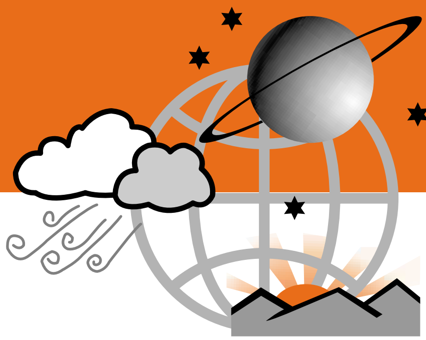


Chapter 16

Oceans and Coastal Processes

THE BLUE PLANET

Scientists' ability to study other planets has increased greatly in the past few decades. The quality of optical telescopes has improved, providing clearer views of the planets in the solar system. Scientists have made even greater strides, placing instruments on or near other planets. In addition, astronomers have detected evidence of dozens of other planets around stars other than the sun. Through studies of other planets, it has become clear that Earth is unique among planets.

The presence of liquid water on Earth's surface is the greatest difference between Earth and other known planets. Early forms of life thrived and evolved in Earth's oceans for several reasons. The oceans protected them from harmful radiation such as the ultraviolet rays that cause sunburn. The circulating water in the oceans also transports oxygen and food to stationary organisms. Other organisms developed that could move through the oceans in search of food. So much of our planet is covered by oceans that Earth has a unique blue color when observed from space.

ACTIVITY 16-1 WATER ON THE PLANETS

Prepare a report on the occurrence of water on and in other planets of our solar system. For each planet, state what astronomers have learned or what they infer about water on or in the planet.

WHAT MAKES OCEAN WATER DIFFERENT?

The explosion of a massive star left a cloud of debris in space that was drawn into various concentrated regions by gravity. The greatest concentration of mass became the sun while smaller clouds of debris were drawn together into the planets. Our planet probably began as a rocky mass without surface water. Although scientists do not know how long it took for oceans to form on Earth, evidence of surface water can be found in rocks that date back to very early in Earth's history.

The Origin of Earth's Water

There are several possible sources of the water now found in the oceans. Perhaps most of the water came from magma originating deep within Earth's molten interior. Most of the water vapor from the earliest eruptions may have remained in the atmosphere until the surface became cool enough for liquid water to accumulate. Even today, water vapor is a major gas component of erupting magma.

Some of the water could have come from outer space. Comets are composed largely of ice. They are sometimes described as dirty snowballs. Comets striking Earth probably contributed some of the water in the oceans. Even rocky meteorites, which bombarded Earth much more frequently early in its history, contained water. There are few remains of Earth's earliest rocks. Details of the formation of oceans will probably remain unknown for many years.

The Composition of Ocean Water

You may have read stories of people stranded at sea who suffered because of a lack of water. Ironically, they were surrounded by more water than they could ever need. However, ocean water contains about 3.5 percent dissolved salts. Figure 16-1 shows the average composition of ocean water.

Much of the water people drink is used to absorb and remove waste products from the body. Drinking ocean water would add unwanted salts rather than help the body get rid of them. That is why people cannot drink ocean water unless most of the salts have been removed. Other than water, the most common substance in seawater is sodium chloride, or table salt. Also present are similar magnesium, calcium,

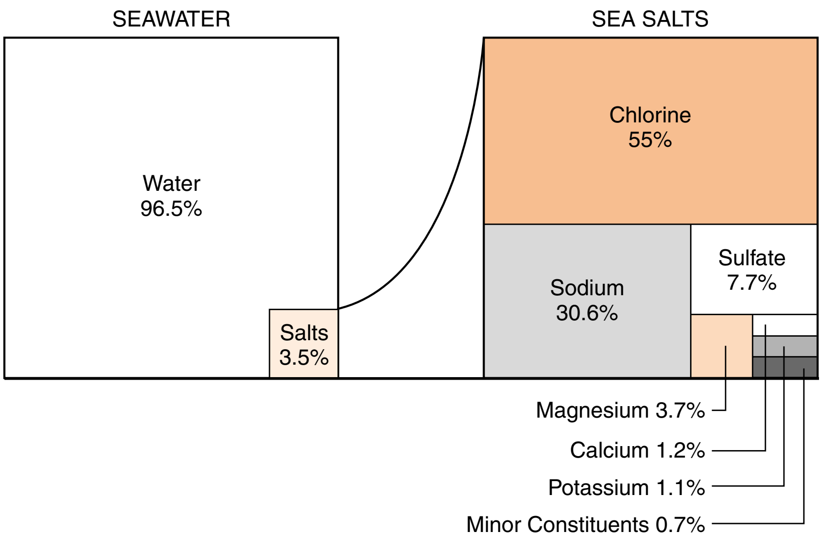


Figure 16-1 On average, about 3.5 percent of the mass of salt water is dissolved salts. The most common salt is sodium chloride, table salt.

and potassium compounds, which are also called salts by chemists.

Source of Salts

Where did all that salt come from? The water in the gases given off by volcanoes is freshwater with few dissolved salts. The kinds of salts found in ocean water are found in the land. Chemical weathering of rocks releases salts. Overland flow (runoff) and groundwater dissolve the salts in bedrock and soil, delivering about 4 billion tons of dissolved solids to the ocean each year. In spite of those salts, most of the water entering the oceans is still considered to be freshwater. Additional dissolved substances enter the oceans through deep-sea vents, which release water that has circulated through the rocks of the oceans' bottom.

ACTIVITY 16-2 THE DENSITY OF SEAWATER

Obtain a few cups of clean ocean water, or mix your own in a ratio of 3.5 grams of table salt per liter of freshwater. Carefully pour the water into a balloon. Be sure that there is no air bubble in the balloon, and then tie the end of the balloon. Gently place the balloon in a large container of freshwater. Does it sink or float? What does this tell you about the density of ocean water? Devise a way to measure the volume and mass of the salt water in order to calculate its density.

The Hydrologic Cycle

If the oceans receive mostly freshwater, why are they salty? The oceans are part of the hydrologic cycle. The water that enters the oceans will eventually evaporate into the atmosphere. The average time a molecule of water stays in the ocean is about 4000 years. However, water cannot take along its load of dissolved solids when it evaporates; the salts are left behind.

You might think that through time the oceans would become more and more salty. However, the salinity of ocean water has been in equilibrium for millions of years. Processes that take dissolved substances out of the oceans balance the dissolved salts that enter the ocean. Some ocean organisms remove salts to make hard body parts. In addition, some salts leave the water as precipitates, forming salt deposits.

Salinity and Latitude

The balance between inflow of freshwater and evaporation of salt water depends on latitude. Figure 16-2 shows that at about 25° north and south of the equator there are regions where the oceans are a little more salty than average. This is because the climate at these latitudes is generally dry. Consequently, there is relatively little rainfall and more evaporation of ocean water in these regions. Therefore, the oceans are a little saltier in these desert latitudes.

Near the equator, precipitation is plentiful and rivers such as the Amazon dilute the salt water of the oceans. Ocean

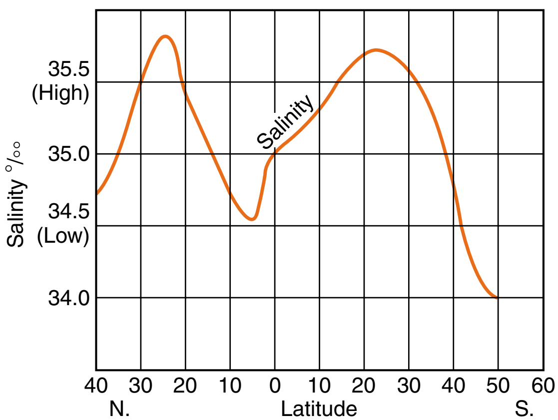


Figure 16-2 In the desert latitudes about 25° north and south of the equator where evaporation of ocean water is most rapid, the salt concentration of the oceans is highest.

water salinity is also lower at high latitudes where temperatures are cool and evaporation is low.

HOW CAN WE INVESTIGATE THE OCEANS?

Until the middle of the last century, finding the depth of the oceans was a tedious process. Rolling out miles of steel cable to reach the ocean bottom took a long time. However, since the Second World War, scientists have been able to measure the depth of the oceans by bouncing sound waves off the seafloor. Figure 16-3 shows the distribution of land elevations

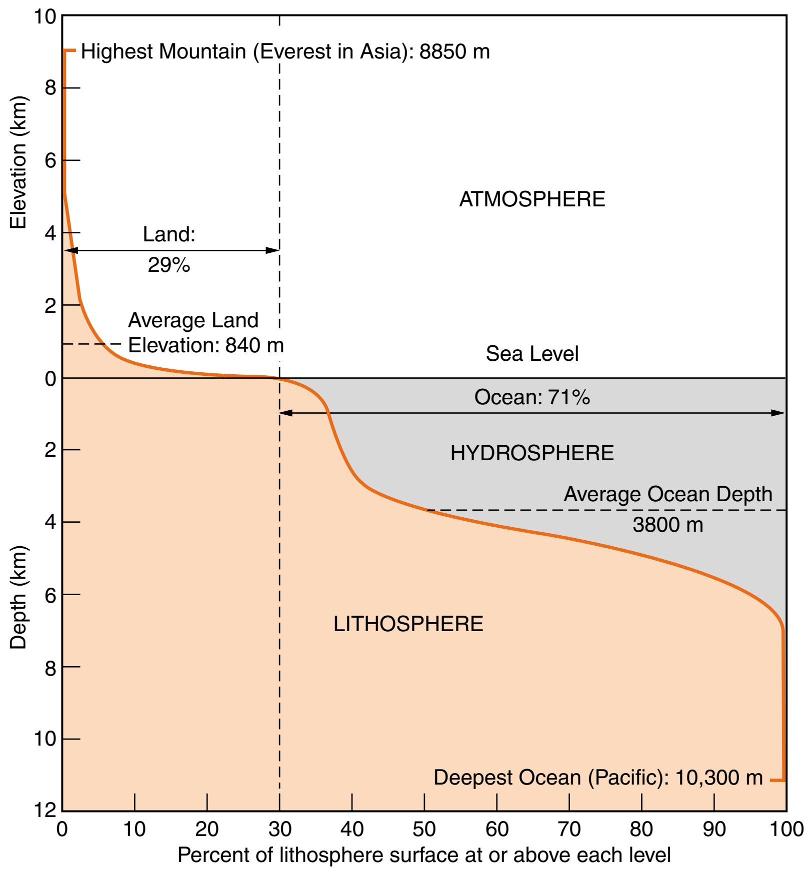


Figure 16-3 This curve shows the surface of the lithosphere at various elevations over Earth's surface. Notice the large portion of the surface just above sea level and about 4 km below sea level. This is not a map, but a variation of a kind of graph called a histogram.

and ocean depths over Earth. From this figure it is clear that the depth of the oceans ranges between sea level at the shore to a maximum depth of more than 10 km.

The Shallow Ocean

Scientists know the most about the shallowest parts of the oceans. Here they can observe the ocean bottom most easily. This is the portion of ocean bottom where light can penetrate, and bottom life is abundant. Divers can descend to several hundred meters, but deeper exploration by humans must be done in special diving chambers known as submersible vehicles. The greatest danger to humans in deep-ocean exploration is the extreme pressure caused by the weight of overlying water. For this reason, most exploration of the deep oceans is now done with remote-controlled diving devices. However, much of the ocean remains unexplored.

The Deep Oceans

Investigations of the oceans have revealed that igneous rocks of mafic composition, such as basalt and gabbro, usually underlie the sediments covering the ocean floor. These rocks are darker in color and more dense than granite and rocks of similar composition that are found in the continents. The two "platforms" seen in Figure 16-3, one just above sea level and another about 4 km below the ocean's surface, are a consequence of this division of Earth's crust into two basic rock types. In Chapter 9, you learned that plate motions constantly renew the ocean bottoms. Upwelling material reaches the surface at the ocean ridges creating new crust. The crust moves away from the ocean ridges toward trenches and zones of subduction carrying the continents with it. At the zones of subduction, oceanic crust is drawn back into the interior while continental rocks are deformed as they resist subduction.

HOW DOES THE WATER IN THE OCEAN CIRCULATE?

The water of the oceans is constantly moving. The primary cause of deep currents is differences in density. Dense water sinks to the bottom and forces water that is less dense to the surface. Near Earth's poles water is cooled, becomes more dense, and sinks to the bottom. Water reaches its greatest density at a temperature of 4°C. Over all the planet, deep-ocean water is near freezing.

Surface temperatures vary considerably with latitude: warmer near the equator and colder near the poles. The sinking of cold water at the poles must be balanced by upwelling that brings deep water back to the surface. Cold water can hold more oxygen and support more marine life than warm water. For this reason, upwelling, cold currents commonly bring nutrients to the surface in some of the world's best fishing grounds.

The Coriolis Effect

The circulation of surface water follows wind circulation. Both are affected by Earth's rotation. Winds and ocean currents generally curve as they travel long distances over Earth's surface. This curvature is called the **Coriolis effect**. Actually, the winds and ocean currents are going as straight as they can, but Earth's rotation makes them appear to curve to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.

Figure 16-4 on page 364 is a map of the world showing the most common surface current directions. Notice that most of the currents in the North Atlantic follow a circular path curving constantly to the right in a great clockwise circle. The currents in the northern part of the Pacific Ocean also follow this clockwise (to the right) pattern. Currents in the South Atlantic and southern parts of the Pacific Ocean curve to the left in a counterclockwise pattern.

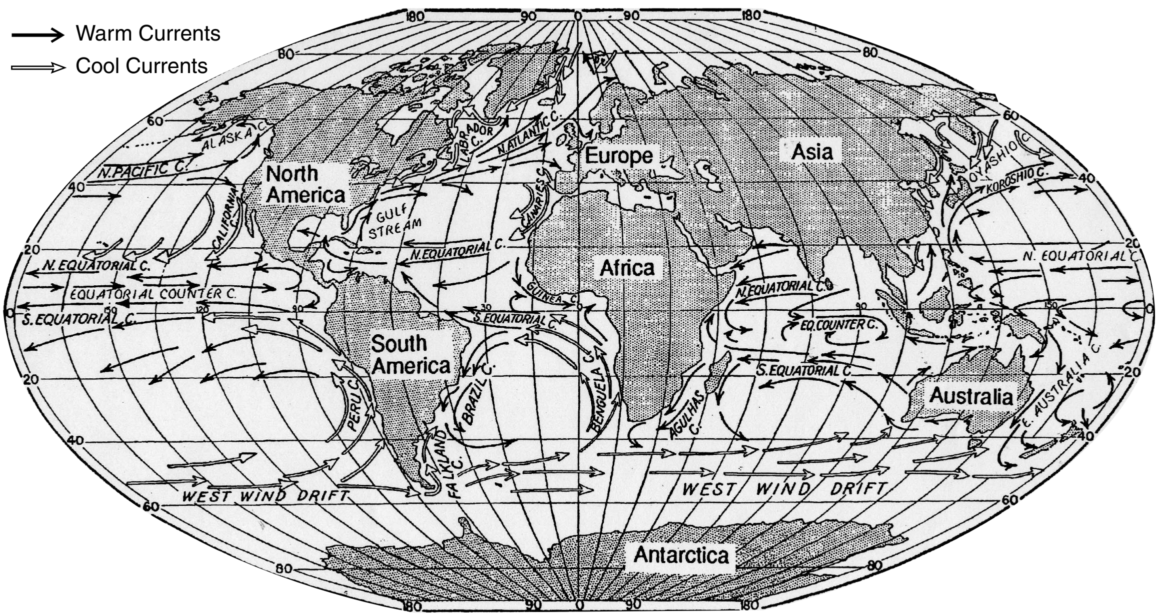


Figure 16-4 Surface currents in the world's oceans generally follow circular routes curving to the right, in clockwise patterns, in the Northern Hemisphere and circling to the left, in counterclockwise motion, in the Southern Hemisphere.

ACTIVITY 16-3 OBSERVING GYRES

A gyre is a large, curving pattern of circulation in the ocean. Use the surface ocean current map in the *Earth Science Reference Tables*, or Figure 16-4, to locate gyres in the Northern Hemisphere as well as in the Southern Hemisphere. For each gyre, list the ocean or part of an ocean it occupies, the names of the surface currents that form the gyre, and the direction in which it circulates (clockwise or counterclockwise). What is the most common direction of circulation in each hemisphere?

Currents and Climate

Ocean currents influence the climates of coastal locations. The temperature of ocean water does not change as quickly as the temperature of rock and soil. Therefore, coastal locations usually have a smaller range of temperature than do inland locations. Cold and warm currents also affect coastal temperatures. For example, people who live along the coast of California are not as likely to swim in the ocean as people who live along the Gulf of Mexico or the Atlantic coastline of the United States. Cold ocean currents along the California coast keep the water temperature too chilly for most swimmers, even in the summer. The cool ocean water also prevents summer temperatures from getting too hot along the coast of southern California.

The climate along the southern coast of Alaska is moderated by relatively warm ocean water. Summer and winter temperatures are relatively mild in this part of Alaska. Palm trees grow in some areas along the west coast of Great Britain where the warm currents of the Gulf Stream and the North Atlantic Current moderate winter temperatures. These coastal locations have winters far less severe than central European cities that are far from the ocean. By looking at the arrows on Figure 16-4 you can tell where warm or cool ocean currents affect coastal areas. The black arrows show warm currents and the white arrows show cool currents.

El Niño

In recent decades, scientists have become more aware of how changes in ocean currents can affect the climate over large areas. Most of the time, cold ocean currents and nutrient-rich water are found off the western coast of South America. Good fishing in this region provides food and employment in oceanside villages. However, in some years the upwelling of cold water is replaced by warm water, which reduces fish production. This usually happens about the time of the Christmas holidays. Local inhabitants call it **El Niño**, a Spanish term for the Christ Child, although it is an unwelcome "Christmas present." However, this event affects more than the local fishing industry. A strong El Niño can cause increased winter rain and flooding along the coast of California and drought in the western Pacific. The relationship between ocean currents and regional climatic changes is giving scientists new methods to predict weather and prepare for its consequences.

WHAT ARE THE TIDES?

Many people who live along ocean coastlines are aware of the periodic rise and fall of the oceans. The twice-daily cycle of change in sea level is known as the **tides**. Currents associated with tides can affect fishing and the ability of boats to navigate in some places. If a storm strikes a coastal area at high tide, wave and water damage is likely to be greater than from a storm that comes ashore at low tide.

Tidal range is the difference between the lowest water level and the highest water level. Most locations have two high tides and two low tides every day, but some places have only a single daily cycle. In some locations, the change in sea level is too small to be noticeable. However, in the Bay of Fundy, along the eastern coast of Canada, the tidal range can be as much as 15 meters. This is about the height of a four-story building. Figure 16-5 shows a beach along the coast of Mexico at high tide. Figure 16-6 shows the same beach at low tide about 6 hours later.

Figure 16-5 High tide at Puerto Peñasco, Mexico. The gravitational pull of the moon and the sun cause sea level to change in a cycle known as the tides.

Figure 16-6 Low tide at Puerto Peñasco, Mexico. Most locations experience two cycles of high and low tides in a period of just over 24 hours.

ACTIVITY 16-4 EXTREMES OF TIDAL RANGES

Prepare a report that identifies places around the world that have an unusually large or small range of ocean tides. Plot these locations on a world map. Why do some locations have higher tides than others, and how do these extreme tides affect the local area?

Gravity

Gravity is the force of attraction between any two or more objects. The force of gravity holds Earth in its path around the sun. It also keeps the moon in orbit around Earth.

People do not feel the gravitational attraction between their body and most of the objects around them because the objects are too small. People certainly do feel the attraction between their body and Earth. That force is weight. It is a strong force because Earth is so massive and because we are so close to it. If you climb a tall mountain, you move a little farther from the center of Earth. This decreases your weight, although the change is too small to observe without careful measurement. If you could move far enough above Earth into space you would actually notice a decrease in your weight. Astronauts in orbit around Earth feel completely weightless as the result of their distance above Earth and their orbital motion.

The tides are caused by gravity of the moon and the sun. Although the moon is much smaller than the sun, it is much closer to Earth. Therefore, the moon has a greater gravitation effect on Earth than does the sun.

Moon and Tides

Consider how the moon's gravity affects the solid Earth and the oceans. The moon pulls most strongly on the part of Earth closest to it. When the moon is directly over the ocean, this part of the ocean experiences a high tide. The moon pulls less strongly on the solid Earth, but it does pull Earth away from the water on the side of Earth away from the moon. So there is also a high tide on the side of Earth away from the moon. That is why most locations have two high tides each 24-hour day. Figure 16-7 shows how the moon pulls more strongly on the side of Earth closer to the moon.

Sun and Tides

The sun also influences ocean tides. When Earth, sun, and moon are in a line with one another, the highest, or **spring tides**, occur. At spring tides, the sun and moon do not need to

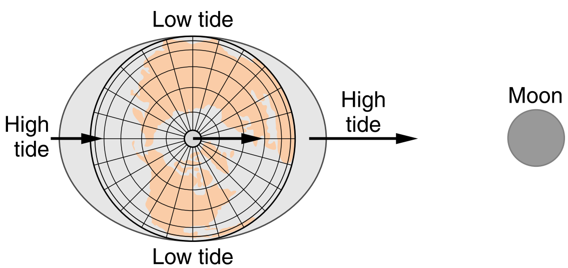


Figure 16-7 Tides are caused mainly by gravity of the moon. The moon pulls water on the near side of Earth away from the solid Earth. It also pulls Earth away from water are the far side. This is why most locations have two high tides every 24 hours. (The length of the arrows represents the strength of the moon's gravity.) Distances are not to scale.

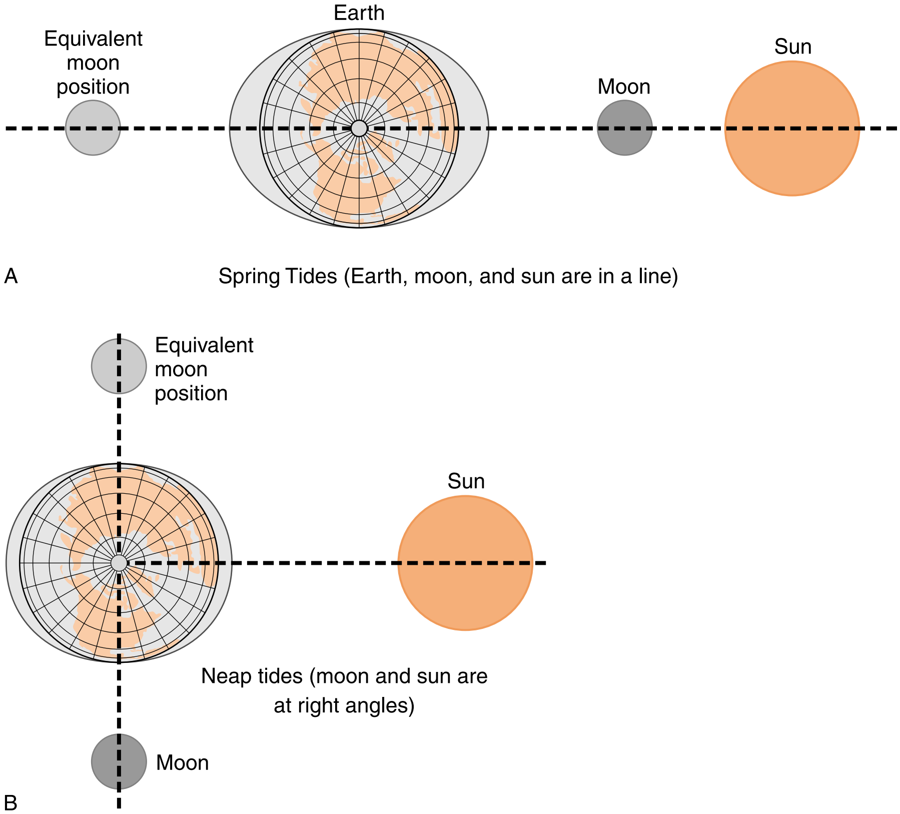


Figure 16-8 A and B: The tidal range at any location depends on the angle between Earth, sun, and moon. When they are in a line (A), the greatest range, or spring tides, occur. The smallest tidal range happens when the sun and moon are at right angles to Earth (B). (Neither distances nor size of the sun are to scale.)

be on the same side of Earth. (See Figure 16-8A.) The range of the tides is the lowest when the sun and moon are at right angles to Earth, and **neap tides** occur. Figure 16-8B shows the configuration of Earth, sun, and moon at neap tides.

The moon orbits Earth every 27 days. As the moon orbits Earth, you see a different portion of its lighted surface—that is why the more of the moon is visible on some nights than on others. Therefore, the period of the tides is not exactly 12 or 24 hours. Each day the moon seems to fall behind the sun by about an hour. A full cycle of the tides is about 12.5 hours, or 25 hours in places that only experience one cycle per day.

ACTIVITY 16-5 **GRAPHING THE TIDES**

Graph the height and time of tides. (Graph time on the horizontal axis and water height on the vertical axis.) If you live on the coast, you may be able collect your own data, or you can use data from a local newspaper. If you live inland, you can use data from the Internet.

HOW DO COASTLINES CHANGE?

In earlier chapters, you read about erosion caused by glaciers, wind, runing water, and gravity acting alone. It is now time to consider coastal erosion and the movement of sediments along coastlines. When you think of visiting an ocean beach you may picture a broad strip of sand where you can play, rest, get a suntan, or enjoy the water. You may not realize that the beach is a dynamic part of a system that transports sediment. The sediment of which the beach is composed is on a journey that transports weathered rock from the land into the ocean. A beach is one of Earth's most active environments of deposition and erosion.

There are two primary sources of sediment for beaches. Waves, particularly in storms, erode the coast and cause the shoreline to migrate toward the land. Rock and sediment fall or are washed onto the beach. Streams and rivers sweep other material into the ocean. Beaches are zones of transport where sediments move along the shore by wave action and currents. Figure 16-9 shows a wide beach composed of sediment eroded from the cliff behind the beach.

Waves

The energy of most waves comes from wind. The greater the wind's velocity and the greater the distance it blows over open water, the larger the waves it creates. Because winds

Figure 16-9 The sand on this beach came from erosion of the cliffs behind the beach. There are no rivers nearby to supply sediment from inland areas.

can blow for greater distances over the ocean than over a lake, ocean waves are usually larger than waves on lakes. Friction between moving air and the surface of the water sets up waves that move forward in the direction of the wind.

The waves you observe can be deceiving. It may look as if the water is moving forward with the waves. However, energy not water is transferred by waves. Figure 16-10 on page 372 shows that as the energy of the wave moves forward, surface water moves in circles. Deep water is not affected by waves. When the wave enters shallow water near shore, the crest moves faster than the bottom of the wave and a breaker forms. As the wave breaks, it gives up its energy along the shore. This energy can do three things along the beach:

1. By causing abrasion, wave energy breaks up sand and rock in the surf zone. (You may recall from Chapter 11 that abrasion is the wearing away of sediments caused by collisions.)
2. Wave energy can erode the beach, including sediments and rock behind the beach.
3. Wave energy transports sand and sediment parallel to the shore.

Longshore Transport

Most beaches have a region called the surf zone. The **surf zone** extends from where the waves' base touches the bottom (a depth of about half the distance between wave crests) to

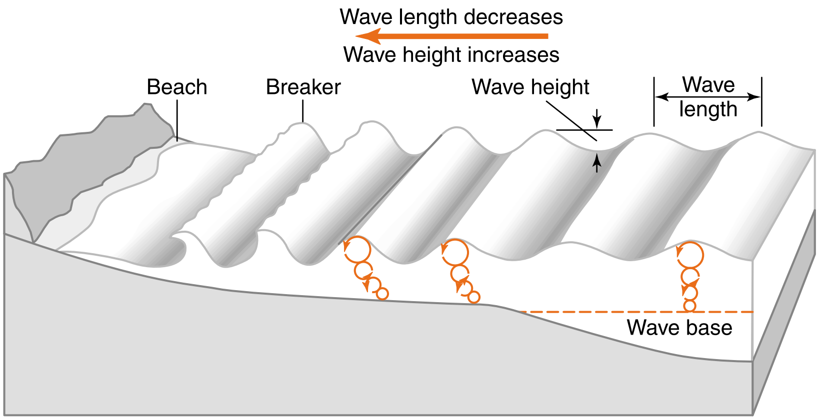


Figure 16-10 Ocean waves are driven by winds. In deep water, waves make the surface water move in circles as they carry their energy forward. Waves break in shallow water, giving up their energy to abrade and transport beach sediments.

the upper limit the waves reach on the beach. The surf zone along most beaches is like a river. Waves cause sand to wash onto the beach with the breakers and then wash back into the water with the return flow. If the waves approach the beach at a right angle, head on, this could be the whole story. However, most waves approach at a different angle. The result is a zigzag motion that carries sand (or whatever sediment the beach is made of) downwind along the beach as shown in Figure 16-11. The resulting motion of the water along the shore

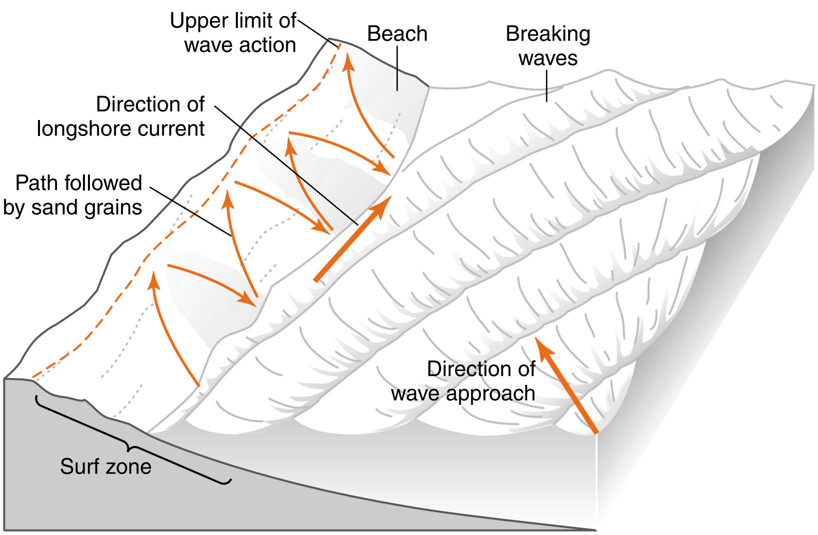


Figure 16-11 As waves wash onto a beach, beach sediment moves forward and back in the surf zone. Beach sediment is also carried parallel to the shore in the downwind direction. The result is longshore transport.

is called a longshore current, and the motion of the sediment is known as **longshore transport**.

Depositional Features

A variety of coastal features are related to wave erosion and longshore transport. Sometimes the advance and retreat of the waves deposits sand that forms low ridges along the shore. They are called **sandbars**. If you have ever waded in the ocean along a sandy beach and encountered a shallow area separated from the shore by deeper water, you have found an underwater sandbar.

A spit is a sandbar that forms a continuation of a beach into deep water. Spits sometimes grow across bays, forming a baymouth bar. Similar offshore features that rise above sea level are **barrier islands**. A shallow bay called a lagoon separates barrier islands from the mainland.

The maps of New York State in the *Earth Science Reference Tables* (Figures 15-9 and 18-8) show the series of islands that separate the south shore of Long Island from the Atlantic Ocean. Jones Beach and Fire Island are a part of this series of barrier islands. These features are common on gently sloping coastlines with abundant sand.

Beaches Figure 16-12 A, B, and C on page 374 illustrates a sequence of events in a shore area with a sandy beach. Part A shows a shoreline in balance. Beach sand originates from sediment carried by the river on the right and eroded from the bluffs along the shore. Waves from the southeast bend as they enter shallow water near the shore, and a longshore current carries sand westward. The sand spit growing across the bay makes it clear that the principal direction of sand carried by longshore transport is toward the west. Part B shows a breakwater built parallel to the shore to protect boats from large waves. A groin/pier has been built from the shore out into the ocean. The structures are very new in Part B and no changes in the beach are visible. Part C shows how the beach changes in response to these two obstructions. The beach gets

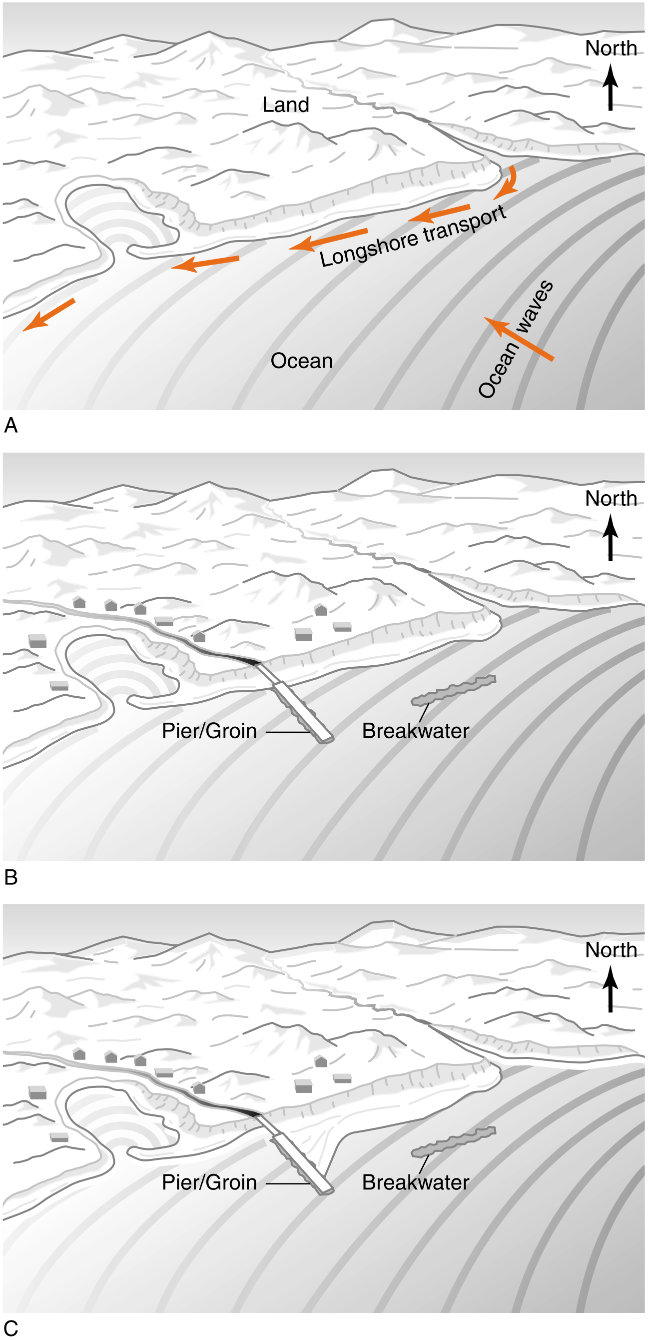


Figure 16-12 (A, B, and C) Part A shows a natural shoreline in dynamic balance. The construction of a breakwater and a groin/pier are shown in Part B. Part C shows how these structures cause the beach and shoreline to change.

wider behind the offshore breakwater as sand builds outward from the beach. This is because wave energy has been reduced behind the breakwater and deposition increases. Westward transport deposits sand on the upwind side of the solid pier. However, the beach shrinks on the downwind side where the flow of sand has been stopped. Even the sand spit is reduced because sand movement was stopped by the groin/pier. In general, when a groin or solid pier is constructed into the ocean in a region of longshore transport, the beach becomes wider on the upwind side and narrower in the downwind side.

ACTIVITY 16-6 COASTLINES AND HUMAN INTERVENTION

While this activity may be more meaningful if you live near a coastline, you may be able to find useful library references or information on the Internet. Prepare a brief report about how a real shore area changed when one or more structures were built into the water. If possible, use maps and images as a part of your report.

HOW SHOULD WE MANAGE ACTIVE SHORELINES?

Humans affect shorelines in many ways. People increase shoreline erosion by trampling on protective vegetation, especially in sand dunes. To protect the beach or unstable features, people build breakwaters, groins, and jetties. This is common in areas where shoreline erosion threatens buildings or other property. Dunes and hills are flattened to make building sites and parking areas. It is important to understand that shore areas are delicate and dynamic features. A growing number of citizens are recognizing that the best way to manage changing coastal regions is to restrict development and allow natural processes to continue without human interference.

Social Issues

Coastal regions are popular home and vacation sites. Recreational opportunities, including swimming, boating, and fishing, make beachfront property highly valued. However, there is discussion of whether there should be private ownership of beaches. In addition, people debate the wisdom of building on unstable areas near shorelines.

This is especially true around New York City and near other urban areas. Should the beaches of Long Island be playgrounds for the wealthy, or should they be available to everyone? Should anyone be allowed to walk along ocean beaches? Should people be allowed to construct homes in unstable, sandy areas and low areas that are subject to storms and flooding? Do roads and buildings seriously affect the natural resources of oceanfront property? Beachside communities constantly deal with these issues. There are probably no solutions acceptable to everyone. Governments simply try to balance the factors and select the best policies from a wide range of controversial solutions.

ACTIVITY 16-7 ZONING FOR COASTAL PRESERVATION

In a cooperative group, develop a set of policies to guide both public and private development of ocean coastal areas. Prepare a document that could be given to coastal communities to help them develop zoning regulations for their ocean front areas.

TERMS TO KNOW

barrier island	**El Niño**	**neap tides**	**spring tides**
Coriolis effect	**longshore transport**	**sandbar**	**surf zone**

CHAPTER REVIEW QUESTIONS

1. A student took home several gallons of unpolluted ocean water and boiled away all the water in a clean metal pot. Which statement below best describes the appearance of the bottom of the pan?

(1) The pan was as clean as it was before the water was boiled away.
(2) A film of calcite was left in the bottom of the pan.
(3) A substance resembling table salt was left in the bottom of the pan.
(4) The pan contained a transparent film of quartz along the bottom.

2. Swimmers notice that it is easier to float in ocean water than it is to float in freshwater. Why is it easier to float in salt water?

(1) Salt water is more dense than freshwater.
(2) The ocean has larger waves than lakes and rivers.
(3) Ocean water is usually deeper than freshwater.
(4) Ocean water has more dissolved gases than freshwater.

3. Which is the best source of nearly pure water?

(1) ocean water from near the south shore of Long Island
(2) ocean water from 100 km off the south of Long Island
(3) water from a shallow desert lake that has no outlet
(4) water from the Hudson River north of Albany

4. A research ship in the middle of the Pacific Ocean took measurements of ocean water both at the surface and near the ocean bottom 6 km below the surface. In what way is most water from deep in the oceans different from the water they observed near the surface?

(1) The water near the bottom of the ocean is warmer than surface water.
(2) Water near the bottom of the ocean is more dense.
(3) Surface water is salty but bottom water is freshwater.
(4) Water near the bottom receives more light than water near the surface.

5. Which location has a coastal climate that is generally made warmer by the influence of a nearby ocean current?

(1) Southern California
(2) Peru in South America
(3) Brazil in South America
(4) Northwestern Africa near the Canary Islands

6. The Canaries Current along the west coast of Africa and the Peru Current along the west coast of South America are both

(1) warm currents that flow away from the equator
(2) warm currents that flow toward the equator
(3) cool currents that flow away from the equator
(4) cool currents that flow toward the equator

7. Warm water from tropical oceans is carried to northern Europe by the Gulf Stream and the

(1) Alaska Current
(2) Canaries Current
(3) North Atlantic Current
(4) Brazil Current

8. Which surface ocean current transports warm water to higher latitudes?

(1) Labrador Current
(2) Falkland Current
(3) Koroshio Current
(4) Peru Current

9. What is the usual period of time from one high tide the next high tide for most oceanfront locations?

(1) about 1 hour
(2) about 12 hours
(3) about 1 week
(4) about 2 weeks

10. A student recorded these times of three successive high tides at a single location:

9:12 A.M.
9:38 P.M.
10:04 A.M.

What is the approximate time of the next high tide?

(1) 10:12 P.M.
(2) 10:30 P.M.
(3) 10:38 P.M.
(4) 11:04 P.M.

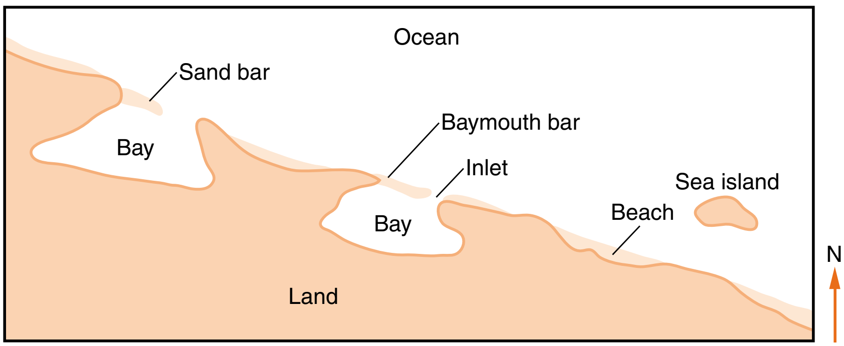
11. Ocean tides are best described as

(1) unpredictable and cyclic
(2) unpredictable and noncyclic
(3) predictable and cyclic
(4) predictable and noncyclic

12. What is the source of most of the quartz and feldspar sand in shallow water along a sandy ocean beach?

(1) Most of the sand came from the deep ocean bottom several kilometers from the shore.
(2) Most of the sand was transported parallel to the beach by waves and currents.
(3) Most of the sand is broken from bedrock at the location.
(4) Most of the sand is the remains of seashells and skeletons of marine organisms.

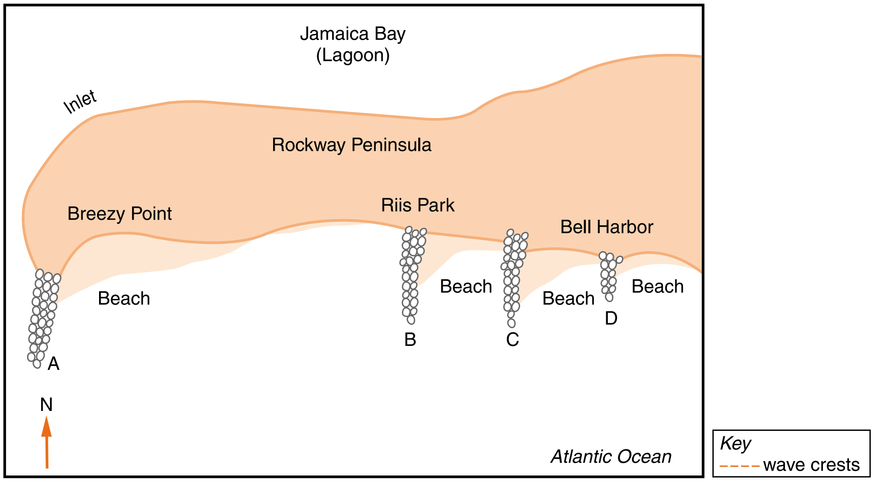
13. The map below shows features along an ocean shoreline.

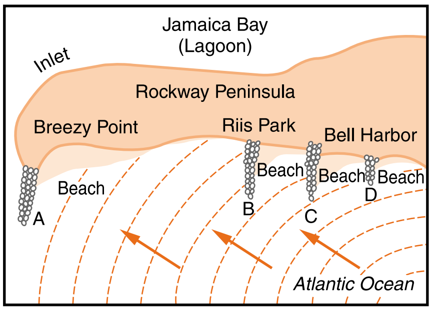


In what general direction is sand moving along the shoreline?

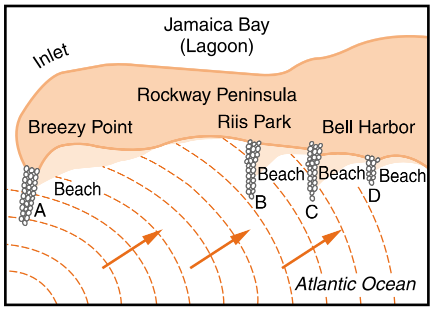
(1) northeast
(2) southeast
(3) northwest
(4) southwest

14. The diagram below shows Rockaway Peninsula along Long Island's south shore. A, B, C, and D are four stone barriers that were built to trap sand being transported along the coast by wave action.

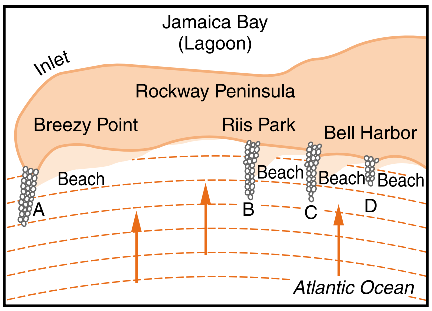




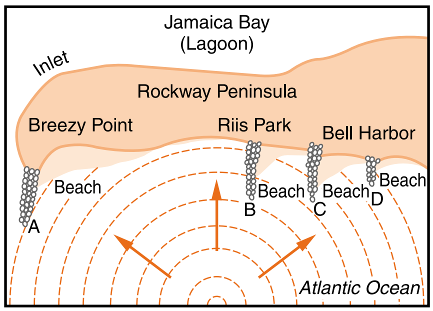
(1)



(3)



(2)



(4)

What can we conclude about the direction of the waves that affect the beaches along this part of the shoreline?

(1) Most of the waves came from the southeast.
(2) Most of the waves came from the southwest.

(3) Most of the waves came from the northeast.
(4) Most of the waves came from the northwest.

15. A solid rock and concrete groin is built from the shore into the ocean at a sandy beach where longshore transport is active. How is the shape of the beach likely to change?

(1) The whole beach will probably get wider.
(2) Only the beach on the side of the groin the wind is coming from will become wider.
(3) Only the beach on the side of the groin the wind is coming from will become narrower.
(4) The whole beach will probably become narrower.

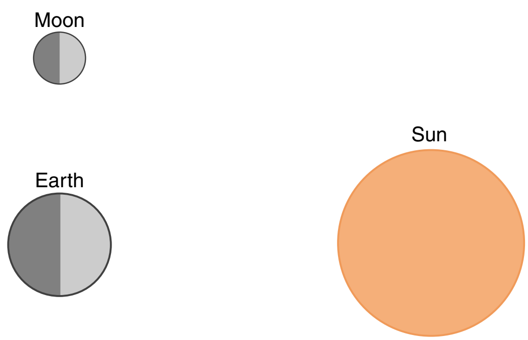
Open-Ended Questions

16. Most surface ocean currents in the northern and southern hemispheres do not curve in the same direction. Describe the direction in which most surface ocean currents curve in the Northern Hemisphere.

17. Describe how ocean currents near the coast change the climate of the southern coastal region of Alaska.

18. If the moon were to orbit at twice its present distance from Earth, this could affect people who live along the oceans. State how an observation that these people could make on a cloudy day would differ from a similar observation with the moon at its present distance.

19. The diagram below represents positions of the sun, moon, and Earth. (The diagram is not to scale.) Show the places on Earth where the highest tides occur at this time by writing the letter "H" in two widely separated places along Earth's surface.



20. The diagram below shows a coastal region in which a solid concrete groin/pier has just been constructed from the shore into deep water. After several years the shoreline near the groin/pier changes. Draw the most likely shape of the new shoreline near the structure.