Section 1
Shoreline Erosion and Deposition

Key Concept Beaches and shorelines are shaped largely by the action of ocean waves.

What You Will Learn
- Energy from waves crashing against rocks affects shorelines.
- Shoreline features are created by wave erosion.
- Waves deposit sediment at the shore to form beaches.

Why It Matters
Waves erode and deposit materials along beaches and shorelines throughout California and the world.

Two ingredients are needed to make sand: rock and energy. Rock is usually available on the shore. Energy is provided by waves that travel through water. When waves crash into rock over long periods of time, the rock breaks down into smaller pieces that are called *sand.*

The formation and movement of sand by wave erosion and deposition shape the shoreline. A **shoreline** is the place where land and a body of water meet. Waves usually play a major part in building up and breaking down the shoreline.

Wave Energy
As wind moves across the ocean surface, it makes disturbances called *waves.* The size of a wave depends on the strength of the wind and the time that it blows. The stronger the wind is and the longer the wind blows, the bigger the waves are.

Wind that results from summer hurricanes and severe winter storms makes large waves that cause dramatic shoreline erosion. Waves may travel hundreds or even thousands of kilometers from a storm before reaching the shoreline. Some of the largest waves to reach the California coast are produced by storms as far away as Australia. So, the California wave that the surfer in **Figure 1** is riding may have formed on the other side of the Pacific Ocean!

Figure 1 Waves produced by storms on the other side of the Pacific Ocean propel this surfer toward a California shore.

Wave Trains

When you drop a pebble into a pond, the pebble makes many ripples, not just one. Waves, like ripples, move in groups, called *wave trains.* **Figure 2** shows a wave train. The waves in a wave train are separated by a period of time called the *wave period.* Wave periods can be observed as the time between breaking waves. Most wave periods are 10 to 20 s long.

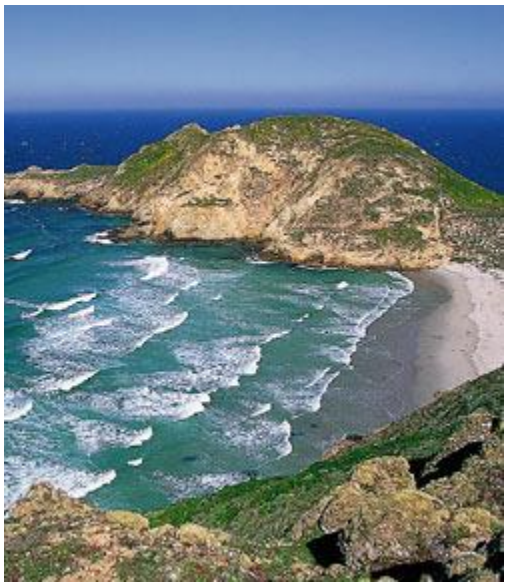


Figure 2 Because waves travel in wave trains, waves break at regular intervals.

As wave trains move away from their source, they travel uninterrupted through deep ocean water. But when a wave in a wave train reaches shallow water, the bottom of the wave drags against the sea floor, which slows the wave down. As a result, the top of the wave moves faster than the bottom of the wave does, and the wave gets taller. Eventually, the wave becomes so tall that it cannot support itself. At that point, it begins to curl and break. Breaking waves are known as *surf.* Now you know why people who ride the waves are called *surfers.*

The Pounding Surf

Look at **Figure 3,** and you will get an idea of how sand is made. A tremendous amount of energy is released when waves break. A crashing wave can break solid rock and can throw broken rocks back against the shore. As water in breaking waves enters cracks in rock, the water helps break off large boulders and wash away fine grains of sand. The loose sand that is picked up by waves wears down and polishes coastal rocks. As a result of these actions, rock is broken down into smaller and smaller pieces that eventually become sand.

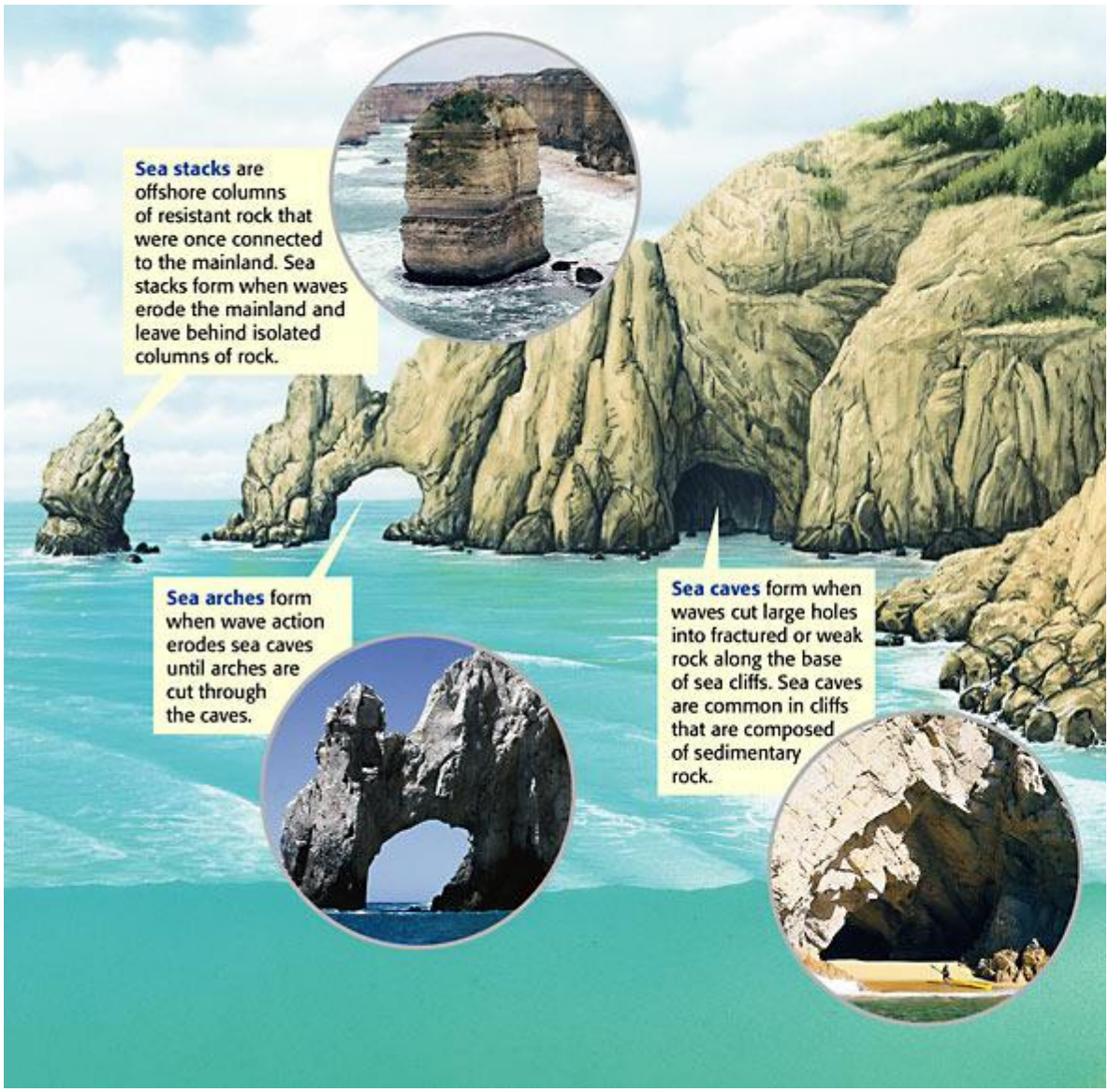
Figure 3 The energy of breaking waves is transferred when the waves crash against the shore.

Standards Check How do waves break rocks?

Wave Erosion

Wave erosion produces a variety of features along a shoreline. *Sea cliffs* form when waves erode and undercut rock to make steep slopes. Waves strike the base of the cliffs. This process wears away the soil and rock and makes the cliffs steeper. The rate at which sea cliffs erode depends on the hardness of the rock and the energy of the waves. Sea cliffs made of hard rock, such as granite, erode very slowly. Sea cliffs made of soft rock, such as shale, erode more rapidly, especially during storms.

Figure 4 Coastal Landforms Created by Wave Erosion



Shaping a Shoreline

Much of the erosion responsible for landforms that you might see along the shoreline takes place during storms. Large waves

caused by storms transfer far more energy than average-sized waves do. This energy is so powerful that it can remove huge chunks of rock. **Figure 4** shows some of the major landscape features that result from wave erosion.

Standards Check Explain why large waves are more able to remove large chunks of rock from a shoreline than average-sized waves are.

Wave Deposits

Waves carry a variety of materials, including sand, rock fragments, dead coral, and shells. Often, these materials are deposited on a shoreline, where they form a beach. A **beach** is any area of shoreline that is made up of material deposited by waves. Some beach material is also deposited by rivers and then is moved down the shoreline by waves.

Beach Materials

You may think that all beaches are sandy places at the seashore. However, not all beaches are made of sand. Notice that the beaches shown in **Figure 5** differ in the texture of their materials. The size and shape of beach material depend on how far the material traveled from its source to where it is deposited. They also depend on how the material is eroded by waves. For example, in areas where stormy seas are common, beaches may be made of pebbles and boulders because smaller particles are eroded by waves.

Figure 5 Beaches are made of various types of materials deposited by waves. **How are the beach materials in these photos different from each other?**

Beach Composition

The color of beach material depends on the material's source. Light-colored sand is the most common beach material. Much of this sand is made of the mineral quartz. Most quartz sand comes from eroded sandstone. Many Florida beaches are made of quartz sand. On many tropical islands, such as the Virgin Islands, beach sand is made of finely ground white coral. But, as **Figure 5** shows, not all beaches are made of light-colored sand. Black sand beaches, such as the ones in Hawaii, are made of eroded lava from Hawaiian volcanoes. This lava is rich in the elements iron and magnesium, which give the sand its dark color.

Standards Check How do source rocks affect beach color?

California Beaches

California has both rocky and sandy shores. Rocky beaches commonly form where mountains or cliffs meet the ocean. Sandy beaches commonly form on the edges of more gently sloping land. Most sandy beaches receive some of their sand from rivers.

The mineral composition of California beaches also varies. The composition and color depend on the source of the sand. For example, the sand at Shelter Cove in Humboldt County is charcoal gray and comes from eroded shale cliffs nearby. The white sand at Carmel is made up of quartz and feldspar. Sands near Santa Cruz contain dark grains of magnetite from igneous rock.

Beach Size

The amount of sand present on a beach can change between seasons. In California, beaches can become narrower in winter as large winter storm waves erode sand away from the beach. Much of the eroded sand is trapped by offshore sandbars and is returned to beaches by small waves during the summer.

Shore Currents

When waves crash on the beach head-on, the water flows back to the ocean underneath new incoming waves. This movement of water carries

pieces of sand and rock away from the shore. This kind of water movement is called an **undertow**.

Longshore Currents

When water travels parallel to the shoreline very near shore, the current is called a **longshore current**. Longshore currents are caused by waves hitting the shore at an angle. Waves that break at oblique angles to the shore move sediment along the coast. Waves wash the sand parallel to the direction in which they break. But the return water flow brings sand directly down the slope of the beach. This process results in a zigzag movement of the sand, as shown in **Figure 6.**

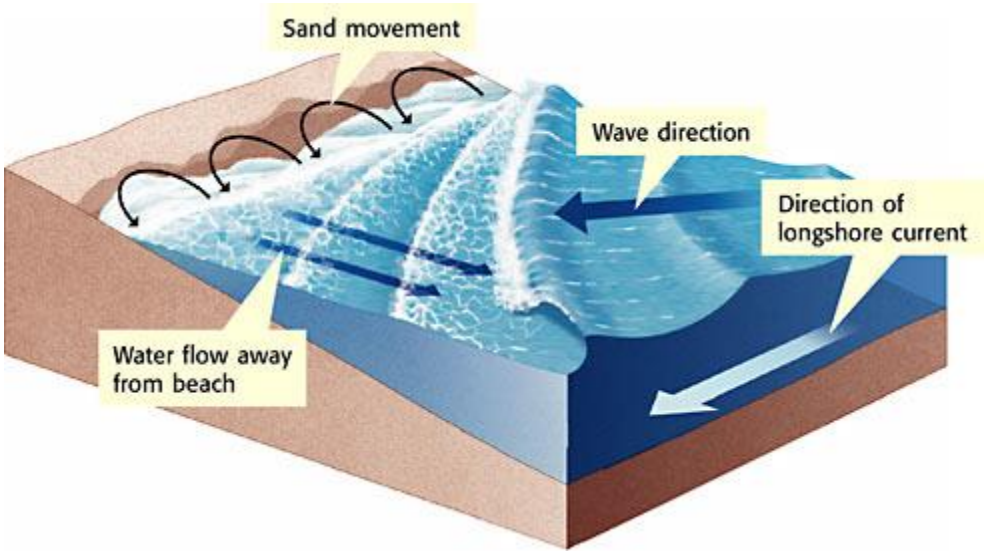


Figure 6 When waves strike the shoreline at an angle, sand migrates along the beach in a zigzag path.

Longshore currents transport most of the sediment in beach environments. This process both tears down and builds up the coastline. Unfortunately, longshore currents also carry and spread trash and other ocean pollution along the shore.

Standards Check How do longshore currents move sand?

Offshore Deposits

Waves that move at an angle to the shoreline push water along the shore and create longshore currents. When waves erode material from the shoreline, longshore currents can transport and deposit this material offshore. This process creates landforms in open water. A *sandbar* is an underwater or exposed ridge of sand, gravel, or shell material. A *barrier spit* is an exposed sandbar that is connected to the shoreline. Cape Cod, Massachusetts, shown in **Figure 7,** is an example of a barrier spit. A *barrier island* is a long, narrow island usually made of sand that forms parallel to the shoreline a short distance offshore.

Figure 7 A barrier spit, such as Cape Cod, Massachusetts, occurs when an exposed sandbar is connected to the shoreline.

Section Summary

- A wave is a disturbance in the water that can be caused by wind.
- As waves break against a shoreline, their energy breaks rocks down into sand.
- Six shoreline features that are created by wave erosion are sea cliffs, sea stacks, sea caves, sea arches, headlands, and wave-cut terraces.
- Beaches are made from material deposited by rivers and waves.
- Longshore currents cause sand to move in a zigzag pattern along the shore.
- Longshore currents can deposit eroded sediment offshore.