This chapter will help you answer the following questions:

1. Why are the oceans salty?
2. How do scientists explore the oceans?
3. How does ocean water circulate?
4. What causes the tides?
5. Why do coastlines change?

**WHY IS EARTH CALLED THE BLUE PLANET?**

Scientists’ ability to study other planets has increased greatly over the past few decades. Through studies of other planets, it has become clear that Earth is unique among all known planets. Earth is the only planet known to have liquid water on its surface. So much of our planet is covered by oceans that Earth has a unique blue color when seen from space.

Early forms of life thrived and evolved in Earth’s oceans. The oceans protected them from harmful ultraviolet rays. The water...
circulating in the oceans carried oxygen and food to organisms that did not move. Other organisms developed that could move through the oceans in search of food.

**WHAT MAKES OCEAN WATER DIFFERENT?**

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 in the oceans. Perhaps most of the water came from magma that formed deep within Earth’s molten interior. Most of the water vapor from the earliest eruptions may have remained in the atmosphere until the surface cooled enough for liquid water to collect. Even today, erupting magma contains large amounts of water vapor.

Some of the water could have come from outer space. Comets are composed mostly of ice. They are sometimes described as dirty snowballs. Comets striking Earth probably added some of the water in the oceans. Even rocky meteorites, which showered Earth much more frequently early in its history, contain water. There are few remains of Earth’s earliest rocks; therefore, 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 from a lack of water. Surprisingly, they were surrounded by more water than they could ever need. However, ocean water contains about 3.5 percent dissolved salts. Figure 11-1 shows the average composition of ocean water.

Our bodies use much of the water we drink to absorb and remove waste products. 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 magnesium, calcium, and potassium compounds, which are also called salts by chemists.

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 a state of dynamic equilibrium for millions of years. Processes that take dissolved salts out of the oceans balance the dissolved salts that enter the ocean. Some animals that live in the ocean remove salts to make bones and shells. In addition, some salts leave the water as precipitates, forming salt deposits.

### Source of Salts

Where did all that salt come from? The water given off by volcanoes is freshwater with few dissolved salts. The salts found in ocean water come from the land. Chemical weathering of rocks releases salts. Overland flow (runoff) and groundwater dissolve the salts in bedrock and soil. This amounts to adding 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 considered to be freshwater. Additional dissolved substances, including salts, enter the oceans through deep-sea vents, which release water that has circulated through the rocks that make up the ocean bottom.

**STUDENT ACTIVITY 11-1 —THE DENSITY OF SEAWATER**

Collect a few cups of clean ocean water, or mix your own in a ratio of 3.5 g 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? Find a way to measure the volume and mass of the salt water to calculate its density. Visit the following Web site to try some oceanography activities: [http://www.msc.ucla.edu/oceanglobe/investigations.htm](http://www.msc.ucla.edu/oceanglobe/investigations.htm)

**Salinity Changes with Latitude**

The balance between inflow of freshwater and evaporation of water depends on latitude. At about 25° north and south of the equator there are regions where the oceans are a little saltier 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.

Near the equator, precipitation is plentiful and rivers such as the Amazon dilute the salt water of the oceans. Ocean-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 twentieth century, finding the depth of the oceans was a time-consuming process. Rolling out miles of steel cable to reach the ocean bottom took a long time. Today, oceanographers can measure the depth of the oceans by bouncing sound waves off the seafloor. Figure 11-2 shows the distribution of land elevations and ocean depths over Earth. From this figure it is clear
that the depth of the oceans ranges from sea level at the shore to a maximum depth of more than 10 km.

**Exploring the Shallow Ocean**

Scientists know the most about the shallowest parts of the oceans. Here they can observe the ocean bottom most easily. Where the ocean is shallowest, light can reach the bottom, and life is abundant. Divers using air tanks can dive down a few hundred meters. The greatest danger to humans in ocean exploration is the extreme pressure caused by the weight of overlying water, which limit the depths of dives.
Exploring the Deep Ocean

To explore deeper parts of the oceans, scientists use special diving chambers known as submersibles. However, most exploration of the deepest parts of the ocean is done with remote-controlled diving devices. Figure 11-3 is a model of a remote controlled deep-ocean exploration vehicle.

Exploration of the ocean bottom has found 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 relatively flat parts of the line seen in Figure 11-2 on page 251, one just above sea level and another about 4 km below the ocean’s surface, are a result of this division of Earth’s crust into two basic rock types.

Geological forces renew the ocean bottom through the processes of plate tectonics, which you will learn about in Chapter 15. Upwelling material from deep within Earth 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.

FIGURE 11-3. Due to the extreme pressure in the deepest part of the oceans, widespread exploration by humans is nearly impossible. Remotely operated vehicles such as the one shown in this museum model are the best way to explore the deepest parts of the oceans. Unlike this unusual location, most of the ocean bottoms are as flat and featureless as any land area.
WHY DOES THE WATER IN THE OCEAN CIRCULATE?

The water of the oceans is moving constantly. 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. Therefore, over the entire planet, deep-ocean water is near freezing.

Surface temperatures vary considerably with latitude. It is 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 bring nutrients to the surface in some of the world’s best fishing grounds.

Turbidity Currents

In Chapter 8 you learned about the vertical sorting of sediments that occurs when particles of mixed sizes settle in deep water. Graded bedding occurs on the ocean bottom when sediment-rich streams, sometimes called turbidity currents or density currents, flow down under water slopes. The largest particles usually settle first. These sudden underwater “landslides” move at surprising speeds, sometimes reaching more than 100 km/h (60 mph). The primary factors affecting these currents are their size, flow density, and the slope, or gradient of the ocean bottom.

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 curving 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 3-1 on page 58 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.

**STUDENT ACTIVITY 11-2 — 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 3-1 on page 58, to locate gyres in the Northern Hemisphere and 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 influenced by relatively warm ocean water. Summer and winter temperatures are fairly 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 regulate 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 3-1 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 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 ocean-side 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 people 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. Visit the following Web site to learn about El Niño and coastal change: [http://coastal.er.usgs.gov/hurricanes/elnino/](http://coastal.er.usgs.gov/hurricanes/elnino/)

**WHAT CAUSES THE TIDES?**

People who live along ocean coastlines are familiar with the periodic rise and fall of the oceans. The twice-daily cycle of change in sea level is the **tides**. Currents associated with tides can affect fishing and the ability of boats to sail 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. Visit the following Web site to find current tides data for the USA: [http://tidesandcurrents.noaa.gov/station_retrieve.shtml?type=Current+Data](http://tidesandcurrents.noaa.gov/station_retrieve.shtml?type=Current+Data)

**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 each day. However, some places have only one
daily cycle. In some locations, the change in sea level is too small to be noticeable. On the other hand, in the Bay of Fundy along the eastern coast of Canada, the tidal range can be as much as 15 m. This is about the height of a four-story building. Figure 11-4 A and B were taken along the Bay of Fundy. They show the same scene at high tide and about 6 h later at low tide.

STUDENT ACTIVITY 11-3 —EXTREMES OF TIDAL RANGES

Prepare a report about 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 people and economy?

Gravity

Gravity is the force of attraction between objects. The strength of the force is determined by the masses of the objects and the distance between them. 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. (Your mass, however, remains the same.) 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 the gravitational pull 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 gravitational effect on Earth than does the sun.

### The Moon and Tides

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 has a smaller affect on the solid Earth, so it pulls Earth away from the water on the far side. This causes a high tide on the side of Earth away from the moon. That is why most locations have two high tides each 24-h day. Figure 11-5 shows how the moon pulls more strongly on the ocean water on the side of Earth closer to the moon.

### The 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 be on the same

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**FIGURE 11-5.** The main cause of the tides is the gravitational attraction 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 on the far side. This is why most locations have two high tides every 24 h. (The length of the arrows represents the affect of the moon’s gravity.) Distances are not to scale.
The range of the tides is the lowest when the sun and moon are at right angles to Earth, and neap tides occur. Figure 11-6B shows the configuration of Earth, sun, and moon at neap tides.

The moon orbits Earth every 27 days. Therefore, the period of the tides is not exactly 12 or 24 h. Each day the moon seems to fall behind the sun by about an hour. A full cycle of the tides is about 12.5 h, or roughly 25 h in places that only experience one cycle per day. Figure 11-7 shows the cyclical nature of the tides. The graph clearly shows the daily cycle of the tides and the cycle of the spring and neap tides. Visit the following Web site to see an animation of the tides animation showing the daily cycle, spring and neap tides: http://www.edumedia-sciences.com/a475_l2-tides.html
STUDENT ACTIVITY 11-4  —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, running 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 making up the beach 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
erode (move inland). 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 11-8 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 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 11-9 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. Wave energy breaks up sand and rock in the surf zone by causing abrasion.
2. Wave energy can erode the beach, including sediments and rock on 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 base of the waves touches the bottom (a depth of about half the distance between wave crests) to 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. Most waves approach the beach at an 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 11-10.
The resulting motion of the water along the shore is called a long-shore current, and the motion of the sediment is known as **long-shore transport**. As a result of these processes, oceanfront features change with time.

**Depositional Features**

Many coastal features are related to wave erosion and longshore transport. Sometimes the back-and-forth motion of the waves deposits sand that forms low ridges along the shore. These ridges are called **sandbars**. If you have ever waded in the ocean along a sandy beach and discovered a shallow area separated from the shore by deeper water, you 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.

Figure 11-11 shows 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 a large amount of sand.

**BEACHES** Figure 11-12 A, B, and C 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

![Figure 11-11](image-url)
FIGURE 11-12 A, B, AND C. Part A shows a natural shoreline in dynamic balance. The construction of a breakwater and a pier/groin are shown in Part B. Part C shows how these structures cause the beach and shoreline to change as sand is deposited in some places, such as upwind from a groin. The downwind side usually experiences increased erosion with a narrowing beach.
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 pier/groin has been built from the shore out into the ocean. The structures are new in Part B and no changes in the beach are visible. Part C shows how the beach changes in response to these two barriers. The beach gets 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/groin. 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 pier/groin. 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.

**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 limit development and allow natural processes to continue without human interference.

**Legal Issues**

Coastal regions are popular home and vacation sites. Recreational opportunities, including swimming, boating, and fishing, make beachfront property highly attractive. 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 only 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. We usually try to balance the factors and select the best policies from a wide range of controversial solutions. Visit the following Web site to access the Environmental Atlas of the Great Lakes: http://www.epa.gov/glnpo/atlas/index.html

STUDENT ACTIVITY 11-5  —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 oceanfront areas.

CHAPTER REVIEW QUESTIONS

Part A

1. 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.

2. Which ocean current transports warm, equatorial waters into the cooler regions of Earth?

   (1) California Current
   (2) Guinea Current
   (3) Falkland Current
   (4) Brazil Current
3. A tombolo is a sandy spit that connects a formerly unconnected island to the shoreline. Which process would form a tombolo?

(1) coastal weathering  
(2) Coriolis effect  
(3) shoreline deposition  
(4) spring tides

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

(1) Southern California  
(2) Peru in South America  
(3) The east coast of Australia  
(4) Northwestern Africa near the Canary Island

5. Most of the Gulf Stream ocean current is

(1) warm water that flows southwestward  
(2) warm water that flows northeastward  
(3) cold water that flows southwestward  
(4) cold water that flows southeastward

6. What process most likely formed the barrier islands along the south shore of Long Island, New York?

(1) mass movement  
(2) wave action  
(3) stream erosion  
(4) glacial deposition

7. According to Figure 11-11 on page 262, in what direction are the longshore currents moving along the south shore of Long Island?

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

8. For most oceanfront locations, what is the usual period of time between one high tide and the next high tide?

(1) about 1 h  
(2) about 12 h  
(3) about 1 week  
(4) about 2 weeks
9. Sand from beaches near recent Hawaiian lava flows is angular. Most other beaches, such as those on New York’s Long Island, are composed of more rounded particles.

How can you account for the difference in the shape of sediment particles in these two places?

(1) The ocean temperature is colder at the Hawaii beach.
(2) The Long Island sediment is derived from harder rocks.
(3) The Hawaii beach has larger waves and more storms.
(4) The Long Island sediments have been on the beach longer.

10. Homes built in coastal sand dunes are more likely to suffer storm damage than homes located several miles from the shore. Which is not a factor in making the shorefront homes more vulnerable to storm damage?

(1) nearness to the ocean
(2) foundations built on sand
(3) a cooler summer climate
(4) changes in sea level

Part B

11. To preserve the wide, sandy beaches in a coastal resort, the local government built rocky groins from the top of the beach 50 m straight out into the ocean. After the construction of these groins, how did the beach change?

(1) The size of the sand particles increased near the groins.
(2) The beach became narrower everywhere near the groins.
(3) The beach became wider everywhere near the groins.
(4) The beach became wider in some places and narrower in others.

12. A student visited the seashore at high tide and at low tide to record her observations of the sun, the moon, and the planet Venus. Which observation was most likely recorded at high tide?

(1) The moon was low in the sky.
(2) The moon was high in the sky.
(3) The bright planet Venus was visible.
(4) The bright planet Venus was not visible.
13. A student collected several gallons of unpolluted ocean water. Using a clean metal pot, he boiled away all the water. Which statement best describes what he saw on the bottom of the pan after the water boiled away?

(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.

14. A research ship in the middle of the Pacific Ocean took measurements of ocean water 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.

Part C

Base your answers to questions 15 through 17 on the diagram below, which represents a part of the Atlantic Ocean seafloor. When an earthquake occurred at A, a sediment flow was released. The times indicated at positions B, C, and D show when the sediment flow arrived at each position.
15. Calculate the average gradient of the ocean floor from \( A \) to \( D \). Be sure to start with the appropriate formula and label your answer with the proper units.

16. How did the velocity of the sediment flow change from the time it was first caused until it arrived at \( D \)?

17. Why did the speed of the sediment flow change as it moved from \( A \) to \( B \), \( C \), and \( D \)?

18. In California, the prevailing winds come from the west. Therefore, how does the California Current affect the climate of coastal locations in California?

19. The double image below is of a coastal area before and after a hurricane hit the area. What can local governments do to reduce storm damage to homes in coastal areas without constructing protective structures or changing the natural beach processes?

20. 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.