Section 1

Changing Earth's Surface

Reading Preview

Key Concepts

- 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

Target Reading Skill

Comparing and Contrasting As you read, compare and contrast the different types of mass movement by completing a table like the one below.

Mass Movement

Type of Mass Movement	Speed	Slope
Landslide		

Lab zone Discover Activity

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 compare? Develop a hypothesis to explain the differences in 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.

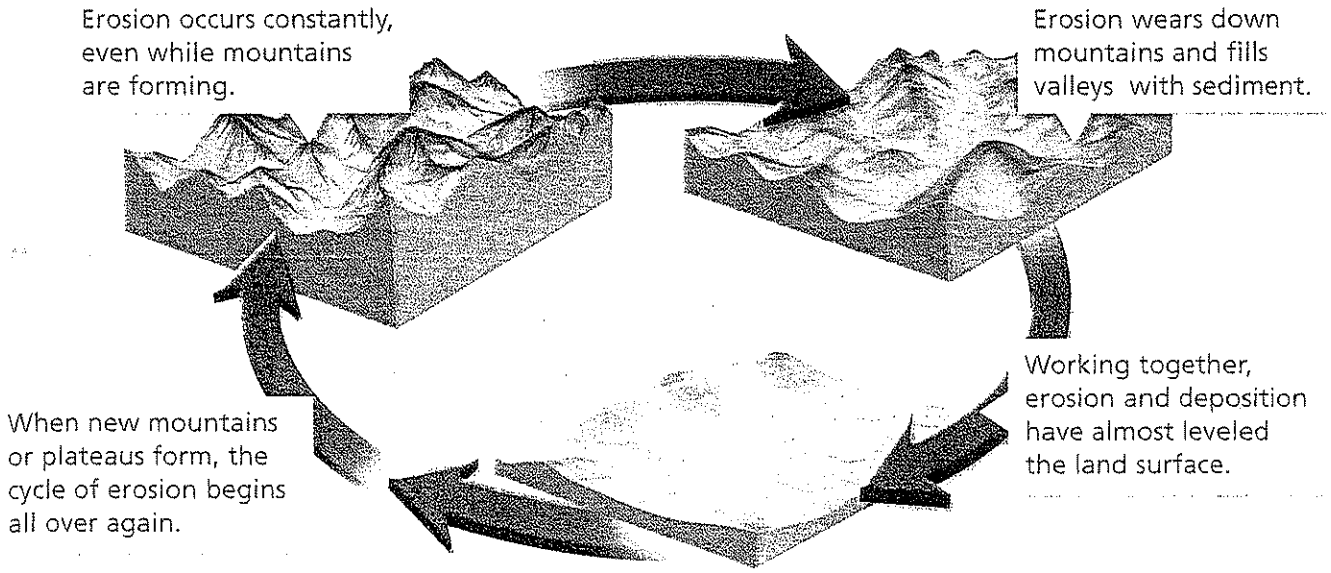


FIGURE 2
Cycle of Erosion and Deposition
Over millions of years, erosion gradually wears away mountains while deposition fills in valleys with sediment.
Predicting *What would happen to the surface of the land if uplift did not occur?*

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. Erosion and deposition are at work everywhere on Earth. As a mountain wears down in one place, new landforms build up in other places. The cycle of erosion and deposition is never-ending.

Reading Checkpoint What is sediment?

Lab zone Skills Activity

Section 5

Waves

Reading Preview

Key Concepts

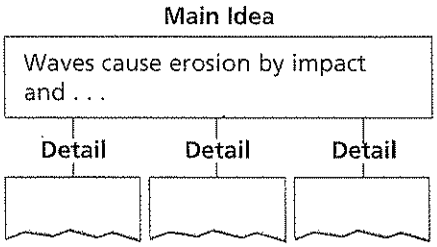
- What gives waves their energy?
- How do waves erode a coast?
- What features result from deposition by waves?

Key Terms

- headland
- beach
- longshore drift
- spit

Target Reading Skill

Identifying Main Ideas As you read Erosion by Waves, write the main idea in a graphic organizer like the one below. Then write three supporting details that further explain the main idea.



Lab zone Discover Activity

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. Are the grains smooth and rounded or angular and rough?
4. 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.

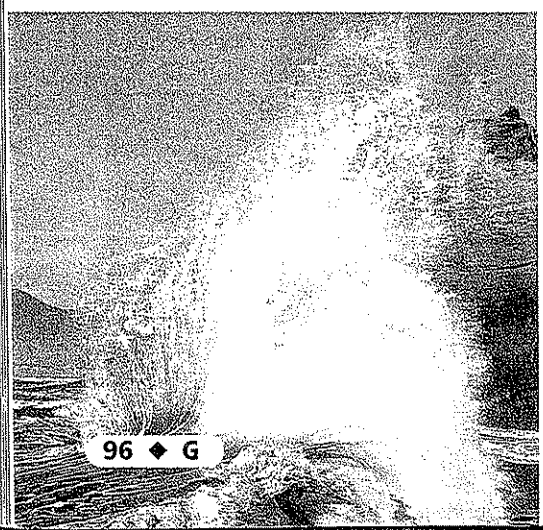
How Waves Form

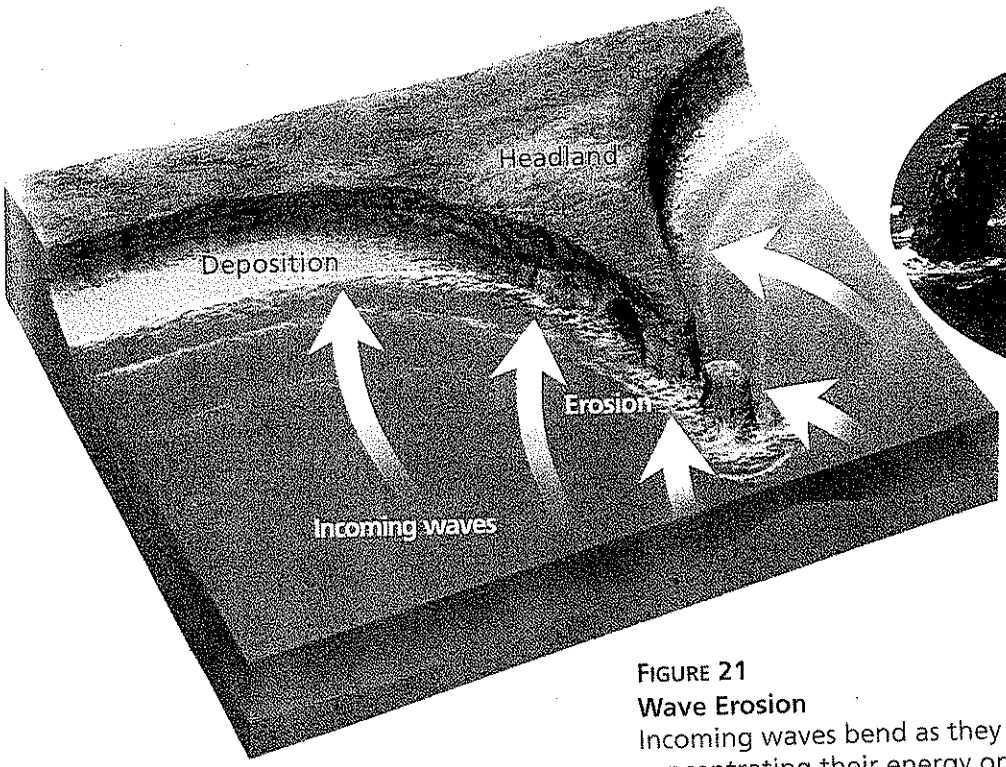
The energy in waves comes from wind that blows across the water's surface. As the wind makes contact with the water, some of its energy transfers to the water. Large ocean waves are the result of powerful storms far out at sea. But ordinary breezes can produce waves in lakes or small ponds.

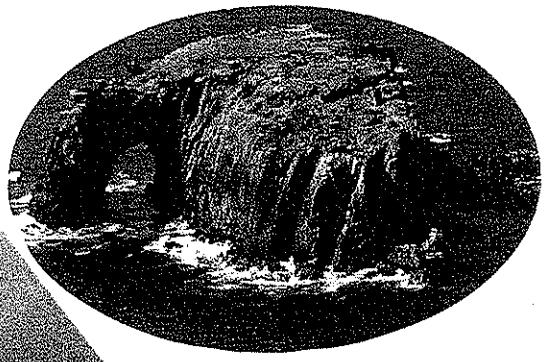
The energy that water picks up from the wind causes water particles to move up and down as the wave goes by. But the water particles themselves don't move forward.

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 friction 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.

▼ Waves on the Oregon coast







▲ Sea arch

FIGURE 21
Wave Erosion
Incoming waves bend as they approach the shore, concentrating their energy on headlands. Waves have shaped these spectacular cliffs (right) along the coast of Cornwall in England.
Relating Cause and Effect *What will eventually happen to the headlands?*

Erosion by Waves

Waves are the major force of erosion along coasts. **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. 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 21 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.

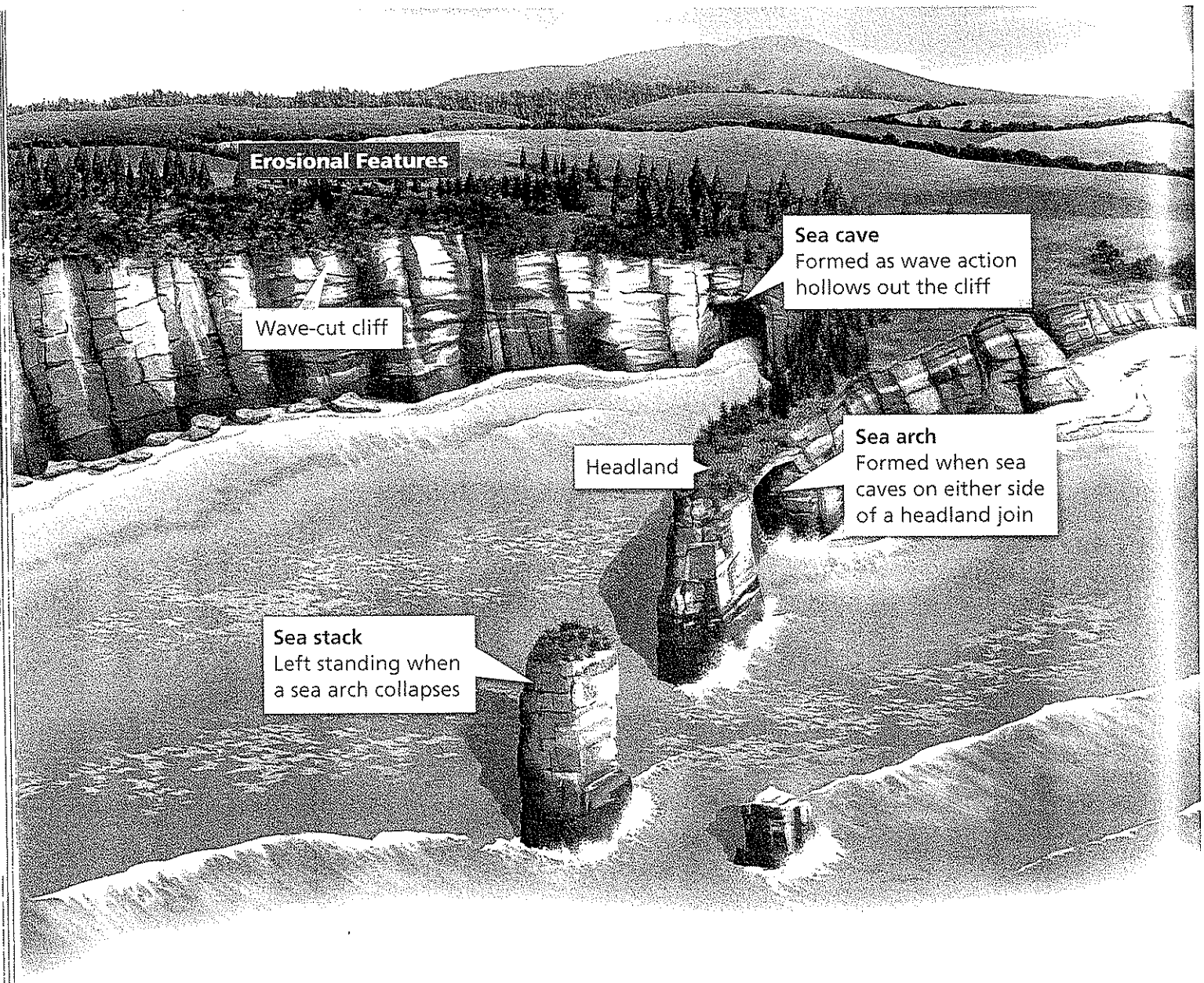


FIGURE 22
The Changing Coast

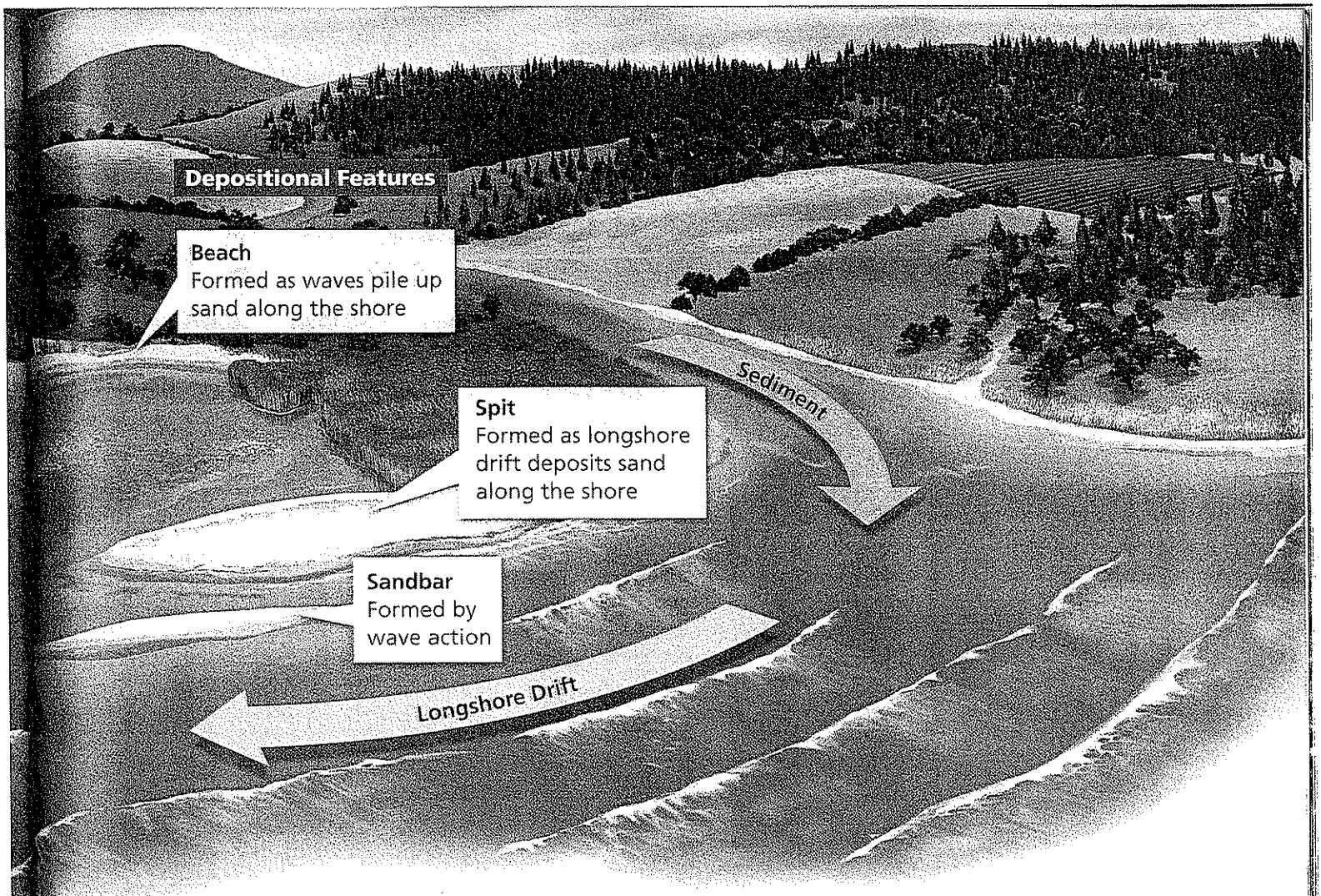
Erosion and deposition create a variety of features along a coast. Predicting *What will eventually happen to the sea arch?*

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 22.

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, 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. But not all beaches are made of sand. Some beaches are made of small fragments of coral or sea shells piled up by wave action. Florida has many such beaches.

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 23
Spits
This aerial photograph shows how longshore drift can carry sand and deposit it to form a spit.
Observing *How many spits can you find in this image?*

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 Atlantic coast of the United States, such as the Outer Banks of North Carolina. 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.

Reading Checkpoint **How does a barrier beach form?**

Section 5 Assessment

Target Reading Skill Identifying Main Ideas Use your graphic organizer to help you answer Question 2 below.

Reviewing Key Concepts

1. a. **Explaining** What is the source of the energy in ocean waves?
   b. **Describing** How does an ocean wave change when it reaches shallow water?
   c. **Inferring** Does an ocean wave possess potential energy or kinetic energy? Explain.
2. a. **Identifying** What are two results of wave erosion along a coast?
   b. **Describing** What are two ways in which waves erode rock?
   c. **Sequencing** Place these features in the order in which they would probably form: sea stack, sea cave, headland, cliff, sea arch.
3. a. **Listing** What are three features formed by wave deposition?
   b. **Relating Cause and Effect** Beginning with the source of sand, explain the process by which a spit forms.

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 6

Wind

Reading Preview

Key Concepts

- How does wind cause erosion?
- What features result from deposition by wind?

Key Terms

- sand dune
- deflation
- loess

Target Reading Skill

Sequencing As you read, make a flowchart like the one below that shows the process of wind erosion and deposition. Write each step of the process in a separate box in the flowchart in the order in which it occurs.

Wind Erosion

Wind picks up smallest particles of sediment.

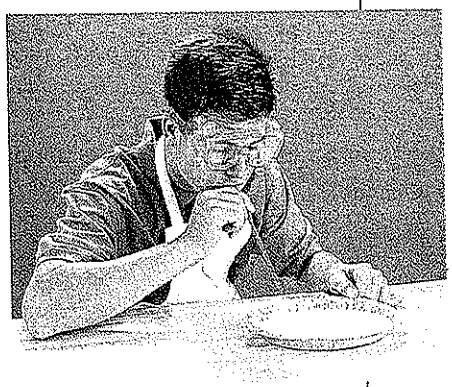
↓

↓

Lab zone Discover Activity

How Does Moving Air Affect Sediment?

1. Cover the bottom of a pan with a flat layer of cornmeal 1–2 cm deep.
2. Gently blow over the layer of cornmeal using a straw to direct your breath. Observe what happens. **CAUTION:** *Do not blow the cornmeal in the direction of another student.*



Think It Over

Observing What changes did the wind you created make in the flat layer of cornmeal?

Imagine a landscape made almost entirely of sand. One such place is the Namib Desert. The desert stretches 1,900 kilometers along the coast of Namibia in Africa. In the southern half of the Namib are rows of giant sand dunes. A **sand dune** is a deposit of wind-blown sand. Some sand dunes in the Namib are more than 200 meters high and 15 kilometers long. Much of the sand in the dunes originally came from the nearby Orange River. Over thousands of years, wind has swept the sand across the desert, piling up huge, ever-changing dunes.

How Wind Causes Erosion

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.**

Wind erosion constantly shapes the giant sand dunes in the Namib Desert of southwestern Africa. ▼

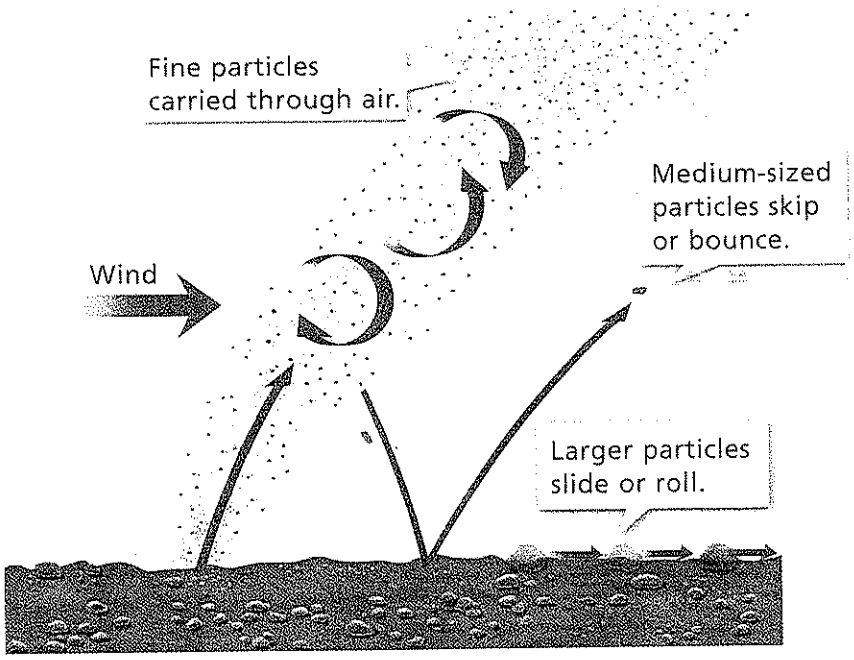


FIGURE 24
Wind Erosion
Wind erosion moves sediment particles of different sizes in the three ways shown at right.
Comparing and Contrasting *Compare the movement of sediment by wind with the movement of sediment by water in Figure 14 on page 87. How are the processes similar? How are they different?*

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 24 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. You can see an area of desert pavement in Figure 25. There, wind has blown away the smaller sediment. All that remains are rocky materials that are too heavy to be moved. Where there is already a slight depression in the ground, deflation can produce a bowl-shaped hollow called a blowout.

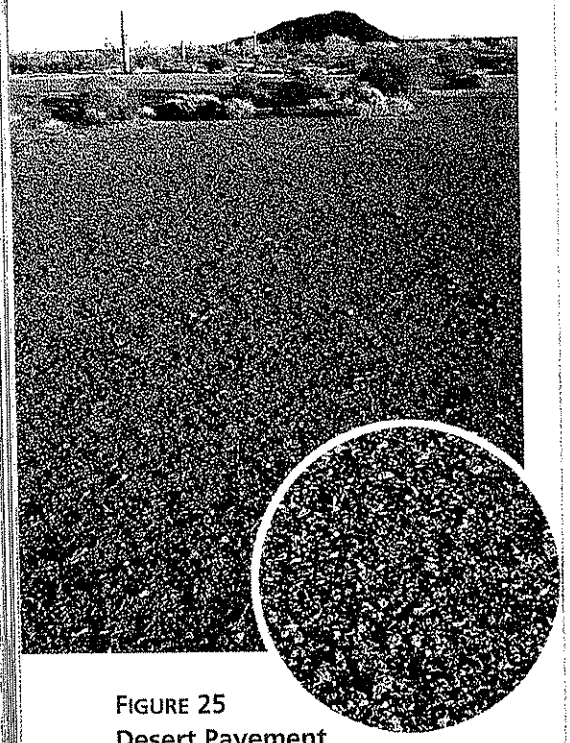


FIGURE 25
Desert Pavement
Wind erosion formed this desert pavement in the Arizona desert. Wind-driven sand may polish and shape individual stones.

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.

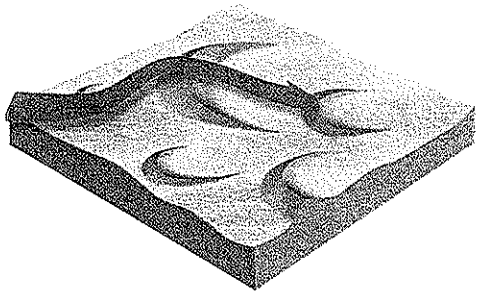
Reading Checkpoint **Where would you be most likely to see evidence of wind erosion?**

Wind Deposition

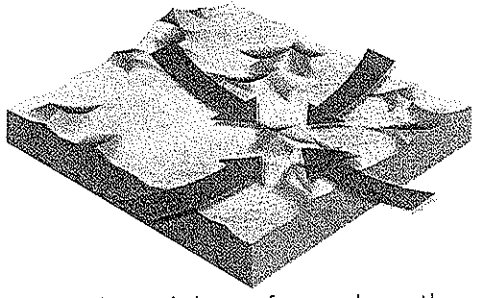
All the sediment picked up by wind eventually falls to the ground. This happens when the wind slows down or some obstacle, such as a boulder or a clump of grass, traps the windblown sand sediment. **Wind erosion and deposition may form sand dunes and loess deposits.** When the wind strikes an obstacle, the result is usually a sand dune. 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 26. Sometimes plants begin growing on a dune. Plant roots can help to anchor the dune in one place.

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 such states as Nebraska, South Dakota, Iowa, Missouri, and Illinois. Loess helps to form fertile soil. Many areas with thick loess deposits are valuable farmlands.



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



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

FIGURE 26
Movement of Sand Dunes
Wind direction is one factor that helps determine the shape and size of sand dunes.

Section 6 Assessment

Target Reading Skill **Sequencing** Refer to your flowchart as you answer the questions below.

Reviewing Key Concepts

1. a. **Reviewing** What are two kinds of wind erosion?
   b. **Explaining** Explain how sediment particles of different sizes move during wind erosion.
   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.
2. a. **Relating Cause and Effect** What causes wind to deposit sand or other sediment?
   b. **Identifying** What are two types of features that result from wind deposition?
   c. **Problem Solving** How could sand dunes be held in place to keep them from drifting onto a parking lot?

Lab zone At-Home Activity

Desert Pavement To model desert pavement, put a few coins in a shallow pan. Sprinkle enough flour over the coins to cover them. Then blow air gently through a straw across the surface of the flour. Be careful not to draw in any flour through the straw. Be certain the blown flour will not get in your or anyone else's eyes. Ask your family to predict what would happen if the "wind" blew for a long time.