

Mount St. Helens in the state of Washington blew up in May of 1980. The force of the explosion ripped off the top of the volcano. The sky turned black in the middle of the day. What material do you think turned the sky black?

Learning Objectives

- Describe the theory of plate tectonics.
- Explain how trenches and mountains are formed.
- Compare and contrast earthquakes and volcanoes.
- Identify the three main types of rock in the Earth's crust and describe how they are formed.
- Describe the processes of weathering and erosion.
- LAB ACTIVITY: Compare the contents of different types of soil.
- ON-THE-JOB SCIENCE: Relate rock identification to the work of a geologist.

Words to Know

earthquake	a sudden, violent shaking of the Earth
geologist	a scientist who studies rocks to learn about the history and structure of the Earth
plate tectonics	the scientific theory that the Earth's crust is made up of plates that slowly shift position
trench	a deep, long valley in the ocean floor
magma	melted rock formed in the Earth's mantle
volcano	an opening in the Earth's surface that releases magma from the mantle
lava	magma that has reached the Earth's surface
igneous rock	a type of rock formed from magma
sedimentary rock	a type of rock formed by the pressing together of smaller particles of rock or the remains of living things
metamorphic rock	a type of rock formed when igneous or sedimentary rock changes under very high temperatures or pressure
weathering	a process that breaks down rocks and minerals
soil	rocks on the Earth's surface broken down by weathering to very tiny pieces that mix with the nutrients from living and once-living things
erosion	the wearing away of rock and soil
glacier	a large, slow-moving field of ice

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Drifting Continents

The Earth's crust moves. Most of the time, we do not feel the movements. An **earthquake** is a sudden, violent shaking of the Earth. In California, there is at least one earthquake every week. Earthquakes are caused by a shifting of pieces of the Earth's crust.

Most earthquakes are so small that only scientists notice them. However, every 50 to 100 years or so, a big one comes along and does a lot of damage.

A **geologist** is a scientist who studies rocks to learn about the history and structure of the Earth. Geologists also study the movements of the Earth's crust and what causes them.

Most geologists think that all the continents were once part of one big supercontinent called *Pangaea*. About 200 million years ago, pieces of land began breaking free from Pangaea. These landmasses came together and separated many times. Eventually they drifted to the positions they are in today.

Plate tectonics is the scientific theory that states that the Earth's crust is made up of plates that slowly shift position. A plate is a large piece of the Earth's crust. The movement of these plates causes earthquakes.

Some of the plates are very big, but there are smaller plates, too. A plate can include a landmass, such as a continent, as well as a section of the ocean floor. The plates are moving all the time. However, they move very slowly. Most of the United States is on the North American plate, which is drifting westward.

Remember

A theory is a guess about something based on evidence.

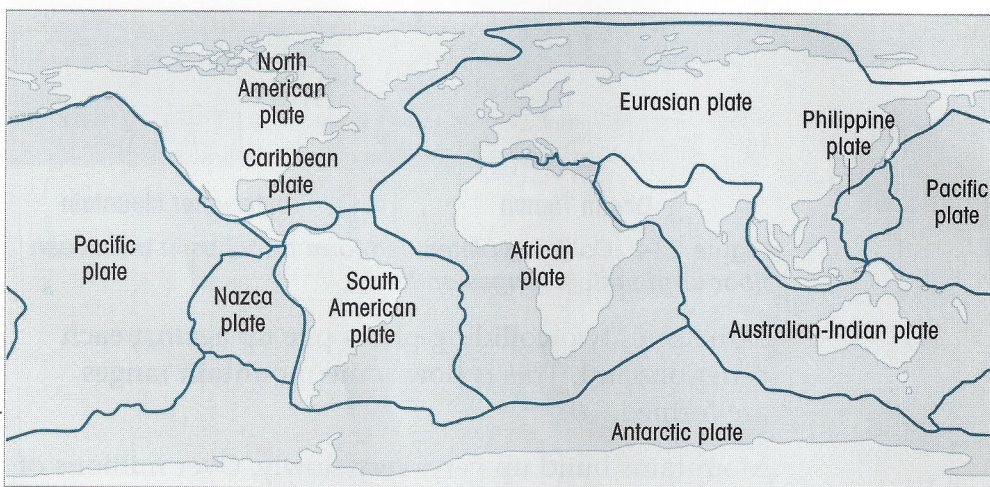


Figure 22-1 This map shows the main plates of the Earth's crust.

Continental drift is the theory that the Earth's large landmasses are carried along, or drift, because of the movement of the plates. Geologists think they know why these pieces of the Earth's crust are moving. It is because the crust floats on the hot, softer rock of the mantle. The plates are carried along in the flow.

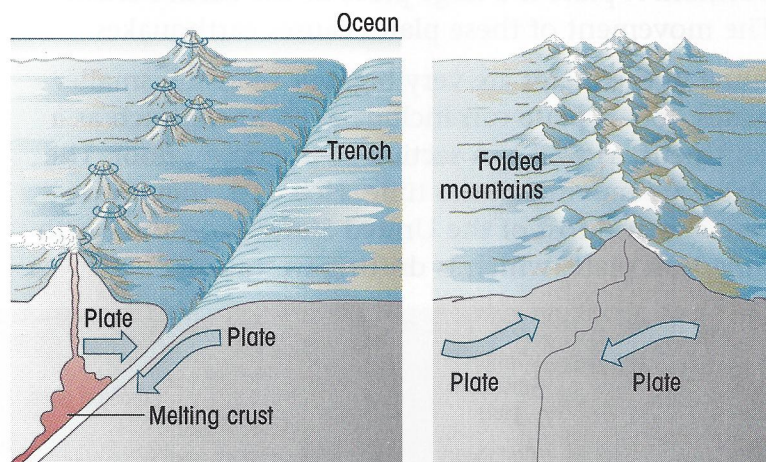
Remember

The outer part of the Earth's mantle is like thick molasses. It flows very slowly.

✓ How do continents drift across the Earth's surface?

Trenches and Mountains

The plates of the Earth's crust may bump into each other, or collide. As they collide, one plate may be forced under the other. This plate gets pushed down into the hot mantle, where the crust melts. When one plate gets pushed down under another beneath the sea, a **trench** forms between them. A trench is a deep, long valley in the ocean floor.



Ocean Trench

Underwater Mountain

Figure 22-2 Colliding plates can form trenches in the ocean floor or mountain ranges on land.

Sometimes two colliding plates pile up against each other on land. This is how some mountain ranges are formed.

Mountains build up very, very slowly. Over millions of years, the plates push against each other. As they push, the land gets shoved upward, making mountains. The Alps in Europe were formed this way. So were the Andes in South America and the Himalayas in Asia. Mount Everest, in the Himalayas, is 29,028 feet (8,848 meters) above sea level. It is the highest point on Earth.

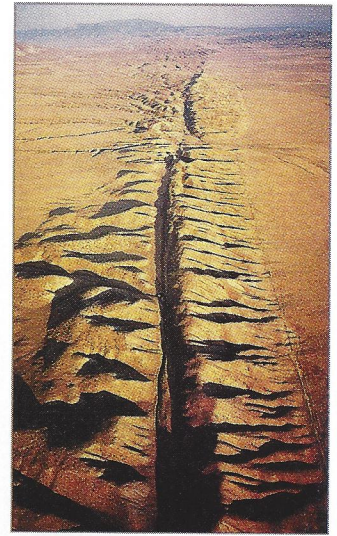
✓ **What two kinds of landforms develop when plates collide? How do they develop?**

Earthquakes

Sometimes, instead of two plates pushing into each other, they slide past each other. This is true of the Pacific and North American plates. They meet along the western coast of North America. The Pacific plate moves about 2 inches (5 centimeters) each year in a northwest direction.

Many earthquakes occur along this coast. Each time there is a sudden slip between the plates, an earthquake occurs.

Two huge pieces of the Earth's crust may rub against each other. The plates do not slip by each other smoothly. Friction holds the upper layers of the crust together. However, the plates continue to move deeper down. Pressure builds up on the surface. Finally, when the strain becomes too great, the plates slip. The sudden movement sends shock waves through the Earth. An earthquake is the result.



The Pacific and North American plates meet in California at the San Andreas fault.

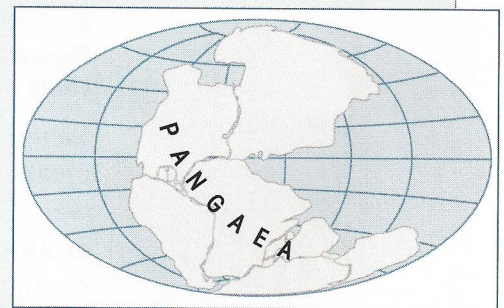
✓ How do moving plates cause earthquakes?

Great Moments in Science

PUTTING THE PUZZLE TOGETHER

A German scientist named Alfred Wegener was looking at a map of the world in 1912. He noticed that the continents looked like jigsaw puzzle pieces that fit together. He thought that at one time these pieces were part of one big continent, which he called Pangaea. This was the beginning of the theory of continental drift. Wegener's discovery was used to develop the theory of plate tectonics.

CRITICAL THINKING How does the theory of plate tectonics explain Wegener's discovery?



Wegener called the supercontinent Pangaea.

Volcanoes

Sometimes, when plates move, openings form in the crust. Melted rock, called **magma**, squeezes up from the Earth's mantle. An opening in the Earth's surface that releases magma from the mantle is called a **volcano**. The word *volcano* is also used to describe the mountain that builds up around the opening.

Volcanoes can form on dry land or on the ocean floor. The magma comes up through openings called **vents**. Magma that has reached the Earth's surface is called **lava**. As the lava cools, it hardens into rock. Over time, the lava builds up and creates a mountain.

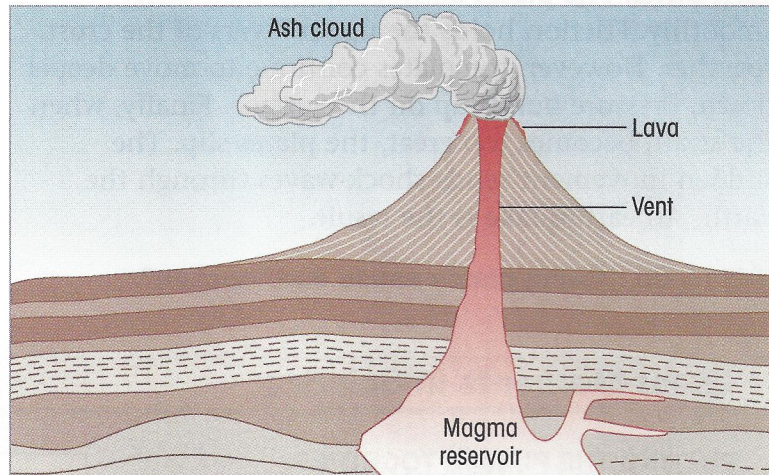


Figure 22-3 *Magma reaches the Earth's surface through vents in volcanoes.*

When volcanoes occur on the ocean floor, they can create islands. The Hawaiian Islands were formed this way. There are many earthquakes and volcanoes around the edge of the Pacific plate. In fact, there are so many volcanoes in this area that it is called the "Ring of Fire."

Some volcanoes erupt violently. Lava, ash, and hot gas explode high into the air. Other volcanoes erupt more gently. The lava flows quietly onto the surface.

✓ How does a volcano form?

Lesson Review

Write *true* or *false* for each sentence. If the sentence is false, replace the underlined term to make the sentence true.

1. Most geologists think that all the continents were once attached.
2. When two plates collide, they can form trenches or mountains.
3. The Earth's plates float on the crust.
4. **CRITICAL THINKING** Why does an earthquake near a volcano warn that the volcano may erupt soon?

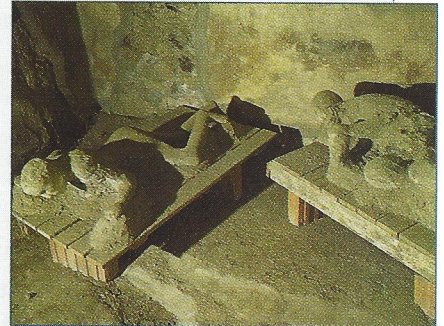
A Closer Look

POMPEII

In 79 A.D., Pompeii was a lively seaside town in what is today called Italy. A volcano named Mount Vesuvius towered over the city. But the people did not fear it. No one had ever seen Vesuvius erupt. It had sat quietly for 800 years. Its slopes were covered with trees and vines. Farmers worked the rich soils around it.

That August, however, Vesuvius erupted suddenly and with great violence. A cloud of hot ash and gas rolled down the slopes of the volcano. Thousands of people were killed as they tried to escape the city. Tons of hot ash and cinders fell on the city for three days. The ash hardened almost instantly around the dead bodies. Today, in Pompeii, you can see the shapes of the people who were taken by surprise when the ash rained down.

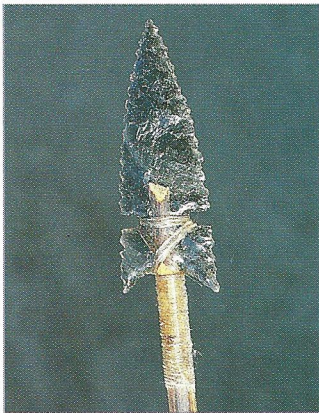
CRITICAL THINKING Why did the eruption of Mount Vesuvius kill so many people?



A thick layer of ash formed molds around the people of Pompeii when they died.

Words to Know

igneous rock	a type of rock formed from magma
sedimentary rock	a type of rock formed by the pressing together of smaller particles of rock or the remains of living things
metamorphic rock	a type of rock formed when igneous or sedimentary rock changes under very high temperatures or pressure
weathering	a process that breaks down rocks and minerals
soil	rocks on the Earth's surface broken down by weathering to very tiny pieces that mix with the nutrients from living and once-living things
erosion	the wearing away of rock and soil
glacier	a large, slow-moving field of ice



Obsidian is a smooth, shiny igneous rock. It looks like glass. Long ago, people made tools from obsidian.

Kinds of Rock

The Earth's crust is made of rock. Maybe you collect or once collected rocks. If so, you know that there are many different kinds. Some of the physical properties of rocks are color, shape, hardness, and texture.

There are three basic kinds of rock. These are igneous, sedimentary, and metamorphic rock.

Igneous Rock

Igneous rock is a type of rock formed from magma. The magma is forced up from the mantle or lower crust. When it reaches the surface, the magma hardens into rock. Some kinds of igneous rock are *obsidian*, *basalt*, and *granite*. Igneous rocks make up about 95 percent of the Earth's crust.

Sedimentary Rock

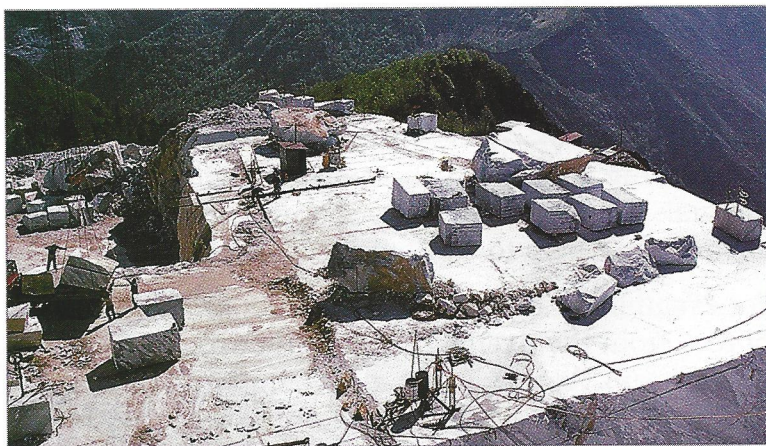
Sedimentary rock is a type of rock formed by the pressing together of smaller particles of rock or the remains of living things. It takes a very long time for sedimentary rock to form. Beds of clay, sand, or gravel may harden to make sedimentary rock. *Shale* is a kind of sedimentary rock made of hardened clay. *Sandstone* is a kind of sedimentary rock made of sand. *Coal* is a sedimentary rock formed from plant fossils. *Limestone* is a common sedimentary rock. Some limestone forms from the shells and bones of tiny animals in the sea. Sedimentary rocks are the most common rocks on the Earth's surface.



Sandstone is made of sand grains cemented together by minerals.

Metamorphic Rock

The third kind of rock is called **metamorphic rock**. Metamorphic rock is a type of rock formed from sedimentary or igneous rock that changes under high temperatures or pressure. When igneous or sedimentary rocks become extremely hot, they change chemically. They *metamorphize*. Two kinds of metamorphic rock are *marble* and *slate*.

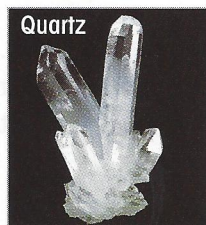
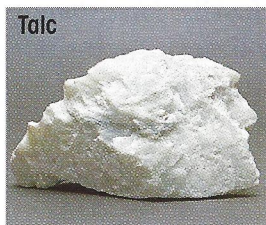


Marble is a metamorphic rock that is used for buildings and monuments. It comes mostly from quarries such as this one.

✓ What are the three kinds of rock, and how do they form?

Building Rocks From Minerals

All rocks are made of minerals. There are at least 2,000 different kinds of minerals. Each one has a unique chemical makeup. Many minerals are pure elements. However, most are combinations of elements. Some examples of minerals are talc, gold, quartz, and bauxite.



Talc is ground into talcum powder. Quartz is made into glass. Gold is used for jewelry. Bauxite is used for aluminum baseball bats.

✓ What are rocks made of?

Weathering

Weathering is a process that breaks down rocks and minerals. Running water, ice, rain, plants, animals, and chemicals all help to weather rocks and minerals.

For example, as a river flows, it washes away little bits of rock from the riverbed. These bits of rock are swept downstream. As they move, they bump into other rocks and tumble along the bottom. Slowly, they break into smaller and smaller pieces.

Ice also causes rocks to weather. Rocks have many cracks. Water fills the cracks in the rocks. When the water freezes, it expands. The freezing water, or ice, acts like a wedge to break the rock into smaller pieces.



Science Fact

Rocks change from one type to another many times as they break down, wear away, get pressed, melt, and cool. This changing of rocks is known as the rock cycle.

Rain causes weathering, too. Raindrops beat on rocks like millions of little hammers. Eventually, the rocks wear down. Rain also causes weathering by mixing with gases in the air to make a weak acid. This acid dissolves certain minerals in rocks. Over time, the rocks crumble. Even plants help weather rocks. Some plants start growing in the cracks of rocks. As the roots grow, they push on the rocks and help break them apart.

Soil is an important product of weathering. Soil is made up of rocks on the Earth's surface broken down by weathering to very tiny pieces that mix with the nutrients from living and once-living things. A layer of soil takes thousands of years to form.

✓ How does weathering create soil?

Erosion

Erosion is the wearing away of rock and soil. Like weathering, a river can cause erosion. Very slowly, a river valley can be carved out of rock by moving water. Valleys that are cut by rivers are V-shaped. Wind can also erode soil by blowing the rich top layer away.

A **glacier** is a large, slow-moving field of ice. Glaciers cause erosion, too. As they move, they clear out everything in their paths. Valleys cut by glaciers are U-shaped.

✓ What are two ways rock and soil are eroded?

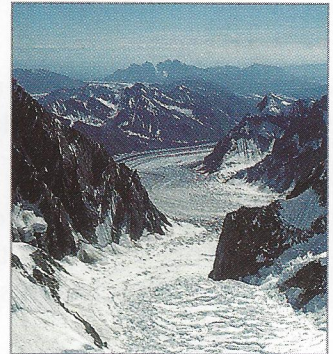
Lesson Review

1. What are four physical properties of rocks?
2. What are three things that cause weathering?
3. How do glaciers cause erosion?
4. **CRITICAL THINKING** How would the Earth's surface look different if there were no weathering or erosion?



Science Fact

Over millions of years, weathering and erosion can wear down entire mountain ranges. Older mountains are usually lower than newer mountains.



Glaciers carve out valleys as they flow downhill.



LAB ACTIVITY

Recognizing Types of Soil

BACKGROUND

Soil comes in many different types. Some soils are dark. Others are light. Some have large grains and are dry. Some have tiny grains that hold moisture better. Very rich soils contain live plants or animals or pieces of dead plants and animals. They add nutrients to the soil.

PURPOSE

You will describe what is in different samples of soil and determine which are good for growing plants.

MATERIALS

paper, pen, 2 different soil samples, hand lens, toothpick

WHAT TO DO

1. Copy the chart to the right.
2. Work with a partner. Put two soil samples on separate sheets of paper.
3. Use a hand lens to observe the first sample close up. Use the toothpick to separate the soil grains and other particles to observe them better. Record your observations in the chart.
4. Repeat Step 3 with the second soil sample.

DRAW CONCLUSIONS

- Which soil would be better for growing plants? Why?
- Which soil would hold moisture better?



Safety Alert

Wear goggles while doing this activity and wash your hands afterward.

	Sample 1	Sample 2
Color		
Size of grains		
Shape of grains		
Live animals or plants?		
Dead animals or animal parts?		
Dead plants or plant parts?		
Other observations		

ON-THE-JOB SCIENCE

Geologist

Maria Ramirez is a geologist. She studies rocks. In high school, Maria liked earth science, math, and chemistry. She went to college and earned a master's degree in geology.

Maria spends a lot of time outdoors. She uses maps and special tools to collect rock samples. Maria studies the samples in a lab. She finds out which minerals a rock contains. Then she studies the properties of the minerals.

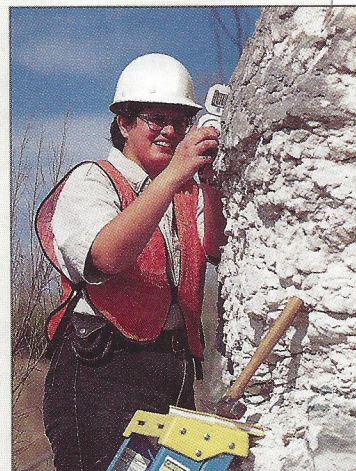
Besides noting the mineral's color, Maria tests the hardness of the mineral. On a scale of 1 to 10, 10 is the hardest. She also finds out if the mineral is made up of crystals. A crystal has many sides. The research helps her find possible uses for the rocks and minerals she identifies.

Maria has just collected five new mineral samples. She made this chart.

Mineral	Color	Hardness	Other Properties
Sample 1	Bright yellow	2.5	Shiny
Sample 2	Clear	10.0	8-sided crystals
Sample 3	Bright yellow	6.5	Shiny
Sample 4	Black	6.0	12-sided crystals, magnetic
Sample 5	Black	6.0	12-sided crystals

Use the chart to answer the questions.

1. Which of the minerals is hardest? softest?
2. How can Maria tell Samples 1 and 3 apart?
3. Samples 4 and 5 are very similar. What can Maria do to tell them apart?



Maria is a geologist.

Critical Thinking

How can observing the properties of rocks and minerals help geologists find uses for rocks and minerals?

Summary

The Earth's crust is made up of a number of rock plates that fit together. Plate movements cause earthquakes and volcanic eruptions. Other processes wear down the rock into soil.

Lesson 22.1

Plate tectonics is the theory that the Earth's crust is made up of moving plates that can cause earthquakes. They also help form mountains and ocean trenches. Volcanoes erupt when magma squeezes up through openings between plates.

Lesson 22.2

The three main kinds of rock are igneous, sedimentary, and metamorphic. Rocks are made of minerals. Weathering breaks down rocks and minerals. Soil is a product of weathering. Erosion carries away soil and rock.

Vocabulary Review

Write *true* or *false* for each sentence. If the sentence is false, replace the underlined term to make the sentence true.

1. A geologist is a scientist who studies rocks to learn about the Earth's history and structure.
2. A trench is a deep, long valley in the ocean floor.
3. Magma is called lava once it reaches the Earth's surface.
4. Igneous rock forms from many different rock particles that are pressed together.
5. Metamorphic rock forms when igneous or sedimentary rock changes under high temperatures or pressure.
6. Erosion breaks down rocks and minerals.
7. The wearing away of rock and soil is called weathering.
8. A glacier is an opening in the Earth's surface that releases magma from the mantle.

Chapter Quiz

Write your answers on a separate sheet of paper.

1. What does the theory of plate tectonics say?
2. What forms when two plates collide under the sea and one plate gets pushed down under the other?
3. What forms when two plates collide and pile up on each other?
4. What causes earthquakes?
5. How are earthquakes and volcanoes similar?
6. What are the three basic kinds of rock?
7. What are the building blocks of rocks?
8. How does weathering change rocks?
9. How do rivers form river valleys?
10. What happens during erosion?

Test Tip

If you do not know the full answer to a question, write down what you do know. As you answer the rest of the questions, you might find clues to help you answer the questions you did not know.

Research Project

Choose a natural feature in or near your community. It could be a mountain, canyon, river, beach, lake, plain, swamp, or glacier. Describe and draw it or take a picture of it. Do research to find its age, size, and anything special about it. Include ways your community uses the feature. If it has changed in recent years, describe how. Share what you find in a short oral report to your class.