Section Objectives

- **Describe how the cooling rate of magma and lava affects the structure of igneous rocks.**
- **Classify igneous rocks according to their mineral composition.**
- **Describe a number of identifiable igneous rock structures.**

10.2 Igneous Rock

As you have read, when magma cools and hardens, it forms igneous rock. There are two groups of igneous rocks. They are classified according to where the molten rock cools and hardens. The cooling of magma deep below the crust produces **intrusive igneous rocks.** These rocks are so named because the magma that forms them intrudes, or enters, into other rock masses beneath the earth's surface. The magma then slowly cools and hardens to form intrusive igneous rocks. The rapid cooling of lava, or melted rock on the earth's surface, produces **extrusive igneous rocks.** Intrusive and extrusive igneous rocks differ mainly in the size of their crystalline mineral masses or grains. The size of the crystalline grains in igneous rock is called its *texture*. The texture of igneous rocks is largely determined by the cooling rate of the magma or lava that formed the rock.

Texture of Igneous Rocks

Intrusive igneous rocks form when magma cools and hardens slowly deep underground. The slow loss of heat allows time for the minerals in the cooling magma to form large, well-developed crystalline grains. Intrusive igneous rocks composed of large mineral grains have a coarse-grained texture. An example of a coarse-grained rock is granite, shown in Figure 10–4. The core of the continental crust is made of granite.

Granite

Figure 10–4. Notice the coarse-grained texture of this sample of granite, an intrusive igneous rock.

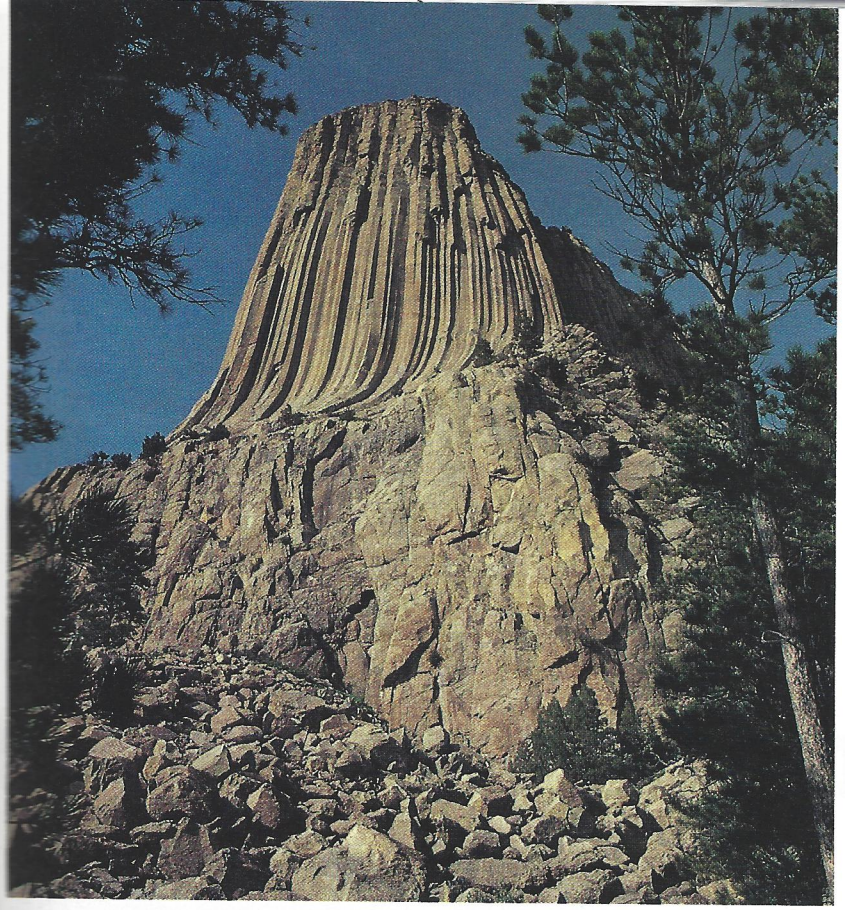
Extrusive igneous rocks form when lava cools rapidly on the earth's surface. The rapid loss of heat to air or sea water does not allow time for large crystalline grains to form, and thus it produces fine-grained rock. Most extrusive igneous rocks are composed of small mineral grains that cannot be seen by the unaided eye. An example of a common fine-grained igneous rock is basalt. Figure 10–5 shows Devils Tower in Wyoming, which is composed of basalt. The oceanic crust is composed of basalt.

Some intrusive igneous rocks form from magma that cools slowly at first and then more rapidly as it nears the surface. This type of cooling produces large crystals embedded within a mass of smaller ones. An igneous rock with a mixture of large and small crystals is called a **porphyry** (POR-fuh-ree).

Extremely rapid cooling produces a kind of igneous rock in which crystals were unable to form. The obsidian, or volcanic glass, shown in Figure 10–5 illustrates the glassy appearance of this type of rock. During extremely rapid cooling, gases escaping from the molten material may become trapped in the rock and form many small bubbles. These are evident in the pumice in Figure 10–5.

Composition of Igneous Rocks

The mineral composition of an igneous rock is determined by the chemical composition of the magma from which the rock develops. Different types of igneous rocks have similar mineral compositions.



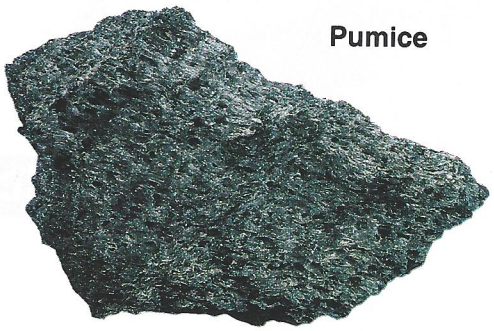


Figure 10–5. Devils Tower (left) in Wyoming, is composed of basalt, a fine-grained igneous rock. Obsidian (top right) has no crystalline structure and thus has a glassy texture. Gases trapped inside magma as it cools give pumice (bottom right) its spongelike appearance. Some pumice samples may actually float in water.

Geologists divide igneous rocks into three families—granite, basalt, and diorite—based on mineral composition.

Rocks in the granite family form from magmas called *felsic,* which are high in silica. Rocks in this family have the light coloring of their main mineral components, orthoclase feldspar and quartz. These rocks may also contain plagioclase feldspar, hornblende, and muscovite mica. In addition to the coarse-grained intrusive rock known as granite, several other rocks are part of the granite family. The fine-grained extrusive rock rhyolite also has the mineral composition that makes it a member of the granite family. Obsidian, or volcanic glass, is of the granite family. It may be bluish, black, or red, depending on its mineral composition.

Rocks in the basalt family form from magmas called *mafic,* which are low in silica but rich in iron. The main mineral components of rocks in this family are plagioclase feldspar and augite. These rocks may also include dark-colored ferromagnesian minerals such as olivine, biotite mica, and hornblende. These three components, along with augite, give basaltic rocks a dark color. The dark gray or black extrusive rock known as basalt is a fine-grained member of this family. Coarse-grained intrusive gabbro is also a member of the basalt family.

The medium-colored rocks of the diorite family are made up of the minerals plagioclase feldspar, hornblende, augite, and biotite mica. Components of rocks in this family include little or no quartz. Rocks in the diorite family include the coarse-grained diorite and the fine-grained andesite. If you know only that an igneous rock has coarse grains, can you identify the family it is in? Why?

Igneous Rock Structures

A number of identifiable rock formations are formed of igneous rock. The underground rock masses made up of intrusive igneous rocks are called *intrusions*. The surface rock masses made up of extrusive igenous rocks are called *extrusions*.

Intrusions

The largest of all intrusions are called **batholiths.** Batholiths are very large masses of igneous rock that cover over 100 square kilometers. The word *batholith* means ''deep rock.'' Batholiths were once thought to extend to great depths. However, studies have shown that many batholiths do have lower boundaries, and they are several thousand meters thick. Batholiths form the cores of many major mountain ranges, such as the Sierra Nevada in California. The largest batholith in North America forms the core of the Coast

Small-Scale Investigation

Crystal Formation

The rate of cooling affects the size of the crystals of minerals found in igneous rock. You can demonstrate this relationship by cooling crystals of Epsom salts at three different rates.

Materials

3 glasses or glass jars, water, ice cubes, 3 large test tubes, small pan, spoon or stirring rod, measuring cup, Epsom salts, stove or hot plate, tongs or test-tube clamp, cork, clock or watch

Procedure

1. In a small sauce pan, mix 120 mL of Epsom salts in 120 mL of water. Heat over low heat. Do not let the mixture boil. Stir until no more crystals will dissolve.
2. Add the following until each glass is 2/3 full: glass 1—water and ice cubes; glass 2—water at room temperature; glass 3—hot tap water
3. Carefully pour equal amounts of the Epsom salts mixture into the 3 test tubes. Use the tongs to steady the test tubes as you pour. Drop a few crystals of Epsom salt into each test tube and gently shake. Place one test tube into each glass.
4. Observe what happens to the solutions as they cool at different rates over the next 10–15 minutes. Let the glasses sit overnight, and examine the solutions again after 24 hours.

Analysis and Conclusions

1. In which test tube are the crystals the largest? the smallest?
2. How does the rate of cooling affect the size of crystals formed? Explain your answer.
3. How would you change the procedure to obtain even larger crystals of Epsom salts? Why?
4. Some igneous rocks that are thrown out of a volcano contain large crystals surrounded by very small ones. Based on your observations in this activity, explain why the crystals are different sizes.

Range in British Columbia. A **stock,** illustrated in Figure 10–6, is an intrusion similar to a batholith that covers less than 100 square kilometers.

When magma flows between rock layers and spreads upward, it sometimes pushes the overlying rock layers into an arc. The floor of the intrusion is parallel to the rock layer beneath it. This type of intrusion is called a **laccolith.** *Laccolith* means "lake of rock." Laccoliths are frequently found in groups. You can sometimes identify them by the small dome-shaped mountains they push up on the earth's surface. Many laccoliths are located beneath the Black Hills of South Dakota.

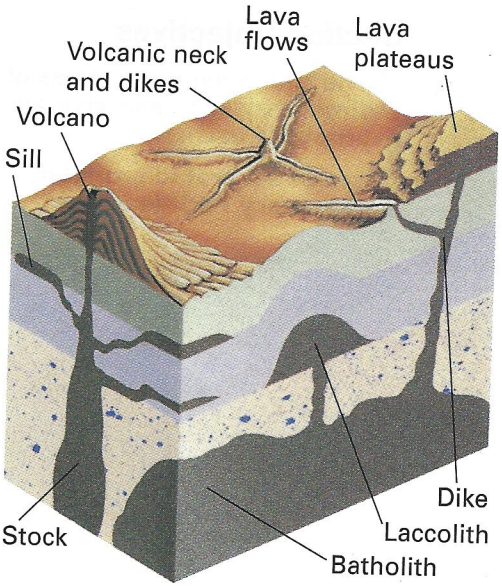
When a sheet of magma flows between the layers of rock and hardens, a **sill** is formed. A sill lies parallel to the rock layers surrounding it, even if the layers are tilted. Sills vary in thickness from a few centimeters to hundreds of meters and can extend laterally for several kilometers. Big Bend National Park in Texas has excellent examples of sills.

Magma sometimes forces its way through rock layers by following existing vertical fractures or by creating new ones. When the magma solidifies, a **dike** is formed. Dikes differ from sills in that they cut across rock layers rather than lying parallel to the rock layers. Dikes are common in areas of volcanic activity.

Extrusions

When lava erupts onto the earth's surface, it often forms a *volcano*. A volcano is a cone of extrusive rock surrounding a central vent through which the lava flows. When the eruption stops, the lava in the vent cools and solidifies. When a volcano stops erupting for a long period, its cone gradually wears away. Eventually the softer parts of the cone are carried away by wind and water, and only the hard, solidified rock in the vent remains. The solidified central vent is called a **volcanic neck.** Narrow dikes that sometimes radiate out from the neck may also be exposed. A dramatic example of a volcanic neck, called *Shiprock,* is located in New Mexico.

Extrusive rock may also take other forms. Many extrusions are simply flat masses of rock called *lava flows*. Some extrusions, however, take the form known as a **lava plateau.** A lava plateau develops from lava that flows out of long cracks in the earth's surface. The lava then spreads over a vast area, filling in valleys and covering hills. When the lava hardens, it forms a plateau.



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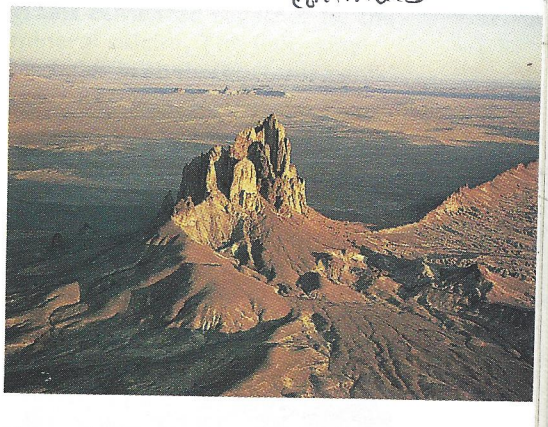

Figure 10–6. Intrusions and extrusions formed from igneous rocks create a number of characteristic landforms (top). Shiprock, in New Mexico, is an example of a volcanic neck and dikes exposed by erosion.

Section 10.2 Review

1. What determines whether an igneous rock will have large crystals or small crystals?
2. Name the three families of igneous rocks.
3. What is a batholith?
4. An unidentified light-colored igneous rock is made up of orthoclase feldspar and quartz. To what family of igneous rocks does it belong? Explain your answer.