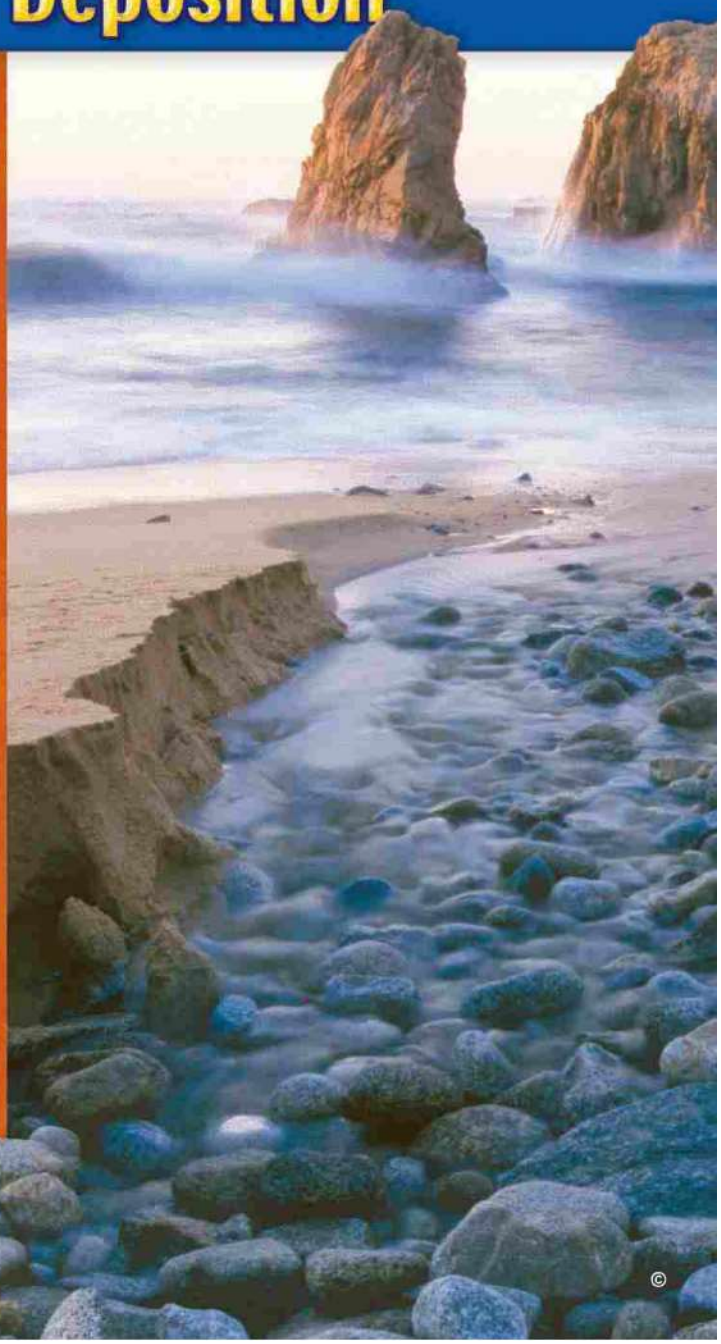
Chapter 3

Erosion and Deposition



CALIFORNIA Standards Preview

S 6.2 Topography is reshaped by the weathering of rock and soil and by the transportation and deposition of sediment. As a basis for understanding this concept:

a. Students know water running downhill is the dominant process in shaping the landscape, including California's landscape.

Framework Surface water flow, glaciers, wind, and ocean waves have all been and continue to be active throughout California and the rest of the world in shaping landscapes.

b. Students know rivers and streams are dynamic systems that erode, transport sediment, change course, and flood their banks in natural and recurring patterns.

c. Students know beaches are dynamic systems in which the sand is supplied by rivers and moved along the coast by the action of waves.

d. Students know earthquakes, volcanic eruptions, landslides, and floods change human and wildlife habitats.

Ocean waves slowly break down California's rocky coast, forming the boulders and sand that make up this beach. ▶

Video Preview
Discovery Channel School
Erosion and Deposition

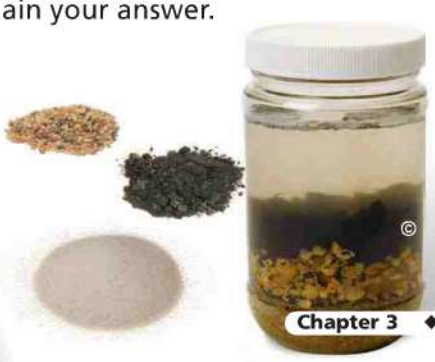
Focus on the
BIG Idea

S 6.2.a

What are the forces of erosion and deposition that shape our landscape?

Check What You Know

Suppose that you fill a jar halfway with layers of gravel, sand, and soil. Then you fill the jar with water, cover it tightly, and shake for 5 seconds. What effect would shaking the jar have on the soil, sand, and gravel? What would happen to them after the shaking stops? Explain your answer.



Build Science Vocabulary

The images shown here represent some of the key terms in this chapter. You can use this vocabulary skill to help you understand the meaning of some key terms in this chapter.

Vocabulary Skill

Latin Word Origins

Many science words come to English from Latin. In this chapter you will learn the term *mass movement*. *Movement* comes from the Latin words *movere* meaning "to move" and *-mentum* meaning "the act of." *Movement* means "the act of moving."

Example The movement of wind and water shape Earth's surface.

movere	+	**-mentum**	=	**movement**
to move		act of		the act of moving

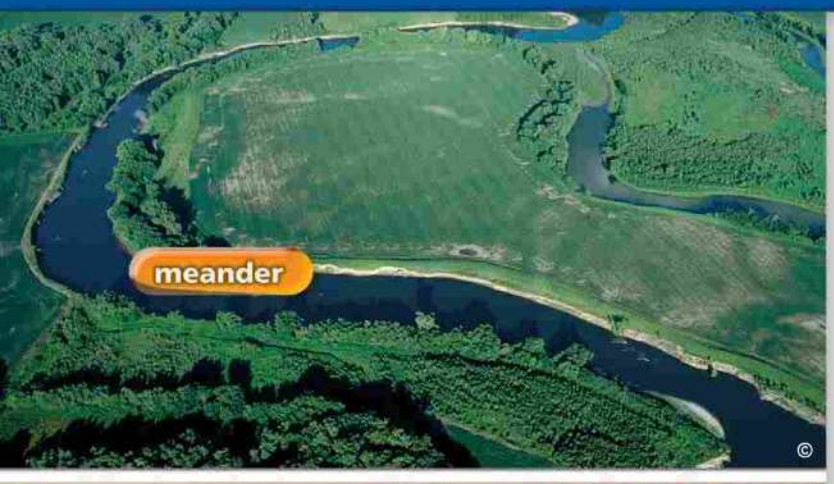
Learn these Latin words to help you remember the key terms.

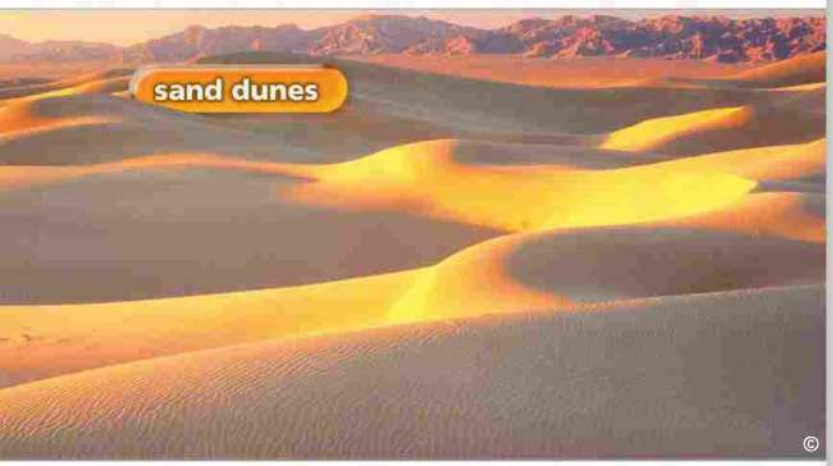
Latin Origin	Meaning	Examples
de-	From, down, away	Deflation, deposition
flare	Blow	Deflation
-mentum	The act of, the result of	Movement
positus	Put	Deposition
sedere	Sit, settle	Sediment

Apply It!

Review the Latin words and meanings. Look at the word *sedere* and the second meaning of *mentum*. Predict the meaning of *sediment*. Revise your definition as you read the chapter.

Chapter 3 Vocabulary





Interactive Textbook

Build Science Vocabulary *Online*

Use interactive flashcards

How to Read Science

Reading Skill

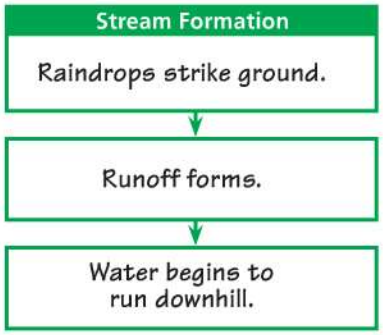
Sequence

Many parts of a science textbook are organized by sequence. Sequence is the order in which a series of events occurs. Sometimes the text uses signal words, such as *begin*, *next*, *then*, and *later* to show sequence. Look for the sequence of events in the paragraph below.

Stream Formation

The formation of a stream begins when raindrops strike the ground. Next, the water collects as runoff on the ground and then begins to run downhill. Later, this flowing water causes tiny grooves, called rills, to form in the ground surface.

A flowchart can help you understand sequence. To make a flowchart, write a description of each step in a box. Place the boxes in order.



Apply It!

In your notebook, write the fourth step in stream formation. As you read about water erosion in Section 2, complete a seven-step flowchart showing the process of stream formation.

Lab zone

Standards Investigation

S 6.2.a

Changes in the Land

What force shaped the rocky cliffs of the California coast? For millions of years, powerful ocean waves have been cutting and grinding the coast. The waves carry away broken particles of rock. The waves also pile up boulders, pebbles, and sand to form beaches. In this investigation, you will model how erosion and deposition shape the landscape.

Your Goal

To make three-dimensional models that show how the forces of erosion and deposition can change a landscape

To complete this investigation you must

- make a three-dimensional landscape
- predict how the model would be affected by erosion
- construct a second model showing how your landscape might look after erosion has continued for millions of years
- follow the safety guidelines in Appendix A

Plan It!

To begin, draw a landscape that shows the land before erosion. Then make a list of materials that you will use to build your model. Once your teacher has approved your drawing and your list of materials, build your first model. Next, make a second model to show the effects of erosion. Finally, explain your models to your class.

Section 1

Changing Earth's Surface

CALIFORNIA Standards Focus

S 6.2 Topography is reshaped by the weathering of rock and soil and by the transportation and deposition of sediment.

- What processes wear down and build up Earth's surface?
- What causes the different types of mass movement?

Key Terms

- erosion
- sediment
- deposition
- gravity
- mass movement

Lab zone Standards Warm-Up

How Does Gravity Affect Materials on a Slope?

1. Place a small board flat on your desk. Place a marble on the board and slowly tip one end of the board up slightly. Observe what happens.
2. Place a block of wood on the board. Slowly lift one end of the board and observe the result.
3. Next, cover the board and the wood block with sandpaper and repeat Step 2.

Think It Over

Developing Hypotheses How do the results of each step differ? Develop a hypothesis to explain your observations.

The ground you stand on is solid. But under certain conditions, solid earth can quickly change to thick, soupy mud. For example, high rains soaked into the soil and triggered the devastating mudflow in Figure 1. A river of mud raced down the mountainside, burying homes and cars. Several lives were lost. In moments, the mudflow moved a huge volume of soil mixed with water and rock downhill.

Wearing Down and Building Up

A mudflow is a spectacular example of erosion. **Erosion** is the process by which natural forces move weathered rock and soil from one place to another. You may have seen water carrying soil and gravel down a driveway after it rains. That's an example of erosion. A mudflow is a very rapid type of erosion. Other types of erosion move soil and rock more slowly. Gravity, running water, glaciers, waves, and wind are all causes, or agents, of erosion. In geology, an agent is a force or material that causes a change in Earth's surface.

FIGURE 1
Mudflow
A mudflow caused by heavy rains in San Bernardino, California, brought this ambulance to a stop.

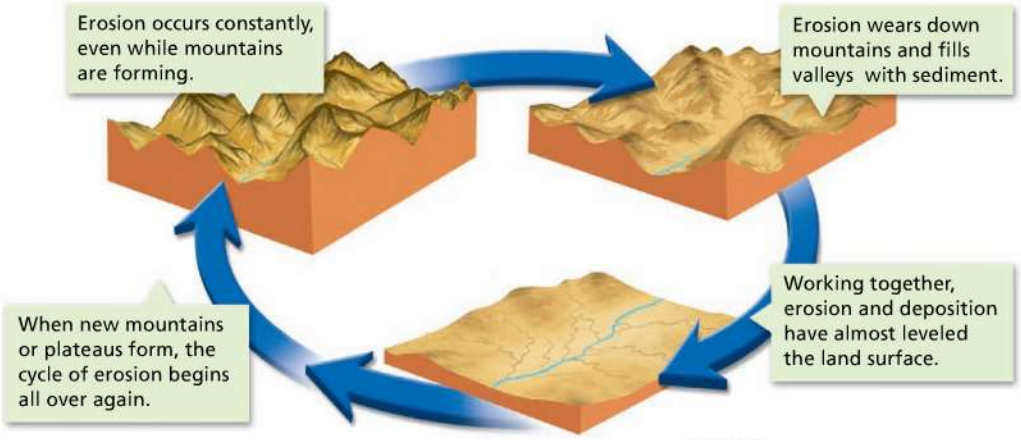


FIGURE 2
Cycle of Erosion and Deposition
Over millions of years, erosion gradually wears away mountains while deposition fills in valleys with sediment.
Predicting *What would happen to the surface of the land if uplift did not occur?*

The material moved by erosion is **sediment.** Sediment may consist of pieces of rock or soil or the remains of plants and animals. Both weathering and erosion produce sediment. **Deposition** occurs where the agents of erosion deposit, or lay down, sediment. Deposition changes the shape of the land. You may have watched a playing child who picked up several toys, carried them across a room, and then put them down. This child was acting something like an agent of erosion and deposition.

Weathering, erosion, and deposition act together in a cycle that wears down and builds up Earth's surface. This cycle, called the geologic cycle, has continued for billions of years. As a mountain wears down in one place, new landforms build up in other places. Erosion and deposition are at work everywhere on Earth.

Reading Checkpoint **What is sediment?**

Mass Movement

Imagine that you are sitting on a bicycle at the top of a hill. With only a slight push, you can coast down the hill. If the slope of the hill is very steep, you will reach a high speed before reaching the bottom. The force that pulls you downward is gravity. Gravity pulls everything toward the center of Earth.

Gravity is the force that moves rock and other materials downhill. Gravity causes **mass movement,** any one of several processes that move sediment downhill. **The different types of mass movement include landslides, mudflows, slump, and creep.** Mass movement can be rapid or slow.

Lab zone Skills Activity

Making Models

You can make a model of mass movement. Design a plan to model one of the types of mass movement using sand, pebbles, and water. With your teacher's approval, make and test your model.

How well did your model represent the type of mass movement you chose? How could you improve your model?

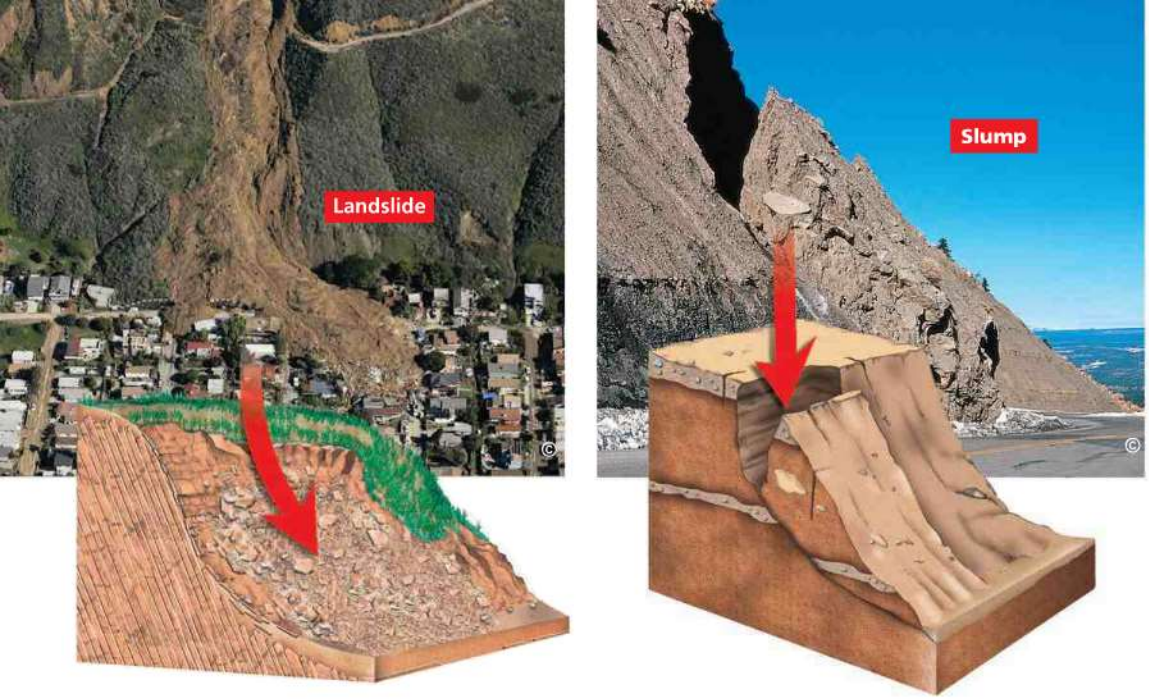


FIGURE 3
Mass Movement
In addition to mudflows, types of mass movement include landslides, slump, and creep. The La Conchita landslide buried 23 homes and killed 10 people.
Making Judgments *Which form of mass movement produces the most drastic change in the surface?*

Landslides A landslide is a kind of mass movement that occurs when rock and soil slide rapidly down a steep slope. Some landslides contain huge masses of rock. But many landslides contain only a small amount of rock and soil. Some landslides occur where road builders have cut highways through hills or mountains. Figure 3 shows a landslide that struck La Conchita, California, in 2005.

Mudflows A mudflow is the rapid downhill movement of a mixture of water, rock, and soil. The amount of water in a mudflow can be as high as 60 percent. Mudflows often occur after heavy rains in a normally dry area. In clay soils with a high water content, mudflows may occur even on very gentle slopes. Under certain conditions, clay soils suddenly turn to liquid and begin to flow. An earthquake can trigger both mudflows and landslides. Mudflows can be very dangerous.

Slump If you slump your shoulders, the entire upper part of your body drops down. A slump is a type of mass movement in which a mass of rock and soil rapidly slips down a slope. Unlike a landslide, the material in a slump moves down in one large mass. It looks as if someone pulled the bottom out from under part of the slope. A slump often occurs when water soaks the bottom of soil that is rich in clay.

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active art
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Creep Creep is the very slow downhill movement of rock and soil. It can even occur on gentle slopes. Creep often results from the freezing and thawing of water in cracked layers of rock beneath the soil. Like the movement of an hour hand on a clock, creep is so slow you can barely notice it. But you can see the effects of creep in objects such as telephone poles, gravestones, and fenceposts. Creep may tilt these objects at spooky angles. Landscapes affected by creep may have the eerie, out-of-kilter look of a funhouse in an amusement park.

Reading Checkpoint **What is the main difference between a slump and a landslide?**

Section 1 Assessment

S 6.2; E-LA: Reading 6.1.0

Vocabulary Skill Latin Word Origins Review the Latin word *de-* and *positus*. Use what you've learned to explain the meaning of *deposition*.

Reviewing Key Concepts

HINT
1. a. Listing What are five agents of erosion?

HINT
b. Defining In your own words, write a definition of *erosion*.

HINT
c. Predicting Over time, how will erosion and deposition affect a mountain range? Explain.

HINT
2. a. Listing What are the four types of mass movement?

HINT
b. Relating Cause and Effect What force causes all types of mass movement?

HINT
c. Inferring A fence runs across a steep hillside. The fence is tilted downhill and forms a curve rather than a straight line. What can you infer happened to the fence? Explain.

Lab zone At-Home Activity

Evidence of Erosion After a rainstorm, take a walk with an adult family member around your neighborhood. Look for evidence of erosion. Try to find areas where there is loose soil, sand, gravel, or rock. **CAUTION:** *Stay away from any large pile of loose sand or soil—it may slide without warning.* Which areas have the most erosion? The least erosion? How does the slope of the ground affect the amount of erosion? Sketch or take photographs of the areas showing evidence of erosion.

Lab zone **Skills Lab**
Guided Inquiry

S 6.2, 6.7.d

Sand Hills

Materials


tray (about 15 cm x 45 cm x 60 cm)


cardboard tube


dry sand, 500 mL


spoon and ruler


several sheets of white paper


masking tape


pencil or crayon


wooden barbecue skewer

Problem What is the relationship between the height and width of a sand hill?

Skills Focus developing hypotheses, interpreting data, predicting

Procedure

1. Begin by observing how gravity causes mass movement. To start, place the cardboard tube vertically in the center of the tray.
2. Using the spoon, fill the cardboard tube with the dry sand. Take care not to spill the sand around the outside of the tube.
3. Carefully lift the sand-filled tube straight up so that all the sand flows out. As you lift the tube, observe the sand's movement.
4. Develop a hypothesis explaining how you think the width of the sand pile is related to its height for different amounts of sand.
5. Empty the sand in the tray back into a container. Then set up your system for measuring the sand hill.
6. Copy the data table into your lab notebook.

Data Table

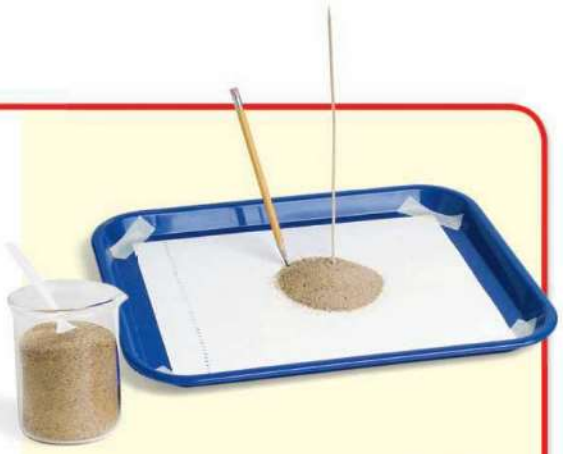
Test	1	2	3	4	5
Width					
Height					

7. Following Steps 1 through 3, make a new sand hill.

8. Measure and record the sand hill's height and width for Test 1. (See the instructions in the yellow box to help you accurately measure the height and width.)
9. Now test what happens when you add more sand to the sand hill. Place your cardboard tube vertically at the center of the sand hill. Be careful not to push the tube down into the sand hill! Using the spoon, fill the tube with sand as before.
10. Carefully raise the tube and observe the sand's movement.
11. Measure and record the sand hill's height and width for Test 2.
12. Repeat Steps 9 through 11 at least three more times. After each test, record your results. Be sure to number each test.

Analyze and Conclude

1. **Graphing** Make a graph showing how the sand hill's height and width changed with each test. (*Hint:* Use the *x*-axis of the graph for height. Use the *y*-axis of the graph for width.)
2. **Interpreting Data** What does your graph show about the relationship between the variables, sand hill height and width?
3. **Drawing Conclusions** Does your graph support your hypothesis about the sand hill's height and width? Why or why not?
4. **Developing Hypotheses** How would you revise your original hypothesis after examining your data? Give reasons for your answer.
5. **Predicting** Predict what would happen if you continued the experiment for five more tests. Extend your graph with a dashed line to show your prediction. How could you test your prediction?
6. **Communicating** Write a paragraph in which you discuss the steps you took to measure your sand hill. Did any problems you had in making your measurements affect your results? How did you adjust your measurement technique to solve these problems?



How to Measure a Sand Hill

1. Cover the bottom of the tray with unlined white paper and tape it firmly in place.
2. Mark off points 0.5 cm apart along one side of the paper in the tray.
3. Carefully draw the sand hill's outline on the paper. The line should go completely around the base of the hill.
4. Now measure the width of the hill against the marks you made along the edge of the paper.
5. Measure the sand hill's height by inserting a barbecue skewer through its center. Make a mark on the skewer at the top of the hill.
6. Remove the skewer and use the ruler to measure how much of the skewer was buried in the hill. Try not to disturb the sand.

Design an Experiment

Do you think the use of different materials, such as wet sand or gravel, would produce different results from those using dry sand? Make a new hypothesis about the relationship between slope and width in hills made of materials other than dry sand. Design an experiment in which you test how these different materials form hills. Obtain your teacher's approval before you try the experiment.

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Section 2

Water Erosion

CALIFORNIA Standards Focus

S 6.2.a Students know water running downhill is the dominant process in shaping the landscape, including California's landscape.

S 6.2.b Students know rivers and streams are dynamic systems that erode, transport sediment, change course, and flood their banks in natural and recurring patterns.

- What process is mainly responsible for shaping the surface of the land?
- What features are formed by water erosion and deposition?
- What factors affect a river's ability to erode and carry sediment?

Key Terms

- runoff
- rill
- gully
- stream
- energy
- flood plain
- meander
- oxbow lake
- alluvial fan
- delta
- load

Lab zone Standards Warm-Up

How Does Moving Water Wear Away Rocks?

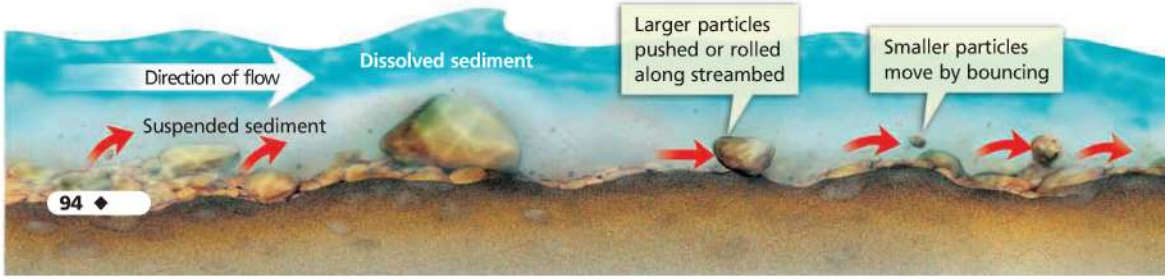
1. Obtain two bars of soap that are the same size and brand.
2. Open a faucet just enough to let the water drip out very slowly. How many drops of water does the faucet release per minute?
3. Place one bar of soap in a dry place. Place the other bar of soap under the faucet. Predict the effect of the dripping water droplets on the soap.
4. Let the faucet drip for 10 minutes.
5. Turn off the faucet and observe both bars of soap. What difference do you observe between them?

Think It Over

Predicting What would the bar of soap under the dripping faucet look like if you left it there for another 10 minutes? For an hour? How could you speed up the process? Slow it down?

Walking in the woods in summer, you can hear the racing water of a stream before you see the stream itself. The water roars as it foams over rock ledges and boulders. When you reach the stream, you see water rushing by. Sand and pebbles tumble along the bottom of the stream. As it swirls downstream, the water also carries twigs, leaves, and bits of soil. In sheltered pools, insects such as water striders skim the water's calm surface. Beneath the surface, a rainbow trout swims in the clear water.

In winter, the stream freezes. Chunks of ice scrape and grind away at the stream's bed and banks. In spring, the stream floods. Then the flow of water may be strong enough to move large rocks. But throughout the year, the stream continues to erode its small part of Earth's surface.



▼ FIGURE 4
Sediment in Motion
Streams carry sediment in several ways.

A stream causes erosion because of the sediment it carries. Look at Figure 4. Notice how large sediment moves by rolling and sliding along the bottom. Grains of sand or small stones move by bouncing. Fast-moving water can lift and carry sand or smaller sediment. Water dissolves some sediment completely.

Video Field Trip
Discovery Channel School
Erosion and Deposition

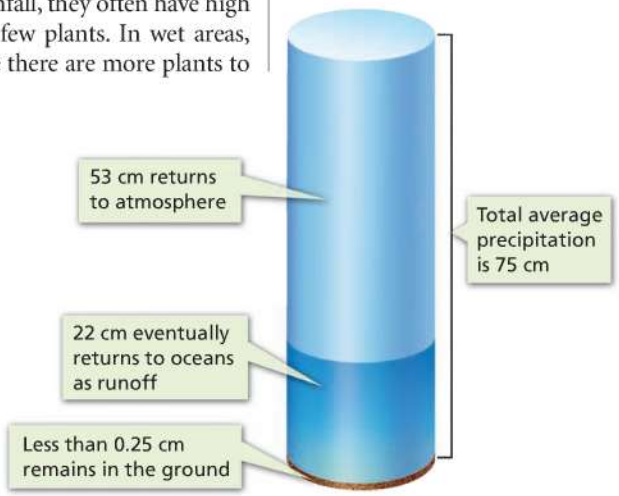
Runoff and Erosion

Water running downhill is the major agent of the erosion that has shaped Earth's land surface. Erosion by water begins with the splash of rain. Some rainfall sinks into the ground. Some evaporates or is taken up by plants. The force of a falling raindrop can loosen and pick up soil particles. As water moves over the land, it carries these particles with it. This moving water is called runoff. **Runoff** is water that moves over Earth's surface. When runoff flows in a thin layer over the land, it may cause a type of erosion called sheet erosion.

Amount of Runoff The amount of runoff in an area depends on five main factors. The first factor is the amount of rain an area receives. A second factor is vegetation. Grasses, shrubs, and trees reduce runoff by absorbing water and holding soil in place. A third factor is the type of soil. Some types of soils absorb more water than others. A fourth factor is the shape of the land. Land that is steeply sloped has more runoff than flatter land. Finally, a fifth factor is how people use the land. For instance, a paved parking lot absorbs no water, so all the rain that falls on it becomes runoff.

The amount of plant cover in an area affects runoff and erosion. Even though deserts have little rainfall, they often have high runoff and erosion because they have few plants. In wet areas, runoff and erosion may be low because there are more plants to protect the soil.

FIGURE 5
Where the Runoff Goes
Precipitation over the United States averages about 75 cm per year. About 22.5 cm becomes runoff. Most returns to the atmosphere by evaporation or through the leaves of plants.
Reading Graphs *How much runoff remains in the ground?*



Lab zone Try This Activity

Raindrops Falling

Find out how the force of falling raindrops affects soil.

1. Fill a petri dish with fine-textured soil to a depth of about 1 cm. Make sure the soil has a smooth flat surface, but do not pack it firmly in the dish.
2. Place the dish in the center of a newspaper.
3. Fill a dropper with water. Squeeze a large water drop from a height of 1 m onto the surface of the soil. Repeat 4 times.
4. Use a meter stick to measure the distance the soil splashed from the dish. Record your observations.
5. Repeat Steps 1 through 4, this time from a height of 2 m.

Drawing Conclusions Which test produced the greater amount of erosion? Why?

Rills and Gullies Because of gravity, runoff and the material it contains move downhill. During sheet erosion, runoff forms tiny grooves in the soil called **rills.** As many rills flow into one another, they grow larger, forming gullies. A **gully** is a large groove, or channel, in the soil that carries runoff after a rainstorm. As water flows through gullies, it moves soil and rocks with it, thus enlarging the gullies through erosion. Gullies contain water only after it rains.

Streams and Rivers Gullies join together to form a larger channel called a stream. A **stream** is a channel along which water is continually flowing down a slope. Unlike gullies, streams rarely dry up. Small streams are also called creeks or brooks. As streams flow together, they form larger and larger bodies of flowing water. A large stream is often called a river.

Reading Checkpoint **What is a gully?**

Erosion by Rivers

As a river flows from the mountains to the sea, the river forms a variety of features. **Through erosion, a river creates valleys, waterfalls, flood plains, meanders, and oxbow lakes.** How does a river cause erosion? A river's water has energy. **Energy** is the ability to do work or cause change. When energy does work, the energy is transferred from one object to another.

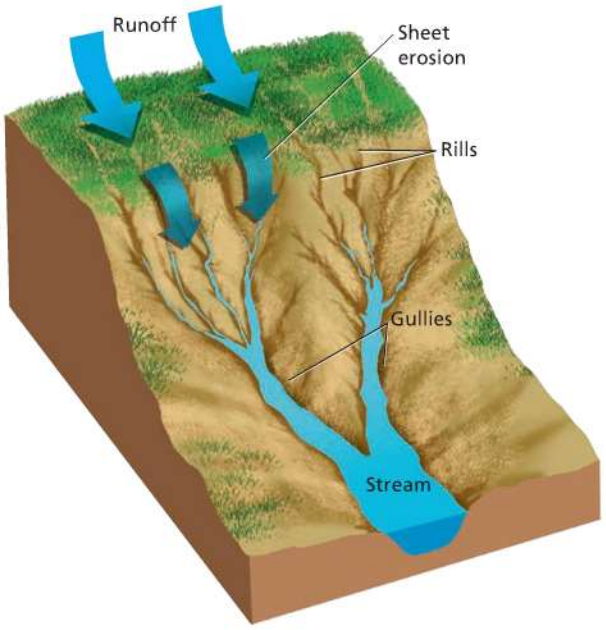


FIGURE 6
Runoff, Rills, and Gullies
Water flowing across the land runs together to form rills, gullies, and streams. **Predicting** *What will happen to the land between the gullies as they grow wider?*

All along a river, the water's energy does work. A river is always moving sediment from the mountains to the sea. At the same time, sediments grind and chip away at the rock of the riverbed, deepening and widening the river's channel.

Rivers often form on steep mountain slopes. Near its source, a river is often fast flowing and generally follows a straight, narrow course. The steep slopes along the river erode rapidly. The result is a deep, V-shaped valley.

Waterfalls Waterfalls may occur where a river meets an area of rock that is very hard and erodes slowly. The river flows over this rock and then flows over softer rock downstream. As you can see in Figure 7, the softer rock wears away faster than the harder rock. Eventually a waterfall develops where the softer rock was removed. Areas of rough water called rapids also occur where a river tumbles over hard rock.

Flood Plain Lower down on its course, a river usually flows over more gently sloping land. The river spreads out and erodes the land, forming a wide river valley. The flat, wide area of land along a river is a **flood plain.** A river often covers its flood plain when it overflows its banks during floods. On a wide flood plain, the valley walls may be kilometers away from the river itself. A flooding river may cut into its banks, changing the river's course through the flood plain.

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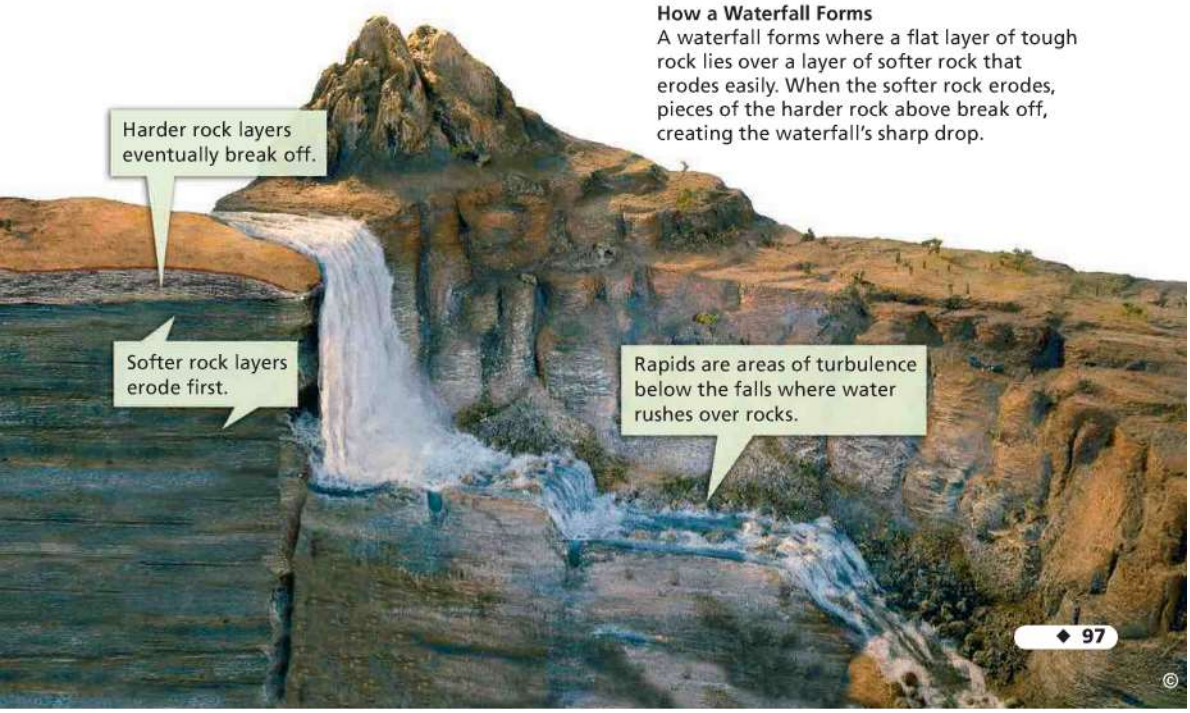
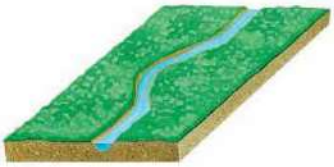
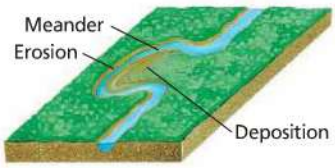


FIGURE 7
How a Waterfall Forms
A waterfall forms where a flat layer of tough rock lies over a layer of softer rock that erodes easily. When the softer rock erodes, pieces of the harder rock above break off, creating the waterfall's sharp drop.

FIGURE 8
Meanders and Oxbow Lakes
Erosion often forms meanders and oxbow lakes where a river winds across its flood plain.

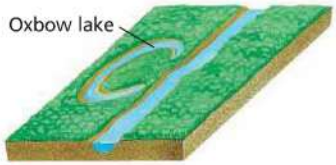


1 A small obstacle creates a slight bend in the river.



2 As water erodes the outer edge of a meander, the bend becomes bigger. Deposition occurs along the inner edge.

3 Gradually, the meander becomes more curved. The river breaks through and takes a new course.



4 An oxbow lake remains.

Meanders A river often develops meanders where it flows through easily eroded rock or sediment. A **meander** is a loop-like bend in the course of a river. As the river winds from side to side, it tends to erode the outer bank and deposit sediment on the inner bank of a bend. Over time, the meander becomes more and more curved.

Because of the sediment a river carries, it can erode a very wide flood plain. Along this part of a river's course, its channel is deep and wide. Meanders are common. The southern stretch of the Mississippi River is one example of a river that meanders on a wide, gently sloping flood plain.

Oxbow Lakes Sometimes a meandering river forms a feature called an oxbow lake. As Figure 8 shows, an **oxbow lake** is a meander that has been cut off from the river. An oxbow lake may form when a river floods. During the flood, high water finds a straighter route downstream. As the flood waters fall, sediments dam up the ends of a meander. The meander has become an oxbow lake.

Reading Checkpoint **How does an oxbow lake form?**

Deposits by Rivers

As water moves, it carries sediments with it. Any time moving water slows down, it drops, or deposits, some of the sediment. As the water slows down, fine particles fall to the river's bed. Larger stones quit rolling and sliding. **Deposition creates landforms such as alluvial fans and deltas. It can also add soil to a river's flood plain.** In Figure 11 on pages 100–101, you can see these and other features shaped by rivers and streams.

Alluvial Fans Where a stream flows out of a steep, narrow mountain valley, the stream suddenly becomes wider and shallower. The water slows down. Here sediments are deposited in an alluvial fan. An **alluvial fan** is a wide, sloping deposit of sediment formed where a stream leaves a mountain range. As its name suggests, this deposit is shaped like a fan. You can see an alluvial fan in Figure 9.

Deltas A river ends its journey when it flows into a still body of water, such as an ocean or a lake. Because the river water is no longer flowing downhill, the water slows down. At this point, the sediment in the water drops to the bottom. Sediment deposited where a river flows into an ocean or lake builds up a landform called a **delta.** Deltas can be a variety of shapes. The delta of the Nile River in Egypt is shaped like a triangle. The delta of the Mississippi River, shown in Figure 10, is an example of a type of delta called a "bird's foot" delta.

Soil on Flood Plains Deposition can also occur during floods. Then heavy rains or melting snow cause a river to rise above its banks and spread out over its flood plain. When the flood water finally retreats, it deposits sediment as new soil. Deposition of new soil over a flood plain is what makes a river valley fertile. Dense forests can grow in the rich soil of a flood plain. The soil is also perfect for growing crops.

Reading Checkpoint **How can a flood be beneficial?**

FIGURE 9
Alluvial Fan
This alluvial fan in Death Valley, California, was formed from deposits by streams from the mountains.

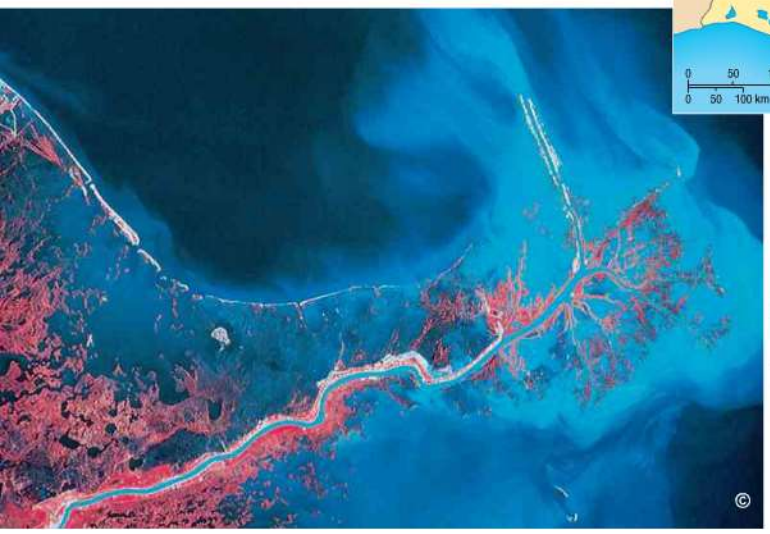


FIGURE 10
Mississippi Delta This satellite image shows the part of the Mississippi River delta where the river empties into the Gulf of Mexico. In 2005, parts of the delta and the city of New Orleans were flooded as a result of Hurricane Katrina. **Observing** *What happens to the Mississippi River as it flows through its delta? Can you find the river's main channel?*


Waterfalls and Rapids
Waterfalls and rapids are common where the river passes over harder rock. Many California rivers have waterfalls and rapids. Rapids are common on fast-flowing rivers like the Trinity and American rivers.
V-Shaped Valley
Near its source, the river flows through a deep, V-shaped valley. As the river flows, it cuts the valley deeper. Many California rivers in the Sierra Nevada have steep, V-shaped valleys, except where glaciers have carved the valley walls. Examples include the Merced and Tuolomne rivers.
Flood Plain
A flood plain forms where the river's power of erosion widens its valley rather than deepening it. The San Joaquin and Sacramento rivers both have vast flood plains.
Meanders
Where the river flows across easily eroded sediment, its channel bends from side to side in a series of meanders. The Sacramento River has both meanders and oxbow lakes where it winds through California's Central Valley.
Beaches
Sand carried downstream by the river spreads along the coast to form beaches.

FIGURE 11

The Course of a River

The slope and size of a river, as well as the sediment it carries, determine how a river shapes the land. **Classifying** *Which features result from erosion? From deposition?*

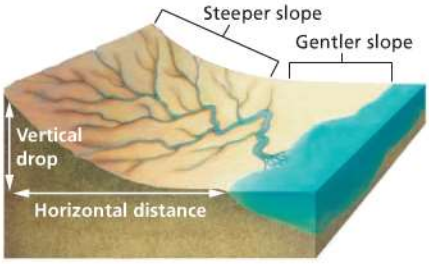


FIGURE 12
The Slope of a River
A river's slope is usually greatest near the river's source. As a river approaches its mouth, its slope lessens.

Erosion and Sediment Load

The power of a river to cause erosion and carry sediment depends on several factors. **A river is a dynamic system. A river's slope, volume of flow, and the shape of its streambed all affect how fast the river flows and how much sediment it can erode.**

The amount of sediment that a river carries is its **load.** A fast-flowing river carries more and larger particles of sediment. When a river slows down, it drops its sediment load. The larger particles of sediment are deposited first.

Slope Generally, if a river's slope increases, the water's speed also increases. A river's slope is the amount the river drops toward sea level over a given distance. If a river's speed increases, its sediment load and power to erode may increase.

Volume of Flow A river's flow is the volume of water that moves past a point on the river in a given time. Volume of flow is also called *discharge*. As more water flows through a river, its speed increases. During a flood, the increased volume of water helps the river to cut more deeply into its banks and bed. The river's power to erode increases greatly. A flooding river can carry huge amounts of sand, soil, and other sediments. It may move giant boulders as if they were pebbles.

Math: Algebra and Functions 6.2.2

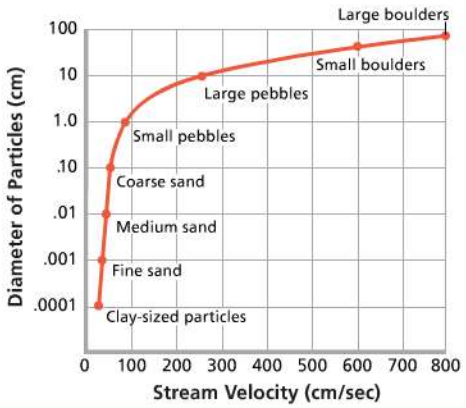
Math Analyzing Data

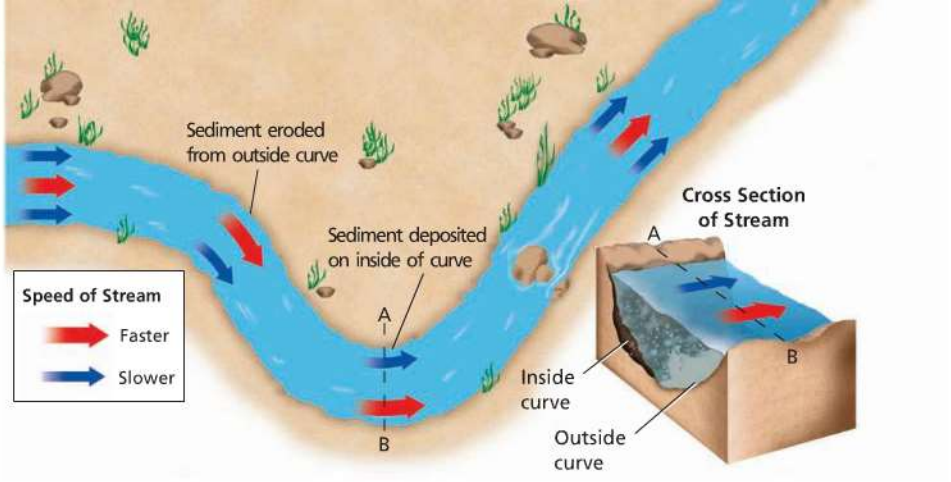
Sediment on the Move

The velocity, or speed, of a stream affects the size of the sediment particles the stream can carry. Study the graph, then answer the questions below.

1. **Reading Graphs** What variable is shown on the *x*-axis of the graph?
2. **Reading Graphs** What variable is shown on the *y*-axis of the graph?
3. **Interpreting Data** What is the speed at which a stream moves small pebbles? Large boulders?
4. **Predicting** A stream's speed increases to about 600 cm per second during a flood. What are the largest particles the stream can move?
5. **Developing Hypotheses** Write a hypothesis that states the relationship between a stream's speed and the size of sediment it can move.

Sediment a Stream Can Carry





Streambed Shape Whether a river flows in a straight line or a curved line affects the way it erodes and deposits sediment. Where a river flows in a straight line, the water flows faster near the center of the river than along its sides. Deposition occurs along the sides of the river, where the water moves more slowly.

If a river curves, the water moves fastest along the outside of the curve. There, the river tends to cut into its bank, causing erosion. Sediment is deposited on the inside curve, where the water speed is slowest. You can see this process in Figure 13.

Reading Checkpoint **Where a stream curves, in what part of the stream does the water flow fastest?**

FIGURE 13
Stream Erosion and Deposition
A river erodes sediment from its banks on the outside curve and deposits sediment on the inside curve.
Relating Cause and Effect *Why does a river deposit sediment on the inside of a curve?*

Section 2 Assessment

S 6.2.a, 6.2.b E-LA: Reading 6.2.0, Writing 6.2.2.

Target Reading Skill **Sequence** Look at the illustration showing Meanders and Oxbow Lakes. Write down in order the steps that occur to form an oxbow lake.

Reviewing Key Concepts

HINT
1. a. **Reviewing** What is the major agent of erosion on Earth's surface?

HINT
b. **Sequencing** List these in order of size: tributary, stream, rill, gully, runoff, river.

HINT
c. **Predicting** Where would gullies be more likely to form: a field with plowed soil and no plants, or a field covered with thick grass?

HINT
2. a. **Listing** What are five features that erosion forms along a river?

HINT
b. **Listing** What are three features that result from deposition along a river?

HINT
c. **Relating Cause and Effect** Why does a delta often form where a river meets the ocean?

HINT
3. a. **Identifying** What three factors affect how fast a river flows?

HINT
b. **Interpreting Diagrams** Study Figure 13 above. Over time, what will happen to the river's bank at point B? Why?

Writing in Science

Comparison Paragraph A river carries different types of sediment particles from its source to its mouth: tiny clay particles, grains of sand, pebbles, and boulders. Write a paragraph that compares clay particles and pebbles in terms of how they move, how fast they travel, and where they would be deposited.

Lab zone **Skills Lab**
Guided Inquiry

S S 6.2.a, 6.2.b

Streams in Action

Materials

plastic container


diatomaceous earth


plastic measuring cup and spray bottle


2 wood blocks about 2.5 cm thick

wire, 13–15 cm long, 20 gauge


plastic stirrers, 10–12 cm long, with two small holes each, and ruler


hand lens, scissors, and clock or watch


blue food coloring and liquid detergent

Problem
How do rivers and streams erode the land?

Skills Focus
making models, observing

Procedure

PART 1 Creating Streams Over Time

1. Your teacher will give you a plastic tub containing diatomaceous earth that has been soaked with water. Place the tub on a level surface. **CAUTION:** *Dry diatomaceous earth produces dust that may be irritating if inhaled.* To keep the diatomaceous earth from drying out, spray it lightly with water.
2. One end of the tub will contain more diatomaceous earth. Use a block of wood to raise this end of the tub 2.5 cm.
3. Place the cup at the upper end of the slope with the notches pointing to the left and right.
4. Press the cup firmly down into the earth to secure its position.
5. Start the dripper (see Step 6 in the yellow box on the opposite page). Allow the water to drip to the right onto the diatomaceous earth.
6. Allow the dripper to drip for 5 minutes. (*Hint:* When you need to add more water, be careful not to disturb the dripper.)
7. Observe the flow of water and the changes it makes. Use the hand lens to look closely at the stream bed.
8. After 5 minutes, remove the dripper.
9. In your lab notebook, draw a picture of the resulting stream and label it "5 minutes."
10. Now switch the dripper to the left side of the cup. Restart the dripper and allow it to drip for 10 minutes. Then remove the dripper.
11. Draw a picture and label it "10 minutes."

PART 2 Changing the Angle of Slope

1. Remove the cup from the stream table.
2. Save the stream bed on the right side of the tub. Using the bowl of the spoon, smooth out the diatomaceous earth on the left side.
3. To increase the angle of slope of your stream table, raise the end of the tub another 2.5 cm.
4. In your lab notebook, predict the effects of increasing the angle of slope.
5. Replace the cup and restart the dripper, placing it in the notch on the left side of the cup. Allow the dripper to drip for 5 minutes. Notice any changes in the new stream bed.
6. After 5 minutes, remove the dripper.
7. Draw the new stream bed in your lab notebook. Label it "Increased Angle."
8. Follow your teacher's instructions for clean-up after this activity. Wash your hands when you have finished.

Analyze and Conclude

1. **Observing** Compare the 5-minute stream with the 10-minute stream. How did the length of time that the water flowed affect erosion along the stream bed?
2. **Drawing Conclusions** Were your predictions about the effects of increasing the angle of slope correct? Explain your answer.
3. **Observing** What happened to the eroded material that was carried downstream?
4. **Making Models** What features of streams were you able to observe using your model? How could you modify the model to observe additional features?
5. **Controlling Variables** What other variables besides time and angle of slope might affect the way rivers and streams erode the land?
6. **Communicating** Describe an example of water erosion that you have seen, such as water flowing down a hillside or street after a heavy rain. Include in your answer details such as the slope of the land, the color of the water, and the effects of the erosion.

Making the Dripper

1. Insert the wire into one of the two holes in a plastic stirrer. The ends of the wire should protrude from the stirrer.
2. Gently bend the stirrer into a U shape. Be careful not to make any sharp bends. This is the dripper.
3. With scissors, carefully cut two small notches on opposite sides of the top of the foam cup.
4. Fill the cup to just below the notches with water colored with two drops of blue food coloring. Add more food coloring later as you add more water to the cup.
5. Add one drop of detergent to keep air bubbles out of the dripper and increase flow.
6. To start the dripper, fill it with water. Then quickly tip it and place it in one of the notches in the cup, as shown above.
7. Adjust the flow rate of the dripper to about 2 drips per 1 second. (*Hint:* Bend the dripper into more of a U shape to increase flow. Lessen the curve to reduce flow.)

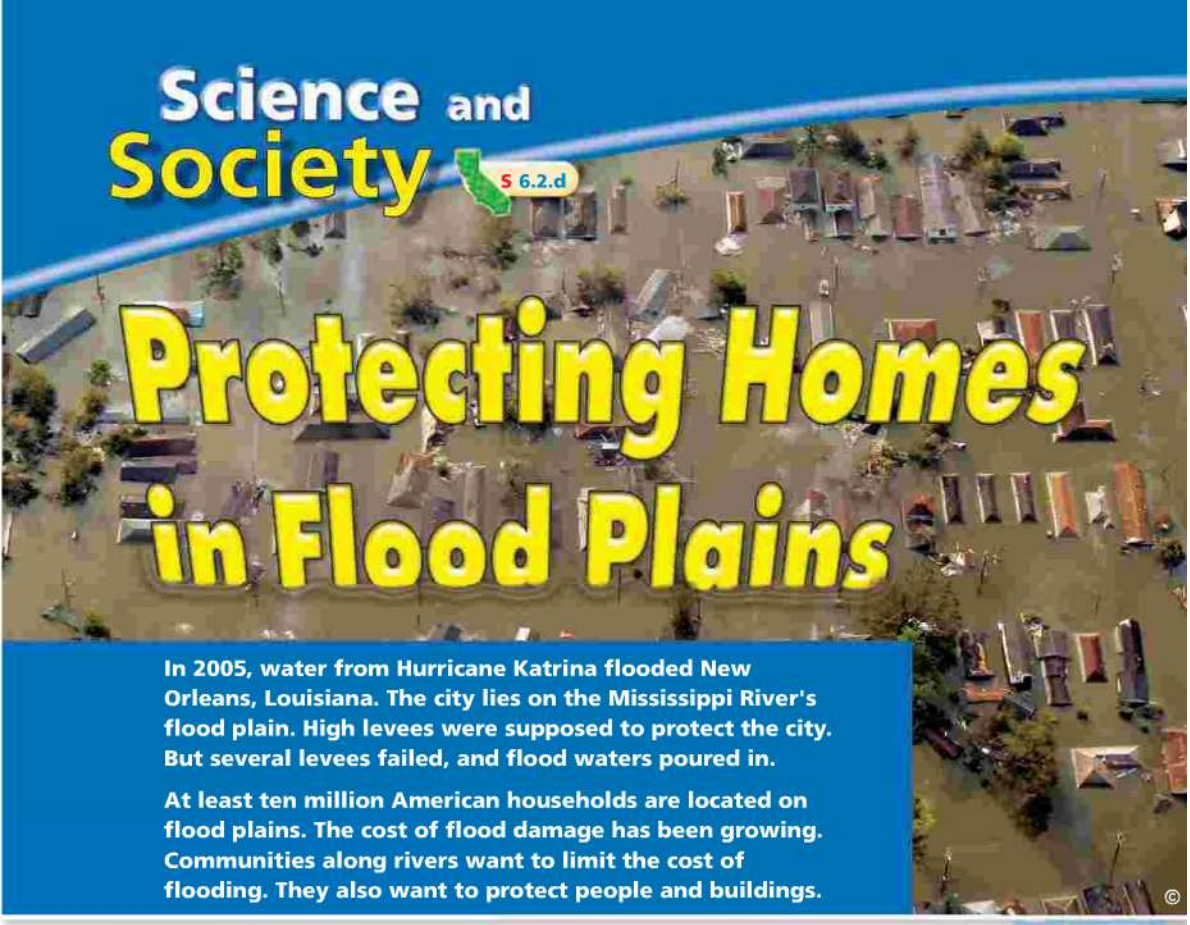
Design an Experiment

Design an experiment in which you use your model to measure how the amount of sediment carried by a river changes as the volume of flow of the river increases. *Obtain your teacher's approval before you try the experiment.*

Science and Society

S 6.2.d

Protecting Homes in Flood Plains



In 2005, water from Hurricane Katrina flooded New Orleans, Louisiana. The city lies on the Mississippi River's flood plain. High levees were supposed to protect the city. But several levees failed, and flood waters poured in.

At least ten million American households are located on flood plains. The cost of flood damage has been growing. Communities along rivers want to limit the cost of flooding. They also want to protect people and buildings.

The Issues

Should the Government Insure People Against Flood Damage?

The United States government offers insurance to households in flood plains. The insurance pays part of the cost of repairs after a flood. However, government flood insurance is available only to towns and cities that take steps to reduce flood damage. Cities must allow new building only on high ground. In addition, the insurance will not pay to rebuild homes that are badly damaged by flood water. Instead, these people must use the money to find a home somewhere else.

Critics say that government insurance just encourages development in areas that flood. Another problem with the insurance is cost. It is very expensive, so most people who live in flood plains don't buy the government insurance. Supporters say government insurance rewards towns and cities that make rules to control building on flood plains. Over time, this approach would mean fewer homes and other buildings on flood plains—and less damage from flooding.

In 2005, floodwaters from Hurricane Katrina rose to the rooftops of many New Orleans houses. Thousands of people were stranded and had to be evacuated by boat.

How Much of the Flood Plain Should Be Protected?

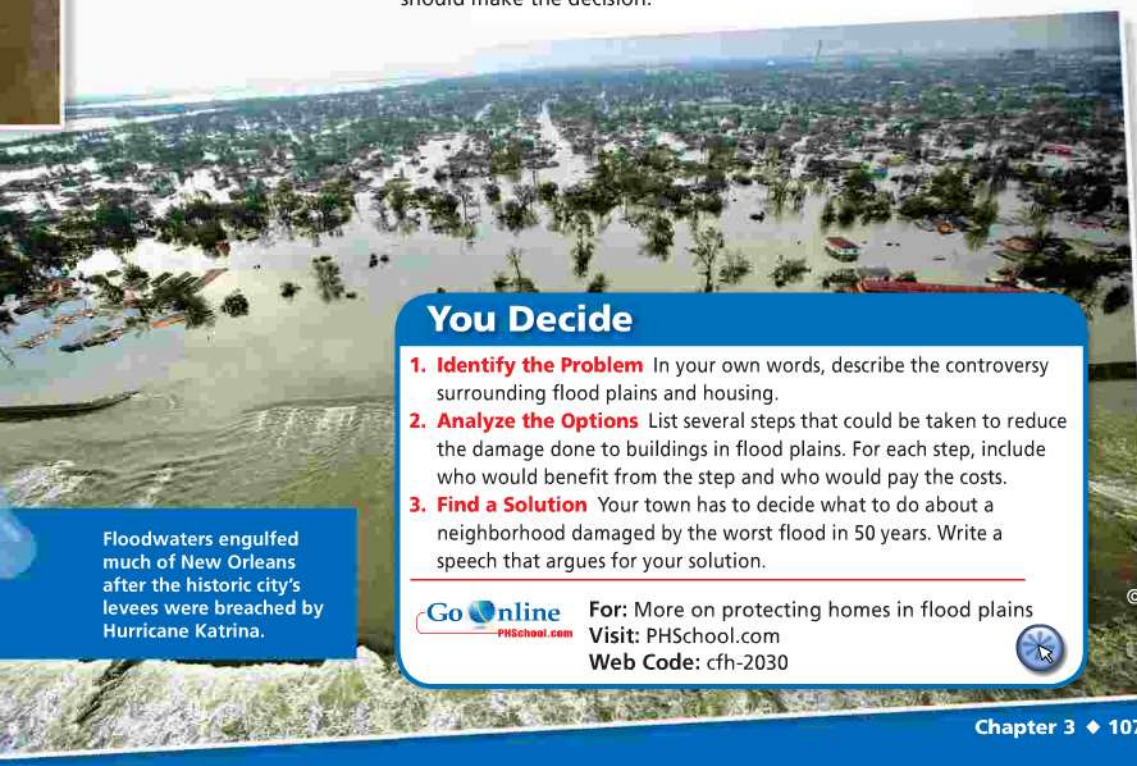
Government flood insurance is available only in areas where scientists expect flooding at least once in 100 years. But such figures are just estimates. Three floods occurred in only 12 years in a government flood insurance area near Sacramento, California.

Should the Government Say Where People Can Live?

The frequency and severity of flooding is an important factor in land-use decisions. Sometimes, no construction on a flood plain is advisable. Some programs of flood control forbid all new building. Other programs may also encourage people to move to safer areas. The 1997 flood on the Red River in Grand Forks, North Dakota, is one example. After the flood, the city of Grand Forks offered to buy all the damaged buildings near the river. The city wants to build high walls of earth to protect the rest of the town.

The Grand Forks plan might prevent future damage, but is it fair? Supporters say that since the government has to pay for flood damage, it has the right to make people leave flood plains. Critics of such plans say that people should be free to live where they want, even in risky areas.

Who should decide that no new houses can be built in a certain area—the local, state, or federal government? Some believe scientists should make the decision.



Floodwaters engulfed much of New Orleans after the historic city's levees were breached by Hurricane Katrina.

You Decide

1. **Identify the Problem** In your own words, describe the controversy surrounding flood plains and housing.
2. **Analyze the Options** List several steps that could be taken to reduce the damage done to buildings in flood plains. For each step, include who would benefit from the step and who would pay the costs.
3. **Find a Solution** Your town has to decide what to do about a neighborhood damaged by the worst flood in 50 years. Write a speech that argues for your solution.

Go Online PHSchool.com
For: More on protecting homes in flood plains
Visit: PHSchool.com
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Section 3

Waves and Wind

CALIFORNIA Standards Focus

S 6.2.a Framework Surface water flow, glaciers, wind, and ocean waves have all been and continue to be active throughout California and the rest of the world in shaping landscapes.

S 6.2.c Students know beaches are dynamic systems in which the sand is supplied by rivers and moved along the coast by the action of waves.

- What gives waves their energy?
- How do waves shape a coast?
- What are the causes and effects of wind erosion?

Key Terms

- headland
- beach
- longshore drift
- spit
- sand dune
- deflation
- loess

Lab zone Standards Warm-Up

What Is Sand Made Of?

1. Collect a spoonful of sand from each of two different beaches.
2. Examine the first sample of beach sand with a hand lens.
3. Record the properties of the sand grains, for example, color and shape.
4. Hold a magnet close to the sand. Are any of the sand grains magnetic?
5. Examine the second sample and repeat Step 3. How do the two samples compare?

Think It Over

Posing Questions What questions do you need to answer to understand beach sand? Use what you know about erosion and deposition to help you think of questions.

Ocean waves contain energy—sometimes a great deal of energy. Created by ocean winds, they carry energy vast distances across the Pacific Ocean. Acting like drills or buzz saws, the waves erode the solid rock of the coast into cliffs and caves. Waves also carry sediment that forms features such as beaches.

How Waves Form

The energy in waves comes from wind that blows across the water's surface. As the wind makes contact with the water, some of its energy transfers to the water. Large ocean waves are the result of powerful storms far out at sea. But ordinary breezes can produce waves in lakes or small ponds.

The energy that water picks up from the wind causes water particles to move up and down as the wave goes by. But the water particles themselves don't move forward.

A wave changes as it approaches land. In deep water, a wave only affects the water near the surface. But as it approaches shallow water, the wave begins to drag on the bottom. The dragging between the wave and the bottom causes the wave to slow down. Now the water actually does move forward with the wave. This forward-moving water provides the force that shapes the land along the shoreline.

▼ A wave nears the shore.

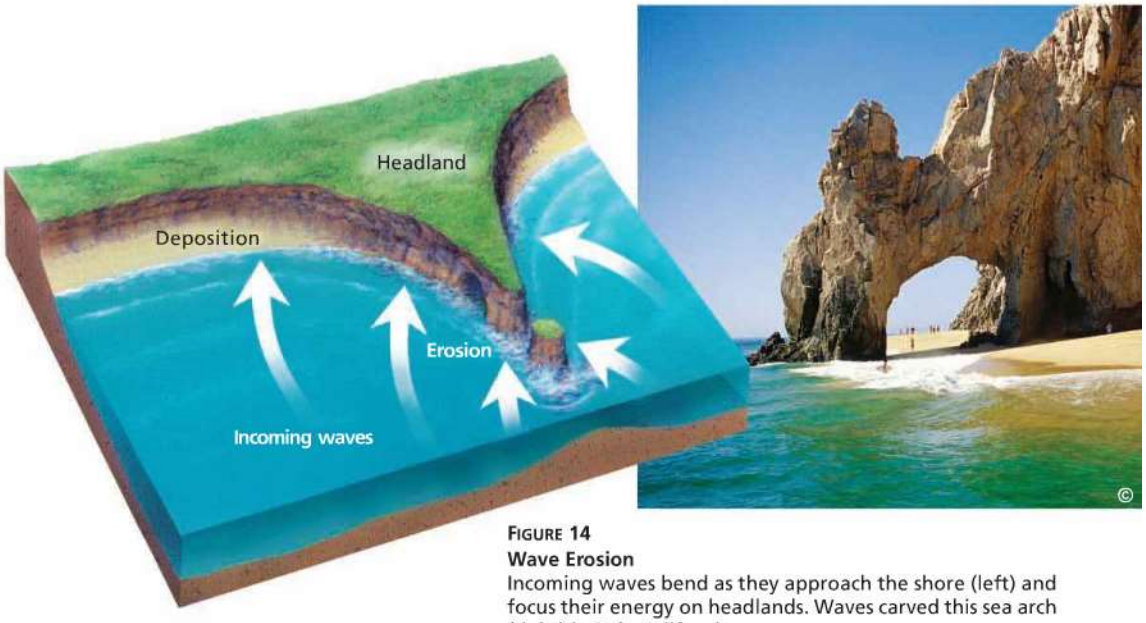


FIGURE 14
Wave Erosion
Incoming waves bend as they approach the shore (left) and focus their energy on headlands. Waves carved this sea arch (right) in Baja California.
Predicting *What will eventually happen to the headlands?*

Erosion by Waves

Waves are the major force of erosion along coasts, including the California coast. **Waves shape the coast through erosion by breaking down rock and transporting sand and other sediment.**

How Waves Erode One way waves erode the land is by impact. Large waves can hit rocks along the shore with great force. This energy in waves can break apart rocks. Over time, waves can make small cracks larger. Eventually, the waves cause pieces of rock to break off.

Waves also erode by abrasion. Recall that abrasion is the wearing away of rock by a grinding action. As a wave approaches shallow water, it picks up sediment, including sand and gravel. This sediment is carried forward by the wave. When the wave hits land, the sediment wears away rock like sandpaper wearing away wood.

Waves coming to shore gradually change direction. The change in direction occurs as different parts of a wave begin to drag on the bottom. Notice how the waves in Figure 14 change direction as they approach the shore. The energy of these waves is concentrated on headlands. A **headland** is a part of the shore that sticks out into the ocean. Headlands stand out from the coast because they are made of harder rock that resists erosion by the waves. But, over time, waves erode the headlands and even out the shoreline.

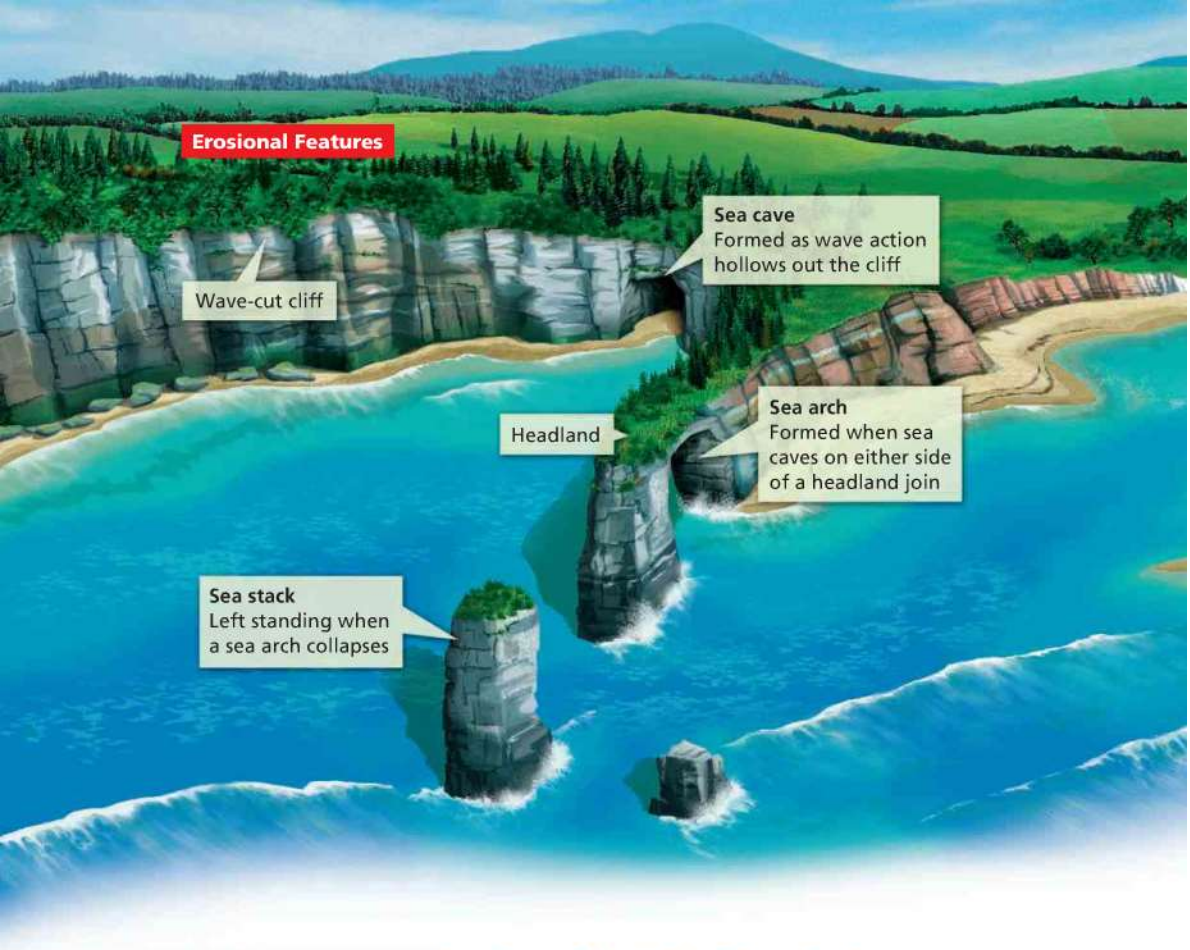


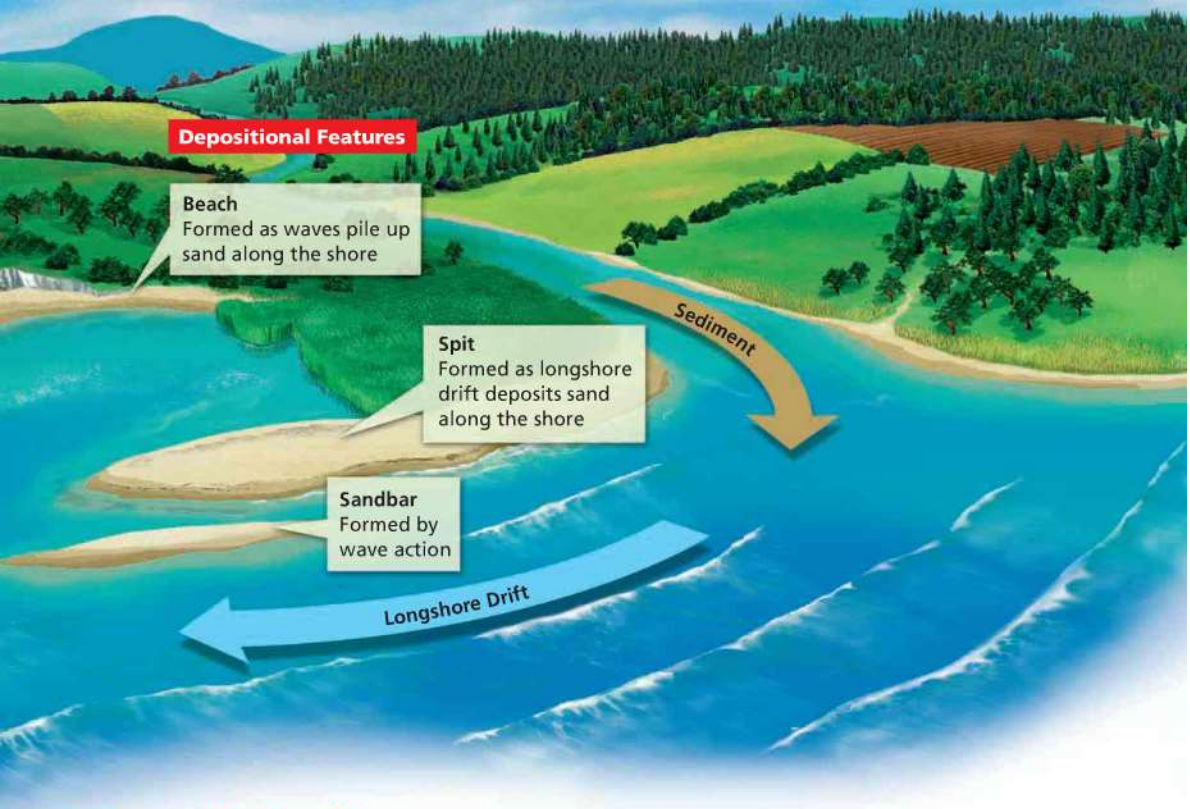
FIGURE 15
The Changing Coast
Erosion (left) and deposition (right) create a variety of features along a coast. You can often see these features along rocky parts of the California coast.
Predicting *What will eventually happen to the sea arch?*

Landforms Created by Wave Erosion When waves hit a steep, rocky coast, they strike the area again and again. Think of an ax striking the trunk of a tree. The cut gets bigger and deeper with each strike of the blade. Finally the tree falls. In a similar way, ocean waves erode the base of the land along a steep coast. Where the rock is softer, the waves erode the land faster. Over time the waves may erode a hollow area in the rock called a sea cave.

Eventually, waves may erode the base of a cliff so much that the rock above collapses. The result is a wave-cut cliff. You can see an example of such a cliff in Figure 15.

Another feature created by wave erosion is a sea arch. A sea arch forms when waves erode a layer of softer rock that underlies a layer of harder rock. If an arch collapses, the result might be a sea stack, a pillar of rock rising above the water.

Reading Checkpoint **Over a long period of time, what effect do waves have on a steep, rocky coast?**



Deposits by Waves

Waves shape a coast when they deposit sediment, forming coastal features such as beaches, spits, sandbars, and barrier beaches. Deposition occurs when waves slow down, causing the water to drop its sediment. This process is similar to the deposition that occurs on a river delta when the river slows down and drops its sediment load.

Beaches As waves reach the shore, they drop the sediment they carry, forming a beach. A **beach** is an area of wave-washed sediment along a coast. The sediment deposited on beaches is usually sand. Most sand comes from rivers that carry eroded particles of rock into the ocean.

Beaches are dynamic systems. Beaches are constantly changing as rivers supply sand and the action of waves moves sand along the coast.

The sediment on a beach usually moves down the beach after it has been deposited. Waves usually hit the beach at an angle instead of straight on. These angled waves create a current that runs parallel to the coastline. As waves repeatedly hit the beach, some of the beach sediment moves down the beach with the current, in a process called **longshore drift**.

Lab zone Skills Activity

Calculating A sandy coast erodes at a rate of 1.25 m per year. But a severe storm can erode an additional 3.75 m from the shore. If 12 severe storms occur during a 50-year period, how much will the coast erode? If you wish, you may use an electronic calculator to find the answer.

FIGURE 16
Spits
This aerial photograph shows how longshore drift can carry sand and deposit it to form a spit.
Inferring *What feature along the coast do you think caused the spit to form? Explain.*

Spits One result of longshore drift is the formation of a spit. A **spit** is a beach that projects like a finger out into the water. Spits form as a result of deposition by longshore drift. Spits occur where a headland or other obstacle interrupts longshore drift, or where the coast turns abruptly.

Sandbars and Barrier Beaches Incoming waves carrying sand may build up sandbars, long ridges of sand parallel to the shore. A barrier beach is similar to a sandbar. A barrier beach forms when storm waves pile up large amounts of sand above sea level forming a long, narrow island parallel to the coast. Barrier beaches are found in many places along the seacoasts of the United States, such as the Outer Banks of North Carolina.

In California, barrier beaches can be found at the mouths of rivers and bays. Examples range from Silver Strand Beach in San Diego to the barrier beach that shelters Humboldt Bay in northern California.

People have built homes on many of these barrier beaches. But the storm waves that build up the beaches can also wash them away. Barrier beach communities must be prepared for the damage that hurricanes and other storms can bring.

Erosion by Wind

Imagine a landscape made almost entirely of sand. A **sand dune** is a deposit of wind-blown sand. Over thousands of years, wind sweeps sand across a desert, piling up huge, ever-changing dunes.

Wind by itself is the weakest agent of erosion. Water, waves, moving ice, and even mass movement have more effect on the land. Yet wind can be a powerful force in shaping the land in areas where there are few plants to hold the soil in place. For example, few plants grow in deserts, so wind can easily move the grains of dry sand. **Wind causes erosion by deflation and abrasion.**

FIGURE 17
Sand Dunes
In California, areas of sand dunes are found in parts of the Mojave Desert.

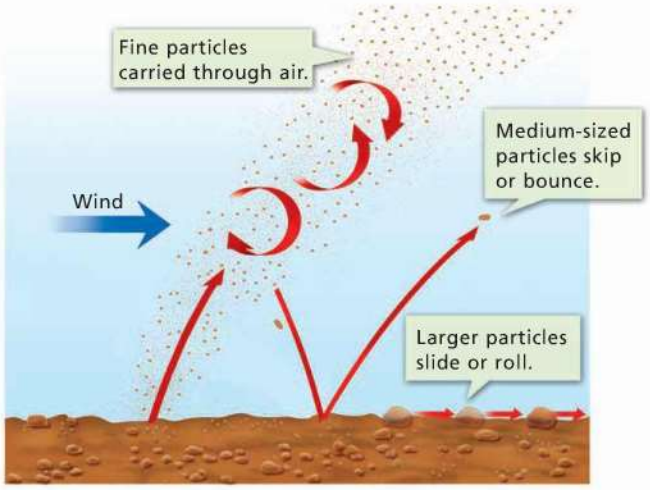


FIGURE 18
Wind Erosion
Wind erosion moves sediment particles of different sizes in the three ways shown at the left.
Comparing and Contrasting *Compare the movement of sediment by wind with the movement of sediment by water in Figure 4 earlier in the chapter. How are the processes similar? How are they different?*

Deflation The main way that wind causes erosion is by deflation. Geologists define **deflation** as the process by which wind removes surface materials. When wind blows over the land, it picks up the smallest particles of sediment. This sediment is made of bits of clay and silt. The stronger the wind, the larger the particles that it can pick up. Slightly heavier particles, such as sand, might skip or bounce for a short distance. But sand soon falls back to the ground. Strong winds can even roll heavier sediment particles over the ground. Figure 18 shows how wind erodes by deflation.

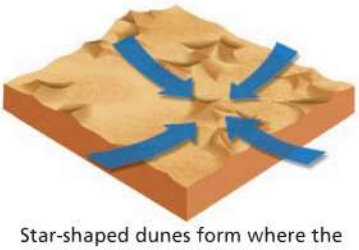
Deflation does not usually have a great effect on land. However, in parts of the Great Plains in the 1930s, deflation caused the loss of about 1 meter of topsoil in just a few years. In deserts, deflation can sometimes create an area of rock fragments called desert pavement, shown in Figure 19. There, wind has blown away the smaller sediment. All that remains are rocky materials that are too heavy to be moved. Areas of desert pavement are common in California's Mojave Desert. Where there is already a slight depression in the ground, deflation can produce a bowl-shaped hollow called a blowout.

Abrasion Abrasion by wind-carried sand can polish rock, but it causes little erosion. At one time, geologists thought that the sediment carried by wind cut the stone shapes seen in deserts. But now evidence shows that most desert landforms are the result of weathering and water erosion.

Reading Checkpoint **Where would you be most likely to see evidence of wind erosion?**

FIGURE 19
Desert Pavement
Wind erosion formed this desert pavement in the Arizona desert. Wind-driven sand may polish and shape individual stones.

Crescent-shaped dunes form where the wind usually blows in the same direction.



Star-shaped dunes form where the wind direction changes frequently.

Wind direction

FIGURE 20
Movement of Sand Dunes
Wind direction helps determine the shape and size of sand dunes.

Deposition by Wind

All the sediment picked up by wind eventually falls to the ground. This happens when the wind slows down or some obstacle, such as a boulder or a clump of grass, traps the wind-blown sand sediment. **Wind erosion and deposition may form sand dunes and loess deposits.** Sand dunes can be seen on beaches and in deserts where wind-blown sediment has built up.

Sand Dunes Sand dunes come in many shapes and sizes. Some are long, with parallel ridges, while others are U-shaped. They can also be very small or very large—some sand dunes in China have grown to heights of 500 meters. Sand dunes move over time. Little by little, the sand shifts with the wind from one side of the dune to the other. This process is shown in Figure 20. In California, sand dunes occur along the coast where rivers have supplied sand to bays. Examples include the dunes near Monterey Bay, Humboldt Bay, and San Diego Bay. Areas of sand dunes can also be found in Death Valley and the Mojave desert.

Loess Deposits Sediment that is finer than sand, such as particles of clay and silt, is sometimes deposited in layers far from its source. This fine, wind-deposited sediment is **loess** (les). Large loess deposits are found in central China and in the midwestern United States. Loess helps to form fertile soil. Many areas with thick loess deposits are valuable farmlands.

Section 3 Assessment

S 6.2.a, 6.2.c; E-LA: Reading 6.1.0, Writing 6.2.2

Vocabulary Skill Latin Word Origins Use what you've learned to complete the following sentence. A process in which wind wears down surface materials is called _____.

Reviewing Key Concepts

HINT 1. a. Explaining What is the source of the energy in ocean waves?

HINT b. Describing How does an ocean wave change when it reaches shallow water?

HINT c. Inferring Does an ocean wave possess potential energy or kinetic energy? Explain.

HINT 2. a. Identifying What are two results of wave erosion along a coast?

HINT b. Listing What are three features formed by wave deposition?

HINT c. Relating Cause and Effect Beginning with the source of sand, explain how a spit forms.

3. a. Reviewing What are two kinds of wind erosion?

HINT b. Identifying What are two types of features that result from wind deposition?

HINT c. Predicting In a desert, soil containing a mixture of sand and small rocks is exposed to wind erosion. Over time, how would the land surface change? Explain.

Writing in Science

Explaining a Process Suppose that you live in a coastal area that has a barrier beach. Write a paragraph in which you explain the processes that formed the barrier beach. Also describe how the forces might change it over time.

Section 4

Glaciers

California Standards Focus

S 6.2.a Framework Surface water flow, glaciers, wind, and ocean waves have all been and continue to be active throughout California and the rest of the world in shaping landscapes.

- What are the two kinds of glaciers?
- How does a valley glacier form and move?
- How do glaciers cause erosion and deposition?

Key Terms

- glacier
- continental glacier
- ice age
- valley glacier
- plucking
- till
- moraine
- kettle

Lab zone Standards Warm-Up

How Do Glaciers Reshape the Land?

1. Put some sand in a small plastic container.
2. Fill the container with water and place the container in a freezer until the water turns to ice.
3. Remove the block of ice from the container. Hold the ice with a paper towel.
4. Rub the ice, sand side down, over a bar of soap. Observe what happens to the surface of the soap.

Think It Over

Inferring Based on your observations, how do you think moving ice could change the surface of the land?

You are on a boat trip near the coast of Alaska. You sail by vast evergreen forests and snow-capped mountains. Then, as your boat rounds a point of land, you see an amazing sight. A great mass of ice flows like a river between rows of mountains. Suddenly you hear a noise like thunder. Where the ice meets the sea, a giant chunk of ice breaks off and plunges into the water. Carefully, the pilot steers your boat around the iceberg and toward the mass of ice. It towers over your boat. You see that it is made up of solid ice that is deep blue and green as well as white. What is this river of ice?

▼ **The Hubbard Glacier in Alaska**

How Glaciers Form and Move

Geologists define a **glacier** as any large mass of ice that moves slowly over land. **There are two kinds of glaciers—continental glaciers and valley glaciers.**

FIGURE 21
Continental Glaciers
During the last ice age, a continental glacier covered most of northern North America.

Continental Glaciers A **continental glacier** is a glacier that covers much of a continent or large island. A continental glacier can cover millions of square kilometers. Today, continental glaciers cover about 10 percent of Earth's land. They cover Antarctica and most of Greenland. The glacier covering Antarctica is over 3 kilometers thick! Continental glaciers can flow in all directions. Continental glaciers spread out much as pancake batter spreads out in a frying pan.

Many times in the past, continental glaciers have covered larger parts of Earth's surface. These times are known as **ice ages.** Beginning about 2.5 million years ago, continental glaciers advanced and retreated, or melted back, several times. They finally retreated about 10,000 years ago.

Valley Glaciers A **valley glacier** is a long, narrow glacier that forms when snow and ice build up high in a mountain valley. The sides of mountains keep these glaciers from spreading out in all directions. Instead, they usually move down valleys that have already been cut by rivers. Valley glaciers are found on many high mountains. Although they are much smaller than continental glaciers, valley glaciers can be tens of kilometers long. In California, small valley glaciers occur on many of the highest peaks in the Sierra Nevada and on Mount Shasta.

High in mountain valleys, temperatures seldom rise above freezing. Snow builds up year after year. The weight of more and more snow compacts the snow at the bottom into ice. **Glaciers can form only in an area where more snow falls than melts. Once the depth of snow and ice reaches more than 30 to 40 meters, gravity begins to pull the glacier downhill.**

Valley glaciers flow at a rate of a few centimeters to a few meters per day. But sometimes a valley glacier slides down more quickly in what is called a surge. A surging glacier can flow as much as 6 kilometers per year.

Reading Checkpoint **On what type of landform are valley glaciers found?**

How Glaciers Shape the Land

The movement of a glacier changes the land beneath it. Although glaciers work slowly, they are a major force of erosion. **The two processes by which glaciers erode the land are plucking and abrasion.**

Glacial Erosion As a glacier flows over the land, it picks up rocks in a process called **plucking.** Beneath a glacier, the weight of the ice can break rocks apart. These rock fragments freeze to the bottom of the glacier. When the glacier moves, it carries the rocks with it. Figure 22 shows plucking by a glacier.

Many rocks remain on the bottom of the glacier, and the glacier drags them across the land. This process, called abrasion, gouges and scratches the bedrock. You can see the results of erosion by glaciers in Figure 22. In a similar way, glacial erosion formed Yosemite Valley in the Sierra Nevada.

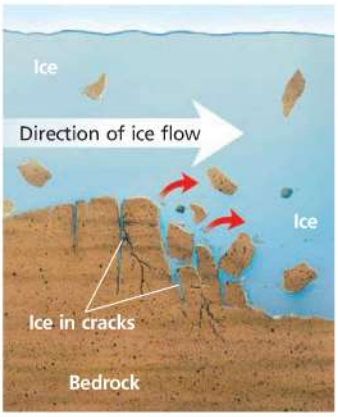
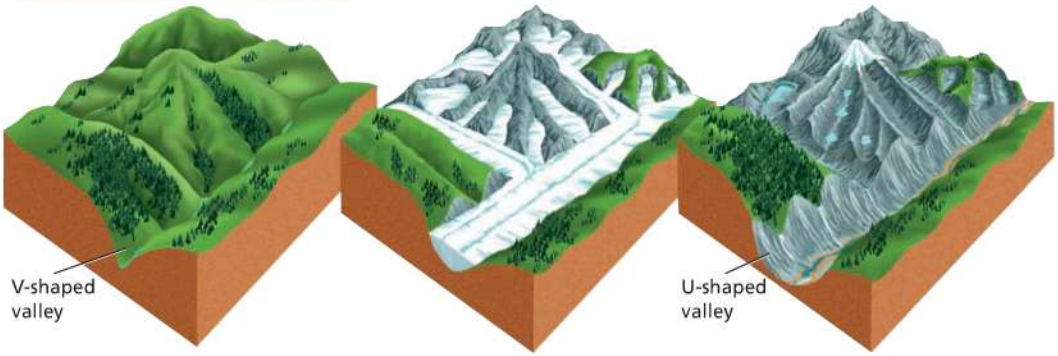


FIGURE 22
Glacial Erosion
As a glacier moves (left), plucking breaks pieces of bedrock from the ground. Erosion by glaciers can carve a mountain peak into a sharp horn (below) and grind out a **V**-shaped valley to form a **U**-shaped valley.
Predicting *What other changes did the glacier produce in this landscape?*



Before Glaciers Form **During Glaciation** **After Glaciers Have Melted**

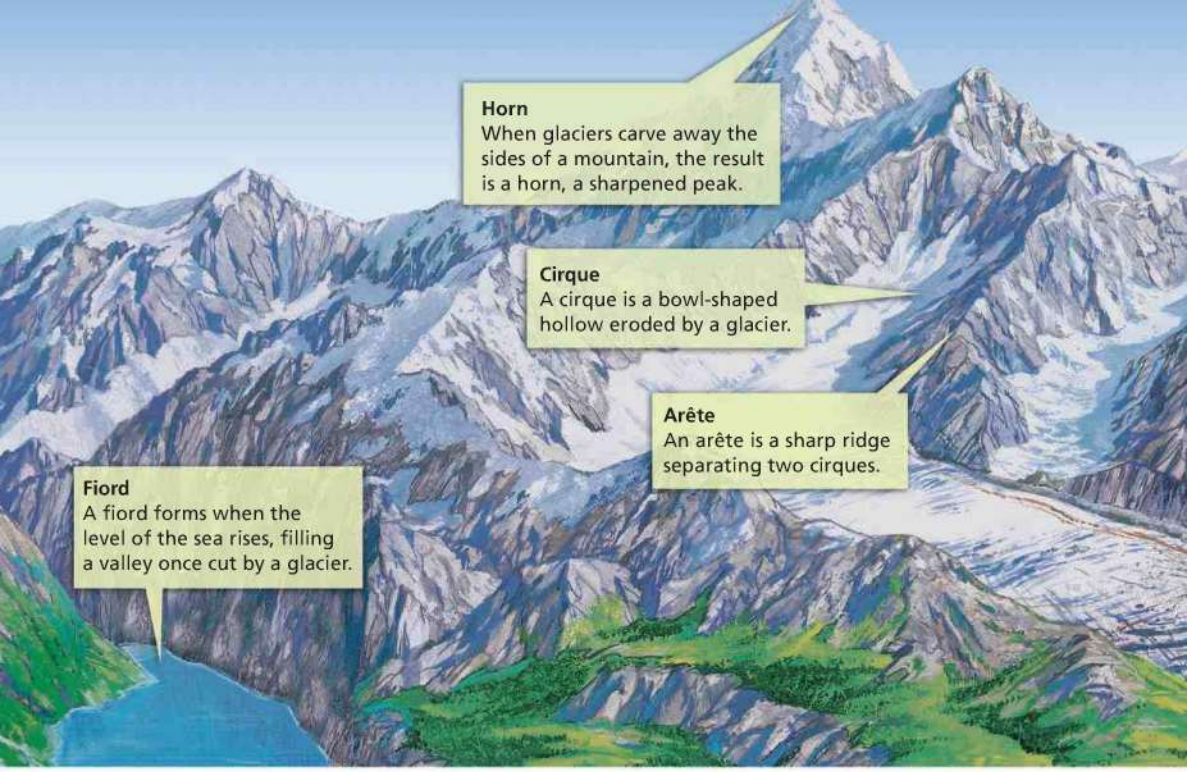


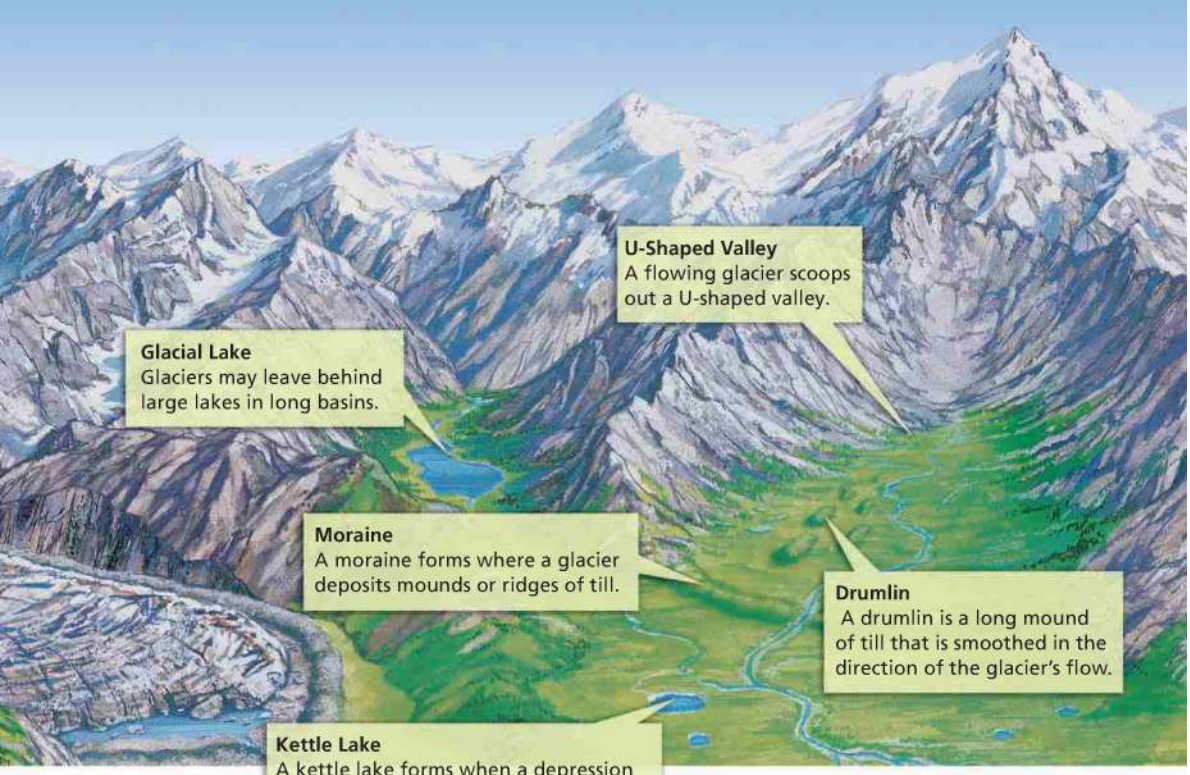
FIGURE 23
Glacial Landforms

As glaciers advance and retreat, they sculpt the landscape by erosion and deposition.
Classifying *Classify these glacial features according to whether they result from erosion or deposition: drumlin, horn, cirque, moraine, U-shaped valley.*

Glacial Deposition A glacier gathers a huge amount of rock and soil as it erodes the land in its path. **When a glacier melts, it deposits the sediment it eroded from the land, creating various landforms.** These landforms remain for thousands of years after the glacier has melted. The mixture of sediments that a glacier deposits directly on the surface is called **till.** Till is made up of particles of many different sizes. Clay, silt, sand, gravel, and boulders can all be found in till.

The till deposited at the edges of a glacier forms a ridge called a **moraine.** A terminal moraine is the ridge of till at the farthest point reached by a glacier. A terminal moraine that formed at the end of the last ice age extends across part of Yosemite Valley in California.

Retreating glaciers also create features. A **kettle** is a small depression that forms when a chunk of ice is left in glacial till. When the ice melts, the kettle remains. The continental glacier of the last ice age left behind many kettles. Kettles often fill with water, forming small lakes called kettle lakes. Small lakes also form in the bowl-shaped hollow eroded by a glacier at the base of a high peak. There are many of these lakes in California's Sierra Nevada.



Section 4 Assessment

S 6.2.a; E-LA: Reading 6.2.0, Writing 6.2.5

Target Reading Skill **Sequence** Review Valley Glaciers under the heading How Glaciers Form and Move. Then organize the text in a flowchart called How a Valley Glacier Forms. In the first box write, "Snow builds up." Write the next 3 steps in the process.

Reviewing Key Concepts

1. a. **Defining** What is a continental glacier? HINT
   b. **Defining** What is a valley glacier? HINT
   c. **Comparing and Contrasting** How are the two types of glaciers similar? How are they different? HINT
2. a. **Reviewing** How does a glacier form? HINT
   b. **Explaining** How does a glacier move? HINT
   c. **Relating Cause and Effect** Why does the snow that forms a glacier change to ice? HINT
3. a. **Identifying** What are two ways in which glaciers erode Earth's surface? HINT
   b. **Describing** How does glacial deposition occur? HINT

Writing in Science

Travel Brochure A travel agency wants people to go on a tour of a mountain region with many glaciers. Write a paragraph for a travel brochure describing what people will see on the tour. In your answer, include features formed by glacial erosion and deposition.

Chapter 3 Study Guide

The BIG Idea Moving water, wind, and ice are forces that shape our landscape.

1 Changing Earth's Surface

Key Concepts S 6.2

- Weathering, erosion, and deposition act together in a cycle that wears down and builds up Earth's surface.
- Gravity causes mass movement, including landslides, mudflows, slump, and creep.

Key Terms

erosion
sediment
deposition
gravity
mass movement

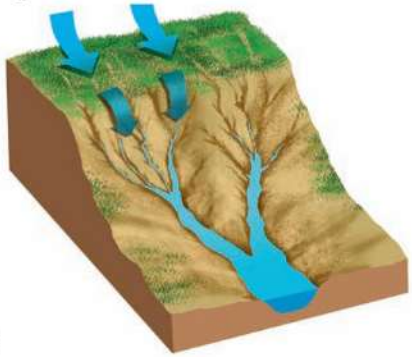
2 Water Erosion

Key Concepts S 6.2.a, 6.2.b

- Moving water is the major agent of the erosion that has shaped Earth's land surface.
- Through erosion, a river creates valleys, waterfalls, flood plains, meanders, and oxbow lakes.
- Deposition creates alluvial fans and deltas. It can also add soil to a river's flood plain.
- A river's slope, volume of flow, and the shape of its streambed all affect how fast the river flows and how much sediment it can erode.

Key Terms

runoff
rill
gully
stream
energy
flood plain
meander
oxbow lake
alluvial fan
delta
load



3 Waves and Wind

Key Concepts S 6.2.a, 6.2.c

- The energy in waves comes from wind that blows across the water's surface.
- Waves shape the coast through erosion by breaking down rock and transporting sand and other sediment.
- Waves shape a coast when they deposit sediment, forming coastal features such as beaches, sand bars, spits, and barrier beaches.
- Wind causes erosion by deflation and abrasion.
- Wind erosion and deposition may form sand dunes and loess deposits.

Key Terms

headland
beach
longshore drift
spit
sand dune
deflation
loess

4 Glaciers

Key Concepts S 6.2.a

- There are two kinds of glaciers—continental glaciers and valley glaciers.
- Glaciers can form only in an area where more snow falls than melts. Once the depth of snow and ice reaches more than 30 to 40 meters, gravity begins to pull the glacier downhill.
- The two processes by which glaciers erode the land are plucking and abrasion.
- When a glacier melts, it deposits the sediment it eroded from the land, creating various landforms.

Key Terms

glacier
continental glacier
ice age
valley glacier
plucking
till
moraine
kettle

Review and Assessment

Go Online
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Target Reading Skill

Sequence Complete a seven-step graphic organizer for Stream Formation.

Stream Formation

Raindrops strike ground.

↓

Runoff forms.

↓

Reviewing Key Terms

Choose the letter of the best answer.

HINT
1. The eroded materials carried by water or wind are called
   a. till.
   b. desert pavement.
   c. sediment.
   d. moraines.

HINT
2. The downhill movement of eroded materials is known as
   a. mass movement.
   b. abrasion.
   c. deposition.
   d. deflation.

HINT
3. As runoff flows over the surface, it forms tiny grooves in soil called
   a. gullies.
   b. deltas.
   c. rills.
   d. fans.

HINT
4. Where a streambed curves, deposition occurs
   a. in the middle.
   b. along the inside of the curve.
   c. along the outside of the curve.
   d. as the water speeds up.

HINT
5. The erosion of sediment by wind is
   a. deposition.
   b. deflation.
   c. plucking.
   d. glaciation.

HINT
6. A mass of rock and soil deposited directly by a glacier is called
   a. load.
   b. till.
   c. loess.
   d. erosion.

HINT
7. Glaciers pick up rocks by a process called
   a. creep.
   b. plucking.
   c. drift.
   d. meandering.

Complete the following sentences so that your answers clearly explain the key terms.

HINT
8. Water carrying sediment eventually slows down, causing **deposition,** which is _____ .

HINT
9. Rain that falls to the surface can form **runoff,** which is _____ .

HINT
10. Where a river flows across its floodplain, it may form a **meander,** which is _____ .

HINT
11. Waves' hitting a beach at an angle creates a current parallel to the coastline, causing **longshore drift,** which is _____ .

HINT
12. One feature formed when a glacier deposits sediment is a **moraine,** which is _____ .

Writing in Science

Article Suppose that you have just returned from a visit to a limestone cave, such as Mammoth Cave in Kentucky. Write an article describing your visit to the cave. Include how the cave formed, what you saw during your visit, and how features inside the cave developed.

Video Assessment
Discovery Channel School
Erosion and Deposition

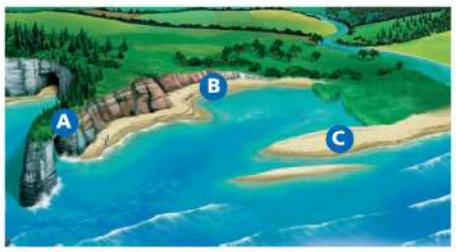
Review and Assessment

Checking Concepts

13. What agents of erosion are assisted by the force of gravity?
14. Beginning with rain hitting the land surface, describe the process by which a stream forms.
15. How does an alluvial fan form?
16. How do a river's slope and volume of flow affect the river's sediment load?
17. Where is the speed of the flowing water in a river the slowest? Explain.
18. How does a loess deposit form?
19. What are ice ages?
20. How does a kettle lake form?

Thinking Critically

21. **Comparing and Contrasting** Compare and contrast landslides and mudflows.
22. **Applying Concepts** Describe a beneficial effect that flooding can have on a flood plain.
23. **Making Judgments** A salesperson offers to sell your family a new house right on a riverbank for very little money. Why might your family hesitate to buy this house?
24. **Relating Cause and Effect** What caused the features labeled A, B, and C in the diagram below? Explain.



25. **Inferring** You see a sandy beach along a coastline. Where did the sand come from?
26. **Problem Solving** Suppose you are a geologist studying a valley glacier. What method could you use to tell if it is advancing or retreating?

Applying Skills

Use the table below to answer Questions 27–29.

The table shows how a river's volume of flow and sediment load change over six months.

Month	Volume of Flow (cubic meters/second)	Sediment Load (metric tons/day)
January	1.5	200
February	1.7	320
March	2.6	725
April	4.0	1,600
May	3.2	1,100
June	2.8	900

27. **Graphing** Make one graph with the month on the *x*-axis and the volume of flow on the *y*-axis. Make a second graph with the sediment load on the *y*-axis. Compare your two graphs. When were the river's volume of flow and load the greatest? The lowest?
28. **Developing Hypotheses** Use your graphs to develop a hypothesis about the relationship between volume of flow and sediment load.
29. **Relating Cause and Effect** What may have occurred in the river's drainage basin in April to cause the changes in volume of flow and sediment load? Explain.

Lab zone Standards Investigation

Performance Assessment Now you are ready to explain your models of erosion to your class. Explain to your classmates the features that formed as the result of erosion. Predict how the topography of your model could change as the cycle of erosion continues.

Choose the letter of the best answer.

1. What is the slow, downhill mass movement of rock and soil, caused by gravity?
   - **A** a landslide
   - **B** creep
   - **C** runoff
   - **D** a glacier

   S 6.2

2. Which statement best describes the process that forms a stream?
   - **A** Sheet erosion digs a deep channel.
   - **B** Tiny rills enlarge to form gullies, which join to form a stream.
   - **C** Small gullies enlarge to form rills, which deepen to form a stream.
   - **D** Water flows down a V-shaped valley.

   S 6.2.a

3. A meander that is cut off from the main course of a river becomes a(n)
   - **A** kettle lake.
   - **B** delta.
   - **C** oxbow lake.
   - **D** alluvial fan.

   S 6.2.a

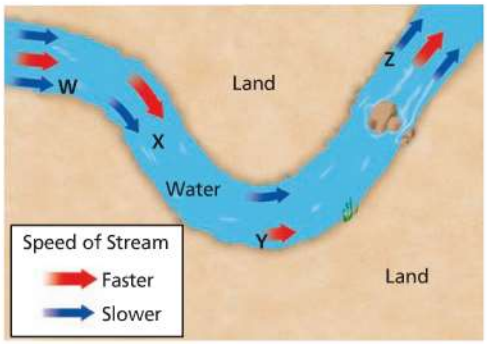
4. As a stream flows from a mountainous area to a flatter area, what happens to the size of the sediment the stream normally carries?
   - **A** The sediment size does not change.
   - **B** The sediment size carried by the stream increases.
   - **C** The sediment size carried by the stream decreases.
   - **D** The stream drops all the sediment it was carrying.

   S 6.2.b

5. Which of the following is an effect of longshore drift?
   - **A** Deep deposits of loess are formed.
   - **B** A meander forms in a river.
   - **C** A delta builds up at a river's mouth.
   - **D** Beach sand moves along a coastline.

   S 6.2.c

Use the diagram below and your knowledge of science to answer Questions 6 and 7.



6. What is the erosional feature in the diagram?
   - **A** a meander
   - **B** a delta
   - **C** a flood plain
   - **D** an alluvial fan

   S 6.2.a

7. In the diagram, where is the speed of the stream the greatest?
   - **A** at Y
   - **B** at X
   - **C** at W
   - **D** at Z

   S 6.2.b

8. Scientists determine that a certain flood plain will probably have a severe flood two or three times in a hundred years. The best type of land use for the flood plain would be
   - **A** a shopping center.
   - **B** homes and schools.
   - **C** farmland and forest.
   - **D** tall office buildings.

   S 6.2.d

Apply the BIG Idea

9. Describe how gravity is involved in the erosion of Earth's surface by mass movement, running water, and glaciers. Be sure to first explain what erosion is.

   S 6.2