TOPIC 4

The Moving Crust

Math CONNECT

If you were travelling at 100 km/h, how long would it take you to travel through Earth's crust? How long would it take you to travel through the entire mantle?

Why does Earth's crust move? The mystery of the moving crust has puzzled people for thousands of years. During the past 25 years technology has been developed to provide clues to solve the mystery. Many of those clues come from deep within Earth. If you could travel through Earth's crust into the centre of our planet, what would you find? Figure 5.35 is a model of the layers of Earth.

A. The crust includes the layer you can walk on, and is home to plants, animals, and soil. It also includes deeper areas where minerals are mined and oil and gas are formed. The crust is very thin under the ocean. In some places it extends only 5 km deep. Under some parts of the continents it reaches a depth of 60 km.

B. The **mantle** is found under the crust. It is made of rock material. The upper mantle is solid, and together with the crust forms the lithosphere. The lower mantle is partly melted and has the consistency of taffy. Rock material in the mantle can flow very slowly.

C. The outer core is composed of iron and nickel. The temperature here is over 5500°C. It is so hot, the iron and nickel are liquid.

D. The intense pressure of all the layers forces the inner core into a solid ball. The inner core has a temperature over 6000°C.

Cool Tools

Satellites high above Earth now take pictures of Earth. These pictures are similar to X-rays because they can show what is underneath the crust. They can detect differences in temperature the same way a CAT scan can detect a tumour inside a person's body. Computers are used to interpret the pictures.

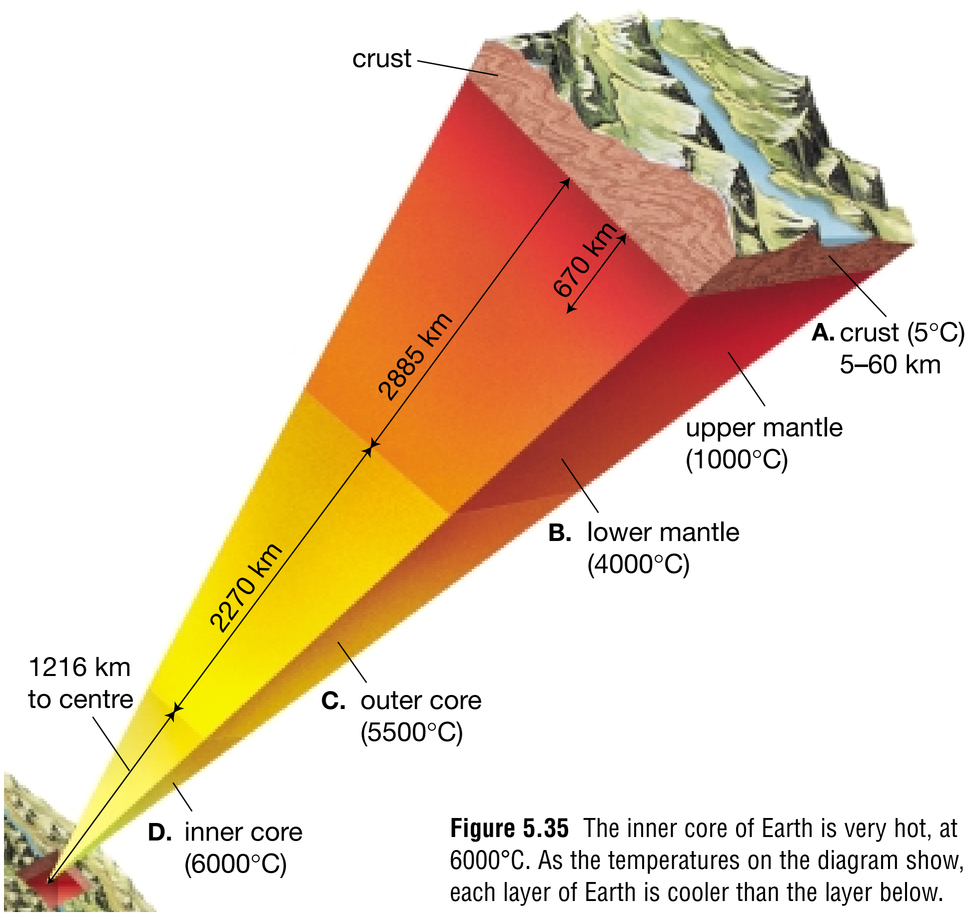


Figure 5.35 The inner core of Earth is very hot, at 6000°C. As the temperatures on the diagram show, each layer of Earth is cooler than the layer below.

Evidence for Continental Drift

The map of the world is a common sight on classroom walls. Look at Figure 5.36. Can you see where the bulge of South America could fit into the indented side of Africa? Are there other continents that might fit together?

The fit of the continents was a mystery to scientists for a long time. If the continents were fixed in place, why did they look as though they had once been joined? One scientist who wondered about the fit of the continents was Alfred Wegener (1880–1930).

Figure 5.36 The map above shows the location of three kinds of fossils that have been found on many different continents. Notice that fossils of *Glossopteris* have been found on Antarctica, which is totally covered with ice now.

Biological Evidence

In his research, Wegener noticed that several fossils of similar plants and animals (like those in Figure 5.36) had been found on different continents. *Mesosaurus* lived in freshwater lakes, and its fossils have been found in eastern South America and southern Africa. If it was able to swim in salt water, why did it not swim to more locations?

Lystrosaurus could not swim at all, but travelled from South America to Africa. It must have travelled by some sort of land connection.

Several explanations were offered for this biological evidence (evidence from plants and animals). Perhaps a bridge of land between the continents had existed, then disappeared. Maybe trees had fallen into the water, enabling animals to cross the ocean. At one time the ocean might have been lower and islands had existed close enough together to allow the animals to cross.

Wegener studied the fossil evidence and the interlocking shapes of the continents. He concluded the continents had been joined together when the fossil animals and plants had been alive. Over thousands, maybe millions, of years, the continents had gradually moved to their present locations. Wegener called his explanation **continental drift**.

Evidence from Rocks

Wegener continued his research. He examined the observations of other scientists to see if there might be more evidence to support the idea of continental movement. He discovered that geologists had found similarities in rocks on both sides of the Atlantic Ocean. A mountain range, called the Appalachians, in eastern North America was made of the same kind and ages of rock as the mountain range that ran through Britain and Norway (see Figure 5.37).

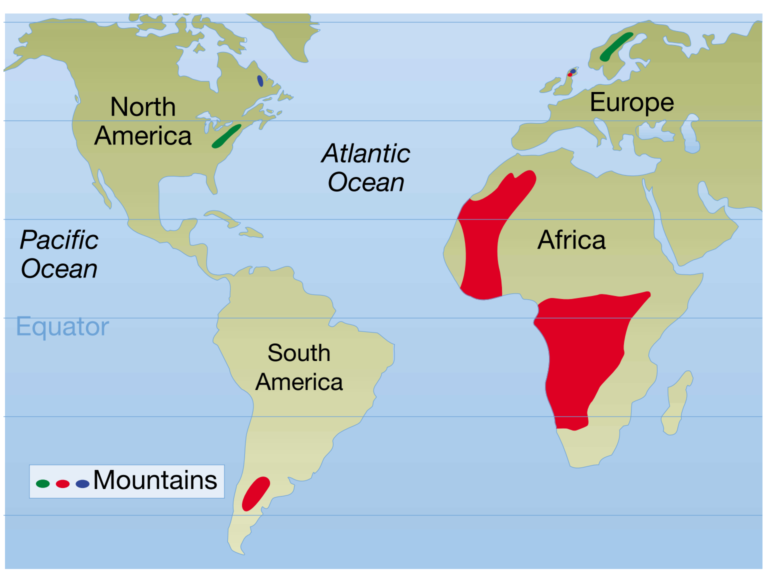
A further clue came from fossils of trilobites found high up on the Himalayan Mountains in India. These trilobites roamed the ancient seas 250 to 500 million years ago. How did trilobites end up on the "roof" of the world? The evidence suggested that India was once a separate piece of land. Many millions of years ago, India drifted into Eurasia. The collision pushed rocks containing fossils from the bottom of the sea up to the top of the Himalayan mountains (see Figure 5.38).

Geological Evidence of Climate

Coal provided further important information about Earth's history. In order for coal to form, there has to be rich, luxurious plant life in a tropical, swampy environment. The coal beds that exist in North America, Europe, and Antarctica are now in moderate to cold climates. How did tropical plants grow there in the past? Why has the climate changed in so many places?

For Wegener, the clues provided by geological evidence of climatic change raised questions that had no easy answers. Since Wegener was trained as a meteorologist, he was especially interested in these clues. He found evidence of even greater climatic changes in places that had probably been covered by glaciers.

Figure 5.37 How could mountains formed from the same type of rock occur thousands of kilometres from each other across an ocean?



Ancient glacial deposits (200 to 300 million years old) were found spread over the southern hemisphere. Layers of deposits left behind by glaciers were found in southern Africa, South America, India, and Australia. Under the deposits in some places, there were grooves in the bedrock showing the direction in which the glaciers had moved. All of these locations now had very warm climates, much too warm for glaciers. Was the whole world cold, or had these land masses moved to their present warm locations from a place nearer to the South Pole?

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus7

Find out more about Wegener by going to the web site above. Click on **Web Links** to find out where to go next. See if you can locate any drawings from Wegener's book. Find some information about him that you did not learn in this text, and use it to prepare a brief biography.

Response to Wegener

In 1915 Wegener published his findings in a book, written in German, called *The Origin of Continents and Oceans*. In the book, he stated that all of Earth's continents had been joined together in a giant supercontinent called Pangaea. Pangaea started breaking up about 200 million years ago, and the pieces began moving or drifting into their present locations. Wegener wrote, "It is just as if we were to refit the torn pieces of a newspaper by matching their edges and then check whether the lines of print run smoothly across. If they do, there is nothing left but to conclude that the pieces were in fact joined in this way."

To support his hypothesis about drifting continents, Wegener thought about what forces might be causing the movement. He proposed that the Moon might be responsible, but other scientists disagreed with him. Because Wegener could not satisfactorily explain the origin of the force that was moving the continents, the scientific community rejected his ideas on continental drift.

Wegener died in Greenland in 1930, still searching for evidence to support his theory of continental drift. Years later, advances in technology and the work of a Canadian scientist led to a new theory that explained Wegener's observations.

Figure 5.38 Earth may have looked like this 180 million years ago. Try to name the seven biggest land masses on the maps. Can you find India on the map?

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Give Me a Clue!

Wegener collected all of the fossil and rock evidence that he could find and put it onto a map of the world. He imagined that all of the continents that we see on Earth today were joined together in one huge supercontinent that he called Pangaea.

Question

What clues do fossils and rocks provide about the ancient world? Can you make the puzzle fit?

Apparatus

coloured pencils
scissors
glue

Materials

world map
blue paper

Procedure

1. **Examine** Figure 5.36. Mark the three fossils shown on your blank world map.
2. Put a legend on your map, telling what each symbol represents.
3. Find other fossil evidence in other sources. Try the Internet or a CD-ROM in your library. Hint: Look for *Cynognathus*!
4. Mark these additional fossil locations on your map. Add the symbols to your legend.
5. **Examine** Figure 5.37. Add the three samples of "rock evidence" to your map. Use four different colours to shade in the locations and call each colour "same rocks" on the legend. Do not cover up your fossil evidence.
6. On the world map, write the names of the seven continents on the land masses.
7. Colour each continent. Do not cover up any evidence you marked on the world map. Decide if India will be the same colour as Eurasia or a different colour.
8. Cut out the land pieces on the world map around the continental shelf edges. Remember to cut India away from Eurasia along the tops of the Himalayas.
9. Fit the pieces of the world map together to resemble Pangaea. Once the pieces are in place, glue them to a sheet of blue paper.
10. Transfer the legend to the blue paper by cutting it out or copying it.

Analyze

1. What difficulties, if any, did you experience in fitting the pieces of land together?
2. Which pieces were the hardest to fit together? How might these pieces have looked 300 million years ago? How could you test your ideas?

Conclude and Apply

3. Why was Wegener's idea on continental drift a reasonable one? Why did it make sense at the time?
4. As a young child, did you have ideas that you had to change as your knowledge increased? Was it easy or hard to give up your old ideas? How might your experience be compared to the experience of scientists?

Advances in Technology

Important and surprising clues about Earth's crust have been collected from the sea floor using **sonar** (sound wave technology), as shown in Figure 5.39A.

When many sonar tests from Earth's oceans were studied, the results amazed everyone. It was obvious that there were mountains on the sea floor. Moreover, there were long mountain ranges or ridges in some places, just like the mountain ranges that existed on land. Scientists identified a mountain ridge that stretched from north to south along the middle of the Atlantic Ocean. They called this ridge the Mid-Atlantic Ridge (see Figure 5.40).

The features found on the sea floor were similar to the features found on land. What was causing these mountains to form? The answer would come from another technology.

Cool Tools

Sonar stands for **So**und **N**avigation **a**nd **R**anging. This technology is used in nature by bats to navigate around objects in the dark. Sonar works by sending out a sound and then recording the time that the sound takes to bounce back. For example, scientists can bounce a sound off the ocean floor and measure the time that it takes to bounce back. Since they know how fast the sound travels, they can calculate the distance to the bottom of the ocean.

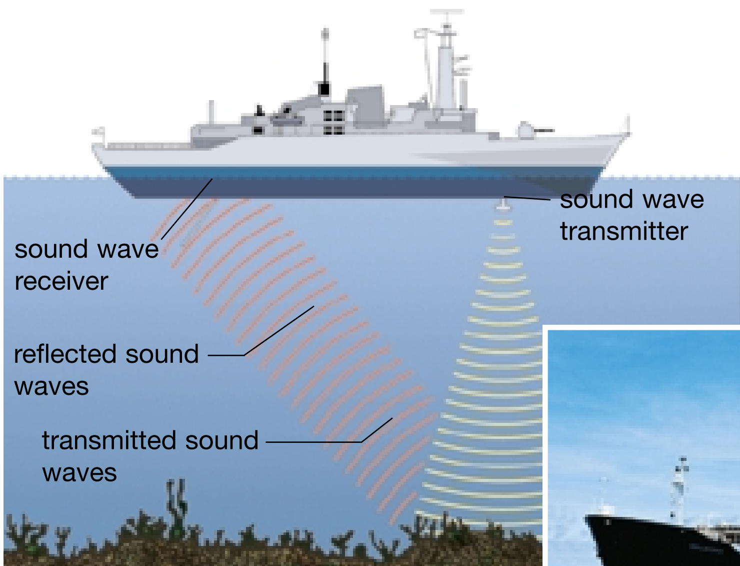


Figure 5.39A Sonar revealed that the ocean floor was not flat, as was previously believed.

Figure 5.39B The *Glomar Challenger* used oil-drilling technology to help scientists explore beneath the ocean floor.

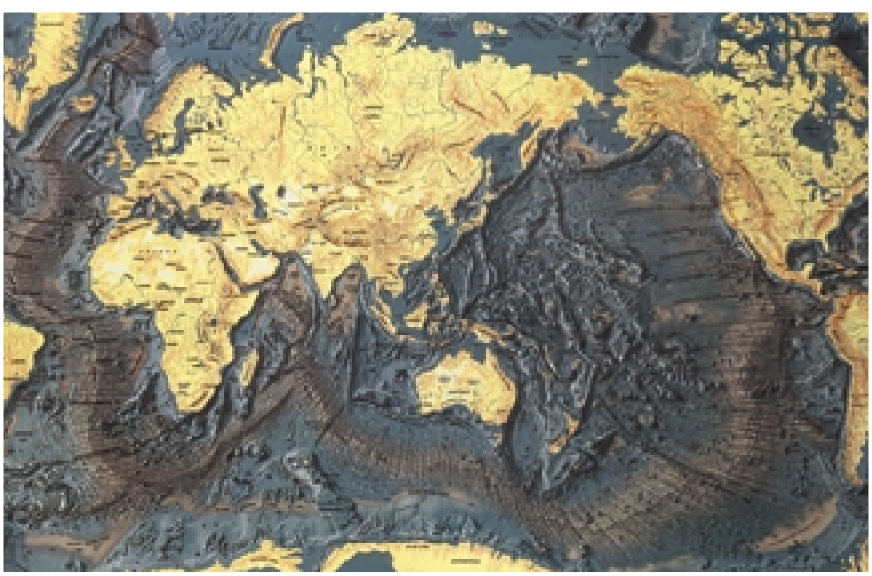


Figure 5.40 This map shows the mid-ocean ridges and the trenches. The long, ridged structures are the mid-ocean ridges.

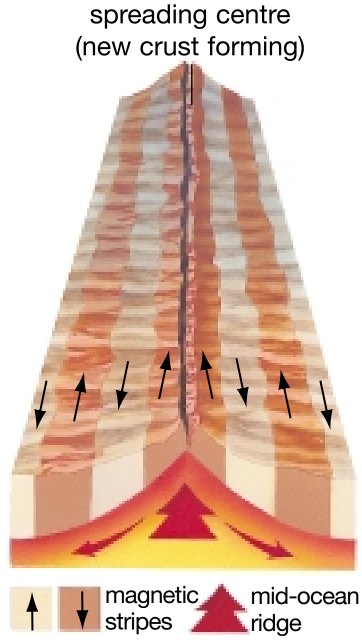


Figure 5.41 The pattern of magnetic reversals on the sea floor led scientists to the theory of sea floor spreading. As new crust forms, it takes on the magnetic polarity of Earth at the time of formation.

Magnetometers are electronic instruments that can detect the direction and strength of a magnetic field. They usually record a magnetic field that points north. However, as the ships that carried them moved across the Atlantic Ocean, sometimes the magnetometers recorded a magnetic field that pointed south. A pattern of magnetic reversals was found travelling parallel to the Mid-Atlantic Ridge. The width and direction of the stripes on both sides of the Ridge were similar (see Figure 5.41). What was causing the reversals?

Igneous rock provided a clue. The magma that forms igneous rock contains iron-bearing minerals such as magnetite. These minerals line themselves up with Earth's magnetic field. As the molten rock hardens at Earth's surface, the mineral particles stay in line with the magnetic field. So the magnetic reversal stripes must have formed at a different time — a time when Earth experienced a reversal of its magnetic field. If the stripes lined up with the ridges, it could mean that the sea floor was spreading. It also meant that new rock was being formed at the mid-ocean ridges. The theory of **sea floor spreading** was formulated.

Ask an Expert

Turn to page 434 to find out how Charlotte Keen studies rock many kilometres below Earth's surface.

Find Out ACTIVITY

What Do the Rocks Tell Us?

What information can rocks provide about the ocean floor?

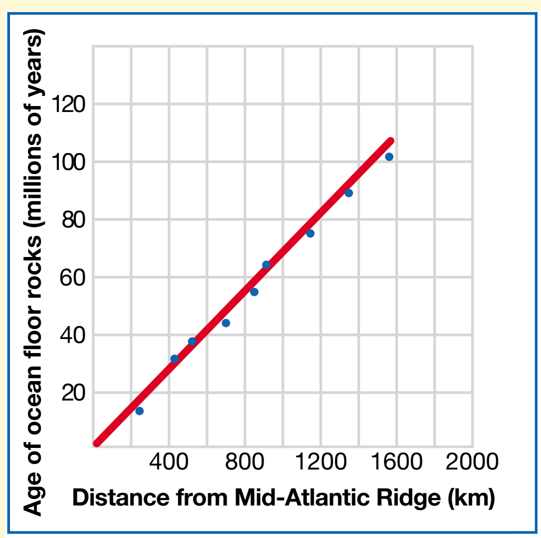
Procedure ✷ Analyzing and Interpreting

The graph on the right is a "best fit" graph. The small dots represent samples of rock taken from the magnetic stripes at the bottom of the Atlantic Ocean. Each dot represents a sample of rock.

1. Find the age of the oldest rock and the youngest rock on the graph.
2. State the distance of the oldest rock and the youngest rock from the Mid-Atlantic Ridge.
3. Infer or predict some additional data for the graph.

What Did You Find Out?

What does this evidence suggest was happening to the sea floor? Explain your answer.



Find Out ACTIVITY

The Spreading Sea Floor

When magma rises from the mid-ocean ridge, it produces a new crust which pushes the plates apart. How can you create a model of this process?

Materials

sheet of paper (21 cm × 28 cm)

paints, markers, or coloured pencils

scissors

tape

Procedure

1. Cut the paper in half lengthwise. Tape the ends together to make one long strip.
2. Push two desks or tables together. Fold the long strip of paper in half. Hold the paper vertically under the crack between the desks. Push the open ends of the folded paper upward until the ends are about 5 cm above the desk.
3. Fold the ends and colour a pattern on them.
4. Push up another 5 cm and colour a different pattern.
5. Repeat until all the paper is at the surface.

What Did You Find Out?

1. What does the paper represent in your model?
2. What does the crack between the desks represent?
3. Which pattern on your strip represents the oldest rock? the youngest rock?

Deep Sea Drilling

Scientists confirmed the theory of sea floor spreading when they were able to bring up samples of rock for testing. The ship *Glomar Challenger* (see Figure 5.39B) carried equipment that could drill deep holes into the sea floor. Rock from the holes was brought onto the ship for testing by scientists. Can you imagine the excitement of the scientists who first examined these rock samples, knowing that they were the first people in the history of the world to do so! Tests of the rock samples showed that younger rock was closer to the Mid-Atlantic Ridge and older rock was closer to the continents. Scientists found that the Atlantic Ocean is getting wider by about 2 cm every year — about the same speed that your fingernails grow!

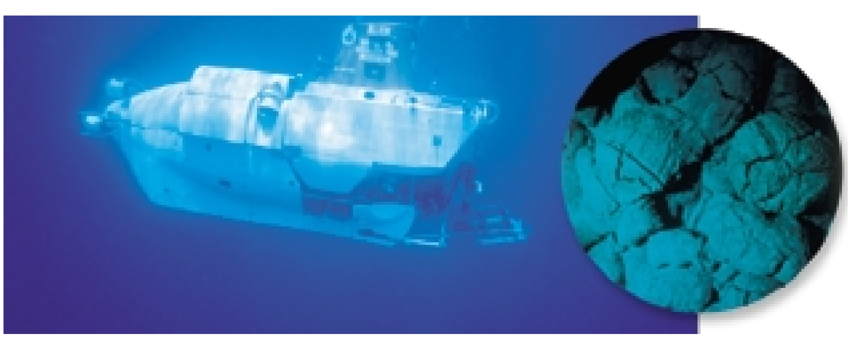


Figure 5.42 Advances in Canadian fibre technology have allowed submersibles to travel even deeper in the ocean. Submersibles like *Alvin* have made it possible for us to see lava coming out of cracks in the sea floor. The lava cools so quickly in the cold water that it is called "pillow lava." Why might it have been given this name?

Cool Tools

Even with scuba (**s**elf-**c**ontained **u**nderwater **b**reathing **a**pparatus) gear, deep-sea divers can go only a few hundred metres down into the ocean because of the tremendous pressure of the water on their bodies. Submersibles allow people to travel deeper into the ocean by protecting them from the pressure of the water. Submersibles are equipped with an air supply and powerful lights.

The Theory of Plate Tectonics

The evidence collected by advanced technology indicated that Earth's crust was moving. The crust was not fixed in place, as most people believed.

A Canadian scientist helped form a new theory to explain how the crust moves. The new theory stated that Earth's crust is broken up into pieces, called **plates**. These plates are always moving on Earth's mantle. Scientists called the new theory **the theory of plate tectonics.**

In Figure 5.43, the major plates are labelled. Can you see that most of the plates are named for the continent that is on the plate? Two plates pushing together are called **converging plates**. Two plates pulling apart are called **diverging plates**.

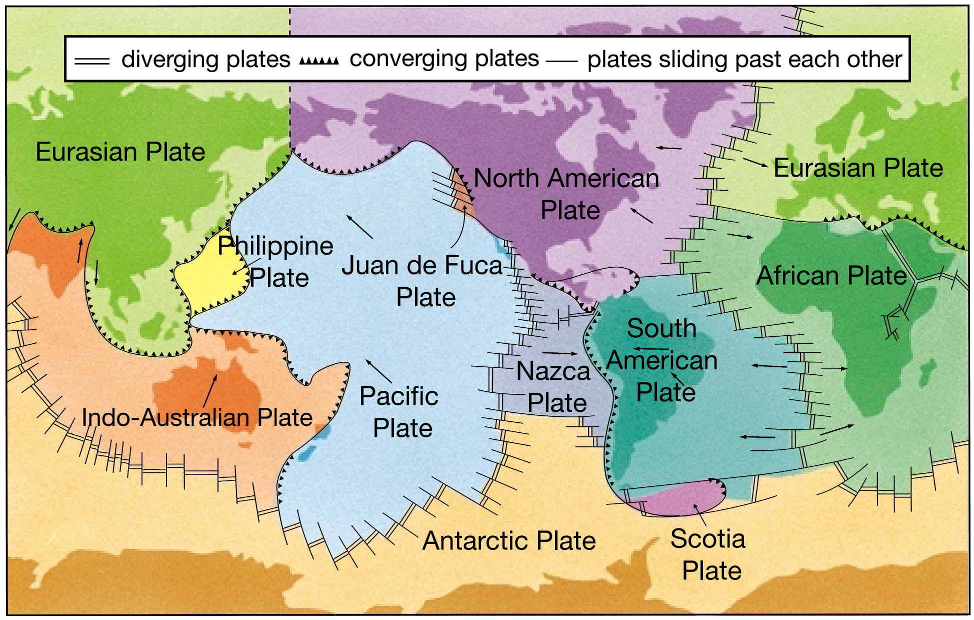


Figure 5.43 This diagram shows the major plates, their direction of movement, and the type of boundary between them. What is happening to the Juan de Fuca Plate where it meets the North American Plate?

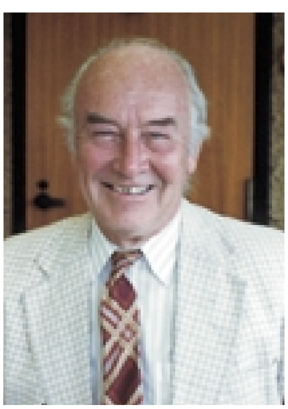


Figure 5.44 Tuzo Wilson (1908–1993)

J. Tuzo Wilson, a Canadian scientist, is one of the long line of scientists who have contributed to our understanding of Earth's crust (see Figure 5.44). He made an important addition to scientific observation when he developed the concept of a third kind of movement along plate boundaries. Instead of pushing together or pulling apart, he hypothesized that plates were sliding past each other.

Wilson's idea of sliding plates brought about a rethinking of Earth's crust movement.

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Building a Model of Plate Tectonics

Geologists often have a difficult time duplicating the conditions found in Earth's crust, so they develop models and computer simulations to use in the laboratory. Models help them develop hypotheses about why Earth's crust behaves the way it does. In this investigation you and your partners may collect the same data, but each of you may develop a different hypothesis. Many geologists create different hypotheses based on the data they collect.

Question

What hypothesis about Earth's crust can you form based on your model?

Apparatus

1 large plastic tub (35 cm x 25 cm x 15 cm) per group
4 petri dishes
measuring container
pieces of puzzles, marbles, building blocks, bingo chips, etc.

Materials

2 boxes (1 kg) of cornstarch per group
water
spoon
disposable gloves (optional)

Procedure

1. Clean the plastic tub.
2. Wear disposable gloves or wash your hands before beginning. Only one person's hands should be in the mixture at one time. It is important that the mixture stays clean.
3. Mix the cornstarch and 500 mL water in the tub. Continue adding water until the mixture is solid when you squeeze it between your fingers and runs through your fingers when you hold it loose in your palm.
4. **Investigate** the properties of this mixture for several minutes. Then squeeze as much cornstarch as possible from your hands back into the tub.
5. Meanwhile, the remaining partners can work with small amounts of the mixture in petri dishes. Use the bingo chips, puzzle pieces, and any other objects approved by the teacher. **Create a model** of plate tectonics in the petri dishes while you wait your turn for the larger tub. Slide the objects slowly across the surface. Create many different types of boundaries between the continental plates. **Form a hypothesis** about Earth's crust based on your observations.
6. **Record** your observations and hypothesis.

Analyze

1. **Describe** the appearance of a freshly broken piece of cornstarch. **Explain** how this might support your hypothesis on plate movement.
2. Why do some substances float and some sink in the mixture?

Conclude and Apply

3. In what ways does the mixture resemble a liquid?
4. In what ways does the mixture resemble a solid?
5. **Explain** why you think the mixture has these unusual properties.
6. **State your hypothesis**. Support it with evidence from your investigation.

Extend Your Knowledge and Skills

7. How do you think your model helps to explain the concept of plate tectonics?
8. **Draw a diagram** of your model. Use arrows to indicate plate movement.
9. **Design** a new experiment to support your hypothesis.

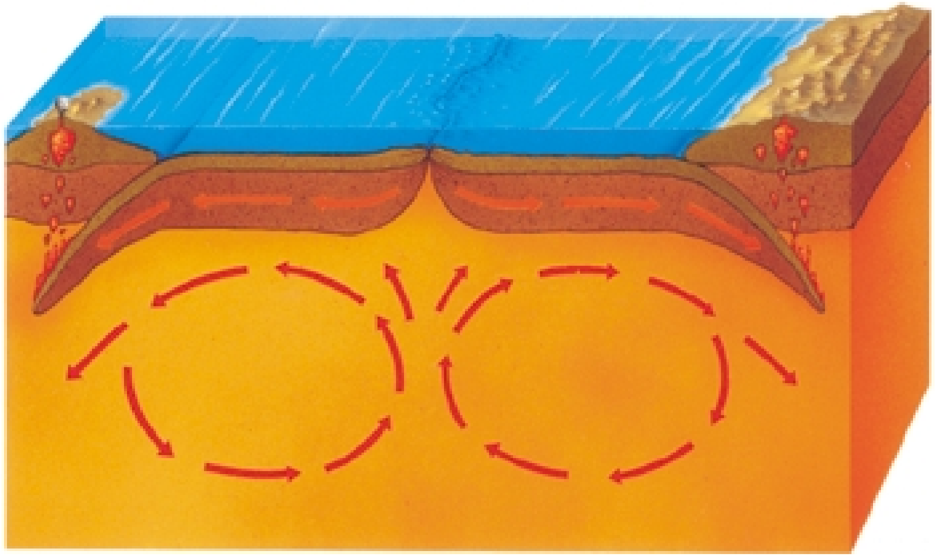


Figure 5.45 This model shows one way that convection currents might move plates.

Convection Currents

Geologists are still not sure what causes Earth's plates to move. One explanation is that convection currents in the mantle under Earth's crust move the plates (see Figure 5.45). A **convection current** is the flow resulting from the rise of warmer materials and the sinking of cooler materials. Many scientists believe convection currents are moving Earth's plates as shown in Figure 5.46 below. Study the diagram.

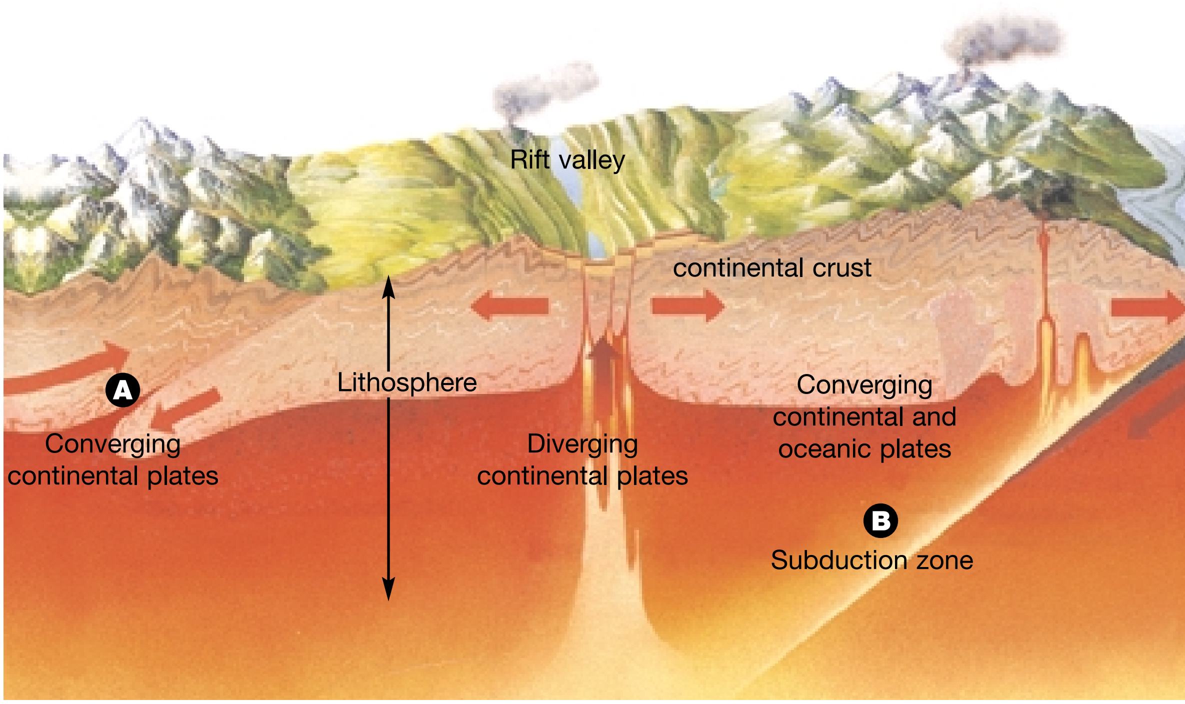


Figure 5.46

A If converging plates are both continental, their leading edges crumple, forming mountains.

B If an oceanic plate slides under the continental plate, melting occurs, forming volcanoes and mountain ranges.

Each plate touches several other plates. Scientists call the places where the two plates collide convergent or collision boundaries. Although they move too slowly for us to notice, each movement affects other plates as shown in Figure 5.46. When two plates collide or converge, one is shoved under the other. These places are called **subduction zones**.

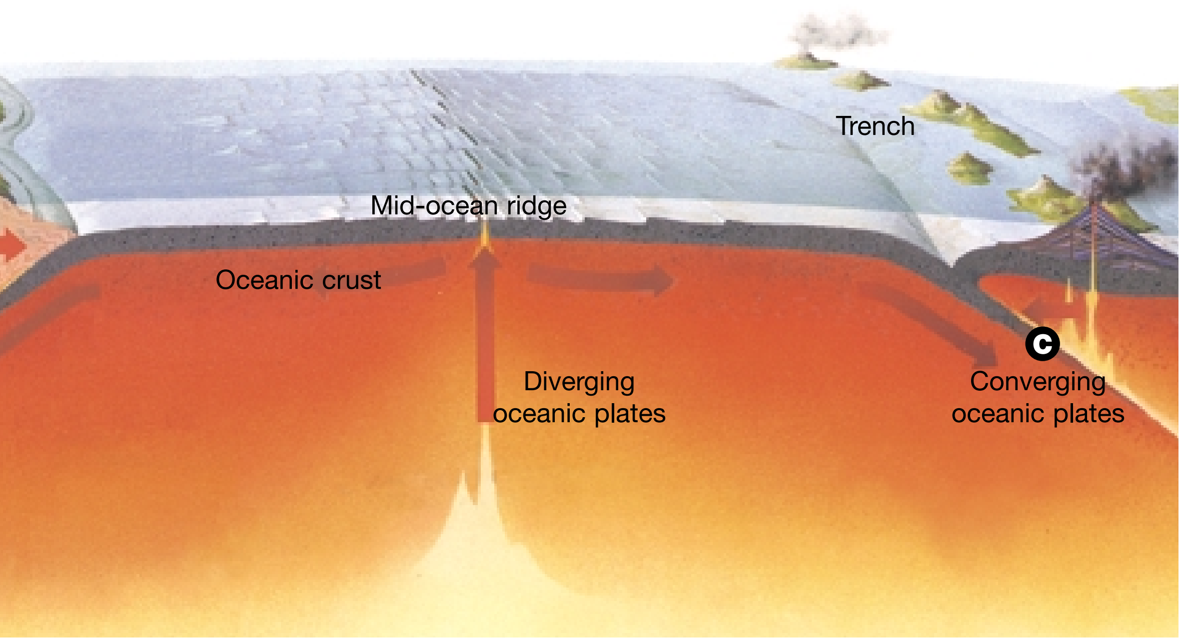
Scientists suggest that subduction zones form where convection currents cool and sink. The same process might be occurring in Earth's mantle, creating the force behind plate tectonics. Hot plastic-like rock in the lower mantle moves upward after it is heated by the intense heat in Earth's core. At the upper part of the mantle, the heated rock moves horizontally under the plate above it. The heated rock moves the plate along as if the plate were on a conveyor belt. When the rock finally cools, it sinks down farther into the mantle. As it does so, it pulls the edge of the plate down with it, forming a deep ocean trench.

The convection currents might be causing the Atlantic Ocean to widen at the Mid-Atlantic Ridge. Does this mean that Earth's crust is getting bigger? No, because while new crust is forming in the middle of the Atlantic Ocean, other crust is being pushed or pulled down into the ocean trenches and recycled back into the mantle as molten rock.

The theory of plate tectonics is called a unifying theory, a single theory that explains different natural events and landforms. The theory is our best explanation for the formation of earthquakes, volcanoes, and mountains. Who knows what further discoveries will be made in your lifetime!

Pause& Reflect

Scientists are using satellites and lasers to measure plate movements. Plates that hold the greatest continental masses move more slowly than plates that hold smaller continental masses. The African, Eurasian, and American Plates move about 20 mm per year. In comparison, the Pacific, Nazca, and Cocos Plates can move up to 130 mm per year. Plate movements are an example of incremental change, which is change that happens slowly. Where might the plates be in a million years? in a billion years? Use library resources to find the answer, or research on the Internet. Find a simulation of plate movements predicted for the next four billion years.



C If the two converging plates are oceanic plates, either plate might subduct, forming island arcs and volcanoes.

Pause& Reflect

Miners of the future may look for gold and other precious metals on the sea floor near volcanic vents called black smokers. Scientists say that the vents act like smelters. The vents dissolve metals from the surrounding rock and send them into the cold water, where they collect outside the vents. Use the Internet or library resources to find out about a fossilized black smoker deposit called Kidd Creek in northern Canada. Write notes about your findings in your Science Log.

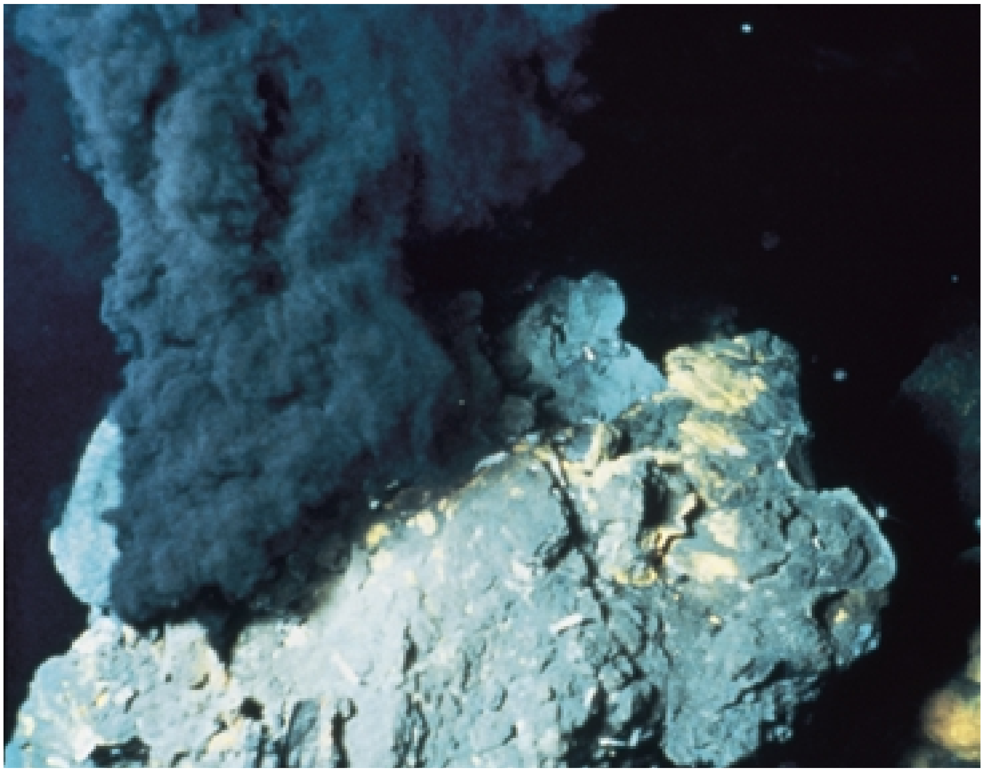


Figure 5.47 When submersibles found deep-sea vents called "black smokers," they also found tube worms. The sulfur compounds escaping from the vents provide an energy source for the worms.

Skill FOCUS

To find out how to use technology tools to research, turn to Skill Focus 9.

TOPIC 4 Review

1. Make a drawing of Earth's interior and label the four main layers.
2. List the three kinds of evidence that Wegener collected to support his idea of continental drift. Give one example for each kind of evidence, and explain why the example suggested that the continents had moved.
3. **Thinking Critically**
   (a) Why were other scientists unwilling to accept Wegener's ideas?
   (b) Are people generally willing or unwilling to change? What does this suggest to you about scientific progress?
4. What do scientists now think is causing the continents to move?
5. (a) What happens when continental plates collide?
   (b) What happens when a continental plate and an oceanic plate collide?
   (c) What happens when oceanic plates collide?
6. In what two ways is the plate tectonics theory different from the ideas of continental drift?

TOPIC 5

Earthquakes

You are in a class at school, and suddenly a bell starts to ring very loudly. The teacher asks you all to leave the room calmly and walk outside to a safe place for attendance to be taken. You are having a fire drill, just as students in schools do every year. Now imagine yourself sitting in your classroom and hearing the same bell ring. This time the teacher asks everyone to get under the desks as shown in Figure 5.48. You are having an earthquake drill. Students who live in places where earthquakes can happen have earthquake drills as well as fire drills.

How do you know if your school should have earthquake drills as well as fire drills? How do people prepare for earthquakes? Where do earthquakes happen in Canada?

DidYouKnow?

Animals have often been thought to "predict" earthquakes. Caged rabbits will hop around wildly for several minutes before an earthquake. Deep-sea fish will swim close to the ocean's surface. Some fish, such as catfish, have actually jumped out of the water onto dry land just before an earthquake has struck. Bees sometimes evacuate their hives in a panic minutes before an earthquake. Mice can be so dazed that they can be captured by hand.

Figure 5.48 These students are crouched under a classroom table during an earthquake drill.

Figure 5.49 Seismologists study earthquakes by reading seismograms.

Cool Tools

The eight dragon heads that are attached to this urn have little balls inside them. Earthquake movement shakes the balls into the toads' open mouths. The direction of the earthquake is determined by which toad swallows the ball.

How accurate was this ancient device? On one occasion long ago, a ball fell from a dragon's mouth but no ground movement was noticed. Several days later, however, a messenger brought news of an earthquake that had happened about 650 km away.

Did You Know?

A seismograph will move only if the bedrock moves. It will not register movement even if you, and everyone else in your whole class, jump up and down right beside it. Usually several seismographs are mounted together in order to sense the different directions of movement that can happen in an earthquake. One seismograph measures vertical (up-and-down) movement, while another measures horizontal (side-to-side) movement.

Measuring Earthquakes

Scientists called seismologists use a special machine called a **seismograph** to measure earthquakes (see Figure 5.49). Seismographs must be attached to **bedrock** (the solid rock that lies beneath the soil and looser rocks) in order to feel the vibrations that result from an earthquake. Inside the seismograph, a marking pen hangs over a rotating drum, just touching the drum. The drum is covered with paper to record the vibrations marked by the pen. When an earthquake strikes, it shakes the bedrock, causing the pen to move while the paper drum stays still. The pen point moves against the paper drum, making a jagged line. Most modern seismographs are electronic, but they are based on the same principle.

Seismologists use a method of measurement called the **Richter scale** to describe the magnitude (strength) of an earthquake. The scale starts at zero and can go as high as necessary. The amount of energy released increases greatly as the numbers increase. An earthquake that registered 7 would be about 30 times stronger than one that registered 6, and about 900 times stronger than one that registered 5. Most earthquakes that cause damage and loss of life register between 6 and 8 on the Richter scale; the Kobe earthquake (see Figure 5.50) registered 7.2.

Table 5.3 shows some of the numbers on the Richter scale, the effects of earthquakes of each magnitude, and their frequency.

Table 5.3 Richter Scale

Richter magnitudes	Earthquake effects	Estimated number per year
< 2.0	generally not felt, but recorded	600 000
2.0 – 2.9	felt by few	300 000
3.0 – 3.9	felt by some	49 000
4.0 – 4.9	felt by most	6200
5.0 – 5.9	damaging shocks	800
6.0 – 6.9	destructive in populated regions	266
7.0 – 7.9	major earthquakes, which inflict serious damage	18
≥ 8.0	great earthquakes, which produce total destruction to communities near the source	1.4

SOURCE: Earthquake Information Bulletin

Earthquake Waves

There can be many episodes of ground-shaking movement in an earthquake caused by **seismic waves**. These are the energy waves that travel outward from the source of the earthquake. These **aftershocks** are actually smaller earthquakes, and they can cause damaged buildings to collapse. The Kobe earthquake in Japan produced over 600 aftershocks.

Figure 5.50 In 1995 an earthquake in Kobe, Japan, caused over 5000 deaths and cost many billions of dollars in property damage.

Find Out **ACTIVITY**

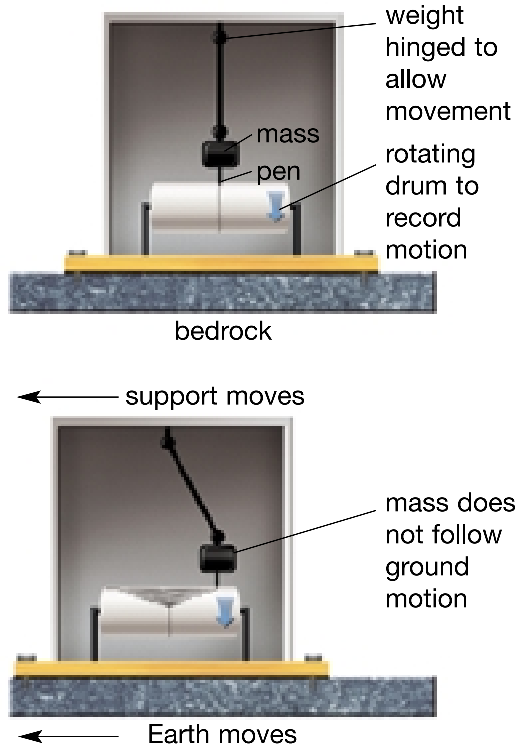
Shake It!

With a partner, design and make your own seismograph.

Procedure ✸ Initiating and Planning

What parts in the diagram might present a challenge? What method could you devise, other than a rotating drum, to record movement? Draw and label your design. Write what you will need to make your seismograph and how you will go about it. If your model differs in any way from your design, draw and label your seismograph. Describe the changes and why you made them.

Demonstrate your seismograph for other students. Compare it with those designed by your classmates. Discuss your comparisons with your partner, and write down what you noticed. How might you improve your seismograph?



Extension

Find out if there is a seismograph located somewhere close to where you live. The best place to start is the university or college closest to your home. If it is close enough to visit, check with your teacher about arranging a field trip for your class to see the seismograph.

Types of Earthquake Waves

Math **CONNECT**

Primary waves travel at about 6 km/s through Earth's crust. The distance from Edmonton to Calgary is about 300 km. How long would it take for primary waves to travel between these two cities?

Three kinds of seismic waves occur in an earthquake.

- **Primary** or **P waves** travel the fastest of all three types of waves and can pass through solids, liquids, and gases. They cause a slight vibration (compression) that would rattle dishes on the shelves. These waves warn people in earthquake areas that an earthquake is happening and can give people a few seconds to prepare for the movement to come.
- **Secondary** or **S waves** travel more slowly than P waves and can pass only through solids, not through liquids or gases.
- **Surface waves** are the slowest of the three waves, but their rolling motion breaks up roads and buildings, so they do the most damage. You have probably thrown a small stone into water and watched the ripples spread out from the point where the stone entered the water. Surface waves travel through Earth in just the same way. They cause part of a building to move up while another part moves down. Rigid structures will collapse if the movement is too great.

Examine Figure 5.51. Which type of wave causes the greatest reaction in the seismograph? What does the seismogram tell you about the arrival times of the different waves?

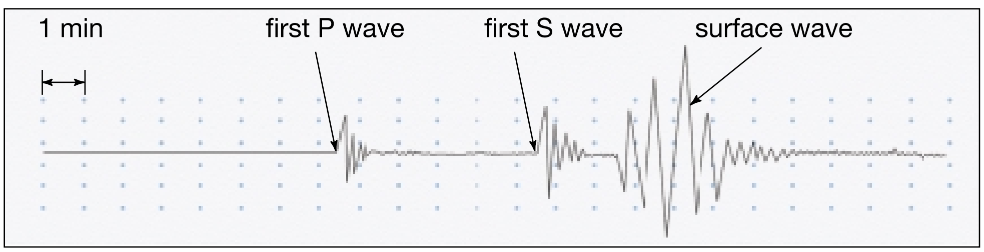


Figure 5.51 The jagged line on this seismogram represents the three different kinds of waves.

Earthquake waves give us some evidence of what might be inside Earth. The earthquake that happened in Kobe, Japan, in 1995, registered on the seismograph at the University of Manitoba because P waves travel right through the centre of Earth. S waves did not register. We know that P waves can travel through liquid and that S waves cannot. Therefore, we can hypothesize that Earth's outer core must be liquid.

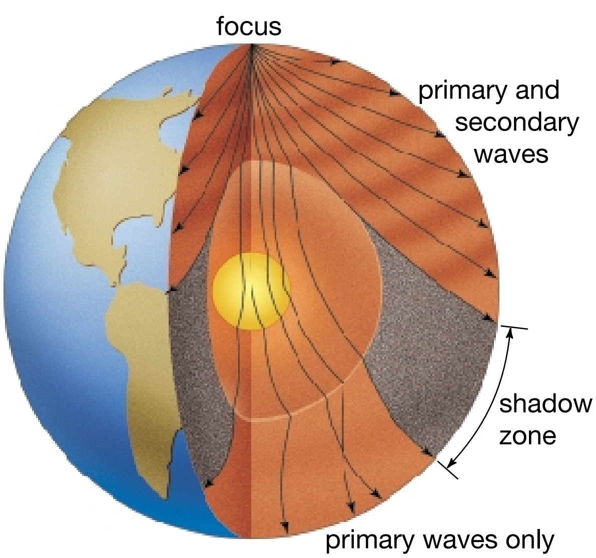


Figure 5.52 Primary waves are bent or refracted as they travel. There is an area where they do not come through on the other side of Earth. This area is called a *shadow zone*.

Locating an Earthquake

During a thunderstorm, you see lightning before you hear thunder. It is possible to estimate how far away the storm is by counting the time that passes between the flash of lightning and the sound of thunder. Light travels many times faster than sound, so you see the lightning flash before you hear the thunder. The more seconds you can count between the lightning and the thunder, the farther away the storm is. If the thunder happens at almost the same time as the lightning, the storm is right above you.

You can use the same idea with earthquake locations. You know that P waves travel faster than S waves. Since this is so, it is possible to determine the location of an earthquake by the interval between the P and S waves. The farther apart the P and S waves are, the farther away the earthquake.

Scientists have a special name for the source of an earthquake. In fact, they use two names. The place deep in the crust where the earthquake begins is called the **focus** of the earthquake. The primary and secondary waves come from the focus of the earthquake. The surface location directly above the focus is called the **epicentre.** Surface waves travel out from the epicentre (see Figure 5.53).

DidYouKnow?

The British Columbia coast is an earthquake area, as are the Atlantic seaboard, the St. Lawrence River Valley, the high Arctic, and the Yukon Territory. About one quarter of the earthquakes in Canada take place in northern regions where there are not many people to notice the vibrations. The first major Canadian earthquake on record occurred about 1535, near Québec City.

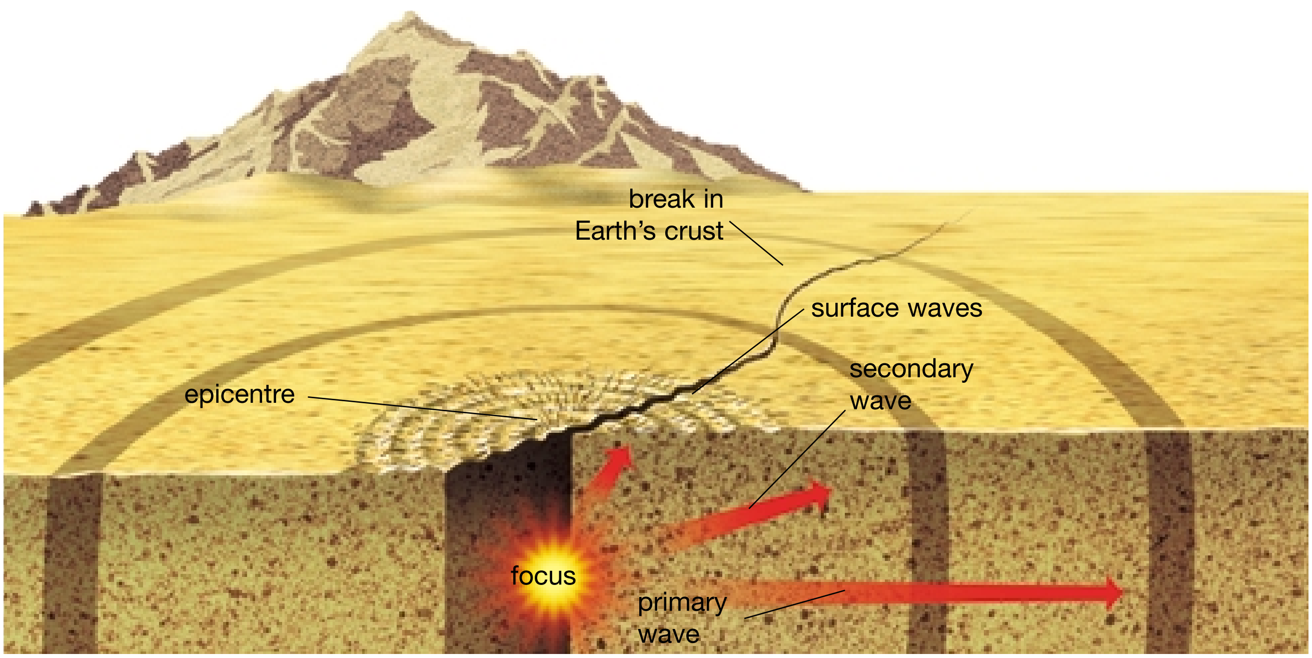


Figure 5.53

A Sudden movement in Earth's crust releases energy that causes an earthquake. The point beneath Earth's surface where the movement occurs is the focus of the earthquake.

B Primary waves and secondary waves originate at the focus and travel outward in all directions. Primary waves travel about twice as fast as secondary waves.

C The place on Earth's surface directly above the focus of the earthquake is called the epicentre. When primary and secondary waves reach the epicentre, they generate the slowest kind of seismic waves, surface waves.

D Surface waves travel outward from the epicentre along Earth's surface much as ripples travel outward from a stone thrown into a pond.

INQUIRY

INVESTIGATION 5-H

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Locate the Epicentres

Each year, areas of Canada experience low-intensity earthquakes. In this activity you will plot data to discover the epicentres of two earthquakes.

Question

How can you use the data from seismograph stations to locate the epicentre of earthquakes?

Materials

compass

pencil

map of Canada provided by your teacher, with scale of 1000 km = 2.2 cm

Part 1

Procedure

1. Copy the data table into your notebook. Use the graph provided to determine the difference in arrival times for primary and secondary waves for each distance in the table. Two differences are already provided.

Data Table

Distance (km)	Difference in arrival time
1500	2 min; 45 s
2250	
2750	
3000	
4000	5 min; 35 s
7000	
9000	

Analyze

1. What happens to the difference in arrival times as the distance from the earthquake increases?
2. Based on your calculations, **make a hypothesis** about how this graph could be used to determine the epicentre of an earthquake.

Part 2

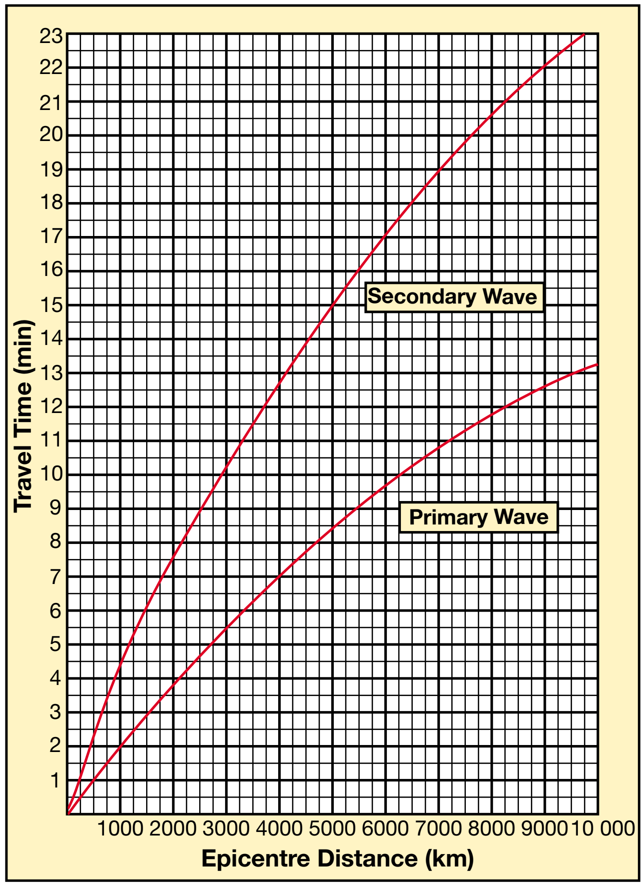
Procedure

1. Use the Epicentre Location chart to determine the difference in arrival time for the primary and secondary waves at each station. **Develop a chart** to record and organize your data.
2. Use the Time Travel Graph for P and S Waves to determine the distance in kilometres of each seismograph from the epicentre of the earthquake. **Record** your data in your chart.
3. Now you know how far each city is from the earthquake. Next you need to draw a circle around each city with the radius of the circle being the time lag distance. Use the scale on the map provided by your teacher. Set your compass radius to the distance Earthquake A is from Edmonton. Draw a circle around St. John's with your compass.
4. Repeat step 3 above, setting your compass radius for the distance of the epicentre from Iqaluit. Using this new radius, draw another circle on your map with Iqaluit as the centre of your circle.
5. Repeat step 3 above for all your data.

Epicentre Location Data and Observations

Location of seismograph	Wave	Wave arrival times	
		Earthquake A	Earthquake B
(1) Edmonton	P	2:36:15 p.m.	4:42:10 p.m.
	S	2:38:52 p.m.	4:48:25 p.m.
(2) Iqaluit	P	2:32:35 p.m.	4:50:23 p.m.
	S	2:39:15 p.m.	4:55:03 p.m.
(3) Whitehorse	P	2:25:00 p.m.	7:50:35 p.m.
	S	2:28:50 p.m.	7:58:10 p.m.
(4) Ottawa	P	1:30:00 p.m.	4:30:05 p.m.
	S	1:36:45 p.m.	4:31:40 p.m.
(5) Yellowknife	P	4:22:15 p.m.	4:42:12 p.m.
	S	4:26:25 p.m.	4:48:32 p.m.

Time Travel Graph for P and S Waves



Analyze

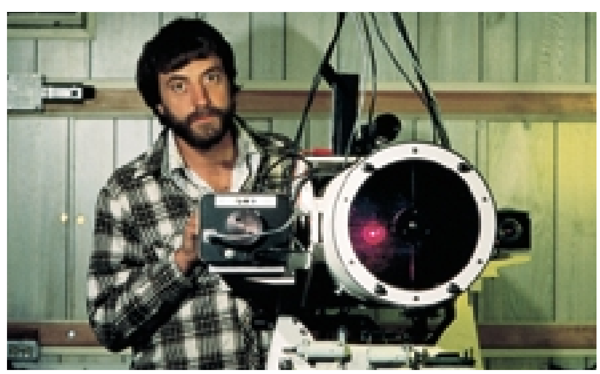
1. Identify the epicentre of each earthquake. Near which two cities did the earthquakes occur?
2. How is the distance of a seismograph from the earthquake related to the arrival time of the waves?
3. How many seismograph stations were needed to accurately locate each epicentre?

Conclude and Apply

4. What does this method reveal about the intensity of an earthquake?
5. How might seismologists use similar techniques to determine the epicentre of earthquakes?

Cool Tools

This system of lasers monitors movement along the San Andreas Fault. A series of 18 reflectors are positioned several kilometres away from the laser station. If a reflector's position changes, the change is measured. Movements of less than 1 mm along the fault can be detected.



INVESTIGATION 5-I

SKILLCHECK
- Initiating and Planning
- ✸ Performing and Recording
- ✸ Analyzing and Interpreting
- Communication and Teamwork

Plotting Earth's Movement

Think About It

Earth scientists use information about earthquake locations to study plate boundaries. Plotting the foci of many earthquakes may indicate the outline of possible plates.

The table below shows the location of 11 earthquake foci that occurred under South America. Thousands of earthquakes have happened in this area. How can earthquake locations tell us how the plates are moving?

Materials

earthquake data   graph paper   pencil

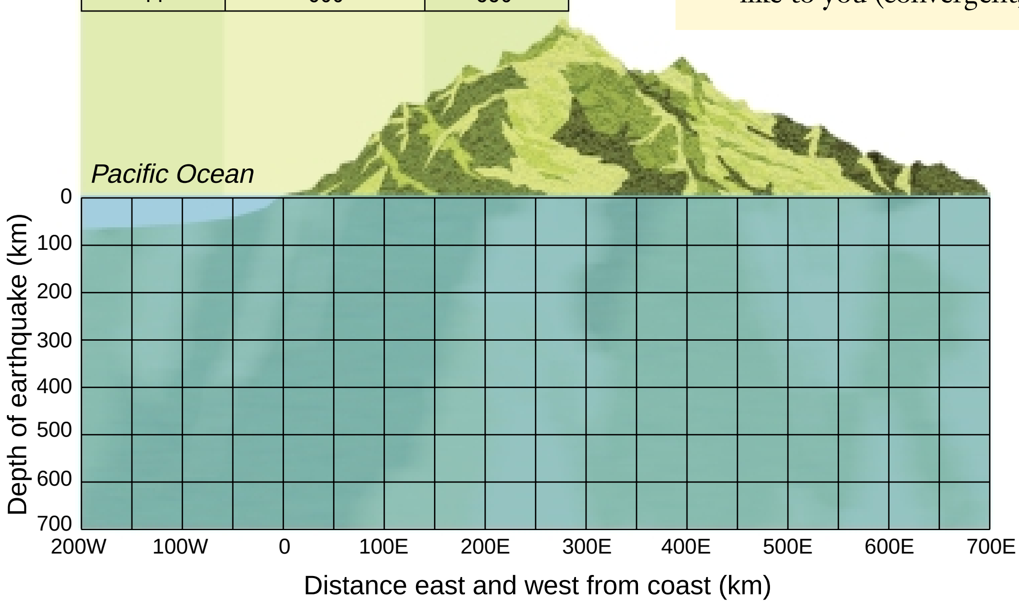
What to Do

1. Make a copy of the graph in your notebook or on a sheet of graph paper.
2. Using the table, plot the 11 earthquake foci on the graph. Note that all data are plotted east of the 0 line.
3. You have only plotted the foci of a few of the earthquakes that have occurred over the years. Therefore, instead of connecting data, you are going to make a "best fit" line graph. Draw a smooth or curved line that illustrates the pattern of data.

Analyze

1. Predict where you think future earthquake foci might occur along this plate boundary. Using the symbol of a triangle, draw in four new foci on the graph.
2. Draw a large arrow on your graph to indicate the motion of one of the plates.
3. What other features besides earthquakes might occur at this location?
4. Which type of plate boundary does this look like to you (convergent, divergent, transform)?

Earthquake	Distance east (km)	Depth (km)
1	400	230
2	80	50
3	450	320
4	220	120
5	10	15
6	480	400
7	250	150
8	500	500
9	150	60
10	300	175
11	600	550



Earthquake Zones

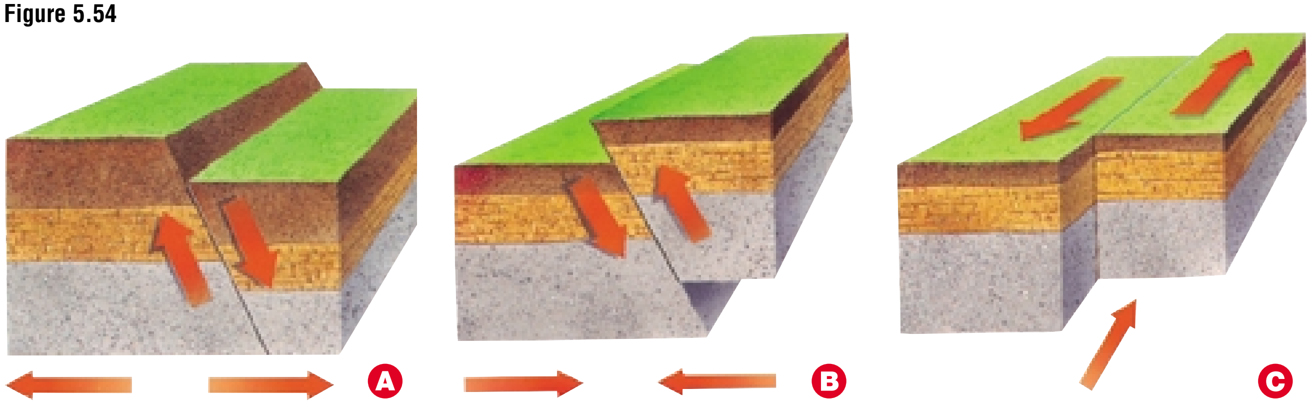
Since 1900, more than 4600 sizable (greater than 3.0 magnitude) earthquakes have been recorded in Canada, the United States, and Mexico. Only 17 of these earthquakes have been magnitude 8 or greater. One of these was off Canada's west coast, eight were in Mexico, and eight were in Alaska. Why might it be important to know when an earthquake has happened elsewhere?

Types of Rock Movement in Earthquakes

The rock in Earth's crust is under pressure all the time from tremendous forces. These stresses can cause the rock to bend and stretch. But when the pressure is too great, the rock breaks suddenly, creating a **fault**. Movement along a fault can spread more than a kilometre in a second. Fault zones exist where tectonic plates meet. Three types of faults are examined below in Figure 5.54.

You could compare the inside structure of Earth to an egg. The crust is the eggshell. The mantle is the white of the egg. The inner and outer cores are represented by the egg yolk. The cracks you make in the shell of a hard-boiled egg could be the faults in the rocks that cause earthquakes to happen!

Figure 5.54



Normal Faults Tension is the force that causes stretching. In places where plates are moving apart, the tension can pull rocks apart and create a normal fault. In this type of fault, rock above the fault moves downward.

Earthquakes that are caused by rock surfaces pulling apart are very shallow. Most of these types happen on the sea floor and cause very little damage. The island of Iceland in the North Atlantic Ocean experiences many shallow earthquakes. It has huge cracks on its surface where the rocks have pulled apart.

Reverse Faults Compression is a force or stress that squeezes or compresses. In places where the rock is squeezed by the movement of the plates, the compression can cause rocks to bend and break. In this type of fault, rock above the fault is forced up and over rock below the fault.

Scientists can tell what kind of rock movement is occurring in an area by measuring the depth and focus of each earthquake. The deepest earthquakes are usually caused by rocks that have been pushed together, forming a subduction zone. One of the deepest subduction zones in the world is in the Pacific Ocean, in the Marianas Trench off the coast of Japan.

Strike-Slip or Transform Faults Shear is a force that causes slipping. In places where plates are moving sideways past each other, the rock along the edges has many bumps and bulges in it. The surfaces get caught on the rock spots and the rock is twisted and strained. As the plates keep trying to move, the forces build up until the rocks break and an earthquake occurs.

The Pacific Plate carries the Pacific Ocean floor, its islands, and a narrow strip of California. It touches seven other plates and has a lot of action on its boundaries where it slides past other plates.

Find Out ACTIVITY

Share Your Faults

Can you build your own working models of faulting?

Materials

Styrofoam™ blocks, cardboard boxes, or blocks of wood, the larger the better (approximately 20 cm × 10 cm × 5 cm)

Procedure Communication and Teamwork

Brainstorm with your group how you could build models of faulting. Do some research about faults on the Internet or at the library. You might even be able to download some 3-D diagrams to help you. Using the supplies approved by your teacher, create working models of different types of faults. If you use wood be sure to have an adult help you with sawing. Colour your models. Work collaboratively and divide up the responsibilities. Compare your models with other students' models. Make any changes that would improve your models.

Skill FOCUS

For tips on using the Internet, turn to Skill Focus 9.

Preparing for Earthquakes

People who live in earthquake zones learn how to prepare for earthquakes. In many homes, people attach the furniture to the walls so that it won't shift or fall over during an earthquake. They store heavier items on shelves that are nearer the floor.

Buildings and roads are constructed differently in areas that experience many earthquakes. Engineers try to make them earthquake-resistant — able to withstand the shaking of the ground that occurs during an earthquake. Rigid structures made of bricks or solid concrete break during an earthquake because they have very little flexibility. Buildings made of steel, wood, and reinforced concrete can bend a little without breaking.

Figure 5.55 This office building in Vancouver is specially built so that it will not collapse in an earthquake. The floors are suspended from the central core of the building by huge cables that are visible at the top. What do you think will happen to this building when the ground moves in an earthquake?

Find Out ACTIVITY

Be Prepared!

Think about how you might prepare for an earthquake.

Procedure Initiating and Planning

Consider what changes might be necessary in your bedroom to prevent you from being injured if an earthquake happened while you were sleeping. For example, are there shelves with heavy objects at the top?

Think about the items you might need in an emergency kit after an earthquake. How long might you need them? Where could you store your emergency kit?

Make a list of changes to your bedroom and another list of items for your emergency kit. Compare your lists with another student's lists, and make any changes that you feel would improve your own work.

Figure 5.56 Tsunamis are common along Japan's coastline. This painting by artist Katsushika Hokusai shows a huge ocean wave near Japan, with Mount Fuji in the background. Tsunami is a Japanese word meaning "harbour wave."

Other Effects of Earthquakes

Some earthquakes happen under the sea. The water displaced by an earthquake can become huge waves called tsunamis (see Figure 5.56). Tsunamis can travel across oceans and cause great damage when they break on the shore. In mountains, earthquakes can trigger avalanches or rock slides. One of the most damaging earthquakes happened about 350 km east of Mexico City in 1985. When the shock waves reached the city, their size was increased by the soft sediments of the ancient lake bed on which the city is built. The sandy base turned into quicksand, and many buildings fell over. The process of changing into a liquid-like substance such as quicksand is called liquefaction. The official number of deaths caused by this earthquake was over 5000.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus7

Find out about the tsunami that struck Port Alberni, B.C., in March 1964 by going to the above web site. Click on **Web Links** to find out where to go next. Write a short story, a poem such as a haiku, or a script, as though you were one of the people whose account you have just read.

TOPIC 5 Review

1. Name the instrument that measures earthquakes, and explain how it works.

2. Explain why three seismographs are required to locate an epicentre.

3. Where do earthquakes usually occur in Canada?

4. (a) Explain the rock movement in a normal fault.
(b) Explain the rock movement in a reverse fault.
(c) Explain the rock movement in a strike-slip or transform fault.

5. Imagine waking up in the middle of the night to find an earthquake occurring. When the shaking stops, you get out of bed to check on the rest of your family. Everyone is fine, but you notice cracks in the walls of your home. Should you stay inside or leave? Explain.

6. Thinking Critically What kinds of structures might suffer the least damage during an earthquake? Write your ideas, and then share them with a classmate. Check your ideas by looking at books or using the Internet.

TOPIC 6 Volcanoes

What would it be like to watch a huge volcano erupt? Imagine the terrific heat, the choking ash, and the streams of molten lava. A volcano is an opening in Earth's crust that releases lava, steam, and ash when it erupts (becomes active). The openings are called **vents**. When volcanoes are not active, they are described as **dormant**. Scientists try to predict when volcanoes will erupt so that the people living near them can avoid injury or death.

DidYouKnow?

One of the worst eruptions in history happened on August 27, 1883, when the volcanic island of Krakatau in Indonesia literally blew up. The blast was heard 4800 km away. At least 32 000 people died when tsunamis reaching 30 m in height were triggered by the eruption.

Figure 5.57 The most active volcano on Earth is Kilauea in Hawaii. It has been continuously erupting since 1983. The lava has flowed into residential areas, causing many millions of dollars of damage.

Like earthquakes, volcanoes can be formed when rock surfaces beneath Earth's crust push against one another. The part of the crust that is pushed downward reaches very hot areas where it melts and becomes magma. Eventually there is so much magma, it is forced up through openings, and erupts.

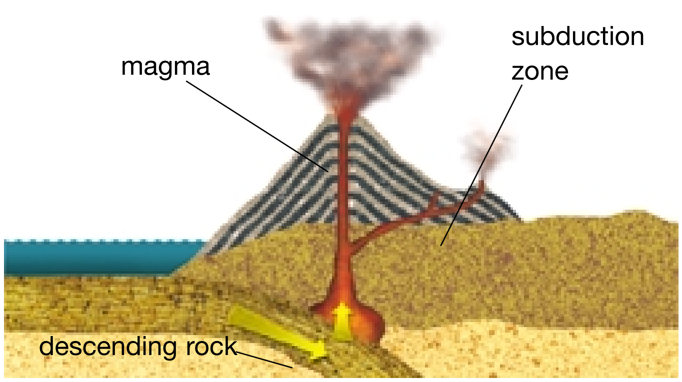


Figure 5.58 In a subduction zone, the descending rock moves deeper and deeper until it melts into magma. This magma rises up through cracks in the rock until it exerts enough pressure to cause the volcano above to erupt.

Famous Volcanoes

Mount St. Helens, in Washington, is an example of a major volcanic eruption. The rock on one side of the mountain began to bulge out in the days before the eruption that occurred in 1980. Scientists knew that an eruption would happen soon, so they had time to warn people to stay away from the area. The eruption literally blew away the side of the mountain. Figure 5.59 shows how magma built up inside the volcano to cause the eruption.

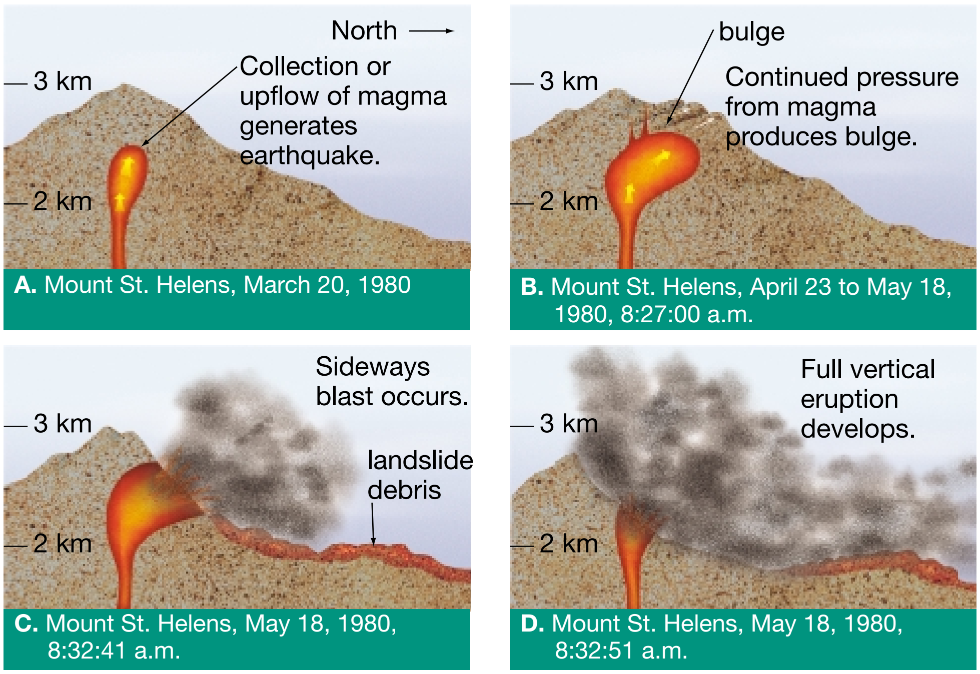


Figure 5.59 Volcanoes erupt in stages, over a period of several weeks, months, or even years.

One of the most famous volcanoes is Mount Vesuvius in southern Italy. Many scientists believe that Vesuvius, dormant since 1944, is due for a large eruption. A huge area beneath the peak is filling with magma. The situation is even more dangerous because the opening at the peak is sealed by a rock "plug." Scientists have produced computer simulations to show that, when pressure forces the rock "plug" out, a cloud of molten rock, ash, and gas will blast about 1.5 km upwards. Plans are being made for emergency measures if such an event occurs.

Figure 5.60 This photograph shows a plaster cast of a body buried in the eruption of Vesuvius in 79 C.E.

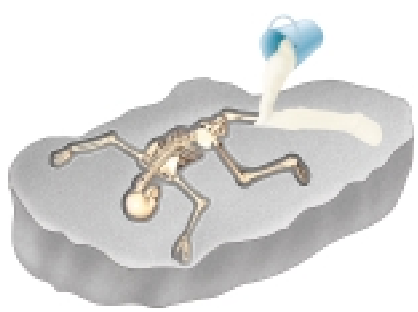


Figure 5.61 After the body decayed, plaster was poured into the cavity it left. When the plaster cast hardened, the surrounding ash was removed.

INQUIRY

INVESTIGATION 5-J

SKILLCHECK

Initiating and Planning

Performing and Recording

Analyzing and Interpreting

Communication and Teamwork

Patterns in Earthquake and Volcano Locations

One way to predict earthquakes and volcanic eruptions is to look for patterns in their occurrence. In this investigation, you will plot earthquake and volcano locations, and plate boundaries on a map using lines of latitude and longitude. You may recognize a pattern of earthquake and volcano activity which suggests that something unusual occurs in Earth's crust in certain areas.

Question

Is there an observable pattern in the occurrence of earthquakes, volcanoes, and plate boundaries?

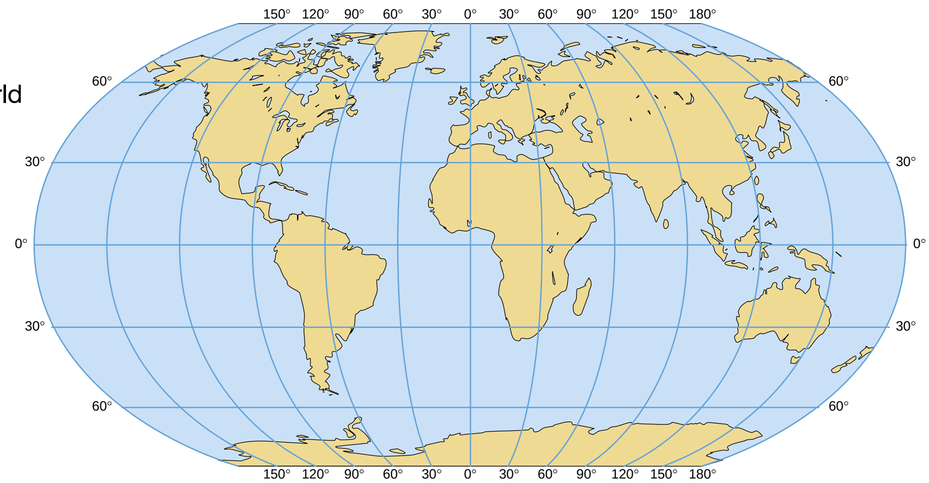
Apparatus

world map with latitude and longitude lines

Table: Earthquakes Around the World

Table: Volcanoes Around the World

coloured pencils or markers



Procedure

1. Use the tables on page 409, or obtain your own earthquake/volcano list from the Internet.
2. Decide on a symbol that you will use to indicate earthquake locations and another symbol that you will use to indicate volcano locations. Use red to mark volcanoes, blue for earthquakes, and purple for plate boundaries. Put your symbols and colours on your map under the title "Legend," indicating what each symbol represents.
3. Mark the locations on the map. Use the Internet or an atlas in your research.
4. Keep your map in a safe place so that you can use it later in this chapter.

Skill FOCUS

For tips on using the Internet, turn to Skill Focus 9.

Earthquakes Around the World

Longitude	Latitude	Location	Year
122°W	37°N	San Francisco, California	1906
72°W	33°S	Valparaiso, Chile	1906
78°E	44°N	Tien Shan, China	1911
105°E	36°N	Kansu, China	1920
140°E	36°N	Tokyo, Japan	1923
102°E	37°N	Nan Shan, China	1927
85°E	28°N	Bihar, India	1934
39°E	35°N	Erzincan, Turkey	1939
136°E	36°N	Fukui, Japan	1948
133°W	54°N	near Queen Charlotte Islands	1949
97°E	29°N	Assam, India	1950
3°E	35°N	Agadir, Morocco	1960
48°E	38°N	Northwestern Iran	1962
147°W	61°N	Seward, Alaska	1964
57°E	30°N	Southern Iran	1972
87°W	12°N	Managua, Nicaragua	1972
92°W	15°N	Central Guatemala	1976
118°E	39°N	Tangshan, China	1976
40°E	40°N	Eastern Turkey	1976
68°W	25°S	Northwestern Argentina	1977
78°W	1°N	Ecuador-Colombia border	1979
137°E	37°N	Honshu, Japan	1983
102°W	18°N	Western Mexico	1985
45°E	41°N	Northwestern Armenia	1988
122°W	37°N	San Francisco, California	1989

Volcanoes Around the World

Longitude	Latitude	Location
122°W	46°N	Mount St. Helens, Washington
123°W	50°N	Garibaldi, British Columbia
130°E	32°N	Unzen, Japan
25°W	39°N	Fayal, Azores
29°E	1°S	Nyiragongo, Zaire
152°W	60°N	Redoubt, Alaska
102°W	19°N	Paricutin, Mexico
156°W	19°N	Mauna Loa, Hawaii
140°E	36°S	Tarwera, Australia
20°W	63°N	Heimaey, Iceland
14°E	41°N	Vesuvius, Italy
78°W	1°S	Cotopaxi, Ecuador
25°E	36°N	Santorini, Greece
123°E	13°N	Mayon, Philippines
93°W	17°N	Fuego, Mexico
105°E	6°S	Krakatoa, Indonesia
132°W	57°N	Edziza, British Columbia
74°W	41°S	Osorno, Chile
138°E	35°N	Fujiyama, Japan
15°E	38°N	Etna, Sicily
168°W	54°N	Bogoslov, Alaska
121°W	40°N	Lassen Peak, California
60°W	15°N	Mount Pelée, Martinique
70°W	16°S	El Misti, Peru
90°W	12°N	Coseguina, Nicaragua
122°W	49°N	Mount Baker, Washington State
121°E	15°N	Mount Pinatubo, Philippines

Analyze

1. Are most of the earthquakes located near volcanoes, or are their locations unrelated?
2. Describe the pattern of earthquakes, volcanoes, and plate boundaries in or around the Pacific Ocean.
3. Does the pattern around the Atlantic Ocean look similar to or different from the Pacific Ocean pattern?
4. Where do most earthquakes in North America occur?
5. Describe any other places in the world that appear to have a large number of earthquakes and volcanoes.

Conclude and Apply

6. What conclusion can you reach about earthquake and volcano locations, based on your observations?
7. If you were a scientist, what might you hypothesize about Earth's crust in these areas?

Extend Your Knowledge

8. Look on the Internet for a map of worldwide earthquake activity prepared by the Geological Survey of Canada and the United States Geological Survey. How does the pattern of earthquake and volcano activity on this map compare with the pattern on the map you prepared?

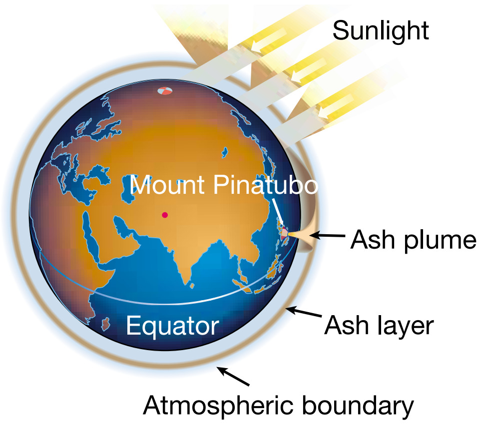


Figure 5.62 Mount Pinatubo erupted in the Philippines in 1991. The huge amount of ash blown out of the volcano formed an ash layer within the atmosphere that circled the globe and cooled temperatures around the world.

Look again at the volcano map you made. Run your finger around the edge of the Pacific Ocean, from New Zealand north to Asia and then down the west coast of North America and South America. Can you see all of the volcanoes in this circle? These volcanoes around the Pacific Ocean make up the **Ring of Fire**. The name comes from the circle of volcanoes that pour out red hot lava, fire, and steam. Mount St. Helens and Mount Pinatubo are part of this Ring of Fire. Most volcanoes in the Ring of Fire occur at subduction zones.

Figure 5.63 Ash from the eruption of Mount Pinatubo blocked the sunlight and buried fields and roads. Torrential rains caused mudflows that destroyed villages and left thousands of people homeless.

Find Out ACTIVITY

Myths Retold

The mythologies of Greeks, Romans, Indonesians, Japanese, Icelanders, and Hawaiians all contain accounts of gods or goddesses whose anger resulted in a volcanic eruption. For example, Hawaiians believed that the Fire Goddess Pele, whose image is shown in the photograph, lived inside the volcano Kilauea. They believed that the volcano erupted when she became angry.

Procedure

Look for myths about volcanoes in library books and on the Internet. Choose one of the myths. Tell it in your own words and illustrate it.

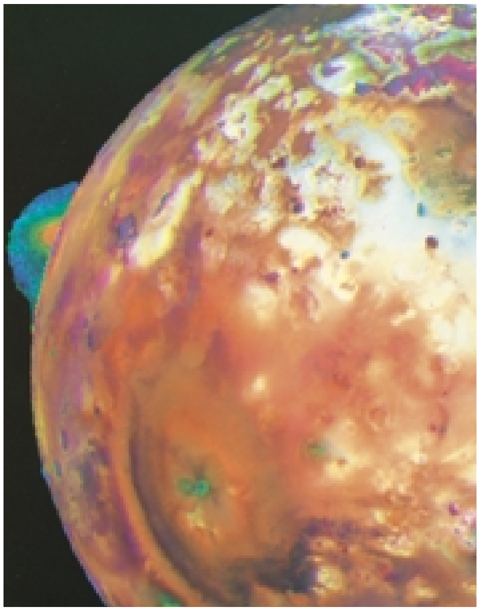


Figure 5.64 These active volcanoes were photographed on Io, one of Jupiter's moons. Volcanoes on Mars and our Moon have been extinct for millions of years, but it may be that Venus's volcanoes are still erupting.

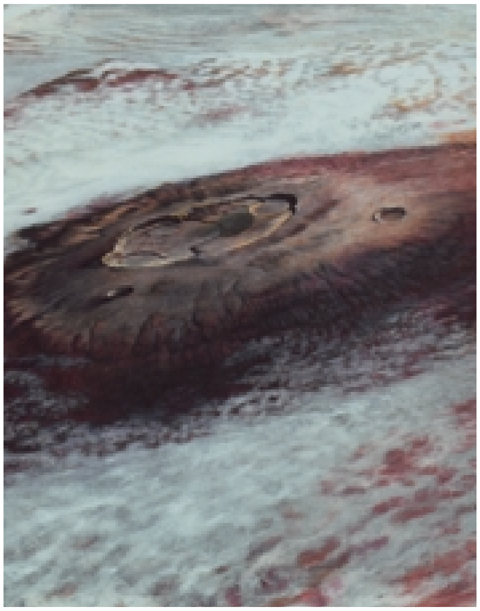


Figure 5.65 The largest volcano yet found in the solar system is the extinct Olympus Mons on Mars. It is 600 km across and 25 km tall!

DidYouKnow?

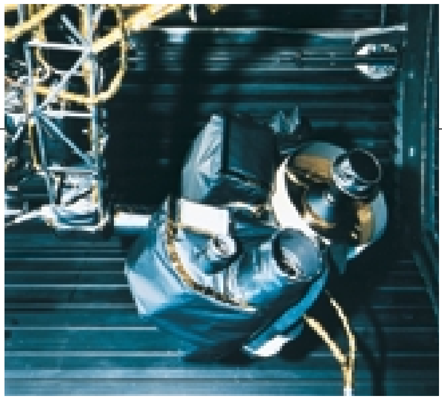
A new volcano is forming under the ocean, right beside the main island of Hawaii. It has already been named Loihi. It will continue to grow until it is another island in the middle of the Pacific Ocean. Perhaps your descendants will visit Loihi in the future!

TOPIC 6 Review

1. How can volcanoes form?
2. What similarities are there between the causes of earthquakes and the causes of volcanoes?
3. Where is the Ring of Fire, and how did it get its name?
4. Where might you find volcanoes in Canada?

Cool Tools

How did we find out about Io's volcanoes? Vidicon, a type of TV camera mounted on the Voyager spacecraft, collected images as it travelled past Jupiter. The camera used an electron gun and a photoconductor, then transmitted the data to Earth in the form of signals. The data were processed and coloured to create the simulated photo.



TOPIC 7 Mountains

Figure 5.66 Trace the sedimentary layers of this mountain with your finger. Which forces can bend and fold a mountain?

"You're really growing, aren't you?" How many times has someone made a comment like this to you? Have you ever thought that the same kind of comment could be applied to a mountain? How do mountains form? Which ones are still growing? Why do they stop growing? These are the kinds of questions that scientists ask as they try to solve some of the mysteries related to Earth's crust.

In Topic 2, you learned how sedimentary rock is formed. Some sedimentary rocks formed at the bottom of ancient oceans from shells of marine creatures. These shells gradually settled to the bottom and, over many, many years, are compressed into layers. Other sedimentary rock is made of sand, gravel, and mud.

How does sedimentary rock turn into mountains? Use the Find Out Activity "Make a Mountain!" to help you visualize the process.

Mountain Formation and Distribution

Mountain building takes many years, and it creates some of the most beautiful scenery in the world. The Canadian Rockies, the American Rockies, and the mountains in Alaska are all part of the Western Cordillera of North America. The name *cordillera* is Spanish for mountain range. Each mountain range has a distinctive and fascinating geological history due to plate tectonics.

Most mountains are large areas that have been uplifted due to the movement or heating of plates. As you learned in Topic 4, the plates can converge, diverge, or slide past each other. The movement along these boundaries can create great heat and pressure. The pressure can cause the rocks to fold and fault, creating mountains. Sometimes the heat can melt the rock and cause it to rise to form volcanoes.

Find Out

Make a Mountain!

How do layers of sedimentary rock form into mountains?

Materials

3 sheets of flexible, spongy Styrofoam™ of different colours

Procedure

Pile the Styrofoam™ sheets on top of each other. Put your hands on each side of the stack and push together. What happens to the layers?

Sedimentary rocks that are placed under slow, gradual pressure can either fold or break. Geologists explain that rocks can fold if they are hot enough to act like bendable plastic. The soft rock may bend into curves. Some of the sedimentary rock can be changed to metamorphic rock during the process of folding.

The upward or top part of the folded rock is called the **anticline**. The bottom of the fold is called the **syncline**. Over time, both of these can erode, but the folded layers still indicate what has happened.

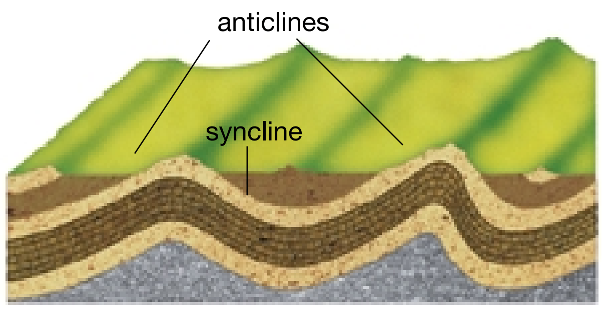


Figure 5.67 These are the main types of folding action in mountain formation.

Sometimes the rocks in Earth's crust are too brittle to fold. When pressure is exerted on them, they break, forming a fault. A fault can be the result of squeezing or stretching of Earth's crust. When sedimentary rock is squeezed from the sides, it can form into slabs that move up and over each other like shingles on a roof. This process is called **thrust faulting**. When tectonic forces stretch Earth's crust, fault blocks can tilt or slide down. The older rock may end up on top of the younger rock. These huge amounts of rock can form mountains called **fault block mountains**.

Rock movement along a fault can be vertical or horizontal. The amount of movement along a fault may be traced by matching rock on opposite sides. One major fault follows the Rocky Mountain Trench west of the Rocky Mountains. Some rocks along this fault have been moved over 400 km.

Push the skin on the back of your hand. Do you see the wrinkles that are formed as the skin slides? A similar process is at work in the Canadian Rockies where the sedimentary rock has come loose and slides on the "basement" rock beneath it. Farther south, in the American Rockies, the basement rock has broken along faults. Large areas of the crust have been shoved on top of each other, raising the underlying metamorphic and igneous rock up high (see Figure 5.68).

Looking Ahead

How could you make a model that shows different types of mountain building? How could you investigate mountain building processes? You may wish to use your ideas for "A Creative Crust" at the end of the unit.

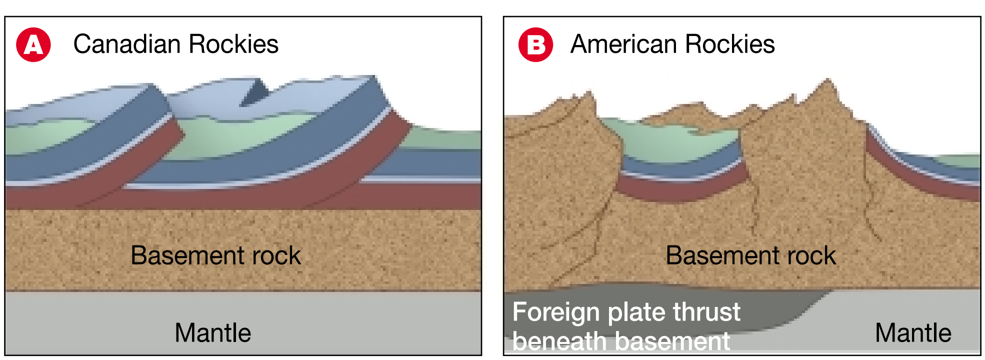


Figure 5.68 In the Canadian Rockies (A), sedimentary rock is seen at the surface. In the American Rockies (B), "basement" rock is at the surface.

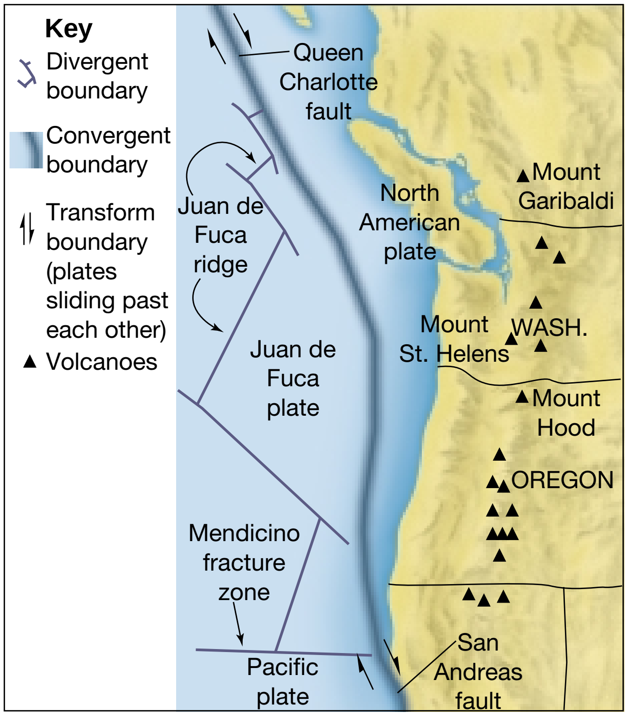


Figure 5.69 The subduction of the Juan de Fuca plate off the west coast of North America has caused a variety of features. The sedimentary rocks have been uplifted, folded, and faulted. Magma bodies have also been created that rise in the crust, forming volcanoes.

Mountains can be formed by the convergence of continental plates and oceanic plates. The continental plate is lighter and rides over the oceanic plate. Melted rock wells up under the edge of the overriding plate, pushing up mountains. The melted rock can break through the surface and erupt as volcanoes.

Usually more than one of these processes occurs. A combination of different processes creates **complex mountains**.

Ages of Mountains

What does a "young" mountain look like? What does an "old" mountain look like? Mountains that are jagged at the top are young; mountains that are more rounded are older. Think back to the rock cycle in Topic 2 and try to identify another difference in appearance between a young and an old mountain range.

Would you describe the Rockies as an old or a young mountain range? Some of the peaks in the Rockies are so high that they are snow-covered all year. The Rockies are one of many younger mountain ranges in the world, with the Himalayas in India being the youngest and highest. The top of Mount Everest in the Himalayas, like you, is still growing taller! The Laurentian Mountains in Québec are not as high as the Rockies. They are an older mountain range that is in the process of being worn down.

Mountain Ranges

Figure 5.70 Compare this map of mountain ranges with your map of earthquakes and volcanoes. Most of the western coastline of North and South America are areas where rock surfaces are pushing against each other.

INQUIRY

INVESTIGATION 5-K

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Building a Mountain-Building Theory

What is a mountain? The term mountain has no simple definition because there are so many different ways mountains can be built. In this investigation you are going to investigate the location of many of Earth's mountain ranges. You will create a legend to distinguish mountains from each other based on how they were formed. As well, you will expand on an existing theory or develop a theory of your own to explain mountain distribution.

Question

Where are the major mountains found on Earth's surface and what has created them?

Apparatus

transparency provided by your teacher

water soluble transparency pens (3 colours)

atlas or other source of mountain locations

Procedure

1. **Research** the location of Earth's major mountain ranges. Be sure to include the mountain ranges under the oceans.
2. **Classify** the mountains based on how they were formed.
3. Choose a separate colour for each type of mountain category. Use the transparency and the special transparency pens.
4. **Record** the location of as many mountain ranges as you can on the transparency.
5. Add a legend to your transparency to explain your system of colouring.
6. You probably found mountains for which you could not explain the origin. **Form a hypothesis** about how these mountains might have developed or expand one of the ideas in the textbook.

Analyze

1. What categories did you create to classify your mountains? Why?
2. Where do most of the mountains on Earth's crust occur?
3. Put the transparency you made for this investigation on your map of volcanoes and earthquakes from Inquiry Investigation 5-J, Patterns in Earthquake and Volcano Locations. What similarities can you **observe** between the location of mountain ranges and that of volcanoes?

Conclude and Apply

4. How do the locations of mountain ranges compare with the locations of plate boundaries? What are the exceptions?
5. **Describe** at least three different ways in which mountains can be created.

Extend Your Knowledge

6. **Predict** where new mountain ranges might occur in the next 3 to 4 million years. On which facts do you base your prediction?
7. **Write a definition** of the word "mountain."

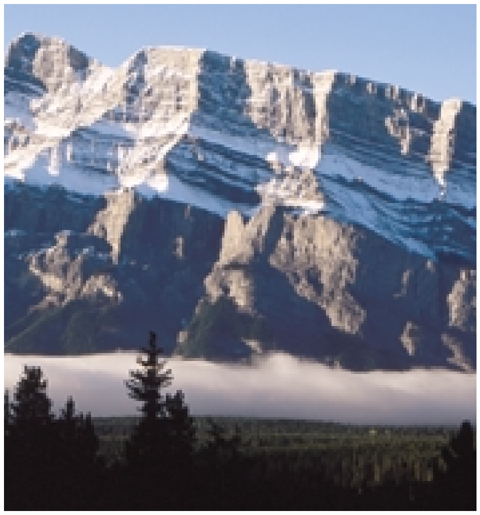


Figure 5.71 Mount Rundle, near Banff, Alberta, has been uplifted and then tilted.

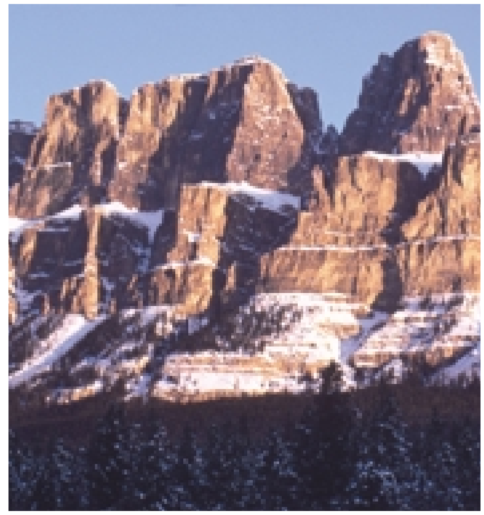


Figure 5.72 Castle Mountain is located between Banff and Jasper. Can you see the almost horizontal layers of sedimentary rock uplifted?

Career CONNECT

Room at the Top

Scenic mountainous areas have long been popular vacation spots. In a small group, brainstorm what sorts of businesses would likely be found in mountainous areas.

What sort of business might you be interested in starting in this type of area? Write a description of your business, explaining what service it would provide, who its clients would be, and why you think it could be successful. With the help of an adult, try to arrange an interview with someone who runs a similar type of business in your own community.

Before the interview, prepare questions such as these:

- How did you plan your business before you actually started?
- How has your business grown?
- What have you learned from having your own business?

TOPIC 7 Review

1. How are folded mountains formed?
2. What are two actions of Earth's crust that can create a fault?
3. How is a fault block mountain formed?
4. How are complex mountains formed?
5. What is an anticline? What is a syncline? What does each indicate to a geologist?
6. **Thinking Critically** Why do you think the Himalayas are getting taller and the Laurentians are getting smaller?
7. **Thinking Critically** Explain how the Olympic Mountains were formed, using Figure 5.73 as a guide.

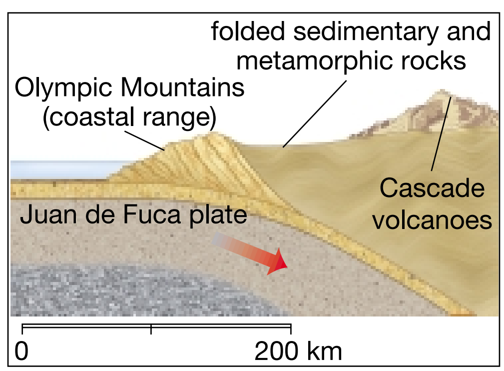


Figure 5.73 The convergent plate boundary just off the coast of British Columbia.

Wrap-up TOPICS 4-7

If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

mantle
continental drift
sonar
sea floor spreading
converging plates
diverging plates
plates
theory of plate tectonics
convection current
subduction zones
seismograph
bedrock
Richter scale
seismic waves
aftershocks
primary (P) waves
secondary (S) waves
surface waves
focus
epicentre
fault
vents
dormant
Ring of Fire
anticline
syncline
thrust faulting
fault block mountains
complex mountains

Reviewing Key Terms

1. In your notebook, match the description in column A with the correct term in column B. There will be some terms left over. Do not write in this book!

A

- fastest travelling earthquake wave
- surface location of an earthquake
- second type of earthquake wave generated
- bottom portion of a rock fold
- person who studies earthquakes
- scale used to measure earthquake magnitude
- wave that causes the most damage
- upward portion of a rock fold
- rock break location under the ground
- huge ocean wave caused by earthquake

B

- epicentre (5)
- focus (5)
- P wave (5)
- anticline (7)
- vents (6)
- seismologist (5)
- tsunami (5)
- Richter scale (5)
- surface wave (5)
- syncline (7)
- S wave (5)
- dormant (6)
- Ring of Fire (6)
- aftershocks (5)

Understanding Key Concepts

2. Name the layers beneath Earth's crust. Which layer is thickest? Which layer is hottest? (4)
3. How does technology help us to understand whether the layers of Earth are solid or liquid? (6)
4. Explain the theory of plate tectonics. (4)
5. Describe the three kinds of rock movement that can cause earthquakes. (5)
6. Explain two main processes of mountain building. (7)