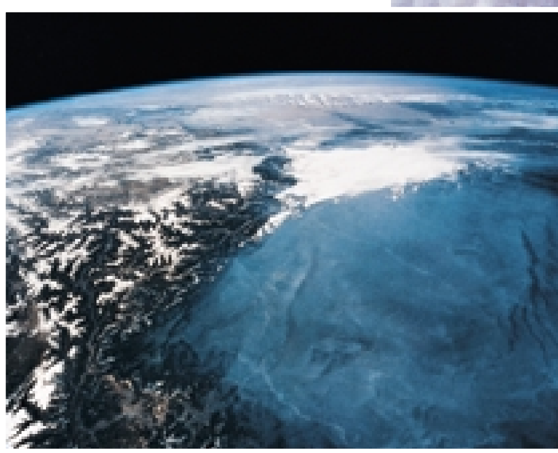
UNIT

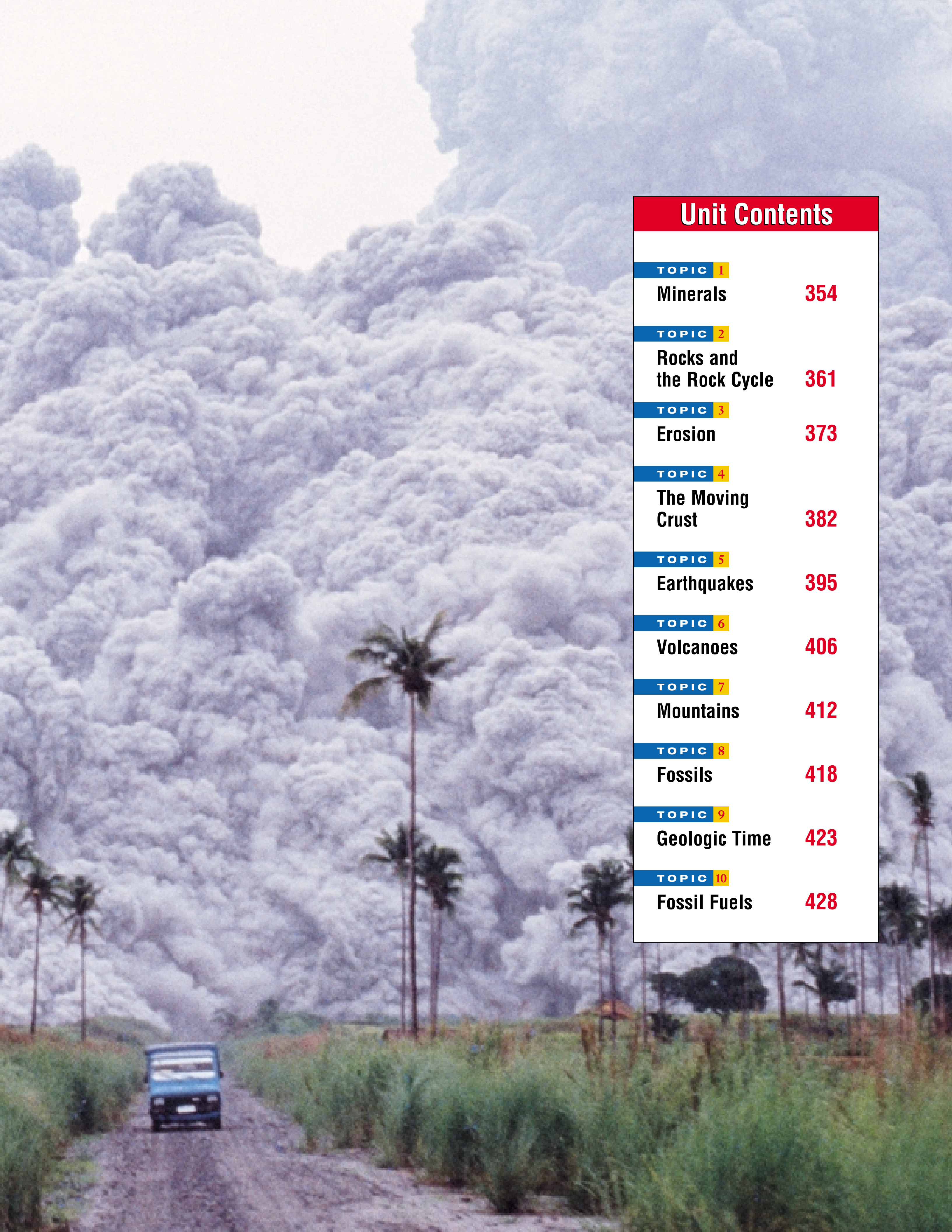
5

Planet Earth

What forces unleash the incredible power of volcanoes and earthquakes? What processes form Earth's mountains, its rocks and boulders, and the minerals and fuels deep within it? How do we know about events that happened millions of years ago? What evidence do we have of activity in Earth's interior?



The answers to these questions lie in Earth's crust and mantle — the thin, ever-changing, outermost layers of our planet. Throughout our history, scientists have been trying to understand the forces that shape and change Earth's crust. In this unit, you will see how theories about Earth's crust were developed and then discarded. You will learn about how scientists made new observations and saw new connections between their past observations. You will consider evidence of Earth's history and of the processes still at work. Enjoy your tour of Planet Earth.



Unit Contents

UNIT 5

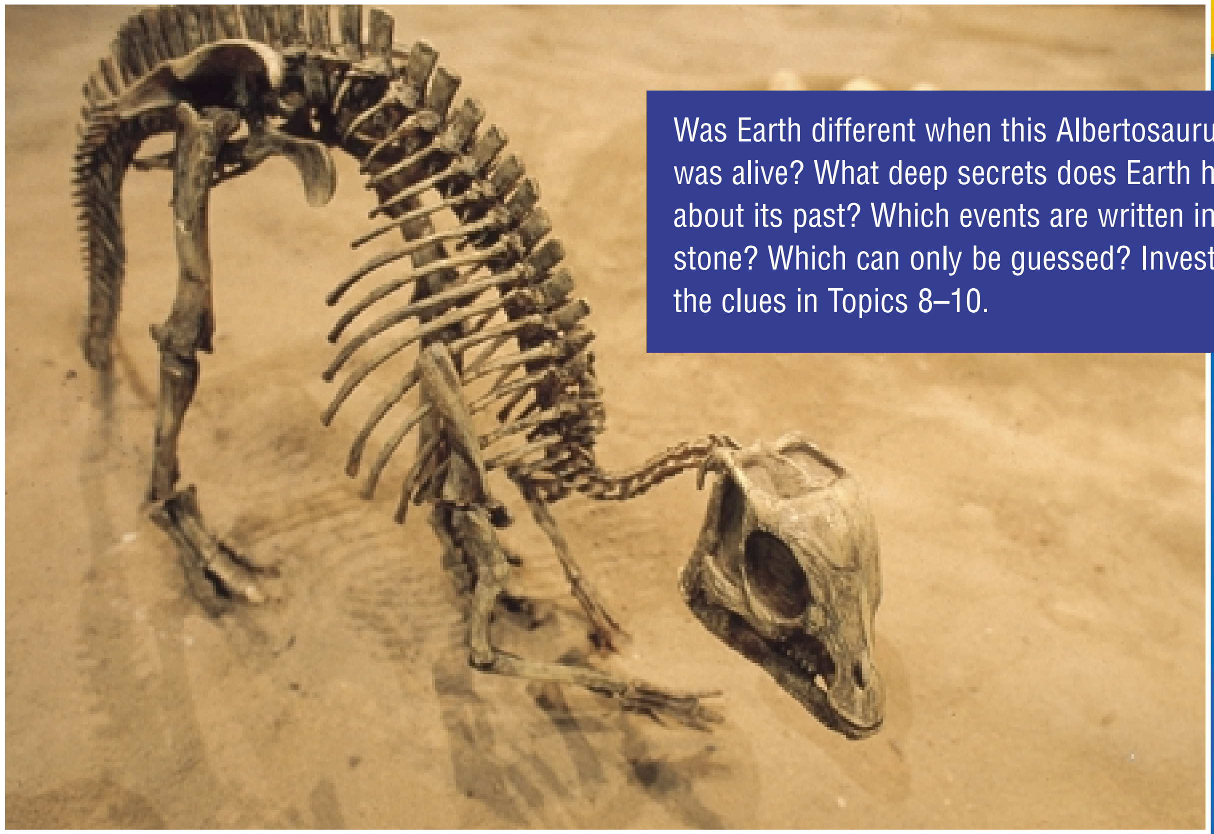
Preview

Focussing Questions

- What do we know about Earth's crust?
- How did we find out?
- Why does the crust change and move?

How do beautiful crystals like this amethyst form? What is the difference between rocks and minerals? How are rocks and sediments created? Dig into the answers in Topics 1–3.

How did this car get stuck in lava? Earth's crust is constantly changing, resulting in fiery volcanoes and powerful earthquakes. What is happening inside Earth? Travel deep into Earth's crust for the answers in Topics 4–7.



Was Earth different when this Albertosaurus was alive? What deep secrets does Earth hold about its past? Which events are written in stone? Which can only be guessed? Investigate the clues in Topics 8–10.

Looking Ahead

Look ahead to pages 436–437, A Creative Crust. In this Investigation you will choose a question to investigate about one of the processes that have shaped Earth's crust. Start thinking now about how you will:

- work together to come up with ideas
- set up an electronic or paper file for material you find
- represent the natural process your group investigates
- choose materials to begin collecting
- evaluate the question you investigate and the results you obtain

TOPIC **1**

Minerals

What is rock made from? **Rock** is made up of one or more pure, naturally occurring, non-living crystalline materials called **minerals**.

Figure 5.1 Granite is a rock that is made up of an assortment of minerals. It is often polished and used in buildings and at the base of statues. Granite contains the minerals feldspar (sparkling grains), quartz (glassy grains), mica (grey flakes), and hornblende (dark flecks).

DidYouKnow?

Iron, gold, zinc, copper — these minerals are useful in appliances and utensils, but what do they have to do with your body? In order to survive, your body needs over 20 different elements found in minerals. Iron and pyrite, help blood carry oxygen. Calcium, from calcite and dolomite, helps to regulate water in the body's cells.

Most minerals are quite rare. Only a few, such as quartz, feldspar, and mica, are found throughout Earth's **crust** (the thin outermost layer of Earth). A mineral can be an **element** (a pure substance) or a compound (two or more elements combined). Quartz, for example, consists of the elements silicon and oxygen. No other mineral has these elements in the same arrangement and proportion. Sulfur, copper, gold, and diamond are each made up of a single element.

If you were a prospector digging for gold, how would you know if you had found it? "No problem," you say? We all know what gold looks like — or do we? Another mineral, pyrite, which is more common than gold, is almost identical to gold in appearance (see Figure 5.3). The value of gold is high, while pyrite is almost worthless. How could you find out if that shiny, yellow metal you found is really gold? You could investigate its properties.

The Mohs Hardness Scale

You can scratch a piece of chalk with your thumbnail, but can you scratch other rock samples the same way?

How can a substance's "scratchability" be used for mineral identification? This is a question that a German scientist, Friedrich Mohs, asked himself in 1812. He developed a scale of ten minerals with a "hardness" value of 1 to 10 (see Table 5.1).

Suppose that you have an unknown mineral that looks like talc or corundum. Scratch it with your fingernail. If it is talc, it will scratch easily, because your fingernail has a hardness value of 2.5 on the scale — much harder than talc, which has a hardness value of 1. If it does not scratch easily, it cannot be talc and must be corundum instead. The hardness of corundum is more difficult to test because corundum is so hard — it is harder than most other objects and minerals. What could you use to test the hardness of corundum?

Diamond is the hardest mineral. One of its uses is shown in Figure 5.2. Tiny rows of diamonds are used to edge surgical scalpels, razor blades, computer parts, record needles, and dental drills. Diamond-tipped drill bits can cut through steel and rock.

Figure 5.2 Although the glass-cutter wheel looks like ordinary metal, its edge is actually embedded with a hard mineral, such as diamond.

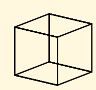
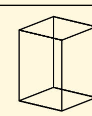
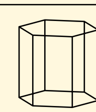
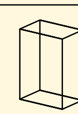
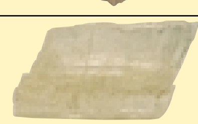
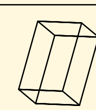
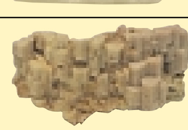
Table 5.1

The Mohs Hardness Scale		
Mineral	**Mineral hardness**	**Hardness of common objects**
talc	1 softest	soft pencil point (1.5)
gypsum	2	fingernail (2.5)
calcite	3	piece of copper (3.5)
fluorite	4	iron nail (4.5)
apatite	5	glass (5.5)
feldspar	6	steel file (6.5)
quartz	7	porcelain tile (7)
topaz	8	flint sandpaper (7.5)
corundum	9	emery paper (9.0)
diamond	10 hardest	carborundum sandpaper (9.5)

Crystals

There are over 3000 minerals. Other properties, such as crystal formation, help to identify them. **Crystals** are the building blocks of minerals. Crystals occur naturally and have straight edges, flat sides, and regular angles. Most of the minerals in Earth's crust grow into beautiful shapes according to the six different crystal systems shown in Table 5.2.

Table 5.2 The Six Major Crystal Systems

Mineral Examples		Systems	
	halite		cubic
	wulfenite		tetragonal
	corundum		hexagonal
	topaz		orthorhombic
	gypsum		monoclinic
	albite		triclinic

Other Clues to Mineral Identification

You have just seen that a mineral's crystal structure provides an important clue to its identity. What other clues can be used?

Lustre

Some minerals, such as gold and other metals, appear shiny — another clue to their identity. Others, such as talc, can appear dull. The "shininess," or **lustre**, of a mineral depends on how light is reflected from its surface. The surface of a mineral can reflect light in many different ways. If a mineral shines like a polished metal surface, it is said to have a metallic lustre. If a mineral has a duller shine, it has a non-metallic lustre.

Colour

Next to lustre, colour is one of the most attractive properties of minerals. The colour of a mineral can also be a clue to its identity. As in the case of gold and pyrite, however, colour alone cannot identify a mineral (see Figure 5.3). In addition, not all minerals are the same colour all the time. For example, the mineral corundum (made of aluminum and oxygen) is white when pure. However, when it contains iron and/or titanium, it is blue (and is called a sapphire). When it contains chromium, it is red (and is called a ruby).

Off the Wall

Sometimes people grow crystals in their bodies. An excess of chemicals can form kidney stones. Mineralogists are often consulted on to indentify the contents of the kidney stones.

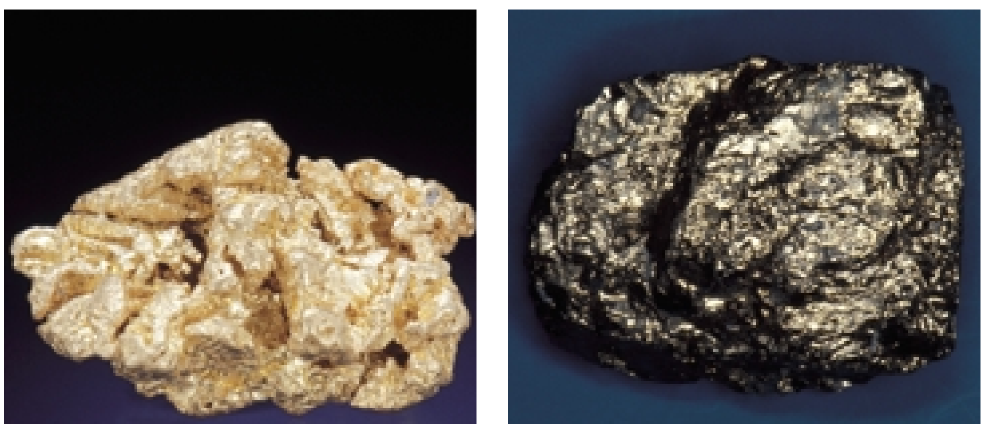


Figure 5.3 Both gold (on the left) and pyrite (on the right) are golden in colour. Which mineral properties could you use to tell them apart?

Skill FOCUS

To learn how to make circle graphs, turn to Skill Focus 10.

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus7

Find out which minerals are used in all Canadian coins by going to the web site above. Click on **Web Links** to find out where to go next. Make a circle graph for each coin to show the percentages of different minerals it contains.

Streak

When a mineral is rubbed across a piece of unglazed porcelain tile, as in Figure 5.4, it leaves a streak. A **streak** is the colour of the powdered form of the mineral. Look-alikes, such as gold and pyrite, can be distinguished using a streak test. Gold leaves a gold streak, while pyrite has a greenish-black or brown-black streak.

Minerals with a greater hardness than the porcelain tile (hardness value of 7) will not leave a streak. Such minerals, especially the black ones, can be crushed into powder. A surprising number of black minerals have lighter-coloured powders.

Graphite is a mineral used in pencils. Pencil marks are merely graphite streaks that are soft enough to be left on a piece of paper.

Figure 5.4 Colour is not always useful for mineral identification. Hematite, for example, can be dark red, grey, or silvery in colour. Its streak, however, is always dark red-brown.

Cleavage and Fracture

Hardness, lustre, colour, and streak are mineral properties that help geologists to identify many minerals fairly easily. Other properties provide further clues to their identity. Cleavage and fracture are two very useful ones.

The way a mineral breaks apart can be a clue to its identity. If it breaks along smooth, flat surfaces, or planes, it is said to have **cleavage**. Mica is an example of a mineral with cleavage (see Figure 5.5). Separating the layers of mica is like separating the pages in a book.

Not all minerals have cleavage. Minerals that break with rough or jagged edges have **fracture** (see Figure 5.6). Quartz is an example of a mineral with fracture. When quartz is hit with a hammer it breaks like glass.

DidYouKnow?

Transparency is another property of minerals. Hold a mineral up to the light. Can you see through it clearly? If so, it is transparent. Can you barely see through it? If so, it is translucent. If you cannot see through it, it is opaque.

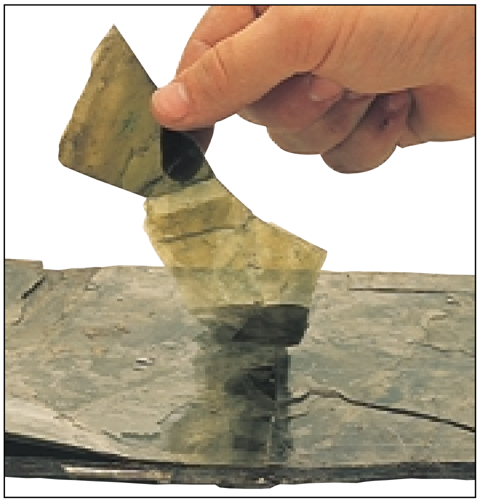


Figure 5.5 Mica is a group of minerals with a single cleavage direction that allows it to be pulled apart into sheets.

Figure 5.6 The picture above shows both the crystal faces of quartz and the fracture on the bottom of the specimen.

INQUIRY

INVESTIGATION 5-A

SKILLCHECK

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

A Geologist's Mystery

You are a geologist. You have just received a parcel from your company's field team in northern Alberta. The attached note reads, "New mines discovered. Enclosed are samples of minerals found there. Please identify." How can the Mohs hardness scale and the use of other mineral properties help you to solve the mystery?

Question

How can you identify different minerals? Which mineral properties will you examine, and in what order?

Safety Precautions

- Be careful when handling materials with sharp points or edges.
- Always wear safety goggles when working with acids.

Apparatus

numbered mineral samples
hand lens
iron nail
copper penny or piece of copper
utility knife
steel file
streak plate
glass plate
mineral guidebook
set of 3 or 4 local minerals

Materials

sandpaper
emery paper
Tables 5.1 and 5.2 (page 355)
10% hydrochloric acid (optional)

Procedure

1. Make a table like the one below.
2. **Record** the number of the first mineral sample in the first column of your table.
   (a) **Record** the mineral's colour. You may use the hand lens to take a closer look. If you see any distinguishing crystal shapes, as in Table 5.2, record your observations under "Crystal shape."

Computer CONNECT

If you have access to a computer, set up a spreadsheet to organize the data in Investigation 5-A.

Characteristics of Some Common Minerals

Mineral number	Colour	Crystal shape (if visible)	Lustre	Streak	Hardness	Other properties	Mineral name

(b) Examine the mineral and **record** its lustre.

(c) Examine the sample, and before you test the sample, **predict** what colour its streak will be. Then scrape the mineral once across the streak plate, and brush off the excess powder. **Record** the colour of its streak. If the mineral is too hard to leave a streak, write "none" in the space under "Streak."

(d) Examine the sample, and before you test the sample, **predict** its hardness. Scratch the sample with your fingernail. If your fingernail does not leave a scratch, continue with the penny, and on up the scale, until something leaves a scratch. Use the hardness table on page 355.

(e) Record any other properties such as cleavage, fracture, and transparency under "Other properties."

(f) Your teacher may give you some 10% hydrochloric acid (HCl) to test a few of your samples. Be sure to wear your safety goggles. Rinse the specimens with water and dry them after you have used the acid.

3. Repeat all of step 2 for the remaining mineral samples.

4. Try to give each mineral a name by using a mineral identification chart provided by your teacher or information collected through your own research. Also use the Mohs hardness scale and other information from this Topic.

5. Wash your hands thoroughly after completing this investigation. Clean the streak plate. Be sure all mineral specimens are returned to their proper places.

Analyze

1. Before testing, which minerals looked the same?

2. **(a)** Which mineral was the softest? Which was the hardest?
   (b) Your predictions were based on appearance only. Were your predictions supported by your observations? Explain.

3. **(a)** Which minerals were the same colour as their streak or powder?
   (b) Which streaks surprised you?

4. Which other features or properties helped you identify samples?

Conclude and Apply

5. Were you able to identify all of the mineral samples? If not, can you suggest some other tests for further investigation?

6. **(a)** Which property was the most useful for identifying a mineral? Why?
   (b) Which property or properties were not very useful for identifying a mineral? Why?

7. How much does hardness seem to affect the similarity of a mineral's colour to the colour of its streak?

8. **Design Your Own** Write a procedure outlining the order for testing mineral properties in further investigations.

Extend Your Skills

9. Obtain a Mohs scale set of minerals. Use these minerals to test the hardness of your test samples more accurately. Based on your observations, create a definition of "hardness."

10. Your teacher will give you several minerals collected from your local area. Can you identify them?

Find Out ACTIVITY

Dig for Treasure

Where are minerals found in Canada?

Materials

mineral map of Canada

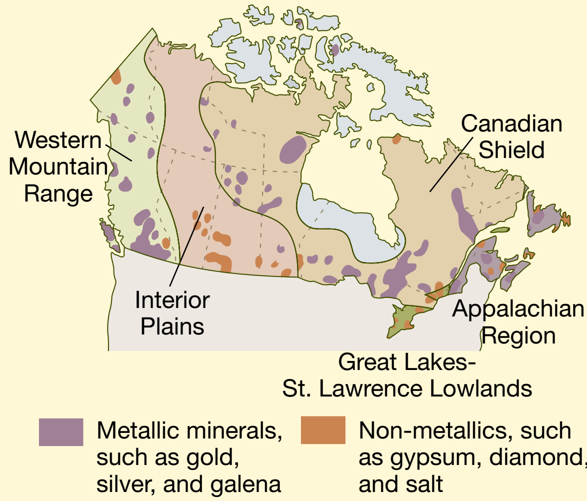
research materials

Procedure

1. Your teacher will give you a map that shows where minerals are found all across Canada.

2. In a group, research and list the minerals found in Canada.

3. Choose one mineral, and research its characteristics: Where is it found? How is it mined? What is it used for?



What Did You Find Out?

Suppose you were meeting with an industrial representative to discuss the mineral you researched. Explain why Canada is a good place to develop an industry that needs a supply of this mineral.

Cool Tools

How many inventions can you name that have crystals in them? Some of the varied uses for crystals include control circuits, credit cards, machines, medicine, electronics, and communication. Synthetic crystals are built into almost every electronic or optical device made today. There is a huge demand for perfect crystals. Natural crystals can contain impurities, so synthetic crystals from minerals such as silicon have been created. In fact, it is so important to have perfect crystals that experiments have been done in space to determine whether crystals form more perfectly in weightless conditions.

TOPIC 1 Review

1. Define the following: rock, mineral, element.
2. List the properties that are used to identify minerals.
3. **Apply** Suppose that you find a white, non-metallic mineral that is harder than calcite. You identify the sample as quartz. What can you infer based on your observations?
4. **Thinking Critically** Many gemstones are polished so much that you can no longer detect a crystal shape. What could you do to a gemstone to determine its crystal shape?

TOPIC 2 Rocks and the Rock Cycle

Rock Families

As you have seen, rocks are made of minerals. How do minerals combine to form rocks? Some of these processes are rapid. Others take millions of years.

Scientists have grouped rocks into three major families, or types, based on how they form. The three families are igneous, sedimentary, and metamorphic rocks. Each can usually be identified by its appearance.

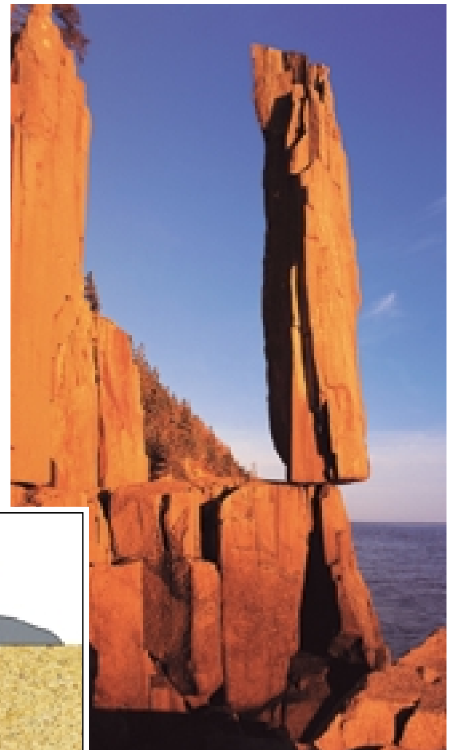


Figure 5.7 Basalt is an example of igneous rock formed on Earth's surface. The "Balancing Rock" on Long Island, near Tiverton in Nova Scotia, is a spectacular basaltic sea stack. How might it have formed?

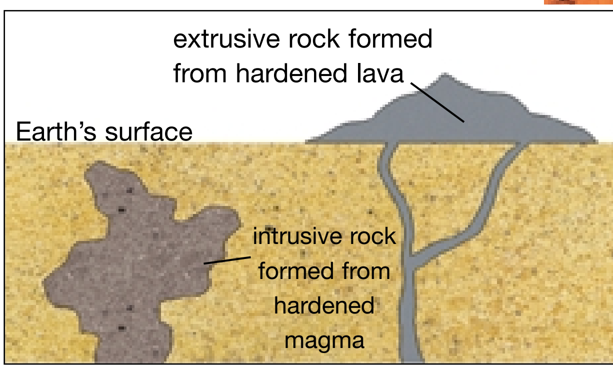


Figure 5.8 This diagram shows two main types of igneous rock and how they are formed.

Word CONNECT

The word "igneous" comes from the Latin word, *ignis*, meaning "fire." Write what you think the word "ignite" means. Then check a dictionary to see how close you were.

Igneous Rock

Igneous rock forms when hot magma or lava cools and solidifies. **Magma** is melted rock found below Earth's crust, where temperatures and pressures are high. Any rock heated at great depths can melt into magma. Under high pressure, the magma can push away or dissolve the surrounding rock, making room for itself. Sometimes fingers of hot magma push up to the surface through cracks in Earth's crust.

Geologists classify igneous rock based on whether it was formed above or below Earth's surface. Magma can cool and harden below the surface. The resulting rock is called **intrusive rock**. Granite is an example of an igneous rock that formed very deep and very slowly in Earth's crust.

When magma breaks through Earth's surface, in the form of a volcanic eruption, it is called **lava**. Rock that forms when lava cools on Earth's surface is called **extrusive rock** (see Figure 5.9).

Magma can contain crystals. The appearance of the crystals in igneous rock samples can differ depending on how fast the rocks cooled. Write a hypothesis about the relationship between speed of cooling and size of crystals. You can test it in the next investigation.

Figure 5.9 Obsidian is an example of extrusive rock that forms when lava cools rapidly.

INQUIRY

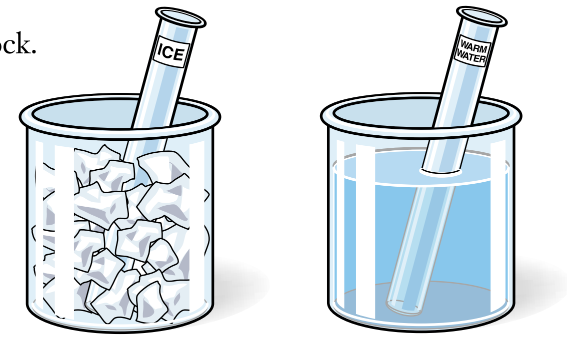
INVESTIGATION 5-B

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

Cool Crystals, Hot Gems!

Can you turn small crystals into larger, dazzling gemstones? You might, if you could re-create the formation of igneous rocks and, at the same time, control the conditions for crystal growth.

You can use a liquid solution to represent the melted rock. The crystal size and rate of cooling represent igneous rock formation.



Question

How does the rate of cooling affect crystal size?

Hypothesis

Formulate a hypothesis about how the rate of cooling affects crystal size.

Safety Precautions

- Heat is used in this activity. Handle heated items with great care.
- Do not touch copper (II) sulfate. Wash your hands thoroughly if you touch it accidentally.
- Be careful pouring hot liquids.
- Wash your hands after completing each day's activity.

Apparatus

2 test tubes
1 beaker (250 mL)
2 beakers (400 mL each)
100 mL graduated cylinder
stirring rod
hot plate
balance
scoopula
watch glass
hand lens
tongs or hot mitts

Materials

40 g copper (II) sulfate (powder or granules)
ice (crushed or broken)
masking tape

Procedure

Day One

1. Use the masking tape to make labels for two test tubes. On one, write your name and the word "ice." On the other, write your name and the words "warm water." Labels are necessary because the ice will eventually melt. Place the labels near the rims of the test tubes.
2. Pour 50 mL of water into the 250 mL beaker.
3. Add 40 g of copper (II) sulfate to the beaker. Stir carefully.

Skill FOCUS

To review safety symbols, turn to Skill Focus 1.

4. Place the beaker on the hot plate and gently heat. Do not let the solution boil vigorously. Continue stirring until all of the copper (II) sulfate has dissolved.

5. Use the mitts and carefully decant (pour) some of the solution into each test tube.

6. Place the test tube marked "ice" into a beaker of crushed ice. Place the test tube marked "warm water" into a beaker of warm water.

7. Leave undisturbed for 24 h.

8. If possible, **observe** when the crystals start to grow.

Day Two

9. Using a scoopula, gently pry the crystals loose from the test tubes. Place them on a watch glass.

Skill FOCUS

To learn how to do scientific and technological drawing, turn to Skill Focus 11.

10. **Examine** the crystals from each tube, using the hand lens.

11. **Make a drawing** in your notebook of what you see. **Describe** the crystals from each test tube.

12. Recycle the crystals and extra solution into an appropriate container supplied by your teacher. Chemicals should never be washed down the sink.

Analyze

1. Which beaker formed larger crystals?
2. Did you observe which beaker took longer to form crystals? If so, which one did?
3. For a fair comparison of crystal size based on rate of cooling, all of the other conditions had to be the same, or controlled. List all of the conditions, or variables, that were controlled for each beaker in this investigation.
4. What was the **manipulated variable** (the feature you changed)?
5. What was the **responding variable** (the feature that changed as a result of the experiment)?

Conclude and Apply

6. How did the rate of cooling affect the size of the crystals?
7. Which sample of crystals could represent extrusive rock? Why?
8. What is more likely to happen to crystal size in intrusive rock?
9. Where might larger gems be found, on the surface of Earth or deep in the ground?

Extend Your Knowledge

10. Repeat the experiment, but divide your crystal solution evenly into *three* beakers. As before, place one beaker in ice and one in hot water. Leave the other beaker at room temperature. After 24 h, **observe** all three. Are the room temperature crystals different from the other two? If so, **explain** (**and draw**) how they are different. If the crystals do not appear to be different, which of the other crystals, the hot or cool ones, do they more closely resemble? The ice water cooled crystals represent crystals found in extrusive rock. The hot water-cooled crystals represent crystals found in intrusive rock. What natural conditions might the room-temperature crystals represent?

Sedimentary Rock

Figure 5.10 In this gorge, layer upon layer of rock is visible. Rocks that break away from this rock face will also have layers. These layers provide clear evidence of how sedimentary rock forms.

Sedimentary rock makes up about 75 percent of all the rock we can see on Earth's surface. As its name indicates, **sedimentary rock** is made from **sediment** — loose material, such as bits of rock, minerals, and plant and animal remains. These sediments become closely packed in layers and cemented together. This arrangement in visible layers is called **stratification** (see Figure 5.10).

Most often stratification happens in lakes and oceans. The larger, heavier fragments settle first and end up near the bottom. Sometimes wind, ice, or gravity moves sediment to a place where it settles. Sediment slowly settles on top of other sediment, forming layers. How does settled sediment become rock? Each layer of sediment is squeezed together by the weight of other sediment and the water on top of it. This process of squeezing together is called **compaction**.

Figure 5.11A Shale, or mudstone, is sedimentary rock formed from fine grains of clay or mud.

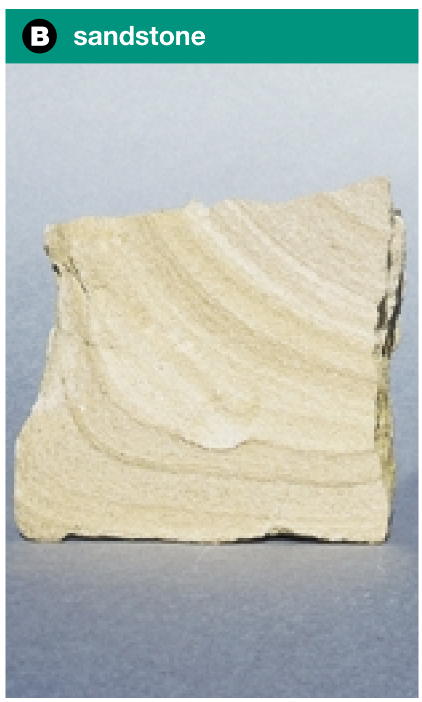


Figure 5.11B A harder, rougher rock called sandstone is formed from larger granules of sand, usually made of quartz.

Figure 5.11C Rounded pebbles and small stones, cemented together, form a type of rock called conglomerate.

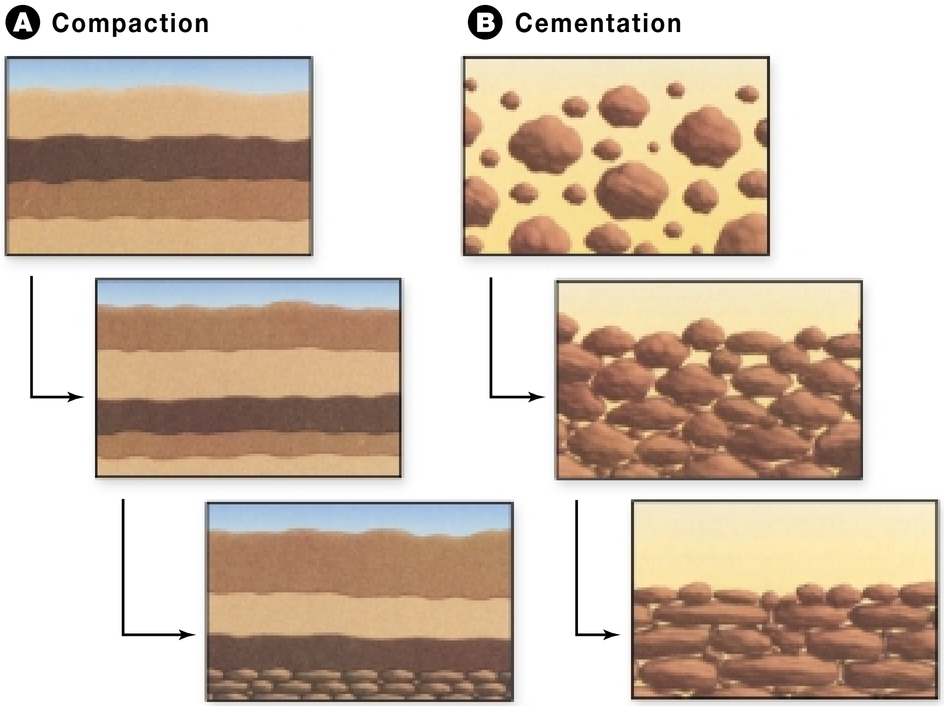


Figure 5.12 The process of compaction is shown by A. Cementation is shown in B. What similarities can you see between the two processes? What differences can you see?

DidYouKnow?

Throughout Canada, enough limestone and sandstone exist to be quarried and sold. Limestone is easy to cut and shape. Sandstone is easily mined. Both these rocks are useful for constructing and decorating buildings. Crushed limestone is used in road construction, and it is also used in the pulp and paper industry. Some schools are made from sandstone. Look on the Internet to find out where limestone and sandstone quarries exist in Alberta.

In some rocks, minerals dissolve as the water soaks into the rock, forming a natural cement that sticks the larger pieces of sediment together. This process is called **cementation**. The appearance of a sedimentary rock can reveal what type of sediment formed it (see Figure 5.13).

Limestone is one of the most common and useful sedimentary rocks. It is also unique because it can include fossils, the remains of plants and animals. For this reason, limestone is in a separate class called organic sedimentary rock. Ocean animals, such as mussels and snails, make their shells mainly from the mineral calcite. When the animals die, their shells accumulate on the ocean floor, where most sedimentary rock is born.

Figure 5.13 In this sedimentary rock, the layers of sediment were formed by both compaction and cementation.

Figure 5.14 Pressure is one condition that causes metamorphic rocks to form. When pressure is applied to granite (A), the mineral grains are flattened and aligned. This results in the formation of gneiss (B). It is a long, slow process.

Metamorphic Rock

Looking Ahead

How could you investigate the processes of rocks changing form? Record your ideas. You may wish to investigate rocks as part of "A Creative Crust" at the end of the unit.

Once a rock is made, can it change its form? The answer is, yes, it can. Geologists have found rocks that resemble certain igneous and sedimentary rocks but differ from them in significant ways. They know that these rocks must have formed deep inside Earth.

The third family of rock is called **metamorphic** (meaning "changed form") **rock**. Metamorphic rock may be formed below Earth's surface when extremely high pressure and heat cause the original rock, or **parent rock**, to change form. The type of rock formed depends on the amount of pressure applied. Shale, for example, can undergo several changes as pressure and temperature increase over time. This change results in the transformation of shale → slate → schist.

Figure 5.14 shows how granite can be changed to form another rock, gneiss. Igneous granite can lie in large bodies, deep below Earth's surface. You can see what can happen to the mineral grains of granite as the pressure of heavy, overlying rock squeezes them closer together. Gneiss, the altered rock in this process, is an example of a metamorphic rock. Slate, schist, and marble are other examples of metamorphic rocks.

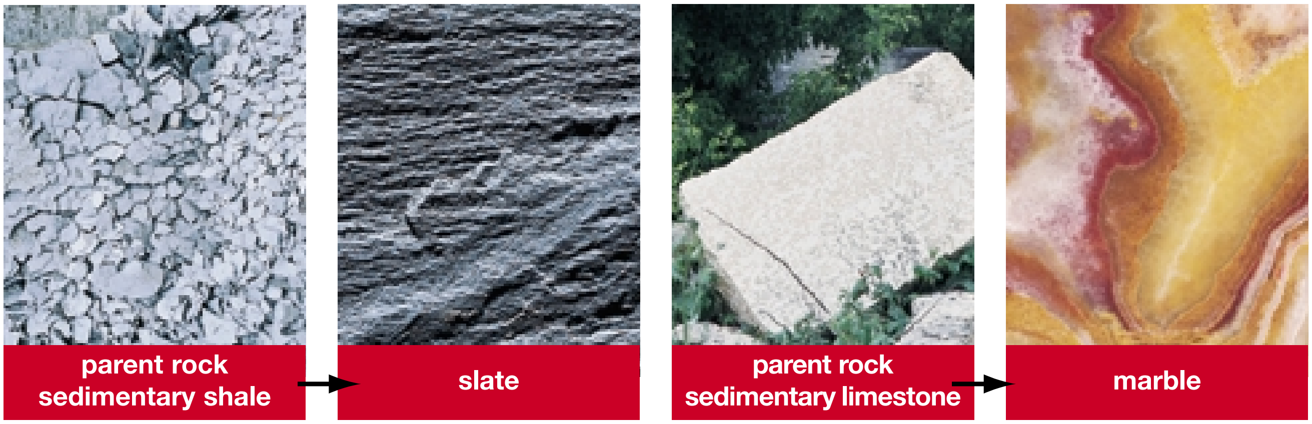


Figure 5.15 Metamorphic rock looks different from its parent rock, but the rocks have common characteristics. What characteristics of shale can you see in slate? Which properties of limestone might you find in marble?

Metamorphic rock can change so completely that it no longer looks like the parent rock. There are enough common characteristics, however, that geologists know the two are related. For example, limestone and marble look different, but both have a hardness value of 3, and both are made of the mineral calcite. Both limestone and marble react with dilute hydrochloric acid.

Figure 5.16 Rock can be a strong and beautiful building material. However, it is heavy as well as durable. A product called Granirex has been developed that is made from crushed granite and is less than 1 cm thick. What uses might this product have?

Figure 5.17 When pressure is applied to shale, it can change into slate. Which characteristics make slate useful for shingles and patio stones?

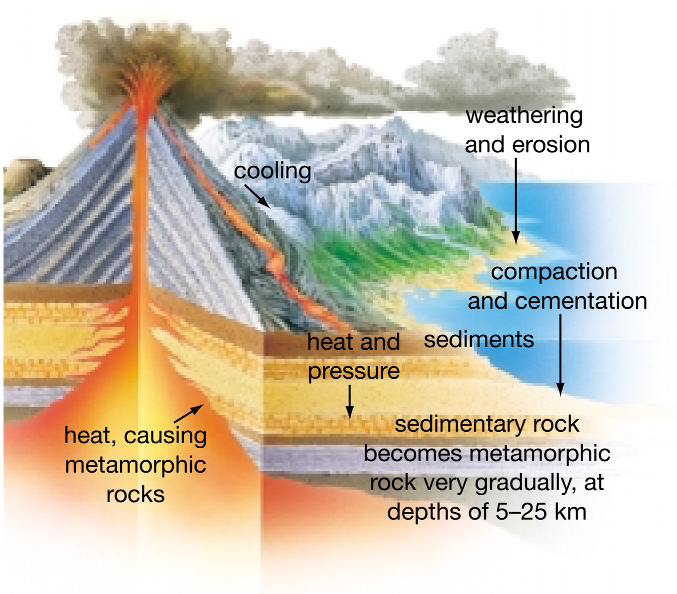


Figure 5.18. This model shows part of the rock cycle. Note that the diagram is not to scale. The production of new magma occurs 25–40 km below Earth's crust.

The Rock Cycle

Much of what you have learned so far in this section suggests that rocks are constantly changing. For example, igneous rock is formed when magma or lava cools. Rock fragments and sediments can be compacted and cemented to form sedimentary rock. Both igneous and sedimentary rock can form metamorphic rock under high pressure and heat (see Figure 5.18).

Do the changes stop there? No, rocks continue to change in an ongoing process called the **rock cycle** (see Figure 5.19). Does the magma ever run out? As rocks sink back into the depths of Earth's crust, the heat and pressure can turn them back into magma. As well, all rocks can be broken down to form smaller rocks, fragments, and sediment. Although human activity is responsible for some of the breakdown process, most of it occurs naturally.

Pause & Reflect

How could you make a model of the rock cycle? You might choose this as an end-of-unit project. Think about different ways you could represent the processes that change rocks.

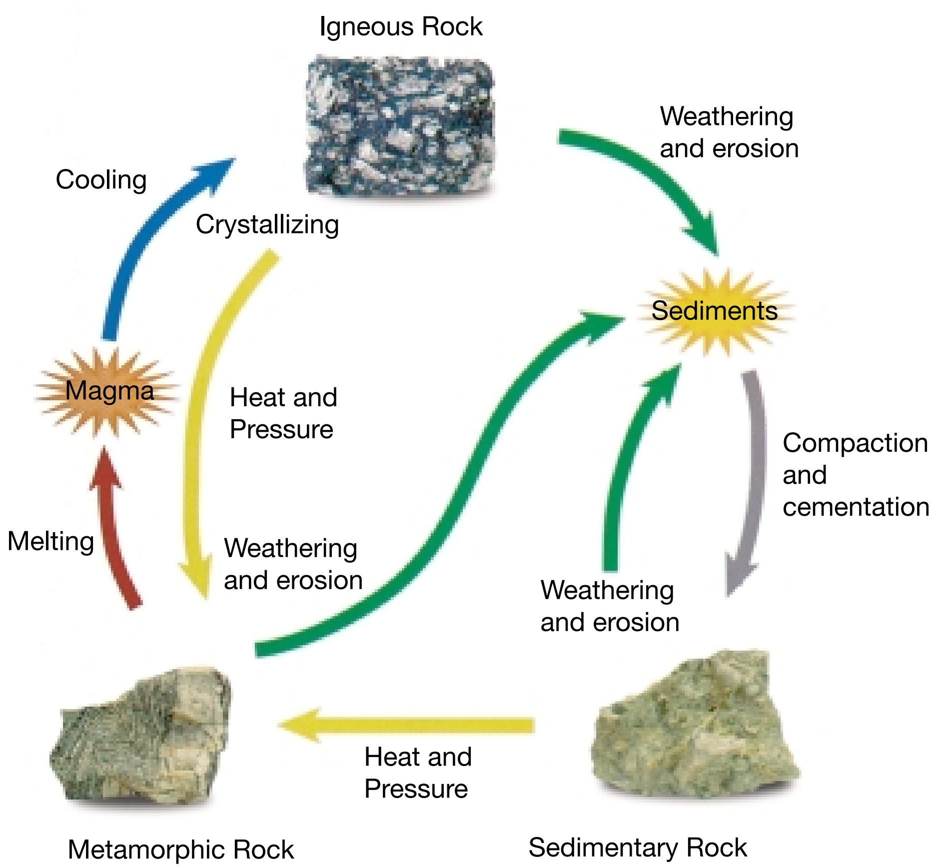


Figure 5.19 There is not a set order to the changes rocks undergo in the rock cycle. Notice the various shortcuts and detours as rocks are weathered, consolidated, buried, melted, and solidified.

Techniques for Identifying Rocks

Rocks can sometimes be identified by appearance. However, if they have been exposed to rain, wind, and extreme temperatures, their colour and appearance may have changed. One step in identifying rocks is to determine from which mineral or combination of minerals they are made. The minerals in many rocks are so fine-grained that they must be observed under a microscope to tell them apart (see Figure 5.20).

Figure 5.20 This basalt is made from magma that contained solidified crystals of minerals. The crystals can be seen clearly when a thin piece of the rock is viewed through a high-powered microscope.

DidYouKnow?

Some rocks come from outer space. Meteorites are pieces of rock and iron that have a fusion crust and smooth pits. They are often strongly magnetic. Billions of tiny meteorites have fallen to Earth. Evidence indicates that Earth, the Moon, and meteorites all formed at the same time, when the solar system formed. Although collisions in space and other processes might have altered the composition of some meteorites, the majority show strong chemical similarities to Earth rock. So, even though some rocks come from outer space, they are related to Earth rock.

Find Out ACTIVITY

Build Your Own System

Scientists have classified all rocks into three categories: igneous, sedimentary, and metamorphic. These are not categories based on colour or shape, but on how they are formed. What are the characteristics of each type? How can you determine in which category a rock belongs?

Materials

a set of rocks, including rocks from your geographic area

hand lens or binocular microscope

Procedure ✷ Initiating and Planning

Research the three categories of rocks and create your own classification system based on your investigations. The more research you do the easier your task will be. These points may help you:

- Sedimentary rocks are sometimes made of small particles compacted or cemented together.
- Igneous rocks often have small crystals of minerals visible and the minerals appear to be interlocking.
- Metamorphic rocks are created under a great deal of heat and pressure, causing them to have thin, flat layers that are easily visible.

You now have a good start on the classification system. Using the research you have gathered, try to classify each of the rocks into one of the three groups. Do not be discouraged if some rocks are difficult to classify. The system you develop is more important than how accurately you sort the rocks.

What Did You Find Out? ✷ Analyzing and Interpreting

1. Which characteristics did you use to classify igneous rocks?
2. Which characteristics did you use to classify sedimentary rocks?
3. Which characteristics did you use to classify metamorphic rocks?
4. Were there any rocks you were unable to classify? If so, describe their characteristics.

PROBLEM-SOLVING

INVESTIGATION 5-C

SKILLCHECK

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

Hot Rocks

If you've ever built a campfire in a rock pit, you may have noticed how hot the rocks became. How long did they stay warm after the campfire was extinguished? The heat capacity of rocks is often put to use in saunas and gas barbeques. Heat capacity is a measure of how easily a material can be heated or cooled. How can you measure the heat capacity of rocks?

Question

Which variables affect the heat capacity of rocks?

Safety Precautions

- Handle containers of boiling water with care.

Materials

a variety of sizes and types of rocks (fist size and smaller)
hot plate
tongs
large beakers or tin cans
thermometer

Procedure

1. You will be heating rocks, one at a time, in water to the boiling point. Then you will transfer them to a second container of water and measure the temperature rise in the water. **Predict** which rock will cause the greatest increase in temperature. **Explain** why.

2. There are a number of variables that will affect your results, including size and type of rock, how long you boil each rock, the amount of water in your second container, the starting temperature of your second container of water, and so on. **Discuss** the different variables with your group, then write out a step-by-step procedure of what you plan to do.

3. Have your teacher approve your procedure. Obtain the necessary equipment and carry out the investigation. **Record** your results. **CAUTION** Use tongs to carefully handle the hot rocks. Gently lower the rocks into the beakers. If you drop the rocks, the beakers will crack.

Analyze

1. Make a graph of your results, showing the change in temperature for each sample used.

2. **Compare** your group's results with those of other groups. Did all groups have the same results? If not, what could be causing the differences?

Conclude and Apply

3. Summarize the evidence you found. Does it support your prediction? Explain why or why not.

4. Which characteristics of rocks affect their heat capacity?

5. If there were any rocks that could not be used in the experiment, what characteristics made them unsuitable? What would you predict their heat capacity might be?

6. How could you change your experiment to take other characteristics into consideration?

Sediment and Soil

Earlier in this Topic you learned that sediment can be compacted or cemented to form sedimentary rock. The slow process of rock formation takes thousands of years to occur. What happens to sediment in the meantime? Some sediment is carried to the ocean. Other sediment becomes soil.

How does soil form? Earth is covered by a layer of rock and sediment. Plants and animals add organic matter, such as leaves, twigs, and dead worms and insects. The organic matter creates spaces that can be filled with air or water. All of these combine to form soil, a material that can support plants (see Figures 5.21A, B, and C). Climate, the type of rock, and the amount of moisture influence soil formation. Even the slope of the land can influence soil formation.

In addition to these non-living factors, the small living creatures that invade the soil can speed up the process of soil formation. As you saw in Unit 1, soil is a complex ecosystem, where small rodents, worms, insects, algae, fungi, bacteria, and decaying organic matter all live in harmony. Most of the decaying matter is made up of dead plant matter, called **compost**. It mixes with other matter to form the dark-coloured portion of the soil called **humus**.

Humus is rich in nutrients such as nitrogen, phosphorus, potassium, and sulfur. These nutrients dissolve in water in the soil. Plants absorb the nutrient-rich water through their roots. Humus also promotes good soil structure and helps keep the water in the soil. As worms, insects, and rodents burrow throughout the soil, they mix the humus with the fragments of rock. In good-quality soil, there are equal parts humus and broken-down rock.

A **fertile** soil is one that can supply nutrients for plant growth. Soils that develop near rivers are generally fertile. Some soils may be nutrient-poor and have low fertility, such as the eroded, rocky soil of steep cliffs and roadsides.

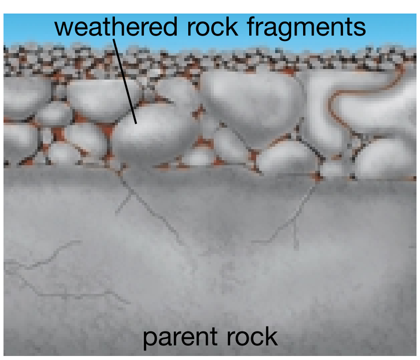


Figure 5.21A: Weathered rock fragments contain many cracks and spaces, providing areas that air and water can fill.

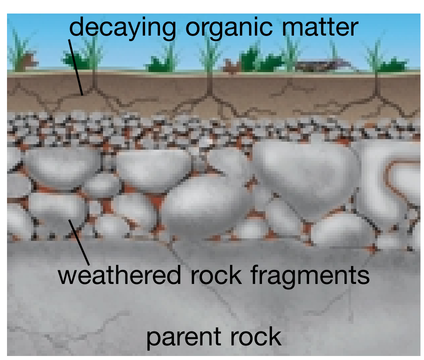


Figure 5.21B: Immature soil can support small hardy plants that attract insects and other small animals. Over time, dead plant and animal material builds up, and bacteria and fungi cause them to decay. The decaying organic matter forms a layer on top of the weathered rock.

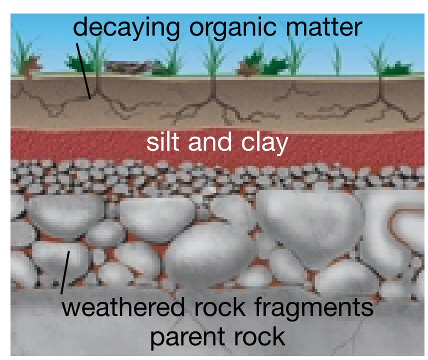


Figure 5.21C: Mature soil contains mineral-rich clay on top of weathered rock. The clay forms when water carries the minerals away from the decaying organic matter and mixes with the weathered rock fragments.

Soil Profiles

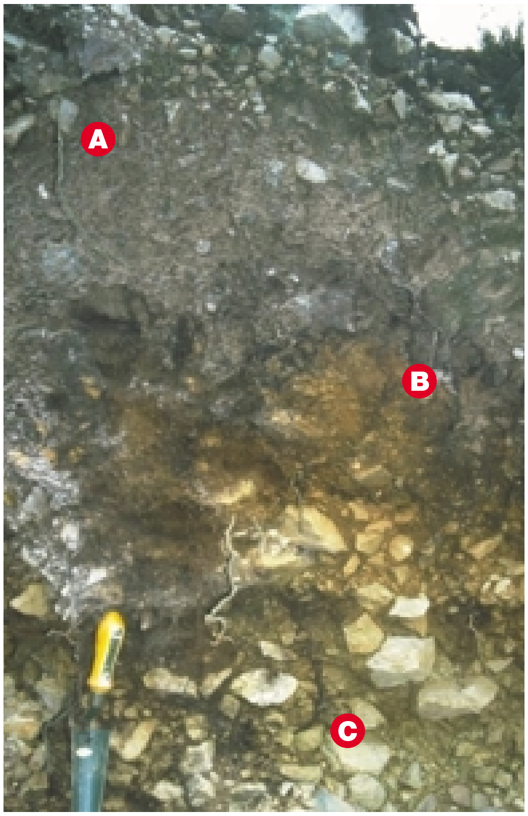


Figure 5.22 Exposed soil profile of an eroded hillside

Soils can take thousands of years to form. They can range in thickness from 60 m in some areas to just a few centimetres in others. Soil varies in structure and appearance, depending on its depth. Scientists have exposed layers of soil with clear differences in appearance and composition. The layers of soil make up a **soil profile**. The soil profile in Figure 5.22 illustrates how the layers are divided. The layers show different degrees of soil evolution.

Examine Figure 5.22. The top layer (A) is called **topsoil**. It consists of dark-coloured, rich soil that contains humus and small grains of rock. It has undergone the greatest number of changes from the underlying rock layer.

The next layer (B) is generally lighter in colour because there is little or no humus, and it contains minerals that have leached from the top layer. **Leaching** is the removal of soil materials dissolved in water. Water reacts with humus to form an acid. Acid can dissolve elements and minerals from upper layers and carry them through the spaces in the soil to lower layers.

The bottom layer (C) contains partly weathered rock and minerals leached from above. This layer most closely resembles the parent rock below and is at the beginning of the long, slow process of rock evolving into soil.

Pause& Reflect

Imagine trying to grow a flower on a rock. In your Science Log, list and explain the reasons why this would be difficult and why it would be easier if you used soil.

TOPIC 2 Review

1. What is the composition of rocks?
2. Name and describe the three families of rocks. Give an example of each.
3. Describe the rock cycle, and explain how rocks may change with time.
4. **Analyse** How does leaching fit into the rock cycle?
5. **Thinking Critically** A core sample was taken from the bottom of a lake that contained first a layer of sandstone, then a layer of shale, and finally a layer of conglomerate on top. Why could these sediments not have settled at the same time? Explain what you think happened.
6. **Thinking Critically** How could you explain the presence of an igneous rock in a bed of sedimentary rock?

TOPIC 3 Erosion

Erosion is the movement of rock and mineral grains from one place to another. Sediment comes from larger rocks that have broken down or worn away through **weathering**. Rocks can be weathered mechanically, chemically, or biologically.

Figure 5.23 Many thousands of years of rain, wind, and ice have eroded this rock in Alberta's Dinosaur Provincial Park. How do you predict this rock will look in 100 years? in a thousand years? Sketch your ideas in your Science Log.

Mechanical Weathering

Mechanical weathering is the physical break-up or disintegration of rocks. For example, gravity causes rocks to fall down a cliff and break apart. Rocks rolling down a slope or in a fast-moving stream rub and bump against each other, becoming smoother and more rounded.

Temperature change can also cause mechanical weathering. In early spring or during winter warm spells, the days are warm, but night time temperatures still dip below freezing. This time of year is known as the freeze-thaw period, and it can continue for several weeks. During the freeze-thaw period, snow and ice melt in the daytime, allowing water to seep into cracks in rock. At night, when the temperature falls below 0°C, the water freezes and expands, pushing the cracks wider apart. Each day, more water fills up the cracks. Each night, it freezes and pushes the rock pieces farther apart. Finally the rock breaks apart. If a rock has many cracks it can seem to crumble at the end of a freeze-thaw period. This entire process is called **frost wedging** (see Figure 5.24). Materials other than water, such as crystal salts, can wedge rocks apart as well.

Wind and water wear away the surfaces of rocks and carry the pieces to another place, where the pieces build up. Mechanical weathering is the part of the process responsible for "wearing away." **Sedimentation** is the part of the process responsible for "building up."

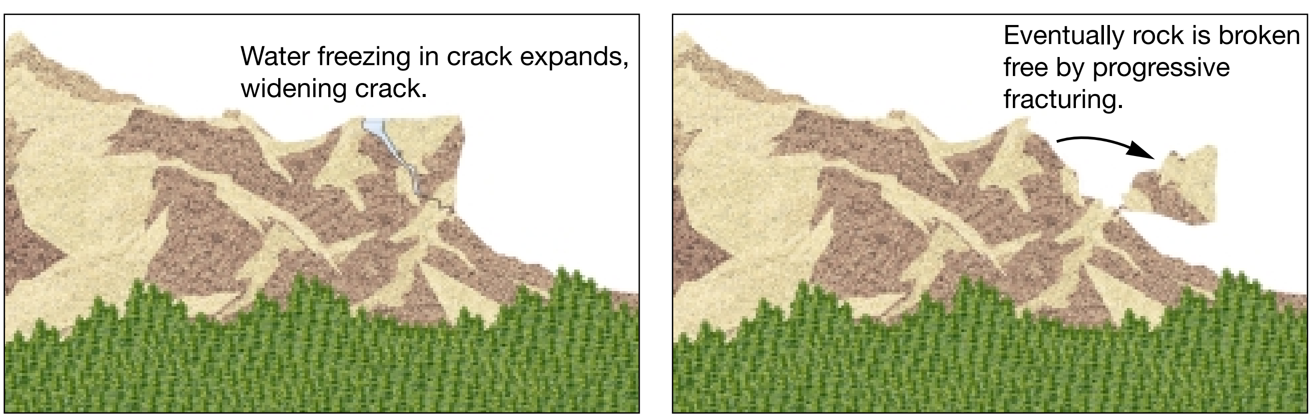


Figure 5.24 Frost wedging is caused by water that repeatedly freezes and thaws.

Pause&Reflect

Road repair crews are a common sight each spring. Use your understanding of weathering processes to explain why our roads are in need of repair at this time of year. Write your ideas in your Science Log.

Chemical and Biological Weathering

Chemical reactions can speed up the process of erosion. **Chemical weathering** breaks down minerals through chemical reactions. Some material may be dissolved. Other material may be weakened. Rocks react with water, with other chemicals dissolved in water, or with gases in the air. An example of a chemical weathering is acid rain, which contains dissolved chemicals from air pollution. Acidic rainwater reacts with some rocks, such as limestone and dolomite. The rock material dissolves easily in the acidic water and washes away (see Figure 5.25).

Figure 5.25 Many old and valuable marble statues and buildings in Europe and Asia have suffered the effects of acid rain and have had to be repaired. The Parthenon in Athens, Greece is shown here under reconstruction.

Biological weathering is the physical or chemical breakdown of rock caused by living organisms, such as plants, animals, bacteria, and fungi. Physical breakdown occurs, for example, when a plant root wedges into a rock by forcing its way into a crack. As the root grows and expands, so does the crack, and the rock is pushed apart until it eventually crumbles and breaks. Acidic fluids produced by plant roots, bacteria, fungi, and some insects and small animals can cause chemical reactions. As the rock slowly dissolves and flows away with rainwater, cracks and crevices increase in size until the rock finally breaks apart (see Figure 5.26).

The physical environment includes natural processes such as weathering, earthquakes, and volcanic eruptions. If the physical environment changes, the rocks in it will also change. Mechanical, chemical, and biological weathering work together constantly to change the landscape around us.

Figure 5.26 Tree roots work their way into cracks and, as they grow, eventually break up the rock.

INQUIRY

INVESTIGATION 5-D

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

Rocks That Fizz

Question

Rain and ground water can be acidic. When acids react with certain rocks, carbonates are dissolved and CO_2 gas is produced. Which rocks are affected by acids?

Hypothesis

Formulate a hypothesis about which rocks would be affected by acid rain or ground water.

Safety Precautions

- Take care handling acids. Wipe all spills immediately with a neutralizer or plenty of water. Wash your hands with cool water. Report spills to your teacher.

Apparatus

watch glass
tongs or tweezers
eye dropper
dropper bottle

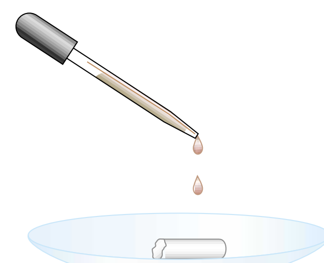
Materials

10% hydrochloric acid
small pieces of rock
two unknown rock samples from your geographic area

Procedure

1. **Make an observation chart** like the one shown here.
2. Obtain a few of the specimens to be tested.
3. **Observe** the physical characteristics, such as colour, texture, and other properties under "General observations."
4. Put a specimen on a watch glass.
5. Put on your safety goggles and place a few drops of 10% hydrochloric acid on the specimen. **Observe** the results. **Record** your observations on your chart.
6. Rinse the specimen under the water tap. Dry the specimen and return it to the proper place.
7. Repeat steps 4–6 for the other specimens.

Name	General observations	Hydrochloric acid test
granite		
chalk		
sandstone		
shale		
marble		
limestone		
unknown rock A		
unknown rock B		



Analyze

1. What was the **manipulated variable** (the feature you changed)?
2. What was the **responding variable** (the feature you observed changing)?

Conclude and Apply

3. What can you conclude from your observations about the types of rock that would be most affected by chemical weathering?
4. Which rocks were not affected by chemical weathering?
5. **Predict** the names of the unknown rocks.

Extend Your Skills

6. **Formulate** your own definition of "chemical weathering."

The Changing Surface of Earth

Figure 5.27 The scrape marks, called striations, indicate the presence of a glacier. Notice the smooth polish.

Glaciers, gravity, wind, and water are agents of erosion. Some changes, such as those caused by glaciers, happen very slowly over many thousands of years. These small changes are called gradual change. Changes such as flash floods, landslides, and rock slides are called sudden change.

There are many glaciers in the mountain ranges of Western Canada. Glaciers have been formed by the weight of layers of snow piling up year after year. When glacier ice spreads out over the top of a slope, the force of gravity causes it to flow down the slope. Geologists study the effects of glaciers, to learn more about past periods of glaciation. During the Ice Ages, sheets of ice covered much of the northern hemisphere.

As glaciers pass over land they erode it, changing its features. Rocks frozen in the glaciers scrape across the bedrock, wearing it down and making scratches called striations. Eroded sediments get pushed in front of a glacier and piled up along its sides. These are called moraines. When glaciers begin to melt and retreat, the meltwater forms channels and deposits sediment in new locations. Large rocks called erratics can be left behind, many kilometres from their source.

Figure 5.28 As the glacier advances, rocks, sediments, and trees are pushed along in front of it.

Figure 5.29 The "Big Rock" near Okotoks, Alberta, is an example of an erratic that has been left behind by a glacier. It might be the largest erratic in the world. Which characteristics would you use to determine its original location?

Figure 5.30 These great piles of moraine were pushed aside by a glacier in Banff National Park only a few decades ago. How many decades do you think it will be until weathering creates enough soil for plants to grow here?

Gravity is one of the forces responsible for landslides and rock slides. Some steps can be taken to protect areas where people live from the effects of water erosion, rock slides, and landslides. Retaining walls can be built, drainage can be improved, and dangerous slopes can be monitored. But slope conditions can change suddenly and unexpectedly.

Wind can also erode rock particles. When it blows across dry ground, wind picks up loose sediment, such as clay, silt, and sand. These windblown particles strike rock and wear it down by **abrasion**. Extreme examples of wind erosion include sand deserts. Wind erosion can be slowed or stopped by planting of vegetation, contour farming, and reduced tillage.

Figure 5.31 The most disastrous rock slide in Canadian history was the Frank Slide in 1903 in Alberta's Crowsnest Pass. Over 80 million tonnes of rock crashed down the side of Turtle Mountain, burying part of the town of Frank. More than 70 people died in the disaster. The slide lasted less than 100 s. Scientists are studying the Frank Slide using new technology and sound waves.

Water in Motion

Water in motion is one of the most powerful causes of erosion. Sudden changes can occur as rivers erode their banks and fast-moving flood waters carry away large amounts of soil. Heavy rain can disturb the stability of a slope, detaching solid blocks of rock and causing landslides. Oceans, seas, and large lakes erode their shorelines. When waves hit cliffs and shores, rocks are broken down and land is eroded. In some places this happens quickly. A coastline can lose several metres every year to erosion.

Slower, incremental changes happen as streams and rivers carry rock fragments along in the water. The fragments rub against each other and the riverbed as they are bounced along and they are gradually rounded and worn down. Rivers can cut straight into rock to form canyons or gorges and steep V-shaped valleys (see Figure 5.32). Eventually the sides of the valleys are worn down by weathering. When a river becomes mature, it cannot dig its channel any deeper. Instead it might start to meander, curving its bed from side to side (see Figure 5.33).

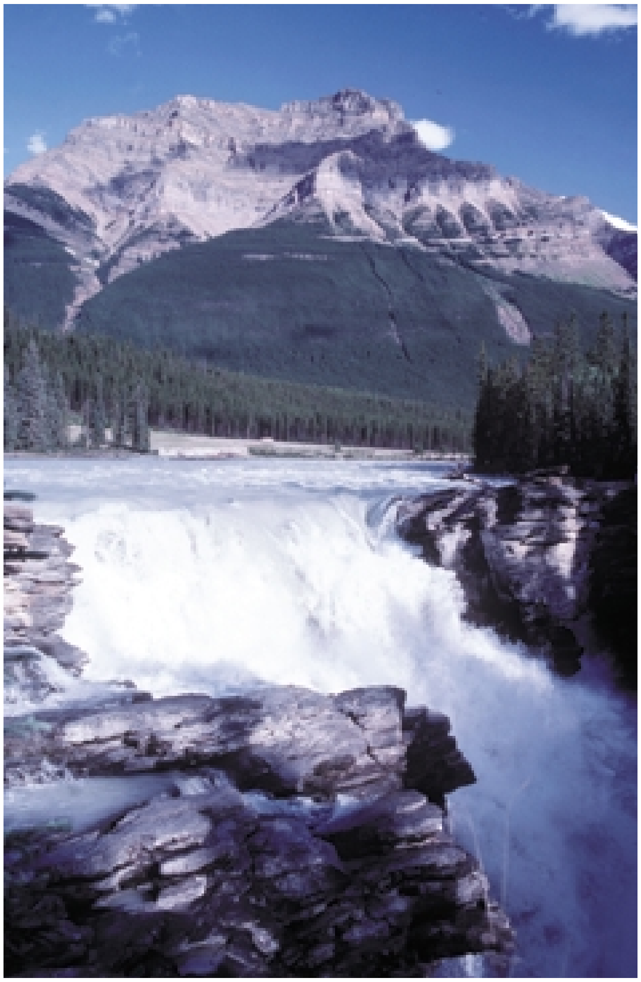


Figure 5.32 The Athabasca River near Jasper is gradually deepening the quartzite rock canyon. Where do you think the eroded material will be deposited?

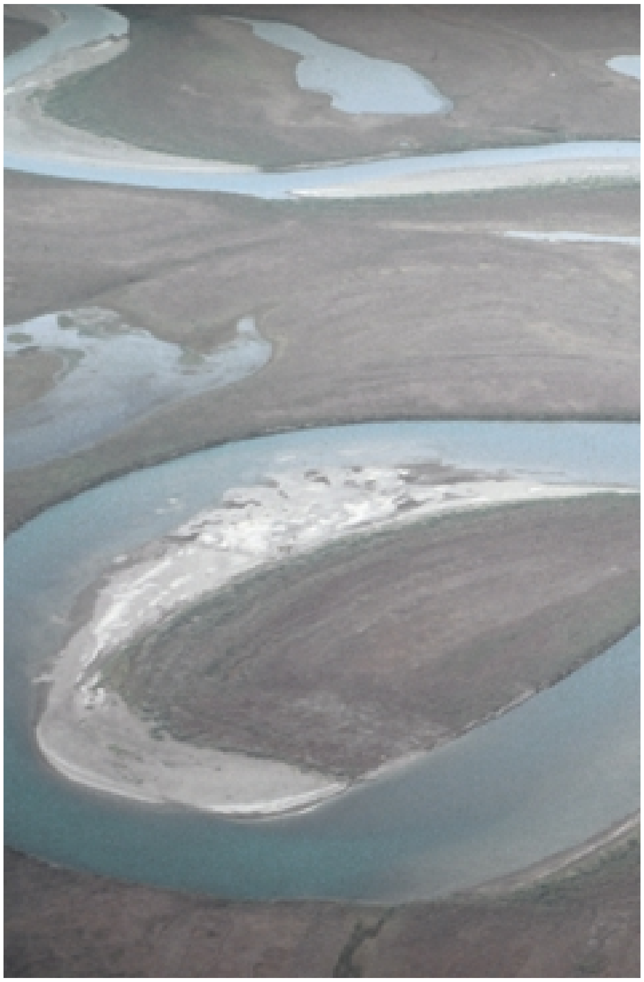


Figure 5.33 A meandering river continually changes the contours of the land. Can you identify where erosion is the fastest? Where are sediments being deposited?

PROBLEM-SOLVING

INVESTIGATION 5-E

SKILLCHECK

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

Nature's Design

Models are useful for investigating some of the processes that take place in Earth's crust. In this investigation, you will design your own model.

Challenge

Design a model to describe the origin and history of a lake or a river valley in your area or an area of your choice in Canada.

Materials

construction materials: wood, plaster of Paris, modelling clay, clay, plastic, plastic bags, rubber, paper, papier mâché, cardboard, wax, sand, stones

other materials: paint, tape, glue, plastic wrap, hardware (such as screws and nails), cotton batting, macaroni, glitter, beads, fabric, yarn

Specifications

A. Your model should be at least 0.5 m × 0.5 m, with clear labels.

B. Use at least two construction media (for example, papier mâché and wood, or plastic and cardboard).

C. Choose a period of time that will be easy to recognize in a model representation of your land formation.

D. Not all models look like the system they represent. Design a new model, for the same land formation and time period, that does not look like the model you have already made.

Plan and Construct

1. With your group, plan how you will construct your model.
   - **(a)** Will you need to make a sequence of small models, or will one large one be enough?
   - **(b)** Will your model include moving parts?
   - **(c)** Which materials will you use to best illustrate the aspects of the land formation?
   - **(d)** How will you show your labels?

2. Prepare a labelled sketch of your model. Build your model based on your sketch.

3. Demonstrate your model for your classmates.

Evaluate

1. (a) Did your model demonstrate lake or river formation effectively?

(b) If it contained moving parts, did they work successfully?

2. (a) Compare your work with that of other groups.

(b) If you were to make another model, how might you improve on your current model?

Extend Your Skills

3. Design Your Own A "working model" is a model that can demonstrate how a sequence of events takes place by making the same events occur in the model itself. For example, a working model of a diverted river might involve dripping water over a cliff. It could demonstrate how dirt would eventually build up along one river bank, changing the river's direction. You could reset the working model by placing the sediment back on the cliff. How would you design a working model for your land formation?

Skill FOCUS

For tips on using models in science, turn to Skill Focus 12.

Across Canada

When Dr. Charles Yonge joined a caving club at university, he didn't know that he would be spending much of his future life underground. Charles was a physics student, but after he experienced the beauty of cave rock, he was hooked. "Ninety-nine percent of the world's caves are limestone or dolomite," he says, "and they are the most fascinating landscapes you'll see anywhere."

After Charles switched his studies to geology, he worked with moon rocks and began investigating the rocks and minerals in caves. One of his expeditions included exploring Mayan caves with the National Geographic Society. He entered a cave system in Belize, a Central American country, and exited the cave over 50 km later in another country, Guatemala. His studies have also taken him to Vietnam and China with the Leakey Foundation. He has searched for evidence of the extinct Great Asian Ape.

While he explores, Charles conducts research in climate studies, searching for clues about the climate hundreds of thousands of years ago. "A cave might be a few million years old, but the parent rock could be 320 million years old or more. The rock can help us understand cycles of glaciation. It can also tell us about the past rain and snowfall, soil, forest cover, and even solar events."


Dr. Charles Yonge

Back home in the Canadian Rockies, he has been exploring Castleguard and Arctomys caves, Canada's longest and deepest caves, and discovering new cave systems. He guides cave tours with his Canmore-based cave consulting company and works with the University of Calgary. "Alberta's caves are treasure troves of information locked up in the mineral formations and hidden in the sediment deposits," he says. "Caves provide one of the last places on Earth for original exploration."

Figure 5.34 Over a million years of melting glacier water has dissolved deposits of limestone, forming Castleguard Cave. This enormous cave system is more than 18 km long. It is located near the Columbia Icefield in Banff National Park.

TOPIC 3 Review

1. What is erosion?
2. What is mechanical weathering?
3. How are chemical and biological weathering related? How are they different?
4. **Thinking Critically** List as many causes of erosion as possible. For each cause, describe the erosion processes that result.

Wrap-up TOPICS 1–3

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

Key Terms

rock
minerals
crust
element
crystals
lustre
streak
cleavage
fracture
igneous rock
magma
intrusive rock
lava
extrusive rock
sedimentary rock
sediment
stratification
compaction
cementation
metamorphic rock
parent rock
rock cycle
compost
humus
fertile
soil profile
topsoil
leaching
erosion
weathering
mechanical weathering
frost wedging
sedimentation
chemical weathering
biological weathering
abrasion

Reviewing Key Terms

1. Fifteen of the key terms are hidden in the word search. Can you find all fifteen? Do not write in this textbook.

T	N	E	M	I	D	E	S	S	O	R	D
R	S	X	F	K	G	N	I	T	P	L	W
I	B	U	E	O	D	C	A	J	R	I	O
G	R	M	R	D	O	V	Q	O	M	O	H
N	O	I	T	C	A	P	M	O	C	S	F
E	C	N	I	L	W	O	V	R	L	P	B
O	K	E	L	E	M	E	N	T	U	O	G
U	Z	R	E	A	M	E	A	M	S	T	L
S	U	A	E	V	I	S	U	R	T	X	E
W	O	L	L	A	A	H	T	S	R	J	A
F	I	S	D	G	K	L	O	V	E	G	C
F	O	I	T	E	M	P	L	H	A	M	H
G	U	M	A	G	M	A	U	O	K	R	I
V	I	U	S	O	G	D	Z	K	Y	I	N
A	S	D	C	R	Y	S	T	A	L	S	G

Understanding Key Concepts

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

2. What is the difference between a mineral that has cleavage and a mineral that has fracture? (1)

3. If a mineral belongs to the hexagonal crystal group, how many sides do its crystals have? (1)

4. Explain why a diamond does not leave a streak on a streak plate. (1)

5. What is the source of sediment? (2)

6. Compare magma and lava. (2)

7. Compare the process of compaction and cementation. (2)

8. Examine the following diagram. What family of rock is being described? Explain how the two types of rock shown in the diagram are formed. (2)

9. Describe the different kinds of weathering. (3)

10. How do glaciers contribute to sedimentation? (3)