Section 5.2

Objectives

- **Classify** different types and textures of igneous rocks.
- **Recognize** the effects of cooling rates on the grain sizes in igneous rocks.
- **Describe** some uses of igneous rocks.

Review Vocabulary

fractional crystallization: a sequential process during which early formed crystals are removed from the melt and do not react with the remaining magma.

New Vocabulary

intrusive rock
extrusive rock
basaltic rock
granitic rock
texture
porphyritic texture
vesicular texture
pegmatite
kimberlite

Classification of Igneous Rocks

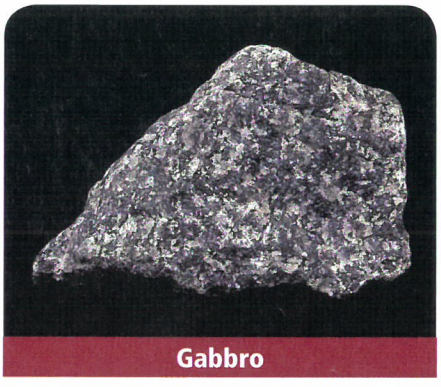
MAIN Idea **Classification of igneous rocks is based on mineral composition, crystal size, and texture.**

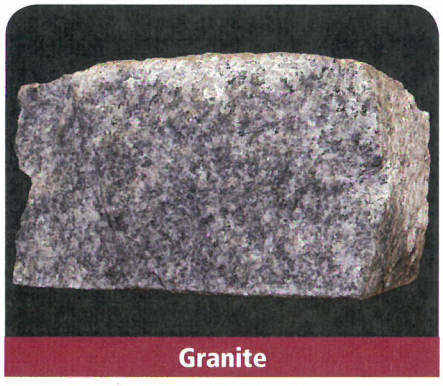
Real-World Reading Link Many statues, floors, buildings, and countertops have something in common. Many of them are made of the popular rock type granite—one of the most abundant rocks in Earth's crust.

Mineral Composition of Igneous Rocks

Igneous rocks are broadly classified as intrusive or extrusive. When magma cools and crystallizes below Earth's surface, **intrusive rocks** form. If the magma is injected into the surrounding rock, it is called an igneous intrusion. Crystals of intrusive rocks are generally large enough to see without magnification. Magma that cools and crystallizes on Earth's surface forms **extrusive rocks.** These are sometimes referred to as lava flows or flood basalts. The crystals that form in these rocks are small and difficult to see without magnification. Geologists classify these rocks by their mineral compositions. In addition, physical properties such as grain size and texture serve as clues for the identification of various igneous rocks.

Igneous rocks are classified according to their mineral compositions. **Basaltic rocks,** such as gabbro, are dark-colored, have lower silica contents, and contain mostly plagioclase and pyroxene. **Granitic rocks,** such as granite, are light-colored, have high silica contents, and contain mostly quartz, potassium feldspar, and plagioclase feldspar. Rocks that have a composition of minerals that is somewhere in between basaltic and granitic are called intermediate rocks. They consist mostly of plagioclase feldspar and hornblende. Diorite is a good example of an intermediate rock. **Figure 5.8** shows examples from these three main compositional groups of igneous rocks. A fourth category, called ultrabasic, contains the rock peridotite. These rocks contain only iron-rich minerals such as olivine and pyroxene and are always dark. **Figure 5.9** summarizes igneous rock identification.


Gabbro


Granite

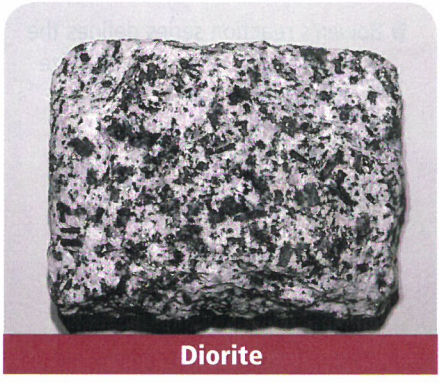
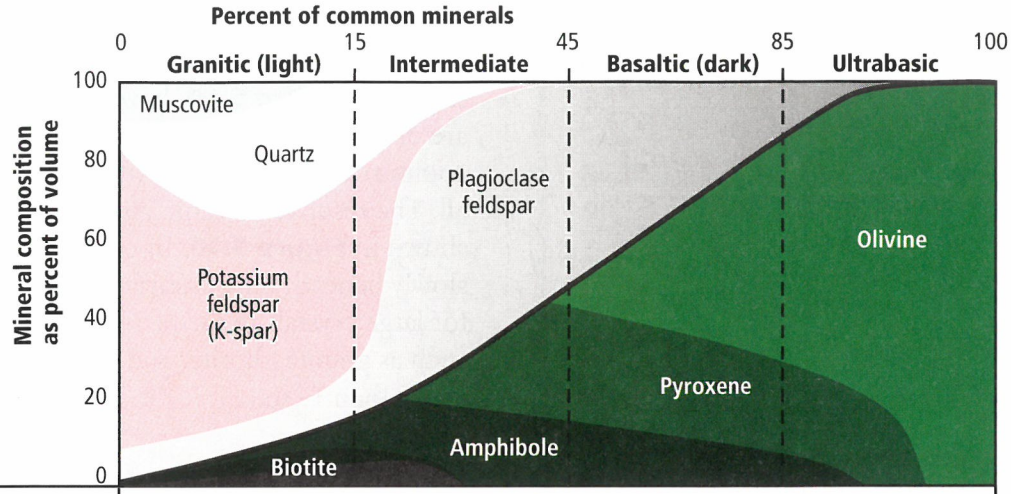

Diorite

Figure 5.8 Differences in magma composition can be observed in the rocks that form when the magma cools and crystallizes.
Observe *Describe the differences you see in these rocks.*



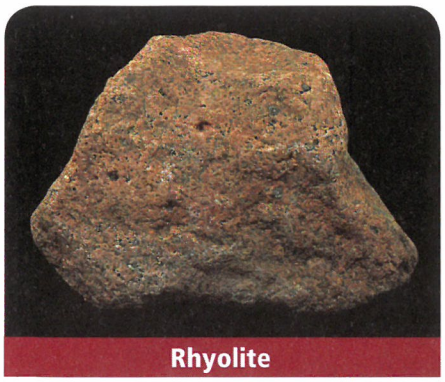
Origin	Texture	Rock Names			
Intrusive	coarse-grained	granite	diorite	gabbro	peridotite
Extrusive	porphyritic	porphyritic rhyolite or granite	porphyritic andesite or diorite	porphyritic basalt or gabbro	
	fine-grained	rhyolite	andesite	basalt	
	glassy	obsidian			
	vesicular	pumice		scoria (vesicular basalt)	

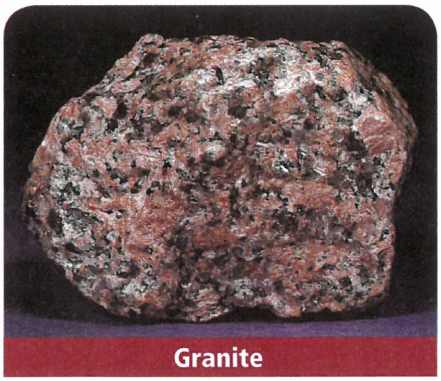
■ **Figure 5.9** Rock type can be determined by estimating the relative percentages of minerals in the rocks.

Texture

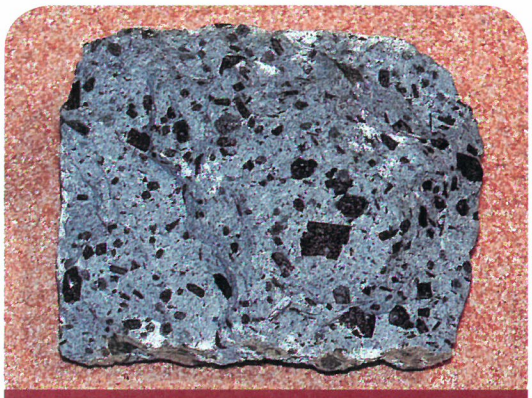
In addition to differences in their mineral compositions, igneous rocks differ in the sizes of their grains or crystals. **Texture** refers to the size, shape, and distribution of the crystals or grains that make up a rock. For example, as shown in **Figure 5.10,** the texture of rhyolite can be described as fine-grained, while granite can be described as coarse-grained. The difference in crystal size can be explained by the fact that one rock is extrusive and the other is intrusive.

■ **Figure 5.10** Rhyolite, granite, and obsidian have different textures because they formed in different ways.


Rhyolite

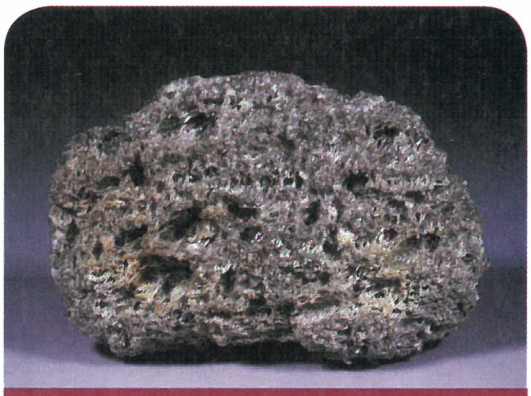

Granite

Obsidian



Porphyry

Vesicular basalt



Pumice

Figure 5.11 Rock textures provide information about a rock's formation. Evidence of the rate of cooling and the presence or absence of dissolved gases is preserved in the rocks shown here.

Crystal size and cooling rates When lava flows on Earth's surface, it cools quickly and there is not enough time for large crystals to form. The resulting extrusive igneous rocks, such as rhyolite, which is shown in **Figure 5.10,** have crystals so small that they are difficult to see without magnification. Sometimes, cooling occurs so quickly that crystals do not form at all. The result is volcanic glass, called obsidian, also shown in **Figure 5.10.** In contrast, when magma cools slowly beneath Earth's surface, there is sufficient time for large crystals to form. Thus, intrusive igneous rocks, such as granite, diorite, and gabbro, can have crystals larger than 1 cm.

Porphyritic rocks Look at the textures of the rocks shown in **Figure 5.11.** The top photo shows a rock with two different crystal sizes. This rock has a **porphyritic** (por fuh RIH tihk) **texture,** which is characterized by large, well-formed crystals surrounded by finer-grained crystals of the same mineral or different minerals.

What causes minerals to form both large and small crystals in the same rock? Porphyritic textures indicate a complex cooling history during which a slowly cooling magma suddenly began cooling rapidly. Imagine a magma body cooling slowly, deep in Earth's crust. As it cools, the first crystals to form grow large. If this magma were to be suddenly moved higher in the crust, or if it erupted onto Earth's surface, the remaining magma would cool quickly and form smaller crystals.

Vesicular rocks Magma contains dissolved gases that escape when the pressure on the magma lessens. If the lava is thick enough to prevent the gas bubbles from escaping, holes called vesicles are left behind. The rock that forms looks spongy. This spongy appearance is called **vesicular texture.** Pumice and vesicular basalt are examples shown in **Figure 5.11.**

Reading Check **Explain** what causes holes to form in igneous rocks.

Thin Sections

It is usually easier to observe the sizes of mineral grains than it is to identify the mineral. To identify minerals, geologists examine samples that are called thin sections. A thin section is a slice of rock, generally 2 cm × 4 cm and only 0.03 mm thick. Because it is so thin, light is able to pass through it.

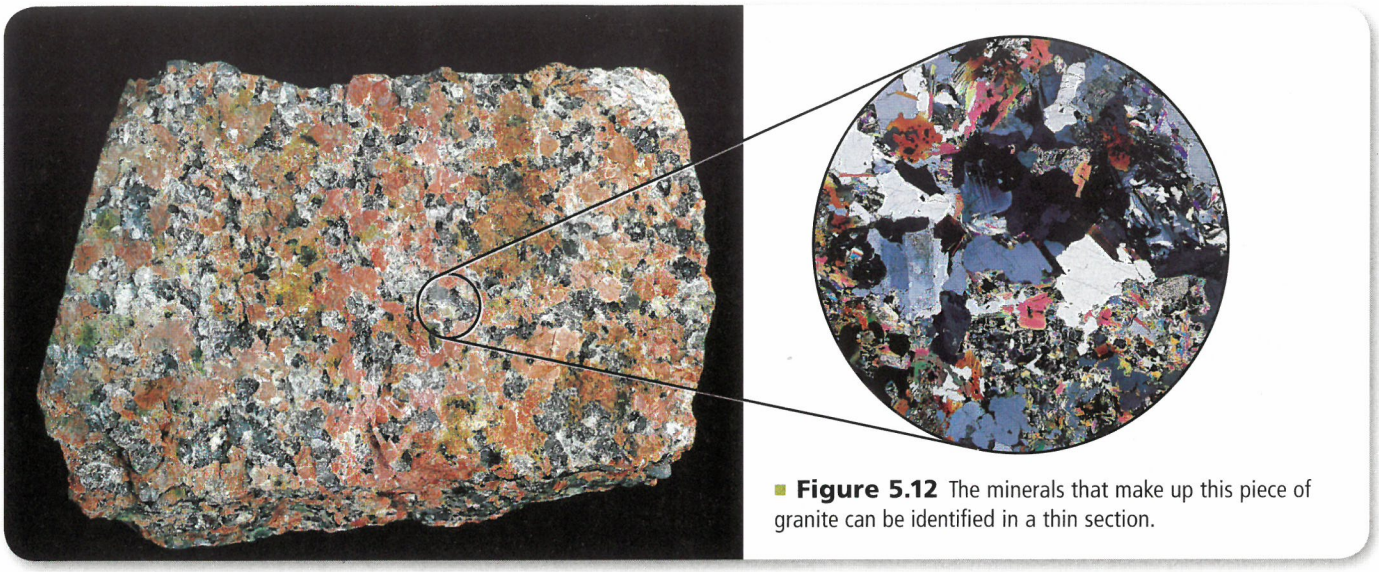


Figure 5.12 The minerals that make up this piece of granite can be identified in a thin section.

When viewed through a special microscope, called a petrographic microscope, mineral grains exhibit distinct properties. These properties allow geologists to identify the minerals present in the rock. For example, feldspar grains often show a distinct banding called twinning. Quartz grains might appear wavy as the microscope stage is rotated. Calcite crystals become dark, or extinguish, as the stage is rotated. **Figure 5.12** shows the appearance of a thin section of granite under a petrographic microscope.

Igneous Rocks as Resources

The cooling and crystallization history of igneous rocks sometimes results in the formation of unusual but useful minerals. These minerals can be used in many fields, including construction, energy production, and jewelry making. Some of these uses are described in the following paragraphs.

Veins As you learned in Chapter 4, ores are minerals that contain a useful material that can be mined for a profit. Valuable ore deposits often occur within igneous intrusions. At other times, ore minerals are found in the rocks surrounding intrusions. These types of deposits sometimes occur as veins. Recall from Bowen's reaction series that the fluid left during magma crystallization contains high levels of silica and water. This fluid also contains any leftover elements that were not incorporated into the common igneous minerals. Some important metallic elements that are not included in common minerals are gold, silver, lead, and copper. These elements, along with the dissolved silica, are released at the end of magma crystallization in a hot, mineral-rich fluid that fills cracks and voids in the surrounding rock. This fluid solidifies to form metal-rich quartz veins, such as the gold-bearing veins in the Sierra Nevada. An example of gold formed in a quartz vein is shown in **Figure 5.13.**

Reading Check **Explain** why veins have high amounts of quartz.

Figure 5.13 Gold and quartz are extracted from mines together. The two are later separated.

Infer ***What can you determine from this photo about the melting temperature of gold?***

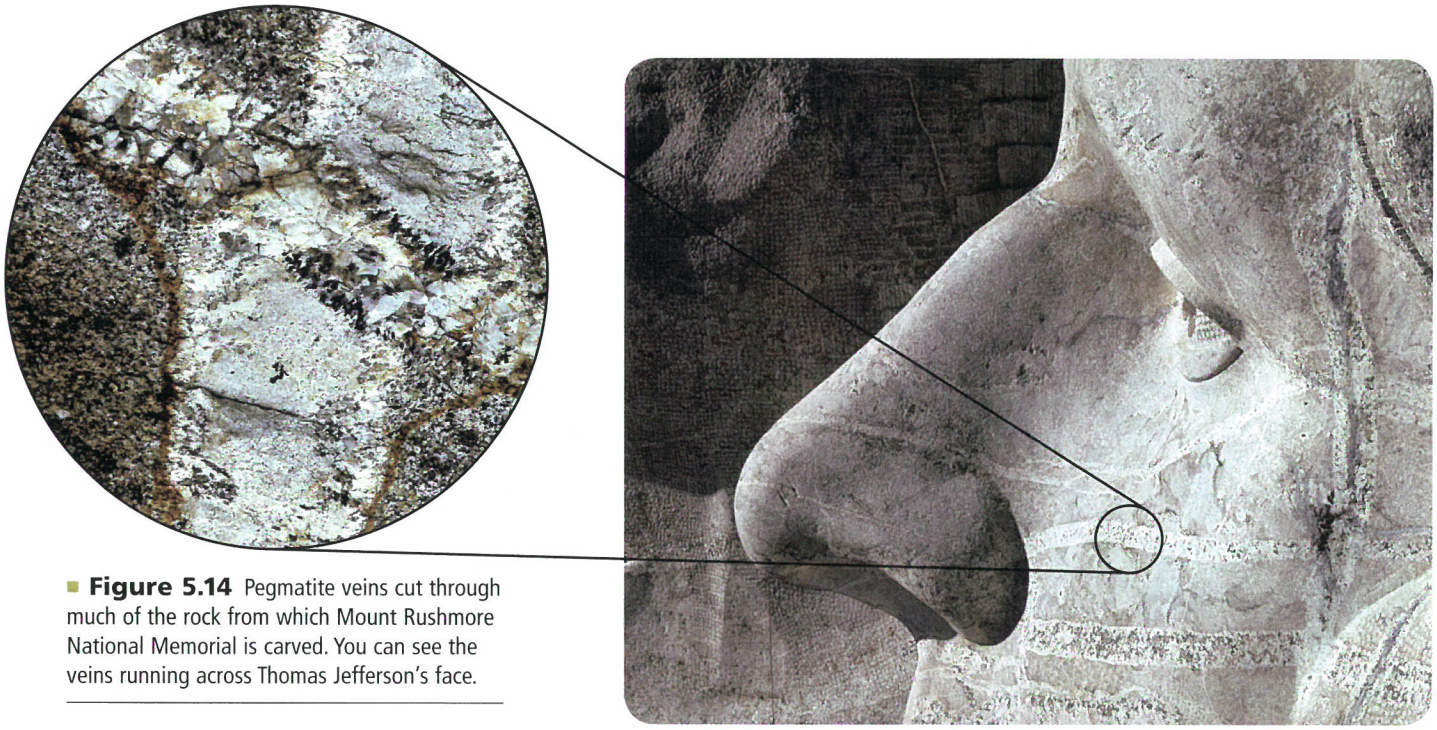


Figure 5.14 Pegmatite veins cut through much of the rock from which Mount Rushmore National Memorial is carved. You can see the veins running across Thomas Jefferson's face.

Pegmatites Vein deposits can contain other valuable resources in addition to metals. Veins of extremely large-grained minerals are called **pegmatites.** Ores of rare elements, such as lithium (Li) and beryllium (Be), form in pegmatites. In addition to ores, pegmatites can produce beautiful crystals. Because these veins fill cavities and fractures in rock, minerals grow into voids and retain their shapes. Some of the world's most beautiful minerals have been found in pegmatites. A famous pegmatite is the rock source for the Mount Rushmore National Memorial located near Keystone, South Dakota. A close-up view of President Thomas Jefferson, shown in **Figure 5.14,** reveals the huge mineral veins that run through the rock.

PROBLEM-SOLVING LAB

Interpret Scientific Illustrations

How do you estimate mineral composition? Igneous rocks are classified by their mineral compositions. In this activity, you will use the thin section in **Figure 5.12** to estimate the different percentages of minerals in the sample.

Analysis

1. Design a method to estimate the percentages of the minerals in the rock sample shown in **Figure 5.12.**
2. Make a data table that lists the minerals and their estimated percentages.

Think Critically

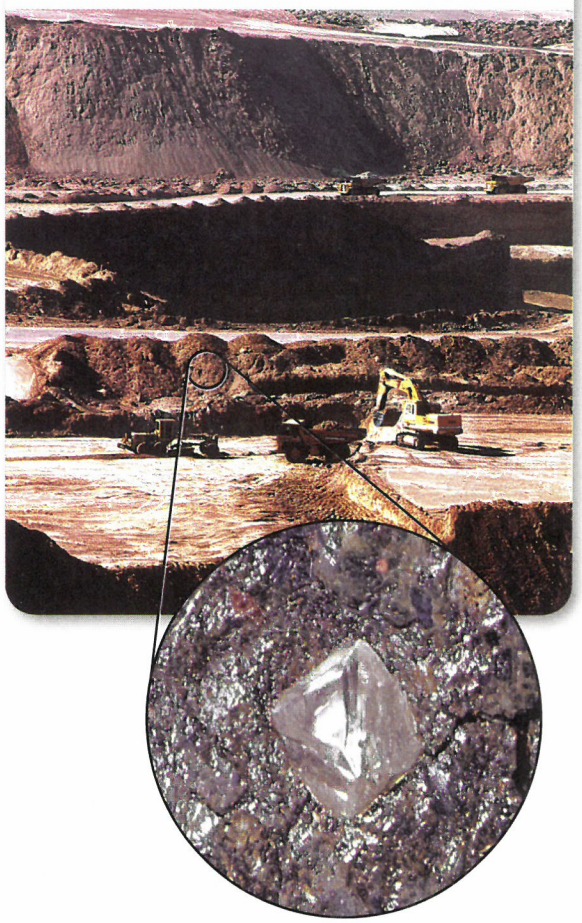
3. **Interpret Figure 5.9** to determine where in the chart this rock sample fits.
4. **Compare** your estimates of the percentages of minerals in the rock with those of your classmates. Why do the estimates vary? What are some possible sources of error?
5. **Propose** a method to improve the accuracy of your estimate.

Kimberlites Diamond is a valuable mineral found in rare, ultrabasic rocks known as **kimberlites,** named after Kimberly, South Africa, where the intrusions were first identified. These unusual rocks are a variety of peridotite. They most likely form deep in the crust or in the mantle at depths of 150 to 300 km, because diamond and other minerals present in kimberlites can form only under very high pressure.

Geologists hypothesize that kimberlite magma is intruded rapidly upward toward Earth's surface, forming long, narrow, pipelike structures. These structures extend many kilometers into the crust, but they are only 100 to 300 m in diameter. Most of the world's diamonds come from South African mines, such as the one shown in **Figure 5.15.** Many kimberlites have been discovered in the United States, but diamonds have been found only in Arkansas and Colorado. The diamond mine in Colorado is the only diamond mine currently in operation in the United States.

Igneous rocks in construction Igneous rocks have several characteristics that make them especially useful as building materials. The interlocking grain textures of igneous rocks make them strong. In addition, many of the minerals present in igneous rocks are resistant to weathering. Granite is among the most durable of igneous rocks. You have probably seen many items, such as countertops, floors, and statues, made from the wide variety of granite that has formed on Earth.

Figure 5.15 Diamonds are mined from kimberlite in mines like this one in Richtersveld, Northern Cape, South Africa.



Section 5.2 Assessment

Section Summary

- Classification of igneous rocks is based on three main characteristics.
- The rate of cooling determines crystal size.
- Ores often occur in pegmatites. Diamonds occur in kimberlites.
- Some igneous rocks are used as building materials because of their strength, durability, and beauty.

Understand Main Ideas

1. MAIN Idea **Infer** why obsidian, which is black or red in color, can have a granitic composition.
2. **Describe** the three major compositional groups of igneous rocks.
3. **Apply** what you know about cooling rates to explain differences in crystal sizes.
4. **Distinguish** between andesite and diorite using two physical properties of igneous rocks.

Think Critically

5. **Speculate** why there are almost no extrusive ultrabasic rocks in Earth's crust.
6. **Determine** whether quartz or plagioclase feldspar is more likely to form a well-shaped crystal in an igneous rock. Explain.

MATH in Earth Science

7. A granite slab has a density of 2.7 g/cm^3. What is the mass of a 2-cm-thick countertop that is 0.6 m $\times$ 2.5 m? How many grams is this?

Earth Science and the Environment

Moon Rocks

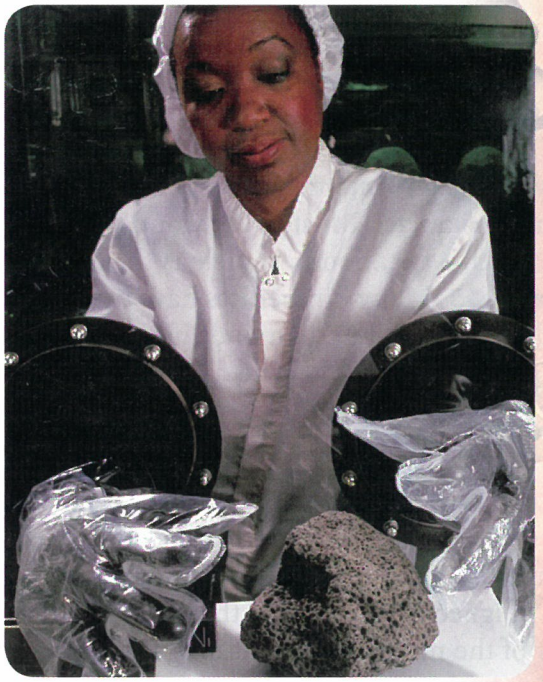
During each of the six Apollo missions, lunar rocks were collected with the hope of providing information about the Moon's origin, history, and environment. How do moon rocks compare with rocks on Earth?

Moon rock types Between 1969 and 1972, astronauts collected approximately 380 kg of lunar rocks. The 2415 individual pieces range in size from a grain of sand to a basketball.

Generally, moon rocks vary in color from gray to black to white to green. Some rocks are glassy, some are hard, and others are fragile. Analysis of the rocks has revealed at least three different rock types on the Moon. Basaltic rocks formed from lava flows and volcanic ash that reached the surface through cracks and fissures caused by meteorite impacts. Breccias formed when meteorites shattered rocks and then fused the pieces together with the heat generated by the impact. Pristine rock is rock that has not been hit by meteorites. Pristine rock is commonly composed of calcium-rich plagioclase feldspar and is gray in color.

Moon rock composition Moon rocks are unique in two ways. First, they contain no water and are not oxidized. Considering how much iron is contained in the rocks, this is a sharp contrast to weathered and rusty iron-bearing rocks on Earth. Second, the surfaces of some moon rocks are covered with tiny pockmarks called zap pits. These are caused by micrometeoroids that impact the rocks on the Moon's surface. Zap pits do not occur on Earth rocks because friction from Earth's atmosphere causes tiny meteoroids to burn up long before they reach Earth's surface.

Moon rock classification Scientists use the same categories for classifying lunar rocks as they use for igneous rocks on Earth.



This scientist is studying a piece of basalt that was collected from the lunar surface during the *Apollo 15* mission.

Based on mineral composition, scientists named a new class of moon rocks called KREEP rocks. These contain high amounts of potassium (K), rare Earth elements (REE), and phosphorus (P). These rocks are more radioactive and higher in thorium than Earth rocks.

Moon rock research Lunar rock research continues at the Johnson Space Center in Houston, Texas. The rocks are protected in stainless steel vaults in a dry nitrogen atmosphere to keep them moisture- and rust-free. Scientists continue to pose questions about these rocks as they study the Moon's origin and history.

WRITING in Earth Science

Lunar Rock Game Use resources to design a game that involves the collection and analysis of lunar rocks by scientists. Trade games with classmates to increase your understanding of lunar rocks.