Earth's Minerals

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CHAPTER 1 Earth's Minerals

CHAPTER OUTLINE

Scientists have discovered more than 4,000 minerals in Earth's crust. Some minerals are found in very large amounts. Most minerals are found in small amounts. Some are very rare. Some are common. Many minerals are useful. Modern society depends on minerals and rocks that are mined. Mining is difficult work, but is necessary for us to have the goods we use.

1.1 Minerals

Lesson Objectives

- Describe the properties that all minerals share.
- Describe some different crystal structures of minerals.
- Identify the groups in which minerals are classified.

Vocabulary

- atom
- chemical compound
- crystal
- compound
- electron
- element
- ion
- matter
- mineral
- molecule
- neutron
- nucleus
- proton
- silicate

Introduction

You use objects that are made from minerals every day, even if you do not realize it. You are actually eating a mineral when you eat food that contains salt. You are drinking from a mineral when you drink from a glass. You might wear silver jewelry. The shiny metal silver, the white grains of salt, and the clear glass may not seem to have much in common, but they are all made from minerals (**Figure** 1.1). Silver is a mineral. Table salt is the mineral halite. Glass is produced from the mineral quartz.

Just looking at that list you see that minerals are very different from each other. If minerals are so different, what do all minerals have in common?

What is Matter?

To understand minerals, we must first understand matter. **Matter** is the substance that physical objects are made of.

FIGURE 1.1
Silver is used to make sterling silver jewelry. Table salt is the mineral halite. Glass is produced from the mineral quartz.

Atoms and Elements

The basic unit of matter is an **atom**. At the center of an atom is its **nucleus**. **Protons** are positively charged particles in the nucleus. Also in the nucleus are **neutrons** with no electrical charge. Orbiting the nucleus are tiny electrons. **Electrons** are negatively charged. An atom with the same number of protons and electrons is electrically neutral. If the atom has more or less electrons to protons it is called an **ion**. An ion will have positive charge if it has more protons than electrons. It will have negative charge if it has more electrons than protons.

An atom is the smallest unit of a chemical **element**. That is, an atom has all the properties of that element. All atoms of the same element have the same number of protons.

Molecules and Compounds

A **molecule** is the smallest unit of a **chemical compound**. A compound is a substance made of two or more elements. The elements in a chemical compound are always present in a certain ratio.

Water is probably one of the simplest compounds that you know. A water molecule is made of two hydrogen atoms and one oxygen atom (**Figure** 1.2). All water molecules have the same ratio: two hydrogen atoms to one oxygen atom.

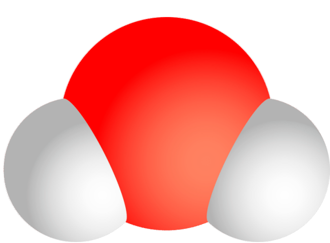

FIGURE 1.2
A water molecule has two hydrogen atoms (shown in gray) bonded to one oxygen molecule (shown in red).

What are Minerals?

A **mineral** is a solid material that forms by a natural process. A mineral can be made of an element or a compound. It has a specific chemical composition that is different from other minerals. One mineral's physical properties differ from others'. These properties include crystal structure, hardness, density and color. Each is made of different elements. Each has different physical properties. For example, silver is a soft, shiny metal. Salt is a white, cube-shaped crystal. Diamond is an extremely hard, translucent crystal.

Natural Processes

Minerals are made by natural processes. The processes that make minerals happen in or on the Earth. For example, when hot lava cools, mineral crystals form. Minerals also precipitate from water. Some minerals grow when rocks are exposed to high pressures and temperatures.

Could something like a mineral be made by a process that was not natural? People make gemstones in a laboratory. Synthetic diamond is a common one. But that stone is not a mineral. It was not formed by a natural process.

Inorganic Substances

A mineral is an inorganic substance. It was not made by living organisms. Organic substances contain carbon. Some organic substances are proteins, carbohydrates, and oils. Everything else is inorganic. In a few cases, living organisms make inorganic materials. The calcium carbonate shells made by marine animals are inorganic.

Definite Composition

All minerals have a definite chemical makeup. A few minerals are made of only one kind of element. Silver is a mineral made only of silver atoms. Diamond and graphite are both made only of the element carbon.

Minerals that are not pure elements are made of chemical compounds. For example, the mineral quartz is made of the compound silicon dioxide, or SiO_2. This compound has one atom of the element silicon for every two atoms of the element oxygen.

Each mineral has its own unique chemical formula. For example, the mineral hematite has two iron atoms for every three oxygen atoms. The mineral magnetite has three iron atoms for every four oxygen atoms. Many minerals have very complex chemical formulas that include several elements. However, even in more complicated compounds, the elements occur in definite ratios.

Solid Crystals

Minerals must be solid. For example, ice and water have the same chemical composition. Ice is a solid, so it is a mineral. Water is a liquid, so it is not a mineral.

Some solids are not crystals. Glass, or the rock obsidian, are solid but not crystals. In a **crystal**, the atoms are arranged in a pattern. This pattern is regular and it repeats. **Figure** 1.3 shows how the atoms are arranged in halite (table salt). Halite contains atoms of sodium and chlorine in a pattern. Notice that the pattern goes in all three dimensions.

The pattern of atoms in all halite is the same. Think about all of the grains of salt that are in a salt shaker. The atoms are arranged in the same way in every piece of salt.

Sometimes two different minerals have the same chemical composition. But they are different minerals because they have different crystal structures. Diamonds are beautiful gemstones because they are very pretty and very hard.

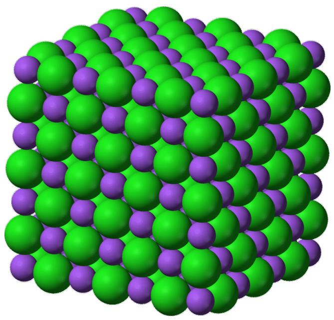

FIGURE 1.3
Sodium ions (purple balls) bond with chloride ions (green balls) to form halite crystals.

Graphite is the "lead" in pencils. It's not hard at all! Amazingly, both are made just of carbon. Compare the diamond with the pencil lead in **Figure** 1.4. Why are they so different? The carbon atoms in graphite bond to form layers. The bonds between each layer are weak. The carbon sheets can just slip past each other. The carbon atoms in diamonds bond together in all three directions. This strong network makes diamonds very hard.

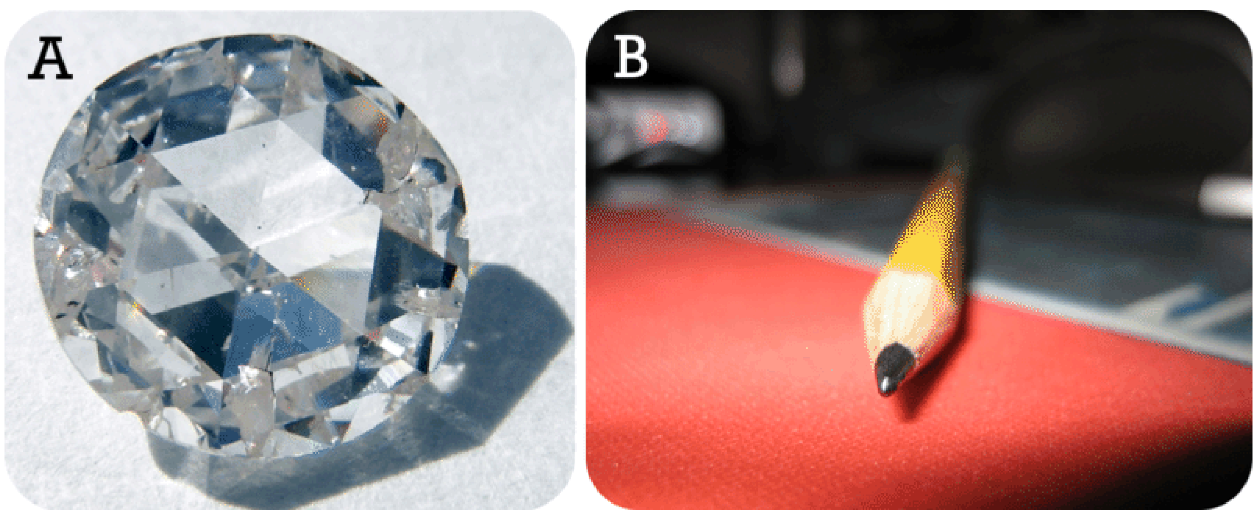

FIGURE 1.4
Diamonds (A) and graphite (B) are both made of only carbon, but they're not much alike.

Physical Properties

The patterns of atoms that make a mineral affect its physical properties. A mineral's crystal shape is determined by the way the atoms are arranged. For example, you can see how atoms are arranged in halite in **Figure** 1.3. You can see how salt crystals look under a microscope in **Figure** 1.5. Salt crystals are all cubes whether they're small or large.

Other physical properties help scientists identify different minerals. They include:

- Color: the color of the mineral.
- Streak: the color of the mineral's powder.

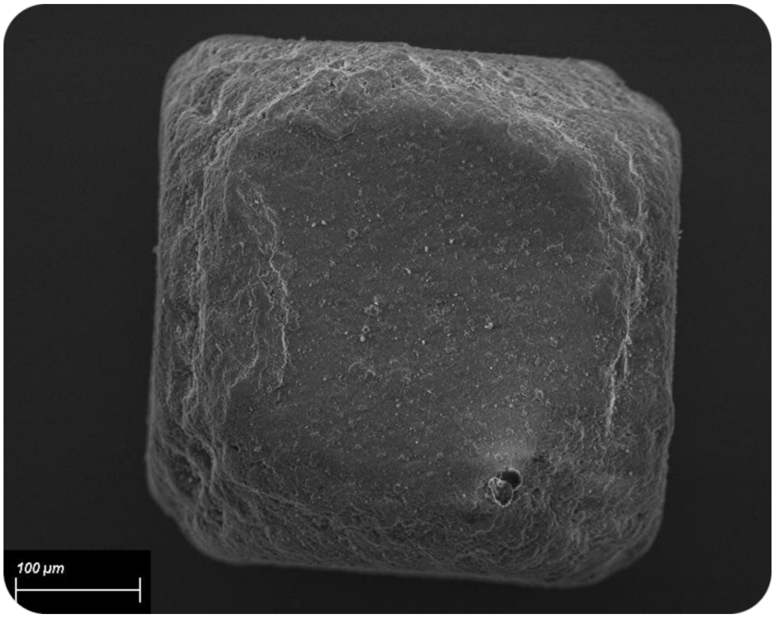

FIGURE 1.5
Under a microscope, salt crystals are cubes.

- Luster: the way light reflects off the mineral's surface.
- Specific gravity: how heavy the mineral is relative to the same volume of water.
- Cleavage: the mineral's tendency to break along flat surfaces.
- Fracture: the pattern in which a mineral breaks.
- Hardness: what minerals it can scratch and what minerals can scratch it.

Groups of Minerals

Imagine you are in charge of organizing more than 100 minerals for a museum exhibit. People can learn a lot more if they see the minerals together in groups. How would you group the minerals together in your exhibit?

Mineralogists are scientists who study minerals. They divide minerals into groups based on chemical composition. Even though there are over 4,000 minerals, most minerals fit into one of eight mineral groups. Minerals with similar crystal structures are grouped together.

Silicate Minerals

About 1,000 silicate minerals are known. This makes silicates the largest mineral group. Silicate minerals make up over 90 percent of Earth's crust!

Silicates contain silicon atoms and oxygen atoms. One silicon atom is bonded to four oxygen atoms. These atoms form a pyramid (**Figure** 1.6). The silicate pyramid is the building block of silicate minerals. Most silicates contain other elements. These elements include calcium, iron, and magnesium.

Silicate minerals are divided into six smaller groups. In each group, the silicate pyramids join together differently. The pyramids can stand alone. They can form into connected circles called rings. Some pyramids link into single and double chains. Others form large, flat sheets. Some join in three dimensions.

Feldspar and quartz are the two most common silicates. In beryl, the silicate pyramids join together as rings. Biotite is mica. It can be broken apart into thin, flexible sheets. Compare the beryl and the biotite shown in **Figure** 1.7.

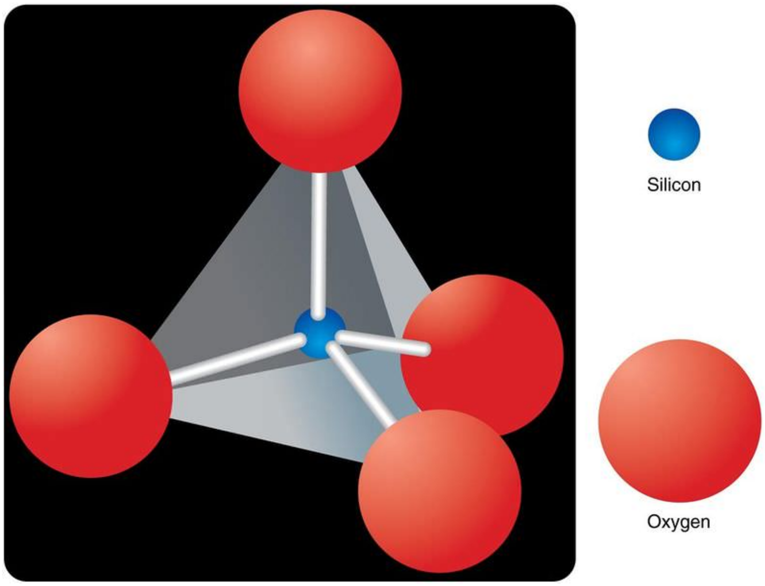

FIGURE 1.6
One silicon atom bonds to four oxygen atoms to form a pyramid

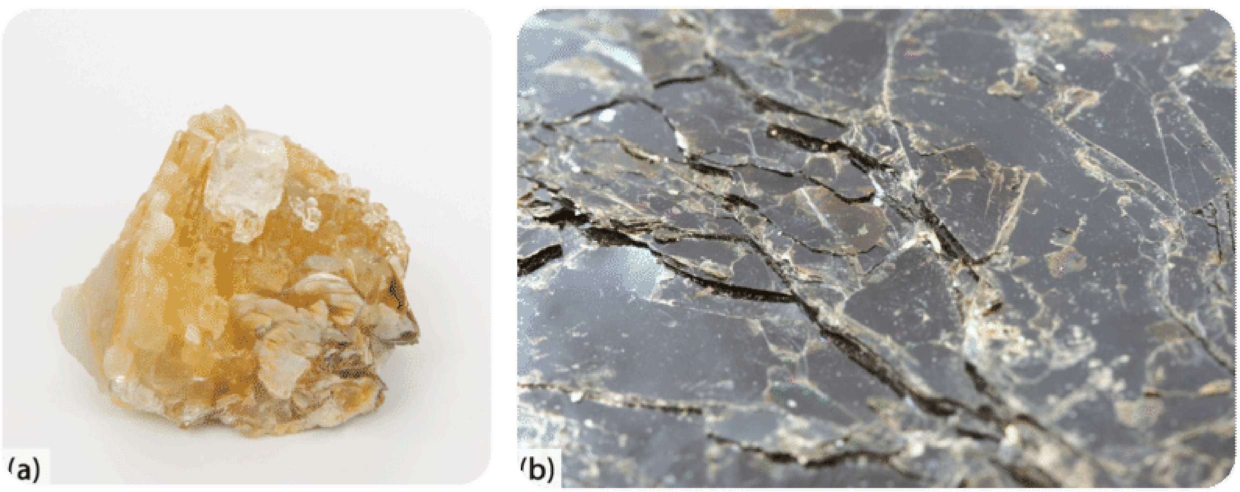

FIGURE 1.7
Beryl (a) and biotite (b) are both silicate minerals.

Native Elements

Native elements contain only atoms of one type of element. They are not combined with other elements. There are very few examples of these types of minerals. Some native elements are rare and valuable. Gold, silver, sulfur, and diamond are examples.

Carbonates

What do you guess **carbonate** minerals contain? If you guessed carbon, you would be right! All carbonates contain one carbon atom bonded to three oxygen atoms. Carbonates may include other elements. A few are calcium, iron, and copper.

Carbonate minerals are often found where seas once covered the land. Some carbonate minerals are very common. Calcite contains calcium, carbon, and oxygen. Have you ever been in a limestone cave or seen a marble tile? Calcite is in both limestone and marble. Azurite and malachite are also carbonate minerals, but they contain copper instead of calcium. They are not as common as calcite. They are used in jewelry. You can see in **Figure** 1.8 that they are very colorful.

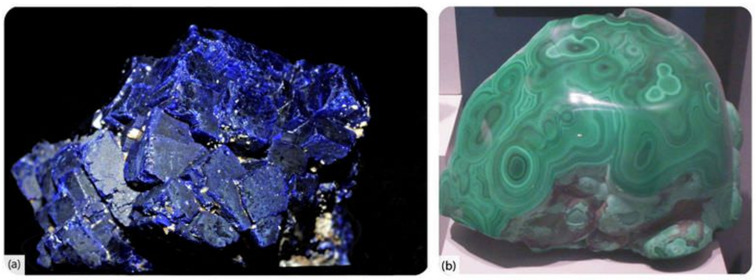

FIGURE 1.8
The deep blue mineral is azurite and the green is malachite. Both of these carbonate minerals are used for jewelry.

Halides

Halide minerals are salts. They form when salt water evaporates. This mineral class includes more than just table salt. Halide minerals may contain the elements fluorine, chlorine, bromine, or iodine. Some will combine with metal elements. Common table salt is a halide mineral that contains the elements chlorine and sodium. Fluorite is a type of halide that contains fluorine and calcium. Fluorite can be found in many colors. If you shine an ultraviolet light on fluorite, it will glow!

Oxides

Earth's crust contains a lot of oxygen. The oxygen combines with many other elements to create oxide minerals. Oxides contain one or two metal elements combined with oxygen. Oxides are different from silicates because they do not contain silicon. Many important metals are found as oxides. For example, hematite and magnetite are both oxides that contain iron. Hematite (Fe_2O_3) has a ratio of two iron atoms to three oxygen atoms. Magnetite (Fe_3O_4) has a ratio of three iron atoms to four oxygen atoms. Notice that the word "magnetite" contains the word "magnet". Magnetite is a magnetic mineral.

Phosphates

Phosphate minerals have a structure similar to silicates. In silicates, an atom of silicon is bonded to oxygen. In phosphates, an atom of phosphorus, arsenic, or vanadium is bonded to oxygen. There are many types of phosphate mineral, but still phosphate minerals are rare. The composition of phosphates is complex. For example, turquoise contains copper, aluminum, and phosphorus. The stone is rare and is used to make jewelry.

Sulfates

Sulfate minerals contain sulfur atoms bonded to oxygen atoms. Like halides, they can form in places where salt water evaporates. Many minerals belong in the sulfate group, but there are only a few common sulfate minerals. Gypsum is a common sulfate mineral that contains calcium, sulfate, and water. Gypsum is found in various forms. For example, it can be pink and look like it has flower petals. However, it can also grow into very large white crystals. Gypsum crystals that are 11 meters long have been found. That is about as long as a school bus! Gypsum also forms at the Mammoth Hot Springs in Yellowstone National Park, shown in **Figure** 1.9.

FIGURE 1.9
Gypsum is the white mineral that is common around hot springs. This is Mammoth Hot Springs in Yellowstone National Park.

Sulfides

Sulfides contain metal elements combined with sulfur. Sulfides are different from sulfates. They do not contain oxygen. Pyrite is a common sulfide mineral. It contains iron combined with sulfur. Pyrite is also known as "fool's gold." Gold miners have mistaken pyrite for gold because pyrite has a greenish gold color.

Lesson Summary

- A mineral is a naturally occurring inorganic solid. It has a definite composition and crystal structure.
- The atoms in minerals are arranged in regular, repeating patterns.
- These patterns are responsible for a mineral's physical properties.
- Minerals are divided into groups. The groups are based on their chemical composition.
- Silicates are the most common minerals.

Lesson Review Questions

Recall

1. What is matter?

2. What are atoms and what are they made of?

3. What is a molecule? What substances do molecules make?

4. Go through the eight mineral groups. List the elements that are contained by all minerals in each group.

Apply Concepts

5. Quartz is made of one silicon atom and two oxygen atoms. If you find a mineral and find that it is made of one silicon atom and one oxygen atom is it quartz?

6. Why is water ice considered a mineral?

7. A shady looking character offers you a valuable mineral made of carbon. You know that diamonds are made of carbon so you give him $100 for one. Have you gotten yourself a good deal? Why or why not?

Think Critically

8. Why are diamonds "a girls best friend?" What other uses might diamonds have?

9. Coal is made of ancient plant parts that were squeezed together and heated. Is coal a mineral? Explain.

Points to Consider

- What is one way you could tell the difference between two different minerals?
- Why would someone want to make minerals when they are found in nature?
- Why are minerals so colorful? Can color be used to identify minerals?

1.2 Identification of Minerals

Lesson Objectives

- Explain how minerals are identified.
- Describe how color, luster, and streak are used to identify minerals.
- Summarize specific gravity.
- Explain how the hardness of a mineral is measured.
- Describe the properties of cleavage and fracture.
- Identify additional properties that can be used to identify some minerals.

Vocabulary

- cleavage
- density
- fracture
- hardness
- luster
- streak

Introduction

How could you describe your shirt when you are talking to your best friend on the phone? You might describe the color, the way the fabric feels, and the length of the sleeves. These are all physical properties of your shirt. If you did a good job describing your shirt, your friend would recognize the shirt when you wear it. Minerals also have physical properties that are used to identify them.

How are Minerals Identified?

Imagine you were given a mineral sample similar to the one shown in **Figure** 1.10. How would you try to identify your mineral? You can observe some properties by looking at the mineral. For example, you can see that its color is beige. The mineral has a rose-like structure. But you can't see all mineral properties. You need to do simple tests to determine some properties. One common one is how hard the mineral is. You can use a mineral's properties to identify it. The mineral's physical properties are determined by its chemical composition and crystal structure.

FIGURE 1.10
You can use properties of a mineral to identify it. The color and rose-like structure of this mineral mean that it is gypsum.

Color, Streak, and Luster

Diamonds have many valuable properties. Diamonds are extremely hard and are used for industrial purposes. The most valuable diamonds are large, well-shaped and sparkly. Turquoise is another mineral that is used in jewelry because of its striking greenish-blue color. Many minerals have interesting appearances. Specific terms are used to describe the appearance of minerals.

Color

Color is probably the easiest property to observe. Unfortunately, you can rarely identify a mineral only by its color. Sometimes, different minerals are the same color. For example, you might find a mineral that is a gold color, and so think it is gold. But it might actually be pyrite, or "fool's gold," which is made of iron and sulfide. It contains no gold atoms.

A certain mineral may form in different colors. **Figure** 1.11 shows four samples of quartz, including one that is colorless and one that is purple. The purple color comes from a tiny amount of iron. The iron in quartz is a chemical impurity. Iron is not normally found in quartz. Many minerals are colored by chemical impurities. Other factors can also affect a mineral's color. Weathering changes the surface of a mineral. Because color alone is unreliable, geologists rarely identify a mineral just on its color. To identify most minerals, they use several properties.

Streak

Streak is the color of the powder of a mineral. To do a streak test, you scrape the mineral across an unglazed porcelain plate. The plate is harder than many minerals, causing the minerals to leave a streak of powder on the plate. The color of the streak often differs from the color of the larger mineral sample, as **Figure** 1.12 shows.

Streak is more reliable than color to identify minerals. The color of a mineral may vary. Streak does not vary. Also, different minerals may be the same color, but they may have a different color streak. For example, samples of hematite and galena can both be dark gray. They can be told apart because hematite has a red streak and galena has a gray streak.

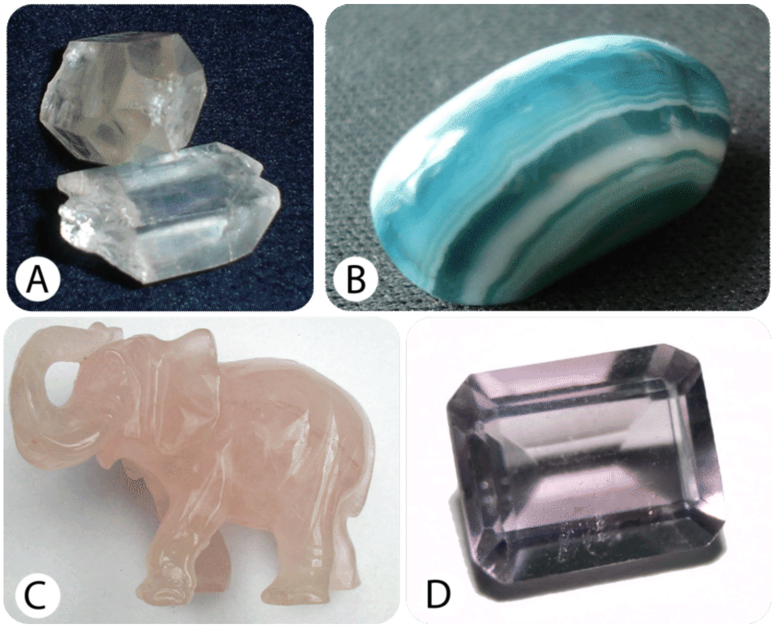

FIGURE 1.11
Quartz comes in many different colors including: (A) transparent quartz, (B) blue agate, (C) rose quartz, and (D) purple amethyst.

FIGURE 1.12
Rub a mineral across an unglazed porcelain plate to see its streak. The hematite shown here has a red streak.

Luster

Luster describes the way light reflects off of the surface of the mineral. You might describe diamonds as sparkly or pyrite as shiny. But mineralogists have special terms to describe luster. They first divide minerals into metallic and non-metallic luster. Minerals that are opaque and shiny, like pyrite, are said to have a "metallic" luster. Minerals with a "non-metallic" luster do not look like metals. There are many types of non-metallic luster. Six are described in **Table** 1.1.

TABLE 1.1: Minerals with Non-Metallic Luster

Non-Metallic Luster	Appearance
Adamantine	Sparkly
Earthy	Dull, clay-like
Pearly	Pearl-like
Resinous	Like resins, such as tree sap
Silky	Soft-looking with long fibers
Vitreous	Glassy

Can you match the minerals in **Figure** 1.13 with the correct luster from **Table** 1.1 without looking at the caption?

Density

You are going to visit a friend. You fill one backpack with books so you can study later. You stuff your pillow into another backpack that is the same size. Which backpack will be easier to carry? Even though the backpacks are the same size, the bag that contains your books is going to be much heavier. It has a greater density than the backpack with your pillow.

Density describes how much matter is in a certain amount of space. Substances that have more matter packed into a given space have higher densities. The water in a drinking glass has the same density as the water in a bathtub or swimming pool. All substances have characteristic densities, which does not depend on how much of a substance you have.

Mass is a measure of the amount of matter in an object. The amount of space an object takes up is described by its volume. The density of an object depends on its mass and its volume. Density can be calculated using the following equation:

$$\text{Density} = \text{Mass}/\text{Volume}$$

Samples that are the same size, but have different densities, will have different masses. Gold has a density of about 19 g/cm^3. Pyrite has a density of only about 5 g/cm^3. Quartz is even less dense than pyrite, and has a density of 2.7 g/cm^3. If you picked up a piece of pyrite and a piece of quartz that were the same size, the pyrite would seem almost twice as heavy as the quartz.

Hardness

Hardness is a mineral's ability to resist being scratched. Minerals that are not easily scratched are hard. You test the hardness of a mineral by scratching its surface with a mineral of a known hardness. Mineralogists use the Mohs Hardness Scale, shown in **Table** 1.2, as a reference for mineral hardness. The scale lists common minerals in order of their relative hardness. You can use the minerals in the scale to test the hardness of an unknown mineral.

Mohs Hardness Scale

As you can see, diamond is a 10 on the Mohs Hardness Scale. Diamond is the hardest mineral; no other mineral can scratch a diamond. Quartz is a 7. It can be scratched by topaz, corundum, and diamond. Quartz will scratch minerals

FIGURE 1.13
(A) Diamonds have an adamantine luster. These minerals are transparent and highly reflective. (B) Kaolinite is a clay with a dull or earthy luster. (C) Opal's luster is greasy. (D) Chalcopyrite, like its cousin pyrite, has metallic luster. (E) Stilbite (orange) has a resinous luster. (F) The white ulexite has silky luster. (G) Sphalerite has a submetallic luster. (H) This Mayan artifact is carved from jade. Jade is a mineral with a waxy luster.

that have a lower number on the scale. Fluorite is one. Suppose you had a piece of pure gold. You find that calcite scratches the gold. Gypsum does not. Gypsum has a hardness of 2 and calcite is a 3. That means the hardness of gold is between gypsum and calcite. So the hardness of gold is about 2.5 on the scale. A hardness of 2.5 means that gold is a relatively soft mineral. It is only about as hard as your fingernail.

TABLE 1.2: Mohs Scale

Hardness	Mineral
1	Talc

TABLE 1.2: (continued)

Hardness	Mineral
2	Gypsum
3	Calcite
4	Fluorite
5	Apatite
6	Orthoclase feldspar
7	Quartz
8	Topaz
9	Corundum
10	Diamond

Cleavage and Fracture

Different types of minerals break apart in their own way. Remember that all minerals are crystals. This means that the atoms in a mineral are arranged in a repeating pattern. This pattern determines how a mineral will break. When you break a mineral, you break chemical bonds. Because of the way the atoms are arranged, some bonds are weaker than other bonds. A mineral is more likely to break where the bonds between the atoms are weaker.

Cleavage

Cleavage is the tendency of a mineral to break along certain planes. When a mineral breaks along a plane it makes a smooth surface. Minerals with different crystal structures will break or cleave in different ways, as in **Figure** 1.14. Halite tends to form cubes with smooth surfaces. Mica tends to form sheets. Fluorite can form octahedrons.

FIGURE 1.14
Minerals with different crystal structures have a tendency to break along certain planes.

Minerals can form various shapes. Polygons are shown in **Figure** 1.15. The shapes form as the minerals are broken along their cleavage planes. Cleavage planes determine how the crystals can be cut to make smooth surfaces. People who cut gemstones follow cleavage planes. Diamonds and emeralds can be cut to make beautiful gemstones.

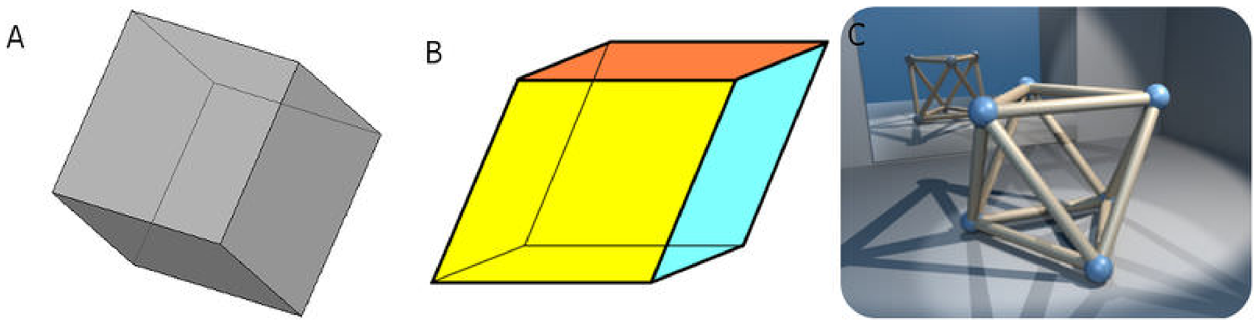

FIGURE 1.15
Cubes have six sides that are all the same size square. All of the angles in a cube are equal to 90°. Rhombohedra also have six sides, but the sides are diamond-shaped. Octahedra have eight sides that are all shaped like triangles.

Fracture

Fracture describes how a mineral breaks without any pattern. A fracture is uneven. The surface is not smooth and flat. You can learn about a mineral from the way it fractures. If a mineral splinters like wood, it may be fibrous. Some minerals, such as quartz, fracture to form smooth, curved surfaces. A mineral that broke forming a smooth, curved surface is shown in **Figure** 1.16.

Other Identifying Characteristics

Minerals have other properties that can be used for identification. For example, a mineral's shape may indicate its crystal structure. Sometimes crystals are too small to see. Then a mineralogist may use a special instrument to find the crystal structure.

Some minerals have unique properties. These can be used to the minerals. Some of these properties are listed in **Table** 1.3. An example of a mineral that has each property is also listed.

TABLE 1.3: Special Mineral Properties

Property	Description	Example of Mineral
Fluorescence	Mineral glows under ultraviolet light	Fluorite
Magnetism	Mineral is attracted to a magnet	Magnetite
Radioactivity	Mineral gives off radiation that can be measured with Geiger counter	Uraninite
Reactivity	Bubbles form when mineral is exposed to a weak acid	Calcite
Smell	Some minerals have a distinctive smell	Sulfur (smells like rotten eggs)

FIGURE 1.16
This mineral formed a smooth, curved surface when it fractured.

Lesson Summary

- You can identify a mineral by its appearance and other properties.
- The color and luster describe the appearance of a mineral, and streak describes the color of the powdered mineral.
- Each mineral has a characteristic density.
- Mohs Hardness Scale is used to compare the hardness of minerals.
- The way a mineral cleaves or fractures depends on the crystal structure of the mineral.
- Some minerals have special properties that can be used to help identify the mineral.

Lesson Review Questions

Recall

1. What is cleavage? What is fracture? If you are looking at a mineral face, how can you tell them apart?

2. What is color? When would you use color to identify a mineral?

3. What is streak? Why would you use streak instead of color to identify a mineral?

Apply Concepts

4. What type of luster do gemstones mostly have? Why do you think this type of luster is popular for jewelry?

5. If a mineral has a unique property that only that type of mineral has is it good for identifying that mineral? Is there any time that it might not be?

Think Critically

6. You are trying to identify a mineral sample. Apatite scratches the surface of the mineral. Which mineral would you use next to text the mineral's hardness—fluorite or feldspar? Explain your reasoning.

7. You have two mineral samples that are about the size of a golf ball. Mineral A has a density of 5 g/cm^3. Mineral B is twice as dense as Mineral A. What is the density of Mineral B?

Points to Consider

- Some minerals are colored because they contain chemical impurities. How did the impurities get into the mineral?
- What two properties of a mineral sample would you have to measure to calculate its density?

1.3 Formation of Minerals

Lesson Objectives

- Describe how melted rock produces minerals.
- Explain how minerals form from solutions.

Vocabulary

- lava
- magma
- rocks

Introduction

Minerals are all around you. They are used to make your house, your computer, even the buttons on your jeans. But where do minerals come from? There are many types of minerals, and they do not all form in the same way. Some minerals form when salt water on Earth's surface evaporates. Others form from water mixtures that are seeping through rocks far below your feet. Still others form when molten rock cools.

Formation from Magma and Lava

You are on vacation at the beach. You take your flip-flops off so you can go swimming. The sand is so hot it hurts your feet. You have to run to the water. Now imagine if it were hot enough for the sand to melt.

Some places inside Earth are so hot that rock melts. Melted rock inside the Earth is called magma. **Magma** can be hotter than 1,000°C. When magma erupts onto Earth's surface, it is known as **lava**, as **Figure** 1.17 shows. Minerals form when magma and lava cool.

Formation from Solutions

Most water on Earth, like the water in the oceans, contains elements. The elements are mixed evenly through the water. Water plus other substances makes a solution. The particles are so small that they will not come out when you filter the water. But the elements in water can form solid mineral deposits.

FIGURE 1.17
Lava is melted rock that erupts onto Earth's surface.

Minerals from Salt Water

Fresh water contains a small amount of dissolved elements. Salt water contains a lot more dissolved elements. Water can only hold a certain amount of dissolved substances. When the water evaporates, it leaves behind a solid layer of minerals, as **Figure** 1.18 shows. At this time, the particles come together to form minerals. These solids sink to the bottom. The amount of mineral formed is the same as the amount dissolved in the water. Seawater is salty enough for minerals to precipitate as solids. Some lakes, such as Mono Lake in California, or Utah's Great Salt Lake, can also precipitate salts.

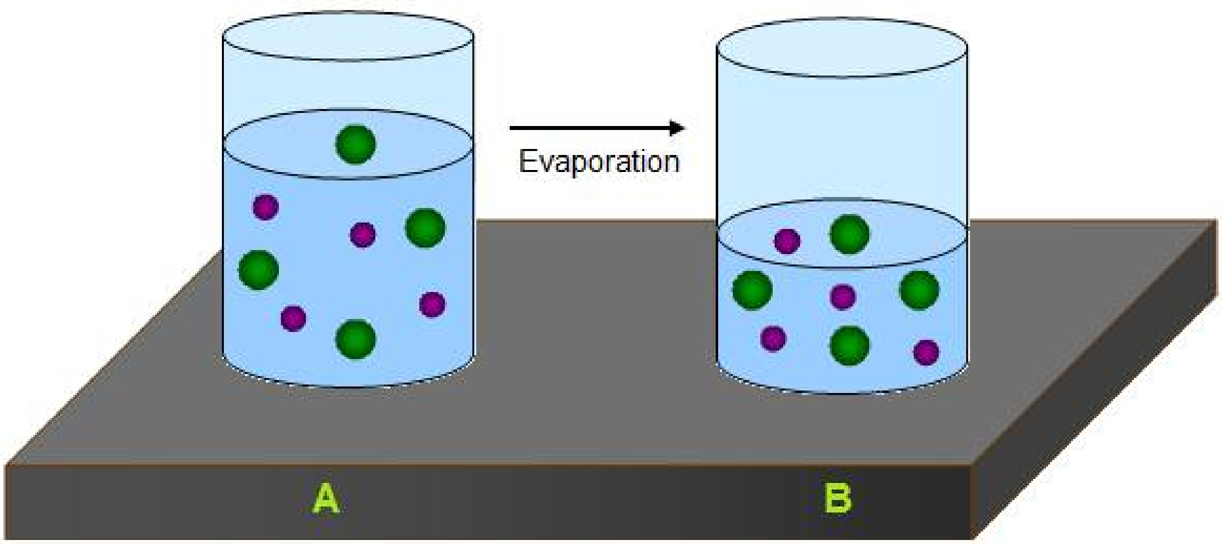

FIGURE 1.18
When the water in glass A evaporates, the dissolved mineral particles are left behind.

Salt easily precipitates out of water, as does calcite, as **Figure** 1.19 shows. The limestone towers in the figure are made mostly of the mineral calcite. The calcite was deposited in the salty and alkaline water of Mono Lake, in California. Calcium-rich spring water enters the bottom of the lake. The water bubbles up into the alkaline lake. The calcite "tufa" towers form. When the lake level drops, the tufa towers are revealed.

FIGURE 1.19
Tufa towers are found in interesting formations at Mono Lake, California.

Minerals from Hot Underground Water

Underground water can be heated by magma. The hot water moves through cracks below Earth's surface. Hot water can hold more dissolved particles than cold water. The hot, salty solution has chemical reactions with the rocks around it. The water picks up more dissolved particles. As it flows through open spaces in rocks, the water deposits solid minerals. When a mineral fills cracks in rocks, the deposits are called "veins." **Figure** 1.20 shows a white quartz vein. When the minerals are deposited in open spaces, large crystals grow. These rocks are called geodes. **Figure** 1.20 shows a "geode" that was formed when amethyst crystals grew in an open space in a rock.

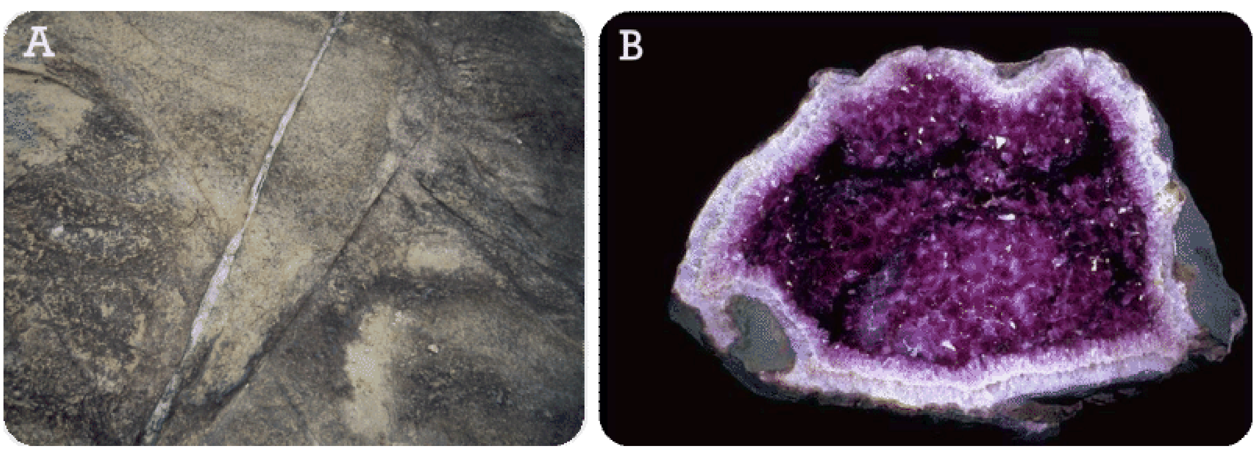

FIGURE 1.20
(A) A quartz vein formed in this rock. (B) Geodes form when minerals evaporate out in open spaces inside a rock.

Lesson Summary

- Mineral crystals that form when magma cools are usually larger than crystals that form when lava cools.
- Minerals are deposited from salty water solutions on Earth's surface and underground.

Lesson Review Questions

Recall

1. How does magma differ from lava?

2. What happens to elements in salt water when the water evaporates?

Apply Concepts

3. Describe how minerals can form out of salt water. What are all the steps in the process?

Think Critically

4. You are handed a rock with large and form beautiful crystals. Another rock is made of the same mineral type but the crystals are small and not well formed. How is the way the two sets of that mineral formed different?

Points to Consider

- When most minerals form, they combine with other minerals to form rocks. How can these minerals be used?
- The same mineral can be formed by different processes. How can the way a mineral forms affect how the mineral is used?

1.4 Mining and Using Minerals

Lesson Objectives

- Explain how minerals are mined.
- Describe how metals are made from mineral ores.
- Summarize the ways in which gemstones are used.
- Identify some useful minerals.

Vocabulary

- gemstone
- ore

Introduction

When you use a roll of aluminum foil or some baby powder, you probably don't think about how the products were made. We use minerals in many everyday items.

Minerals have to be removed from the ground and made into the products. All the metals we use start out as an ore. Mining the ore is just the first step. Next, the ore must be separated from the rest of the rock that is mined. Then, the minerals need to be separated out of the ore.

Ore Deposits

A mineral deposit that contains enough minerals to be mined for profit is called an **ore**. Ores are rocks that contain concentrations of valuable minerals. The bauxite shown in the **Figure** 1.21 is a rock that contains minerals that are used to make aluminum.

Finding and Mining Minerals

Ores have high concentrations of valuable minerals. Certain places on Earth are more likely to have certain ores. Geologists search for the places that might have ore deposits. Some of the valuable deposits may be hidden underground. To find an ore deposit, geologists will go to a likely spot. They then test the physical and chemical properties of soil and rocks. Ore deposits contain valuable minerals. They may also contain other chemical elements that indicate an ore deposit is nearby.

FIGURE 1.21
Aluminum is made from the minerals in rocks known as bauxite.

After a mineral deposit is found, geologists determine how big it is. They outline the deposit and the surrounding geology on a map. The miners calculate the amount of valuable minerals they think they will get from the deposit. The minerals will only be mined if it is profitable. If it is profitable, they must then decide on the way it should be mined. The two main methods of mining are surface mining and underground mining. Placers are a type of surface deposit.

Surface Mining

Surface mining is used to obtain mineral ores that are near the surface. Blasting breaks up the soil and rocks that contain the ore. Enormous trucks haul the broken rocks to locations where the ores can be removed. Surface mining includes open-pit mining, quarrying, and strip mining.

As the name suggests, open-pit mining creates a big pit from which the ore is mined. **Figure** 1.22 shows an open-pit diamond mine in Russia. The size of the pit grows as long as the miners can make a profit. Strip mines are similar to open-pit mines, but the ore is removed in large strips. A quarry is a type of open-pit mine that produces rocks and minerals that are used to make buildings and roads.

Placer Mining

Placer minerals collect in stream gravels. They can be found in modern rivers or ancient riverbeds. California was nicknamed the Golden State. This can be traced back to the discovery of placer gold in 1848. The amount of placer gold brought in miners from around the world. The gold formed in rocks in the Sierra Nevada Mountains. The rocks also contained other valuable minerals. The gold weathered out of the hard rock. It washed downstream and then settled in gravel deposits along the river. Currently, California has active gold and silver mines. California also has mines for non-metal minerals. For example, sand and gravel are mined for construction.

FIGURE 1.22
This diamond mine is more than 500 m deep.

Underground Mining

If an ore is deep below Earth's surface it may be too expensive to remove all the rock above it. These deposits are taken by underground mining. Underground mines can be very deep. The deepest gold mine in South Africa is more than 3,700 m deep (that is more than 2 miles)! There are various methods of underground mining. Underground mining is more expensive than surface mining. Tunnels must be blasted into the rock so that miners and equipment can get to the ore. Underground mining is dangerous work. Fresh air and lights must be brought in to the tunnels for the miners. The miners breathe in lots of particles and dust while they are underground. The ore is drilled, blasted, or cut away from the surrounding rock and taken out of the tunnels. Sometimes there are explosions as ore is being drilled or blasted. This can lead to a mine collapse. Miners may be hurt or killed in a mining accident.

Making Metals from Minerals

Most minerals are a combination of metal and other elements. The rocks that are taken from a mine are full of valuable minerals plus rock that isn't valuable. This is called waste rock. The valuable minerals must be separated from the waste rock. One way to do this is with a chemical reaction. Chemicals are added to the ores at very high temperatures.

For example, getting aluminum from waste rock uses a lot of energy. This is because temperatures greater than 900^{o}C are needed to separate out the aluminum. It also takes a huge amount of electricity. If you recycle just 40 aluminum cans, you will save the energy in one gallon of gasoline. We use over 80 billion cans each year. If all of these cans were recycled, we would save the energy in 2 billion gallons of gasoline!

Uses of Ore Minerals

We rely on metals, such as aluminum, copper, iron, and gold. Look around the room. How many objects have metal parts? Metals are used in the tiny parts inside your computer, in the wires of anything that uses electricity, and to make the structure of a large building, such as the one shown in the **Figure** 1.23.

FIGURE 1.23
The dome of the capital building in Hartford, Connecticut is coated with gold leaf.

Gemstones and Their Uses

Some minerals are valuable simply because they are beautiful. Jade has been used for thousands of years in China. Native Americans have been decorating items with turquoise since ancient times. Minerals like jade, turquoise, diamonds, and emeralds are gemstones. A **gemstone** is a material that is cut and polished to use in jewelry. Many gemstones, such as those shown in **Figure** 1.24, are minerals.

FIGURE 1.24
Gemstones come in many colors.

Gemstones are beautiful, rare, and do not break or scratch easily. Generally, rarer gems are more valuable. If a gem is popular, unusually large or very well cut, it will be more valuable.

Most gemstones are not used exactly as they are found in nature. Usually, gems are cut and polished. **Figure** 1.25 shows an uncut piece of ruby and a ruby that has been cut and polished. The way a mineral splits along a surface allows it to be cut to produce smooth surfaces. Notice that the cut and polished ruby sparkles more. Gems sparkle because light bounces back when it hits them. These gems are cut so that the most amount of light possible bounces back. Other gemstones, such as turquoise, are opaque, which means light does not pass through them. These gems are not cut in the same way.

FIGURE 1.25
Ruby is cut and polished to make the gemstone sparkle. Left: Ruby Crystal. Right: Cut Ruby.

Gemstones also have other uses. Most diamonds are actually not used as gemstones. Diamonds are used to cut and polish other materials, such as glass and metals, because they are so hard. The mineral corundum, which makes the gems ruby and sapphire, is used in products like sandpaper. Synthetic rubies and sapphires are also used in lasers.

Other Useful Minerals

Metals and gemstones are often shiny, so they catch your eye. Many minerals that we use everyday are not so noticeable. For example, the buildings on your block could not have been built without minerals. The walls in your home might use the mineral gypsum for the sheetrock. The glass in your windows is made from sand, which is mostly the mineral quartz. Talc was once commonly used to make baby powder. The mineral halite is mined for rock salt. Diamond is commonly used in drill bits and saw blades to improve their cutting ability. Copper is used in electrical wiring, and the ore bauxite is the source for the aluminum in your soda can.

Mining and the Environment

Mining provides people with many resources they need, but mining can be hazardous to people and the environment. Miners should restore the mined region to its natural state. It is also important to use mineral resources wisely. Most ores are non-renewable resources.

Land Reclamation

After the mining is finished, the land is greatly disturbed. The area around the mine needs to be restored to its natural state. This process of restoring the area is called "reclamation." Native plants are planted. Pit mines may be refilled or reshaped so that they can become natural areas again. The mining company may be allowed to fill the pit with water to create a lake. The pits may be turned into landfills. Underground mines may be sealed off or left open as homes for bats.

Mine Pollution

Mining can cause pollution. Chemicals released from mining can contaminate nearby water sources. **Figure** 1.26 shows water that is contaminated from a nearby mine. The United States government has mining standards to protect water quality.

FIGURE 1.26
Scientists test water that has been contaminated by a mine.

Lesson Summary

- Geologists look for mineral deposits that will be profitable to mine.
- Ores that are close to the surface are mined by surface mining methods. Ores that are deep in Earth are mined using underground methods.
- Metals ores must be melted to make metals.
- Many gems are cut and polished to increase their beauty.
- Minerals are used in a variety of ways.

Lesson Review Questions

Recall

1. What are placers? How do placer deposits form?

2. What makes an ore deposit valuable?

Apply Concepts

3. Why would a mining company choose to do a surface mine? Why would it choose to do an underground mine?

4. Once the ore rocks are taken to a refinery, what happens to get the ore out?

Thinking Critically

5. What are some disadvantages of underground mining?
6. What is the bottom line when it comes to deciding how what and how to mine?
7. How is land reclaimed after mining? Is it ever fully recovered?
8. How might the history of the Golden State been different if placers had not been found in its rivers?

Points to Consider

- Are all mineral deposits ores?
- An open-pit diamond mine may one day be turned into an underground mine. Why would this happen?
- Diamonds are not necessarily the rarest gem. Why do people value diamonds more than most other gems?

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