Chapter 12
Beaches

You have learned that weathering eventually causes mountains to become tiny pieces of rock called sediment. And you have learned that streams and rivers carry this sediment to bodies of water like ponds, lakes and oceans. This chapter is a continuation of that story. Sediment that reaches the ocean is first deposited on the beach. But beaches are just a brief resting stop for sediment. After sediment leaves a beach, it continues its journey to the deep ocean floor.

Key Questions

1. *Why are beaches sandy?*
2. *What is sand made of?*
3. *What is the difference between a winter beach and a summer beach?*

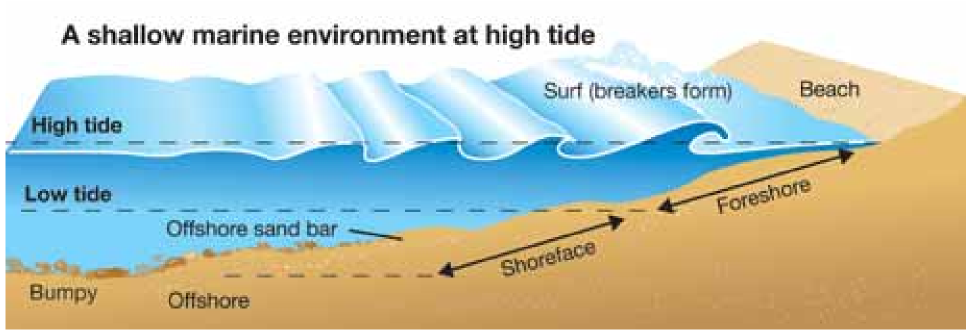
12.1 The Shallow Marine Environment

Read the section title. You have probably heard each word before. *Shallow* means water that is not deep. **Marine** is a term that describes anything that has to do with the ocean. *Environment* refers to the characteristics of a place. So, a shallow marine environment is the area near the ocean where the water is shallow. In this section, you will read about what happens to sediment in a shallow marine environment.

The parts of a beach

Beach zones The *foreshore* in the shallow marine environment lies between the high and low tide lines (Figure 12.1). A **beach** is a sandy zone above the foreshore. Marine biologists have a different name for the foreshore. They call it the **intertidal zone**.

Onshore and offshore regions Below the foreshore is the *shoreface*. The shoreface is always underwater. Passing waves affect the sediments of the shoreface, especially the upper part nearest the beach. Waves smooth land surfaces. Because waves have little effect on the lower part of the shoreface, the surface of this region is bumpy. Anything that is on the beach, foreshore, or shoreface is onshore. Anything beyond the shoreface is offshore.



VOCABULARY

marine - a term that describes things that are part of or from the ocean.

beach - a sandy zone above the foreshore in a shallow marine environment.

intertidal zone - the zone of a marine environment between the high and low tide lines; also called the foreshore.

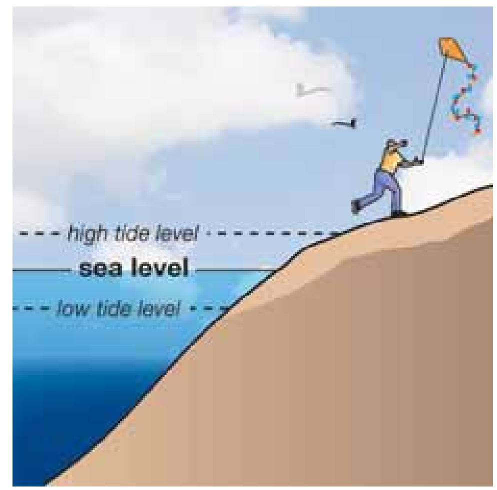


Figure 12.1: *The range of land between the high and low tide lines is called the foreshore. Sea level is the average ocean height between the high and low tide levels.*

Sandy beaches and tidal flats

Beaches have sand Sand is the most obvious feature of a beach. The light-colored, rounded grains slip easily through your hands. (Figure 12.2). Sand is not sticky. Blankets and towels only need a quick shake to remove sand before they are put away for the next beach trip.

Tidal flats have mud **Tidal flats**, often part of *salt marshes,* are located in the intertidal zone (Figure 12.3). However, tidal flats are different from beaches. Tidal flats often have sandy areas, but most of a tidal flat is dark, sticky mud. And the sticky mud can smell very bad! Why are tidal flats different from beaches?

Why are tidal flats and beaches different? Tidal flats and beaches are both made of sediment. Streams and rivers carry the sediment down from the mountains and other high places. The sediment includes small, medium, and large particles when it arrives at both areas. What happens to the sediment after it arrives is what makes tidal flats and beaches different.

VOCABULARY

tidal flat - a flat, muddy area in the intertidal zone.

Figure 12.2: *People enjoy the clean, light-colored, rounded sand grains that slip easily through their hands.*

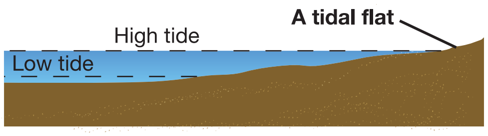


Figure 12.3: *A tidal flat is in the same area as a beach.*

Waves and sand

Tidal flats do not have waves Waves are the key difference between tidal flats and beaches. Tidal flats are not like beaches because they are not affected by waves. Waves change the size of sediment particles. A sample of tidal flat mud contains different kinds and different sizes of sediment particles.

Waves at the beach If you have ever stood on a beach, you know that waves seem to come in and go out from the edge of the beach. If you have swam at the beach, you know it is a thrilling experience. As each wave passes over you, you feel the strong rush of water. The rush and crash of the waves churns the sandy ocean floor. Sand grains are broken into smaller pieces.

What is sand? The largest particles are heavy enough to settle to the ocean floor. The smallest particles and broken grains are carried out to sea with the waves and ocean currents. The remaining particles, called *coarse sand,* build the beach (Figure 12.4). The coarse sand grains tumble and roll over each other with every passing wave. The tumbling action wears away any sharp edges or corners. It also polishes the grains. The only grains that are hard enough to stand this harsh treatment are the minerals—light-colored quartz and feldspar. Both quartz and feldspar contain silica. Beach sand is made of visible, rounded grains of quartz and feldspar.

Quartz

Photo courtesy U.S House Subcommittee on Energy and Natural Resources

Feldspar

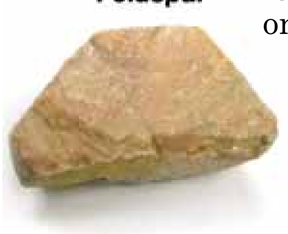


Figure 12.4: *(A) Scientists use special digital cameras to photograph and then measure the size of sand grains on a beach. (B) This image of sand grains is one centimeter across. By studying sand grains on a beach over time, scientists can determine how much wave energy affects the beach.*

SOLVE IT!

Image B in Figure 12.4 is 1 centimeter across. Count how many grains you see going across the bottom of the image.

Multiply the number you get by 100 to estimate out how many grains would fit along a length of one meter.

Waves

Wind causes waves

Ocean waves at a beach occur as a repeating pattern of wave crests and troughs. A **crest** is the high point of a wave, and a **trough** is the low point. The height of a wave is the distance between the wave crest and trough.

Wave height

The wind is the most common cause of ocean waves. The height of a wave is influenced by:

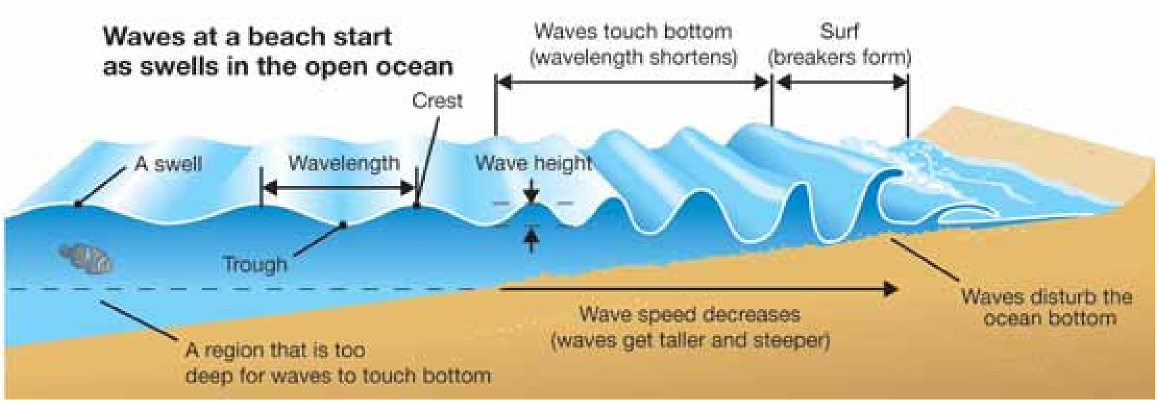
- The strength of the wind.
- How long the wind blows.
- How much open water the wind blows over.

Wavelength

The distance between two wave crests is called the **wavelength** of a wave. The ability of a wave to disturb the ocean bottom as it approaches a beach depends on its wavelength. A passing wave can "reach" down about half its wavelength. That means that a wave with a wavelength of 10 meters can only disturb the ocean bottom if it is five meters deep or less.

Waves stir up sediment on the ocean bottom

Most waves will reach deep enough to affect the part of the shoreface nearest the beach. The lower part of the shoreface is only affected by the strongest waves with the longest wavelengths.



VOCABULARY

crest - the high point of a wave.

trough - the low point of a wave.

wavelength - the distance between two wave crests, or the distance between two wave troughs.

Swells

In the open ocean, most waves look like moving humps of water called swells. Swells can travel great distances over open water without losing much energy because although the swell moves, the water stays close to the same place.

If you could watch a blob of water as a swell passed by, you would see it move in a circle. First the blob would drop and move toward the approaching swell. Then the swell would lift the blob and push it forward. Finally, the blob would drop back to its starting place. Because the blob would end up right where it started, little energy is lost. That's why swells can travel great distances without losing much energy.

By the time a swell reaches a beach, if it has a lot of energy, it can become a huge breaker! A breaker is a wave that becomes foamy as it hits the beach.

12.1 Section Review

1. What are the two names given to the area that lies between the high and low tide lines?
2. Why is the lower shoreface bumpy?
3. What is different about the sediment you find at a beach versus a tidal flat?
4. What natural phenomenon happens at beaches but not at tidal flats? How does this phenomenon affect the sediment found at these locations?
5. What can scientists learn from studying and measuring the size of sand grains at a beach?
6. How do waves affect the smoothness of sand grains?
7. Beach sand is made mostly of what two minerals?
8. What causes waves?
9. What three factors affect the height of a wave?
10. Why are swells able to travel great distances without losing much energy?
11. The wavelength of a wave in the open ocean is 12 meters. At what depth will it begin to stir up sediments as it comes toward the beach?

    a. 5 meters   b. 6 meters
    c. 12 meters   d. 24 meters

12. Challenge questions:
    a. What is the difference between high tide level, sea level, and low tide level at a beach or tidal flat?
    b. Most coastlines on Earth experience high and low tide levels at least once a day. What causes the water level to change at coastlines?

CHALLENGE

Tidal flats and beaches are special environments. Use the Internet or reference books to find out what kinds of plants and animals live in tidal flats. Then, find out what kinds of plants and animals live on beaches. Make a poster to display what you learn.

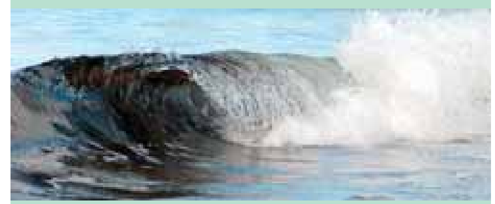
STUDY SKILLS

Surf while you study

You can improve how fast you learn by applying your knowledge to new situations.

For example, the answer to review question 9 is related to why some of the biggest breakers are found at the shore lines of the Hawaiian Islands. These big breakers are why the sport of surfing is very popular there.

Do some Internet surfing to find out why Hawaii is such a good spot for big breaking waves.



12.2 Waves Shape Beaches

The shape and appearance of a beach is determined by its waves. In this section, you will learn more about waves, sand, and beaches.

Beaches in winter and summer

Winter versus summer beaches You have learned that fast-moving water will pick up large, heavy particles, and that slow-moving water will drop these particles. Winter waves are stronger than summer waves on the east and west coasts of the United States. Gentle summer waves tend to carry sand from deeper water onto beaches. The stronger winter waves carry the sand back to deeper water (Figure 12.5). This back-and-forth action creates two distinctly different environments on the same beach, a summer beach and a winter beach (Figure 12.6).

What is a bony beach? Waves that create summer and winter beaches are not the same year after year. Just like one summer may have a little more or less rain than another, waves may be more or less energetic from year to year. During the winter, the sand that is removed from the beach winds up in sandbars, not too far out from shore. During a harsh winter, the beach may be eroded by a series of very strong storms. High-energy waves carry away more sand than usual, carrying the sand further out from the shore. After a harsh winter, it may take years for the beach to recover from the erosion. During this recovery time, beach regulars will call it a "bony beach" because the beach is full of rocks.

How does a beach get too much sand? On the other hand, the gentle waves of a mild winter may not remove all of the summer sand. In this case, when the next summer arrives, the beach may start out with an extra amount of sand, and the summer waves will build up even more sand. After several mild winters, the sand may reach unusually high levels.

Figure 12.5: *This is a winter beach. Compare this image to the summer beach image in Section 12.1.*

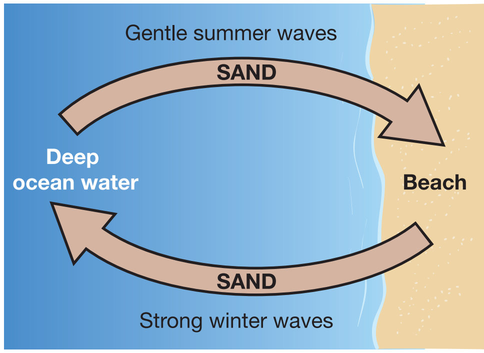


Figure 12.6: *Gentle summer waves carry sand from deep ocean water to beaches. Strong winter waves carry the sand from the beaches to deep ocean water.*

Losing and gaining sand

Beaches lose sand The amount of sand that is moved from the beach to the deep ocean by the summer-winter wave cycle is not even. Over time, more sand is lost than is returned in summer. This sand is lost because eventually it is carried too far from shore for gentle waves to return it. In some places the shore is more durable than others. Waves will cut away the softer rock on both sides of these more durable places. Eventually, the durable places, called sea stacks, will stand in the water separated from the shore.

Rivers and streams supply new sand Beaches never completely wear away because rivers and streams bring new sand from the mountains to the beaches. But this sand doesn't stay in one location. Instead, it flows along the coast.

What is longshore drift? A **coast** is the boundary between land and a body of water like the ocean. This flow of sand along a coast is called **longshore drift**. The beach sand that is lost to deep water is replaced by new sediments flowing from a river or stream. Therefore, sandy beaches do not stay the same—they are constantly changing due to waves, longshore drift, and replenishment by rivers and streams.

VOCABULARY

coast - the boundary between land and a body of water like the ocean.

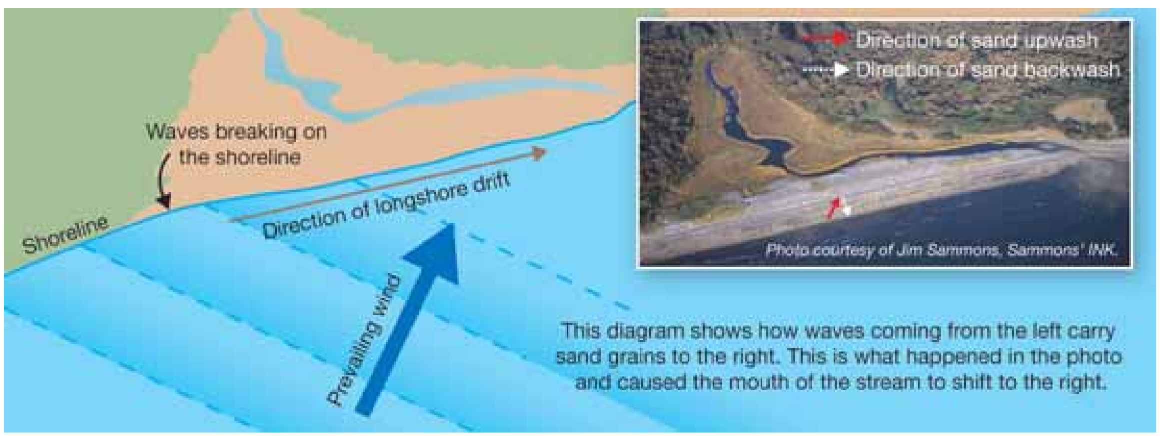
longshore drift - the flow of sand along a coast.

Figure 12.7: *Some sediment is taken from beaches by the action of waves against the shore. In some places the shore resists wearing away. Waves cut away the softer rock on both sides of these more durable places. Eventually, the durable places, called sea stacks, will stand in the water separated from the shore.*

How does longshore drift work?

Waves carry sand in the direction they move

Longshore drift shapes beaches. First of all, waves carry sand grains in the directions that they move. For example, as a wave moves toward and away from the beach, it drags sand grains forward and backward. If a wave came in a straight line to the beach, sand would go up and back the same path. The sand grains would end up just about where they began before the wave broke. Longshore drift occurs because waves approach the beach at an angle. This means the waves come in at one direction (the *upwash*) and then leave the beach at a different angle (the *backwash*). This process causes sand grains to move along the coastline of a beach.



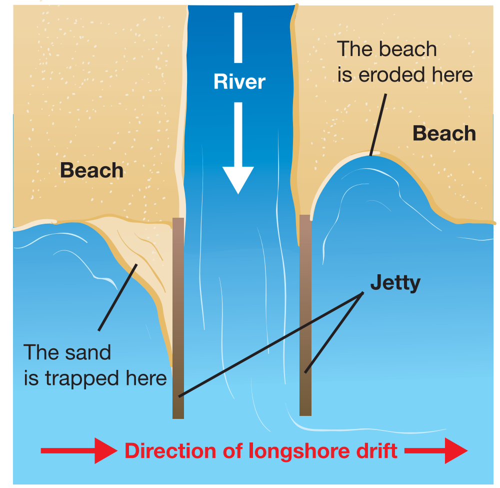


Figure 12.8: *A jetty is a barrier to longshore drift. Sand gets trapped on one side of the jetty, but the beach erodes on the other side.*

Barriers to longshore drift

Because the sand of a beach is constantly coming and going, a beach is like a river of sand. Evidence of the flow of sand at a beach can be seen wherever there are barriers to longshore drift. A *jetty* is a barrier that is built to control or slow down ocean currents near a coast (Figure 12.8). Another barrier is a *breakwater*, which protects a harbor from waves.

What happens to sand at a barrier

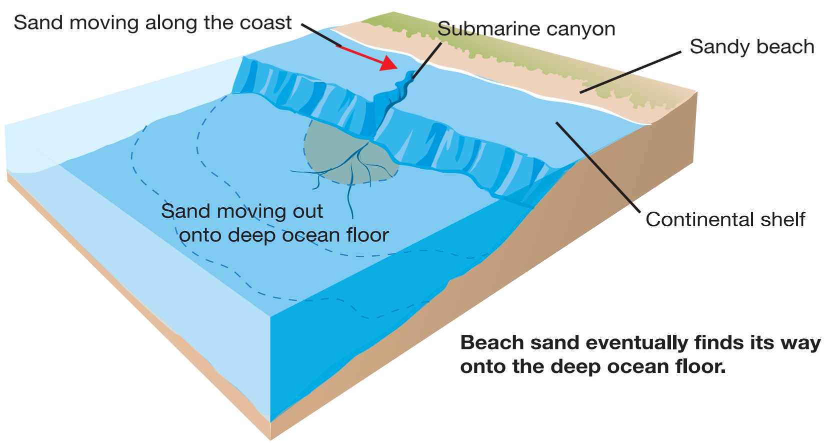
When a jetty or breakwater is located off the coast of the ocean, longshore drift will be disrupted. Sand will quickly build up on the side of the barrier where the waves first hit. At the same time, the beach will erode away on the other side of the barrier.

Protecting a harbor leads to a new problem

Many breakwaters have been built in front of marinas or harbor entrances to protect them from high waves. But soon after solving the problem of high waves, a new problem appears. The water behind the breakwater is calmer than it used to be. The calm water drops its sediment and the marina or harbor entrance fills with sand (Figure 12.9). The only solution is to remove the breakwater or use pumps, called *dredges*, to remove the sand.

Continental shelves and canyons

Eventually, beach sand finds its way to the edge of the **continental shelf** and drops off into very deep water. Sand drifting down the steep face of a continental shelf cuts into the shelf just like streams cut into valleys. These cuts are called *submarine canyons*. As a canyon is cut, the cut grows in the direction of the shore. Some canyons are so close to the shore that sand moving along the coast by longshore drift lands in the canyon and gets deposited directly into the deep ocean basins. Beaches can lose a lot of sand quickly at submarine canyon locations.



VOCABULARY

continental shelf - the ocean bottom that extends from a coast; where the continental shelf ends, the ocean become distinctly deeper.

Figure 12.9: *A breakwater is a barrier to longshore drift that protects harbors. Excess sand can build up near a breakwater.*

12.2 Section Review

1. Which season is known for having stronger waves on the east and west coast of the United States? Which season has weaker waves?
2. How do these seasonal waves affect the shape of a beach?
3. Why is a winter beach sometimes called a bony beach?
4. Which beach profile (A or B) in Figure 12.10 is a summer beach? Which profile is a winter beach?
5. Is the amount of sand moved between the beach and deep ocean water equal over time? Explain.
6. What is the main source of beach sand?
7. If a dam was built to block a river from flowing toward a beach, what might happen to this beach over time?
8. Answer true or false. If a statement is false, rewrite it so that it is true.
   a. Longshore drift occurs when waves move toward and away from a beach along the same path.
   b. A jetty is a barrier that disrupts longshore drift.
   c. A breakwater is a large wave.
   d. Submarine canyons prevent beaches from losing sand.
9. What are sea stacks?
10. How does longshore drift move sand along the beach?
11. What happens when a barrier is built in front of marinas or harbors to protect boats from high waves?
12. Sand drifting down the steep face of a continental shelf creates cuts or valleys, which over time, can migrate toward the coast, becoming quick pathways for sand to move to deeper waters. What are these valleys called?

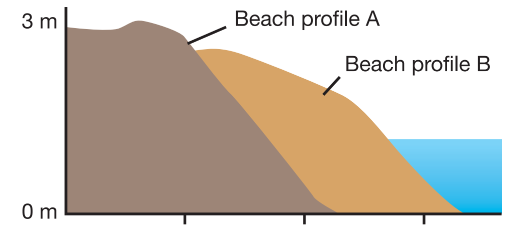


Figure 12.10: *Use this graphic to answer question 4.*

GEOLOGY CONNECTION

From Sea to Shining Sea

The first verse of Katharine Lee Bates's poem *America the Beautiful* (1913) ends with 0this memorable line: "From sea to shining sea." She was envisioning the Atlantic and Pacific oceans that border the United States, but what comes to mind in your "America the beautiful"? The Rocky Mountains, perhaps? The Mississippi River, or the Grand Canyon? One of the Great Lakes? How about a beach beside those shining seas? Beaches are geological formations, and they are both plentiful and varied in this country.

If you have been to the seaside, you know that beaches have big things in common: sand, water, and waves. But they differ in ways people might not notice if they never see other beaches. What are the sand, wind, and waves like? These elements differ depending on location.

Waves are the big thing

Waves are what shape beaches: smaller ones build up beaches, larger waves take sand out to sea. Wave size is affected by wind, land formation, and the distance a wave travels. In the United States, prevailing winds blow from west to east. So if you live on the Pacific Coast, winds blow in the same direction that waves move. These winds increase wave energy and create larger waves.

On the East Coast, winds blow against the waves. So there the winds decrease the energy of waves, creating smaller waves.

Along both coasts, the continental shelf extends into the ocean. The continental shelf is the underwater part of a continent that ends in a steep slope to the ocean floor. The West Coast shelf is narrow and slopes sharply. On the East Coast, the shelf is wider and slopes gradually. Friction from the gradual slope causes East Coast waves to slow down and decrease in size. West Coast waves are not slowed by such friction and so they are larger when they reach shore.

Beach by beach

Keep in mind that winds, waves, tides, and currents all change—and all change what a beach looks like. Its location also changes a beach's size and shape, its sediment and color.

Look at the Pacific Coast in Oregon: Over eons, rock from mountains was moved by rivers and slowly turned into smaller sediment. The beaches may have fine sand or coarse sand with cobblestones. Beaches in the rugged Northwest are not as big as those on the Atlantic Coast; instead, many small beaches and coves dot the coastline. Oregon has the largest area of coastal dunes in all of North America.

Looking south, California has numerous beaches of varying shape, size, and texture. In Northern California, the coast is rugged with strong surf, and there are many cove beaches made of granite from the sea cliffs. On the central coast along the Big Sur, steep cliffs drop into the ocean.

In Southern California, beaches are larger and made of white sand. Sand colors vary depending on the mineral content: At Carmel Beach, ground quartz and feldspar have created white beaches; at Sand City, iron has created amber-colored sand.

On the Atlantic Coast, the Carolinas have miles of white sand beaches. Most South Carolina beaches are wide and flat, and in the south of the state, the coast includes salt marshes, rivers, and creeks. To protect South Carolina beaches from erosion, sea oats are planted on sand dunes to keep them in place.

Photo - courtesy of NOAA - Cap. Albert E. Theberge

Looking north to New England, sandy beaches are a nice complement to the area's rocky coastline. Metamorphic rock with quartz meets the sea along the coastline in Maine.

Cape Cod in Massachusetts was shaped by large ice sheets in the last ice age. As ice melted, the sea level rose. The action of water and waves and tides loosened and moved glacial deposits to create sandy beaches and bays.

Next time you visit the sea, enjoy how it shines—and see how the wind, the waves, the sand all have made it unique.

Questions:

1. What factors influence wave size?
2. Why are West Coast waves bigger than East Coast waves?
3. Describe several big differences between East and West coast beaches.
4. Explain why sand color may vary from beach to beach.

Chapter 12 Connection

CHAPTER ACTIVITY Beach Trip

In this activity, you will go on a beach trip to make observations. Among the things to take with you—take what you have learned from this chapter and its investigations!

Materials

- Supplies for a beach trip (Be sure to bring sunscreen!)
- Field guides to help you identify beach animals and plants
- A notebook or sketch book
- Pencil or pen
- Colored pencils
- A ruler
- Sampling bottles
- Binoculars
- A camera

What you will do

1. Schedule a beach trip with your family or perhaps you will take a beach trip with your whole class.
2. Before the beach trip, write down your predictions for what the beach will be like once you are there. If you have visited this beach before, use your prior experience to help you write your paragraph. If you have never been to this beach, make predictions about what you will see based on reading this chapter.
3. Make a checklist of the items you will need for your beach trip. What kind of beach supplies will you need—a towel? snacks? sunglasses? Be sure to take the items listed in the materials list above.
4. At the beach, use the table to guide your observations. You may want to make a copy of this table in your notebook or sketch book.
   Notes for making observations: If permitted at the beach, collect a small sample of sand to take home. See if you can determine how big your sand grains are using a ruler, but they may be too small to measure easily! Use your binoculars to quietly observe any birds you see from a distance so you don't disturb them. Take photographs too.
5. Observations table:

Things to observe	Observations
Cloud cover Is it cloudy or clear?	
Weather What is the weather like?	
Temperature Is it cold, warm, or hot?	
Waves Are the waves big, medium, or small?	
Sand What color is the sand? Describe the size and shape of the sand.	
Animals What animals do you see? How many of each animal do you see?	
Plants and seaweed What kinds of plants and seaweed do you see?	

6. Make a large bird's eye view diagram of your beach (a diagram that shows what the beach looks like from the air). Make other sketches of the beach and its wildlife.

Applying your knowledge

a. After your beach trip, compile your sketches, photographs, and written observations into a scrapbook.
b. Based on your observations and sketches, how is the sand deposited on the beach and how it is affected by waves?
c. Is your beach being eroded by waves? If so, how?
d. Does your beach have a jetty? Do you see evidence of how the jetty might be affecting the beach? If so, describe what you see.
e. Share your scrapbook with your class.

Chapter 12 Assessment

Vocabulary

Select the correct term to complete the sentences.

longshore drift	continental shelf	intertidal zone
marine	coast	beach
tidal flat	crest	trough
wavelength		

Section 12.1

1. Sea water, a fish that lives in the ocean, and seaweed are all part of the _____ environment.
2. The sandy zone above the foreshore in a shallow marine environment is called a _____.
3. The _____ lies between the high and low tide lines.
4. A _____ is a muddy, flat area in the intertidal zone.
5. _____ is the distance between two wave crests.
6. The _____ is the high point of a wave while the _____ is the low point.

Section 12.2

7. In the end, beach sand finds its way to the boundary between the ocean and land called the _____.
8. The flow of sand along the coast is called _____.
9. Eventually, beach sand moves out to the _____ and then drops off into deep water.

Concepts

Section 12.1

1. How does the surface of the lower shoreface bottom compare to the upper shoreface bottom? Why?
2. What is meant by the term sea level?
3. Where does the sand on a beach come from? What is sand made of?
4. What is the difference between the sediment in a tidal flat and the sediment at a beach?
5. Which condition below *does not* affect the height of a wave?

a. how long the wind blows	b. the strength of the wind
c. how much open water the wind blows over	d. whether the wind is from the north or the south

Section 12.2

6. Is it possible for a beach to get too much sand? If so, how does this happen?
7. What are sea stacks?
8. When sediment reaches a beach from a river, does it stay in one place? Describe at least one thing that can happen to this sand.
9. What is the difference between a jetty and a breakwater?
10. Look at Figure 12.8 in the text. Make a sketch of this diagram and indicate the place that would be best to have a public beach. Explain your answer.

Math and Writing Skills

Section 12.1

1. For some people, the coast is their favorite place to be. Write a paragraph or story about visiting a beach, intertidal area, or tidal flat. Your story can be real or made up. However, you must describe the appearance of the coastal area in your story or paragraph.

2. The intertidal zone can be a place with many different kinds of organisms. Some of these include barnacles, sea stars, crabs, and many different varieties of seaweed. Find out for yourself about the organisms of the intertidal. Pick one organism and write about it.
3. One type of seaweed called the sea palm (*Postelsia palmaeformis*) lives on the northern west coast of the United States. You have read that waves can break down rocks to sand. Research this fascinating seaweed and find out how it is adapted to survive waves. If you have trouble finding information, find a picture and predict from its appearance how it survives.
4. Which situation would potentially make a bigger wave?
   a. If wind blew over the ocean surface for a distance of 10 kilometers.
   b. If wind blew over the ocean surface for a distance of 5 kilometers.
5. Which situation would potentially make a bigger wave?
   a. If wind blew at a speed of 10 kilometers per hour over the ocean.
   b. If wind blew at a speed of 30 kilometers per hour over the ocean.
6. A wave coming in towards a beach has a wavelength of 12 meters. At what depth will it disturb the ocean bottom?

Section 12.2

7. Imagine you are a particle of sand on a beach. What effect would longshore drift have on you? Write a short paragraph in answer to this question.

Chapter Project—Looking at Sand

Gather sand samples in jars or bags from your own travels or ask friends to send you samples of sand (if they live on or near a beach). Note: Only collect samples if it is permitted at the beach! Make sure each sample of sand you collect is labeled with its location and date. When you have gathered at least three samples, look at each one. Place some of each sample in separate dishes. Copy the table below on a separate piece of paper and fill it in as you make your observations.

In order to determine the types of materials present, you may have to get help from your teacher. Quartz and feldspar are common minerals in sand. Magnetite is common in California sand and can be identified by passing a magnet through the sand—the magnet attracts the particles. You may need a magnifying glass to see and identify particles that are parts of shells.

Location	Size and shape of the grains	Color or colors of the grains	Which types of weathered material are present?					What do your observations tell you about the how much weathering by waves occurs at this beach?
			Quartz (mineral)	Feldspar (mineral)	Shell fragments	Magnetite (mineral)	Other types of materials	