Chapter 12

Soil is the living component of Earth's crust.

What do you hold when you hold a handful of healthy soil? You have in your hands a combination of minerals, organic matter, water, air, and organisms such as bacteria and earthworms. These five basic components work together to provide nutrition to plants to keep you—and other organisms—healthy. The soil in your hands can take thousands of years to form but can be easily lost. You hold a handful of valuable possibilities for your community and for the world.

What You Will Learn

In this chapter, you will
- **investigate** how rocks are affected by weathering
- **explore** how sediment is moved from location to location
- **identify** effects of enriching soils
- **research** current issues related to agriculture
- **investigate** how organic matter affects soil moisture

Why It Is Important

Soil is created from sediment, which in turn is produced through the processes of weathering and erosion. The health of the soil is directly related to our own health. We need to safeguard our soil. The misuse or loss of soil has an impact on us.

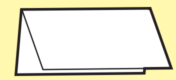
Skills You Will Use

In this chapter, you will
- **observe** evidence of weathering in your community
- **predict** which rocks will be most affected by weathering
- **classify** a soil sample based on its characteristics

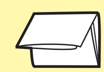
FOLDABLES™
Reading & Study Skills

Make the following Foldable to take notes on what you will learn in Chapter 12.

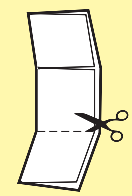
STEP 1 **Fold** an 8.5 × 11″ sheet of paper in half along the long axis.



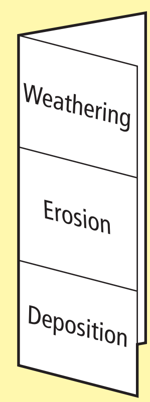
STEP 2 **Fold** the paper in thirds along its length.



STEP 3 **Unfold** the sheet and **cut** the bottom tab along the fold lines as shown.



STEP 4 **Label** the tabs as "Weathering", "Erosion", and "Deposition".



Organize Define each term on the front of the tabs. Take notes and explain the cause and effect of each term under the tabs.

12.1 Weathering, Erosion, and Soil Formation

Weathering is the process that breaks rock down into sediments. In mechanical weathering, the rock is simply broken into smaller pieces. In chemical weathering, chemical reactions with the rock produce new substances. Weathered rocks may be loosened and transported to other locations through the process of erosion. They are deposited in their new locations by the process of deposition. Weathered rocks and minerals can be combined with organic matter, water, and air to form soil.

Key Terms

chemical weathering
deposition
erosion
mechanical weathering
soil
weathering

Figure 12.1 You might have noticed a pile of rocks at the bottom of a rocky cliff. Why did the rocks break off from the side of the cliff? What force caused the rocks to fall?

Earth's crust is constantly being changed. Some changes, such as earthquakes and volcanoes, are sudden. Other changes, such as mountain building, are very slow processes. Rocks on the sea floor and the continents have many forces acting on them and wearing them down. Animals and plants can weaken and break apart rocks at Earth's surface. Water and ice can also break rocks into smaller pieces. Even tiny moss plants, burrowing shrews, and the oxygen in the air are part of the processes that wear down rocks. **Weathering** is the mechanical and/or chemical breakdown of rock. Rocks that are created by magma or lava, sedimentation, or metamorphic processes are all exposed to the forces of weathering when they are at or near Earth's surface.

Over millions of years, weathering has changed Earth's surface. The weathering process continues today. Weathering affects rocks, caves, mountains, and even buildings and streets.

Two types of weathering—mechanical weathering and chemical weathering—work together to shape Earth's surface and create sediments.

Did You Know?

Over hundreds of thousands of years, weathering can transform mountains into rolling hills.

12-1A Use the Force

Find Out ACTIVITY

Which forces in nature can move sediment? In this activity, you will use a model to explore how sediment is moved from location to location.

Safety Precautions

- Wash your hands thoroughly after completing this activity.
- Clean all surfaces.

Materials

- a mixture of sand and gravel
- a stream table or metal pan

What to Do

1. Place a small pile of sand and gravel in one end of a stream table or metal pan.
2. Your task is to move the sediment to the other end of the pan without touching the particles with your hands. You can touch and move the outside of the pan, but you cannot touch the sediment. You can use forces or objects approved by your teacher.
3. Try to move the mixture in a number of different ways. Each time, record your method. Record and draw what happens to the sand and gravel.
4. Pile up the sand and gravel in the centre of the pan. Slowly drip water onto the pile, and watch how the sand and the gravel move as the water flows down. Record and draw your observations.
5. Add a total of one half cup of water. Record and draw where the sand and gravel end up.

What Did You Find Out?

1. Describe the methods you used to move the sediment.
2. Which method was most effective?
3. Explain how your methods compare with forces of nature that move sediment.
4. Which human activities affect the movement of sediment in nature?
5. Describe a local example where grass is used to prevent the movement of sediment.

Mechanical Weathering

During **mechanical weathering**, rocks are simply broken into smaller pieces. The overall chemical make-up of the rocks stays the same, so each piece of rock is similar to the original rock. Gravity causes these broken rocks to fall down a cliff and they may land with enough force to break into smaller pieces. Three common causes of mechanical weathering are described below.

- The most common type of mechanical weathering is *frost wedging*. Recall from your earlier studies and observations that water expands when it freezes. When water enters the cracks in a rock and freezes, it expands. The cracks enlarge and the rock breaks apart (see Figure 12.2). Then, more water can enter the cracks, freeze, and expand, causing the cracks to grow even bigger. The cycle of freezing and thawing that breaks up rocks can also break up roads. When water enters cracks in the pavement and freezes, ice forces the pavement apart and causes potholes in roads.

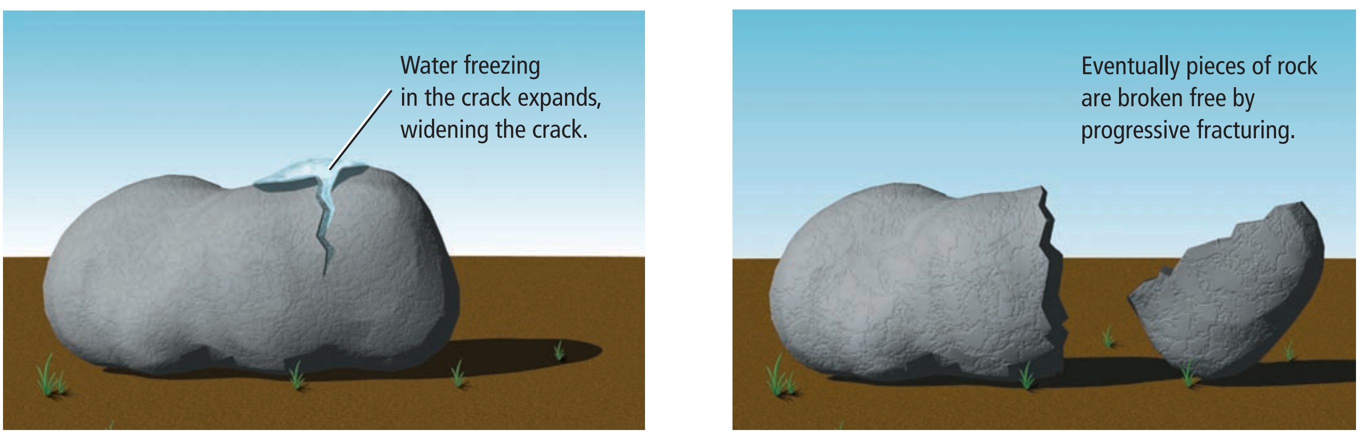


Figure 12.2 Frost wedging occurs when water entering cracks in rocks repeatedly freezes and thaws.

- Mechanical weathering can also occur when a plant wedges its way into a crack in a rock, just as frost does. Water and nutrients that collect in the cracks of a rock allow plants to grow. As the roots of the plants grow, so does the crack. The rock is pushed apart until it eventually crumbles and breaks (Figure 12.3).

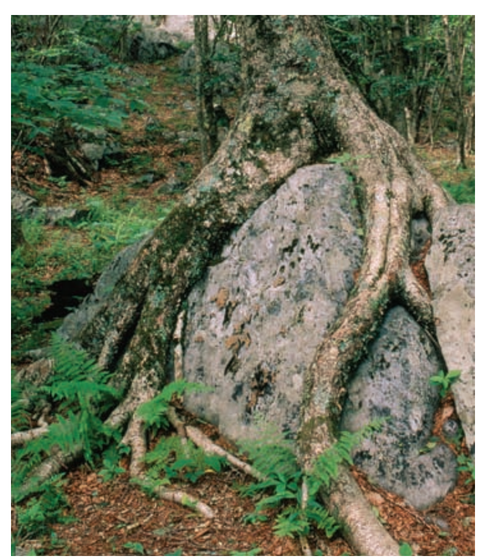


Figure 12.3 The roots of a tree can break a rock apart.

- Mechanical weathering can be caused by animals, such as earthworms, rodents, and ants. As the animals move through the soil, they loosen sediments and push the sediments to the surface. Once the sediments are at the surface, other weathering processes can act on them.

Did You Know?

Humans can influence mechanical weathering by mining, quarrying, and excavating foundations for buildings.

Chemical Weathering

In **chemical weathering,** chemical reactions occur with rocks to create new substances. The larger the surface area of rock, the faster the rate of chemical weathering. Some rocks, such as salt, gypsum, and limestone, may be dissolved. Other rocks may be weakened.

Rocks can react with water, with chemicals dissolved in water, or with gases in the air. For example, hydrogen in water can react with minerals such as feldspars, and chemically alter them to become clays. When oxygen combines with the iron in a rock, iron oxide (rust) can form. This chemical change weakens the rock's structure, making it easier for the rock to break apart. Chemical weathering occurs more quickly in areas where the climate is warm and humid. Common causes of chemical weathering include the following.

Suggested Activity

Conduct an Investigation 12-1B on page 416

Figure 12.4 Chemical weathering of limestone can create underground caves and caverns. If the caves collapse they can form a sinkhole, like the one in Codroy Valley shown here.

- Acidic groundwater can dissolve minerals such as calcite. Calcite is the main mineral that makes up limestone. When acidic groundwater flows through layers of limestone, rock is dissolved and caves are produced (Figure 12.4).
- Acidic rainwater reacts with some rocks, such as limestone and dolomite. The rock material dissolves easily in the acidic water and washes away (Figure 12.5).

Figure 12.5 Many old headstones, statues, and buildings have been chemically weathered by acid rain.

Figure 12.6 What signs of weathering can you see in the rock in this photograph?

- The acidic action of some organisms that live on rocks, such as lichens, can cause chemical weathering (Figure 12.6). As well, chemical reactions can take place between rock material and acidic fluids that are produced by plant roots, bacteria, fungi, and some insects and other small animals. As the rock slowly dissolves and flows away with rainwater, cracks and crevices increase in size until the rock finally breaks apart.

Mechanical and chemical weathering work together to break down rock. For example, mechanical weathering can crack a rock, exposing more surface area for chemical weathering to dissolve. In a cold, harsh climate, mechanical weathering may be more common. In a hot, humid climate, chemical weathering may be more common. However, both types of weathering are always working to change the landscape.

Reading Check

1. What is weathering?
2. What are two types of weathering?
3. What are three causes of mechanical weathering?
4. What are three causes of chemical weathering?

Erosion

For millions of years, nature has been weathering rocks into sediment, breaking down softer materials, and exposing more resistant rock. The work of water, ice, and gravity has changed the surface of rocks. Sometimes plants and animals have helped in the process.

Have you ever been by a river or stream after a heavy rain? The water looks muddy because it is carrying a lot of sediment (Figure 12.7). Some of the sediment comes from the riverbank. The rest of the sediment comes from more distant sources and is carried by wind, water, and ice. Muddy water is a product of erosion. **Erosion** is the process that loosens and moves weathered rock particles (sediment) over Earth's surface. Some types of erosion are gradual, and happen over many thousands of years. Other types of erosion, such as flash floods and landslides, happen suddenly.

Figure 12.7 A stream carries away sediment after a heavy rain.

Agents of Erosion

Water in motion is the most powerful agent of erosion (Figure 12.8). Bodies of water erode their shorelines. When waves hit cliffs and shores, rocks are broken down and eroded. In some places, erosion happens quickly. A coastline can lose several metres every year to erosion by seawater. Rivers can cut straight into rock to form canyons or gorges and steep v-shaped valleys. Streams and rivers carry rock fragments along in the water. The faster the water flows, the bigger and denser are the sediments it can carry.

internet connect

Find out why the province of Newfoundland and Labrador is sometimes called "Earth's Geological Showcase." Start your search at **www.discoveringscience.ca.**

Figure 12.8 When powerful waves break against a shoreline, they help to break up rocks (weathering) and carry them away (erosion).

- *Meteorological processes,* such as rain and wind, can cause erosion. In addition to causing flooding, heavy rain can disturb the stability of a slope, causing landslides (Figure 12.9). Wind can pick up fine particles, like clay and sand, which act like sandpaper on Earth's surface. The faster the wind is, the larger the particles it can carry.
- *Geological processes,* such as gravity and glaciers, can also cause erosion. An example of gravity's force occurs when weathering breaks down rock on mountainsides and hillsides. The force of gravity pulls the rock and sediment down from higher places to lower places. The rock and sediment can move quickly after a heavy rain or an earthquake, when it is no longer being supported by the material beneath it.

Figure 12.9 Heavy rains at the top of the cliffs and erosion at the bottom of the cliffs caused landslides in Daniel's Harbour on Newfoundland's west coast in 2006 and 2007.

Figure 12.10 This huge rock near Conception Bay South was left behind by a glacier thousands of years ago.

Glacial Erosion

As recently as 10 000 years ago, glaciers covered Newfoundland and other northern lands. Remnants of these glaciers are found today in Greenland. Glaciers are large bodies of ice that move like slow bulldozers. Glaciers flow across Earth's surface, carving and scraping, pushing loose rocks and soil out of their path, and dragging rocks and sediment far away. When glaciers melt and retreat, they deposit the rocks and sediment in new locations (Figure 12.10). Materials deposited by glaciers, sometimes called ice age sediments, provide excellent drainage and important building materials for roads and concrete buildings. Ice age sediments include sand, gravel, silt, and clay.

Did You Know?

Glacial ice layers are a record of global climate change over millions of years. Scientists use long drills to remove cores of ice from glaciers. Each layer of ice in a core corresponds to a single year or season. The layers include wind-blown dust, ash, and atmospheric gases.

Deposition

Gravity, ice, wind, and water all wear away materials and carry them off. However, agents of erosion erode materials only when they have enough energy to do so. All agents of erosion deposit the sediment they are carrying when their energy decreases. For example, a river *erodes* materials where it is flowing fastest and has the most energy. A river *deposits* these materials along its route when it slows down and loses energy. The dropping of sediment is called **deposition.** Deposition is the final stage of erosion.

Erosion is generally considered to be a destructive process because it wears down land features and carries them away. Deposition is considered to be a constructive process because land features are produced and built up.

Erosion and deposition work together. Earth's materials are picked up from one place and are dropped off somewhere else. Sediments are deposited every day in Newfoundland and Labrador, changing the surface of the land (Figure 12.11). Mountains are gradually worn down from steep peaks to rolling hills. Valleys are gradually widened and filled with rock and soil. The same sediment may be eroded again and again over millions of years.

Figure 12.11 These photographs were taken before and after a series of storms along Conception Bay. What evidence of erosion and deposition can you see in the photograph on the right?

Formation of Soil

Sediments are an in-between stage in the rock cycle. Eventually, these eroded materials will be recycled to form new rocks. The slow process of rock formation takes thousands of years to occur. What happens to these materials in the meantime? They may become part of the soil. **Soil** is a combination of eroded rocks and minerals, water, air, and organic matter such as decaying plant and animal materials.

Explore More

Billions of dollars worth of oil is trapped in sedimentary rock that was once eroded and deposited on the continental shelf off the shores of Newfoundland and Labrador. Learn more about the resources of the continental shelf by visiting **www.discoveringscience.ca.**

Reading Check

1. What is erosion?
2. What is the most powerful agent of erosion?
3. What is deposition?
4. What are the main components of soil?

12-1B Rocks that Fizz

Skill Check

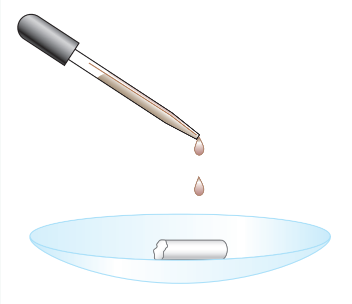
- Observing
- Predicting
- Measuring
- Classifying

Safety

- If acid gets on your skin, immediately wash the area with lots of cool water.

Materials

- small pieces of identified rock
- two unidentified rock samples from your geographic area
- watch glass
- tongs or tweezers
- medicine dropper
- 1% hydrochloric acid



In this activity, you will investigate which types of rocks are affected by chemical weathering.

Question

When acids react with certain rocks, some minerals dissolve, and carbon dioxide gas is formed. Which rocks do acids affect?

Hypothesis

Formulate an hypothesis about which rocks are affected by acid rain and acid groundwater.

What to Do

1. Make a table of observations like the one below. Give your table a title.

Name	General Observations	Amount of Fizz
granite		
chalk		
sandstone		
shale		
marble		
limestone		
unknown rock A		
unknown rock B		

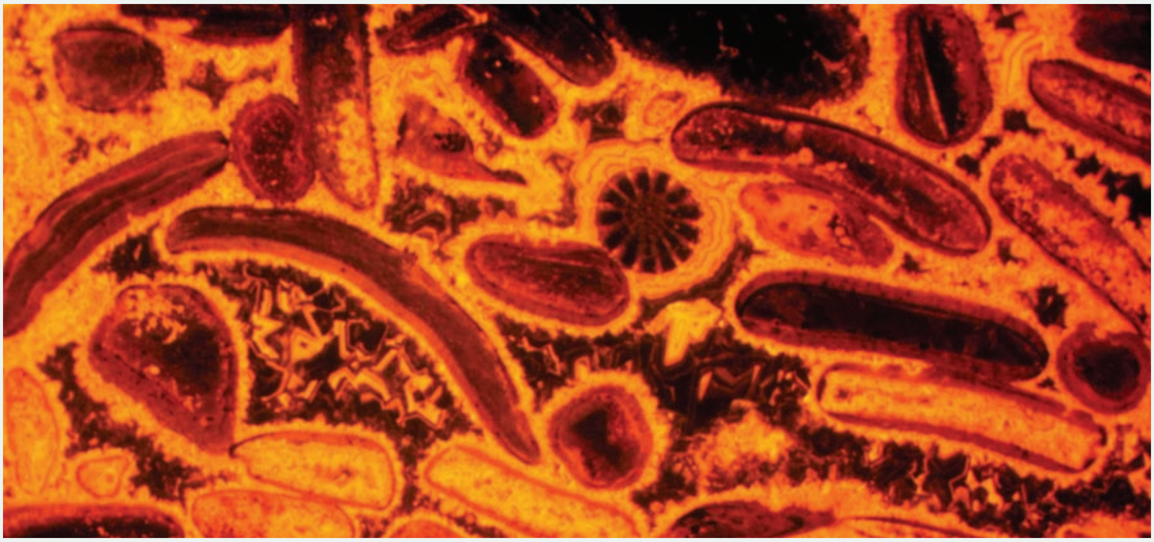
2. Observe the physical characteristics (such as colour and texture) of one of the specimens. Record your observations under "General Observations."
3. Put a specimen on a watch glass.
4. Put on your safety glasses. Use the medicine dropper to place a few drops of acid on the specimen. Observe what happens. Record the amount of fizz in your table.
5. Rinse the specimen with water. Dry the specimen. Return the specimen to the proper place.
6. Repeat steps 2 to 5 for each of the other specimens.

Analyze

1. (a) What was the manipulated variable (the feature that you changed)?
   (b) What was the responding variable (the feature that you observed changing)?
2. (a) Which rocks were affected by chemical weathering?
   (b) How could you tell?
3. Could you formulate a reasonable prediction about whether a rock would fizz or not just by looking at it? Explain why or why not.

Conclude and Apply

1. What is happening to the rock when the acid makes it fizz?
2. (a) Which unknown rock was affected by chemical weathering?
   (b) Based on the information collected in your table, which other rock specimen does this unknown rock most closely resemble?
3. How could chemical weathering make it easier for a rock to undergo mechanical weathering?



This is a photograph of a very thin slice of limestone. Over 200 million years ago, these sea shell fragments were compacted together and then cemented with calcite.

12-1C Crystals in a Cave

Find Out ACTIVITY

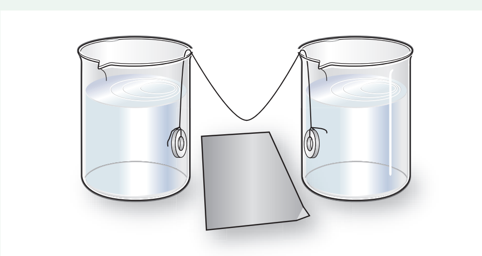
Chemical weathering can result in interesting formations in a cave or cavern. Stalactites are crystals that form on the roof of a cave. Stalagmites are crystals that form on the floor of the cave. In this activity, you will model the formation of stalactites and stalagmites.

Safety Precautions

- Never eat or drink anything in the science room.

Materials

- 2 small beakers or jars (such as baby food jars)
- Epsom salts or baking soda
- tap water
- spoon
- 2 washers
- 30 cm cotton string or yarn
- sheet of dark construction paper



Setup as described in step 4

What to Do

1. Fill the jars about three-quarters full of tap water. Add a spoonful of Epsom salts or baking soda to the water in each jar. Stir until it is dissolved. Continue adding Epsom salts or baking soda to the water and stirring until no more can dissolve.
2. Tie a washer to each end of the string or yarn.
3. Place the sheet of dark construction paper between the jars.
4. Place one washer in each of the jars. Position the jars so that the string hangs between them. The lowest part of the string should be a few centimetres above the paper.
5. Leave the jars in an area where they will be undisturbed and out of any drafts.
6. Allow the jars to stand undisturbed for one week or longer. Observe the results.

What Did You Find Out?

1. How does this activity model chemical weathering in caves?
2. Would the crystal formation likely be faster in a cool, dry classroom, or in a warm, humid classroom? Explain your answer.

Chemical weathering can form stalactites and stalagmites in caves.

12-1D Weathered Lettering

Find Out ACTIVITY

In this activity, you will observe evidence of weathering in your community cemetery, either on a field trip, or by viewing photographs of headstones. By examining changes to the surface of headstones, you can gather evidence about how much weathering has taken place.

Materials

- photographs of headstones

What to Do

1. Make a table of observations like the following one. Give your table a title.

Amount of Weathering		
1	No obvious weathering	Lettering is sharp and clear
2	Little weathering	Lettering easy to read but shows some signs of weathering
3	Some weathering	Most letters still legible but all clean edges removed
4	Quite a bit of weathering	Difficult to distinguish lettering
5	Very weathered	Unable to read any of lettering

Headstone Name	Date on Headstone	Age of Headstone	Type of Rock	Amount of Weathering

2. Record your prediction of which type(s) of rock will weather the fastest.
3. Observe the headstones as instructed by your teacher. If you are in the cemetery, be respectful. Be careful not to disturb any plants growing nearby.
4. Record your observations in your table. Assign each headstone a value for its amount of weathering using the Amount of Weathering chart at the top of the page.

What Did You Find Out?

1. (a) What evidence of mechanical weathering did you observe?
   (b) What evidence of chemical weathering did you observe?
2. (a) Do all headstones of the same age have the same amount of weathering?
   (b) Explain why or why not.
3. What type or types of rock were the headstones made of?
4. Have headstones that are the same rock type and approximately the same age weathered differently? Explain.
5. What other factors besides age, type of rock, and position in the cemetery might play a role in how much a headstone has weathered?
6. Are headstones of the distant past made from the same materials as more recent headstones? Why?

Wild, Weird, Wonderful

www Science

Sails Made of Stone

They rise up 500 m or more from a flat plain in central Newfoundland. We call them "tolts," but elsewhere in the world they are known as inselbergs, monadnocks, tors, and bornhardts.

We also call three of them the Topsails. They have the names of sails, the Main, the Gaff, and the Mizzen, because at a distance they look like the upper sails on a three-masted ship.

They might look like sails, but woe betide any ship's captain who tries to hoist one of them up a mast! The Topsails are huge rocky knobs surrounded by smaller rocky debris on Buchans Plateau east of Grand Lake. They are relics, all that is left over from a former higher landscape level that has all but disappeared due to erosion.

How were the tolts formed? For the past 200 million years, erosion has been the main event in the geological history of Newfoundland and Labrador. During this time, glaciers repeatedly advanced and retreated across our province, carving up the land and polishing it smooth. Rivers eroded the ground, stripping rock and soil from the land's surface and carrying it to the ocean. River erosion, also known as fluvial erosion, led to the development of the plains and plateaus that make up parts of our province.

The combined effect of glacial and fluvial erosion wore the land that used to be level with the tolts down to a featureless plateau. The plateau is a windswept highland area much of which is over 400 m above sea level.

In addition to the towering granite tolts that managed to resist the erosion that went on around them, the plateau is also littered with glacial till and erratics. Erratics are large boulders left behind long ago by retreating glaciers.

Although they withstood earlier glacial and fluvial erosion, the tolts themselves cannot escape erosion altogether. They are slowly being worn down as wind and rain remove weathered debris from their slopes. With time, the tolts will slowly be reduced. As mighty and impenetrable as they look, eventually even the Topsails will surrender to the slow but powerful forces of erosion.

Main Topsail, Central Newfoundland

Check Your Understanding

Checking Concepts

1. Make a series of drawings with captions and labels showing how frost wedging occurs.
2. How is chemical weathering different from mechanical weathering?
3. How do plants contribute to
   (a) mechanical weathering?
   (b) chemical weathering?
4. Explain how both chemical weathering and mechanical weathering can wear down a marble headstone in a cemetery.
5. What is the process called that loosens and moves weathered sediments over Earth's surface?
6. Describe two processes that cause erosion.
7. Describe two ways that glaciers move sediments.
8. What is the final stage of erosion?
9. (a) Why is erosion considered to be a destructive process?
   (b) Why is deposition considered to be a constructive process?
10. What is the name of the in-between stage in the rock cycle between a parent rock and a sedimentary rock?

Understanding Key Ideas

11. A hard candy dissolves much faster in your mouth if you first break it into pieces. How is this process like
    (a) mechanical weathering?
    (b) chemical weathering?

12. What evidence of weathering have you observed in your community?
13. Use the example of a rock falling off a cliff to explain the difference between weathering and erosion. Draw a labelled illustration as part of your answer.

Pause and Reflect

Imagine you are a writer for a scientific magazine. Write a short article describing how a mountain can be weathered and eroded into a rolling hill and what happens to the sediments.

12.2 Soil Types and Characteristics

Soil can take thousands of years to form. Soil gradually develops into three layers, called a soil profile. The topsoil is the most fertile part of the soil, and includes humus and living organisms, as well as air, water, and weathered rock fragments. Soils are different depending on the parent material, climate, vegetation, landscape, and amount of time they have been forming. Different soils have different textures. Sandy, gravelly soils are gritty and have large particles. Clay soils are greasy and have small particles. Loam can be both gritty and greasy and has a variety of particle sizes.

Key Terms

humus
leaching
permeability
porosity
soil profile
subsoil
texture
topsoil

Why is the rock cycle so important to our daily lives? We need plants to survive. Plants need soil containing the right balance of air, nutrients, and water to survive.

Soil is created as part of the rock cycle. Rocks are weathered and eroded by water, wind, ice, and gravity and other factors. The end result of weathering is fine sediment or dirt. Dirt is mainly weathered minerals with little organic matter. How does dirt become fertile soil like the soil found in Codroy Valley (Figure 12.12)?

Figure 12.12 The fertile soil of Codroy Valley is some of the best farmland in Newfoundland. The soft sedimentary rocks of the valley, such as sandstone, limestone, and shale, erode easily and help form excellent soil.

12-2A Comparing Dirt and Soil

Find Out ACTIVITY

In this activity, you will compare and contrast a sample of soil with a sample of dirt.

Materials

- 250 mL dirt/ground rocks
- paper
- 250 mL rich garden soil
- hand lens
- stir stick
- optional: goose-neck camera to magnify and view specimens

What to Do

1. Place a sample of dirt on a piece of paper. Examine the dirt using the hand lens. Use the stir stick to separate the particles. Make as many observations as you can. Record your observations.
2. Place a sample of soil on a piece of paper. Examine the soil using the hand lens or goose-neck camera. Use the stir stick to separate the particles. Make as many observations as you can. Record your observations.
3. Clean up and put away the equipment you have used. Wash your hands thoroughly.

What Did You Find Out?

1. Create a Venn diagram to compare and contrast dirt and soil.
2. What components (parts) of the soil could you identify?
3. What type of processes do you think soil has undergone that dirt has not?
4. Why do you think soil is a better medium for growing most plants than dirt?

Humus

Soil is a mixture of weathered and eroded rock, humus, air, water, and living things, such as fungi, mould, bacteria, and earthworms. **Humus** (HYEW-muhs) is material produced by breaking down plant and animal remains. Decayed plant and animal remains are the main source of nutrients for plant growth. Humus is rich in nutrients, such as nitrogen, phosphorus, potassium, and sulphur. 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. Figure 12.13 on the next page illustrates how humus and weathered rock fragments can become soil.

A *fertile* soil is soil 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.

Did You Know?

About one half the volume of good soil is air and water. The other half is about 90% rock and mineral sediments and 10% organic matter, including living organisms as well as decaying plant and animal remains.

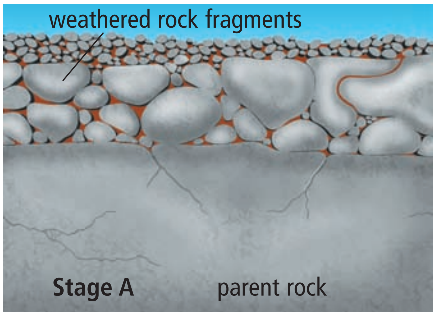


Figure 12.13A These weathered rock fragments contain many cracks and spaces, providing areas that air and water can fill.

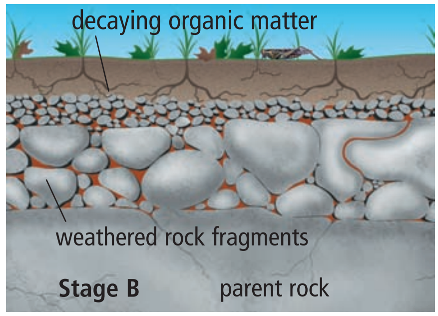


Figure 12.13B Immature soil can support small hardy plants that attract insects and other small animals. Over time, dead plant and animal material build up, and bacteria and fungi cause them to decay. The decaying organic matter forms a layer of humus on top of the weathered rock.

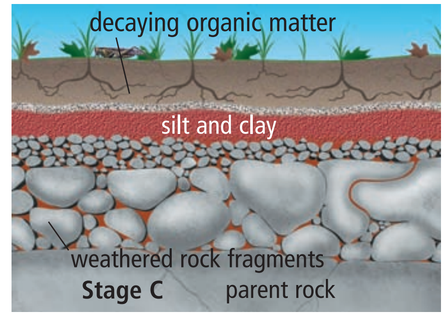


Figure 12.13C Mature soil contains mineral-rich clay on top of weathered rock. The clay forms when water carries the minerals away from the decaying organic matter above. Above the clay, the topsoil extends to the surface and contains humus, plant roots, and living organisms.

Soil Profiles

Did You Know?

There can be billions of microorganisms in every gram of healthy topsoil.

Soils can take thousands of years to form. They can range in thickness from more than 60 m in some areas to just a few centimetres in others. Soil varies in structure and appearance, depending on its depth. As the soil forms, it slowly develops layers with clear differences in appearance and composition. A **soil profile** is the series of layers in soil from the surface down to bedrock. The soil profile in Figure 12.14 on the next page shows how the layers are divided. The layers show different degrees of soil evolution.

The top layer (A) is called the **topsoil.** The topsoil is the most fertile part of the soil and can range in depth from a few centimetres to one metre or more. Topsoil consists of dark-coloured, rich, crumbly soil that contains humus and small grains of rock. As well as supporting plants, this layer is home to insects, earthworms, rodents, and microorganisms.

The next layer (B) is the **subsoil.** Subsoil is more tightly packed and generally lighter in colour than topsoil because there is little or no humus, and because 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. This acid can dissolve elements and minerals from upper layers and carry them through the spaces in the soil to lower layers. Subsoil may be brownish or red because of the clay and iron oxides (rust) washed down from the top layer. Subsoil is less productive than topsoil because the subsoil contains less water and organic nutrients.

Figure 12.14 You can often see soil profiles along roadsides and riverbeds. If you notice a soil profile, try to identify the different layers.

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

Mature soils have all three layers. Some plants grow better on rocks or dirt or early soils. Other plants grow better on mature soils. A newly developing soil does not yet have a subsoil layer. It has a thin layer of topsoil over a layer of bedrock. As the soil continues to develop, a subsoil layer forms and over time becomes more distinct.

How Do Soils Develop?

Weathered and eroded rocks form the parent material of soils. Organic material provides the nutrient base for a variety of soil ecosystems. The type of soil that forms depends on the type of rock that is being weathered. For example, when shale is weathered, clay-type soil results.

Five major factors affect the rate at which soil forms as well as soil texture and composition: parent material, climate, vegetation, landscape, and time (see Table 12.1 on the next page). Wildlife and human populations also affect soil development. Animals help to recycle nutrients as they dig and burrow in the soil. Humans plough, irrigate, and fertilize soil, change drainage patterns, and use soil for non-agricultural developments and disposal of wastes.

Table 12.1 Major Factors that Determine how Soil Develops

Factor	What It Does	Examples
Parent material	– determines physical and chemical properties of soil	– red soils indicate parent rock is rich in iron – limestone bedrock helps make soil less acidic
Climate	– determines what kinds of plants will grow, and how fast they decompose – affects weathering and causes erosion, carrying nutrients from the soil – determines severity of erosion, the rate and amount of water entering the soil, and the rate of chemical reactions and biological activity	– moisture is required for soil organisms to change organic matter into humus – high rainfall leaches mineral nutrients from topsoil – spring run-off helps create rich river-bottom land – wind can blow away sediment before soil has a chance to form – coastal sand dunes contain wind-blown sand
Vegetation	– determines the amount and type of organic matter in and on the soil – protects the soil from erosion	– decaying plants add nutrients and organic matter to the soil – leaf litter in pine forests increases soil acidity – plant roots help hold the soil in place
Landscape	– affects drainage, warmth, and protection from weather – movement of glaciers exposes bedrock, moves parent materials, and deposits sediments	– soil may be eroded from slopes and deposited in lowlands – glaciers deposit sand and gravel; unusually rocky fields; sediment with a wide variety of particle size, from fine clay to coarse gravel
Time	– influences the availability of minerals and the extent of humus development	– young soils do not yet have much humus

Reading Check

1. What is dissolved from upper soil layers in leaching?
2. What are the three layers in a soil horizon?
3. What are five factors that determine how soils develop?

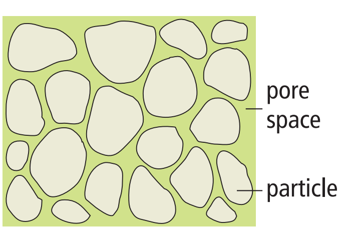


Figure 12.15 Particle size helps determines how much space in the soil will be available for air and water.

Particle Size, Porosity, and Permeability

Rock particles in soil are the result of weathering and erosion, so the particles vary depending on the parent material from which they formed, such as sandstone or granite. The formation of topsoil depends largely on the particle size of the rock fragments (see Table 12.2 on the next page). The particle size determines how large the spaces will be in the soil. The amount of empty space in a soil or rock is called **porosity.**

The particle size, texture, and porosity affect how quickly water will drain through, or permeate, the soil. **Permeability** is a measure of how easily liquids and gases pass through a soil or a rock.

Table 12.2 Average Particle Size

Name of rock sediment	Average particle diameter
Gravel	over 2.0 mm
Sand	0.05 mm to 2.0 mm
Silt	0.002 mm to 0.05 mm
Clay	less than 0.002 mm

Suggested Activitiy

Conduct an Investigation 12-2B on page 428.

Types of Soil

There are many types of soil possible because there are so many different types and amounts of components that make up soil (Figure 12.16). One way to classify soil is to determine its texture. **Texture** relates to how soil feels when it is rubbed between two fingers. Texture can tell us much about the soil: what is in it and what it can do.

- *Sandy/gravelly soil:* This kind of soil has a high permeability. The relatively big spaces between the particles mean that there is a lot of air in the soil. Sandy/gravelly soil tends to be dry and well-drained most of the time. The particles feel gritty when you roll them between your fingers.
- *Clay soil:* Clay particles are so small that they fill up most of the spaces in soil, leaving little room for air, water, or plant roots. Rainwater often sits on top of the soil in puddles and soaks in very slowly. Clay-rich soil feels sticky or greasy, like toothpaste. These soils have very little texture, especially when wet.
- *Loam:* To grow most plants, topsoil should allow water to permeate at a moderate rate. Farmers and gardeners prefer a type of soil referred to as *loam*. A loamy soil is composed of sand, silt, and clay in nearly equal proportions. Loam is medium-textured and may feel gritty and sticky at the same time.

Soils may also be classified according to the climate and area where they occur. Different types of vegetation can be found in different soil types.

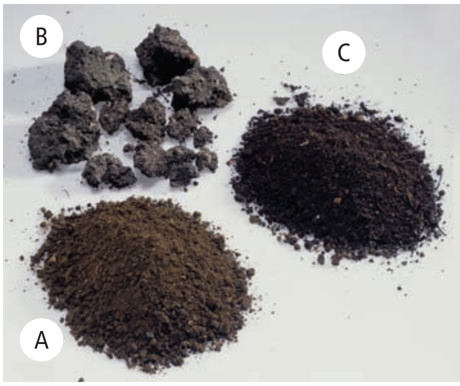


Figure 12.16 Three types of soil: sand (A), clay (B), and loam (C).

Explore More

What kinds of soil are in deserts, rain forests, prairies, and mountains? Find out more about different types of soil. Start your search at **www.discoveringscience.ca.**

Reading Check

1. What is porosity?
2. What is permeability?
3. Which rock sediment has the smallest particle size?
4. What are three main types of soil?

12-2B Be a Soil Sleuth

Core Lab

SkillCheck

- Observing
- Measuring
- Classifying
- Evaluating information

Safety Precaution

- Be careful when using objects with sharp points or edges.

Materials

- soil sample, sand, gravel, clay
- paper
- hand lens
- ruler
- 4 large plastic cups
- thumbtack or pushpin
- cheesecloth
- rubber bands
- scissors
- 4 plastic coffee-can lids
- 4 glasses or beakers (250 mL)
- measuring cup or graduated cylinder
- water
- watch

What is the difference between clay, sand, and gravel? In this activity, you will use tests to determine the characteristics of a soil sample by comparing it to samples of clay, sand, and gravel.

Question

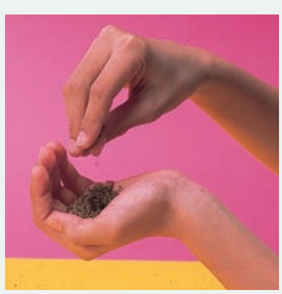
What are the characteristics of a soil sample?

Procedure

1. Make a table of observations like the one below.

Soil Sample				
	Your Soil Sample	**Clay**	**Sand**	**Gravel**
Colour				
Average particle size				
Texture when wet				
Texture when dry				
Time to drain 25 mL				

2. Spread your soil sample on a sheet of paper.
   (a) Record the colour of the soil.
   (b) Measure the diameter of an average particle while looking through the hand lens. If there is a variety in the size of particles, measure the diameter of a group of particles. Divide the diameter by the number of particles you estimate are present along the diameter. This will give you an estimate of the size of one particle.
3. Repeat step 2 with the sand, gravel, and clay samples.




4. Rub a small amount of your soil sample between your fingers to evaluate its texture. How does it feel? Press the soil sample together. Does it stick together or crumble? Wet the sample and try again. Record your observations in the table.

5. Repeat step 4 with the sand, gravel, and clay samples.
6. Test for water drainage.
   (a) Label the plastic cups "sand," "clay," "gravel (with sand and clay)," and "area soil sample." Using the thumbtack, punch an equal number of holes around the bottom of each cup.
   (b) Cover the area of holes on each cup with a cheesecloth square. Secure the cheesecloth with a rubber band.
7. To hold each cup over the glass or beaker, cut a hole in a coffee-can lid so that the cup will just fit inside the hole. Place a cup and lid over each glass or beaker.
8. Half-fill the appropriate cups with dry sand, clay, and your soil sample. Make a mixture of equal parts gravel, sand, and clay, and half-fill the last cup with this mixture.
9. Use the measuring cup (or graduated cylinder) to pour 100 mL of water into each cup. Record the time for 25 mL of water to drain through the sample.
10. Wash your hands thoroughly after completing this investigation. Clean up and put away the equipment you have used.

Analyze

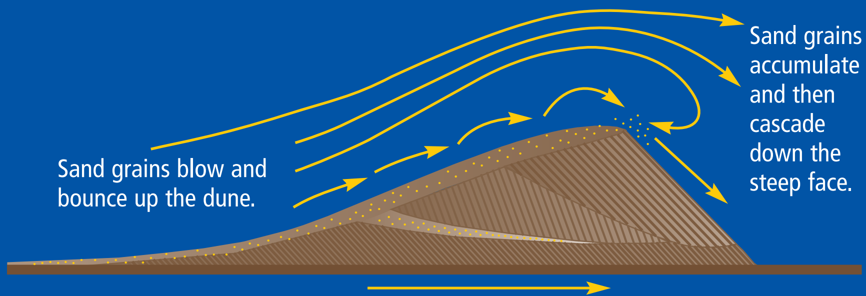
1. Compare the feel and stickiness (texture) of the sand, gravel, and clay samples.
   (a) Which one is the grittiest?
   (b) Which one is the stickiest?
   (c) How does your soil sample compare to these? Is it more like one than another?
2. (a) Compare the drainage of the sand, clay, and gravel mixture. Which drained the most quickly? Which drained the least quickly?
   (b) How did the drainage rate of the gravel mixture compare with the drainage rate of the others?
   (c) Which one did your soil sample resemble the most in drainage?

Conclude and Apply

1. How does the addition of gravel and sand affect the speed at which water drains through the clay?
2. What would you do to increase the speed at which water drains through your soil? What would you do to decrease its speed? Why would this be useful to know?
3. (a) Describe three characteristics of soil.
   (b) Which characteristics do you think most affect how quickly water drains through the soil?
4. Rank the size of the soil particles from largest to smallest in clay, sand, and gravel.
5. Which types of soil would be the best to grow vegetables in your garden? Why?

VISUALIZING HOW DUNES FORM AND MIGRATE

Sand blown loose from dry desert soil often builds up into dunes. A dune may begin to form when windblown sand is deposited in the sheltered area behind an obstacle, such as a rock outcrop. The sand pile grows as more grains accumulate. As shown in the diagram to the right, dunes are mobile, gradually moved along by wind.



A dune migrates as sand blows up its sloping side and then cascades down the steeper side. Gradually, a dune moves forward—in the same direction that the wind is blowing—as sand, lost from one side, piles up on the other side.

Dunes are made of sediments eroded from local materials. Although many dunes are composed of quartz and feldspar, the brilliant white dunes in White Sands National Park, New Mexico, are made of gypsum.

Deserts may expand when humans move into the transition zone between habitable land and desert. Here, villagers in Mauritania in northwestern Africa shovel the sand that encroaches on their schoolhouse daily.

The dunes to the left are coastal dunes from the Laguna Madre region of South Texas on the Gulf of Mexico. Note the vegetation in the photo, which has served as an obstacle to trap sand.

(tl)Stephen J. Krasemann/Photo Researchers, (tr)Steve McCurry, (b)Wyman P. Meinzer, (bkgd)Breck P. Kent/Earth Scenes

Checking Concepts

1. What are the main components of soil?
2. What is the role of humus in the soil?
3. (a) Draw a diagram of a soil profile.
   (b) Label each layer.
   (c) Describe what is happening in each layer.
4. What are the five major factors that determine how soils develop?
5. Put the following sediments in order from smallest particle size to largest: clay, gravel, and sand.
6. What is the difference between porosity and permeability?
7. (a) What are the three basic types of soil?
   (b) Describe the basic characteristics of each type of soil.

Understanding Key Ideas

8. How does the amount of weathered rock material change as you go deeper into a soil profile?
9. Is leaching a helpful process or a harmful process in soil development? Explain your answer.
10. (a) What kinds of organisms live in the soil?
    (b) What role do they play?
11. A sample of soil is greasy, sticky when wet, and does not let water drain very quickly.
    (a) What particle type do you think this soil is made from?
    (b) What could you do to turn it into good gardening soil?
12. How would the soil profile in a rain forest be different from the soil profile in a desert?
13. Give three examples of how the type of soil determines the type of plants present.
14. Why do you think there is relatively little farmland in Newfoundland and Labrador?
15. Copy and complete the following chart in your notebook. Place a checkmark in each of the columns that describes each factor that influences soil development.

	Factor	Meteorological	Geological	Biological	Chemical
(a)	Acidic action				
(b)	Glaciers				
(c)	Gravity				
(d)	Plants				
(e)	Rain				
(f)	Wind				

Pause and Reflect

Make a hypothesis about how to change the permeability of a soil sample. Design an investigation to test your hypothesis. What will be your manipulated and responding variables? What factors will you need to control?

12.3 Sustaining Fertile Soils

Fertile, healthy soil is the nutrient-rich, but delicate basis of healthy plants and animals. Soil can be easily lost to erosion, resulting in desertification. Modern farming methods can reduce productivity and affect other parts of the ecosystem. Ecological farming practices aim at preventing soil erosion. Composting is a method of producing humus. Forestry conservation practices include covering the soil and planting trees.

Key Terms

algal blooms
composting
desertification
fertilizers
no-till farming

Soil is an amazing natural system with billions of residents per cubic metre. To lose the soil, or its ability to grow plants, would be a disaster. Without healthy topsoil, life on our planet would be in danger.

It takes hundreds of years to form a few centimetres of soil, but it takes only a short time to lose the soil to erosion. In the 1930s, farmers in Canada and the United States learned a hard lesson about the importance of conserving topsoil. For years, they had overplanted their fields without adding any nutrients to replace those that were lost. Eventually, there was no humus left, so the soil could not use what little moisture was available during times of drought. The soil turned to dust and was carried away by the wind as shown in Figure 12.17.

Did You Know?

The health of all animals, including humans, is directly related to the health of the soil.

Figure 12.17 Uncovered soil can be blown away.

12-3A Save the Soil

Find Out ACTIVITY

If some topsoil is lost to erosion, how much does it matter? In this activity, you will use a model to represent the amount of topsoil on Earth.

What You Need

- cutting board
- knife
- apple

Safety Precautions

- The knife is sharp and may cause cuts if not handled properly.
- Never eat anything in the science room.

What to Do

1. Carefully cut the apple into quarters.
2. Set aside three quarters. Cut the fourth quarter lengthwise into two equal pieces (each piece is one eighth of the apple).
3. Set aside a one-eighth piece. Carefully cut the other one-eighth piece into four equal pieces. (Each piece is one-thirty-second of the apple.)
4. Set aside three thirty-second pieces. Carefully peel the skin from the last thirty-second piece.
5. Each piece of apple represents the following:
   - The three quarters represent the part of Earth covered by oceans.
   - The one-eighth piece represents land that is unsuitable for human life.
   - The three thirty-second pieces represent land that is unsuitable for food crops.
   - The peel from the last piece represents the layer of topsoil that can support life.

What Did You Find Out?

1. Suppose a crop of food that could only grow in fairly limited regions was affected by loss of topsoil.
   (a) What might be the effect on this food supply?
   (b) What might be the effect on other species?
2. Aside from the loss of food crops, what other long-term effects can be caused by loss of topsoil?

Desertification

Soil is an important resource in Canada and throughout the world. When vegetation is removed by harvesting crops, the soil is exposed to the direct action of rain and wind. Topsoil, which contains the nutrient-rich humus, can be eroded and carried away. Also, without plants, soil development slows and sometimes stops because humus is no longer being produced. When natural vegetation is removed from land that receives little rain, plants do not return. All of these conditions can contribute to the destruction of the natural ecosystem and lead to desert formation. **Desertification** is the process in which nutrient depleted soils are formed through erosion of fertile soil. Desertification is currently happening the world over.

internet connect

Desertification is happening in Canada as well as in other countries of the world. Find out more about desertification in Canada. Start your search at **www.discoveringscience.ca.**

Figure 12.18 This topsoil is exposed to wind and water erosion.

Farming, Soil Loss, and the Environment

Modern farming methods are capable of feeding billions of people on Earth. However, these methods can contribute to the destruction of the very environment that is needed for such large-scale farming. Large equipment requires that farmers plough long straight lines (Figure 12.18). This can contribute to loss of topsoil due to water erosion. Trees that are used as windbreaks often have to be cut down to make larger fields, which can expose the fields to a loss of topsoil due to wind erosion. In many cases, marshes have been drained and fields ploughed right to the edge of rivers or streams. This can contribute to the elimination of different species of wildlife. The machinery used in large-scale agricultural operations relies on the combustion of fossil fuels, which adds to air pollution.

When farmland is cultivated to grow field crops, vegetation is removed. Water enters the soil since there are no plants to absorb water. Irrigation brings even more water into the soil, adding to the groundwater. The excess groundwater leaches minerals (salts) from the soil. Eventually, when the water evaporates the salts are left behind. Every year that salt collects in soil, the soil becomes less and less able to grow crops. In some areas, growing crops is no longer possible (Figure 12.19).

Figure 12.19 A white crust on the soil is evidence of too much salt. Two factors lead to salty soil: too little vegetation and too much water.

Suggested Activity

Find Out Activity 12-3C on page 439

Enriching the Soil

Like you, crops need minerals to survive and stay healthy. Healthy, growing plants require large amounts of three nutrients: nitrogen (N), phosphorus (P), and potassium (K). Different parts of plants use different amounts of each of these nutrients. For example, nitrogen helps make leaves green. Phosphorus is required for the development of roots and new seedlings. Flower and fruit production is stimulated by potassium. Farmers must find ways to replace minerals in the soil that crops have used.

One method of preserving or returning minerals to the soil is crop rotation. Farmers plant a different crop in each field each year. This ensures that the minerals used by one crop are replaced the following year by a different crop (Figure 12.20). For example, a crop of soybeans will replace nitrogen that has been used by a previous crop of corn.

Figure 12.20 Many farmers use forages (legumes and grasses) in a crop rotation to add organic matter and provide protection from wind and water erosion.

Fertilizers

The most common method of enriching the soil is to apply fertilizers. **Fertilizers** are substances that provide nutrients for plants. You may have seen fertilizers being applied in your community, in your garden or greenhouse, or on a local farm. Organic fertilizers are made from plant and animal remains and waste. Inorganic fertilizers are made from essential elements and minerals. Types of fertilizers include compost, manure, and natural and synthetic chemical fertilizers.

- **Composting** is the breakdown of plant material (decomposition). Various organic materials, such as dry leaves, manure, and vegetable peelings are piled together in the right conditions to be transformed into humus. You might have a compost pile or bin at home for food scraps and yard clippings (Figure 12.21).
- Manure from livestock is often used to add organic matter, improve soil structure, and increase nutrients and biological activity. Farmers have added animal manure and bedding to soil for centuries. Manure from herbivores (plant eating animals) such as cows, sheep, goats, and horses is high in nitrogen.
- Chemical fertilizers may be natural or synthetic (human made). Some chemical fertilizers include decomposed animal or plant material, such as bone meal, fish emulsion, and seaweed. Other chemical fertilizers include minerals from Earth's crust, such as volcanic ash and rock dust (crushed basalt, granite, and other rocks).

Figure 12.21 A compost bin

Effects of Using Fertilizers

There are both positive and negative effects of using fertilizers. The *intended* positive effect of using fertilizers is enhanced plant growth. Enhanced plant growth means decreased erosion, more food, and better looking plants and crops.

The *unintended* negative effect of fertilization is increased pollution in run-off. When phosphates from fertilizers run off into nearby ponds or lakes, the result may be **algal blooms,** which are huge increases in the amount of algae in the water. Algal blooms remove dissolved oxygen from the water, which makes it impossible for fish and other aquatic creatures to live there (Figure 12.22).

Nitrogen compounds and other substances in fertilizers and manure, as well as chemicals in pesticides and herbicides, dissolve in water and find their way into the rivers, streams, and groundwater systems. The result is the pollution of human drinking water. How can farmers minimize the damage?

Did You Know?

Run-off from fertilizer was probably the cause of E. coli bacteria entering the water supply of Walkerton, Ontario in 2000. Hundreds of people became ill and within a few days seven people had died as a result of drinking the water.

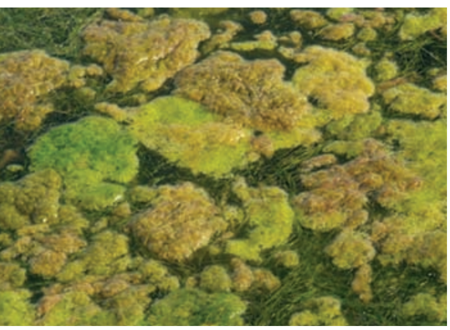


Figure 12.22 An algal bloom caused by run-off from fertilized fields removes oxygen from the water.

Reading Check

1. What is desertification?
2. What are three types of plant nutrients?
3. What is the intended positive effect of using fertilizers?
4. What is the unintended negative effect of using fertilizers?

12-3B Agriculture in the News

Think About It

In this activity, you will research current issues related to agriculture.

What to Do

1. Research current information on agriculture issues in your community or region. You could search local newspapers, news magazines, and the Internet, and talk with local farmers and gardeners.
2. Post the information you find, or summaries of your conversations with experts, on a bulletin board.

What Did You Find Out?

1. Read the information collected by the class, and then, answer the following questions:
   (a) Which issues seem to be receiving the most attention in the media?
   (b) Why do you think they are receiving so much attention?

Ecological Farming Practices

Most farmers try to prevent soil erosion and to minimize the environmental impact of their farming practices. Many of the problems associated with our use of soils, including desertification, can be solved using more ecological farming practices. An *ecological* approach considers the relationship of living things to their environment and to each other. Ecological farming practices include the following.

Suggested Activities

Find Out Activity 12-3D on page 439

Conduct an Investigation 12-3E on page 440

Reducing reliance on chemical fertilizers

Chemical fertilizers can inhibit or kill soil microorganisms that are needed to provide a balanced diet to crops. Ecological soil management aims at helping all parts of the soil ecosystem.

Limiting run-off

Soil erosion can be solved by planting a cover of vegetation on the surface of the ground to slow the flow of water. This gives the soil more time to absorb the water. When more water soaks in to the soil, less water will flow along the surface and cause erosion. Less water will seep into the groundwater and cause salty soils. Vegetation covers also protect soil from the wind. Even covering bare soils with decaying plants helps to hold soil particles in place. In dry areas, instead of ploughing the natural vegetation under the soil to plant crops, farmers graze animals on the natural vegetation. Proper grazing management can retain plants and reduce soil erosion.

No-till farming

Some farmers till or plough their fields two or three times a year, exposing the topsoil to dangerous wind erosion each time. In recent years, many farmers have switched to the practice of no-till farming. In **no-till farming,** plant stalks are left in the field (Figure 12.23). At the next planting, farmers use seed drills to push seed right through the stubble of the previous crop into the undisturbed soil.

Figure 12.23 No-till farming provides cover for the soil all year round and reduces soil erosion.

Planting windbreaks

Farmers plant windbreaks (rows of trees) along edges of fields (Figure 12.24). Windbreaks reduce wind damage to crops, trap snow to increase soil moisture, and provide habitat for wildlife.

Figure 12.24 Rows of trees can reduce soil erosion and damage from wind.

Saving Soil in Forests

Forestry also has an impact on soils. When trees are cut and removed from an area, wind and water can erode the soil. To minimize damage, some trees and debris such as logs and stumps are left on cut areas. As the debris decays, it adds organic matter to the soil. Forests are also replanted with new trees shortly after they are harvested (Figure 12.25). As well, trees and shrubs are usually left around streams to minimize soil loss.

Figure 12.25 Forestry erosion control methods slow the flow of water and the loss of soil to erosion.

Explore More

What are other alternative farming practices that reduce erosion and safeguard the precious topsoil? You can find out by visiting **www.discoveringscience.ca.**

Reading Check

1. What does "ecological" mean?
2. What are four ecological farming practices?
3. Why are trees and shrubs left near streams in forestry conservation practices?

12-3C Maintaining Moisture

Find Out ACTIVITY

In this activity, you will investigate how organic matter affects soil moisture.

Materials

- 3 metal baking pans or similar pans
- garden soil or potting soil
- organic material, such as wood shavings, grass clippings, or leaves
- water
- fan (optional)
- grow light or heat lamp (optional)
- paper towel
- soil moisture metre (optional)

What to Do

1. Add equal amounts of soil to each tray.
2. Cover the soil in one tray with organic matter. Mix the same amount of organic matter in with the soil in the second tray. Do not add organic matter to the third tray.
3. Dampen the soil in the trays using equal amounts of water. Do not saturate the soil.
4. Leave the trays in a warm area, under grow lights, or place them in front of a fan.
5. After several hours, press a sheet of paper towel onto the soil in each tray. Compare the amount of moisture on each paper towel. You can also use a soil moisture metre for this step.

What Did You Find Out?

1. Which tray had the highest soil moisture?
2. How was the amount of soil moisture affected by placing the organic matter on top of the soil or mixing it?
3. What is another way you could measure soil moisture?

12-3D Fertilizer Formulations

Find Out ACTIVITY

A container of fertilizer usually has three numbers that indicate the percentage of each of the three major nutrients of nitrogen, phosphorus, and potassium. For example, a bag of fertilizer marked 12-14-18 contains 12 percent nitrogen, 14 percent phosphorus, and 18 percent potassium. In this activity, you will research fertilizer formulations.

What to Do

Arrange to visit a garden store or nursery or speak with a knowledgeable person. Find answers to the following questions:

- What formulations of fertilizer are available locally?
- How is each formulation used?
- Which fertilizer is used most commonly?
- What other forms of fertilizer are popular, and how are they used?

What Did You Find Out?

1. Organize your findings in a table to present to your class.
2. (a) What amount of fertilizer is best for a plant?
   (b) Can plants have too much fertilizer?
   (c) Rewrite questions (a) and (b) as hypotheses that you could test.

12-3E Decomposing Dinner

Skill Check

- Observing
- Classifying
- Controlling variables
- Evaluating information

Safety Precautions

- Never eat anything in the science classroom.

Materials

- 4 identical plastic pots with drainage holes
- saucers to go under pots
- pieces of window screen or similar material
- magnifying glass
- small stones
- labels for pots
- garden soil (not sterilized)
- water
- Approximately 250 mL of 2 items from List A and 2 items from List B

List A: banana peels, cabbage leaves, grass clippings, potato peels, carrot peels, egg shells

List B: aluminum foil, small pieces of plastic, shredded wax paper, shredded paper

Imagine cooking dinner at your home. You may peel potatoes, chop lettuce, and crack an egg. Each of these actions leaves you with waste material to throw away. Kitchen "waste" does not need to be garbage, however. Under the right conditions, it can be composted. When waste is composted, it is broken down so that the nutrients can be released. The composted material can be recycled, for example, as fertilizer in your garden. In this activity, you will explore the process of composting.

Question

What kinds of materials decompose?

Procedure

Part 1

1. Before starting this investigation, formulate a hypothesis about the kinds of materials that can decompose. Choose four materials to test: two from List A and two from List B. Based on your hypothesis, predict what will happen to each of the materials you are going to test.
2. Set each pot on a saucer.
   (a) Put a few small stones over the drainage hole in each pot.
   (b) Add garden soil to each pot until the pot is about half full.
3. Put one test material in each pot. Label the pots to show what material is in it.
   (a) Cover the materials in the pots with equal amounts of soil.
   (b) Estimate the amount of water that you can add to each pot so that a little water will come out of the bottom of the pot into the saucer. Add the same amount of water to each pot. If no water drains out of the bottom of the pots, add small but equal amounts of water to each pot until some water drains out.
   (c) Cover the open top of each pot with a piece of window screen.
   (d) Put the pots in a sheltered location. Moisten the soil every few days. Be sure to add the same amount of water to each pot.

Part 2

4. After a week, remove the uppermost layer of soil. Check that the soil underneath is moist. Use a hand lens to observe the amount of decomposition of your materials. Record your observations.
5. Replace the soil, and continue to check the decomposition each week until you can see a difference in the condition of the test materials.
6. Clean up your work area as your teacher directs. Wash your hands thoroughly after completing each part of this investigation.

Analyze

1. (a) Which test materials decomposed rapidly?
   (b) Why do you think these test materials decompose rapidly?
2. (a) Which test materials decomposed slowly?
   (b) Why do you think these test materials decompose slowly?
3. (a) Which materials did not decompose over the course of the investigation?
   (b) Why do you think these materials did not decompose?
4. Did your results support your hypothesis? Explain.

Conclude and Apply

1. (a) What factors might speed up the decomposition of the materials you listed in your answer to Analyze question 2?
   (b) Design an investigation to test one of the factors.

Earthworms are an important part of composting and creating healthy soil. As they burrow through the soil, earthworms create channels for air and drainage. They pull down organic matter from the soil surface into their burrows where they partially digest it and mix it with mineral particles to help form humus.

Science Watch

Putting a Stop to Desertification

Desertification is a global problem that currently threatens about 30 percent of the land on Earth. The United Nations declared 2006 to be the International Year of Deserts and Desertification. In doing so, the United Nations was not celebrating desertification. It was making the point that desertification is a serious problem facing the entire world and that we can all help to prevent it. More than 110 countries around the world, including Canada, have land that is at risk of desertification.

The term "desertification" refers to what happens when people overuse or misuse lands. The main culprits behind desertification are overcultivation, overgrazing by livestock, deforestation, and poor irrigation practices. All of these human activities eventually lead to the erosion of topsoil making the land almost useless.

Earth's landmasses are losing as much as 24 billion tons of topsoil each year. Projects in Canada to prevent desertification started in the 1930s are still underway today, including planting windbreaks and developing community pastures. Canada is also active in supporting countries around the world in reclaiming land and preventing desertification.

What are people in other countries doing to combat desertification? In many countries, farmers use different materials to build multi-level terraces on the land to prevent soil erosion. In the African country of Burkina Faso, farmers use rocks to build terraces. In Thailand and the Philippines, farmers plant tall hedges of vetiver grass to terrace land along sloped fields. In South America and Africa, farming techniques such as no-till farming are used to keep soil moist and fertile.

Planting trees is another way to combat desertification. In Niger's Majjia Valley, farmers plant trees to act as windbreaks to reduce wind erosion. Planting trees also helps bind soil and nutrients in the soil together. In the Sahel region of North Africa, trees are planted and grow among crops and pastures, providing shade, moisture, and nutrients to the soil.

Projects to stop desertification can be small and involve a handful of farmers, or they can be projects on a grand scale, like the Great Green Wall project in China, which is named after the Great Wall of China. The Chinese government plans to plant a 4480-km windbreak of trees across the northwest rim of the country along the Gobi Desert. Once the planting is completed in approximately 2074, the Great Green Wall will be longer than the Great Wall itself!

In Niger in West Africa, a girl helps plant drought-resistant plants to hold the topsoil in place.

Questions

1. How do humans cause desertification?
2. Why is desertification such a serious problem?
3. How does planting trees help combat desertification?

Check Your Understanding

Checking Concepts

1. Why is topsoil valuable?
2. (a) What is desertification?
   (b) When does it happen?
   (c) Where is it happening?
3. What are five modern farming practices that contribute to soil loss or destruction of the environment?
4. (a) Define fertilizers.
   (b) What are three types of fertilizers?
5. Explain the process of composting.
6. Draw a flow chart showing the unintended negative effect of using fertilizers.
7. Name five farming or forestry practices that help prevent soil erosion or improve soil health.

Understanding Key Ideas

8. What impact does loss of soil have on humans?
9. Why might you choose not to use chemicals to help your lawn grow?
10. Why is it important to limit run-off on farms?
11. What are the benefits of limiting reliance on chemical fertilizers?
12. Draw a labelled illustration that explains the process of no-till farming. Include and label a windbreak in your drawing.
13. (a) Forests are often cut down to provide space for homes to be built. How do the conditions shown in the photograph below increase erosion of soil?
    (b) How could this erosion be reduced?

Pause and Reflect

"Feed the soil, not the plant," is one way of expressing an ecological approach to enhancing soil. What does this expression mean? How could you put this expression into practice if you were a farmer or a gardener?

Chapter Review

Prepare Your Own Summary

In this chapter, you investigated the processes of weathering, erosion, and soil formation as well as the importance of topsoil. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 9 for help using graphic organizers.) Use the following headings to organize your notes.

1. Weathering
2. Erosion
3. Soil Formation
4. Soil Loss
5. Soil Enrichment

Checking Concepts

1. How do animals that dig in the soil help weather rocks?
2. Where do acids used in chemical weathering come from?
3. In what type of climate is chemical weathering more rapid? Why?
4. What is the most powerful agent of erosion on the surface of Earth?
5. Explain the difference between
   (a) weathering and erosion
   (b) erosion and deposition
6. (a) List three agents of erosion.
   (b) Describe one affect that each agent might cause.
7. (a) What is humus?
   (b) Why is humus important to soil development?
8. Explain what process is occurring in the top, middle, and bottom layers of a soil profile.
9. (a) Define porosity.
   (b) Define permeability.
   (c) Relate porosity and permeability to soil types.
10. (a) What are the three main soil types?
    (b) How is each soil type different in terms of texture?
11. What are two problems that can be caused by overuse of chemical fertilizers?

Understanding Key Ideas

12. (a) How are weathering and erosion harmful to life on Earth?
    (b) How are weathering and erosion helpful to life on Earth?
13. In what ways can humans cause erosion? Make a list and record your ideas of how humans can prevent each cause.
14. The rock formation below is called a sea stack.
    (a) What process has carved and shaped the sea stack?
    (b) Draw what these rocks might have looked like thousands of years ago.
    (c) Draw how these rocks might look thousands of years in the future.

15. Discuss an example of human action in your community that has been taken to prevent damage from one of the environmental changes described in this chapter.

16. (a) Explain how soils that develop under grassland might be different from those that develop under forest vegetation.
    (b) What causes the soils to develop differently?

17. Imagine that you are an experienced field crop farmer. You are thinking about buying a particular parcel of land and want to check the soil. Answer the following questions:
    (a) How could you test the soil for organic matter?
    (b) Why would you be concerned about organic matter?
    (c) If the soil is low in organic matter, how could you improve it?

18. (a) Explain ways in which farming practices can actually damage the soil.
    (b) Why is it in a farmer's best interest to take steps to reduce the impact that large-scale farming can have on the environment? Use specific examples in your answer.

19. What can be done to slow erosion? Record your ideas for each of these landforms: a steep slope, the plains, and an ocean shoreline.

Pause and Reflect

Sediment from weathered and eroded rock is necessary for forming soil. Could it be possible to have too much sediment in an area? Explain your ideas with examples.

Unit Summary

10 Earth's crust is made up of rocks and minerals.

- A mineral is a pure, naturally occurring, inorganic solid substance, such as quartz, hematite, mica, and magnetite. (10.1)
- Minerals can be identified by their properties, such as lustre, colour, streak, hardness, cleavage, and fracture. Lustre can be dull, glassy, or metallic. The Mohs Hardness Scale is used to rank the hardness of minerals. (10.1)
- A rock is a mixture of two or more minerals. Rocks are grouped into three families based on how they were formed: igneous, sedimentary, and metamorphic. (10.2)
- Igneous rocks result from the cooling of magma below Earth's surface (intrusive) or the cooling of lava at Earth's surface (extrusive). (10.2)
- Sedimentary rocks are formed through the processes of compaction and cementation and are composed of sediment from rocks, minerals, and decaying plants and animals. (10.2)
- Metamorphic rocks are made when heat, pressure, and/or hot fluids change one type of rock into another type. (10.2)
- Rocks change from one family to another as they are heated up, cooled down, worn away, and placed under pressure in the ongoing processes of the rock cycle. (10.3)
- Rocks and minerals have many uses. Many rock and mineral resources are found in Newfoundland and Labrador. (10.3)

11 Earth's crust is constantly changing.

- Earth is made of four layers: crust, mantle, outer core, and inner core. (11.1)
- Evidence from the shape of continents, fossils, rocks, and climate change indicates that Earth's crust is broken into pieces. Evidence has also been gathered from the sea floor by sonar, magnetometers, and deep sea drilling. (11.1)
- The theory of plate tectonics replaced the continental drift theory and suggests that convection currents in the mantle may be the reason for the movement of the crust. (11.1)
- Earthquakes can occur where plates push together, pull apart, or move sideways past each other. (11.2)
- Where plates meet on convergent boundaries, mountains can form. When one plate subducts under another plate, melting occurs, forming volcanoes and mountain ranges. (11.3)
- The geologic time scale divides Earth's history into eras based on the appearance of life forms in the fossil record. (11.3)

12 Soil is the living component of Earth's crust.

- Weathering, erosion, and deposition work together to break rock down and transport the sediments to other locations. (12.1)
- Eroded minerals, organic matter such as decaying plant and animal materials (humus), water, and air can combine to form soil that can support the life of plants. (12.2)
- Soils are considered to be sandy/gravelly, clay, or loam depending on their particle size. Five factors that determine the type of soil formed are parent rock, climate, vegetation, landscape, and time. (12.2)
- Topsoil is a precious and valuable resource that can easily be lost due to misuse. There are ecological farming and forestry practices that can reduce erosion and help improve the quality of the soil. (12.3)

Key Terms

- beds
- cementation
- cleavage
- compaction
- extrusive rock
- fracture
- gems
- hardness
- igneous
- intrusive rock
- lava
- lustre
- magma
- metamorphic
- mineral
- parent rock
- resource
- rock
- rock cycle
- sedimentary
- streak

Key Terms

- bedrock
- continental drift
- convection currents
- convergent boundary
- crust
- divergent boundary
- earthquake
- epicenter
- fault
- focus
- fold
- fossil
- geologic time scale
- inner core
- magnetometer
- mantle
- outer core
- pangaea
- plate tectonics
- Richter scale
- Ring of Fire
- seismic waves
- seismograph
- sonar
- subduction zones
- transform boundary
- volcano

Key Terms

- algal blooms
- chemical weathering
- composting
- deposition
- desertification
- erosion
- fertilizers
- humus
- leaching
- mechanical weathering
- no-till farming
- permeability
- porosity
- soil
- soil profile
- subsoil
- texture
- topsoil
- weathering

Modelling Geological Processes in Your Community

There are many examples of geological processes at work in your community and across the province of Newfoundland and Labrador. Scientists and researchers from all around the world have come to our province to investigate the stories written in our rock about the effects of the rock cycle, the movement of Earth's crust over time, evidence from the fossil record and geologic time, and the development of soils.

Now it is your turn to research the geology of our province. You can investigate evidence of a geological process at work in your community or elsewhere in our province and share your findings with your classmates. Your teacher might assign your group a topic, or you might choose your own.

Problem

What evidence of geological processes in your local community or elsewhere in our province can you identify and model?

Criteria

- You should research your geological process by visiting the site and making direct observations, by researching using the library and Internet, and/or by speaking with local experts.
- You should represent the evidence or process visually, either with detailed photographs, drawings, a mural, a 3-D model, a computer slide show, or through a skit or dance.
- Your presentation should be accompanied by a summary explaining the site you researched, the evidence you have found, and the conclusions you have made based on the evidence.

Procedure

1. After you have chosen or been assigned a topic, meet with your group to brainstorm information you already know about your topic. Make a list of questions you would like to answer about your topic.
2. Assign group roles for gathering information and preparing the presentation. Decide on which format you will use to present your information.
3. Research to answer your questions and to create illustrations, photographs, scenery, and so on, as needed. You can start your research at www.discoveringscience.ca.
4. Make an outline of your presentation. Discuss improvements and refinements to the outline. Try to encourage ideas from all group members.
5. Create your presentation and practise sharing it. Make refinements to improve the presentation.
6. Create the written summary to accompany the presentation.
7. Be prepared to answer questions about your presentation.

Report Out

Share your presentation with members of your class, school, and/or community. Answer questions from your audience.

Soil Super Stars

Introduction


Adding leaves to compost

Soil super stars are students who know how to compost. Students in schools across Canada are discovering that it is easy and fun to compost. They are setting up composting programs in their schools and communities, indoors as well as outdoors, and using the compost to help beautify the school property or to add to the school garden. You can start a program in your school. All you need to start is a little bit of research, a suitable space or container, yard trimmings, and fruit and vegetable scraps.

Background

Adding compost to soil is an effective way of improving the fertility of the soil and the health of plants that grow in it. Compost releases its nutrients to the soil gradually, in small doses over long periods of time. It improves soil structure and texture, loosens clay soils and helps sandy soils hold water. Compost also helps soils control soil erosion and stimulates healthy root development in plants.

Find Out More

Find out more about how other schools have set up their compost programs. Create a list of questions to guide your research. You might want to ask questions such as the following:

- How does compost benefit the soil?
- What kind of container did they use?
- Where did they place their compost container or pile?
- What does ready-to-use compost look like?
- Is there a smell?
- How long does it take to produce compost?
- What role does moisture content play in decomposition?

If you are researching indoor composting, you might want to know:

- What are red wrigglers? What are their habitat requirements? How can they be used to help recycle waste?

Start your research at www.discoveringscience.ca

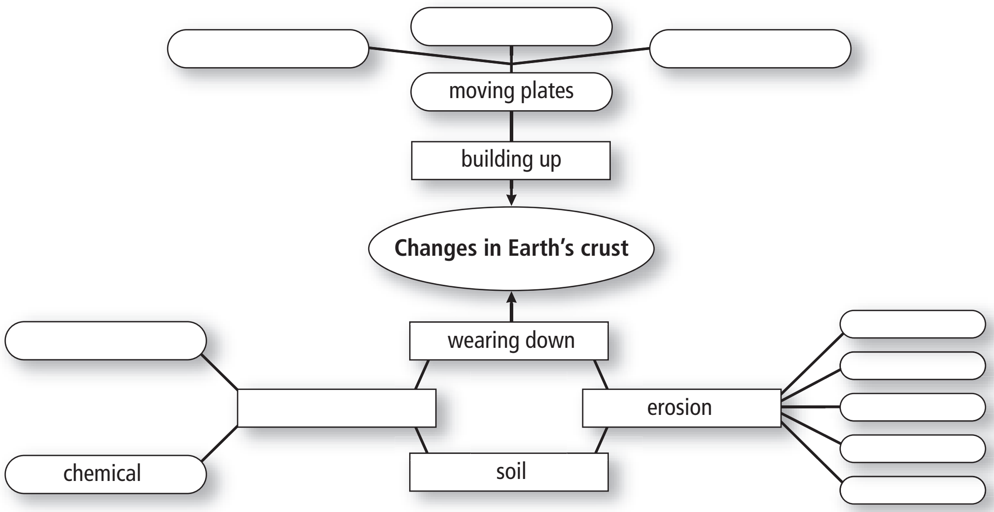
Report Out

1. Write an article for a school web site or webcast explaining how to set up a compost program.
2. Create a flow chart of instructions that other classes or schools could use to set up a compost program.

Unit Review

Visualizing Key Ideas

1. Copy the following concept map about Earth's crust into your notebook. Complete the map.



Using Key Terms

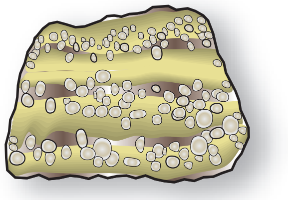
2. In your notebook, state whether the following statements are true or false. If a statement is false, rewrite it to make it true.
   (a) If a mineral has cleavage, it splits along smooth, flat planes.
   (b) Metamorphic rocks form through the processes of compaction and cementation.
   (c) The processes in the rock cycle do not occur in a set order.
   (d) Two plates pull apart at a subduction zone.
   (e) Seismic waves spread out like ripples on a pond.
   (f) Earth is estimated to be 4600 million years old.
   (g) Weathering affects only natural features such as rocks, caves, and mountains.
   (h) Leaching is the removal of soil dissolved in water.

Checking Concepts

10

3. (a) What six properties would you use to identify minerals?
   (b) Explain how you would use each property.
4. What is the difference between a rock and a mineral?
5. Where do rocks come from?
6. How can sediment change into sedimentary rock?
7. If igneous rocks and metamorphic rocks both form from heat, why are these two kinds of rock different?

8. (a) Place the rock below in its correct family.



(b) How did you decide?

9. Draw and label an illustration of the rock cycle.

11

10. How can two coastlines be separated by an ocean and have matching shapes?
11. What are mid-ocean ridges?
12. What is happening to the crust at mid-ocean ridges?
13. How is Earth's crust recycled through the mantle?
14. "An earthquake starts at the epicentre." Is this statement true or false? Explain your answer.
15. What effects does a volcano have on the surrounding environment?
16. (a) What is the relationship between the locations of earthquakes, volcanoes, and mountain ranges?
    (b) Which parts of the world have all three?
17. What is the difference between a mountain formed by folding and a mountain formed by faulting?
18. Many fossils of trilobites are found in Newfoundland. What does this tell you about Newfoundland's past?

12

19. What property of water makes frost wedging possible?
20. (a) How can wind change Earth's surface?
    (b) How can gravity change Earth's surface?
21. (a) What is soil?
    (b) How does it form differently in different places?
22. What is the difference between topsoil and subsoil?
23. What is the main property used to classify a soil?
24. (a) Compare compost and humus.
    (b) Explain their importance in the formation of soils.
25. Explain how procedures such as clear cutting, overgrazing, and farming can lead to desertification.
26. Imagine you are a farmer. What could you do to help reduce soil erosion on your land?

Unit Review

Understanding Key Ideas

27. Imagine yourself in one part of the rock cycle. For instance you could be "magma man" or "weathered woman." Write a story of your voyage through one complete cycle of the rock cycle. Be creative!

28. Is a rock a permanent thing? Explain your answer.

29. (a) Why do you think some igneous rocks have holes or air spaces?
(b) Do you think such rocks are likely to be intrusive or extrusive? Explain why.

30. These layers of sedimentary rock in Gros Morne National Park were once horizontal. How did they become tilted?

31. Prepare a poem or a song in which you compare and contrast volcanoes and earthquakes.

32. Why do you think the Precambrian era was so much longer than the other eras?

33. Imagine that you are designing a display showing dinosaurs in their environment. Would you include any models of humans in the display? Explain why or why not.

34. How does water contribute to
(a) mechanical weathering?
(b) chemical weathering?
(c) erosion?
(d) soil fertility?

35. Use diagrams to describe the processes involved in moving material from a mountain to the bottom of a river over time.

36. Explain the importance of glaciers to the mineral resource industry.

37. (a) How do organisms help soils to develop?
(b) Is their activity an example of mechanical weathering or chemical weathering? Explain.

38. (a) Name three processes that build up Earth's surface.
(b) Is Earth's crust getting thicker? Why or why not?

39. (a) Give two examples of gradual change in Earth's crust.
(b) Explain their causes.

40. (a) Give two examples of sudden change in Earth's crust.
(b) Explain their causes.

Thinking Critically

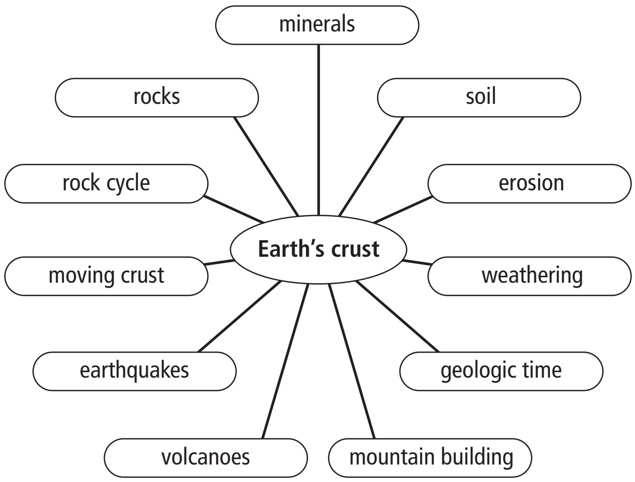
41. A core sample was taken from the bottom of a lake. The sample contained first a layer of sandstone, then a layer of shale, and finally a layer of conglomerate on top.
(a) Why could these sediments not have settled at the same time?
(b) Explain what you think happened.

42. Suppose you were given two rocks to classify. Rock A was formed deep underground and was found at the surface. Rock B was found in an underground mine but was formed at the surface. Write a paragraph about each rock in which you predict how each might have been formed and moved to its new location.

43. Imagine returning to your community 100 years from now. How might weathering and erosion have changed the landscape? Use specific examples from your community.

Developing Skills

44. Copy this chart into your notebook. For each topic, choose one question that you would like to investigate. Write each question next to its topic.



45. Research in newspapers and magazines, or on the Internet to find an article about an earthquake or volcano. Write a summary of the article to share with the class. Identify three questions that the article did not answer.

46. Design a fair test to investigate the effectiveness of using natural fertilizers as compared to human-made fertilizers.

Pause and Reflect

Suppose you are trying to find out what geological processes have taken place where you live. What kinds of clues would you look for? Where would you look?