



Weathering and Erosion

chapter preview

sections

1 Weathering and Soil Formation

Lab *Classifying Soils*

2 Erosion of Earth's Surface

Lab *Measuring Soil Erosion*



Virtual Lab *How are Earth's materials broken down?*

What happened to his face?





Well, how would you feel if wind, sand, and rain blew in your face for over 5,000 years? Don't forget the blistering sun and nightly chill! Would you feel weathered and torn? Two processes help shape Earth's surface—weathering and erosion.

Science Journal Describe a place—a home, a park, river, or mountain. What would happen in a year, a hundred years, even 5,000 years?

Start-Up Activities



Water's Force

The Grand Canyon is 446 km long, up to 29 km wide, and up to 1,829 m deep. The water of the Colorado River carved the canyon out of rock by wearing away particles and carrying them away for millions of years. Over time, erosion has shaped and reshaped Earth's surface many times. In this lab, you will explore how running water formed the Grand Canyon.    

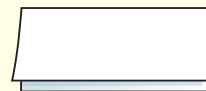
1. Fill a bread pan with packed sand and form a smooth, even surface.
2. Place the bread pan in a plastic wash tub. Position one end of the washtub in a sink under the faucet.
3. Place a brick or wood block under the end of the bread pan beneath the faucet.
4. Turn on the water to form a steady trickle of water falling into the pan and observe for 10 min. The washtub should catch the eroded sand.
5. **Think Critically** In your Science Journal, draw a top view picture of the erosion pattern formed in the sand by the running water. Write a paragraph describing what the sand would look like if you had left the water running overnight.

FOLDABLES™ Study Organizer

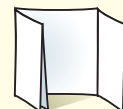
Weathering and Erosion

Make the following Foldable to compare and contrast weathering and erosion.

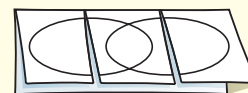
- STEP 1** Fold one sheet of paper lengthwise.



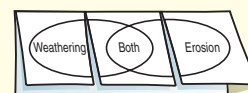
- STEP 2** Fold into thirds.



- STEP 3** Unfold and draw overlapping ovals. Cut the top sheet along the folds.



- STEP 3** Label the ovals as shown.



Construct a Venn Diagram As you read the chapter, list the characteristics unique to weathering under the left tab, those unique to erosion under the right tab, and those characteristics common to both under the middle tab.



Preview this chapter's content and activities at red.msscience.com



Weathering and Soil Formation

as you read

What You'll Learn

- **Identify** processes that break rock apart.
- **Describe** processes that chemically change rock.
- **Explain** how soil evolves.

Why It's Important

Soil forms when rocks break apart and change chemically. Soil is home to many organisms, and most plants need soil in order to grow.



Review Vocabulary

acid rain: acidic moisture, with a pH below 5.6

New Vocabulary

- weathering
- mechanical weathering
- chemical weathering
- soil
- topography

Weathering

Have you noticed potholes in roadways and broken concrete in sidewalks and curbs? When a car rolls over a pothole in the road in late winter or when you step over a broken sidewalk, you know things aren't as solid or permanent as they look. Holes in roads and broken sidewalks show that solid materials can be changed by nature. **Weathering** is a mechanical or chemical surface process that breaks rocks into smaller pieces. Freezing and thawing, oxygen in the air, and even plants and animals can affect the stability of rock. These are some of the things that cause rocks on Earth's surface to weather, and in some cases, to become soils.

Mechanical Weathering

When a sidewalk breaks apart, a large slab of concrete is broken into many small pieces. The concrete looks the same. It's just broken apart. This is similar to mechanical weathering of rocks. **Mechanical weathering** breaks rocks into smaller pieces without changing them chemically. The small pieces are identical in composition to the original rock, as shown in **Figure 1**. Two of the many causes of mechanical weathering are ice wedging and living organisms.

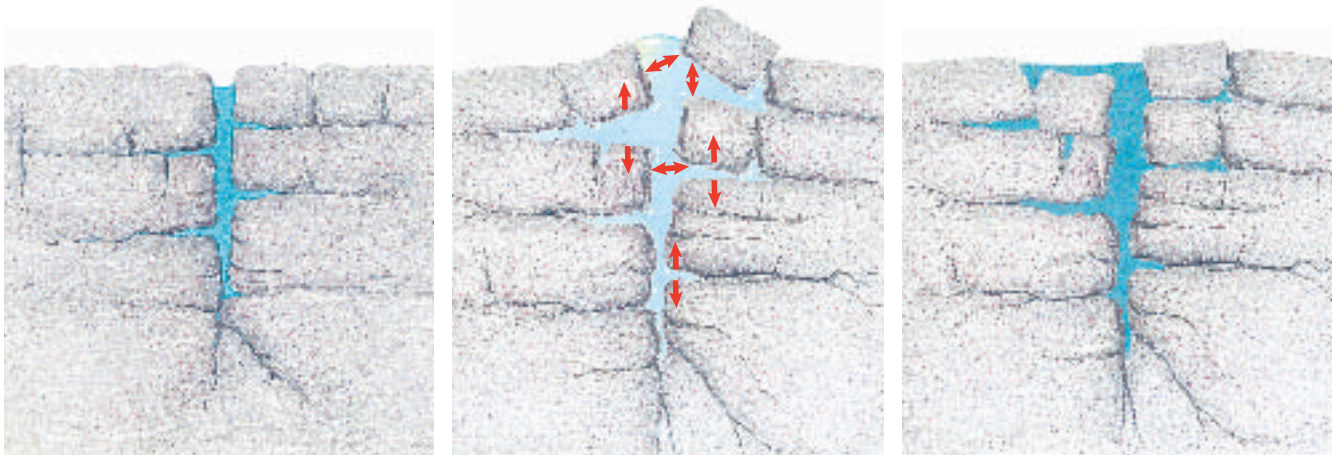
Figure 1 The forces of mechanical weathering break apart rocks.

Describe how you know that the smaller pieces of granite were produced by mechanical weathering.





Figure 2 Over time, freezing water can break apart rock.



Water seeps into cracks. The deeper the cracks are, the deeper water can seep in.

The water freezes and expands, forcing the cracks to open further.

The ice melts. If the temperature falls below freezing again, the process will repeat itself.

Ice Wedging In some areas of the world, air temperature drops low enough to freeze water. Then, when the temperature rises, the ice thaws. This freezing and thawing cycle breaks up rocks. How can this happen? When it rains or snow melts, water seeps into cracks in rocks. If the temperature drops below freezing, ice crystals form. As the crystals grow, they take up more space than the water did because when water freezes, its molecules move apart. This expansion exerts pressure on the rocks. With enough force, the rocks will crack further and eventually break apart, as shown in **Figure 2**. Ice wedging also causes potholes to form in roadways.



Reading Check

Explain how ice wedging can break rock apart.

Plants and Animals Plants and animals also cause mechanical weathering. As shown in **Figure 3**, plants can grow in what seem to be the most inconvenient places. Their roots grow deep into cracks in rock where water collects. As they grow, roots become thicker and longer, slowly exerting pressure and wedging rock apart.

Gophers and prairie dogs also weather rock—as do other animals that burrow in the ground. As they burrow through sediment or soft sedimentary rock, animals break rock apart. They also push some rock and sediment to the surface where another kind of weathering, called chemical weathering, takes place more rapidly.

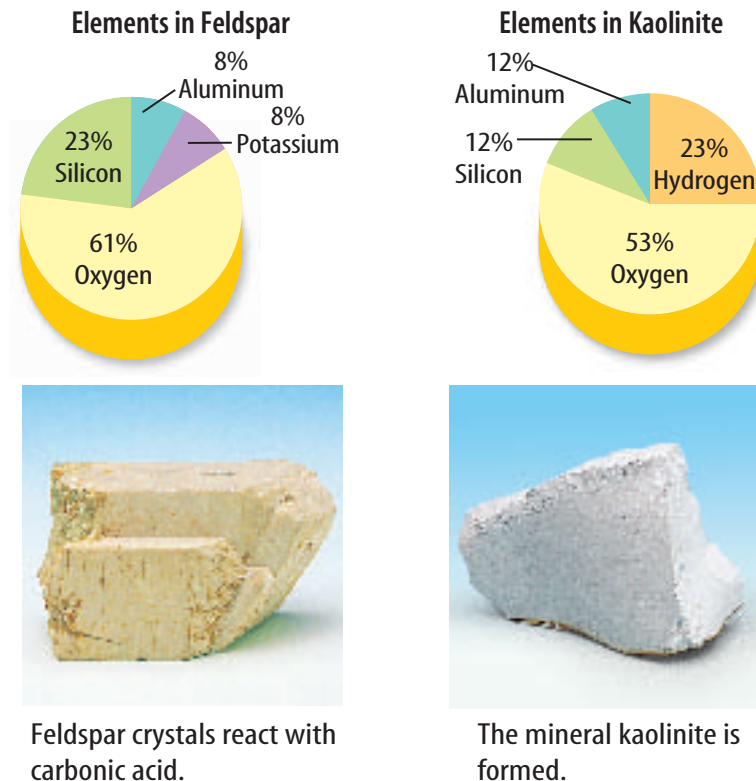
Figure 3 Tree roots can break rock apart.





Figure 4 Chemical weathering changes the chemical composition of minerals and rocks.

Describe how kaolinite is different from feldspar.



Chemical Weathering

Chemical weathering occurs when the chemical composition of rock changes. This kind of weathering is rapid in tropical regions where it's moist and warm most of the time. Because desert areas have little rainfall and polar regions have low temperatures, chemical weathering occurs slowly in these areas. **Table 1** summarizes the rates of chemical weathering for different climates. Two important causes of chemical weathering are natural acids and oxygen.

Reading Check Why is chemical weathering rapid in the tropics?

Table 1 Rates of Weathering	
Climate	Chemical Weathering
Hot and dry	Slow
Hot and wet	Fast
Cold and dry	Slow
Cold and wet	Slow



Natural Acids Some rocks react chemically with natural acids in the environment. When water mixes with carbon dioxide in air or soil, for example, carbonic acid forms. Carbonic acid can change the chemical composition of minerals in rocks, as shown in **Figure 4**.

Although carbonic acid is weak, it reacts chemically with many rocks. Vinegar reacts with the calcium carbonate in chalk, dissolving it. In a similar way, when carbonic acid comes in contact with rocks like limestone, dolomite, and marble, they dissolve. Other rocks also weather when exposed to carbonic acid.



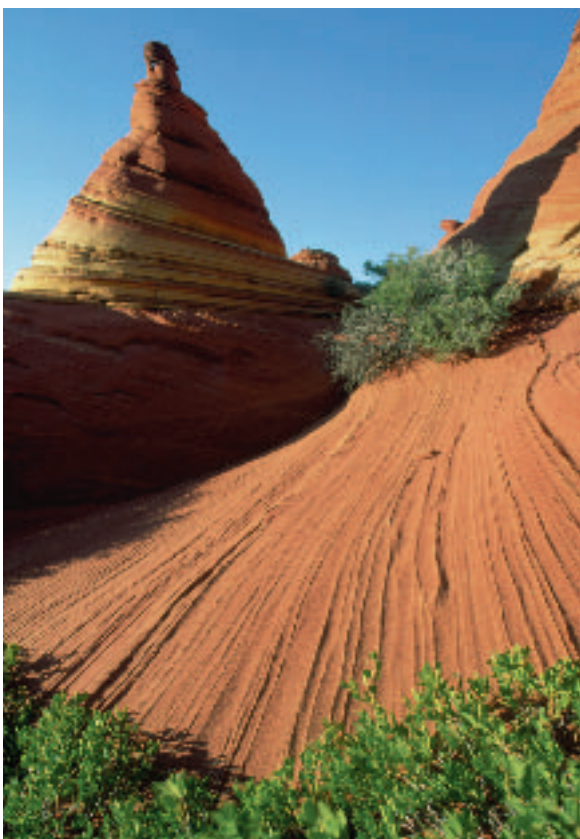
Plant Acids Plant roots also produce acid that reacts with rocks. Many plants produce a substance called tannin. In solution, tannin forms tannic acid. This acid dissolves some minerals in rocks. When minerals dissolve, the remaining rock is weakened, and it can break into smaller pieces. The next time you see moss or other plants growing on rock, as shown in **Figure 5**, peel back the plant. You'll likely see discoloration of the rock where plant acids are reacting chemically with some of the minerals in the rock.



Figure 5 Moss growing on rocks can cause chemical weathering.

Effect of Oxygen When you see rusty cars, reddish soil, or reddish stains on rock, you are witnessing oxidation, the effects of chemical changes caused by oxygen. When iron-containing materials such as steel are oxidized, a chemical reaction causes the material to rust. Rocks chemically weather in a similar way. When some iron-containing minerals are exposed to oxygen, they can weather to minerals that are like rust. This leaves the rock weakened, and it can break apart. As shown in **Figure 6**, some rocks also can be colored red or orange when iron-bearing minerals in them react with oxygen.

Figure 6 Oxidation occurs in rocks and cars.



Even a tiny amount of iron in rock can combine with oxygen and form a reddish iron oxide.



The iron contained in metal objects such as this truck also can combine with oxygen and form a reddish iron oxide called rust.

Mini LAB

Dissolving Rock with Acids

Procedure






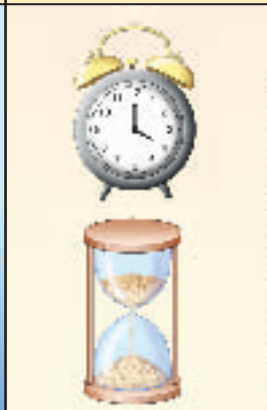

WARNING: Do not remove goggles until lab cleanup and handwashing are completed.

1. Use an eyedropper to put several drops of **vinegar** on pieces of **chalk** and **limestone**. Observe the results with a **magnifying lens**.
2. Put several drops of 5% **hydrochloric acid** on the chalk and limestone. Observe the results.

Analysis

1. Describe the effect of the hydrochloric acid and vinegar on chalk and limestone.
2. Research what type of acid vinegar contains.

**Table 2 Factors that Affect Soil Formation**

Parent Rock	Slope of Land	Climate	Time	Organisms
				

Soil

Is soil merely dirt under your feet, or is it something more important? **Soil** is a mixture of weathered rock, organic matter, water, and air that supports the growth of plant life. Organic matter includes decomposed leaves, twigs, roots, and other material. Many factors affect soil formation.

Parent Rock As listed in **Table 2**, one factor affecting soil formation is the kind of parent rock that is being weathered. For example, where limestone is chemically weathered, clayey soil is common because clay is left behind when the limestone dissolves. In areas where sandstone is weathered, sandy soil forms.

The Slope of the Land The **topography**, or surface features, of an area also influence the types of soils that develop. You've probably noticed that on steep hillsides, soil has little chance of developing. This is because rock fragments move downhill constantly. However, in lowlands where the land is flat, wind and water deposit fine sediments that help form thick soils.

Climate Climate affects soil evolution, too. If rock weathers quickly, deep soils can develop rapidly. This is more likely to happen in tropical regions where the climate is warm and moist. Climate also affects the amount of organic material in soil. Soils in desert climates contain little organic material. However, in warm, humid climates, vegetation is lush and much organic material is present. When plants and animals die, decomposition by fungi and bacteria begins. The result is the formation of a dark-colored material called humus, as shown in the soil profile in **Figure 7**. Most of the organic matter in soil is humus. Humus helps soil hold water and provides nutrients that plants need to grow.

Mini LAB

Analyzing Soils

Procedure

1. Obtain a sample of **soil** from near your home.
2. Spread the soil out over a piece of **newspaper**.
3. Carefully sort through the soil. Separate out organic matter from weathered rock.
4. Wash hands thoroughly after working with soils.

Analysis

1. Besides the organic materials and the remains of weathered rock, what else is present in the soil?
2. Is some of the soil too fine-grained to tell if it is organic or weathered rock?



Time It takes time for rocks to weather. It can take thousands of years for some soils to form. As soils develop, they become less like the rock from which they formed. In young soils, the parent rock determines the soil characteristics. As weathering continues, however, the soil resembles the parent rock less and less. Thicker, well-developed soils often are found in areas where weathering has gone on undisturbed for a long period of time. For this to happen, soil materials must not be eroded away and new sediment must not be deposited over the land's surface too quickly.

Organisms Organisms influence soil development. Lichens are small organisms that consist of an alga and a fungus that live together for mutual benefit. You may have seen lichens in the form of multicolored patches growing on tree branches or cliff faces. Interestingly, lichens can grow directly on rock. As they grow, they take nutrients from the rock that they are starting to break down, forming a thin soil. After a soil has formed, many types of plants such as grasses and trees can grow.

The roots of these plants further break down the parent rock. Dead plant material such as leaves accumulates and adds organic matter to the soil. Some plants contribute more organic matter to soil than others. For example, soil under grassy areas often is richer in organic matter than soil developing under forests. This is why some of the best farmland in the midwestern United States is where grasslands used to be.

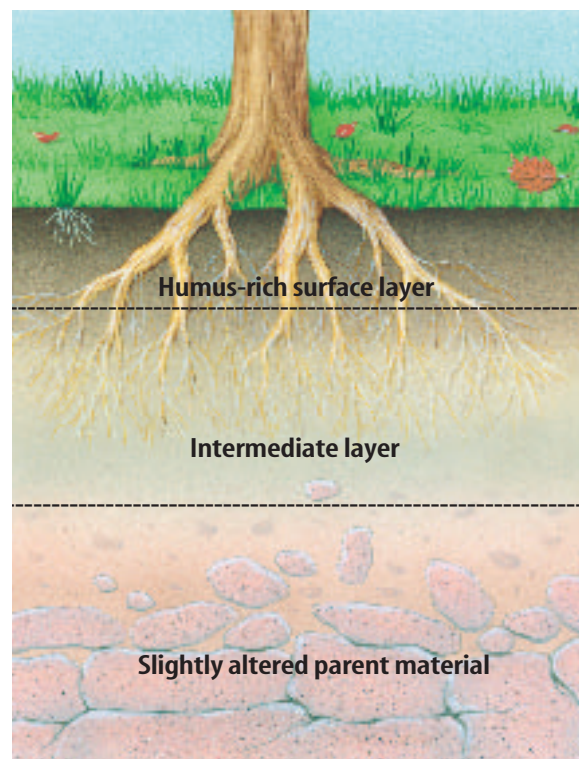


Figure 7 Soils contain layers that are created by weathering, the flow of water and chemicals, and the activities of organisms. **Explain** what part microorganisms play in soil development.

section 1 review

Summary

Mechanical Weathering

- The freezing and thawing cycle breaks up rocks.
- Plants' roots and burrowing animals can break rocks apart.

Chemical Weathering

- Some rocks react chemically with natural acids.

Soil

- A factor affecting soil formation is the kind of parent rock that is being weathered.

Self Check

1. **Describe** how rocks are mechanically weathered.
2. **Name** two agents of chemical weathering.
3. **Explain** how carbonic acid weather rocks.
4. **Describe** how soil forms. What factors are important?
5. **Think Critically** How could climate affect rates of mechanical weathering? What about chemical weathering? How are the two kinds of weathering related?

Applying Skills

6. **Compare and contrast** mechanical weathering caused by ice and growing roots.

Classifying Soils

Not all soils are the same. Geologists and soil scientists classify soils based on the amounts and kinds of particles they contain.

Real-World Question

How is soil texture determined?

Goals

- **Classify** a soil using an identification key.
- **Observe** soil with a stereomicroscope.

Materials

soil sample
stereomicroscope
*magnifying lens
*Alternate materials

Safety Precautions



Procedure

1. Place a small sample of moistened soil between your fingers. Then follow the directions in the classification key below.
 - a. Slide your fingers back and forth past each other. If your sample feels gritty, go to **b**. If it doesn't feel gritty, go to **c**.
 - b. If you can mold the soil into a firm ball, it's sandy loam soil. If you cannot mold it into a firm ball, it's sandy soil.
 - c. If your sample is sticky, go to **d**. If your sample isn't sticky, go to **e**.
 - d. If your sample can be molded into a long, thin ribbon, it's clay soil. If your soil can't be molded into a long, thin ribbon, it's clay loam soil.
 - e. If your sample is smooth, it's silty loam soil. If it isn't smooth, it's loam soil.



2. After classifying your soil sample, examine it under a microscope. Draw the particles and any other materials that you see.
3. Wash your hands thoroughly after you are finished working with soils.

Conclude and Apply

1. **Determine** the texture of your soil sample.
2. **Describe** two characteristics of loam soil.
3. **Describe** two features of sandy loam soil.
4. **Record Observations** Based on your observations with the stereomicroscope, what types of particles and other materials did you see? Did you observe any evidence of the activities of organisms?

Communicating Your Data

Compare your conclusions with those of other students in your class. **For more help, refer to the Science Skill Handbook.**

Erosion of Earth's Surface

Agents of Erosion

Imagine looking over the rim of the Grand Canyon at the winding Colorado River below or watching the sunset over Utah's famous arches. Features such as these are spectacular examples of Earth's natural beauty, but how can canyons and arches form in solid rock? These features and many other natural landforms are a result of erosion of Earth's surface. **Erosion** is the wearing away and removal of rock or sediment. Erosion occurs because gravity, ice, wind, and water sculpt Earth's surface.

Gravity

Gravity is a force that pulls every object toward every other object. Gravity pulls everything on Earth toward its center. As a result, water flows downhill and rocks tumble down slopes. When gravity alone causes rock or sediment to move down a slope, the erosion is called **mass movement**. Mass movements can occur anywhere there are hills or mountains. One place where they often occur is near volcanoes, as shown in **Figure 8**. Creep, slump, rock slides, and mudflows are four types of mass movements, as seen in **Figure 9**.

as you read

What You'll Learn

- **Identify** agents of erosion.
- **Describe** the effects of erosion.

Why It's Important

Erosion shapes Earth's surface.



Review Vocabulary

deposition: dropping of sediments occurs when an agent of erosion can no longer carry its load

New Vocabulary

- | | |
|-----------------|-------------|
| • erosion | • slump |
| • mass movement | • deflation |
| • creep | • abrasion |
| | • runoff |

Figure 8 The town of Weed, California, was built on top of a landslide that moved down the volcano known as Mount Shasta.

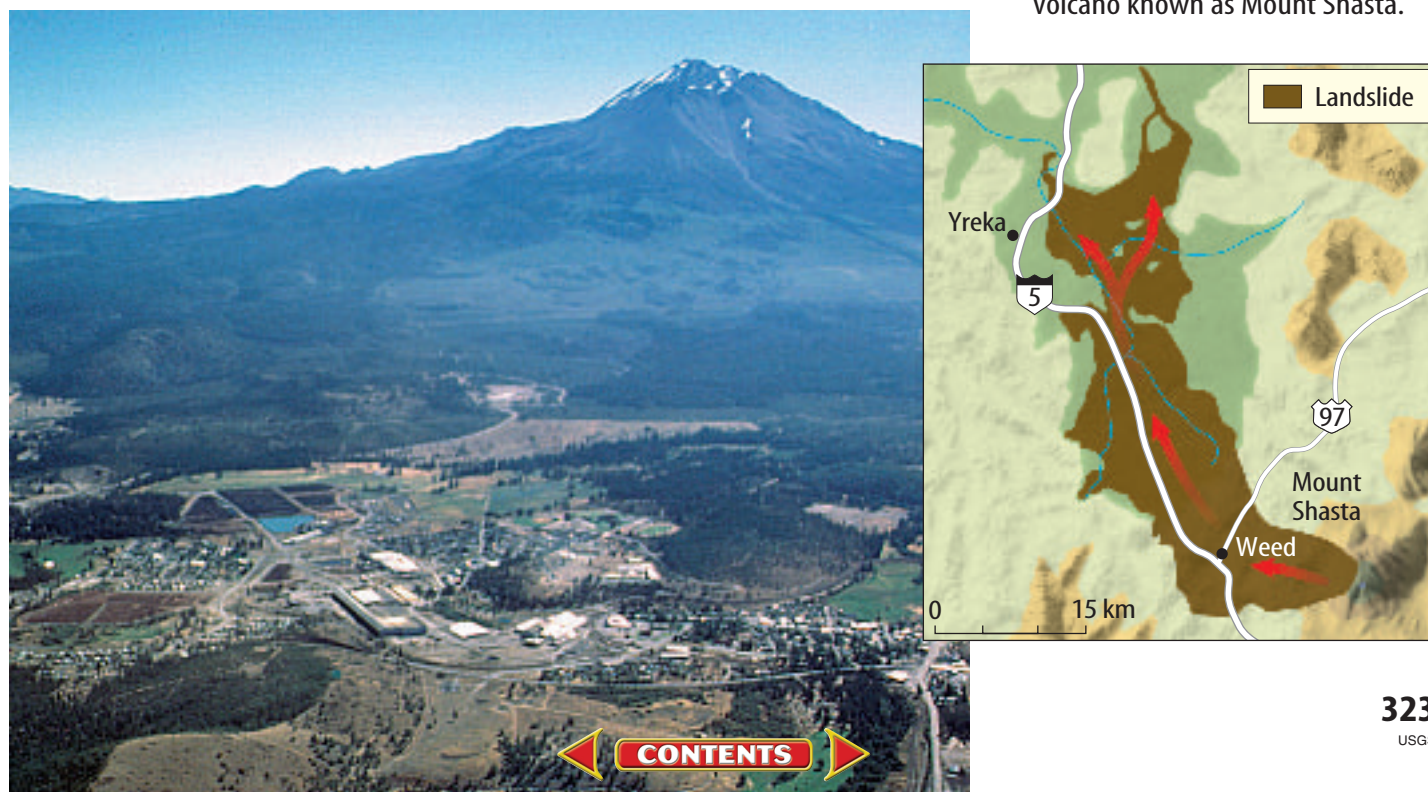




Figure 9

When the relentless tug of gravity causes a large chunk of soil or rock to move downhill—either gradually or with sudden speed—the result is what geologists call a mass movement. Weathering and water often contribute to mass movements. Several kinds are shown here.

A CREEP When soil on a slope moves very slowly downhill, a mass movement called creep occurs. Some of the trees at right have been gradually bent because of creep's pressure on their trunks.



B SLUMP This cliff in North Dakota shows the effects of the mass movement known as slump. Slumping often occurs after earthquakes or heavy and prolonged rains.



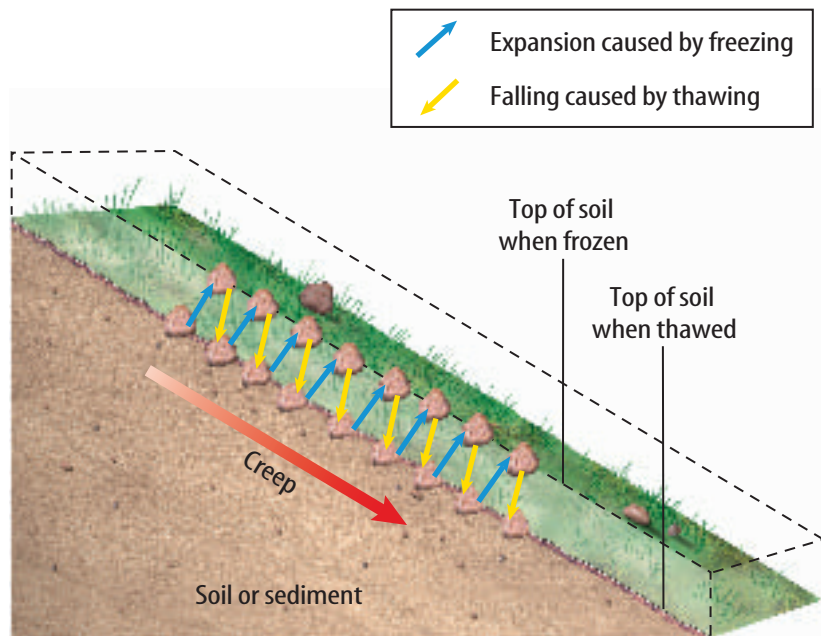
C ROCK SLIDES When rocks break free from the side of a cliff or a mountain, they crash down in what is called a rock slide. Rock slides, like the one at the left in Yosemite National Park, can occur with little warning.

D MUDFLOWS A Japanese town shows the devastation that a fourth type of mass movement—a mudflow—can bring. When heavy moisture saturates sediments, mudflows can develop, sending a pasty mix of water and sediment downhill over the ground's surface.





Creep The process in which sediments move slowly downhill, as shown in **Figure 9A**, is called **creep**. Creep is common where freezing and thawing occur. As ice expands in soil, it pushes sediments up. Then as soil thaws, the sediments move farther downslope. **Figure 10** shows how small particles of sediment can creep downslope. Over time, creep can move large amounts of sediment, possibly causing damage to some structures. Do you live in an area where you can see the results of creep?



Slump A **slump** occurs when a mass of rock or sediment moves downhill, leaving a curved scar, as shown in **Figure 9B**. Slumps are most common in thick layers of loose sediment, but they also form in sedimentary rock. Slumps frequently occur on slopes that have been undercut by erosion, such as those above the bases of cliffs that have been eroded by waves. Slumping of this kind is common along the coast of Southern California, where it threatens to destroy houses and other buildings.

Figure 10 When soil freezes, particles are lifted. When it thaws, the particles are pulled downhill by gravity. Eventually, large amounts of sediment are moved by this process.

Rock Slides Can you imagine millions of cubic meters of rock roaring down a mountain at speeds greater than 250 km/h? This can happen when a rock slide occurs. During a rock slide layers of rock break loose from slopes and slide to the bottom. The rock layers often bounce and break apart during movement. This produces a huge, jumbled pile of rocks at the bottom of the slope, as you can see in **Figure 9C**. Rock slides can be destructive, sometimes destroying entire villages or causing hazards on roads in mountainous areas.

Mudflows Where heavy rains or melting snow and ice saturate sediments, mudflows, as shown in **Figure 9D**, can develop. A mudflow is a mass of wet sediment that flows downhill over the ground surface. Some mudflows can be thick and flow slowly downhill at rates of a few meters per day. Other mudflows can be much more fluid and move downslope at speeds approaching 160 km/h. This type of mudflow is common on some volcanoes.



Mass Movement Slumps and rock slides often occur when sediment becomes saturated by rain. Water between sediment grains helps lift up overlying rock and sediment. This makes it easier for the sediment to overcome the forces holding it in place. Can you think of a way some slopes might be protected from slumps and rock slides? Explain.

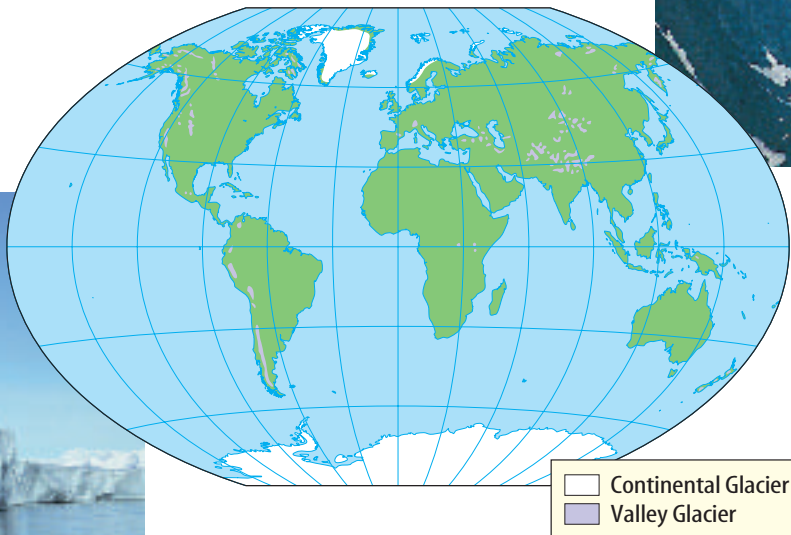
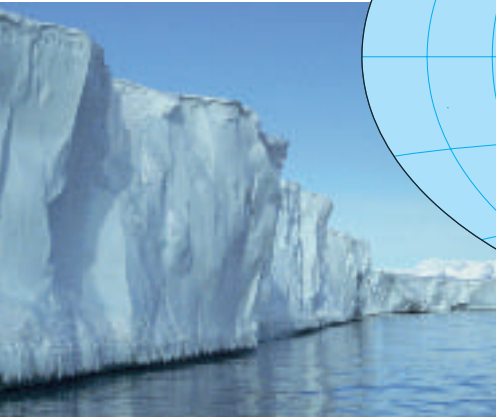


What is the slowest of the four kinds of mass movement?



Figure 11 Glaciers form in cold regions.

Continental glaciers are located near the poles, in Antarctica and Greenland.



Valley glaciers are found at high elevations on many continents.

Ice

In some parts of the world, ice is an agent of erosion. In cold regions, more snow might fall than melt. Over many years, the snow can accumulate to form large, deep masses of ice called glaciers. When the ice in a glacier becomes thick enough, its own weight causes it to flow downhill under the influence of gravity. As glaciers move over Earth's surface, they erode materials from some areas and deposit sediment in other areas. **Figure 11** shows the two kinds of glaciers—continental glaciers and valley glaciers.

Today, continental glaciers in polar regions cover about ten percent of Earth. These glaciers are so large and thick that they can bury mountain ranges. Valley glaciers are much smaller and are located in high mountains where the average temperature isn't warm enough to melt the ice sheets. The average flow rate of a valley glacier is 0.01 to 2.0 meters per day, but during a surge, they can flow up to 100 meters per day.

Glacial Erosion Glaciers can erode rock in two different ways. If the underlying rock has cracks in it, the ice can pull out pieces of rock. This causes the rock to erode slowly. Loose pieces of rock freeze into the bottom of the glacier and are dragged along as the glacier moves. As these different-sized fragments of rock are dragged over Earth's surface, they scratch the rock below like giant sheets of sandpaper. This scratching is the second way that glaciers can erode rock. Scratching produces large grooves or smaller striations in the rock underneath. The scratching also can wear rock into a fine powder called rock flour.



Topic: Glacial Erosion and Deposition

Visit red.msscience.com for Web links to information about glacial erosion and deposition.

Activity Research glacial erosion and describe how it has affected the topography in an area.



Figure 12 Many high-altitude areas owe their distinctive appearance to glacial erosion.



Mountain glaciers can carve bowl-shaped depressions called cirques.



Glaciers can widen valleys, giving them a U-shaped profile.

Effects of Glacial Erosion Glacial erosion of rock can be a powerful force shaping Earth's surface. In mountains, valley glaciers can remove rock from the mountaintops to form large bowls, called cirques (SURKS), and steep peaks. When a glacier moves into a stream valley, it erodes rock along the valley sides, producing a wider, U-shaped valley. These features are shown in **Figure 12**. Continental glaciers also shape Earth's surface. These glaciers can scour large lakes and completely remove rock layers from the land's surface.

Glacial Deposition Glaciers also can deposit sediments. When stagnant glacier ice melts or when ice melts at the bottom of a flowing glacier or along its edges, the sediment the ice was carrying gets left behind on Earth's surface. This sediment, deposited directly from glacier ice, is called till. Till is a mixture of different-sized particles, ranging from clay to large boulders.

As you can imagine, a lot of melting occurs around glaciers, especially during summer. So much water can be produced that streams often flow away from the glacier. These streams carry and deposit sediment. Sand and gravel deposits laid down by these streams, shown in **Figure 13**, are called outwash. Unlike till, outwash usually consists of particles that are all about the same size.

Figure 13 This valley in New Zealand has been filled with outwash.

Explain how you could distinguish outwash from till.





Figure 14 In a desert, where small particles have been carried away by wind, larger sediments called desert pavement remain behind.

Figure 15 Wind transportation of sand creates sand dunes.



Sand dunes do not remain in one location—they migrate.

Wind

If you've had sand blow into your eyes, you've experienced wind as an agent of erosion. When wind blows across loose sediments like silt and sand, it lifts and carries it. As shown in **Figure 14**, wind often leaves behind particles too heavy to move. This erosion of the land by wind is called **deflation**. Deflation can lower the land's surface by several meters.

Wind that is carrying sediment can wear down, or abrade, other rocks just as a sandblasting machine would do. **Abrasion** is a form of erosion that can make pits in rocks and produce smooth, polished surfaces. Abrasion is common in some deserts and in some cold regions with strong winds.

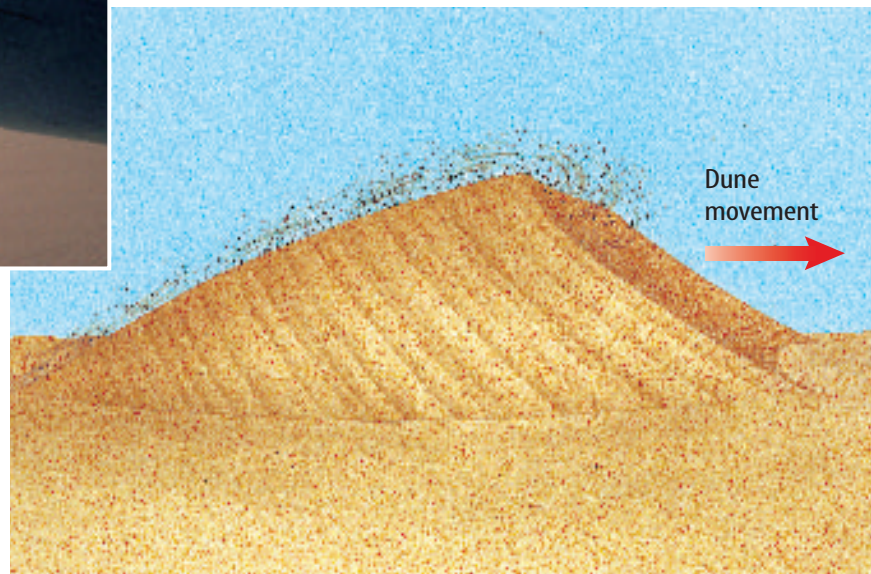


Reading Check *How does abrasion occur?*

When wind blows around some irregular feature on Earth's surface, such as a rock or clump of vegetation, it slows down. This causes sand carried by the wind to be deposited. If this sand deposit continues to grow, a sand dune like that shown in **Figure 15** might form. Sand dunes move when wind carries sand up one side of the dune and it avalanches down the other, as shown in **Figure 15**.

Sometimes, wind carries only fine sediment called silt. When this sediment is deposited, an accumulation of silt called loess (LOOS) can blanket Earth's surface. Loess is as fine as talcum powder. Loess often is deposited downwind of large deserts and deflated glacial outwash deposits.

As wind blows over a sand dune, sand blows up the windward side and tumbles down the other side. In this way, a sand dune migrates across the land.





Water

You probably have seen muddy water streaming down a street after a heavy rain. You might even have taken off your shoes and waded through the water. Water that flows over Earth's surface is called **runoff**. Runoff is an important agent of erosion, especially if the water is moving fast. The more speed water has, the more material it can carry with it. Water can flow over Earth's surface in several different ways, as you will soon discover.



Figure 16 Water flows over the hood of a car as a thin sheet. **Describe** how this is similar to sheet flow on Earth's surface.

Sheet Flow As raindrops land on Earth's surface, they break up clumps of soil and loosen small grains of sediment. If these raindrops are falling on a sloped land surface, a thin sheet of water might begin to move downhill. You have observed something similar if you've ever washed a car and seen sheets of water flowing over the hood, as shown in **Figure 16**. When water flows downhill as a thin sheet, it is called sheet flow. This thin sheet of water can carry loose sediment grains with it, causing erosion of the land. This erosion is called sheet erosion.

Applying Science

Can evidence of sheet erosion be seen in a farm field?

If you've ever traveled through parts of your state where there are farms, you might have seen bare, recently cultivated fields. Perhaps the soil was prepared for planting a crop of corn, oats, or soybeans. Do you think sheet erosion can visibly affect the soil in farm fields?

Identifying the Problem

The top layer of most soils is much darker than layers beneath because it contains more organic matter. This layer is the first to be removed from a slope by sheet flow. How does the photo show evidence of sheet erosion?



Solving the Problem

1. Observe the photo and write a description of it in your Science Journal.
2. Infer why some areas of the field are darker colored than others are. Where do you think the highest point(s) are in this field?
3. Make a generalization about the darker areas of the field.



Figure 17 Gullies often form on vegetation-free slopes.



(t)Gerard Laziz/Earth Scenes (b)Vanessa Vick/Photo Researchers



Topic: Power of Water

Visit red.msscience.com for Web links to information about the erosional force of running water.

Activity Research your watershed and see if the topography was shaped by running water.

Figure 18 Streams that flow down steep slopes such as this one in Yosemite National Park often have white-water rapids and waterfalls.



Rills and Gullies Where a sheet of water flows around obstacles and becomes deeper, rills can form. Rills are small channels cut into the sediment at Earth's surface. These channels carry more sediment than can be moved by sheet flow. In some cases, a network of rills can form on a slope after just one heavy rain. Large amounts of sediment can be picked up and carried away by rills.

As runoff continues to flow through the rills, more sediment erodes and the channel widens and deepens. When the channels get to be about 0.5 m across, they are called gullies, as shown in **Figure 17**.

Streams Gullies often connect to stream channels. Streams can be so small that you could jump to the other side or large enough for huge river barges to transport products along their course. Most streams have water flowing through them continually, but some have water only during part of the year.

In mountainous and hilly regions, as in **Figure 18**, streams flow down steep slopes. These streams have a lot of energy and often cut into the rock beneath their valleys. This type of stream typically has white-water rapids and may have waterfalls. As streams move out of the mountains and onto flatter land, they begin to flow more smoothly. The streams might snake back and forth across their valley, eroding and depositing sediments along their sides. All streams eventually must flow into the ocean or a large lake. The level of water in the ocean or lake determines how deeply a river can erode.



Shaping Earth's Surface In the Launch Lab, you saw a small model of erosion by a stream. Streams are the most important agent of erosion on Earth. They shape more of Earth's surface than ice, wind, or gravity. Over long periods of time, water moving in a stream can have enough power to cut large canyons into solid rock. Many streams together can sculpt the land over a wide region, forming valleys and leaving some rock as hills. Streams also shape the land by depositing sediment. Rivers can deposit sandbars along their course, and can build up sheets of sand across their valleys. When rivers enter oceans or lakes, the water slows and sediment is deposited. This can form large accumulations of sediment called deltas, as in **Figure 19**. The city of New Orleans is built on the delta formed by the Mississippi River.



Figure 19 A triangular area of sediment near the mouth of a river is called a delta. Ancient deltas that are now dry land are often excellent places to grow crops.

Effects of Erosion

All agents of erosion change Earth's surface. Rock and sediment are removed from some areas only to be deposited somewhere else. Where material is removed, canyons, valleys, and mountain cirques can form. Where sediment accumulates, deltas, sandbars, sand dunes, and other features make up the land.

section 2 review

Summary

Gravity

- Erosion of rock or sediment, moved down a slope by gravity, is called mass movement.
- Creep, slump, rock slides, and mudflows are four types of mass movement.

Ice

- Glaciers move over Earth's surface, eroding materials from some areas and depositing sediments in other areas.

Wind

- Deflation and abrasion are two common forms of wind erosion.

Water

- Runoff is water flowing over Earth's surface.
- Water erosion can create sheet erosion, rills, gullies, streams, valleys, and canyons.

Self Check

1. **Describe** four agents of erosion. Which of these is the fastest? The slowest? Explain your answers.
2. **Explain** the difference between deflation and abrasion.
3. **Describe** how a cirque forms.
4. **Explain** When do streams deposit sediments? When do streams erode sediments?
5. **Think Critically** Why might a river that was eroding and depositing sediment along its sides start to cut into Earth to form a canyon?

Applying Math

6. **Solve One-Step Equations** If wind is eroding an area at a rate of 2 mm per year and depositing it in a smaller area at a rate of 7 mm per year, how much lower will the first area be in meters after 2 thousand years? How much higher will the second area be?

Measuring Soil Erosion

Goals

- **Design** an experiment to measure soil loss from grass-covered soil and from soil without grass cover.
- **Calculate** the percent of soil loss with and without grass cover.

Possible Materials

blocks of wood
**books*
 paint trays (2)
 soil
 grass sod
 water
 pails (2)
 1,000-mL beaker
 triple-beam balance
 calculator
 watch

**Alternate materials*

Safety Precautions



Wash your hands thoroughly when you are through working with soils.

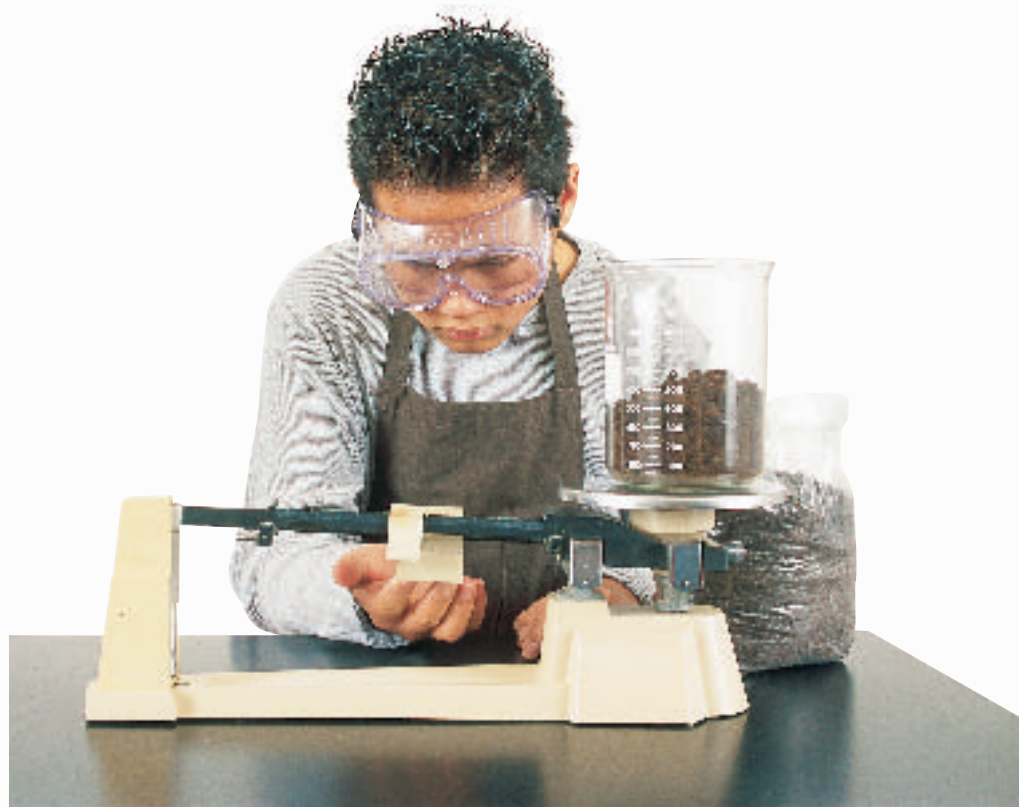
Real-World Question

During urban highway construction, surface mining, forest harvesting, or agricultural cultivation, surface vegetation is removed from soil. These practices expose soil to water and wind. Does vegetation significantly reduce soil erosion? How much does vegetation reduce soil erosion?



Form a Hypothesis

Based on what you've read and observed, hypothesize about how a grassy field will have less erosion than a field that is bare soil.



Using Scientific Methods

Test Your Hypothesis

Make a Plan

1. As a group, agree upon the hypothesis and decide how you will test it. Identify which results challenge or confirm the hypothesis.
2. **List** the steps you will need to take to test your hypothesis. Describe exactly what you will do in each step.
3. **Prepare** a data table in your Science Journal to record your observations.
4. Read over the entire experiment to make sure all steps are in logical order, and that you have all necessary materials.
5. **Identify** all constants and variables and the control of the experiment. A control is a standard for comparing the results of an experiment. One possible control for this experiment would be the results of the treatment of an uncovered soil sample.

Follow Your Plan

1. Make sure your teacher approves your plan before you start.
2. Carry out the experiment step by step as planned.
3. While doing the experiment, record your observations and complete the data table in your Science Journal.

Vegetation and Erosion			
	(A) Mass of Soil at Start	(B) Mass of Eroded Soil	% of Soil Loss (B/A) \times 100
Covered soil sample	Do not write in this book.		
Uncovered soil sample			

Analyze Your Data

1. **Compare** the percent of soil loss from each soil sample.
2. **Compare** your results with those of other groups.
3. What was your control in this experiment? Why is it a control?
4. Which were the variables you kept constant?
Which did you vary?

Conclude and Apply

1. Did the results support your hypothesis? Explain.
2. **Infer** what effect other types of plants would have in reducing soil erosion. Do you think that grass is better or worse than most other plants at reducing erosion? Explain your answer.

Communicating Your Data

Write a letter to the editor of a newspaper. In your letter, summarize what you learned in your experiment about the effect of plants on soil erosion.

Acid rain is destroying some of the world's most famous monuments

CRUMBLING MONUMENTS

The Taj Mahal in India, the Acropolis in Greece, and the Colosseum in Italy have stood for centuries. They've survived wars, souvenir-hunters, and natural weathering from wind and rain. But now, something far worse threatens their existence—acid rain. Over the last few decades, this form of pollution has eaten away at some of history's greatest monuments.

Most of these structures are made of sandstone, limestone, and marble. Acid rain causes the calcium in these stones to form calcium sulfate, or gypsum.

Gypsum's powdery little blotches are sometimes called “marble cancer.” When it rains, the gypsum washes away, along with some of the surface of the monument.

In Agra, India, the smooth, white marble mausoleum called the Taj Mahal has stood since the seventeenth century. But acid rain is making the surface of the building yellow and flaky. The pollution is caused by hundreds of factories surrounding Agra that emit damaging chemicals.

What moisture, molds, and the roots of vegetation couldn't do in 1,500 years, acid rain is doing in a few decades. It is destroying the Mayan ruins of Mexico. Acid rain is causing statues to crumble and paintings on walls to flake off.



Acid rain has not been kind to this Mayan figure.

Acid rain is a huge problem affecting national monuments and treasures in just about every urban location in the world. These include the Capitol building in Washington, D.C., churches in Germany, and stained-glass windows in Sweden. In London, acid rain has forced workers to repair and replace so much of

Westminster Abbey that the structure is becoming a mere copy of the original.

Throughout the world, acid rain has weathered many structures more in the last 20 years than in the 2,000 years before. This is one reason some steps have been taken in Europe and the United States to reduce emissions from the burning of fossil fuels. If these laws don't work, many irreplaceable art treasures may be gone forever.

Identify What are some famous monuments and buildings in the United States? Brainstorm a list with your class. Then choose a monument and, using your school's media center or the Science Online address, learn more about it. Is acid rain affecting it in any way?

Science Online

For more information, visit
red.msscience.com/time

Reviewing Main Ideas

Section 1

Weathering and Soil Formation

1. Weathering includes processes that break down rock.
2. During mechanical weathering, physical processes break rock into smaller pieces.
3. During chemical weathering, the chemical composition of rocks is changed.
4. Soil evolves over time from weathered rock. Parent rock, topography, climate, and organisms affect soil formation.

Section 2

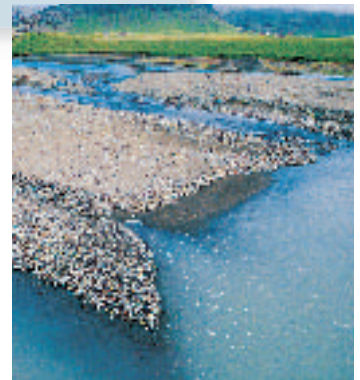
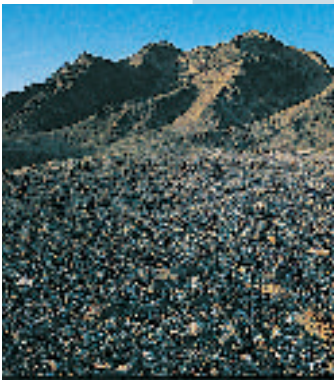
Erosion of Earth's Surface

1. Erosion is the wearing away and removal of rock or sediment.
2. Agents of erosion include gravity, ice, wind, and water. Downslope movement of a portion of the land's surface is called mass movement.
3. All agents of erosion move rock and sediment. When energy of motion decreases, sediment is deposited.
4. Erosion and deposition determine the shape of the land.

Visualizing Main Ideas

Copy and fill in the following table, which compares erosion and deposition by different agents.

Erosion and Deposition		
Erosional Agent	Evidence of Erosion	Evidence of Deposition
Gravity		material piled at bottom of slopes
Ice	cirques, striations, U-shaped valleys	
Wind		sand dunes, loess
Surface Water	rills, gullies, stream valleys	



Using Vocabulary

abrasion p. 328	mechanical weathering p. 316
chemical weathering p. 318	runoff p. 329
creep p. 325	slump p. 325
deflation p. 328	soil p. 320
erosion p. 323	topography p. 320
mass movement p. 323	weathering p. 316

Use each of the following pairs of terms in a sentence.

- chemical weathering—mechanical weathering
- erosion—weathering
- deflation—runoff
- mass movement—weathering
- soil—abrasion
- soil—erosion
- mass movement—mechanical weathering
- weathering—chemical weathering
- creep—slump
- topography—runoff

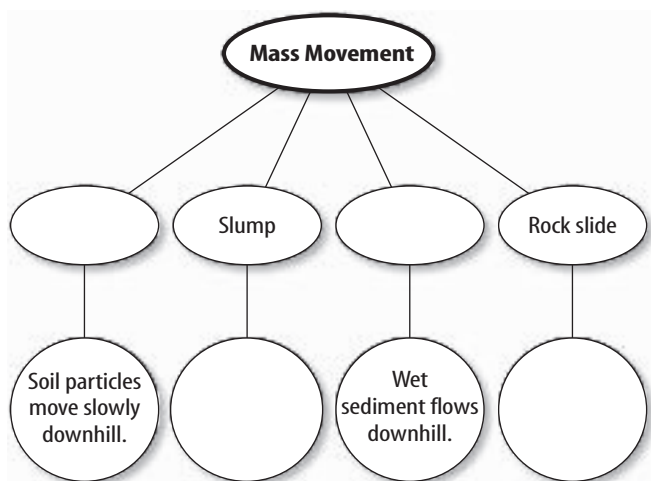
Checking Concepts

Choose the word or phrase that best answers the question.

- Which of the following agents of erosion forms U-shaped valleys?
 - gravity
 - surface water
 - ice
 - wind
- In which of these places is chemical weathering most rapid?
 - deserts
 - mountains
 - polar regions
 - tropical regions
- Which of the following forms when carbon dioxide combines with water?
 - calcium carbonate
 - carbonic acid
 - tannic acid
 - dripstone
- Which process causes rocks to weather to a reddish color?
 - oxidation
 - deflation
 - carbon dioxide
 - frost action
- Which type of mass movement occurs when sediments slowly move downhill because of freezing and thawing?
 - creep
 - rock slide
 - slump
 - mudflow
- Which of the following helps form cirques and U-shaped valleys?
 - rill erosion
 - ice wedging
 - deflation
 - till
- What is windblown, fine sediment called?
 - till
 - outwash
 - loess
 - delta
- Which of the following refers to water that flows over Earth's surface?
 - runoff
 - slump
 - weathering
 - till
- Which of the following is an example of chemical weathering?
 - Plant roots grow in cracks in rock and break the rock apart.
 - Freezing and thawing of water widens cracks in rocks.
 - Wind blows sand into rock, scratching the rock.
 - Oxygen causes iron-bearing minerals in rock to break down.
- Which one of the following erosional agents creates desert pavement?
 - wind
 - gravity
 - water
 - ice

Thinking Critically

21. **Explain** why mass movement is more common after a heavy rainfall.
22. **Describe** how climate affects the development of soils.
23. **Explain** how some mass movement could be prevented.
24. **Describe** why chemical weathering would not be rapid in Antarctica.
25. **Describe** why caves form only in certain types of rock.
26. **Recognize Cause and Effect** Explain how water creates stream valleys.
27. **Form hypotheses** about how deeply water could erode and about how deeply glaciers could erode.
28. **Recognize Cause and Effect** Explain how valley glaciers create U-shaped valleys.
29. **Classify** the following by the agent that deposits each: sand dune, delta, till, and loess.
30. **Concept Map** Copy and complete the concept map showing the different types of mass movements.



Performance Activities

31. **Poster** Use photographs from old magazines to make a poster that illustrates different kinds of weathering and erosion. Display your poster in your classroom.
32. **Model** Use polystyrene, cardboard, and clay to make a model of a glacier. Include a stream of meltwater leading away from the glacier. Use markers to label the areas of erosion and deposition. Show and label areas where till and outwash sediments could be found. Display your model in your classroom.

Applying Math

Use the table below to answer questions 33–34.

Loss and Formation of Topsoil

Years Soil Erodes	Topsoil Lost (cm)	Years to Re-create Soil Lost
10	1	500
15	1.5	
20	2	Do not write in this book.
25	2.5	
30	3	
40	4.5	

33. **Formation of Topsoil** In a given region, it takes 500 years to form 1 cm of topsoil. For the past 20 years, the area has lost 1 cm of topsoil every 10 years because of erosion. If erosion stops today, how long will it take to re-create the lost topsoil? How long will it take to re-create the topsoil lost in 15, 25, and 30 years?
34. **Weather's Affect** In the 30th year, climate changes and precipitation increases, causing a new erosion rate of 1.5 cm every 10 years. How many years will it now take to re-create the topsoil lost at the end of 40 years?

Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

1. Which is an example of mechanical weathering?
 - A. creep
 - B. ice wedging
 - C. oxidation
 - D. slump
2. Which forms as a glacier moves into a stream valley?
 - A. cirque
 - B. outwash
 - C. U-shaped valley
 - D. V-shaped valley
3. Which factor in soil formation deals with the slope of the land?
 - A. climate
 - B. parent rock
 - C. time
 - D. topography
4. Which is a mixture of weathered rock, organic matter, water, and air?
 - A. humus
 - B. organisms
 - C. parent rock
 - D. soil
5. Which type of erosion occurs when a thin sheet of water flows downhill?
 - A. creep
 - B. gully erosion
 - C. runoff
 - D. sheet erosion
6. What causes potholes to form in roadways?
 - A. creep
 - B. ice wedging
 - C. oxidation
 - D. slump

Use the photo below to answer questions 7–8.



7. Which form of mass movement is shown in this picture?
 - A. creep
 - B. mudflow
 - C. rockslide
 - D. slump
8. Which agent of erosion causes this?
 - A. gravity
 - B. ice
 - C. water
 - D. wind
9. What form of mass movement occurs when a pasty mix of water and sediment moves downhill?
 - A. creep
 - B. mudflow
 - C. rockslide
 - D. slump
10. What type of erosion is similar to using sandpaper to smooth the edges of wood?
 - A. abrasion
 - B. creep
 - C. deflation
 - D. runoff

Test-Taking Tip

Double Check For each question, double check that you are filling in the correct bubble for the question number you are working on.

Part 2 Short Response/Grid In

Record your answers on the answers sheet provided by your teacher or on a sheet of paper.

Use the photo below to answer question 11.



11. How do lichens growing on rocks contribute to soil development?
12. What is the difference between till and outwash?

Use the illustration below to answer question 13.



13. Using the diagram, explain how a sand dune moves.
14. What effect does climate have on the formation of humus?
15. What type of mass movement causes problems along the Southern California coast? Why?
16. What type of sediment is carried by the wind?
17. Explain whether grasslands or forests make for better farmland.

Part 3 Open Ended

Record your answers on a sheet of paper.

18. Compare and contrast chemical and mechanical weathering.
19. How do freeze and thaw cycles contribute to both weathering and erosion?

Use the photo below to answer question 20.



20. Explain in detail what type of weathering is taking place in this picture. Describe the type of environment where this weathering would take place the quickest.
21. What types of glaciers are there and how do they erode the land?

Use to the photo below to answer question 22.



22. What type of erosion is pictured here? How can this type of erosion help to carry harmful chemicals that are deposited in the soil to rivers, lakes and oceans?