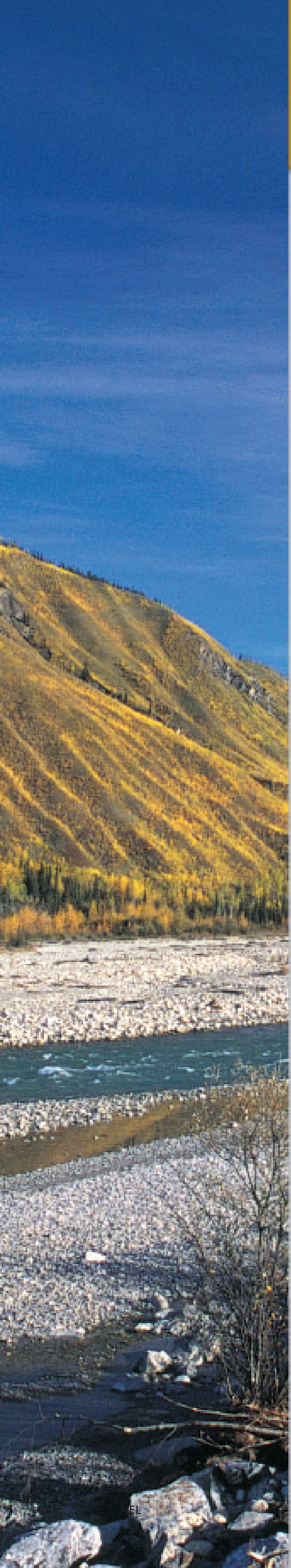
UNIT C

EARTH'S CRUST

CHAPTER 7 Old rocks can be recycled into new rocks.

CHAPTER 8 Earth's crust is made up of moving plates.

CHAPTER 9 Plate movements cause both sudden and gradual changes to Earth's crust.



Preview

Does the land around your community look like the land in the photograph? If not, what land features are found on Earth's surface around your community? Are there mountains, hills, or cliffs? Are there lakes, rivers, or streams? Are you near the ocean? Have you ever noticed any changes in the land features? Do local Aboriginal peoples tell any stories about these land features?

Earth has not always looked the way it does today. Many of the land features that you see every day—including rocks, rivers, and hills—have changed during Earth's long history. In fact, they are still changing. Some of these changes happen rapidly, while others occur over long periods of time.

In this unit, you will learn about changes to Earth's surface and what causes these changes. It is not possible to bring large land features into the classroom to study. It is also not possible to stay in grade 7 long enough to study changes to Earth's surface that take millions of years! Instead, you will create and use models to study features of Earth's surface that are too large to bring into your classroom. As well, you will create and use models to demonstrate, in a few minutes, changes that normally take millions of years.

TRY THIS: OBSERVE LOCAL LAND FEATURES

Skills Focus: observing, inferring

Go outside and observe your community. On a large piece of paper, sketch all the land features in your local area. Remember to include mountains, hills, cliffs, valleys, rivers and streams, and other bodies of water. Beside each feature, write a few brief notes to summarize any stories or legends you have heard about this feature, how you think this feature might have been formed, and how it might be slowly changing. Put the paper in your notebook so that you can add to it during the unit.

This photo was taken at Racing River in northern British Columbia.

CHAPTER 7

Old rocks can be recycled into new rocks.

KEY IDEAS

- Minerals are the building blocks of rocks and can be identified by their physical properties.
- Earth's crust is made up of three families of rocks: igneous, sedimentary, and metamorphic.
- Fossils provide evidence of changes in life over time.
- Rock materials are broken into smaller pieces by mechanical, chemical, and biological weathering.
- Weathered materials are moved from one place to another by gravity, wind, water, and ice in a process called erosion.
- Rocks and weathered rock materials can be transformed into new rocks.

Rocks are all around you. You have even eaten rocks. Those tiny white grains in the saltshaker may be ground-up particles of rock salt, mined from the ground. Materials in everyday products—from glassware, toothpaste, baby powder, and pencils to buildings, automobiles, and computers—come from rocks. Rocks can be used in so many different ways because the materials that make up rocks have different properties.

Some ordinary rocks you see may be very beautiful inside, like the geode above. How did such a beautiful rock form? Why are there layers and different colours? In this chapter, you will investigate what rocks are made of and learn how to classify different types of rocks. As well, you will look for clues in rocks that tell you how they were formed. You will look at evidence that shows how rocks have changed in the past and are still changing today. If you think of rocks as solid and unchanging, you may be in for a surprise! Earth is really a huge rock recycler.

Minerals: Building Blocks of Rocks

7.1

If you look carefully at rocks, you will soon see that they are not all the same. Some are white, and some black. Others are brightly coloured or have several different colours. One rock may be soft and dull, whereas another rock may be hard and shiny. An important step in learning how to understand rocks is finding ways to classify them into groups based on their properties. Properties are observable facts about a material, such as colour.

TRY THIS: OBSERVE ROCKS

Skills Focus: observing

Find two or three small, interesting-looking rocks in your schoolyard or at home. Each rock should have some features that make it different from the other(s). Examine and record the properties of your rocks.

1. Make a chart to organize the properties of rocks that you observe.

Properties	Rock 1	Rock 2	Rock 3
colour			

2. What colour(s) are the rocks?
3. Do they look the same throughout, or do they have different types of materials mixed together?
4. Do they feel heavy or light in comparison to their size?
5. Do they have pieces that sparkle or reflect light?
6. Which of your rocks is the hardest? How can you tell?
7. Do your rocks look like most other local rocks? If not, why do you think they are different? How do you think they got to where you found them?

All rocks are made of minerals. **Minerals** are pure, naturally occurring substances that are found in Earth's crust. Do you know someone who wears a diamond ring? Diamonds come from rocks. The graphite in your pencil is a mineral (Figure 1). You can think of minerals as the "building blocks" of rocks.

Scientists who study, identify, and classify rocks are called geologists [gee-OL-o-gists]. On the next few pages, you will learn about some of the properties that geologists use to identify the minerals that make up rocks.

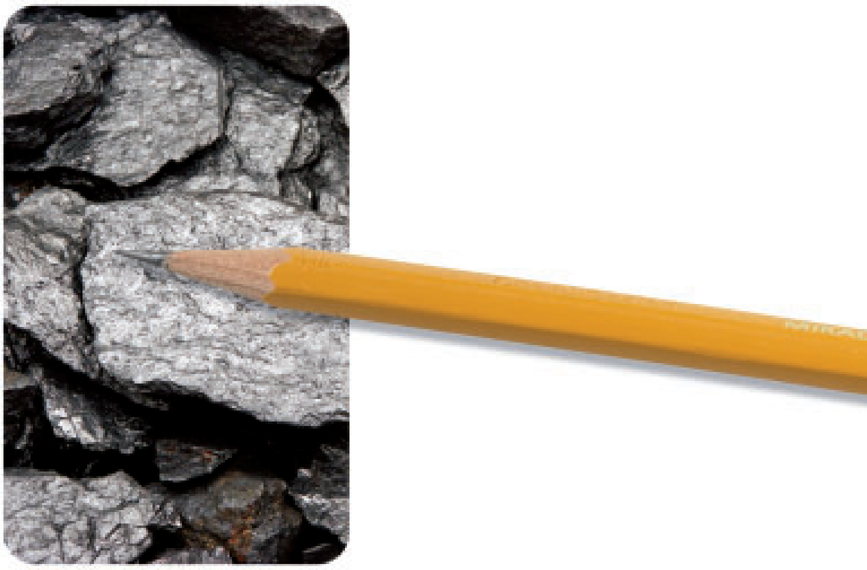


Figure 1
Graphite is used to make pencils.

> **LEARNING TIP**
>
> Preview the next four pages. Each heading is a property. Under each heading, the property is explained and you are given examples in both words and photographs. Make notes using this structure.

Colour

Colour is easy to determine and can be an important clue to a mineral's identity (**Figure 2**). By itself, however, colour is not a reliable way to identify minerals. Different minerals may be the same colour. For example, both gold and pyrite (fool's gold) are yellow. Some minerals occur in many different colours. For example, quartz is often white, but it can also be violet, gray, black, or colourless (**Figure 3**).

Figure 2
Jade is usually a shade of green

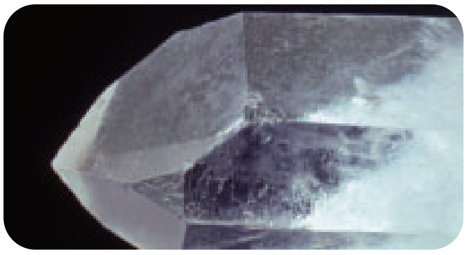


Figure 3
Quartz is sometimes colourless.

Streak

Streak describes the colour of the powdery mark that some minerals make when they are scratched against a hard surface. To see the streak clearly, geologists scratch a mineral on a streak plate. A streak plate is an unpolished piece of porcelain tile. The colour of the streak may be the same as the colour of the mineral, or it may be different. The colour of the streak is more reliable than the colour of the mineral. For this reason, it is very useful for identifying some minerals. For example, hematite can be shiny silver or reddish, but it always has a reddish streak (**Figure 4**). Pyrite (fool's gold) and gold are both yellow, but gold makes a yellow streak and pyrite makes a dark streak (**Figure 5**).

Figure 4
Different colours of hematite make the same colour streak.

Figure 5
During the gold rush, prospectors used streak to test if they had found real gold.

Lustre

Lustre [LUST-er] is the degree of shininess. Some minerals, such as gold, have a metallic lustre (**Figure 6**). Others, such as obsidian, look glassy (**Figure 7**). Still others, such as asbestos, have a dull appearance (**Figure 8**).

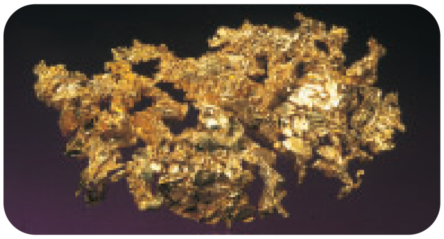


Figure 6
Gold has a metallic lustre.

Figure 7
Obsidian has a glassy lustre.

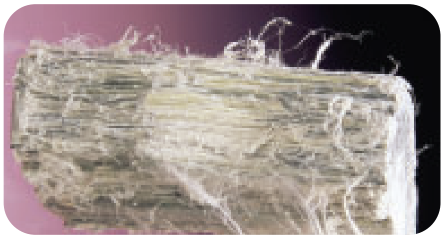


Figure 8
Asbestos has a low lustre.

Hardness

The hardness of a mineral can be determined by scratching one mineral against another. A mineral can make a scratch on any mineral that is softer than it is, but it cannot make a scratch on a mineral that is harder than it is. Geologists use a set of 10 standard minerals, ranging from very soft to very hard, to compare hardness. This is called the Mohs hardness scale (**Table 1**) after Friedrich Mohs (1773–1839), the German scientist who developed it. If you cannot obtain a set of Mohs hardness scale minerals, you can make your own using everyday materials.

Table 1 Scale for Comparing the Hardness of Minerals

Mohs hardness scale			Hardness scale of materials you can easily find	
1	talc	*SOFTEST*	**1**	soft pencil point
2	gypsum		**2–3**	fingernail
3	calcite			
4	fluorite		**3–4**	copper penny
5	apatite		**5–6**	nail or glass bottle
6	feldspar			
7	quartz		**6–7**	steel file
8	topaz		**7–8**	sandpaper
9	corundum		**9**	emery paper
10	diamond	*HARDEST*		

Crystal Structure

All minerals are crystals (**Figures 9** and **10**). Crystals have regular shapes because they are made up of tiny particles that are connected in a repeating pattern. The size of the crystals tells geologists how quickly a mineral cooled from a liquid to a solid. Large crystals indicate that the mineral cooled slowly. Small crystals indicate that the mineral cooled rapidly. Most crystals are too small to be seen without magnification.

Figure 9
Crystals of wulfenite

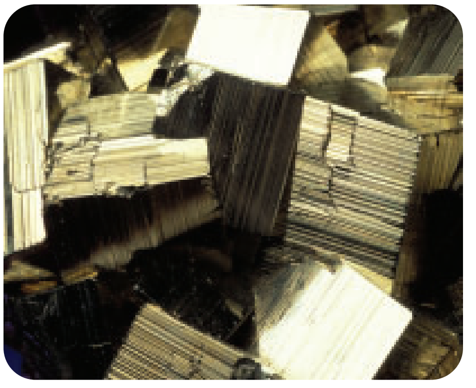


Figure 10
Crystals of pyrite

Cleavage

Some minerals break, or fracture, into pieces with rough, uneven surfaces. Quartz breaks in this way. Other minerals usually split or crack along parallel or flat surfaces. This property is called cleavage. You can test a mineral by breaking it with a hammer or splitting off sheets with a dinner knife. For example, mica (**Figure 11**) always splits into thin sheets. Other minerals, such as halite (**Figure 12**), always split into cubes.

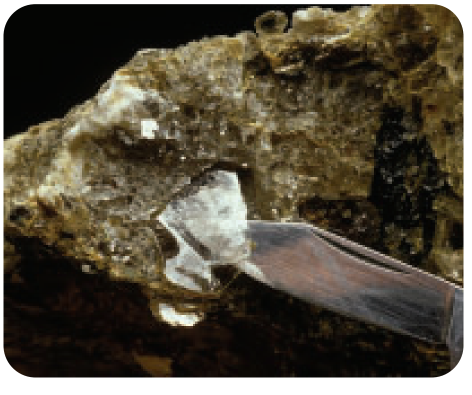


Figure 11
Mica

Figure 12
Halite (also called table salt)

Magnetism

Magnetism is the ability of a mineral to attract a magnet. Only minerals that contain iron are magnetic, so most minerals are not magnetic. You can use a magnet to find out if a mineral is magnetic (**Figure 13**).

Figure 13
Magnetite will attract or repel a magnet.

Reaction with Certain Chemicals

Some minerals can be identified by their reaction with certain chemicals. For example, calcite, limestone, and marble react with acidic solutions, such as vinegar (**Figure 14**). The acidic vinegar reacts with the carbonate materials in these minerals, creating a fizzing or bubbling on the surface. The gas that fizzes or bubbles up is carbon dioxide.

Figure 14
Limestone fizzes as it reacts with vinegar.

CHECK YOUR UNDERSTANDING

1. List the eight properties that are used to classify minerals.
2. What is one advantage of using colour to identify a mineral? What is one disadvantage of using colour to identify a mineral?
3. Why do geologists use both the colour of a mineral and the colour of its streak to identify the mineral?
4. Why do you think geologists use drill bits covered with small diamonds to drill into Earth's crust?

LEARNING TIP

Do not guess. Look back through the section to find the answers. Even if you remember the answer, it is good to go back and check it.

7.2 Conduct an Investigation

▶ SKILLS MENU

○ Questioning	● Observing
○ Predicting	○ Measuring
○ Hypothesizing	● Classifying
○ Designing Experiments	○ Inferring
○ Controlling Variables	● Interpreting Data
○ Creating Models	● Communicating

Identifying Minerals

In this investigation, you will identify several different minerals by examining some of the properties you have just learned about (**Figure 1**). Geologists use these properties, as well as others, to identify minerals.

Figure 1
Hardness tests can be used to help identify unknown minerals.

Question

Can you identify unknown minerals by their properties?

Materials

- safety goggles
- apron
- set of numbered mineral samples
- Mohs hardness scale set of minerals (or substitutes)
- hand lens
- streak plate (unglazed tile)
- magnet
- dropper
- vinegar
- hammer

Procedure

1 Copy the table below into your notebook.

Data Table for Investigation 7.2

Mineral number	Colour	Streak	Lustre	Hardness	Magnetism	Reaction with vinegar	Cleavage	Name
1	grey-black	reddish brown	metallic					

2 Select a mineral from the set your teacher provides. Record the number of the mineral in the first column of your table.

3 *Colour:* What colour is your mineral? Record the colour of your mineral in your table.

4 *Streak:* Rub your mineral across the streak plate. Brush off the extra powder with your fingers. Record the colour of the streak, if any.

5 *Lustre:* Is the lustre of your mineral metallic (like polished metal) or non-metallic? Is it brilliant, glassy, pearly, silky, waxy, or dull? Try to find the best words to describe the lustre of your mineral, and record your observations.

6 *Hardness:* Scratch your mineral with Mohs mineral #5 (or a nail). If this does not leave a scratch or groove in your mineral, continue along the scale toward #10. If mineral #5 does leave a scratch in your mineral, move along the scale toward #1. Rank the hardness of your mineral. (It will be between two numbers unless your mineral is identical to one of the minerals in the Mohs hardness scale.) Record your results.

7 *Magnetism:* Use a magnet to determine if your mineral is magnetic. Record your result.

8 *Reaction with vinegar:* Use the dropper to put a few drops of vinegar on your mineral. Does it fizz? Record your results.

Wear safety goggles during step 9.

9 *Cleavage:* Your teacher will use a hammer to break your mineral. Does it break along flat surfaces, or does it break into pieces with rough, uneven surfaces? Record your observations.

10 Repeat steps 2 to 9 for the rest of the minerals in your set.

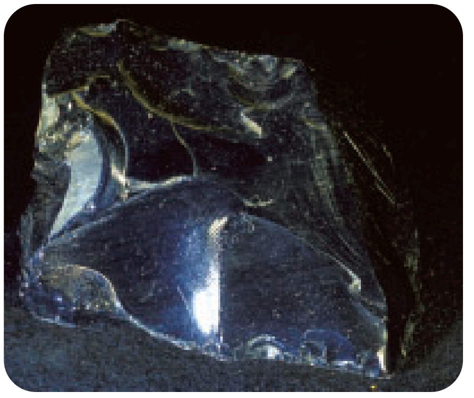
11 Use **Table 2** to help you identify your minerals. If you can identify a mineral, write its name in the last column of your data table. If you cannot identify a mineral, write "do not know."

Table 2 Characteristics of Some Common Minerals

Mineral	Colour	Streak	Lustre	Hardness	Magnetism	Reaction with acid	Cleavage	Other
graphite	black	black	metallic	1–2				slippery feel
galena	grey	grey	metallic	2–3				square corners
halite	white	colourless	glassy	2–3			three cleavage planes	square corners
biotite	black	white/ pale grey	glassy/ brilliant	2–3			splits into leaves; one cleavage plane	
calcite	white	colourless	glassy	3		fizzes		
pyrrhotite	yellow-brown	black	metallic	4	magnetic			
serpentine	shades of green	colourless	silky/waxy	2–5				
magnetite	black	black	metallic	6	magnetic			
hematite	red/black	red	metallic/ dull	5–7				
feldspar	white/ pink/ greenish	colourless	pearly	6			two cleavage planes	
pyrite	yellow	brown/ black	metallic	6–7				
quartz	colourless/ white/rose	colourless	glassy	7			two reflective surfaces	will scratch glass

Analyze and Evaluate

1. Did lustre help you identify any of the minerals in your set? If so, which one(s)?



2. Do you think that streak is more useful for identifying minerals than colour or lustre? Explain your answer using an example.

3. Do you think that magnetism is a useful property for identifying minerals? Suggest a reason for your answer.

Apply and Extend

4. Which properties could you use to identify minerals if you were out for a walk and had no equipment?

CHECK YOUR UNDERSTANDING

1. Why is it important to wear safety goggles when investigating the cleavage of minerals?
2. Why do you think you were asked to record your observations and results in a table?

7.3 Families of Rocks

There are many different minerals, but they are usually found mixed together in rocks. For example, granite contains mica, quartz, and feldspar.

Geologists classify rocks into three families based on how they are formed. These are igneous, sedimentary, and metamorphic rock.

Igneous Rock

> **LEARNING TIP**
> The word "igneous" comes from the Latin word *ignis*, meaning "fire."

Hot molten rock under Earth's surface is called **magma.** Rock that forms from the hardening of liquid magma is called **igneous rock** [IG-nee-us]. Most of Earth's surface is composed of igneous rock, and igneous rock is still being formed today.

If the magma cools underground, the rock that is formed is called **intrusive** igneous rock. This type of igneous rock is seen on Earth's surface only after years of erosion have worn away the layers of rock over it. Stawamus Chief near Squamish, British Columbia is one of the world's largest chunks of granite, a common intrusive igneous rock (**Figure 1**).

If the magma is forced out onto Earth's surface, it is called **lava.** Igneous rock that is formed on Earth's surface when the lava cools is called **extrusive** igneous rock. Basalt is extrusive igneous rock that is common in British Columbia.

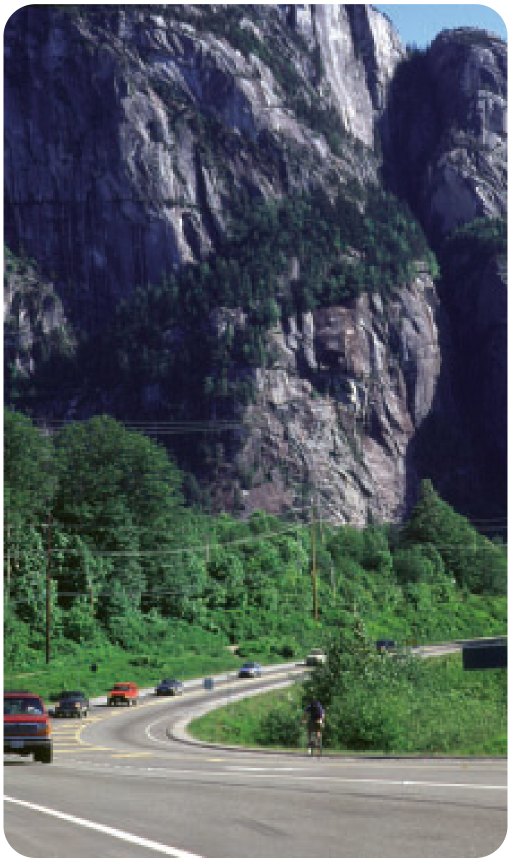


Figure 1
The Stawamus Chief is popular with climbers. Many Aboriginal groups have special stories and legends about unique features like the Stawamus Chief.

The formation of both intrusive and extrusive igneous rock is shown in **Figure 2**.

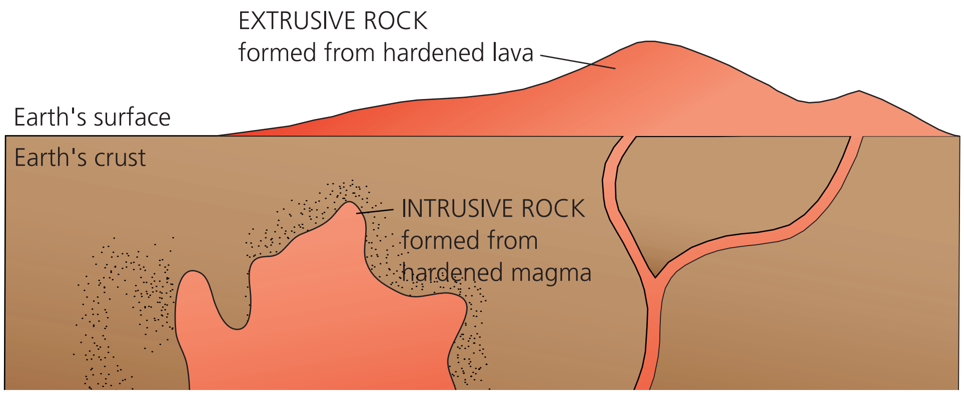


Figure 2
Two types of igneous rock

LEARNING TIP

Are you able to explain the difference between intrusive and extrusive igneous rocks in your own words? If not, ask yourself, "What do I need to figure out? What don't I understand?" Then re-read the explanation, and re-examine **Figure 2**.

The rate at which the molten material cools determines the size of the crystals in the rock. Granite (**Figure 3**) is intrusive rock that is formed when magma cools very slowly within Earth. Granite has a mottled appearance and it contains crystals that can be seen with the unaided eye. Obsidian (**Figure 4**) is an extrusive igneous rock that is formed when lava cools very quickly, forming very tiny crystals that cannot be seen without magnification.

Figure 3
Granite

Figure 4
Obsidian

Some igneous rock even floats. Off certain South Pacific islands, small pieces of pumice can be found floating in the ocean (**Figure 5**). Small pockets of volcanic gases, which are trapped as frothy lava quickly cools, allow this rock to float.

Figure 5
Pumice is a type of igneous rock that floats.

Sedimentary Rock

When bare rock is exposed at Earth's surface, it may be broken into smaller pieces, or particles, in many different ways. These small rock particles are moved from one place to another. Rain and melted snow wash the rock particles into streams and rivers, which then carry the rock particles for many kilometres. The rock particles, along with clay, mud, sand, gravel, and boulders, are called **sediment.** As the water approaches a lake or ocean, and the current slows, the sediment gradually sinks to the bottom (**Figure 6**).

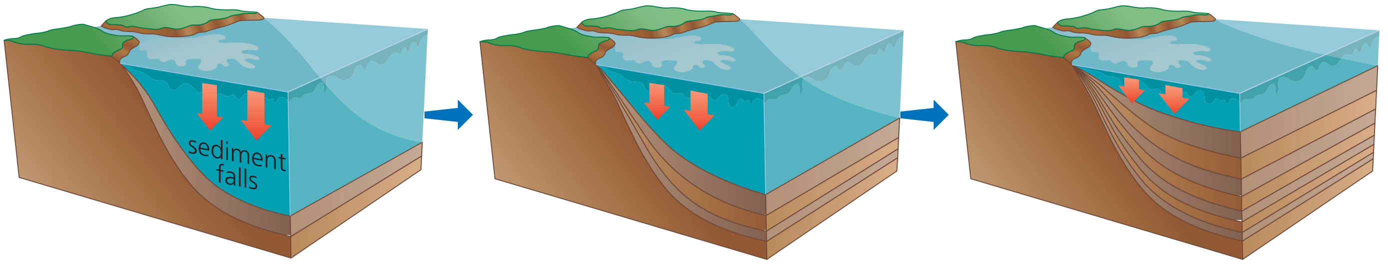
Figure 6
As this satellite photo shows, sediment carried by the Fraser River pours out into the sea.

LEARNING TIP

As you study **Figure 7**, ask yourself, "What is the purpose of this illustration? What am I supposed to notice and remember?"

There, on the lake or ocean floor, the sediment gradually piles up in layers. Over millions of years, the enormous weight of the upper layers of sediment presses down on the lower layers. Under the pressure, the lower layers are compacted (pushed together). Dissolved minerals act as a natural cement that hardens the lower layers into rock. Rock that is formed by the breaking down, depositing, compacting, and cementing of sediment is called **sedimentary rock** (**Figure 7**). Sedimentary rock may also contain animal and plant remains that have been deposited along with the sediment.

Figure 7
Sedimentary rock is formed as layers of sediment are added by a river.



Rock and soil particles and gravel are carried by the river. They sink to the bottom, forming a layer of sediment.

Each new layer puts pressure on the layers below.

Eventually, the lower layers cement into rock.

Figure 8

Shale is a smooth sedimentary rock that is formed from layers of tiny particles of clay or silt.

Sandstone, a rougher rock, is formed from layers of compressed sand.

Conglomerate is made from sediment that contains rounded pebbles and small stones.

As the layers are compressed, they form different kinds of rock, depending on the nature of the particles in the sediment (**Figure 8**).

The appearance and properties of a sedimentary rock can tell you what the original sediment was like. The size of the rock particles that settle to the bottom of a river, lake, or ocean depends on the speed of the water that carried the particles. For example, a narrow, swift-flowing mountain stream on a steep slope can move large rocks. A wide, slow-moving river on flat land can carry only fine clay particles. By studying the layers of sediment in different places today, geologists can understand what the land was like in the past (**Figure 9**).

Although most of Earth's surface is made up of igneous rock, much of the rock you see on the surface is sedimentary rock. New sedimentary rock is being formed all the time as additional layers of sediment are deposited by wind and water.

Figure 9
The layered appearance of these sedimentary rocks is a clue to how they were formed.

TRY THIS: *MAKE YOUR OWN SEDIMENT*

Skills Focus: observing, creating models

Fill a jar with a screw-on lid half full of water. Add some clay, sand, and fine gravel or pebbles. Cap the jar tightly and shake it gently until all the sediment is moving. Put down the jar and observe the sediment settling. What do you notice about the sizes of the particles in each layer?

▶ LEARNING TIP

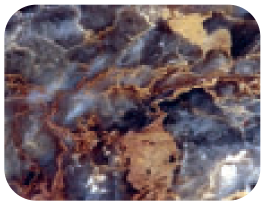
The word "metamorphic" means "changed in form." It comes from the Greek words *meta*, meaning "after," and *morphe*, meaning "form." The root "metamorph" is used in other areas of science as well. For example, the change in form of a caterpillar into a butterfly is called "metamorphosis."

Metamorphic Rock

When igneous or sedimentary rock becomes buried at a great depth, it is subjected to increased temperature and pressure. As well, magma moving through Earth heats and squeezes the neighbouring rock. As a result, the rock may change. The changed rock is different from the original rock in appearance or in the minerals it contains. Rock formed below Earth's surface, when heat and pressure cause the properties of existing rocks to change, is called **metamorphic rock.**

Some metamorphic rocks have been changed so much that they no longer resemble the original rock, or parent rock. Often, however, geologists can trace the relationship between a metamorphic rock and its parent rock. For example, slate is a metamorphic rock that is formed from the sedimentary rock shale. Gneiss [NICE] is a metamorphic rock that is formed from the igneous rock granite. **Table 1** shows some types of metamorphic rocks and their parent rocks.

Table 1 Metamorphic Rocks

Parent rock		Metamorphic rock	
shale (sedimentary)		slate	
granite (igneous)		gneiss	
limestone (sedimentary)		marble	
sandstone (sedimentary)		quartzite	

The cycle does not always stop here, however. With more heat and pressure, metamorphic rock can change into other types of metamorphic rock. For example, with additional heat and pressure within Earth, the metamorphic rock slate can change into phyllite, and phyllite can change into schist (**Figure 10**). Schist is one of the strongest rocks in the world. New metamorphic rocks are being formed all the time, deep within Earth.


Slate


Phyllite


Schist

Figure 10

CHECK YOUR UNDERSTANDING

1. Copy and complete **Table 2**.

Table 2 How Rocks Are Formed

Type of rock	How it is formed	Examples
igneous		
sedimentary		
metamorphic		

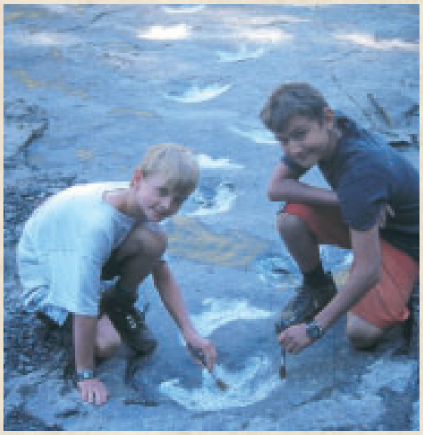
2. What is the difference between intrusive and extrusive igneous rock?
3. How are minerals different from rocks?
4. A rock that contains a cavity filled with crystals is called a geode. Look at the photograph at the beginning of this chapter. Why are the crystals in the middle of the geode larger than the crystals toward the outside?

7.4 Fossils

NEWS Flash!! Dinosaur tracks discovered!

Two elementary school boys find evidence of Ankylosaur while tubing down Flatbed Creek.

MARY CHANG



CHARLES HELM

In August 2000, two boys went tubing down Flatbed Creek near Tumbler Ridge, British Columbia. As they walked along the banks of the creek, they came across unusual impressions in the rock. What Daniel Helm and Mark Turner had discovered were 20 dinosaur footprints preserved in sedimentary rock that

David Helm and Mark Turner discovered fossilized dinosaur footprints

was over 90 million years old. Further investigations by scientists revealed more footprints, as well as fossilized dinosaur bones

LEARNING TIP

Before you read this section, make a web to show what you already know about fossils.

How Fossils Form

Fossils are rock-like casts, impressions, or actual remains of organisms that were covered by sediment when they died, before they could decompose (**Figure 1**). Only a tiny fraction of organisms are preserved as fossils. This is because most dead organisms decay or are eaten by scavenging animals. Also, soft tissue, such as muscle and body organs, does not fossilize well.

Figure 1
A fossil of a turtle.

An organism that is suddenly buried by falling into mud or quicksand may become a fossil. An organism that is covered quickly by a landslide of sediment or blowing volcanic ash may also become a fossil. The layer of sediment that contains the organism is covered by other layers of sediment and gradually becomes sedimentary rock.

As the wet sediment becomes rock, minerals that are dissolved in the water gradually replace minerals in the body of the buried organism. Minerals in bone, shell, and parts of plants can be replaced this way. Eventually, particle by particle, all the minerals in the organism are replaced by minerals in the water. The final result is a fossil that looks exactly like the original organism but is in a rock-like form (**Figure 2**).

Ammonites were marine animals that looked like octopuses with shells. Although they no longer live on Earth, a close relative, called the chambered nautilus, still does. Vancouver Island and the Gulf Islands are well known for their ammonite fossils, like the one in **Figure 2**. Is there a rocky area near your school where your class could look for fossils?

Figure 2
This ammonite, found in British Columbia, is 170 million years old.

How Fossils Tell Us About Geological Change

Fossils record the history of changes to life on Earth. All the information we have from fossils is called the **fossil record.** The fossil record is important because it shows what types of animals and plants lived on Earth hundreds of millions of years ago. The fossil record also shows how life has changed over time. If you look at exposed layers of sedimentary rock from bottom to top, the fossils are like a series of snapshots of how life has changed on Earth, from the distant past near the bottom to more recent times near the top.

Scientists have used fossils to make a time line of the changes in life on Earth. This time line is called the **geologic time scale** (**Figure 3**).

Geologists use fossils to compare the ages of rocks. For example, if a certain type of ancient fossil is found in rocks in two different places, then these rocks were probably formed about the same time.

LEARNING TIP

Observe how **Figure 3** is organized. You can read it across and down. Each tells a different story.

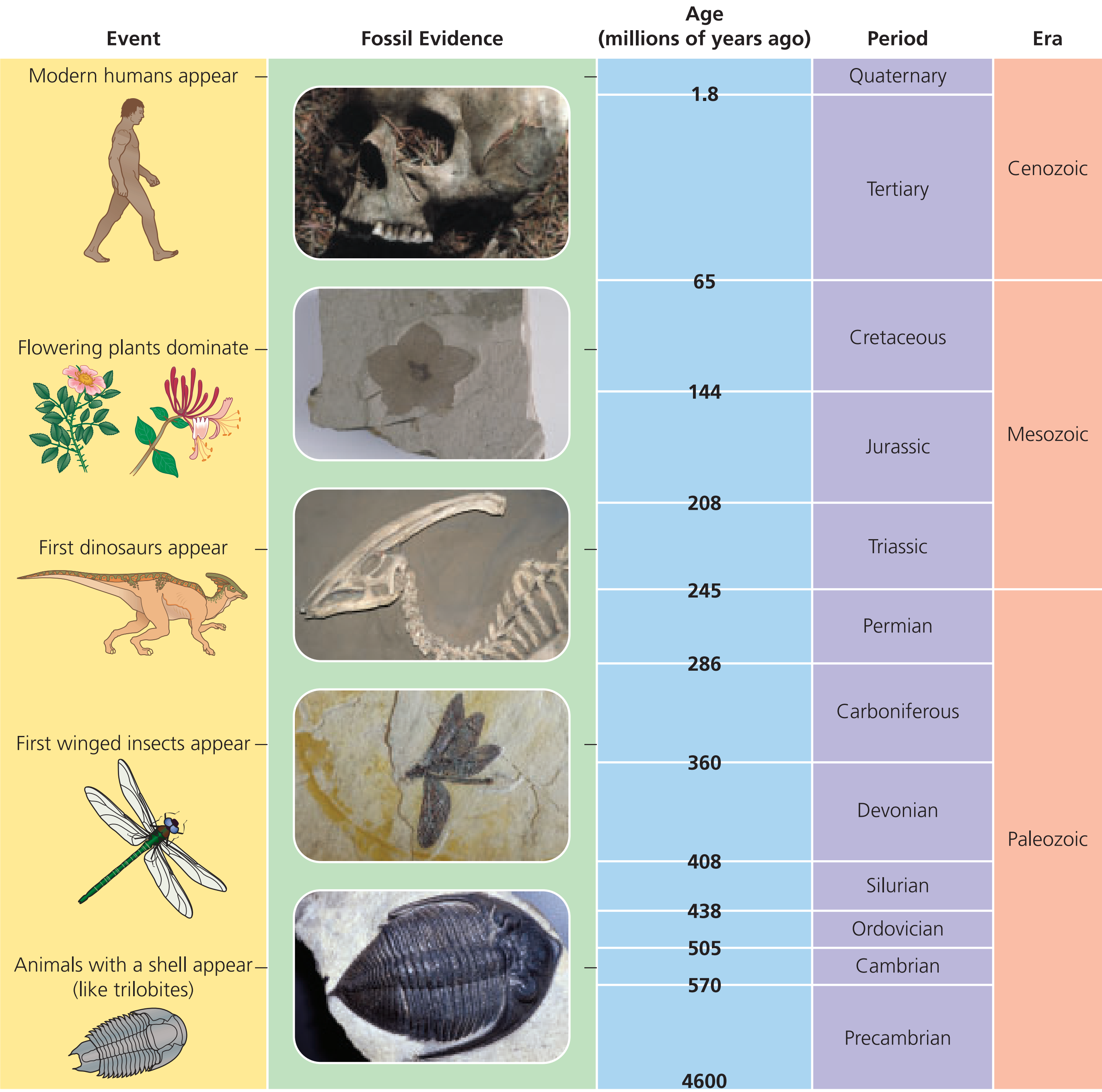


Figure 3
Geologic time scale

Geologists also use fossils to track how Earth has changed or how parts of Earth have moved over time. The oldest known fossils in Canada are located at the Burgess Shale in Yoho National Park, near Field in eastern British Columbia (**Figure 4**). The fossils here are not dinosaur fossils. They are fossils of soft-bodied marine organisms that existed on Earth 500 million years ago, in a period of geologic time known as the Cambrian era. These fossils are so rare and unusual that the area has been made a World Heritage Site by the United Nations.

The rock that contains these fossils is black shale. Geologists determined that the rock originally formed in the ocean, close to a reef where the marine organisms lived. The reef was at the edge of the ancient North American continent. Occasional underwater mudslides trapped the organisms and, over many millions of years, their bodies were covered by more than 8 km of sediment. Forces inside Earth gradually moved the fossils eastward to their current location, high in the mountains.

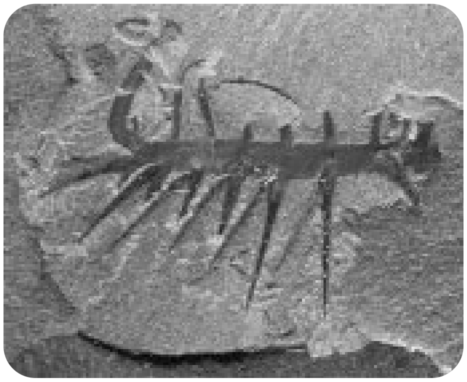


Figure 4
The Burgess Shale (left) is one of the most famous fossil finds in the world. This Burgess Shale fossil (right) is so strange that the geologists who first saw it thought they must be hallucinating. They named it *Hallucinogenia*.

CHECK YOUR UNDERSTANDING

1. Describe how fossils form.
2. Why do very few organisms become fossils?
3. Would you expect to find fossils of dinosaur bones in rock that was 250 million years old? Why or why not?
4. Why are fossils found in sedimentary rock but not in metamorphic rock? (Think about how the three families of rock are formed.)
5. Write "Fossils" in the middle of your page. Then make a mind map of all the things that scientists have learned from fossils.

LEARNING TIP

Compare what you learned about fossils in this section to what you already knew about fossils.

7.5 Weathering Breaks Down Rocks

LEARNING TIP

Preview the section and read the headings. How many types of weathering will you be learning about in this section?

An old cemetery can be an interesting place to visit. You can see how small, slow changes make a big difference after many years. For example, almost 200 years ago, the gravestone in **Figure 1** was polished and new. Today, the edges are chipped and the surface of the stone has tiny holes. In a few more years, the writing will be worn away. Eventually, the stone will crumble apart and disappear into the soil.

Figure 1

This old gravestone is starting to show wear. Compare it with a new gravestone to see how rock weathers over time.

The process that slowly breaks down natural materials, such as rocks and boulders, into smaller pieces is called **weathering.** Weathering also breaks down human-made structures, such as roads and buildings. Weathering can be caused by physical forces or by chemical reactions.

The term "weathering" indicates that the changes to the rock material are caused by the weather. Weather includes changing temperature, wind, rainfall, and snowfall. Weathering slowly breaks down all rock materials in contact with the air.

There are three kinds of weathering: mechanical, chemical, and biological.

Mechanical Weathering

Weathering that is caused by a physical force is called **mechanical weathering.** Many different physical forces can cause weathering.

Have you ever left a full bottle of water or pop in the freezer? The container either swells or breaks as the water expands from freezing. Rocks often have cracks in them. During colder months, rainwater is caught in the cracks and then freezes. As the water expands, it puts pressure on the walls of the cracks, forcing them to widen. This is called **ice wedging.** Eventually, as ice wedging occurs again and again, the cracks may widen or pieces of rock may break off (**Figure 2**).

Figure 2
Ice wedging has weathered this rock face. Notice the pieces of rock that have fallen off and collected below.

Mechanical weathering may be caused by the wind as well. Sand particles and small rocks carried by the wind have the same effect as sandpaper as they rub the surface of the rock. The sand and small rocks slowly wear down exposed surfaces into small pieces or particles of rock.

LEARNING TIP

Compare what you are learning with what you already know. How do the examples of mechanical weathering fit with what you already know?

Figure 3
These rocks have been rounded as they tumbled in a fast-flowing river.

Similarly, rocks carried by fast-flowing water rub against each other. This action gradually wears away and smoothes the outer surfaces of the rocks (**Figure 3**). The force of pounding waves on a seashore can break large rocks into smaller fragments.

One of the most dramatic causes of mechanical weathering is glaciers. Although glaciers seem to stay in one place, they actually move very slowly downhill due to their immense weight. As they move, the rocks that are trapped in the ice scrape the ground below (**Figure 4**). This type of mechanical weathering is easily identified by the long scratches, called striations, it leaves on rocks.

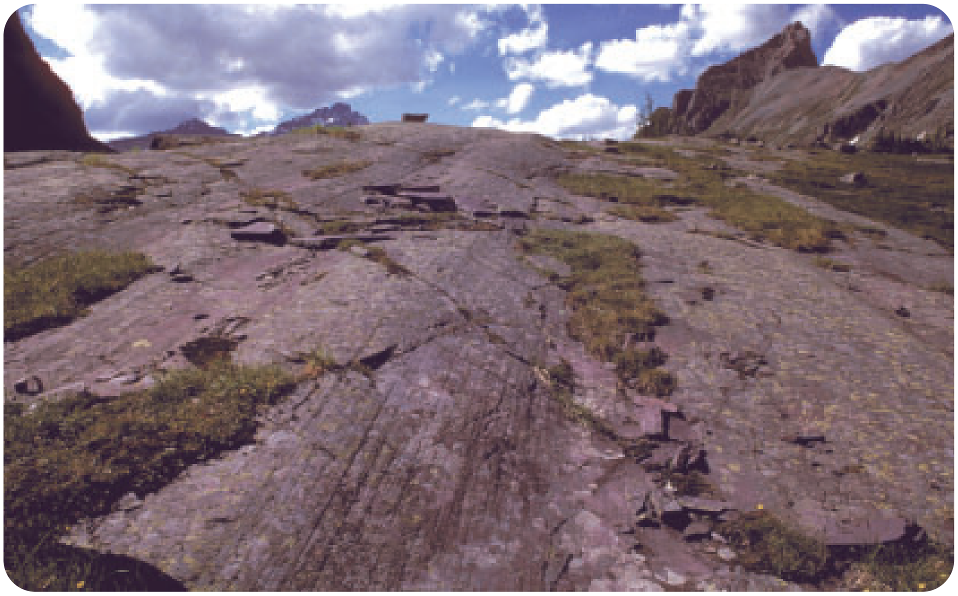


Figure 4
During the last ice age, a huge glacier covered most of North America. You may find a rock like this, with marks that have been cut into it by rocks in the moving ice.

TRY THIS: *MODEL MECHANICAL WEATHERING*

Skills Focus: observing, inferring, creating models

Make a model to show how glaciers carrying rocks cause mechanical weathering. Fill an ice-cube tray with water. Sprinkle some sand in half of the sections. Freeze the water. Pop out a regular ice cube, and rub it along on a piece of foil. Then do the same with a sand cube. As you rub the sand cube along the foil, what do you observe (**Figure 5**)?

Figure 5

Chemical Weathering

As you have learned, rocks are made up of many different materials. Chemicals can weaken and break down some of these materials. **Chemical weathering** occurs when there is a chemical reaction between water, air, or another substance and the materials in rocks.

Water can dissolve some rock materials. If the water contains natural or human-made acids, the dissolving process will occur much more quickly. In nature, carbon dioxide gas in the air dissolves in rainwater to form a weak acid. When the rainwater passes over or through limestone, it dissolves some of the rock. Holes form in the rock. Over very long periods of time, these holes grow larger to form caves (**Figure 6**). In British Columbia, there are caves that were formed like this on Vancouver Island, in Glacier National Park, and near Mount Robson.

Figure 6

Rainwater dissolves the mineral calcite in limestone, sometimes forming large underground tunnels. The cave above is in Fernie, in the Southern Rockies of British Columbia.

LEARNING TIP

Check your understanding of how this cave formed by explaining it in your own words to a partner.

Pollutants in the air can create acid precipitation (either rain or snow). Acid rain dissolves more minerals than normal rain. The limestone that is used to make statues and other monuments and buildings can be severely damaged by acid rain (**Figure 7**). Over many years, the mineral calcite in the limestone dissolves as acid rain pours over it, causing the limestone to crumble.

Air can also cause chemical weathering. The oxygen in air can rust any iron in minerals found in rocks.

Figure 7
The chemical weathering of ancient statues has been speeded up by the modern pollutants in acid rain.

TRY THIS: MODEL CHEMICAL WEATHERING

Skills Focus: creating models, observing, inferring

Create a model of chemical weathering by acid rain using chalk, water, and vinegar. Chalk is made of a compound called calcium carbonate. Calcium carbonate is found in the marble and limestone that are often used to make statues and buildings. Use a model to compare the effects of normal rain and acid rain on chalk. Put one piece of chalk in a glass or cup of tap water (rain). Put another piece of chalk in a glass or cup of vinegar (acid rain). Label the cups and leave the cups overnight. The next day, observe and compare the two pieces of chalk.

Biological Weathering

Sometimes living things cause mechanical or chemical weathering. This is called **biological weathering.**

Figure 8
Lichen can wear down rocks.

Lichen grows on rocks and uses some of the materials in the rocks as a source of nutrients (**Figure 8**). It produces an acid that dissolves and wears down the rocks. When the lichen dies, it leaves a thin layer of weathered rock materials in which other plants can grow.

Plants that grow in the cracks in rocks help to split the rocks. Wind and water deposit soil particles in the cracks caused by ice wedging. Roots grow in the cracks, splitting the rocks even more (**Figure 9**).

a) Trees grow very slowly where there is little soil. As the tree's roots grow, they split the rock.

b) This small tree may be hundreds of years old.

Figure 9

The roots of trees and other plants cause biological weathering.

TRY THIS: OBSERVE BIOLOGICAL WEATHERING

Skills Focus: observing, classifying

Take a walk around your schoolyard. Find and sketch examples of biological weathering. Look for lichen on rocks and weeds growing in cracks in the sidewalk. Post sketches in your classroom. Did other students find similar examples of biological weathering? Different examples?

CHECK YOUR UNDERSTANDING

1. Draw a Venn diagram to show the relationships among mechanical, chemical, and biological weathering. On your diagram, define each type of weathering and give examples.
2. Explain how water can be involved in both mechanical and chemical weathering.
3. Old gravestones are sometimes so weathered that the writing is worn away. What types of weathering could act on a gravestone?
4. What human activities can increase the rate of weathering?

LEARNING TIP

To review how to use a Venn diagram, see "Using Graphic Organizers" in the Skills Handbook.

7.6 Erosion

The movement of weathered rock materials from one place to another is called **erosion.** Erosion may occur rapidly, such as when a landslide races down a mountain. It may also occur slowly, over hundreds or thousands of years. Erosion can be the movement of grains of sand or the movement of gigantic boulders. Erosion can drop materials at any distance from their source—from a few centimetres to hundreds of kilometres away. When eroded rock materials stop moving, they settle on Earth's surface. The laying down of sediments is called **deposition.** Gravity, wind, water, and ice all help to move weathered rock materials.

LEARNING TIP

Scan the subheadings in this section. How many types of erosion do you think you will learn about?

Gravity

Gravity causes rock falls and avalanches along many of British Columbia's highways. Early in the morning on January 9, 1965, a landslide near Hope, British Columbia, sent millions of tonnes of rock down a mountain into the valley below (**Figure 1**). Four people died, buried under rocks that reached depths of over 60 m. A small earthquake may have loosened the rocks, but the force of gravity caused the rocks to fall.

Figure 1
This rock slide, east of Hope, British Columbia, raced down the mountain with deadly force on January 9, 1965.

Wind

Wind can carry dust, sand, and soil for many kilometres. Particles in the air are deposited when the wind speed drops. On some beaches and deserts, the wind picks up dry, loose sand and deposits it in regular piles called dunes.

The devastating dust storms in the Prairies during the severe droughts of the 1930s demonstrated the wind's power (**Figure 2**). Due to the lack of rain, the rich surface soil became very dry. The wind was able to pick up the light, dry soil particles and blow them several kilometres away. In many places, the surface soil was completely blown away. The layers of soil that remained were not rich enough to grow crops, and many farmers were forced to abandon their farms. The effects of dust storms are not just local. Wind can even carry dust across oceans (**Figure 3**).

Figure 2
Dust storms on the Prairies in the 1930s damaged farmland.

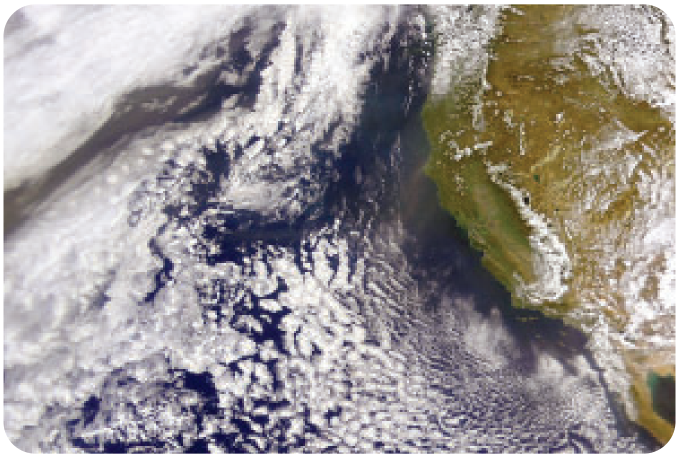


Figure 3
The dark streak in the cloud approaching North America is dust from a dust storm in China six days earlier.

Water

Little by little, a large river like the Fraser River can move billions of tonnes of rock from the land it crosses. As the river does this, it cuts into the land and makes a deeper and deeper valley. A **valley** is any low region of land between hills or mountains. Valleys that are formed by flowing water tend to be V-shaped. On the way to the sea, many rivers cross flat areas, or **plains,** near the coast. Since a river moves slowly on a plain, the heavier sediment is deposited on the riverbed or riverbanks in the plains.

A river also slows down when it runs into a lake or ocean. Much of the sediment that the river was carrying is deposited on the bottom of the lake or ocean. As the sediment builds up, it causes the river to fan out over a broad area, often shaped like a large triangle. This area is called a **delta** (**Figure 4**). At a delta, the river often breaks into a number of smaller channels, separated by islands of sediment.

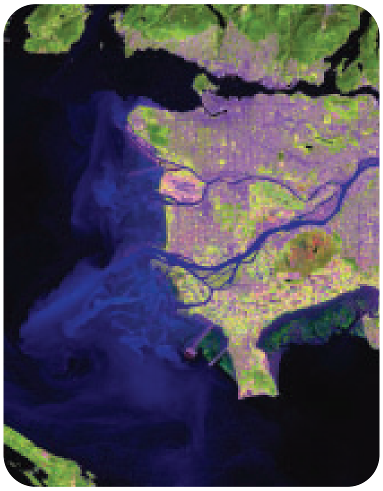


Figure 4
This satellite photograph shows the Fraser River delta in southern British Columbia.

The Fraser Canyon was carved out of the land by the action of flowing water (**Figure 5**). Over the years, the Fraser River cut deeper and deeper into the land until the canyon was formed. The Fraser River continues to carry rocks, gravel, sand, and mud. As time goes by, a large river extends its delta farther and farther out into the ocean. For example, 10 000 years ago, the end of the Fraser River delta was in the New Westminster area, 30 km east of where it is today.

Figure 5
The Fraser Canyon was carved out of the land by the action of flowing water.

Ice

Glaciers form when snow builds up over many years in the valleys and hollows of mountains (**Figure 6**). As the snow builds up, the layers are pressed together. The pressure gradually turns the snow to ice. The weight of the ice mass causes the glacier to move slowly downhill.

Figure 6
Bear Glacier, near Stewart, British Columbia, is a popular tourist attraction.

Rocks and soil that are frozen in the ice travel with the glacier. These materials can be carried many kilometres before being dropped in a new location when the glacier begins to melt. Glaciers can leave large, individual boulders in areas where they would not normally occur. These out-of-place boulders are called erratics (**Figure 7**).

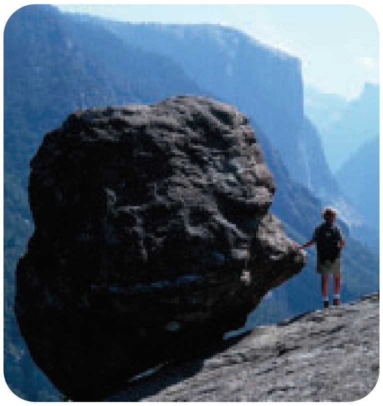


Figure 7
An erratic boulder.

Evidence indicates that the last ice age ended in most parts of Canada about 10 000 years ago. The effects of this ice age, however, can still be seen in many areas today. As rivers of ice moved down mountainsides, they eroded deep U-shaped valleys with round bottoms and steep sides. Along the coast, many of these valleys became filled with seawater after the glaciers melted. The resulting long, narrow inlets of the sea are called **fiords** (**Figure 8**). Howe Sound and Knight Inlet are two of the many fiords that are found along the coastline of British Columbia.

Figure 8
Rivers Inlet is a fiord on the central coast of British Columbia.

CHECK YOUR UNDERSTANDING

1. What is erosion? How is it different from weathering?
2. List four forces that cause erosion, and give an example of each.
3. Give two examples of erosion that can happen quickly. Give two examples of erosion that happens slowly.
4. Deltas are often good areas for farming. Explain why.
5. How do you think Delta, in British Columbia, got its name?

7.7 Design Your Own Experiment

SKILLS MENU

○ Questioning	● Observing
○ Predicting	○ Measuring
● Hypothesizing	○ Classifying
● Designing Experiments	○ Inferring
● Controlling Variables	○ Interpreting Data
○ Creating Models	● Communicating

Factors That Affect Erosion by Water

Moving water erodes soil (Figure 1). Several factors determine the amount of erosion that occurs and how fast it occurs.

Figure 1
Why might more erosion occur in some situations?

LEARNING TIP

For help writing hypotheses or writing up your lab report, see the Skills Handbook sections "Hypothesizing" and "Writing a Lab Report."

Question

What factors affect the rate of erosion by water?

Hypothesis

With your group, brainstorm a list of factors that could affect the rate at which soil is eroded by water. Write down each factor as a hypothesis. Then decide, as a group, which hypothesis you will investigate.

Materials

- apron
- plastic tray
- 4-L pail of soil
- container for water

Decide if there are other materials you will need. Check with your teacher to make sure that these materials are safe for you to use.

Procedure

- Design a procedure to test your hypothesis. A procedure is a step-by-step description of how you will conduct your experiment. It must be clear enough for someone else to follow and do the exact same experiment.
- Submit your procedure, including any safety precautions, to your teacher for approval. Also submit a diagram, at least half a page in size, showing how you will set up your experiment.

Data and Observations

Create a table to record your observations. Record your observations as you carry out your experiment.

Analysis

Compile the findings of all the groups in your class. Make a list of all the factors that affect the rate of erosion by water.

Conclusion

Look back at your hypothesis. Did your observations support, partly support, or not support your hypothesis? Write a conclusion for your investigation.

Applications

1. Where might you expect to see serious effects of water erosion?
2. How might erosion be a problem in your schoolyard or in your community?
3. Based on the findings of your class, how could you reduce the erosion of soil by water? Decide if there are other materials you will need to test your idea. Check with your teacher to make sure that these materials are safe for you to use.

CHECK YOUR UNDERSTANDING

1. Did any other groups test the same hypothesis that your group tested? If so, how were their results the same as, or different from, yours?
2. What advice about the design of your experiment would you give to another group of students testing the same hypothesis?
3. When designing your own experiment, why is it important to write down every step in the procedure?

7.8 The Rock Cycle

Over long periods of time, one kind of rock may change into another. The ways igneous, sedimentary, and metamorphic rocks change from one to another is called the **rock cycle** (**Figure 1**).

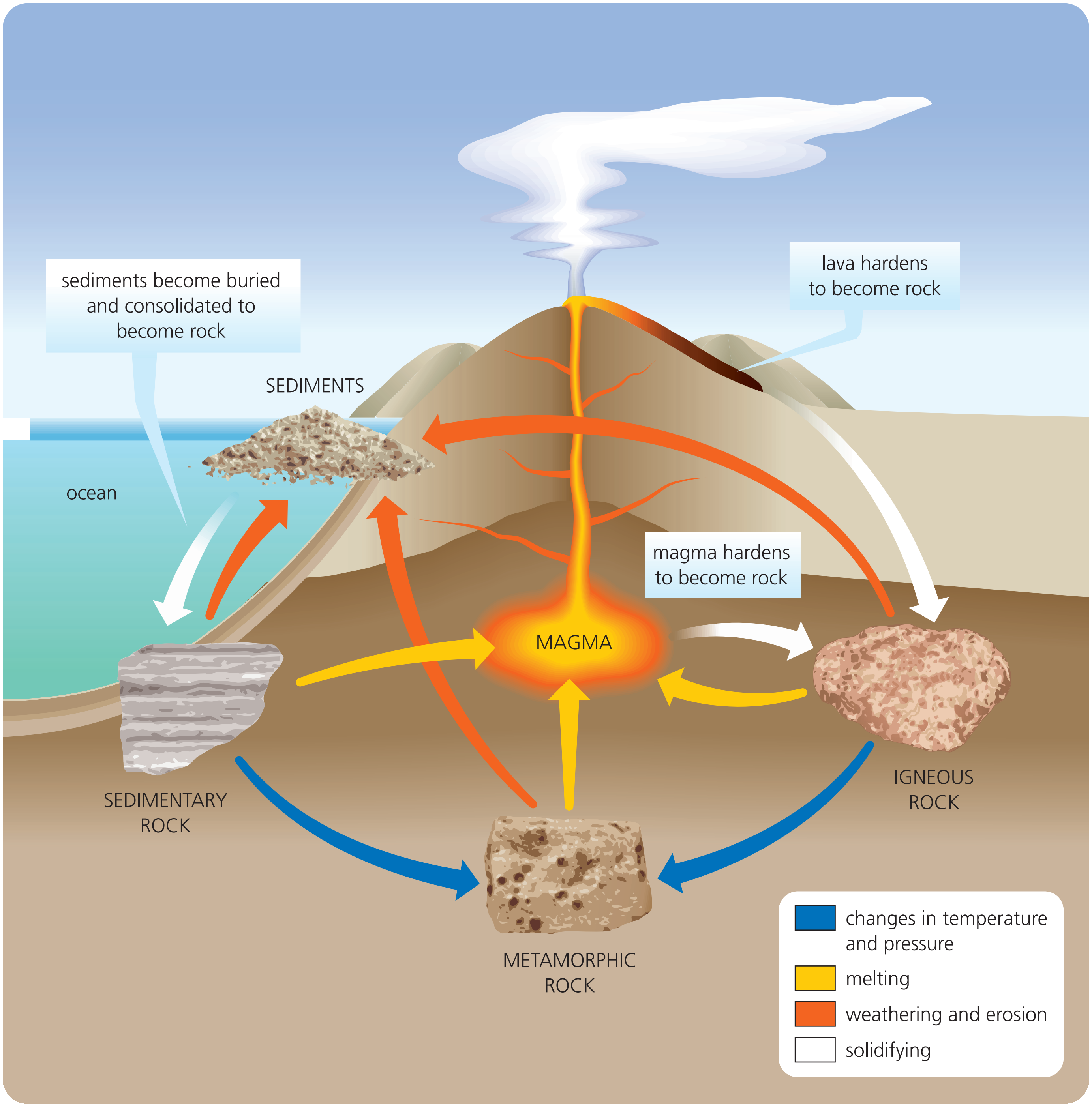


Figure 1
The rock cycle

New igneous, sedimentary, and metamorphic rocks are constantly being formed. Rocks from all three families may eventually become exposed on Earth's surface, where weathering will wear them down. The resulting sediment will gradually form layers, which will get compressed into sedimentary rock.

Any rock, if pushed far enough into Earth, will become metamorphic due to the high temperatures and pressure beneath Earth's surface. If the rock is part of a continent or ocean floor and gets pushed deep within Earth, the rock will become extremely hot and melt, turning into magma. The magma can rise and erupt out of a volcano (**Figure 2**) or cool gradually near the surface, forming igneous rock. Each family of rock is linked to the others in this cycle.

Figure 2
This lava will harden to form igneous rock.

LEARNING TIP

As you read the material on this page, follow the cycle in **Figure 1**. Look at the overall diagram, and then look closely at each part of the rock cycle. What family of rock is formed in each part of the cycle? What do the different coloured arrows mean?

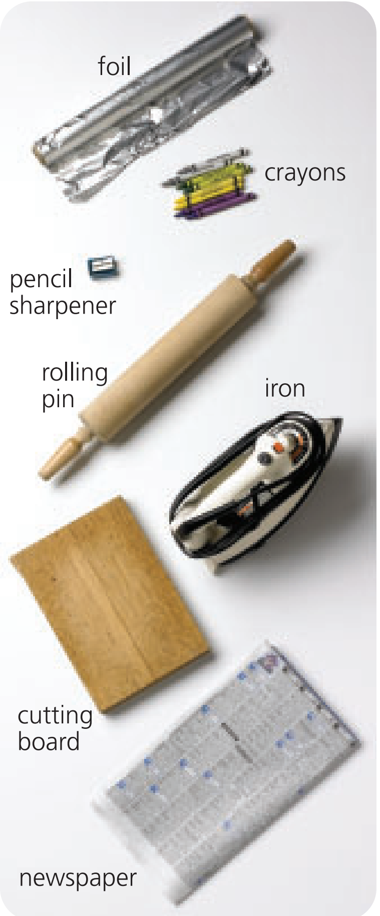
*CHECK YOUR **UNDERSTANDING***

1. Why is the process in which rocks from one family change into rocks from a different family called the rock cycle? (*Hint:* What does "cycle" mean?)
2. How is the recycling of rocks by Earth like the recycling of newspapers, pop cans, or plastics by your community? How is it different?
3. Use the diagram of the rock cycle in **Figure 1** to explain how
   - an igneous rock can become a sedimentary rock
   - a sedimentary rock can become an igneous rock
   - an igneous rock can be broken down and become an igneous rock again

7.9 Conduct an Investigation

SKILLS MENU

○ Questioning	● Observing
○ Predicting	○ Measuring
○ Hypothesizing	○ Classifying
○ Designing Experiments	● Inferring
○ Controlling Variables	● Interpreting Data
● Creating Models	● Communicating



Creating a Model of the Rock Cycle

Creating a model allows you to observe something that is otherwise difficult to observe because it is too big, too dangerous, or takes too long. For example, you cannot observe some parts of the rock cycle because they take millions of years or happen deep within Earth. In this investigation, you will create a model of the rock cycle in your classroom.

Question

How can I model the changes to rock that take place in Earth?

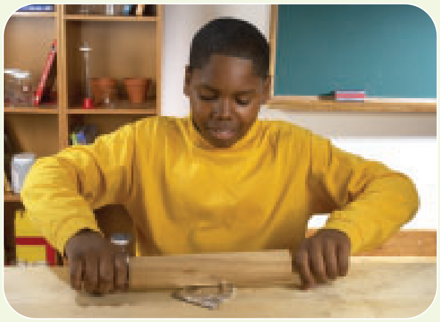
Materials

- aluminum foil
- 8 crayons: 2 yellow, 2 grey, 2 green, and 2 purple
- pencil sharpener
- rolling pin
- iron
- heat-proof cutting board
- newspaper (optional; to protect work surface)

Procedure

1 Remove the paper from around the crayons. Use the pencil sharpener to turn the crayons into shavings. Collect each colour of shavings in a separate pile.

2 On a 20 cm by 20 cm square of aluminum foil, carefully layer the crayon shavings by colour, the way that wind or water would deposit sediment.



3 Fold the aluminum foil over the layers of sediment. The foil package should be approximately 7 cm by 7 cm. Press the layers together with a rolling pin. Open the foil and sketch your "sedimentary rock."

4 Wrap your "sedimentary rock" in the aluminum foil again. Take the package to your teacher, who will press on the package with an iron set at medium-high heat for 5 to 8 s.

Wax has a low melting and burning point. Let your teacher change your "sedimentary rock" into "metamorphic rock."

5 After your package has cooled, open it, and break your "rock" in half. How has it changed? Sketch your new "metamorphic rock."

Analyze and Evaluate

1. How did your "rock" change during the investigation? Use your sketches to help answer this question.
2. What did the rolling pin represent? What did the iron represent?

Apply and Extend

3. Based on your model, explain why sedimentary rock often appears in horizontal layers.
4. How could you extend your model to show igneous rock being formed?

CHECK YOUR UNDERSTANDING

1. How did your model help you understand the formation of rocks?
2. How did your model differ from the real rock cycle?

7 Chapter Review

Old rocks can be recycled into new rocks.

Key Idea: Minerals are the building blocks of rocks and can be identified by their physical properties.


Hardness


Colour, streak


Crystal structure, cleavage


Magnetism


Reaction with certain chemicals

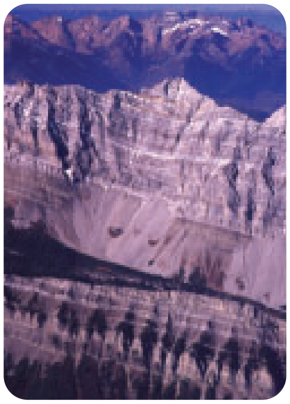

Lustre

Vocabulary

minerals p. 179

Key Idea: Earth's crust is made up of three families of rocks.


Igneous


Sedimentary


Metamorphic

Vocabulary

magma p. 188

igneous rock p. 188

intrusive p. 188

lava p. 188

extrusive p. 188

sediment p. 190

sedimentary rock p. 190

metamorphic rock p. 192

Key Idea: Fossils provide evidence of changes in life over time.

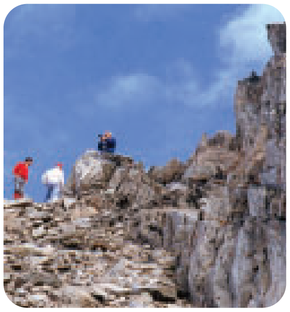
Vocabulary

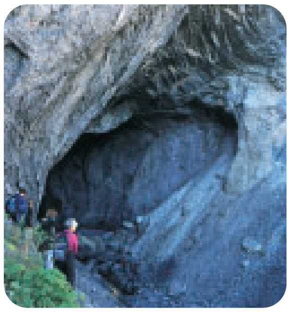
fossils p. 194

fossil record p. 195

geologic time scale p. 196

Key Idea: **Rock materials are broken down into smaller pieces by mechanical, chemical, and biological weathering.**


Mechanical weathering


Chemical weathering


Biological weathering

Vocabulary

weathering p. 198
mechanical weathering p. 199
ice wedging p. 199
chemical weathering p. 201
biological weathering p. 202

Key Idea: **Weathered materials are moved from one place to another by gravity, wind, water, and ice in a process called erosion.**


Gravity


Water

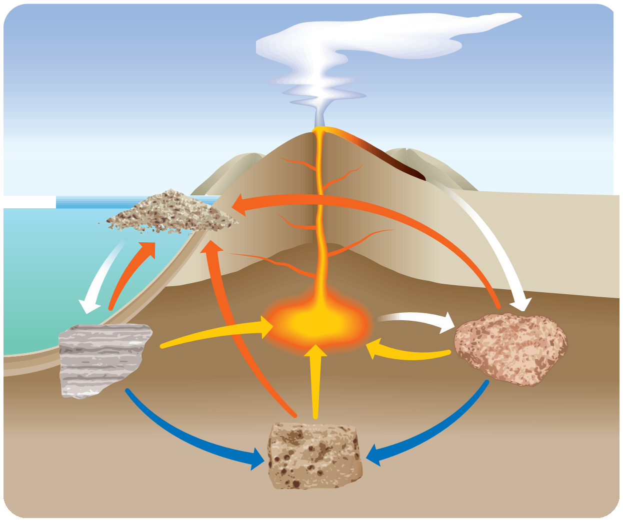

Wind


Ice

Vocabulary

erosion p. 204
deposition p. 204
valley p. 205
plains p. 205
delta p. 205
fiords p. 207

Key Idea: **Rocks and weathered rock materials can be transformed into new rocks.**



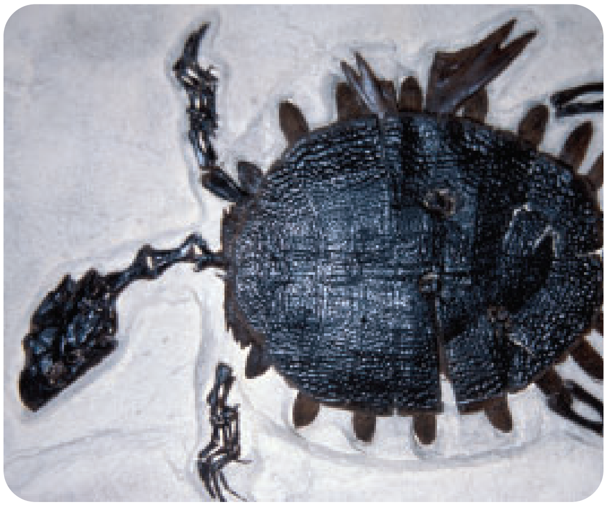
Vocabulary

rock cycle p. 210

Review Key Ideas and Vocabulary

When answering the questions, remember to use vocabulary from the chapter.

1. What properties of minerals are used to identify them?
2. Create a chart to show the three families of rocks and how each is formed.
3. How do fossils help geologists compare the age of rocks?



4. Make a table to explain the differences among mechanical, chemical, and biological weathering. Include examples of each type of weathering in your table.

4. Type of Weathering	Explanation	Examples
Mechanical		
Chemical		
Biological		

5. Explain how weathering is related to erosion.
6. Gravity, wind, water, and ice can all cause erosion. Give an example of how each can move weathered rock materials.
7. Use words and diagrams to explain how rock particles can go through the rock cycle from igneous to sedimentary to metamorphic rock, and back to igneous rock.

Use What You've Learned

8. Begin your own rock and mineral collection. A good way to start is to look for samples on weekends and during your holidays. You can also buy or trade samples through rock and mineral clubs and at shops that sell rocks and crystals. As well, you can look for scraps at building-stone suppliers.
9. Find out what minerals are mined in British Columbia. Report to the class on the minerals that are mined, where they are found, and their uses.

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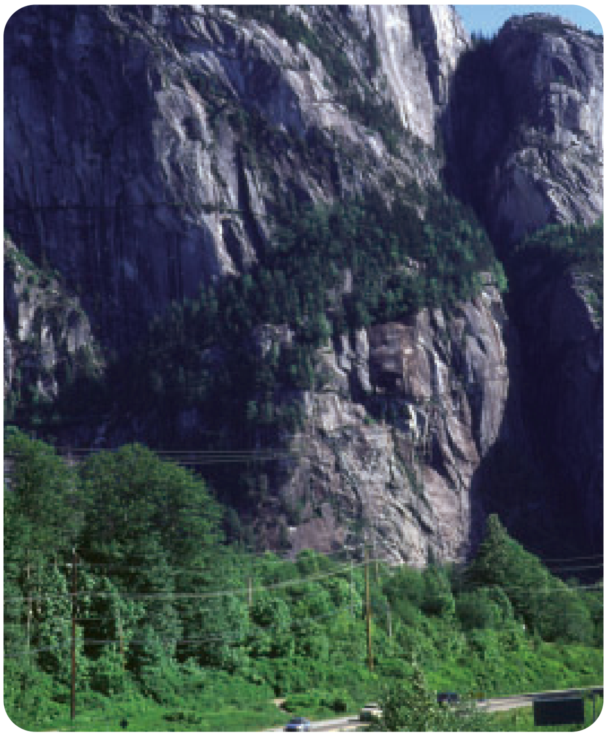
10. How can you tell whether a rock cliff beside a highway is made of igneous rock or sedimentary rock?



11. When learning new concepts it is sometimes helpful to think of something that you already know about. This is called an analogy. Look at the photographs below. Which type of cookie is an analogy for granite? Explain why.

12. The Burgess Shale, near the town of Field, British Columbia, is one of the most famous fossil discoveries in the world. Research what types of fossils can be found there. Create a brochure that explains why these fossils are so important and why the Burgess Shale should be protected.

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13. Which area would be more likely to lose its topsoil: a gently sloping area or a steep hill? Explain.

14. Name a natural or a human-made feature in your community that shows the effects of weathering and/or erosion. Make a diagram to show the kinds of weathering that are occurring. Has an attempt been made to prevent the weathering? If so, describe what has been done.

Think Critically

15. Look at a road map of British Columbia. What route would you take if you were travelling by car between Prince Rupert and Vancouver? Use the scale on the map to estimate the number of kilometres. About how many kilometres less would you travel if there were a highway straight down the coast? Why do you think there is not a more direct route between Prince Rupert and Vancouver?

16. List four or five local landforms. Predict how each landform might look in a million years.

Reflect on Your Learning

17. Recall what you have learned about rocks in this chapter. List some things that you did not know before you read this chapter. Then list any questions that you still have about rocks. Glance through the rest of the unit to see if your questions will be answered. If not, where can you go to find the answers?

18. Test yourself on your way home from school tonight. Look at different rocks and rock formations. See if you can identify them as igneous, sedimentary, or metamorphic rocks.