SECTION 2

Mineral Exploration and Mining

The rate of technological change in the mining industry is increasing rapidly. Computers are commonly used to make models that show the location of ore within a deposit. Mineral exploration data are now obtained from orbiting satellites or from airplanes that carry sophisticated instruments. These instruments give scientists clues as to where new ore deposits lie hidden underground.

Objectives

- Describe the manner in which mining companies explore for new mineral deposits.
- Describe three methods of subsurface mining.
- Describe two methods of surface mining.
- Define placer deposit, and explain how placer deposits form.
- Describe the steps that take place in smelting an ore.

Key Terms

subsurface mining
surface mining
placer deposit
smelting

Mineral Exploration

Through mineral exploration, mining companies can identify areas where there is a high likelihood of finding valuable mineral resources in quantities that are worth mining. Usually, a mineral deposit has 100 to 1,000 times the concentration of the mineral than ordinary rocks do and enough material to justify opening a mine.

Exploring rock for mineralization is the first step in finding an ore deposit. Planes that carry instruments that identify patterns in gravity, magnetism, or radioactivity fly over and collect these data as well as images and photographs of an area. When used with satellite images, these data and aerial photographs can be used to create an accurate geological map of the surface. As shown in **Figure 6,** rock samples are then taken from the exploration area. The samples are analyzed to determine ore grade—the metal content of an ore. If the ore grade is high enough, the companies will drill test holes that help them estimate the three-dimensional extent of the ore. If the ore grade is high enough and the deposit extensive enough, the cost to open a mine may be warranted.

Figure 6 ▶ A geologist takes ore samples across the freshly blasted tunnel of a Canadian gold mine.

Figure 7 ▶ This photo shows a room-and-pillar salt mine in Germany. A bucket wheel excavator is used to remove the salt.

Subsurface Mining

Ore deposits that are usually 50 m or more beneath Earth's surface are mined by using **subsurface mining** methods. A common method of subsurface mining that is used to extract coal and salt is known as *room-and-pillar mining*. In coal mines, a network of entries, called *rooms*, are cut into a seam, a horizontal layer of coal. Between the rooms, pillars of coal are left standing to support the roof. When the mining of rooms is completed, the pillars are then removed, beginning with pillars at the farthest point in the mine. A room in a German salt mine, along with mining equipment, is shown in **Figure 7.**

Longwall Mining A more efficient way to remove coal from a subsurface seam is to use a method called *longwall mining*. In longwall mining, a machine called a shearer moves back and forth across the face of a coal seam. A shearer that is used in longwall mining is shown in **Figure 8.** The wall of the seam, called the *longwall,* may be more than 300 m long. As coal is sheared from the face, it falls onto a conveyor. The conveyor transports the coal out of the mine. A row of hydraulic roof supports protects the miners and the equipment. As the shearer advances forward through the coal seam, the mine roof behind the hydraulic supports collapses.

Figure 8 ▶ Heavy equipment, like the rotating shearer of the longwall mining system shown here, is used to remove coal in subsurface mines.

Solution Mining For underground deposits of soluble mineral ores such as potash, salt, and sulfur, solution mining is an economical mining method. In solution mining, hot water is injected into the ore and dissolves it. Compressed air is then pumped into the dissolved ore, and air bubbles lift it to the surface.

Surface Mining

Surface mining methods are used when ore deposits are located close to Earth's surface. *Open-pit mining* is a method that is often used when large quantities of near-surface ore are mined. Coal and metals such as gold and copper are mined using the open-pit method.

In an open-pit mine, the ore is mined downward, layer by layer. First, explosives are used, if needed, to break up the ore. Then, the ore is loaded into haul trucks. The haul trucks transport the ore from the mine. Some ores, such as gold ore, are taken to heap leaching pads, such as the pads shown in **Figure 9.** There, the gold is extracted from the ore using chemicals.

Figure 9 ▶ Cyanide heap leaching is being used to extract gold from ore at this open-pit mine in Idaho.

Surface Coal Mining In the 19th-century American Midwest, horse- or mule-drawn plows were used to remove the rock, called *overburden,* that covered near-surface coal seams. Today, some of the largest machines in the world are used to strip the overburden that covers shallow coal deposits.

The first step in surface coal mining is to remove and set aside the soil that covers the area to be mined. Next, the overburden is removed by heavy equipment in cuts that may be up to 50 m wide and over a kilometer long. The overburden is piled alongside the cut. Loaders enter the pit and remove the exposed coal seam. Once the coal is taken out, the pit is refilled with the overburden and contoured. The soil that has been set aside is now laid on top of the overburden.

Quarrying Building stones such as granite, limestone, and marble are mined in quarries like the one shown in **Figure 10.** Sand, gravel, and crushed rock, which are known as *aggregates*, are the principal commodities produced by quarrying. Quarries also produce large quantities of clay, gypsum, and talc.

Connection to Chemistry

Cyanide Heap Leaching
Sodium cyanide, NaCN, has been used to extract gold from low-grade ore deposits since the cyanide heap-leaching process was pioneered in the United States in the early 1970s. Crushed ore from a mine is placed on pads that have bottoms of asphalt or on impervious plastic sheets. A solution of dilute cyanide is sprayed on the ore. The cyanide percolates down through the ore for several weeks to months and leaches out the gold. The gold, which is now in solution, drains off the pad into a pond. From the pond, the gold-bearing solution is pumped to a recovery plant, where the gold is removed from solution.

Figure 10 ▶ Open pits called *quarries* are used to mine near-surface materials such as building stone, crushed rock, sand, and gravel.

Figure 11 ▶ This is an aerial view of solar evaporation ponds that are used to produce salt on San Francisco Bay.

Solar Evaporation The solar evaporation process consists of placing sea water, which is about 2.7 percent sodium chloride, into enormous, shallow ponds. The sun evaporates the sea water, which causes the sodium chloride concentration to increase. When the concentration of sodium chloride in the sea water reaches a little over 25 percent, salt crystals begin to form. With further evaporation, layers of crystalline salt, or halite, build up. When these layers reach the desired thickness, the salt is harvested. Salt harvesting generally occurs once a year.

Solar evaporation is a method of salt production that is used in areas that receive little rainfall and that have high evaporation rates. Along the Mediterranean Sea, on San Francisco Bay, and particularly in Australia, solar evaporation is practical because evaporation far exceeds rainfall. Steady prevailing winds, which increase the rate of evaporation, are also important to solar evaporation. **Figure 11** shows solar evaporation ponds on San Francisco Bay.

The solar evaporation process has been used to produce salt for thousands of years. Today, solar evaporation is used largely in developing countries. About 30 percent of the world's salt comes from the solar evaporation process.

CASE STUDY

Hydraulic Mining in the California Goldfields

About 50 million years ago, rivers bearing gold flowed across present-day northern California. Over time, the geologic processes that formed the Sierra Nevada Mountains buried the gold-bearing river gravels beneath as much as 60 m of soil. A method was needed to remove this soil and recover the gold from the gravels of the ancient riverbeds.

The technology to perform this task, called *hydraulic mining,* was developed in the early 1850s. Hydraulic miners used huge 4 to 5.5 m long water cannons, called *monitors,* to send high-pressure streams of water into the Sierra Nevada mountainsides. The sediments that were blasted from the mountainsides mixed with the water to form a slurry, which was washed through a series of long, inclined

▶ By 1874, giant water monitors worked 24 hours a day, 7 days a week, at the Malakoff mine and processed about 50,000 tons of gravel a day. The resulting canyon was more than 2,000 m long, 900 m wide, and 180 m deep.

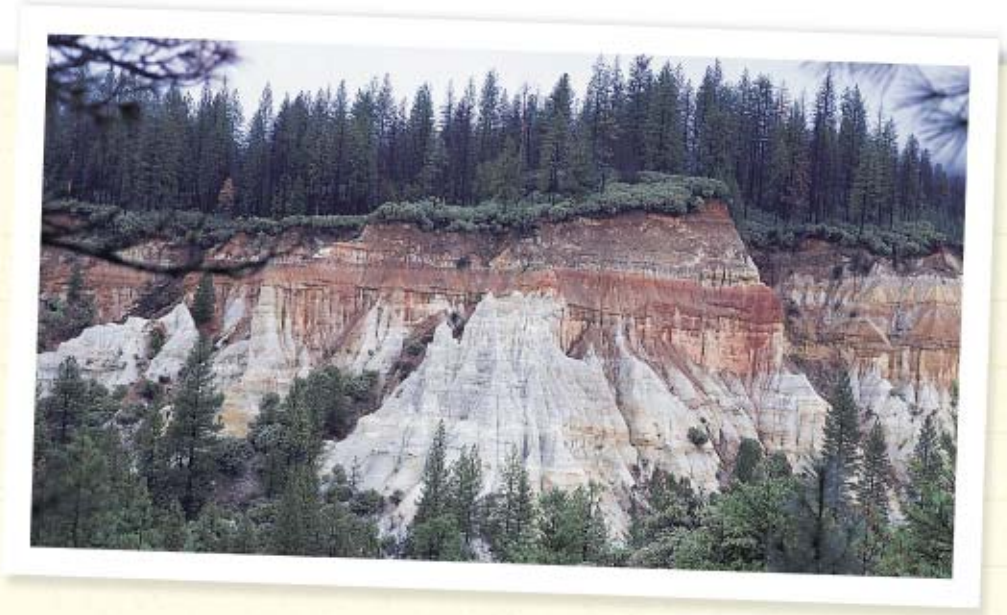
Placer Mining

When rock weathers and disintegrates, minerals within the rock are released. These minerals are concentrated by wind and water into surface deposits called **placer deposits.** The most important placers are stream placers. Streams transport mineral grains to a point where they fall to the streambed and are concentrated. Concentration occurs at places where currents are weak and the dense mineral grains can no longer be carried in the water. These stream placers often occur at bends in rivers, where the current slows.

Placer deposits may form along coastlines by heavy minerals that wash down to the ocean in streams. These heavy minerals are concentrated by wave action.

Placer gold, diamonds, and heavy minerals are mined by dredging. As shown in **Figure 12,** a dredge consists of a floating barge on which buckets fixed on a conveyor are used to excavate sediments in front of the dredge. Gold, diamonds, or heavy minerals are separated from the sediments within the dredge housing. The processed sediments are discharged via a conveyor that is located behind the dredge.

Figure 12 ▶ This dredge is mining gold from placer deposits along a river on New Zealand's South Island.



▶ To this day, the mountainsides in the Sierra Nevada bear the scars of hydraulic mining.

troughs called *sluices.* The sluices were lined with a series of devices known as *riffles* to catch the gold. Mercury was also added to the riffles to help capture the gold. The muddy water and processed sediments were then discharged into adjacent rivers.

Hydraulic mining proved to be an environmental disaster. Muddy water and sediments polluted rivers and caused them to fill with silt. The silt from the hydraulic mines traveled as far downstream as San Francisco and into the Pacific Ocean. As much as 1.4 to 3.6 million kilograms of mercury may have been released downstream, which poisoned fish, amphibians, and invertebrates. Farmers in California's central valley sustained millions of dollars in damage as their fields were flooded when the sediment-choked Sacramento River overflowed its banks. But the farmers fought back. In January 1884, Judge Lorenzo Sawyer ruled that mine tailings could no longer be discharged into the rivers. The Sawyer decision was the first environmental ruling to be handed down in the United States. This ruling closed the door on hydraulic mining in the Sierra Nevada goldfields, where 2 billion cubic meters of soil and rocks had been carved from the mountainsides in slightly over 30 years.

CRITICAL THINKING

1. Making Inferences What do you think were other environmental effects of hydraulic mining that were not mentioned in this article?

2. Analyzing Relationships Write a paragraph about how the mercury that was lost during hydraulic mining may still be affecting the environment today. WRITING SKILLS

Figure 13 ▶ At a smelter, such as this aluminum smelter in Venezuela, ore is melted at high temperatures in a furnace to obtain a desired metal.

QuickLAB

Surface Coal Mining

Procedure

1. Cut off the top part of a **2 L plastic soda bottle** to make a container that has an open end.
2. Spread a 5 cm layer of **soil** on the bottom of the bottle.
3. Spread a 0.75 cm layer of **rice** on top of the soil to represent a coal seam.
4. Spread a 12.5 cm layer of soil on top of the coal.
5. To excavate the coal, dig out the top layer of soil with a **spoon,** and place it in a **bowl.** Measure the volume of this soil by using a **graduated cylinder.** Record the volume.
6. Dig out the layer of coal, and place it in a second bowl. Measure and record the volume.

Analysis

1. What is the ratio of overburden to coal?
2. What are some factors that you would need to consider if you were going to surface-mine coal economically?

Smelting

In the process called **smelting,** crushed ore is melted at high temperatures in furnaces to separate impurities from molten metal. In the furnace, material called a *flux* bonds with impurities and separates them from the molten metal. The molten metal, which is desired, falls to the bottom of the furnace and is recovered. The flux and impurities, which are less dense, form a layer called *slag* on top of the molten metal. Gases such as sulfur dioxide form within the furnace and are captured, so they do not enter the environment. **Figure 13** shows a smelter in Venezuela.

Undersea Mining

The ocean floor contains significant mineral resources, which include diamonds, precious metals such as gold and silver, mineral ores, and sand and gravel. Since the late 1950s, several attempts have been made to mine the ocean. These attempts met with varying degrees of success. Competition with land-based companies that can mine minerals more cheaply and the great water depths at which some mineral deposits are found are two of the reasons undersea mining has been largely unsuccessful to date.

SECTION 2 Review

1. **List** the steps in mineral exploration.
2. **Describe** three methods of subsurface mining.
3. **Describe** two methods of surface mining.
4. **Describe** the steps involved in smelting ore.
5. **Define** the term placer deposit, and explain how placer deposits form.

CRITICAL THINKING

6. **Making Comparisons** Read about surface and subsurface mining techniques. What are some of the advantages and disadvantages of each technique?
   READING SKILLS
7. **Understanding Relationships** If a mining company were exploring a river for potential placer deposits, where are some likely places they would focus their exploration?