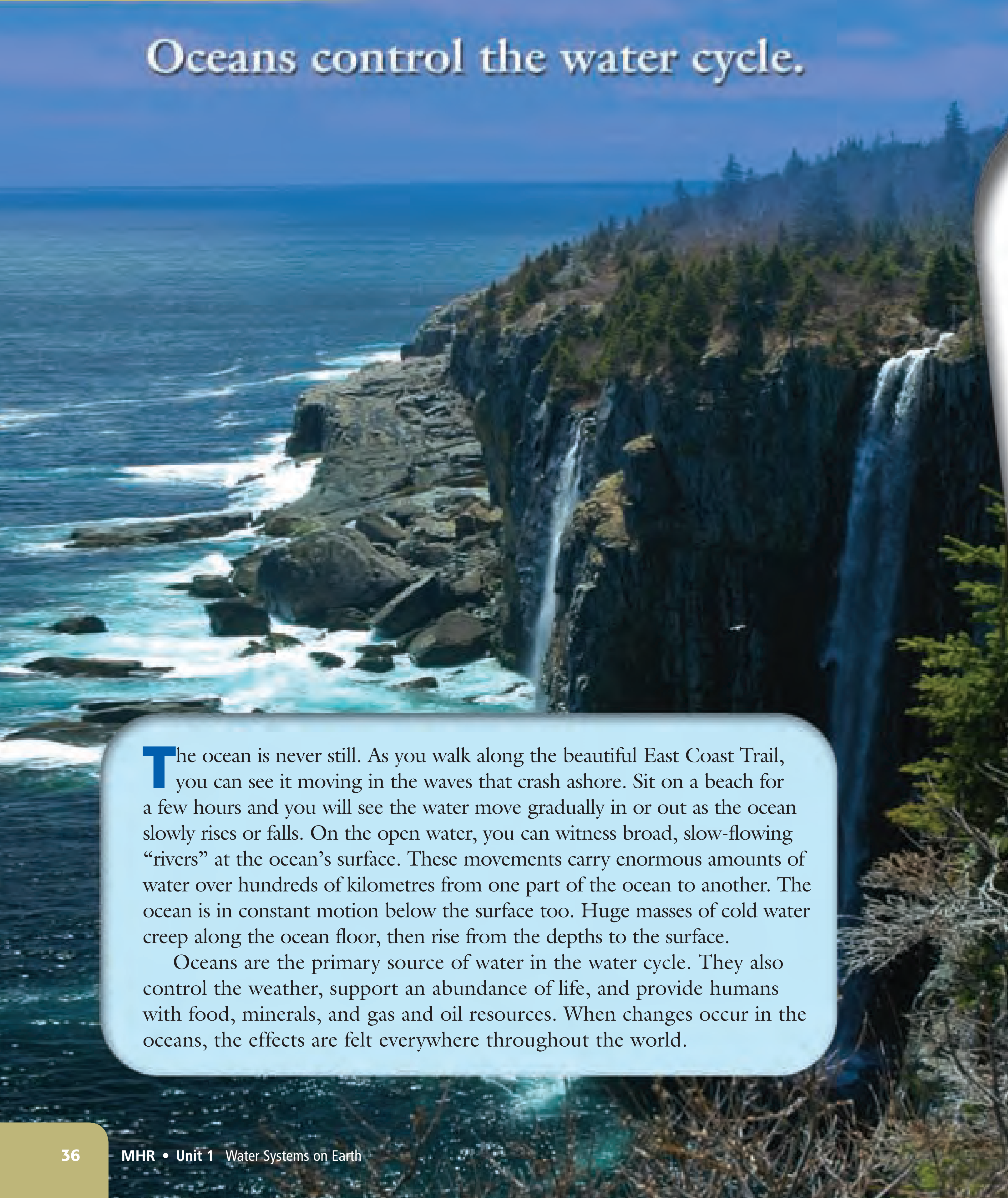
Chapter 2

Oceans control the water cycle.



The ocean is never still. As you walk along the beautiful East Coast Trail, you can see it moving in the waves that crash ashore. Sit on a beach for a few hours and you will see the water move gradually in or out as the ocean slowly rises or falls. On the open water, you can witness broad, slow-flowing "rivers" at the ocean's surface. These movements carry enormous amounts of water over hundreds of kilometres from one part of the ocean to another. The ocean is in constant motion below the surface too. Huge masses of cold water creep along the ocean floor, then rise from the depths to the surface.

Oceans are the primary source of water in the water cycle. They also control the weather, support an abundance of life, and provide humans with food, minerals, and gas and oil resources. When changes occur in the oceans, the effects are felt everywhere throughout the world.

What You Will Learn

In this chapter, you will
- **describe** the features of Earth's ocean basins and the processes that created them
- **define** ocean currents and identify factors that influence their formation
- **describe** waves and tides and their interactions with shorelines

Why It Is Important

No matter where you live, you cannot escape the influence of the ocean. Learning about oceans and their connection to Earth's water cycle helps us to better understand the relationship between human activities and the balance of nature.

Skills You Will Use

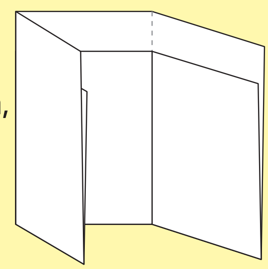
In this chapter, you will
- **investigate** mapping of the sea floor
- **graph** the temperature of ocean water at different depths
- **research** historical disasters and new technologies to prevent erosion

FOLDABLES™ Reading & Study Skills

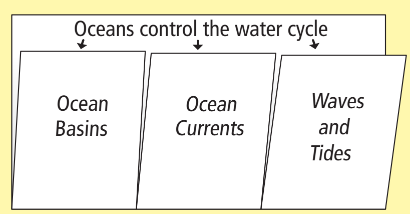
Make the following Foldable to guide your notetaking on Chapter 2.

STEP 1 **Fold** a sheet of unlined legal paper in half lengthwise. Make the back edge about 3 cm longer than the front edge.

STEP 2 **Turn** the paper so the fold is on the bottom. Then, **fold** it into thirds.



STEP 3 **Unfold** and cut only the top layer along both folds to make three tabs. **Label** the Foldable as shown.



Show You Know As you read the chapter, take notes under the appropriate tab to *describe* the features of Earth's ocean basins, *define* ocean currents and sediment movement, and *describe* how waves erode coastlines and how tides are linked to the Moon.

2.1 Ocean Basins

A basin is a low spot in Earth's surface that is completely or partially surrounded by higher land. Oceans are basins into which water has flowed and accumulated over millions of years. The same tectonic processes that gave continents their valleys, mountains, and plains also shaped the ocean floor. Long ridges of mountains, deep trenches, and flat plains are part of the underwater world that is still slowly changing. Through advances in underwater technology, scientists are able to explore the ocean depths and learn more about the ocean environment.

Key Terms

abyssal plain
continental drift
continental shelf
continental slope
ocean ridges
trench

As you learned in Chapter 1, a little over two thirds of Earth's surface is covered by oceans. The five major oceans, in order from largest to smallest, are the Pacific, Atlantic, Indian, Southern, and Arctic (see Figure 2.1). The Southern Ocean includes all the southern portions of the Pacific, Indian, and Atlantic Oceans. It completely surrounds the continent of Antarctica.

Figure 2.1 Earth's oceans

Did You Know?

In 2000, the International Hydrographic Organization created the fifth world ocean – the Southern Ocean – from the southern portions of the Atlantic Ocean, Indian Ocean, and Pacific Ocean. The Southern Ocean completely surrounds Antarctica.

2-1A How Ocean Basins Become Bigger

Find Out ACTIVITY

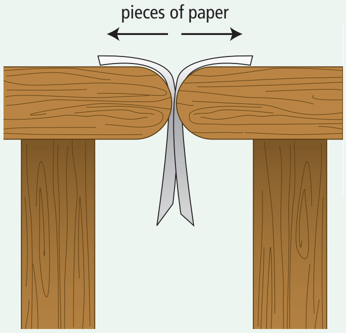
Earth's surface is always in motion because the crust is made up of large, separate plates that float over molten (partially melted) rock. The ocean floor is both moving and getting wider. When molten rock rises to the surface between the plates, it cools and turns to solid rock, creating an ocean ridge. As more molten material comes up, it pushes the new rock away to both sides. This constant process gradually widens the ocean floor. Near the ridge is the young rock, and farther from the ridge is the old rock. In this activity, you will simulate the motion of the plates beneath ocean basins, and calculate how fast the floor is spreading.

Materials

- 2 flat-topped desks (or tables)
- 2 pieces of legal-size paper
- pencil
- calculator
- ruler

What to Do

1. Working with a partner, slide the desks together, leaving only a small gap between. The gap represents a spreading ridge on the bottom of the ocean.
2. Place the pieces of paper together, one on top of the other. Slide them down into the gap between the desks, leaving the top 2 cm of paper sticking up above the desks.



3. Place an X on your piece of paper. Now your partner should place an X opposite of yours on their sheet of paper. The two X's indicate the position where new rock forms at a spreading ridge.
4. Slowly start sliding each piece of paper along the desk tops away from each other.
5. Just before the end of the pieces of paper leaves the gap, place a "Y" near the gap on both pieces of paper.
6. Pull both papers out and measure the distance (to the nearest centimetre) between X and Y on each piece.

What Did You Find Out?

1. (a) What do the two pieces of paper moving in opposite directions represent?
   (b) At the end of the activity, which letter represents the oldest rock? Explain why.
2. How fast plates move away from the spreading ridge is called their rate of motion. It is usually expressed as the distance moved (in centimetres) in a specific time period (a year). To calculate the rate of plate motion in your example, take the distance between X and Y on one piece of paper and divide it by the age (in years) of the oldest rock. Assume that the rock at "X" is 10 years old.
3. Your calculation shows the rate of motion for one plate. Would the plate on the other side of the ridge show the same rate or a different one? Explain your answer.
4. How old would you expect the rock to be at half the distance to X? Explain.
5. Imagine that a plate near a spreading ridge in the Atlantic Ocean was found to have moved 25 000 000 cm in 10 000 000 years. Calculate the rate of plate movement for this plate. How does this rate compare to the rate you calculated above? Can you think of a reason why plates might move at different rates?

Origin of the Oceans

Over 200 million years ago, the surface of Earth looked very different from the one you know today. All of the continents were together in one land mass called Pangea.

Figure 2.2 Over 200 million years ago, all the continents formed one large land mass called Pangea.

Slowly, Pangea began to split up. In a process called plate tectonics, pieces of the land mass began to move over Earth's surface. The entire surface of Earth is made up of large, slow-moving sections of rock called tectonic plates. These sections of rock are solid, but float over a layer of molten rock called magma. As the magma heats up from the heat energy in Earth's core, the molten rock rises. This pressure can force two plates apart. Over millions of years these plates moved the land into the map that we are familiar with today. As they moved into their current position, they formed the oceans that now exist on Earth. Today, the continents are still slowly moving. The Pacific Ocean is actually shrinking while the Atlantic Ocean is getting wider.

Figure 2.3 The process of plate tectonics slowly moved continents into their current position.

The Origin of Ocean Water

Scientists believe that the oceans have been on Earth for more than 3 billion years. When the planet first formed about 4.5 billion years ago, it started as a hot ball of molten (melted) rock. The outside of Earth gradually cooled down, but heat continued to be released from deep within the planet through volcanoes (Figure 2.4). Water trapped inside the volcanic materials was also released into the atmosphere in the form of water vapour—much like steam escaping from a kettle. As the water vapour cooled and condensed, it fell to Earth's surface as precipitation. Because gravity causes water to flow downhill, the vast amounts of water that fell began collecting in the lowest parts of Earth's surface, the ocean basins.

Some scientists speculate that much of the original water on the planet came from ice in comets that hit the young Earth.

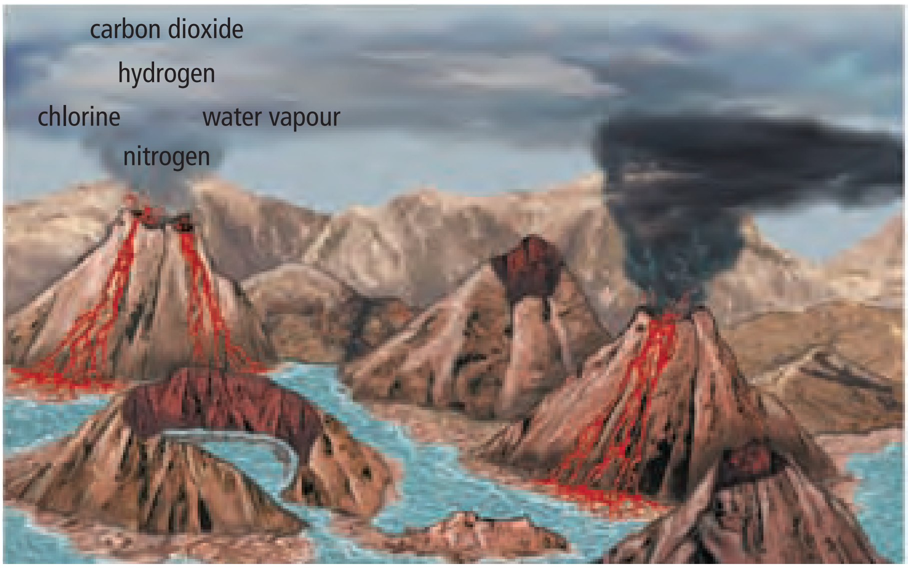


Figure 2.4 Vapour from volcanic eruptions helped to create the oceans.

A Journey on the Ocean Floor

Imagine you could empty the oceans of water and take a journey along the sea floor. What would you see? For one thing, you might be surprised to find many of the features that you see on land. There are mountain ranges, steep valleys, and vast plains (see Figure 2.5). Not only that, but all of these features under the ocean tend to be much larger than the similar features on land. But how did these formations get here?

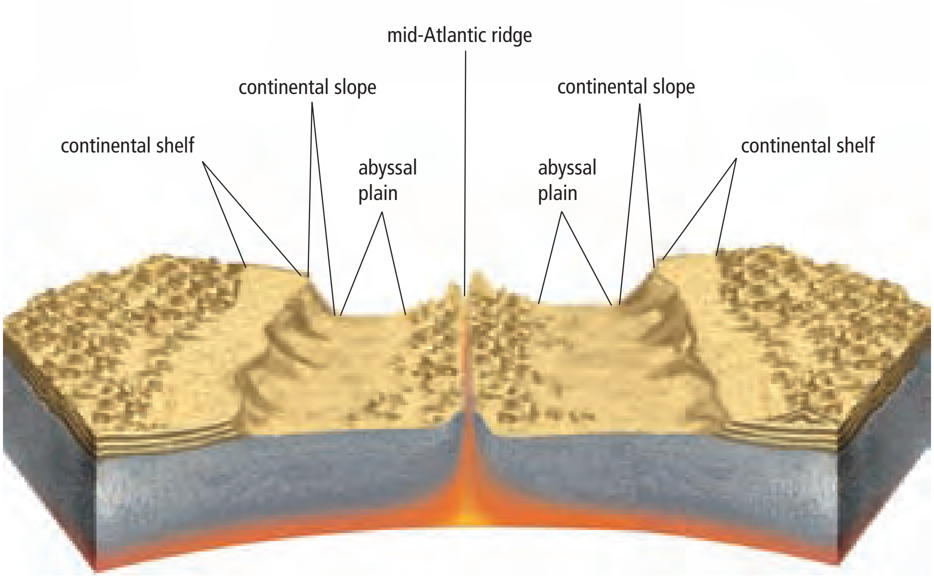


Figure 2.5 The ocean basins contain mountain ranges, deep valleys, and wide plains.

The greatest influence in shaping the ocean floor is the movement of Earth's crust through the tectonic processes you just read about. When two plates are pushed apart, the underlying magma oozes up and quickly hardens, and forms long, undersea mountain chains called **ocean ridges**. These ridges are the youngest areas of the sea floor and are still being formed by volcanic eruptions underneath the ocean. With each new eruption, the new material pushes the tectonic plates further apart. Ocean ridges may be more than 1000 km wide and rise 1000-3000 m above the sea floor. The largest oceanic ridge is the Mid-Atlantic Ridge in the Atlantic Ocean.

Did You Know?

Did you know that North America and Europe are moving further apart by about 3 cm each year? This means that the Atlantic Ocean is getting larger and the Pacific Ocean is getting smaller!

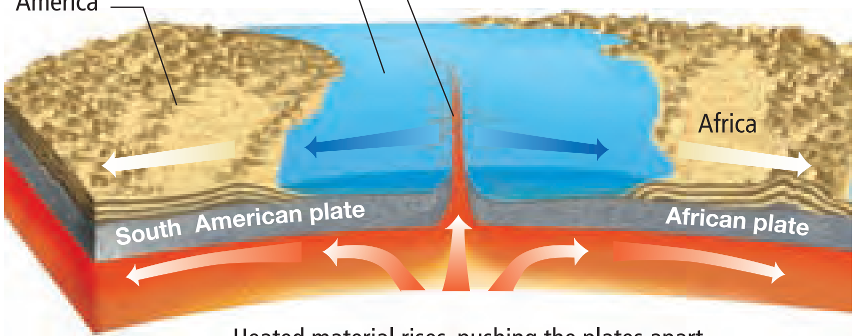


Figure 2.6 As the tectonic plates are pushed apart, a ridge is formed. In the Atlantic, it is known as the mid-Atlantic ridge and stretches from the North Atlantic to the South.

internet connect

Scientists estimate there are over 10 000 underwater volcanoes. Find out how Canadian technology is helping to investigate some of them. Go to **www.discoveringscience8.ca** to find out where to go next.

As you can imagine, however, plates cannot simply be pushed away from each other forever. At some point, plates moving apart from a mid-ocean ridge must come in contact with other plates. When an oceanic plate collides with a continental plate, the denser ocean plate is forced to bend steeply down beneath the less dense continental plate. When this happens, an ocean **trench** is formed. Most trenches occur around the margin of the Pacific Ocean. The deepest trench, called the Marianas Trench, extends 11 km below sea level. This distance is deep enough to submerge an object as tall as Mount Everest.

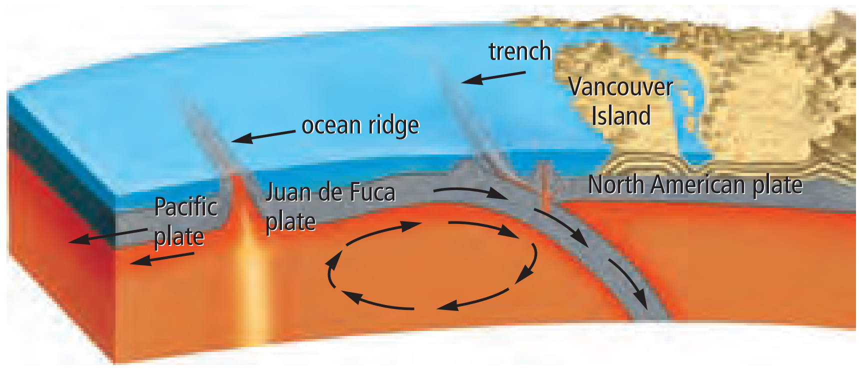


Figure 2.7 When tectonic plates collide, an ocean trench forms as the oceanic plate is forced beneath the continental plate.

Between the high mountain ranges at the centre of the basin and the deep trenches at their edges, the ocean floors are very flat. These wide, open features of the deep sea are called **abyssal plains**. They are formed of thick deposits of sediment, up to 1 km deep in places. The sediments come from the continents, brought to the ocean edge by rivers. They reach the sea floor by great underwater landslides. These landslides, also called turbidity currents, are started by earthquakes, or simply by the force of gravity. From time to time, massive volumes of mud and sand slide down the slopes at the edge of the continents, and are spread over the abyssal plains by ocean currents.

Reading Check

1. What is a basin?
2. Where do scientists believe that water originated?
3. Describe what is meant by plate tectonics.
4. Define ocean ridge, trench, and abyssal plains. Explain how these features are created.

Did You Know?

In 1929, an earthquake triggered an underwater landslide off the coast of the island of Newfoundland. The ocean landslide carried material almost 1000 km eastward and cut 12 telegraph cables on the ocean floor. Knowing the exact time the earthquake occurred and the time each cable was broken, scientists calculated the speed of the landslide at 60–100 km/h.

Continental Margins

Ocean basins do not begin at the coastline. Instead they begin many kilometres out at sea. The area between the basin and the coastline is called the continental margin. The continental margins are the regions of the ocean floor that lie underwater along the edge of the continents (see Figure 2.8). These margins are made up of the **continental shelf**, and the **continental slope**. The continental shelf is the submerged part of the continent between the coast and the edge of the basin. Continental shelves slope gradually away from the land before dropping steeply downward at the shelf edge. The average width of a continental shelf is about 80 km. However, the Grand Banks, the continental shelf off of the island portion of Newfoundland and Labrador's east coast, is 480 km wide, one of the widest in the world. The depth of the water on the continental shelves ranges from 30 m to 600 m.

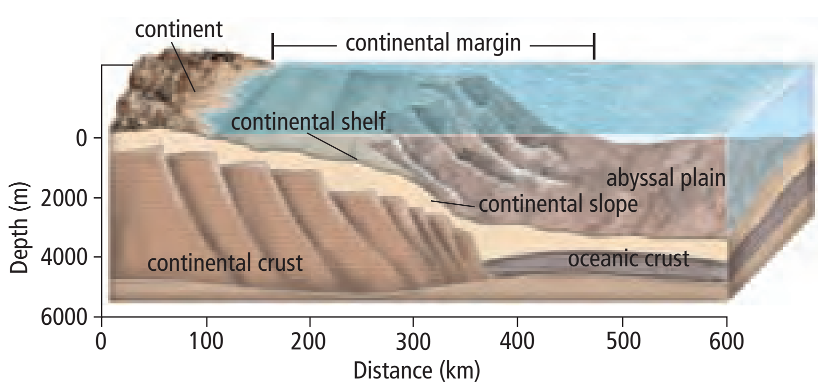


Figure 2.8 Continental margin

From the edge of the shelf, the continental slope plunges at a steep angle to the sea floor. Continental slopes are usually less than 200 km wide and descend to about 3 km. Beyond the base of the continental slope lies the floor of the ocean basin (the abyssal plain).

Suggested Activity

Investigation 2-1B on page 48.

Exploring the Oceans

The first map of the sea floor was produced in the 1870s. Scientists on board the expedition ship HMS *Challenger* lowered weighted wire lines at intervals to the ocean floor. When the weight hit the bottom, they would measure the length of line that was released into the water. By using this method, they discovered the Mid-Atlantic Ridge.

Did You Know?

The HMS *Challenger* expedition discovered over 4500 previously unknown species of marine life. The space shuttle Challenger was named after the HMS *Challenger.* Can you think of a reason why they would name a space shuttle after this ship?

Sonar Mapping

Since the *Challenger* expedition, many new technologies have been developed to help scientists explore the ocean basins. Sonar mapping uses sound waves to probe the seabed. The depth of water is found by sending sound waves directly down from a ship and measuring the time it takes for the signals to hit the sea floor and bounce back to the surface.

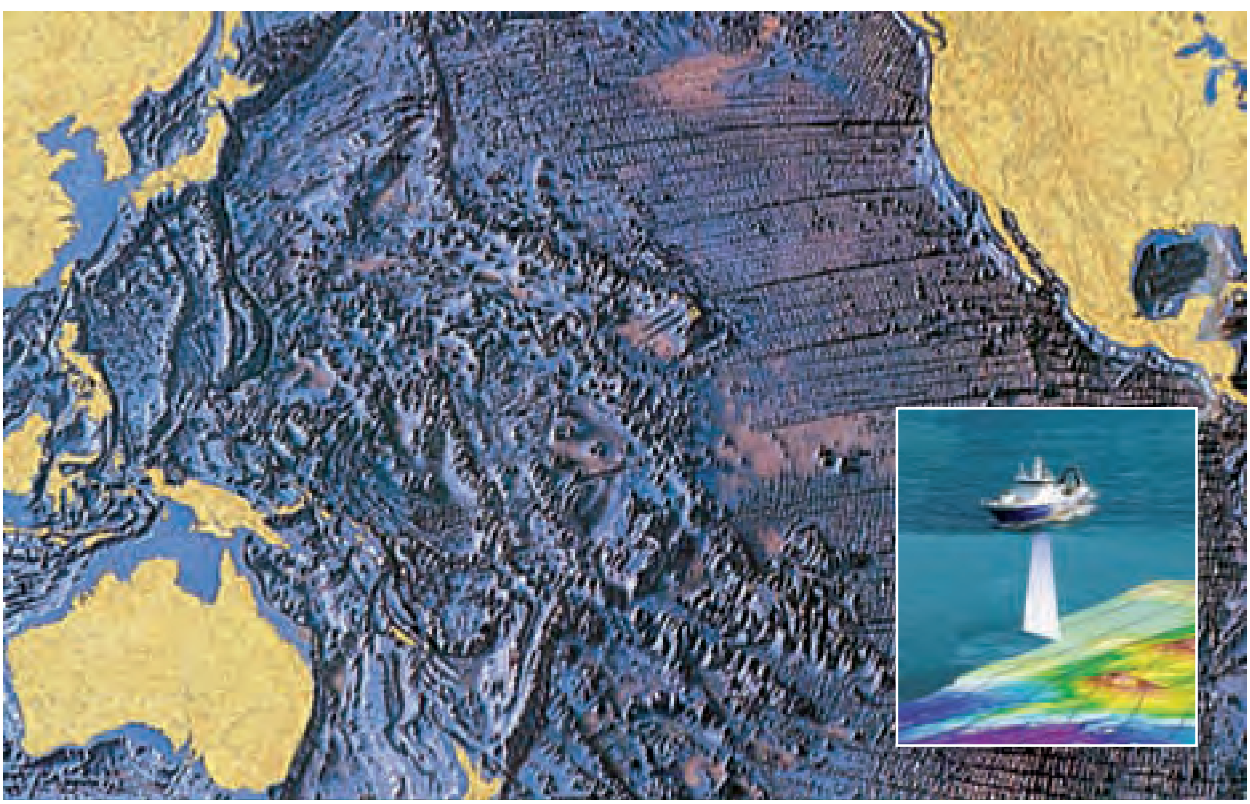


Figure 2.9 By measuring the reflection of sound waves bouncing back from the ocean bottom, scientists have been able to map mountains, valleys, and canyons on the ocean floor.

Satellites

Today we have detailed pictures of the oceans produced by satellites in orbit far above Earth. Spacecraft can automatically record data using radar, infrared light, or other technologies to measure features on Earth. A great advantage of satellites over ships is that satellites can survey very large areas of ocean in a relatively short time. Satellites are also able to record and transmit data in all kinds of weather, and in both day and night.

Satellites can also receive information from buoys that are anchored to the ocean floor at fixed points. Instruments on these buoys collect information about water and air temperature, and transmit the information to satellites. These satellites then transmit this data to stations all over the world. This data can help scientists predict weather changes and monitor water movements.

Word Connect

The word "sonar" comes from term sound navigation ranging.

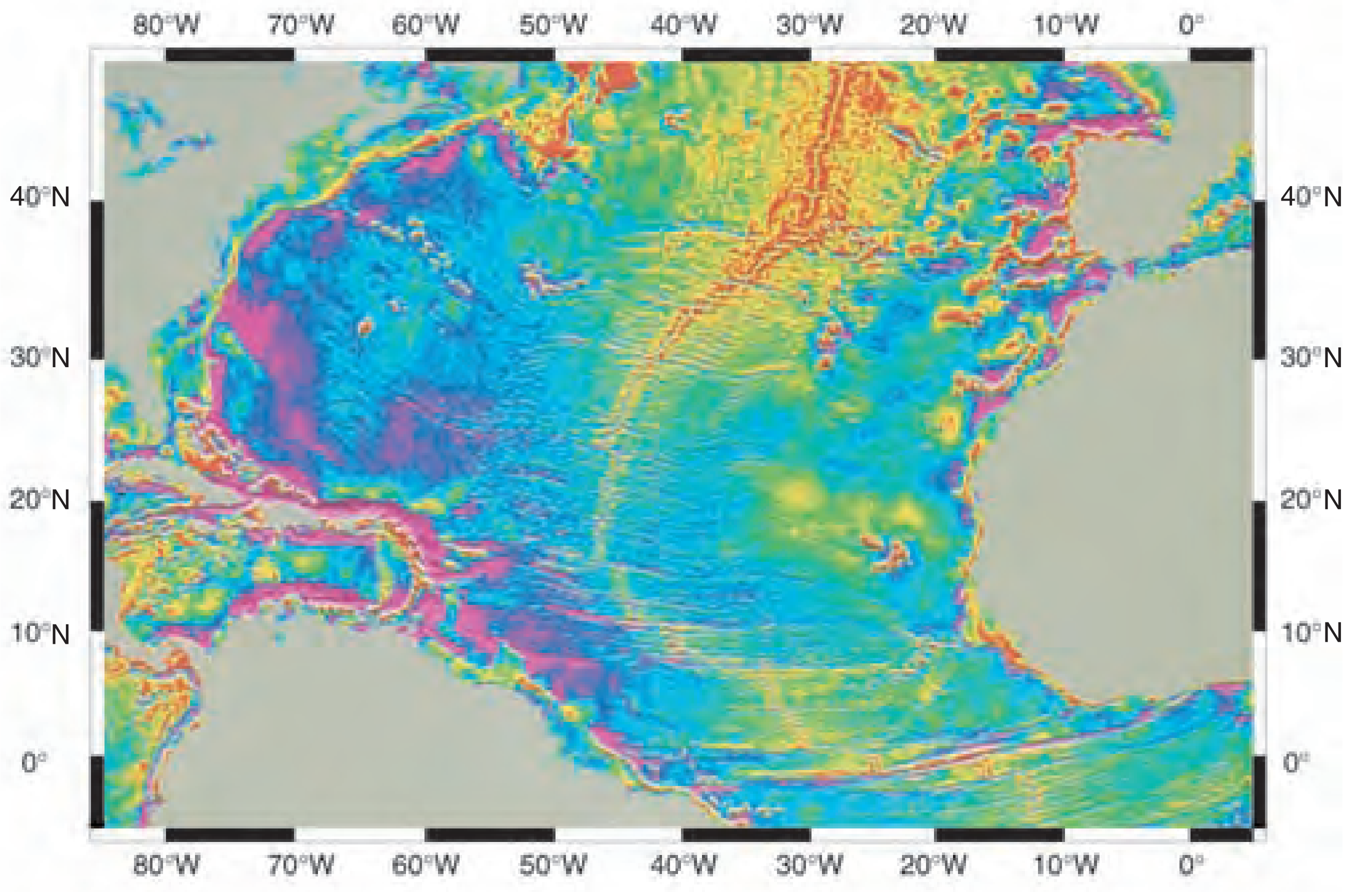


Figure 2.10 This image of the Atlantic sea floor was produced by instruments on a satellite.

Submersibles

The most detailed information we have about the deepest parts of the ocean comes from submersibles. Much of the ocean is permanently dark and extremely cold. At the deepest sections, there is more than 2000 kPa of pressure. All of these factors together make it impossible for people to explore the deep sea without the help of technology.

Submersibles are small but extremely strong vehicles that are capable of travelling to great depths. There are two types of submersibles: manned submersibles and remotely-operated vehicles. Manned submersibles carry people inside and allow them to make their own observations of the deep sea. Remotely-operated vehicles (ROVs) allow people to control the vehicle from a ship that is safely on the surface. They can control the arms, lights, and cameras of the vehicle with a device that is similar to the joystick you use for playing video games. ROVs can stay down much longer than manned submersibles and continuously send data to the ship.

Figure 2.11 Remotely-operated vehicles are controlled by people from the surface. They can collect data, pictures, and objects.

Scientists are also working on a third type of submersible called an automated underwater vehicle. These submersibles will run on artificial intelligence, need little control from people, and will be able to stay underwater for months at a time.

Deep Sea Cameras and Video

Deep sea photography and videography are providing a chance for people to see the undersea world as never before. Cameras towed from ships can take thousands of high-resolution photographs a day. New deep sea cameras and video allow pictures and video to be taken 6000 m beneath the surface. Scientists are still discovering new species at deep sea levels that were never known to have existed before.

Figure 2.12 Deep sea cameras such as the NEPTUNE can reach ocean depths of 6 km.

internet connect

Right now, there are scientists living under the sea and studying the oceans. To find out more about *Aquarius*, the only undersea laboratory, go to **www.discoveringscience8.ca** to find out where to go next.

Reading Check

1. What two features make up the continental margin?
2. Describe the process of sonar mapping.
3. What is an advantage of satellite mapping?
4. Describe two types of submersibles.

2-1B Getting to Know the Ocean Floor

SkillCheck

- Measuring
- Graphing
- Modelling
- Evaluating systems

Materials

- shoebox with lid
- a variety of small objects (such as little blocks of wood, erasers, rolled up paper, and modelling clay)
- tape
- felt pen
- ruler
- scissors
- drinking straw
- graph paper
- pencil

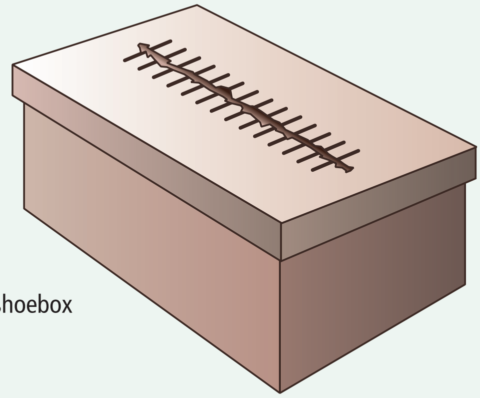
Scientists make both direct and indirect measurements. Direct measurement can be done when an object can be physically touched or the quantity to be measured can be seen. An example is measuring the length of a table with a metre stick or weighing a bag of apples. When the object to be measured cannot be physically reached or seen, indirect measurement must be used. For example, scientists wanting to measure the size of a rock on Mars have to do it by using a remote-sensing device. In this investigation, you will use indirect measurement to map a model of an ocean floor.

Question

How can you determine what the bottom of the ocean looks like if you cannot see it?

Procedure

1. You are going to make a model of a section of the ocean floor, which you will then exchange with a classmate. Tape the different objects you have gathered down the middle of the shoebox, lengthwise. Make sure the objects vary in how high they sit from the bottom of the shoebox. Do not let your partner see how you have set up your model.
2. Draw a line with the felt pen down the centre of the shoebox lid lengthwise. Along the full length of the line, mark off spaces about 2 cm apart.
3. Use the scissors to make a slot down the long line drawn on the shoebox lid. Make the slot wide enough to allow the straw to slide through. Put the lid on the shoebox.



Set-up of shoebox model

4. Using the felt pen and the ruler, mark the straw with 1 cm intervals.
5. Exchange shoeboxes with a classmate.
6. Copy a data table like the one on the next page into your notebook. Give your table a title.

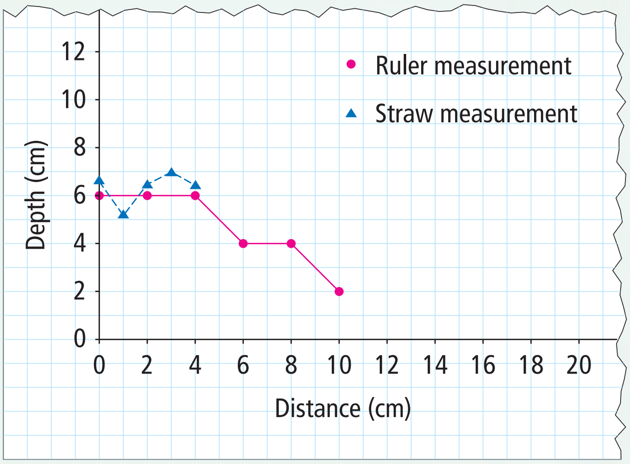
Distance	Depth 1 (cm) Ruler	Depth 2 (cm) Straw
0		
1		
2		
3		
4		

7. To begin your task of mapping this ocean floor you cannot see, make your first measurement by sliding the ruler through the slot in the first interval marked. Gently push the ruler far enough down so that you can feel it just touching the first object on the ocean floor. The reading on the ruler at the level of the shoebox lid will be the depth. Record this measurement, as well as the distance along the line from where the slot begins.
8. Raise the ruler and insert it at the next 2 cm interval and repeat Procedure step 7. Continue to take measurements at every interval until you have reached the opposite end of the shoebox.
9. Using the straw as your measuring device, repeat Procedure step 7. This time, however, take measurements every 1 cm (half-way between the interval lines marked on the shoebox lid). When a reading on the straw lies between two marked lines, estimate the depth (for example, 2.5 cm). Record the depth to the ocean floor, as well as the distance along the line from where the slot begins.
10. On the piece of graph paper, plot a line graph of your depth and distance data. This will give you a cross section of the ocean floor model. Use a different symbol (such as ● and ▲) for each measuring device you used.

Analyze

1. Once you have completed your cross section, open the lid and see how closely your drawing matches the actual model.

Ocean Floor Measurements



Guidance for graphing your data.

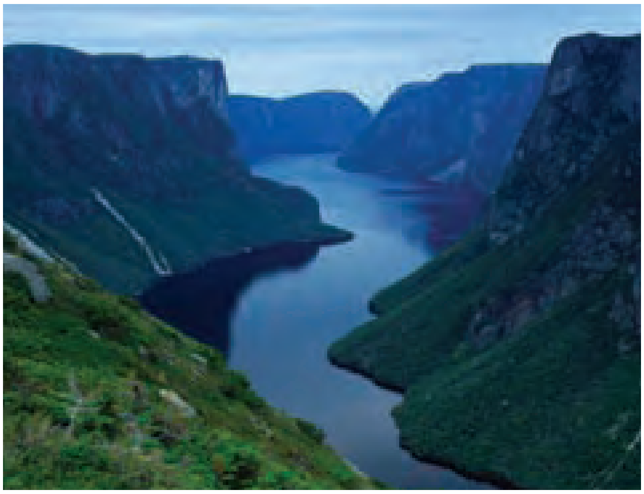
2. Which measuring device provided the best match to the actual model? Explain the difference.
3. What were the strengths and weaknesses of the ruler and the straw as measuring devices?

Conclude and Apply

1. Why is this method not the most accurate way to make a cross section?
2. Suggest ways of making this method more accurate.
3. Does this method of measurement give a clear picture of the model ocean floor? Explain why or why not.
4. What could you do to improve the accuracy of your measuring method?
5. When oceanographers are mapping sections of the ocean floor, they do not map the entire floor all at once. Instead, they map many small portions, or samples, and put the pieces together to construct an overall "picture" that represents the ocean floor. In this activity, how does the size of your ocean floor sample (that is, the shoebox) relate to the amount of detail shown in the picture you constructed?

Gros Morne National Park: Tablelands Provide Evidence of Plate Tectonics

There are few landscapes that compare to the beauty of Gros Morne National Park on the west coast of the province. Visitors from all over the world travel to hike its trails, canoe or kayak its waters, and enjoy its breathtaking scenery. However, did you know that Gros Morne National Park is also famous for providing scientists with the first evidence of the process of plate tectonics?



The idea that Earth's crust is made of sections that move around was first introduced in the 1500s. But it was not until the 1970s that scientists found evidence for the theory of tectonic plate movement—and they found it in Gros Morne!

Several hundred million years ago, tectonic plates collided and part of Earth's mantle (its rocky shell) was pushed upwards. The rocky material that was pushed up is called peridotite. Scientists knew that if they could find evidence of this material, they would have proof for plate tectonics. Peridotite is lacking in minerals that are needed to sustain plant life, so they knew they would be looking for barren landscape.

In the 1960s, Dr. Harold Williams discovered that the Tablelands in Gros Morne National Park were made of peridotite. Along with other geological evidence in the area, Williams was able to advance the theory of plate tectonics.

The Tablelands in Gros Morne National Park are composed of peridotite, which is from deep in the Earth's mantle.

Because of its importance to our geological understanding of Earth's history, Gros Morne National Park was designated a UNESCO World Heritage Site in 1987. This means that it is protected and will be conserved for future generations.

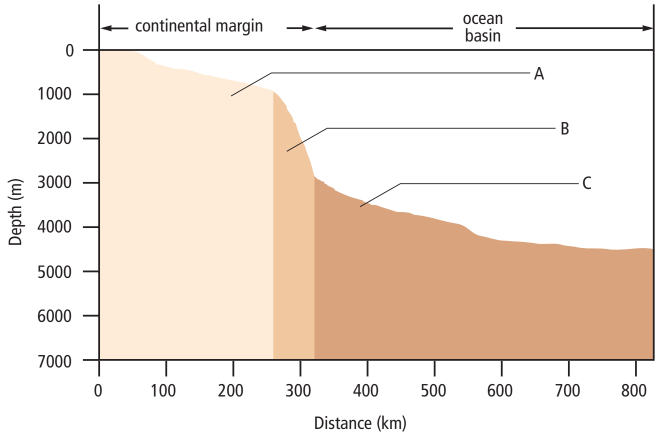
Check Your Understanding

Checking Concepts

1. (a) Name the five major oceans on Earth.
   (b) Which is the largest and which is the smallest?
2. Scientists speculate that most of the water that originally formed the oceans several billion years ago came from two different sources. What are these sources?
3. What are the wide, flat areas of ocean basins called?
4. What is the name of the ocean floor where two tectonic plates are moving apart?
5. What feature marks the location where one tectonic plate is pushed underneath another plate?
6. What is the steep side of the edge of a continent called?

Understanding Key Ideas

7. How did the continents move into their current location?
8. Explain how erupting volcanoes contributed to the formation of oceans.
9. Briefly describe each of the following features of the ocean floor and explain how they formed:
   (a) ridge
   (b) trench
10. The diagram below shows the cross section of an edge of a continent. Draw the diagram in your notebook and label each part.



11. Name three modern technologies that have helped scientists explore the deep ocean.

Pause and Reflect

As tectonic plates slide around, they occasionally bump into one another. Colliding plates are responsible for everything from building mountains to triggering earthquakes and volcanoes. In some places on Earth, tectonic plates move as fast as 17 cm a year. However, the average rate of movement is about 2.5 cm a year. With that information, calculate how far the average plate (a) has moved in your lifetime, and (b) how far it will move if you live to be 100 years old.

2.2 Ocean Currents

Ocean currents are large masses of moving ocean water, almost like a river within an ocean. Like a river, a current flows in one direction and connects one place with another. Knowing how and why the ocean's water moves is important to understanding how oceans can affect the whole planet. Ocean currents exist both on the surface of the water, and deep within the ocean.

Key Terms

Coriolis effect
density current
ocean current
thermocline
upwelling

An **ocean current** is a large amount of ocean water that moves in a particular and unchanging direction. There are more than 20 major ocean currents in the world (see Figure 2.13). The largest current in the ocean is the Antarctic Circumpolar Current (also called the West Wind Drift) in the Southern Ocean. It is 24 000 km long and circles the entire continent of Antarctica. Each year, the current carries 100 times more water than all the rivers on Earth combined—3 million cubic kilometres.

Figure 2.13 There are many different currents on the ocean surface.

Beginning in the Caribbean and ending in the North Atlantic, the Gulf Stream Current is important to Newfoundland and Labrador. Carrying warm water from the tropics, the Gulf Stream helps make the Grand Banks one of the world's largest and richest resource areas. The warm water mixes with the cold water from the Labrador Current, making the area an ideal location for nutrients that provide food for fish and other marine life. The mixing of the two currents is also what generates the heavy fog along much of the province's coastline, especially in the spring.

Ocean currents can be divided into two types: surface currents (that extend to an average depth of 200 m) and deep water currents (that occur deeper than 200 m). Depending on their origin, currents can also be either a warm or a cold current. All types have major effects on ocean ecosystems and on human activities. The movement of surface currents are caused by wind action, Earth's spin, and the shape of the continents. (The effects that are the result of Earth's spin are called Coriolis Effects.) The movement of deep currents is caused by the temperature and salinity of the water.

2-2A Winds and Currents

Find Out ACTIVITY

How do winds affect surface currents? If you turn a skateboard upside down and run your hand across a wheel, friction between your hand and the wheel starts the wheel moving. The direction in which you move your hand determines the direction in which the wheel spins. Similary, winds blowing over the surface of the ocean cause the surface waters to move. The surface currents flow in the same direction as the wind. What happens when a moving ocean current reaches land?

Safety

Materials

- rectangular pan
- water
- 2 drinking straws
- stone
- 12 small circles of paper from a hole punch

What to Do

1. Fill the pan with water. Place six of the pieces of paper on the water at one end.
2. Hold a straw just above the water over the floating papers and gently blow. Repeat several times until the papers have reached the far side of the pan. Watch what happens and sketch your observations in your notebook.
3. Place the other six pieces of paper in the opposite end of the pan. With a partner, gently blow through the straws from opposite ends of the pan toward the middle. Watch what happens when the floating papers meet, and sketch your observations.
4. Place an object in the centre of the pan (but not on the top of the papers). Repeat step 3.
5. Clean up and put away the equipment you have used.

What Did You Find Out?

1. How did the wind you created affect the movement of water on the surface of the pan?
2. What was the effect of two winds coming from opposite directions?
3. How did the object affect the path of the paper?
4. Based on the results of this activity, what do you think happens when surface currents in the ocean meet an object such as a large island?

Surface Currents

Currents of water at the ocean surface are driven by winds. Most surface currents flow in the top 100–200 m of water. The steady flow of currents results from major wind patterns. These wind patterns blow in fairly constant directions around the world (see Figure 2.14).

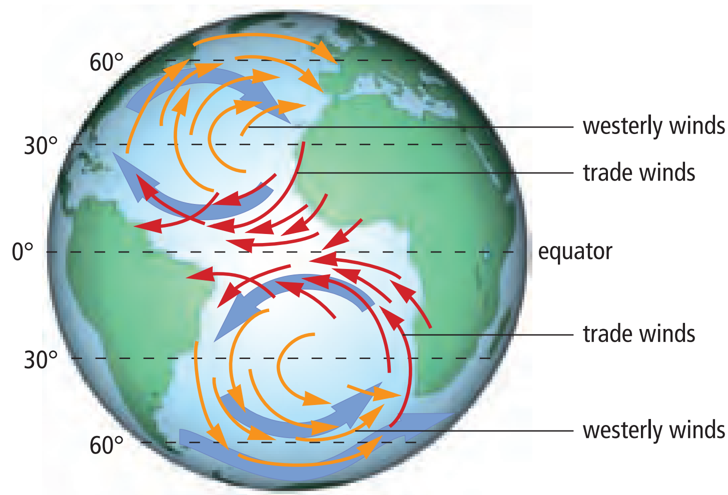


Figure 2.14 Winds (red and orange arrows) travel in a clockwise direction north of the equator, and counter-clockwise south of the equator. Ocean currents (blue arrows) move in the same directions as the winds.

Three factors influence ocean surface currents: wind, rotation of Earth, and the shape of Earth's continents.

The Effect of Wind

Winds are the result of masses of air moving rapidly from one area to another because of uneven heating of Earth's surface. Air near a warm surface is heated and its particles move farther

Figure 2.15A Wind energy can set the ocean's surface in motion.

Figure 2.15B Air movement caused by uneven heating creates winds.

apart. As a result, the warm air is less dense and rises. This produces an area of low air pressure beneath the rising warm air. Cool air, with a higher pressure, moves into the area of low pressure. These moving masses of air create wind. As this moving air crosses over the ocean's surface, its energy is transferred by friction to the water molecules, causing the ocean water to move (Figure 2.15A). The direction and speed of surface currents are directly connected to the direction and speed of the wind blowing over the water.

Did You Know?

The volume of water in ocean currents makes even the mightiest rivers appear tiny by comparison. For example, the Gulf Stream moves about 26 000 000 m^3 of water per second, or about 1000 times more than the Mississippi River!

The Effect of Earth's Rotation

The spinning of Earth on its axis affects both winds and ocean currents all over the planet. Earth spins from west to east (counter-clockwise). As winds and currents move over this spinning body, their path gets redirected (deflected) depending on what side of the equator they are on. This alteration of direction is called the **Coriolis effect**. In the northern hemisphere, no matter which direction the winds begin to blow, they will be deflected to the right, or in a clockwise direction. In the southern hemisphere, winds will be deflected to the left, or in a counter-clockwise direction.

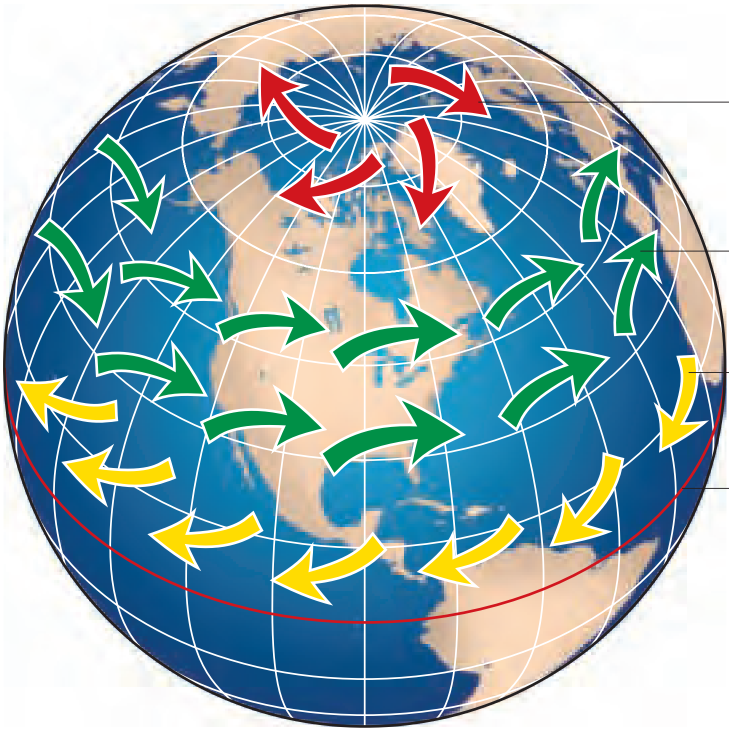


Figure 2.16 The Coriolis effect, caused by Earth's rotation, results in the path of air being directed clockwise in the northern hemisphere and counter-clockwise in the southern hemisphere.

The Effect of Continent Shape

The third factor that affects ocean currents is the shape of continents. As you observed in the Find Out Activity on page 53, moving currents are forced to turn when they meet a solid surface. Continents deflect east-west currents either to the north or to the south.

The combined influence of winds, the Earth's rotation and the shape of continents keep ocean surface currents circulating clockwise in the northern hemisphere, and counter-clockwise in the southern hemisphere.

internet connect

Water travelling in some currents can take decades to make it back to where it started! Find out more about ocean currents at **www.discoveringscience8.ca**

Reading Check

1. What is an ocean current?
2. What three factors produce ocean surface currents?
3. Explain how wind influences ocean currents.
4. How does the spin of Earth affect ocean currents?
5. Explain how the shape of continents affects ocean currents.

Deep Currents

You have seen how wind, the spin of Earth, and the shape of continents can affect the movement of surface currents in the ocean. For currents deep in the ocean, the most important influences on movement are water temperature and salinity.

Water Temperature and Deep Currents

Water in the ocean does not have the same temperature at every depth, nor does it decrease steadily with depth. Figure 2.17 shows that water temperature changes sharply to form three distinct layers: the surface (or mixed layer), the thermocline, and deep water. The warmest layer is the surface, where the Sun's energy heats the water. Surface currents keep the surface water mixing and the temperature fairly consistent, thus it is sometimes referred to as the mixed layer. Lower down where the effects of the Sun cannot be felt, the water temperature drops rapidly. This layer is called the **thermocline** and it exists approximately 200 m to 1000 m beneath the surface. The temperature in the thermocline may fall from 20°C to a chilly 5°C. Below the thermocline lies the deep water layer. Temperatures at this level approach the freezing point of water.

Word Connect

The root word of thermocline is "thermo," which comes from the Greek word *thermos*, meaning "hot." What other words can you think of that start with the root word "thermo"?

Thermoclines also occur in lakes. If you have gone swimming in a lake early in the summer, you might have noticed that the surface water is much warmer than the water even just a few centimetres down. Later in the summer, the cold water is much deeper. Fish such as trout retreat to the cool of deep water in the heat of the summer.

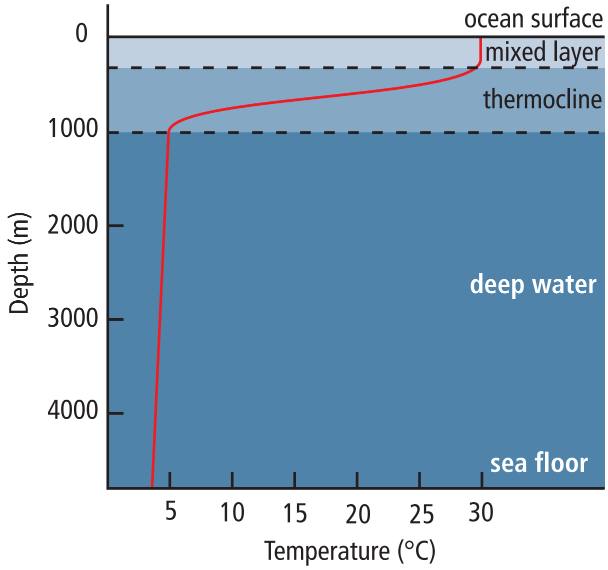


Figure 2.17 Ocean water has different temperature layers at different depths, as the red line in this diagram shows.

Temperature affects the density of ocean water. Cold water is more dense than warm water, and tends to sink. In the oceans, sinking masses of cold water flow downward and move along the ocean floor. These masses of cold water produce **density currents** that flow beneath the surface waters.

Suggested Activity

Investigation 2-2B on page 60.

Water Salinity and Deep Currents

Density currents are also produced by the differences in the salinity (the amount of salt) of seawater. Water with high salinity is denser than water with low salinity. How does the salinity of ocean water change from one place to another? One way to lower salinity is to add more fresh water. For example, seawater is less salty at the mouth of large rivers where fresh water is entering the ocean. Fresh water also enters the ocean where icebergs and glaciers melt, and in regions with high levels of precipitation.

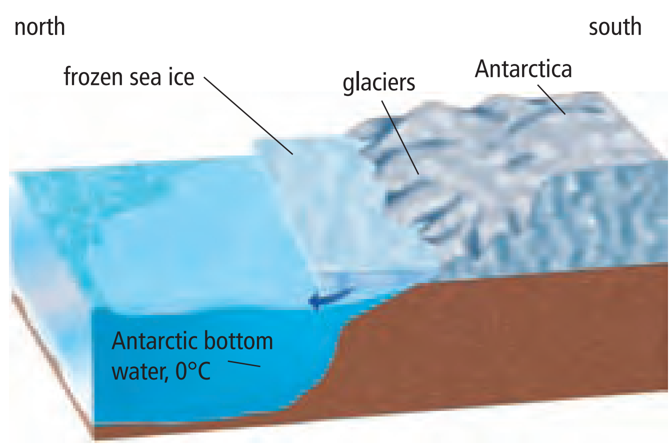


Figure 2.18 Differences in salinity produce density currents.

In contrast, regions with hot, dry conditions and a high rate of evaporation produce ocean water with high levels of salinity. When this dense, salty water sinks it forms a downward-moving density current.

Just as evaporation increases salinity, so does freezing. When water turns into ice, salt is left behind in the remaining water, increasing its saltiness. Dense, salty water, therefore, is produced in oceans cold enough to form ice on the sea surface, such as at the North and South Poles.

Upwelling

Flowing in the opposite direction of density currents are currents called upwellings. **Upwellings** are the vertical movement of water from the sea floor to the ocean surface. Upwellings are most common along coastlines where strong winds blow offshore. These winds push the surface water away from the land. Cold, deep water then rises from below to replace the surface water that has been moved out to sea. Figure 2.19 shows the process of upwelling.

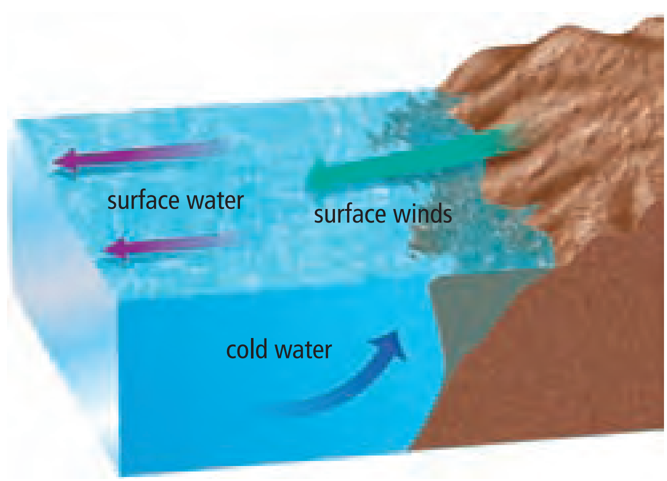


Figure 2.19 Upwelling brings cold water from the depths of the ocean to surface along the shoreline.

Upwellings have an important effect on the ecology of the sea and on human fisheries. The upwelling water contains large amounts of nutrients from the sea floor, such as phosphates and nitrates. Plants living in the surface waters use these nutrients to grow. The plants, in turn, attract fish to these areas. Upwelling on the Grand Banks of Newfoundland and Labrador result from the interaction of the Gulf Stream and the Labrador Current, producing nutrient-rich waters and historically one of the world's most productive fisheries.

Farther south, near the equator, the trade winds blow from east to west. Winds blowing off the west coast of Africa and both North and South America, create the same situation that is found in the Grand Banks. The map in Figure 2.20 shows where the major upwellings occur. Many large commercial fisheries are located near these productive waters.

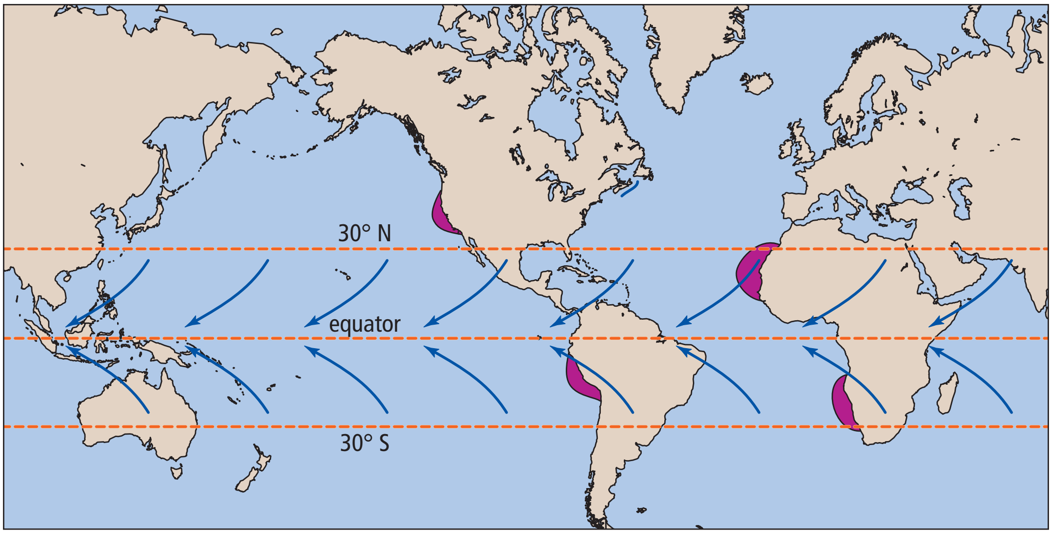


Figure 2.20 The purple areas show the locations of upwellings caused by the trade winds near the equator.

The fishing off the west coast in Peru, in South America, however, is interrupted every few years. A unique weather pattern called El Niño, reverses the winds in the southern part of the Pacific Ocean. The winds temporarily blow from west to east. These winds prevent the upwellings on the coast of Peru with devastating effects on fishing and families who depend on fishing for a living.

Reading Check

1. What is a density current?
2. Sketch and label the three layers of ocean water.
3. Fresh water reduces the salinity of ocean water, making it less dense. Name two ways fresh water can be added to the ocean.
4. What is upwelling of ocean water?
5. Why is upwelling important for marine life?

2-2B Temperature and Water Density

SkillCheck
- Observing
- Measuring
- Modelling
- Evaluating information

Cold water, like cold air, becomes dense and therefore sinks. What happens to the temperature of ocean water the deeper you go? You will explore the answer to that in this activity by plotting a graph of ocean temperature against ocean depth.

Materials

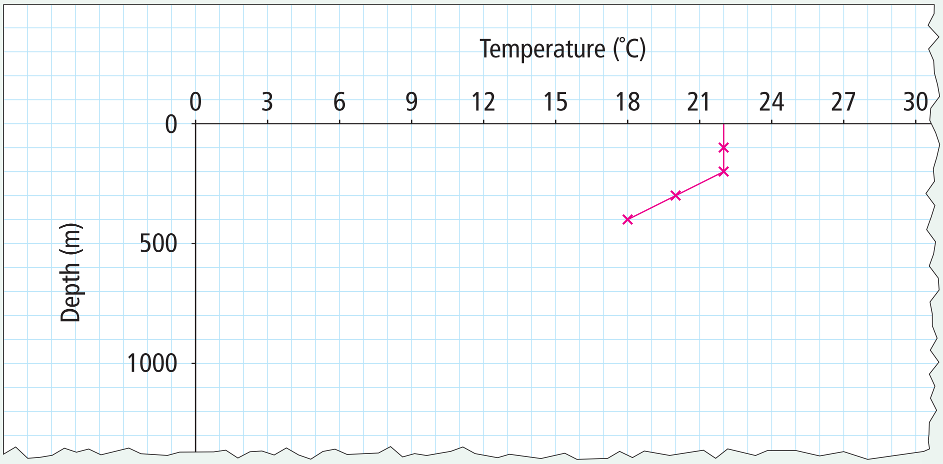
- 1 piece of graph paper
- pencil
- eraser

What to Do

1. Create a graph by plotting the following data points. Be sure to look at the sample graph before beginning.

Depth (m)	Temperature (°C)
0	22
100	22
200	22
300	20.5
400	18
500	14
600	10
700	8
900	6
1000	5
1200	4

2. Connect the points with a straight line.



Plot your data on a graph

What Did You Find Out?

1. What is the relationship between temperature and water depth?
2. Does the temperature of water change at a constant rate as you go deeper?
3. Between what depths is the temperature difference the greatest?
   (a) 0–400 m (b) 400–800 m
   (c) 800–1200 m
4. (a) Which is denser, hot or cold water? Explain why.
   (b) How does density of water affect the water's ability to float or sink?
   (c) What do you think would happen when cold water from the Labrador Current meets the warm water from the Gulf Stream?

Science Watch

World's Largest Flume Tank

Every year, many new designs are created to improve the fishing technology that is used in the oceans. But just how do they know if these new designs will work? Luckily, the province of Newfoundland and Labrador is home to the largest flume tank in the world, and the only one of its kind in North America.

What exactly is a flume tank? To begin, a flume is a channel of flowing water, much like a current. A flume tank is like a massive aquarium tank, but it also has a circulating water channel. This circulating water allows engineers and scientists to simulate underwater and near surface conditions in the ocean. This lets them test model-scale fishing gear in a controlled environment.

The flume tank is 22 m long, 8 m wide, 4 m deep, and holds 1.7 million litres of water. That's more water than could fill over 12 000 bath tubs! It has a glass viewing area to allow people to study the equipment that is being tested.

Figure 2.19 A researcher at the Centre for Sustainable Aquatic Resources observes tests in the flume tank.

The flume tank is located at the Centre for Sustainable Aquatic Resources. It is one of five centres that are a part of the Marine Institute at Memorial University of Newfoundland. The other centres are:

- The Offshore Safety and Survival Centre
- Centre of Marine Simulation
- Centre for Aquaculture and Seafood Development
- Marine Institute International

These centres, along with the Marine Institute's Schools of Fisheries, Maritime Studies, and Ocean Technology make the Marine Institute one of the best places in the world to learn about and study marine environments, industries, and technologies. From studying to be a captain of a freighter, to an emergency rescuer for offshore industries, to being a food technologist in the food industry, the Marine Institute has more opportunities for you to study for an ocean career than you can imagine!

internet connect

To find out more about the Marine Institute at Memorial University of Newfoundland, go to **www.discoveringscience8.ca**

Check Your Understanding

Checking Concepts

1. List the three main causes of an ocean's surface currents.
2. How does the Coriolis effect influence wave and wind motion:
   (a) north of the equator?
   (b) south of the equator?
3. Define thermocline.
4. Describe what happens when cold, dense ocean water meets warmer, less dense water.
5. Describe an example where upwelling can occur.

Understanding Key Ideas

6. Make a graph showing how ocean temperature varies with depth.
7. How is a density current produced?
8. Explain the difference between a surface current and a deep current.
9. Explain why water may have a different density in different parts of the ocean.
10. When upwelling occurs in the ocean, water rich in nutrients comes to the surface. Explain why areas of upwelling might be good places to fish.

Pause and Reflect

As water gets colder, its density increases. However, this is true only up to a certain temperature. Water achieves its maximum density at a temperature of 4°C. When water is cooled to 0°C, its density decreases. Therefore, bodies of water freeze from the top down, rather than from the bottom up. Imagine if these differences did not exist. How would life on Earth be affected if bodies of water, such as lakes and ponds, froze from the bottom up?

2.3 Waves and Tides

Waves, tides, and currents drive the ocean in perpetual motion. This never ending action erodes coastlines, and forms beaches and interesting landscapes. The rise and fall of daily tides connects us with the universe surrounding our world. On occasion, waves also remind us of their destructive power.

Key Terms

bays
breaker
crest
headlands
neap tide
spring tide
swell
tidal range
tide
trough
tsunami
wavelength

Ocean Waves

Surfers ride ocean waves, using the motion of the water to carry them to the shore. What causes waves? You can find the answer in a bowl of soup! If you blow on the soup to cool it, your breath makes small ripples on the surface of the liquid. Ocean waves are just large ripples, set in motion by steady winds.

Ocean waves begin on the open ocean. Their height depends on how fast, how long, and how far the wind blows over the water. An increase in any one of these variables can cause an increase in wave height. Normal winds produce waves of 2–5 m in height. Hurricane winds can create waves 30 m high—two thirds of the height of Niagara Falls! Even on a calm day, there is a steady movement of smooth waves. These smooth waves are called **swells**. They are caused by winds and storms far out in the ocean.

Figure 2.20 Some of the largest waves occur along the coasts of California and Hawaii. The waves in these places have been blown by wind over thousands of kilometres of open ocean —as far away as Japan!

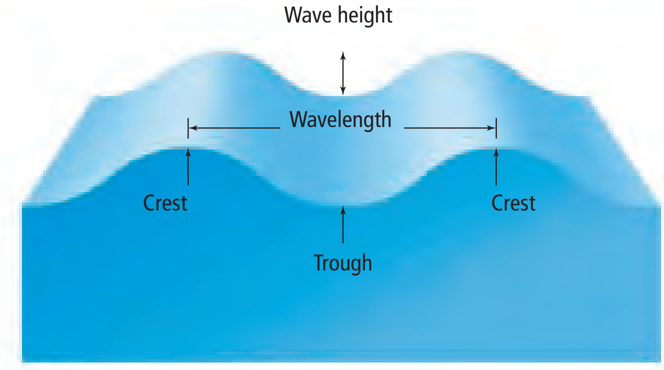


Figure 2.21 Features of a wave

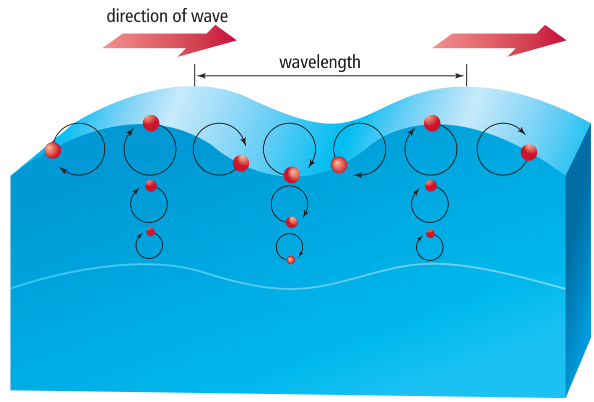


Figure 2.22 Individual particles of water move in circles as a wave passes through the water. The circular motion of each of the particles of water is called an oscillation.

Whether large or small, waves on the water have features in common with all the other types of waves studied by scientists – such as sound waves, light waves, or radio waves. First, waves have height, as shown in Figure 2.21. A wave's height is measured from its **crest** (the highest part of the wave) to its **trough** (the lowest part of the wave). Second, ocean waves also have a **wavelength,** which is the distance from one crest to the next. Third, waves have a speed of motion, which is measured by the time required for one wave to pass a given point.

Breaking Waves

Near the ocean surface, water particles move in a circular motion as wave passes. As each particle moves, it bumps into the next particle and passes its energy along.

When a wave reaches shore, it changes shape (see Figure 2.23). As the trough of the wave touches the beach, it is slowed down by friction. The crest of the wave, however, continues moving at the same speed. The wavelength shortens, and the wave height increases. The crest of the wave eventually outruns the trough and topples forward. The wave collapses onshore in a tumble of water called a **breaker**.

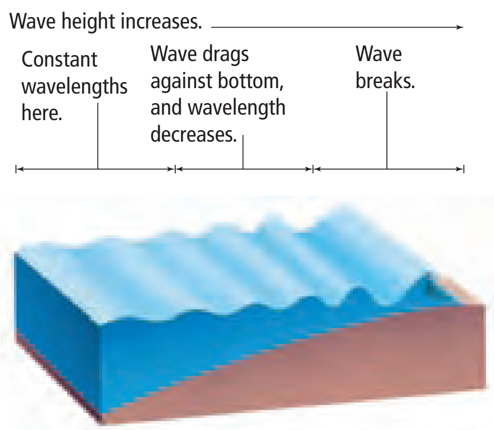


Figure 2.23 The movement of waves as they approach the shore

Figure 2.24 As a wave approaches the shore, its wavelength decreases and its height increases. It collapses onshore as a breaker.

Word Connect

Tsunami comes from the Japanese terms *tsu* meaning "harbour," and *nami*, meaning "wave."

Tsunamis

Some of the highest ocean waves are not caused by winds but by earthquakes, volcanic eruptions, or landslides on the ocean floor. These events give the ocean water a push, just as you can make a wave in a bathtub by pushing your hand underwater. Ocean floor events sometimes produce giant waves called **tsunamis** (pronounced SUE-NAH-MEE). The wavelength of a tsunami may be 150 km. It may travel over the open ocean at a speed of up to 800 km/h. When the tsunami approaches land, the speeding water is pushed up into a towering, powerful wave that destroys buildings, coastlines, and can kill many people.

Figure 2.25 On December 26, 2004, a large (magnitude 9.0) earthquake in the Indian Ocean created tsunamis that crashed upon the coastlines of 10 different countries. Over 280 000 people were killed, and over 1 000 000 people lost their homes and communities. This picture shows the aftermath of the tsunami in Indonesia. This town was 250 km away from the earthquake.

How Waves Change Shorelines

Waves shape shorelines by eroding and redepositing sediments. Waves usually collide with the shoreline at slight angles. This creates a longshore current of water that runs along the shore (see Figure 2.26). Longshore currents carry many tonnes of loose sediment. They act like rivers of sand in the ocean. Longshore currents also erode the shoreline.

Figure 2.26 Along shorelines, waves move sediments back and forth.

Along some rocky shorelines, waves may slowly wear away the rocks and eventually form hollows. Over time, these hollows enlarge and become caves. As the caves increase in size, they eventually meet and a sea arch is formed. When too much erosion occurs, overhanging rock may fall off into the ocean. Rock fragments are slowly ground into sediments by the endless motion of the waves. Seawater can also dissolve certain minerals in rock, increasing erosion by chemical action. The combined action of waves and chemical processes can erode areas of rocky shorelines by as much as 1 m in a year.

Did You Know?

Coastlines are areas of land that meet the ocean. Canada has the longest coastline in the world, approximately 243 042 km, or about one seventh of the world's total.

Figure 2.27 Ancient limestone in Arches Provincial Park, Newfoundland and Labrador has been eroded by waves and ice for thousands of years.

How quickly a coastline erodes depends on the force of the waves hitting the land and the type of rock the land is made from. Some softer rock, such as sandstone, erodes more easily compared with harder rock, such as granite. This mixture of hard and soft rock leads to uneven erosion and the formation of headlands and bays.

Headlands and Bays

As waves continuously erode away a shoreline, the rate of erosion can differ in areas where the composition of rock varies. Softer rock (such as sedimentary rock) that is more susceptible to erosion is broken down faster than an area composed of harder rock (such as igneous rock). The areas that are more easily eroded recede faster than other areas, creating **bays** in the coastline that are in between **headlands** (see Figure 2.28).

Because headlands reach farther out into the water than the land next to them, incoming waves hit them before reaching the rest of the shoreline on either side (see Figure 2.29). As a result, headlands receive the main force of the waves, which creates interesting features such as sea stacks (Figures 2.30 and 2.31).

Figure 2.28 Waves erode the shore into headlands and bays, such as shown here in Northern Bay, Newfoundland and Labrador.

After the headlands have absorbed most of the wave energy, the remaining waves refract and spread out, losing some of their power to erode.

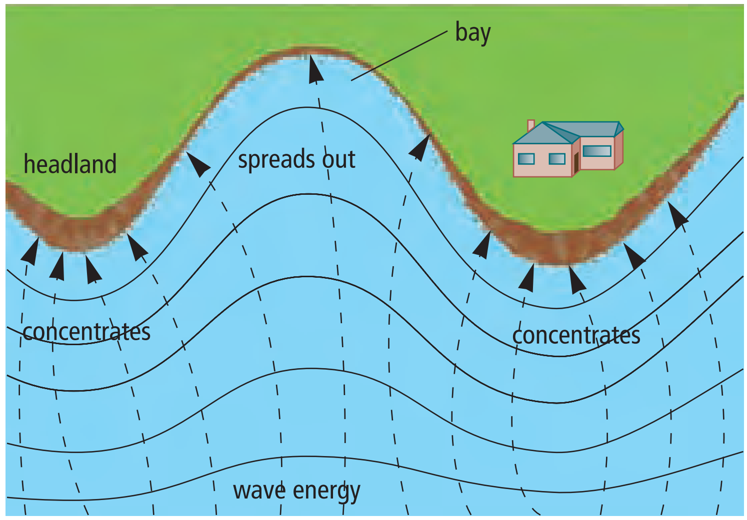


Figure 2.29 Headlands receive a concentrated force of wave energy, allowing the bays to receive a gentler force.

By the time ocean waves reach a bay, the waves are not travelling with the same amount of energy as when they hit the headlands. Once the waves slow down, they also deposit some of the sediments they have eroded from the headlands and elsewhere.

Figure 2.30 The province of Newfoundland and Labrador has many spectacular examples of sea stacks, such as this one on the East Coast Trail. Sea stacks can be formed from eroded headlands or when a sea arch collapses.

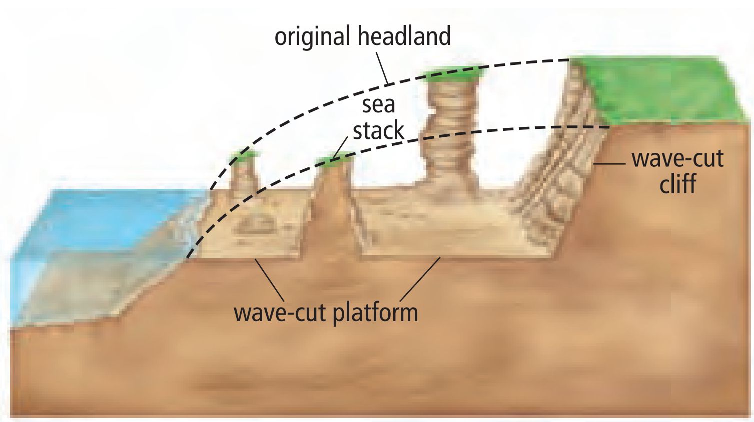


Figure 2.31 The results of headland erosion form interesting features.

How Beaches Are Formed

What happens to all the fragments of rock carried from the coast by crashing waves? As they rub against each other in the surging water, rock fragments are smoothed and ground down into smaller pebbles and grains of sand. Along steeply-sloping shorelines, these rock fragments wash back into the sea. This leaves a shoreline of only bare rock, with scattered boulders and larger stones. Where the shoreline has a gentler slope and calmer waters, smaller rock fragments can settle and build up, forming a beach.

Suggested Activity

Think About It 2-3A on page 72.

Beaches are deposits of sediment that run along the shoreline. The materials that form a beach range in size from fine grains of sand less than 2 mm in diameter to pebbles and small boulders. Most beach sediments are fragments of hard minerals such as quartz. Beaches can also include other minerals of various colours, or fragments of seashells and coral.

Due to the continuous action of waves, beaches are in a constant state of change. In winter, strong winds bring larger waves that remove more sediment from the beach than they deposit. The beach erodes and becomes narrower. Calmer summer weather produces low, gentle waves that deposit sediments on shore, rebuilding the beach.

Figure 2.32 Shorelines with a gentle slope allow the build up of sediment that is deposited by waves, creating sandy beaches such as this one in Sandbanks Provincial Park, Newfoundland and Labrador.

Reading Check

1. What is a swell?
2. How is a breaker formed?
3. What causes a tsunami?
4. What types of erosion happen on a shoreline?
5. How are headlands and bays created?

Suggested Activity

Investigation 2-3B on page 73.

Tides

Ocean beaches are sometimes covered by water, and sometimes they are not. They are covered and uncovered in regular daily cycles by the slow rise and fall of the ocean, called **tides**. The upper and lower edges of a beach are determined by the high-tide mark and the low-tide mark.

Centuries ago, people realized that the cycle of tidal movement is linked to the motion of the Moon. The largest tidal movements, called **spring tides**, occur when Earth, the Moon, and the Sun are in a line (see Figure 2.33A). At these times, the tides are extra high and extra low. The smallest tidal movements, called **neap tides**, occur when the Sun and the Moon are at right angles to each other (see Figure 2.33B). On these days, there is very little difference in depth between high and low tides. The difference in level between a high tide and a low tide is called the **tidal range**.

The link between Earth, the Moon, the Sun, and tides is gravity. Gravity is the force of attraction between two masses. Tidal movements result mainly from the pull of the Moon's gravity on

Explore More

In a few places in the world – including areas in Nova Scotia – there are "singing sands." These special sands make a fiddle-like sound when they are rubbed. Explore more about what exactly makes these sands "sing" by going to **www.discoveringscience8.ca**

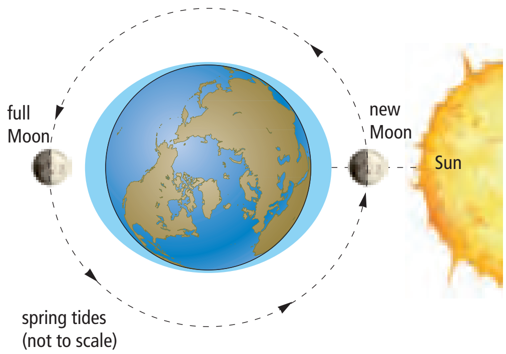


Figure 2.33A Spring tides occur twice per month, at full Moon (when Earth is between the Moon and the Sun) and at new Moon (when the Moon is between Earth and the Sun).

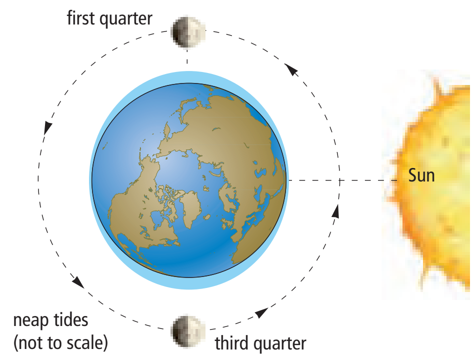


Figure 2.33B Neap tides occur twice per month, during the first-quarter phase and third-quarter phase of the Moon.

Explore More

Aboriginal peoples along the Atlantic coast have relied on low tides for food gathering. Low spring tides expose shellfish-covered rocks that are usually under water. To learn more about the history of Aboriginal fishing on the Atlantic coast, go to **www.discoveringscience8.ca**

the ocean. The Sun is much farther from Earth than the Moon is. The Sun has less than half as much influence on the tides as the Moon does, despite the Sun's much greater size.

During spring tides, the Sun adds its gravitational pull to the Moon's during the new moon and pulls in the opposite direction during the full moon, producing a large tidal range. During neap tides, the Sun and Moon pull in different directions.

If you look at the water moving up a beach as the tide rises, you may think that the volume of the ocean is increasing. However, the bulge of water that produces a high tide along one coastline draws water away from the other side of the ocean, just like water sloshing from one end of a bath tub to the other.

This movement of water causes a low tide along the opposite coastline (see Figure 2.34). As Earth turns on its axis, different locations on Earth's surface face the Moon. The result is a sequence of high and low tides that follow each other around the world. On many of Earth's shorelines, tides rise and fall about twice a day.

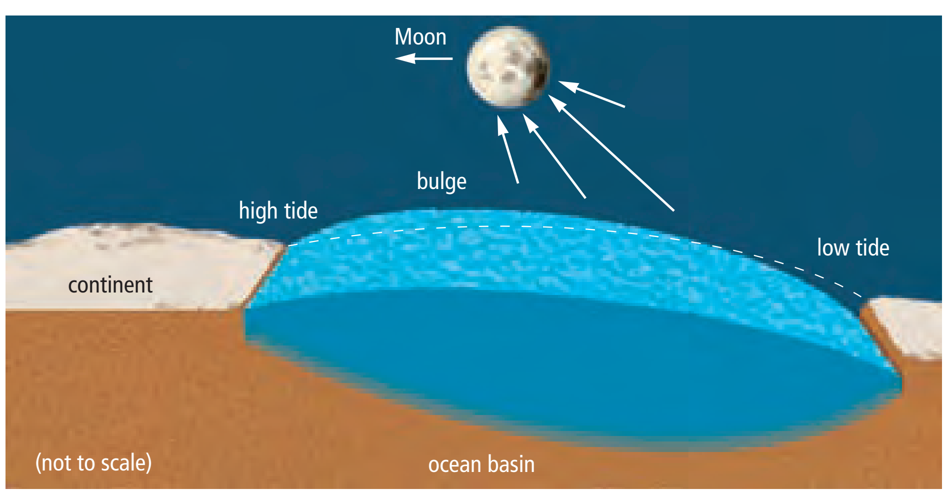


Figure 2.34 The gravitational pull of the Moon shifts water from one side of the ocean to the other.

In mid ocean, the rise and fall of the ocean averages less than 1 m. Along shorelines, the tidal movement is more noticeable. The shape of a shoreline can have a great influence on the size of the tidal range. For example, in the Gulf of Mexico, the tidal range is only about 0.5 m. The Gulf has a narrow passage, or mouth, to the open ocean, and a long curved coastline (see Figure 2.35A). A rising tide that enters the mouth spreads out around the bay, giving a small tidal range. In the Bay of Fundy in Nova Scotia, the opposite occurs. The bay there is long and V-shaped (see Figure 2.35B). Tides enter the wide mouth of the V and pile up as they are funnelled down to the narrow end of the bay. The tidal range in the Bay of Fundy can be as great as 20 m.

Figure 2.35A The Gulf of Mexico has a small tidal range.

Figure 2.35B The narrow Bay of Fundy produces a large tidal range.

Reading Check

1. What is the difference between a spring tide and a neap tide?
2. What is a tidal range?
3. What causes a tide?
4. How does the shape of a shoreline affect the size of a tidal range?

2-3A By the Seashore

Think About It

Question

What features exist along a shoreline due to erosion and depositing of material from waves?

From scenic cliffs to soft sandy beaches, shorelines have unique features due to their composition and the never ending waves that crash upon them. You can learn a lot about what a beach is composed of and what it formerly looked like from the features that presently exist. In this activity, you will research the processes of erosion and deposition that have resulted from wave action and water flow.

What to Do

1. Choose one of the following topics that relate to wave erosion and deposits:
   - beaches
   - shoals
   - sand bars
   - sea caves
   - sea arches
   - sea stacks
2. Using your resource centre and the Internet, locate and record information about the following aspects of your topic:
   - description of your shoreline feature
   - how it is created
   - local examples of your feature
3. After locating and recording your information, create a computer presentation (such as Powerpoint) or use the overhead projector to share your findings with the class.

2-3B Waves and Beaches

Conduct an INVESTIGATION

SkillCheck

- Observing
- Analyzing
- Interpreting
- Communicating

Safety

Materials

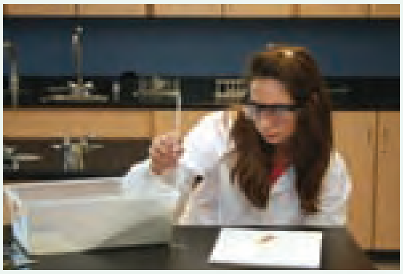
- beaker or measuring cup (500 mL)
- clear plastic or glass pan or small aquarium
- ruler
- small block of wood
- clock or watch
- plastic pail or container
- beach mixture 1 (450 mL sand + 150 mL gravel)
- beach mixture 2 (450 mL gravel + 150 mL sand)
- water

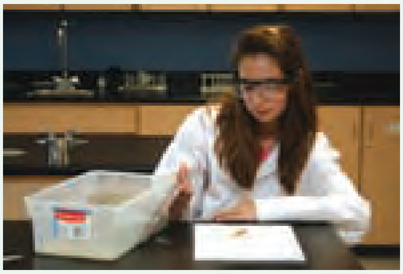
What happens to the material on a beach when waves strike it? Depending on the type of rock and the slope of the coastline, waves can either erode the land or build it up.

Question

How do waves affect beaches? Form a hypothesis about how the slope and materials of a beach will affect its size and shape.

What to Do





1. Using beach mixture 1, build a small beach at one end of the pan or aquarium. Use your ruler to measure the height of the beach at the top of the slope. Record the measurement.
2. Then, measure the width of the beach (from the top of the slope to the bottom of the slope). Draw a side view of the beach to scale and record your measurement.
3. Carefully pour water into the other end of the pan or aquarium until the water level reaches about one third of the way up the beach.
4. Make waves by holding the block of wood in the water and quickly moving it up and down for 2 min. Try to keep the speed and size of the waves constant.
5. After 2 min, draw a side view of the beach to scale. (Use your ruler to measure its dimensions and record this measurement.)

   (a) Label the position of the sand and gravel.

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Inquiry Focus

(b) Carefully pour off the water into a container provided by your teacher.

6. Rebuild a beach with a slope twice as steep as the first. Measure, record, and sketch the dimensions of the beach.
7. Repeat steps 3 to 5. Then, empty the water and beach materials into a container provided by your teacher.
8. Repeat steps 1 to 7, using beach mixture 2.
   (a) Wipe up any spills as wet floors are slippery.
   (b) Wash your hands after this investigation.

Analyze

1. Based on your models, describe the effect that wave action has on a beach made mostly of sand compared with a beach made mostly of gravel.
2. How does the slope of a beach affect erosion by waves?
3. How do the materials on a beach affect erosion by waves? Explain your observations by referring to the difference in the mass of grains of sand and pieces of gravel.

Conclude and Apply

4. Based on the results of this investigation, what effect do you think a large storm at sea might have on a sandy beach?
5. Beach erosion is a problem for many seaside communities. Suggest what might be done to prevent a beach from eroding.

2-3B Safeguarding Our Shorelines

Think About It

Question

How are shorelines changing in Newfoundland and Labrador, and what is being done to protect them?

Newfoundland and Labrador's coastlines are home to many communities as well as attracting thousands of tourists each year. Due to the erosion from waves, storms, winds, and tides, however, the coastlines are forever changing and are sometimes critically damaged. In this activity, you will research an historical event that affected local shorelines. You will not only look at the environmental damage, but also at the destruction of people and property. You will then research and learn about technologies that can help lower damage in future similar situations.

What to Do

1. As a class brainstorm about shorelines that you know have experienced damage because of erosion (from an event or a storm, or just gradual erosion).
2. Using books and newspapers from your library, and the Internet, research a recent or past event that has affected a local shoreline and created damage to property and the environment. Events may include the 1929 Grand Banks tsunami that struck the Burin Peninsula, coastal flooding, extreme high tides, and storms. A documented list of all coastal floods can be found at www.heritage.nf.ca/environment.
3. Find out what technologies exist that could help prevent such damage in the future. You may want to look at such structures as sea walls, breakwaters, jetties, groynes, vegetation.
4. Create a small presentation or poster display, describing the date, event, and the damage that was caused. Share your information with your class.

Wild, Weird, Wonderful

www Science

Wave-Weathered Wonders

Newfoundland and Labrador's coasts are home to hundreds of spectacular examples of how wave action weathers and erodes coastal rock. Below are just a few of these incredible features. How many more examples of coastal formations in Newfoundland and Labrador can you think of?

The Arches

The Arches were once sea caves.

Located north of Parsons Pond on the Great Northern Peninsula, the Arches are a spectacular example of rock erosion by the ocean. Wave action eventually separated this piece of limestone from the coast. The two arches were once sea caves and the continuous wear from waves slowly transformed the caves into arches.

The Spout

Located on the East Coast Trail, the Spout is a popular attraction for hikers.

Located midway between Petty Harbour and Bay Bulls, "The Spout" is a natural wave-driven geyser that exists because of the unique combination of several factors. A vertical crevasse in the rock sits above the sea cave far below. Fresh water run-off from the Spout River flows and fills the crevasse. At the same time, wave action from the ocean is flowing into the cave below and exerts pressure on the fresh water in the crevasse above it. The result is the fresh water being forced out of the crevasse and into the air, making it look like a geyser. When the ocean is rough, the wave action can force a spout up to 50 m high!

The Dungeon

The Dungeon is a huge sea cavern that collapsed. It is located near the tip of the Bonavista Peninsula.

Over thousands of years, the continuous waves of the Atlantic Ocean wore away rock, creating a cavern that was connected by two sea caves. Eventually, the cavern became so wide that it could not support the ground above it, and the roof of the cavern collapsed. Wave action has removed the material from the collapse, leaving a hole that is 250 m in diameter and 15 m deep. It is still connected to the ocean by two sea caves.

The Hole in the Wall

This feature is located near the community of Joe Batt's Arm. Wave and frost action eroded a weak section of rock material, creating a hole in the ocean-side cliff. The hole extends through the other side of the cliff, making it possible to see the valley on the other side.

Check Your Understanding

Checking Concepts

1. How do sea stacks form?
2. Why are shorelines in a constant state of change?
3. Why are we able to predict when the tide will rise and fall?
4. How does a tidal wave differ from a tsunami?
5. Why are tsunamis so destructive when they strike land?
6. Explain why tidal ranges (the difference between the height of high tide and low tide) vary in different areas.
7. A tide table for Corner Brook, on the province's west coast, lists a high tide at 1.45 m and a low tide at 0.58 m. What is the tidal range?

Understanding Key Ideas

8. How are ocean waves similar to sound, light, and radio waves?
9. Explain why headlands receive more force from waves coming to shore than bays do. Use a diagram to support your answer.
10. What causes breakers to form?
11. Why would there be no high and low tides if Earth did not have a moon?
12. You might have noticed that the Moon rises and moves across the night sky a little later each night. This causes the tides to rise 50 min later each day. If the tide rose at 6:20 A.M. one day at coastal town A, how many days would a resident there have to wait for a midday (near 12 noon) high tide to occur?
13. Referring to the maps below, explain why the tidal range in the Gulf of Mexico is so much smaller than that in the Bay of Fundy.

Pause and Reflect

Think back to the description of how tides are created, and then make one or more drawings (as necessary) to help you answer the following question.

What do you think would happen to spring tides and neap tides if the Moon were closer to Earth?

Chapter Review

Prepare Your Own Summary

In this chapter, you discovered the importance of the oceans to life on Earth. Create your own summary of key ideas from this chapter. You may include graphic organizers or illustrations with your notes. Use the following headings to organize your notes:

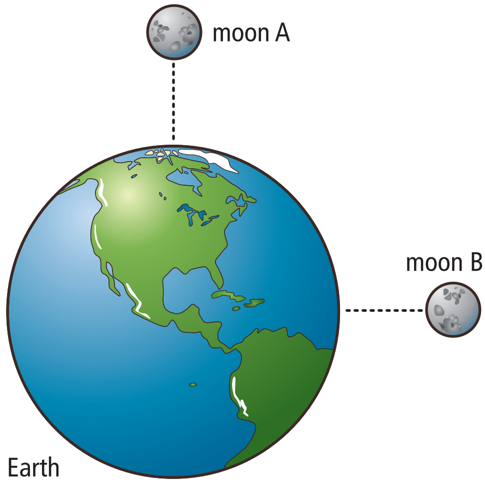
1. Ocean Basins
2. Ocean Currents
3. Waves and Tides

Checking Concepts

1. Explain why the ocean floor is not perfectly flat.
2. Describe three factors that affect surface currents on oceans.
3. How do winds form?
4. What causes waves in the ocean to form?
5. Why is it important for people who make their living from the sea to know the time of high and low tides?
6. What causes a wave to "break?"
7. Imagine two shorelines. One contains mostly limestone and another is made up of granite. Which shoreline will change more quickly than the other? Explain why.
8. Where do you expect to find ocean trenches?

Understanding Key Ideas

9. Why do trenches form at the edge of some continents?
10. As you have learned in this chapter, the Moon has a gravitational pull that affects the water in Earth's oceans. How would the tides be different if Earth had two moons, as shown in the figure below?



11. What processes produce bays and headlands?
12. Explain the difference between spring tides and neap tides.
13. How is a sandy beach formed?
14. How are satellites used to explore oceans?
15. What causes density currents?

16. The data below were collected from samples of water in the Atlantic Ocean. One sample came from near the surface, one from a depth of 750 m, and the third from near the ocean floor.

Sample	Temperature (°C)	Density (g/mL)
1	6	1.02416
2	3	1.02781
3	14	1.02630

Which sample do you think came from near the ocean floor? How do you know?

17. What is an upwelling?
18. Where does the sediment on the abyssal plains come from?
19. Name three factors that can either increase or decrease the salinity of the ocean. Explain how and where each of these might occur.
20. Why is the Atlantic Ocean getting wider?
21. How can scientists take pictures of objects at the bottom of an ocean without going down there in submarines?
22. Describe the motion of ocean water that occurs where strong winds are blowing from land offshore over the surface of the ocean. What is the term that is used to name this type of motion of water?
23. How could an earthquake at the bottom of an ocean create hazards for several different countries?
24. If the Sun, Moon, and Earth are lined up in a straight line, how does it influence the tides?
25. Before satellites were available for mapping ocean floors, how did scientists determine the shape of the ocean floors?
26. When an area of Earth's surface is heated by the Sun, the air becomes heated and rises. How does this rising air cause winds to blow horizontally or across Earth's surface?
27. When the Sun heats the surface of an ocean in some regions, large amounts of water to evaporate. How does this evaporation affect the salinity of the water near the surface? How does this change in salinity affect the motion of the water?
28. Which two ocean currents meet near the Grand Banks? How do these currents affect fishing off the Grand Banks?
29. Describe the shape of a shoreline that will produce a large tidal range.