

Section 7.1

Objectives

- ▶ **Distinguish** between mechanical and chemical weathering.
- ▶ **Describe** the different factors that affect mechanical and chemical weathering.
- ▶ **Identify** variables that affect the rate of weathering.

Review Vocabulary

acid: solution that contains hydrogen ions

New Vocabulary

weathering
mechanical weathering
frost wedging
exfoliation
chemical weathering
oxidation

Weathering

MAIN <Idea> **Weathering breaks down materials on or near Earth's surface.**

Real-World Reading Link You might have noticed that rust will begin to form at places on a car where the paint has chipped. In regions that are cold, rust seems to eat away at the paint of the car. This is an example of weathering.

Mechanical Weathering

Weathering is the process in which materials on or near Earth's surface break down and change. **Mechanical weathering** is a type of weathering in which rocks and minerals break down into smaller pieces. This process is also called physical weathering. Mechanical weathering does not involve any change in a rock's composition, only changes in the size and shape of the rock. A variety of factors are involved in mechanical weathering, including changes in temperature and pressure.

Effect of temperature Temperature plays a role in mechanical weathering. When water freezes, it expands and increases in volume by 9 percent. You have observed this increase in volume if you have ever frozen water in an ice cube tray. In many places on Earth's surface, water collects in the cracks of rocks and rock layers. If the temperature drops to the freezing point, water freezes, expands, exerts pressure on the rocks, and can cause the cracks to widen slightly, as shown in **Figure 7.1**. When the temperature increases, the ice melts in the cracks of rocks and rock layers. The freeze-thaw cycles of water in the cracks of rocks is called **frost wedging**. Frost wedging is responsible for the formation of potholes in many roads in the northern United States where winter temperatures vary frequently between freezing and thawing.

- **Figure 7.1** Frost wedging begins in hairline fractures of a rock. Repeated cycles of freeze and thaw cause the crack to expand over time. **Predict** the results of additional frost wedging on this boulder.



Effect of pressure Another factor involved in mechanical weathering is pressure. Roots of trees and other plants can exert pressure on rocks when they wedge themselves into the cracks in rocks. As the roots grow and expand, they exert increasing amounts of pressure which often causes the rocks to split, as shown in **Figure 7.2**.

On a much larger scale, pressure also functions within Earth. Bedrock at great depths is under tremendous pressure from the overlying rock layers. A large mass of rock, such as a batholith, may originally form under great pressure from the weight of several kilometers of rock above it. When the overlying rock layers are removed by processes such as erosion or even mining, the pressure on the bedrock is reduced. The bedrock surface that was buried expands, and long, curved cracks can form. These cracks, also known as joints, occur parallel to the surface of the rocks. Reduction of pressure also allows existing cracks in the bedrock to widen. For example, when several layers of overlying rocks are removed from a deep mine, the sudden decrease of pressure can cause large pieces of rocks to explode off the walls of the mine tunnels.

Over time, the outer layers of rock can be stripped away in succession, similar to the way an onion's layers can be peeled. The process by which outer rock layers are stripped away is called **exfoliation**. Exfoliation often results in dome-shaped formations, such as Moxham Mountain in New York and Half Dome in Yosemite National Park in California, shown in **Figure 7.3**.



- **Figure 7.2** Tree roots can grow within the cracks and joints in rocks and eventually cause the rocks to split.

FOLDABLES

Incorporate information from this section into your Foldable.



- **Figure 7.3** The rock that makes up Half Dome in Yosemite National Park fractures along its outer surface in a process called exfoliation. Over time this has resulted in the dome shape of the outcrop.



■ **Figure 7.4** This statue has been chemically weathered by acidic water and atmospheric pollutants.

Chemical Weathering

Chemical weathering is the process by which rocks and minerals undergo changes in their composition. Agents of chemical weathering include water, oxygen, carbon dioxide, and acid precipitation. The interaction of these agents with rock can cause some substances to dissolve, and some new minerals to form. The new minerals have properties different than those that were in the original rock. For example, iron often combines with oxygen to form iron oxide, such as in hematite.

✓ **Reading Check Express** in your own words the effect that chemical weathering has on rocks.

The composition of a rock determines the effects that chemical weathering will have on it. Some minerals, such as calcite, which is composed of calcium carbonate, can decompose completely in acidic water. Limestone and marble are made almost entirely from calcite, and are therefore greatly affected by chemical weathering. Buildings and monuments made of these rocks usually show signs of wear as a result of chemical weathering. The statue in **Figure 7.4** is made of sandstone, which also weathers relatively easily.

Temperature is another significant factor in chemical weathering because it influences the rate at which chemical interactions occur. Chemical reaction rates increase as temperature increases. With all other factors being equal, the rate of chemical weathering reactions doubles with each 10°C increase in temperature.

Effect of water Water is an important agent in chemical weathering because it can dissolve many kinds of minerals and rocks. Water also plays an active role in many reactions by serving as a medium in which the reactions can occur. Water can also react directly with minerals in a chemical reaction. In one common reaction with water, large molecules of the mineral break down into smaller molecules. This reaction decomposes and transforms many silicate minerals. For example, potassium feldspar decomposes into kaolinite, a fine-grained clay mineral common in soils.

Effect of oxygen An important element in chemical weathering is oxygen. The chemical reaction of oxygen with other substances is called **oxidation**. Approximately 21 percent of Earth's atmosphere is oxygen gas. Iron in rocks and minerals combines with this atmospheric oxygen to form minerals with the oxidized form of iron. A common mineral that contains the oxidized form of iron is hematite.

Effect of carbon dioxide Another atmospheric gas that contributes to the chemical weathering process is carbon dioxide. Carbon dioxide is a gas that occurs naturally in the atmosphere as a product of living organisms. When carbon dioxide combines with water in the atmosphere, it forms a very weak acid called carbonic acid that falls to Earth's surface as precipitation.

Precipitation includes rain, snow, sleet, and fog. Natural precipitation has a pH of 5.6. The slight acidity of precipitation causes it to dissolve certain rocks, such as limestone.

Decaying organic matter and respiration produce high levels of carbon dioxide. When slightly acidic water from precipitation seeps into the ground and combines with carbon dioxide in the soil, carbonic acid becomes an agent in the chemical weathering process. Carbonic acid slowly reacts with minerals such as calcite in limestone and marble to dissolve rocks. After many years, limestone caverns can form where the carbonic acid flowed through cracks in limestone rocks and reacted with calcite.

🌿 **Effect of acid precipitation** Another agent of chemical weathering is acid precipitation, which is caused by sulfur dioxide and nitrogen oxides that are released into the atmosphere, in large part by human activities. Sulfur dioxide is primarily the product of industrial burning of fossil fuels. Motor-vehicle exhausts also contribute to the emissions of nitrogen oxides. These two gases combine with oxygen and water in the atmosphere, forming sulfuric and nitric acids, which are strong acids.

The acidity of a solution is described using the pH scale, as you learned in Chapter 3. Acid precipitation is precipitation that has a pH value below 5.6—the pH of normal rainfall. Because strong acids can be harmful to many organisms and destructive to human-made structures, acid precipitation often creates problems. Many plant and animal populations cannot survive even slight changes in acidity. Acid precipitation is a serious issue in New York, as shown in **Figure 7.5**, and in West Virginia and much of Pennsylvania. 🌿



■ **Figure 7.5** The forests of the Adirondack Mountains have been damaged by the effects of acid precipitation. Acid precipitation can make forests more vulnerable to disease and damage by insects.

VOCABULARY

ACADEMIC VOCABULARY

Process

a natural phenomenon marked by gradual changes that lead toward a particular result

The process of growth changes a seedling into a tree.

Rate of Weathering

The natural weathering of Earth materials occurs slowly. For example, it can take 2000 years to weather 1 cm of limestone, and most rocks weather at even slower rates. Certain conditions and interactions can accelerate or slow the weathering process, as demonstrated in the GeoLab at the end of this chapter.

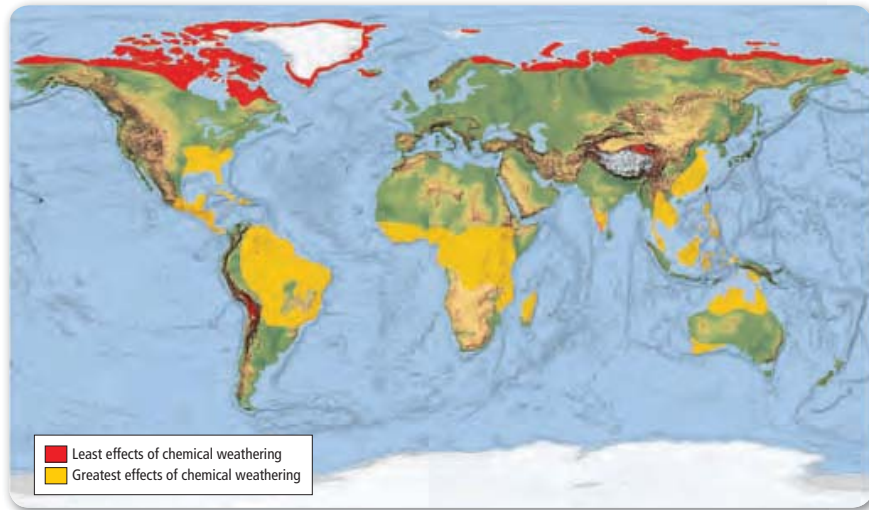
Effects of climate on weathering Climate is the major influence on the rate of weathering of Earth materials. Precipitation, temperature, and evaporation are factors that determine climate. The interaction between temperature and precipitation in a given climate determines the rate of weathering in a region.

Reading Check Explain why different climates have different rates of weathering.

Rates of chemical weathering Chemical weathering is rapid in climates with warm temperatures, abundant rainfall, and lush vegetation. These climatic conditions produce soils that are rich in organic matter. Water from heavy rainfalls combines with the carbon dioxide in soil organic matter and produces high levels of carbonic acid. The resulting carbonic acid accelerates the weathering process. Chemical weathering has the greatest effects along the equator, where rainfall is plentiful and the temperature tends to be high, as shown in **Figure 7.6**.

Figure 7.6 The impact of chemical weathering is related to a region's climate. Warm, lush areas such as the tropics experience the fastest chemical weathering.

Infer what parts of the world experience less chemical weathering.



Rates of physical weathering Conversely, physical weathering can break down rocks more rapidly in cool climates. Physical weathering rates are highest in areas where water in cracks within the rocks undergoes repeated freezing and thawing. Conditions in such climates do not favor chemical weathering because cool temperatures slow or inhibit chemical reactions. Little or no chemical weathering occurs in areas that are frigid year-round.

The different rates of weathering caused by different climatic conditions can be emphasized by a comparison of Asheville, North Carolina, and Phoenix, Arizona. Phoenix has dry, warm conditions; temperatures do not drop below the freezing point of water, and humidity is low. In Asheville, temperatures frequently drop below freezing during the winter months, and Asheville has more monthly rainfall and higher levels of humidity than Phoenix. Because of these differences in their climates, rocks and man-made structures in Asheville experience higher rates of mechanical and chemical weathering than those in Phoenix.

Figure 7.7 shows how rates of weathering are dependent on climate. Both Egyptian obelisks were carved from granite more than one thousand years ago. For more than a thousand years, they stood in Egypt's dry climate, showing few effects of weathering. In 1881, Cleopatra's Needle was transported from Egypt to New York City. In the time that has passed since then, the acid precipitation and the repeated cycles of freezing and thawing in New York City accelerated the processes of chemical and physical weathering. In comparison, the obelisk that remains in Egypt appears unchanged.

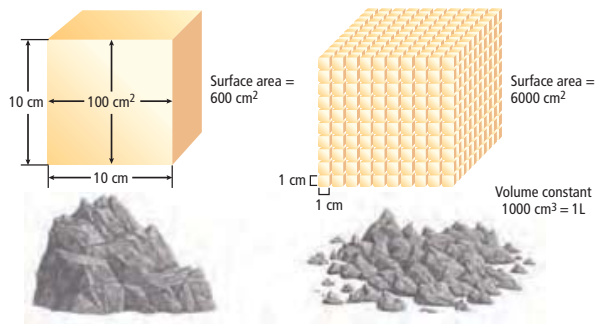
Rock type and composition. Not all the rocks in the same climate weather at the same rate. The effects of climate on the weathering of rock also depends on the rock type and composition. For example, rocks containing mostly calcite, such as limestone and marble, are more easily weathered than rocks containing mostly quartz, such as granite and quartzite.



NATIONAL GEOGRAPHIC To read about desert landscapes formed by weathering and erosion, go to the **National Geographic Expedition** on page 898.

Figure 7.7 The climate of New York City caused the obelisk on the left to weather rapidly. The obelisk on the right has been preserved by Egypt's dry, warm climate.

■ **Figure 7.8** When the same object is broken into two or more pieces, the surface area increases. The large cube has a volume of 1000 cm^3 . When it is broken into 1000 pieces, the volume is unchanged, but the surface area is increased one thousand times.



Surface area The rate of weathering also depends on the surface area that is exposed. Mechanical weathering breaks rocks into smaller pieces. As the pieces get smaller, their surface area increases, as illustrated in **Figure 7.8**. When this happens, there is more total surface area available for chemical weathering. The result is that weathering has more of an effect on smaller particles, as you learned in the Launch Lab.

Topography The slope of a landscape also determines the rate of weathering. Rocks on level areas are likely to remain in place over time, whereas the same rocks on slopes tend to move as a result of gravity. Steep slopes therefore promote erosion and continually expose less-weathered material.

Section 7.1 Assessment

Section Summary

- ▶ Mechanical weathering changes a rock's size and shape.
- ▶ Frost wedging and exfoliation are forms of mechanical weathering.
- ▶ Chemical weathering changes the composition of a rock.
- ▶ The rate of chemical weathering depends on the climate, rock type, surface area, and topography.

Understand Main Ideas

1. **MAIN Idea Distinguish** between the characteristics of an unweathered rock and those of a highly weathered rock.
2. **Describe** the factors that control the rate of chemical weathering and those that control the rate of physical weathering.
3. **Compare** chemical weathering to mechanical weathering.
4. **Analyze** the relationship between surface area and weathering.

Think Critically

5. **Infer** which would last longer, the engraving in a headstone made of marble, or an identical engraving in a headstone made of granite.

MATH in Earth Science

6. Infer the relationship between weathering and surface area by graphing the relationship between the rate of weathering and the surface area of a material.

Section 7.2

Objectives

- ▶ **Describe** the relationship of gravity to all agents of erosion.
- ▶ **Contrast** the features left from different types of erosion.
- ▶ **Analyze** the impact of living and nonliving things on the processes of weathering and erosion.

Review Vocabulary

gravity: a force of attraction between objects due to their masses

New Vocabulary

erosion
deposition
rill erosion
gully erosion

Erosion and Deposition

MAIN Idea Erosion transports weathered materials across Earth's surface until they are deposited.

Real-World Reading Link Have you ever noticed the mud that collects on sidewalks and streets after a heavy rainfall? Water carries sediment to the sidewalks and streets and deposits it as mud.

Gravity's Role

Recall that the process of weathering breaks rock and soil into smaller pieces, but never moves it. The removal of weathered rock and soil from its original location is a process called **erosion**. Erosion can remove material through a number of different agents, including running water, glaciers, wind, ocean currents, and waves. These agents of erosion can carry rock and soil thousands of kilometers away from their source. After the materials are transported, they are dropped in another location in a process known as **deposition**.

Gravity is associated with many erosional agents because the force of gravity tends to pull all materials downslope. Without gravity, neither streams nor glaciers would flow. In the process of erosion, gravity pulls loose rock downslope. **Figure 7.9** shows the effects of gravity on the landscape of Watkins Glen State Park in New York. The effects of gravity on erosion by running water can often produce dramatic landscapes with steep valleys.

■ **Figure 7.9** Within about 3000 m, the stream descends 120 m at Watkins Glen State Park in New York.
Calculate the average descent of the stream per meter along the river.





Rill erosion



Gully erosion

■ **Figure 7.10** Rill erosion can occur in an agricultural field. Gully erosion often develops from rills.

Infer land management practices that can slow or prevent the development of gully erosion.

Erosion by Water

Moving water is perhaps the most powerful agent of erosion. Stream erosion can reshape entire landscapes. Stream erosion is greatest when a large volume of water is moving rapidly, such as during spring thaws and torrential downpours. Water flowing down steep slopes has additional erosive potential resulting from gravity, causing it to cut downward into the slopes, carving steep valleys and carrying away rock and soil. Swiftly flowing water can also carry more material over long distances. The Mississippi River, for example, carries an average of 400,000 metric tons of sediment each day from thousands of kilometers away.

Reading Check Predict what time of year water has the most potential for erosion.

Erosion by water can have destructive results. For example, water flowing downslope can carry away fertile agricultural soil. **Rill erosion** develops when running water cuts small channels into the side of a slope, as shown in **Figure 7.10**. When a channel becomes deep and wide, rill erosion evolves into **gully erosion**, also shown in **Figure 7.10**. The channels formed in gully erosion can transport much more water, and consequently more soil, than rills. Gullies can be more than 3 m deep and can cause major problems in farming and grazing areas.

Rivers and streams Each year, streams carry billions of metric tons of sediments and weathered material to coastal areas. Once a river enters the ocean, the current slows down, which reduces the potential of the stream to carry sediment. As a result, streams deposit large amounts of sediments in the region where they enter the ocean. The buildup of sediments over time forms deltas, such as the Colorado River Delta, shown in **Figure 7.11**. The volume of river flow and the action of tides determines the shapes of deltas, most of which contain fertile soil. The Colorado River Delta shows the classic fan shape associated with many deltas.

Wave action Erosion of materials also occurs along the ocean floor and at continental and island shorelines. The work of ocean currents, waves, and tides carves out cliffs, arches, and other features along the continents' edges. In addition, sand particles accumulate on shorelines and form dunes and beaches. The constant movement of water and the availability of accumulated weathered material result in a continuous erosional process, especially along ocean shorelines. Sand along a shoreline is repeatedly picked up, moved, and deposited by ocean currents. As a result, sandbars form from offshore sand deposits. If the sandbars continue to be built up with sediments, they can develop into barrier islands. Many barrier islands, such as the Outer Banks of North Carolina shown in **Figure 7.12**, have formed along both the Gulf and Atlantic Coasts of the United States.

Just as shorelines are built by the process of deposition in some areas, they are reduced by the process of coastal erosion in other areas. Changing tides and conditions associated with coastal storms can also have a great impact on coastal erosion. Human development and population growth along shorelines have led to attempts to control the erosion of sand. However, efforts to keep the sand on one beachfront disrupt the natural migration of sand along the shore, depleting sand from another area. You will learn more about ocean and shoreline features in Chapters 15 and 16.



■ **Figure 7.11** Streams slow down when they meet the ocean. In these regions, sediments are deposited by the river, resulting in the development of a delta.



■ **Figure 7.12** The Outer Banks of North Carolina have been built over time by deposition of sand and sediments.

MiniLab

Model Erosion

How do rocks erode? When rocks are weathered by their surrounding environment, particles can be carried away by erosion.

Procedure

1. Read and complete the lab safety form.
2. Carve your name deeply into a **bar of soap** with a **toothpick**. Measure the mass of the soap.
3. Measure and record the depth of the letters carved into the soap.
4. Place the bar of soap on its edge in a **catch basin**.
5. Slowly pour **water** over the bar of soap until a change occurs in the depth of the carved letters.
6. Measure and record the depth of the carved letters.

Analysis

1. **Describe** how the depth of the letters carved into the bar of soap changed.
2. **Infer** whether the shape, size, or mass of the bar of soap changed.
3. **Consider** what additional procedure you could follow to determine whether any soap wore away.



■ **Figure 7.13** Iceberg Lake in Glacier National Park, Montana, was formed by glaciers.


Glacial Erosion

Although glaciers currently cover less than 10 percent of Earth's surface, they have covered over 30 percent of Earth's surface in the past. Glaciers left their mark on much of the landscape, and their erosional effects are large-scale and dramatic. Glaciers scrape and gouge out large sections of Earth's landscape. Because they can move as dense, enormous rivers of slowly flowing ice, glaciers have the capacity to carry huge rocks and piles of debris over great distances and grind the rocks beneath them into flour-sized particles. Glacial movements scratch and grind surfaces. The features left in the wake of glacial movements include steep U-shaped valleys and lakes, such as the one shown in **Figure 7.13**.

The effects of glaciers on the landscape also include deposition. For example, soils in the northern parts of the United States are formed from material that was transported and deposited by glaciers. Although the most recent ice age ended 15,000 years ago, glaciers continue to affect erosional processes on Earth.

Wind Erosion

Wind can be a major erosional agent, especially in arid and coastal regions. Such regions tend to have little vegetation to hold soil in place. Wind can easily pick up and move fine, dry particles. The effects of wind erosion can be both dramatic and devastating. The abrasive action of windblown particles can damage both natural features and human-made structures. Winds can blow against the force of gravity and easily move fine-grained sediments and sand uphill.

 **Wind barriers** One farming method that can reduce the effects of wind erosion is the planting of wind barriers, also called windbreaks, shown in **Figure 7.14**. Windbreaks are trees or other vegetation planted perpendicular to the direction of the wind. A wind barrier might be a row of trees along the edge of a field. In addition to reducing erosion, wind barriers can trap blowing snow, conserve moisture, and protect crops from the effects of the wind.


■ **Figure 7.14** A windbreak can reduce the speed of the wind for distances up to 30 times the height of the tree.

Calculate If these trees are 10 m tall, what is the distance over which they can serve as a windbreak?



■ **Figure 7.15** In this construction project, the landscape was considerably altered. **Analyze** the results of this alteration of the landscape.

Erosion by Living Things

Plants and animals also play a role in erosion. As plants and animals carry out their life processes, they move Earth's surface materials from one place to another. For example, Earth materials are moved when animals burrow into soil. Humans excavate large areas and move soil from one location to another, as shown in **Figure 7.15**. Planting a garden, developing a new athletic field, and building a highway are all examples of human activities that result in the moving of Earth materials from one place to another. You will learn more about how human activity impacts erosion in Chapter 26. 

Section 7.2 Assessment

Section Summary

- ▶ The processes of erosion and deposition have shaped Earth's landscape in many ways.
- ▶ Gravity is the driving force behind major agents of erosion.
- ▶ Agents of erosion include running water, waves, glaciers, wind, and living things.

Understand Main Ideas

1. **MAIN Idea** Discuss how weathering and erosion are related.
2. **Describe** how gravity is associated with many erosional agents.
3. **Classify** the type of erosion that could move sand along a shoreline.
4. **Compare and contrast** rill erosion and gully erosion.

Think Critically

5. **Generalize** about which type of erosion is most significant in your area.
6. **Diagram** a design for a wind barrier to prevent wind erosion.

Earth Science

7. Research how a development in your area has alleviated or contributed to erosion. Present your results to the class, including which type of erosion occurred, and where the eroded materials will eventually be deposited.

Section 7.3

Objectives

- ▶ **Describe** how soil forms.
- ▶ **Recognize** soil horizons in a soil profile.
- ▶ **Differentiate** among the factors of soil formation.

Review Vocabulary

organism: anything that has or once had all the characteristics of life

New Vocabulary

soil
residual soil
transported soil
soil profile
soil horizon

Soil

MAIN Idea Soil forms slowly as a result of mechanical and chemical processes.

Real-World Reading Link What color is soil? Soils can be many different colors—dark brown, light brown, red, or almost white. Soils develop through the interaction of a number of factors, which determine the color of soil.

Soil Formation

What is soil? It is found almost everywhere on Earth's surface. Weathered rock alone is not soil. **Soil** is the loose covering of weathered rock particles and decaying organic matter, called humus, overlying the bedrock of Earth's surface, and serves as a medium for the growth of plants. Soil is the product of thousands of years of chemical and mechanical weathering and biological activity.

Soil development The soil-development process often begins when weathering breaks solid bedrock into smaller pieces. These pieces of rock continue to undergo weathering and break down into smaller pieces. Worms and other organisms help break down organic matter and add nutrients to the soil as well as creating passages for air and water, as shown in **Figure 7.16**.

As nutrients are added to the soil, its texture changes, and the soil's capacity to hold water increases. While all soil contains some organic matter in various states of decay, the amount varies widely among different types of soil. For example, as much as 5 percent of the volume of prairie soils is organic matter, while most desert soils have almost no organic matter.

- **Figure 7.16** Organisms in the soil change the soil's structure over time by adding nutrients and passages for air. **Infer** how animals also alter the soil by adding organic material.



Soil Layers

During the process of its formation, soil develops layers. Most of the volume of soil is formed from the weathered products of a source rock, called the parent material. The parent material of a soil is often the bedrock. As the parent material weathers, the weathering products rest on top of the parent material. Over time, a layer of the smallest pieces of weathered rock develops above the parent material. Eventually, living organisms such as plants and animals become established, and use nutrients and shelter available in the material. Rainwater seeps through this top layer of materials and dissolves soluble minerals, carrying them into the lower layers of the soil.

A soil whose parent material is the local bedrock is called **residual soil**. Kentucky's bluegrass soil is an example of residual soil, as are the red soils in Georgia. Not all soil develops from local bedrock. **Transported soil**, shown in the valley in **Figure 7.17**, is soil that develops from parent material that has been moved far from its original location. Agents of erosion transport parent material from its place of origin to new locations. For example, glaciers have transported sediments from Canada to many parts of the United States. Streams and rivers, especially during times of flooding, also transport sediments downstream to floodplains. Winds also carry sediment to new locations. Over time, processes of soil formation transform these deposits into mature soil layers.

- ✔ **Reading Check Explain** how residual soils are different from transported soils.

CAREERS IN EARTH SCIENCE

Landscaper A landscaper uses his or her knowledge of soils and performs tests to evaluate soils at different sites. Landscapers use the information they gather to choose plants that are appropriate to the soil conditions. To learn more about Earth science careers, visit glencoe.com.

- **Figure 7.17** In a stream valley, transported soils are often found in the flood plain. Residual soils are often found in the higher, mountainous regions.






Undeveloped soil



Mature soil

■ **Figure 7.18** An undeveloped soil has few, if any, distinct layers, while mature soils are characterized by several soil horizons that have developed over time.

Soil profiles Digging a deep hole in the ground will reveal a soil profile. A **soil profile** is a vertical sequence of soil layers. Some soil profiles have more distinct layers than others. Relatively new soils that have not yet developed distinct layers are called undeveloped soils, shown in **Figure 7.18**. It can take tens of thousands of years for distinct layers to form in a soil. Those soils are called mature. An example is shown in **Figure 7.18**.

 **Reading Check** Explain the difference between a mature and an undeveloped soil.

Soil horizons A distinct layer within a soil profile is called a **soil horizon**. There are typically four major soil horizons in mature soils, O, A, B, and C. The O-horizon is the top layer of organic material, which is made of humus and leaf litter. Below that, the A-horizon is a layer of weathered rock combined with a rich concentration of dark brown organic material. The B-horizon, also called the zone of accumulation, is a red layer that has been enriched over time by clay and minerals deposited by water flowing from the layers above, or percolating upward from layers below. Usually the clay gives a blocky structure to the B-horizon. Accumulations of certain minerals can result in a hard layer called hardpan. Hardpan can be so dense that it allows little or no water to pass through it. The C-horizon contains little or no organic matter, and is often made of broken-down bedrock. The development of each horizon depends on the factors of soil formation.

Factors of Soil Formation

Five factors influence soil formation: climate, topography, parent material, biological organisms, and time. These factors combine to produce different types of soil, called soil orders, from region to region. Soil taxonomy (tak SAH nuh mee) is the system that scientists use to classify soils into orders and other categories. The five factors of soil formation result in 12 different soil orders.

Climate Climate is the most significant factor controlling the development of soils. Temperature, wind, and the amount of rainfall determines the type of soil that can develop.

Recall from Section 7.1 that rocks tend to weather rapidly under humid, temperate conditions, such as those found in climates along the eastern United States. Weathering results in soils that are rich in aluminum and iron oxides. Water from abundant rainfall moves downward, carrying dissolved minerals into the B-horizon. In contrast, the soils of arid regions are so dry that water from below ground moves up through evaporation, and leaves an accumulation of white calcium carbonate in the B-horizon. Tropical areas experience high temperatures and heavy rainfall. These conditions lead to the development of intensely weathered soils where all but the most insoluble minerals have been flushed out.

Topography Topography, which includes the slope and orientation of the land, affects the type of soil that forms. On steep slopes, weathered rock is carried downhill by agents of erosion. As a result, hillsides tend to have shallow soils, while valleys and flat areas develop thicker soils with more organic material. The orientation of slopes also affects soil formation. In the northern hemisphere, slopes that face south receive more sunlight than other slopes. The extra sunlight allows more vegetation to grow. Slopes without vegetation tend to lose more soil to erosion. **Figure 7.19** shows how the orientation and slope of a landscape can affect the formation of soil.




■ **Figure 7.19** The slope on the right side faces south, and the slope on the left side faces north.

Interpret why one slope has more vegetation than the other.

Parent material Recall that a soil can be either residual or transported. If the soil is residual, it will have the same chemical composition as the local bedrock. For example, in regions near volcanoes, the soils form from weathered products of lava and ash. Volcanic soils tend to be rich in the minerals that were present in the lava. If the soil is transported, the minerals in the soil are likely to be different from those in the local bedrock.

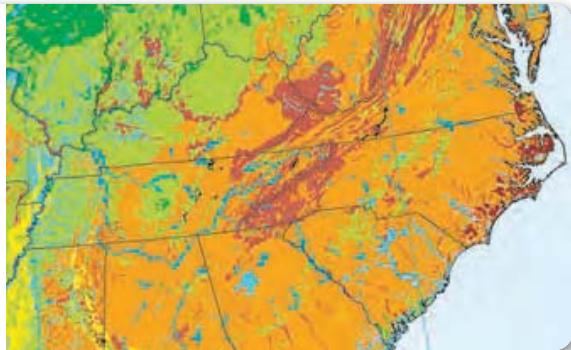
Biological organisms Organisms including fungi and bacteria, as well as plants and animals, interact with soil. Microorganisms decompose dead plants and animals. Plant roots can open channels, and when they decompose, they add organic material to the soil. Different types of biological organisms in a soil can result in different soil orders. Mollisols (MAH lih sawlz), which are called prairie soils, and alfisols (AL fuh sawlz), also called woodland soils, both develop from the same climate, topography, and parent material. The different sets of organisms result in two soils with entirely different characteristics. For example, the activity of prairie organisms in mollisols produces a thick A-horizon, rich in organic matter. Some of the most fertile agricultural lands in the Great Plains region are mollisols.

 **Reading Check** Describe how microorganisms affect soil formation.

Time The effects of time alone can determine the characteristics of a soil. New soils, such as entisols (EN tih sawlz), are often found along rivers, where sediment is deposited by periodic flooding. This type of soil is shown as a light blue color in **Figure 7.20**. These soils have had little time to weather and develop soil horizons. The effects of time on soil can be easy to recognize. After tens of thousands of years of weathering, most of the original minerals in a soil are changed or washed away. Minerals containing aluminum and iron remain, which can give older soils, such as ultisols (UL tih sawlz), a red color. **Figure 7.21** shows the locations of the 12 soil orders in the United States.

Figure 7.20 Soil types vary widely from one area to the next, depending on the local climate, topography, parent material, organisms, and age of the soil. Entisols are shown in light blue and ultisols are shown in orange on this map.

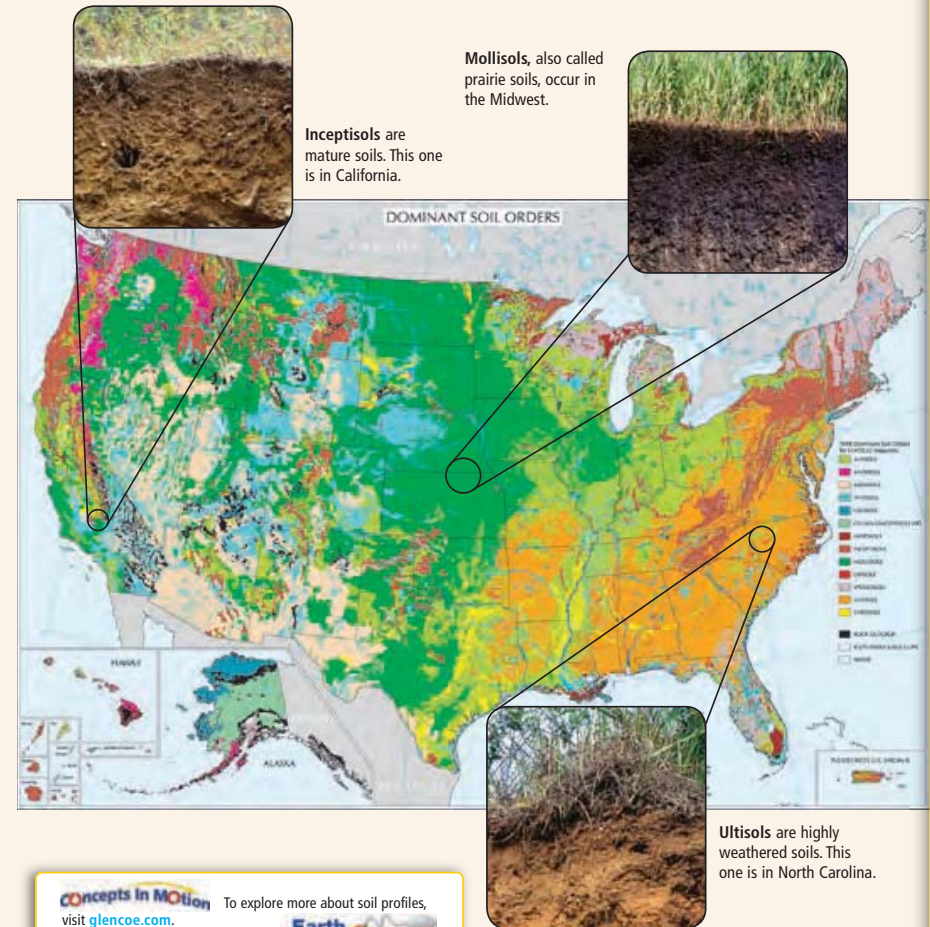
Infer how differences in topography have affected the types of soils in North Carolina.



Visualizing Soil Orders

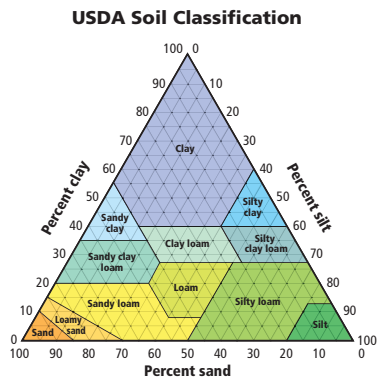


Figure 7.21 The five factors of soil formation determine how the soil orders are distributed across the United States. Soil profiles of three soil orders from different parts of the country are shown. Each soil profile has soil horizons expressed differently.



Concepts in Motion To explore more about soil profiles, visit glencoe.com.





■ **Figure 7.22** A soil textural triangle is used to determine a soil's texture.

Soil Texture

Particles of soil are classified according to size as clay, silt, or sand, with clay being the smallest and sand being the largest. The relative proportions of particle sizes determine a soil's texture, as shown in **Figure 7.22**. Soil texture affects its capacity to retain moisture and therefore its ability to support plant growth. Soil texture also varies with depth.

Soil Fertility

Soil fertility is the measure of how well a soil can support the growth of plants. Factors that affect soil fertility include the topography, availability of minerals and nutrients, the number of microorganisms present, the amount of precipitation available, and the level of acidity.

Conditions necessary for growth vary with plant species. Farmers use natural and commercially produced fertilizers to replace minerals and maintain soil fertility. Commercial fertilizers add nitrates, potassium, and phosphorus to soil. The planting of legumes, such as beans and clover, allows bacteria to grow on plant roots and replace nitrates in the soil. Pulverized limestone is often added to soil to reduce acidity and enhance crop growth.



■ **Figure 7.23** Hue, value, and chroma can be found using the Munsell System of Color Notation.

Soil Color

The minerals, organic matter, and moisture in each soil horizon determine its color. An examination of the color of a soil can reveal many of its properties. For example, the layers that compose the O-horizon and A-horizon are usually dark-colored because they are rich in humus. Red and yellow soils might be the result of oxidation of iron minerals. Yellow soils are usually poorly drained and are often associated with environmental problems. Grayish or bluish soils are common in poorly drained regions where soils are constantly wet and lack oxygen.

Scientists use the Munsell System of Color Notation, shown in **Figure 7.23**, to describe soil color. This system consists of three parts: hue (color), value (lightness or darkness), and chroma (intensity). Each color is shown on a chip from a soil book. Using the components of hue, value, and chroma, a soil's color can be precisely described.

DATA ANALYSIS LAB

Based on Real Data* Interpret the Data

How can you determine a soil's texture? Soils can be classified with the use of a soil textural triangle. Soil texture is determined by the percentages of the sand, silt, and clay that make up the soil. These also vary with depth, from one soil horizon to another. Below are data from three horizons of a soil in North Carolina.

Data and Observations

Soil Sample	Percent Clay	Percent Silt	Percent Sand	Texture
A	11	48		Loam
B	67		5	
C		53	38	

Data obtained from: Soil Survey Staff. 2006. National Soil Survey Characterization Data. Soil Survey Laboratory. National Soil Survey Center. (November 9) USDA-NRCS-Lincoln, NE

Think Critically

- Examine** the soil texture triangle shown in **Figure 7.22** to complete the data table. Record the percentages of particle sizes in the soil samples and the names of their textures.
- Infer** from the data table which soil sample has the greatest percentage of the smallest-sized particles.
- Identify** which soil horizon contains a silty clay texture.
- Infer**, if water passes quickly through sand particles, what horizon will have the most capacity to hold soil moisture.
- Identify** one characteristic of soil, other than water-holding capacity, that is determined by the soil's particle size.

Section 7.3 Assessment

Section Summary

- Soil consists of weathered rock and humus.
- Soil is either residual or transported.
- A typical soil profile has O-horizon, A-horizon, B-horizon, and C-horizon.
- Five factors influence soil formation: climate, topography, parent material, biological organisms, and time.
- Characteristics of soil include texture, fertility, and color.

Understand Main Ideas

- MAIN Idea** Describe how soil forms.
- Summarize** the features of each horizon of soil.
- Classify** a soil profile based on whether it is mature or immature.
- Generalize** the effect that topography has on soil formation.

Think Critically

- Infer** Soil scientists discover that a soil in a valley has a C-horizon of sand that is 1 km deep. Is this a transported soil or a residual soil? Justify your answer.
- Hypothesize** what type of soil exists in your area, and describe how you would determine whether your hypothesis is correct.

WRITING in Earth Science

- Soil in a portion of a garden is found to be claylike and acidic. Design a plan for improving the fertility of this soil.