Section 2

Igneous Rocks and the Geologic History of Your Community

What Do You See?

Learning Outcomes

In this section, you will

- **Identify** and **classify** several igneous rocks using a rock chart.
- **Describe** how the two main types of igneous rocks form.
- **Determine** that igneous rocks are classified based on how they form.
- **Use** a geologic map and legend to search for evidence of past igneous rock formation.
- **Recognize** that classification helps scientists organize the natural world into smaller, workable components.

Think About It

Igneous rocks cool and crystallize from molten rock (*magma*).

- **In what kinds of environments do igneous rocks form?**
- **In what ways are some igneous rocks different from others?**

Record your ideas about these questions in your *Geo* log. Include a quick sketch. Be prepared to discuss your responses with your small group and the class.

Investigate

In this *Investigate*, you will examine the properties of a set of igneous rocks. You will then use a *geologic map* of your area to locate igneous rocks.

Part A: Working With Igneous Rocks

1. Examine the photographs of the igneous rocks shown, or a set of igneous rock samples that you are provided.

a) List some ways you can divide these igneous rocks into groups or categories.

2. Separate the samples into the categories you have decided to use. You might sort them in more than one way.

a) List the rocks that you place in each category.

b) Describe the difficulties you experienced trying to categorize them in each way you used.

3. Compare your classification system with the categories used by a different group.

a) Add any categories to your list that the other group used that you had not thought about.

4. Refer to the Classification of Igneous Rocks table in the *Digging Deeper*.

a) Use the table to name each igneous rock sample.

b) How do geologists classify igneous rocks?

c) Describe the similarities and differences between your classification scheme and that of geologists.

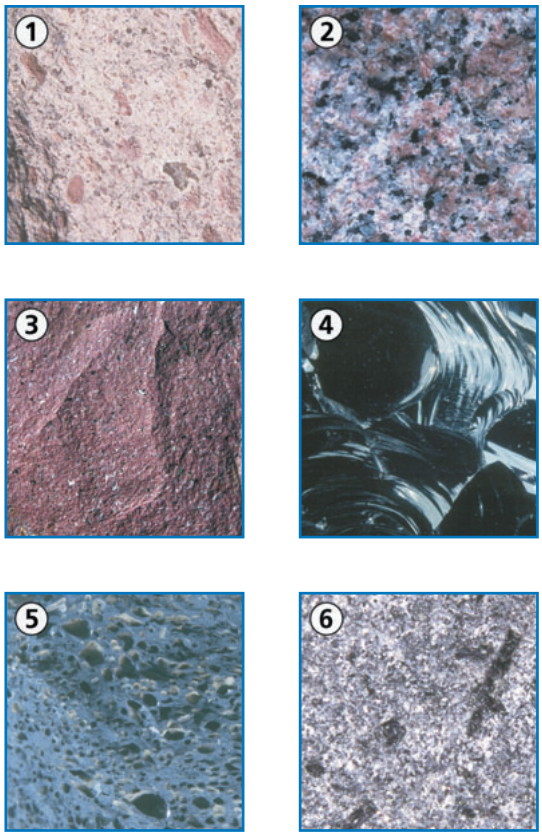
d) What is an advantage of classifying rocks into different groups?

5. Magma cools faster at Earth's surface (for example, after a volcanic eruption) than it does when it cools below the ground. The faster the cooling and crystallization occur, the smaller the crystals. Observe the rock samples (or photographs) and use the Classification of Igneous Rocks table to answer the following questions:

a) Does rhyolite form at or below Earth's surface? Explain.

b) Does gabbro form at or below Earth's surface? Explain.

c) Does obsidian form at or below Earth's surface? Explain.



Part B: Evidence of Igneous Rocks in Your Community

1. A geologic map shows the rocks and *sediments* at Earth's surface. Each color or symbol on the map stands for a type and/or age of rock. Geologic maps have a legend. Colors and symbols in the legend explain the types and/or ages of rock shown on the map. Examine the geologic map of your community or region.

a) Are there any igneous rocks described in the legend? If so, write down a list of the rock types, locations, and ages (in millions of years) if possible. Make a data table to record your observations. If there are numerous igneous rocks in your community, limit your data table to about five different examples.

b) What are the most common igneous rocks in your area?

c) Many igneous rocks are very resistant to *weathering*, and thus *erode* more slowly than other kinds of rocks. When igneous rock is surrounded by softer rock, a distinct elevated landform may develop. Locate an elevated or prominent landform in your community or region (choose a familiar hill, mountain, rock exposure, or cliff). Is the landform made of igneous rock?

Digging Deeper

IGNEOUS ROCKS

The Nature of Igneous Rocks

Geo Words

geologic map: a special map that shows geologic features.

igneous rock: a rock that solidified from molten or partly molten material, that is, from magma.

magma: naturally occurring molten rock material, generated within Earth, from which igneous rocks have been derived through solidification and related processes.

physical weathering: the processes of weathering by which rock is broken down by physical forces or processes, including gravity, water, ice, wind, or human actions at or near Earth's surface.

In the *Investigate*, you first looked at the properties of igneous rocks. Then you used a **geologic map** to locate these rocks in your area. All **igneous rocks** are made of interlocking crystals of minerals. The minerals have cooled and crystallize out of **magma**. (Recall that magma is molten rock.) These crystals make the rocks very resistant to **physical weathering** and **erosion**. Minerals are the building blocks of igneous rocks and all other rocks as well. As you read in *Section 1*, minerals are usually are made up of several chemical elements. Each mineral has a specific chemical makeup and crystal structure. Each mineral has a chemical formula. The chemical formula shows the amount of the various chemical elements in its makeup.

There are thousands of kinds of minerals in Earth's crust. However, only six are common in igneous rocks. They are quartz, feldspars, micas, pyroxenes, amphiboles, and olivines. These are all called **silicate** minerals. Their basic structure is very tightly bonded units made up of silicon and oxygen (called silica). These units are bonded less strongly to various other atoms. Of the six kinds, all but quartz are listed in the plural form. This is because the details of their chemical makeup can vary widely even though the basic nature of the mineral is the same. For example, plagioclase and potassium are two kinds of feldspar. They have slightly different structures and very different chemical makeups. Muscovite and biotite are two kinds of mica. Again, both have slightly different structures, but very different chemical makeups.

Magma, Lava, and Igneous Rock

Igneous rocks are formed from the cooling of magma. Suppose that you could drill a hole very deep into Earth. You would find that Earth's temperature initially rises by about 30°C with every kilometer of depth. This rate of increase slows down at deeper depths. At a depth of 100 to 350 km, the temperature is high enough for large volumes of rock to melt and form magma at certain times and places. Nearly all substances expand when they are heated. When rock is melted into magma, its volume increases by about 10 percent. This makes the magma less dense than the surrounding rock. Like a hot-air balloon that rises through less dense surrounding air, magma rises toward Earth's surface. (See *Figure 1*.) Some magmas cool and solidify into igneous rock before they reach the surface. The rock that forms in this way is called **intrusive igneous rock.** The magma "intrudes" into solid rock that was already there. In some places, magma reaches the surface before it solidifies into igneous rock.

Magma that reaches the surface is called **lava**. Rock that is formed when lava cools is called **extrusive igneous rock**. The lava is "extruded" onto Earth's surface, like toothpaste from a tube. As you will see, the appearance of an igneous rock reveals whether or not it formed below or at Earth's surface.

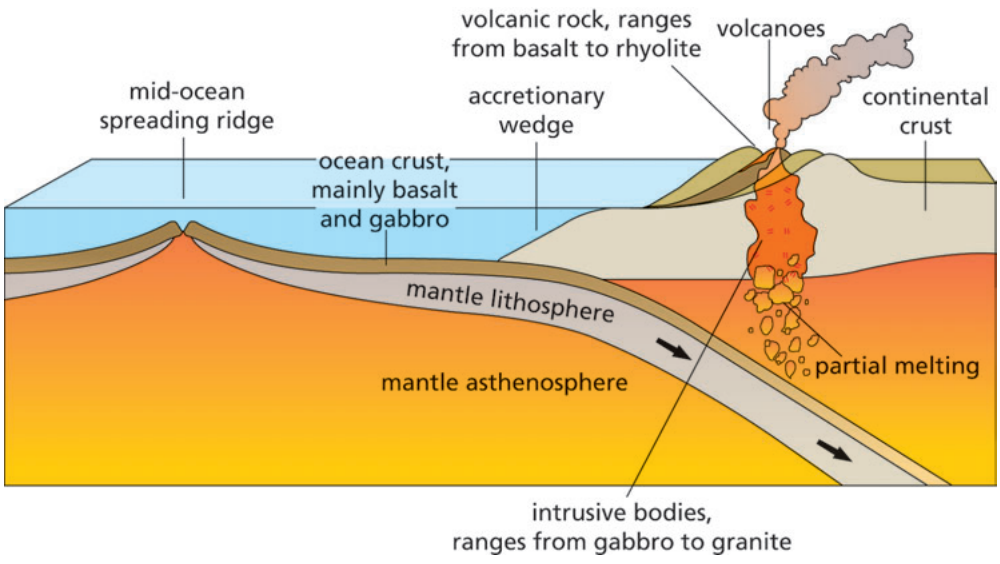


Figure 1 Cross section of a subduction zone showing the locations of igneous rocks that form by the solidification of minerals from cooling magma in various settings. Seafloor spreading typically produces igneous rocks that are closer in composition to the mantle asthenosphere compared to those in continental crust produced by partial melting.

Geo Words

erosion: the wearing away of soil or rock by weathering, mass wasting (downhill movement of material under the influence of gravity), and the action of streams, glaciers, waves, wind, and underground water.

silicate: a compound whose basic structure consists of very tightly bonded units consisting of silicon and oxygen (called silica) that are bonded less strongly to various other atoms.

intrusive igneous rock: an igneous rock formed at considerable depth by the crystallization of magma.

lava: magma that reaches Earth's surface.

extrusive igneous rock: an igneous rock formed by the crystallization of lava that has erupted onto the surface of Earth.

Classifying Igneous Rocks: Texture

The crystal size of an igneous rock largely depends on how fast the magma cools. When magma cools very slowly, only a small number of crystals are formed in a given volume of the magma. However, these crystals have plenty of time to grow large. The resulting igneous rock is coarse grained. The mineral grains are usually several millimeters, or even a few centimeters, in size. See *Figure 2*. On the other hand, when magma is extruded at Earth's surface and cools very rapidly, a large number of crystals are formed in a given volume of the magma. However, there is not enough time for them to grow large. The resulting igneous rock is very fine grained. The mineral grains are usually too small to be seen without a magnifying glass. If the lava cools even more quickly, a glassy-textured rock called obsidian can form. Obsidian forms when magma cools so quickly that crystals do not have time to form.

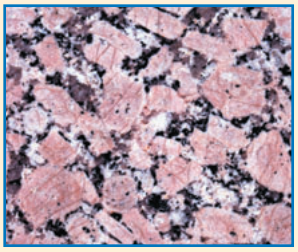


Figure 2 Granite with coarse-grained texture.

Figure 3 Granite with medium-grained texture.

Classifying Igneous Rocks: Chemical and Mineral Composition

The color of an igneous rock is due mainly to its chemical makeup. Therefore, the color depends on what minerals the rock contains. Think of the common minerals found in igneous rocks. Quartz, potassium feldspar, and muscovite mica are light in color. Igneous rocks with high percentages of these minerals tend to be light in color. They are the most common minerals in igneous rocks found in the continental crust. Pyroxenes, amphiboles, plagioclase feldspar, biotite mica, and olivines are darker in color. Igneous rocks with high percentages of these minerals tend to be dark in color.

Igneous rocks that consist mostly of minerals such as quartz, potassium feldspar, and muscovite mica are lighter in color. This is because these minerals contain a lot of silica (silicon and oxygen). They contain little iron and magnesium. Igneous rocks containing these minerals are usually white, light gray, or pink. These rock types, whether intrusive or extrusive, are associated with **lithospheric plates**. They are found where the plates are moving together and magma is formed. Magmas rich in silica do not flow very easily. They usually cool before they reach Earth's surface, forming granite. Granites found at Earth's surface today formed below the surface long ago. They have been exposed by *uplift* and erosion. Uplift is the slow raising of the crust by large-scale forces acting within Earth. You will read more about this in a later section. If the same magma reaches the surface, it cools quickly. It forms an extrusive igneous rock called rhyolite.

Geo Words

lithospheric plate: a rigid, thin segment of the outermost layer of Earth, consisting of Earth's crust and part of the upper mantle. It can be assumed that the plate moves horizontally and adjoins other plates.

Igneous rocks that contain minerals rich in iron and magnesium (olivines, amphiboles, pyroxenes, and biotite mica) are dark in color. They are typically black to dark green. One extrusive igneous rock of this kind, basalt, is the most common rock on Earth's surface. It is the major rock found in the oceanic crust. Basalt is formed where lithospheric plates are spreading apart. Here magma is rising through a mantle hot spot. These rocks are common in the Hawaiian Islands and Iceland. Gabbro is an intrusive igneous rock that contains minerals rich in iron and magnesium. It is the coarse-grained counterpart of basalt. It is common deep in the oceanic crust.

Some igneous rocks are mixed in chemical makeup. These rocks are made of a mix of minerals that contain iron and magnesium. As a result, they are also mixed in color. Two examples are andesite and diorite. Andesite is an extrusive rock. Diorite is the corresponding intrusive rock. Andesite is named for the Andes Mountains. It is abundant in that area. Diorite often forms where an oceanic lithospheric plate is being subducted beneath a continental lithospheric plate. Water rising up into the mantle from the downward-moving plate causes some of the mantle rock to melt. The magma rises up through the continental plate. There it melts some of the continental rocks, causing it to have a mixed makeup.

Classification of Igneous Rocks

Color		Light	Intermediate	Dark	Dark
Mineral composition		quartz (≥ 5%) plagioclase feldspar potassium feldspar iron-magnesium rich minerals (≤ 15%)	quartz (< 5%) plagioclase feldspar potassium feldspar iron-magnesium rich minerals (15–40%)	no quartz plagioclase feldspar (~50%) no potassium feldspar iron-magnesium rich minerals (~40%)	nearly 100% iron-magnesium rich minerals
Texture	Crystals > 10 mm	granite pegmatite	diorite pegmatite	gabbro pegmatite	
	Crystals 1–10 mm	granite	diorite	gabbro	peridotite
	Crystals < 1 mm	rhyolite	andesite	basalt	
	Glassy	obsidian		obsidian	
	Frothy	pumice		scoria	

Explosive Volcanic Eruptions

Some magmas have a high content of dissolved gases, such as water vapor and carbon dioxide. This is especially true of magmas with high-silica content. When these magmas rise up near Earth's surface, the dissolved gases tend to bubble out of the magma. This happens because the pressure is so much lower at the surface than deep in Earth. Sometimes the pressure is released suddenly by an explosive volcanic eruption.

This was the case at Mt. St. Helens in the Pacific Northwest in 1980. The products of such an eruption are pieces of mineral grains and broken igneous rock, called volcanic ash. In one sense, the rock formed from volcanic ash is a *sedimentary rock* because it is formed by the deposition of material. (You will investigate sedimentary rocks in the next section.) However, because it came directly from a volcano, it is usually considered to be an igneous rock. Pumice is a volcanic rock that consists mainly of bubble holes. There are only thin walls between the holes. Because of its very low density, pumice floats on water.

Figure 4 Pumice sample from Mt. St. Helens.

Checking Up

1. In your own words, describe the difference between an intrusive igneous rock and an extrusive igneous rock.
2. How do the two main types of igneous rocks form?
3. Explain the relationship between the mineral composition of an igneous rock and the color of the rock.
4. Explain how the texture of an igneous rock reveals how the rock formed.

Think About It Again

At the beginning of this section, you were asked the following:

- **In what kinds of environments do igneous rocks form?**
- **In what ways are some igneous rocks different from others?**

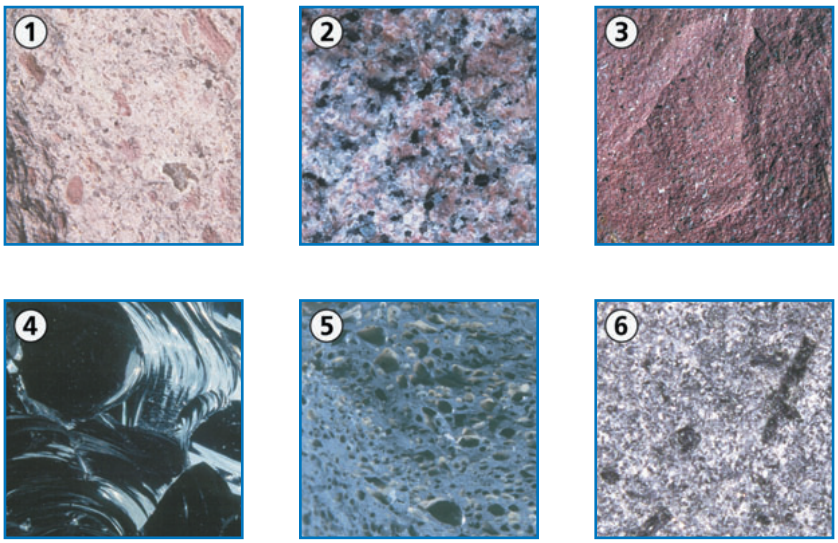
Record your ideas about these questions now. Include a description of the chemical and mineral composition of both intrusive and extrusive igneous rocks in your answer.

Reflecting on the Section and the Challenge

Visitors to your museum exhibit will need to understand that different igneous rocks have different physical and/or chemical properties. Your exhibit will need to explain how the properties of igneous rocks are connected to how these rocks formed over time. You might want to use an animation as part of your exhibit to demonstrate how the igneous rocks formed.

Understanding and Applying

1. Use the photographs of the rocks shown, or obtain several new samples of igneous rocks. Use the Classification of Igneous Rocks table to answer the following questions:
   a) Is the rock light, intermediate, or dark in color?
   b) Is the rock glassy, or does it have fine crystals or coarse crystals?
   c) Is the rock intrusive or extrusive?
   d) What is the name of each rock?



2. Examine the geologic map of your community and the list of igneous rocks that you generated in *Part B* of the *Investigate*.
   a) Did the igneous rocks in your community or area form underground or at Earth's surface? Explain your answer.
   b) Describe any evidence of igneous rocks in your local community.
3. ***Preparing for the Chapter Challenge***

   In your exhibit, you will need to explain where igneous rocks can be found in your region. Use the information you have gathered about the igneous rocks in your local area to explain to museum visitors what geologic processes resulted in the formation of igneous rock in your region.

Inquiring Further

1. **Igneous rocks and famous landscapes**

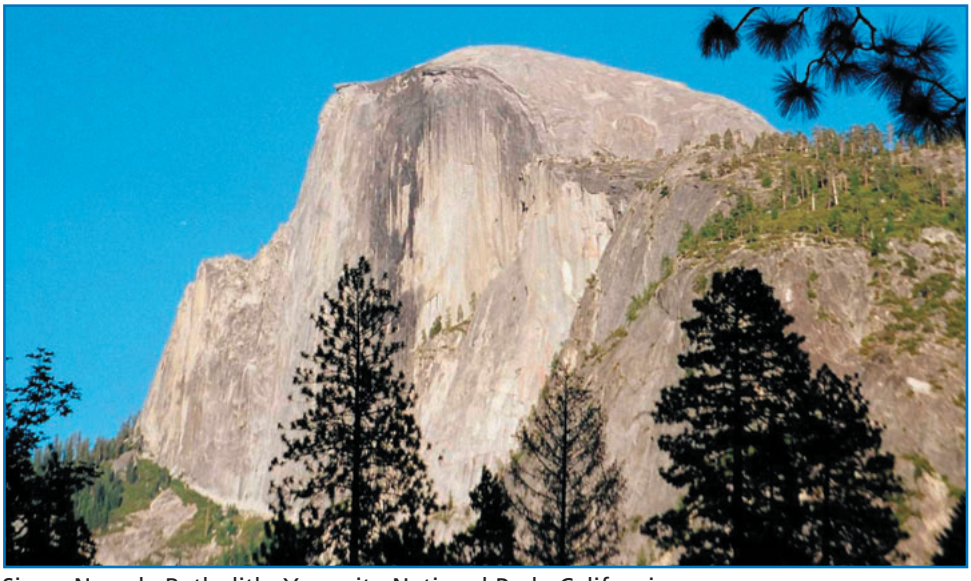
   Investigate one of the following:

   - Ship Rock, New Mexico
   - Sierra Nevada Batholith, Yosemite National Park, California
   - Devil's Postpile National Monument, California

   From what igneous rock is the famous landform made? What does the landform and its rock composition tell you about the geologic history of that location?

Devil's Postpile National Monument, California.

Ship Rock, New Mexico.



Sierra Nevada Batholith, Yosemite National Park, California.