Module 4

Earth's Crust

Introduction

In this module there are **10** lessons:

Lesson 1 Rocks and the Earth

Lesson 2 Rock Cycle

Lesson 3 Geological Energy Resources

Lesson 4 Geological Resources

Lesson 5 Soil

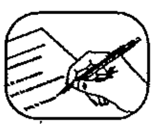
Lesson 6 Soil Conservation

Lesson 7 Sustainable Development

Lesson 8 Plate Tectonics

Lesson 9 Careers

Lesson 10 Reviewing



Module Assignment

In Lesson 4, you will complete Assignment #4, which you will hand in to your tutor/marker for grading. In this assignment, you will create an information booklet about a geographical resource in Manitoba. You will use the magazine *What Metals & Minerals Mean to Canadians* to help you with this assignment.

Module Objectives

After completing this module you will be able to answer the following questions:

- ❑ How are rocks formed, classified, and changed?
- ❑ What are some geological resources found in Canada? How are they located, extracted, and processed?
- ❑ Why is soil important and what are some ways to control soil erosion?
- ❑ How do scientists use theories to explain present-day features of the Earth? How have these theories changed?

Notes

Vocabulary

- inner core
- crust
- mantle
- outer core
- minerals
- rocks
- igneous rock
- sedimentary rock
- metamorphic rock
- intrusive
- extrusive
- crystals

Lesson 1

Rocks and the Earth

Learning Outcomes

After completing this lesson you will be able to

❑ describe the main features of the Earth's structure

❑ describe how rocks and minerals are formed and classified

In terms of exploring the Earth, we have barely scratched the surface, literally. Humans have mined and explored the Earth to a depth of 12-13 kilometres. The distance to the centre portion of the Earth is 6400 km. This centre portion of the Earth is called the **inner core**.

Due to advancements in technology, humans have been able to create a model of the Earth. This model helps us to understand how some of the things we see on the surface of the Earth, or just below it, were formed. This includes things such as rocks, minerals, mountains, and volcanoes.

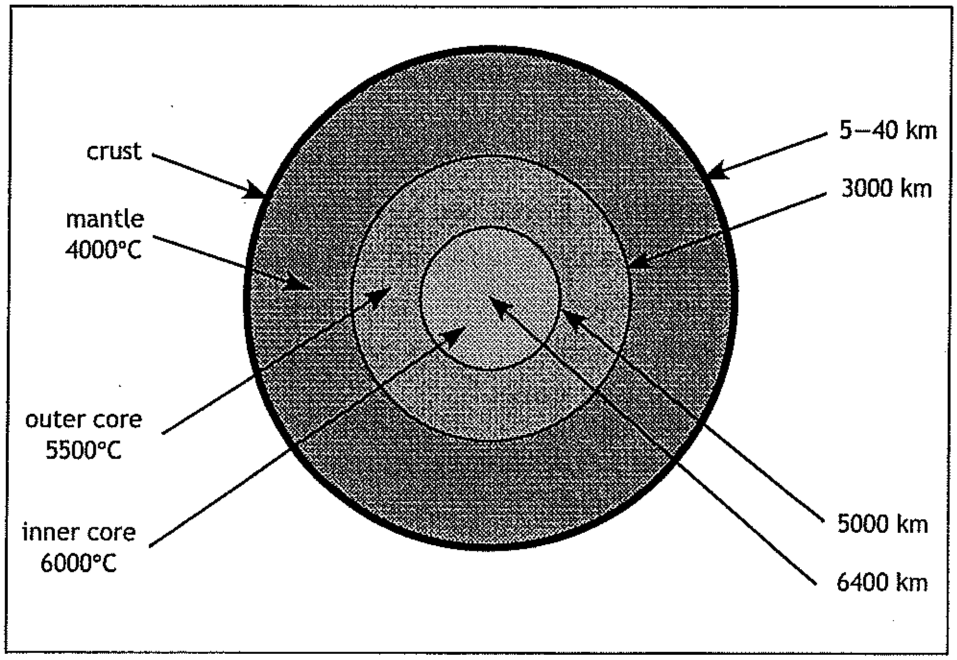
Model of the Earth

The model of the Earth that scientists have developed is provided on the following page. To understand this model, it is helpful to visualize a three-dimensional object. In this case, a hard-boiled egg will work for comparison, as there are three layers to both the egg and the Earth.

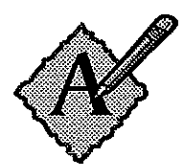
The thin shell of the egg represents the **crust**. The Earth's crust is solid rock and very thin compared to the other layers. Like the shell of an egg, the Earth's crust is brittle and can break.

The white of the hard-boiled egg, or the **mantle** on the Earth, is a hot layer of semi-solid rock, just below the crust. The mantle, which contains more iron, magnesium, and calcium than the crust, is also hotter and thicker. If some of the material in the mantle is allowed to cool, it forms rock.

At the centre of the Earth lies the core, which is nearly twice as dense as the mantle (there are two times as many particles packed into a given amount of space). The core is composed mostly of iron with some nickel also present. Unlike the yolk of an egg, however, the Earth's core is actually made up of two distinct parts: a liquid **outer core** and a solid **inner core**.



Learning Activity: Journey to the Centre of the Earth



Imagine that you have been hired as a scientific advisor on the crew for a science fiction movie about a group of people travelling to the centre of the Earth. Although the movie is science fiction, the director would like it to represent the scientific facts as closely as possible.

The movie includes a voice-over of one of the characters reading from her diary. Complete the diary entries by filling in the blanks with the appropriate words. Remember, your goal is to be scientifically accurate.

Diary Entry #1

We began our amazing journey today. Our specially designed ship has been fitted with a large drill bit so that we can drill through the first layer of the Earth which is ____________________ *(solid rock, thick fluid rock, thin fluid molten rock).* The professor calls this layer the ______________ *(mantle, outer core, crust).* Our ship travels 100 km/hour through solid rock. It should take us ________ *(1 day , 1/2 day, 2 days)* to get to the next layer, which is called the ____________ *(mantle, outer core, crust, inner core).*

Diary Entry #2

We made it through the first layer. Everyone is rejoicing. The drill bits held but now we have to see if the heat shields can withstand the high temperatures. This ______ *(is, is not)* the hottest part of our trip. Because our ship stays so cool the professor fears that this _______ *(thin, thick)* heavy material will stick to the ship, cool, and turn into rock. At one point we got caught in some type of current. The __________ *(molten, solid)* rock seemed to carry us along but we had to restart our engines when we started heading back in the direction of the surface of the Earth.

Diary Entry #3

We are finally to the upper part of the third layer called the ____________________ *(inner core, mantle, outer core).* I thought that this layer would be much different than the last one but it has some similarities. One similarity is that it is a ____________________ *(solid mass, flowing mass).* Our sensors indicate that it is mainly made of __________ *(iron, nickel, copper).* Our temperature sensors are really reaching the end of their range. Their readings in this layer have reached ______________ *(1000°C , 4000°C , 5500°C , 6000°C).*

Diary Entry #4

We made it to the inner core — the centre most portion of the Earth. We could tell that we definitely reached this level because ______________________________

____

(our ship bumped into the inner core's solid mass, our heat sensors went up over 2000°C, we came across a completely different mineral than what we have seen so far). The professor said that it is a good thing that the material our ship is made of melts at a ____________ *(higher, lower)* temperature than 6000°C. Looking back at our journey, the layer with the greatest thickness was ____________ *(crust, mantle, outer core).*

Rocks and Minerals

Minerals are inorganic solids (not composed of plant or animal material) that occur naturally on the Earth. A mineral is usually made up of crystals, which can be identified by properties such as colour, hardness, and crystal form. Another important property of minerals is that they look the same inside and out.

If you sliced a mineral in half, it would look the same throughout. However, if you sliced a **rock** in half, you would see that it contains different substances. Minerals are the building blocks of rocks, and rocks are mixtures of minerals. They vary in the number and amount of minerals present.

Rocks are classified in the way they are formed. The three types of rock and their methods of formation are as follows:

1. **Igneous rock.** Igneous rock is made from magma, that is, the liquefied rock originally found in the Earth's mantle. Igneous rock can also be formed when this liquefied rock reaches the Earth's surface as molten lava. The lava that flows out of volcanoes or cracks in the ocean floor cools and hardens (solidifies) and becomes igneous rock. Examples of igneous rock include pumice, basalt, and granite.

2. **Sedimentary rock.** Sedimentary rock is made of sediment (small particles of sand, mud, pebbles, silt, and the remains of plants and animals). This sediment settles in layers on the ground and at the bottom of lakes and oceans. This deposition of sediment is called sedimentation. The weight of the layers eventually compresses them into rock, a process called compression. Plant and animal remains are often trapped in the layers and can result in fossil formation. Examples of sedimentary rock include sandstone, limestone, and shale.

3. **Metamorphic rock.** Metamorphic rock is sedimentary rock or igneous rock that has been changed by heat and pressure. This heat and pressure occurs below the Earth's surface. Examples of metamorphic rock include marble, slate, and gneiss.

Learning Activity: Classifying Rock As Sedimentary, Igneous, or Metamorphic

Classification keys are tools that help to identify materials or living things. In this activity you will use a classification key to determine the rock type of some collected samples. Although additional testing would need to be done to make a definite decision about a rock type, this classification key will help you become familiar with the characteristics of the three types of rocks.

Go on a walk through your community and collect some samples of rocks. (You may wish to try this activity with some rocks you may have already collected at an earlier date.) Use the following rock classification key to determine whether a rock is sedimentary, igneous, or metamorphic.

Using a Rock Classification Key

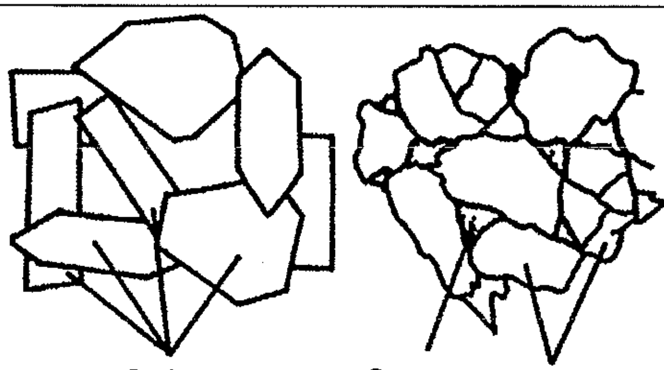
To use the key, start with #1 and move through the key until you have identified the rock type: igneous, sedimentary, or metamorphic.

1a. The rock is made up of distinguishable minerals.
If so, go to 2a.

1b. The rock is not made up of distinguishable minerals.
Go to 5a.

2a. The rock is made up of minerals that are interlocking.
If so, go to 3a.

2b. The rock is made up of minerals that are non-interlocking.
Go to 6a.



Interlocking and Non-Interlocking Minerals

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3a. The minerals in the sample are of the same kind.
The rock is *metamorphic.*

3b. The minerals in the sample are of two or more different types. Go to 4a.

4a. The minerals in the sample are distributed in a random pattern. The rock is *igneous.*

4b. The minerals in the sample are not distributed randomly but show a preferred arrangement, or banding.
The rock is *metamorphic.*

5a. The rock is either glassy or frothy (has small holes).
The rock is *igneous.*

5b. The rock is made up of strong, flat sheets that look as though they will split off into sheet-like pieces.
The rock is *metamorphic.*

6a. The rock is made of silt, sand, or pebbles cemented together. It may have fossils. The rock is *sedimentary.*

6b. The rock is not made of silt, sand, or pebbles but contains a substance that fazes when dilute HCl (hydrochloric acid) is poured on it. The rock is *sedimentary.*

Taking a Closer Look at Igneous Rock

As discussed earlier, igneous rock is produced when magma (liquefied rock beneath the Earth's surface) or molten lava (liquefied rock on the Earth's surface) solidifies. Igneous rock can further be classified according to crystal size and formation. When rock solidifies beneath the Earth's surface, it is called **intrusive**. This type of rock usually cools slowly. When molten rock solidifies above the Earth's surface, it is called **extrusive**. If this rock comes in contact with cool water it can cool quite quickly.

As molten rock cools, it creates **crystals**. Crystals are solids composed of particles of a mineral. These particles are internally connected to form a geometric shape. The size of the crystals depends on how fast or slow the molten rock solidifies.

Learning Activity: Cooling Rate and Crystal Size

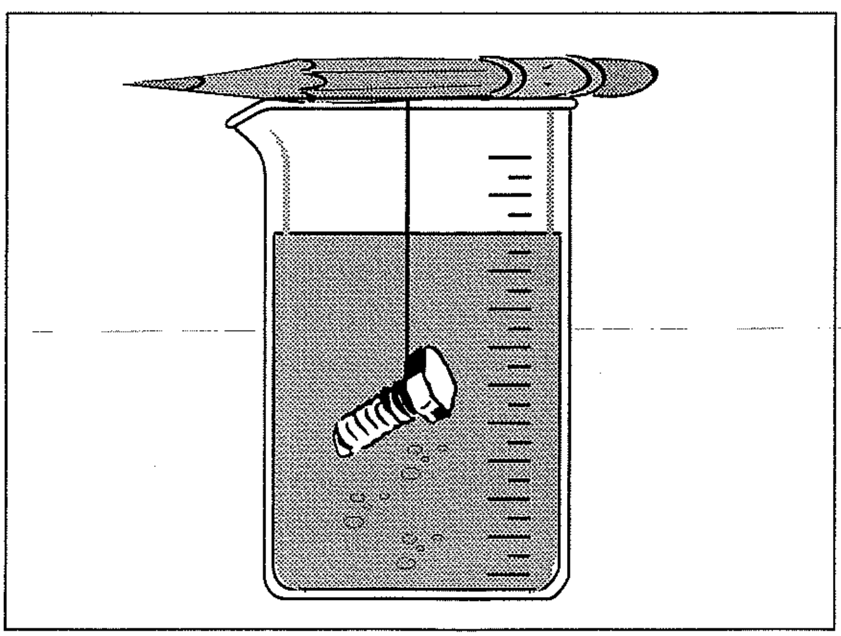
Conduct the following experiment to determine how cooling rate affects crystal size. To conduct this experiment, you'll need a pot of water, sugar, bolts, pencils, string, and clear plastic cups. As you conduct the experiment:

- ❑ record your observations
- ❑ draw diagrams depicting the two samples of crystals
- ❑ write a conclusion stating the relationship between the cooling rate of a solution and the size of the crystals formed

1. Place two cups of water in a pot. With adult supervision, heat the pot on the stove.

2. When the water begins to boil, add three cups of sugar and stir until the sugar dissolves and the solution looks clear. If the solution begins to bubble vigorously, remove it from the heat and let it settle in order to see whether it has cleared.

3. Attach a bolt (any type of small weight can be used) to a piece of string suspended from a pencil across the top of a container (clear plastic cups work well). Prepare a second cup in the same manner. See the diagram below.



4. Divide the heated solution evenly between the two prepared containers.

5. Place one cup in the fridge and leave the other on the counter overnight. Observe the crystals the next day.

Observations

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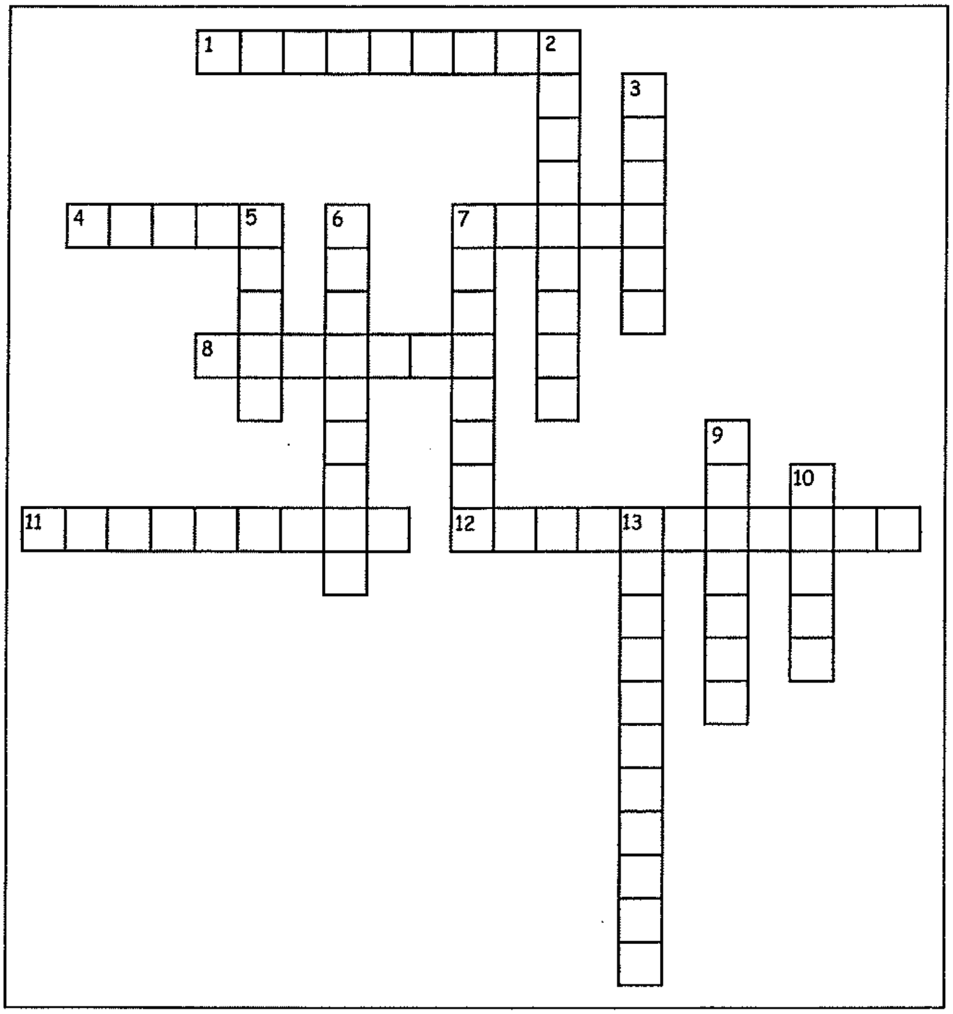
Diagram 1 (Refrigerated)

Diagram 2 (Room Temperature)

Conclusion (circle the appropriate words to make a true statement)

Earth's Crust Crossword Puzzle

Complete the following crossword puzzle to test your knowledge of the Earth's crust.



Across

1. when an igneous rock solidifies beneath the Earth's surface
4. the size of crystal created when molten rock cools quickly
7. thin layer of solid rock covering the Earth
8. type of rock made from magma
11. hot but solid portion of Earth that is made of iron and nickel
12. type of rock that consists of layers of small particles of sand, mud, pebbles, silt, and remains of plants and animals compressed together

Down

2. when an igneous rock solidifies above the Earth's surface
3. hot, partly molten layer located just below crust
5. the size of crystal created when a rock cools slowly
6. molten layer of mainly iron
7. particles of a mineral that are internally connected to form a geometric shape
9. inorganic solids that occur naturally on the Earth
10. liquefied rock originally found in the Earth's mantle
13. type of rock that has been changed by heat and pressure

Notes

- physical weathering
- biological weathering
- chemical weathering
- rock cycle

Lesson 2

Rock Cycle

Learning Outcomes

After completing this lesson you will be able to

- ❑ investigate and describe how weathering and erosion cause changes to the landscape over time
- ❑ explain how rocks on the Earth, through the rock cycle, constantly undergo a slow process of change

Part 1: Physical Weathering

Physical weathering occurs when water, ice, and/or wind cause rocks to break down into smaller pieces.

- When water is in the form of waves crashing against a shore, it break down rocks. The water causes the rocks to knock against other rocks in the water, and thus causes them to break into smaller pieces. River water also helps to break down riverbanks as it rushes through waterways.
- When water is in the form of ice, it assists in the weathering of rocks.
- Wind also causes physical weathering. Wind blows materials (such as sand) against rocks, which causes them to wear down or break apart.

Learning Activity: Physical Weathering

To observe how freezing water can break down rocks, complete the following learning activity. To conduct this learning activity you'll need a small glass jar, a thick plastic bag, and water.

1. Fill a small glass jar with water. Cover it with a lid.
2. Place the jar in a thick plastic bag, then put the plastic bag (containing the jar of water) into the freezer (or outdoors in winter).

3. After the water has frozen, pull out the bag from the freezer. Open the bag and observe its contents.

Questions: Physical Weathering

1. In the previous learning activity, what happened to the water in the jar? Why did this happen?

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2. Based on your explanation for question #1, explain how water freezing could break down rocks.

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Part 2: Chemical Weathering

Chemical weathering breaks up rocks by chemically changing the rock into a softer form that then falls apart. For example, this happens when the rock is exposed to acid rain, or secretions from lichen or moss.

Learning Activity: Chemical Weathering

Conduct the following investigation to observe chemical weathering in action. To conduct this learning activity you'll need limestone gravel*, two plastic containers, two dishes, water, vinegar, and a coin.

(*Look for limestone gravel on driveways, walkways, or ask for a small sample from a local greenhouse or garden landscape centre.)

1. Place coarse limestone gravel into a plastic container half filled with water.
2. Place the same amount of gravel into a plastic container half filled with vinegar.
3. Cover each container with a lid and shake the containers for 10 minutes.
4. Record your observations.

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5. Let the containers stand overnight.

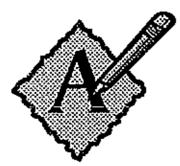
6. Pour the contents of each container into separate dishes.
7. Use a coin to attempt to scratch gravel from each container.
8. Record your observations.

> **Option:**
> **EXTRA! EXTRA! Read all about it!**
> You may find the following related topics of interest—check the Internet or your library for resources:
> - how acid rain affects rocks and concrete structures
> - how mosses and lichens slowly help wear down rocks with the secretion of acids

Part 3: Biological Weathering

Animals and plants are living (or biological) factors that assist in **biological weathering**. They do this by causing chemical or physical weathering to occur. For example:

- When animals burrow, they create holes that expose rocks to air and water. These rocks then become weathered.
- Plant roots grow in rock cracks and separate the rock as the plant grows. The roots also secrete an acid that softens the rock and causes it to wear down more quickly.
- Lichens and mosses secrete acids and chemically weather the rock beneath them.

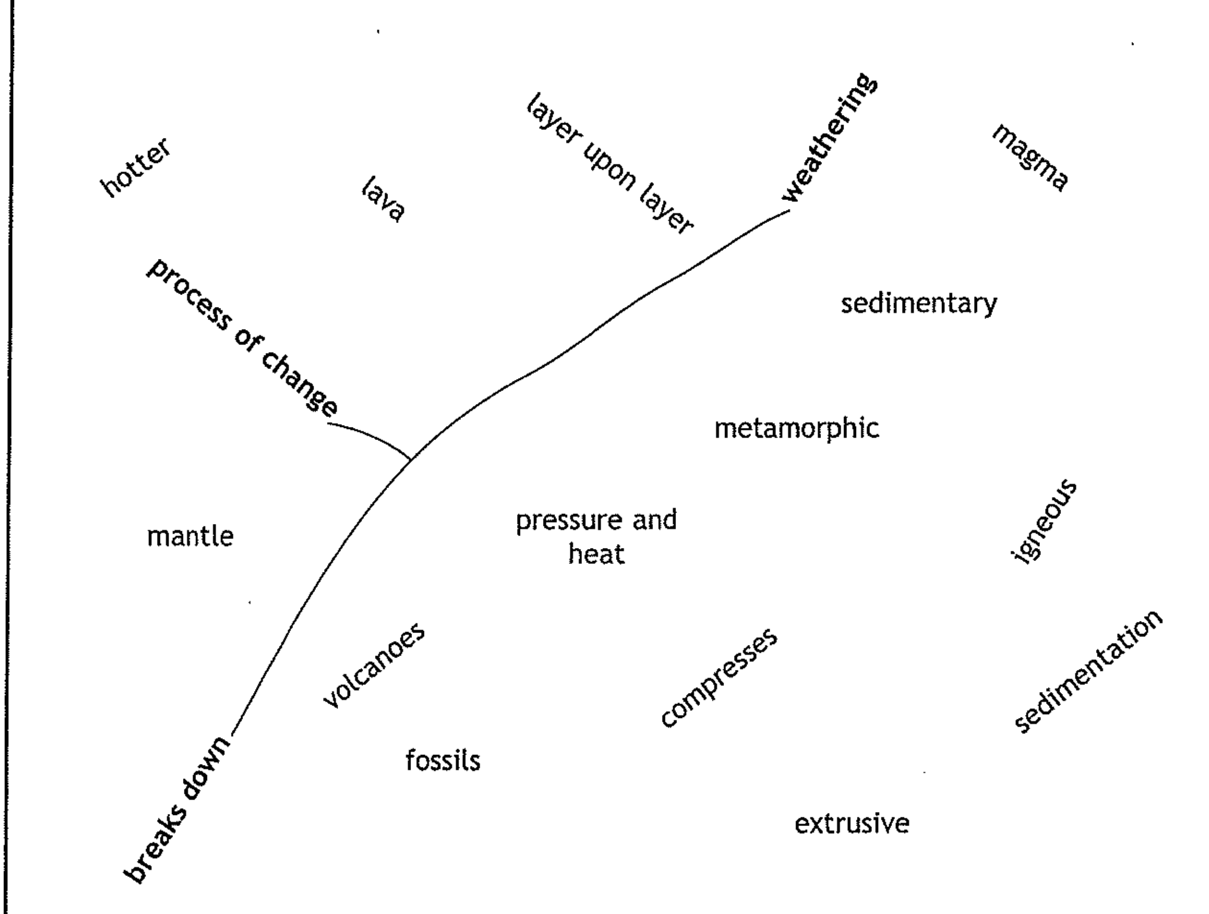


Learning Activity: Rock Cycle Word Splash

1. Study the words in the word splash on the following page.
2. Identify possible relationships between words. (You may connect more than two words. One example is already given.)
3. Connect the words with a line.
4. In the space below the word splash, write a sentence containing the words you have chosen. The sentence should illustrate the relationship between the words.

5. Make as many word connections as you can. Note that the same word can be connected several times.
6. Star the thought connections you feel very confident about.
7. When you have made as many connections as you can, read the article "The Rock Cycle" and identify the differences and similarities between your map and the given article.

Word Splash: The Rock Cycle



Sentences

Example: **Weathering breaks down** rocks as part of a **process of change**.

The Rock Cycle

Igneous Rock

Rock begins as a molten mass of magma in the mantle of the Earth. Magma can ooze into already formed rock in the Earth's crust and cool to create *intrusive igneous rock*. If there is enough pressure, or if there are cracks in the crust, the magma itself comes to the surface of the Earth. Now known as lava, it flows out of volcanoes both on land and under the sea, creating *extrusive igneous rock* as it cools and hardens.

There are several things that could happen to igneous rock:

- It could be worn away in the process called weathering. Weathering breaks down the igneous rock, and sediment is created. This sediment may be transported elsewhere or it may collect layer upon layer (sedimentation). As the layers build up, their combined weight compresses the sediments, and sedimentary rock is formed. In many forms of sedimentary rock, layers may be seen, particles may be separated easily, or fossils (shells or bones of long-dead organisms) may be preserved.
- Besides being worn down and changed into sedimentary rock, igneous rock can be pushed lower and closer to the hotter mantle region of the Earth. Pressure and high heat can change igneous rock into metamorphic rock. Metamorphic rock can find its way back to the surface of the Earth by the movement of lower or neighbouring rock or by the weathering of the rock above. If igneous rock is pushed so low that it joins the hot mantle, it will become magma and eventually create new igneous rock.

Sedimentary Rock

Sedimentary rock can result from the wearing away of igneous rock. Sediment that forms sedimentary rock can also come from the breaking down of pre-existing sedimentary or metamorphic rock. Just as weathering can occur in igneous rock, so wind, water, ice, gravity, other rocks, and animals can break down sedimentary and metamorphic rock.

Sedimentary rock, in turn, could become metamorphic rock if enough heat and pressure were applied to it. It could even find itself turning back into igneous rock if it were forced back toward the Earth's mantle and allowed to melt. It may eventually return closer to the Earth's crust and become igneous rock.

Metamorphic Rock

Metamorphic rock could weather and provide sediment to create sedimentary rock or, if enough force were applied, metamorphic rock could be transformed into magma in the Earth's mantle.

Summary

All rock starts off as magma and hardens into igneous rock. Sedimentary rock is made as a result of the weathering of igneous and metamorphic rock. High heat and pressure applied to sedimentary or igneous rock can change them into metamorphic rock. These three types of rock continue to change from one form to another and back again. This process of change is called the *rock cycle*.

Vocabulary

- fossil fuels
- coal
- natural gas
- crude oil
- geothermal reservoir
- geothermal energy

Lesson 3

Geological Energy Resources

Learning Outcomes

After completing this lesson you will be able to

- ❑ describe the formation of fossil fuels and geothermal energy
- ❑ compare the advantages and disadvantages of fossil fuels and geothermal energy as sources of energy for human use

Geological Resources as Sources of Energy

People use geological resources in a variety of ways. One very important way that people use geothermal resources is as a source of energy. What you have learned in previous lessons about the Earth will help you to understand the following descriptions of fossil fuels and geothermal energy. Be prepared to identify the advantages and disadvantages of each source of energy.

Fossil Fuels

Formation of Fossil Fuels

Fossil fuels are one of the most important sources of energy today. The name "fossil fuels" reflects the fact that the fuels are literally the remains of thick layers of plant and animals that died millions of years ago. These remains became buried and folded in to the Earth, then heated and compressed to be transformed into either a type of sedimentary rock **(coal)** or deposits of liquids (oil and gas). Depending on the original vegetation type and the geological history, different deposits of coal, oil, and gas end up with different chemical compositions.

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You may think that fossil fuels are a renewable resource, as they are formed through natural processes that continue (at least in some form) today. However, because fossil fuels take millions of years to form and cannot be replaced within our lifetime, we call them non-renewable resources.

Use of Fossil Fuels

Fossil fuels have been important sources of heat for people around the world for centuries. Today, in North America, 90% of our energy comes from fossil fuels. We rely upon them to power our cars and trucks, heat our homes, and generate much of our electricity. Without these fuels, industries could not function. Ironically, the more we depend upon coal, oil, and **natural gas**, the less abundant they become.

Fossil Fuel Resources

Much of the petroleum (oil) used in North America comes from the Persian Gulf and is subject to major price fluctuations, although some fossil fuel extraction does take place in Canada and the United States. Coal has been mined in New Brunswick commercially since the early 1800s; however, 97% of Canada's coal deposits are actually in the western provinces of Alberta, Saskatchewan, and British Columbia. This is currently the source of over 90% of the coal mined in the country. Up until the 1950s, when oil and gas squeezed coal out of many markets, coal was the primary source of fuel for home heating, industrial energy, and transportation. Coal now supplies only 11% of Canada's energy, and it is used mostly in coal-fired power plants.

Oil replaced coal as Canada's most important fuel after World War II. In addition to standard oil deposits, synthetic **crude oil** is also refined from *bitumen*, or tar sands deposits in Alberta. The tar sands represent a major fuel reserve, but generating oil from the bitumen is still prohibitively expensive. It is also environmentally unacceptable because of the large-scale habitat destruction and atmospheric emissions associated with extracting and refining the bitumen.

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Since the 1970s, natural gas has gained importance. Prior to the rapid petroleum price increase of the 70s, natural gas had been treated as a waste product of oil wells and simply burned off. Since then, transportation pipelines and storage systems have been built, and this fuel is now replacing oil for industrial, residential, and commercial heating, as well as for petrochemical production and use. While steps have been taken to lessen the effects of fossil fuels on the environment, pollution caused by fossil fuels remains a global concern, and alternative energy sources are being pursued.

Geothermal Energy

Formation of Geothermal Resources

"Geothermal" comes from the Greek words geo (earth) and therme (heat). So, geothermal means Earth heat. Geothermal resources have the potential to become an important energy source of the future. Since heat always moves from hotter regions to colder regions, the Earth's heat flows from its interior toward the surface. When temperatures and pressures become high enough, some mantle rock melts, becoming magma. Then because it is lighter than the surrounding rock, the magma rises, moving slowly up toward the Earth's crust, carrying the heat from below.

Sometimes the hot magma reaches all the way to the surface, where we know it as lava. But most often the magma remains below the Earth's crust, heating nearby rock and water (rainwater that has seeped deep into the Earth) — sometimes as hot as 350°C. Some of this hot geothermal water travels back up through faults and cracks and reaches the Earth's surface as hot springs or geysers, but most of it stays deep underground, trapped in cracks and porous rock. This natural collection of hot water is called a **geothermal reservoir**.

Geothermal energy is considered a renewable resource as the heat flowing from the Earth's interior is constantly replenished.

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Use of Geothermal Resources

Today, we drill wells into the geothermal reservoirs to bring the hot water to the surface. These wells are sometimes over three kilometres deep. Deep wells can bring very hot water (120–370°C) to the surface for use in generating electricity in geothermal power plants. As of 1999, some 250 geothermal power plants were running day and night in 22 countries around the world, providing reliable power for over 60 million people, mostly in developing countries. While geothermal power projects are proposed in the Cascade Mountain range in British Columbia, none have currently been developed.

Direct use of geothermal energy from shallower reserves (without a geothermal plant) is more widespread. In Canada, 10–20°C groundwater is used directly or with heat pumps to heat more than 30,000 buildings, including Carleton University in Ottawa and factories in Nova Scotia (using water from the flooded Springhill coal mine). In the Yukon, geothermal energy keeps city water pipes from freezing. A more local example of geothermal energy use is the Alloway Centre in Winnipeg. For more information on how this geothermal heating system works, or on other energy efficient features of the Alloway Centre, contact the Fort Whyte Centre at 989-8355.

Environmental Considerations

Geothermal power plants, like wind and solar power plants, do not have to burn fuels to manufacture steam to turn the turbines. This helps to conserve non-renewable fossil fuels as well as reduce pollution created by burning fossil fuels. Geothermal power plants are a very reliable source of electricity as they are designed to run 24 hours a day, all year.

Possibilities for the Future

Since the 1970s, the geothermal industry, with the assistance of government research funding, has overcome many technical drilling and power plant problems. This research, combined with industry experience, has reduced the cost of generating geothermal power by 25% over the past two decades. Research is underway to make additional improvements to processes and technologies to further reduce cost.

Complete the following chart to compare the advantages and disadvantages of the use fossil fuels and geothermal energy to supply energy for human needs.

Advantages	
Fossil Fuels	**Geothermal Energy**

Disadvantages	
Fossil Fuels	**Geothermal Energy**

The major disadvantage of fossil fuels is ______________________

____.

The major disadvantage of geothermal energy is ______________

____.

Notes