Section 2

# Igneous Rocks

## Reading Focus

### Key Concepts

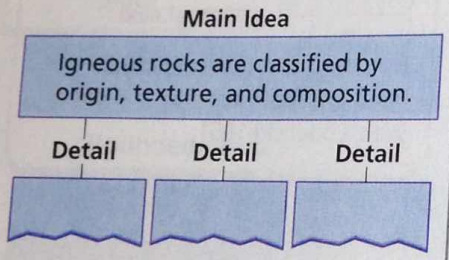
- What characteristics are used to classify igneous rocks?
- How are igneous rocks used?

### Key Terms

- extrusive rock
- intrusive rock

### Target Reading Skill

**Identifying Main Ideas** As you read Classifying Igneous Rocks, write the main idea in a graphic organizer like the one below. Then write three supporting details that further explain the main idea.




Lab zone **Discover Activity**

### How Do Igneous Rocks Form?

1. Use a hand lens to examine samples of granite and obsidian.
2. Describe the texture of both rocks using the terms coarse, fine, or glassy.
3. Which rock has coarse-grained crystals? Which rock has no crystals or grains?

**Think It Over**

**Inferring** Granite and obsidian are igneous rocks. From your observations, what can you infer about how each type of rock formed?

**Obsidian**

**Granite**

The time is 4.6 billion years ago. You are in a spacecraft orbiting Earth. Do you see the blue and green globe of Earth that astronauts today see from space? No—instead, Earth looks like a charred and bubbling marshmallow heated over hot coals.

Soon after Earth formed, the planet's interior became so hot that magma formed. Lava repeatedly flowed over the surface. The lava quickly hardened, forming a rocky crust. Because this early crust was denser than the material beneath it, chunks of crust sank into Earth's interior. This allowed more lava to erupt over the surface and harden to form rock.

## Classifying Igneous Rocks

The first rocks to form on Earth probably looked like the igneous rocks that can be seen today. Igneous rock is any rock that forms from magma or lava. The name *igneous* comes from the Latin word *ignis*, meaning "fire." **Igneous rocks are classified according to their origin, texture, and mineral composition.**

**Origin** Igneous rock may form on or beneath Earth's surface. **Extrusive rock** is igneous rock formed from lava that erupted onto Earth's surface. Basalt is the most common extrusive rock. Basalt forms much of the crust, including the oceanic crust, shield volcanoes, and lava plateaus.

Igneous rock that formed when magma hardened beneath Earth's surface is called **intrusive rock.** The most abundant intrusive rock in continental crust is granite. Batholiths made of granite form the core of many mountain ranges.

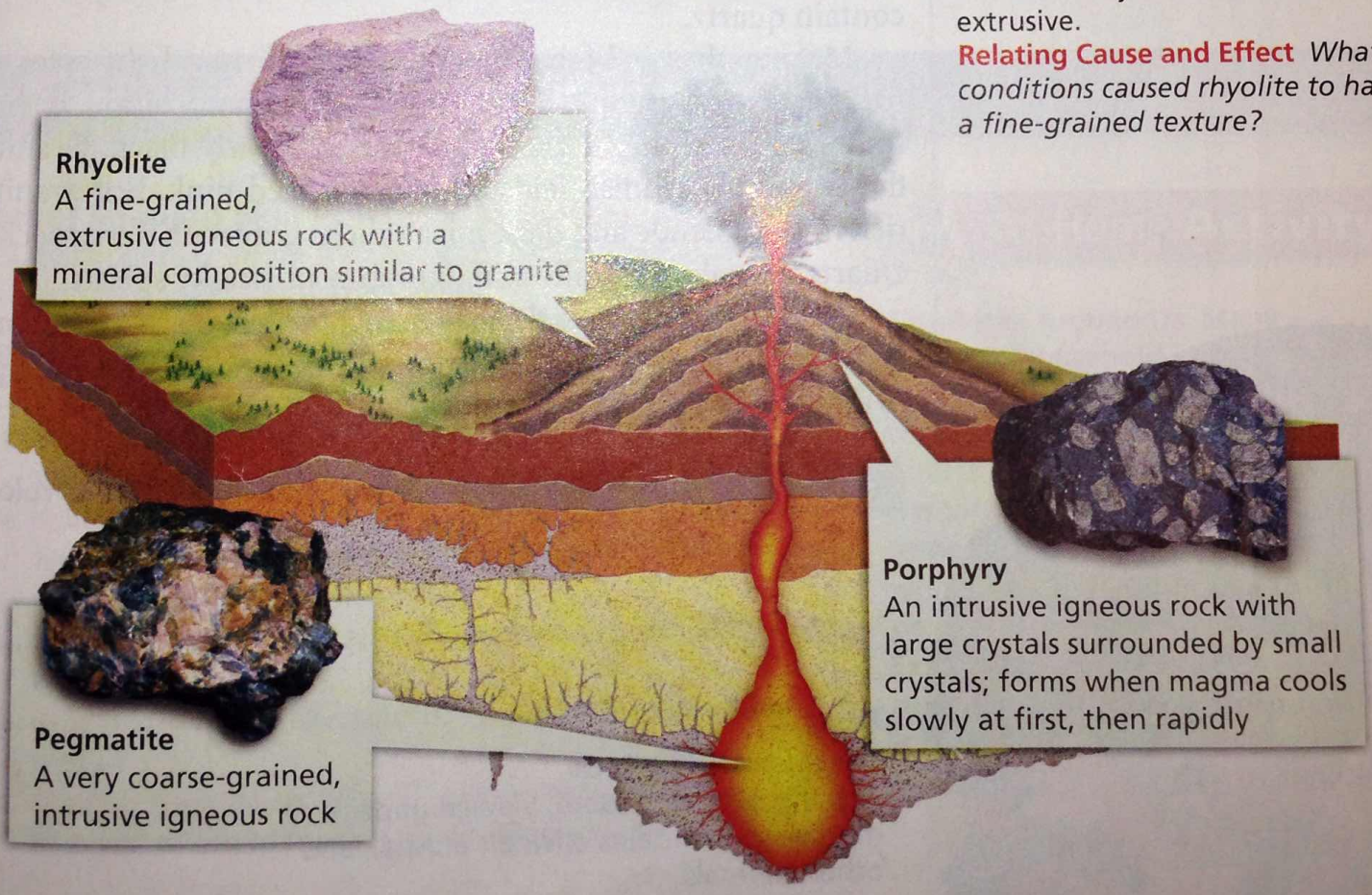
**Texture** The texture of an igneous rock depends on the size and shape of its mineral crystals. The only exceptions to this rule are the different types of volcanic glass—igneous rock that lacks a crystal structure.

Igneous rocks may be similar in mineral composition and yet have very different textures. Rapidly cooling lava forms fine-grained igneous rocks with small crystals. Slowly cooling magma forms coarse-grained rocks with large crystals. Therefore, intrusive and extrusive rocks usually have different textures.

Intrusive rocks have larger crystals than extrusive rocks. If you examine a coarse-grained rock such as granite, you can easily see that the crystals vary in size and color. Some intrusive rocks, like the porphyry in Figure 6, have a texture that looks like a gelatin dessert with chopped-up fruit mixed in.

Extrusive rocks have a fine-grained or glassy texture. Basalt is a fine-grained extrusive rock. It consists of crystals too small to be seen without a microscope. Obsidian is an extrusive rock that cooled very rapidly without forming crystals. As a result, obsidian has the smooth, shiny texture of a thick piece of glass.


**FIGURE 6**
**Igneous Rock Textures**
Igneous rocks such as rhyolite, pegmatite, and porphyry can vary greatly in texture depending on whether they are intrusive or extrusive.
**Relating Cause and Effect** *What conditions caused rhyolite to have a fine-grained texture?*



## Math Analyzing Data

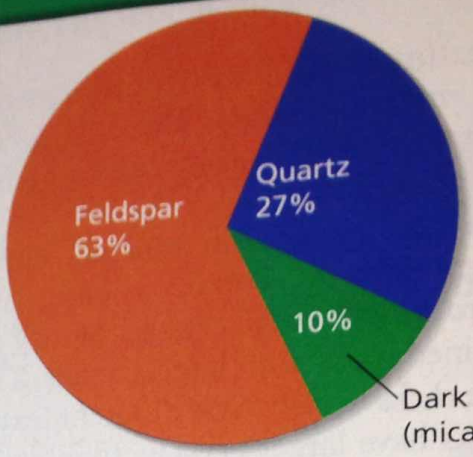
### Mineral Mixture

Granite is a mixture of light-colored minerals such as feldspar and quartz and dark-colored minerals including hornblende and mica. But, granite can vary in mineral composition, affecting its color and texture.

Study the circle graph and then answer the questions.

1. **Reading Graphs** What mineral is most abundant in granite?
2. **Reading Graphs** About what percentage of granite is made up of dark minerals?
3. **Calculating** If the amount of quartz increases to 35 percent and the amount of dark-colored minerals stays the same, what percentage of the granite will be made up of feldspar?

**Mineral Composition of Granite**




4. **Predicting** How would the color of the granite change if it contained less feldspar and more mica and hornblende?

**Mineral Composition** You may recall that the silica content of magma and lava can vary. Lava that is low in silica usually forms dark-colored rocks such as basalt. Basalt contains feldspar as well as certain dark-colored minerals, but does not contain quartz.

Magma that is high in silica usually forms light-colored rocks, such as granite. Granite's mineral composition determines its color—light gray, red, pink, or nearly black. Granite that is rich in reddish feldspar is a speckled pink. But granite rich in hornblende and dark mica is light gray with dark specks. Quartz crystals in granite add light gray or smoky specks.

Geologists can make thin slices of a rock, such as the gabbro in Figure 7. They study the rock's crystals under a microscope to determine the rock's mineral composition.

**Reading Checkpoint** **How can mineral composition affect a rock's color?**

**FIGURE 7**
**Thin Section of a Rock**
This thin slice of gabbro, viewed under a microscope, contains olivine, feldspar, and other minerals.

## Uses of Igneous Rocks

Many igneous rocks are hard, dense, and durable. **People throughout history have used igneous rock for tools and building materials.**

**Building Materials** Granite has a long history as a building material. More than 3,500 years ago, the ancient Egyptians used granite for statues like the one shown in Figure 8. About 600 years ago, the Incas of Peru carefully fitted together great blocks of granite and other igneous rocks to build a fortress near Cuzco, their capital city. In the United States during the 1800s and early 1900s, granite was widely used to build bridges and public buildings and for paving streets with cobblestones. Today, thin, polished sheets of granite are used in curbstones, floors, and kitchen counters. Basalt is crushed to make gravel that is used in construction.

**Other Uses** Igneous rocks such as pumice and obsidian also have important uses. The rough surface of pumice makes it a good abrasive for cleaning and polishing. Ancient native Americans used obsidian to make sharp tools for cutting and scraping. Perlite, formed from the heating of obsidian, is often mixed with soil for starting vegetable seeds.

**Reading Checkpoint** **What igneous rock is most often used as a building material?**

**FIGURE 8**
**Durable Granite**
The ancient Egyptians valued granite for its durability. These statues from a temple in Luxor, Egypt, were carved in granite.

Section 3

# Sedimentary Rocks

## Reading Focus

### Key Concepts

- How do sedimentary rocks form?
- What are the three major types of sedimentary rocks?
- How are sedimentary rocks used?

### Key Terms

- sediment
- erosion
- deposition
- compaction
- cementation
- clastic rock
- organic rock
- chemical rock

### Target Reading Skill

**Outlining** As you read, make an outline about sedimentary rocks. Use the red section headings for the main topics and the blue headings for the subtopics.

| Sedimentary Rocks |
| --- |
| I. From sediment to rock |
| A. Erosion |
| B. |
| II. |
| A. |

## Lab zone Discover Activity

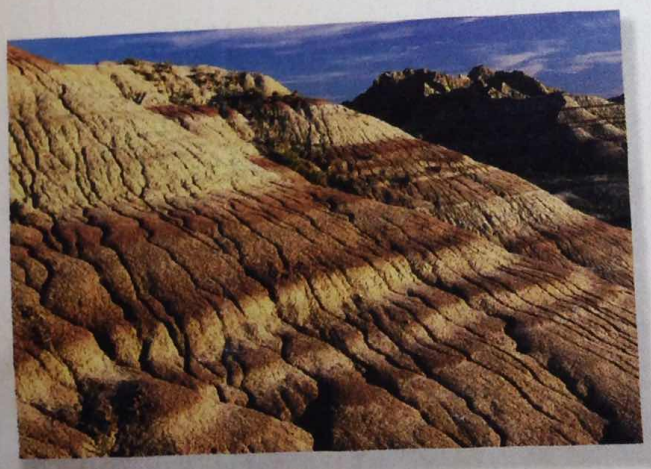
### How Does Pressure Affect Particles of Rock?

1. Place a sheet of paper over a slice of soft bread.
2. Put a stack of several heavy books on top of the paper. After 10 minutes, remove the books. Observe what happened to the bread.
3. Slice the bread so you can observe its cross section.
4. Carefully slice a piece of fresh bread and compare its cross section to that of the pressed bread.

**Think It Over**

**Observing** How did the bread change after you removed the books? Describe the texture of the bread. How does the bread feel? What can you predict about how pressure affects the particles that make up sedimentary rocks?

Visitors to Badlands National Park in South Dakota see some of the strangest scenery on Earth. The park contains jagged peaks, steep cliffs, and deep canyons sculpted in colorful rock that is layered like a birthday cake. The layers of this cake are red, orange, pink, yellow, or tan. These rocks formed over millions of years as particles of mud, sand, and volcanic ash were deposited in thick layers. The mud and sand slowly changed to sedimentary rock. Then, uplift of the land exposed the rocks to the forces that wear away Earth's surface.



Badlands National Park ▲

## From Sediment to Rock

If you have ever walked along a stream or beach you may have noticed tiny sand grains, mud, and pebbles. These are particles of sediment. **Sediment** is small, solid pieces of material that come from rocks or living things. In addition to particles of rock, sediment may include shells, bones, leaves, stems, and other remains of living things. Sedimentary rocks form when sediment is deposited by water and wind. **Most sedimentary rocks are formed through a series of processes: erosion, deposition, compaction, and cementation.** Figure 9 shows how sedimentary rocks form.

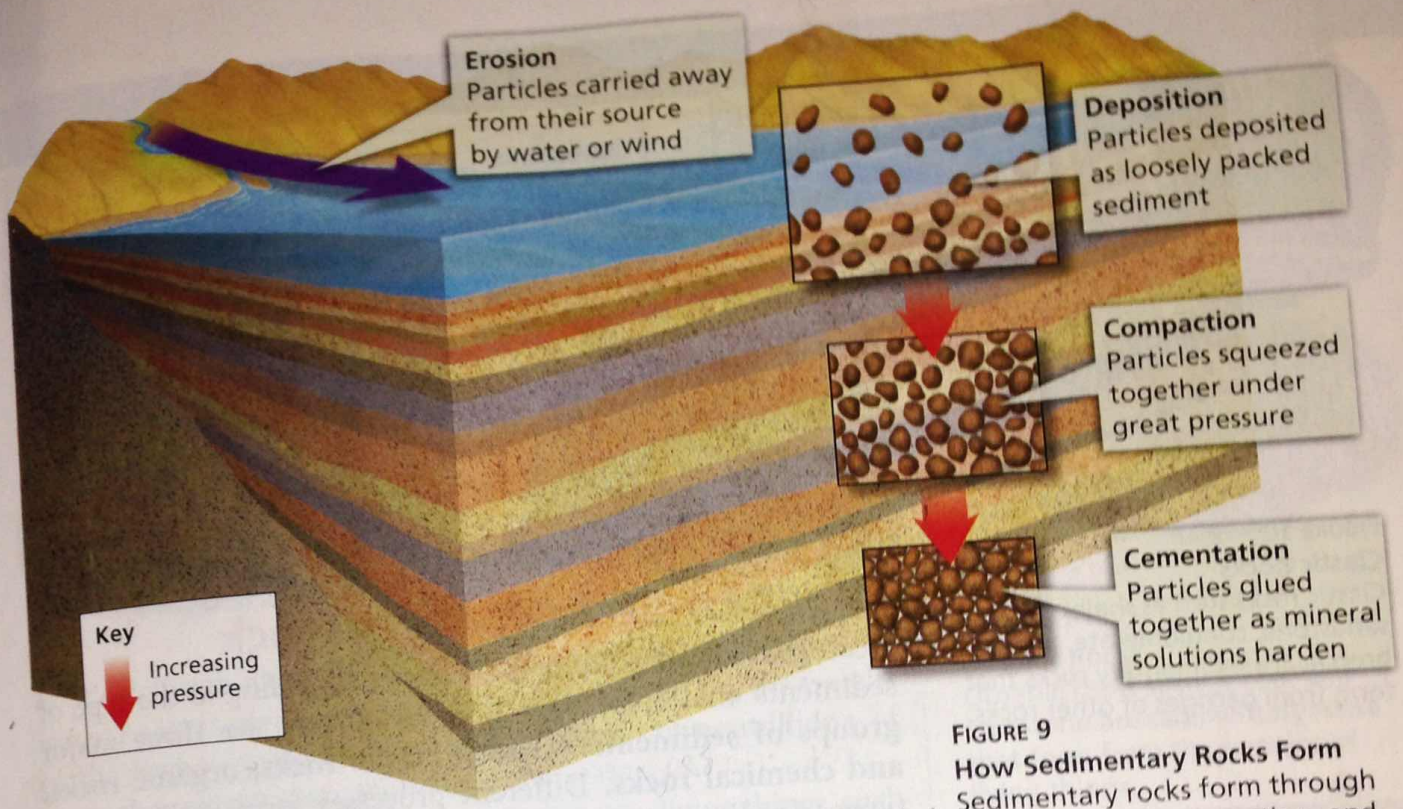



FIGURE 9
**How Sedimentary Rocks Form**
Sedimentary rocks form through the deposition, compaction, and cementation of sediments over millions of years.
**Relating Cause and Effect** *What conditions are necessary for sedimentary rocks to form?*

**Erosion** Destructive forces are constantly breaking up and wearing away, or weathering, all the rocks on Earth's surface. These forces include heat and cold, rain, waves, and grinding ice. The forces of erosion form sediment. In **erosion,** running water, wind, or ice loosen and carry away fragments of rock.

**Deposition** Eventually, the moving water, wind, or ice slows and deposits the sediment in layers. If water is carrying the sediment, rock fragments and other materials stick to the bottom of a lake or ocean. **Deposition** is the process by which sediment settles out of the water or wind carrying it.

**Compaction** The process that presses sediments together is **compaction.** Thick layers of sediment build up gradually over millions of years. These heavy layers press down on the layers beneath them. The weight of new layers further compacts the sediments, squeezing them tightly together. The layers often remain visible in sedimentary rock.

**Cementation** While compaction is taking place, the minerals in the rock slowly dissolve in the water. **Cementation** is the process in which dissolved minerals crystallize and glue particles of sediment together. In cementation, dissolved minerals seep into the spaces between particles and then harden.

**Reading Checkpoint** **What is deposition?**

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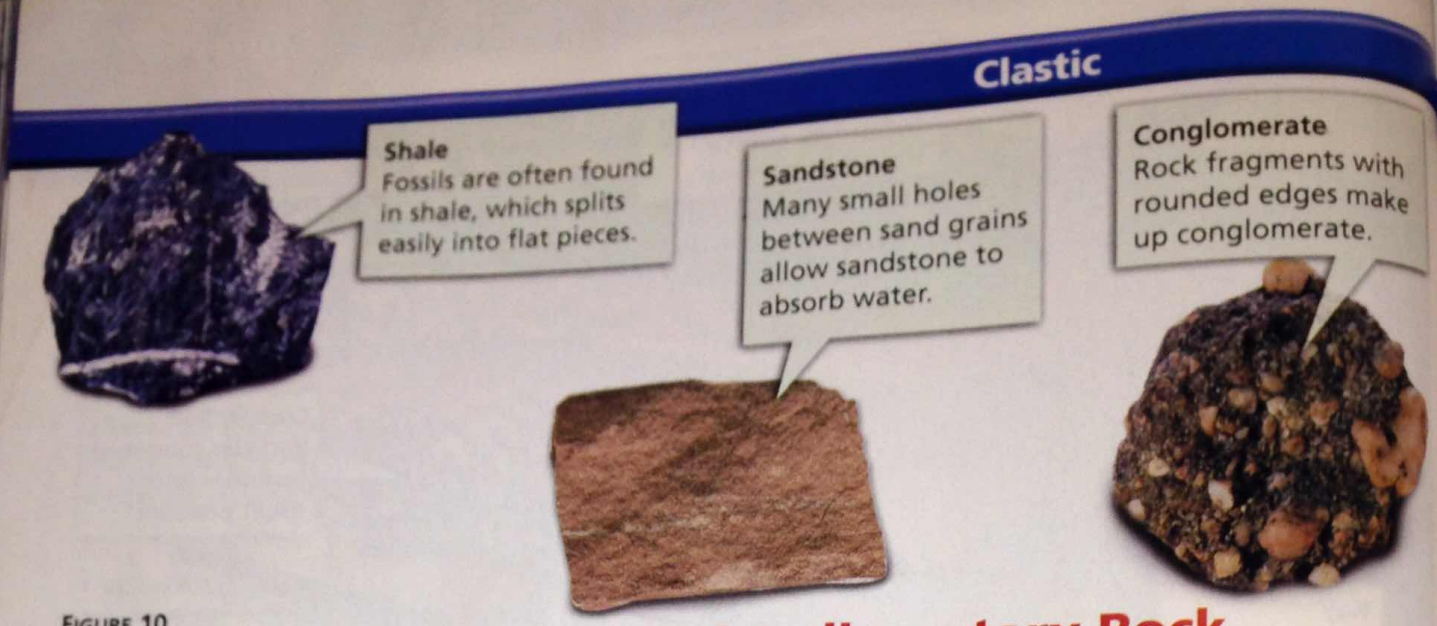



**FIGURE 10**
**Clastic Rocks**
Clastic rocks such as shale, sandstone, conglomerate, and breccia are sedimentary rocks that form from particles of other rocks.

## Types of Sedimentary Rock

Geologists classify sedimentary rocks according to the type of sediments that make up the rock. **There are three major groups of sedimentary rocks: clastic rocks, organic rocks, and chemical rocks.** Different processes form each of these types of sedimentary rocks.

**Clastic Rocks** Most sedimentary rocks are made up of broken pieces of other rocks. A **clastic rock** is a sedimentary rock that forms when rock fragments are squeezed together. These fragments can range in size from clay particles that are too small to be seen without a microscope to large boulders that are too heavy for you to lift. Clastic rocks are grouped by the size of the rock fragments, or particles, of which they are made. Common clastic rocks include shale, sandstone, conglomerate, and breccia (BRECH ee uh), shown in Figure 10.

Shale forms from tiny particles of clay. Water must deposit the clay particles in thin, flat layers. Sandstone forms from the sand on beaches, the ocean floor, riverbeds, and sand dunes. Most sand particles consist of quartz.

Some sedimentary rocks contain a mixture of rock fragments of different sizes. If the fragments have rounded edges, they form a clastic rock called conglomerate. A rock made up of large fragments with sharp edges is called breccia.

**Organic Rocks** Not all sedimentary rocks are made from particles of other rocks. **Organic rock** forms where the remains of plants and animals are deposited in thick layers. The term "organic" refers to substances that once were part of living things or were made by living things. Two important organic sedimentary rocks are coal and limestone, shown in Figure 11.

**Lab zone Try This Activity**

### Rock Absorber

Here's how to find out if water can soak into rock.

1. Using a hand lens, compare samples of sandstone and shale.
2. Use a balance to measure the mass of each rock.
3. Place the rocks in a pan of water and watch closely. Which sample has bubbles escaping? Predict which sample will gain mass.
4. Leave the rocks submerged in the pan overnight.
5. The next day, remove the rocks from the pan and find the mass of each rock.

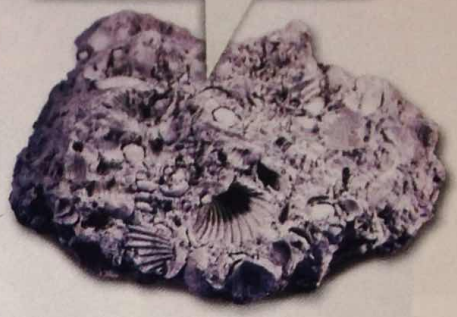
**Drawing Conclusions** How did the masses of the two rocks change after soaking? What can you conclude about each rock?

Organic

**Breccia**
Rock fragments with sharp edges form breccia.

**Coal**
Swamp plants that formed millions of years ago slowly changed to form coal.

**Limestone**
Coquina is a form of limestone in which the shells that makeup the rock are easy to see.



Coal forms from the remains of swamp plants buried in water. As layer upon layer of plant remains build up, the weight of the layers squeezes the decaying plants. Over millions of years, they slowly change into coal.

Limestone forms in the ocean, where many living things, such as coral, clams, and oysters, have hard shells or skeletons made of calcite. When these animals die, their shells pile up on the ocean floor. Over millions of years, these layers of sediment can grow to a depth of hundreds of meters. Slowly, compaction and cementation change the sediment to limestone.

**FIGURE 11**
**Organic Rocks**
Organic rocks such as coal and limestone are sedimentary rocks that form from the remains of living things.

**Chemical Rocks** When minerals that are dissolved in a solution crystallize, **chemical rock** forms. For example, limestone can form when calcite that is dissolved in lakes, seas, or underground water comes out of solution and forms crystals. This kind of limestone is considered a chemical rock. Chemical rocks can also form from mineral deposits left when seas or lakes evaporate. For example, rock salt is made of the mineral halite, which forms by evaporation.

**Reading Checkpoint** How does coal form?

**FIGURE 12**
**Chemical Rocks**
These rock "towers" in Mono Lake California, are made of tufa, a form of limestone. Tufa is a chemical rock that forms from solutions containing dissolved materials. **Classifying** *What type of sedimentary rock is tufa?*

**FIGURE 13**
**Carving Marble**
This stone carver is sculpting a block of pink marble.

## Uses of Sedimentary Rocks

**People have used sedimentary rocks throughout history for many different purposes, including building materials and tools.** For example, people made arrowheads out of flint for thousands of years. Flint is a hard rock, yet it can be shaped to a point. Flint is formed when small particles of silica settle out of water.

Sedimentary rocks such as sandstone and limestone have been used as building materials for thousands of years. Both types of stone are soft enough to be cut easily into blocks or slabs. You may be surprised to learn that the White House in Washington, D.C., is built of sandstone. Builders today use sandstone and limestone on the outside walls of buildings. Limestone also has many industrial uses. For example, limestone is used in making cement and steel.

**Reading Checkpoint** Why are sandstone and limestone useful as building materials?

## Section 3 Assessment

**Target Reading Skill** **Outlining** Use the information in your outline about sedimentary rocks to help you answer the questions below.

### Reviewing Key Concepts

1. a. **Defining** What is sediment?
   b. **Sequencing** Place these steps in the formation of sedimentary rock in the proper sequence: compaction, erosion, cementation, deposition.
   c. **Inferring** In layers of sedimentary rock, where would you expect to find the oldest sediment? Explain your answer.
2. a. **Listing** What are the three main types of sedimentary rock?
   b. **Explaining** Which type of sedimentary rock forms from the remains of living things? Explain how this sedimentary rock forms.
   c. **Relating Cause and Effect** What process causes deposits of rock salt to form? What type of sedimentary rock is rock salt?
3. a. **Listing** What are some uses of sedimentary rocks?
   b. **Predicting** The particles of sediment that make up shale are not usually cemented. Would shale be a good choice of building material in a wet climate?

### Writing in Science

**Explaining a Process** Suppose that a large mass of granite lies exposed on Earth's surface. Explain the steps in the process by which the granite could become sedimentary rock. Your answer should also state which of the main types of sedimentary rock will result from this process.

Section 5

# Metamorphic Rocks

## Reading Preview

### Key Concepts

- Under what conditions do metamorphic rocks form?
- How do geologists classify metamorphic rocks?
- How are metamorphic rocks used?

### Key Term

- foliated

## Target Reading Skill

**Previewing Visuals** Before you read, preview Figure 17. Then write two questions that you have about metamorphic rocks in a graphic organizer like the one below. As you read, answer your questions.

**Metamorphic Rocks**

| |
|---|
| Q. Why do the crystals in gneiss line up in bands? |
| A. |
| Q. |

## Lab zone Discover Activity

### How Do Grain Patterns Compare?

1. Using a hand lens, observe samples of gneiss and granite. Look carefully at the grains or crystals in both rocks.
2. Observe how the grains or crystals are arranged in both rocks. Draw a sketch of both rocks and describe their textures.

**Think It Over**

**Inferring** Within the crust, some granite becomes gneiss. What do you think must happen to cause this change?

Every metamorphic rock is a rock that has changed its form. In fact, the word *metamorphic* comes from the Greek words *meta*, meaning "change," and *morphosis*, meaning "form." But what causes a rock to change into metamorphic rock? The answer lies inside Earth.

**Heat and pressure deep beneath Earth's surface can change any rock into metamorphic rock.** When rock changes into metamorphic rock, its appearance, texture, crystal structure, and mineral content change. Metamorphic rock can form out of igneous, sedimentary, or other metamorphic rock.

Collisions between Earth's plates can push the rock down toward the heat of the mantle. Pockets of magma rising through the crust also provide heat that can produce metamorphic rocks. The deeper a rock is buried in the crust, the greater the pressure on that rock. Under high temperature and pressure many times greater than at Earth's surface, the minerals in a rock can be changed into other minerals. The rock has become a metamorphic rock.

## Types of Metamorphic Rocks

While metamorphic rocks are forming, high temperatures change the size and shape of the grains, or mineral crystals, in the rock. Extreme pressure squeezes rock so tightly that the mineral grains may line up in flat, parallel layers. **Geologists classify metamorphic rocks according to the arrangement of the grains that make up the rocks.**

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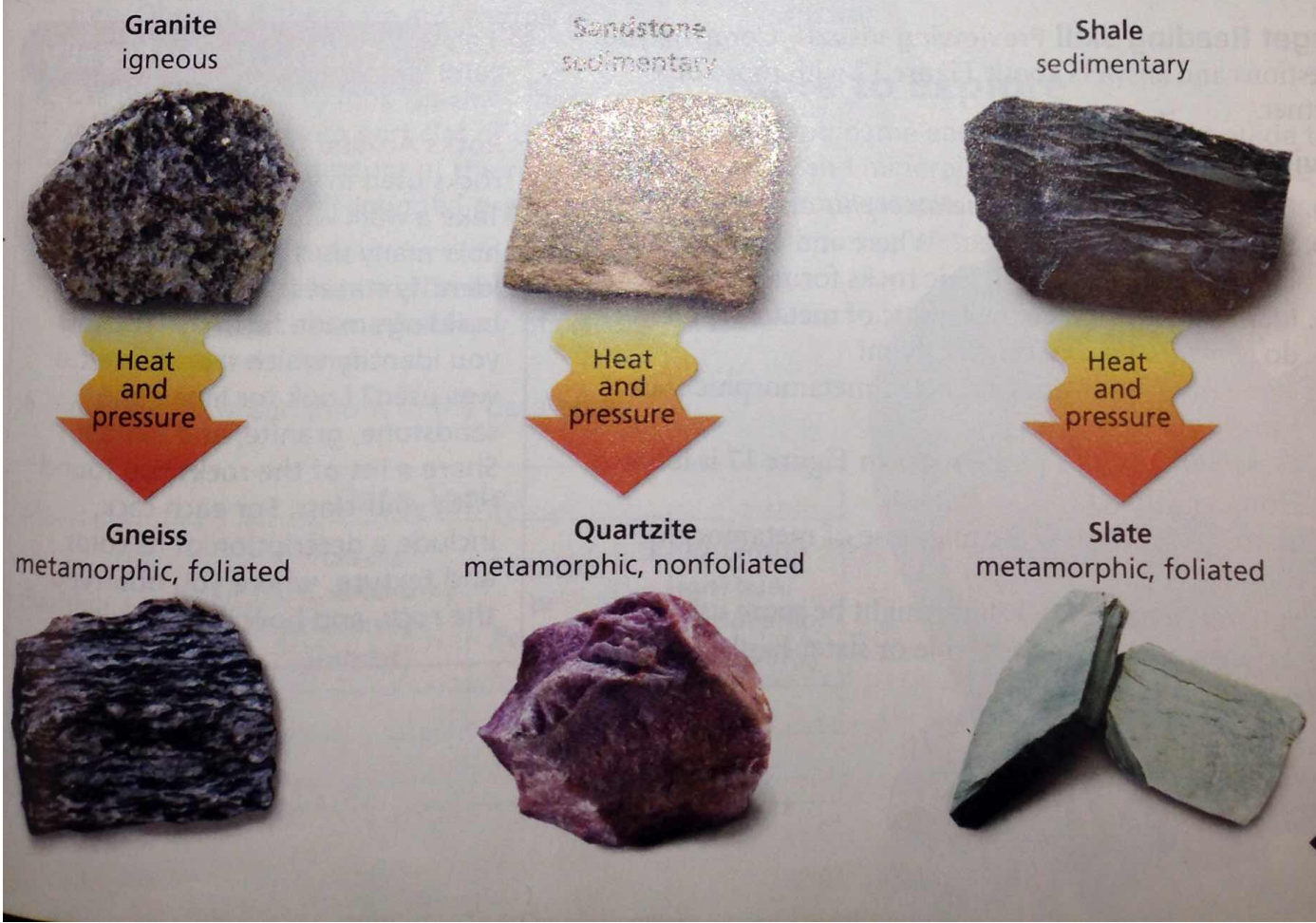
**Foliated Rocks** Metamorphic rocks that have their grains arranged in parallel layers or bands are said to be **foliated.** The term *foliated* comes from the Latin word for "leaf." It describes the thin, flat layering found in most metamorphic rocks. Foliated rocks—including slate, schist, and gneiss—may split apart along these bands. In Figure 17, notice how the crystals in granite have been flattened to create the foliated texture of gneiss.

One common foliated rock is slate. Heat and pressure change the sedimentary rock shale into slate. Slate is basically a denser, more compact version of shale. During the change, new minerals such as mica form in the slate.

**Nonfoliated Rocks** Some metamorphic rocks are nonfoliated. The mineral grains in these rocks are arranged randomly. Metamorphic rocks that are nonfoliated do not split into layers. Marble and quartzite are two metamorphic rocks that have a nonfoliated texture. Quartzite forms out of sandstone. The weakly cemented quartz particles in the sandstone recrystallize to form quartzite, which is extremely hard. Notice in Figure 17 how much smoother quartzite looks than sandstone.

**Reading Checkpoint** **What is a foliated rock?**

**FIGURE 17**
**Forming Metamorphic Rocks**
Great heat and pressure can change one type of rock into another. **Observing** *How does slate differ from shale?*




**Lab zone Try This Activity**

## A Sequined Rock

1. Make three balls of clay about 3 cm in diameter. Gently mix about 25 sequins into one ball.
2. Use a 30-cm piece of string to cut the ball in half. How are the sequins arranged?
3. Roll the clay with the sequins back into a ball. Stack the three balls with the sequin ball in the middle. Set these on a block of wood. With another block of wood, press slowly down until the stack is about 3 cm high.
4. Use the string to cut the stack in half. How are the sequins arranged?

**Making Models** What do the sequins in your model rock represent? Is this rock foliated or nonfoliated?

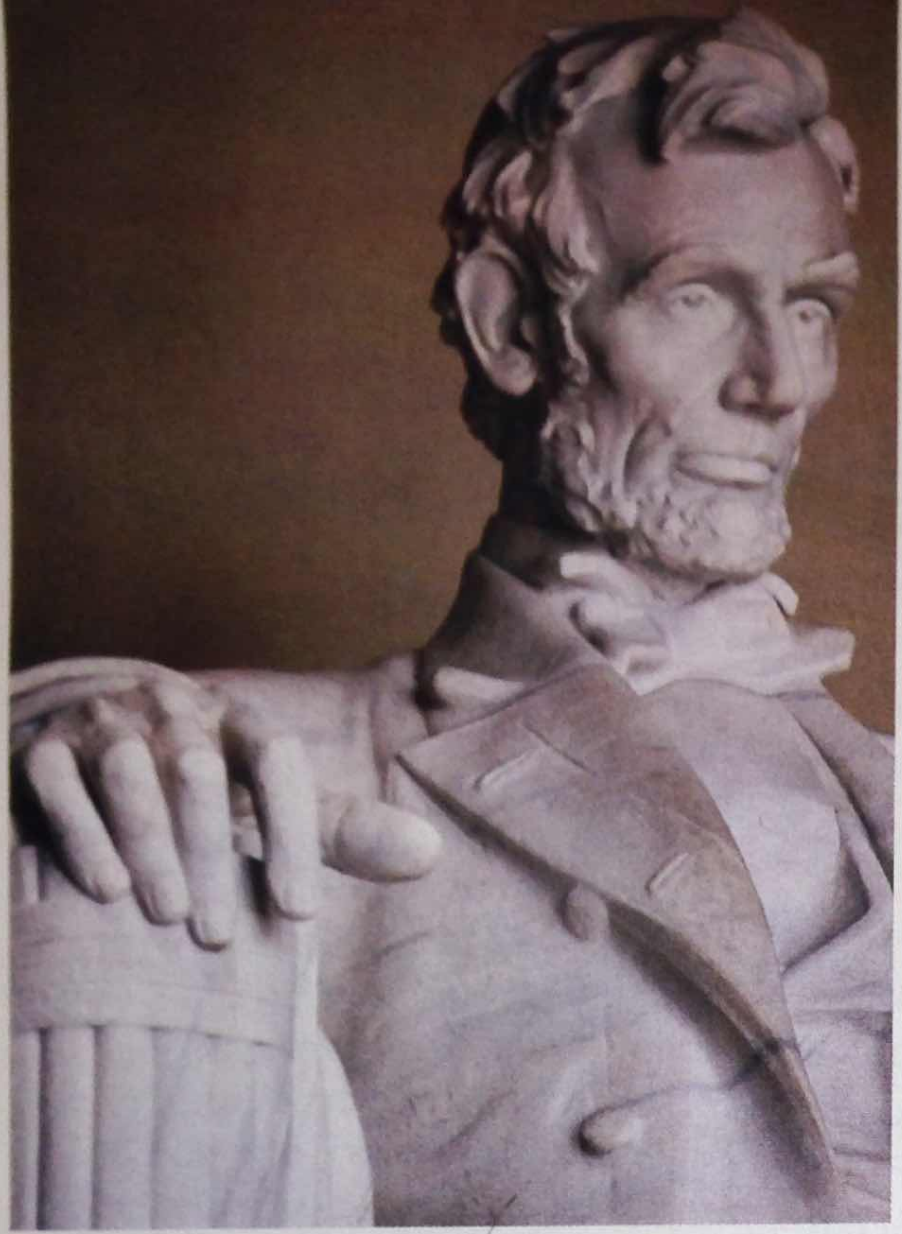


FIGURE 18
**The Lincoln Memorial**
The statue of Abraham Lincoln in the Lincoln Memorial in Washington, D.C., is made of gleaming white marble.

## Uses of Metamorphic Rock

**Certain metamorphic rocks are important m als for building and sculpture.** Marble and sl two of the most useful metamorphic rocks. M usually forms when limestone is subjected to he pressure deep beneath the surface. Because m has a fine, even grain, it can be cut into thin sl carved into many shapes. And marble is easy t ish. These qualities have led architects and scu to use marble for many buildings and statue example, one of America's most famous sculpt in the Lincoln Memorial in Washington, D.C. S tor Daniel Chester French carved this portr Abraham Lincoln in gleaming white marble.

Like marble, slate comes in a variety of c including gray, black, red, and purple. Because it i ated, slate splits easily into flat pieces. These piec be used for flooring, roofing, outdoor walkways, c boards, and as trim for stone buildings.

**Reading Checkpoint** **What characteristics of slate make i useful?**