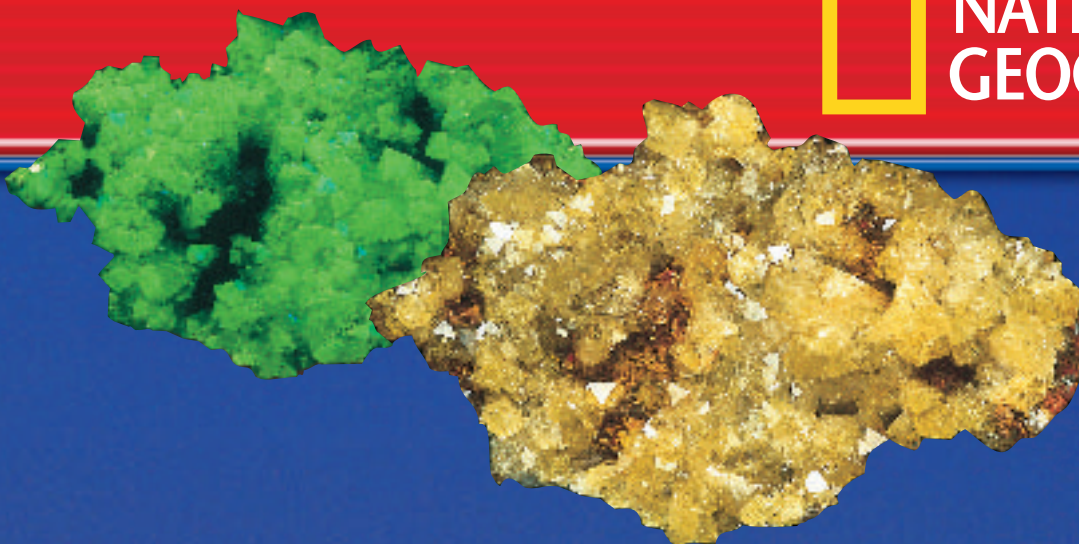


# How Are Rocks & Fluorescent Lights Connected?





**A**round 1600, an Italian cobbler found a rock that contained a mineral that could be made to glow in the dark. The discovery led other people to seek materials with similar properties. Eventually, scientists identified many fluorescent and phosphorescent (fahs fuh RE sunt) substances—substances that react to certain forms of energy by giving off their own light. As seen above, a fluorescent mineral may look one way in ordinary light (front), but may give off a strange glow (back) when exposed to ultraviolet light. In the 1850s, a scientist wondered whether the fluorescent properties of a substance could be harnessed to create a new type of lighting. The scientist put a fluorescent material inside a glass tube and sent an electric charge through the tube, creating the first fluorescent lamp. Today, fluorescent lightbulbs are widely used in office buildings, schools, and factories.

## unit projects

Visit [red.msscience.com/unit\\_project](http://red.msscience.com/unit_project) to find project ideas and resources. Projects include:

- **History** Research the chemist/industrialist that created dynamite and established the Nobel Prizes.
- **Technology** Analyze soil properties from horizon profile, temperature, texture, particle size, and more. Post your results on the Web.
- **Model** Research and prepare to represent a rock sample in a classroom rock debate using a variety of rock characteristics.



*Mars Rocks!* is an interactive investigation of Mars, and the evidence that leads scientists to believe that life may have once

existed there

(background)Mike Zens/CORBIS, (t)Mark A. Schneider/Visuals Unlimited

**CONTENTS**



# Rocks and Minerals

## chapter preview

### sections

- 1 Minerals—Earth's Jewels
- 2 Igneous and Sedimentary Rocks
- 3 Metamorphic Rocks and the Rock Cycle

**Lab** Gneiss Rice

**Lab** Classifying Minerals



**Virtual Lab** How are rocks classified?

## How did this terrain form?


To a hiker lucky enough to view this spectacular landscape, these rugged peaks might seem unchanging. Yet the rocks and minerals forming them alter constantly in response to changing physical conditions.

**Science Journal** Observe a rock or mineral sample you collected yourself, or obtain one from your teacher. Write three characteristics about it.

# Start-Up Activities



## Observe a Rock

Upon reaching the top, you have a chance to look more closely at the rock you've been climbing. First, you notice that it sparkles in the Sun because of the silvery specks that are stuck in the rock. Looking closer, you also see clear, glassy pieces and pink, irregular chunks. What is the rock made of? How did it get here? 

1. Obtain a sparkling rock from your teacher. You also will need a magnifying lens.
2. Observe the rock with the magnifying lens. Your job is to observe and record as many of the features of the rock as you can.
3. Return the rock to your teacher.
4. Describe your rock so other students could identify it from a variety of rocks.
5. **Think Critically** How do the parts of the rock fit together to form the whole thing? Describe this in your Science Journal and make a drawing. Be sure to label the colors and shapes in your drawing.

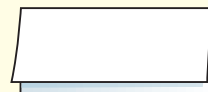


Preview this chapter's content and activities at [red.msscience.com](http://red.msscience.com)

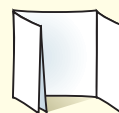
## FOLDABLES™ Study Organizer

**Rocks and Minerals** Make the following Foldable to compare and contrast the characteristics of rocks and minerals.

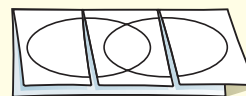
- STEP 1** Fold one sheet of paper lengthwise.



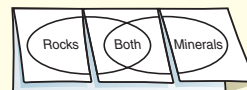
- STEP 2** Fold into thirds.



- STEP 3** Unfold and draw overlapping ovals. Cut the top sheet along the folds.



- STEP 4** Label the ovals as shown.



**Construct a Venn Diagram** As you read the chapter, list the characteristics unique to rocks under the left tab, those unique to minerals under the right tab, and those characteristics common to both under the middle tab.



# Minerals—Earth's Jewels

## as you read

### What You'll Learn

- **Identify** the difference between a mineral and a rock.
- **Describe** the properties that are used to identify minerals.

### Why It's Important

Minerals are basic substances of nature that humans use for a variety of purposes.

### Review Vocabulary

**physical property:** any characteristic of a material that you can observe without changing the identity of the material

### New Vocabulary

- mineral
- rock
- crystal
- gem
- ore

## What is a mineral?

Suppose you are planning an expedition to find minerals (MIH nuh rulz). Where would you look? Do you think you'll have to crawl into a cave or brave the depths of a mine? Well, put away your flashlight. You can find minerals in your own home—in the salt shaker and in your pencil. Metal pots, glassware, and ceramic dishes are products made from minerals. Minerals and products made from them, shown in **Figure 1**, surround you.

**Minerals Defined** **Minerals** are inorganic, solid materials found in nature. *Inorganic* means they usually are not formed by plants or animals. You could go outside and find minerals that occur as gleaming crystals—or as small grains in ordinary rocks. X-ray patterns of a mineral show an orderly arrangement of atoms that looks something like a garden trellis. Evidence of this orderly arrangement is the beautiful crystal shape often seen in minerals. The particular chemical makeup and arrangement of the atoms in the crystal is unique to each mineral. **Rocks**, such as the one used in the Launch Lab, usually are made of two or more minerals. Each mineral has unique characteristics you can use to identify it. So far, more than 4,000 minerals have been identified.

**Figure 1** You use minerals every day—maybe without even realizing it. Minerals are used to make many common objects.



The “lead” in a pencil is not really lead. It is the mineral graphite.



The mineral quartz is used to make the glass that you use every day.



**How do minerals form?** Minerals form in several ways. One way is from melted rock material inside Earth called magma. As magma cools, atoms combine in orderly patterns to form minerals. Minerals also form from magma that reaches Earth's surface. Magma at Earth's surface is called lava.

Evaporation can form minerals. Just as salt crystals appear when seawater evaporates, other dissolved minerals, such as gypsum, can crystallize. A process called precipitation (prih sih puh TAY shun) can form minerals, too. Water can hold only so much dissolved material. Any extra separates and falls out as a solid. Large areas of the ocean floor are covered with manganese nodules that formed in this way. These metallic spheres average 25 cm in diameter. They crystallized directly from seawater containing metal atoms.

**Formation Clues** Sometimes you can tell how a mineral formed by how it looks. Large mineral grains that fit together like a puzzle seem to show up in rocks formed from slow-cooling magma. If you see large, perfectly formed crystals, it means the mineral had plenty of space in which to grow. This is a sign they may have formed in open pockets within the rock.

The crystals you see in **Figure 2** grew this way from a solution that was rich in dissolved minerals. To figure out how a mineral was formed, you have to look at the size of the mineral crystal and how the crystals fit together.

## Properties of Minerals

The cheers are deafening. The crowd is jumping and screaming. From your seat high in the bleachers, you see someone who is wearing a yellow shirt and has long, dark hair in braids, just like a friend you saw this morning. You're sure it's your friend only when she turns and you recognize her smile. You've identified your friend by physical properties that set her apart from other people—her clothing, hair color and style, and facial features. Each mineral, too, has a set of physical properties that can be used to identify it. Most common minerals can be identified with items you have around the house and can carry in your pocket, such as a penny or a steel file. With a little practice you can learn to recognize mineral shapes, too. Next you will learn about properties that help you identify minerals.



**Figure 2** This cluster of fluorite crystals formed from a solution rich in dissolved minerals.



### Bone Composition

Bones, such as those found in humans and horses, contain tiny crystals of the mineral apatite. Research apatite and report your findings to your class.



**Figure 3** The mineral pyrite often forms crystals with six faces.

**Determine** why pyrite also is called “fool’s gold.”

**Crystals** All minerals have an orderly pattern of atoms. The atoms making up the mineral are arranged in a repeating pattern. Solid materials that have such a pattern of atoms are called **crystals**. Sometimes crystals have smooth growth surfaces called crystal faces. The mineral pyrite commonly forms crystals with six crystal faces, as shown in **Figure 3**.



### Reading Check

*What distinguishes crystals from other types of solid matter?*

**Cleavage and Fracture** Another clue to a mineral’s identity is the way it breaks. Minerals that split into pieces with smooth, regular planes that reflect light are said to have cleavage (KLEE vihj). The mica sample in **Figure 4A** shows cleavage by splitting into thin sheets. Splitting mica along a cleavage surface is similar to peeling off a piece of presliced cheese. Cleavage is caused by weaknesses within the arrangement of atoms that make up the mineral.

Not all minerals have cleavage. Some break into pieces with jagged or rough edges. Instead of neat slices, these pieces are shaped more like hunks of cheese torn from an unsliced block. Materials that break this way, such as quartz, have what is called fracture (FRAK chur). **Figure 4C** shows the fracture of flint.

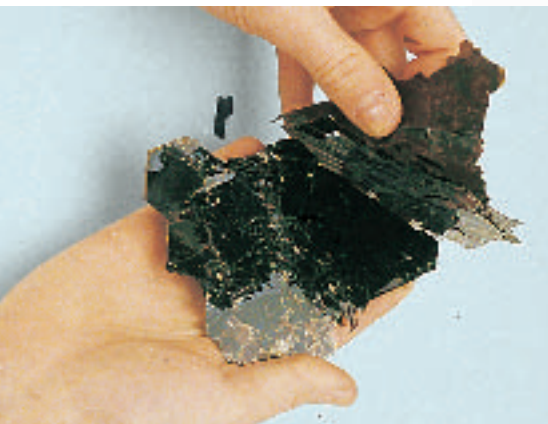
**Figure 4** Some minerals have one or more directions of cleavage. If minerals do not break along flat surfaces, they have fracture.

**A** Minerals in the mica group have one direction of cleavage and can be peeled off in sheets.



**B** The mineral halite, also called rock salt, has three directions of cleavage at right angles to each other.

**Infer** Why might grains of rock salt look like little cubes?



**C** Fracture can be jagged and irregular or smooth and curvy like in flint.





**Figure 5** The mineral calcite can form in a variety of colors. The colors are caused by slight impurities.

**Color** The reddish-gold color of a new penny shows you that it contains copper. The bright yellow color of sulfur is a valuable clue to its identity. Sometimes a mineral's color can help you figure out what it is. But color also can fool you. The common mineral pyrite (PI rite) has a shiny, gold color similar to real gold—close enough to disappoint many prospectors during the California Gold Rush in the 1800s. Because of this, pyrite also is called fool's gold. While different minerals can look similar in color, the same mineral can occur in a variety of colors. The mineral calcite, for example, can occur in many different colors, as shown in **Figure 5**.

**Streak and Luster** Scraping a mineral sample across an unglazed, white tile, called a streak plate, produces a streak of color, as shown in **Figure 6**. Oddly enough, the streak is not necessarily the same color as the mineral itself. This streak of powdered mineral is more useful for identification than the mineral's color. Gold prospectors could have saved themselves a lot of heartache if they had known about the streak test. Pyrite makes a greenish-black or brownish-black streak, but gold makes a yellow streak.

Is the mineral shiny? Dull? Pearly? Words like these describe another property of minerals, called luster. Luster describes how light reflects from a mineral's surface. If it shines like a metal, the mineral has metallic (muh TA lihk) luster. Nonmetallic minerals can be described as having pearly, glassy, dull, or earthy luster. You can use color, streak, and luster to help identify minerals.

**Figure 6** Streak is the color of the powdered mineral. The mineral hematite has a characteristic reddish-brown streak.

**Explain** how you obtain a mineral's streak.





Table 1 Mohs Scale		
Mineral	Hardness	Hardness of Common Objects
Talc	1 (softest)	
Gypsum	2	fingernail (2.5)
Calcite	3	copper penny (3.0)
Fluorite	4	iron nail (4.5)
Apatite	5	glass (5.5)
Feldspar	6	steel file (6.5)
Quartz	7	streak plate (7)
Topaz	8	
Corundum	9	
Diamond	10 (hardest)	

**Figure 7** Calcite has the unique property of double refraction.



**Hardness** As you investigate different minerals, you'll find that some are harder than others. Some minerals, like talc, are so soft that they can be scratched with a fingernail. Others, like diamond, are so hard that they can be used to cut almost anything else.

In 1822, an Austrian geologist named Friedrich Mohs also noticed this property of minerals. He developed a way to classify minerals by their hardness. The Mohs scale, shown in **Table 1**, classifies minerals from 1 (softest) to 10 (hardest). You can determine hardness by trying to scratch one mineral with another to see which is harder. For example, fluorite (4 on the Mohs scale) will scratch calcite (3 on the scale), but fluorite cannot scratch apatite (5 on the scale). You also can use a homemade mineral identification kit—a copper penny, a nail, and a small glass plate with smooth edges. Simply find out what scratches what. Is the mineral hard enough to scratch a penny? Will it scratch glass?

**Specific Gravity** Some minerals are heavier for their size than others. Specific gravity compares the weight of a mineral with the weight of an equal volume of water. Pyrite—or fool's gold—is about five times heavier than water. Pure gold is more than 19 times heavier than water. You could easily sense this difference by holding each one in your hand. Measuring specific gravity is another way you can identify minerals.

**Other Properties** Some minerals have other unusual properties that can help identify them. The mineral magnetite will attract a magnet. The mineral calcite has two unusual properties. It will fizz when it comes into contact with an acid like dilute HCl. Also, if you look through a clear calcite crystal, you will see a double image, as shown in **Figure 7**. Scientists taste some minerals to identify them, but you should not try this yourself. Halite, also called rock salt, has a salty taste.

Together, all of the properties you have read about are used to identify minerals. Learn to use them and you can be a mineral detective.

## Common Minerals

Rocks that make up huge mountain ranges are made of minerals. But only a small number of the more than 4,000 minerals make up most rocks. These minerals often are called the rock-forming minerals. If you can recognize these minerals, you will be able to identify most rocks. Other minerals are much rarer. However, some of these rare minerals also are important because they are used as gems or they are ore minerals, which are sources of valuable metals.

Most of the rock-forming minerals are silicates (SIH luh kaytz), which contain the elements silicon and oxygen. The mineral quartz is pure silica ( $\text{SiO}_2$ ). More than half of the minerals in Earth's crust are types of a silicate mineral called feldspar. Other important rock-forming minerals are carbonates—compounds containing carbon and oxygen. The carbonate mineral calcite makes up most of the common rock limestone.

 **Reading Check** *Why is the silicate mineral feldspar important?*

Other common minerals can be found in rocks that formed at the bottom of ancient, evaporating seas. Rock comprised of the mineral gypsum is abundant in many places, and rock salt, made of the mineral halite, underlies large parts of the Midwest.

## Mini LAB

### Classifying Minerals

**Procedure**    

1. Touch a **magnet** to samples of **quartz**, **calcite**, **hornblende**, and **magnetite**. Record which mineral attracts the magnet.
2. With a **dropper**, apply a small amount of **dilute hydrochloric acid (HCl)** to each sample.
3. Rinse the samples with **water**.

### Analysis

1. Describe how each mineral reacted to the tests in steps 1 and 2.
2. Describe in a data table the other physical properties of the four minerals.

## Applying Science

### How hard are these minerals?

**S**ome minerals, like diamonds, are hard. Others, like talc, are soft. How can you determine the hardness of a mineral?

#### Identifying the Problem

The table at the right shows the results of a hardness test done using some common items as tools (a fingernail, copper penny, nail, and steel file) to scratch certain minerals (halite, turquoise, emerald, ruby, and graphite). The testing tools are listed at the top from softest (fingernail) to hardest (steel file). The table shows which minerals were scratched by which tools. Examine the table to determine the relative hardness of each mineral.

#### Hardness Test

Mineral	Fingernail	Penny	Nail	Steel File
Turquoise	N	N	Y	Y
Halite	N	Y	Y	Y
Ruby	N	N	N	N
Graphite	Y	Y	Y	Y
Emerald	N	N	N	N

#### Solving the Problem

1. Is it possible to rank the five minerals from softest to hardest using the data in the table above? Why or why not?
2. What method could you use to determine whether the ruby or the emerald is harder?

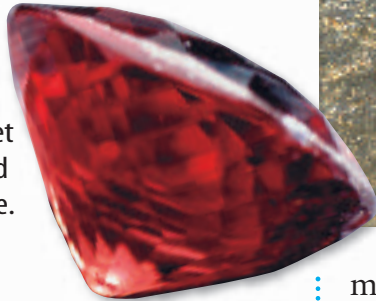


**Figure 8** The beauty of gem-quality minerals often is enhanced by cutting and polishing them.

This garnet crystal is encrusted with other minerals but still shines a deep red.



Cut garnet is a prized gemstone.



**Gems** Which would you rather win, a diamond ring or a quartz ring? A diamond ring would be more valuable. Why? The diamond in a ring is a kind of mineral called a gem. **Gems** are minerals that are rare and can be cut and polished, giving them a beautiful appearance, as shown in **Figure 8**. This makes them ideal for jewelry. To be gem quality, most minerals must be clear with few or no blemishes or cracks. A gem also must have a beautiful luster or color. Few minerals meet these standards. That's why the ones that do are rare and valuable.

**The Making of a Gem** One reason why gems are so rare is that they are formed under special conditions. Diamond, for instance, is a form of the element carbon. Scientists can make synthetic diamonds in laboratories, but they must use extremely high pressures. These pressures are greater than any found within Earth's crust. Therefore, scientists suggest that diamond forms deep in Earth's mantle. It takes a certain kind of volcanic eruption to bring a diamond close to Earth's surface, where miners can find it. This type of eruption forces magma from the mantle toward the surface of Earth at high speeds, bringing diamond along with it. This type of magma is called kimberlite magma. **Figure 9** shows a rock from a kimberlite deposit in South Africa that was mined for diamond. Kimberlite deposits are found in the necks of some ancient volcanoes.

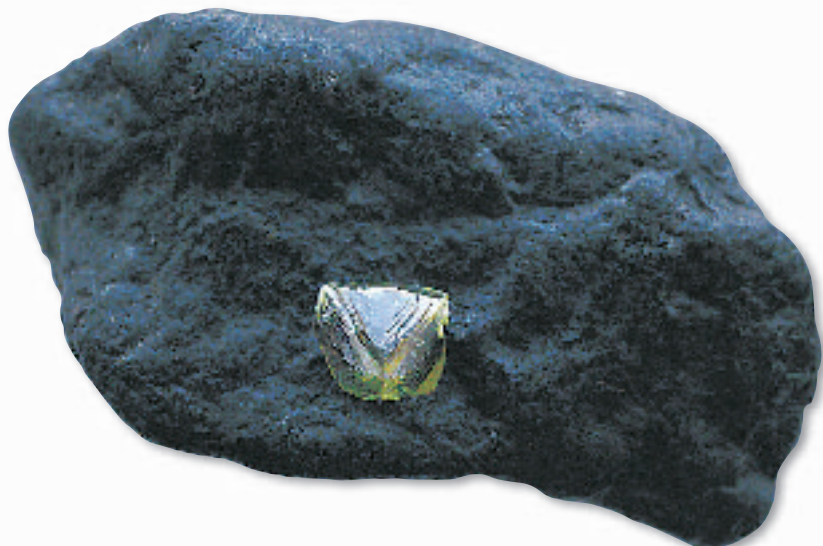


#### Topic: Gem Locations

Visit [red.msscience.com](http://red.msscience.com) to find Web links to information about the geography of gems.

**Activity** Select a continent, such as Africa, and list three examples of gems found there. Locate mining operations for each of these gems on a map for your class.

**Figure 9** Diamonds sometimes are found in kimberlite deposits.





**Figure 10** Mining is expensive. To be profitable, ores must be found in large deposits or rich veins. Copper ore is obtained from this mine in Arizona.

**List** three advantages of recycling metals.

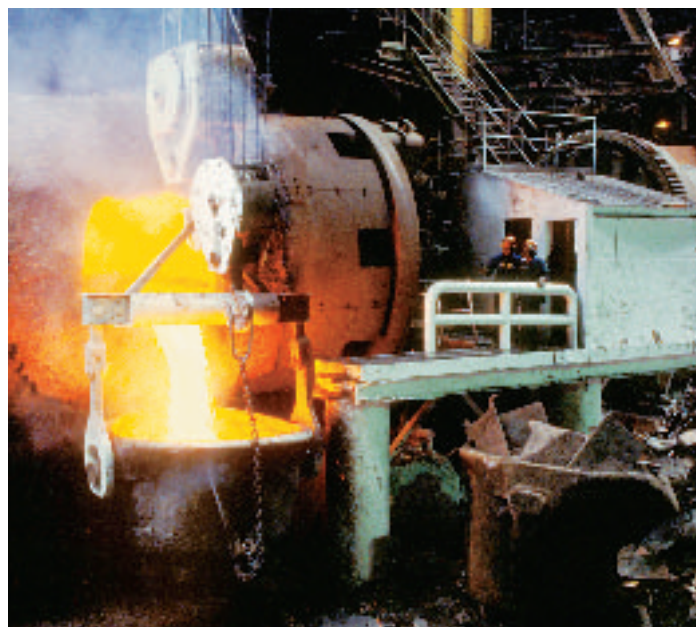
**Ores** A mineral is called an **ore** if it contains enough of a useful substance that it can be sold for a profit. Many of the metals that humans use come from ores. For example, the iron used to make steel comes from the mineral hematite, lead for batteries is produced from galena, and the magnesium used in vitamins comes from dolomite. Ores of these useful metals must be extracted from Earth in a process called mining. A copper mine is shown in **Figure 10**.

Scrap metal often is reused or recycled to help reduce the rate that minerals are extracted from Earth. Because minerals may take millions of years to form, they are considered a nonrenewable resource. Conservation efforts can decrease mining and production costs, preserve resources, and reduce the volume of landscape disrupted when minerals are extracted from Earth.

**Ore Processing** After an ore has been mined, it must be processed to extract the desired mineral or element. **Figure 11** shows a copper smelting plant that melts the ore and then separates and removes most of the unwanted materials. After this smelting process, copper can be refined, which means that it is purified. Then it is processed into many materials that you use every day. Examples of useful copper products include sheet-metal products, electrical wiring in cars and homes, and just about anything electronic. Some examples of copper products are shown in **Figure 12**.

**Figure 11** This smelter in Montana heats and melts copper ore.

**Explain** why smelting is necessary to process copper ore.





**Figure 12** Many metal objects you use every day are made with copper.

**List** other metals that are used to produce everyday objects.

**Minerals Around You** Now you have a better understanding of minerals and their uses. Can you name five things in your classroom that come from minerals? Can you go outside and find a mineral right now? You will find that minerals are all around you and that you use minerals every day. Next, you will look at rocks, which are Earth materials made up of combinations of minerals.

## section 1 review

### Summary

#### What is a mineral?

- Many everyday products are made from minerals.
- Minerals form in several ways, such as crystallizing from magma or from solutions rich in dissolved materials.

#### Properties of Minerals

- Minerals are identified by observing their physical properties.
- Some minerals exhibit unusual physical properties, such as reaction to acid, formation of a double image, or magnetism.

#### Common Minerals

- Of the more than 4,000 minerals known, only a small number make up most rocks.
- Gems are highly prized mineral specimens often used as decorative pieces in jewelry or other items.

### Self Check

- Explain** the difference between a mineral and a rock. Name five common rock-forming minerals.
- List** five properties that are used most commonly to identify minerals.
- Describe** an event that must occur in order for diamond to reach Earth's surface. Where in Earth is diamond formed?
- Describe** the steps of mining, smelting, and refining that are used to extract minerals or elements from ores. When is a mineral considered to be an ore?
- Think Critically** Would you want to live close to a working gold mine? Explain.

### Applying Math

- Use Percentages** In 1996, the United States produced approximately 2,340,000 metric tons of refined copper. In 1997, about 2,440,000 metric tons of refined copper were produced. Compared to the 1996 amount, copper production increased by what percentage in 1997?

# Igneous and Sedimentary Rocks

Kyodo/APWide World Photos

## Igneous Rock

A rocky cliff, a jagged mountain peak, and a huge boulder probably all look solid and permanent to you. Rocks seem as if they've always been here and always will be. But little by little, things change constantly on Earth. New rocks form, and old rocks wear away. Such processes produce three main kinds of rocks—igneous, sedimentary, and metamorphic.

The deeper you go into the interior of Earth, the higher the temperature is and the greater the pressure is. Deep inside Earth, it is hot enough to melt rock. **Igneous** (IHG nee us) **rocks** form when melted rock material from inside Earth cools. The cooling and hardening that result in igneous rock can occur on Earth, as seen in **Figure 13**, or underneath Earth's surface. When melted rock material cools on Earth's surface, it makes an **extrusive** (ehk STREW sihv) igneous rock. When the melt cools below Earth's surface, **intrusive** (ihn TREW sihv) igneous rock forms.

**Chemical Composition** The chemicals in the melted rock material determine the color of the resulting rock. If it contains a high percentage of silica and little iron, magnesium, or calcium, the rock generally will be light in color. Light-colored igneous rocks are called granitic (gra NIH tihk) rocks. If the silica content is far less, but it contains more iron, magnesium, or calcium, a dark-colored or basaltic (buh SAWL tihk) rock will result. Intrusive igneous rocks often are granitic, and extrusive igneous rocks often are basaltic. These two categories are important in classifying igneous rocks.

**Figure 13** Sakurajima is a volcano in Japan. During the 1995 eruption, molten rock material and solid rock were thrown into the air.

### as you read

#### What You'll Learn

- **Explain** how extrusive and intrusive igneous rocks are different.
- **Describe** how different types of sedimentary rocks form.

#### Why It's Important

Rocks form the land all around you.



#### Review Vocabulary

**lava:** molten rock material that exists at or above Earth's surface

#### New Vocabulary

- igneous rock
- extrusive
- intrusive
- sedimentary rock





## INTEGRATE Social Studies

**Obsidian Uses** Humans have developed uses for obsidian from ancient through modern times. Research how people have used obsidian. Include information on where it has been found, processed, and distributed.

**Rocks from Lava** Extrusive igneous rocks form when melted rock material cools on Earth's surface. When the melt reaches Earth's surface, it is called lava. Lava cools quickly before large mineral crystals have time to form. That's why extrusive igneous rocks usually have a smooth, sometimes glassy appearance.

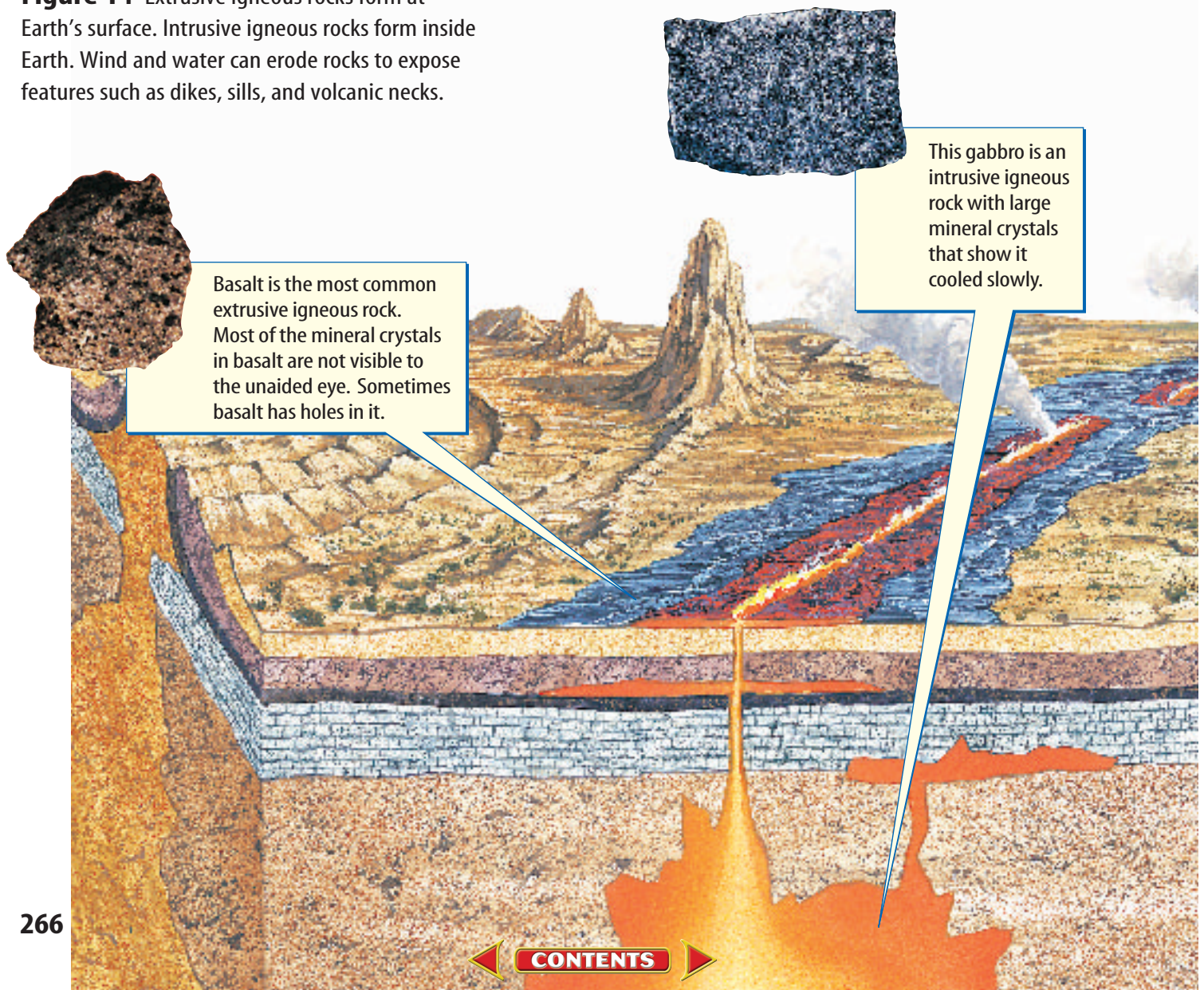
Extrusive igneous rocks can form in two ways. In one way, volcanoes erupt and shoot out lava and ash. Also, large cracks in Earth's crust, called fissures (FIH shurz), can open up. When they do, the lava oozes out onto the ground or into water. Oozing lava from a fissure or a volcano is called a lava flow. In Hawaii, lava flows are so common that you can observe one almost every day. Lava flows are quickly exposed to air or water. The fastest cooling lava forms no grains at all. This is how obsidian, a type of volcanic glass, forms. Lava trapping large amounts of gas can cool to form igneous rocks containing many holes.

(Stephen J. Krasemann/DRK Photo, (c) Brent P. Kent/Earth Scenes



**Reading Check** What is a fissure?

**Figure 14** Extrusive igneous rocks form at Earth's surface. Intrusive igneous rocks form inside Earth. Wind and water can erode rocks to expose features such as dikes, sills, and volcanic necks.





(l)Breck P. Kent/Earth Scenes, (r)Brent Turner/BLT Productions

**Rocks from Magma** Some melted rock material never reaches Earth's surface. Such underground molten material is called magma. Intrusive igneous rocks are produced when magma cools below the surface of Earth, as shown in **Figure 14**.

Intrusive igneous rocks form when a huge glob of magma from inside Earth is forced upward toward the surface but never reaches it. It's similar to when a helium balloon rises and gets stopped by the ceiling. This hot mass of rock material sits under the surface and cools slowly over millions of years until it is solid. The cooling is so slow that the minerals in the magma have time to form large crystals. Intrusive igneous rocks generally have large crystals that are easy to see. Some extrusive igneous rocks do not have large crystals that you can see easily. Others are a mixture of small crystals and larger, visible crystals. **Figure 15** shows some igneous rock features.



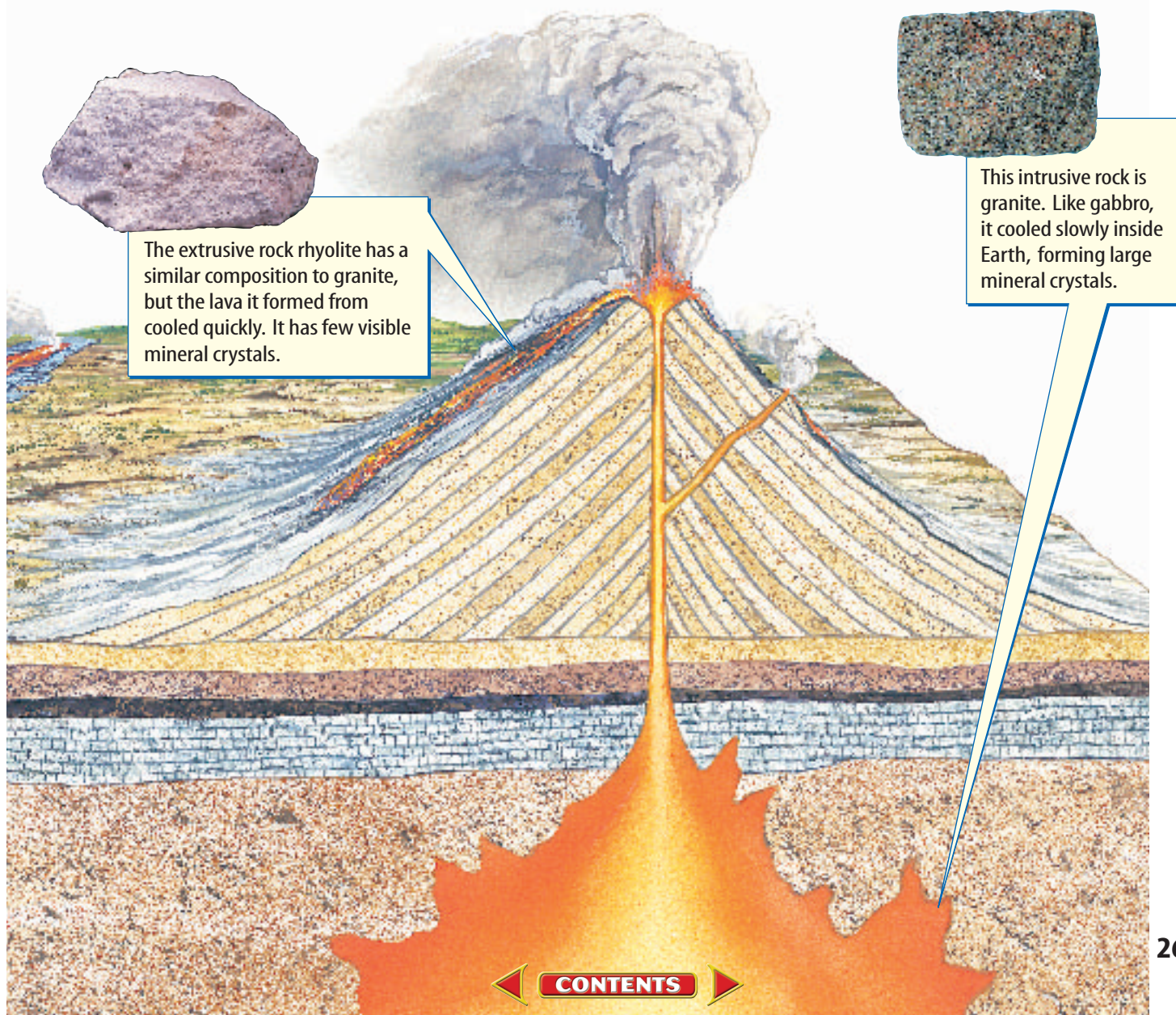
### Reading Check

*How do intrusive and extrusive rocks appear different?*



### INTEGRATE Physics

**Thermal Energy** The extreme heat found inside Earth has several sources. Some is left over from Earth's formation, and some comes from radioactive isotopes that constantly emit heat while they decay deep in Earth's interior. Research to find detailed explanations of these heat sources. Use your own words to explain them in your Science Journal.

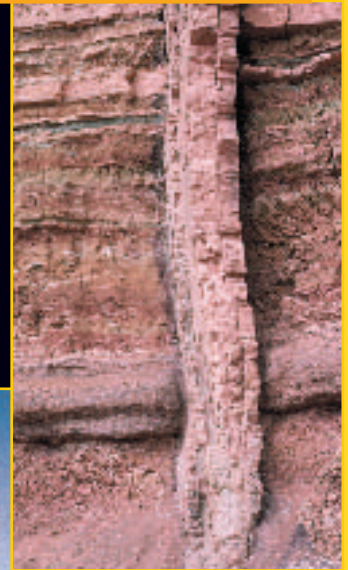




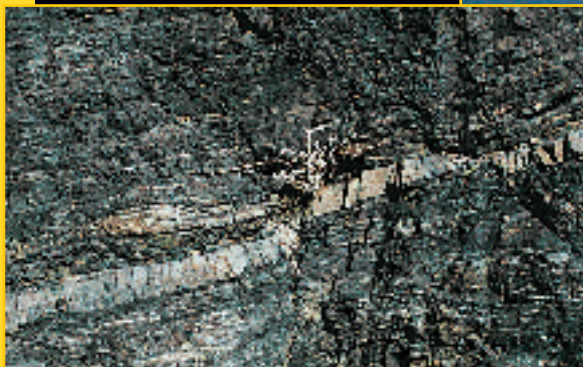
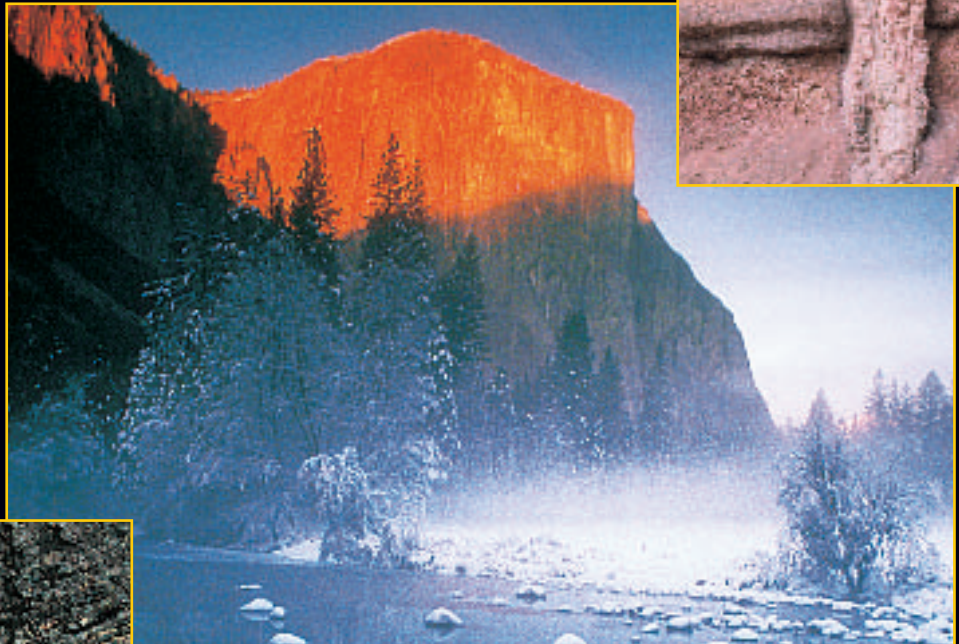
**Figure 15**

**I**ntrusive igneous rocks are formed when a mass of magma is forced upward toward Earth's surface and then cools before emerging. The magma cools in a variety of ways. Eventually the rocks may be uplifted and erosion may expose them at Earth's surface. A selection of these formations is shown here.

▶ This dike in Israel's Negev Desert formed when magma squeezed into cracks that cut across rock layers.



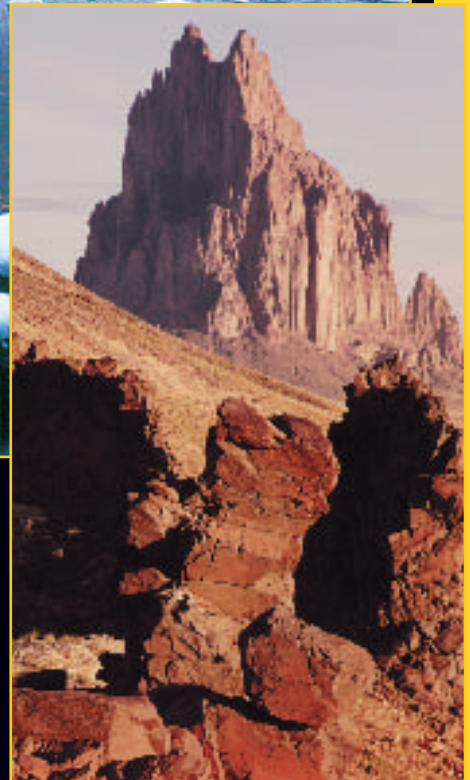
▶ A batholith is a very large igneous rock body that forms when rising magma cools below the ground. Towering El Capitan, right, is just one part of a huge batholith. It looms over the entrance to the Yosemite Valley.



▶ Sills such as this one in Death Valley, California, form when magma is forced into spaces that run parallel to rock layers.



▶ Volcanic necks like Shiprock, New Mexico, form when magma hardens inside the vent of a volcano. Because the volcanic rock in the neck is harder than the volcanic rock in the volcano's cone, only the volcanic neck remains after erosion wears the cone away.





## Sedimentary Rocks

Pieces of broken rock, shells, mineral grains, and other materials make up what is called sediment (SE duh munt). The sand you squeeze through your toes at the beach is one type of sediment. As shown in **Figure 16**, sediment can collect in layers to form rocks. These are called **sedimentary** (sed uh MEN tuh ree) **rocks**. Rivers, ocean waves, mudslides, and glaciers can carry sediment. Sediment also can be carried by the wind. When sediment is dropped, or deposited, by wind, ice, gravity, or water, it collects in layers. After sediment is deposited, it begins the long process of becoming rock. Most sedimentary rocks take thousands to millions of years to form. The changes that form sedimentary rocks occur continuously. As with igneous rock, there are several kinds of sedimentary rocks. They fall into three main categories.

 **Reading Check** *How is sediment transported?*

**Detrital Rocks** When you mention sedimentary rocks, most people think about rocks like sandstone, which is a detrital (dih TRI tuhl) rock. Detrital rocks, shown in **Figure 17**, are made of grains of minerals or other rocks that have moved and been deposited in layers by water, ice, gravity, or wind. Other minerals dissolved in water act to cement these particles together. The weight of sediment above them also squeezes or compacts the layers into rock.

**Figure 17** Four types of detrital sedimentary rocks include shale, siltstone, sandstone, and conglomerate.



**Figure 16** The layers in these rocks are the different types of sedimentary rocks that have been exposed at Sedona, in Arizona.

**Explain** *what causes the layers seen in sedimentary rocks.*



## Mini LAB

### Modeling How Fossils Form Rocks

#### Procedure



1. Fill a small **aluminum pie pan** with pieces of broken **macaroni**. These represent various fossils.
2. Mix 50 mL of **white glue** into 250 mL of **water**. Pour this solution over the macaroni and set it aside to dry.
3. When your fossil rock sample has set, remove it from the pan and compare it with an actual **fossil limestone** sample.

#### Analysis

1. Explain why you used the glue solution and what this represents in nature.
2. Using whole macaroni samples as a guide, match the macaroni “fossils” in your “rock” to the intact macaroni. Draw and label them in your **Science Journal**.



**Figure 18** The minerals left behind after a geyser erupts form layers of chemical rock.

**Identifying Detrital Rocks** To identify a detrital sedimentary rock, you use the size of the grains that make up the rock. The smallest, clay-sized grains feel slippery when wet and make up a rock called shale. Silt-sized grains are slightly larger than clay. These make up the rougher-feeling siltstone. Sandstone is made of yet larger, sand-sized grains. Pebbles are larger still. Pebbles mixed and cemented together with other sediment make up rocks called conglomerates (kun GLAHM ruts).

**Chemical Rocks** Some sedimentary rocks form when seawater, loaded with dissolved minerals, evaporates. Chemical sedimentary rock also forms when mineral-rich water from geysers, hot springs, or salty lakes evaporates, as shown in **Figure 18**. As the water evaporates, layers of the minerals are left behind. If you’ve ever sat in the Sun after swimming in the ocean, you probably noticed salt crystals on your skin. The seawater on your skin evaporated, leaving behind deposits of halite. The halite was dissolved in the water. Chemical rocks form this way from evaporation or other chemical processes.

**Organic Rocks** Would it surprise you to know that the chalk your teacher is using on the chalkboard might also be a sedimentary rock? Not only that, but coal, which is used as a fuel to produce electricity, also is a sedimentary rock.

Chalk and coal are examples of the group of sedimentary rocks called organic rocks. Organic rocks form over millions of years. Living matter dies, piles up, and then is compressed into rock. If the rock is produced from layers of plants piled on top of one another, it is called coal. Organic sedimentary rocks also form in the ocean and usually are classified as limestone.





**Figure 19** There are a variety of organic sedimentary rocks.

The pyramids in Egypt are made from fossiliferous limestone.

A thin slice through the limestone shows that it contains many small fossils.

**Fossils** Chalk and other types of fossiliferous limestone are made from the fossils of millions of tiny organisms, as shown in **Figure 19**. A fossil is the remains or trace of a once-living plant or animal. A dinosaur bone and footprint are both fossils.

## section 2 review

### Summary

#### Igneous Rock

- The chemistry of an igneous rock often is indicated by its color.
- Starting materials that form igneous rocks include lava and magma.

#### Sedimentary Rocks

- Sedimentary rocks form as layers. They originate because wind, water, and ice transport and deposit sediment on Earth's surface.
- Some rocks have grainy textures because they are composed of rock, mineral, or organic fragments cemented together by mineral-rich solutions.
- Other sedimentary rocks appear crystalline as they form directly from mineral-rich solutions.

### Self Check

1. **Compare and contrast** the ways in which extrusive and intrusive igneous rocks are formed.
2. **Diagram** how each of the three kinds of sedimentary rock forms. List one example of each kind of rock: detrital, chemical, and organic.
3. **List** in order from smallest to largest the grain sizes used to describe detrital rocks.
4. **Think Critically** Why do igneous rocks that solidify underground cool so slowly?

### Applying Skills

5. **Communicate** Research a national park where volcanic activity has taken place. Read about the park and the features that you'd like to see. Then describe the volcanic features in your Science Journal. Be sure to explain how each feature formed.



# Metamorphic Rocks and the Rock Cycle

## as you read

### What You'll Learn

- **Describe** the conditions needed for metamorphic rocks to form.
- **Explain** how all rocks are linked by the rock cycle.

### Why It's Important

Metamorphic rocks and the rock cycle show that Earth is a constantly changing planet.



### Review Vocabulary

**pressure:** force applied over a given area

### New Vocabulary

- metamorphic rock
- foliated
- nonfoliated
- rock cycle

## New Rock from Old Rock

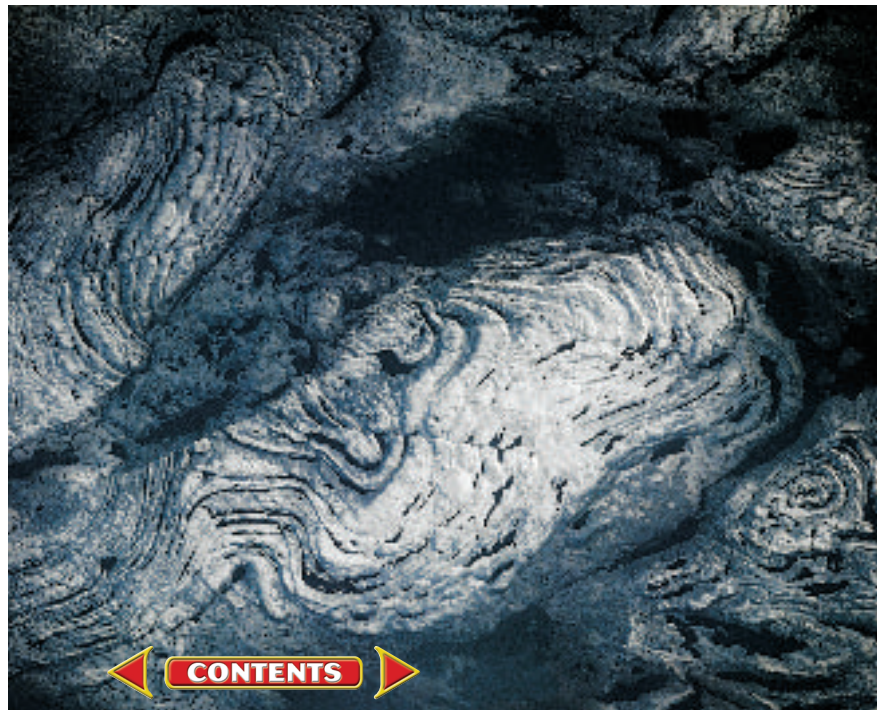
Many physical changes on and within Earth are at work, constantly changing rocks. From low-temperature processes such as weathering and erosion, to high-temperature conditions that form molten rock material, new rocks are always forming. There are conditions in between those that form igneous and sedimentary rock that also produce new rocks. Pressures and temperatures increase as rocks are compressed or buried deeply, which can change the chemistry and grain sizes of rocks without even melting them. These conditions often happen where Earth's tectonic plates collide to form mountains, like those shown in **Figure 20**.

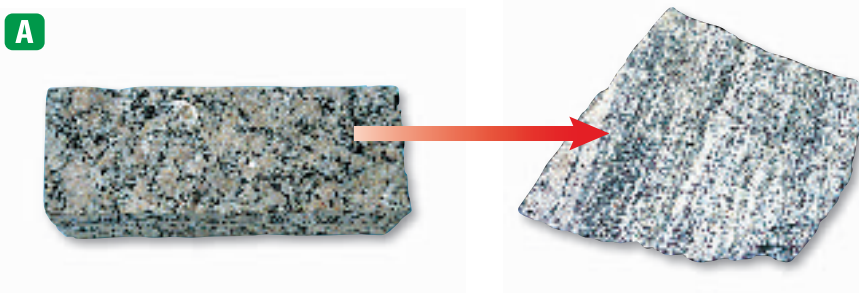
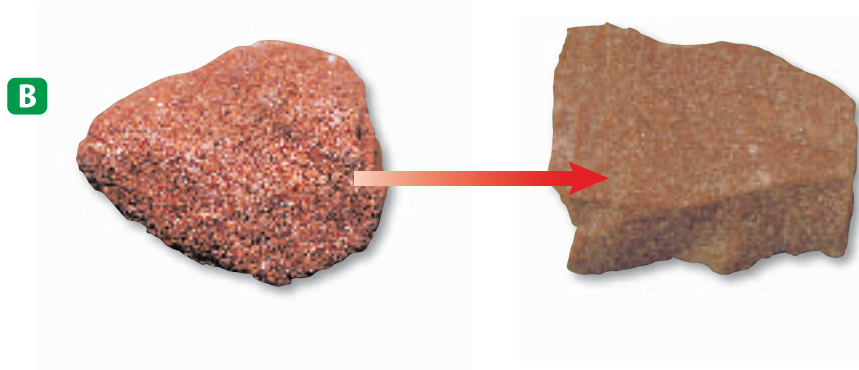
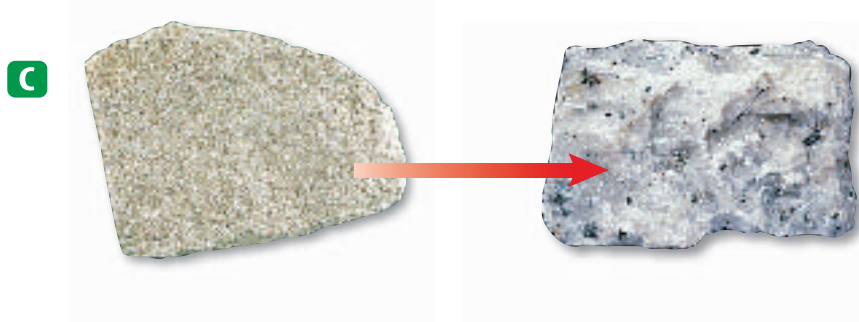
It can take millions of years for rocks to change. That's the amount of time that often is necessary for extreme pressure to build while rocks are buried deeply or continents collide. Sometimes existing rocks are cooked when magma is forced upward into Earth's crust, changing their mineral crystals. All these events can make new rocks out of old rocks.



**Reading Check** What events can change rocks?

**Figure 20** The rocks of the Labrador Peninsula in Canada were squeezed into spectacular folds. This photo was taken during the space shuttle *Challenger* mission STS-41G in 1984.



**A****B****C**

**Figure 21** High pressure and temperature can cause existing rocks to change into new metamorphic rocks. **A** Granite can change to gneiss. **B** The sedimentary rock sandstone can become quartzite, and **C** limestone can change to marble.

**Metamorphic Rocks** Do you recycle your plastic milk jugs? After the jugs are collected, sorted, and cleaned, they are heated and squeezed into pellets. The pellets later can be made into useful new products. It takes millions of years, but rocks get recycled, too. This process usually occurs thousands of meters below Earth's surface where temperatures and pressures are high. New rocks that form when existing rocks are heated or squeezed but are not melted are called **metamorphic** (me tuh MOR fihk) **rocks**. The word *metamorphic* means “change of form.” This describes well how some rocks take on a whole new look when they are under great temperatures and pressures.

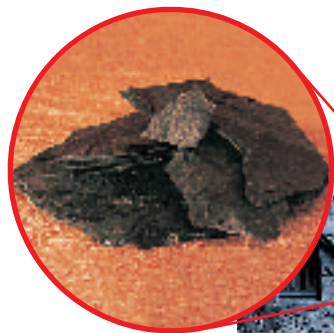


**Reading Check** What does the word *metamorphic* mean?

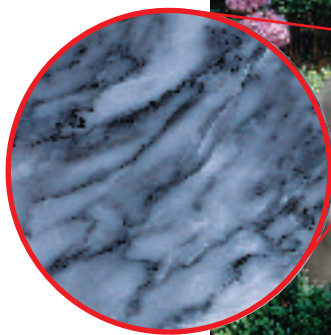
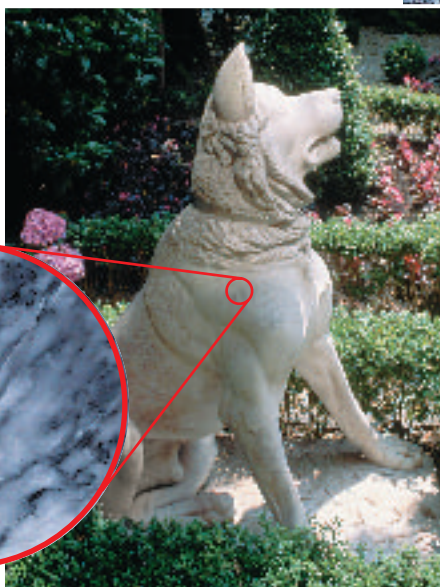
**Figure 21** shows three kinds of rocks and what they change into when they are subjected to the temperatures, pressures, and hot fluids involved in metamorphism. Not only do the resulting rocks look different, they have recrystallized and might be chemically changed, too. The minerals often align in a distinctive way.



**Figure 22** There are many different types of metamorphic rocks.



This statue is made from marble, a non-foliated metamorphic rock.



The roof of this house is made of slate, a foliated metamorphic rock.

**Types of Changed Rocks** New metamorphic rocks can form from any existing type of rock—igneous, sedimentary, or metamorphic. A physical characteristic helpful for classifying all rocks is the texture of the rocks. This term refers to the general appearance of the rock. Texture differences in metamorphic rocks divide them into two main groups—foliated (FOH lee ay tud) and nonfoliated, as shown in **Figure 22**.

**Foliated** rocks have visible layers or elongated grains of minerals. The term *foliated* comes from the Latin *foliatus*, which means “leafy.” These minerals have been heated and squeezed into parallel layers, or leaves. Many foliated rocks have bands of different-colored minerals. Slate, gneiss (NISE), phyllite (FIH lite), and schist (SHIHST) are all examples of foliated rocks.

**Nonfoliated** rocks do not have distinct layers or bands. These rocks, such as quartzite, marble, and soapstone, often are more even in color than foliated rocks. If the mineral grains are visible at all, they do not seem to line up in any particular direction. Quartzite forms when the quartz sand grains in sandstone recrystallize after they are squeezed and heated. You can form ice crystals in a similar way if you squeeze a snowball. The pressure from your hands creates grains of ice inside the ball.



#### Topic: Rock Types

Visit [red.msscience.com](http://red.msscience.com) for Web links to information about types of metamorphic rocks.

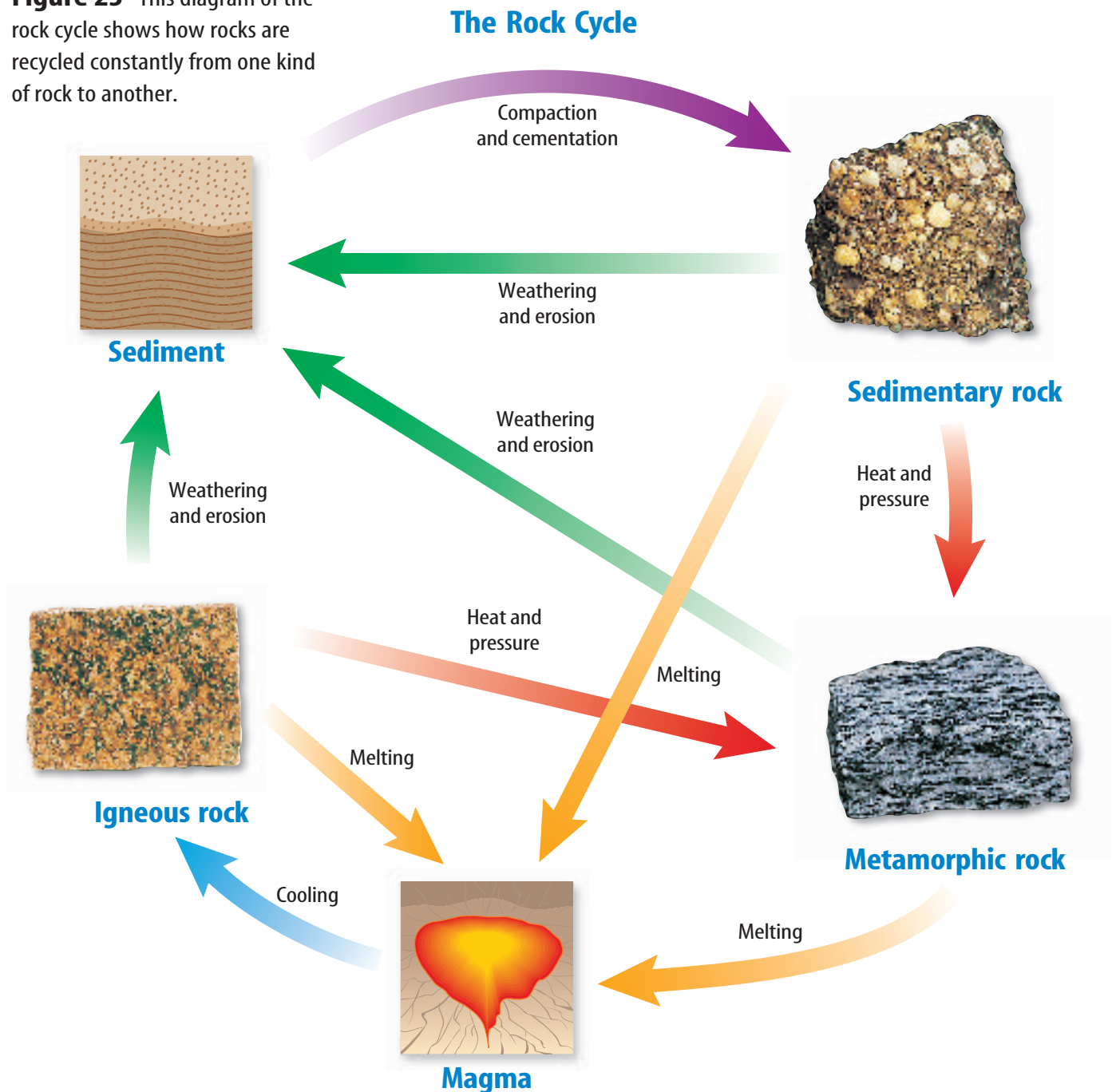
**Activity** Make a two-column table with *Foliated* and *Nonfoliated* as table headings at the top. Find three examples of each of these metamorphic rock classifications. List minerals commonly found in each example.



## The Rock Cycle

Rocks are changing constantly from one type to another. If you wanted to describe these processes to someone, how would you do it? Scientists have created a model called the **rock cycle** to describe how different kinds of rock are related to one another and how rocks change from one type to another. Each rock is on a continuing journey through the rock cycle, which is shown in diagram form in **Figure 23**. A trip through the rock cycle can take millions of years.

**Figure 23** This diagram of the rock cycle shows how rocks are recycled constantly from one kind of rock to another.





**Figure 24** This lava in Hawaii is flowing into the ocean and cooling rapidly.

heat inside Earth can change it into a metamorphic rock. Metamorphic rock deep inside Earth can melt and begin the cycle again. Rocks on Earth are changed over millions of years. These processes are taking place right now.



#### Reading Check

*Describe how a metamorphic rock might change into an igneous rock.*

## section

## 3

## review

### Summary

#### New Rock from Old Rock

- Changing conditions can cause new minerals to form, or the same minerals to change form as they align and recrystallize.
- Large-scale formation of metamorphic rock often occurs where tectonic plates collide.
- Metamorphic rocks sometimes are classified according to the textures they exhibit.
- Metamorphic rock textures can be foliated or nonfoliated.

#### The Rock Cycle

- Processes that are part of the rock cycle change rocks slowly through time.
- Igneous, sedimentary, and metamorphic rocks constantly are changing and exchanging matter through processes such as melting, weathering, and changing temperature and pressure.
- There is no beginning and no end to the rock cycle.

### Self Check

1. **Identify** two factors that can produce metamorphic rocks.
2. **List** examples of foliated and nonfoliated rocks. Explain the difference between the two types of metamorphic rocks.
3. **Explain** Igneous rocks and metamorphic rocks can form at high temperatures and pressures. What is the difference between these two rock types?
4. **Explain** what the rock cycle describes.
5. **Think Critically** Trace the journey of a piece of granite through the rock cycle. Explain how this rock could be changed from an igneous rock to a sedimentary rock and then to a metamorphic rock.

### Applying Skills

6. **Use a Spreadsheet** Using a spreadsheet program, create a data table to list the properties of rocks and minerals that you have studied in this chapter. After you've made your table, cut and paste the rows to group like rocks and minerals together.

## Gneiss Rice

You know that metamorphic rocks often are layered. But did you realize that individual mineral grains can change in orientation? This means that the grains can line up in certain directions. You'll experiment with rice grains in clay to see how foliation is produced.

### Real-World Question

What conditions will cause an igneous rock to change into a metamorphic rock?

#### Goals

- **Investigate** ways rocks are changed.
- **Model** a metamorphic rock texture.

#### Materials

rolling pin  
lump of modeling clay  
uncooked rice (wild rice, if available) (200 g)  
granite sample  
gneiss sample

#### Safety Precautions



**WARNING:** Do not taste, eat, or drink any materials used in the lab.

### Procedure

1. **Sketch** the granite specimen in your Science Journal. Be sure that your sketch clearly shows the arrangement of the mineral grains.
2. Pour the rice onto the table. Roll the ball of clay in the rice. Some of the rice will stick to the outside of the ball. Knead the ball until the rice is spread out fairly evenly. Roll and knead the ball again, and repeat until your clay sample has lots of "minerals" distributed throughout it.

3. Using the rolling pin, roll the clay until it is about 0.5 cm thick. Don't roll it too hard. The grains of rice should be pointing in different directions. Draw a picture of the clay in your Science Journal.
4. Take the edge of the clay closest to you and fold it toward the edge farthest from you. Roll the clay in the direction you folded it. Fold and roll the clay in the same direction several more times. Flatten the lump to 0.5 cm in thickness again. Draw what you observe in your "rock" and in the gneiss sample in your Science Journal.



### Conclude and Apply

1. **Describe** What features did the granite and the first lump of clay have in common?
2. **Explain** what force caused the positions of rice grains in the lump of clay to change. How is this process similar to and different from what happens in nature?

### Communicating Your Data

Refer to your Science Journal diagrams and the rock samples provided for you in this lab and make a poster relating this lab to processes in the rock cycle. Be sure to include diagrams of what you did, as well as information on how similar events occur in nature. **For more help, refer to the Science Skill Handbook.**

## Classifying Minerals

### Goals

- **Test** and observe important mineral characteristics.

### Materials

set of minerals  
magnifying lens  
putty knife  
streak plate  
Mohs scale  
minerals field guide

### Safety Precautions



**WARNING:** *Be careful when using a knife. Never taste any materials used in a lab.*

### Real-World Question

Hiking along a trail, you encounter what looks like an interesting mineral. You notice that it is uniform in color and shows distinct crystal faces. You think it must be valuable and want to identify it, so you open a guidebook to rocks and minerals. What observations must you make in order to identify it? What tests can you perform in the field?

### Procedure

1. Copy the data table into your Science Journal. Based on your observations and hardness tests, you will fill in columns 2 through 6. In the sixth column—"Scratches which samples?"—you will list the number of each mineral sample that this sample is able to scratch. This information will allow you to rank each sample from softest to hardest. Comparing these ranks to Mohs scale should help identify the mineral.
2. Obtain a classroom set of minerals.



## Using Scientific Methods

- Observe** each sample and conduct appropriate tests to complete as much of your data table as possible. Consult the *Minerals* Reference Handbook at the back of this book to help fill in the last column.

Mineral Characteristics							
Sample Number	Crystal Shape	Cleavage/ Fracture	Color	Streak and Luster	Scratches which samples?	Hardness Rank	Mineral Name
1							
2							
3		Do not write in this book.					
4							
5							
...							
No. of samples							

### Analyze Your Data

- Identify** each mineral based on the information in your data table.
- Evaluate** Did you need all of the information in the table to identify each mineral? Explain why or why not.
- Explain** which characteristics were easy to determine. Which were somewhat more difficult?

### Conclude and Apply

- Evaluate** Were some characteristics more useful as indicators than others?
- Apply** Would you be able to identify minerals in the field after doing this activity? Which characteristics would be easy to determine on the spot? Which would be difficult?
- Describe** how your actions in this lab are similar to those of a scientist. What additional work might a scientist have done to identify these unknown minerals?

### Communicating Your Data

**Create** a visually appealing poster showing the minerals in this lab and the characteristics that were useful for identifying each one. Be sure to include informative labels on your poster.



# Accidents in SCIENCE

SOMETIMES  
GREAT  
DISCOVERIES  
HAPPEN BY  
ACCIDENT!



## Going for the Gold

A time line history of the accidental  
discovery of gold in California

Sutter's Mill



**1840**

California is a quiet place. Only a few hundred people live in the small town of San Francisco.

**1848**

On January 24, Marshall notices something glinting in the water. He hits it with a rock. Marshall knows that "fool's gold" shatters when hit. But this shiny metal bends. After more tests, Sutter and Marshall decide it is gold! They try to keep the discovery a secret, but word leaks out.

**1850**

California becomes the thirty-first state.

**1864**

California's gold rush ends. The rich surface deposits are largely exhausted.

**1880**

His pension ended, Marshall is forced to earn a living through various odd jobs, receiving charity, and by selling his autograph. He attempts a lecture tour, but is unsuccessful.

**1885**

James Marshall dies with barely enough money to cover his funeral.

**1840**

**1850**

**1860**

**1870**

**1880**

**1890**

**1847**

John Sutter hires James Marshall to build a sawmill on his ranch. Marshall and local Native Americans work quickly to harness the water power of the American River.

**1849**

The Gold Rush hits! A flood of people from around the world descends on northern California. Many people become wealthy—but not Marshall or Sutter. Because Sutter doesn't have a legal claim to the land, the U.S. government claims it.

**1854**

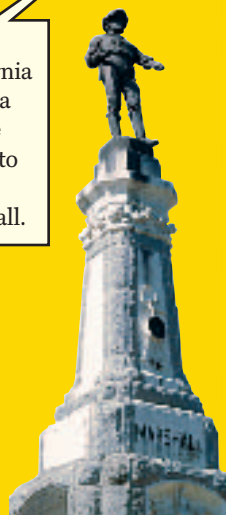
A giant nugget of gold, the largest known to have been discovered in California, is found in Calaveras County.

**1872**

As thanks for his contribution to California's growth, the state legislature awards Marshall \$200 a month for two years. This pension is renewed until 1878.

**1890**

California builds a bronze statue to honor Marshall.



**Research** Trace the history of gold from ancient civilizations to the present. How was gold used in the past? How is it used in the present? What new uses for gold have been discovered? Report to the class.

Science  online

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[red.msscience.com/time](http://red.msscience.com/time)

### Reviewing Main Ideas

#### Section 1 Minerals—Earth's Jewels

1. Minerals are inorganic solid materials found in nature. They have a definite chemical makeup, and an orderly arrangement of atoms. Rocks are combinations of two or more minerals.
2. Physical properties of minerals are observed to help identify them.
3. Gems are minerals that are rare and beautiful.
4. Ores of useful materials must be mined and processed to extract the desired substance.

#### Section 2 Igneous and Sedimentary Rocks

1. Igneous rocks form when melted rock material from inside Earth cools and hardens.

Extrusive rocks form above Earth's surface. Intrusive rocks solidify beneath the surface.

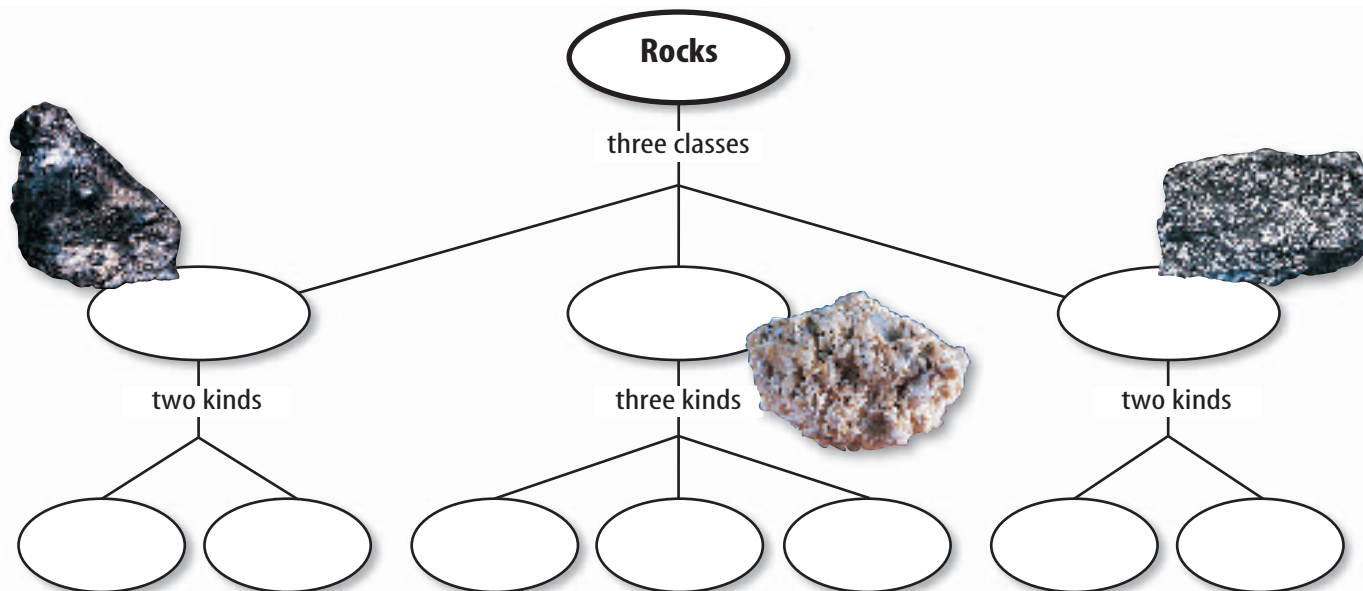
2. Sedimentary rocks formed from mineral or rock fragments are called detrital rocks.
3. Rocks formed as mineral-rich water evaporates are examples of chemical rocks. Rocks composed of fossils or plant remains are organic rocks.

#### Section 3 Metamorphic Rocks and the Rock Cycle

1. Metamorphic rocks form as a result of changing temperature, pressure, and fluid conditions inside Earth.
2. The rock cycle describes how all rocks are subject to constant change.

### Visualizing Main Ideas

Copy and complete the concept map using the following terms and phrases: extrusive, organic, foliated, intrusive, chemical, nonfoliated, detrital, metamorphic, and sedimentary.



## Using Vocabulary

crystal p.258	mineral p.256
extrusive p.265	nonfoliated p.274
foliated p.274	ore p.263
gem p.262	rock p.256
igneous rock p.265	rock cycle p.275
intrusive p.265	sedimentary rock p.269
metamorphic rock p.273	

Explain the difference between each pair of vocabulary words.

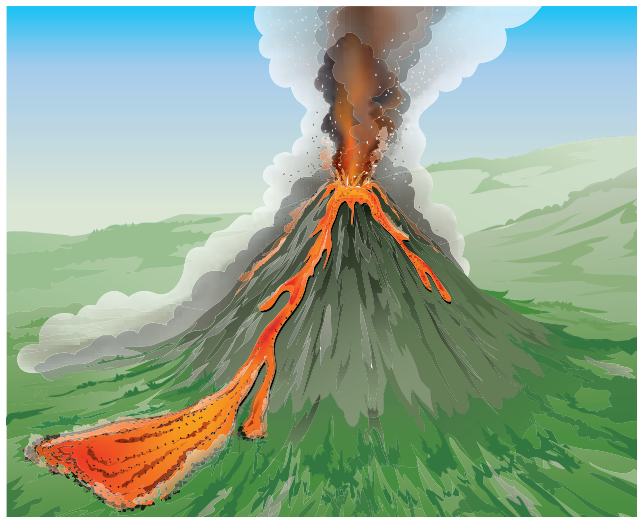
1. mineral—rock
2. crystal—gem
3. cleavage—fracture
4. hardness—streak
5. rock—rock cycle
6. intrusive—extrusive
7. igneous rock—metamorphic rock
8. foliated—nonfoliated
9. rock—ore
10. metamorphic rock—sedimentary rock

## Checking Concepts

Choose the word or phrase that best answers the question.

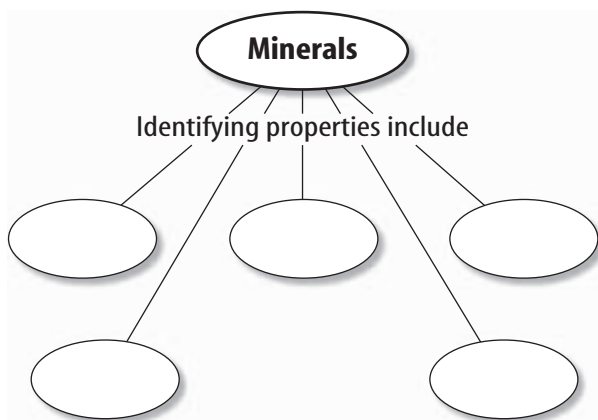
11. When do metamorphic rocks form?
  - A) when layers of sediment are deposited
  - B) when lava solidifies in seawater
  - C) when particles of rock break off at Earth's surface
  - D) when heat and pressure change rocks
12. Which of the following must be true for a substance to be considered a mineral?
  - A) It must be organic.
  - B) It must be glassy.
  - C) It must be a gem.
  - D) It must be naturally occurring.
13. What kind of rocks are produced by volcanic eruptions?
  - A) detrital
  - B) foliated
  - C) organic
  - D) extrusive
14. Which is true about how all detrital rocks form?
  - A) form from grains of preexisting rocks
  - B) form from lava
  - C) form by evaporation
  - D) form from plant remains
15. Which of the following describes what rocks usually are composed of?
  - A) pieces
  - B) minerals
  - C) fossil fuels
  - D) foliations
16. How can sedimentary rocks be classified?
  - A) foliated or nonfoliated
  - B) gems or ores
  - C) extrusive or intrusive
  - D) detrital, chemical, or organic
17. Which is true of all minerals?
  - A) They are inorganic solids.
  - B) They have a hardness of 4 or greater.
  - C) They have a glassy luster.
  - D) They can scratch a penny.

Use the illustration below to answer question 13.



## Thinking Critically

18. **Classify** Is a sugar crystal a mineral? Explain.
19. **List** some reasons why metal deposits in Antarctica are not considered to be ores.
20. **Describe** How is it possible to find pieces of gneiss, granite, and basalt in a single conglomerate?
21. **Predict** Would you expect to find a well-preserved dinosaur bone in a metamorphic rock like schist? Explain.
22. **Explain** how the mineral quartz could be in an igneous rock and in a sedimentary rock.
23. **Classify** Your teacher gives you two clear minerals. What quick test could you do in order to determine which is halite and which is calcite?
24. **Concept Map** Copy and complete this concept map about minerals.



25. **Test a Hypothesis** Suppose your teacher gives you a glass plate, a nail, a copper penny, and a bar magnet. Using a word processing program on a computer, describe how you would use these items to determine the hardness and special property of the mineral magnetite. Refer to Mohs scale in **Table 1** for help.

## Performance Activities

26. **Make Models** Determine what materials and processes you would need to use to set up a working model of the rock cycle. Describe the ways in which your model is accurate and the ways in which it falls short. Present your model to the class.

## Applying Math

Use the table below to answer questions 27–29.

**Modified Wentworth Scale, after Lane et. al., 1947**

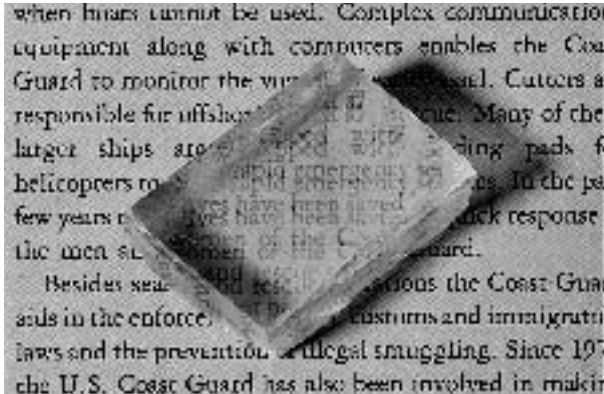
Grain Sizes (mm)	U.S. Standard Sieve Series	Grain Types
— 2	No. 10	very coarse
1	No. 18	coarse
0.500	No. 35	medium
0.250	No. 60	fine
0.125	No. 120	very fine
— 0.062	No. 230	coarse
0.031	—	medium
0.016	—	fine
0.008	—	very fine
— 0.004	—	coarse
0.002	—	medium
0.001	—	CLAY

27. **Grain Type** According to the table, if a rock contains grains that are 0.5 mm in dimension, what type of grains are they?
28. **Filtering** Which U.S. standard sieve would you use to filter out all sediment in a sample less than one-fourth of one millimeter?
29. **Grain Size** A siltstone contains grains that range in size from 0.031 to 0.008 mm. Convert this size range from millimeters to micrometers.

**Part 1 Multiple Choice**

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Use the photo below to answer question 1.

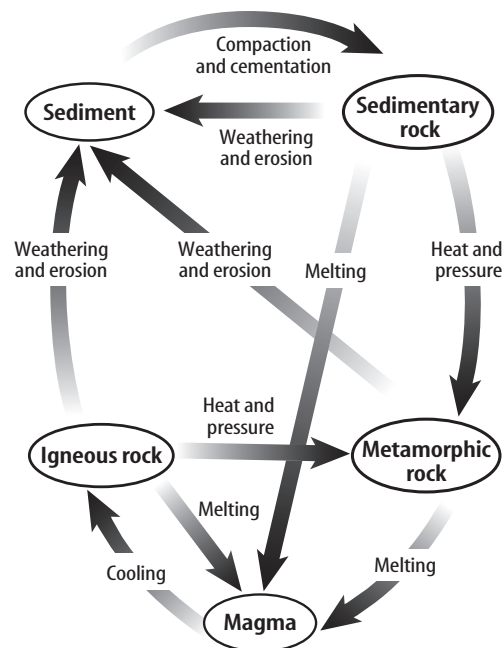


- Which special property is illustrated by the piece of calcite shown above?
  - magnetism
  - double refraction
  - reaction to acid
  - salty taste
- What forms when lava cools so quickly that crystals cannot form?
  - volcanic glass
  - intrusive rock
  - bauxite
  - a gem
- Which is the color of powdered mineral?
  - hardness
  - luster
  - cleavage
  - streak
- Varieties of which mineral are most abundant in Earth's crust?
  - quartz
  - calcite
  - feldspar
  - gypsum
- What is a solid material that has an orderly, repeating pattern of atoms?
  - crystal
  - gem
  - ore
  - rock

- Which feature is a tabular body of igneous rock that is parallel to surrounding rock layers?
  - sill
  - volcanic neck
  - batholith
  - dike

- Which type of rock is made mostly of clay?
  - conglomerate
  - shale
  - siltstone
  - sandstone

Use the diagram below to answer questions 8–9.



- Which changes sediment into sedimentary rock?
  - weathering and erosion
  - heat and pressure
  - compaction and cementation
  - melting
- Which type of rock forms when magma cools?
  - sedimentary
  - chemical
  - metamorphic
  - igneous

## Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

10. How is a rock different from a mineral?
11. How do organic sedimentary rocks form? List one example of an organic sedimentary rock.
12. How are extrusive igneous rocks different from intrusive igneous rocks?
13. How can minerals be identified by their physical properties?
14. What is a batholith? How do they form?

Use the table below to answer questions 15–17.

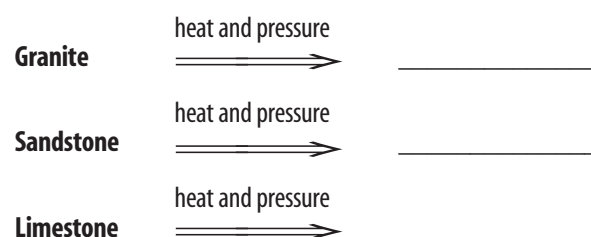
World Gold Production (metric tons)		
Country	2001 Production	2002 Production
United States	335	300
Australia	285	280
Canada	160	160
China	185	175
Indonesia	130	170
Peru	138	140
Russia	152	170
South Africa	402	395
Other countries	783	740
World total	2,570	2,530

15. Identify which single country produced the most gold in 2002. How many more metric tons did this country produce than the United States?
16. How many fewer metric tons did the U.S. produce in 2002 than in 2001?
17. What percentage of 2002 world gold production came from the United States?

## Part 3 Open Ended

Record your answers on a sheet of paper.

18. Why are minerals important to society?
19. Compare and contrast mineral cleavage and mineral fracture.
20. Complete the diagram below to show which rock would form when the rock on the left is exposed to heat and pressure.



21. Why must ores be processed after they are mined?
22. Why do sedimentary rocks occur in layers?
23. Which type of rock would you expect to exist deep in Earth's crust? Why?
24. Summarize the differences between granitic igneous rocks and basaltic igneous rocks.
25. Describe how a layer of rock containing fossils could be present in a mountain wall that is several thousand feet above sea level.
26. Explain at least two ways that a sedimentary rock can change to become a metamorphic rock. Include specific processes in your explanations.
27. Select two physical properties that you think are most reliable when identifying minerals. Explain your choices.

### Test-Taking Tip

**Eyes** During the test, keep your eyes on your own paper. If you need to rest them, close them or look up at the ceiling.