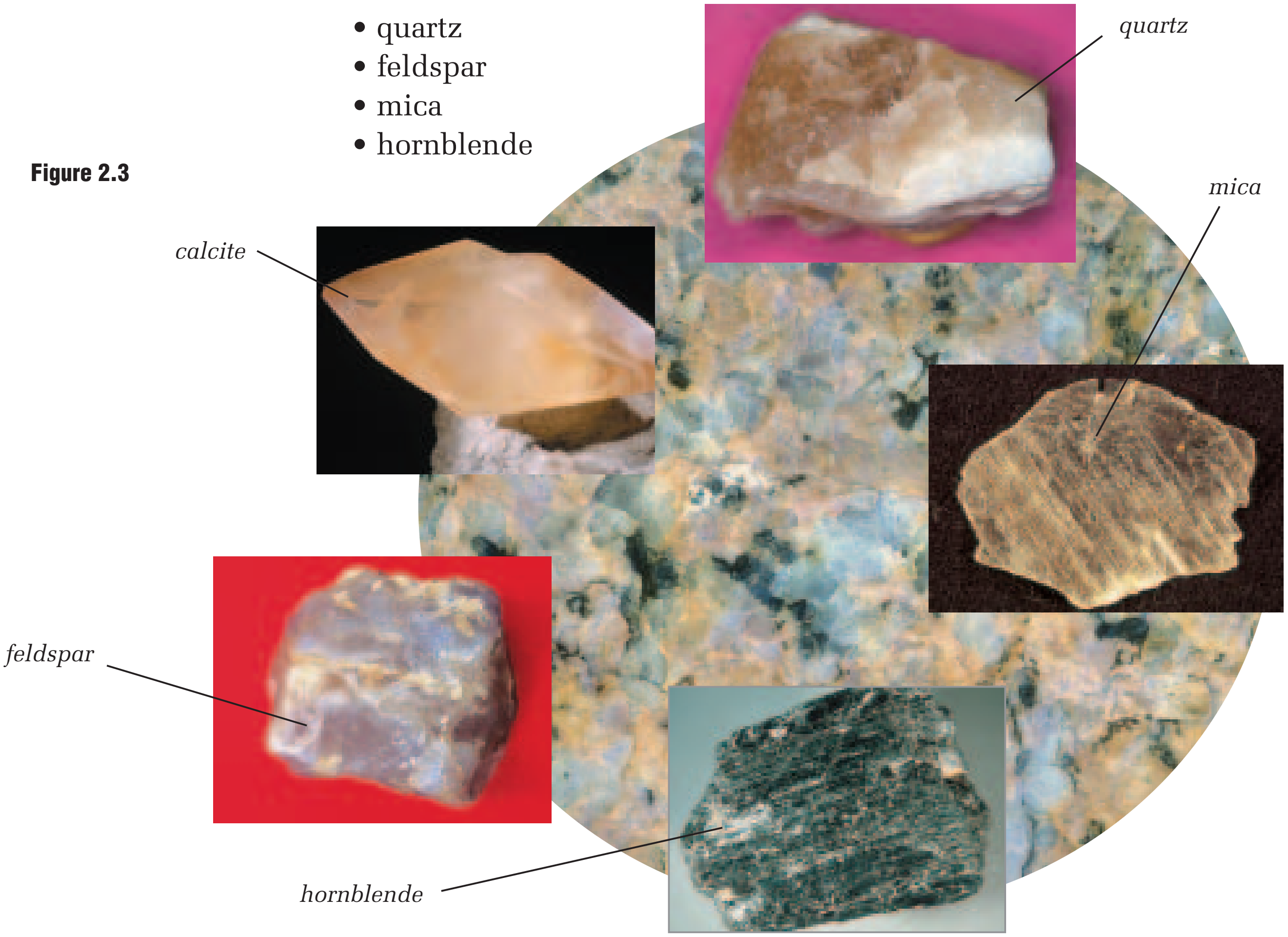
You may have heard the names of common minerals, such as quartz and mica. In fact, more than 3500 different minerals have been identified. However, you don't have to recognize or know all of them to identify most of the rocks you'll find. Just five minerals combine in different ways to form the majority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

- calcite
- quartz
- feldspar
- mica
- hornblende

Figure 2.3



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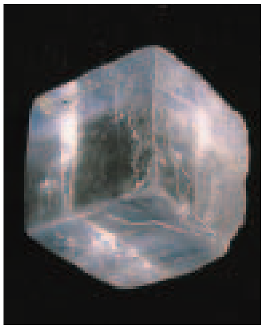
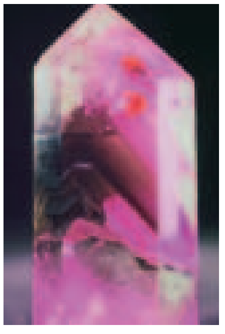
Rock Crystals

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



Halite crystal (sodium chloride)



Quartz

Using Properties to Identify Minerals

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

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

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

Colour

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

Lustre

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

Streak

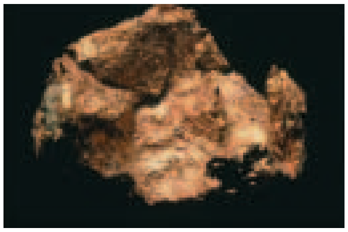
A mineral's **streak** is the colour of the powder that it leaves behind when you rub it across a rough surface. The colour of the streak is not always the same as the colour of the mineral. Usually, geologists use an unglazed ceramic tile (like the tile used on bathroom walls, but not shiny). They scratch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

Cleavage and Fracture

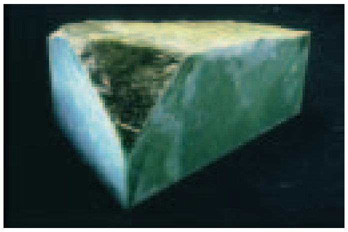
If you drop or break a mineral, you may notice the sample will break in a certain way. If a mineral splits easily into two smooth surfaces, this can be described as **cleavage**. In contrast to cleavage, **fracture** is a mineral breakage with rough and uneven surfaces. (However, any mineral can be fractured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

Figure 2.4 Properties of different minerals

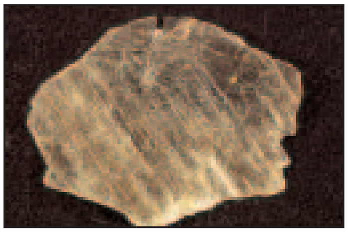
The *colour* of amber is yellow.



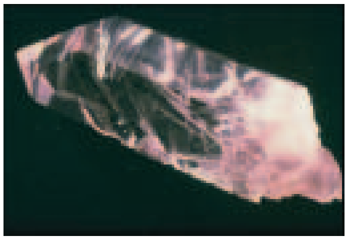
The *lustre* of native copper is shiny.



Jade makes a white *streak.*



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



The *hardness* of quartz is 7.

Hardness

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

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

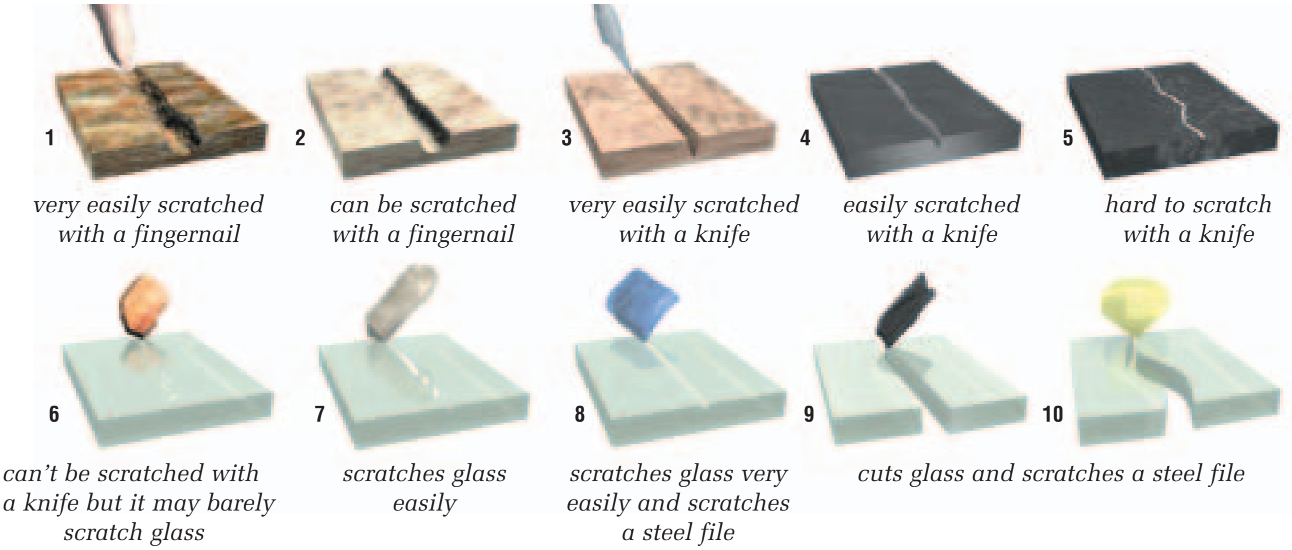


Figure 2.5 The hardness scale is a guide to identifying minerals. Each mineral can scratch *all* the minerals with a lower scale ranking than its own.

IDENTIFYING MINERALS

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

Careers and Profiles

Volcanologist

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

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

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

Seismologist

Figure 2.7 Seismographs record movement deep inside Earth.

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

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

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

Inquiry Activity

Prospecting for Minerals

Materials & Equipment

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

The Question

How can you identify a mineral by its properties?

The Hypothesis

TOOLBOX

Develop a hypothesis based on the question above.

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

Procedure

Part 1

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

Part 2

8 For each unknown mineral, record its number in your chart.

9 Repeat steps 2 to 6 from Part 1 of the procedure for each unknown mineral.

10 Use the information in your database of known minerals to identify your unknown samples. Enter the name of the mineral in the "Mineral Name" column.

Collecting Data

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

Mineral ID No.	Mineral Name	Colour	Lustre	Streak	Hardness	Other

Analyzing and Interpreting

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

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

Forming Conclusions

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

Applying and Connecting

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

Figure 2.9 Native copper

Extending

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

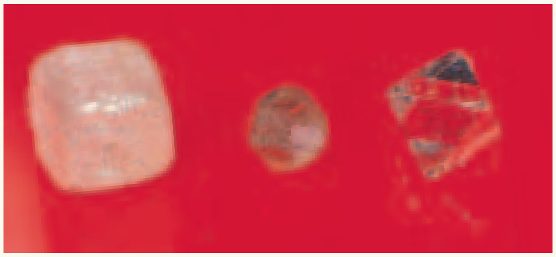


Figure 2.10 Raw diamonds

Prospecting for Wealth

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

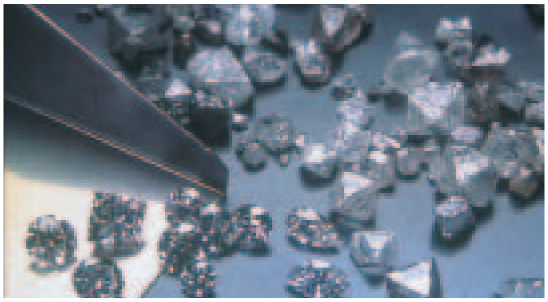


Figure 2.11 These diamonds are from Canada's first diamond mine, the Ekati mine near Lac de Gras, Northwest Territories. It began operations in 1998.

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

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

Check and Reflect

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

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

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

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

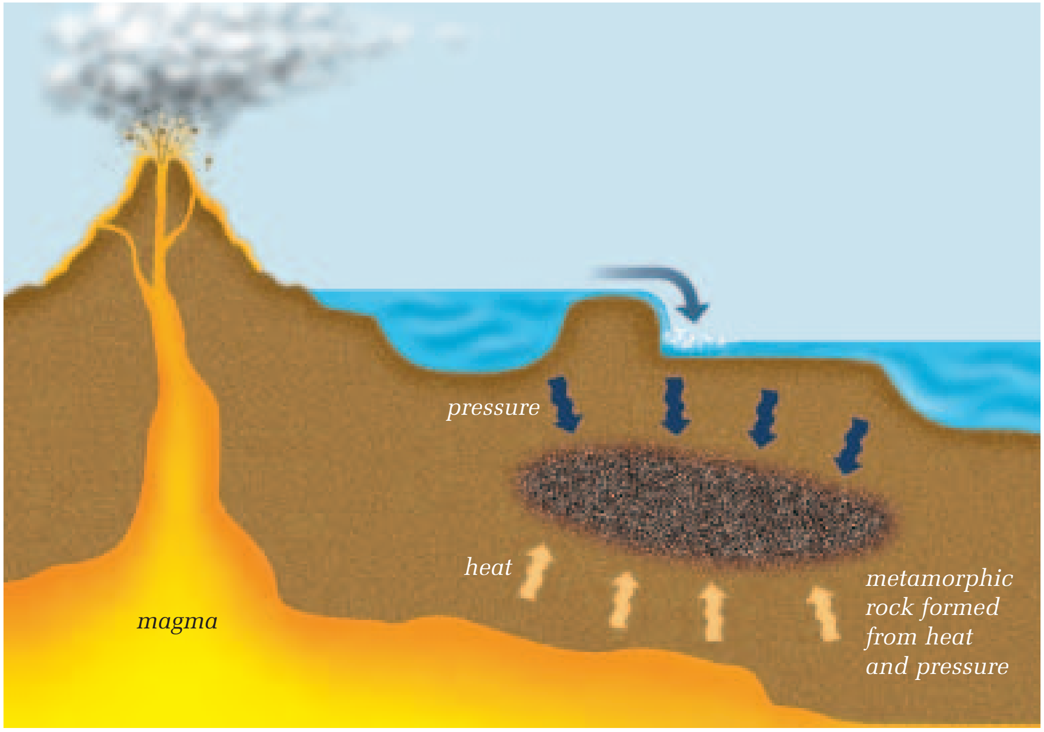


Figure 2.14 How rocks are formed

Types of Rock

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

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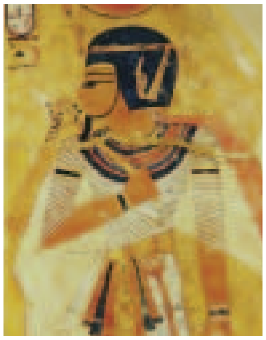
Treasures in Earth's Crust

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

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



A wall painting of an Egyptian wearing precious stones

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

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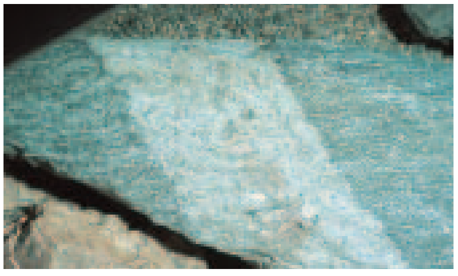
Rock Hounds

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

Igneous Rocks

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



pegmatite

basalt

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

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

Sedimentary Rocks

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

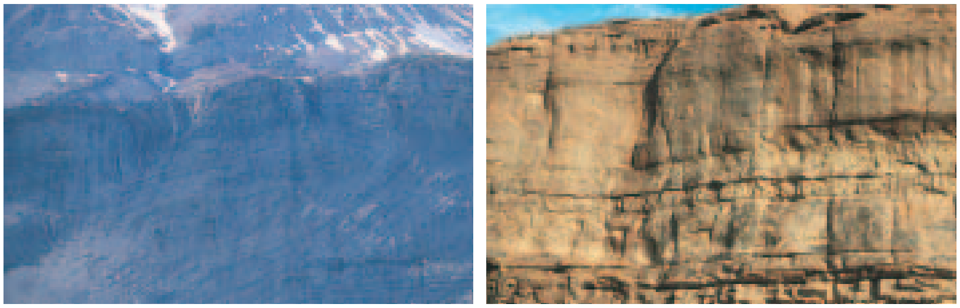


Figure 2.17 Limestone (left) and sandstone (right) are two kinds of sedimentary rock that usually occur in layers.

Give it a **TRY** ACTIVITY

Graph It! TOOLBOX

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

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

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

*t = tonnes

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

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

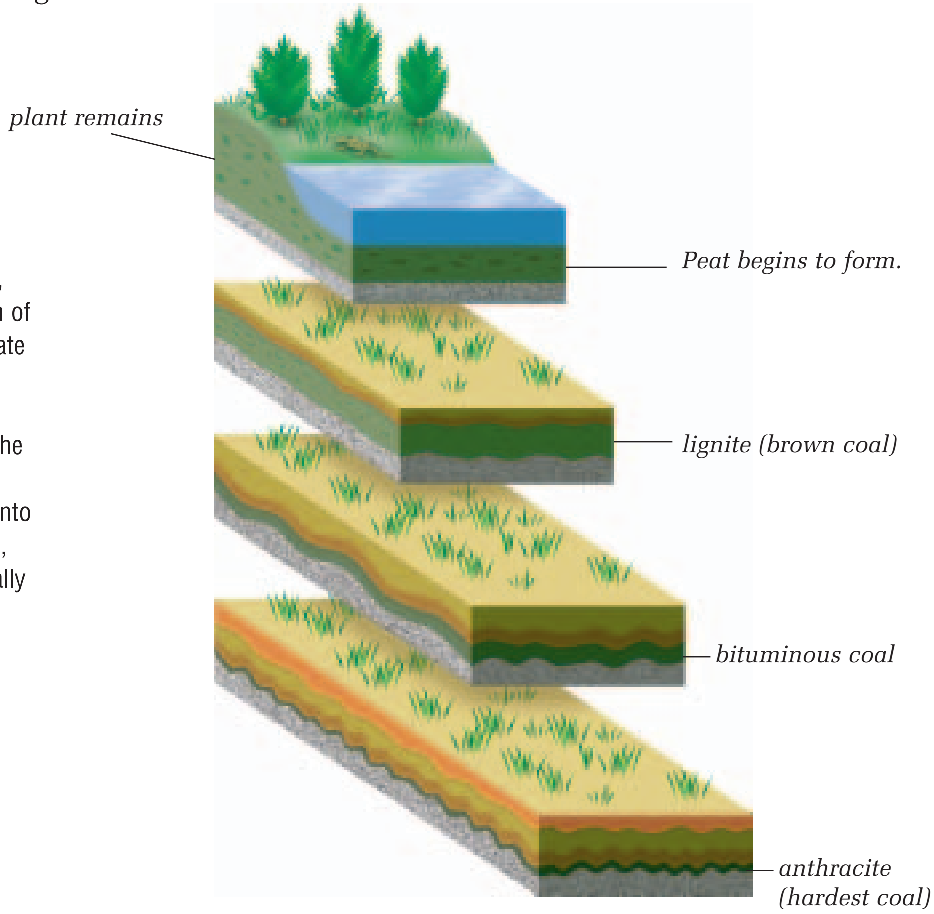


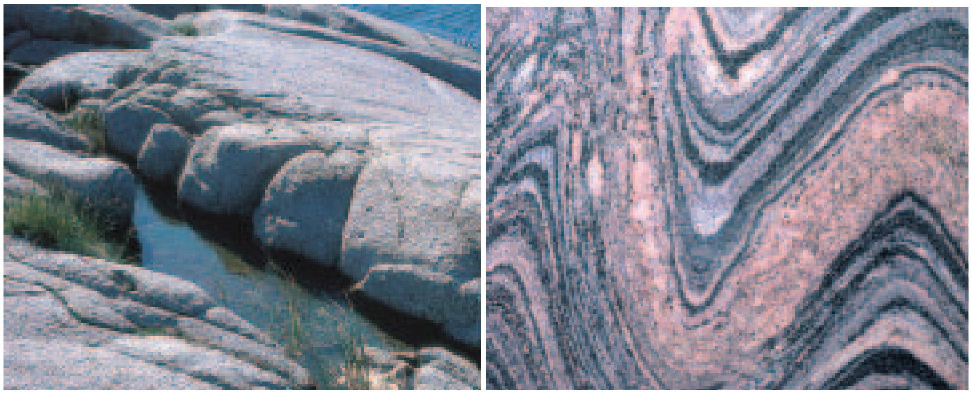
Figure 2.18 Two hundred and seventy-five million years ago, there was an extensive growth of vegetation in the tropical climate of ancient Alberta. Over time, plant debris was trapped between layers of sediment. The increasing pressure has since compressed this debris, first into *peat*, then *lignite*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

Metamorphic Rocks

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

shale *slate* *schist*

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



granite outcrop *gneiss*

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

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

Identifying Classes of Rock

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

Inquiry Activity

Classifying Rocks

The Question

What properties help you determine the class of rock?

The Hypothesis

Develop a hypothesis based on the above question.

Materials & Equipment

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

Rock Summary Table

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

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

Procedure

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

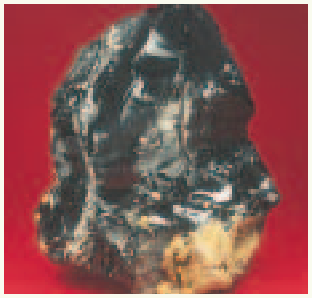


Figure 2.22 *Obsidian* [ob SID ē an] is an example of igneous rock.

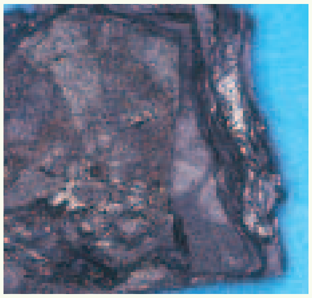


Figure 2.23 *Coal* is sedimentary rock.

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

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

Collecting Data

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

Sample	Colour	Texture	Rock Group

Analyzing and Interpreting

5 Which samples did you classify as igneous?

6 Which samples did you classify as sedimentary?

7 Which samples did you classify as metamorphic?

Forming Conclusions

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

Applying and Connecting

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

Sample	Name	Colour	Lustre	Streak	Hardness	Other

Extending

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

*re*SEARCH

Alberta Oil and Gas

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

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

Geology Tools and Techniques

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

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

Check and Reflect

1. Using your own words, complete the following sentences:
   a) Igneous rocks form when …
   b) Sedimentary rocks form when ...
   c) Metamorphic rocks form when …
2. Lava always forms igneous rock, but not all igneous rocks are formed from lava.
   a) What is lava?
   b) If an igneous rock didn't form from lava, from what did it form?
3. What are some of the characteristics used to classify rocks from each of the three different rock classes?
4. What are some of the methods geologists use to locate valuable mineral deposits?

2.3 The Rock Cycle

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

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

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

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

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

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Encouraging Weathering

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

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

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

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

The Rock Cycle

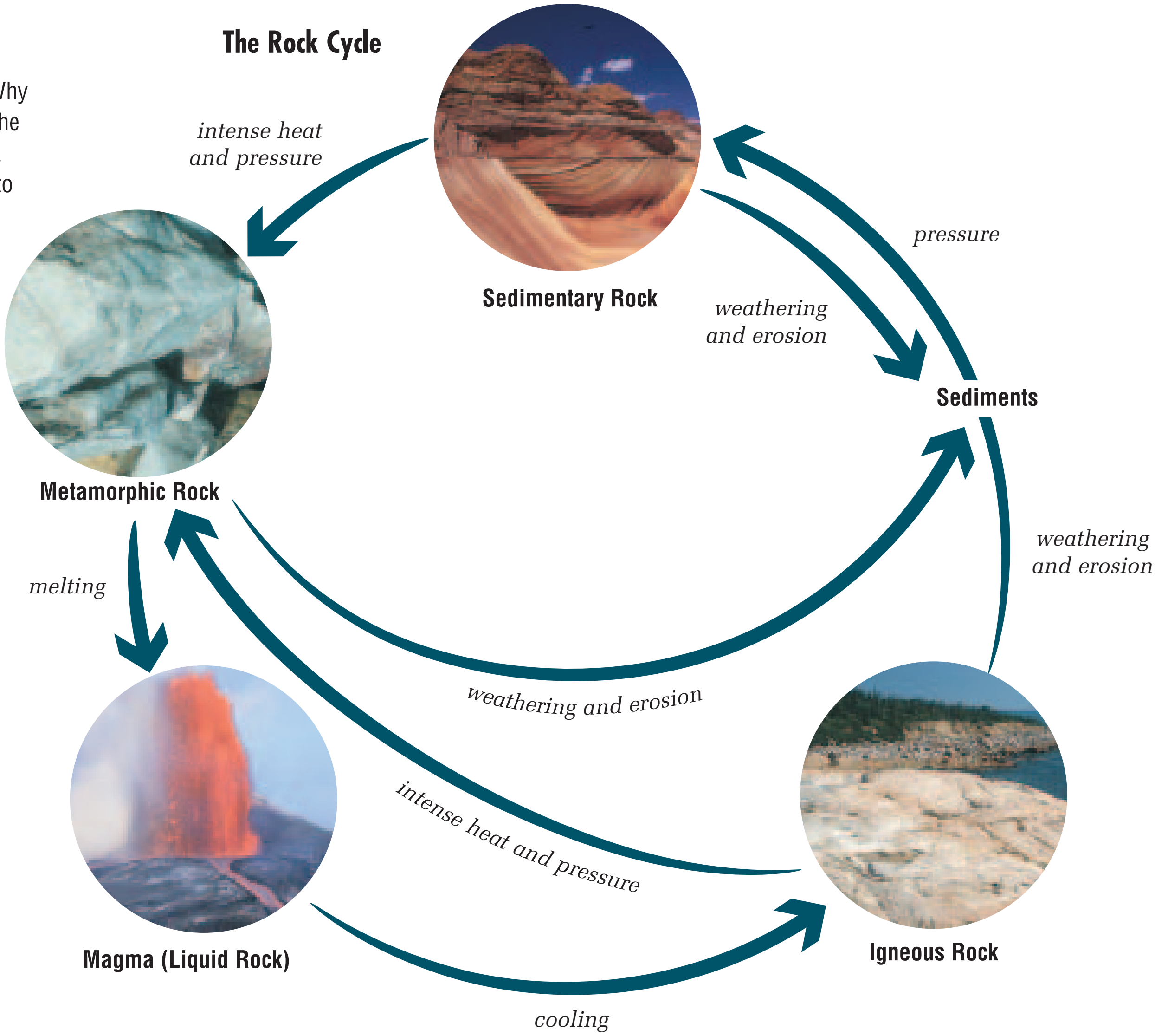


Figure 2.27 Why do you think the rock cycle is a useful model to geologists?

Investigating the Rock Cycle

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

The Alberta Story: Investigating the Changing Earth

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

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

Rocks in Your Backyard

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

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

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

Inquiry Activity

Sorting Out the Soil

The Question

What is the rock material in soil composed of?

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

Materials & Equipment

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

Procedure

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

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

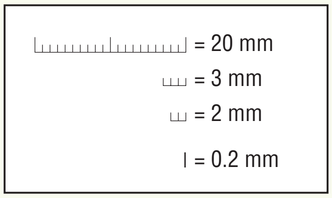


Figure 2.32 Use this scale to estimate the size of particles in your soil samples.

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

Collecting Data

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

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

Analyzing and Interpreting

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

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

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

10 Which size of sediment settled last?

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

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

Forming Conclusions

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

Applying and Connecting

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

Extending

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

Figure 2.33 Gravel

Figure 2.34 Sand

Figure 2.35 Clay

Check and Reflect


Figure 2.36

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

Careers and Profiles

Geologist

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

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

In the Field

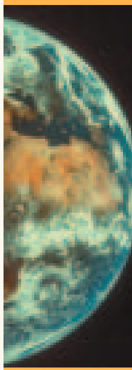
Nancy spends about a quarter of her time in the field. The rock layers she studies often lie deep underground, buried by thousands of years of sedimentation. To get at the underlying rock, drill core samples are taken. She takes careful notes to keep track of where each sample came from.

Does Nancy Chow Like Her Job?

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


Figure 2.37 Nancy Chow investigating sedimentary rock layers

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



Assess Your Learning

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

Focus On THE NATURE OF SCIENCE

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

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

3.0 Landforms provide evidence of change.

Key Concepts

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

- continental drift
- plate tectonics
- mountain building

Learning Outcomes

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

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

The Rocky Mountains

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

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

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

3.1 Continental Drift

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

Continents on the Move

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

*info***BIT**

Looking for Evidence

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

Satellite view of South America and Africa

Figure 3.1 The super continent: Pangaea

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

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

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

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

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

*re***SEARCH**

Researching Continental Drift

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

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

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

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

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

Check and Reflect

1. a) What was Wegener's theory of continental drift?
   b) What were the three types of evidence Wegener used to support his theory?
   c) Why did most scientists reject Wegener's theory of continental drift?
2. If the "shrinking apple" theory for mountain formation were correct, explain where you think mountains would be found on Earth's crust.

3.2 Plate Tectonics

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

Developing a New Theory

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

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

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

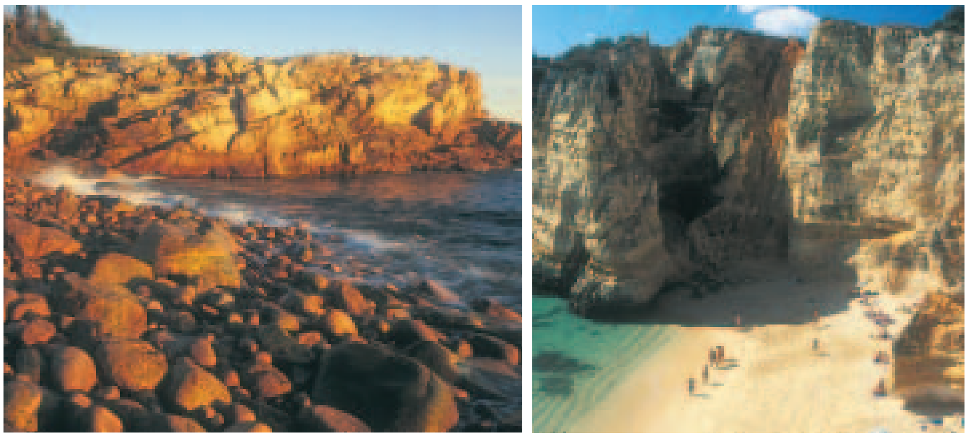


Figure 3.3 Look at these two landforms (to the left is the east coast of Cape Breton, Nova Scotia; to the right are cliffs near Lagos, Portugal, on the Atlantic Ocean). Can you imagine that they were once connected, as suggested by Wegener?

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The Active Earth

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