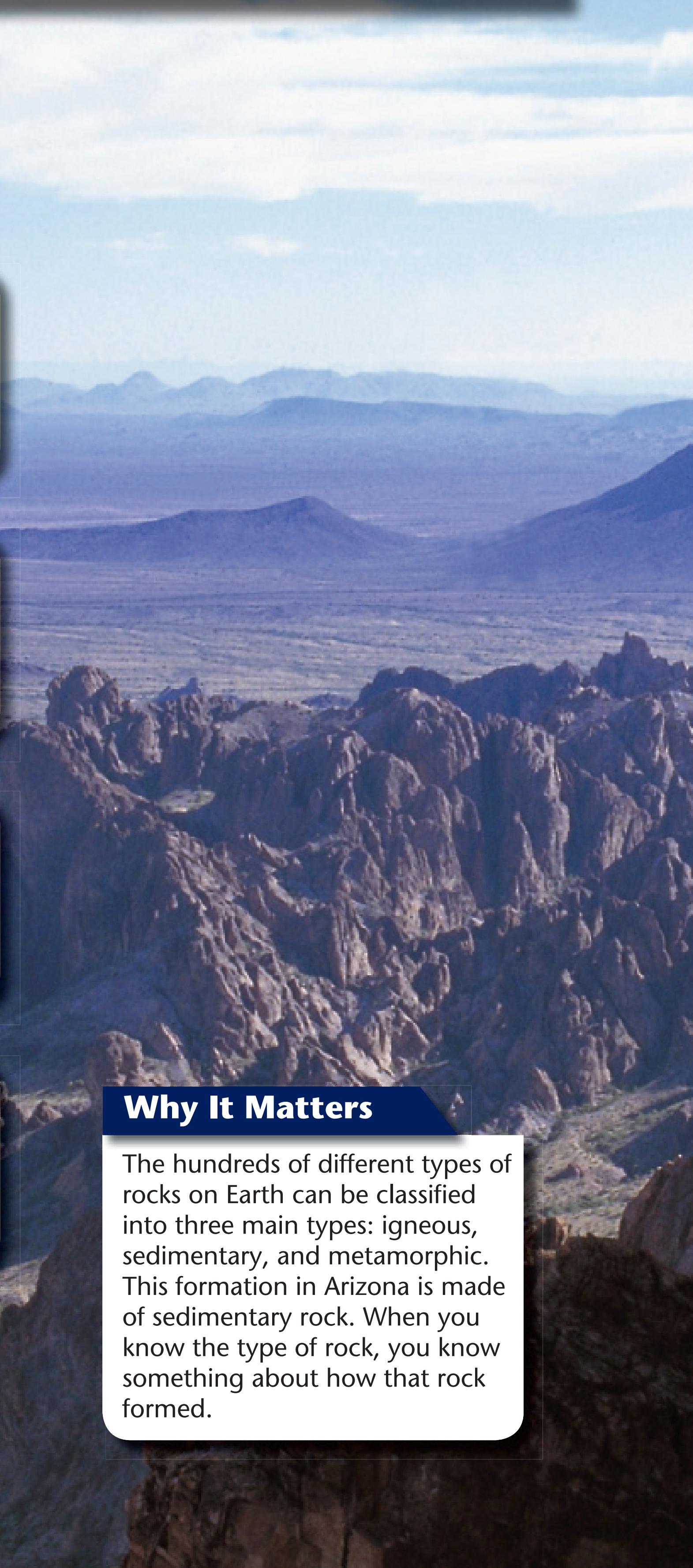
Chapter 6 Rocks



Chapter Outline

Why It Matters

The hundreds of different types of rocks on Earth can be classified into three main types: igneous, sedimentary, and metamorphic. This formation in Arizona is made of sedimentary rock. When you know the type of rock, you know something about how that rock formed.

Inquiry Lab

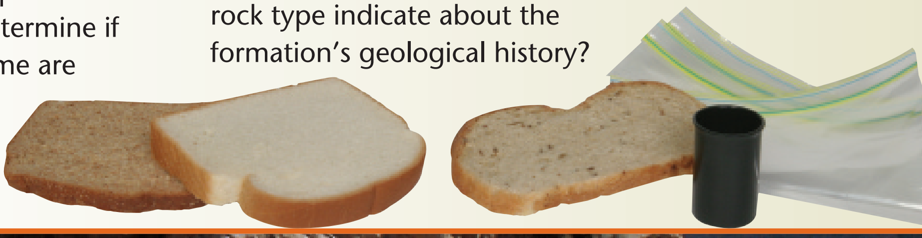
Sedimentary Sandwich

15 min

Use **slices of different types of bread** to model layers of different types of sediment deposits. Next, put your model in a **plastic bag.** Place a **weight** on top of the bag to simulate the process of compacting sediment into rock. Then, use an empty **film canister** to obtain a core sample of the sedimentary sandwich. Trade samples with another group and observe the other group's sample. Identify the different layers of rock and determine if rock layers are the same thickness or if some are thicker than others.

Questions to Get You Started

1. Make a labeled diagram showing the rock layers in the sample you observed.
2. Which factors might affect the thickness of a rock layer in a real rock formation?
3. Your model has layers of different types of rocks. In a real formation, what might changes in rock type indicate about the formation's geological history?



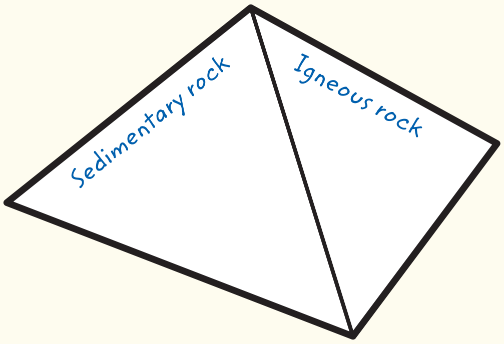
READING TOOLBOX

These reading tools will help you learn the material in this chapter.

FoldNotes

Pyramid Pyramid FoldNotes help you compare words or ideas in sets of three.

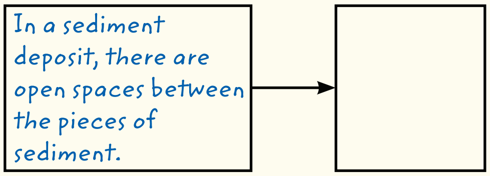
Your Turn Before you read this chapter, make a Pyramid FoldNote as described in **Appendix A.** Label the sides of the pyramid with "Igneous rock," "Sedimentary rock," and "Metamorphic rock." As you read the chapter, define each type of rock, and write characteristics of each type of rock on the appropriate side of the pyramid.



Graphic Organizer

Chain-of-Events Chart A chain-of-events chart is similar to a flow chart. A chain-of-events chart shows the order in which the steps of a process occur.

Your Turn In Section 3, you will read about the formation of sedimentary rocks. Make a chain-of-events chart like the one started below to describe *compaction,* one of the processes that form sedimentary rock. Use as many boxes as you need to record all steps of the process.



Note Taking

Summarizing Ideas Summarizing the content of each paragraph or set of paragraphs under a heading is a simple way to take notes. A few tips on summarizing are listed below.

1. Summary statements should be short, but fully express the idea.
2. Use the green subheadings for guidance in forming summary statements.
3. Many paragraphs start or end with a sentence that summarizes the main idea of the paragraph.

Your Turn As you read each section, take notes by summarizing the main ideas. You may add structure to your notes by also writing the section title and red headings in the appropriate places.

For more information on how to use these and other tools, see **Appendix A.**

SECTION 1

Rocks and the Rock Cycle

Key Ideas	Key Terms	Why It Matters
❯ Identify the three major types of rock, and explain how each type forms. ❯ Summarize the steps in the rock cycle. ❯ Explain Bowen's reaction series. ❯ Summarize the factors that affect the stability of rocks.	**rock cycle** **Bowen's reaction series**	Some rocks crumble and others make for solid buildings. The physical and chemical properties of rock are determined by the conditions under which the rock forms.

The material that makes up the solid parts of Earth is known as *rock*. Rock can be a collection of one or more minerals, or rock can be made of solid organic matter. In some cases, rock is made of solid matter that is not crystalline, such as glass. Geologists study the forces and processes that form and change the rocks of Earth's crust. Based on these studies, geologists have classified rocks into three major types by the way the rocks form.

Three Major Types of Rock

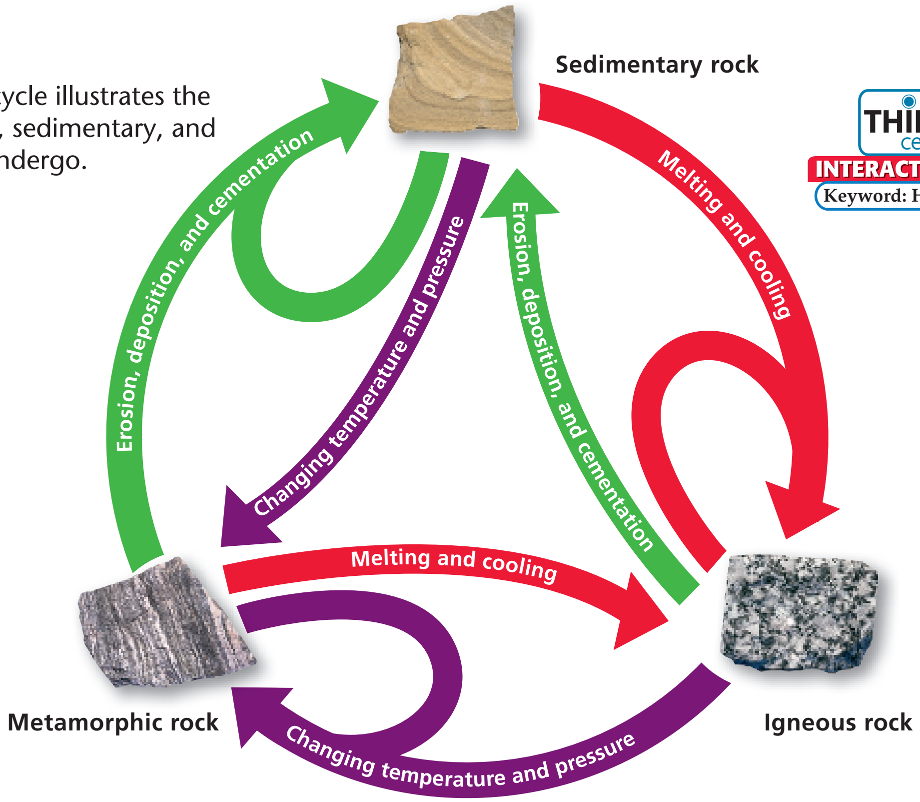
Volcanic activity produces *igneous rock*. The word *igneous* is derived from a Latin term that means "from fire." Igneous rock forms when *magma*, or molten rock, cools and hardens. Magma is called *lava* when it is exposed at Earth's surface.

Over time, natural processes break down all types of rock into small fragments. Rocks, mineral crystals, and organic matter that have been broken into fragments are known as *sediment*. Sediment is carried away and deposited by water, ice, and wind. When these sediment deposits are compressed, cemented together, and harden, *sedimentary rock* forms.

Certain forces and processes, including tremendous pressure, extreme heat, and chemical processes, also can change the form of existing rock. The rock that forms when existing rock is altered is *metamorphic rock*. The word *metamorphic* means "changed form." **Figure 1** shows an example of each major type of rock.

Figure 1 These rocks are examples of the three major rock types.

Figure 2 The rock cycle illustrates the changes that igneous, sedimentary, and metamorphic rocks undergo.



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The Rock Cycle

Any of the three major types of rock can be changed into another of the three types. Geologic forces and processes cause rock to change from one type to another. This series of changes is called the **rock cycle,** which is shown in **Figure 2.**

rock cycle the series of processes in which rock forms, changes from one type to another, is destroyed, and forms again by geological processes

One starting point for examining the steps of the rock cycle is igneous rock. When a body of igneous rock is exposed at Earth's surface, a number of processes break down the igneous rock into sediment. When sediment from igneous rocks is compacted and cemented, the sediment becomes sedimentary rock. Then, if sedimentary rocks are subjected to changes in temperature and pressure, the rocks may become metamorphic rocks. Under certain temperature and pressure conditions, the metamorphic rock will melt and form magma. Then, if the magma cools, new igneous rock will form.

Much of the rock in Earth's continental crust has probably passed through the rock cycle many times during Earth's history. However, as **Figure 2** shows, a particular body of rock does not always pass through each stage of the rock cycle. For example, igneous rock may never be exposed at Earth's surface where the rock could change into sediment. Instead, the igneous rock may change directly into metamorphic rock while still beneath Earth's surface. Sedimentary rock may be broken down at Earth's surface, and the sediment may become another sedimentary rock. Metamorphic rock can be altered by heat and pressure to form a different type of metamorphic rock.

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Topic: The Rock Cycle
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Properties of Rocks

All rock has physical and chemical properties that are determined by how and where the rock formed. The physical characteristics of rock reflect the chemical composition of the rock as a whole and of the individual minerals that make up the rock. The rate at which rock weathers and the way that rock breaks apart are determined by the chemical stability of the minerals in the rock.

Bowen's Reaction Series

In the early 1900s, a Canadian geologist named N. L. Bowen began studying how minerals crystallize from magma. He learned that as magma cools, certain minerals tend to crystallize first. As these minerals form, they remove specific elements from the magma, which changes the magma's composition. The changing composition of the magma allows different minerals that contain different elements to form. Thus, different minerals form at different times during the solidification (cooling) of magma, and they generally form in the same order.

In 1928, Bowen proposed a simplified pattern that explains the order in which minerals form as magma solidifies. This simplified flow chart is known as **Bowen's reaction series** and is shown in **Figure 3.** According to Bowen's hypothesis, minerals form in one of two ways. The first way is characterized by a gradual, continuous formation of minerals that have similar chemical compositions. The second way is characterized by sudden, or discontinuous, changes in mineral types. As magma cools, the discontinuous and continuous reaction series occur simultaneously, or at the same time.

Reading Check **Summarize Bowen's reaction series.** (See Appendix G for answers to Reading Checks.)

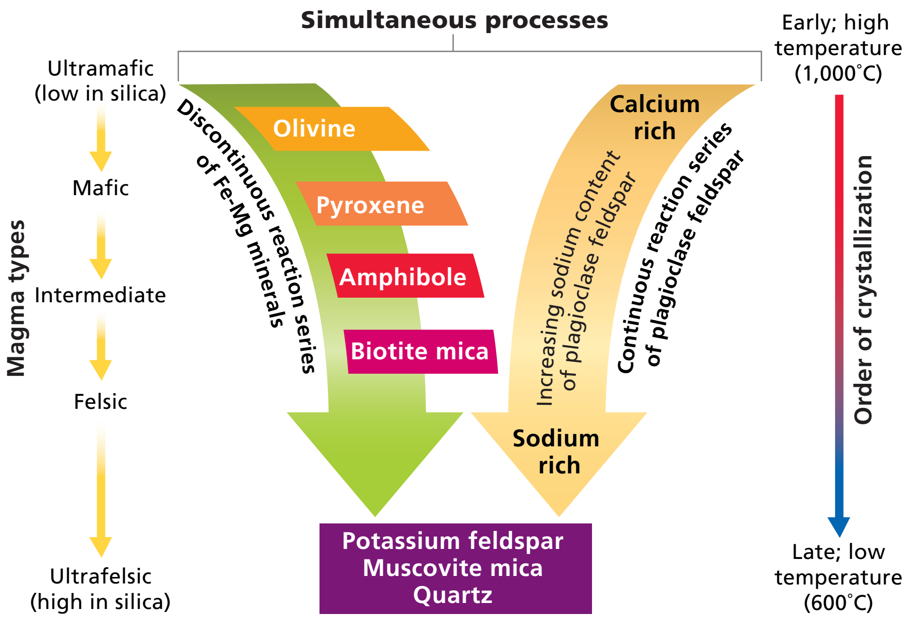


Figure 3 Different minerals crystallize at different times during the solidification of magma. Thus, as minerals crystallize from magma, the composition of the magma changes.

READING TOOLBOX

Chain-of-Events Chart

Make a chain-of-events chart to show each step of the discontinuous reaction series of Bowen's reaction series. Remember to use as many boxes as you need to show all steps.

Academic Vocabulary

remove (ri MOOV) to take away or eliminate

Bowen's reaction series the simplified pattern that illustrates the order in which minerals crystallize from cooling magma according to their chemical composition and melting point

Figure 4 Devils Postpile National Monument in California is one of the world's finest examples of the igneous rock structures known as columnar joints.

Chemical Stability of Minerals

The rate at which a mineral chemically breaks down is dependent on the chemical stability of the mineral. *Chemical stability* is a measure of the tendency of a chemical compound to maintain its original chemical composition rather than break down to form a different chemical. In general, the minerals that are most stable are minerals that formed at the lowest temperatures, under conditions similar to those on Earth's surface. Minerals that formed at the highest temperatures, under conditions very different than those on Earth's surface, are least stable.

Physical Stability of Rocks

Rocks have natural zones of weakness that are determined by how and where the rocks form. For example, sedimentary rocks may form as a series of layers of sediment. These rocks tend to break between layers. Some metamorphic rocks also tend to break in layers that form as the minerals in the rocks align during metamorphism.

Massive igneous rock structures commonly have evenly spaced zones of weakness, called *joints*, that form as the rock cools and contracts. Devils Postpile, shown in **Figure 4,** is igneous rock that has joints that cause the rock to break into columns.

Zones of weakness may also form when the rock is under intense pressure inside Earth. When rock that formed under intense pressure is uplifted to Earth's surface, decreased pressure allows the joints and fractures to open. Once these weaknesses are exposed to air and water, chemical and physical processes begin to break down the rock.

Section 1 Review

Key Ideas

1. **Identify** the three major types of rock.
2. **Explain** how each major type of rock forms.
3. **Describe** the steps in the rock cycle.
4. **Summarize** Bowen's reaction series.
5. **Explain** how the chemical stability of a mineral is related to the temperature at which the mineral forms.
6. **Describe** how the conditions under which rocks form affect the physical stability of rocks.

Critical Thinking

7. **Applying Ideas** Does every rock go through the complete rock cycle by changing from igneous rock to sedimentary rock, to metamorphic rock, and then back to igneous rock? Explain your answer.
8. **Identifying Relationships** How could a sedimentary rock provide evidence that the rock cycle exists?

Concept Mapping

9. Use the following terms to create a concept map: *rock, igneous rock, sedimentary rock, metamorphic rock,* and *rock cycle.*

SECTION 2

Igneous Rock

Key Ideas	Key Terms	Why It Matters
❯ Summarize three factors that affect whether rock melts. ❯ Describe how the cooling rate of magma and lava affects the texture of igneous rocks. ❯ Classify igneous rocks according to their composition and texture. ❯ Describe intrusive and extrusive igneous rock.	**igneous rock** **intrusive igneous rock** **extrusive igneous rock** **felsic** **mafic**	The many different compositions and textures of igneous rocks make sense once you understand the processes by which they form. Useful applications of these properties include nuclear-waste disposal.

When magma cools and hardens, it forms **igneous rock.** Because minerals usually crystallize as igneous rock forms from magma, most igneous rock can be identified as *crystalline,* or made of crystals.

The Formation of Magma

Magma forms when rock melts. Rock melts when the temperature of the rock increases to above the melting point of minerals in the rock. The chemical composition of minerals determines their melting temperatures. In general, rock melts at lower temperatures under lower pressures. If excess pressure is removed from rock that is close to melting, the rock may melt. Hot rock may also melt when fluids such as water are added. The addition of fluids generally decreases the melting point of certain minerals in the rock, which can cause those minerals to melt.

igneous rock rock that forms when magma cools and solidifies

Partial Melting

Different minerals have different melting points, and minerals that have lower melting points are the first minerals to melt. When the first minerals melt, the magma that forms has a specific composition. As the temperature increases and as other minerals melt, the magma's composition changes. The process by which different minerals in rock melt at different temperatures is called *partial melting*. Partial melting is shown in **Figure 1.**

Figure 1 How Magma Forms by Partial Melting

This solid rock contains the minerals quartz (yellow), feldspar (gray), biotite (brown), and hornblende (green).

The first minerals that melt are quartz and some types of feldspars. The orange background represents magma.

Minerals such as biotite and hornblende generally melt last, which changes the composition of the magma.

Figure 2 As the temperature decreases, the first minerals to crystallize from magma are minerals that have the highest freezing points. As the magma changes composition and cools, minerals that have lower freezing points form.

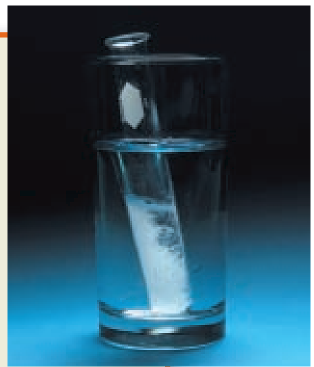
Fractional Crystallization

When magma cools, the cooling process is the reverse of the process of partial melting. Chemicals in magma combine to form minerals, and each mineral has a different freezing point. Minerals that have the highest freezing points crystallize first. As minerals crystallize, they remove specific chemicals from the magma. As the composition of the magma changes, new minerals begin to form. The crystallization and removal of different minerals from the cooling magma, as occurs in Bowen's reaction series, is called *fractional crystallization* and is shown in **Figure 2.**

Minerals that form during fractional crystallization tend to settle to the bottom of the magma chamber or to stick to the ceiling and walls of the magma chamber. Crystals that form early in the process are commonly the largest because they have the longest time to grow. In some crystals, the chemical composition of the inner part of the crystal differs from the composition of the outer parts of the crystal. This difference occurs because the magma's composition changed while the crystal was growing.

Quick Lab Crystal Formation

20 min



Procedure

1. Add the following until **three glasses** are 2/3 full: glass 1—water and **ice cubes;** glass 2—water at room temperature; and glass 3—hot tap water.
2. In a small **sauce pan,** mix **120 mL of Epsom salts** in **120 mL of water.** Heat the mixture on a **hot plate** over low heat. Do not let the mixture boil. Stir the mixture with a **spoon or stirring rod** until no more crystals dissolve.
3. Using a **funnel,** carefully pour equal amounts of the Epsom salts mixture into **three test tubes.** Use **tongs** to steady the test tubes as you pour. Drop a few crystals of Epsom salt into each test tube, and gently shake each one. Place one test tube into each glass.
4. Observe the solutions as they cool for 15 minutes. Let the glasses sit overnight, and examine the solutions again after 24 hours.

Analysis

1. In which test tube are the crystals the largest?
2. In which test tube are the crystals the smallest?
3. How does the rate of cooling affect the size of the crystals that form? Explain your answer.
4. How are the differing rates of crystal formation you observed related to igneous rock formation?
5. How would you change the procedure to obtain larger crystals of Epsom salts? Explain your answer.

Textures of Igneous Rocks

Igneous rocks may form beneath Earth's surface or on Earth's surface. Magma that cools deep inside the crust forms **intrusive igneous rock.** The magma that forms these rocks intrudes, or enters, into other rock masses beneath Earth's surface. The magma then slowly cools and hardens. Lava that cools at Earth's surface forms **extrusive igneous rock.**

intrusive igneous rock rock formed from the cooling and solidification of magma beneath Earth's surface

extrusive igneous rock rock that forms from the cooling and solidification of lava at Earth's surface

Intrusive and extrusive igneous rocks differ from each other not only in where they form but also in the size of their crystals or grains. The texture of igneous rock is determined by the size of the crystals in the rock. The size of the crystals is determined mainly by the cooling rate of the magma. Examples of different textures of igneous rocks are shown in **Figure 3.**

Figure 3 Igneous Rock Textures

Coarse-grained (granite)

Fine-grained (rhyolite)

Porphyritic (granite)

Glassy (obsidian)

Vesicular (pumice)

Coarse-Grained Igneous Rock

Intrusive igneous rocks commonly have large mineral crystals. The slow loss of heat allows the minerals in the cooling magma to form large, well-developed crystals. Igneous rocks that are composed of large mineral grains are described as having a *coarse-grained texture.* An example of a coarse-grained igneous rock is granite. The upper part of the continental crust is made mostly of granite.

Fine-Grained Igneous Rock

Many extrusive igneous rocks are composed of small mineral grains that cannot be seen by the unaided eye. Because these rocks form when magma cools rapidly, large crystals are unable to form. Igneous rocks that are composed of small crystals are described as having a *fine-grained texture*. Examples of common fine-grained igneous rocks are basalt and rhyolite (RIE uh LIET).

Other Igneous Rock Textures

Some igneous rock forms when magma cools slowly at first but then cools more rapidly as it nears Earth's surface. This type of cooling produces large crystals embedded within a mass of smaller ones. Igneous rock that has a mixture of large and small crystals has a *porphyritic texture* (POHR fuh RIT ik TEKS chuhr).

When a highly viscous, or thick, magma cools quickly, few crystals are able to grow. Quickly cooling magma may form a rock that has a *glassy* texture, such as obsidian. When magma contains a large amount of dissolved gases and cools rapidly, the gases become trapped as bubbles in the rock that forms. The rapid cooling process produces a rock full of holes called *vesicles,* such as those in pumice. This type of rock is said to have a *vesicular texture*.

Reading Check **What is the difference between fine-grained and coarse-grained igneous rock?**

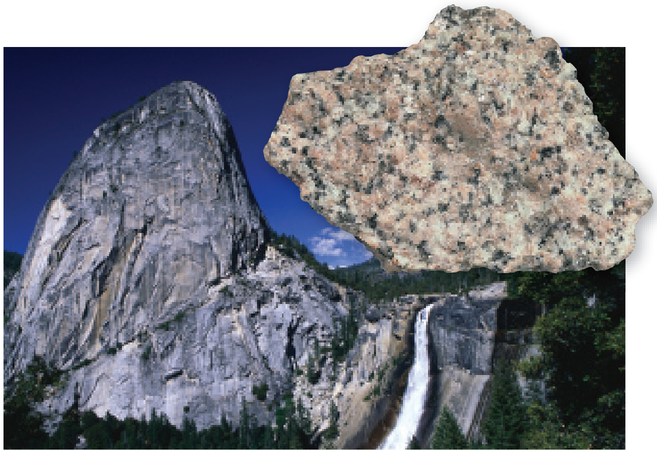


Figure 4 Felsic rocks, such as the outcropping and hand sample shown above (left), have light coloring. Mafic rocks (right) are usually darker in color.

Composition of Igneous Rocks

The mineral composition of an igneous rock is determined by the chemical composition of the magma from which the rock formed. Each type of igneous rock has a specific mineral composition. Geologists divide igneous rock into three families—felsic, mafic (MAF ik), and intermediate. Each of the three families has a different mineral composition. Examples of rock from the felsic and mafic families are shown in **Figure 4.**

Academic Vocabulary

proportion (proh POHR shuhn) the relation of one part to another or to the whole

Felsic Rock

Rock in the **felsic** family forms from magma that contains a large proportion of silica. Felsic rock generally has the light coloring of its main mineral components, potassium feldspar and quartz. Felsic rock commonly also contains plagioclase feldspar, biotite mica, and muscovite mica. The felsic family includes many common rocks, such as granite, rhyolite, obsidian, and pumice.

felsic describes magma or igneous rock that is rich in feldspars and silica and that is generally light in color

mafic describes magma or igneous rock that is rich in magnesium and iron and that is generally dark in color

Mafic Rock

Rock in the **mafic** family forms from magma that contains lower proportions of silica than felsic rock does and that is rich in iron and magnesium. The main mineral components of rock in this family are plagioclase feldspar and pyroxene minerals. Mafic rock may also include dark-colored *ferromagnesian minerals,* such as hornblende. These ferromagnesian components, as well as the mineral olivine, give mafic rock a dark color. The mafic family includes the common rocks basalt and gabbro.

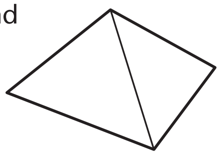
Intermediate Rocks

Rocks of the intermediate family are made up of the minerals plagioclase feldspar, hornblende, pyroxene, and biotite mica. Rocks in the intermediate family contain lower proportions of silica than rocks in the felsic family do but contain higher proportions of silica than rocks in the mafic family contain. Rocks in the intermediate family include diorite and andesite.

READING TOOLBOX

Pyramid

Create a pyramid FoldNote to record your notes on the three families of igneous rock—felsic, mafic, and intermediate. For each term, write the definition and include an example of a rock from that family.



Intrusive Igneous Rock

Igneous rock masses that form underground are called *intrusions*. Intrusions form when magma intrudes, or enters, into other rock masses and then cools deep inside Earth's crust. A variety of intrusions are shown in **Figure 5.**

Batholiths and Stocks

The largest of all intrusions are called *batholiths*. Batholiths are intrusive formations that spread over at least 100 km^2 when they are exposed on Earth's surface. The word *batholith* means "deep rock." Batholiths were once thought to extend to great depths beneath Earth's surface. However, studies have determined that many batholiths extend only several thousand meters below the surface. Batholiths form the cores of many mountain ranges, such as the Sierra Nevadas in California. The largest batholith in North America forms the core of the Coast Range in British Columbia. Another type of intrusion is called a *stock*. Stocks are similar to batholiths but cover less than 100 km^2 at the surface.

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Laccoliths

When magma flows between rock layers and spreads upward, it sometimes pushes the overlying rock layers into a dome. The base of the intrusion is parallel to the rock layer beneath it. This type of intrusion is called a *laccolith*. The word *laccolith* means "lake of rock." Laccoliths commonly occur in groups and can sometimes be identified by the small dome-shaped mountains they form on Earth's surface. Many laccoliths are located beneath the Black Hills of South Dakota.

Reading Check **What is the difference between stocks and batholiths?**

Sills and Dikes

When magma flows between the layers of rock and hardens, a *sill* forms. A sill lies parallel to the layers of rock that surround it, even if the layers are tilted. Sills vary in thickness from a few centimeters to hundreds of meters.

Magma sometimes forces itself through rock layers by following existing vertical fractures or by creating new ones. When the magma solidifies, a *dike* forms. Dikes cut across rock layers rather than lying parallel to the rock layers. Dikes are common in areas of volcanic activity.

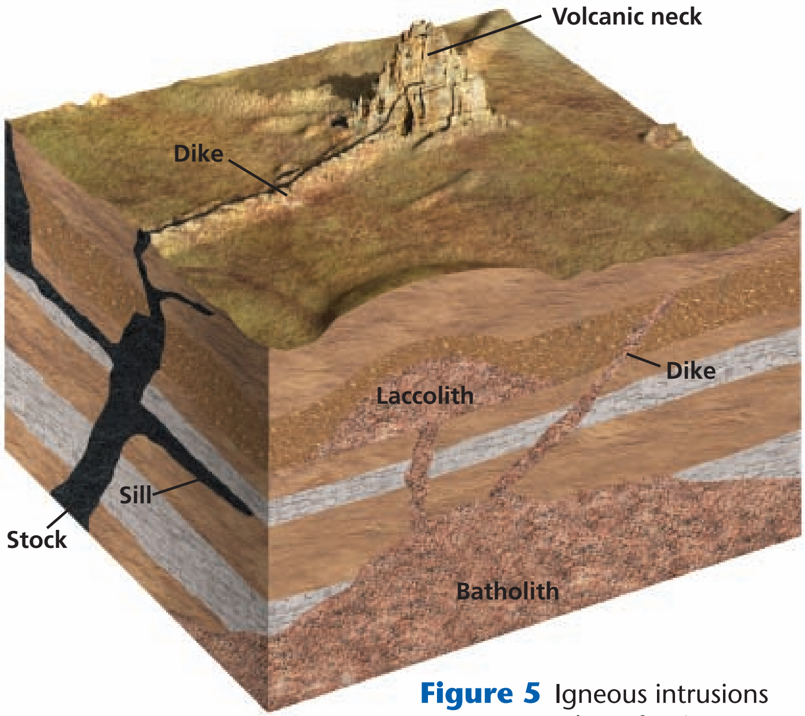


Figure 5 Igneous intrusions create a number of unique landforms. ***What is the difference between a dike and a sill?***

Figure 6 Shiprock, in New Mexico, is an example of a volcanic neck that was exposed by erosion.

Extrusive Igneous Rock

A *volcano* is a vent through which magma, gases, or volcanic ash is expelled. When a volcanic eruption stops, the magma in the vent may cool to form rock. Eventually, the soft parts of the volcano are eroded by wind and water, and only the hardest rock in the vent remains. The solidified central vent is called a *volcanic neck*. Narrow dikes that sometimes radiate from the neck may also be exposed. A dramatic example of a volcanic neck called Shiprock is shown in **Figure 6.**

Igneous rock masses that form on Earth's surface are called *extrusions.* Many extrusions are simply flat masses of rock called *lava flows*. A series of lava flows that cover a vast area with thick rock is known as a *lava plateau*. Volcanic rock called *tuff* forms when a volcano releases ash and other solid particles during an eruption. Tuff deposits can be several hundred meters thick and can cover areas of several hundred kilometers.

Section 2 Review

Key Ideas

1. **Summarize** three factors that affect the melting of rock.
2. **Contrast** partial melting and fractional crystallization.
3. **Describe** how the cooling rate of magma affects the texture of igneous rock.
4. **Name** the three families of igneous rocks, and identify their specific mineral compositions.
5. **Describe** five intrusive igneous rock structures.
6. **Identify** four extrusive igneous rock structures.

Critical Thinking

7. **Applying Ideas** If you wanted to create a rock that has large crystals in a laboratory, what conditions would you have to control? Explain your answer.
8. **Applying Ideas** An unidentified, light-colored igneous rock is made up of potassium feldspar and quartz. To what family of igneous rocks does the rock belong? Explain your answer.

Concept Mapping

9. Use the following terms to create a concept map: *igneous rock, magma, coarse grained, fine grained, felsic, mafic,* and *intermediate.*

SECTION 3

Sedimentary Rock

Key Ideas

- Explain the processes of compaction and cementation.
- Describe how chemical and organic sedimentary rocks form.
- Describe how clastic sedimentary rock forms.
- Identify seven sedimentary rock features.

Key Terms

compaction
cementation
chemical sedimentary rock
organic sedimentary rock
clastic sedimentary rock

Why It Matters

Sedimentary rock is a common building material. Understanding its properties is crucial to public safety. The ways in which it is formed affects the rock's properties.

Loose fragments of rock, minerals, and organic material that result from natural processes, including the physical breakdown of rocks, are called *sediment*. Most sedimentary rock is made up of combinations of different types of sediment. The characteristics of sedimentary rock are determined by the source of the sediment, the way the sediment was moved, and the conditions under which the sediment was deposited.

Formation of Sedimentary Rocks

After sediments form, they are generally transported by wind, water, or ice to a new location. The source of the sediment determines the sediment's composition. As the sediment moves, its characteristics change as it is physically broken down or chemically altered. Eventually, the loose sediment is deposited.

Two main processes convert loose sediment to sedimentary rock—compaction and cementation. **Compaction,** as shown in **Figure 1,** is the process in which sediment is squeezed and in which the size of the pore space between sediment grains is reduced by the weight and pressure of overlying layers. **Cementation** is the process in which sediments are glued together by minerals that are deposited by water.

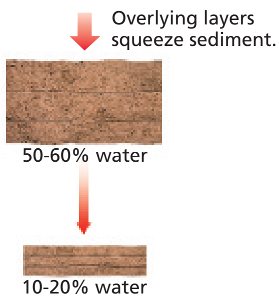
Geologists classify sedimentary rocks by the processes by which the rocks form and by the composition of the rocks. There are three main classes of sedimentary rocks—chemical, organic, and clastic.

compaction the process in which the volume and porosity of a sediment is decreased by the weight of overlying sediments as a result of burial beneath other sediments

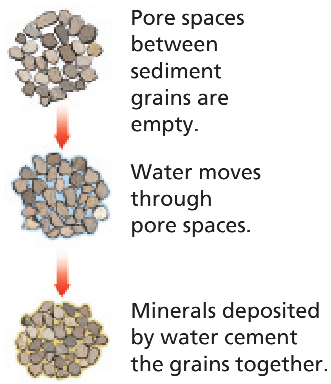
cementation the process in which minerals precipitate into pore spaces between sediment grains and bind sediments together to form rock

Figure 1 Processes That Form Sedimentary Rock

When mud is deposited, there may be a lot of space between grains. During compaction, the grains are squeezed together, and the rock that forms takes up less space.



When sand is deposited, there are many spaces between the grains. During cementation, water deposits minerals such as calcite or quartz in the spaces around the sand grains, which glues the grains together.



chemical sedimentary rock sedimentary rock that forms when minerals precipitate from a solution or settle from a suspension

organic sedimentary rock sedimentary rock that forms from the remains of plants or animals

Chemical Sedimentary Rock

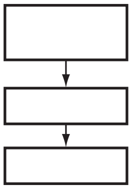
Minerals made up of ions such as calcium, potassium, and chloride can dissolve in water. **Chemical sedimentary rock** forms when the ions from dissolved minerals precipitate out of water because of changing concentrations of chemicals.

One reason minerals precipitate is due to evaporation. When water evaporates, the minerals that were dissolved in the water are left behind. Eventually, the concentration of minerals in the remaining water becomes high enough to cause minerals to precipitate out of the water. The minerals left behind form rocks called *evaporites*. Gypsum and halite, or rock salt, are two examples of evaporites. The Bonneville Salt Flats near the Great Salt Lake in Utah are a good example of evaporite deposits.

READING TOOLBOX

Chain-of-Events Chart

Make a chain-of-events chart to show the steps in the formation of organic sedimentary rocks. Write the first step of the process in a box. Add boxes with additional steps, and connect the boxes with arrows.

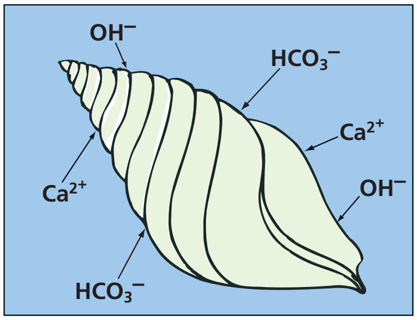


Organic Sedimentary Rock

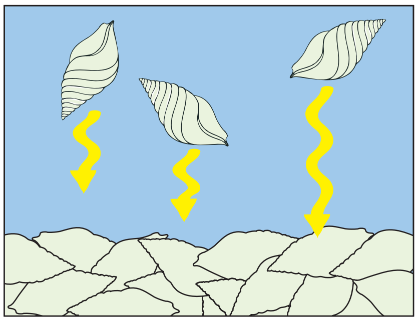
The second class of sedimentary rock is **organic sedimentary rock.** Organic sedimentary rock is rock that forms from the remains of living things. Coal and some limestones are examples of organic sedimentary rocks. Coal forms from plant remains that are buried before they decay and are then compacted into matter that is composed mostly of carbon.

While chemical limestones precipitate from chemicals dissolved in water, organic limestones form when marine organisms, such as coral, clams, oysters, and plankton, remove the chemical components of the minerals calcite and aragonite from sea water. These organisms make their shells from these minerals. When they die, their shells eventually become limestone. This process of limestone formation is shown in **Figure 2.** Chalk is one example of limestone made up of the shells of tiny, one-celled marine organisms that settle to the ocean floor.

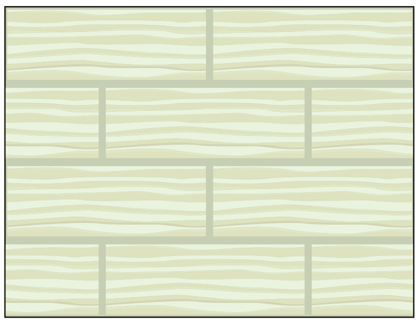
Figure 2 **Organic Limestone Formation**



Organisms that live in lakes or oceans take chemicals from the water and produce the mineral calcium carbonate, $CaCO_3$. They use the $CaCO_3$ to build their shells or skeletons.



When the organisms die, the hard remains that are made of $CaCO_3$ settle to the lake or ocean floor.

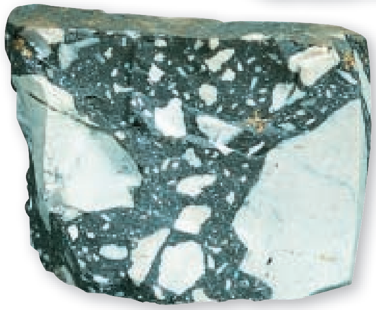


The shells of the dead organisms pile up. Eventually, the layers are compacted and cemented to form limestone.

Figure 3 Types of Clastic Sedimentary Rock

Conglomerate is composed of rounded, pebble-sized fragments that are held together by a cement.

Sandstone is made of small mineral grains that are cemented together.



Breccia is similar to conglomerate, but breccia contains angular fragments.

Shale is made of flaky clay particles that compress into flat layers.

Clastic Sedimentary Rock

The third class of sedimentary rock is made of rock fragments that are carried away from their source by water, wind, or ice and left as deposits. Over time, the individual fragments may become compacted and cemented into solid rock. The rock formed from these deposits is called **clastic sedimentary rock.**

Clastic sedimentary rocks are classified by the size of the sediments they contain, as shown in **Figure 3.** One group consists of large fragments that are cemented together. Rock that is composed of rounded fragments that range in size from 2 mm to boulders is called a *conglomerate*. If the fragments are angular and have sharp corners, the rock is called a *breccia* (BRECH ee uh). In conglomerates and breccias, the individual pieces of sediment can be easily seen.

Another group of clastic sedimentary rocks is made up of sand-sized grains that have been cemented together. These rocks are called *sandstone*. Quartz is the major component of most sandstones. Many sandstones have pores between the sand grains through which fluids, such as groundwater, natural gas, and crude oil, can move.

A third group of clastic sedimentary rocks, called *shale,* consists of clay-sized particles that are cemented and compacted. The flaky clay particles are usually pressed into flat layers that will easily split apart.

Reading Check **Name three groups of clastic sedimentary rock.**

clastic sedimentary rock sedimentary rock that forms when fragments of preexisting rocks are compacted or cemented together

Math Skills

Sedimentation Rates The rate at which sediment accumulates is called the *sedimentation rate*. The sedimentation rate of an area is 1.5 mm per year. At this rate, how many years must pass for 10 cm of sediment to be deposited?

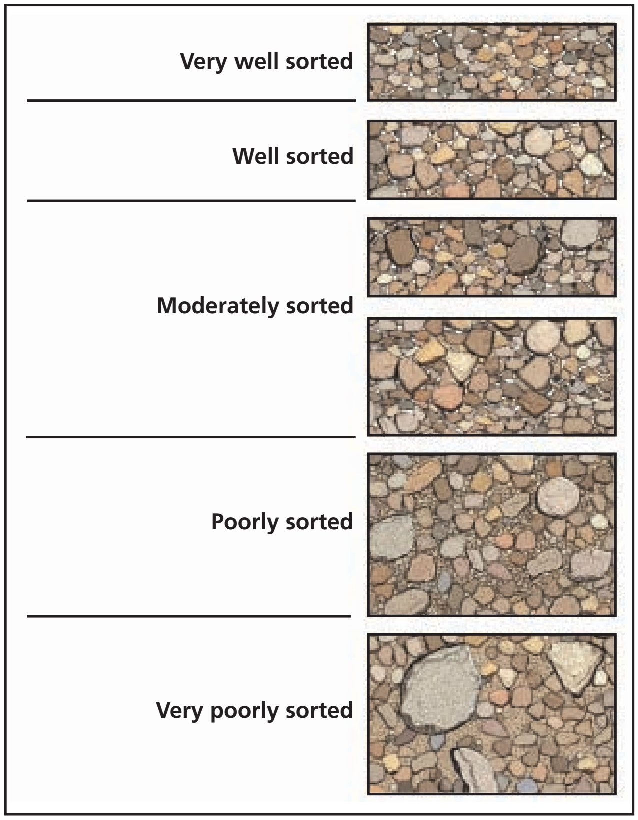


Figure 4 Sorting of Sediments

Characteristics of Clastic Sediments

The physical characteristics of sediments are determined mainly by the way sediments were transported to the place where they are deposited. Sediments are transported by four main agents: water, ice, wind, and the effects of gravity. The size of sediment particles that can be carried and the distance that the particles will move depends on the speed with which the sediment is moved. In general, both the distance the sediment is moved and the agent that moves the sediment determine the characteristics of that sediment.

Sorting

The tendency for currents of air or water to separate sediments according to size is called *sorting*. Sediments can be very well sorted, very poorly sorted, or somewhere in between, as shown in **Figure 4.** In well-sorted sediments, all of the grains are roughly the same size and shape. Poorly sorted sediment consists of grains that are many different sizes. The sorting of a sediment is the result of changes in the speed of the agent that is moving the sediment. For example, when a fast-moving stream enters a lake, the speed of the water decreases sharply. Because large grains are too heavy for the current to carry, these grains are deposited first. Fine grains can stay suspended in the water for much longer than large grains can. So, fine particles are commonly deposited farther from shore or on top of coarser sediments.

Academic Vocabulary

transport (trans POHRT) to carry from one place to another

Angularity

As sediment is transported from its source to where it is deposited, the particles collide with each other and with other objects in their path. These collisions can cause the particles to change size and shape. When particles first break from the source rock, they tend to be angular and uneven. Particles that have moved long distances from the source tend to be more rounded and smooth. In general, the farther sediment travels from its source, the finer and smoother the particles of sediment become.

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Topic: Sedimentary Rock
Code: HQX1365

Sedimentary Rock Features

The place or setting in which sediment is deposited is called a *depositional environment*. Common depositional environments include rivers, deltas, beaches, and oceans. Each depositional environment has different characteristics that create specific structures in sedimentary rock. These features allow scientists to identify the depositional environment in which the rock formed.

Stratification

Layering of sedimentary rock, as shown in **Figure 5,** is called *stratification*. Stratification occurs when the conditions of sediment deposition change. The conditions may vary when there is a change in sediment type or of depositional environment. For example, a rise in sea level may cause an area that was once a beach to become a shallow ocean, which changes the type of sediment that is deposited in the area.

Stratified layers, or *beds,* vary in thickness depending on the length of time during which sediment is deposited and how much sediment is deposited. *Massive beds,* or beds that have no internal structures, form when similar sediment is deposited under similar conditions for long periods of time or when a large amount of sediment is deposited at one time.

Cross-beds and Graded Bedding

Some sedimentary rocks are characterized by slanting layers called *cross-beds* that form within beds. Cross-beds, which generally form in sand dunes or river beds, are shown in **Figure 5.**

When various sizes and kinds of materials are deposited within one layer, a type of stratification called *graded bedding* may occur. Graded bedding occurs when different sizes and shapes of sediment settle to different levels. Graded beds commonly transition from largest grains on the bottom to smallest grains on the top. However, certain depositional events, such as some mudflows, may cause *reverse grading,* in which the smallest grains are on the bottom and the largest grains are on top.

Reading Check **What is graded bedding?**

Quick Lab

10 min

Graded Bedding

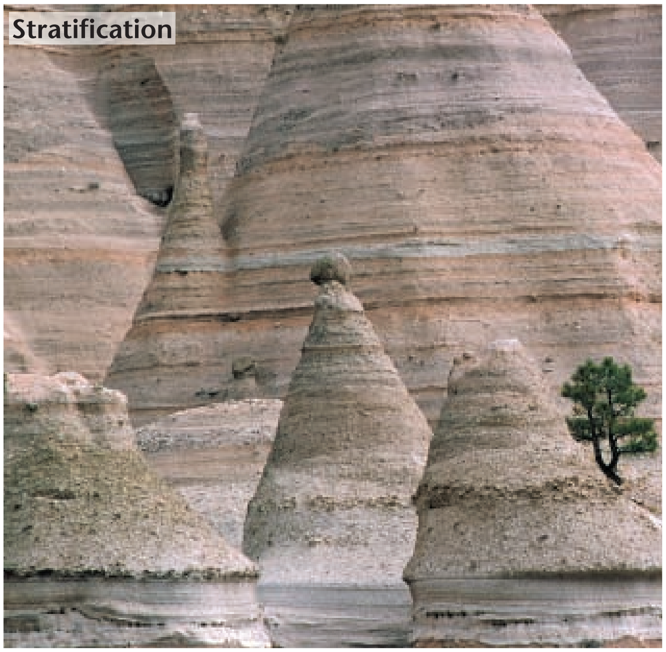
Procedure

1. Place **20 mL of water** into a **small glass jar.**
2. Pour **10 mL of poorly sorted sediment** into the jar. Place a **lid** securely on the jar.
3. Shake the jar vigorously for 1 min, and then let it sit still for 5 min.
4. Observe the settled sediment.

Analysis

1. Describe any sedimentary structures you observed.
2. Name two factors responsible for the sedimentary structures you observed.

Figure 5 Examples of Sedimentary Rock Structures



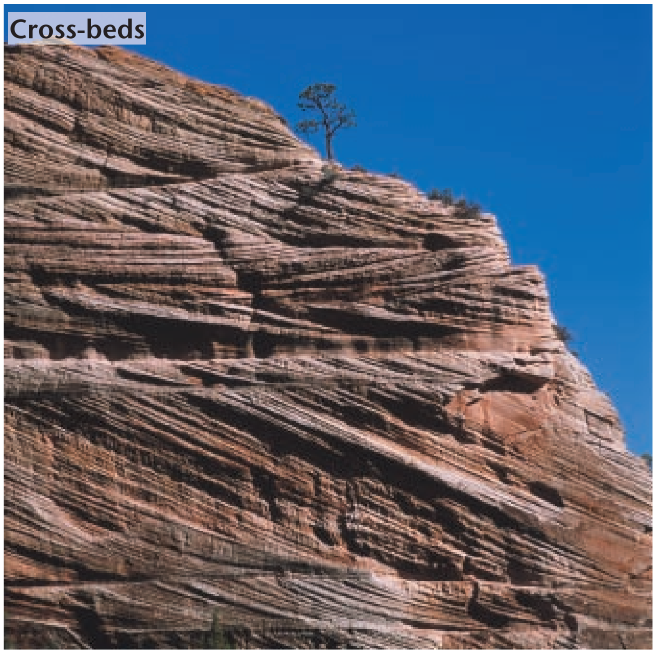


Figure 6 This dry and mud-cracked river bed is in Nagasaki, Japan.

Ripple Marks

Some sedimentary rocks clearly display *ripple marks*. Ripple marks are caused by the action of wind or water on sand. When the sand becomes sandstone, the ripple marks may be preserved. When scientists find ripple marks in sedimentary rock, the scientists know that the sediment was once part of a beach or a river bed.

Mud Cracks

The ground in **Figure 6** shows mud cracks, which are another feature of sedimentary rock. Mud cracks form when muddy deposits dry and shrink. The shrinking causes the drying mud to crack. A river's flood plain or a dry lake bed is a common place to find mud cracks. Once the area is flooded again, new deposits may fill in the cracks and preserve their features when the mud hardens to solid rock.

Fossils and Concretions

The remains or traces of ancient plants and animals, called *fossils,* may be preserved in sedimentary rock. As sediments pile up, plant and animal remains are buried. Hard parts of these remains may be preserved in the rock. More often, even the hard parts dissolve and leave only impressions in the rock. Sedimentary rocks sometimes contain lumps of rock that have a composition that is different from that of the main rock body. These lumps are known as *concretions*. Concretions form when minerals precipitate from fluids and build up around a nucleus. Groundwater sometimes deposits dissolved minerals inside cavities in sedimentary rock. The minerals may crystallize inside the cavities to form a special type of rock called a *geode*.

Section 3 Review

Key Ideas

1. **Explain** how the processes of compaction and cementation form sedimentary rock.
2. **Describe** how chemical and organic sedimentary rocks form, and give two examples of each.
3. **Describe** how clastic sedimentary rock differs from chemical and organic sedimentary rock.
4. **Explain** how the physical characteristics of sediments change during transport.
5. **Identify** seven features that you can use to identify the depositional environment in which sedimentary rocks formed.

Critical Thinking

6. **Making Comparisons** Compare the histories of rounded, smooth rocks and angular, uneven rocks.
7. **Identifying Relationships** Which of the following would most effectively sort sediments: a fast-moving river or a small, slow-moving stream? Explain your answer.

Concept Mapping

8. Use the following terms to create a concept map: *cementation, clastic sedimentary rock, sedimentary rock, chemical sedimentary rock, compaction,* and *organic sedimentary rock.*

SECTION 4

Metamorphic Rock

Key Ideas

- Describe the process of metamorphism.
- Explain the difference between regional and contact metamorphism.
- Distinguish between foliated and nonfoliated metamorphic rocks, and give an example of each.

Key Terms

metamorphism
contact metamorphism
regional metamorphism
foliation
nonfoliated

Why It Matters

Metamorphism can produce marble and gemstones, such as rubies. Materials such as these are important to civilization, both ancient and modern.

The process by which heat, pressure, or chemical processes change one type of rock to another is called **metamorphism.** Most metamorphic rock, or rock that has undergone metamorphism, forms deep within Earth's crust. All metamorphic rock forms from existing igneous, sedimentary, or metamorphic rock.

Formation of Metamorphic Rocks

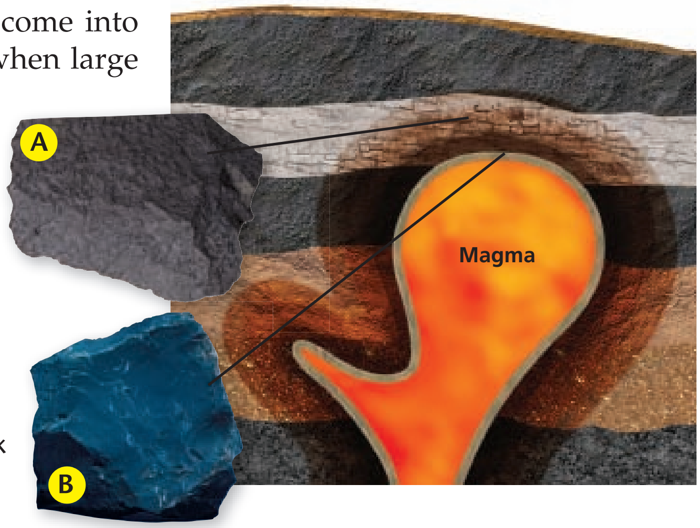
During metamorphism, heat, pressure, and hot fluids cause some minerals to change into other minerals. Minerals may also change in size or shape, or they may separate into parallel bands that give the rock a layered appearance. Hot fluids from magma may circulate through the rock and change the mineral composition of the rock by dissolving some materials and by adding others. All of these changes are part of metamorphism.

The type of rock that forms because of metamorphism can indicate the conditions that were in place when the original rock changed, as shown in **Figure 1.** The composition of the rock being metamorphosed, the amount and direction of heat and pressure, and the presence or absence of certain fluids cause different combinations of minerals to form.

Two types of metamorphism occur in Earth's crust. One type occurs when small volumes of rock come into contact with magma. The second type occurs when large areas of Earth's crust are affected by the heat and pressure that is caused by the movement and collisions of Earth's giant tectonic plates.

metamorphism the process in which one type of rock changes into metamorphic rock because of chemical processes or changes in temperature and pressure

Figure 1 Indicators of Metamorphic Conditions



Slate (A) is a metamorphic rock that commonly forms in the outer zone of metamorphism around a body of magma where clay-rich rock is exposed to relatively small amounts of heat.
Hornfels (B) is a metamorphic rock that forms in the innermost zone of metamorphism, where clay-rich rock is exposed to large amounts of heat from the magma.

contact metamorphism a change in the texture, structure, or chemical composition of a rock due to contact with magma

regional metamorphism a change in the texture, structure, or chemical composition of a rock due to changes in temperature and pressure over a large area, generally as a result of tectonic forces

Academic Vocabulary

generate (JEN uhr AYT) to bring about; to produce

Contact Metamorphism

When magma comes into contact with existing rock, heat from the magma can change the structure and mineral composition of the surrounding rock by a process called **contact metamorphism.** This process forms the hornfels shown on the previous page. During contact metamorphism only a small area of rock that surrounds the hot magma is changed by the magma's heat. Hot chemical fluids moving through fractures may also cause changes in the surrounding rock during contact metamorphism.

Regional Metamorphism

Metamorphism sometimes occurs over an area of thousands of square kilometers during periods of high tectonic activity, such as when mountain ranges form. The type of metamorphism that occurs over a large area is called **regional metamorphism.**

Tectonic activity generates tremendous heat and pressure, which cause chemical changes in the minerals of rock. Most metamorphic rock forms as a result of regional metamorphism. However, volcanism and the movement of magma often accompany tectonic activity. Thus, rocks that are formed by contact metamorphism are also commonly discovered in locations where regional metamorphism has occurred.

Reading Check **How are minerals affected by regional metamorphism?**

Why It Matters

Why Are Rubies so Rare?

The pressure and heat that form metamorphic rock may also result in the formation of certain gemstones, such as rubies. Natural rubies are rare because they made of the rare mineral corundum, Al_2O_3, and form only in very specific conditions. These natural conditions can be replicated in a laboratory to form synthetic, or human-made, rubies.

Synthetic rubies can be produced by mixing the right chemicals at extremely high temperatures. Only an expert can distinguish a synthetic ruby from a natural ruby.

Gneiss, schist, and marble are metamorphic rocks that may contain rubies. A gem in its natural form is called a rough gem. It may then be cut in special patterns to make it sparkle.

YOUR TURN

COMPARING PROCESSES

In what ways are the natural and synthetic processes that form rubies similar? In what ways are they different?

Classification of Metamorphic Rocks

Minerals in the original rock help determine the mineral composition of the metamorphosed rock. As the original rock is exposed to changes in heat and pressure, the minerals in the original rock often combine chemically to form new minerals. While metamorphic rocks are classified by chemical composition, they are first classified according to their texture. Metamorphic rocks have either a foliated texture or a nonfoliated texture.

READING TOOLBOX

Summarizing Ideas
As you read this page and the next, summarize the main ideas about the classification of metamorphic rocks. Include a summary of the differences between foliated and nonfoliated rocks.

Foliated Rocks

The metamorphic rock texture in which minerals are arranged in planes or bands is called **foliation.** Foliated rock can form in one of two ways. Extreme pressure may cause the mineral crystals in the rock to realign or regrow to form parallel bands. Foliation also occurs as minerals that have different compositions separate to produce a series of alternating dark and light bands.

foliation the metamorphic rock texture in which mineral grains are arranged in planes or bands

Foliated metamorphic rocks include the common rocks slate, schist, and gneiss (NIES). Slate forms when pressure is exerted on the sedimentary rock shale, which contains clay minerals that are flat and thin. The fine-grained minerals in slate are compressed into thin layers, which split easily into flat sheets. Flat sheets of slate are used in building materials, such as roof tiles or walkway stones.

When large amounts of heat and pressure are exerted on slate, a coarse-grained metamorphic rock known as *schist* may form. Deep underground, intense heat and pressure may cause the minerals in schist to separate into bands as the minerals recrystallize. The metamorphosed rock that has bands of light and dark minerals is called *gneiss*. Gneiss is shown in **Figure 2.**

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Figure 2 Large amounts of heat and pressure may change rock into the metamorphic rock gneiss, which shows pronounced foliation.

Figure 3 Marble is a nonfoliated metamorphic rock that is used as building and sculpting material.

Nonfoliated Rocks

Rocks that do not have bands or aligned minerals are **nonfoliated.** Most nonfoliated metamorphic rocks share at least one of two main characteristics. First, the original rock that is metamorphosed may contain grains of only one mineral or contains very small amounts of other minerals. Thus, the rock does not form bands of different mineral compositions when it is metamorphosed. Second, the original rock may contain grains that are round or square. Because the grains do not have some long and some short sides, these grains do not change position when exposed to pressure in one direction.

Quartzite is one common nonfoliated rock. Quartzite forms when quartz sandstone is metamorphosed. Quartzite is very hard and does not wear away easily. For this reason, quartzite remains after weaker rocks around it have worn away and may form hills or mountains.

Marble, the beautiful stone that is used for building monuments and statues, is a metamorphic rock that forms from the compression of limestone. The Parthenon, which is shown in **Figure 3,** has been standing in Greece for more than 1,400 years. However, the calcium carbonate in marble reacts with acid rain, which is caused by air pollution. Many ancient marble structures and sculptures are being damaged by acid rain.

nonfoliated the metamorphic rock texture in which mineral grains are not arranged in planes or bands

Section 4 Review

Key Ideas

1. **Describe** the process of metamorphism.
2. **Explain** the difference between regional and contact metamorphism.
3. **Distinguish** between foliated and nonfoliated metamorphic rocks.
4. **Identify** two foliated metamorphic rocks and two nonfoliated metamorphic rocks.

Critical Thinking

5. **Analyzing Relationships** What do a butterfly and metamorphic rock have in common?
6. **Making Comparisons** If you have samples of the two metamorphic rocks slate and hornfels, what can you say about the history of each rock?
7. **Identifying Relationships** The Himalaya Mountains are located on a boundary between two colliding tectonic plates. Would most of the metamorphic rock in that area occur in small patches or in wide regions? Explain your answer.

Concept Mapping

8. Use the following terms to create a concept map: *contact metamorphism, foliated, regional metamorphism, metamorphic rock,* and *nonfoliated.*

Why It Matters

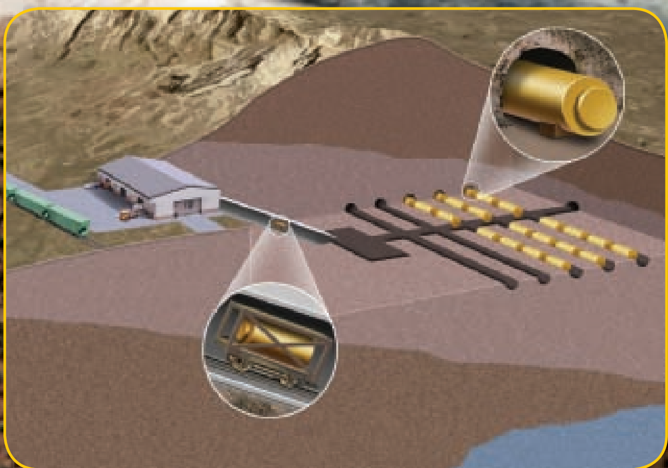
A Nuclear Waste Basket

EYE ON THE ENVIRONMENT

Each day, about 6 tons of highly reactive used fuel rods from nuclear reactors are added to the 30,000 tons held at various sites across the country. These rods and other radioactive waste must be stored for thousands of years, away from people and water. But where? One solution is to place the waste 300 m below ground, in the very stable rock under Yucca Mountain in Nevada.

Used fuel rods are only part of the nuclear waste problem. A large volume of low- and medium-level radioactive waste is piling up in drums like these.

Nuclear waste will be placed in containers for transportation to Yucca Mountain. Tens of thousands of truck and train shipments will be required.



A ramp into the mountain will lead to a network of storage tunnels for the containers.

YOUR TURN

CRITICAL THINKING

Nuclear waste at Yucca Mountain may remain hazardous for 10,000 years. What changes might occur in that time period that could affect the safety of the site?

APPLYING INFORMATION

Use what you know about different types of rock to predict the likely type of rock under Yucca Mountain. Explain your reasoning.

Skills Practice **Lab**

90 min

What You'll Do

- **Observe** the characteristics of common rocks.
- **Compare and contrast** the features of igneous, sedimentary, and metamorphic rocks.
- **Identify** igneous, sedimentary, and metamorphic rocks.

What You'll Need

hand lens
hydrochloric acid, 10% dilute
medicine dropper
rock samples

Safety

Classification of Rocks

There are many different types of igneous, sedimentary, and metamorphic rocks. Therefore, it is important to know distinguishing features of the rocks to identify the rocks. The classification of rocks is generally based on the way in which they formed, their mineral composition, and the size and arrangement (or texture) of their minerals.

Igneous rocks differ in the minerals they contain and the sizes of their crystals. Metamorphic rocks often look similar to igneous rocks, but they may have bands of minerals. Most sedimentary rocks are made of fragments of other rocks that are compressed and cemented together. Some common features of sedimentary rocks are parallel layers, ripple marks, cross-bedding, and the presence of fossils. In this lab, you will use these features to identify various rock samples.

Procedure

1. In your notebook, make a table that has columns for sample number, description of properties, rock class, and rock name. List the numbers of the rock samples you received from your teacher.
2. Examine the rocks carefully. You can use a hand lens to study the fine details of the rock samples. Look for characteristics such as the shape, size, and arrangement of the mineral grains. For each sample, list in your table the distinguishing features that you observe.

Sample	Descriptions of Properties	Rock Class	Rock Name

DO NOT WRITE IN THIS BOOK

3. Refer to the Guide to Common Rocks in the Reference Tables section of the Appendix. Compare the properties for each rock sample that you listed with the properties listed in the identification table. If you are unable to identify certain rocks, examine these rock samples again.

4. Certain rocks react with acid, which indicates that they are composed of calcite. If a rock contains calcite, the rock will bubble and release carbon dioxide. Using a medicine dropper and 10% dilute hydrochloric acid, test various samples for their reactions. **CAUTION** Wear goggles, gloves, and an apron when you work with hydrochloric acid. Rinse each sample and wash your hands thoroughly afterward.

5. Complete your table by identifying the class of rock—igneous, sedimentary, or metamorphic—that each sample belongs to, and then name the rock.

Analysis

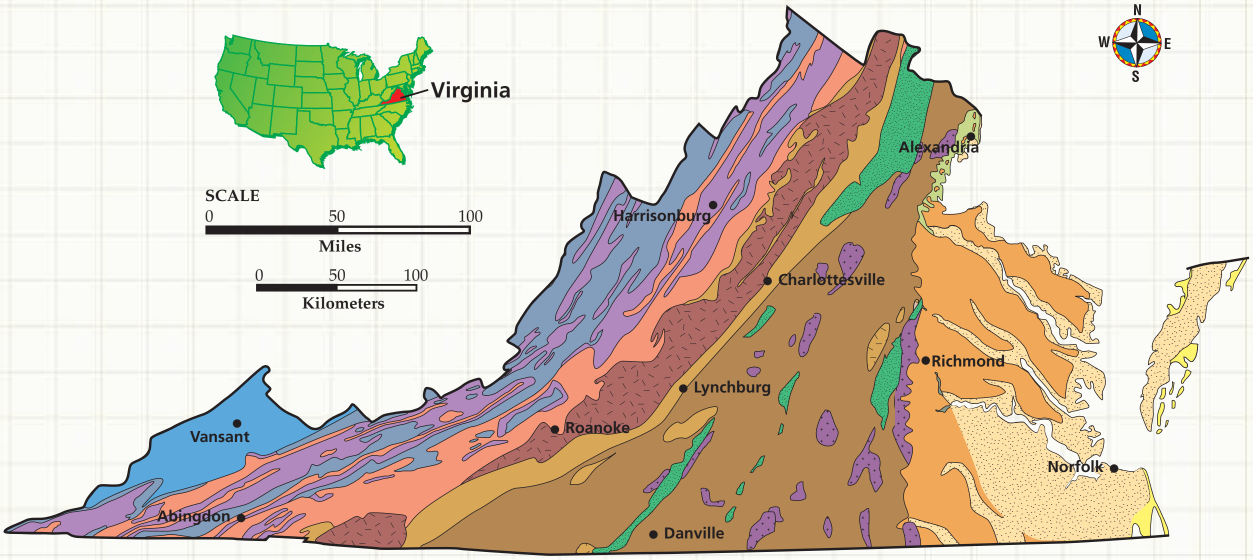
1. **Analyzing Methods** Which properties were most useful and least useful in identifying each rock sample? Explain.
2. **Evaluating Results** Were there any samples that you found difficult to identify? Explain.
3. **Making Comparisons** Describe any characteristics common to all of the rock samples.
4. **Evaluating Ideas** How can you distinguish between a sedimentary rock and a foliated metamorphic rock if both have observable layering?

Extension

Applying Conclusions Collect a variety of rocks from your area. Use the Guide to Common Rocks to see how many you can classify. How many igneous rocks did you collect? How many sedimentary rocks did you collect? How many metamorphic rocks did you collect? After you identify the class of each rock, try to name the rock.

MAPS in Action

Geologic Map of Virginia



Precambrian

- **Precambrian (550–750 Ma)** Metasedimentary rocks, metarhyolite, and metabasalt
- **Precambrian (550–750 Ma)** Gneiss, schist, slate, phyllite, quartzite, and marble
- **Precambrian (980–1400 Ma)** Granite, granitic gneiss, charnockite, and layered gneiss

Paleozoic

- **Cambrian (500–550 Ma)** Dolomite, limestone, shale, and sandstone
- **Mississippian-Devonian (320–410 Ma)** Sandstone and shale with minor gypsum and coal
- **Silurian-Ordovican (410–500 Ma)** Limestone, dolomite, shale, and sandstone
- **Pennsylvanian (290–320 Ma)** Sandstone, shale, and coal
- **Paleozoic (300–500 Ma)** Granite and other felsic igneous rocks
- **Paleozoic (300–500 Ma)** Gabbro and other mafic igneous rocks

Mesozoic

- **Cretaceous (65–140 Ma)** Partly lithified sand, clay, and sandstone
- **Triassic-Jurassic (200–225 Ma)** Red and gray shale, sandstone, and conglomerate intruded by diabase and basalt

Cenozoic

- **Quaternary (20 ka–2 Ma)** Sand, mud, and gravel
- **Holocene (present–20 ka)** Sand, mud, and peat deposited in beaches, marshes, swamps, and estuaries
- **Tertiary (2–65 Ma)** Sand, mud, limy sand, and marl

Map Skills Activity

The colors on this map of Virginia represent rocks that formed at different times in Earth's past. These time spans are divisions of the geologic time scale, which divides Earth's history into eons, eras, periods, and epochs. Use the map to answer the questions below.

1. **Using a Key** From what geologic era and period are rocks found in Roanoke, Virginia?
2. **Analyzing Data** Near which cities in Virginia are the oldest rocks in the state found?
3. **Analyzing Data** Near which city in Virginia are the youngest rocks in the state found?
4. **Inferring Relationships** Some of the youngest sediments in Virginia are found along rivers. What do you think might explain this pattern?
5. **Identifying Trends** What are the differences between the three types of Precambrian rocks found in Virginia? Why do you think they are all located near each other?
6. **Analyzing Relationships** What are the age ranges of the oldest of each of the three rock types—igneous, metamorphic, and sedimentary—found in Virginia?

Chapter 6

Summary

THINK central SUPER SUMMARY
Keyword: HQXRXSS

Key Ideas | **Key Terms**

Section 1

Rocks and the Rock Cycle

- The three major types of rock are igneous rock, sedimentary rock, and metamorphic rock.
- The rock cycle describes the natural processes through which each type of rock can change into any other type of rock.
- Bowen's reaction series describes the order in which different minerals form as magma cools.
- Chemical factors, such as mineral make up, and physical factors, such as joints and fractures, affect the stability of rocks.

Key Terms

rock cycle, p. 136
Bowen's reaction series, p. 137

Section 2

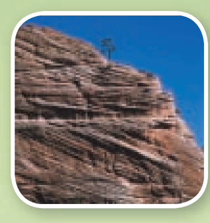
Igneous Rock

- Three factors that affect whether rock melts are temperature, pressure, and the presence of fluids in the rock.
- The rate at which magma cools determines the texture of the igneous rock that forms.
- Igneous rocks may be classified according to their composition and their texture.
- Intrusive igneous rock structures form underground and extrusive igneous rock structures form above ground.

Key Terms

igneous rock, p. 139
intrusive igneous rock, p. 141
extrusive igneous rock, p. 141
felsic, p. 142
mafic, p. 142

Section 3



Sedimentary Rock

- Compaction and cementation are two main processes that form sedimentary rock.
- Chemical sedimentary rock forms from minerals that were once dissolved in water, and organic sedimentary rocks form from the remains of living things.
- Clastic sedimentary rock forms from fragments of preexisting rocks that get compacted and cemented together.
- Seven sedimentary rock features are stratification, cross-beds, graded bedding, ripple marks, mud cracks, fossils, and concretions.

Key Terms

compaction, p. 145
cementation, p. 145
chemical sedimentary rock, p. 146
organic sedimentary rock, p. 146
clastic sedimentary rock, p. 147

Section 4

Metamorphic Rock

- Metamorphism changes one type of rock into another.
- Regional metamorphism occurs over a large geographic area. Contact metamorphism occurs in a small area near magma.
- Foliated metamorphic rocks have minerals arranged in bands, while nonfoliated metamorphic rocks do not.

Key Terms

metamorphism, p. 151
contact metamorphism, p. 152
regional metamorphism, p. 152
foliation, p. 153
nonfoliated, p. 154

Chapter 6 Review

1. **Summarizing Ideas** Look back at your summaries of each section. Now, summarize your summaries. For each section, write one or two sentences that summarize the main ideas of the whole section.

READING TOOLBOX

USING KEY TERMS

Use each of the following terms in a separate sentence.

2. *rock cycle*
3. *Bowen's reaction series*
4. *sediment*

For each pair of terms, explain how the meanings of the terms differ.

5. *igneous rock* and *metamorphic rock*
6. *intrusive igneous rock* and *extrusive igneous rock*
7. *chemical sedimentary rock* and *organic sedimentary rock*
8. *contact metamorphism* and *regional metamorphism*
9. *foliated* and *nonfoliated*

UNDERSTANDING KEY IDEAS

10. Intrusive igneous rocks are characterized by a coarse-grained texture because they contain
    a. heavy elements.
    b. small crystals.
    c. large crystals.
    d. fragments of different sizes and shapes.
11. Light-colored igneous rocks are generally part of the
    a. basalt family.
    b. intermediate family.
    c. felsic family.
    d. mafic family.
12. Magma that solidifies underground forms rock masses that are known as
    a. extrusions.
    b. volcanic cones.
    c. lava plateaus.
    d. intrusions.
13. One example of an extrusion is a
    a. stock.
    b. dike.
    c. batholith.
    d. lava plateau.
14. Sedimentary rock formed from rock fragments is called
    a. organic.
    b. chemical.
    c. clastic.
    d. granite.
15. One example of chemical sedimentary rock is
    a. an evaporite.
    b. coal.
    c. sandstone.
    d. breccia.
16. The splitting of slate into flat layers illustrates its
    a. contact metamorphism.
    b. formation.
    c. sedimentation.
    d. foliation.

SHORT ANSWER

17. Describe partial melting and fractional crystallization.
18. Name and define the three main types of rock.
19. How do clastic sedimentary rocks differ from chemical and organic sedimentary rocks?
20. What is Bowen's reaction series?
21. What factors affect the chemical and physical stability of rock?
22. Describe three factors that affect whether rock melts.
23. Why are some metamorphic rocks foliated while others are not?
24. How does transport affect the size and shape of sediment particles?

CRITICAL THINKING

25. Making Inferences A certain rock is made up mostly of plagioclase feldspar and pyroxene minerals. It also includes olivine and hornblende. Will the rock have a light or dark coloring? Explain your answer.

26. Classifying Information Explain how metamorphic rock can change into either of the other two types of rock through the rock cycle.

27. Applying Ideas Imagine that you have found a piece of limestone, which is a sedimentary rock, that has strange-shaped lumps on it. Will the lumps have the same composition as the limestone? Explain your answer.

28. Analyzing Ideas Which would be easier to break, the foliated rock slate or the nonfoliated rock quartzite? Explain your answer.

CONCEPT MAPPING

29. Use the following terms to create a concept map: *rock cycle, foliated, igneous rock, intrusive, sedimentary rock, clastic sedimentary rock, metamorphic rock, chemical sedimentary rock, extrusive, organic sedimentary rock,* and *nonfoliated*.

MATH SKILLS

Math Skills

30. Making Calculations The gram formula weight (weight of one mole) of the mineral quartz is 60.1 g, and the gram formula weight of magnetite is 231.5 g. If you had 4 moles of magnetite, how many moles of quartz would be equal to the weight of the magnetite?

31. Making Calculations The gram formula weight (weight of one mole) of the mineral hematite, Fe_2O_3, is 159.7 g, and the gram formula weight of magnetite, Fe_3O_4, is 231.5 g. Which of the following would weigh more: half a mole of hematite or one-third of a mole of magnetite?

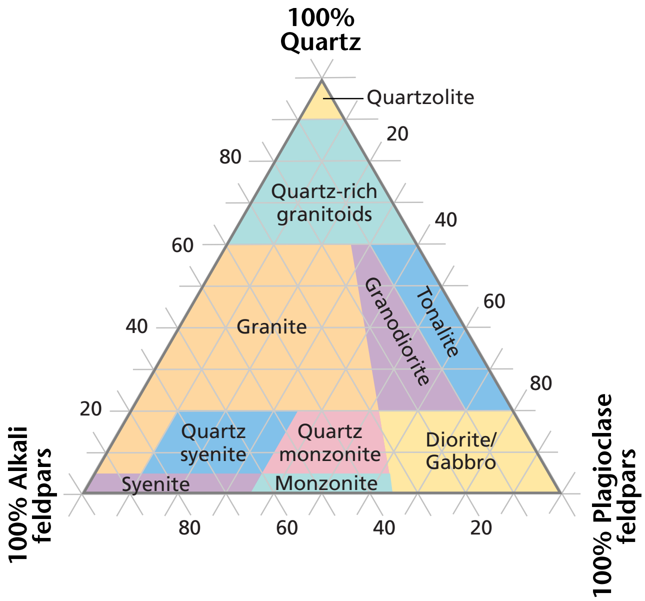
WRITING SKILLS

32. Outlining Topics Outline the essential steps in the rock cycle.

33. Writing from Research Find out what types of rock are most abundant in your state. Research the geologic processes that form those types of rock, and write a brief report that describes how the rocks in your state most likely formed.

INTERPRETING GRAPHICS

The graph below is a ternary diagram that shows the classification of some igneous rocks. Refer to Graphing Skills in Appendix B for instructions on how to read a ternary diagram. Use the diagram to answer the questions that follow.



34. What is the maximum amount of quartz in a quartz syenite?

35. What would a rock that contains 30% quartz, 20% alkali feldspar, and 50% plagioclase feldspar be called?

Standardized Test Prep

Understanding Concepts

Directions (1–5): For each question, write on a sheet of paper the letter of the correct answer.

1. A rock that contains a fossil is most likely
   - **A.** igneous.
   - **B.** sedimentary.
   - **C.** metamorphic.
   - **D.** felsic.
2. The large, well-developed crystals found in some samples of granite are a sign that
   - **F.** the magma from which it formed cooled rapidly.
   - **G.** the magma contained a lot of dissolved gases.
   - **H.** the magma from which it formed cooled slowly.
   - **I.** water deposited minerals in the rock cavities.
3. How does coal differ from breccia?
   - **A.** Coal is an example of sedimentary rock, and breccia is an example of metamorphic rock.
   - **B.** Coal is an example of metamorphic rock, and breccia is an example of igneous rock.
   - **C.** Coal is an example of organic rock, and breccia is an example of clastic rock.
   - **D.** Coal is an example of clastic rock, and breccia is an example of a conglomerate.
4. Which term describes the metamorphic rock texture in which minerals are arranged in bands?
   - **F.** stratification
   - **G.** cementation
   - **H.** foliation
   - **I.** precipitation
5. What occurs when heat from nearby magma causes changes in the surrounding rocks?
   - **A.** contact metamorphism
   - **B.** fluid metamorphism
   - **C.** intrusive metamorphism
   - **D.** regional metamorphism

Directions (6–7): For each question, write a short response.

6. What type of sedimentary rock is formed when angular clastic materials cement together?
7. What type of rock is formed when heat, pressure, and chemical processes change the physical properties of igneous rock?

Reading Skills

Directions (8–10): Read the passage below. Then, answer the questions.

Igneous and Sedimentary Rocks

Scientists think that Earth began as a melted mixture of many different materials. These materials underwent a physical change as they cooled and solidified. These became the first igneous rocks. Igneous rock continues to form today. Liquid rock changes from a liquid to a solid, when lava that is brought to Earth's surface by volcanoes hardens. This process can also take place far more slowly, when magma deep beneath the Earth's surface changes to a solid.

At the same time that new rocks are forming, old rocks are broken down by other processes. Weathering is the process by which wind, water, and gravity break up rock. During erosion, broken up pieces of rock are carried by water, wind, or ice and deposited as sediments elsewhere. These pieces pile up and, under heat and pressure, form sedimentary rock—rock composed of cemented fragments of older rocks.

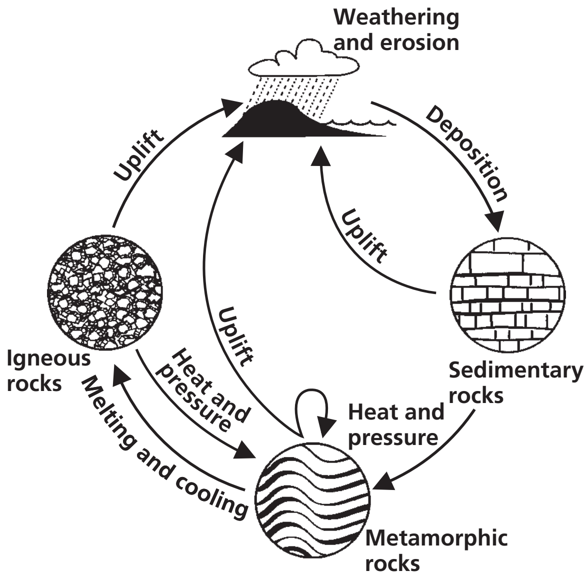
8. Which of the following statements about the texture of sedimentary rock is most likely true?
   - **F.** Sedimentary rocks are always lumpy and made up of large pieces of older rocks.
   - **G.** Sedimentary rocks all contain alternating bands of lumpy and smooth textures.
   - **H.** Sedimentary rocks are always smooth and made up of small pieces of older rocks.
   - **I.** Sedimentary rocks have a variety of textures that depend on the size and type of pieces that make up the rock.
9. Which of the following statements can be inferred from the information in the passage?
   - **A.** Igneous rocks are the hardest form of rock.
   - **B.** Sedimentary rocks are the final stage in the life cycle of a rock.
   - **C.** Igneous rocks began forming early in Earth's history.
   - **D.** Sedimentary rocks are not affected by weathering.
10. Is igneous rock or sedimentary rock more likely to contain fossils? Explain your answer.

Interpreting Graphics

Directions (11–13): For each question below, record the correct answer on a separate sheet of paper.

The diagram below shows the rock cycle. Use this diagram to answer question 11.

The Rock Cycle



11. Which of the following processes brings rocks to Earth's surface, where weathering and erosion occur?

F. deposition
G. heat and pressure
H. melting and cooling
I. uplift

Use this table to answer questions 12 and 13.

Rock Types

Rock sample	Characteristics
Rock A	multiple compacted, round, gravel-sized fragments
Rock B	coarse, well-developed, crystalline mineral grains
Rock C	small, sand-sized grains, tan coloration
Rock D	gritty texture; many small, embedded seashells

12. Is rock D igneous, sedimentary, or metamorphic? Explain the evidence that supports this classification.

13. Is rock A made up of only one mineral or more than one mineral? Explain the evidence supporting this classification.

Test Tip

When several questions refer to the same graph, table, or diagram, or text passage, answer the questions you are sure of first.