1 FOCUS

Section Objectives

3.5 **Compare and contrast** intrusive and extrusive igneous rocks.

3.6 **Demonstrate** how the rate of cooling affects an igneous rock's texture.

3.7 **Classify** igneous rocks according to texture and composition.

Reading Focus

Build Vocabulary L2

Word Parts To help students distinguish between intrusive and extrusive rocks, have them look up the meanings of the prefixes *in-* and *ex-*. Students will find that both prefixes stem from Latin terms. *In-* means "within or into"; *ex-* means "out of" or "outside." Point out that by knowing the meaning of these prefixes, students can better remember which igneous rocks form "within" Earth and which form "outside," or on, Earth's surface.

Reading Strategy L2

A.1. rock that forms when magma hardens beneath Earth's surface
A.2. Common example of igneous intrusive rock is granite.
B.1. rock that forms when lava hardens
B.2. Common example of igneous extrusive rock is rhyolite.

2 INSTRUCT

Build Science Skills L2

Inferring Reiterate that magma, which occurs beneath Earth's surface, often cools more slowly than lava, which occurs at Earth's surface. Then have students examine Figure 5. Ask them to use the photograph to infer why lava often cools more quickly than magma. *(Lava is exposed to air and water, which speeds up its cooling rate.)*
Logical

3.2 Igneous Rocks

Reading Focus

Key Concepts

- How are intrusive and extrusive igneous rocks alike and different?
- How does the rate of cooling affect an igneous rock's texture?
- How are igneous rocks classified according to composition?

Vocabulary

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

Reading Strategy

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

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

Recall from the discussion of the rock cycle that igneous rocks form when magma or lava cools and hardens. When the red hot lava shown in Figure 5 cools, a dark-colored igneous rock called basalt will form. If this melted material had stayed deep beneath Earth's surface, a very different kind of igneous rock would have been produced as the material cooled. Different kinds of igneous rocks form when magma and lava cool and harden.

Go Online PLANETDIARY

For: Links on Extrusive Igneous Rocks
Visit: PHSchool.com
Web Code: czd-1032

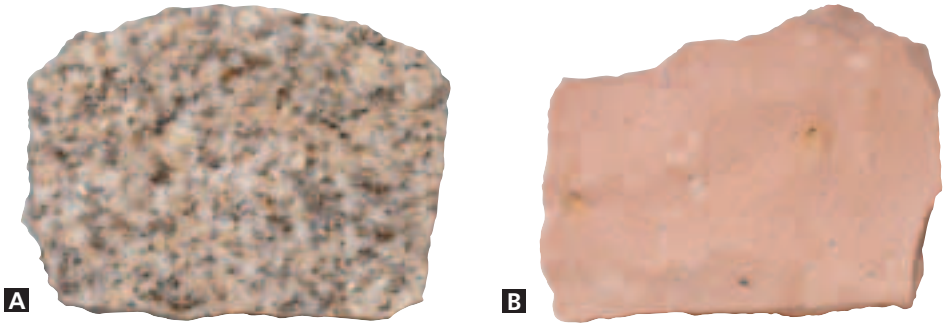
Figure 5 Basaltic Lava Lava from this Hawaiian volcano flows easily over Earth's surface. When the lava cools and hardens, the igneous rock called basalt will form.

Go Online PLANETDIARY

Find links to additional activities and have students monitor phenomena that affect Earth and its residents.

Formation of Igneous Rocks

The word *igneous* comes from the Latin word *ignis,* which means "fire." Perhaps that is why people often associate igneous rock with fiery volcanic eruptions like the one shown in Figure 5. Igneous rock also forms deep beneath Earth's surface.



Intrusive Igneous Rocks

Rocks that form when magma hardens beneath Earth's surface are called intrusive igneous rocks. That is because they *intrude* into the existing rocks. We would never see these deep rocks were it not for erosion stripping away the overlying rock.

Magma consists mainly of the elements silicon and oxygen, plus aluminum, iron, calcium, sodium, potassium, and magnesium. Magma also contains some gases, including water vapor. These gases are kept within the magma by the pressure of the surrounding rocks. Because magma is less dense than the surrounding rocks, it slowly works its way toward the surface. As magma rises, it cools, allowing elements to combine and form minerals. Gradually, the minerals grow in size, forming a solid mass of interlocking crystals. Granite, shown in Figure 6A, is a common intrusive igneous rock.

Extrusive Igneous Rocks

You know that when magma reaches Earth's surface, it is called lava. Lava is similar to magma, except that in lava, most of the gases have escaped. **When lava hardens, the rocks that form are called extrusive igneous rocks.** That is because they are *extruded* onto the surface. The rhyolite shown in Figure 6B is an extrusive igneous rock.

Figure 6 **A** Granite is an intrusive igneous rock that forms when magma cools slowly beneath Earth's surface. **B** Rhyolite is an extrusive igneous rock that forms when lava cools quickly at Earth's surface.

Q & A

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

A Magma and lava are both terms used to describe melted rock. The composition of magma and lava can be the same. However, magma is melted material beneath Earth's surface. Lava is melted material at Earth's surface.

Formation of Igneous Rocks

Use Visuals

L1

Figure 6 Ask: **In what ways are the two rocks similar?** *(Sample answer: Both are solids. Both are light-colored igneous rocks.)* **In what ways are the two rocks different?** *(Sample answer: The granite is multicolored and has a rough surface. The rhyolite is more uniformly colored and has a smoother surface.)*

Visual

Address Misconceptions

L2

Ask students to describe the mass of rocks in relation to other solid objects. Some may mistakenly think that all rocks are heavy. Bring a sample of pumice into class. Pass around the rock, giving all students an opportunity to feel its heft. Many pumice samples will float in water. Place your sample in a pan of water to demonstrate this. Explain that some rocks, such as pumice, form when lava cools very quickly, leaving numerous air bubbles in the rock. The air bubbles cause pumice to be light.

Kinesthetic

Customize for Inclusion Students

Learning Disabled Have samples of igneous rocks available for students to examine. As they read the section, have them arrange the samples on a posterboard and write details about the texture and composition of the rocks under each sample. For example, students can write "coarse-grained, granitic" under a sample of granite.

Classification of Igneous Rocks

Teacher Demo

Crystal Formation L2

Purpose Students will observe how the rate of cooling affects crystal size.

Materials 2 shallow pans, 250-mL beaker, water, teaspoon, sulfur powder, thermal mitt, hot plate, magnifying glass

Procedure Put a teaspoon of sulfur powder into a shallow pan. Heat the pan until the sulfur melts, then place it aside to slowly cool. Heat another teaspoon of sulfur powder in a second shallow pan. Pour the melted sulfur into a beaker half-filled with water so that the sulfur cools quickly. Allow students to view the resulting crystals from both trials with a magnifying glass.

Expected Outcome Students will observe that cooling rates affect the size of crystals—the sulfur that cooled slowly formed larger crystals than the sulfur that cooled quickly.
Visual

Build Reading Literacy L1

Refer to **p. 362D** in **Chapter 13,** which provides the guidelines for using prior knowledge.

Use Prior Knowledge Ask students what they think of when they hear the word *texture*. Students will likely say that texture refers to the way an object feels to the touch. Ask them to describe some textures they have felt. *(Sample answers: rough, smooth, sticky, powdery)* Explain that the scientific meaning of *texture* in this section refers to the overall appearance of a rock based on the size, shape, and arrangement of its crystals.
Intrapersonal, Verbal

Q & A

Q *Native Americans used obsidian for making arrowheads and cutting tools. Is this the only material they used?*

A No. Native Americans used whatever materials were locally available to make tools, including any hard dense rock material that could be shaped. This includes materials such as the metamorphic rocks slate and quartzite, sedimentary deposits made of silica called jasper, chert, opal, flint, and even jade. Some of these deposits occur in only a few areas. That helps anthropologists reconstruct trade routes between different Native American groups.

Figure 7 This sample of andesite displays igneous rock with a porphyritic texture.
Describing *Describe how this rock probably formed.*

Classification of Igneous Rocks

A quick glance at the two rocks in Figure 6 tells you that they are different. The granite contains large mineral grains. Only a few of the mineral grains in the sample of rhyolite can be seen with the unaided eye. **Texture and composition are two characteristics used to classify igneous rocks.** Texture describes the appearance of an igneous rock based on its size, shape, and the arrangement of its interlocking crystals. The composition classes of igneous rocks are based on the proportions of light and dark minerals in the rock.

Coarse-Grained Texture The rate of cooling strongly affects the textures of igneous rocks. If magma cools very slowly, few centers of crystal growth develop. Slow cooling also allows charged atoms, or ions, to move large distances within the magma. **Slow cooling results in the formation of large crystals.** Igneous rocks with large crystals exhibit a coarse-grained texture.

Fine-Grained Texture If cooling of magma or lava occurs rapidly, the ions in the melted material lose their motion and quickly combine. This results in a large number of tiny crystals that all compete for the available ions. **Rapid cooling of magma or lava results in rocks with small, interconnected mineral grains.** Igneous rocks with small grains are said to have a fine-grained texture.

Glassy Texture When lava spews onto Earth's surface, there may not be enough time for the ions in the lava to arrange themselves into a network of crystals. So the solids produced this way are made of randomly distributed ions. Such rocks have a glassy texture. The obsidian and pumice shown in Figure 1 on page 66 are igneous rocks with glassy textures.

Porphyritic Texture A large body of magma located deep within Earth may take tens of thousands of years to harden. Minerals that crystallize from the magma do not form at the same rate or at the same time. It is possible for some crystals to become quite large before others even start to form. The resulting rock can have large crystals, called phenocrysts, surrounded by fine-grained minerals. Rocks with very different-size minerals experience different rates of cooling. These rocks have a **porphyritic texture.** The igneous rock shown in Figure 7 has a porphyritic texture.

Reading Checkpoint

How does the rate of cooling of magma or lava affect the texture of igneous rocks?

Granitic Composition Igneous rocks in which the light-colored silicate minerals quartz and feldspar are the main minerals are said to have a **granitic composition.** In addition to quartz and feldspar, most granitic rocks contain about 10 percent dark silicate minerals. These dark minerals are often biotite mica and amphibole. Granitic rocks contain about 70 percent silica. Rhyolite is an extrusive granitic rock.

Intrusive granitic rocks make up much of the continental crust. Plate movements push crustal rock deep beneath the surface, where it melts and then cools, forming granite. Uplift and erosion later expose this rock at the surface. You will learn how these huge masses of granite rock form in Chapter 10.

Go Online NSTA SCILINKS

For: Links on igneous rocks
Visit: www.SciLinks.org
Web Code: cjn-1032

Basaltic Composition Rocks that contain many dark silicate minerals and plagioclase feldspar have a **basaltic composition.** Basaltic rocks are rich in the elements magnesium and iron. Because of their iron content, basaltic rocks are typically darker and denser than granitic rocks. The most common basaltic rock is basalt, shown in Figure 8. Gabbro is an intrusive igneous rock with a basaltic composition.

Basaltic igneous rocks make up Earth's ocean floor. As tectonic plates move apart, magma with a basaltic composition erupts through the gap between the plates and hardens to form the ocean floor. You will learn about this process in Chapter 9.

Figure 8 Basalt is an igneous rock made mostly of dark-colored silicate minerals.
Describing ***Describe the texture of this igneous rock.***

Other Compositional Groups Rocks with a composition between granitic and basaltic rocks have an **andesitic composition.** This group of igneous rocks is named after the common volcanic rock andesite. Andesitic rocks contain at least 25 percent dark silicate minerals—mainly amphibole, pyroxene, and biotite mica. The other dominant mineral in andesitic rocks is plagioclase feldspar.

Certain volcanoes are made up of rocks with andesitic composition. As you will learn in Chapter 10, these volcanoes form where tectonic plates collide. In this type of collision between plates, the dense basaltic rock of the ocean floor sinks back into the mantle beneath less dense continental crust.

Another important igneous rock is peridotite. This rock contains mostly the minerals olivine and pyroxene. Because peridotite is composed almost entirely of dark silicate minerals, its chemical composition is referred to as **ultramafic.** Although ultramafic rocks are rare at Earth's surface, much of the upper mantle is thought to be made of peridotite.

Integrate Chemistry

L2

In the early twentieth century, N. L. Bowen, a geologist, discovered that as magma cools, certain minerals crystallize first at very high temperatures. At successively lower temperatures, other minerals form. Bowen also demonstrated that if a mineral remains in the molten solution after crystallization, it will react with the remaining liquid to produce the next mineral, in a sequence known as Bowen's reaction series. Allow students to study Bowen's reaction series, Transparency 15. Tell them to compare the chart with Table 1 on p. 74. Ask: **What do you notice about the minerals that make up the rocks?** *(Each rock group consists of minerals that crystallize in the same temperature range.)*
Logical, Visual

Go Online NSTA SCILINKS

Download a worksheet on igneous rocks for students to complete, and find additional teacher support from NSTA SciLinks.

Answer to . . .

Figure 7 *The rock experienced at least two episodes of cooling. Slow cooling resulted in the larger mineral grains. Rapid cooling produced the fine-grained minerals.*

Figure 8 *The rock is a fine-grained igneous rock.*

Reading Checkpoint *A slowly cooling magma or lava will produce rocks in which the mineral grains are relatively large. Quickly cooling molten material will result in rocks with small mineral grains. Lava that is cools extremely rapidly will produce a glassy rock. Rocks that form as the result of different cooling rates will have both large and small mineral grains.*

Facts and Figures

Magma is basically a very hot, thick fluid, but it also contains solids and gases. The solids are mineral crystals. The liquid portion of the magma body is composed of ions that move about freely. However, as magma cools, the random movements of the ions slow, and the ions begin to arrange themselves into orderly patterns. This process is called crystallization. Usually not all of the molten material solidifies at the same time. Rather, as it cools, numerous small crystals develop. In a systematic fashion, ions are added to these centers of crystal growth. When the crystals grow large enough for their edges to meet, their growth ceases for lack of space, and crystallization continues elsewhere. Eventually, all of the liquid is transformed into a solid mass of interlocking crystals.

Section 3.2 (continued)

Use Visuals L1

Table 1 Make sure all students can clearly read the table. If necessary, make enlarged copies of the table for students. Ask: **Which rocks have the highest percentage of dark minerals?** *(ultramafic rocks)* **Identify a coarse-grained basaltic rock.** *(gabbro)* **What minerals are in granite?** *(quartz, potassium feldspar, sodium-rich plagioclase feldspar)*
Visual

3 ASSESS

Evaluate Understanding L2

Using Table 1 as a guide, have each student make two tables. One table should show the different textures of igneous rocks. The second table should show the composition of igneous rocks.

Reteach L1

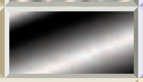
Use a simple graphic to help summarize the relationship between cooling rate and crystal size in igneous rocks. For example, draw an arrow pointing upward on the board. Label the arrow "Cooling rate." Ask: **As the rate of cooling increases, what happens to crystal size?** *(It decreases.)* To illustrate the answer, draw a downward-pointing arrow next to the first arrow. Label this second arrow "Crystal size."

Writing in Science

Sample answer: Obsidian likely formed when lava reached Earth's surface and cooled very rapidly. Refer to the text and Table 1 to evaluate students' answers.

To summarize, igneous rocks form when magma or lava cools and hardens. Intrusive rocks form when magma cools and hardens deep within Earth. Extrusive rocks form when lava cools and hardens on Earth's surface. Igneous rocks can be classified according to texture and composition. A general classification scheme based on texture and mineral composition is shown in Table 1.

Table 1 Classification of Major Igneous Rocks

			Granitic	Andesitic	Basaltic	Ultramafic
Chemical Composition						
Dominant Minerals			Quartz Potassium feldspar Sodium-rich plagioclase feldspar	Amphibole Sodium- and calcium-rich plagioclase feldspar	Pyroxene Calcium-rich plagioclase feldspar	Olivine Pyroxene
TEXTURE	Coarse-grained		Granite	Diorite	Gabbro	Peridotite
	Fine-grained		Rhyolite	Andesite	Basalt	Komatiite (rare)
	Porphyritic		"Porphyritic" precedes any of the above names whenever there are appreciable phenocrysts.			Uncommon
	Glassy		**Obsidian** (compact glass) **Pumice** (frothy glass)			
Rock Color (based on % of dark minerals)			0% to 25%	25% to 45%	45% to 85%	85% to 100%

Section 3.2 Assessment

Reviewing Concepts

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

Critical Thinking

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

Writing in Science

Explanatory Paragraph Write a paragraph to explain how one of the igneous rocks pictured in this chapter may have formed.

Section 3.2 Assessment

1. Both types of rocks form when molten material cools and solidifies. Intrusive igneous rocks form when magma cools and solidifies within Earth. Extrusive igneous rocks form when lava cools and hardens at the surface.
2. Coarse-grained igneous rocks form when magma cools slowly within Earth.
3. Igneous rocks can be classified by composition based on the major minerals in the rocks. Light-colored rocks have granitic compositions. Dark-colored rocks have basaltic compositions. Dark-colored rocks that contain only olivine and pyroxene are ultramafic rocks.
4. Fine-grained igneous rocks form when lava cools quickly at Earth's surface.
5. Igneous rocks with glassy textures form when lava cools very quickly.
6. Granite forms as magma slowly cools below the surface. This slow rate of cooling produces large mineral grains. Most of these minerals are quartz and feldspar, thus granite is light-colored, with a granitic composition. Basalt forms when lava cools quickly at the surface. This quick cooling rate results in very small mineral grains. The major minerals in basalt are dark-colored silicates that give basalt its dark color. A basalt has a basaltic composition.
7. Lava is magma that reaches the surface. As it rises, reduced pressure on the magma causes some of its gases to come out of solution. These gases form bubbles or holes as the molten material cools.