3 Rocks

Big idea

Earth's Materials and Systems

Q: What are the different types of rock and how do they form?

VIRGINIA SCIENCE STANDARDS OF LEARNING

ES.5.a, ES.5.b, ES.5.c. **See lessons for details.**

A climber scales a formation of sedimentary rock in the Dolomite Alps, Italy

INQUIRY
TRY IT!

WHAT ARE SOME SIMILARITIES AND DIFFERENCES AMONG ROCKS?

Procedure

1. Your teacher will provide you with six rock samples. Examine them closely.
2. Record at least three ways in which the rocks are alike.
3. Now determine and record at least three ways in which the rocks differ.
4. Classify the rock samples into three groups based on your observations. Give reasons for your groupings.

Think About It

1. **Compare and Contrast** How are the rock samples similar? How do they differ?
2. **Compare and Contrast** How does your classification scheme compare with the classification schemes of at least two other students? How do they differ?
3. **Form a Hypothesis** Each of the rocks used in this activity belongs to one of the three major groups of rocks. Hypothesize what makes one group of rocks different from the others.

3.1 The Rock Cycle

ES.5 The student will investigate and understand the rock cycle as it relates to the origin and transformation of rock types and how to identify common rock types based on mineral composition and textures. Key concepts include **a.** igneous rocks; **b.** sedimentary rocks; and **c.** metamorphic rocks.

Key Questions

What is a rock?

What are the three major types of rock?

What is the rock cycle?

How do igneous, sedimentary, and metamorphic rocks differ?

What processes transform rocks from one type to another?

Vocabulary

- rock • rock cycle
- magma • lava
- igneous rock
- weathering • sediment
- sedimentary rock
- metamorphic rock

Reading Strategy

Build Vocabulary Copy and expand the table to include each vocabulary term. As you read, write down the definition for each term.

Term	Definition
rock	a. ___?___
igneous rock	b. ___?___
sedimentary rock	c. ___?___
sediments	d. ___?___

MANY OF the most dramatic Earth processes—from volcanic eruptions, to mountain building, to earthquakes—involve rocks. Rocks give us clues about the environment in which they formed. If a rock contains fragments of seashells, for example, you can infer that the rock formed in the ocean. By understanding how rocks form, you can look at a rock and infer whether it formed at Earth's surface or deep below it, at high temperatures or low, and even whether its pieces were transported by water, wind, or ice.

Rocks

What is a rock? **A rock is a solid mass of minerals or mineral-like materials.** As you have learned, a mineral is a naturally occurring, inorganic solid with a crystalline structure. Most rocks are a mix, or aggregate, of many minerals. However, there are a few rocks, such as limestone, that are composed of just one mineral. Then there are rocks that are not made up of minerals at all. For example, obsidian and pumice, shown in **Figure 1,** are made of natural glass. Glass does not have a crystalline structure, so it is not considered a mineral. Coal, which is made of organic material, is another example of a nonmineral rock.

Rocks vary widely in appearance, texture, and composition. They are classified into one of three categories based on how they form. **The three major types of rock are igneous, sedimentary, and metamorphic.** The **rock cycle** summarizes how each of these rock types form and also describes how they can be transformed from one type to another.

Reading Checkpoint *What are the three types of rocks?*

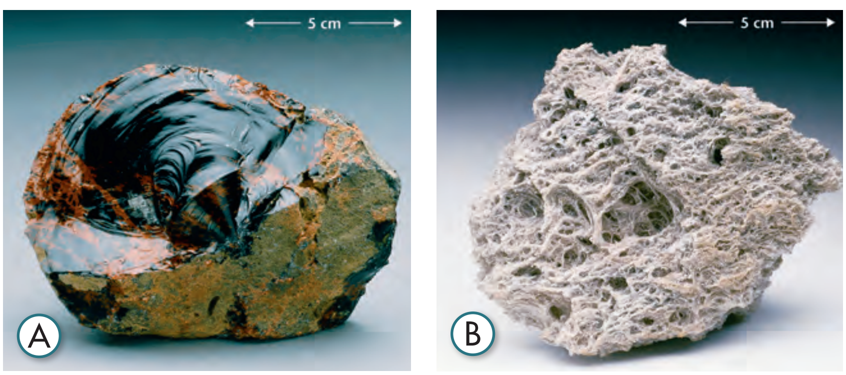


FIGURE 1 Nonmineral Rocks **A** Obsidian and **B** pumice are two examples of rocks that are not composed of minerals.

The Rock Cycle

The phrase "like a rock" is used to describe something as unchanging. But rocks are in fact always changing as they interact with Earth systems. **The rock cycle is a model that describes the ways in which rocks transform from one type to another.** The processes involved in the rock cycle do not follow a particular order. The following describes just one possible path through the cycle.

We will begin our discussion of the rock cycle deep underground with melted rock called **magma.** You are likely more familiar with **lava,** which is magma that reaches Earth's surface. When magma or lava cools, it crystallizes and forms igneous rock. **Igneous rocks form from cooled magma or lava.**

When exposed at Earth's surface, rocks such as the igneous rock shown in **Figure 2** undergo a process called weathering. **Weathering** is the breakdown of rock. Weathering can be caused by physical or chemical processes. Loose bits of weathered rock are called **sediment.** Sediment is often picked up and moved, or eroded, and then dropped, or deposited, in a new location by water, wind, glaciers, or gravity. Once deposited, pressure exerted over time on the sediments may turn them into sedimentary rock through a process known as *lithification*. **Sedimentary rocks form from layers of weathered, eroded, and deposited sediment.**

Heat, pressure, and fluids can act to change a rock's structure and composition. This process, called *metamorphism,* is usually associated with mountain building. **Metamorphic rocks form when preexisting rocks are altered by pressure, heat, and/or fluids.** If exposed to extreme enough pressure and temperature, rocks may melt to form magma, and the cycle begins again. The rock cycle is summarized in **Figure 3** on the next page.

FIGURE 2 Exposed *El Capitan* is a huge piece of granite in Yosemite National Park that was once buried deep beneath Earth's surface. Now that it is exposed, it weathers and forms sediments.

ACTIVE ART

For: Rock Cycle activity
Visit: PearsonSchool.com
Web Code: czp-1031

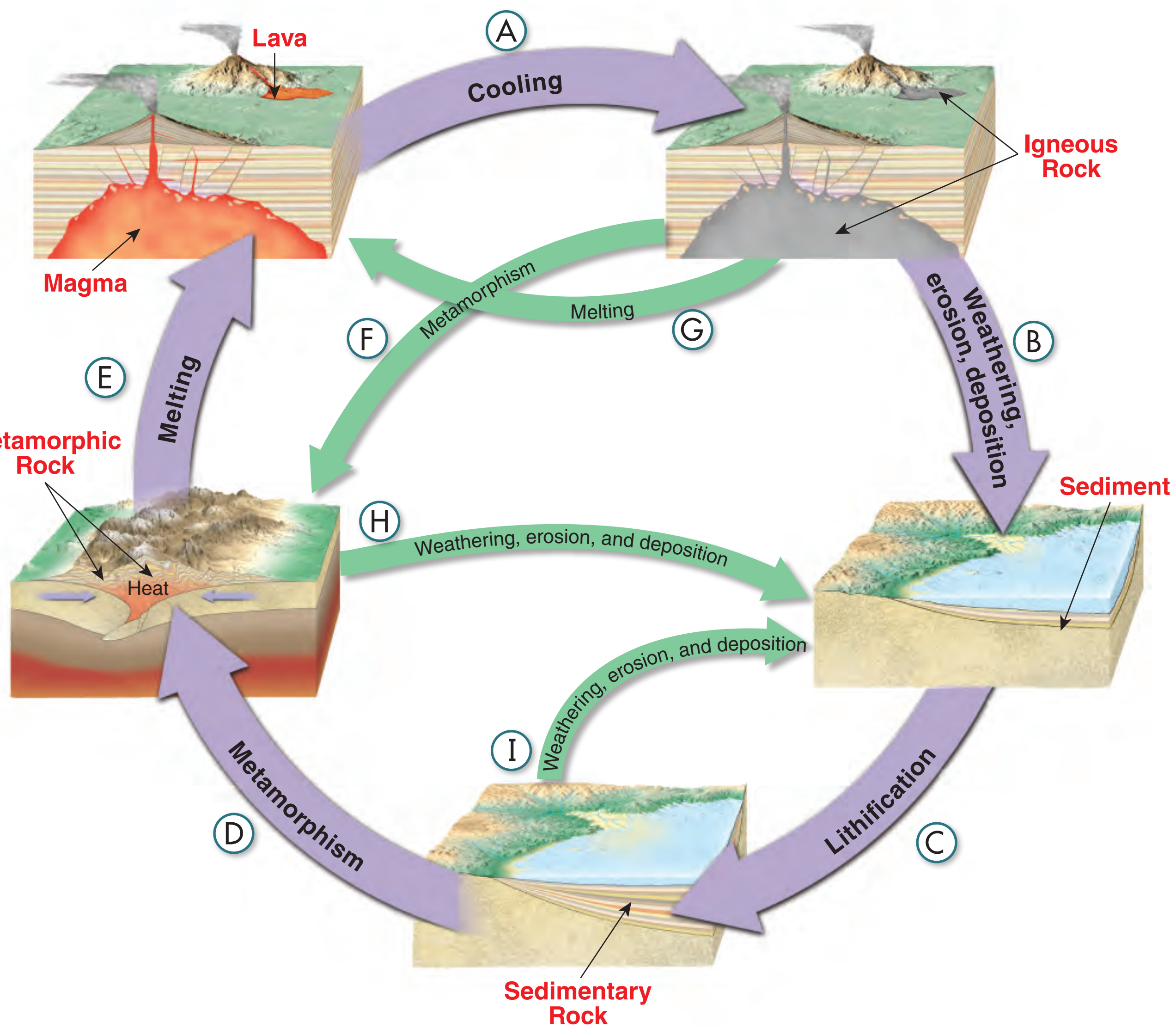
Alternate Paths

So far, we have described just one path through the rock cycle, as shown with the purple arrows below: (A) Magma or lava cools to form igneous rock. (B) Igneous rock is weathered, eroded, and deposited as sediment. (C) Sediment is lithified forming layers of sedimentary rock. (D) Sedimentary rock is metamorphosed, forming metamorphic rock, such as the slate in **Figure 4.** (E) Metamorphic rock melts, resulting in magma and lava.

VISUAL SUMMARY

ROCK CYCLE

FIGURE 3 Rocks are constantly changing from one form to another through the processes of the rock cycle, shown as lettered arrows in the figure. **Infer** *Why do most sedimentary rocks form near or in water?*



There is not just one path through the cycle, however. The green arrows in Figure 3 show some alternative paths between rock types that are just as likely to occur: (F) Igneous rock is buried and metamorphosed, forming metamorphic rock. (G) Given high enough pressures and temperatures, igneous rock can even melt to form magma and lava. (H) Metamorphic and (I) sedimentary rock are weathered and eroded when exposed at the surface. The deposited sediments can then form sedimentary rock. **The processes of melting, cooling, weathering, erosion, deposition, and lithification can transform any type of rock into another.**

These processes are unending. Today, for example, magma under the island of Hawaii is cooling to form igneous rock. As plates collide on the western coast of South America, intense heat and pressure are transforming areas of continental crust to metamorphic rock. In the American west, sediments that were once part of the Rocky Mountains are settling in the Gulf of Mexico and may one day form new layers of sedimentary rock.

FIGURE 4 Slate The roof on this house is made of slate. Slate is a metamorphic rock that forms from the sedimentary rock shale.
Interpret Diagrams *What process turns shale to slate?*

3.1 Assessment

Review Key Concepts

1. What is a rock?
2. What are the three major types of rocks?
3. How do igneous, sedimentary, and metamorphic rocks differ?
4. What is the rock cycle?
5. What processes are involved in the rock cycle?

Think Critically

6. **Compare and Contrast** Compare and contrast igneous and metamorphic rocks.
7. **Apply Concepts** How might a sedimentary rock become an igneous rock?
8. **Apply Concepts** List in order the processes that could change one sedimentary rock into another sedimentary rock.

BIGIDEA EARTH'S MATERIALS AND SYSTEMS

9. **Explain** Use your understanding of the rock cycle to explain this statement: *One rock is the raw material for another rock.*

3.2 Igneous Rocks

ES.5 The student will investigate and understand the rock cycle as it relates to the origin and transformation of rock types and how to identify common rock types based on mineral composition and textures. Key concepts include **a.** igneous rocks.

Key Questions

How are intrusive and extrusive igneous rocks alike and different?

How does the rate of cooling affect an igneous rock's texture?

How are igneous rocks classified according to composition?

Vocabulary

- intrusive igneous rock
- extrusive igneous rock
- texture
- granitic composition
- basaltic composition
- andesitic composition

Reading Strategy

Outline Copy the outline and complete it as you read. Include points about how each of these rocks form, some of the characteristics of each rock type, and some examples of each.

I. Igneous Rocks
  A. Intrusive Rocks
    1. ___?___
    2. ___?___
  B. Extrusive Rocks
    1. ___?___
    2. ___?___

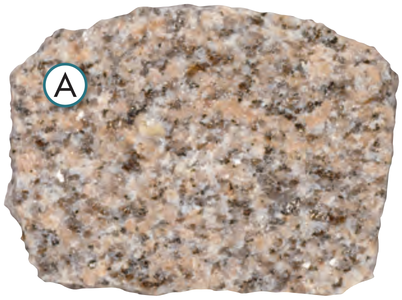
IGNEOUS ROCKS are sometimes called *volcanic rocks.* Recall from the discussion of the rock cycle that igneous rocks form when magma or lava cools and hardens. When the red hot lava shown in **Figure 5** cools, a dark-colored igneous rock called basalt will form. When magma instead cools deep beneath Earth's surface, a very different kind of igneous rock forms. Why?

Formation of Igneous Rocks

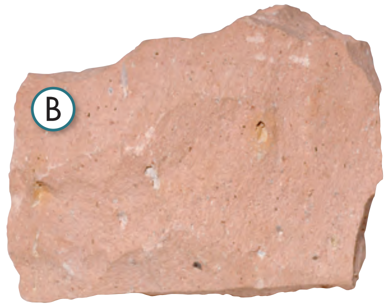
The word *igneous* comes from the Latin word *ignis,* which means “fi e.” While some igneous rock does form at the surface after fiery volcanic eruptions, most forms from magma deep beneath the surface. Geologists describe igneous rocks as either intrusive or extrusive based on where they form.

FIGURE 5 Basaltic Lava Lava from this Hawaiian volcano flows easily over Earth's surface. When the lava cools and hardens, the igneous rock called basalt will form.

FIGURE 6 Igneous Rocks There are two basic ways igneous rocks form.



A Granite, an intrusive igneous rock, forms when magma cools beneath Earth's surface.



B Rhyolite is an extrusive igneous rock that forms when lava cools at Earth's surface.

Intrusive Igneous Rocks Magma is mostly made of oxygen and silicon, with lesser amounts of elements such as aluminum, iron, calcium, sodium, potassium, and magnesium. Magma also contains gases, such as water vapor, that contribute to its relatively low density. Because magma is less dense than the surrounding rock, it slowly works its way to the surface. Most of the time, magma cools and crystallizes before reaching the surface. **Igneous rocks formed from magma beneath Earth's surface are known as intrusive igneous rocks.** Occasionally, intrusive igneous rocks are exposed when overlying rocks are stripped away by weathering and erosion. Mount Rushmore in South Dakota is carved out of exposed granite, an intrusive igneous rock. A sample of granite is shown in **Figure 6A.**

Extrusive Igneous Rocks When magma manages to reach Earth's surface, most of the gases it contains escape. The substance is now called lava. **Igneous rocks formed from lava at Earth's surface are called extrusive igneous rocks.** Extrusive igneous rocks, such as rhyolite, shown in **Figure 6B,** are common in places such as Iceland, which has many active volcanoes.

Classification of Igneous Rocks

Igneous rocks are classified based on more than just where they formed. **Texture and composition together are used to classify igneous rocks.**

Texture A rock's **texture** describes the size, shape, and arrangement of its component parts. The rate of cooling strongly affects an igneous rock's texture. **Slow cooling causes large crystals to form, while rapid cooling results in small crystals.** Why does the rate of cooling affect texture? If molten material cools very slowly, as it tends to do deep beneath Earth's surface, its ions can move over large distances without combining. This results in only a few centers of crystal growth. As they cool, each crystal can grow quite large. When molten material cools quickly, as it tends to do at Earth's surface, its ions quickly lose their motion and combine. This results in a large number of tiny crystals that all compete for space.

PLANET DIARY

For an activity about **Igneous Rocks** visit PlanetDiary.com/HSES

INQUIRY APPLY IT!

Q: *How are magma and lava the same, and how are they different?*

A: **Both magma and lava are melted rock and their mineral composition may be identical. However, magma is melted material beneath Earth's surface. Lava is melted material at Earth's surface from which most gases have escaped.**

▶ ***Coarse-Grained and Fine-Grained Texture*** Look back at the igneous rocks in Figure 6. The granite, which formed deep underground, has large mineral grains. The rhyolite, which formed at the surface, has grains so small you cannot see them without a magnifying lens. Igneous rocks with large crystals, such as granite, are said to have *coarse-grained texture.* Igneous rocks with small grains, such as rhyolite, are said to have *fine-grained texture.*

▶ ***Glassy Texture*** Sometimes, lava cools so rapidly at Earth's surface that there is not enough time for the ions to combine and arrange themselves into a network of crystals. Instead, the hardened rock has a random, non-crystalline arrangement of atoms. Igneous rocks formed in this way are said to have a *glassy texture.* Look back at Figure 1. Obsidian is a common, glassy igneous rock that looks like manufactured, dark-colored glass. Pumice, another common, glassy igneous rock, has a very nonglassy appearance due to the presence of escaping gases at the time of formation.

▶ ***Porphyritic Texture*** Not all minerals crystallize at the same rate. During the slow cooling process beneath the surface of Earth, it is possible for some minerals to form large crystals before other minerals even begin the crystallization process. But what would happen if this mixture of magma and crystals suddenly erupted to the surface? The remaining molten material would cool rapidly around the larger crystals. The resulting rock would have some very large crystals, called *phenocrysts,* surrounded by more fine-grained minerals. Rocks formed by slow and then rapid cooling, such as the andesite in **Figure 7,** are said to have *porphyritic texture.*

FIGURE 7 Porphyritic Texture
This sample of andesite has a porphyritic texture. Note the large, light-colored crystals surrounded by darker, smaller ones. **Describe** ***How did this rock form?***

☑ **Reading Checkpoint** *How does the rate of cooling of magma or lava affect the texture of igneous rocks?*

Composition

Recall that magma contains silicon, oxygen, and smaller amounts of many other elements. As magma and lava cool, their minerals combine to form silicate minerals. Magma and lava that are rich in potassium, sodium, and calcium form light silicates such as quartz, muscovite mica, and feldspars. Magma and lava rich in iron and/or magnesium form dark silicates such as olivine, pyroxenes (such as augite), amphiboles (such as hornblende), and biotite mica. **The relative amounts of light and dark silicates within an igneous rock defi e its composition.**

▶ ***Granitic Composition*** Igneous rocks with **granitic composition** are generally light-colored, containing just about 10 to 25 percent dark silicate minerals. Granitic rocks are primarily composed of quartz and feldspars. Granitic rocks are named for granite, a common, coarse-grained granitic rock. Much of the continental crust is made of granite. Rhyolite is an example of a fi e-grained granitic rock. Granitic rocks are sometime described as *felsic,* a combination of the words *fel*dspar and *si*lica.

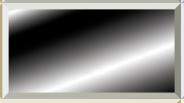
▶ ***Basaltic Composition*** Igneous rocks with **basaltic composition** contain at least 45 percent magnesium and iron-rich dark silicates, making them generally dark-colored and dense. Basalt, which has a fi e-grained texture, is the most common basaltic rock. Most of the ocean floor is made of basalt. Gabbro is a coarse-grained basaltic rock. Basaltic rocks are sometimes described as *mafic,* a term derived from the minerals *ma*gnesium and *f*errum, the Latin name for iron.

▶ ***Andesitic Composition*** Igneous rocks with an intermediate composition between granitic and basaltic are said to have an **andesitic composition**. Andesitic rocks contain 25 to 45 percent dark silicate minerals. Andesitic composition is named for the common, fi e-grained volcanic rock andesite. Diorite is a coarse-grained andesitic rock.

To summarize, igneous rocks form when magma or lava cools and hardens. Intrusive igneous rocks form when magma cools and hardens deep within Earth. These rocks tend to have a coarse-grained texture. Extrusive igneous rocks form when lava cools and hardens on Earth's surface. These rocks tend to have a fi e-grained texture. The balance of elements present in the magma or lava upon cooling determines an igneous rock's mineral composition. Together, texture and composition are used to classify igneous rocks. A general classification scheme is shown in **Table 1** on the next page.

FIGURE 8 Basaltic Composition Basalt is an igneous rock made mostly of dark-colored silicate minerals. **Infer** ***Basalt has a fine-grained texture. What can you infer about the rate of cooling at its formation?***

Table 1 Classification of Major Igneous Rocks

Composition			Granitic	Andesitic	Basaltic
Dominant Minerals			Light silicates	Light and dark silicates	Dark silicates
TEXTURE	Coarse-grained (intrusive)		**Granite**	**Diorite**	**Gabbro**
	Fine-grained (extrusive)		**Rhyolite**	**Andesite**	**Basalt**
	Porphyritic		"Porphyritic" precedes any of the above names whenever there are appreciable phenocrysts.		
	Glassy		**Obsidian** (compact glass) **Pumice** (frothy glass)		
Rock Color (based on % of dark minerals)			0% to 25%	25% to 45%	45% to 85%
					

3.2 Assessment

Review Key Concepts

1. Compare and contrast the formation of intrusive and extrusive igneous rocks.
2. How do coarse-grained igneous rocks form?
3. How are igneous rocks classified according to composition?
4. How do fine-grained igneous rocks form?
5. How do igneous rocks with porphyritic textures form?

Think Critically

6. **Contrast** Contrast basalt and granite in terms of how each forms, the texture of each rock, the color of each rock, and each rock's composition.
7. **Form a Hypothesis** The extrusive igneous rock pumice contains many small holes. Hypothesize how these holes might form.

WRITING IN SCIENCE

8. **Explain** Write a paragraph to explain how one of the igneous rocks pictured in this chapter may have formed.

3.3 Sedimentary Rocks

ES.5 The student will investigate and understand the rock cycle as it relates to the origin and transformation of rock types and how to identify common rock types based on mineral composition and textures. Key concepts include **b.** sedimentary rocks.

GEOLOGISTS ESTIMATE that 90 to 95 percent of the outer 16 kilometers (10 miles) of Earth's crust is either igneous or metamorphic rock. However, most of Earth's solid surface, including nearly the entire ocean floor, is covered in sediment or sedimentary rock. Because of their position at or near Earth's surface, sediments and sedimentary rock contain evidence of past conditions and events. As we will see, this group of rocks provides geologists with much of the basic information they need to reconstruct details of Earth's history.

FIGURE 9 Rocks That Tell Tales Geologists can infer a lot about past environmental conditions from these sedimentary rocks in Canyonlands National Park, Utah.

Key Questions

What are the major processes involved in the formation of sedimentary rocks?

What are the three types of sedimentary rocks?

What features are unique to some sedimentary rocks?

Vocabulary

- erosion • deposition
- compaction • cementation
- clastic sedimentary rock
- chemical sedimentary rock
- biochemical sedimentary rock

Reading Strategy

Outline Copy this outline beneath the outline you made for Lesson 2. Complete this outline as you read. Include points about how each of these rocks form, some of the characteristics of each rock type, and some examples of each.

II. Sedimentary Rocks
- A. Clastic Rocks
  1. ___?___
  2. ___?___
- B. Chemical Rocks
  1. ___?___
  2. ___?___
- C. Biochemical Rocks
  1. ___?___
  2. ___?___

Formation of Sedimentary Rocks

Look at the rocks shown in **Figure 10.** Without doing any research, how would you say they formed? The rock in Figure 10A looks like a bunch of pebbles dropped into a pile of wet sand that then hardened, doesn't it? The rock in 10B just looks like sand that hardened into rock. As it turns out, that is pretty much exactly what happened.

FIGURE 10 Different, Yet the Same Although these two rocks appear quite different, both **A** conglomerate and **B** sandstone are formed by the same processes of weathering, erosion, deposition, compaction, and cementation.

Weathering, Erosion, and Deposition Recall that weathering is any process that breaks down rock. Chemical weathering occurs when the minerals in rocks change into new substances. For example, when oxygen combines with iron, it forms a crumbly layer of iron oxide, or rust, on a rock's surface. Physical weathering is sometimes called mechanical weathering because it occurs when rocks are broken down mechanically. For example, when a tree root forces its way into bedrock, it pushes pieces of rock apart. Th s type of weathering does not involve a change in a rock's composition.

Weathered sediments do not usually remain in one place for long. **Erosion is the picking up and carrying away of sediments.** Usually, sediments are broken down further during this transport phase. When an agent of erosion, such as water, wind, ice, or gravity, loses energy, it drops off ts sediment load. Th s process is called **deposition.** The word *sedimentary* is derived from the Latin word *sedimentum,* meaning "settling." As an agent of erosion slows down, sediments are deposited according to size, with larger sediments settling out before smaller ones.

Compaction and Cementation From studying the rock cycle, we know that deposited sediments can be lithifi d, or turned into rock. There are two processes involved in lithifi ation: compaction and cementation. **Compaction is a process that squeezes, or compacts, sediments.** Compaction is caused by the weight of sediments as they pile on top of each other in layers. The deeper those sediments are buried, the more they are compacted and the fi mer they become. During compaction, most of the water between sediment particles is driven out. However, the water leaves behind the minerals it contained. These minerals essentially glue the sediments together. **Cementation takes place when dissolved minerals are deposited in the tiny spaces among sediments, binding them together into a solid mass.**

Reading Checkpoint *Briefly describe the five major processes involved in the formation of sedimentary rocks.*

Classification of Sedimentary Rocks

Sandstone, halite (rock salt), and coal are all sedimentary rocks in that they are made of accumulated sediments. However, they each belong to a separate sedimentary rock category because the origin of their sediments differs. **Sedimentary rocks are classified into three groups—clastic, chemical, and biochemical.**

Clastic Sedimentary Rocks You are likely most familiar with **clastic sedimentary rocks,** rocks made of sediments that come from preexisting rocks. Many different kinds of minerals are found in clastic sedimentary rocks. The most common are clay minerals and quartz. Clastic sedimentary rocks are further classified according to the size of their sediments. If a rock has sediments that are pebble-sized (2 mm or larger), it is either a conglomerate or a breccia. Conglomerates, such as the one in Figure 10A, have large, rounded sediments. Breccias, such as the one in **Figure 11A,** have large, angular sediments. Angular sediments indicate that the particles have not traveled far enough away from their source to have their corners and rough edges smoothed during transport. Rocks with primarily sand-sized sediments (1/16–2 mm) are called sandstone, and rocks with primarily silt-sized sediments (1/256–1/16 mm) are called siltstones. Shales, such as the one in **Figure 11B,** are made up of very fi e, clay-sized (< 1/256 mm) sediments.

Particle size provides useful information about the environment in which the sediment was deposited. The larger the particle size, the more energy required to carry it. Pebbles, for example, are moved by swiftly flowing rivers, rockslides, and glaciers. Less energy is required to move sand and silt. Moreover, recall that sediments settle according to size. If an agent of erosion, such as a river, is carrying sediments of various sizes, the smallest sediments will settle last. So, when a river meets the ocean and begins to deposit its load, the smallest sediments will be deposited the farthest offshore.

FIGURE 11 Clastic Sedimentary Rocks A Breccia and **B** shale are common clastic sedimentary rocks.
Infer *Did the shale seen here most likely form in a terrestrial (land) environment or an aquatic environment? Explain.*

Chemical Sedimentary Rocks Rocks made of dissolved sediments that precipitate, or separate, directly from water are called **chemical sedimentary rocks.** Precipitation usually occurs when water evaporates, leaving once-dissolved solids behind. Rock salt is a chemical rock that forms when the mineral halite precipitates from sea water. You can model halite formation by leaving a container of salt water outside in the sun. Over time, the water will evaporate, leaving the salt behind. When dissolved calcite precipitates directly from water, it forms chemical limestones.

☑ **Reading Checkpoint** *Describe the major types of clastic sedimentary rocks.*

FIGURE 12 Biochemical Sedimentary Rock You can see shell fragments that make up this piece of coarse limestone, called coquina.

Biochemical Sedimentary Rocks Rocks made of sediments derived from biological processes are called *organic rocks,* or **biochemical sedimentary rocks.** Living organisms take up dissolved minerals and use them to form their hard and soft issues. When the organisms die, their bodies are broken down and turned to sediments that can turn to rock. Examples of biochemical rocks include limestone, which is formed primarily from the shells of marine organisms, and coal, which is made up of the remains of swamp plants. Coquina, a type of limestone, is shown in **Figure 12.**

Sedimentary Rock Features

Because sedimentary rocks form at Earth's surface, they often contain clues about past environmental conditions. **Unique features of sedimentary rocks include strata, fossils, ripple marks, and mud cracks. These features indicate how, when, and where the rocks formed.** Sedimentary rock forms in layers called *strata.* Each layer records a period of deposition. Thus, unless disturbed, sedimentary rocks closer to the surface are younger than those that are buried deeper.

Knowing the relative age of sedimentary rock layers can be particularly helpful when the rocks contain fossils. A *fossil* is the remains or trace of ancient life. Only sedimentary rocks contain fossils. In general, a fossil forms when an organism is quickly buried by sediment and then preserved in some way as the sediment is turned to rock. Fossils play a key role in matching up rocks of similar age that are found in different places. You will learn more about this in a later chapter.

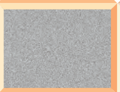
Sediments may also preserve information about the environment in which they formed. Ripple marks, like those in **Figure 13A,** indicate that the rock formed in the presence of moving water. Mud cracks, like those in **Figure 13B,** indicate that the rock formed as sediments were drying.

FIGURE 13 Water or No Water? A Ripple marks and **B** mud cracks are features of sedimentary rocks that can be used to learn about the environments in which the rocks formed.

To summarize, sedimentary rocks form through the processes of erosion, weathering, deposition, compaction, and cementation. Based on the origin of their sediments, there are three basic types: clastic, chemical, and biochemical. Their unique features such as strata, fossils, ripple marks, and mud cracks give clues to when, how, and where they formed.

Table 2 Classification of Major Sedimentary Rocks

Clastic Sedimentary Rocks

Sediment Type	Sediment size		Rock Name
Pebble (rounded)	> 2 mm		Conglomerate
Pebble (angular)	> 2 mm		Breccia
Sand	1/16 to 2 mm		Sandstone
Silt	1/16 to 1/256 mm		Siltstone
Clay	<1/256 mm		Shale

Chemical Sedimentary Rocks

Composition	Rock Name
Calcite ($CaCO_3$)	Chemical limestone
Halite (NaCl)	Rock salt

Biochemical Sedimentary Rocks

Composition	Rock Name
Calcite ($CaCO_3$)	Biochemical limestone
Plant remains	Coal

3.3 Assessment

Review Key Concepts

1. Contrast weathering, erosion, and deposition.
2. Name four clastic sedimentary rocks and explain how these rocks form.
3. What is the difference between a clastic sedimentary rock and a chemical sedimentary rock?
4. Explain how three different features of sedimentary rocks can be used to determine how, where, or when the rocks formed.
5. What is compaction?
6. Where do the cements that hold sediments together come from?

Think Critically

7. **Apply Concepts** Briefly describe how the rock shown in Figure 12 may have formed.
8. **Predict** Which type of sediments do you think would undergo more compaction—grains of sand or grains of clay? Explain your choice.
9. **Draw Conclusions** Suppose you found a sedimentary rock with ripple marks. What could you conclude about the rock?

CONNECTING CONCEPTS

10. **Research** Choose one of the sedimentary rocks pictured in this section. Find out how the rock is useful to people.

3.4 Metamorphic Rocks

ES.5 The student will investigate and understand the rock cycle as it relates to the origin and transformation of rock types and how to identify common rock types based on mineral composition and textures. Key concepts include **c.** metamorphic rocks.

Key Questions

Where does most metamorphism take place?

How is contact metamorphism different from regional metamorphism?

What are three agents of metamorphism, and what kinds of changes does each cause?

What are foliated metamorphic rocks, and how do they form?

How are metamorphic rocks classified?

Vocabulary

- metamorphism
- contact metamorphism
- regional metamorphism
- hydrothermal solution
- foliated metamorphic rock
- nonfoliated metamorphic rock

Reading Strategy

Outline Copy this outline beneath the outline you made for Lesson 3. Complete it as you read. Include points about how each of these rocks form, some of the characteristics of each rock type, and some examples of each.

III. Metamorphic Rocks
  A. Foliated Rocks
    1. ___?___
    2. ___?___
  B. Nonfoliated Rocks
    1. ___?___
    2. ___?___

RECALL THAT metamorphic rocks form when existing rocks undergo **metamorphism,** transformation of preexisting rock. A rock that has undergone metamorphism is said to have been metamorphosed. These rocks, such as the one shown in **Figure 14,** tend to be very different from their *parent rocks*—the rocks from which they formed.

Types of Metamorphism

Metamorphism most often occurs in rocks that are buried deeply beneath Earth's crust. Here, they are exposed to an environment that is very different from the one in which they originally formed. **Most metamorphic changes occur in the region between the upper mantle and a few kilometers below Earth's surface.** There are two general types of metamorphism: contact metamorphism and regional metamorphism.

FIGURE 14 Deformed Rock Intense pressure not only caused these rocks to fold, but also changed the mineral composition of the parent rock.

Contact Metamorphism When magma forces its way into rock, contact metamorphism may occur. **During contact metamorphism, intruding magma causes localized areas of elevated temperature that alter rock.** Contact metamorphism usually results in minor changes to the parent rock. Marble, shown in **Figure 15,** is sometimes formed from limestone in this way.

Regional Metamorphism When tectonic plates collide and form mountains, large areas of rock are exposed to very high temperatures and pressures. **Regional metamorphism occurs over large areas of Earth's crust, usually during mountain building, and is associated with very high temperatures and pressures.** Regional metamorphism can result in major changes caused by the extreme temperatures and pressures of the upper mantle and lower crust.

FIGURE 15 Marble Marble is a common metamorphic rock that can form as the result of contact metamorphism of limestone.

Agents of Metamorphism

We have said repeatedly that metamorphism occurs when rocks are subjected to intense heat and pressure. Heat and pressure, as well as fluids, are called *agents of metamorphism.* **The agents of metamorphism are heat, pressure, and fluids.** Usually, a rock undergoing metamorphosis is exposed to all three of these agents. However, the effect of each agent varies greatly.

Heat The most important agent of metamorphism is heat. Heat provides the energy needed to drive chemical reactions. Some of these reactions cause existing minerals to recrystallize and form larger crystals. Other reactions cause new minerals to form. The heat for metamorphism comes mainly from two sources—magma and the change in temperature with depth. Magma essentially "bakes" any rocks that are in contact with it. Heat also comes from the gradual increase in temperature with depth. In the upper crust, this increase averages between 20°C and 30°C per kilometer.

The temperature needed to change a rock depends on its composition. Minerals become unstable at temperatures higher than those at which they formed. When this happens, they will transform into other minerals that are stable at the new, higher temperature. Thus, rocks composed of minerals that formed deep within Earth's crust will require higher temperatures to metamorphose than those that formed closer to the surface.

Reading Checkpoint *Compare and contrast contact and regional metamorphism.*

INQUIRY APPLY IT!

Q: ***How hot is it deep in the crust?***

A: **The deeper a person goes beneath Earth's surface, the hotter it gets. The deepest mine in the world is the Western Deep Levels mine in South Africa, which is about 4 kilometers deep. Here, the temperature of the surrounding rock is so hot that it can scorch human skin. In fact, miners in this mine often work in groups of two. One miner mines the rock, and the other operates a large fan that keeps the worker cool.**

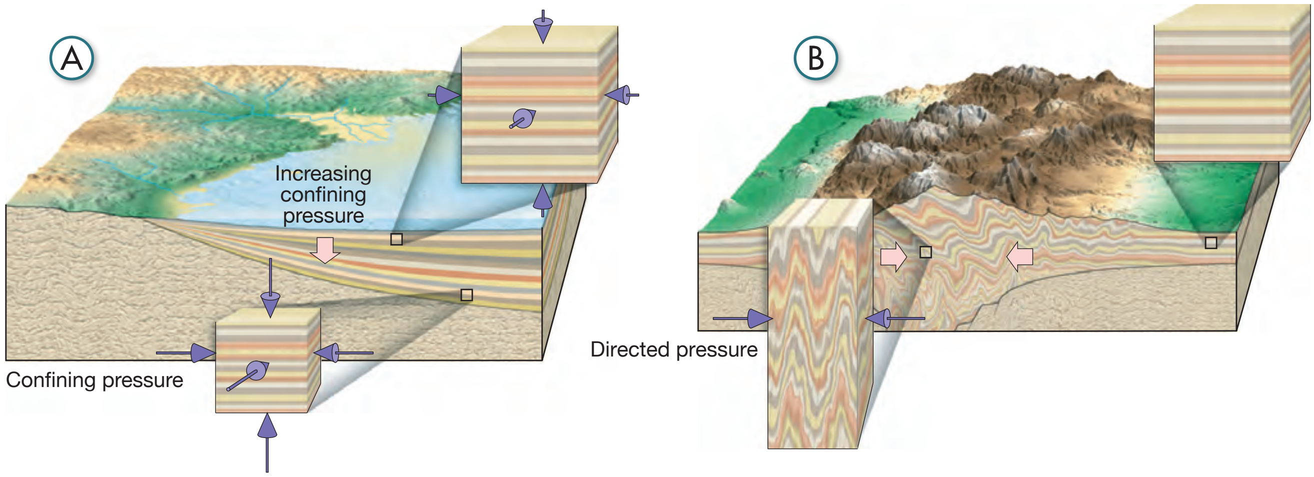


FIGURE 16 Pressure As a Metamorphic Agent
A Confining pressure is applied in all directions when rocks are buried.

B During mountain building, rocks are subjected to directed pressure, pressure that is greater in one direction than in others.

FIGURE 17 The Effects of Pressure Imagine the tremendous amounts of pressure that caused these rocks to fold.

Pressure There are two types of pressure, as shown in **Figure 16.** *Confining pressure* is pressure associated with burial. Confi ing pressure occurs equally in all directions and, like temperature, increases with depth. The primary effect of confi ing pressure is to make rocks more compact and dense. Unlike confi ing pressure, *directed pressure* is greater in one direction than others. This type of pressure is associated with mountain building and can cause dramatic folds such as those shown **Figure 17.**

Fluids Solutions that surround mineral grains aid in recrystallization by making it easier for dissolved minerals to move. When solutions increase in temperature, reactions among substances can occur at a faster rate. Many of these solutions are associated with magma and are called **hydrothermal solutions.** Hydrothermal solutions promote recrystallization by dissolving original minerals and then depositing new ones. A change in a rock's overall mineral composition is often the result.

Classification of Metamorphic Rocks

Metamorphic rocks are classified into groups based on their texture. **Metamorphic rocks are classified as having either a foliated or nonfoliated texture.**

Foliated Metamorphic Rocks Metamorphic rocks that are formed under high temperatures and elevated, directed pressure may become foliated. **Foliated metamorphic rock** contains minerals that are oriented perpendicular to the direction of greatest pressure. This reorientation of minerals gives foliated metamorphic rocks a layered appearance. When the minerals separate into distinct layers, the rocks appear banded, such as the gneiss shown in **Figure 18A.** Slate, phyllite, schist, and gneiss make up a series of foliated metamorphic rocks that form at increasing temperatures and pressures.

Nonfoliated Metamorphic Rocks Metamorphic rocks that are formed under high temperatures and even, confi ing pressure are not foliated. **Nonfoliated metamorphic rock** lacks a layered or banded appearance. Most nonfoliated metamorphic rocks contain only one mineral and form by contact metamorphism. For example, limestone, the parent rock of marble **(Figure 18B)**, is composed entirely of the mineral calcite. When exposed to intruding magma, the calcite crystals recrystallize forming larger, randomly oriented crystals. Quartzite and anthracite are two other common, nonfoliated metamorphic rocks.

☑ **Reading Checkpoint** *Contrast foliated and nonfoliated metamorphic rocks.*

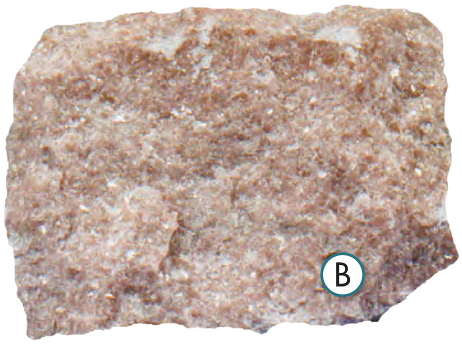


FIGURE 18 Foliated and Nonfoliated Metamorphic rocks have two general textures. **A** Gneiss has a foliated texture. **B** Marble has a nonfoliated texture. **Infer** *In which direction was pressure exerted on the gneiss?*

INQUIRY QUICK LAB

OBSERVING SOME OF THE EFFECTS OF PRESSURE ON MINERAL GRAINS

Materials

• soft modeling clay • 2 pieces of waxed paper (each 20 cm × 20 cm) • 20–30 small, round, elongated plastic beads • small plastic knife

Procedure

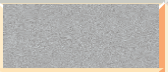
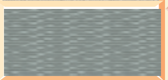
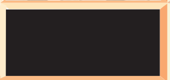
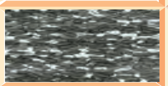
1. Use the clay to form a ball about the size of a golf ball. Randomly place all of the beads into this model rock.
2. Make a sketch of the rock. Label the sketch *Before*.
3. Sandwich the model rock between the two pieces of waxed paper. Use your weight to apply pressure to the model rock.
4. Remove the waxed paper and observe your "metamorphosed" rock.
5. Draw a top view of your rock and label it *After*. Include arrows to show the directions from which you applied pressure.
6. Make a cut through your model rock. Sketch this view of the rock.

Analyze and Conclude

1. **Compare and Contrast** How did the *Before* sketch of your model rock compare with the *After* sketch?
2. **Draw Conclusions** How does pressure affect the mineral grains in a rock?
3. **Infer** Was pressure the only agent of change that affected your rock? Explain.

To summarize, metamorphic rocks form when existing rocks are changed by heat, pressure, and/or fluids. There are two types of metamorphism. Contact metamorphism is often caused when hot magma intrudes into a body of rock. Regional metamorphism is associated with mountain building. The intensity of metamorphism can vary greatly from one environment to another. Samples of shale and its parent rock slate, for example, are often very hard to tell apart. This illustrates that the transition between one rock type to another can be gradual and the changes can be subtle. On the other hand, in more extreme environments, metamorphism can be so complete that the identity of a metamorphic rock's parent rock can not be determined. Metamorphic rocks can be classified by texture as foliated or nonfoliated, as shown in **Table 3.**

Table 3 Classification of Major Metamorphic Rocks

Foliated Metamorphic Rocks			Nonfoliated Metamorphic Rocks		
Parent Rock	**Texture**	**Rock Name**	**Parent Rock**	**Texture**	**Rock Name**
Siltstone or Shale		**Slate**	Limestone		**Marble**
Slate		**Phyllite**	Sandstone		**Quartzite**
Phyllite		**Schist**	Coal		**Anthracite**
Schist or Granite		**Gneiss**			

Increasing metamorphism

3.4 Assessment

Review Key Concepts

1. Where does most metamorphism take place?
2. Compare and contrast contact metamorphism and regional metamorphism.
3. Name the agents of metamorphism and explain how each changes a rock.
4. What are foliated rocks? How do they form?
5. How are metamorphic rocks classified?

Think Critically

6. **Apply Concepts** What is the major difference between igneous and metamorphic rocks?
7. **Predict** What type of metamorphism, contact or regional, would result in a schist? Explain your choice.
8. **Draw Conclusions** Why can the composition of gneiss vary but overall texture cannot?

WRITING IN SCIENCE

9. **Compare and Contrast** Write a paragraph explaining the major differences and similarities among the three rock groups.

EARTH & ITS SYSTEMS

The Carbon Cycle

Carbon moves among Earth's major spheres by way of the carbon cycle. The carbon cycle is one of Earth's biogeochemical cycles. A biogeochemical cycle is a cycle in which matter and energy move through the Earth system in a series of steps. These steps in the carbon cycle have different flow characteristics: Some steps involve chemical changes, as when wood is burned, releasing carbon dioxide gas (CO_2). Other steps involve the movement of materials containing carbon. For example, during a volcanic eruption, carbon dioxide gas is released into the atmosphere. Some steps involve the life processes of living things.

At each step in the cycle, carbon is stored for varying lengths of time in different reservoirs, or parts of the Earth system. These reservoirs include the atmosphere, oceans, biomass, fossil fuels, and carbonate rocks. For example, carbon may be part of an organism's biomass for the short span of the organism's lifetime. But the carbon that makes up coal may remain in Earth for millions of years.

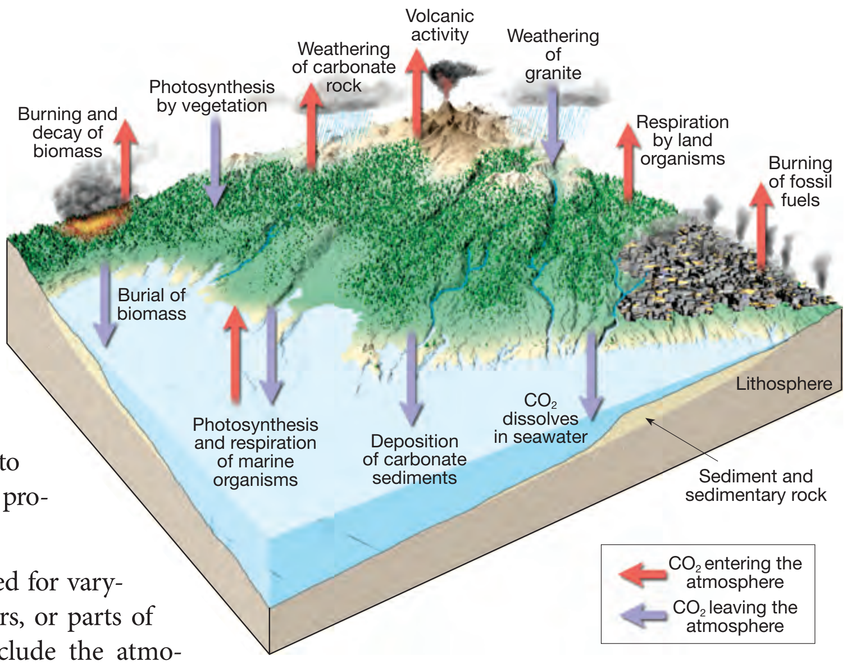


FIGURE 19 The Carbon Cycle

Carbon Dioxide on the Move

In the atmosphere, carbon is found mainly as carbon dioxide. The source of most CO_2 in the atmosphere is thought to be from volcanic activity early in Earth's history. Carbon dioxide moves into and out of the atmosphere by way of photosynthesis, respiration, organic decay, and combustion of organic material.

In photosynthesis, carbon dioxide gas is taken up by plants. Carbon thus becomes part of the compounds, called hydrocarbons, that make up living things. As a result, the biomass of all living organisms on Earth forms a major reservoir of carbon. Respiration, organic decay, and combustion release carbon from this reservoir back into the atmosphere as carbon dioxide.

Carbon and Fossil Fuels

The remains of once living things form another major reservoir of carbon. Some carbon from decayed organic matter is deposited as sediment. Over long periods of time, this carbon becomes buried. Under the right conditions, some of these carbon-rich deposits are changed to fossil fuels, such as coal. When fossil fuels are burned, carbon dioxide is released.

The Role of Marine Animals

Chemical weathering of certain rocks produces bicarbonate ions that dissolve in water. Rivers and streams carry these ions to the ocean. Here, some organisms extract this substance to produce shells and skeletons made of calcite ($CaCO_3$). When the organisms die, these hard parts settle to the ocean floor and become a sedimentary rock called limestone. If this rock is then exposed at the surface and subjected to chemical weathering, CO_2 is also produced. Use **Figure 19** to follow the carbon cycle.

Rock Identification

Problem How can you use composition and texture to identify common rocks?

Materials rock samples; hand lens; pocket knife; dilute hydrochloric acid; colored pencils; Chapter 2, Table 2; Chapter 3, Tables 1, 2, and 3

Skills Observe, Compare and Contrast, Measure

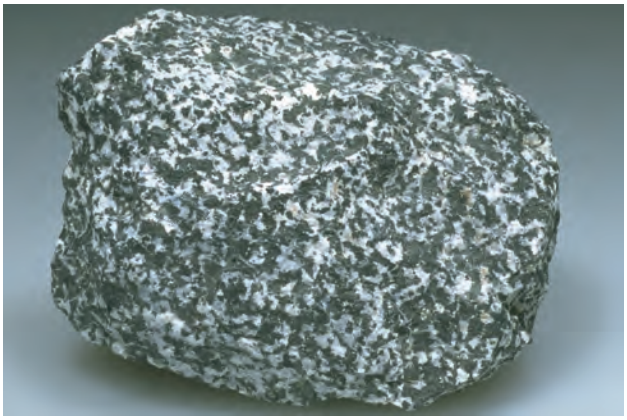
Connect to the Big idea Most rocks can be easily identified by texture and composition. In this lab, you will use what you have learned about rocks as well as the information on minerals from Chapter 2 to identify some common rocks.

Procedure

1. On a separate sheet of paper, make a copy of the data table shown below. Add any other columns that you think might be useful.
2. Examine each rock specimen with and without the hand lens. Determine and record the overall color of each rock.
3. Try to identify all of the minerals in each rock, using the information in Chapter 2 Table 2. Record your observations.
4. Determine and record the presence of any organic matter in any of the samples.
5. Observe the relationships among the minerals in each rock to determine texture. Refer to Chapter 3 Tables 1, 2, and 3 if necessary. Record your observations.
6. Note and record any other unique observations of the samples.
7. In your data table, make and color a detailed sketch of each sample.
8. Identify each sample as being an igneous rock, a sedimentary rock, or a metamorphic rock.
9. Name each sample. Use the photographs in this chapter and Tables 1, 2, and 3 if necessary.

Data Table

Rock	Overall Color	Composition	Texture	Sketch	Rock Type	Rock Name
1.						
2.						
3.						
4.						
5.						



Analyze and Conclude

1. **Evaluate** Which of the rock identification characteristics did you fi d most useful? Which of the characteristics did you fi d least useful? Give reasons for your answers.
2. **Compare and Contrast** How did identifying rocks compare with the mineral identification lab you did in Chapter 2? How is identifying rocks different from identifying the minerals that compose the rocks?
3. **Apply Concepts** Match the metamorphic rocks with their probable parent rocks.

4. **Apply Concepts** Choose two pairs of rocks used in this investigation. Write a brief description for each pair that explains how one rock can be changed into the other. Refer to a diagram of the rock cycle to help you.

GO FURTHER Obtain permission to collect some local rock samples from a park or nearby road. Use what you have learned about rocks and minerals to identify the rocks. Then write a brief history of each sample to explain how it formed and how it has changed since being formed.

ES.5 The student will investigate and understand the rock cycle as it relates to the origin and transformation of rock types and how to identify common rock types based on mineral composition and textures. Key concepts include **a.** igneous rocks; **b.** sedimentary rocks; and **c.** metamorphic rocks.

3 Study Guide

Big idea Earth's Materials and Systems

3.1 The Rock Cycle

A rock is a solid mass of minerals or mineral-like materials.

The three major types of rock are igneous, sedimentary, and metamorphic.

The rock cycle is a model that describes the ways in which rocks transform from one type to another.

Igneous rocks form from cooled magma or lava.

Sedimentary rocks form from layers of weathered, eroded, and deposited sediment.

Metamorphic rocks form when preexisting rocks are altered by pressure, heat, and/or fluids.

Earth's internal heat and the processes of weathering, erosion, deposition, and lithification can transform any type of rock into another.

rock (66)
rock cycle (66)
magma (67)
lava (67)
igneous rock (67)
weathering (67)
sediment (67)
sedimentary rock (67)
metamorphic rock (67)

3.2 Igneous Rocks

Igneous rocks formed from magma beneath Earth's surface are known as intrusive igneous rocks.

Igneous rocks formed from lava at Earth's surface are called extrusive igneous rocks.

Slow cooling of magma or lava causes large crystals to form, while rapid cooling results in small crystals.

The relative amounts of light and dark silicates within an igneous rock define its composition.

intrusive igneous rock (71)
extrusive igneous rock (71)
texture (71)
granitic composition (72)
basaltic composition (73)
andesitic composition (73)

3.3 Sedimentary Rocks

Erosion is the picking up and carrying away of sediments.

Compaction is a process that squeezes, or compacts, sediments.

Cementation takes place when dissolved minerals are deposited in the tiny spaces among sediments, binding them together into a solid mass.

Sedimentary rocks are classified into three groups—clastic, chemical, and biochemical.

Unique features of sedimentary rocks include strata, fossils, ripple marks, and mud cracks. These features indicate how, when, and where the rocks formed.

erosion (76)
deposition (76)
compaction (76)
cementation (76)
clastic sedimentary rock (77)
chemical sedimentary rock (77)
biochemical sedimentary rock (78)

3.4 Metamorphic Rocks

Most metamorphic changes occur in the region between the upper mantle and a few kilometers below Earth's surface.

During contact metamorphism, intruding magma causes localized areas of elevated temperature that alter rock.

Regional metamorphism occurs over large areas of Earth's crust, usually during mountain building, and is associated with very high temperatures and pressures.

The agents of metamorphism are heat, pressure, and fluids.

Metamorphic rocks are classified as having either a foliated or nonfoliated texture.

metamorphism (80)
contact metamorphism (81)
regional metamorphism (81)
hydrothermal solution (82)
foliated metamorphic rock (82)
nonfoliated metamorphic rock (83)

3 Assessment

Review Content

Choose the letter that best answers the question or completes the statement.

1. Which of the following is NOT one of the three major types of rocks?
a. anthracite **c.** metamorphic
b. igneous **d.** sedimentary

2. Which of the following is the primary process by which a sedimentary rock transforms into an igneous rock?
a. metamorphism **c.** erosion
b. melting **d.** deposition

3. Which of the following would NOT be a major process in the formation of sedimentary rocks?
a. erosion **c.** deposition
b. melting **d.** compaction

4. The formation of igneous rocks is powered by
a. the sun.
b. compaction.
c. erosion.
d. Earth's internal heat.

5. A fi e-grained igneous rock forms
a. deep within Earth.
b. from magma.
c. as the result of slow cooling.
d. as the result of quick cooling.

6. Cementation is one of the fi al processes involved in the formation of which type of rock?
a. contact metamorphic
b. intrusive igneous
c. extrusive igneous
d. clastic sedimentary

7. Ripple marks likely indicate that the rock formed
a. underground. **c.** in water.
b. under a glacier. **d.** from magma.

8. A major process in the formation of clastic sedimentary rocks is
a. contact with magma. **c.** hardening.
b. cementation. **d.** foliation.

9. Metamorphic rocks that have a banded appearance due to the alignment of minerals are called
a. foliated. **c.** clastic.
b. nonfoliated. **d.** glassy.

10. Which rock is made of the smallest sediments?
a. shale **c.** breccia
b. conglomerate **d.** sandstone

Understand Concepts

11. What is a rock?

12. Which igneous rock forms when basaltic lava hardens? When basaltic magma hardens?

13. A rock has a porphyritic texture. What can you conclude about the rock?

14. How are granite and rhyolite the same, and how do they differ?

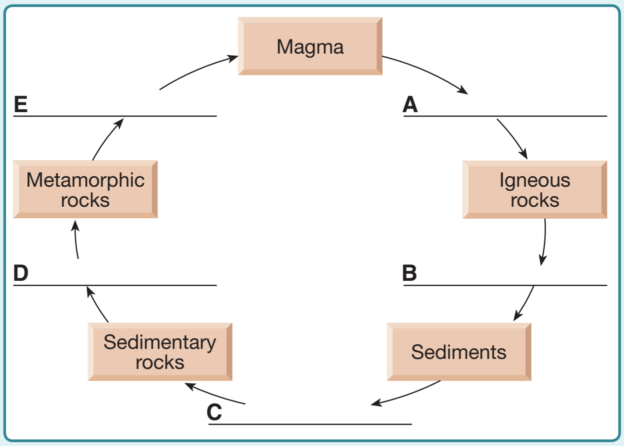
15. Explain the two main types of weathering.

16. Why is most of Earth's solid surface composed of sediments or sedimentary rocks?

17. Distinguish between regional and contact metamorphism.

18. What is the difference between shale and slate?

Use the following diagram to answer Questions 19–22.



19. What process occurs at point A?

20. What three processes can occur at point B?

21. Name two processes that occur at point C.

22. What two processes occur at points D and E?

Think Critically

23. **Explain** Is it possible for two different types of igneous rocks to have the same composition and the same texture? Explain.
24. **Compare and Contrast** Compare and contrast the three types of sedimentary rocks and give an example of each type.
25. **Form a Hypothesis** Think about the sediments that comprise both conglomerate and breccia. What one sedimentary process makes these two rocks different? Explain.
26. **Compare and Contrast** Compare and contrast the effects of heat and pressure in the formation of metamorphic rocks.
27. **Review** What are the three agents of metamorphism?
28. **Contrast** In what ways do metamorphic rocks differ from the sedimentary and igneous rocks from which they form?

Use the photograph to answer Questions 29–33.

29. **Observe** Describe the texture of the rock.
30. **Identify** To which of the three major groups of rocks does the rock belong?
31. **Classify** Classify the rock as specifically as possible.
32. **Form a Hypothesis** Briefly describe how this rock formed.
33. **Apply Concepts** Explain how this rock might become an igneous rock.

Concepts in Action

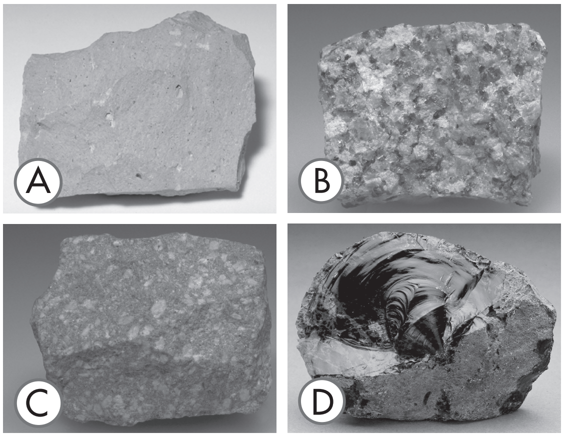
34. **Apply Concepts** Your friend shows you a rock with distinct layers. How can you and your friend determine if the rock is a sedimentary rock or a metamorphic rock?
35. **Apply Concepts** Explain how the position of a sedimentary rock layer can provide clues as to its age compared to layers above and below it.
36. **Calculate** Each year, roughly 9100 kilograms of rock, sand, and gravel are mined for each person in the United States. Calculate how many kilograms of rock, sand, and gravel have been mined for you thus far in your life. Then calculate how much will have been mined when you are 75 years old.
37. **Writing in Science** Suppose you're a writer for the school newspaper. You have been asked to do a story on one of the rocks described in this chapter. Pick a rock and write a short, newspaper-type story. Include facts about the rock—its texture, mineral composition, and how it formed. Also describe how the rock might change into a rock in each of the other two categories of rocks. Be creative, but scientifically accurate.

Performance-Based Assessment

Apply Concepts Go on a field trip around your house, neighborhood, and community to find at least ten items that are made from rocks or show ways in which rocks are used. Make a poster that shows what you found and display it for the class.

Virginia SOL Test Prep

Use the photographs below to answer Questions 1–4. Choose the letter that best answers the question or completes the statement.



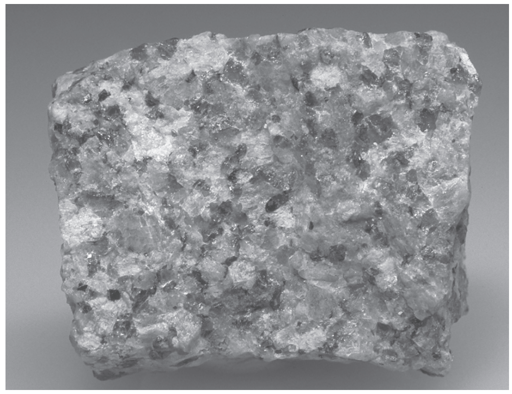
1 Which of the rocks has a fine-grained texture?
A A
B B
C C
D D
ES.5.a

2 Which photo shows an igneous rock that formed from rapidly cooling lava?
F A
G B
H C
J D
ES.5.a

3 Which of the rocks formed completely deep beneath the surface?
A only A
B only B
C only D
D both A and B
ES.5.a

4 Which of the following best describes the texture of the rock labeled D?
F porphyritic
G glassy
H fine-grained
J coarse-grained
ES.5.a

Use the photograph below to answer Question 5.



5 What type of rock is shown in the photograph?
A lava
B igneous
C sedimentary
D metamorphic
ES.5.a

6 Which of the following processes involves pressure that causes sediments to combine and form rock?
F cementation
G compaction
H deposition
J erosion
ES.5.a

Tips for Success

Use Visuals Sometimes an answer to a test question requires that you interpret a drawing, a table, or a photograph. When this occurs, carefully study the visual before you read the questions pertaining to it. Refer to the visual again as you read each of the questions to which it pertains.

If You Have Trouble With . . .

Question	1	2	3	4	5	6
See Lesson	3.2	3.2	3.2	3.2	3.2	3.3