UNIT E

Planet Earth

In this unit, you will cover the following sections:

1.0 Earth's surface undergoes gradual and sudden changes.

1.1 A Model for Earth

1.2 Sudden Earth Events

1.3 Incremental Changes: Wind, Water, and Ice

2.0 The rock cycle describes how rocks form and change over time.

2.1 What Are Rocks and Minerals?

2.2 Three Classes of Rocks: Igneous, Sedimentary, and Metamorphic

2.3 The Rock Cycle

3.0 Landforms provide evidence of change.

3.1 Continental Drift

3.2 Plate Tectonics

3.3 Mountain Building

4.0 The fossil record provides evidence of Earth's changes over time.

4.1 Tracing Evidence of Geologic Change Using Fossils

4.2 Methods Used to Interpret Fossils

4.3 Geologic Time

Exploring

Oldman River, Alberta

If you look out the window of your classroom, what kind of land features do you see: mountains? hills? valleys? What characteristics do you notice about these features? Are the mountains tall with steep, jagged cliffs or are they rounded like huge hills? Is there a river running through the valley or is the bottom of the valley a large, flat plain? In this unit, you will learn about Earth—our constantly changing planet. You will learn about its surface features and the forces that affect its interior. This knowledge will help you understand the models scientists have developed to explain the changes that Earth has undergone over its long history.

Earth-Shattering Events

Most of what people have known about Earth they have known because of what they could directly observe. However, observations don't always tell the whole story. Consider the two news stories on the next page. One shows a volcano in Washington State that literally "blew its top!" The other describes an earthquake that happened in Kobe, Japan.

Mountain blows its top

On May 18, 1980, Mount St. Helens in Washington State exploded. Gas and ash shot 19 km into the sky. The mountain's top collapsed—it lost 400 m of its original height.

Shocking shock waves!

At 5:46 a.m. on January 17, 1995, the million plus residents of Kobe, Japan, were thrown from their beds by a massive earthquake. Broken gas lines led to huge fires and thousands died.

What caused these dramatic natural disasters? Surely not wind or water or other events that you have noticed occurring on Earth's surface.

Earth is a planet that is in constant motion and change. Intense heat from deep inside Earth creates volcanoes that spew lava. Huge plates of rock moving across its surface cause earthquakes that shake and split the ground. Mountains grow upward, while wind and water wear them down and carry them away.

Give it a **TRY** ACTIVITY

EXAMINING EARTH

What do you know about Earth and the events that shape and change its surface features? Look at the photos below. They show situations where Earth's features have been changed in some way. Discuss with a partner what you think is happening in each picture, and answer these questions in your notebooks:

- What do you think caused these features to occur?
- Do you think this change happened slowly or quickly?

A

What forces could have shaped this rock?

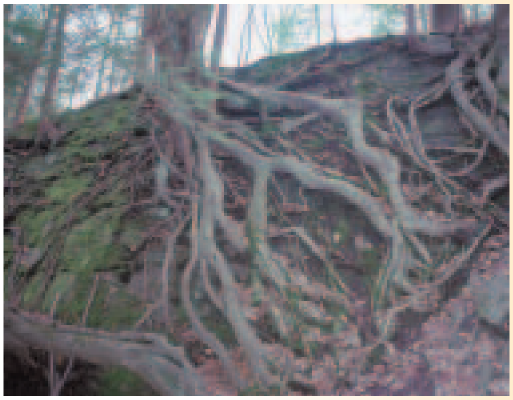
B

Why are the bands of rock not straight across the sides of the mountain?

C

What can this fossilized insect in amber tell us about insects today?

D



What are the roots of this tree doing to the rock?

As you go through this unit, think about what you are learning, and modify or revise your answers to these questions.

Focus On: The Nature of Science

While studying this unit, you will be asked to organize your thoughts based on your own observations and the evidence of the science community. This evidence has come about in a number of ways:

- through experimentation
- by interpreting facts and observations
- by creating and interpreting models

Think about the following questions while you study how the forces of Earth have transformed its features. The answers to these and other questions about Earth will help you understand the nature of the forces that shape and change our planet.

1. **What do we know about Earth, its surface, and what lies below?**
2. **What forces act on Earth to change its landforms?**
3. **What are the processes and techniques we use to develop an understanding of Earth and its changes?**

Ocean inlets, British Columbia

The Badlands in southern Alberta

1.0 Earth's surface undergoes gradual and sudden changes.

Key Concepts

In this section, you will learn about the following key concepts:

- developing models
- Earth models
- earthquakes
- volcanoes
- tools and techniques for studying Earth
- the effects of water, wind, and ice
- glaciers

Learning Outcomes

When you have completed this section, you will be able to:

- interpret models of Earth's interior structure
- investigate evidence that Earth's surface undergoes both sudden and gradual changes
- identify tools and techniques for studying Earth
- interpret and investigate examples of weathering, erosion, and sedimentation
- use suitable terms and conventions in describing Earth's substances

Canada's Precambrian Shield

It may seem to you that Earth's landscape doesn't change very much. Earth is, after all, made up largely of rocks, and rocks are hard and difficult to move. But the fact is, nothing could be further from the truth. Rocks and the structure of Earth are part of a landform cycle of *creation, loss,* and *renewal.*

Most of the time this change goes unnoticed, but sometimes, it shows up in dramatic and devastating ways. Sudden geologic events, such as earthquakes, volcanic eruptions, and landslides, can occur quickly with catastrophic results. Other events, such as glacial and river erosion, happen more slowly and are not nearly as harmful to humans.

1.1 A Model for Earth

Think of Earth's long history as a story, a cross between an adventure and a mystery. The adventure part of the story is about people facing the powerful forces of Earth—earthquakes, mountain building, volcanoes—in their efforts to understand it. The mystery is about the fact that we can't easily see inside our home planet. We live on its outermost skin. We have only indirect evidence of what is happening deep below its surface.

Have you ever looked at a present you've received and wondered what is inside? Its wrapping paper keeps you from quickly figuring it out, but that shouldn't stop you from guessing. You can still note the size of the package, lift it and guess its weight, and shake it to hear how it sounds. Using this information, you can make an "educated guess" as to what is inside.

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Our Ancient Past

Geologists estimate that Earth is about 4.6 billion years old. Human-like creatures did not appear on Earth's surface until about 3 million years ago, making us newcomers to an ancient planet.

Developing a Model

A **model** is an idea of something that can't be fully known or seen. It is a way of demonstrating an object or an idea that is difficult to picture in its real form. Models are useful when something is too big or too small or too complicated for us to study easily. They can take many forms: drawings, actual constructions, or comparisons to familiar things. For example, a globe is a model for Earth.

Give it a TRY — ACTIVITY

What's Inside?

You will be given a "mystery container." It may contain one or more different objects, and you will be asked to create a model to help explain what's inside. Your goal, in co-operation with your group, is to use your senses to gather as much evidence as possible about what might be inside the mystery container. After gathering your evidence, each member of your group should independently sketch a diagram, or "model," of the container's contents.

- Compare the diagrams and discuss the similarities and differences and the evidence that supports them. You may want to revise and improve your model as you gather more evidence.
- Sketch a final diagram of what your group believes the contents to be.
- Explain to another group how you came up with your model.
- What further evidence could you get to provide you with even more information about your mystery container?
- Now open the container. How does your model differ from the real object?

What you have just done is very similar to the methods scientists use to develop, debate, and change the models that they use to explain the structure of Earth.

What's Inside Earth

In 1864, the French author Jules Verne wrote a novel called *Journey to the Centre of the Earth*. He described a land deep inside the core of Earth populated by strange plants and animals. The story captured everyone's imagination, and for years afterward, people wondered about what really lay below Earth's surface.

Scientists began to wonder, too. What are the layers that make up Earth? How thick is its outer skin? Is the interior solid or molten liquid? What does the centre core look like?

Because Earth is so large, **geologists**, who are scientists that study Earth, have had to use a model to help them understand its inner structure. They know a lot about its surface because they can easily study it, but digging a hole to Earth's centre to examine its core is out of the question. The extreme conditions there prevent any kind of exploration. Geologists would have to travel more than 1700 times the depth of the deepest mine in the world (a gold mine in South Africa, which reaches a depth of 3.8 km).

Figure 1.1 It's never cold in deep mines. At 1 km below the surface, temperatures can be around 29°C—even on the coldest day in winter.

Geologists also use many indirect methods of studying Earth, some of which you will learn about later in this unit. What they have discovered is that there's more to Earth than what can be seen on its surface. Earth appears to be made up of three major layers. Each layer surrounds the layer beneath it, much like an onion.

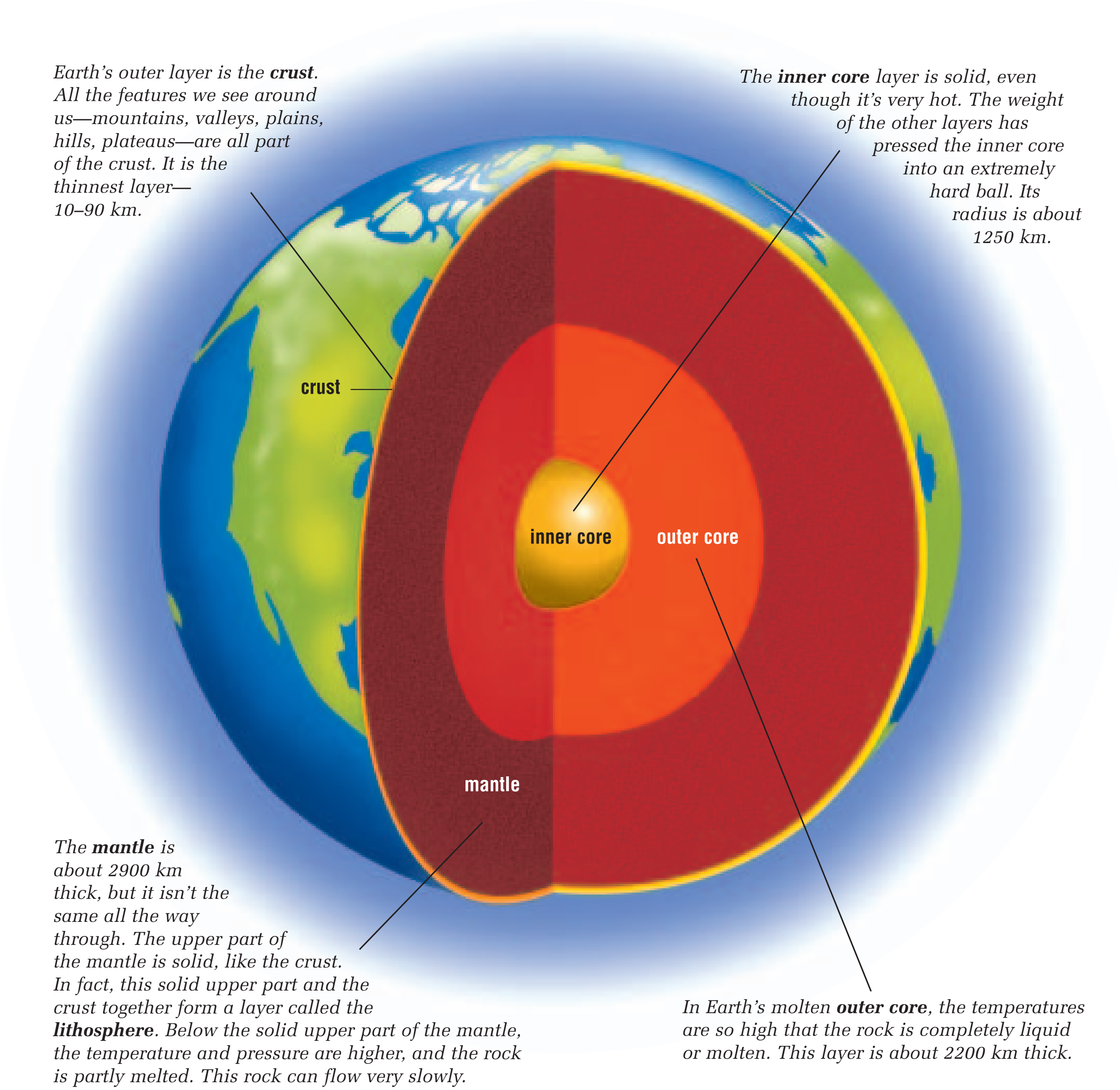

Figure 1.2 Model of Earth's interior

Here are some more facts about Earth's interior:

- **Inner Core**—Geologists believe it consists mainly of *solid* iron and nickel. It reaches temperatures as high as 7000°C.
- **Outer Core**—The outer core is thought to be liquid because the pressure isn't great enough to make the molten rock into a solid.
- **Mantle**—The mantle makes up about two thirds of Earth's mass.
- **Crust**—Because Earth is so hot in the inner core, the crust radiates heat into the atmosphere.

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Two Rock Ridges

There are many stories about the structure of Earth. One of these is the Dene story, "The Two Rock Ridges." Research this or any other idea about Earth's structure. In a paragraph, describe the story, briefly explaining its origin.

The Crust

The **crust** is the layer that covers the surface of Earth. All living things are found here. It is the rich storehouse of minerals, such as iron and copper ore, used in manufacturing many of the products you buy. It is also here we get the fossil fuels, such as oil, natural gas, and coal, that supply our energy needs.

As you can see in Figure 1.2, it is the thinnest layer of Earth, with an average thickness of about 50 km. Under the ocean, it can be as thin as 10 km. Beneath tall mountain ranges, such as the Rocky Mountains, the crust thickens to about 90 km. Still, that's not very thick, considering the total distance from Earth's surface to its centre is nearly 6400 km.

So what exactly makes up the crust? At first glance, Earth's surface seems thickly covered with vegetation and fresh and saltwater areas. Yet these features form only a thin covering. The crust is made up of solid rock.

Check and Reflect

1. Look at the three photos below.

Figure 1.3

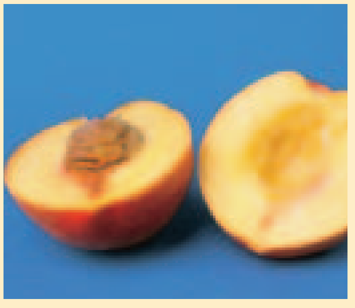

Figure 1.4

Figure 1.5

Do you think that any of these would make a good model for Earth's interior? Give reasons for your answers.

2. Give two examples where models are used to serve different purposes.
3. Why do you think computers are useful in creating and displaying models?
4. Make and label a drawing showing Earth's layers as you would see them if a wedge were cut from Earth. Be sure to use a ruler and try to make your drawing to scale. For example, 1 cm could represent 500 km, or 1000 km. Show the increasing depth as you reach the centre.

1.2 Sudden Earth Events

You wake up suddenly from a deep sleep feeling as though your bed is on a ship in a bad storm. You have trouble reaching the light to turn it on. When you do, you can see the walls of your bedroom changing shape in front of your eyes. And the noise! The whole building sounds as if it's being pulled apart board by board. Everything on the shelves crashes to the floor. But outside you can hear the twisting of metal and shattering of concrete mixed with the shouts of people.

Figure 1.6 Armenia, Columbia, January 1999 (6.0 on the Richter scale)—This earthquake lasted less than a minute, but look at the results!

Few forces in nature are as dramatic and devastating as earthquakes and volcanoes. In a matter of moments, they can transform a peaceful countryside into a violent, twisted landscape. The earthquake in Kobe, Japan, lasted only a few seconds, but resulted in 5000 deaths. When Mount St. Helens erupted in Washington State, 57 people died, and the ash from its spewing top destroyed an area of 560 km^2. People from as far away as Ontario and Quebec were cleaning the grey dust off their cars a few days later.

Have you ever felt an earthquake? Have you read about its effects? What happened? What do you think it was like? Share your experience with the rest of the class.

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Some Canadian Earthquakes

Date	Richter Scale	Place
1663	?	St. Lawrence region
1700	~9	off coast of B.C.
1918	~7	Vancouver Island
1946	7.3	Vancouver Island
1949	8.1	near the Queen Charlotte Islands, B.C.
1990	4.9	Fraser Lowland, B.C.

What Causes Earthquakes?

Earthquakes are tremblings or vibrations of the ground. They are caused by the sudden release of energy that has slowly been building up in Earth's crust. Large masses of rock in the crust move and sometimes become locked together or stuck. A tremendous force is created until finally the rocks break. This sudden break causes an earthquake.

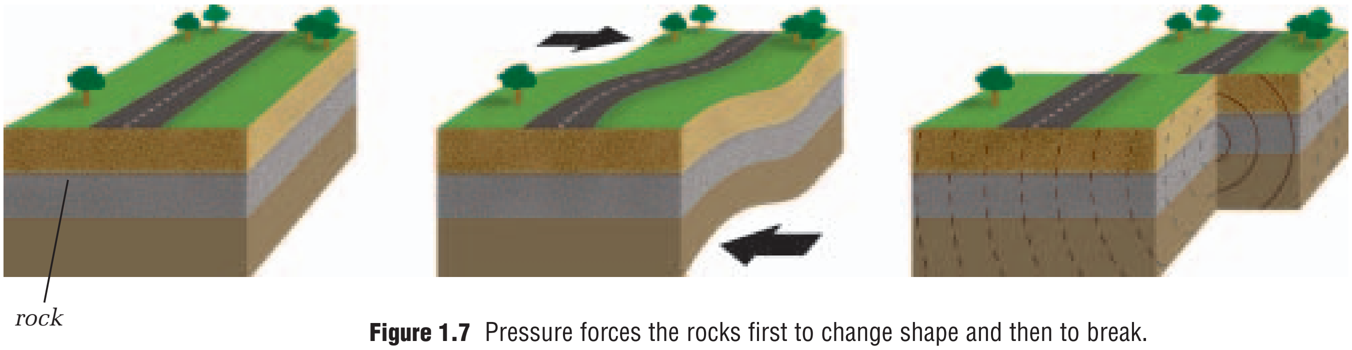


Figure 1.7 Pressure forces the rocks first to change shape and then to break.

The First Break

The first place that the rocks break below the surface in an earthquake is called the **focus**. The sudden breaking of rocks at the focus releases energy that spreads as waves through Earth. These earthquake waves are called **seismic waves** (from the Greek word "*seismos*," meaning "earthquake"). The shaking you feel in an earthquake is caused by the seismic waves moving through the ground. Powerful ones can damage and change Earth's surface. Geologists use these waves to study Earth's interior because the waves travel right through Earth's layers, just like X-rays do inside your body.

*re*SEARCH

Alberta Quakes

Earthquakes are a rare occurrence in Alberta, but on October 19, 1996, people near Rocky Mountain House were awakened to one. The National Earthquake Hazards Program of Natural Resources Canada records and researches all earthquakes felt in Canada. Use an Internet search engine to find their regional western Web site so you can find out more about this earthquake.

- What time did the earthquake occur?
- What did the quake measure on the Richter scale?
- Were there any aftershocks? If so, how many and how powerful were they?
- Did the quake cause any damage?
- Research where in Canada earthquakes are most likely to occur.

Because of the effect an earthquake can have on the surface of Earth, geologists look for its **epicentre**. This is the point on the surface directly above the focus ("*epi-*" means "above"). Officials need to know where the epicentre is to provide disaster relief. It helps them determine if the earthquake was in a location where it would harm people, buildings, transportation systems, or communications. Figure 1.8 shows how the focus and the epicentre are related.

Measuring the Strength of Earthquakes

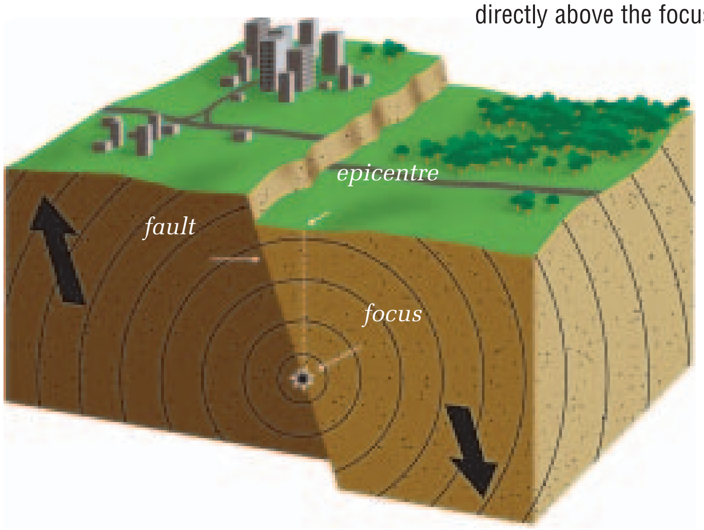
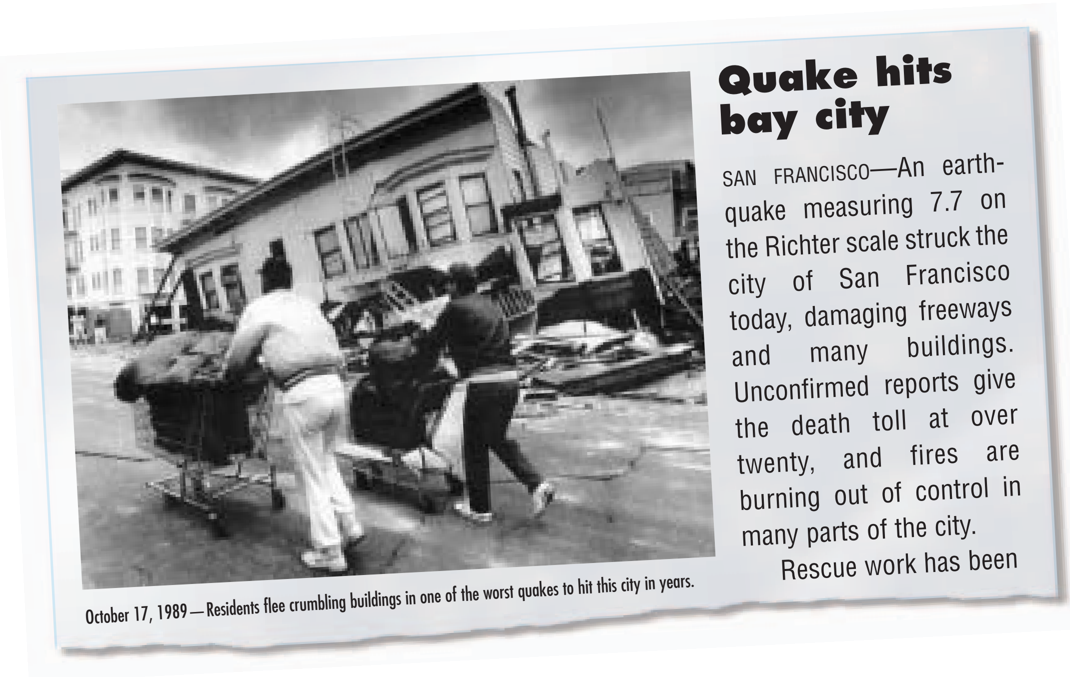


Figure 1.8 The epicentre of an earthquake is directly above the focus.

Geologists have developed various scales to determine the strength or magnitude of an earthquake. These scales allow scientists around the world to share and compare data. When you hear reports of the magnitude of an earthquake, it's usually given as a number on the **Richter scale**.

Charles Richter, an American, developed the scale in 1935. The scale starts at 0, and each increase of 1 represents an increase of 10 times the amount of ground motion of an earthquake. For example, an earthquake of Richter magnitude 2 is 10 times stronger than one that measures 1. Look at the newspaper article below. What was the magnitude of the earthquake? Do you think this was a strong earthquake or a mild one?



Quake hits bay city

SAN FRANCISCO—An earthquake measuring 7.7 on the Richter scale struck the city of San Francisco today, damaging freeways and many buildings. Unconfirmed reports give the death toll at over twenty, and fires are burning out of control in many parts of the city.

Rescue work has been

October 17, 1989—Residents flee crumbling buildings in one of the worst quakes to hit this city in years.

Figure 1.9

VOLCANOES

"A deep rumbling in the ground and a fiery flash in the night sky—the volcano is about to erupt! Run for your life!" How accurate do you think this description is of a volcanic eruption?

A **volcano** is an opening in Earth's crust through which solid and molten rock, ash, and gases escape. Scientists have generally been more successful predicting volcanic eruptions than they have earthquakes. Even though they can't say exactly *when* an eruption will happen, they usually can tell if one is about to occur. As you read through this subsection, think about what signs people could watch for that might tell them when a volcano is going to erupt. Jot down notes as you go along.

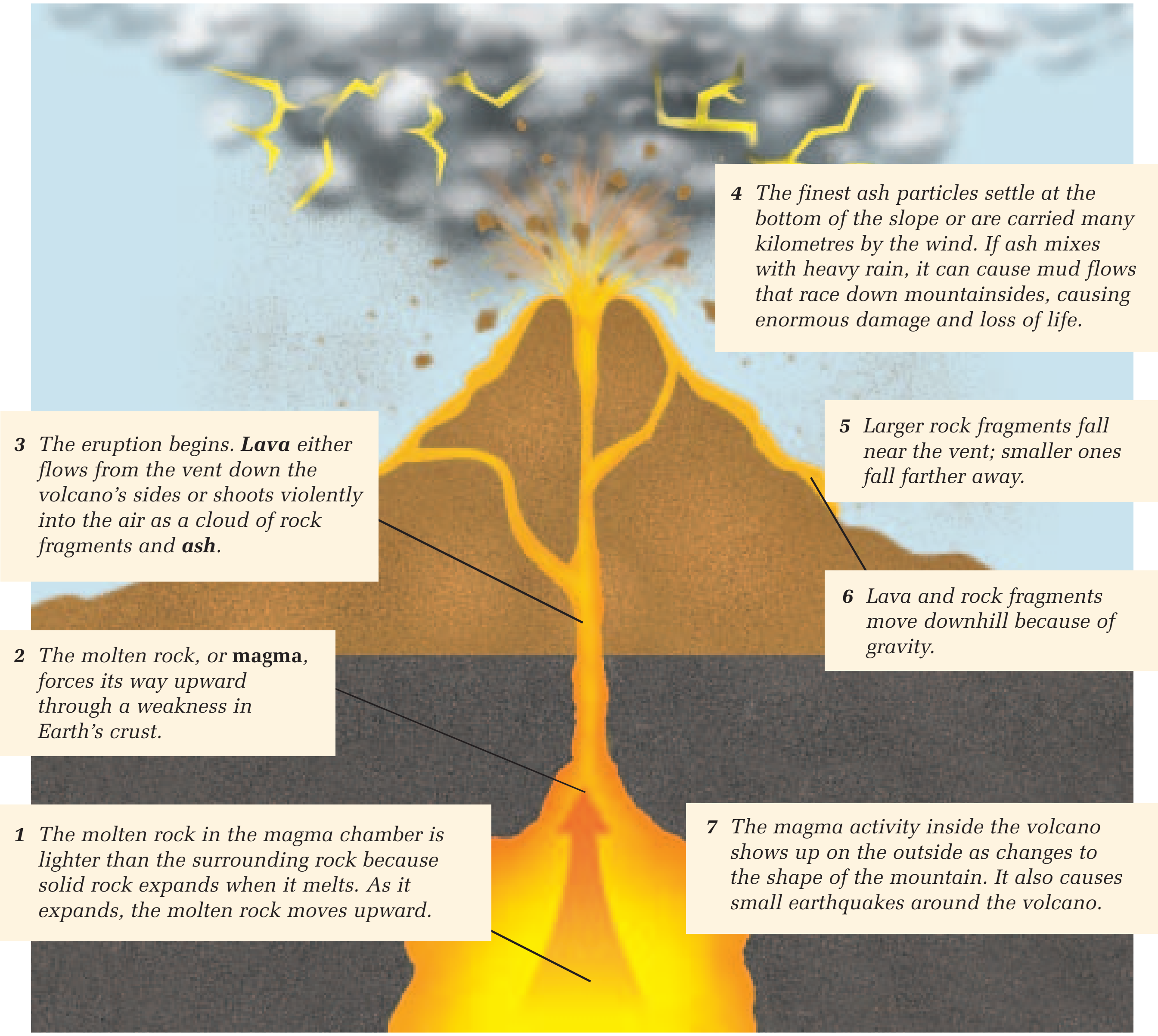


Figure 1.10 What happens when a volcano erupts

TOOLS AND TECHNIQUES FOR STUDYING EARTH

Investigating earthquakes and volcanoes can be a risky business. Geologists often venture into dangerous territory to take measurements or collect samples. Their efforts to learn more about sudden, violent Earth events may one day make these events more predictable. Below are some of the tools and techniques geologists use to get the job done. Use your library resources and the Internet to find out more about how geologists study these Earth events.

math Link

Each number on the Richter scale represents an increase of 10 times in the ground vibrations caused by an earthquake. How would you calculate how much more powerful Richter magnitude 7 is than 3?

Tools of the Trade

Figure 1.11 Geologists studying volcanoes must wear a special suit with a metal coating that reflects these intense temperatures. This allows them to get close enough to an eruption to make observations, take measurements, or collect gas and lava samples.

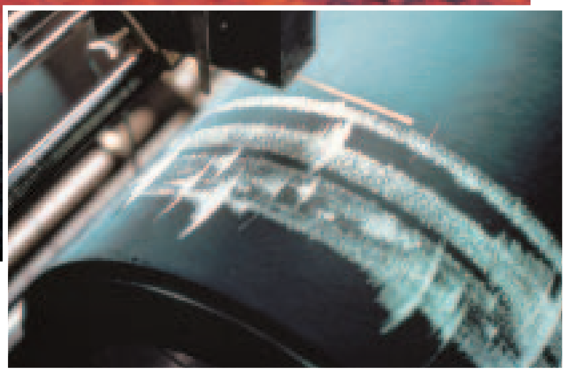


Figure 1.12 A seismograph is a device that detects the waves of energy that spread through Earth from the focus of an earthquake. Geologists read the **seismogram** produced by the seismograph to determine the strength of an earthquake and its location.

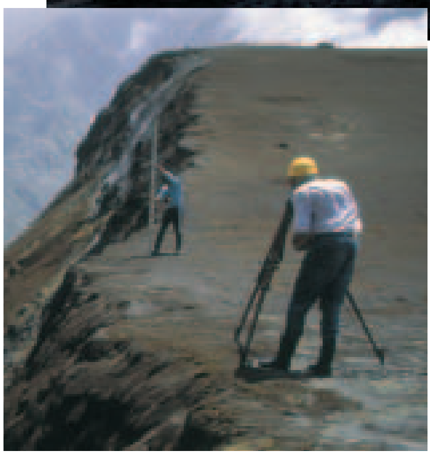


Figure 1.13 Some volcanoes bulge outward slightly when the pressure from rising molten rock inside them builds up. Before an earthquake, stress builds up causing the ground to tilt slightly. These signs, although not visible to the naked eye, can be detected using a **surveyor's level**, a device that measures minute changes in the angle of the ground's slope.

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Frozen in Time

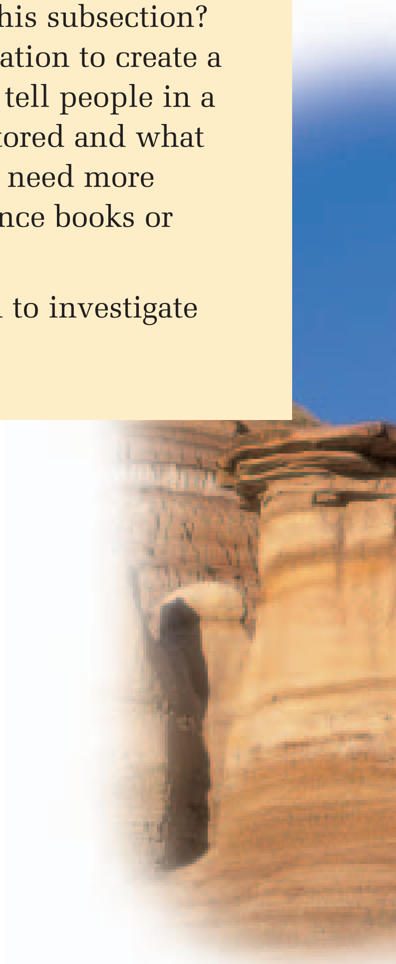
Nearly 2000 years ago, in A.D. 79, a volcanic eruption completely destroyed the city of Pompeii in Roman Italy. Mount Vesuvius suddenly and without warning erupted, spewing out volcanic ash and burying the city and most of its inhabitants. Find out more about Pompeii.

- Why is Pompeii a famous tourist attraction?
- Why didn't the people of Pompeii just close their windows and doors to keep the ash out, or just run away?

A plaster cast of a body at Pompeii, Italy

Check and Reflect

1. What is believed to be the cause of earthquakes?
2. Where in Canada do you think earthquakes are common?
3. Why do you think it is difficult to predict earthquakes?
4. You were asked to look for clues that people could use to determine if a volcano were about to erupt.
   a) What other information might be useful for predicting volcanic activity that was not mentioned in this subsection?
   b) Working with a small group, use your information to create a poster, a television program, or a brochure to tell people in a volcanic area how the volcano is being monitored and what the signs of an upcoming eruption are. If you need more information to complete your task, use reference books or information from the Internet.
5. What are some instruments and equipment used to investigate earthquakes and volcanoes?



1.3 Incremental Changes: Wind, Water, and Ice

While earthquakes and volcanoes offer sudden and catastrophic change, the shaping or sculpting of Earth's surface is accomplished by a combination of slow, step-by-step changes called weathering and erosion. **Weathering** refers to the mechanical and chemical process that breaks down rocks by means of water, glacial ice, wind, and waves. **Erosion** occurs when the products of weathering are transported from place to place. **Deposition** is the process of these materials being laid down or deposited by wind, water, and ice. Throughout the weathering/deposition process, material is not gained or lost—it simply changes form. In other words, weathering or the process that wears down rocks and other objects *never* produces new material. It is just part of a greater process of transforming Earth's features.

Mechanical Weathering

Mechanical weathering happens when rock is broken apart by physical forces, such as water or wind. In our climate, rock is often broken down by water freezing in cracks. This action slowly helps to break apart even the largest rock formations.

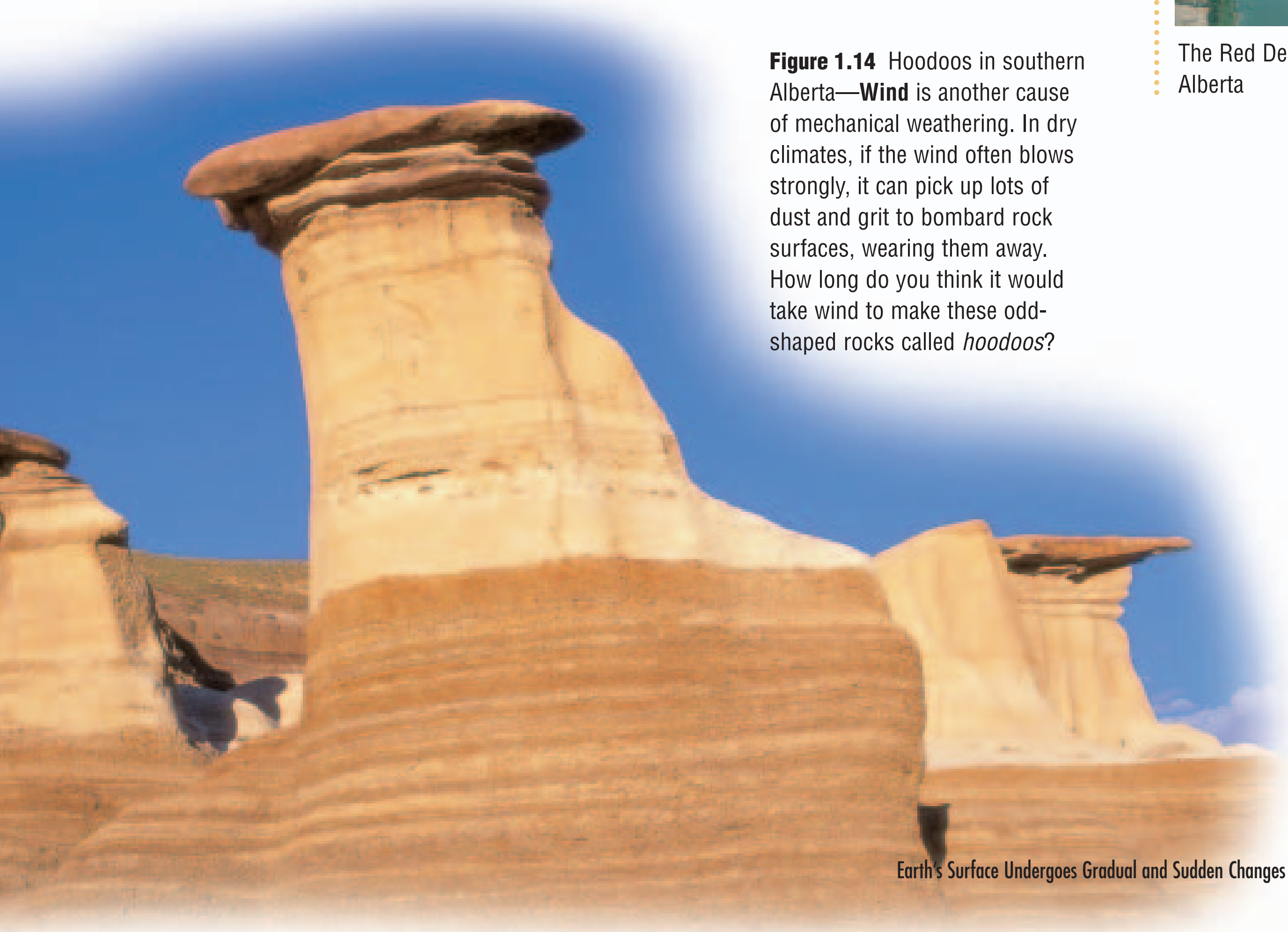


Figure 1.14 Hoodoos in southern Alberta—**Wind** is another cause of mechanical weathering. In dry climates, if the wind often blows strongly, it can pick up lots of dust and grit to bombard rock surfaces, wearing them away. How long do you think it would take wind to make these odd-shaped rocks called *hoodoos*?

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Muddy Rivers

The Red Deer River begins from the crystal clear waters high in the Rocky Mountains of Alberta's southeastern slopes. As the river travels eastward, it accumulates tremendous amounts of silt, sand, and dirt—causing the river to change from clear to chocolate brown.

The Red Deer River, Alberta

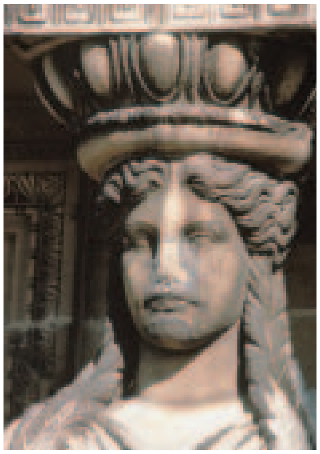

Figure 1.15 Look at older buildings and statues in your community. How have they been affected by acid rain? How can you tell?

Chemical Weathering

Chemical weathering happens when water and oxygen react with the minerals in rocks to produce new minerals. Often these new minerals are softer and can crumble more easily. For example, gases in the air combine with rain or snow to form solutions called *acids*. These acids can wear away rocks by dissolving the minerals in them (see Figure 1.15). Think of a sugar cube dissolving in water—it gets smaller and smaller until it disappears. Certain kinds of rocks exposed to chemical weathering wear away in the same way.

Biological Weathering

Biological weathering is the wearing away of rocks by living things. Growing things can be powerful destructive forces for rocks. The need to grow causes plants to force their roots into any small space where a little soil has collected. Then, as their roots and stems get bigger, they put enormous pressure on their surroundings.

Figure 1.16 This tree started growing in a small crack in the rock. As it grew, it made the crack bigger. What do you think will happen if the tree continues to grow?

The Effects of Moving Water

Have you ever seen a river that looks really "muddy"? Rivers flowing through soil, not rock, pick up fine grains and carry them along, giving the water a muddy appearance. Rivers and streams are probably the most powerful forces of erosion that alter the landscape.

Figure 1.17 How does damming up a river affect its flow below the dam?

Figure 1.18 Bow Falls, Alberta—How do you think waterfalls affect riverbeds?

As rivers flow, they carry a load of silt, sand, mud, and gravel, called **sediment**. This weathering process can take a great deal of time and is influenced by the nature of the moving water (for example, the amount of water or the steepness of the terrain). **Sedimentation** is the process of sediments being deposited, usually at the bottom of oceans, lakes, and rivers.

Landforms that are created by running water are known as **fluvial landforms**. Alberta has many examples of fluvial landforms, such as the Badlands of southern Alberta (see the illustration in Exploring at the beginning of this unit).

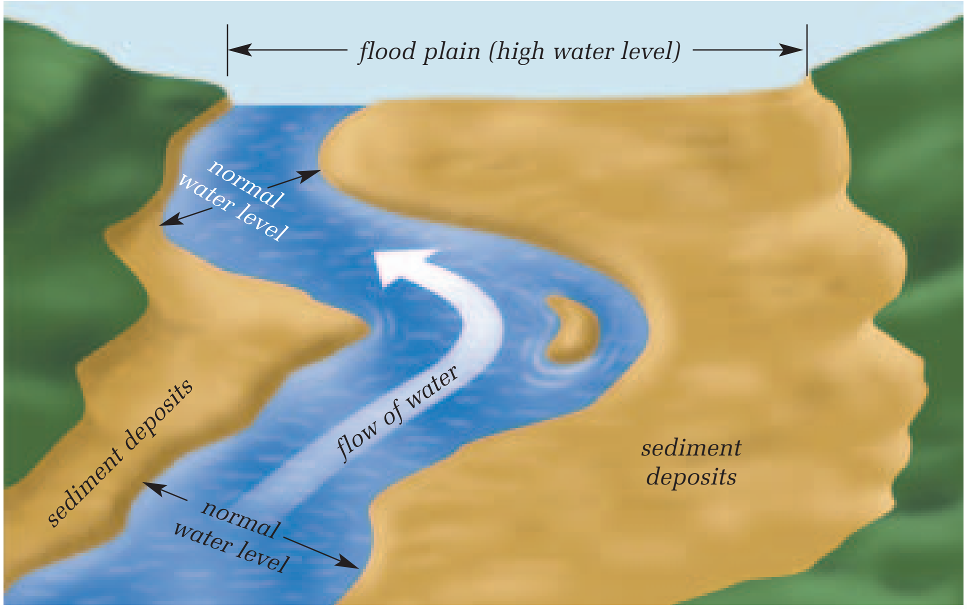

Figure 1.19 A *flood plain* is the high water level caused by the extra water from melting snow and heavy rain. This extra water flow erodes the stream and river banks. *Sediment deposits* are left when the water levels return to normal.

Eroding Away

The powerful forces of erosion caused by moving water gradually wear away rock and soil, transporting them to other locations. Sometimes, though, erosion can change the landscape very quickly. **Landslides** are sudden and fast movements of rocks and soil down a slope. They usually happen where soil on the side of a hill gets soaked with water. The wet soil then slides quickly down the hillside, taking with it all the vegetation. If any houses or other buildings were built there, they slide too.

Figure 1.20 Landslides are common in areas with steep hillsides and high rainfall at certain times of the year. What do you think people could do to prevent landslides?

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Global Warming and Glaciers

Current research suggests that increased burning of fossil fuels is emitting harmful gases (called *greenhouse gases*) that are warming the planet. Search your library or the Internet for information on glaciers and climate change. What do you think will happen if much of the polar glacial ice melts?

Glaciers—Rivers of Ice

Picture a field of snow as far as the eye can see. The air is extremely cold, and the wind tears at your face, stinging you with sharp grains of ice and snow. There are many holes and cracks in the snow that are deeper than you can see. This icy world is thousands of years old and it's not standing still, either. It creeps along, making cracking and groaning noises.

A **glacier** is a moving mass of ice and snow. For over two million years, this force of erosion has visited North America at least four times. In fact, ice once covered areas of Alberta to heights of 600–1000 m and has greatly shaped its landscape.

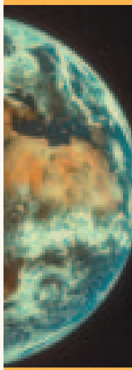
Figure 1.21 Big Rock, near the Sheep River south of Calgary—This large boulder is called a *glacial erratic*. Weighing 16 500 t and as tall as a 3-storey building, it was moved many kilometres and deposited by glacial ice.

As glaciers flow, they pick up large rock fragments that act as grinding tools to carve and scrape the landscape beneath them. Erosion occurs when this advancing ice mass scoops up rock fragments and drags them along its base. In doing so, the glacier grinds the **bedrock** (the layer of solid rock beneath the loose rock fragments), producing a polished but often scratched or furrowed surface. When the glacier melts (or retreats), it leaves its eroded rock fragments in the form of small hills called *drumlins* and *moraines* and snake-like hills called *eskers*.

Check and Reflect

1. Explain the relationship between erosion and weathering.
2. Give some examples of weathering.
3. How does moving water change the landscape?
4. What might happen to a riverbed if sediments are deposited?
5. How do glaciers change the landscape?

Section Review



Assess Your Learning

1. a) Why do we use models when we study Earth?
   b) Why are some models changed or revised over a long period of time?
2. Name the layers that make up the interior of Earth. Describe some of the characteristics of each one.
3. What is the difference between the crust and the mantle? Explain two causes for this difference.
4. What is the difference between the focus and the epicentre of an earthquake?
5. What instruments do scientists use to help monitor earthquake activity?
6. Explain in your own words what causes a volcano.
7. What kind of indirect evidence do scientists use to study the inside of Earth?
8. What is deposition? Why is this force different from erosion?
9. a) Describe two types of weathering.
   b) Where would you look for these types of weathering in your area? Why?
10. Explain how wind, water, rivers, and glacier erosion differ in shaping the landscape.

Focus On — The Nature of Science

Because science is studied by people from many different language backgrounds and cultures, scientific language and classifying systems need to be precise.

1. Why is it important when studying Earth's surface features for everyone to use the same system of classification?
2. What terms and concepts did you study in this section that you still don't understand?
3. What terms and concepts in this section do you feel you understand?

2.0 The rock cycle describes how rocks form and change over time.

Key Concepts

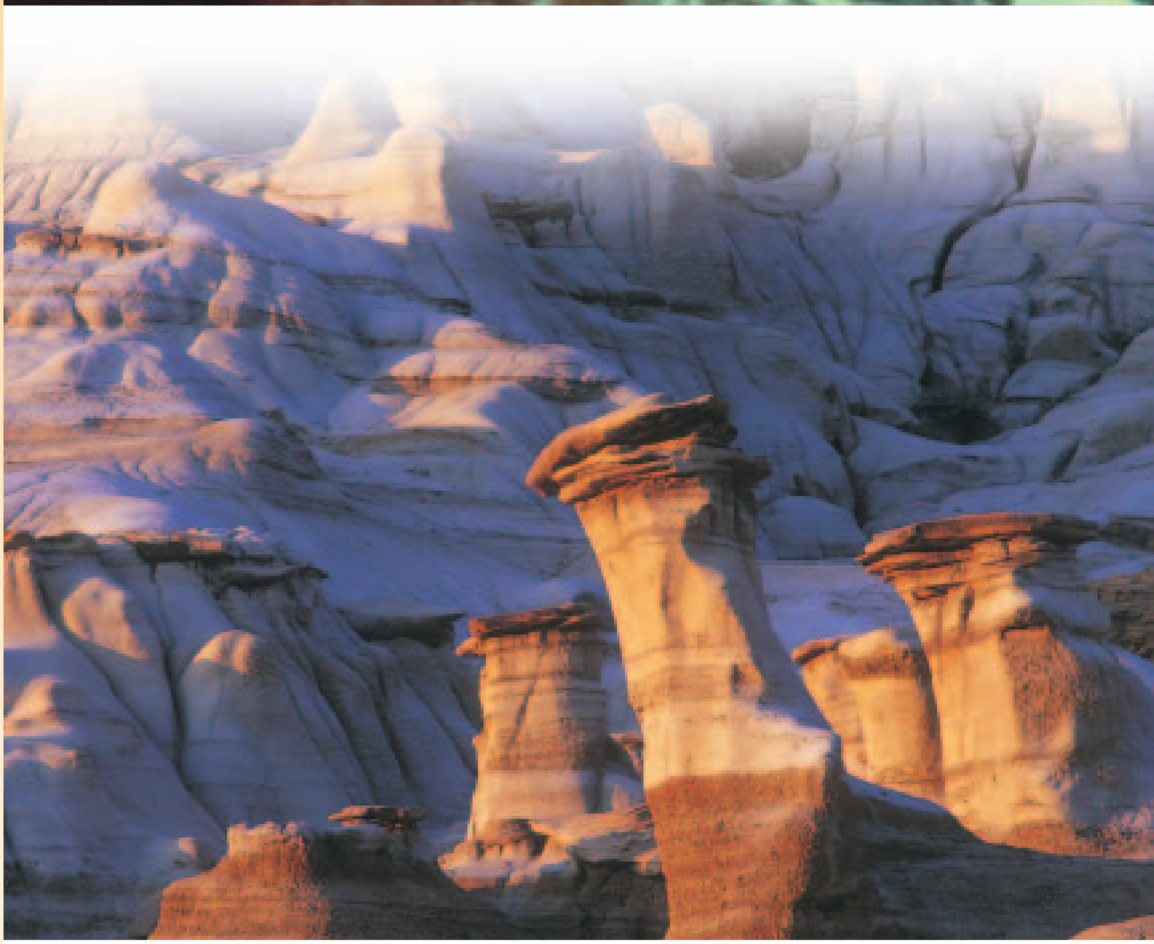
In this section, you will learn about the following key concepts:

- rocks and minerals
- classes of rocks: igneous, sedimentary, and metamorphic
- geology tools and techniques
- the rock cycle
- describing and interpreting local rock formations

Learning Outcomes

When you have completed this section, you will be able to:

- distinguish between rocks and minerals
- describe characteristics of the three main classes of rocks
- use suitable terms and conventions in describing Earth's substances
- describe local rocks and sediments
- interpret and investigate examples of weathering, erosion, and sedimentation (the rock cycle)



What can rocks tell us about Earth? They tell a story of change. Scientists, such as geologists, can "read" rocks to learn their stories. You can start to read the story yourself by carefully looking at rocks. What do you see when you look at a rock? Can you tell what it is made of or how it was formed?

Figure 2.1 Do you realize there is a rock that you eat: the salt on these chips! (See the *info*BIT on page 370.)

2.1 What Are Rocks and Minerals?

Rocks: You have probably walked on them, ridden over them, and even eaten them! But if you had to describe them to someone, what would you say?

Minerals in Rocks

To read the story of a rock, you have to know something about the substances that are part of it. If you examine a rock closely, you will notice it is made up of many little particles called *grains*. The appearance and properties of a rock depend on the nature of these many grains and the particular materials of which they are made.

The building blocks of rock are pure, naturally occurring solid materials called **minerals**. All rocks are made of minerals. Some rocks, such as limestone, are formed of only one mineral, while others, such as granite, are made up of several different minerals.

*info***BIT**

Rock Products

An area of the Bow Valley in the Rocky Mountains near Exshaw, Alberta, is mined for limestone. This mineral is used to make a variety of products, from stomach relief tablets that relieve upset stomachs, to concrete.

Give it a **TRY** — ACTIVITY

Mission Control, This Is ...

Pathfinder was a robot vehicle sent by NASA to investigate and gather information from the surface of Mars. Imagine you are with Pathfinder, and you must transmit a description of the rocks and minerals you've found on the planet's surface. Use a hand lens or magnifying glass to study the rock samples your teacher gives you. (Be sure to wash your hands after handling the rocks.) Describe each one using words or pictures, and use the following questions to help you with the description.

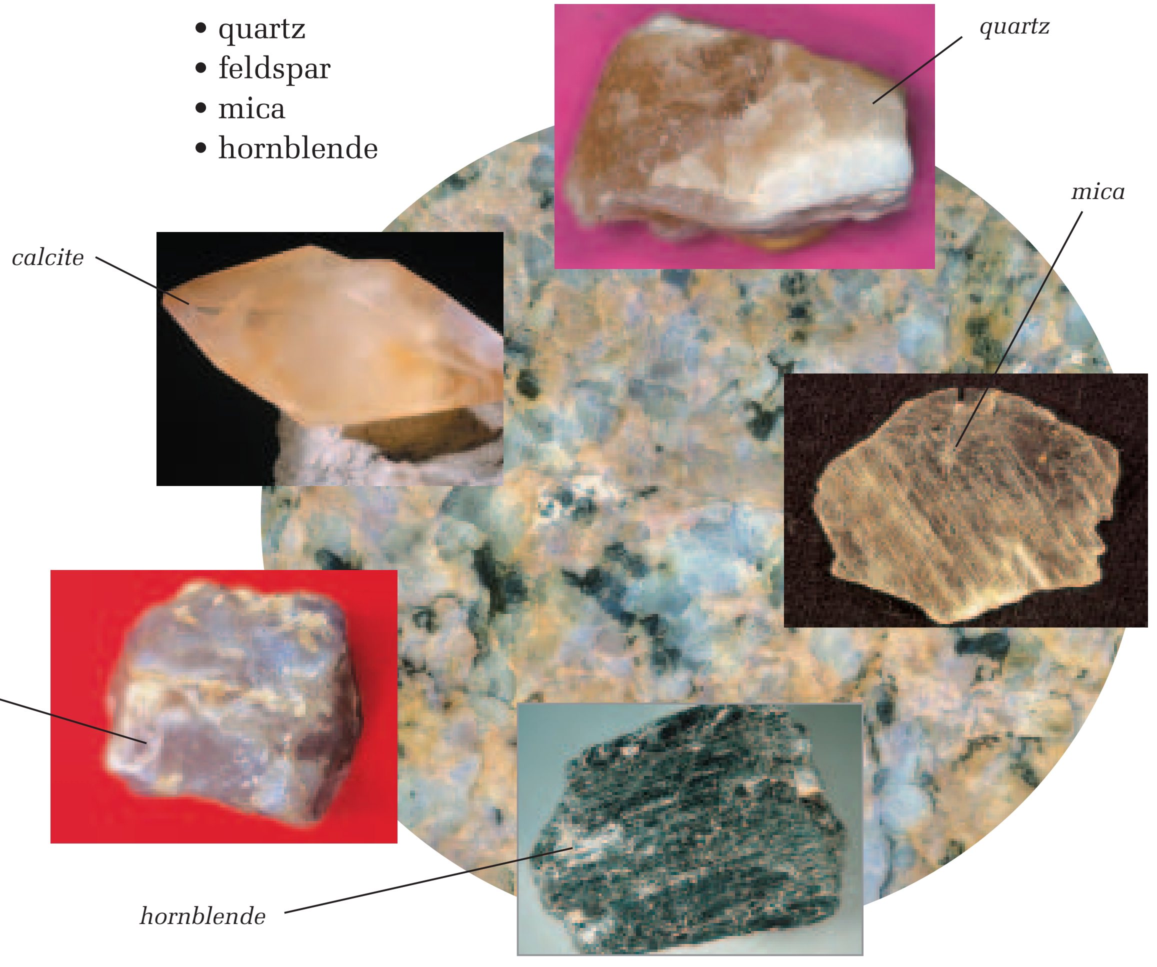
- What colour is the sample? Is it the same colour all around? (Wet the surface and see if the colour changes.)
- Does it have a smell?
- What does the surface feel like?
- Is it living or non-living?
- Does it seem to be made up of one substance or a combination of several others?
- Are any of the samples similar to each other?
- What else can you say about these samples?

Figure 2.2 Mars Pathfinder

You may have heard the names of common minerals, such as quartz and mica. In fact, more than 3500 different minerals have been identified. However, you don't have to recognize or know all of them to identify most of the rocks you'll find. Just five minerals combine in different ways to form the majority of the rocks in Earth's crust. These minerals are:

- calcite
- quartz
- feldspar
- mica
- hornblende

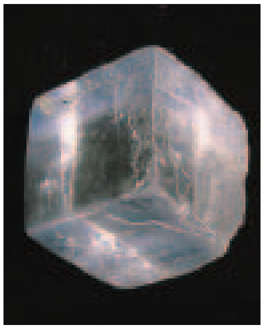
Figure 2.3



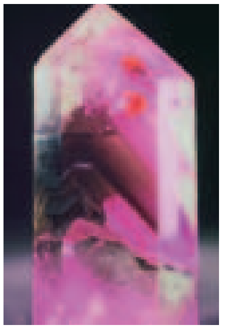
*info*BIT

Rock Crystals

Crystals form when the particles in a mineral line up in a regular pattern that creates smooth surfaces and sharp edges. Each mineral has its own, unique crystal pattern. Crystals that cool slowly, for example, will form bigger crystals than those that cool quickly. Halite (common table salt) forms cubes. Quartz forms long, six-sided crystals with a pointed end. What kind of conditions do you think a mineral would need to allow it to grow into a crystal?



Halite crystal (sodium chloride)



Quartz

Using Properties to Identify Minerals

To identify rocks, you need to identify the minerals they contain. Because many of the same rocks and minerals are found in different parts of the world, geologists have developed a series of classifications for describing their properties. **Properties** are the features that a material or object has. For minerals, some important properties are:

- colour
- lustre
- streak
- cleavage
- fracture
- hardness

Knowing only one of these properties is usually not enough for you to identify the mineral. You need to look at a combination of these properties. Think of this process as a jigsaw puzzle: one piece does not give you the whole picture. (See Figure 2.4 for some examples.)

Colour

Colour is a useful starting point because it's the first property you notice.

Lustre

Lustre is the way the surface of a mineral reflects light. Some minerals have a metallic lustre. This means they are shiny like metals, such as gold or silver. Even though two minerals may have the same colour, their lustre may help to tell them apart. Other words to describe a mineral's lustre are pearly, glassy, waxy, silky, greasy, and brilliant.

Streak

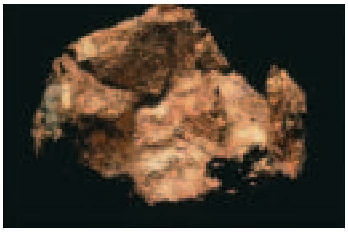
A mineral's **streak** is the colour of the powder that it leaves behind when you rub it across a rough surface. The colour of the streak is not always the same as the colour of the mineral. Usually, geologists use an unglazed ceramic tile (like the tile used on bathroom walls, but not shiny). They scratch a mineral sample on the plate, and the colour of that streak gives a clue as to the mineral's identity.

Cleavage and Fracture

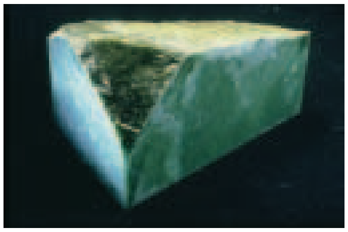
If you drop or break a mineral, you may notice the sample will break in a certain way. If a mineral splits easily into two smooth surfaces, this can be described as **cleavage**. In contrast to cleavage, **fracture** is a mineral breakage with rough and uneven surfaces. (However, any mineral can be fractured if enough force is applied.)

Figure 2.4 Properties of different minerals

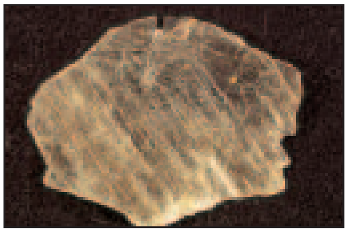
The *colour* of amber is yellow.



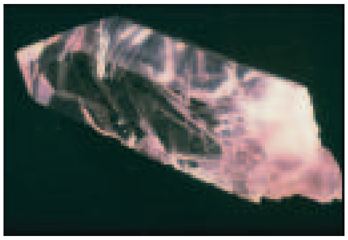
The *lustre* of native copper is shiny.



Jade makes a white *streak.*



Mica is a mineral that *cleaves* easily into flat sheets.



The *hardness* of quartz is 7.

Hardness

The **hardness** of a mineral is measured by how easily it can be scratched. The harder mineral leaves a scratch on the softer one. The relative hardness of a mineral is measured with a scale developed by a German scientist, named Frederic Mohs. **Mohs scale of hardness** consists of 10 minerals ranked in order of hardness. The scale is described below and in Figure 2.5.

Mohs Scale of Hardness		
Scale	**Mineral**	**Can Be Scratched With**
1	talc (softest)	soft pencil point
2	gypsum	fingernail
3	calcite	copper wire
4	fluorite	iron nail
5	apatite	glass
6	feldspar	steel file
7	quartz	sandpaper
8	topaz	sandpaper
9	corundum	emery board
10	diamond (hardest)	diamond

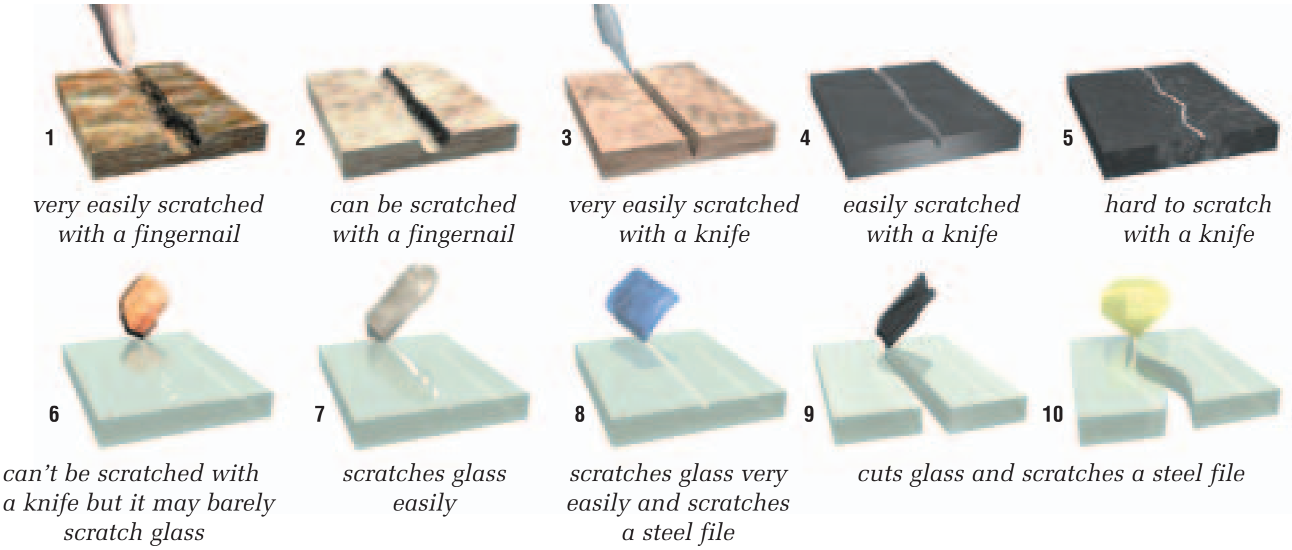


Figure 2.5 The hardness scale is a guide to identifying minerals. Each mineral can scratch *all* the minerals with a lower scale ranking than its own.

Identifying Minerals

The first step in identifying a rock is determining what minerals it contains. This is not always an easy task as two rocks can have exactly the same minerals in them, yet they may look different because they formed in different ways. However, if you use the six properties of minerals, the Mohs scale of hardness, and a good database of mineral characteristics, you can identify most rocks.

Careers and Profiles

Volcanologist


Figure 2.6 Volcanologists taking samples from a lava tube on the island of Hawaii

It's Monday, and you're back on the job ... but where are you? You're walking over a rocky black mountain and it's rumbling gently under your feet! A few metres away, you can see jets of smoke coming from cracks in the rock. Oh no! It's a volcano! But instead of running, you haul out your instruments and set them up. This is your job: you're a volcanologist.

Volcanologists study volcanoes. They measure the movement in volcanoes to see if they're going to erupt. When an eruption occurs, they watch carefully to see how it happens. They also study the way lava comes out of a volcano and how it moves. The most serious part of their job is predicting whether or not a particular volcano will erupt. If they are right, many lives could be saved.

Seismologist


Figure 2.7 Seismographs record movement deep inside Earth.

Seismologists study earthquakes. They watch carefully for changes in Earth's surface, like twisting or moving rocks. Devices such as the seismograph are used to record the shaking and trembling of an earthquake. Yet even though seismologists know the areas of earthquake activity, they unfortunately can't predict when and where earthquakes will occur.

Another important part of a seismologist's job is to make sure buildings are earthquake-safe. Buildings made of brick often fall apart in an earthquake. It is better to have a building with a steel or wooden frame. Seismologists teach people in earthquake areas how to be safe in case of danger.

1. What does the work of volcanologists tell us about Earth's structure?
2. In what areas in Canada might you expect to find seismologists at work?

Inquiry Activity

Prospecting for Minerals

Materials & Equipment

- samples of known minerals
- hand lens
- streak plate
- copper wire
- iron nail
- sandpaper
- samples of unknown minerals
- database of minerals (or a rock and mineral field guide)

The Question

How can you identify a mineral by its properties?

The Hypothesis

TOOLBOX

Develop a hypothesis based on the question above.

Figure 2.8 Step 6. Use a hand lens to examine the mineral's structure.

Procedure

Part 1

1. Choose a sample of a known mineral, and record its number and name in your chart. (See the chart example on the opposite page.)
2. Record its colour in your chart.
3. Describe its lustre as metallic (shiny like metal) or non-metallic. If it's non-metallic, try to describe it in another word. For example, if it looks like glass, you could describe it as "glassy."
4. Scrape the sample across the streak plate. Brush off the loose powder with your fingers. If there is a streak, record its colour.
5. To test hardness, start by scratching the sample with your fingernail. If it doesn't leave a scratch or groove on the sample, try the copper wire. If the wire doesn't leave a scratch or groove, try an iron nail. Then try the sandpaper. Record the hardness of the sample. (It might be between two numbers on the hardness scale, so you could rank it as 4–5 or 6–7.)
6. Use a hand lens to examine the mineral's structure.
7. Add any other information that you've observed about the mineral. Record this in your "Other" column.
8. Repeat steps 1 to 7 with the other samples of known minerals.

Part 2

8. For each unknown mineral, record its number in your chart.
9. Repeat steps 2 to 6 from Part 1 of the procedure for each unknown mineral.
10. Use the information in your database of known minerals to identify your unknown samples. Enter the name of the mineral in the "Mineral Name" column.

Collecting Data

11 Use a chart like the one below to record the information about the properties of each mineral sample.

Mineral ID No.	Mineral Name	Colour	Lustre	Streak	Hardness	Other

Analyzing and Interpreting

12 Is colour a reliable property to use for identifying minerals? Why or why not?

13 Which property or properties did you find the most useful for identifying minerals? Why?

Forming Conclusions

14 Write a summary paragraph that answers the question: "How can you identify a mineral by its properties?"

Figure 2.9 Native copper

Applying and Connecting

Can you think of another way to display the information in your database so it can be used easily? Work with a partner to create an identification key to help you and others identify minerals. After you and your partner have completed your identification key, see if other students can figure out how to use it. Can they suggest ways to improve it?

Extending

Use a rock and mineral field guide to find out about the properties of copper and diamond. List some of the commercial uses for these two minerals. How are their properties related to these uses?

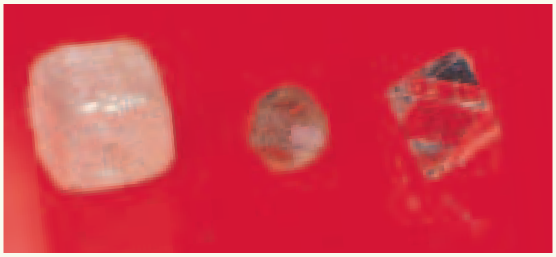


Figure 2.10 Raw diamonds

Prospecting for Wealth

Identifying rocks and minerals isn't just a fascinating hobby; it's big business! Canada is the world's largest mineral exporter and is one of the world's leading producers of gold, copper, nickel, zinc, lead, silver, iron ore, asbestos, potash, sand, gravel, and clay. There are over 500 mines and quarries scattered across Canada, with mining operations taking place in every province and territory.

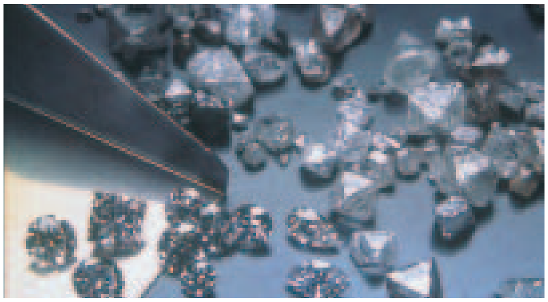


Figure 2.11 These diamonds are from Canada's first diamond mine, the Ekati mine near Lac de Gras, Northwest Territories. It began operations in 1998.

Figure 2.12 The Highland Valley open-pit mine near Kamloops, British Columbia, is the largest base metal mine in Canada. It produces copper and molybdenum ore.

Figure 2.13 Alberta's coal mines produce nearly half of all of Canada's coal. (It is estimated that there is enough coal in Alberta to last about 1000 years at current rates of use.) The Highvale mine pictured above is 80 km west of Edmonton. It is Canada's largest coal mine.

Check and Reflect

1. One of the steps in identifying a rock is to identify the minerals it contains. For example, granite is made of quartz, feldspar, and mica. If you were given an unknown rock, how would you use what you learned in this section to identify it?
2. The properties of minerals are useful for more than just identifying them. Sometimes, properties make a mineral valuable. For example, colour is important in gemstones. What other property that you learned about in this subsection might make a mineral useful or valuable?

2.2 Three Classes of Rocks: Igneous, Sedimentary, and Metamorphic

Even though you've been able to identify rocks by knowing their minerals, to learn the whole story, you need to know how the rock was formed. You need to look at the way the minerals are arranged and the sizes of the individual grains.

As you explore the different types of rocks in this section, use a diagram like the one below to keep track of the information (Figure 2.14). Copy this diagram into your notebook, using a whole page. Label your diagram as you go through the text. On your diagram, indicate where the different types of rock are forming. Add any notes that will help you remember what process formed them. To get you started, the diagram shows one example.

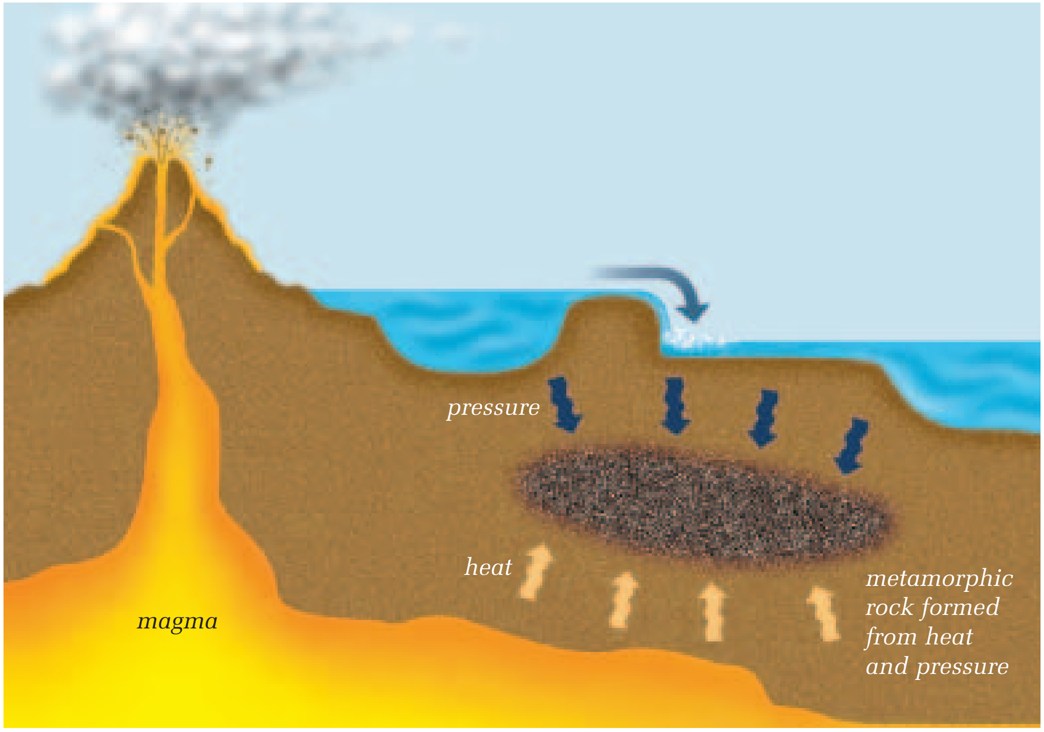


Figure 2.14 How rocks are formed

Types of Rock

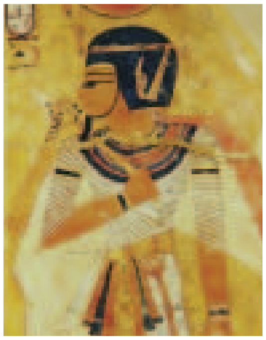
Although there are many different kinds of rocks, all rocks can be organized into three major families or types according to how they were formed as: *igneous, sedimentary,* and *metamorphic*.

*info***BIT**

Treasures in Earth's Crust

Earth's crust is a treasure house of valuable things. Gold, silver, and precious stones are all found in Earth's crust.

- The ancient Egyptians were mining for emeralds as far back as 1650 B.C. That's more than 3000 years ago.
- Canada is one of the top 10 gold producers in the world.



A wall painting of an Egyptian wearing precious stones

Figure 2.15 One place where you can watch igneous rock forming is at active volcanoes, like those in Hawaii and Iceland.

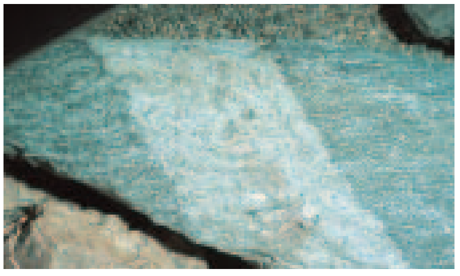
Igneous Rocks

The word *igneous* comes from the Latin word "ignis," meaning fire. **Igneous rocks** form from hot, molten rock called **magma**, but by the time you hold them in your hands, they are hard and cold. Magma may cool deep inside Earth or it may reach the surface before it cools. When it flows out onto the surface of Earth either on land or beneath the ocean, it's called **lava**. The photographs of pegmatite and basalt show one way that you can tell the difference between igneous rock that cools on the surface and one that cools deep inside Earth.

*info***BIT**

Rock Hounds

Are you a rock hound? A rock hound is someone who collects and studies rocks as a hobby. Every spring, many rock hounds attend the Calgary Rock and Lapidary Club's Gem, Mineral, and Fossil Show. The Calgary area and the nearby Rocky Mountains are famous for the unique geology that can be found there. If you're a rock hound and want to get involved, look up a local rock club in the phone directory or on the Internet.



pegmatite

basalt

Figure 2.16 Pegmatite and basalt are both igneous rocks. The pegmatite formed when magma cooled deep in Earth. Molten rock cools slowly underground. This gives the mineral grains more time to grow, so the pegmatite has larger grains. The basalt formed when lava flowed out of a volcano. It cooled very quickly, so its mineral grains are much smaller.

Igneous rock is classified into two groups, depending on whether it was formed on or below Earth's surface. Rock formed from magma that cooled and hardened beneath the surface is called **intrusive rock**. This type of rock is found on the surface only where erosion has worn away the rock that once lay above it. Rock that was formed from lava cooling on the surface is called **extrusive rock**.

Sedimentary Rocks

Have you ever seen rocks that have layers in them, like the ones in the photographs (Figure 2.17)? These are called **sedimentary rocks**. They form when small pieces of rock are carried by water or wind and settle or sink down onto the rocks below them. Sometimes these pieces are made up mainly of tiny shells from dead animals. As more and more sediments pile up, the ones on the bottom are squeezed by the weight of the ones above. Over time, this pressure causes the sediments to turn into sedimentary rock. You'll find out more about sedimentary rocks later in this unit.

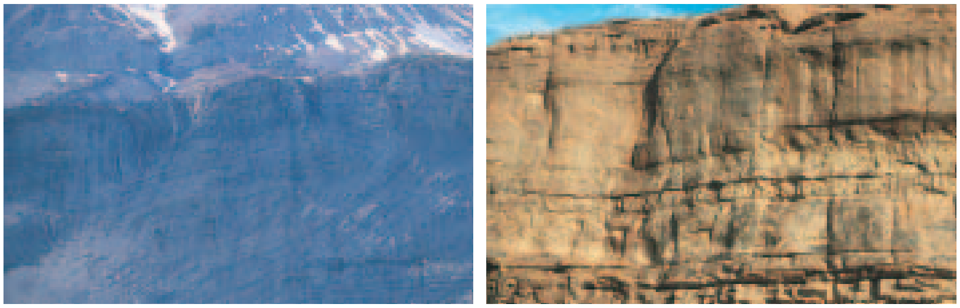


Figure 2.17 Limestone (left) and sandstone (right) are two kinds of sedimentary rock that usually occur in layers.

Give it a **TRY** ACTIVITY

Graph It!

TOOLBOX

If you examine this table of the world's top producers, you will probably notice that Canada is among the world leaders in mining. But numbers are difficult to visualize. (See Toolbox 7 for help in graphing data.)

- Your challenge is to take the numbers in the table and create a graph (or graphs) that compares Canada with the other countries listed.
- Choose one of these countries, and use your library resources and the Internet to research its mineral production. How does your research compare with the data given here?

Copper (×1000 t*)	China (3200)	U.S. (1920)	Canada (700)	Australia (550)	Indonesia (530)
Lead (×1000 t)	China (650)	Australia (530)	U.S. (450)	Canada (260)	Peru (250)
Zinc (×1000 t)	Canada (1250)	China (1130)	Australia (1100)	Peru (770)	U.S. (600)
Nickel (×1000 t)	Russia (230)	Canada (200)	New Caledonia (130)	Australia (120)	Indonesia (90)
Aluminum (×1000 t)	U.S. (3600)	Russia (2900)	Canada (2300)	China (1900)	Australia (1400)
Gold (t)	South Africa (500)	U.S. (320)	Australia (290)	Canada (170)	Russia (130)
Silver (t)	Mexico (2500)	U.S. (1440)	Peru (1950)	Canada (1310)	Chile (1150)

*t = tonnes

Not all sedimentary rocks form from fragments of rocks or shells. As water flows over and under Earth's surface, it can dissolve substances called "salts" from the rocks. The salt you use on your food is one of these salts. In fact, the reason the ocean is salty is that rivers carry so much of these salts into the ocean. Sometimes, bodies of water that contain dissolved salts dry up, leaving salts behind and forming thick beds.

Another type of sedimentary rock is formed from organic, living material. One of the most common examples is coal, an important fossil fuel that comes from the decay of plant matter. Alberta has always been an important producer of this source of fuel. Figure 2.18 illustrates how coal is formed.

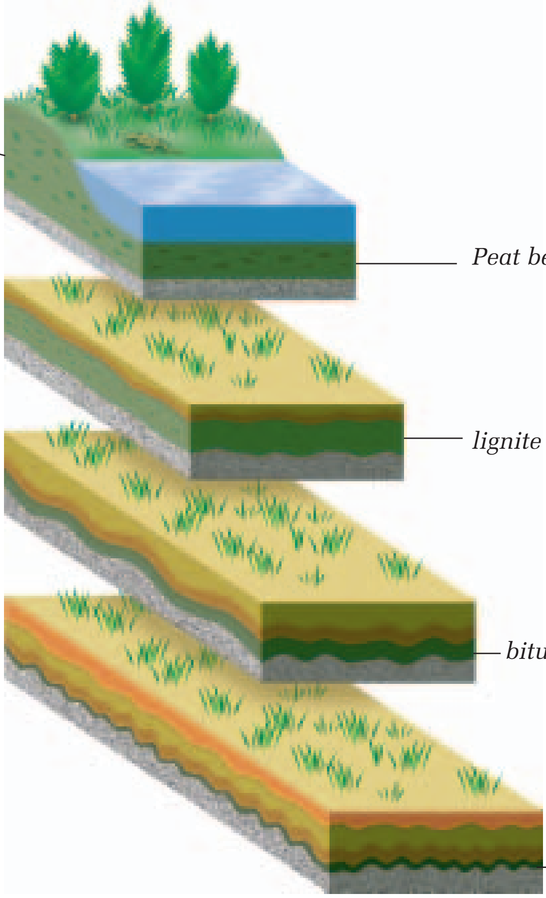


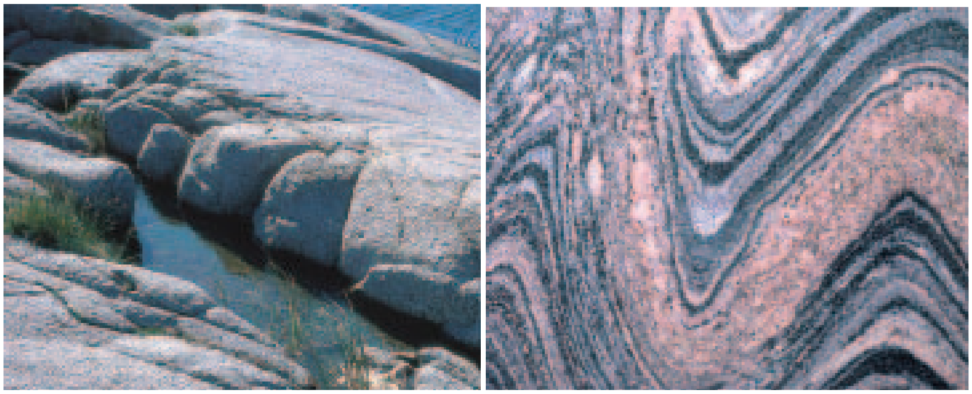
Figure 2.18 Two hundred and seventy-five million years ago, there was an extensive growth of vegetation in the tropical climate of ancient Alberta. Over time, plant debris was trapped between layers of sediment. The increasing pressure has since compressed this debris, first into *peat*, then *lignite* (brown coal), then *bituminous coal*, and finally into *anthracite*.

Metamorphic Rocks

Metamorphic rocks are rocks that have been changed. The word "metamorphic" is a combination of two Greek words: "meta" means change, and "morph" means form. These rocks started out as igneous, sedimentary, or other metamorphic rocks. The intense heat and pressure deep below Earth's surface changed their appearance. Figures 2.19 and 2.20 show examples of changes to sedimentary, igneous, and metamorphic rocks caused by heat and pressure.

shale *slate* *schist*

Figure 2.19 *Shale* is a sedimentary rock that changes to *slate* if it is exposed to strong heat and pressure. Slate is harder than shale. If slate is exposed to more heat and pressure, the different kinds of mineral grains in it become larger and separate from each other. The rock is then called *schist* [shist].



granite outcrop *gneiss*

Figure 2.20 Granite and gneiss contain the same minerals (quartz, feldspar, mica, and hornblende) but as you can see, the rocks look different. *Gneiss* [nīs] is a metamorphic rock that can form from the igneous rock, *granite*. Heat and pressure cause the mineral grains in the granite to separate and flatten into the bands you can see in the photo on the right.

Over long periods of time, rocks are constantly undergoing changes. For example, the sand on a beach may have once been part of a large boulder.

Identifying Classes of Rock

Scientists spend much of their time collecting, organizing, and trying to understand their data. **Classifying** is the grouping of objects or events that have the same characteristics. When geologists find a new rock or rock formation, the first thing they need to do is to classify it.

Inquiry Activity

Classifying Rocks

The Question

What properties help you determine the class of rock?

The Hypothesis

Develop a hypothesis based on the above question.

Materials & Equipment

- sample rocks (igneous, sedimentary, and metamorphic)
- magnifying glass

Rock Summary Table

Class of Rock	Texture	Colour
igneous		
basalt	extremely fine grained	dark grey to black
obsidian	glassy	usually black, sometimes reddish or green
granite	coarse to medium grain	various: white to dark grey, pink, or red
sedimentary		
sandstone	coarse to medium grained; layered	varies
limestone	fine grained	usually white to dark grey
coal	fine to medium grained	brown to velvet black
metamorphic		
gneiss	banded	varies
marble	coarse grained	usually white, but may have other colours as veins
slate	banded	usually medium to dark grey or black

Figure 2.21 Compare the properties of your rock samples with the properties listed in this table.

Procedure

1. Before you begin, review the three classes of rocks. Are the rocks pictured below typical examples of each class?

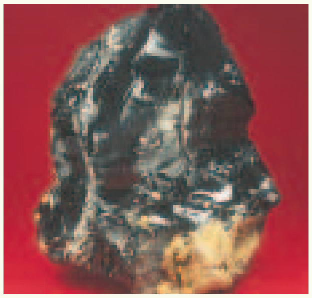


Figure 2.22 *Obsidian* [ob SID ē an] is an example of igneous rock.

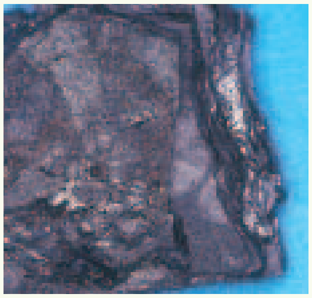


Figure 2.23 *Coal* is sedimentary rock.

Figure 2.24 *Marble*, a metamorphic rock, comes in many colours.

2. Work with a partner or in a small group to identify the rock samples your teacher gives you as either igneous, sedimentary, or metamorphic.
3. Use the Rock Summary Table to help you identify your rock samples (Figure 2.21). The summary will give you an idea of some typical characteristics for each type of rock classification.

Collecting Data

4 Record your observations in the form of a chart such as the one below:

Sample	Colour	Texture	Rock Group

Analyzing and Interpreting

5 Which samples did you classify as igneous?

6 Which samples did you classify as sedimentary?

7 Which samples did you classify as metamorphic?

Forming Conclusions

8 What physical property (or properties) did you find the most useful in classifying rocks?

Applying and Connecting

Use a rock and mineral field guide to identify the names of your rock samples. Organize your data in a chart similar to the one below:

Sample	Name	Colour	Lustre	Streak	Hardness	Other

Extending

Go on a rock-search field trip. Collect several rock samples, and using what you have learned and a rock and mineral field guide, identify the samples you find. Write a brief report of your trip. Explain in your report how you planned and organized your field trip. Was your field trip successful? Did you find interesting rocks? Plan a display for your rock samples.

reSEARCH

Alberta Oil and Gas

Oil and gas are important fossil fuels. Alberta produces about 40% of all oil and gas in Canada.

- Where are the major oil and gas areas in Alberta?
- Is there a pattern to their location? (Hint: Look at the types of rocks they are found in.)
- Why are the oil sands important to Alberta's and Canada's economy?

Geology Tools and Techniques

Geologists no longer wander the countryside on foot looking for gold, iron, and other valuable minerals. Today, they rely on a number of high-tech tools and techniques to find mineral ore bodies.

- **Remote sensing**—mapping of Earth's surface from aircraft or orbiting satellites. By examining rock formations, soil types, and vegetation in aerial images, geologists can infer possible locations of valuable mineral deposits hidden below the surface.
- **Geophysical prospecting**—using sensitive instruments to detect mineral deposits hidden deep underground. For example, some minerals, such as iron and copper, are magnetic and can be detected with a *magnetometer*.
- **Geochemical prospecting**—making chemical analysis of samples taken from the environment. Geologists look for evidence of traces of metals that may indicate the presence of an ore body buried in a given area.
- **Exploration**—drilling holes to verify an ore body's existence. A diamond-tipped drill bit is used to extract a cylindrical core of rock that can be thousands of metres long!

Check and Reflect

1. Using your own words, complete the following sentences:
  a) Igneous rocks form when …
  b) Sedimentary rocks form when ...
  c) Metamorphic rocks form when …

2. Lava always forms igneous rock, but not all igneous rocks are formed from lava.
  a) What is lava?
  b) If an igneous rock didn't form from lava, from what did it form?

3. What are some of the characteristics used to classify rocks from each of the three different rock classes?

4. What are some of the methods geologists use to locate valuable mineral deposits?

2.3 The Rock Cycle

Figure 2.25 Water is an important element in the rock cycle.

You recycle things all the time—cans, paper, and glass bottles. After you throw them into the recycling bin, they are taken away, broken down, and made into new products. Does that sound familiar?

You have learned about the three families of rocks and learned how they can change in structure and appearance over time. Think about how Earth recycles rocks:

- any rock that is heated may melt into magma and later form igneous rock
- any rock that is exposed on Earth's surface may be broken down into sediments and later become sedimentary rock

The physical environments determine what kind of rock is formed. If the environment changes, the rocks may eventually change into different kinds of rocks.

*info***BIT**

Encouraging Weathering

In order for weathering to occur, rocks need to be exposed to air and water.

- *Landslides* remove large areas of topsoil and other surface material.
- *Avalanches* of snow loosen rock and soil debris.
- *Floods* break down river banks and deposit material over a large area.

Figure 2.26 When this house was built, it had a fresh coat of paint and sparkling windows. A family moved in and grew up there. Children played in the yard. Flowers grew in the front. Vegetables grew in the back. Fifty years later, it looks like this. What happened to it?

Rocks can be altered so much that they change classifications (igneous, sedimentary, or metamorphic). For example, an igneous rock may be weathered, and its grains deposited to form a sedimentary rock. Rocks can also be altered so that they become another type of rock within the same classification. For example, as you saw in Figure 2.19, schist is a metamorphic rock formed from slate, another metamorphic rock. Geologists call this process of change in rocks the **rock cycle**. Figure 2.27 is a model of this process.

The Rock Cycle

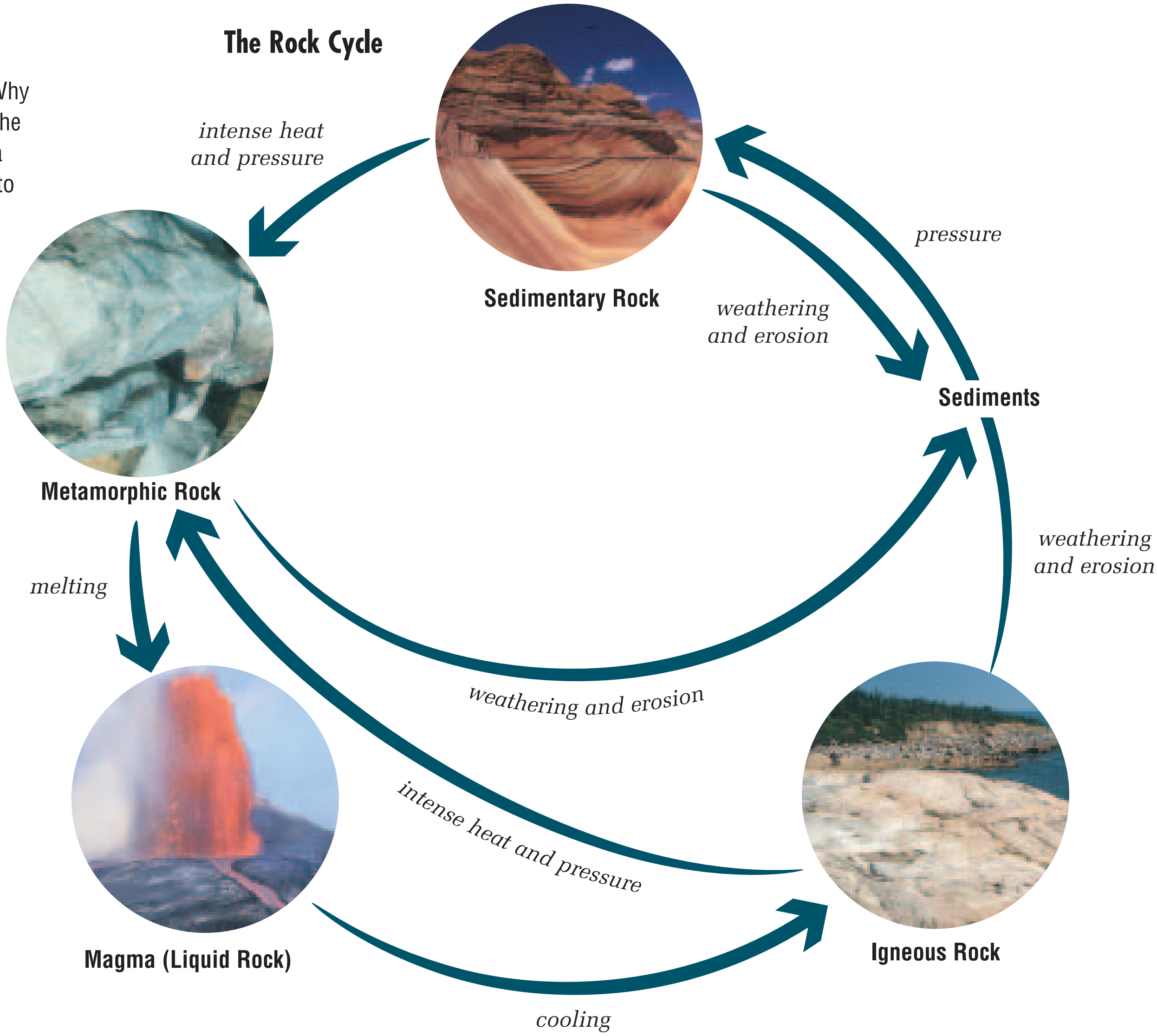


Figure 2.27 Why do you think the rock cycle is a useful model to geologists?

Investigating the Rock Cycle

It takes nearly 1000 years for just 5 mm of soil to form. Soil is mainly composed of two materials: rock and decaying organic matter. The rock is in the form of stones, gravel, sand, silt, and clay that eroded from the rock of Earth's crust. The organic matter comes from plants and animals.

THE ALBERTA STORY: INVESTIGATING THE CHANGING EARTH

What kind of rocks do you think you would find in your backyard? Would you even find any rocks? Well, for the first 50 or so metres, all you would probably dig up would be sand, gravel, stones, and boulders. Below this material (called *overburden*), the story is different.

The rocks that make up Alberta were laid down in layers over hundreds of millions of years ago. The oldest layer, the **Precambrian Shield**, is at the bottom. This layer is made of igneous and metamorphic rocks that were formed between 544 and 4500 million years ago. It is the world's oldest rock and underlies all of Alberta. However, it is only exposed in the northeast corner, covering about 3% of the province. Eighty-seven percent of Alberta's landscape lies over the **Interior Plain**. This wedge-shaped piece of land is sandwiched between the Canadian Shield and the Rocky Mountains. (It also extends across Saskatchewan and Manitoba.) The plain is made up of various layers of sedimentary rock that are between 544 million and 1.5 million years old.

Rocks in Your Backyard

Figure 2.28 Pelican Rapids—Most of Alberta's metamorphic rocks lie hidden beneath the surface. Pelican Rapids, in the northeast corner of the province, is one area where these outcroppings can be seen.

Figure 2.29 Dinosaur Provincial Park Badlands—The Badlands, located in Dinosaur Provincial Park, is a dramatic example of sedimentary rock layers. Glaciers eroded the rocks into these unusual features about 15 000 years ago.

Figure 2.30 Rock Slide in the Mountains—Huge rock slides sometimes occur in the mountains because of erosion. They may also be triggered by earthquakes.

Inquiry Activity

Sorting Out the Soil

The Question

What is the rock material in soil composed of?

Materials & Equipment

- samples of soil (from sandy to black loam)
- magnifying glass
- 1.5-L jars, one for each soil sample
- millimetre ruler
- sheets of white paper, one for each soil sample
- scoop

Figure 2.31 This soil is not as rich in organic matter as black loam garden soil.

Procedure

1. Examine each of the soil samples. If necessary, add a little water to the dry samples so that all samples seem to have the same amount of moisture.
2. Pick up a little of each soil in your fingers and record how many lumps it contains (many, few, or none). Also record whether the soil feels smooth or gritty. Wash your hands after handling the soil.
3. Add enough of each soil sample to fill 1/4 of a separate jar, then almost fill the jar with water. Stir the contents well to break up all the clumps. Let stand overnight or until the particles have settled to the bottom.
4. Meanwhile, take a small scoop of one soil sample and spread it out as a very thin layer on a sheet of white paper. Use the magnifying glass to examine the soil. Look for rock fragments in your sample, and describe their grain size according to the following classification. Repeat step 4 for each soil sample.

Rock Sample	Size of Particle
stone	larger than 20 mm
gravel	about 3 mm to 20 mm
sand	smaller than 2 mm, but visible without a magnifying glass
silt	smaller than 0.07 mm, only visible through a magnifying glass
clay	smaller than 0.004 mm, only visible through a microscope

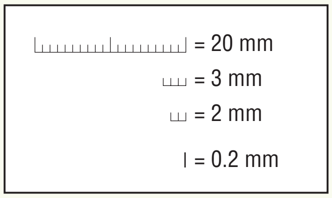


Figure 2.32 Use this scale to estimate the size of particles in your soil samples.

5. Observe the water and soil mixtures in the jars. Draw a diagram of each sample to show the different layers and the different-size particles in each. Indicate the colour of the water that remains above each settled sample.

Collecting Data

6 Use a chart, such as the one below, to record your observations:

Sample/Location	Colour	Lumpiness	Feel	Type of Rock Particle				
				stone	gravel	sand	silt	clay

Analyzing and Interpreting

7 How do the soil samples differ in the amounts of different sizes of sediments they contain?

8 What are some of the characteristics of the different kinds of rock material in your soil samples (colour, shape, lustre, etc.)?

9 In the jars of soil and water, which size of sediment settled to the bottom first?

10 Which size of sediment settled last?

11 What colour was the water above the settled sediment? If it wasn't colourless, what do you think created the colour?

12 What material, other than rock fragments, do you think the different soil samples contain?

Forming Conclusions

13 Write a summary paragraph describing what you learned about the composition of soil in this activity. Use data from your observations to support your description. Illustrate your description with drawings.

Applying and Connecting

The shape of a grain of sand can often tell you how much it has been moved around. For example, wave action will remove sharp edges faster than other forms of weathering. Soft minerals are more easily broken down than hard minerals. What inferences can you make about how long your rock particle samples have spent in soil? How do you think the rock grains got in your soil samples?

Extending

Use a rock and mineral field guide to try to identify the minerals in your sand samples. (Hint: You will need to examine your rock fragments with a magnifying glass or hand lens.)

Figure 2.33 Gravel

Figure 2.34 Sand

Figure 2.35 Clay

Check and Reflect

1. What does the rock cycle tell us about how rocks are formed?
2. The picture at left, Figure 2.36, shows the footprint left behind by one of the astronauts who landed on the moon about 30 years ago. This footprint looks exactly the same today as it did when it was made. What does this tell you about the rock cycle on the moon?

Figure 2.36

Careers and Profiles

Geologist

Nancy Chow studies coral reefs, but not the kind found in tropical destinations like the Bahamas or the Red Sea. She studies coral reefs found in Manitoba, Alberta, and the interior of Australia!

These coral reefs existed 380 million years ago when large parts of North America and Australia were covered in water. Nancy is a geologist who analyzes the sedimentary rock layers formed by these ancient reefs.

In the Field

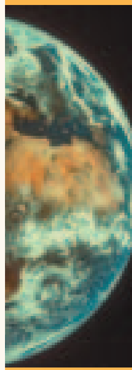
Nancy spends about a quarter of her time in the field. The rock layers she studies often lie deep underground, buried by thousands of years of sedimentation. To get at the underlying rock, drill core samples are taken. She takes careful notes to keep track of where each sample came from.

Does Nancy Chow Like Her Job?

"It's been great for me," she says. "I've travelled to Australia to work on spectacular rock exposures. I've been to the Caribbean to look at modern reefs. I have no complaints!"

Figure 2.37 Nancy Chow investigating sedimentary rock layers

1. What can geologists learn about Earth's surface when they study rock formations?
2. What types of businesses might use the services of geologists?



Assess Your Learning

1. How are rocks and minerals related?
2. Describe four properties of minerals that are used for identification. How is each different?
3. Review the rock samples you examined at the beginning of subsection 2.1 (Mission Control, This Is ...). Use a rock and mineral field guide to classify these rocks as either igneous, sedimentary, or metamorphic.
4. Why do some igneous rocks have bigger mineral grains than other igneous rocks?
5. A metamorphic rock is a changed rock. What did it change from? What changed it?
6. Kathy was on a bus that drove past a steep hillside of bare rock. “Look,” she said to her friend, “sedimentary rocks!” How did she know?
7. Why can two rocks look very different even though they are made of the same minerals?
8. Write a paragraph explaining the rock cycle.
9. What is the Precambrian Shield, and why do you think it is of interest to geologists?
10. Describe a rock formation found in Alberta.

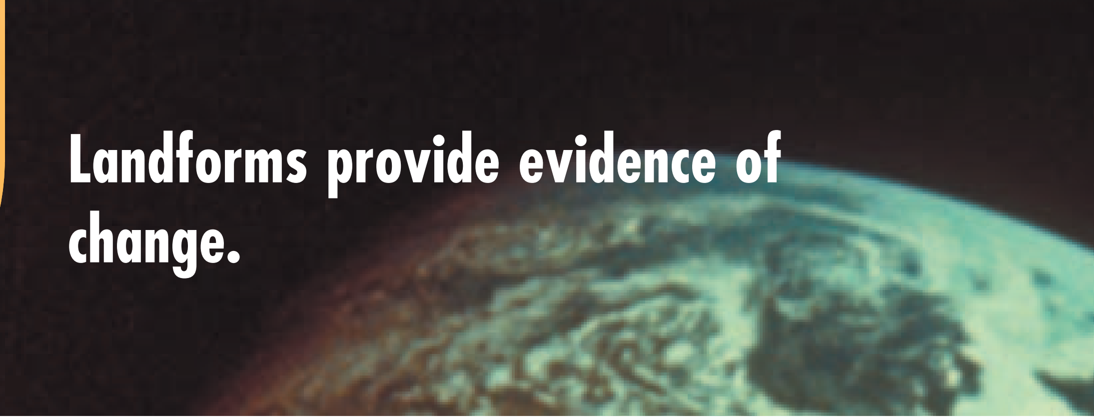
Focus On — The Nature of Science

Performing successful experiments is often the result of having a clear hypothesis. Think back to the experiments you did in this section.

1. Did each experiment prove its hypothesis?
2. Which hypothesis did you have to revise as a result of the data you collected?
3. If you did have to revise a hypothesis, why do you think it wasn’t correct or accurate or complete enough in the first place?

3.0

Landforms provide evidence of change.



The Rocky Mountains

Key Concepts

In this section, you will learn about the following key concepts:

- continental drift
- plate tectonics
- mountain building

Learning Outcomes

When you have completed this section, you will be able to:

- describe evidence and identify patterns of continental movement
- interpret evidence for the Theory of Plate Tectonics
- investigate and interpret patterns of mountain building
- interpret the structure and movement of fold and fault mountains

The Sawback Mountain Range is in the Rocky Mountains of Alberta. The rocks that make up the mountains were originally deposited in stages on the sea floor hundreds of millions of years ago as flat-lying layers. You can still see the layers in this photograph, but they are no longer flat. How would you describe them? What forces do you think pushed these layers skyward? How long ago did it happen? Could it happen again?

Earth is a planet in constant motion and change. You have already seen how weather and water wear the surface features of rocks down; how rocks can be transformed from one form into another. But there are even greater forces on the planet that affect its surface. Intense heat from deep inside Earth creates volcanoes that gush lava. Huge plates moving across its surface cause earthquakes that shake and split the ground. Mountains are pushed upward toward the sky. Science is only now beginning to understand these powerful forces that shape our Earth.

For Web links relating to 3.0, visit **www.pearsoned.ca/scienceinaction**

3.1 Continental Drift

When you watch TV or a mystery movie, do you try to solve it along with the detective? Detectives look for clues in the connections between events and between characters. Who was near the scene of the crime? Who had a motive? Investigating Earth's structure is like solving a mystery. Just as detectives do, scientists look for patterns and connections in their observations as they try to solve the mystery of Earth's surface.

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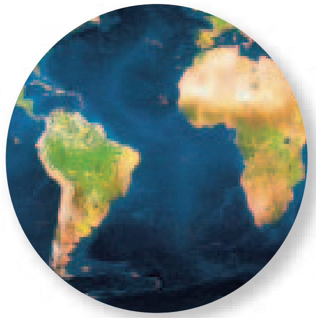
Looking for Evidence

What do you notice about the coastlines of South America and Africa? Do they have anything in common?



Satellite view of South America and Africa

Continents on the Move

In 1910, the German scientist Alfred Wegener [VAY guh nur] noticed something interesting about the shapes of the continents that could be seen on a map of the world—just as you might have observed. He noticed that the outlines of the continents looked as if they could fit together. He developed a hypothesis that all the continents had at one time been joined together in a single land mass that he named "Pangaea" [pan JEE uh], meaning "all lands." He hypothesized that since the time of Pangaea, the continents have slowly drifted apart. Geologists today refer to this idea as **continental drift**.

Figure 3.1 The super continent: Pangaea

Glossopteris Fossils*—These were plants that resembled ferns. They lived about 250 million years ago. Their seeds could not have travelled across the ocean.*

Folded Mountains*—Similar mountain formations were found on different continents.*

Glacial Deposits*—Deep scratches in the rocks show that glaciers once covered this land.*

Coal Deposits*—Ancient tropical forests produced these coal deposits, which seem to have once been connected.*

Figure 3.2 Wegener supported his theory of continental drift with these four pieces of evidence. Do you see how he came up with his theory?

*re*SEARCH

Researching Continental Drift

Find out more about Wegener's theory of continental drift. (Ask your librarian for help in finding print and media resources.)

- Use geology and geography textbooks to find an example of a geological formation of rock and/or fossil evidence that supports Wegener's theory.
- Use the map of Pangaea (Figure 3.1) to help you decide what evidence to look for.

But to convince others to accept his theory, Wegener needed evidence. So he studied the specific types of rock formations on each continent as well as other geological evidence. He also looked at land formations, such as mountain ranges, to see if they were similar from continent to continent. What he found was startling in view of what scientists at the time believed about Earth. Fossil and rock evidence suggested that some tropical continents had previously existed in polar regions!

Wegener did more than try to just explain the amazing fit of the continents. He even offered an explanation for how mountains form. Wegener thought that when drifting continents collided, their edges crumpled and folded, forming mountains. Unfortunately, he could not provide an explanation for the force that caused the continents to drift over Earth's surface.

Many geologists thought then that Earth was slowly cooling and shrinking, so the science community rejected his idea. Scientists at the time believed that mountains formed when the crust wrinkled like the skin of a dried-up apple. For nearly half a century, from the 1920s to the 1960s, most scientists paid little attention to his idea of continental drift. Then, new evidence about Earth's structure led scientists to reconsider and later accept Wegener's bold theory.

Check and Reflect

1. a) What was Wegener's theory of continental drift?
b) What were the three types of evidence Wegener used to support his theory?
c) Why did most scientists reject Wegener's theory of continental drift?

2. If the "shrinking apple" theory for mountain formation were correct, explain where you think mountains would be found on Earth's crust.

3.2 Plate Tectonics

Have you ever dropped a hard-boiled egg? If so, you may have noticed that the eggshell cracked in an irregular pattern of broken pieces. Earth's solid outer shell, or lithosphere, is much like a cracked eggshell. It is also divided into large, irregular pieces.

Developing a New Theory

Since Wegener's time, scientists have studied major features on the continents and ocean floors. Advances in technology have helped them learn more about the composition and structure of Earth's surface, its crust, and its inner structure. Earlier in this unit, you learned about seismic waves from earthquakes. Using seismographs, scientists have been able to study the structure of the crust and the mantle. This information has helped them develop a new theory to explain many of the major features on Earth's surface.

Technology development for exploring the oceans has also been helpful to scientists studying Earth. Advances in sensing technology using sound waves have enabled scientists to map the ocean floors in detail. Deep-sea submersible vehicles have carried scientists to parts of the ocean floors where they have been able to observe geological processes in action. Robotic submersibles controlled from the surface have added even more to our understanding of the deepest parts of the oceans.

As scientists collected more and more information about Earth, they plotted the positions of features such as mountains, deep-ocean valleys, earthquakes, and volcanoes. When they looked at these features on a map of Earth, they noticed an interesting pattern.

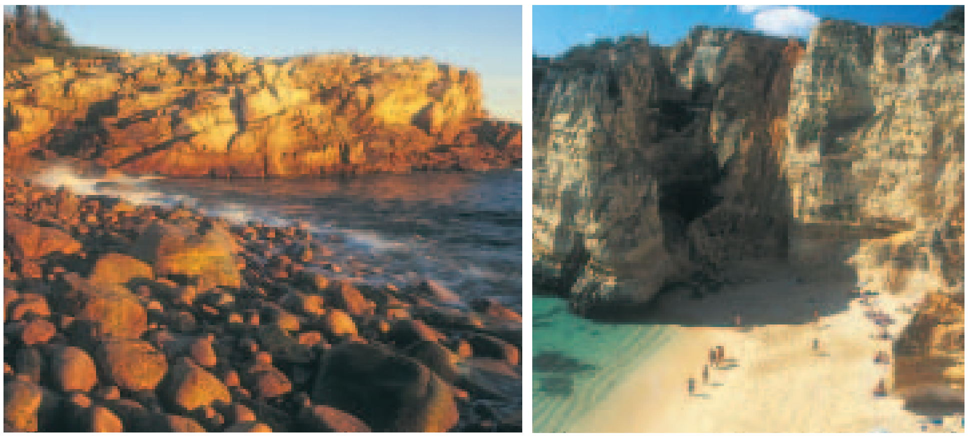


Figure 3.3 Look at these two landforms (to the left is the east coast of Cape Breton, Nova Scotia; to the right are cliffs near Lagos, Portugal, on the Atlantic Ocean). Can you imagine that they were once connected, as suggested by Wegener?

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The Active Earth

Where plates collide with each other is usually a location that has either active volcanoes or occasional earthquakes. Can you think of any places in Alberta or the rest of Canada that experience either of these events?

Inquiry Activity

Earthquakes, Volcanoes, and Plate Tectonics

The Question

Where in the world do earthquakes occur? Where in the world do volcanoes occur? Is there a pattern?

The Hypothesis

Develop a hypothesis based on the earthquake and volcano data given on this page.

Earthquake Activity

Place	Magnitude
Kobe, Japan	7.2
Anchorage, Alaska	9.2
San Francisco, California	7.7
Southern Chile	9.5
Los Angeles, California	6.7
Western Iran	7.7
Mexico City	8.1
Tokyo-Yokohama, Japan	8.2
Guatemala	7.5
Peru	7.9

Volcano Activity

Name	Place
Arenal	Costa Rica
Krakatoa	Java, Indonesia
Mount Pele	Martinique
Mount Pinatubo	Philippines
Mount Ruapehu	New Zealand
Mount St. Helens	Washington, United States
Mount Tambora	Sumbawa, Indonesia
Mount Vesuvius	Naples, Italy
Paricutin	Paricutin, Mexico
Surtsey Island	Iceland

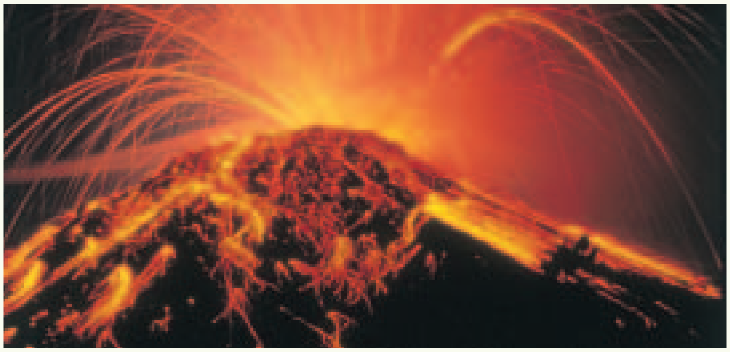

Figure 3.4 Arenal Volcano, Costa Rica

Procedure

1. Mark on a world map the location of the volcanoes and earthquakes listed in the charts to the left.
2. Review subsection 1.2, Sudden Earth Events.
3. Note any patterns you observe on your map.
4. Indicate on your map the principal mountain ranges in the world.

Analyzing and Interpreting

5. Work with a partner or small group and brainstorm possible reasons for your observations. Choose one of the reasons that you think best explains your observations. Does your reason fit your hypothesis? Do you need to revise your hypothesis?

Forming Conclusions

6. Write a brief report that supports your hypothesis.

Applying and Connecting

Compare your report with others in the class. What similarities do you find? What differences do you find? If necessary, revise your hypothesis to reflect what you have learned from the other reports.

Extending

Research other volcanic and earthquake activity and mark their locations on your map. Are these new locations in the same regions as the other volcanoes and earthquakes?

Interpreting the Patterns

Scientists noticed that volcanoes and earthquakes tended to occur in the same areas around the world. They also noticed distinctive deep valleys under the oceans, usually near the edges of continents. These valleys are called **trenches**. And they noticed long underwater mountain ranges called **ridges**.

The mountain range in the middle of the Atlantic Ocean was an important piece of evidence in the development of the new theory to explain Earth's surface structures. This mountain range is called the Mid-Atlantic Ridge. The rock at its top was younger than the rock on the surrounding ocean floor and the edges of the continents.

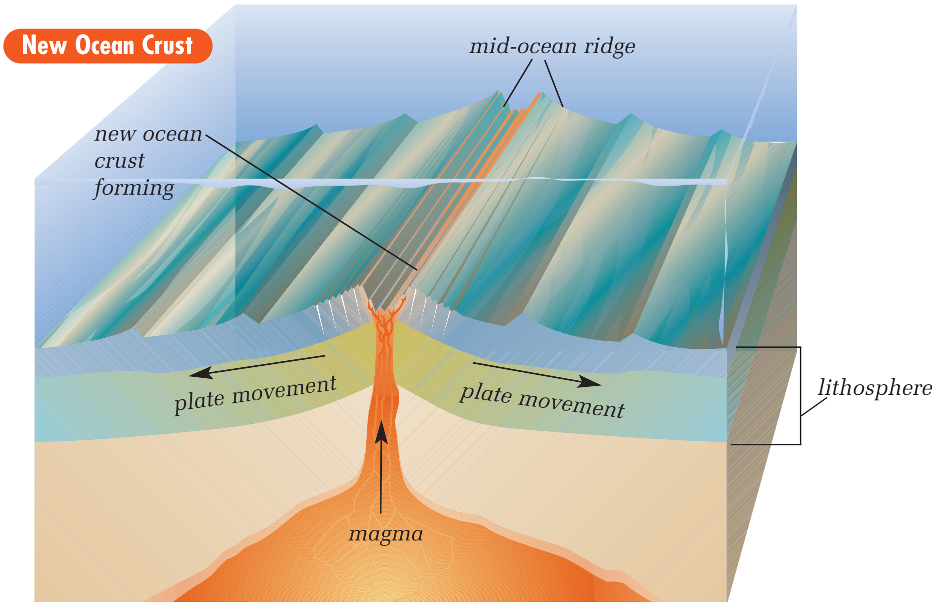

Figure 3.5 Deep under the water, new crust is forming continuously from lava at mid-ocean ridges.

Figure 3.5 shows what is occurring at the Mid-Atlantic Ridge. Magma rises from deep within Earth and flows out at the ridge. On either side of the ridge, scientists found that the farther rock is away from the top of the ridge, the older the rock is. This means that the rock must be moving away from the ridge and toward the continents.

Evidence showed that this sea floor spreading was taking place in other areas as well. Did this mean that the planet was increasing in size? No, it isn't because, in other areas, the sea floor is moving down into the deep ocean trenches. Scientists now had strong evidence for their new theory.

- Most earthquakes and volcanoes are concentrated in specific areas.
- There are large areas on Earth where few or no earthquakes and volcanoes occur.

Figure 3.6 Water within the crust layer is superheated by hot magma just a few kilometres below the surface. This is called **geothermal activity**. When water returns to the surface, hot springs like this one are the result.

- The ocean floor is spreading away from mid-ocean ridges.
- The ocean floor is moving down into deep trenches on or near the edges of continents.

The Theory of Plate Tectonics

When all this evidence was pieced together, scientists suggested the **Theory of Plate Tectonics**. According to this theory, the lithosphere is broken up into large areas much like a cracked eggshell. These areas are called **plates**. The plates usually carry both continental and oceanic crust. All these plates are moving very slowly on a semi-solid layer of crust.

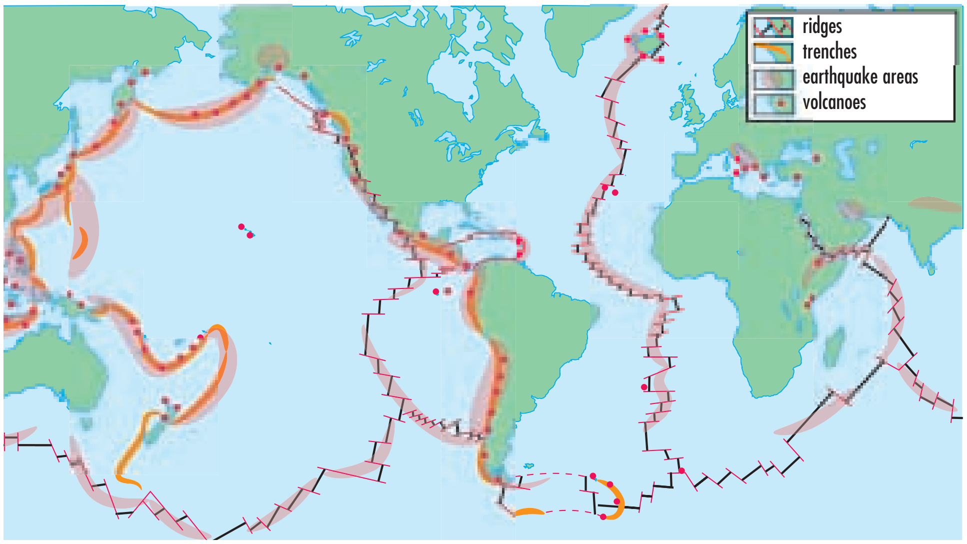

Figure 3.7 This map shows the major features scientists discovered when they surveyed the ocean floors. They found deep valleys called **trenches** and mountain chains called **ridges.**

The following illustrations show what happens at the different types of plate boundaries around the world. A **boundary** is the edge where plates meet. Look at the map of The Plates of Earth (Figure 3.8) while you read these descriptions so you can see where they are.

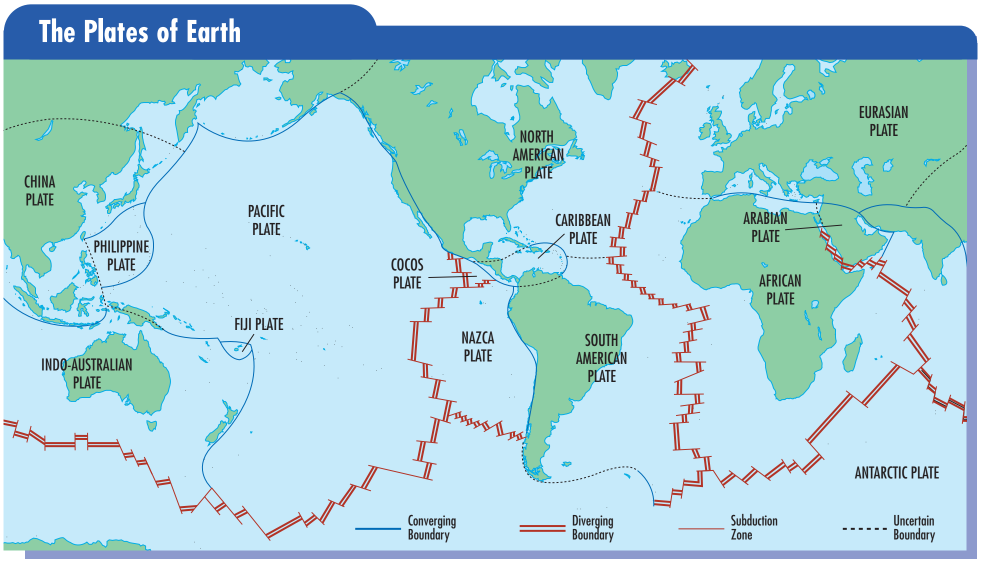

Figure 3.8 Earth's lithosphere is broken up into many large and small plates. The plates are all solid rock, but they "float" on the partly melted layer of the mantle below the lithosphere.

Diverging Boundaries

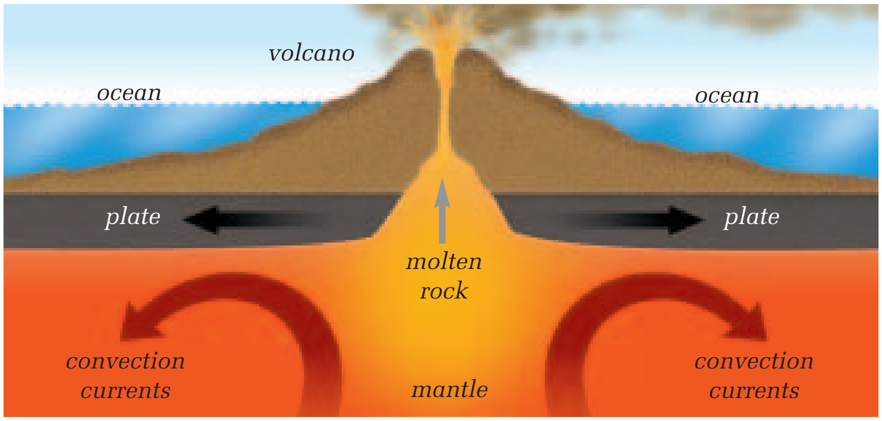

Figure 3.9 A diverging boundary

A **diverging boundary** is one where two of Earth's plates are moving apart. The Mid-Atlantic Ridge on the floor of the Atlantic Ocean is an example of a diverging plate boundary. At this type of boundary, lava flows from the ridge to form new oceanic crust. Sometimes, volcanoes grow high enough that they are visible above the ocean's surface, like those that form Iceland.

Converging Boundaries

At **converging boundaries**, plates are moving toward each other. Although plates move very slowly, they are so huge that we experience the effects of their collision. We can feel the earthquakes and see the mountains, including volcanoes, that grow up at or near these boundaries. There are two kinds of converging boundaries.

One kind of converging boundary happens where a trench forms. One plate carries *oceanic crust*, and the other one carries *continental crust*. When the plates push together, the heavier, thinner oceanic crust is forced down below the lighter, thicker continental crust (see Figure 3.11). This process is called **subduction**. As one plate grinds down past the other, earthquakes rumble, and the continental crust wrinkles to form mountains. The oceanic crust moves lower and gets hotter and melts. This molten rock rises in some places to form volcanoes.

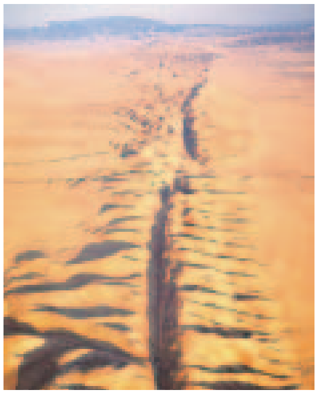

Figure 3.10 The San Andreas fault is a crack in Earth's crust that runs along part of the west coast of the United States.

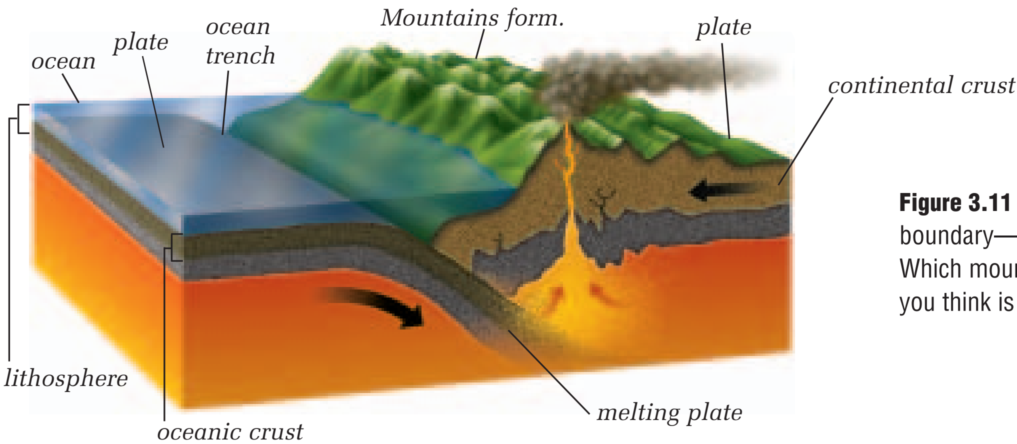

Figure 3.11 Converging boundary—*at an ocean trench.* Which mountain range in Canada do you think is formed by this process?

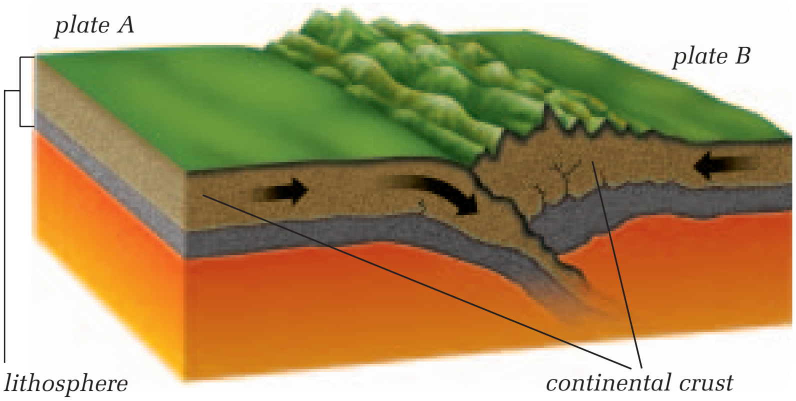

Figure 3.12 Converging boundary—*when two continental plates collide*

The second kind of converging boundary happens where two plates with continental crust move up against each other. They crush together to form huge mountain ranges. Which high mountain range in Asia is being formed by this process?

reSEARCH

Hawaiian Islands

J. Tuzo Wilson proposed an interesting theory of why the Hawaiian islands formed.

- Find out how these islands formed.
- Find out more about J. Tuzo Wilson and his work as a scientist.

Transform Boundaries

The third type of boundary is called a **transform boundary** (Figure 3.13). Here, plates slide sideways past each other. But this sliding doesn't take place smoothly. The rocks bind and catch on each other, causing earthquakes. You can find a transform boundary along the west coast of the United States at the San Andreas fault (Figure 3.10).

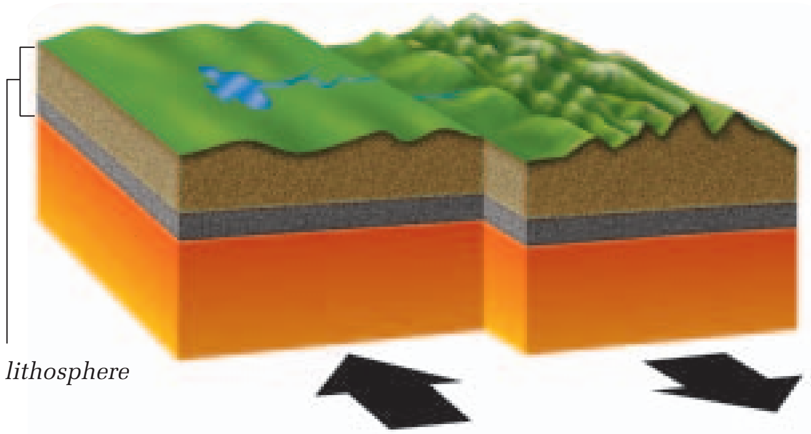

Figure 3.13 Transform boundary—*when two plates slide*

Check and Reflect

1. Explain three pieces of evidence to support the belief that Earth's crust is slowly moving.
2. List the three types of plate boundaries.
3. Look at the map of The Plates of Earth (Figure 3.8). Do you think South America is moving closer to or farther away from Africa?
4. If the South American and African Plates are diverging at a rate of 2 cm/year, calculate how much wider the Atlantic Ocean will be when you are 50 years old.

Experiment ON YOUR OWN

PREDICTING CONTINENTAL DRIFT

Before You Start ...

As you can see from your studies, scientists think that the continents once formed one large land mass called Pangaea. They believe that the continents have been slowly drifting apart at the rate of about 10 cm a year. Figure 3.14 shows the possible positions over the last 200 million years.

Continental Drift

200 million years ago

180 million years ago

100 million years ago

Figure 3.14 The changing positions of the continents over the last 200 million years

The Question

What will a map of the globe look like 100 million years from now, assuming the continents move apart at the current rate? (See Toolbox 2 to review The Inquiry Process of Science.)

Design and Make Your Model

1 The map below shows the continental plates and the direction they are moving.

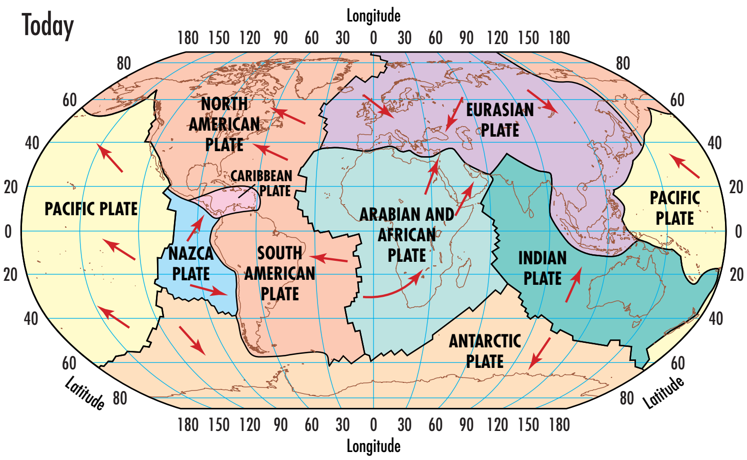

Figure 3.15 Direction of continental drift today

2 Create a plan of how you will use the map information to build a model map of the planet. List the materials and equipment you will need. Show your plan to your teacher for approval.

3 Make your model. Be prepared to explain and defend your model and how you developed it to your class.

4 Compare your model with others in the class. How successful were the other models? Were many models similar to yours?

3.3 Mountain Building

Think about Alberta's landscape. There is a tremendous diversity of mountains, plateaus, valleys, and rolling hills. Now think of the landscape where you live. What are some of the dominant features on it? What's the highest point of land in your area? Would you call it a mountain? Why or why not? Have you ever visited the Rocky Mountains? Describe in words or a drawing your impression of mountains.

What Is Mountain Building?

A **mountain** is part of Earth's surface that is much higher than the land around it. A **mountain range** is a series of mountains. The Rocky Mountains extend from the north in the Yukon territory, through the United States and into southern Mexico, making it one of the longest mountain ranges in the world. In Alberta, the Rocky Mountains straddle the border with British Columbia. These mountains are the result of several processes that geologists call **mountain building**.

In subsection 3.2, you learned that Earth's crust is not one smooth piece of rock. It is made of several plates that fit together like a giant jigsaw puzzle, and that are in constant motion.

Figure 3.16 The Canadian Rockies near Pincher Creek, Alberta

You also have learned that mountains form in places where these plates collide. For example, the land mass we call India is currently pressing into southern Asia. We have evidence of this as there are many earthquakes in this region in places like Turkey, Azerbaijan, Armenia, and other countries that border northern India. Evidence of this movement is also seen from the ever-growing Himalayas. (Mt. Everest, in the Himalayas, is about 50 cm higher than it was 40 years ago—and it's still growing!) Alberta's Rocky Mountains formed in much the same way over 200 million years ago, but the building stopped after about 140 million years.

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Mountain Trivia Quiz

- What is the highest mountain in the world?
- What is the highest mountain in Canada?
- What is the highest mountain in Alberta?

Answers:
Mt. Everest 8850 m
Mt. Logan 5920 m
Mt. Columbia 3747 m

Building the Mountains: An Alberta Story

Nearly 500 million years ago, Alberta had a much different climate than it does now. It was tropical. The border that is now shared with British Columbia was on the coast of a warm, shallow sea.

The shallow sea was constantly being filled with sediments. They flowed over the land and carried all sorts of debris, depositing it in layers on the coast. Over time, these layers of sediment created a pile that was 10–15 km thick. Rivers and streams that drained into that ancient sea carried with them a great deal of sand, mud, and gravel. These sediments were deposited in thick layers on the sea floor, reaching depths of up to 15 km.

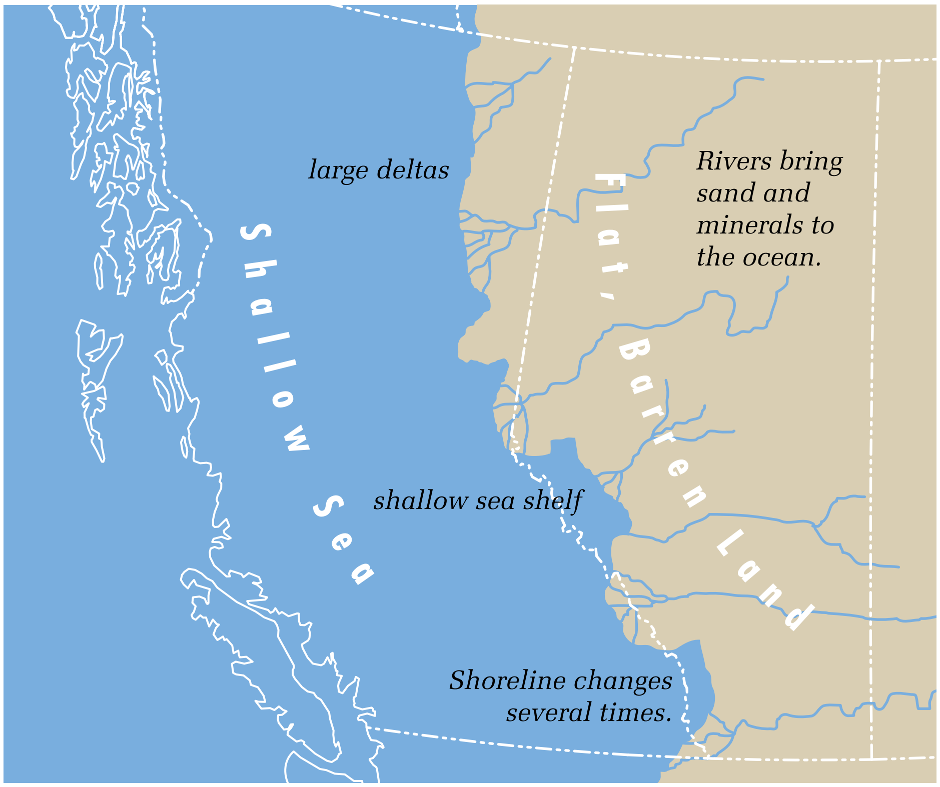


Figure 3.17 Five hundred million years ago, Alberta had no mountains, just flat land at the edge of a warm shallow sea.

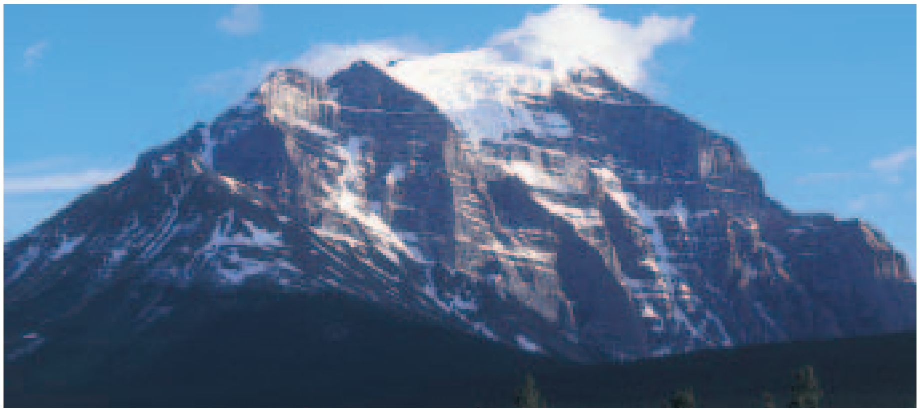


Figure 3.18 Mt. Temple was formed at the leading edge of the collision between the North American Plate and the Pacific Plate. It was here that sedimentary rocks were first stacked on top of each other like a wedding cake.

After more than a billion years of sediment deposition, the collision of two plates occurred. The North American Plate, carrying what is now Alberta, collided with the edge of the Pacific Plate. The force of this collision had two major effects. It forced the denser oceanic crust of the Pacific Plate downward below the lighter continental crust of the North American Plate, as you can see in Figure 3.19.

At the same time, the pressure of the two plates ramming against each other forced the sediments on the edge of the North American Plate to fold and break. Some of these sediment layers were pushed so hard that they separated and slid over top of each other. The continuing pressure moved them more than 250 km east of where they were originally deposited. Mount Rundle in Banff was formed in this way. This folding, breaking, sliding, and piling created the Rocky Mountains.

The continental plate, which is thicker and lighter, rides over the oceanic plate. Farther back, it buckles under the stress.

The oceanic plate, which is thinner and heavier, slides under the continental plate.

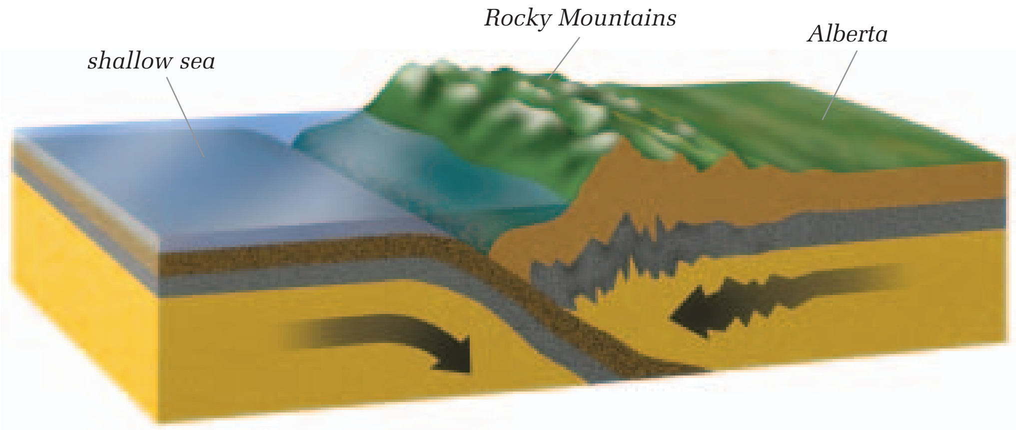


Figure 3.19 How the Rocky Mountains were formed

The Structure and Development of Fold and Fault Mountains

Have you ever seen interesting shapes or landforms when you drive in a car? Many Canadian roads travel through some amazing places that can leave you wondering: "How did it get to look like that?"

When mountains are built, they undergo several processes that result in the final formations that we see today. For example, as a result of the collision between plates, all of the sedimentary rocks in the present Rocky Mountains felt compression forces. These forces caused the sedimentary rocks to bend and break. Folding and faulting are the results. The bends in these rock beds are called **folds**. Large cracks in the rock beds also formed. **Faults** occurred wherever the rocks on either side of a crack moved. Most mountains were created by a combination of folding and faulting. There are two kinds of folds found in rocks:

- an *anticline* or an upfold in the rock
- a *syncline* or a downfold in the rock

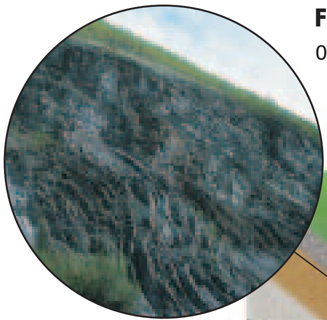
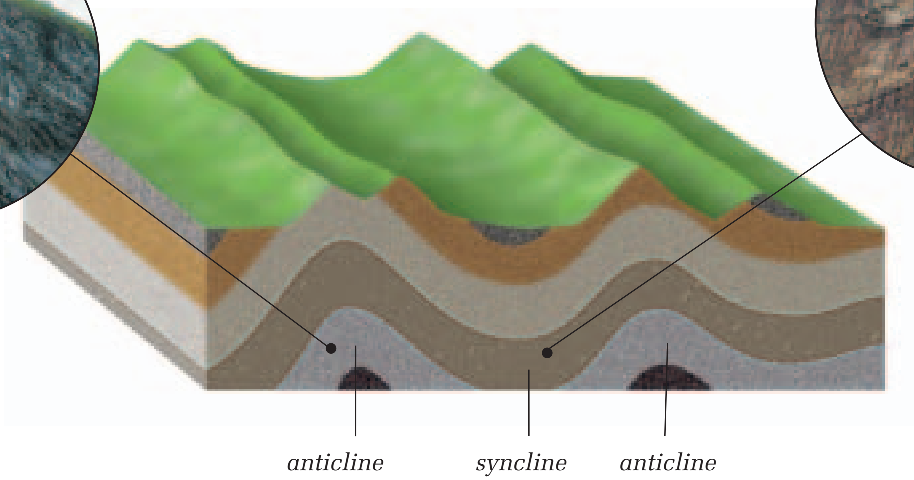


Figure 3.20 An example of an anticline fold



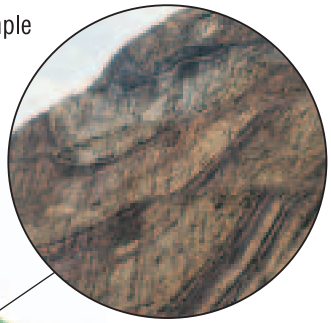


Figure 3.21 An example of a syncline fold

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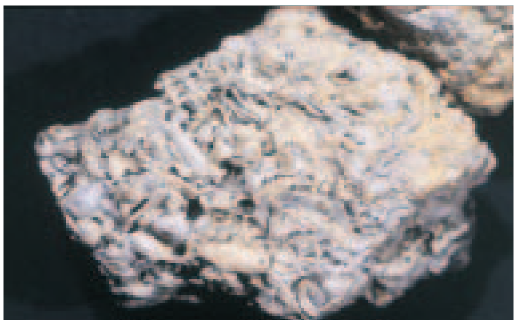
An Ancient Limestone Reef

Deep below the surface of southern Alberta are fossil remains of sea animals that lived millions of years ago. These ancient limestone reefs contain oil and gas.



This piece of limestone shows the fossilized remains of ancient sea animals.

Inquiry Activity

Forming Folded Mountains

The Question
How can mountains form by folding?

The Hypothesis
Form or develop a hypothesis that you think best predicts what will happen.

Materials & Equipment
- 5 rectangular strips of modelling clay, each a different colour but the same size
- 2 pieces of wood, each 10 cm × 8 cm × 8 cm
- bar clamp, longer than 50 cm

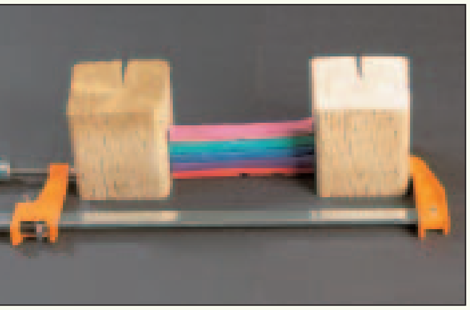


Figure 3.22 Step 2

Procedure
1. Place one piece of modelling clay on your desk. Lay the other pieces one by one on top of each other to form a pile.
2. Put a block of wood at each end. Place the clamp so that the modelling clay and the blocks of wood are between the clamps.
3. One person holds both ends of the clamp as another person slowly closes the clamp.
4. Stop when the clamp is half closed.
5. Clean up after you have completed the activity, and wash your hands.

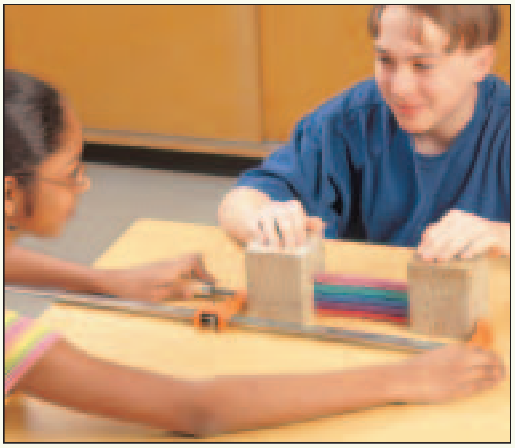


Figure 3.23 Step 3

Collecting Data
6 As you slowly close the clamp, stop from time to time to record your observations in words and diagrams.

Analyzing and Interpreting
7 Is the clay folded into an anticline or a syncline? or both?

8 What does the clamp represent in this model?

9 What does the modelling clay represent in this model?

10 What happens to the modelling clay as you close the clamp?

11 Why doesn't the clay break from the pressure of the clamp?

Forming Conclusions
12 Write a summary statement that answers the question: "How do mountains fold?" Include a diagram with your answer.

Applying and Connecting
Look through the photographs on pages 392 to 405 and identify examples of anticline and syncline folding.

Extending
Find other pictures in magazines that show these two types of folding. Use these pictures to create a poster describing and explaining this folding.

Where Does the Folding Happen?

The clay you used in the previous activity may seem much too soft to be a good model for layered rocks. Rocks are hard. How can they fold? Rocks can only fold after they have been softened by heat and pressure within Earth's crust. This heat and pressure allows the rocks to bend without breaking. These conditions are most likely to happen where powerful forces are at work in the crust.

Think about the Theory of Plate Tectonics that you studied earlier in this section. Colliding plates provide the heat and pressure needed to soften the rock. As the plates push against each other, the rock "wrinkles" into folds and is forced upward.

Look back at the map of The Plates of Earth (Figure 3.8). What two plates are colliding to form the Himalayas? If the Himalayas keep rising at 1 cm per year, how much taller will they be in 1 000 000 years?

Figure 3.24 The Himalayas are still rising at a rate of 1 cm each year.

Figure 3.25 This fence was one straight piece when it was built. Why do you think it now has this gap?

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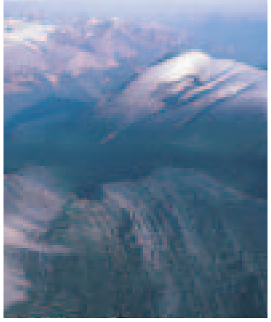
Researching the Rockies

Use library resources and the Internet to research what major fault (or faults) is in North America.



The Rocky Mountains—were these mountains built by a fault?

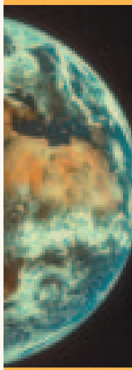
Mountains with Faults

Another powerful Earth process that can build mountains is faulting. Earlier in this unit, you learned that earthquakes can sometimes happen at faults far from plate boundaries. Faults can be so deep in the crust that we can't see them. However, some faults are visible on Earth's surface. Have you ever noticed a fault? How could you tell it was a fault?

Figure 3.26 One place where faults are easy to find is in layered rock. Where is the fault in this picture? What evidence do you see of movement along the fault?

Check and Reflect

1. Describe how the Rocky Mountains were formed.
2. How does the Theory of Plate Tectonics explain why ancient plant fossils found in Alberta rock represent a climate very different from today?
3. You have been asked to join a scientific expedition to investigate a remote mountain region in the Antarctic. Your team wants to discover how these mountains formed. Describe the evidence you will look for.



Assess Your Learning

1. Describe the three types of plate boundaries.
2. Coal deposits have been found beneath the ice of Antarctica, but coal only forms in warm swamps. Use Wegener's theory to explain how coal could be found so near the South Pole.
3. Explain why the rock of the Mid-Atlantic Ridge is younger than the rock found on the edge of the continents.
4. It has been suggested that we should dispose of our dangerous waste materials near a converging plate boundary. What do you think of this idea?
5. What would you expect to see when divergent boundaries occur on land? Draw a diagram of the result.
6. a) Describe the difference between a fold and a fault.
   b) Why do you think folded mountains contain faults?
7. During the building of the Rocky Mountains, the fault activity resulted in very thick layers of rocks to be pushed on top of one another. What do you think this additional weight did to Earth's crust? (Hint: Imagine what would happen if weights were piled onto a floating raft.)
8. Using what you know about the formation of faults, explain how mountain building can be compared with shovelling a sidewalk after a snowstorm.

Focus On — THE NATURE OF SCIENCE

The goal of scientists is to try to explain and interpret their observations. These interpretations are recorded in the form of scientific theories and models.

1. What theories did you learn about in this section?
2. What do you think are the differences between a scientific theory and a model?
3. What should scientists do if they discover that a theory or model doesn't explain all their observations?

4.0 The fossil record provides evidence of Earth's changes over time.

Key Concepts

In this section, you will learn about the following key concepts:

- tracing evidence of geologic change using fossils
- methods used to interpret fossils
- geologic time
- understanding fossil evidence

Learning Outcomes

When you have completed this section, you will be able to:

- describe the nature and formation of different kinds of fossils
- explain and apply methods used to interpret fossils
- describe different life forms based on fossil records
- identify uncertainties in interpreting fossil records

Dinosaur Provincial Park—These paleontologists are carefully digging out the skull of *Albertosaurus*, a dinosaur that lived 75 million years ago.

Geologists can have a difficult time studying Earth's history and the events that occurred. Fortunately, they have "time capsules" that they can use to give them a picture of life long ago. These time capsules are called fossils. They are found in the sedimentary rocks and can tell us a great deal about Earth's past.

Perhaps you've been to a museum or gallery that has different kinds of fossils on display. Was the fossil you saw an animal or a plant? Could you tell what the organism could have looked like when it was alive? Have you ever found a fossil in the field? What would you do if you found a fossil? Describe with words and a diagram your experiences with or knowledge of fossils.

For Web links relating to 4.0, visit www.pearsoned.ca/scienceinaction

4.1 Tracing Evidence of Geologic Change Using Fossils

Kathy and Roberto went on a field trip to a canyon in the mountains. There they found some fossils embedded in the sedimentary rock layers. Below is a copy of a drawing they made of what they saw, and some of their comments. Think of what you know about sedimentary rocks, and answer the following questions related to their comments:

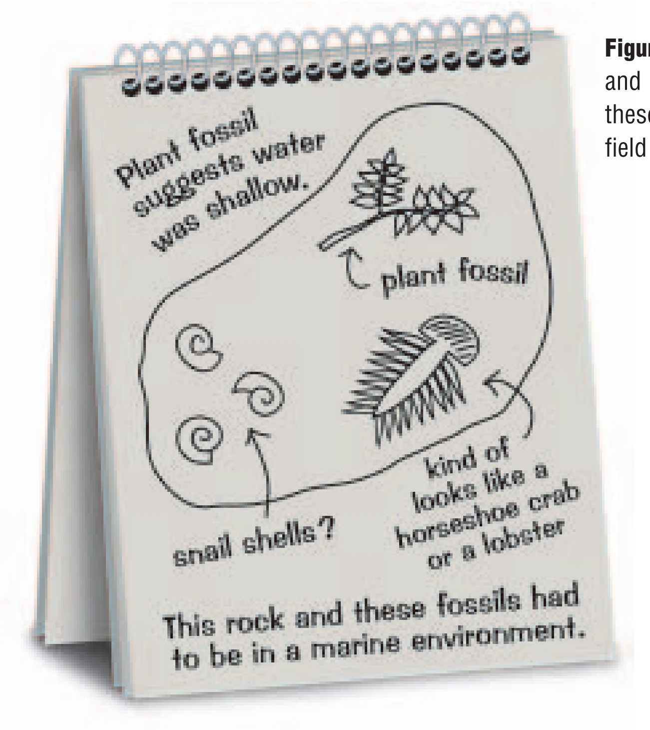


Figure 4.1 Kathy and Roberto made these notes on their field trip.

- How did Kathy and Roberto know that the fossils found in this sedimentary rock used to live in a marine environment?
- How did they know the water was shallow at the time the organism lived?
- What modern classification groups did Kathy and Roberto suggest were found on their sample?

Fossils

Fossils are traces of once-living things that are preserved in rocks. They form when animals or plants die and sink to the bottom of a body of water. There, they are buried by layers of sediments. This means fossils are the same age as the sedimentary rock in which they are found.

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Dug Out of the Ground

The word *fossil* is originally from Latin, meaning "dug out of the ground." Sedimentary rocks that are exposed at the surface are where the majority of fossils—usually marine animals—are found. Limestone, sandstone, and shale are the most common types of fossil rocks.

Figure 4.2 Trilobites lived on the bottoms of oceans 300–600 million years ago. No trilobites exist today. If you found a rock with a trilobite in it, what could you say about that rock?

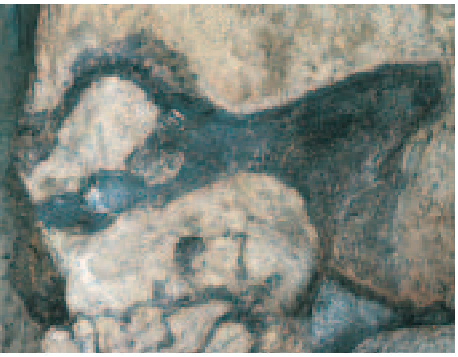
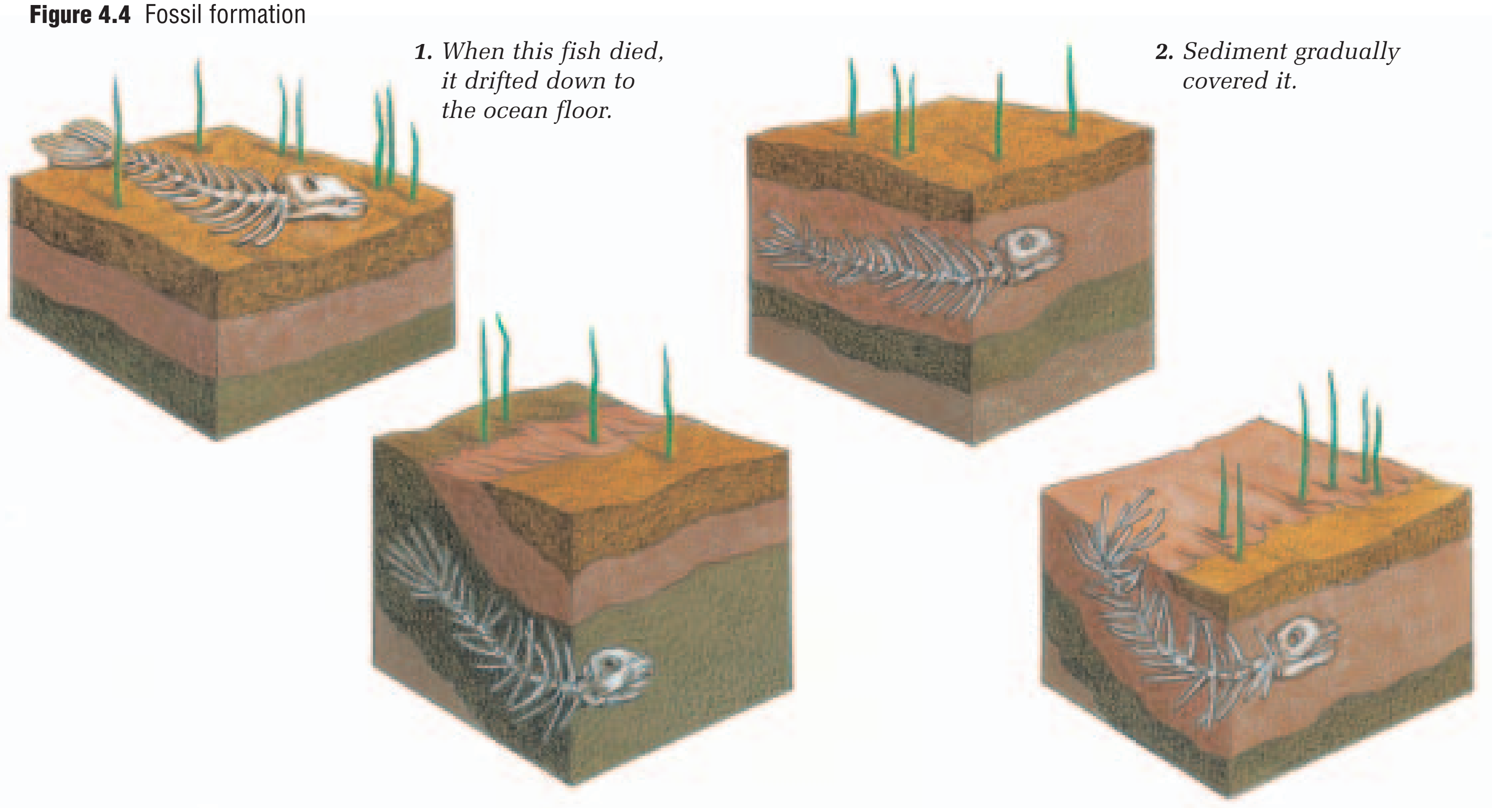


Figure 4.3 Sauropod vertebrae—the family of Sauropod dinosaurs were the largest animals to ever live on Earth. They include *Brachiosaurus* (24 m long) and *Apatosaurus*, or *Brontosaurus* as it was once called (21 m long).

Paleontologists [pāl lē on TOL e jists] are scientists who study early life forms by interpreting animal and plant fossils. It's a profession that takes a great deal of patience. Most fossils have to be carefully removed from the rock that surrounds them. Often, the fossils that are found are not complete, consisting of only parts of skeletons, shells, or other animal traces. Trying to make inferences based on these bits and pieces can be very challenging.

However, these inferences, together with a growing body of evidence, suggest that life on Earth has changed a great deal over the past millions of years. The fossils that we find in younger rocks are sometimes similar to animals and plants we see today. But older rocks often contain fossils of animals and plants that are extinct (no longer exist). Many of these fossils don't look like the plants and animals we see today. The trilobite in Figure 4.2 is a good example of an animal that once lived on the ocean floor, but became extinct about 300 million years ago.

Figure 4.4 Fossil formation



1. *When this fish died, it drifted down to the ocean floor.*

2. *Sediment gradually covered it.*

3. *Eventually, the sediment with the fish inside it hardened into rock.*

4. *When you crack open the rock, you find the impression of the fish's skeleton preserved.*

Becoming a Fossil

Not every living thing has the potential to become a fossil. In fact, the whole process of turning into a fossil is a rare experience. Furthermore, there is more than one way to become fossilized.

- Firstly, sediments quickly have to bury the original plant or animal remains. A quick burial usually means scavengers and other decomposers are not able to break the remains down further.
- Sometimes, a cavity is created as the original organic form decays. This cavity can then be filled by other sediments, which eventually harden into rock.
- In other cases, a fossil can be formed when the original organism is slowly replaced by mineral crystals.

Fossils may not just be the actual plant or animal. A *trace fossil* is a cavity or track left behind by an organism (for example, a footprint). Another type of fossil is a *cast*. Casts are the filled-in cavities left by the original organic bodies.

Trees and other plants can also become fossils. These are sometimes found in the form of petrified wood or remarkably preserved as in the photograph below.

Figure 4.5 Fifty million years ago, this was just another leaf on a tree.

Figure 4.6 A paleontologist carefully reveals an *Albertosaurus* skull that's 75 million years old.

Studying fossils is one of the ways geologists and paleontologists track changes in Earth's geologic history. But how do these fossils become preserved? Do all living things leave behind fossilized evidence of their existence? Fossilization is a process that can take thousands of years and only happens under certain conditions. Animals with hard parts (bones, shells, etc.) are the most common fossils. Fossils of earthworms and jellyfish have been found, but they are rare.

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Index Fossils

Paleontologists use particular fossils to identify certain time periods. These are known as **index fossils**. Using the Internet, your library, or other resources, try to identify index fossils that can be found in your area. For example, why is the trilobite in Figure 4.2 considered an index fossil?

TELLING TIME GEOLOGICALLY

The layers of sediment that have formed over millions of years are called **strata**. They provide important information about what happened in the past.

From studying the kind of rock and the grain size in a layer of strata, geologists can gather information about the environment in which it formed. For example, if it's limestone, this layer of rock was originally at the bottom of an ocean. If a layer of strata is very thick, it means that the environment remained stable for a long period. A new, different layer forms when something changes in the environment. For example, a rise in sea level would show up as a change in sediments along the former shoreline. The shoreline sediments would be replaced by the type of sediments that form in deeper water.

Figure 4.7 Mt. Rundle, Alberta—sometimes there is no change for many millions of years in the type of material that is deposited. While the bottom of this cliff was formed, the sedimentary deposits remained the same.

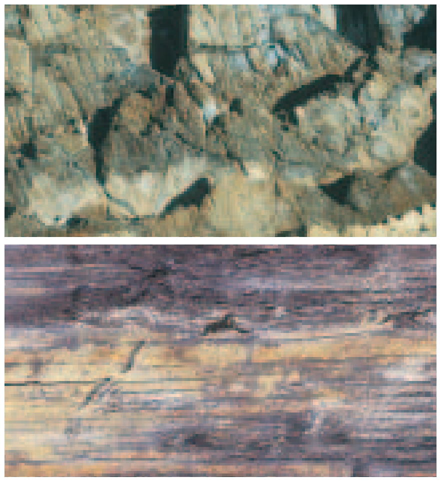

Figure 4.8 A changing rhythm of sedimentary deposits caused these different layers of shale to appear.

CHECK AND REFLECT

1. Suppose you went to a quarry and found some fossils in sedimentary rocks. Then you visited another quarry 5 km away and found exactly the same kinds of rocks, containing the same kinds of fossils. What could you say about the second set of rocks you found?
2. If there were fossils in sedimentary strata layers, and they were buried extremely deep (perhaps as much as 8 km beneath the surface), what would happen to the fossils? Would the clearness of their images change? Why or why not?

4.2 Methods Used to Interpret Fossils

The fossil record found in rocks shows a sequence, but not one based on size, habitat, or shape. Rather, the fossil record shows a sequence of *different life forms* appearing through time. For example, single-celled life forms appeared before multi-celled life forms, plants before animals, and invertebrates before vertebrates. Fossil records show that older rocks contain increasingly different organisms from those living today.

Have you ever looked at old pictures of your relatives who have passed away and wondered what they were like? Did they sound like you, do the same things, live in the same area? Piecing together the past life of someone is sometimes difficult because often there is no one around to answer those questions.

The ability to reconstruct fossils based on knowledge of current living things is an important part of understanding the history of life on Earth. The obvious challenge for paleontologists who study ancient life is that the animals and plants they are trying to study no longer exist. Fossils do provide important pieces of information. However, much of what science knows about them is based upon inferences or educated guesses.

Figure 4.9 Amber is fossilized tree sap that sometimes preserves trapped insects like this mosquito. Genetic material has been successfully extracted from insects encased in amber.

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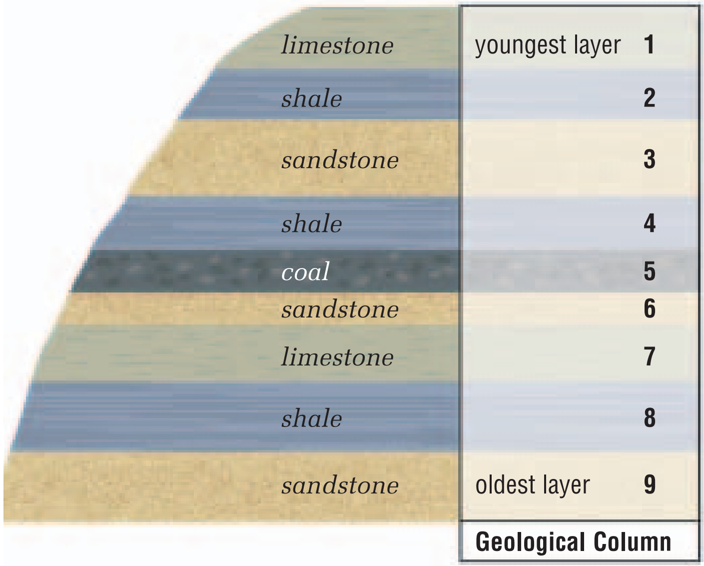
Geological Columns

Rock formations are deposited in layers from the oldest on the bottom to the youngest at the top. Paleontologists use these layers, or *geological columns*, to help determine the age of the fossils they find.



Fossils found in layer 7 will be older than those found in layers 1 to 6.

Studying Sedimentary Layers of Rock

In areas where the layers of sedimentary rock are deeply eroded, geologists can study the fossil record over a large portion of Earth's history. The Grand Canyon is one of these places. Down at the bottom of the canyon, where the oldest rock is found, there are no fossils. Then, just one layer higher, many fossils of trilobites appear (such as the one in Figure 4.2). As you travel up the canyon wall, other fossils can be found that are more similar to those that exist on Earth today.

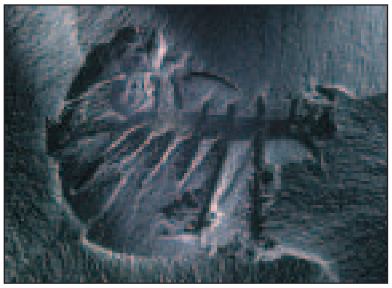
The Red Deer River in central Alberta, through Drumheller and Dinosaur Provincial Park, also has a vertical story to tell.

Give it a **TRY** — ACTIVITY

Fossils through Time

Below are a series of photographs of fossils from the era in Earth's history when life began to become extremely diverse in a short period of time. This was during the Cambrian period, about 515 million years ago.

Anomolocaris



Hallucigena

Opabina

Figure 4.10 These fossils are some of the ancient creatures found in the world-famous Burgess Shale Fossil beds in Yoho National Park, British Columbia.

Choose one of the fossils in Figure 4.10, and, like a paleontologist, try to answer the following questions based on these photographs.

- What do you think are the characteristics of this animal?
- How did the animal move?
- Where did the animal live?
- How large do you think the animal was?
- What and how did this animal eat?
- Sketch a possible likeness of a relative for this creature.
- Suggest any possible related animals that might exist today. What new questions can you ask about your animal?

Fossil Beds

These are three-dimensional models of animals that once lived in The Burgess Shale Community (Ayshella, left, and Marella, right).

Figure 4.11 The *Burgess Shale Community* is a diorama that illustrates the type of community in which these animals may have lived. Western Canada has many other fossil locations that help explain the history of life on Earth. In fact, the Royal Tyrrell Museum of Paleontology in Drumheller, Alberta, is one of the best places in the world to meet the most famous of fossils—dinosaurs.

The Burgess Shale Fossil Beds have preserved the soft tissue of many species, allowing scientists to study these specimens in detail. Usually, scavengers, decomposers, and the passing of time ensure that only the most durable parts of an organism are preserved. Thanks to very fine sediments, a quick burial, and a lack of life-giving oxygen for bacteria, these shale fossils look much the same as they did half a billion years ago. So well preserved are the fossils in the shale, that scientists have been able to determine what final meal they had before they died!

Figure 4.12 Joseph Burr Tyrrell

The Royal Tyrrell Museum

The Royal Tyrrell Museum of Paleontology, located in the Badlands area of Alberta, opened on September 25, 1985. It was named after Joseph Burr Tyrrell, a geologist with the Geological Survey of Canada.

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Earth Giants

So you think *Tyrannosaurus rex* is the biggest dinosaur at 12 m? Or maybe you thought it was *Seismosaurus* at 30 m or *Supersaurus* at between 35 m and 40 m? (That's as tall as a 12-storey building.)

Well, you would be wrong. In January 2000, a dinosaur vertebra measuring 1.2 m was found in an Argentine village. That means this creature was probably close to 50 m in length, or nearly half the length of a football field! And who is to say what the next dinosaur fossil find will reveal?

Figure 4.13 Skeleton of *Tyrannosaurus rex*, more than 12 m long, on display in the Tyrrell Museum's "Dinosaur Hall"

Figure 4.14 A paleontologist unearths new dinosaur remains on one of the museum's many summer digs.

reSEARCH

Researching Ancient Life

Canada has many locations where there is ongoing research on a variety of ancient life. Using the Internet, your library, or other resources, find some of these projects and share what you find with the rest of the class.

In 1884, while studying coal deposits in the Badlands, he discovered a 70-million-year-old dinosaur skull, later named *Albertosaurus*. The find sparked international interest in the area, which turned out to be one of the richest sources of dinosaur bones in the world. The Alberta government recognized the area's importance and financed a major museum and research facility in the Badlands.

The Tyrrell Museum is one of the largest museums of paleontology in the world. It displays more than 200 dinosaur remains, the largest number under one roof anywhere. Most of the dinosaurs on display were found in Alberta. As well as dinosaur bones, the 11 200 m^2 facility contains computer terminals where visitors can design their own dinosaurs or play simulation games. Visitors can also watch from a special viewing area as technicians prepare and preserve fossils for study and display. One can even sign up to spend a day or a week working with paleontologists on a real dinosaur dig!

Check and Reflect

1. Scientists often try to determine if the fossilized animal they are examining is related to a group of animals living today. What things might they look for to help make this connection?
2. Do you think any fossilized animals are related to animals living today? If so, how could that be possible?
3. If you found a piece of petrified wood and bones in the same location, what could you say about the age of the two specimens?

4.3 Geologic Time

Figure 4.15 An artist's view of life during the age of dinosaurs (the Mesozoic Era)

Virtually everything that humans do today is affected by time. Classes, practices, meetings, departures, and arrivals are dependent on knowing what time it is. Everyone knows what a week, an hour, or a year feels like. But can you imagine a thousand years, a million years, a billion years? Perhaps that's why it's so hard to understand the history of life on Earth. How can anyone have a sense of what a half-billion years is like when 10 or 20 years seems like a long time?

Looking Back into Time

All that science knows about the ancient past, it has learned from rock and fossil records. Geologists have used this knowledge (some of which is not very exact) to organize Earth's history into geologic time intervals. These time periods are called **eras**. Geologists have based these eras on the sequence of rock strata, with the oldest

*info***BIT**

Geologic Periods
Some geologic periods are named after areas where rocks from that period are well exposed. For example, the time period Jurassic is named after Jura, a mountain range in France.

layer being on the bottom, and the youngest layer on the top. This sequence was established by identifying fossils and matching them with sedimentary rock layers from all over the world. There are four main divisions in these sequences. Each represents a major change in the global environment and is characterized by different life forms.

Scientists estimate that Earth is about 4.6 billion years old. The following illustration (see Figure 4.16) is an artist's representation of what the stages of Earth's evolution might have looked like.

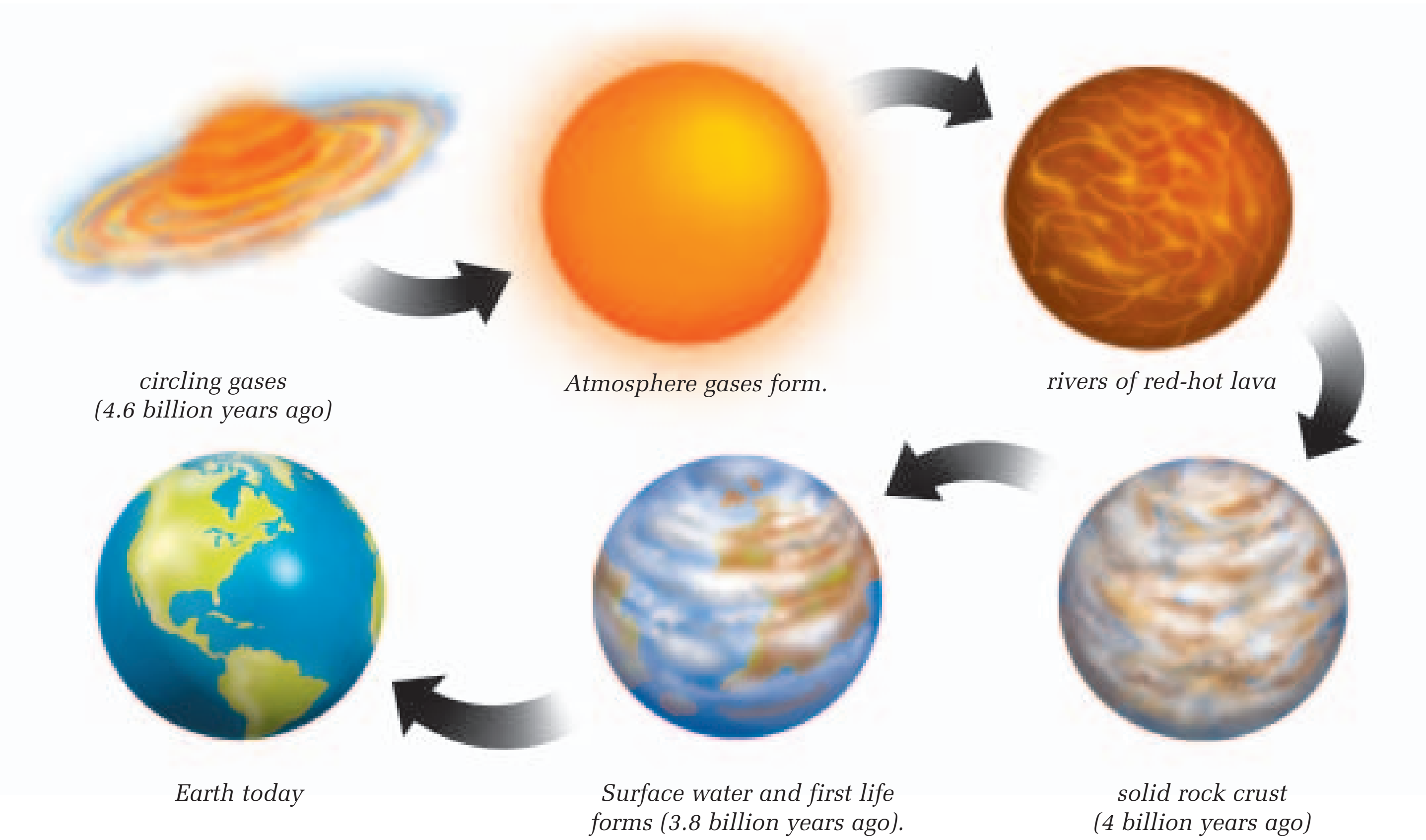
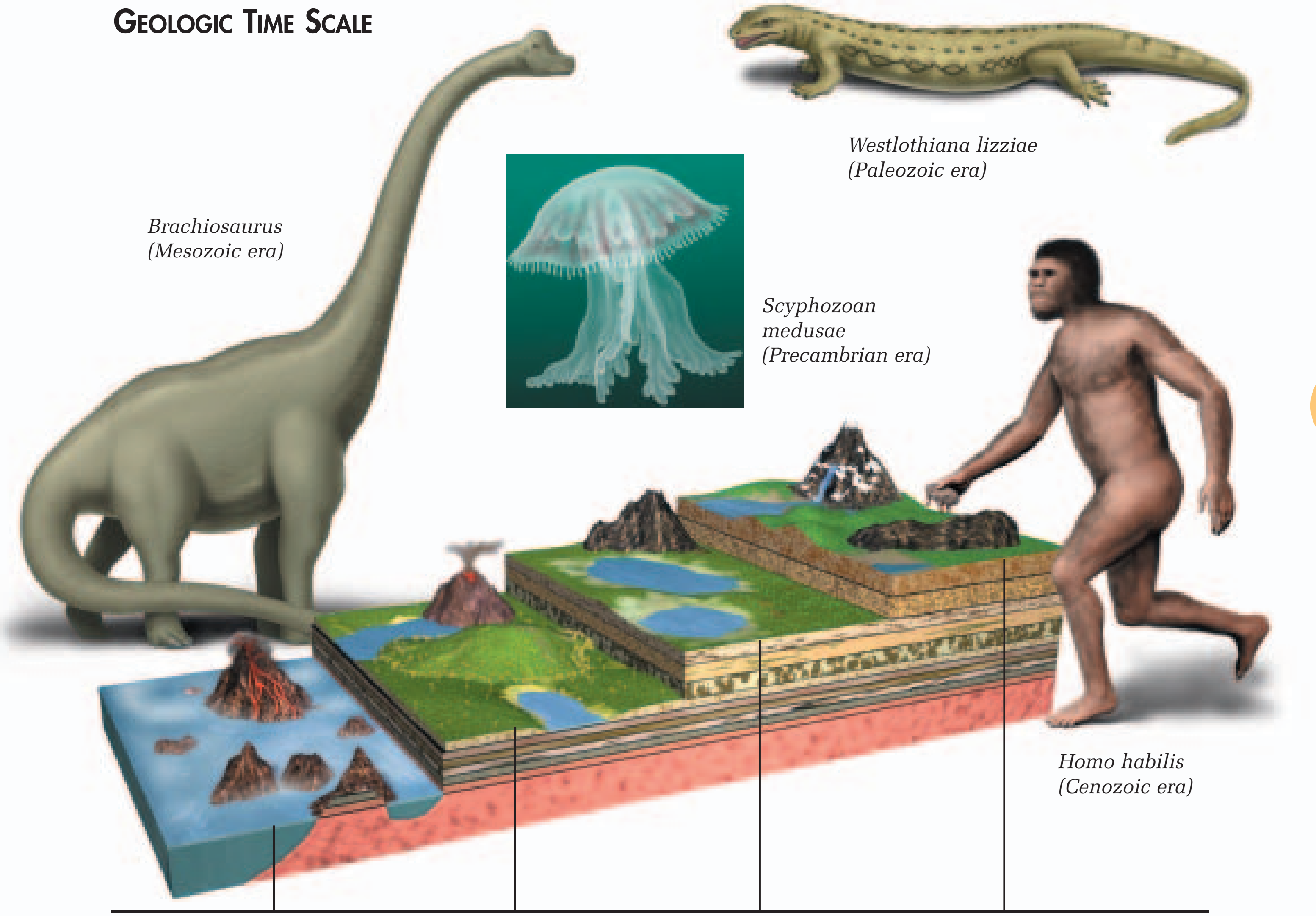


Figure 4.16 One representation of the evolution of Earth

Observations by scientists of bodies in outer space and geological evidence suggest that our planet was first a swirling cloud of gas that had once been part of a newly formed sun. In time, the outer layer began to cool. Massive eruptions of magma from below this outer layer spread sheets of lava over the surface.

Geologic Time Scale



Precambrian Era: 4600 to 600 millions of years ago
- formation of Earth
- first simple organisms (bacteria)
- first soft-bodied animals (no vertebrae)

Paleozoic Era: 600 to 225 millions of years ago
- first reptiles
- first large land animals (amphibians—frogs)
- first insects
- first large land plants
- first fish with jaws

Mesozoic Era: 225 to 65 millions of years ago
- dinosaurs rule and then become extinct
- first flowering plants
- first birds and mammals

Cenozoic Era: 65 millions of years ago to present day
- appearance of most modern species
- many more species of mammals
- first grasses
- first human-like species (about 2–3 millions of years ago)

Figure 4.17 The four eras of Earth's history

*re*SEARCH

Dating Rocks and Fossils

Use your library resources and the Internet to search some of the methods geologists and paleontologists use to date rock and fossil samples. For example:
- radioactive dating of certain elements, such as carbon and uranium
- examining the composition of dead organic material

Mammuthus primigenus
(Cenozoic era)

Give it a TRY — ACTIVITY

MEASURING TIME

Using a length of string, a long strip of tape, a length of wood, or any other piece of material, construct your own geologic time scale. (See Toolbox 5 for a review of measurement.)

- The beginning must read 4.6 billion years and extend to the present day.
- Use the chart below as a guide for your time line.
- When you have completed your time scale, bring it to a friend and explain your scale and some of the events that took place.

Significant Dates in Earth's History

Event	Years ago
Glaciers cover most of Canada and United States	11 000
Earliest human relative	3 000 000 (about)
Dinosaurs disappear	65 000 000
Evidence of first birds	150 000 000
Evidence of first mammals	190 000 000
First dinosaurs	225 000 000
First amphibians	350 000 000
First large land plants	430 000 000
Earliest fish	500 000 000
The Burgess Shale fossils and the Cambrian explosion	515 000 000
Multicelled organisms	700 000 000
First evidence of life	3 500 000 000
Earth formed	4 600 000 000

UNDERSTANDING FOSSIL EVIDENCE

Fossils are the only evidence scientists have of early life forms. Paleontologists use fossil evidence to help them develop theories about prehistoric life. Fossils are rare, however. And fossils of complete animals are very rare because the remains of animals usually disappear long before they can become fossilized.

Because fossils are rare, paleontologists cannot always make general statements about what life forms existed millions of years ago. For example, a few fossils, such as *Archaeopteryx* [ar kee OP ter iks], have impressions that look like feathers. But because so few of these fossils have been found, paleontologists cannot say that all similar creatures at that time had feathers. More evidence is needed.

Often when fossil remains are found, they are only broken fragments. Reconstructing these fragments (see Figure 4.18) into a full-size animal (Figure 4.19) takes skill and inferences based on a knowledge of modern animal anatomy. Creating a life-like illustration from these fossilized bones (Figure 4.20) requires careful study of the bones, a knowledge of anatomy, and imagination. Imagination is needed where we have no evidence; for example, for the colour of the skin.

Fossil Inferences

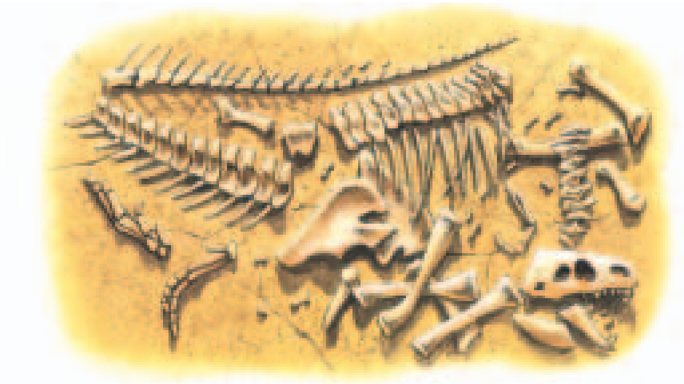


Figure 4.18 *Allosaurus skeleton before reconstruction*—Reconstructing fossil bones into a full-size skeleton is like trying to put a three-dimensional puzzle together without the picture on the box!

Figure 4.19 *Allosaurus skeleton after reconstruction*—Reconstructing a dinosaur skeleton requires a team of experts with a wide range of knowledge. Scientists compare the new bones they find to known dinosaur skeletons and to the skeletons of modern creatures.

Figure 4.20 *Completed Allosaurus*—After the skeleton has been reconstructed, the next step is to put the muscles on the bare bones. The arrangement of the different muscles is established by examining "scars" on the bones where the muscles were once attached. Next, the skin is added. Fossilized skin impressions that have been found suggest that dinosaur skin was scaly, similar to a reptile's skin.

TRY This at Home

ACTIVITY

MAKING A FOSSIL

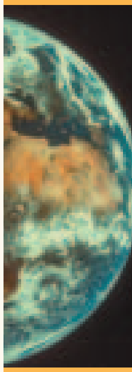
Try making your own fossil mould and cast. You can use seashells or other small objects that have an interesting texture to make your fossil.

- Coat the outside of your seashell with petroleum jelly.
- Mix up about a cup of plaster of Paris and water in a small bowl so that it looks like thick cream. Add food colouring, mixing well.
- Slowly pour the plaster mixture into a plastic cup until it is about 3 cm from the top. Press the seashell, greased side down, into the wet plaster. Wash your hands after cleaning up. Leave overnight.
- Remove the shell the next day. The coloured plaster is the fossil mould. Coat the entire surface of the plaster mould with petroleum jelly.
- Mix up a new batch of plaster of Paris, but this time *don't* add food colouring. Pour the plaster onto the mould so that it fills the cup. Wash your hands.
- The next day, carefully separate the two plaster pieces. Examine the coloured *mould* and the white *cast*.
- What is the difference between the two pieces? Which one, the mould or the cast, looks more like your original seashell?

Figure 4.21 Pour the coloured plaster mixture so that it is about 3 cm from the top.

CHECK AND REFLECT

1. Why do geologists divide the history of Earth into eras?
2. What changes on Earth occurred between 515 000 000 years ago and 250 000 000 years ago?
3. During what era did dinosaurs become extinct? What other life forms lived during this era?
4. The fossil record indicates plants appeared before animals did. Do you think this could ever occur in reverse order? Explain your answer.



Assess Your Learning

1. What is a fossil and how is it different from a rock or mineral?
2. What kinds of information or data do paleontologists gather?
3. What information do the layers of sedimentary rock give scientists who study fossil records?
4. If fossils are found on the side of a mountain at 2500 m, and the same kind of fossil is found 30 km north at 1900 m, what could be said about the strata they are found in? Could they be the same? Would it be likely that more would be found along the same layer? Explain your answer.
5. What can the study of life forms on Earth today tell us about life forms of the past?
6. What are some of the types of fossils found in Alberta?
7. Why are inferences necessary when studying fossils?
8. What environmental influences could explain the appearance of some life forms and the disappearance of others?
9. What kind of life forms appeared in each of the four eras of Earth's history?
10. Why do you think it took about one billion years before the first life forms appeared on Earth?
11. Make a chart or another illustration that represents the four major periods in Figure 4.22.

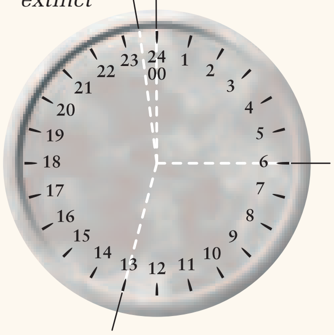


Figure 4.22 Comparing the evolution of life forms to a 24-h time clock

Focus On THE NATURE OF SCIENCE

So many of the discoveries and theories in science are the result of the work of a great many people. Scientists have been working co-operatively for over a hundred years to learn about and understand Earth's history.

1. Why do you think sharing knowledge is important in understanding fossil records?
2. Why is it important when working in a group for everyone to have a definite task to perform?

S C I E N C E W O R L D

Case Study

What Happened to the Dinosaurs?

The Issue

Dinosaurs ruled Earth for 150 million years, then suddenly became extinct about 65 million years ago. Many theories have been proposed:

- Small mammals ate the dinosaur's eggs.
- A deadly virus caused a dinosaur plague.
- Vicious meat-eaters ate all of the plant-eaters and then starved to death themselves.
- Hungry caterpillars devoured all of the dinosaur's plant-based food supply.
- Dinosaurs were hunted to extinction by aliens.

Some of these theories are obviously more believable than others. Over the years, a growing amount of evidence suggest two other theories. Evidence has led many scientists to believe that 65 million years ago, a giant meteor 10 km in diameter crashed into Earth. The impact created a crater over 100 km in diameter and ejected enormous amounts of dust and debris into the atmosphere. The cloud of dust encircled the entire Earth and blocked out sunlight for months or even years. Without sunlight, much of Earth's vegetation died off and the plant-eating dinosaurs starved to death. Without any prey to eat, the meat-eating dinosaurs soon followed.

Did the impact of a giant meteor destroy the dinosaurs?

Is this the end of the dinosaur story? Not according to other scientists. From the fossil evidence, they have developed the theory that dinosaurs did not disappear completely—they evolved into birds. The skeletons of birds have many similar features to small predatory dinosaurs known as *theropods*. A recent fossil find suggests that some theropods had feathers. However, one scientific study has suggested that this fossil is a fake. What is the real answer?

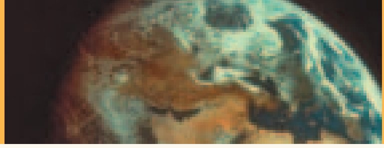
Go Further

Look into the following resources to help you form your own opinion about how dinosaurs became extinct:

- Look on the Web: Check out dinosaurs or paleontology on the Internet.
- Ask the Experts: Try to find an expert such as a paleontologist or an ornithologist (bird expert).
- Look It Up in Newspapers and Magazines: Look for articles about the extinction of dinosaurs or the origin of birds.
- Check out Scientific Studies: Look for scientific studies about dinosaurs, theropods, or Archaeopteryx.

In Your Opinion

- Which extinction theories seem most believable to you? Why?
- Could more than one extinction theory be correct? For example, if the meteor theory is true, does this mean the bird theory must be false?



Unit Summary: Planet Earth

Key Concepts	Section Summaries
1.0 • developing models • Earth models • earthquakes • volcanoes • tools and techniques for studying Earth • the effects of water, wind, and ice • glaciers	**1.0 Earth's surface undergoes gradual and sudden changes.** • Earth is viewed as a layered planet. The main layers are the crust, the mantle, and the core. Only the crust has been investigated because Earth's other layers are many hundreds of kilometres below its surface. • Earthquakes and volcanoes are examples of forces that take place within Earth's interior. These forces have the ability to suddenly and dramatically change Earth's surface. • Scientists use a variety of tools and techniques to investigate Earth's forces. • Wind, water, and ice are forces that slowly change Earth's features.
2.0 • rocks and minerals • classes of rocks: igneous, sedimentary, and metamorphic • geology tools and techniques • the rock cycle • describing and interpreting local rock formations	**2.0 The rock cycle describes how rocks form and change over time.** • Rocks are the hard structures that make up Earth's crust. They are composed of minerals, substances that give rocks their distinctive characteristics, such as hardness and colour. • There are three classes of rocks that make up Earth's crust: igneous, sedimentary, and metamorphic. • Rocks are always being broken down and transformed into different forms. This process is called the rock cycle. • All three classes of rocks can be found in Alberta although sedimentary rocks are the most common.
3.0 • continental drift • plate tectonics • mountain building	**3.0 Landforms provide evidence of change.** • The Theory of Plate Tectonics describes Earth's surface as being broken up into huge areas of rock called plates. • The continents and the ocean floors are carried on these plates. The plates are slowly moving on the partly melted mantle. • Mountains are formed as a result of plates colliding or rubbing together, pushing up part of the plate.
4.0 • tracing evidence of geologic change using fossils • methods used to interpret fossils • geologic time • understanding fossil evidence	**4.0 The fossil record provides evidence of Earth's changes over time.** • Fossils are traces or remains of past life preserved in stone. They have given scientists a picture of how life has evolved over the last three and a half billion years. • Scientists use a variety of methods and tools to interpret fossil evidence. However, since fossil remains are often incomplete, much of what is known is based on inferences. • Geologists have divided Earth's history into four periods, called eras. • Determining what animals looked like from fossil records is often based on inferences.

PROJECT

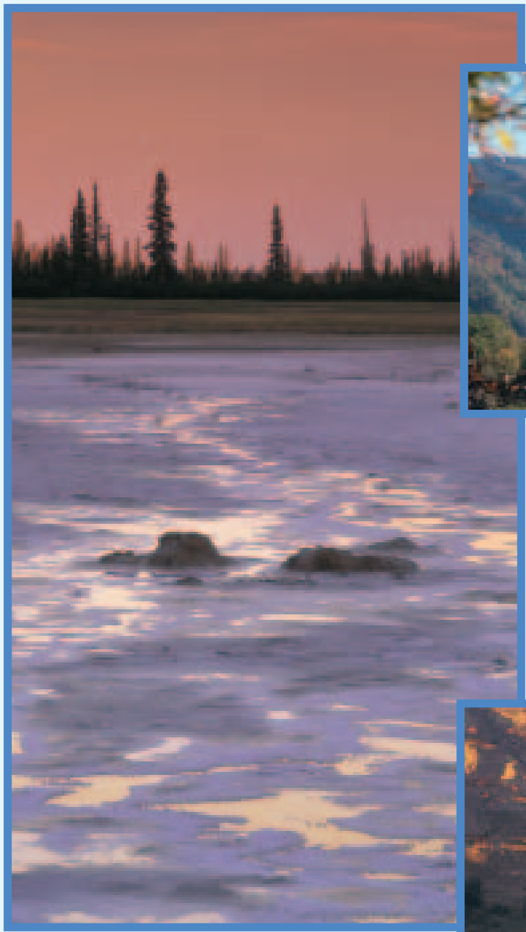
EARTH MODELS AND SIMULATIONS

Getting Started

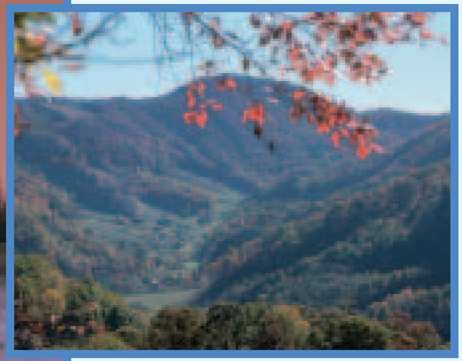
In this unit, you have explored the different processes that create features on Earth's surface. Forces inside Earth, such as the movements of tectonic plates or movements along faults, can create mountains. Forces on Earth's surface, such as ice and wind, can wear down and move mountains through weathering and erosion. For this project, you can use what you've learned about Earth's processes.

Think about the features that you would include in a display about the landscape in your area. To help your thinking, look at the pictures on this page, and see if you can answer the questions in the captions.

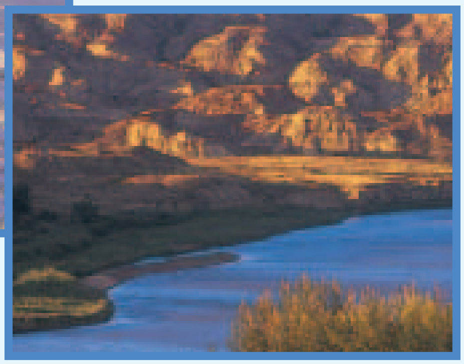
The features in these pictures are just examples of what you might see. Your area may be completely different. You may not have any mountains or deep valleys. Your major features may be large areas of flat fertile soil beside a large body of water. Or you may have large grassy areas between low rocky hills. Whatever the features in your area, you can use this project to apply the ideas about Earth that you developed in this unit.



Rock formations and deposits can tell us a great deal about a location's history. These salt flats are in Wood Buffalo National Park, Alberta. How would salt deposits end up far from the Pacific Ocean?



These mountains formed millions of years ago. When they first formed, they were tall and jagged. Now they are worn down and rounded. What processes do you think could have changed them?



The Red River runs through the Badlands of southern Alberta. What do you think happens to the soil when the river slows down or stops flowing?

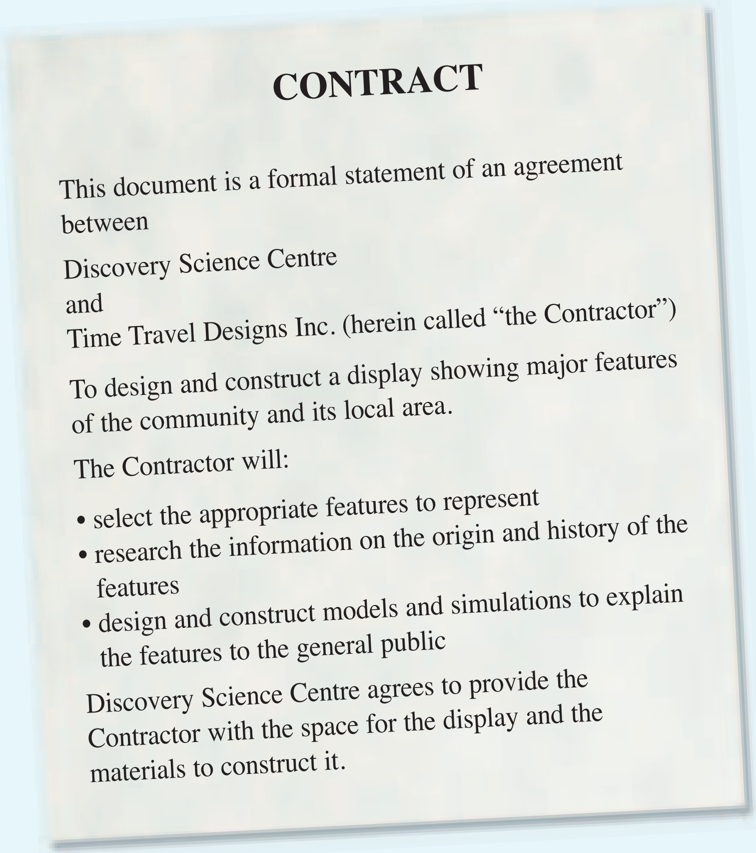
Your Goal

Imagine that you are a designer who designs and builds models and simulations for science centres and other museums. Your community is building a new science centre. Your job is to provide a display that shows how the local features in your landscape began, and how they became the way they are today.

What You Need to Know

You and your classmates are partners in Time Travel Designs Inc., a company specializing in displays that show the origin and history of features on Earth's surface. For your assignment, as described, you can use any information you gathered as you worked through this unit. You will need to collect additional information about your local geology and geography from reference books, the Internet, and other resources.

Your company has found that the best way to develop these displays is for all the partners to work together to determine which features to model and simulate. Then you divide up the features among smaller teams. Each team is responsible for modelling or simulating one feature. When they are completed, all the features are combined in one large display.



CONTRACT

This document is a formal statement of an agreement between

Discovery Science Centre

and

Time Travel Designs Inc. (herein called "the Contractor")

To design and construct a display showing major features of the community and its local area.

The Contractor will:

- select the appropriate features to represent
- research the information on the origin and history of the features
- design and construct models and simulations to explain the features to the general public

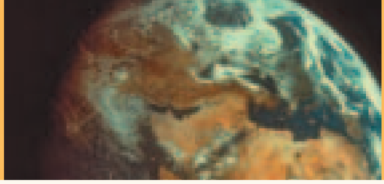
Discovery Science Centre agrees to provide the Contractor with the space for the display and the materials to construct it.

Steps to Success

1. With classmates, brainstorm answers and questions that will help your team develop a plan to build your model display.
2. Design your model or simulation. Give the design to your teacher for approval before you start building it. Include in your design:
   a) a drawing of your model
   b) a diagram showing how you will simulate the processes
   c) a list of materials
   d) a procedure for building your model
   e) your schedule
   f) safety considerations
3. Build your model or simulation according to the design and plan that your teacher approved.
4. Decide how you will explain your model or simulation to the rest of the class. You may want to have different team members explain different parts of the model or perform different parts of the simulation.

How Did It Go?

5. Write a report of the planning and building of your model. Share and compare it with the reports of other teams.
6. Explain your model or simulation to your class. As you watch other teams, write down:
   a) what you liked best about their models or simulations
   b) any ideas or materials that you could have used for your model or simulation
7. Combine your model or simulation with those of your classmates to create the display. Invite other classes to see your displays.



Unit Review: Planet Earth

Unit Vocabulary

1. Write a short story about Earth's crust using the following terms:

   Theory of Plate Tectonics
   deposition
   erosion
   sediments
   earthquake
   volcano
   landscape
   mineral
   rock cycle
   fossil
   Mesozoic Era

Check Your Knowledge

1.0

2. Describe the model scientists have developed that explains Earth's structure.
3. Describe the cause of an earthquake.
4. What is a volcano?
5. Describe some of the forces that slowly change Earth's surface.

2.0

6. What are the differences between rocks and minerals?
7. Briefly describe the three classes of rock found in Earth's crust.
8. What is meant by the rock cycle?

3.0

9. What evidence is there that the continents are drifting farther apart?
10. In a paragraph, explain the Theory of Plate Tectonics.
11. Describe the formation of the Rocky Mountains.

4.0

12. Why do scientists study fossils?
13. How is the age of a fossil determined?
14. During what geologic era did life on Earth first develop?

Connect Your Understanding

15. What do earthquakes and volcanoes have in common?
16. What model do geologists use to show how igneous, sedimentary, and metamorphic rocks are related?
17. Could all rocks become sedimentary rocks? Why or why not?
18. If Earth's plates are constantly moving, why aren't earthquakes occurring all of the time along every boundary?

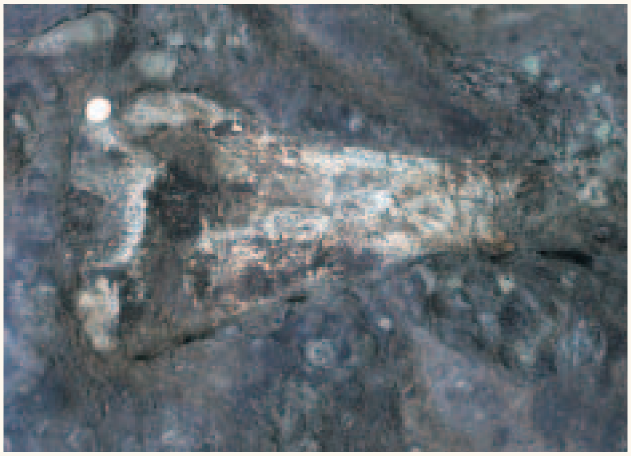
Practise Your Skills

19. Can geologists predict where new earthquakes, volcanoes, and mountain ranges will occur? Explain your answer.
20. Why is it probable that scientists will *never* have a complete understanding of how all life forms evolved on Earth?

21. A space probe lands on an unknown planet in another solar system. There are many volcanoes but only a few large bodies of water. Thick clouds of dust and water vapour cover the planet. Based on what is known about Earth, what inferences can you make about this planet? its composition? its rock formations? the presence of life forms?

22. You're looking at earthquakes in and around the eastern and western regions of northern India over the last 25 years. Major earthquakes of a Richter magnitude greater than 7 have caused tremendous damage. Why are they occurring, and what could your prediction be over the next 25 years?

23. The fossil skull's upper jaw (see below) has 14 teeth, and the lower jaw was missing. (A dime to the left of the skull gives an idea of the fossil's size.) What inferences can you make about what this creature looked like?



Self Assessment

Think back to the work you did in this unit:

24. Give an example where a number of people have contributed to the understanding of what Earth's structure is like.

25. Describe a subject area in the study of Earth where scientific evidence must be interpreted using inferences.

26. What is one idea, subject, or issue in this unit that you would like to explore in more detail?

Focus On THE NATURE OF SCIENCE

27. Turn back to the Focus on the Nature of Science on page 351 of this unit. Use a creative way to demonstrate your understanding of one of the questions.

28. What experiments did you do that helped you understand some of the characteristics of our planet?

29. Describe a possible situation where using precise scientific language and a classification system would be important in identifying a newly discovered rock formation.

30. Describe the process involved in developing a theory or a model that best explains a natural phenomena.

31. Describe a situation where working in a group was important in completing a task or experiment.

32. Why do you think it is important that only qualified people be allowed to remove fossils from the ground?