The lower regions of regolith are partly protected by those above and thus do not weather as rapidly as the upper regions do. The uppermost rock fragments weather to form a layer of very fine particles. This layer of small rock particles provides the basic components of soil. **Soil** is a complex mixture of minerals, water, gases, and the remains of dead organisms.

Soil Characteristics

The characteristics of soil depend largely on the rock from which the soil was weathered, which is called the soil's *parent rock*. Soil that forms and stays directly over its parent rock is called *residual soil*. However, the weathered mineral grains within soil may be carried away from the location of the parent rock by water, wind, or glaciers. Soil that results from the deposition of this material is called *transported soil*, and it may have different characteristics than the bedrock on which it rests.

Soil Composition

Parent rock that is rich in feldspar or other minerals that contain aluminum weathers to form soils that contain large amounts of clay. Parent rock that contains large amounts of quartz, such as granite, weathers to form sandy soils. Soil composition refers to the materials of which it is made. The color of soil is related to the composition of the soil. Black soils are commonly rich in organic material, while red soils may form from iron-rich parent rock. Soil moisture can also affect color, as shown in **Figure 1**.

soil a loose mixture of rock fragments and organic material that can support the growth of vegetation

Figure 1 These soil scientists are testing soil moisture to determine whether irrigation will be needed. Moister soils are generally darker than drier soils are.



Soil Texture

Rock material in soil can be grouped into three main sizes: clay, silt, and sand. Clay particles have a diameter of less than 0.002 mm. Silt particles have diameters from 0.002 to 0.05 mm. Silt particles are too small to be seen easily, but they make soil feel gritty. Sand particles have diameters from 0.05 to 2 mm. The proportion of clay, silt, and sand in soil determines a soil's texture.

Soil Profile

Transported soils are commonly deposited in unsorted masses by water or wind. However, residual soils commonly develop distinct layers over time. To determine a soil's composition, scientists study a soil profile. A **soil profile** is a cross section of the soil and its bedrock. The different layers of soil are called **horizons**.

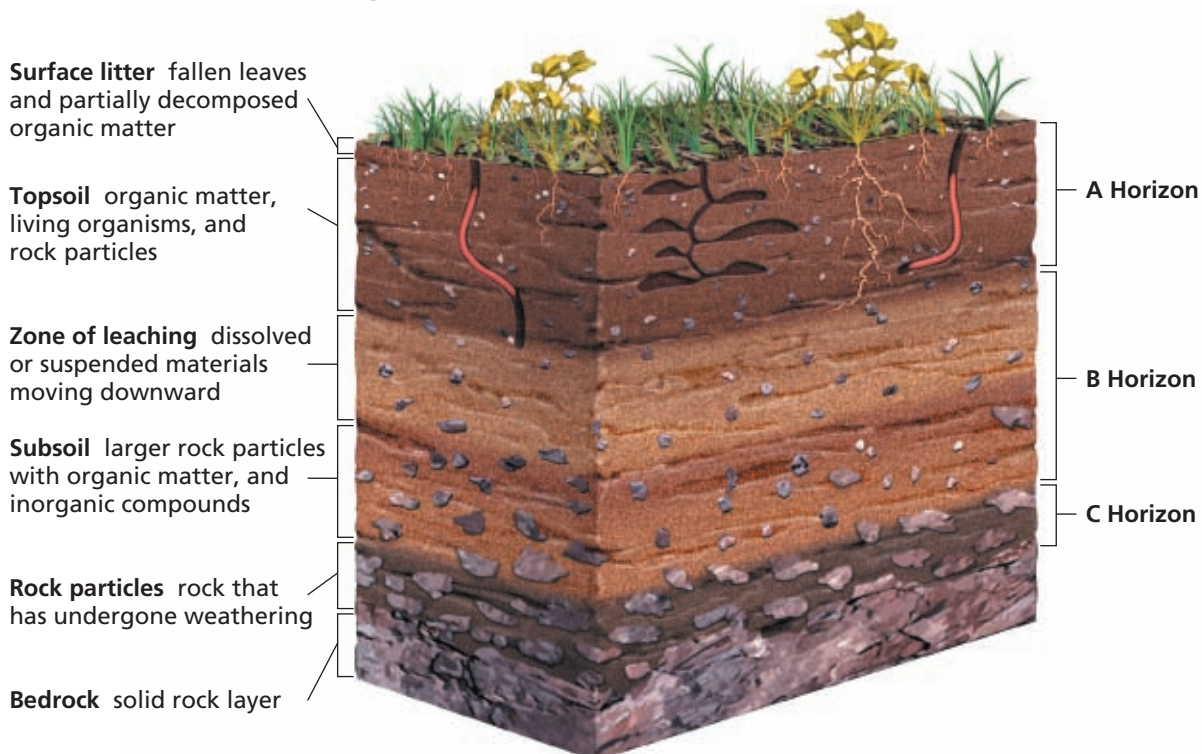
soil profile a vertical section of soil that shows the layers, or horizons

horizon a horizontal layer of soil that can be distinguished from the layers above and below it

humus dark, organic material formed in soil from the decayed remains of plants and animals

Residual soils generally consist of three main horizons. The *A horizon*, or *topsoil*, is a mixture of organic materials and small rock particles. Almost all organisms that live in soil inhabit the A horizon. As organisms die, their remains decay and produce **humus**, a dark, organic material. The A horizon is also the layer from which surface water leaches minerals. The *B horizon*, or *subsoil*, contains the minerals leached from the topsoil, clay, and sometimes humus. In dry climates, the B horizon also may contain minerals that accumulate as water in the soil evaporates. The *C horizon* consists of partially weathered bedrock. The first stages of mechanical and chemical change happen in this bottom layer. **Figure 2** shows the relationships between the three soil horizons.

Figure 2 Soil Horizons of Residual Soils



Soil and Climate

Climate is one of the most important factors that influence soil formation. Climate determines the weathering processes that occur in a region. These weathering processes, in turn, help to determine the composition of soil.

Tropical Soils

In humid tropical climates, where much rain falls and where temperatures are high, chemical weathering causes thick soils to develop rapidly. These thick, tropical soils, called *laterites* (LAT uhr IETS), contain iron and aluminum minerals that do not dissolve easily in water. Leached minerals from the A horizon sometimes collect in the B horizon. Heavy rains, which are common in tropical climates, cause a lot of leaching of the topsoil, and thus keep the A horizon thin. But because of the dense vegetation in humid, warm climates, organic material is continuously added to the soil. As a result, a thin layer of humus usually covers the B horizon, as shown in **Figure 3**.

Temperate Soils

In temperate climates, where temperatures range between cool and warm, and where rainfall is not excessive, both mechanical and chemical weathering occur. Temperate soils have the thickest A horizon, as shown in **Figure 3**.

Two main soil types form in temperate climates. In areas that receive more than 65 cm of rain per year, a type of soil called *pedalfer* (pi DAL fuhr) forms. Pedalfer soil contains clay, quartz, and iron compounds. The Gulf Coast states and states east of the Mississippi River have pedalfer soils. In areas that receive less than 65 cm of rain per year, a soil called *pedocal* (PED oh KAL) forms. Pedocal soil contains large amounts of calcium carbonate, which makes it very fertile and less acidic than pedalfer soil. The southwestern states and most states west of the Mississippi River have pedocal soils.

Reading Check Compare the formation of tropical soils and temperate soils.

Desert and Arctic Soils

In desert and arctic climates, rainfall is minimal and chemical weathering occurs slowly. As a result, the soil is thin and consists mostly of regolith—evidence that the soil in these areas forms mainly by mechanical weathering. Also, desert and arctic climates are often too warm or too cold to sustain life, so their soils have little humus.

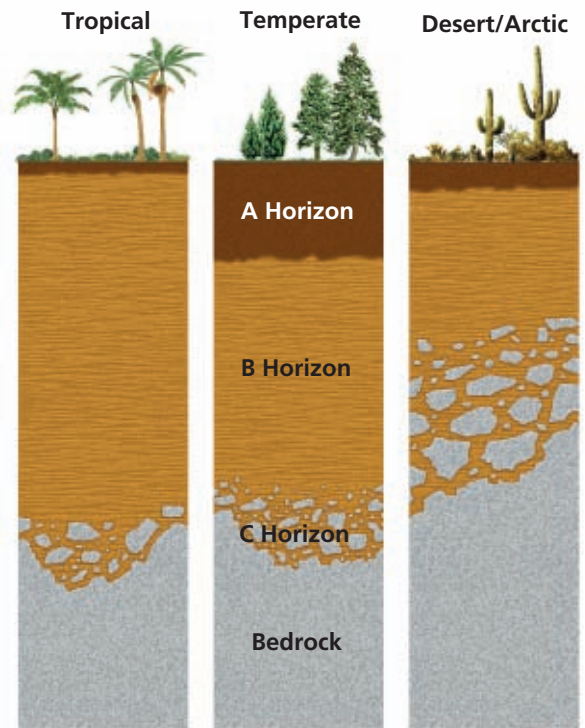


Figure 3 Tropical climates produce thick, infertile soils. Temperate climates produce thick, fertile soils. Desert and arctic climates produce thin soils.

Academic Vocabulary

determine (dee TUHR muhn) to define or decide

READING TOOLBOX

Tri-Fold

Create a tri-fold FoldNote to compare soil types in different climates. In the first column, write the type of soil. In the second column, describe the climate. In the third column, describe the soil.

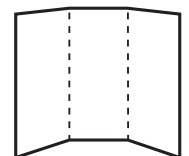
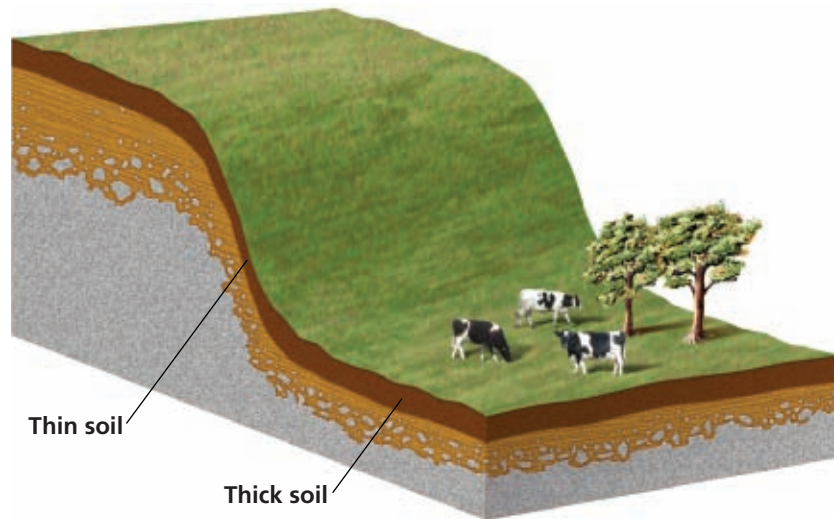


Figure 4 Soil is thick at the top and bottom of a slope. Soil is thin along the slope.



Soil and Topography

The shape of the land, or topography, also affects soil formation. Because rainwater runs down a slope, much of the topsoil of the slope washes away. Therefore, as shown in **Figure 4**, the soil at the top and bottom of a slope tends to be thicker than the soil on the slope.

One study of soil in Canada showed that A horizons on flat areas were more than twice as thick as those on 10° slopes. Topsoil that remains on a slope is often too thin to support dense plant growth. The lack of vegetation contributes to the development of a poor-quality soil that lacks humus. The soils on the sides of mountains are commonly thin and rocky, with few nutrients. Lowlands that retain water tend to have thick, wet soils with a high concentration of organic matter, which forms humus. A fairly flat area that has good drainage provides the best surface for the formation of thick, fertile layers of residual soil.

SCILINKS

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Topic: Soil

Code: HQX1407

Section 3 Review

Key Ideas

1. **Summarize** how soils form.
2. **Explain** how the composition of the parent rock affects soil composition.
3. **Describe** the three horizons of a residual soil.
4. **Predict** the type of soil that will form in arctic and tropical climates.

Critical Thinking

5. **Applying Ideas** What combination of soil and climate would be ideal for growing deep-rooted crops? Explain your answer.

6. **Analyzing Relationships** Would you expect crop growth to be more successful on a farm that has an uneven topography or on a farm that has level land? Explain your answer.
7. **Analyzing Ideas** Why would tropical soil not be good for sustained farming?
8. **Making Comparisons** Although desert and arctic climates are extremely different, their soils may be somewhat similar. Explain why.

Concept Mapping

9. Use the following terms to create a concept map: *soil, bedrock, regolith, humus, parent rock, residual soil, transported soil, horizon, soil profile, climate, and topography.*

Key Ideas

- Define erosion, and list four agents of erosion.
- Identify four farming methods that conserve soil.
- Discuss two ways that gravity contributes to erosion.
- Describe the three major landforms shaped by weathering and erosion.

Key Terms

erosion
sheet erosion
mass movement
solifluction
creep
landform

Why It Matters

Erosion destroys homes, buildings, and lives every year—sometimes through dramatic events such as landslides. By understanding the factors involved in erosion, some of these consequences may be avoided.

When rock weathers, the resulting rock particles do not always stay near the parent rock. Various forces may move weathered fragments of rock away from where the weathering occurred. The process by which the products of weathering are transported is called **erosion**. The most common agents of erosion are gravity, wind, glaciers, and water. Water can move weathered rock in several different ways, including by ocean waves and currents, by streams and runoff, and by the movements of groundwater.

Soil Erosion

As rock weathers, it eventually becomes very fine particles that mix with water, air, and humus to form soil. The erosion of soil occurs worldwide and is normally a slow process. Ordinarily, new soil forms about as fast as existing soil erodes. However, some forms of land use and unusual climatic conditions can upset this natural balance. Once the balance is upset, soil erosion often accelerates.

Soil erosion is considered by some scientists to be the greatest environmental problem that faces the world today. As shown in **Figure 1**, vulnerability to erosion affects fertile topsoil around the world. This erosion prevents some countries from growing the crops needed to prevent widespread famine.

erosion a process in which the materials of Earth's surface are loosened, dissolved, or worn away and transported from one place to another by a natural agent, such as wind, water, ice, or gravity

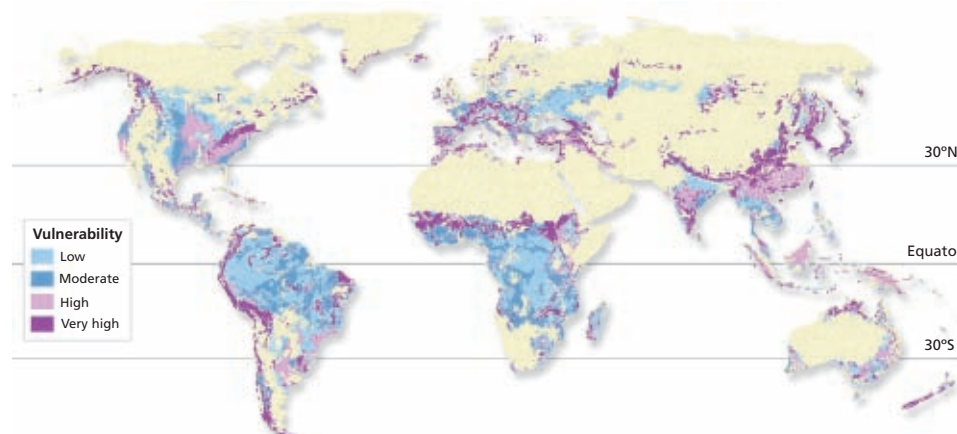
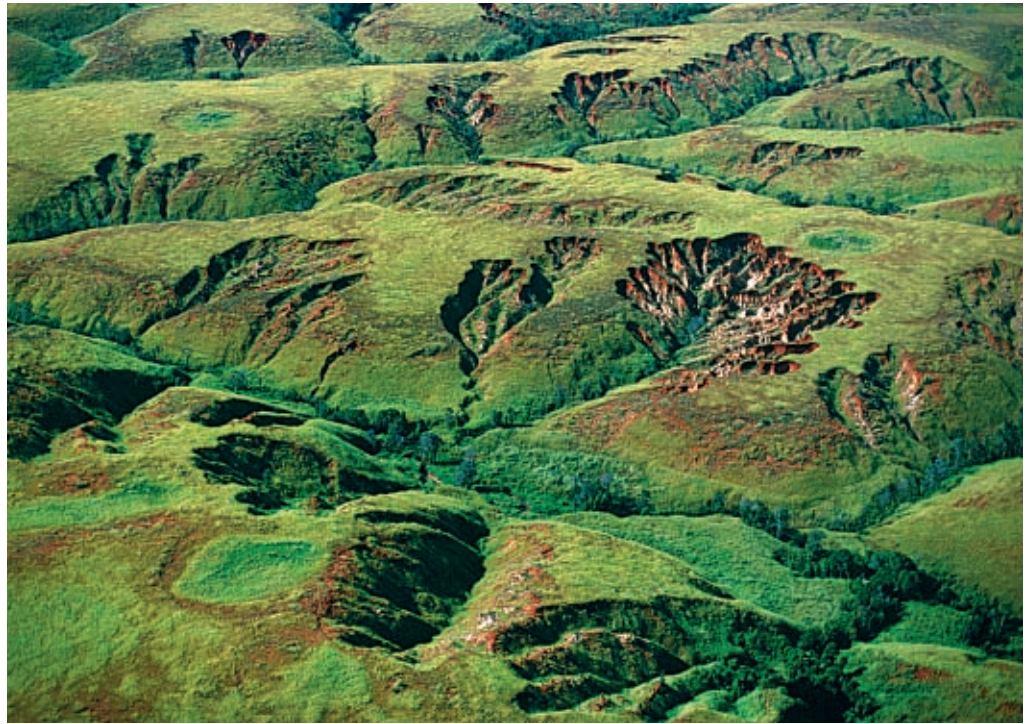


Figure 1 This map shows the vulnerability of soils to erosion by water.

Figure 2 This land in Madagascar can no longer be used for farming because of a form of rapid erosion called *gullying*.



SCILINKS

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Topic: Soil Erosion

Code: HQX1410

Topic: Soil Conservation

Code: HQX1409

sheet erosion the process by which water flows over a layer of soil and removes the topsoil

Gullying and Sheet Erosion

One farming technique that can accelerate soil erosion is the improper plowing of furrows, or long, narrow rows. Furrows that are plowed up and down slopes allow water to run swiftly over soil. As soil is washed away with each rainfall, the furrows become larger and form small gullies. Eventually, the land can become covered with deep gullies. This type of accelerated soil erosion is called *gullying*. The farmland shown in **Figure 2** has been ruined by gullying.

Another type of soil erosion strips away layers of topsoil. Eventually, erosion can expose the surface of the subsoil. This process is called **sheet erosion**. Sheet erosion may occur where continuous rainfall washes away layers of the topsoil. Wind also can cause sheet erosion during unusually dry periods. The soil, which is made dry and loose by a lack of moisture, is carried away by the wind as clouds of dust and drifting sand. These wind-borne particles may produce large dust storms.

Reading Check Describe one way that a dust storm may form, and explain how a dust storm can affect the fertility of land.

Results of Soil Erosion

Constant erosion reduces the fertility of the soil by removing the A horizon, which contains the fertile humus. The B horizon, which does not contain much organic matter, is difficult to farm because it is much less fertile than the A horizon. Without plants, the B horizon has nothing to protect it from further erosion. So, within a few years, all the soil layers could be removed by continuous erosion.

Soil Conservation

Erosion rates are affected not only by natural factors but also by human activities. Certain farming and grazing techniques and construction projects can also increase the rate of erosion. In developing urban areas, vegetation is removed to build houses and roads, such as those shown in **Figure 3**. This land clearing removes protective ground-cover plants and accelerates topsoil erosion. In some areas, such as deserts and mountainous regions, it may take hundreds or thousands of years for the topsoil to be replenished.

But rapid, destructive soil erosion can be prevented by soil conservation methods. People, including city planners and some land developers, have begun to recognize the environmental impact of land development and are beginning to implement soil conservation measures. Some land development projects are leaving trees and vegetation in place whenever possible. Other projects are planting cover plants to hold the topsoil in place. Farmers are also looking for new ways to minimize soil erosion and thus preserve fertile topsoil.



Figure 3 Urban development and agriculture both contribute to the erosion of topsoil.

Why It Matters

Putting Worms to Work

Composting breaks down waste to produce nutrient-rich humus-like material. One type of composting, called vermicomposting, uses worms to break down food waste. Vermicomposting can be set up indoors or outdoors, and can be used in agriculture, at home, or at school.

Vermicomposting produces a natural fertilizer that can be added to potted plants or to garden soil.

EYE ON THE ENVIRONMENT

These worms eat food waste. They excrete nutrient-dense castings, which can enrich soil.

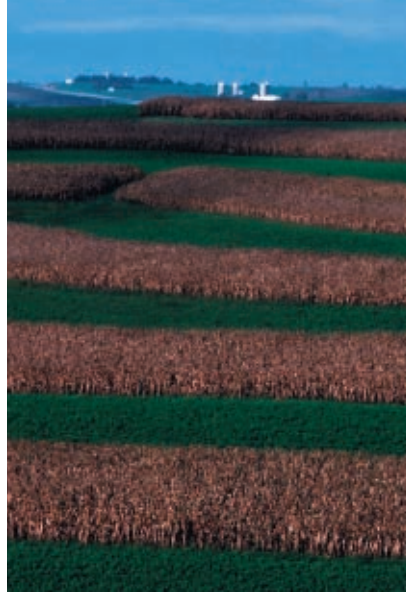
YOUR TURN

WRITING IN SCIENCE

Research how to set up a vermicomposter. Write two or three paragraphs explaining how it should be maintained.



Contour Plowing These fields were plowed in contours (or curves) that follow the shape of the land.



Strip-Cropping These fields were planted with alternating strips of different crops.



Terracing These terraced fields help slow runoff and prevent rapid soil erosion.

Figure 4 Soil Conservation Methods

Contour Plowing

Farmers in countries around the world use different planting methods to reduce soil erosion. In one method, called *contour plowing*, soil is plowed in curved bands that follow the contour, or shape, of the land. This method of planting, shown in the first part of **Figure 4**, prevents water from flowing directly down slopes, so it prevents gullying.

Strip-Cropping

In *strip-cropping*, crops are planted in alternating bands, also shown in **Figure 4**. A crop planted in rows, such as corn, may be planted in one band, and another crop that fully covers the surface of the land, such as alfalfa, will be planted next to it. The *cover crop* protects the soil by slowing the runoff of rainwater. Strip-cropping is often combined with contour plowing. The combination of these two methods can reduce soil erosion by 75%.

Terracing

The construction of steplike ridges that follow the contours of a sloped field is called *terracing*, as shown in **Figure 4**. Terraces, especially those used for growing rice in Asia, prevent or slow the downslope movement of water and thus prevent rapid erosion.

Crop Rotation

In *crop rotation*, farmers plant one type of crop one year and a different type of crop the next. For example, a farmer might plant a crop that will be harvested one year, and then plant a cover crop the next year. The cover crop does not get harvested. It helps to slow runoff and hold the soil in place. The main purpose of other types of crop rotation is to help maintain soil fertility.

READING TOOLBOX

Spider Map
Create a spider map and label the center oval "Soil conservation methods." Then, fill in the map with at least four methods for soil conservation.

Gravity and Erosion

Gravity causes rock fragments to move down a slope. This movement of fragments down a slope is called **mass movement**. Some mass movements occur rapidly, and others occur very slowly.

Rockfalls and Landslides

The most dramatic and destructive mass movements occur rapidly. The fall of rock from a steep cliff is called a *rockfall*. A rockfall is the fastest kind of mass movement. Rocks in rockfalls often range in size from tiny fragments to giant boulders.

When masses of loose rock combined with soil suddenly fall down a slope, the event is called a *landslide*. Large landslides, in which loosened blocks of bedrock fall, generally occur on very steep slopes. You may have seen a small landslide on cliffs and steep hills overlooking highways, such as the one shown in **Figure 5**. Heavy rainfall, spring thaws, volcanic eruptions, and earthquakes can trigger landslides.

Reading Check What is the difference between a rockfall and a landslide?

Mudflows and Slumps

The rapid movement of a large amount of mud creates a *mudflow*. Mudflows occur in mountainous regions during sudden, heavy rainfall or as a result of volcanic eruptions. Mud churns and tumbles as it moves down slopes and through valleys, and it frequently spreads out in a large fan shape at the base of the slope. The mass movements that sometimes occur in hillside communities, such as the one shown in **Figure 5**, are often referred to as landslides, but they are actually mudflows.

Sometimes, a large block of soil and rock becomes unstable and moves downhill in one piece. The block of soil and rock then slides along the curved slope of the surface. This type of movement is called a *slump*. Slumping occurs along very steep slopes. Saturation by water and loss of friction with underlying rock causes loose soil and rock to slip downhill over the solid rock.

mass movement the movement of a large mass of sediment or a section of land down a slope

Academic Vocabulary

dramatic (druh MAT ik) vivid or striking

Figure 5 An earthquake in El Salvador caused this dramatic landslide (left). Heavy rains in the Philippines caused this destructive mudflow (right).



Solifluction

Although most slopes appear to be unchanging, some slow mass movement commonly occurs. Catastrophic landslides are the most hazardous mass movement. However, more rock material is moved by the greater number of slow mass movements than by catastrophic landslides.

One form of slow mass movement is called solifluction. **Solifluction** is the process by which water-saturated soil slips over hard or frozen layers. Solifluction occurs in arctic and mountainous climates, where the subsoil is permanently frozen. In spring and summer, only the top layer of soil thaws. The moisture from this layer cannot penetrate the frozen layers beneath. So, the surface layer becomes muddy and slowly flows downslope, or downhill. Solifluction can also occur in warmer regions, where the subsoil consists of hard clay. The clay layer acts like the frozen subsoil in arctic climates by forming a waterproof barrier.

Creep

The extremely slow downhill movement of weathered rock material is known as **creep**. Soil creep moves the most soil of all types of mass movements. But creep may go unnoticed unless buildings, fences, or other surface objects move along with soil.

Many factors contribute to soil creep. Water separates rock particles, which allows them to move freely. Growing plants produce a wedgelike pressure that separates rock particles and loosens the soil. The burrowing of animals and repeated freezing and thawing loosen rock particles and allow gravity to slowly pull the particles downhill.

As rock fragments accumulate at the base of a slope, they form piles called *talus* (TAY luhs), as shown in **Figure 6**. Talus weathers into smaller fragments, which move farther down the slope. The fragments wash into gullies, are carried into successively larger waterways, and eventually flow into rivers.

solifluction the slow, downslope flow of soil saturated with water in areas surrounding glaciers at high elevations
creep the slow downhill movement of weathered rock material

Figure 6 The movement of rock fragments downslope formed these talus cones at the base of the Canadian Rockies.





Erosion and Landforms

Through weathering and erosion, Earth's surface is shaped into different physical features, or **landforms**. There are three major landforms that are shaped by weathering and erosion: *mountains*, *plains*, and *plateaus*. Minor landforms that are shaped by weathering and erosion include hills, valleys, and dunes. The shapes of landforms are also influenced by rock composition.

All landforms are subject to two opposing sets of processes. One set of processes bends, breaks, and lifts Earth's crust and thus creates elevated, or uplifted, landforms. The other set of processes includes weathering and erosion, which wear down land surfaces.

Erosion of Mountains

During the early stages in the history of a mountain, the mountain undergoes uplift. Generally, while tectonic forces are uplifting the mountain, it rises faster than it is eroded. Mountains that are being uplifted tend to be rugged and have sharp peaks and deep, narrow valleys. When forces stop uplifting the mountain, weathering and erosion wear down the rugged peaks to rounded peaks and gentle slopes. The formations in **Figure 7** show how the shapes of mountains are influenced by uplift and erosion.

Over millions of years, mountains that are not being uplifted become low, featureless surfaces. These areas are called *penneplains* (PEE nuh PLAYNZ), which means "almost flat." A penneplain commonly has low, rolling hills, as seen in New England.

 **Reading Check** Describe how a mountain changes after it is no longer uplifted.

Figure 7 The mountains in the Patagonian Andes, shown on the left, are still being uplifted and are more rugged than the more eroded Appalachian mountains on the right.

landform a physical feature of Earth's surface



Figure 8 Ancient rivers carved plateaus into mesas, which eventually eroded into the buttes of Monument Valley in Arizona.

Erosion of Plains and Plateaus

A *plain* is a relatively flat landform near sea level. A *plateau* is a broad, flat landform that has a high elevation. A plateau is subject to much more erosion than a plain. Young plateaus, such as the Colorado Plateau in the southwestern United States, commonly have deep stream valleys that separate broad, flat regions. Older plateaus, such as those in the Catskill region in New York State, have been eroded into rugged hills and valleys.

The effect of weathering and erosion on a plateau depends on the climate and the composition and structure of the rock. In dry climates, resistant rock produces plateaus that have flat tops. As a plateau ages, erosion may dissect the plateau into smaller, tablelike areas called *mesas* (MAY suhz). Mesas ultimately erode into small, narrow-topped formations called *buttes* (BYOOTS). In dry areas, such as in the area shown in **Figure 8**, mesas and buttes have steep walls and flat tops. In areas that have wet climates, humidity and precipitation weather landforms into round shapes. 🌿

Section 4 Review

Key Ideas

1. **Define** erosion.
2. **List** four agents of erosion.
3. **Summarize** two processes of soil erosion.
4. **Identify** four farming methods that result in soil conservation.
5. **Discuss** two ways gravity contributes to erosion.
6. **Compare** rapid mass movements with slow mass movements.
7. **Describe** the erosion of the three major landforms.

Critical Thinking

8. **Analyzing Relationships** Describe an experiment that could help you determine whether a nearby hill is undergoing creep.

9. **Applying Ideas** Suppose that you wanted to grow grapevines on a hillside in Italy. What farming methods would you use? Explain your answer.

10. **Predicting Consequences** Describe two ways that a small butte would change if it was in a wet climate, rather than a dry climate.

11. **Drawing Conclusions** A hillside community has asked you to help brainstorm ways to prevent future mudflows. Describe three of your ideas.

Concept Mapping

12. Use the following terms to create a concept map: *erosion, gully, sheet erosion, landslide, mudflow, slump, solifluction, creep, talus, landform, mountain, plain, plateau, mesa, and butte*.

Why It Matters

Living on the Edge

Weathering and erosion are natural processes that reshape Earth's surface. Mass movements are characteristic of steep hills and shorelines—landforms that humans value, and on which homes are often built. About 25% of the homes and buildings within 150 m of the U.S. coastline and shores of the Great Lakes will be lost due to erosion within the next 60 years, according to the Federal Emergency Management Agency.

SCIENCE & SOCIETY



Erosion barriers, like these, are intended to slow the movement of sediment. These barriers must be maintained, replaced, and repaired regularly.



Living on the edge can be risky. Each year, landslides in the United States kill over 25 people and cost over \$1 billion in damages. In La Conchita, a small coastal town in southern California, a sudden landslide killed ten people and destroyed 18 homes on January 10, 2005.

YOUR TURN

CRITICAL THINKING

What rules or restrictions do you think should govern construction in areas with a high risk of erosion?

ONLINE RESEARCH

Look up *recent landslide news* on the U.S. Geological Survey Web site: www.usgs.gov. Write a description of the most recent landslide reported.

What You'll Do

- › **Test** the acidity of soil samples.
- › **Identify** the composition of soil samples.

What You'll Need

ammonia solution
 stoppers, cork (9)
 hydrochloric acid, dilute
 medicine dropper
 pH paper
 subsoil sample (B and C horizons)
 test tubes, 9
 test-tube rack
 topsoil sample (A horizon)
 water

Safety



Soil Chemistry

Different soil types contain different kinds and amounts of minerals. To support plant life, soil must have a proper balance of mineral nutrients. For plants to take in the nutrients they need, the soil must also have the proper acidity.

Acidity is measured on a scale called the *pH scale*. The pH scale ranges from 0 (acidic) to 14 (alkaline). A pH of 7 is neutral (neither acidic nor alkaline). In this lab, you will test the acidity of soil samples.

Procedure

- 1 pH paper changes color in the presence of an acidic or alkaline substance. Wet a strip of pH paper with tap water. Compare the color of the wet pH paper with the pH color scale. What is the pH of the tap water?
- 2 Put some topsoil in a clean test tube until it is one-eighth full. Add water to the test tube until it is three-quarters full. Place a cork stopper on the test tube, and shake the test tube.
- 3 Set the soil and water mixture aside in the test-tube rack to settle. When the water is fairly clear, test it with a piece of pH paper. What is the pH of the soil sample? Is the soil acidic or alkaline?
- 4 Repeat steps 2 and 3 with the subsoil sample.
- 5 Pedalfers soils tend to be acidic. Pedocal soils tend to be alkaline. Based on the pH results in steps 3 and 4, predict whether your soil is pedalfers or pedocal.

Step 3



- 6 To test your prediction, you will need to test the soil's composition. Take five rock particles from the subsoil sample. Place each particle in a separate test tube. Use the dropper to add two drops of hydrochloric acid, HCl, to the test tubes. **CAUTION** If you spill any acid on your skin or clothing, rinse immediately with cool water and alert your teacher.
- 7 HCl has little or no effect on silicates, but HCl reacts with calcium carbonate and causes CO₂ gas to bubble out of solution. How many of the rock particles were silicates? How many were calcium carbonate?
- 8 Put some of the subsoil in another test tube until it is one-eighth full. Slowly add HCl to the test tube until it is about two-thirds full. Cork the test tube, and gently shake it. **CAUTION** Always shake the test tube by pointing it away from yourself and other students.
- 9 After shaking the test tube, remove the stopper and set the test tube in the rack. Record your observations. After the mixture has settled, draw the test tube and its contents. Label each layer. If iron is present, the solution may look brown. What color is the liquid above the soil sample?
- 10 Use a medicine dropper to place 10 drops of the liquid in a clean test tube. Carefully add 12 drops of ammonia to the test tube. Test the pH of the solution. If the pH is greater than 8, any iron should settle out as a reddish-brown residue. The remaining solution will be colorless.
- 11 If the pH is less than 8, add two more drops of ammonia and test the pH again. Continue adding ammonia until the pH reaches 8 or higher. Record your observations, and draw a diagram of the test tube. Label each layer of material in the test tube.



Step 6

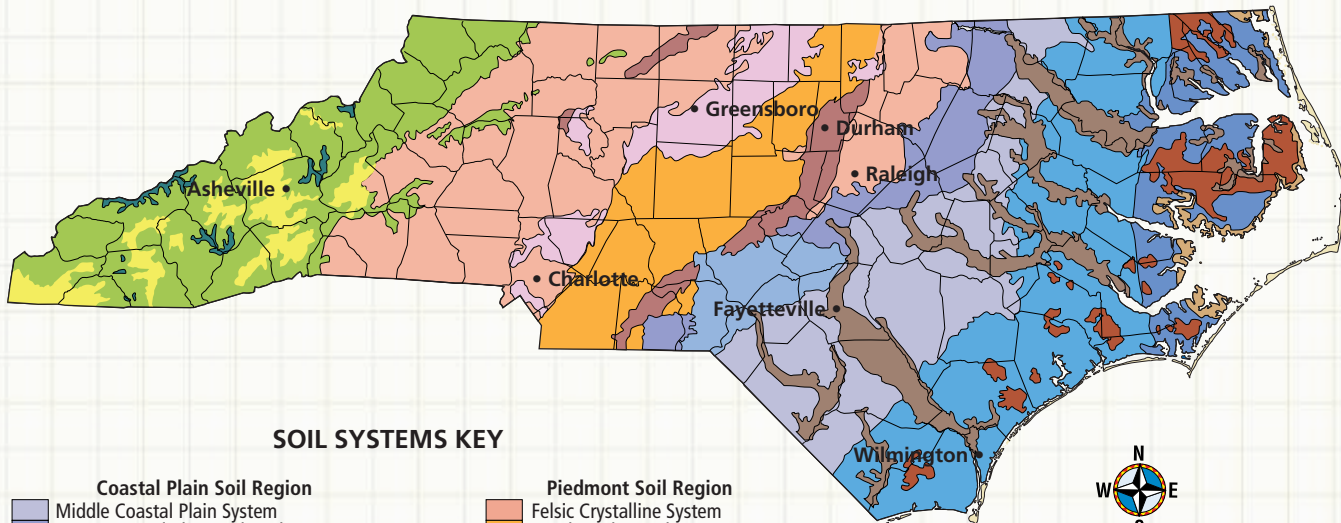
Analysis

1. **Analyzing Results** Is your soil sample most likely pedalfer or pedocal? Explain your answer.
2. **Drawing Conclusions** What type of soil, pedalfer or pedocal, would you treat with acidic substances, such as phosphoric acid, sulfur, and ammonium sulfate, to help plant growth? Explain your answer.
3. **Recognizing Relationships** Explain why acidic substances are usually spread on the surface of the soil.

Extension

Research Use a library or the Internet to learn why the use of phosphate and nitrate detergents has been banned in some areas. Report your findings to the class.

Soil Map of North Carolina



SOIL SYSTEMS KEY

Coastal Plain Soil Region

- Middle Coastal Plain System
- Upper Coastal Plain and Piedmont System
- Sandhills System
- Lower Coastal Plain—Wicomico and Talbot System
- Lower Coastal Plain—Pamlico System
- Organic Soil System
- Brackish and Freshwater Marsh Systems
- Outer Banks System
- Large River Valleys and Flood Plain Systems

Piedmont Soil Region

- Felsic Crystalline System
- Carolina Slate Belt System
- Triassic Basin System
- Mixed Felsic and Mafic System

Mountain Soil Region

- Low and Intermediate Mountain System
- Broad Basins, River Terraces, and Flood Plain System
- High Mountain System



0 20 40 Miles

0 30 60 Kilometers

Map Skills Activity

This map shows soil systems in the state of North Carolina, including the Outer Banks barrier island system. Use the map to answer the questions below.

- 1. Using a Key** How many colors on the map represent soil systems in the Piedmont Soil Region?
- 2. Using a Key** Which soil systems are present along the eastern shore of North Carolina?
- 3. Analyzing Data** Which city is located on the banks of a large river or in a river valley? Explain your answer.
- 4. Inferring Relationships** What landforms would you expect to surround the town of Asheville? Explain your answer.
- 5. Analyzing Relationships** Brackish water is water that is somewhat salty but not as salty as sea water. How does this fact explain the location of the Brackish and Freshwater Marsh soil systems?
- 6. Identifying Trends** How would you describe the change in elevation of North Carolina, from west to east, based on the locations of soil systems? Explain your answer.

Section 1**Section 2****Section 3****Section 4****Key Ideas****Weathering Processes**

- › Ice, plants and animals, gravity, running water, and wind are all agents of mechanical weathering.
- › Mechanical weathering physically breaks down rock. Chemical weathering changes the chemical composition of rock.
- › Oxidation, hydrolysis, carbonation, and acid precipitation are four chemical reactions that decompose rock.

Rates of Weathering

- › Softer rock weathers more rapidly than harder rock.
- › Rock weathers faster when more surface area is exposed.
- › Rock weathers fastest in climates with alternating hot and cold weather and steady moisture. Higher elevations may have more ice wedging. Gravity affects slopes.

Soil

- › Weathered rock, water, gases, and organic material form soils.
- › The composition of parent rock determines the proportion of clay, sand, and silt in the resulting soil.
- › Mature residual soils contain three layers: the A horizon, B horizon, and C horizon.
- › Thick soils form in tropical and temperate climates. Thin soils form in arctic and desert climates, where rainfall is minimal.

Erosion

- › Erosion transports weathered rock. Gravity, wind, glaciers, and water are four agents of erosion.
- › Contour plowing, strip-cropping, terracing, and crop rotation are four farming methods that conserve soil.
- › Gravity contributes to erosion through rapid mass movements, such as rockfalls, and through slow mass movements, such as creep.
- › Mountains, plains, and plateaus are three major landforms shaped by weathering and erosion.

Key Terms

weathering, p. 373
mechanical weathering, p. 373
abrasion, p. 374
chemical weathering, p. 376
oxidation, p. 376
hydrolysis, p. 377
carbonation, p. 377
acid precipitation, p. 378

differential weathering, p. 379

soil, p. 383
soil profile, p. 384
horizon, p. 384
humus, p. 384

erosion, p. 387
sheet erosion, p. 388
mass movement, p. 391
solifluction, p. 392
creep, p. 392
landform, p. 393

- 1. Finding Examples** Review Section 4. As you review, list four examples of farming practices that increase soil erosion and four examples of farming methods that help to conserve soil.



USING KEY TERMS

Use each of the following terms in a separate sentence.

2. *abrasion*
3. *humus*
4. *landform*

For each pair of terms, explain how the meanings of the terms differ.

5. *weathering* and *erosion*
6. *mechanical weathering* and *chemical weathering*
7. *oxidation* and *carbonation*
8. *soil profile* and *horizon*
9. *solifluction* and *creep*

UNDERSTANDING KEY IDEAS

10. A common kind of mechanical weathering is called
 - a. oxidation.
 - b. ice wedging.
 - c. carbonation.
 - d. leaching.
11. Oxides of sulfur and nitrogen that combine with water vapor cause
 - a. hydrolysis.
 - b. acid rain.
 - c. mechanical weathering.
 - d. carbonation.
12. The surface area of rocks exposed to weathering is increased by
 - a. burial.
 - b. accumulation.
 - c. leaching.
 - d. jointing.
13. Chemical weathering is most rapid in
 - a. hot, dry climates.
 - b. cold, dry climates.
 - c. cold, wet climates.
 - d. hot, wet climates.

14. The chemical composition of soil depends to a large extent on
 - a. topography.
 - b. the soil's A horizon.
 - c. the parent material.
 - d. the soil's B horizon.
15. The soil in tropical climates is often
 - a. thick.
 - b. thin.
 - c. dry.
 - d. fertile.
16. All of the following farming methods prevent gullying, *except*
 - a. terracing.
 - b. strip-cropping.
 - c. contour plowing.
 - d. irrigation.
17. The type of mass movement that moves the most soil is
 - a. a landslide.
 - b. a mudflow.
 - c. a rockfall.
 - d. creep.
18. The grinding away of rock surfaces through the mechanical action of rock or sand particles is called
 - a. carbonation.
 - b. hydrolysis.
 - c. abrasion.
 - d. erosion.
19. The process by which softer rock wears away and leaves harder rock behind is
 - a. chemical weathering.
 - b. mechanical weathering.
 - c. differential weathering.
 - d. erosion.

SHORT ANSWER

20. What is the difference between natural rain and acid precipitation?
21. Explain two reasons why soil conservation is important.
22. Describe how a mountain changes from a rugged mountain to a peneplain.
23. Describe three landforms that are shaped by weathering and erosion.
24. Explain two ways that weathering and erosion are related.
25. Identify three ways that climate affects the rate of weathering.
26. Name three landforms that you would expect to find in a desert.

CRITICAL THINKING

- 27. Making Comparisons** Compare the weathering processes that affect a rock on top of a mountain with those that affect a rock beneath the ground surface.
- 28. Understanding Relationships** Which do you think would weather faster, a sculpted marble statue or a smooth marble column? Explain your answer.
- 29. Making Inferences** Mudflows in the southern California hills are usually preceded by a dry summer and widespread fires, which are followed by torrential rainfall. Explain why these phenomena are followed by mudflows.
- 30. Evaluating Ideas** How can differential weathering help you determine whether a rock is harder or softer than the rock that surrounds it?
- 31. Inferring Relationships** Suppose that a mountain has been wearing down at the rate of about 2 cm per year for 10 years. After 10 years, scientists find that the mountain is no longer losing elevation. Why do you think the mountain is no longer losing elevation?

CONCEPT MAPPING

- 32.** Use the following terms to create a concept map: *composition, mechanical weathering, chemical weathering, topography, erosion, conservation, exposure, weathering, surface area, and climate.*

MATH SKILLS

Math Skills

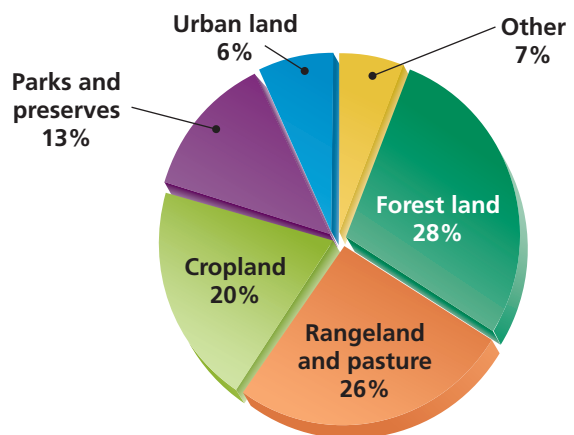
- 33. Making Calculations** A group of scientists calculates that an acre of land has crept 18 cm in 15 years. What is the average rate of creep in millimeters per year?
- 34. Making Calculations** For a given area of land, the average rate of creep is 14 mm per year. How long will it take the area to move 1 m?

WRITING SKILLS

- 35. Writing from Research** Research a mudslide or landslide that occurred in the past. Describe the conditions that led to this mass movement and the impact it had.
- 36. Communicating Ideas** You are in charge of preserving a precious marble statue. Write a paragraph that describes how you would protect the statue from weathering.

INTERPRETING GRAPHICS

The graph below shows land use in the United States. Use this graph to answer the questions that follow.



- 37.** How much more land is rangeland and pasture than is urban land?
- 38.** If cropland increased to 25% and all the other categories remained the same, except for forests, what would the percentage of forests be?

Understanding Concepts

Directions (1–5): For each question, write on a separate sheet of paper the letter of the correct answer.

- The processes of physical weathering and erosion shape Earth's landforms by
 - expanding the elevation of Earth's surface.
 - decreasing the elevation of Earth's surface.
 - changing the composition of Earth's surface.
 - bending rock layers near Earth's surface.
- Which of the following rocks is most likely to weather quickly?
 - a buried rock in a mountain
 - an exposed rock on a plain
 - a buried rock in a desert
 - an exposed rock on a slope
- The red color of rocks and soil containing iron-rich minerals is caused by
 - chemical weathering.
 - mechanical weathering.
 - abrasion.
 - erosion.
- In which of the following climates does chemical weathering generally occur most rapidly?
 - cold, wet climates
 - cold, dry climates
 - warm, humid climates
 - warm, dry climates
- Which of the following has the greatest impact on soil composition?
 - the activities of plants and animals
 - the characteristics of the parent rock
 - the amount of precipitation
 - the shape of the land

Directions (6–7): For each question, write a short response.

- In what type of decomposition reaction do hydrogen ions from water displace elements in a mineral?
- What form of mechanical weathering is caused by sand carried by wind?

Reading Skills

Directions (8–10): Read the passage below. Then, answer the questions.

How Rock Becomes Soil

Earthworms are crucial for forming soil. As they search for food by digging tunnels, they expose rocks and minerals to the effects of weathering. Over time, this process creates new soil.

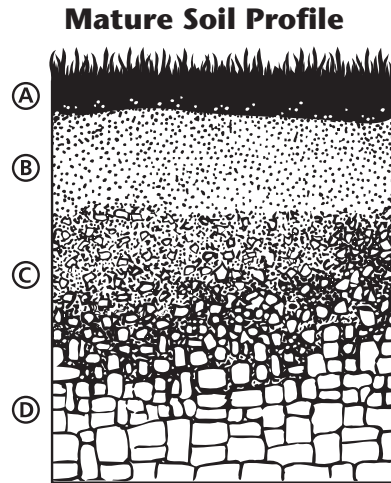
Worms are not the only living things that help to create soil. Plants also play a part in the weathering process. As the roots of plants grow and seek out water and nutrients, they help to break large rock fragments into smaller ones. Have you ever seen a plant growing in a sidewalk? As the plant grows, its roots spread into tiny cracks in the sidewalk. These roots apply pressure to the cracks, and, over time, the cracks become larger. As the plants make the cracks larger, ice wedging can occur more readily. As the cracks expand, more water can flow into them. When the water freezes, it expands and presses against the walls of the cracks, which makes the cracks larger. Over time, the weathering caused by water, plants, and worms helps to form soil.

- Which of the following statements can be inferred from the passage?
 - Weathering can occur only when water freezes in cracks in rocks.
 - Only large plants have roots that are powerful enough to increase the rate of weathering.
 - Local biological activity may increase the rate of weathering in a given area.
 - Plant roots often prevent weathering by filling cracks and keeping water out of cracks.
- Ice wedging, as described in the passage, is an example of which of the following?
 - oxidation
 - mechanical weathering
 - chemical weathering
 - hydrolysis
- What are some ways, not mentioned in the passage, in which the activity of biological organisms may increase weathering?

Interpreting Graphics

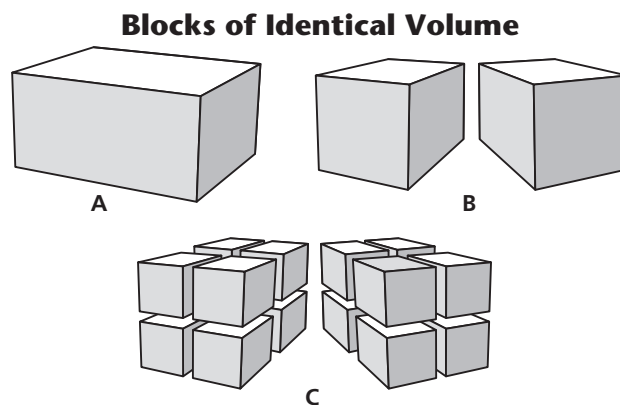
Directions (11–13): For each question below, record the correct answer on a separate sheet of paper.

The diagram below shows the soil profile of a mature soil. Use this diagram to answer questions 11 and 12.



11. Which layer in the soil profile contains the greatest number of soil organisms?
- F. layer A
G. layer B
H. layer C
I. layer D
12. Which two layers in the soil profile are least likely to contain the dark, organic material humus?
- A. layers A and B
B. layers B and C
C. layers C and D
D. layers A and D

Use the diagrams of stone blocks below to answer question 13.



13. If the blocks shown in diagrams A, B, and C have the same volume and are made of the same types of minerals, will they weather at the same rate? Explain your answer.

Test Tip

Whenever possible, highlight or underline numbers or words that are important for correctly answering a question.