MERIT BADGE SERIES



MINING IN SOCIETY

Scouting America

STEM-Based

SCOUTING AMERICA
MERIT BADGE SERIES

MINING IN SOCIETY

On our cover: **Mining provides the 30 minerals it takes to make a smartphone and up to 12 for a bicycle. Mining equipment, typically enormous like these haul trucks, dwarf the pickup truck in the open pit mine.**

"Enhancing our youths' competitive edge through merit badges"

Scouting America

Requirements

Always check scouting.org for the latest requirements.

1. Do the following:
   (a) Select 10 different minerals. For each one, name a product for which the mineral is used.
   (b) Explain the role mining has in producing and processing things that are grown.
   (c) From the list of minerals you chose for requirement 1(a), determine the countries where those minerals can be found, and discuss what you learned from your counselor.
2. Obtain a map of your state or region showing major cities, highways, rivers, and railroads. Mark the locations of five mining enterprises. Find out what resource is processed at each location, and identify the mine as a surface or underground operation. Discuss with your counselor how the resources mined at these locations are used.
3. Discuss with your counselor the potential hazards a miner may encounter at an active mine and the protective measures used by miners. In your discussion, explain how:
   (a) The miner's personal protective equipment is worn and used, including a hard hat, safety glasses, earplugs, dust mask or respirator, self-rescue device, and high-visibility vest.
   (b) Miners protect their hands and feet from impact, pinch, vibration, slipping, and tripping/falling hazards.
   (c) Monitoring equipment warns miners of imminent danger, and how robots, drones, and other technology may be used in mine rescues.
4. Discuss with your counselor the dangers someone might encounter at an abandoned mine or quarry.
5. Do ONE of the following:
   (a) With your parent or guardian's approval and your counselor's assistance, use the internet to find and take a virtual tour of two types of mines. Determine the similarities and differences between them regarding resource exploration, mine planning and permitting, types of equipment used, and the minerals produced. Discuss with your counselor what you learned from your internet-based mine tours.

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ISBN 978-0-8395-0049-0

2025 Printing

(b) With your parent or guardian's permission and counselor's approval, visit a mining or minerals exhibit at a museum. Find out about the history of the museum's exhibit and the type of mining it represents. Give three examples of how mineral resources have influenced history.

(c) With your parent or guardian's permission and counselor's approval, visit an active mine. Find out about the tasks required to explore, plan, permit, mine, and process the resource mined at that site. Take photographs, if allowed, and request brochures from your visit. Share photos, brochures, and what you have learned with your counselor. **Note:** Visiting a mine site, a mining equipment manufacturer, or an equipment supplier requires advance planning. These sites can be potentially dangerous. You will need permission from your parent or guardian and counselor, and the manager of the mine site, or equipment manufacturer or supplier. While there, you will be required to follow closely the site manager's instructions and comply with all safety rules and procedures, including wearing appropriate clothing, footwear, and personal protective equipment (PPE).

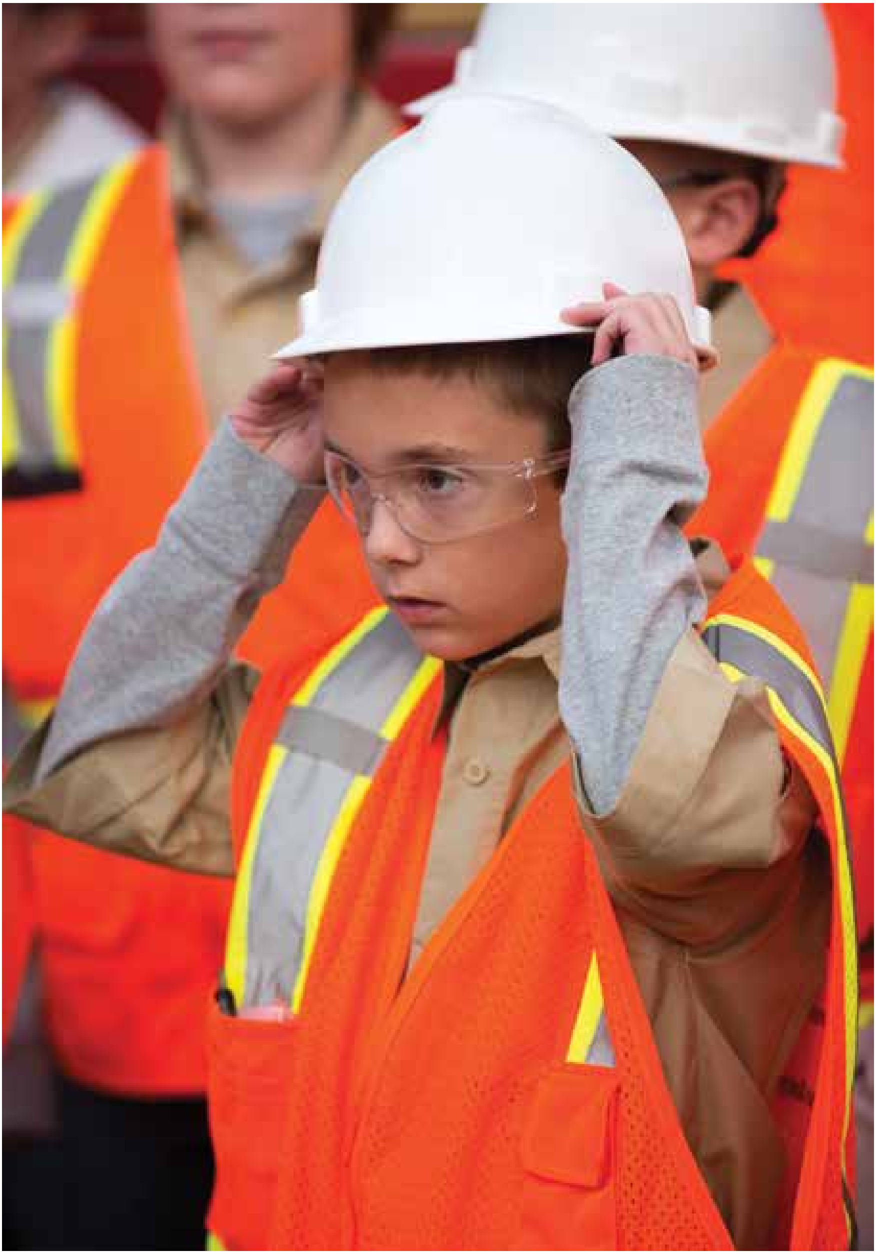
(d) With your parent or guardian's permission and counselor's approval, visit a mining equipment manufacturer or supplier.* Discuss the types of equipment produced or supplied there, and in what part of the mining process this equipment is used. Take photographs if allowed, and request brochures from your visit. Share photos, brochures, and what you have learned with your counselor.

(e) Discuss with your counselor two methods used to reduce rock in size, one of which uses a chemical process to extract a mineral. Explain the difference between smelting and refining.

(f) Learn about the history of a local mine, including what is or was mined there, how the deposit was found, the mining techniques and processes used, and how the mined resource is or was used. Find out from a historian, community leader, or business person how mining has affected your community. Note any social, cultural, or economic consequences of mining in your area. Share what you have learned with your counselor.

6. Do the following:
   (a) Choose a modern mining site. Find out what is being done to help control environmental impacts. Share what you have learned about mining and sustainability.
   (b) Explain reclamation as it is used in mining and how mine reclamation pertains to Scouting's Leave No Trace Seven Principles and Outdoor Code.
   (c) Discuss with your counselor what values society has about returning the land to the benefit of wildlife and people after mining has ended. Discuss the transformation of Scouting America's Summit Bechtel Family National Scout Reserve from a mine site to its current role.
7. Do ONE of the following:
   (a) Explore the anticipated benefits of interplanetary mining. Learn how NASA and private investors may search for, extract, and process minerals in outer space, and the primary reasons for mining the moon, other planets, or near-Earth asteroids. Find out how exploration and mineral processing in space differ from exploration on Earth. Share what you have learned with your counselor, and discuss the difficulties encountered in exploring, collecting, and analyzing surface or near-surface samples in space.
   (b) Identify three minerals found dissolved in seawater or found on the ocean floor, and list three places where the ocean is mined today. Share this information with your counselor, and discuss the chief incentives for mining the oceans for minerals, the reclamation necessary after mining is over, and any special concerns when mining minerals from the ocean. Find out what sustainability problems arise from mining the oceans. Discuss what you learned with your counselor.
   (c) Learn what metals and minerals are recycled after their original use has ended. List four metals and two nonmetals, and find out how each can be recycled. Find out how recycling affects the sustainability of natural resources and how this idea is related to mining. Discuss what you learned with your counselor.
   (d) With your parent or guardian's permission, use the internet and other resources to determine the current price of gold, copper, aluminum, or other commodities like cement or coal, and find out the five-year price trend for two of these. Report your findings to your counselor.

8. Do ONE of the following:
   (a) With your parent or guardian's and counselor's approval, interview a worker in the mining industry. Discuss the work, equipment, and technology used in this individual's position, and learn about a current project. Ask to see reports, drawings, and/or maps made for the project. Find out about the educational and professional requirements for this individual's position. Ask how the individual's mining career began. Discuss with your counselor what you have learned.
   (b) Find out about three career opportunities in the mining industry. Pick one and find out the education, training, and experience required for this profession. Discuss this with your counselor, and explain why this profession might interest you.
   (c) With your parent or guardian's permission and counselor's approval, visit a college, university, or trade school to learn about educational and training requirements for a position in the mining industry that interests you. Find out why this position is critical to the mining industry, and discuss what you learned with your counselor.



Contents

The largest haul trucks have tires up to 13 feet or more in diameter, each costing $42,500. The haul truck has a sticker price of about $5 million.

Introduction to Mining: Earth's Mineral Wealth

Mining is the removal of materials of value from Earth so they can be used by society to create products and services we need.

Miners have a saying: "If it can't be grown, it has to be mined." Look around your room. Notice everything that was made from something grown, like wood or cotton. Now look at all the things in the room that were *not* grown, such as plaster, glass, and metallic objects. These were made using materials that were mined from Earth. Yet even the things that were grown required equipment for their planting, cultivation, and harvesting; this equipment was made from minerals.

How important is mining to society? From communications, transportation, power, construction, agriculture, and medicine to education, entertainment, and recreation, every aspect of society relies on mining. Whether it's a car, computer, surgeon's scalpel, smartphone, television, goalpost, or almost any other object you can name, the materials for making it (or for making the machines that produce it) must come from a mine.

What's in Your Smartphone?

Producing a typical smartphone calls for the following metals and elements found in minerals: aluminum, antimony, beryllium, cadmium, carbon, chromium, cobalt, copper, gallium, gold, indium, iron, lanthanum, lead, lithium, manganese, mercury, neodymium, nickel, niobium, nitrogen,oxygen, palladium, platinum,silicon, silver, tantalum, tin, tungsten, vanadium, zinc.

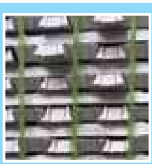
Rapid communications, information technologies, and the ability to store, retrieve, and transmit data for education, industry, and recreation—such as video games and music downloads—are important to us. Mining provides the raw materials for all the hardware for these conveniences. For example, about 34 different products from mining are required to produce a car; a smartphone requires about 30.

Mining produces coal for generating electricity and for use as a raw material for many industrial processes. Uranium, used mostly for nuclear power, is also mined. Even the devices that convert renewable energy (solar, wind, water) to electricity are made from mined materials.

Minerals in Your Everyday Life

Many minerals must be mined to manufacture a bicycle—here are just a few.

[1] Rubber contains sulfur, zinc, salt, iodine, and silica.
[2] Steel contains mainly iron, carbon, and manganese.
[3] Stainless steel contains mainly iron, chromium, and nickel.


Aluminum

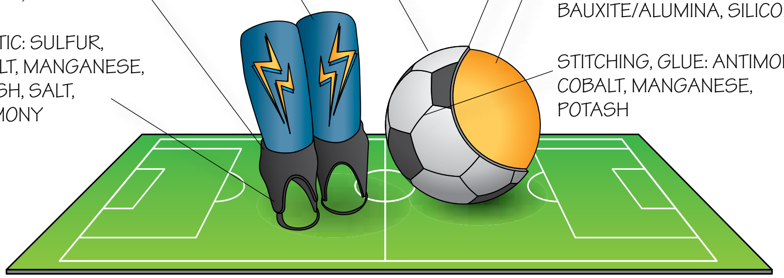

Titanium


Silica


Sulfur


Carbon

In soccer, the ball and protective gear require many minerals.



Source: Minerals Education Coalition

The Importance of Mining

In geology, a mineral is a naturally occurring crystalline substance with its own chemical formula and its own distinctive physical properties. A rock may be made up of one or more minerals.

In mining, the term *mineral* has a wider meaning. It refers to all the substances that are extracted from Earth for human use. Mined minerals are classified as metallic, energy, or industrial.

- *Metallic* elements and compounds conduct heat and electricity, are ductile (can be drawn or stretched into wire), malleable (can be hammered into sheets), and shiny. Examples are copper, aluminum, iron, and zinc.
- *Energy* minerals mostly supply electrical and mechanical power by their combustion. They can also be used as a feed stock (raw materials) for liquid transportation fuels and coke (a solid fuel made by heating coal in the absence of air), which is used to make steel. Fossil fuels, such as coal, are energy minerals. Another is uranium, which undergoes nuclear fission in a reactor to produce heat, which turns water into steam, which drives a turbine to make electricity.
- *Industrial* minerals are neither metals nor fuels, but are mined because we use them every day: in construction, in manufacturing, and even in the food we eat. Examples include clay, sand, limestone, gypsum, sulfur, salt, quartz and pumice.

Glass was first made and used in the Bronze Age.

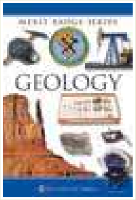
Your home is built of numerous materials that were mined. Are the outside walls of your home or apartment made of brick, stone, or aluminum siding? All had to come from a mine at one stage or another. In a typical home, the inside walls are wallboard made of gypsum. The foundation is concrete with crushed stone in it, and the roofing shingles contain fine crushed stone. Window glass is made by combining silica sand, dolomite or limestone, and soda ash. Appliances are made mostly of metals. Paint has mineral pigments. Except for wood doors and window frames, wood framing, and the like, most of your home and everything in it came from mines and quarries.

The typical family home is composed of many mined resources. With your parent or guardian's permission, you can learn more by visiting the website of the Minerals Education Coalition at mineralseducationcoalition.org/outreach-awareness/mining-in-society-merit-badge/

The power to heat and cool homes and to run entertainment and communications devices comes from minerals such as coal and uranium. Electricity generated from energy minerals is transmitted long distances on metal wires—aluminum and copper. Minerals are essential for affordable and convenient electricity on which we depend. Without mining there is no electricity!

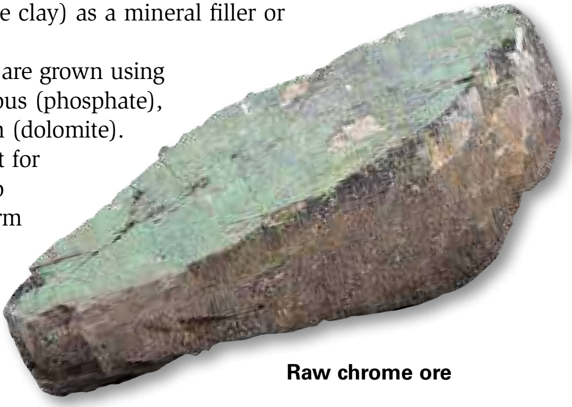
Transportation depends on the products of mining. Bicycles, automobiles, trucks, ships, and airplanes are made from minerals. Highways and airport runways are made of quarried crushed stone bonded with asphalt or cement—all minerals.

For more about rocks and minerals, see the *Geology* merit badge pamphlet.



Even things we think of as organic (grown) depend on mining. For example, paper made mostly from wood pulp may have limestone or kaolin (fine white clay) as a mineral filler or coating.

Wood products and food crops are grown using fertilizers that are mined: phosphorous (phosphate), potassium (potash), and magnesium (dolomite). The manufacture of farm equipment for cultivating and harvesting crops also depends on the mining industry. Farm machinery is made mostly of steel (made from iron and carbon), with copper for wires, aluminum in engine blocks and wheels, lead in batteries, and chrome for trim.



Raw chrome ore

At mealtimes, you use all sorts of minerals. You eat with metals—stainless steel utensils. You cook with power from energy minerals. You eat off ceramic dishes, and drink from glass containers—made from industrial minerals.

Minerals in Human History

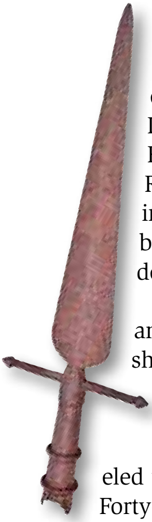
People have depended on Earth's mineral wealth throughout history. Periods of human civilization are named for these materials—the Stone Age, Bronze Age, and Iron Age. In prehistoric times, humans made stone tools and weapons: arrowheads, spear points, knives, axes, and hammers, among other objects. People adorned themselves with necklaces, rings, and amulets made of stone, and they shaped clay into pots and other containers.

Metals such as copper, gold, and silver, found on or near the surface of the ground, were first used as decoration. Gold was easily noticed in streambeds because of its bright yellow color. It was easy to pound and stretch into desired shapes, often as jewelry and as objects of art and worship.

For early humans, copper served many practical purposes: tools, weapons, jewelry, and decoration. Although copper is brittle in its native state, people learned to make it more workable by heating it in a fire (annealing). Heating also melted the copper out of the rocks that contained the metal—a process known as *smelting*.

Early metalworkers discovered bronze by smelting together rocks that contained both copper and tin. Bronze is harder, less brittle, and more durable than copper; tools and weapons of bronze were better able to maintain a sharp cutting edge. The Bronze Age was named for this alloy (an alloy is a combination of two or more metals); its properties made it so significant in human history.

With technological advances came the Iron Age, when iron and steel became extensively used, especially for cutting tools. Smelted iron was hammered into the desired shape to make steel swords and other weapons and tools.

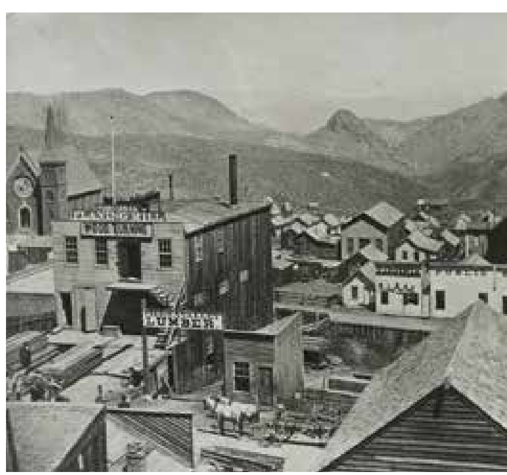


In ancient Rome, soldiers carried steel swords, and they were sometimes paid with another mineral: salt. In fact, the word *salary* comes from the Latin word for salt, *salarium*. It was important to Romans as a food preservative and seasoning. The Romans built roads to make it easier to ship salt into the city. For instance, the *Via Salaria*, a road between the Adriatic Sea and Rome, made the delivery of highly valued sea salt faster and easier.

As important as salt was to the ancient Romans, an even more valuable mineral—gold—helped to shape the history of North America. It sparked mass migrations of people in search of their fortunes. After gold was discovered at Sutter's Mill, California, in 1848, more than 300,000 people traveled to California over the next seven years. Known as the Forty-Niners, the newcomers came by land and sea, helping to settle the western United States.

The Klondike Gold Rush of 1896–1899 brought more than 100,000 gold seekers to Alaska on their way to the Yukon region of northwest Canada. The harsh conditions stopped many, but then in 1899 gold was discovered in Nome, Alaska, triggering another mad dash by gold prospectors.

Gold was not the only valuable metal found in the American West. When silver was discovered in the Comstock Lode in 1859, Virginia City, Nevada, became a bustling boomtown almost overnight. San Francisco, California, grew into a major financial center because its banks funded the mining. Comstock Lode silver helped finance the Union in the Civil War (1861–1865).



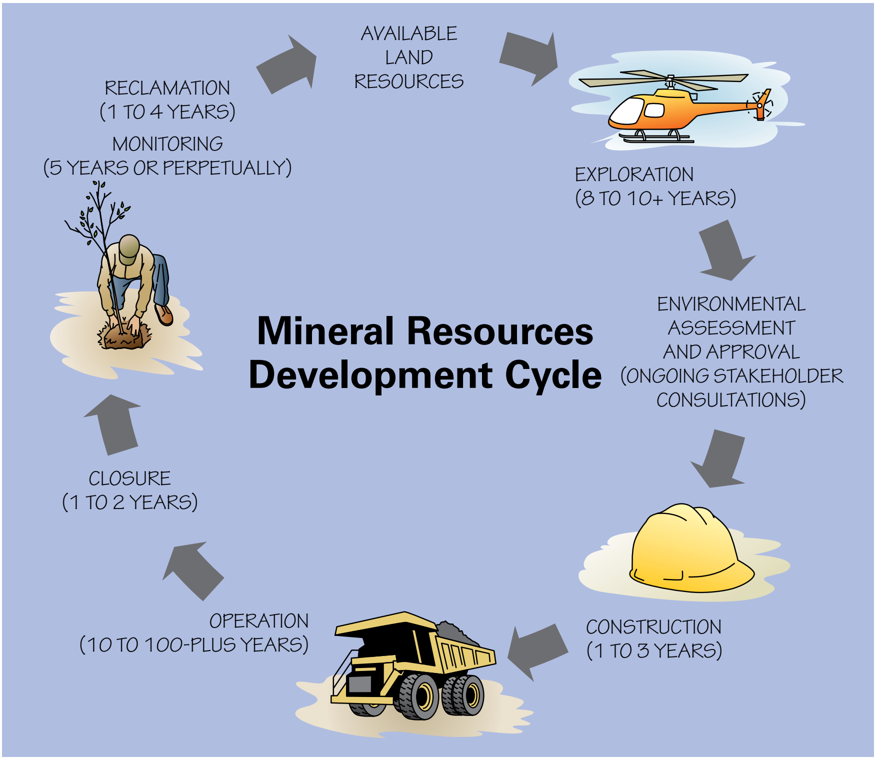
Because legal battles were waged over claims ownership, the U.S. Congress in 1866 passed the first law to govern how Americans could prospect and mine on federal public lands. Then in 1872, Congress passed the General Mining Act, which is still in effect today.

One Miner's Story: John W. Mackay

John William Mackay (1831–1902) was born in Dublin, Ireland. His immigrant parents came to New York in 1840. As a 20-year-old, Mackay made his way west, hoping to strike it rich with the rest of the Forty-Niners during the California Gold Rush. He didn't find much gold, but in 1873 he struck the Big Bonanza, one of the greatest silver veins ever found. In just four years, the Big Bonanza mine in Nevada produced over $400 million in silver. As senior partner, Mackay kept the largest share for himself. When the silver played out in 1877, he and his partners moved to San Francisco as millionaires.

Mackay was a great philanthropist. He donated generously to the Nevada School of Mines, originally established in 1888 and renamed The Mackay School of Mines to honor its benefactor. Today the school is called the Mackay School of Earth Sciences at the University of Nevada, Reno. The school has graduated generations of mining professionals who have worked throughout the world.

In what other ways have minerals influenced history? Consider this more recent example. In the 1920s and '30s, the Empire of Japan sought to conquer its Asian neighbors. Japan needed iron and petroleum, which it did not have in large amounts. China and Southeast Asia, however, were rich in these mineral resources. To stop Japan's aggression, the United States cut off shipments of iron and steel along with oil exports to Japan. Japan considered this an act of war, and on Dec. 7, 1941, the Japanese attacked the U.S. Navy battleship fleet at Pearl Harbor, Hawaii. Japan's surprise attack brought the United States into World War II.



There are many steps in finding the mineral resource; planning, constructing, and operating the mine; then closing the mine after the resource is removed. This illustration shows the sequence of events. *Source: Mineral Resources Education Program of British Columbia*

Minerals and Rocks

A rock is made up of one or more minerals, glass (volcanic), or inorganic and/or organic material. An *ore* is a type of rock that can be mined at a profit. The three rock types are *igneous*, *sedimentary*, and *metamorphic*.

- Igneous rocks come from the cooling of molten rock called *magma*. Examples include granite, which forms deep inside Earth, and basalt, which occurs on or near the surface as volcanic eruptions or lava flows.
- *Clastic* sedimentary rocks form when particles eroded from older rocks are transported, deposited, compressed, and typically cemented into new rock. Examples are sandstone and shale. *Biochemical* sedimentary rocks form by accumulating the remains of organisms that extract materials dissolved in air and water to form their tissue. Examples are coal and most limestone. *Chemical* sedimentary rocks form by minerals precipitating from fluids or when fluids evaporate. Examples are rock salt and some limestone.
- Metamorphic rocks form when older rocks are exposed to high temperature, high pressure, or both, to create a new rock. Under these conditions, limestone becomes marble, shale becomes slate, and granite becomes gneiss.

Geology is the study of minerals and rocks, the processes that form them, and how they are distributed on Earth. The *Geology* merit badge pamphlet can help you identify rocks and minerals and understand their origins.

Geologic events determine where different rock formations are found that contain the minerals we value. How often geologic events happen determine how commonly or rarely a mineral occurs near Earth's surface. Some common minerals are mined at many locations. Others are so rare, they are mined in only a few places on Earth. If a mineral is mined only in foreign countries, then it must be imported into the United States.

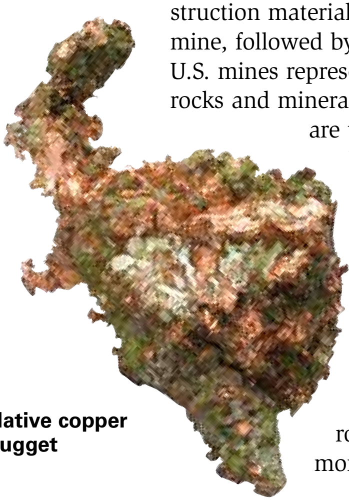
Stone is any hard igneous, sedimentary, or metamorphic rock used for construction or decoration. It is an example of an industrial mineral.

Important Minerals Used Every Day

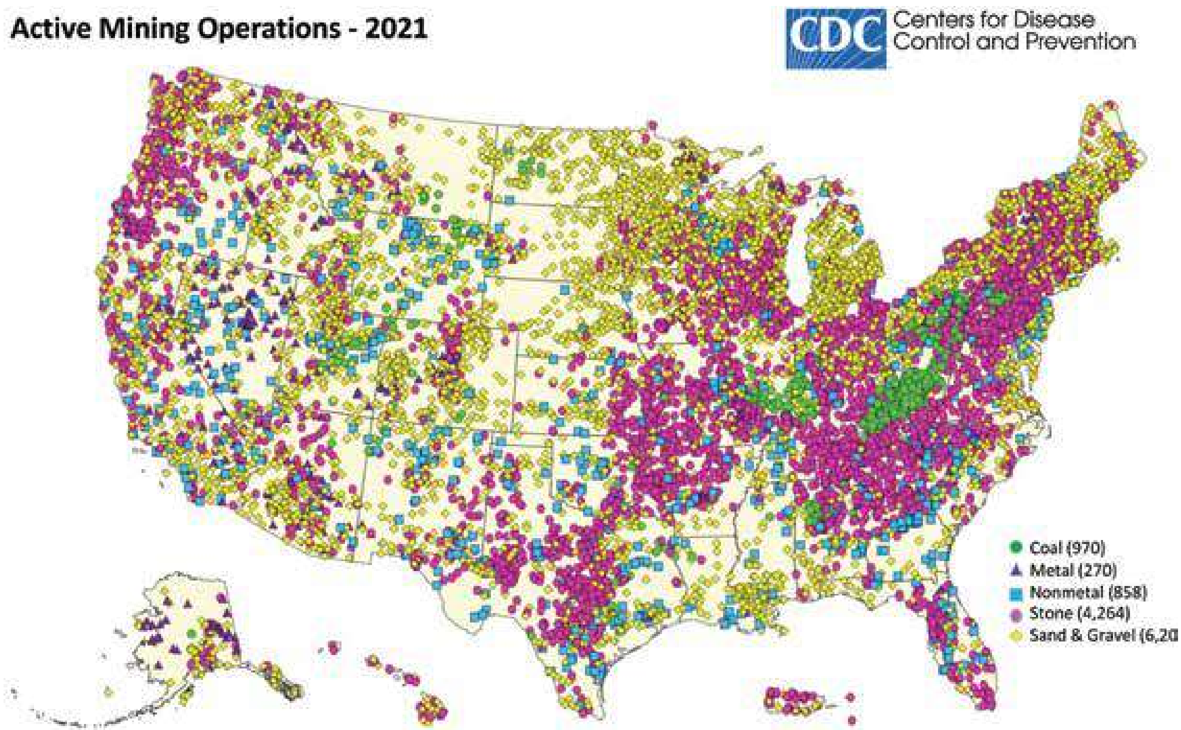
All three categories of minerals—metallic, energy, and industrial—are mined in the United States. Sand and gravel mines are the most common. Sand and gravel are used mostly as construction materials. Stone quarries are the next most common mine, followed by coal mines. The blue triangles on the map of U.S. mines represent a wide range of less common nonmetal rocks and minerals such as gypsum and clay. Metal mines are the least common type of mines in the United States.

The following describes some important mined materials: sand, limestone, clay, coal, copper and gold.

Sand. Sand is a simple material readily found all over the world. It is used in many things you encounter every day, such as glass, concrete, playground sandboxes, beach volleyball courts, and paint (to give walls a rough surface texture). You probably know of more uses, but you might not think of these.



Native copper nugget



This map, which shows all 12,567 active mining operations in the United States in 2021, illustrates how widespread mining is in this country. The land seems to be covered by the 12,567 mining operations, but only because the size of the map symbols is large. In fact, only 2.5 of every 1,000 acres in North America are occupied by mines. From this small area come all the minerals we use. Interested in learning more about what is mined near you? Visit wwwn.cdc.gov/niosh-mining/MMWC

- The petroleum industry uses sand in the process of hydraulic fracturing to improve oil and gas flow in its wells.
- Highway departments spread sand on icy, snowy roads in winter to keep cars and trucks from sliding.
- Foundries cast metals such as iron and bronze in molds made of sand. The mold holds the molten metal while it cools, giving shape to the engine block in your family car, for instance.

Limestone. Limestone is a common biochemical sedimentary rock formed mostly from the accumulation of the shells of marine organisms. Some limestone can form as a chemical precipitate from fresh or salt water. Here are some everyday uses of limestone.

- Limestone blocks of different shapes and sizes are cut for building stone, countertops, flooring, monuments, and landscape rock.
- Crushed limestone is used in concrete and as a base for roads and foundations.
- Limestone is the main ingredient in making portland cement.
- Limestone is pulverized into a fine powder for filler in paper, plastics, and paint.
- Limestone is a soil conditioner, neutralizing acidic soils; a neutralizer in municipal water treatment; and a scrubbing agent, removing sulfur from smokestack emissions.
- Limestone removes impurities in glass- and steelmaking; purifies sugar; and prepares wools and dyes.
- Heated in large kilns, limestone becomes lime (CaO) for use in steelmaking; removing sulfur from smokestack emissions; water treatment; and construction. Pure calcite is produced with lime for use in paper, plastics, paint, toothpaste, food additives, antacids, and calcium supplements.

The U.S. Geological Survey estimated that in 2022 about 94.5 million metric tons of cement was produced at 96 plants in 34 states and Puerto Rico.

Clay. Common clay is used to make bricks. Other types of clay are kaolin, bentonite, and fuller's earth. The United States is one of the largest producers and exporters of these. Kaolin is a white pigment used in papermaking, paint, rubber, and plastics and as a major component in ceramics such as china, sinks, and toilets. Bentonite is swelling clay used mainly for muds in drilling for oil and gas, and in landfill barriers protecting groundwater from toxins that may leak from landfills. Because fuller's earth absorbs odors and fluids, it is commonly used in cat litter and spill kits.

Coal. Coal (an energy mineral) is a sedimentary rock formed from plant debris deposited in swamps and bogs. Sediments covered the swamps and bogs over millions of years, squeezing the plant material into a black solid (coal). Coal is classified into several kinds based on its carbon content and density: peat, lignite, bituminous, and anthracite. From lowest to highest—that is, from peat to anthracite—the ranking also indicates the level of energy released when the coal is burned.

The United States has 25 percent of the known coal in the world. Discovered as the "burning rock," coal later provided the energy to power the industrial revolution over a century ago. Today it is used mostly for generating about 20 percent of the country's electric power.

Coal is also burned in kilns to make bricks, cement, and lime. In making iron, coal serves as a fuel when converting the iron ore into iron metal; in steelmaking it serves as a fuel and as a source of carbon. Coal is important in papermaking and in chemicals and pharmaceuticals. Products containing coal or its byproducts include soap, aspirin, dyes, plastics, rayon, nylon, toothpaste, and cosmetics. Coal mining employs about 20.4 percent of all U.S. miners.

Copper. The most noticeable thing about copper is its color: a rich reddish-orange. It is one of only two metals with its own distinctive color (the other is gold). It was easy to find in ancient times because some of its many ores are green and blue. Copper was also found in its native metal state.

Copper is an excellent conductor of electricity and heat. It is ductile (easily drawn into wire); it is malleable (can be beaten into thin sheets); and it easily forms *alloys*. Copper is widely used in electrical wiring, electronics, water pipes and tubing, and as gutters and roofing material. Copper's antimicrobial property makes its use valuable in hospitals, kitchens, and doctor's offices.

Copper's main alloys are brass and bronze. Brass is an alloy of copper and zinc; bronze is an alloy of copper and tin. Bronze is hard and tough and typically used in statues, church bells, medals like those awarded in the Olympics, and musical instruments such as cymbals. Brass resists corrosion and has a bright yellow color, somewhat like gold. Common objects made of brass include doorknobs, musical instruments like trombones and trumpets, door keys, and plumbing fixtures such as faucets and showerheads.

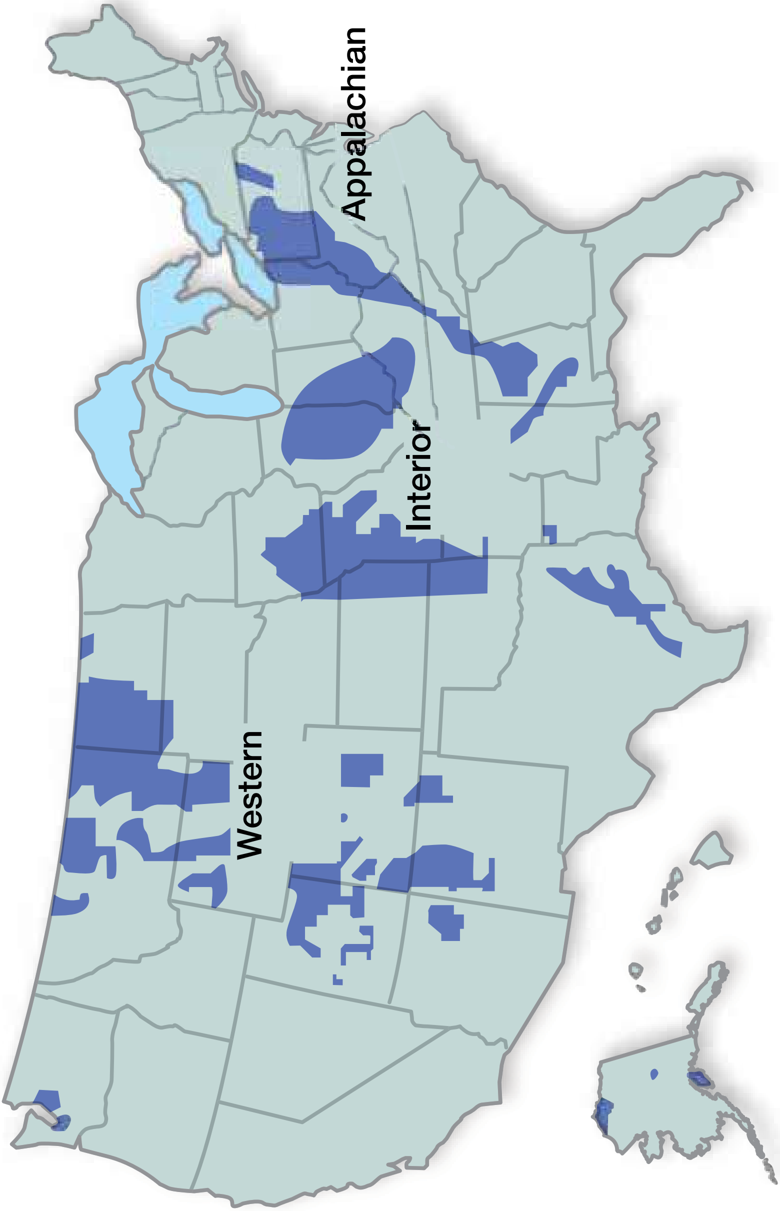
Some of the largest mines in the world today are copper mines. The metal is in high demand because of its wide variety of uses, and the search for large deposits never ends. As civilization depends more on electricity and electronic technology, the demand for copper will continue.

Gold. Gold is produced at hard rock mines from what are called *lodes* (vein or bedrock ore deposits) and a few large *placer* (river or lake deposits) mines, as well as many smaller placer mines. In addition, a small amount of gold is recovered when mining silver and when processing metals such as copper, lead, and zinc. The U.S. exports gold, and in 2022 produced 170 metric tons, ranking fifth after China, Russia, Australia, and Canada. About 98 percent of the gold produced in the U.S. comes from only 28 mines. Nevada was the leading gold-producing state, accounting for about 72 percent of domestic production.

Gold is used mostly in jewelry, coins, and medals, accounting for about 47 percent of global gold production. Central banks and other institutions consume around 20 percent. Another 17 percent of gold production goes into physical bars, and 9 percent goes into coins and medals. Gold is a good conductor that does not corrode, making it reliable for electronics and other electrical uses. These uses account for 6 percent of gold production. The remaining 1 percent goes into medical, industrial and other uses.

Gold is so malleable that it can be pounded into extremely thin sheets called *gold leaf*. Used mainly for decoration, gold leaf adorns artwork, food (such as desserts), and even parts of buildings. The domes of several state capitols are covered with gold leaf; Colorado and West Virginia are examples.

Open-pit and placer mines are described in more detail under "Types of Mining," later in this pamphlet.



Coal is found and mined in 25 states but mostly in Appalachia and Wyoming.

Major Sources and Uses of Minerals

The following charts list minerals, their major sources, and their main uses. Note how many mineral resources are mostly or entirely mined outside the United States.

Metals

Metal (chemical symbol)	Ore (Mineral or Rock) or the host mineral when produced as a byproduct	Major Sources	Major Uses
Aluminum (Al)	Bauxite, laterite soils; (converted to alumina first)	China, Brazil, Indonesia	Lightweight metal parts of all types
Antimony (Sb)	Stibnite	China	Flame retardant, lead alloys (batteries), chemicals
Beryllium (Be)	Beryl and bertrandite	USA, China	Electronics, defense applications, nonsparking tools
Chromium (Cr)	Chromite	South Africa, Kazakhstan	Stainless steel, electroplating
Cobalt (Co)	Cobaltite	Republic of Congo, Zambia	Superalloys, chemicals
Copper (Cu)	Copper sulfides	Chile, China, Peru, USA	Electrical applications, building construction
Gallium (Ga)	From bauxite and sphalerite	China, Germany, Kazakhstan, Ukraine	Electronics
Gold (Au)	Native metal in lode and placer deposits	China, USA, Australia, Russia, South Africa	Jewelry, dentistry, electronics
Indium (In)	From zinc ores	China, Canada, Japan, South Korea	Liquid crystal displays (LCDs)
Iron (Fe)	Hematite and magnetite	China, Australia, Brazil, India	Wrought iron, cast iron, steel
Lead (Pb)	Galena	China, Australia, USA	Lead-acid batteries, bullets, ballast, glass

Metal (chemical symbol)	Ore (Mineral or Rock) or the host mineral when produced as a byproduct	Major Sources	Major Uses
Lithium (Li)	Igneous rock and brine (salt) deposits	Australia, Chile, China	Ceramics and glass, batteries
Manganese (Mn)	Pyrolusite	South Africa, USA, China, Gabon	Steelmaking, pig iron production
Molybdenum (Mo)	Molybdenite, from copper and tungsten ores	China, USA, Chile, Peru	Iron and steelmaking, superalloys, lubricants
Nickel (Ni)	Pentlandite, laterite deposits	Philippines, Indonesia, Russia, Australia, Canada	Stainless steel, superalloys
Palladium (Pd)	Native metal in alluvial deposits, copper and nickel ores	USA, South Africa, Russia, Zimbabwe, Canada	Catalytic converters, petroleum refining, dentistry, jewelry
Platinum (Pt)	Native metal in alluvial deposits, copper and nickel ores	USA, South Africa, Russia, Zimbabwe, Canada	Catalytic converters, petroleum refining, jewelry, laboratory equipment
Silver (Ag)	Ores of copper, copper-nickel, lead, and lead-zinc	Mexico, China, Peru	Electronics, coins and medals, photography
Tantalum (Ta)	Tantalite, coltan ores	Rwanda, Mozambique	Electronic components, alloys, superalloys
Titanium (Ti)	Rutile, ilmenite	Australia, South Africa, Canada, China, USA	White pigments, welding rods, alloys, airplane parts
Tungsten (W)	Wolframite, scheelite	China, Russia, Canada	Tungsten carbide, tungsten metal wire, alloys
Zinc (Zn)	Sphalerite	China, Australia, Peru, USA	Galvanizing, zinc-based alloys, brass and bronze

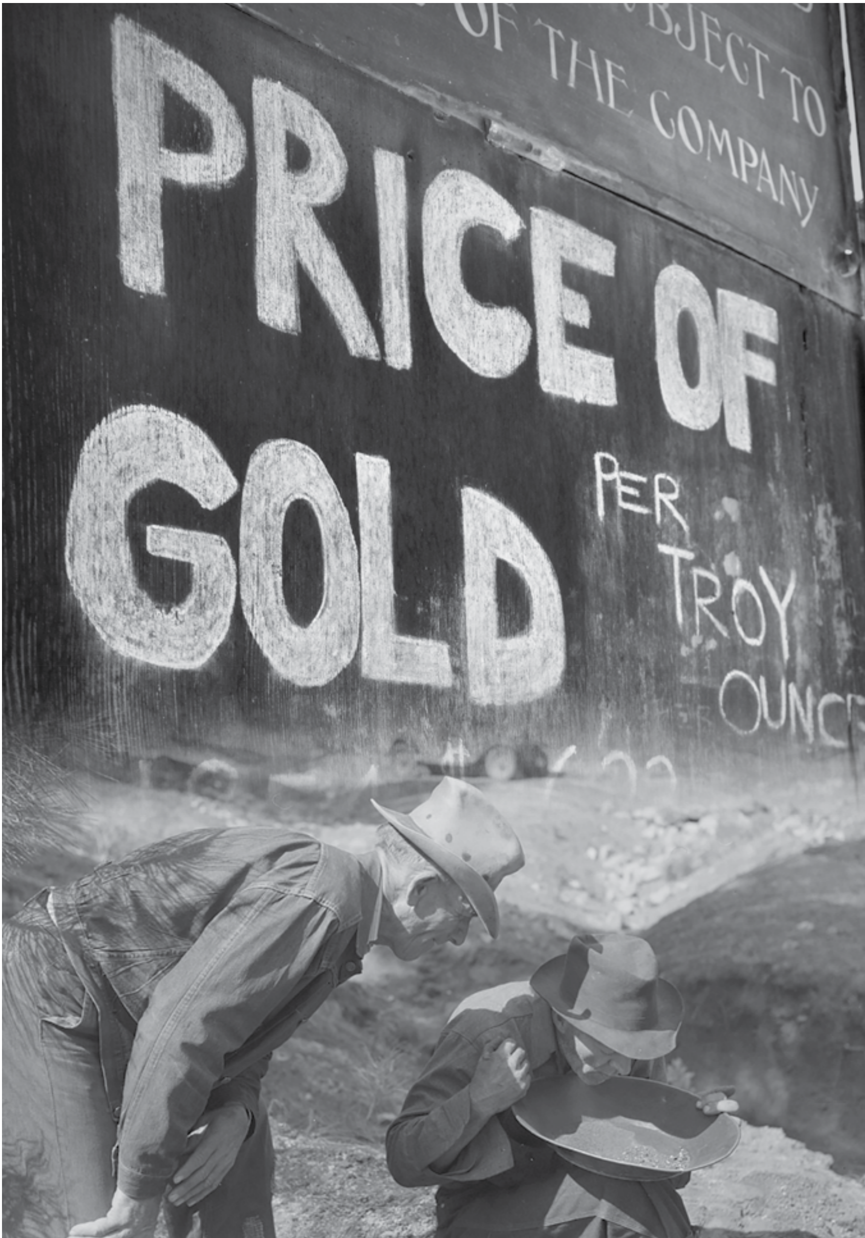
Industrial Minerals

Mineral	Ore (Mineral or Rock)	Major Sources	Major Uses
Barite	Lead-zinc veins in limestone, hot-spring deposits, and hematite ore	China, India, USA	Drilling mud, filler in paint and plastic
Bauxite	Sedimentary rock (lateritic soils)	USA, China, Brazil, Indonesia	Production of alumina and aluminum, abrasives, ceramics, paper
Bromine	Salt deposits and seawater	Oceans, salt domes	Flame retardants, water purification
Diatomite	Sedimentary rock	USA, China, Denmark, Japan	Filtration, absorbents, abrasives, fillers and extenders
Dolomite	Sedimentary rock	China, India, European Union, USA	Aggregates, refractories, lime
Feldspar	Igneous rock, metamorphic rock, and sedimentary rock	Italy, Turkey, China	Glassmaking, ceramics, fillers in paint, plastics and rubber
Fluorite	Veins associated with lead-zinc, barite, quartz, and calcite	China, Mexico, Mongolia	Hydrofluoric acid, steelmaking, glassmaking, enamels
Gypsum	Sedimentary (evaporite) rock	China, Iran, Thailand, Spain	Wallboard, plaster, retardant in cement, soil amendment
Iodine	Caliche, oil-field brine, seaweed (extracted from seawater)	Chile, Japan, USA	Medicine, catalysis in plastics, nutrition, liquid crystal displays
Limestone	Sedimentary rock	China, India, European Union, USA	Aggregates, cement, dimension stone, lime
Perlite	Igneous (volcanic) rock	USA, Greece, Turkey, Japan	Construction products, fillers, horticultural, filter aids
Phosphate	Sedimentary rock	China, USA, Morocco, Russia	Fertilizer, animal feed supplements, food additives

Mineral	Ore (Mineral or Rock)	Major Sources	Major Uses
Potash	Sedimentary (evaporite) rock	Canada, Russia, Belarus, China	Fertilizer, chemicals
Quartz (silica)	Sedimentary rock, sand, and igneous rock	China, Brazil, USA	Computer chips, sand, glassmaking, ceramics, food additives, gems
Salt	Sedimentary (evaporite) rock	China, USA, Germany, India	Road deicing, chemicals, food processing and additives, plastics
Sulfur	Byproduct of petroleum refining and sulfide mineral smelting	China, USA, Canada, Saudi Arabia	Fertilizer, sulfuric acid, petroleum refining, metal mining
Trona	Sedimentary (evaporite) rock	USA, Turkey	Glassmaking, chemicals, soaps and detergents
Zeolites (aluminum silicate)	Igneous (volcanic) rock and sedimentary rock	China, South Korea, Japan, Jordan, Turkey	Laundry detergent, water purification, catalysts

Energy Minerals

Mineral	Ore (Mineral or Rock)	Major Sources	Major Uses
Coal	Sedimentary rock	China, USA, India, European Union, Australia, South Africa, Canada, Russia	Electricity generation, coke, chemicals
Lignite	Sedimentary rock	European Union, USA	Electricity generation
Peat	Sedimentary rock	European Union, Belarus, Russia, Canada	Plant-growth medium, filtration, industrial absorbent
Tar sands, bitumen, oil shale	Sedimentary rock, sand, clastics, shale, clay	Canada, Venezuela, Russia, Kazakhstan, USA, Nigeria, Estonia, China, Brazil, Germany, Australia, Israel, Jordan, Morocco, Sweden, Turkey, Thailand, Syria	Crude oil, combustible gas, asphalt
Uranium	Uraninite and pitchblende	Kazakhstan, Canada, Australia, USA	Electricity generation, military projectiles, nuclear weapons


OF THE COMPANY
PRICE OF GOLD
PER TROY

Exploring for Minerals

In mining, *exploration* is the search for a useful mineral that can be extracted from Earth's crust. When you think of exploration, you might imagine an old-time prospector with a trusty mule. With pick and shovel, the prospector would go off in search of something valuable. One common method of exploration was to find a place that had geology similar to a known ore deposit. For example, in 1849 in California, prospectors who knew that gold could be found in some streams would pan for gold there.

Panning is a method of separating gold from other particles. Small amounts of gravel and sediment from the streambed are put in the pan. The pan's contents are swirled gently, allowing lighter materials to wash out of the pan. Heavier particles fall to the pan's bottom. Any gold will remain in the bottom of the pan.

A prospector would follow the gold upstream, panning every so often, seeking the "mother lode," or major ore deposit. When gold could no longer be found in the sediments, a prospector would backtrack to locate where the gold was entering the stream, narrowing the search. Traditionally, once the place was found, the prospector would shout, "Eureka!"—Greek for, "I found it!"

Modern Exploration Methods

Many old methods are still used, but today's "professional prospectors" have more high-tech ways of locating the right geological conditions for the kind of deposit being sought. Modern-day specialists include geologists, geochemists, mining engineers, metallurgists (experts in metals), and logistics specialists (experts in handling the details of an exploration venture).

In their planning, exploration teams often use remote sensing. Using satellites and airplanes, the team collects and processes data using different detection methods, from photography to multispectral scanning. Some methods that use laser technology even allow scientists to “see through” trees and vegetation to the ground beneath.

Because we can’t see below Earth’s surface to identify deposits underground, the team relies on geophysical methods that measure differences in gravity, magnetism, radiation, and electrical resistance. For shallow studies, the team may use ground-penetrating radar. Seismic techniques give the team a picture of underground rock formations, similar to how earthquakes are located and measured.

One basic method that has long been used is to conduct an assay. Just as an 1849 California prospector might bring in a rock sample to have its composition analyzed, so do modern prospectors. By a series of chemical and physical tests, assaying reveals the elements of a rock sample. If an element of value has a high enough concentration, then an exploration program may follow. Some people choose exploration as a career because much of it is done outdoors.

Steps in Exploration

Mineral rights are property rights that allow the owner to extract minerals within an area; they may be separate from surface property ownership.

An exploration team always plans ahead. Team members first read the scientific literature about the area and the type of mineral deposit they are seeking. This research helps make the most of valuable field time. The team determines what tools to use for exploration. Basic tools used for geologic mapping and sampling in the initial fieldwork include a sturdy field vest or backpack, maps and GPS devices, a compass, a hat that provides shade, a full canteen, good hiking boots, a jacket, eye protection, a rock hammer, sample bags, a notebook and writing instrument(s), a pocketknife, a dilute hydrochloric acid solution, and sometimes a four-wheel-drive vehicle.

The team then sets a timetable for when the work will be done and prepares a budget to determine how much the project will cost. Good communications are essential so the team members’ location, and when they plan to return, is always known.

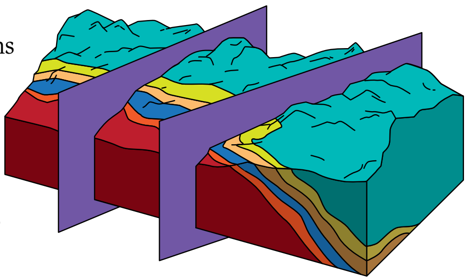
Land ownership is an important consideration. The exploration team needs to avoid trespassing (exploring on land without authorization). Local government offices have records of land ownership as well as information on who owns the mineral rights.

Besides asking the surface owner(s) for permission to prospect on a piece of land, the team may need to get permits from local, state, or federal government agencies before exploration on the ground begins. Typically, a team has specialists who find out about land ownership and obtain the necessary permits.

Drilling and Imaging

If the fieldwork uncovers good signs of valuable minerals, the next step may be to drill core holes. This allows the geologists to see underground. Drilling also provides more geochemical or geophysical data.

The exploration team enters all the data collected into a computer, constructing a geological model of the mineral resource. With enough data, a three-dimensional computer image can be created to show what the mineral deposit looks like underground.



Mining software uses prospecting data to build images of mineral deposits. This "slice" through such a model provides a 3-D view.

The next phase of exploration involves additional drilling of the mineral deposit. This helps determine the concentration of an element or a compound, along with other characteristics that allow it to be mined and processed. Once team members know how big the deposit is and what the grade is, they calculate the amount of the resource present. The resources calculation estimates how much ore is in the deposit. If the analysis is positive, then the next step is mine planning to see if mining is feasible.

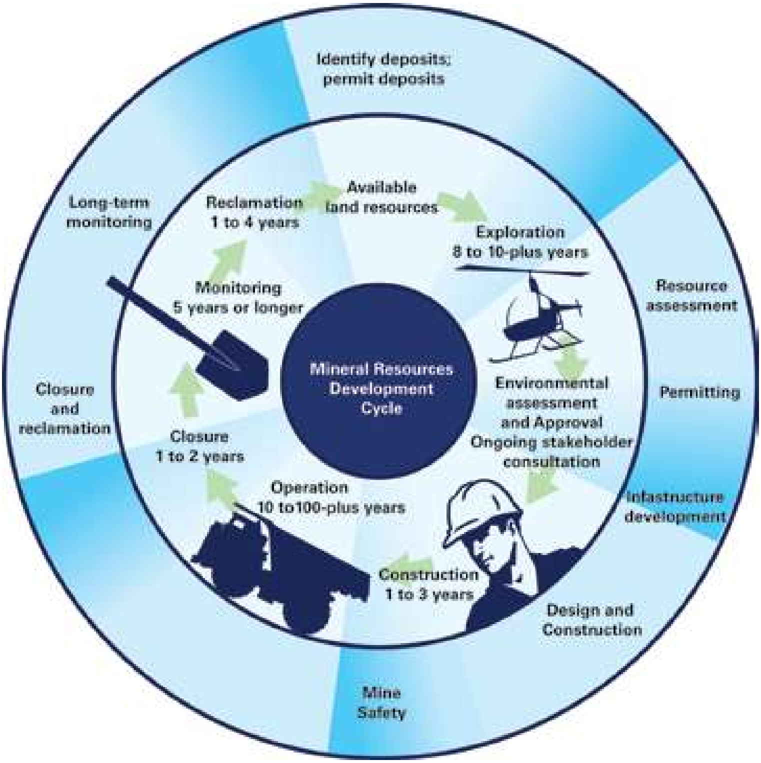
The Major Steps in Exploration

1. Library studies identify geological formations that may hold a mineral.
2. Remote sensing may help to identify places to send an exploration team.
3. Fieldwork planning is completed (obtaining permits, getting permission to explore the site, etc.).
4. After geologic mapping and sampling, more tests, like drilling, may be necessary.
5. Field data is used to build a computer model of the mineral deposit.
6. If there is potential economic value, core drill sampling is done.
7. Enough data is collected to confirm the size and quality of the deposit.
8. If the deposit still has potential economic value, mine planning begins.

Mine Planning and Operations

If you're preparing to write a report for school or take a hike, your first step is to make a plan. You may plan by yourself, or have help from friends and family. The same is true in organizing a mining operation. Mine planning is the realm of the mining engineer, supported by geologists, metallurgists, and others.

Planning a new mine takes several steps as seen in this illustration. The steps are all connected. For instance, mine design and safety go hand-in-hand; land reclamation and mine closure may occur at the same time.



Major Considerations

When *identifying resources* that could be mined, mining engineers (with the geologist) review the site information and analyze geographic, geologic, technical, and economic information. As mining engineers calculate the resources that are recoverable (obtainable), they evaluate all the advantages and disadvantages of the mine site. This tells if it is feasible to mine and process resources economically and legally. A *feasibility study* completed at this point allows the mining company, bank(s), or investor(s) to decide if the project is worth their spending additional funds on it.

Resource control confirms ownership of land and minerals through lease or purchase. If the mineral is privately owned, surface and mineral owners and the mining company must all negotiate contract agreements to build the mine and share the profits.

When state or federal governments own the minerals in the ground, a U.S. citizen or corporation may stake a mining claim on land over the mineral occurrence. A claim owner has the right to possess and extract any minerals under the claim starting on the date the claim was located. There are several kinds of claims. Lode and placer claims are named for the type of mineral deposit under it. Mill site and tunnel site claims are necessary to locate and erect mills and other structures for mineral processing. We'll use a lode claim on federal land to describe how to locate a mining claim.

To locate a lode claim, you have to discover a valuable mineral there. Next you erect claim posts at the point of discovery and at each of the four corners of the claim. You then attach a location notice at the discovery post. Posted information typically includes the name of the claim, date of location, county and state, description of the land by township and range (see the *Geology* merit badge pamphlet), name and address of the locator (you), and a map of the claim. You must record this within 90 days with the U.S. Bureau of Land Management, the agency that administers all land owned by the U.S. government. You pay any filing fees at the time you record the claim.

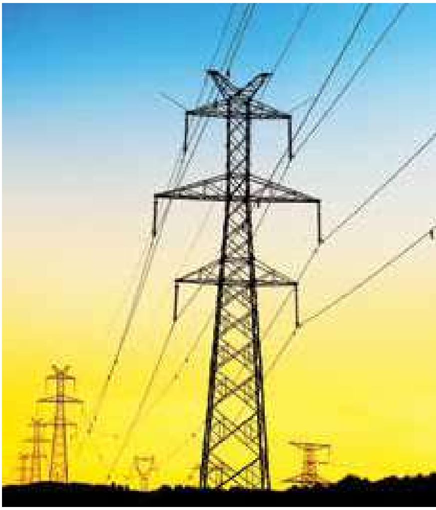
Different states may require additional information as well as recording the claim with the county and state where the claim is located. More information about staking mining claims can be found at the Bureau of Land Management website, blm.gov.
(See "Mining Resources" in this pamphlet.)

Permitting a new mine can be a lengthy process, typically five years or more. A mine plan must meet all government rules, including local ordinances, to protect air, water, land, and wildlife. Permits are needed in several categories, including:

- Mining
- Reclamation
- Water discharge
- Air emissions
- Zoning
- Safety
- Wastewater control
- Explosives material handling and storage

Local, state, and federal agencies review and approve permits. Interested people and groups can learn about the mine plan and comment on it beforehand. Mine construction begins once permits are approved and the mining company posts a bond (a financial guarantee) to ensure that funds will be available for reclamation.

Infrastructure includes roads, water wells, gas pipelines, buildings, and electric power lines that are already there. In addition, mining infrastructure needs to be built. The mine may require haul roads; shafts; elevators; additional power, fuel, and water utilities; office facilities; showers and lockers for miners; warehouse and maintenance buildings; material handling, processing, disposal, and transportation facilities; and drainage and sediment-control systems (such as sediment ponds and ditches). Parts of the existing infrastructure may be unaffected, relocated, or mined around. Mine infrastructure is built so that it doesn't interfere with mining operations. For example, processing plants should not be constructed directly over minable resources.



For more about land reclamation, see "Sustainability in Mining" later in this pamphlet.

Mine design varies according to the mining method. Plans for a surface mine take into account the shape of the pit, the amount of material to be handled, and the sequence of mining. Plans for an underground mine set the location of shafts, slopes, entries, ventilation systems, and roof supports, and the sequence of mining. Detailed plans and cost estimates determine whether a mine is economically feasible. The success or failure of the mining operation often depends on the success of the design phase.

Mine safety is an essential part of mine planning. Safe conditions provide a place where miners want to work. See "Health and Safety in Mines" in this pamphlet.

Mine closure and land reclamation shuts down the mine and restores the site to a natural condition or to a useful purpose. Former mine sites are reshaped and contoured so they blend in with the surrounding area; restored sites are then replanted with vegetation. Reclamation of underground mines tends to be less involved because affected areas are smaller than for surface mines. When government authorities declare reclamation successful, it allows the release of bonds posted before the mining started.

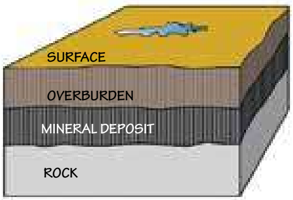
Long-term monitoring of a restored site is often necessary if there is a special concern. Examples may include specific needs for revegetation or perhaps erosion control.

Even after mining begins, mine planning doesn't stop. Ongoing mine planning can be short-term or long-term. Short-term planning typically covers less than five years, focusing on current mine operations, production goals, and economic budgets. Long-term planning extends more than a year beyond current mining activity. It provides detailed plans for at least 10 years as well as general plans for the life of the mine.

Types of Mining

The type of mine is determined by the size and shape of the mineral deposit, how deep it is, and the kind of rock that surrounds it.

TABULAR

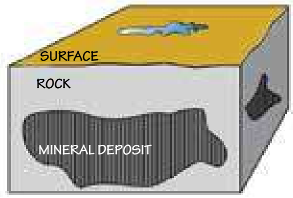


Types of Mineral Deposits

The main types of mineral deposits include *tabular*, *massive*, *vein*, and *placer*.

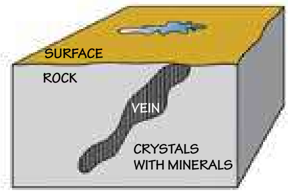
Tabular. The mineral deposit is basically horizontal and fairly uniform in thickness, like a slab or countertop. It can be at the surface or thousands of feet below. Examples of minerals found in tabular deposits are bituminous and lignite coal, limestone, salt, and trona (sodium carbonate or soda ash). Many tabular deposits like coal, gypsum, and potash may have layers of unwanted rock types in between.

MASSIVE



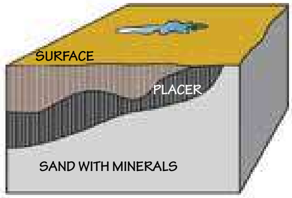
Massive. The mineral deposit lies within a large rock formation and is usually hundreds of feet thick and thousands of feet wide. It can be at the surface or thousands of feet below. Massive mineral deposits include metals like gold, silver, copper, lead, and zinc.

VEIN



Vein. The mineral deposit is a narrow sheetlike seam of mineral crystals within a host rock. Veins come from crystal growth on the walls of fractures in rocks. They usually are inclined (tilted). Some minerals found in veins include gold and silver. Steeply inclined anthracite coal formations resemble vein deposits, but they developed by folding and faulting tabular deposits.

PLACER



Placer. The deposit is an accumulation of minerals in loose sand and gravel. Streambeds and beaches are the usual sites for placers. They are mined for gold, platinum, diamonds, titanium, and uranium.

The mining engineer decides how to mine a mineral deposit safely with the least environmental impact and at the lowest cost. The type of mining depends on: 1. the material being mined; 2. the location of the material; and 3. the shape of the deposit. *Surface mining* is usually the first choice if the mineral deposit is at or near the surface. If it is deep below the surface, then *underground mining* is required.

The majority of all mined substances are mined by surface methods. Tabular, massive, and placer-type deposits are mined this way.

Surface Mines

In a surface mine, the unwanted material above the mineral deposit is called the *overburden*. Mining starts when the overburden is removed by blasting and excavating. Once the mineral deposit is exposed, miners load the ore mineral into haul trucks or conveyor belts to transport it to a mineral processing plant.

Surface methods usually involve moving large amounts of material at a relatively low cost per ton or per cubic yard. A surface mine almost always appears larger than an underground mine that produces the same mineral because all the mine-works are visible. Underground mines can be the size of cities, but are hidden from view. Many underground mines range up to 24 square miles, as large as the island of Manhattan.

ROTARY BLAST-HOLE DRILL

WHEEL LOADER

DOZER

ELECTRIC ROPE SHOVEL

HYDRAULIC SHOVEL

HAUL TRUCK

Types of equipment used in a surface mine

Surface Mining Equipment

Surface mining requires huge equipment. For example, the largest bucket from a modern rubber-tire loader, used to excavate the blasted minerals and rocks, can hold 53 cubic yards. That's 160,000 pounds of material, which is equal to the weight of about 40 pickup trucks.

EXAMPLES OF SURFACE MINES

Open-pit mine. This type of mine is typically used for massive deposits close to the surface. A quarry is a common open-pit mine. Quarries produce building materials such as sand, gravel, and stone. Quarries are often located near populated areas where the construction materials are used, so cooperation between the mine and its neighbors is essential.

Notice the benches and roadways around the inside of Utah's Bingham Canyon, an open-pit copper mine. Bench design helps maintain the stability of the mine wall. Haul roads are required to remove rock from the pit.

Strip mine. This type of surface mining is generally used for tabular deposits. The picture shows a strip mine in a coal deposit. Mine planners carefully design the angle of the rock wall (above the coal) so that it does not fail during mining.

Underground Mines

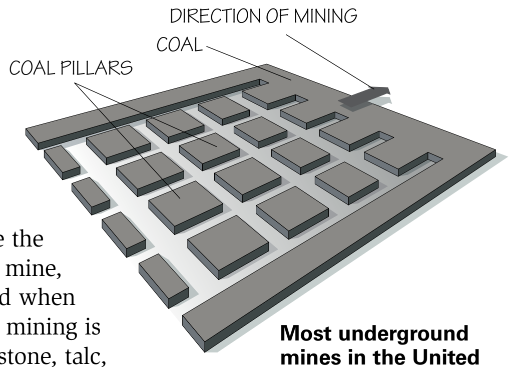
Underground mining is more selective in the way minerals are extracted. Underground mines require careful designing and planning with more structures than surface mines. The necessary structures include shafts, hoists (elevators), ventilation fans, underground maintenance shops, and conveyance (transport) systems.

The geometry, or shape, of the deposit determines which underground method to use. No two mineral deposits are identical, so the mine design is customized to the size, shape, and location of the deposit.

Types of equipment used in an underground mine

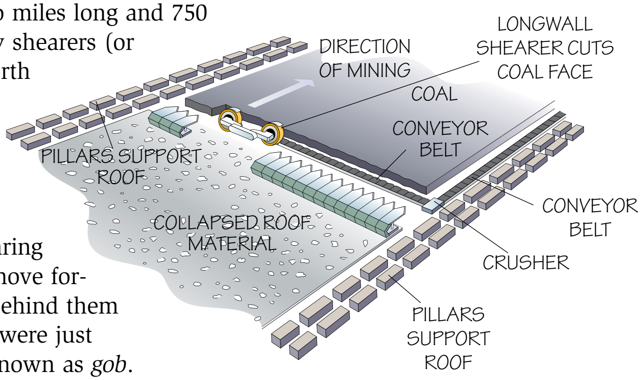
EXAMPLES OF UNDERGROUND MINES

Room and pillar. This mining method extracts minerals (tabular and massive) from a series of "rooms" along horizontal openings. Because part of the deposit is left behind as support pillars to hold up the mine roof, it is not the most efficient method. Each pillar tends to be the same size and shape for a particular mine, forming a pattern like a checkerboard when viewed from above. Room-and-pillar mining is used to extract coal and metal ores, stone, talc, soda ash, salt, and potash.

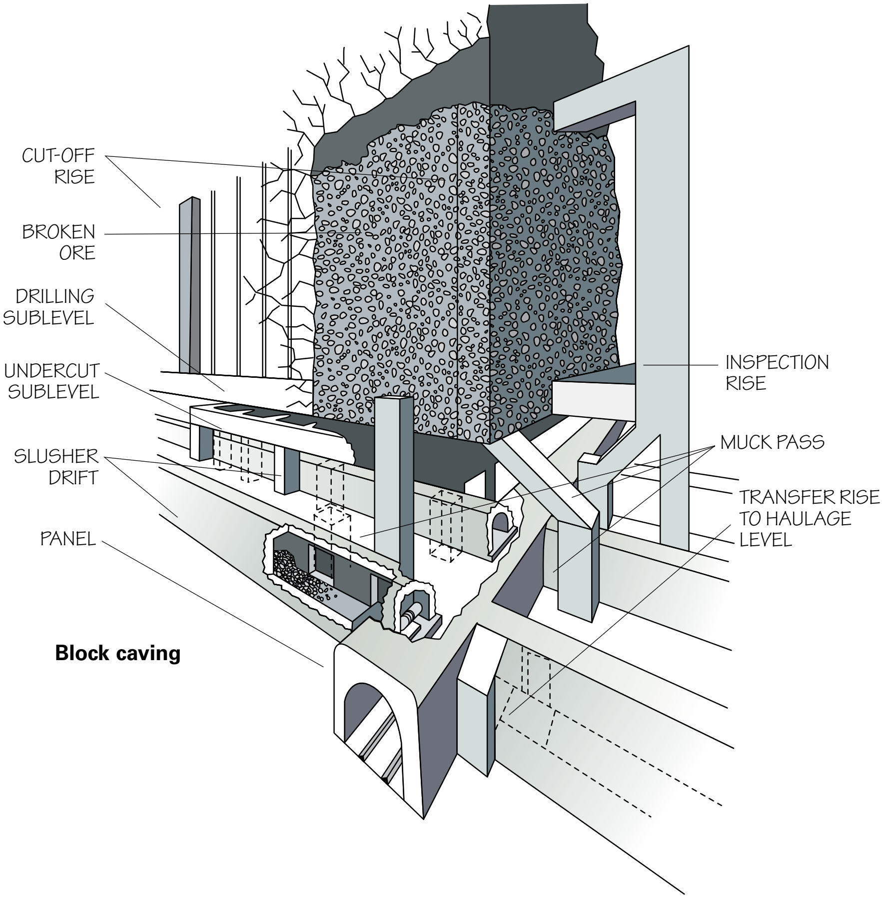


Most underground mines in the United States use the room-and-pillar method.

Longwall mining. In a longwall mine, a panel of coal or trona, measuring about two miles long and 750 to 1,500 feet wide, is cut by shearers (or plows) moving back and forth along the mine face (wall). Conveyors bring the mineral to the surface. Heavy-duty shields protect the miners working along the face and the shearing edge itself. As the shields move forward, overlying rock falls behind them into the empty spaces that were just mined. The fallen rock is known as *gob*.

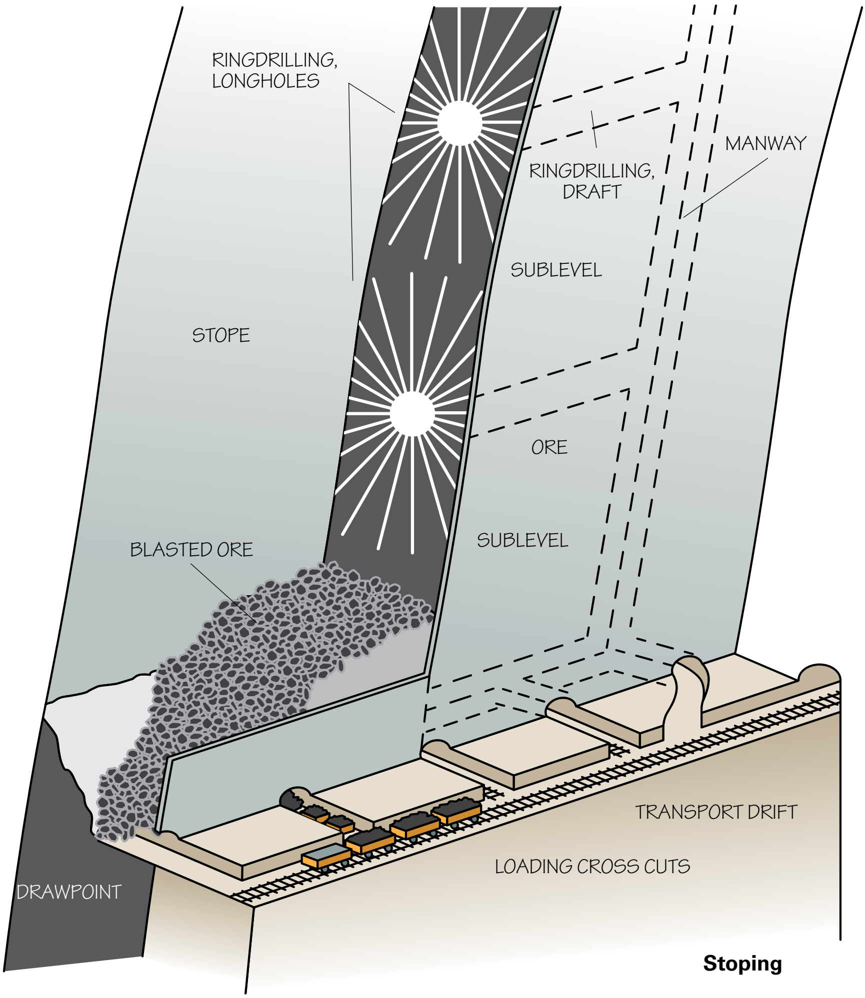


Longwall mining



Block caving

Block caving. This method mines large, low-grade ore bodies that are vertical or slightly inclined (massive or veins). The ore body is undercut (dug out from underneath), or undermined, over a large area. Then it is drilled and blasted above the undercut rock opening. The rock mass drops into *draw bells* and is removed at loading *draw points*, then conveyed or hoisted to the surface for processing.



Stoping

Stoping. Stoping is used when surrounding rock is strong enough to prevent a cave-in of the *stope,* or open space. Vertical shafts reach down to the ore body (massive or vein). Miners remove the ore along horizontal levels, or tunnels. Stoping is used to mine large deposits of gold, silver, lead, platinum, molybdenum, and many minerals.

SURFACE SUBSIDENCE

When minerals are removed from underground mines, the surface above may *subside* or sink. A room-and-pillar mine generally has no subsidence on the surface, unless the pillars fail after the mine closes. However, longwall or block caving methods will—by design—cause surface subsidence. So precautions are necessary to avoid mining under surface structures (buildings, highways, etc.) and may call for a plan to restore the surface structures after mining ends.

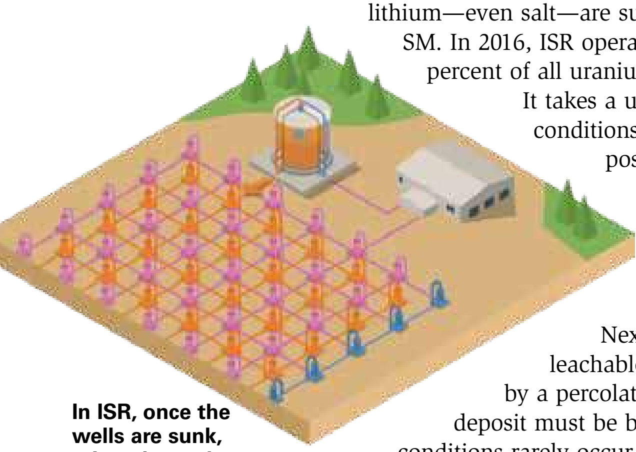
Mining companies are required to provide alternative sources of water if they are responsible for water loss or poor water quality.

Many areas rely on groundwater for irrigation or drinking water. When there is subsidence, the water supply can be disrupted. In most cases, the interruption is temporary; in others it is permanent.

IN-SITU RECOVERY AND SOLUTION MINING

In-situ recovery (ISR) and solution mining (SM) extract mineral resources without traditional mining methods. Both methods dissolve a mineral resource in place (underground), and then process it at the surface. Copper, gold, uranium, and lithium—even salt—are substances extracted by ISR and SM. In 2016, ISR operations accounted for over 55 percent of all uranium mined worldwide.

It takes a unique combination of geologic conditions to make these methods possible. In the case of ISR, the mineral deposit must be highly permeable. Copper deposits for example, must be naturally fractured to create high permeability. Next, the mineral should be leachable—capable of being removed by a percolating liquid. Finally, the mineral deposit must be below the water table. These conditions rarely occur in nature, but when they do, ISR is an option. SM uses only water as its leaching liquid, therefore requiring the mineral to be water soluble—salt, potash, and trona are examples. SM methods also extract minerals from naturally occurring subterranean brine—iodine, bromine, and salt are prominent examples.

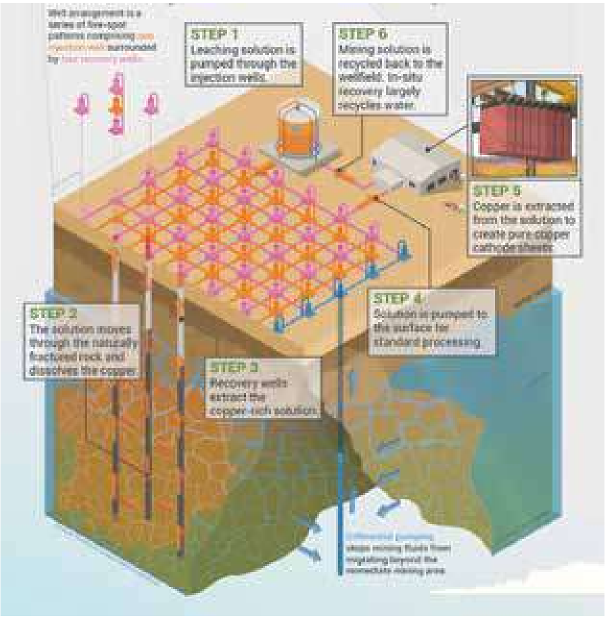


In ISR, once the wells are sunk, minerals can be mined via the process detailed in the illustration on page 47.

In ISR and SM, a pattern of injection and recovery wells penetrate the subterranean mineral deposit. Pumps deliver a leaching solution into the deposit and retrieve the mineral mixture at the surface. Extraction processes harvest the desired mineral, and once the deposit yields all possible ore, the wellfield is flushed with water. When processing natural brine, recovery wells retrieve the brine, then injection wells return the depleted brine back underground. Reclamation recycles process-water and returns the surface to pre-mining conditions. In some cases, SM converts resultant underground cavities into storage facilities and other uses.

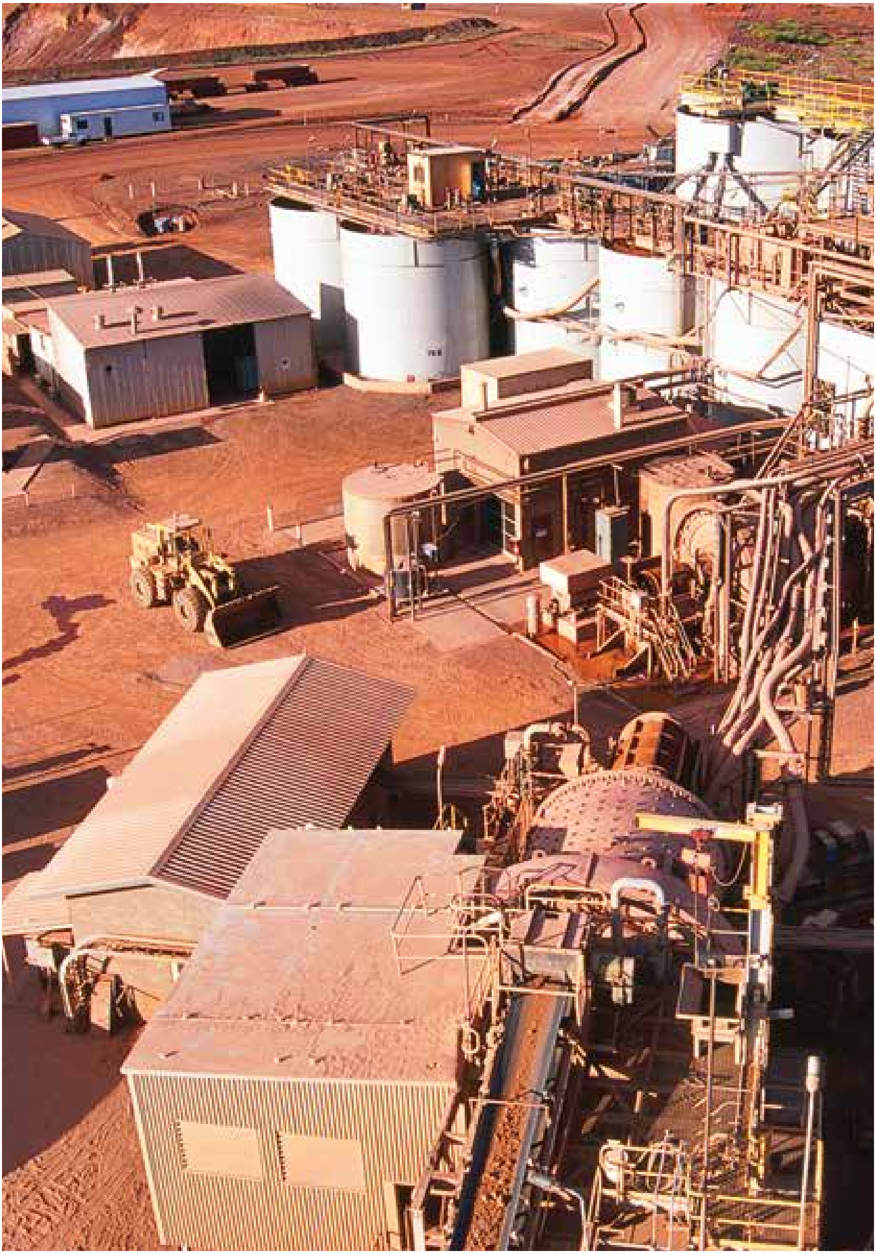
Advantages of in-situ mining are:

- Minimal noise, dust, or greenhouse gas emissions
- Minimal visual disturbance
- No open holes, waste piles, leach pads and tailing piles
- Lower capital and operating costs



Scouting America's Summit Bechtel Reserve

The Summit Bechtel Family National Scout Reserve near New River Gorge, West Virginia, was a mining site before reclamation and conversion to Scouting America's newest high-adventure facility. The picture at right shows the SBR site as a 1900s underground coal mine. This is a good example of how mine reclamation returns mined land to other uses.



Mineral Processing

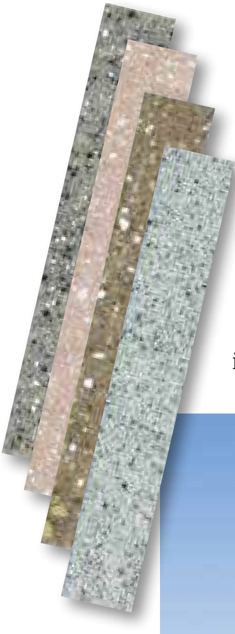
Companies mine minerals to sell at a profit to customers who need and demand them. However, most minerals cannot be sold immediately after they are extracted, because customers can't use them in that form. Mineral processing gets the minerals ready for the customers. Processing converts rock into a form that is usable, transforming it into such things as a gold bar, or separating it into different sizes for sand and gravel, or in the case of coal, it's cleaned to reduce pollution when it's burned.

Mineral processing can be simple with only a few transformation steps, or it can take many steps to release the minerals or metals. Each step uses specialized tools and equipment. The equipment used in modern mineral processing is huge, highly automated, and worth millions of dollars.

One responsibility of the mineral processing engineer and metallurgist is devising methods to remove valuable minerals from the ore rock after it is hauled out of the mine.

Processing Methods

Separating and purifying an ore into a useful product can be difficult. In gold-bearing ores, for example, the gold particles may be microscopic. Mineral processing engineers have developed ways to recover gold from ore with grades as low as 0.01 ounce of gold per *ton*. To put it another way, a ball of gold ore 3 feet in diameter would contain the equivalent weight in gold of only 10 Cheerios® (one-hundredth of an ounce).



Rock Cutting

Dimension stone is natural stone or rock that is cut to specific sizes or shapes. To make dimension stone, diamond saws and wedges separate large blocks of rock in quarries. The blocks are cut into smaller pieces: from small slate roofing tiles and walkway pavers to large rectangular slabs for granite kitchen and bath countertops and marble monuments or interior walls.

Material Separation

To separate different sizes of materials, screens are used. A mixture of sand and gravel may be fed into a series of screens to separate the various sizes. The fine sand might be used in a sand trap on a golf course, while the gravel could be used to make concrete or road base.

Crushing and Grinding

When valuable minerals are only a small percentage of the ore rock that is mined, they must be liberated from the host rock. Many mineral processing plants have equipment to break different sizes of rocks into smaller ones. Large, heavy-duty crushers can reduce boulders the size of an automobile. Some crushers pinch the rocks between moving walls and fixed walls, much like a hammer and anvil.

Other kinds of crushers drop the rocks onto hard materials or other rocks to break them. In coal processing, for example, the coal is softer than the rocks, so the coal shatters. Rotary breakers reduce the size of the coal, which passes through holes in a drum. The larger rocks are rejected out one end.

After going through a crusher, rocks may be ground to a fine powder using a *mill*. A mill is a cylinder or drum filled with rock, water, and steel balls or rods. As it rotates, the steel balls crush and grind the rock into tiny particles making it possible later to separate the mineral from the waste rock. Modern grinding mills may be up to 40 feet in diameter, and use 30,000 horsepower. A typical family car may have only 200 hp.

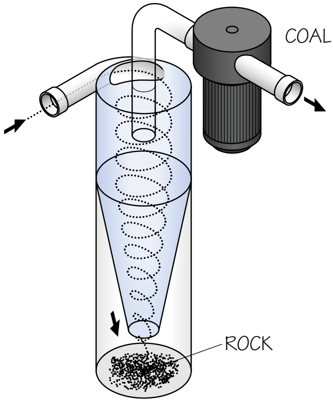
Crushed stone from primary crusher

Grinding liberates individual mineral crystals in the ore rock. This separates valuable minerals from waste minerals, concentrating them in high purity form. Separation methods take advantage of different physical and chemical properties of distinctive minerals. For example, magnetic minerals, such as magnetite, are easily separated from nonmagnetic minerals, such as quartz, using magnetic separators.

Gravity separators separate heavy, dense minerals such as gold from lighter rock fragments. An example of a simple gravity separator is the prospector's gold pan.

Cyclone Separation

Coal removed from a mine is often contaminated with rock and sulfur-bearing minerals, such as pyrite, which are heavier (more dense) than coal. The coal and rock are mixed with water to form a slurry, which is swirled in a cyclone, a special type of gravity separator. Lighter (less dense) coal is pulled into the center vortex of the cyclone exiting out the top while heavier rock flows out the bottom.



A cyclone separator uses density to separate coal from waste (rock and pyrite).

Flotation

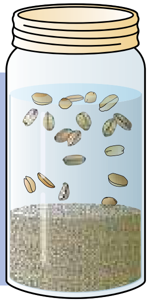
In the flotation method, a chemical called a *flotation agent* or *conditioner* coats tiny valuable mineral particles making them hydrophobic. Another chemical, a *frother*, is mixed with a slurry of the tiny particles in a large tank or *flotation cell*. The frother, like soap, forms small air bubbles when the slurry is agitated. As the bubbles rise, the hydrophobic mineral particles attach to them. Mineral-rich bubbles are skimmed off when they reach the top. Meanwhile, waste particles remain in the slurry and flow out the bottom. In some cases known as *reverse flotation*, the waste mineral is floated while valuable mineral particles are removed from the bottom of the flotation cell.

Flotation cell

Other Chemical Processes

Some minerals can be chemically dissolved, then recrystallized or precipitated into a highly pure solid form. Examples include titanium dioxide used in sunscreen to block ultraviolet radiation; sodium carbonate used in baking soda; and table salt formed by the evaporation of seawater. Some metal mines use a technique called *heap leaching* to chemically dissolve and separate valuable metals such as gold, copper, and silver from a pile of crushed rock.

You can try the flotation method yourself. Throw some peanuts and sand into water, and both will sink. If you mix the peanuts and sand and drop them into a glass of carbonated water (such as soda), you will see that the oily peanuts attach to the gas bubbles (the oil acts as a flotation agent) and float to the top, while the sand sinks to the bottom.



Smelting

Metal-containing minerals are concentrated by mineral processing and shipped to a smelter where high temperatures transform the metal-bearing mineral into pure metal. During smelting a *flux*, such as limestone, is added to the molten metal to combine with unwanted impurities called *gangue*. The combined gangue and flux form *slag* that is separated from the molten metal. The molten metal is then poured into a mold to make very pure bars or ingots.

> Smelting involves a chemical change to the raw material, but in refining, the final material is usually chemically identical to the original one, only purer.

The molten gold being poured here will soon become gold ingots.

Refining

Refining is usually the last step in processing metals. After smelting, a metal is dissolved in acid and electroplated (deposited in a thin layer by electrolysis) as an almost pure metal. In copper production, the copper coming from the smelter may contain impurities such as arsenic. The copper is dissolved in acid and then plated out in a way similar to how a car battery works, by creating an electric current. The pure copper is sold to make wire or other products.

Copper waiting to be manufactured

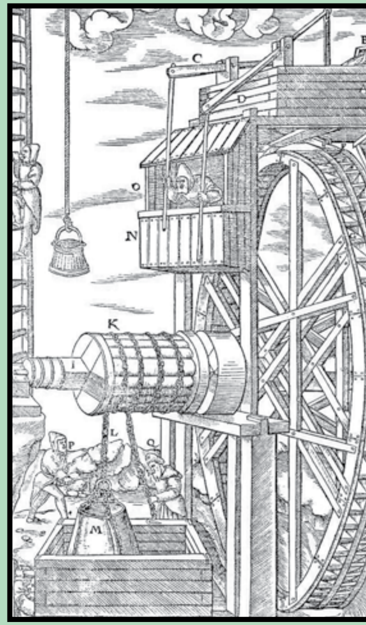
Calcination

Another process of heat-treating rock or mineral is called *calcination*. In one example, calcination is used to transform calcite, the major component in limestone, into lime. (This was mentioned in the "Rocks and Minerals" section). Gypsum is calcined at 250 to 300 degrees Fahrenheit to remove the water of crystallization as water vapor. Calcined gypsum is called *stucco*.

Waste Products

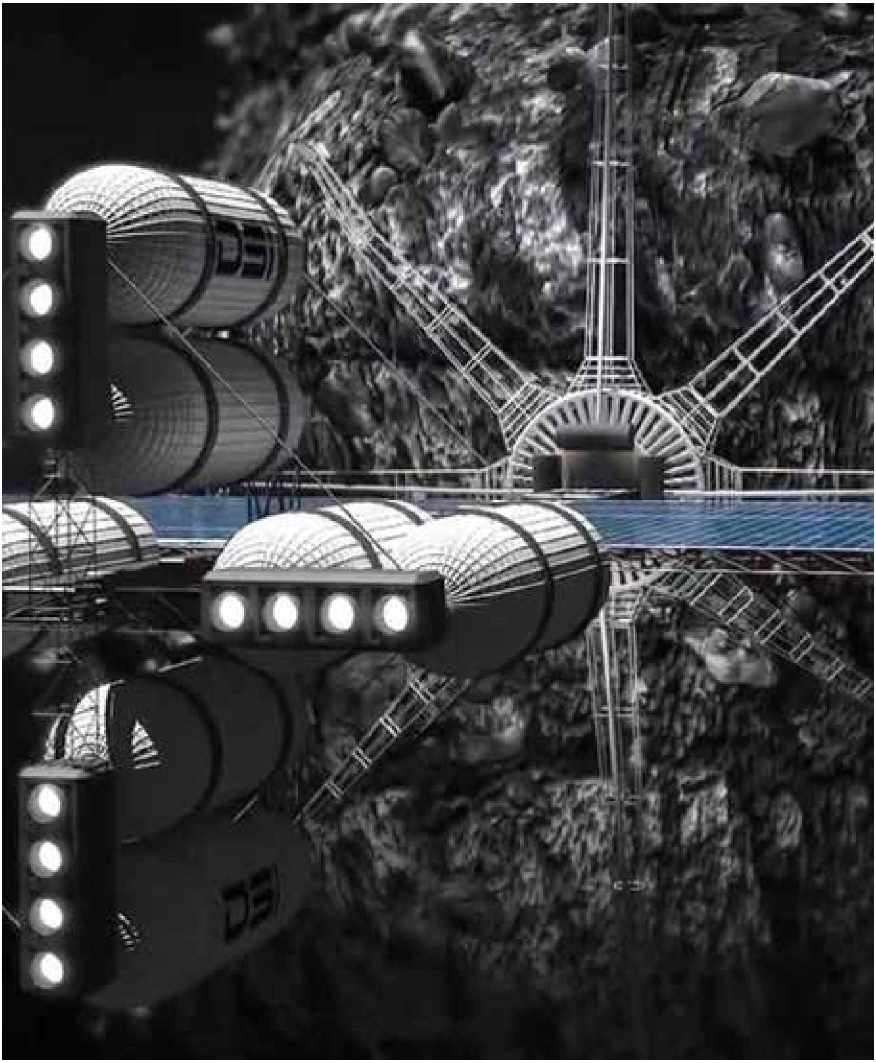
After processing ore to recover valuable minerals, the leftover materials are called *refuse*, *gangue*, or *tailings*. These must be disposed of in an environmentally safe manner. Disposal facilities are designed to hold all the waste generated during decades of mining and processing plant operations.

Processing rocks and minerals is done in a plant that houses all the equipment and has storage space for ore, processed materials, and waste. Mineral processing requires moving and storing large volumes of rock, water, tailings, and finished products. Mineral processing plants can look very complicated with all the tanks, silos, conveyors, and pipes that transport materials from one stage to the next.



Georgius Agricola (1494–1555), a German scholar and scientist, is known as "the father of mineralogy" and is considered the founder of geology as a science. Agricola wrote on many subjects, including history and paleontology (the study of ancient life forms; fossils) as well as metallurgy and geology. His publications were based on his field observations.

His book *De Re Metallica*, published in 1556, was among the first and most important books on mining and mineral extraction. While natural resources had been obtained from Earth for thousands of years before then, his was the first complete work on the subject. Agricola explained and illustrated metal veins, exploration and surveying methods, and types of mining machines. His explanation of water mills and water power was especially important for its time—from crushing rocks to mine-shaft ventilation to separating minerals by gravity—centuries before the use of steam power. *De Re Metallica* championed the importance of metals in human civilization, and it remains in print today, as evidence of its timeless relevance.



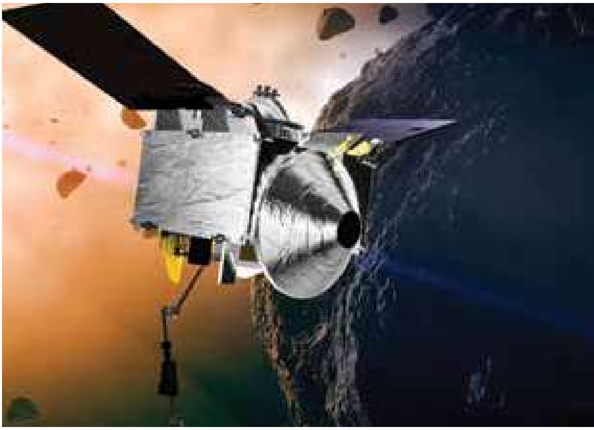
Above: A digital rendition of robotic asteroid mining equipment.
Right: OSIRIS-REx, the first U.S. mission to collect a sample from an asteroid.

Mining in the Future

In the future, mineral deposits most easily mined from Earth will be depleted. Miners will need to dig deeper and work in more challenging conditions to mine newly discovered deposits. Other potential sources of minerals exist beyond these, however. It may sound like science fiction to talk about mining the oceans or interplanetary space, but we already harvest minerals from the ocean. Also, detailed plans are in the works to mine the moon, near-Earth asteroids, and even other planets.

Miners have many reasons to look beyond the usual places for minerals. A mineral deposit in a remote location on Earth might not have water, electrical power, roads, or workers nearby, and the cost to install or obtain these might be excessive. In addition, the grade might not be high enough; that is, the mineral concentration might not be at the necessary level to cover the cost of the machines and processes to mine it. Also, an unfriendly country might control the only source of a certain mineral, charging high prices for it or preventing others from extracting it. Wars are sometimes fought over such resources.

Finally, the environmental cost of mining "the usual places" may be too high in terms of loss of species (biodiversity), water and air pollution, damage to Earth's natural landscapes, or any combination of these.



Mining the Ocean and Seabed

Electrolysis removes magnesium metal from seawater in one step. The magnesium forms alloys with other metals, especially aluminum.

If you have ever tasted ocean water, you know how salty it is. The ocean is Earth's greatest storehouse of minerals. Besides hydrogen and oxygen that make up water, the most abundant elements in the ocean are sodium and chlorine, the elements that form salt. While these elements come mostly from surface erosion of the continental landmass, most sodium is leached from the ocean floor and most chlorine is emitted from Earth's interior by volcanoes and hydrothermal vents.

Other abundant elements dissolved in seawater are magnesium, sulfur, calcium, potassium, carbon, bromine, boron, strontium, and fluorine. Some are already mined from the oceans. You are eating salt harvested from seawater if the package says "sea salt." Common salt is obtained from seawater by collecting it in ponds where the sun's energy evaporates the water. The salt is left behind as sodium chloride crystals and is then harvested for consumption. Salt is used for seasoning and preserving food. It is also used in water softening and for deicing roads in wintertime.

Bromine, too, is extracted from seawater. It is used in flame retardants; water purification, particularly in swimming pools and hot tubs; pesticides; over-the-counter and prescription drugs; and photography.

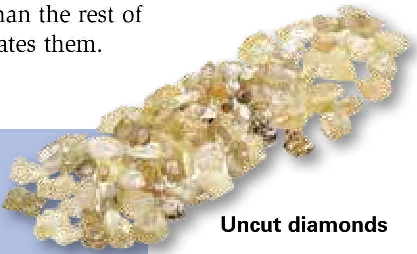
Iodine is mined from ocean water by harvesting seaweed. Its dry weight can have up to 0.45 percent iodine. Iodine is essential for human and animal thyroid function and brain development. Without iodine as a catalyst, or booster, plastic drinking bottles would not be possible. Other uses for iodine include pesticides, medical applications, pharmaceuticals, and stain-resistant chemicals.

Seaweed

The shallow near-shore realm concentrates some minerals. Gravel for concrete and beach reconstruction is mined by dredging the sea bottom close to shore. Titanium dioxide is mined along beaches and offshore sandbars as the minerals rutile, anatase, leucoxene, and ilmenite. These are heavier than the rest of the sand grains, so gravity processing easily separates them.

Deep-Sea Mining

Diamonds and tin are also dredged from shallow waters close to shore. Mining these depends on dredging and gravity separation that can handle large volumes of materials.



Uncut diamonds

Volcanic activity and hydrothermal vents on the ocean floor yield iron, manganese, copper, cobalt, and zinc. Harvesting these requires deep-sea mining methods. The crushing pressure of the water, frigid temperatures, and total darkness are among the challenges of deep-sea mining. New exploration methods are needed—mobile exploration platforms for deep-sea drilling and mapping, and remote sampling techniques. Remote-control methods and robotics are likely answers to the challenges.

Some minerals might be scooped off the ocean bottom at a depth of two to three miles (13,000 to 18,000 feet). Manganese nodules, composed mostly of manganese and iron compounds, might be mined this way. The nodules are valued for other metals they contain—copper, nickel, and cobalt.

For locating, sampling, and drilling these hard-to-reach deposits, new approaches are necessary. How can these minerals be dug from the ocean floor? How can they be brought to the surface? Can they be processed in factory ships or shipped to processing plants onshore? What is to be done with leftover materials after separating the desired metals? These are questions that still must be answered for a successful deep-sea mining operation.

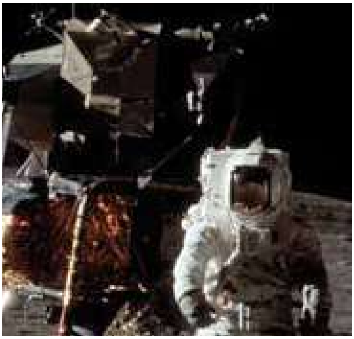
Manganese nodule

Protecting the Marine Environment

The environmental impacts of ocean mining must be considered before launching any operations. Where unique marine habitats exist, mine operations face restrictions.

- Seasonal limitations may be necessary to protect marine organisms during special life stages such as breeding and egg or embryo development.
- Dredging changes seabed topography which may need to be restored.
- Mining could displace certain bottom-dwellers. Miners will need to consider how long it would take for these organisms to recover and reestablish colonies.
- Miners will need to limit the amount of disturbed seafloor sediment that increases cloudiness or turbidity (measure of light transmitted through water).

Mining in Space



Most of the Apollo astronauts were not geologists, so they received extensive training in geology before their moon missions. It was essential for them to know about rocks before they landed. Rocks would reveal how Earth and the moon were similar and whether they shared a common origin.

In 1972, the last moon mission landed a geologist-astronaut on the lunar surface so that a better geological assessment could be made. **Harrison H. "Jack" Schmitt**, holder of a Ph.D. in geology, could expertly judge the rocky terrain and quickly saw the potential mineral wealth right at his feet. He later proposed commercial ventures to mine lunar helium-3, which could theoretically be used for fuel for nuclear fusion, replacing nuclear fission and fossil fuels.

Developing such space enterprises would help to use resources from space to support human space activities and settlement, and help develop efficient and cost-effective ways to launch large payloads from Earth into deep space.

Iron, nickel, platinum, and cobalt are among the valuable elements that may be mined from asteroids or other cosmic bodies.

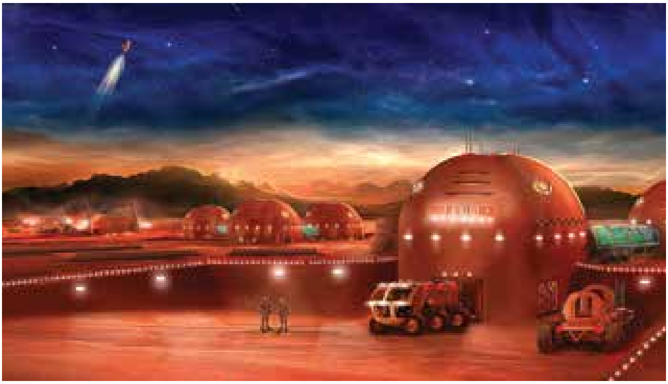
Challenges of Space Mining

Mining methods in space would resemble those on Earth, but adjusted for the absence of oxygen and differences in gravity. Surface methods will be used when minerals are at or near the surface. Devices will collect magnetic metals and minerals such as those associated with iron meteorites. Underground shafts will be dug when the target is a deep lode or vein. Space miners will likely melt ice to get water and to generate oxygen for breathing.

For interplanetary mining, the equipment would have to be shipped or manufactured in space on site, or shipped as parts from Earth, then assembled on-site. Space mining poses major transportation challenges at every stage that must yet be overcome. Designs are on the drawing boards, however, for space barges, space tugs, and power-generation systems.

Another issue is whether to process raw materials on-site, ship them to mills on Earth, or transport them to mills on specially designed space stations. Interplanetary shipping of large, bulky loads will be expensive, so processing on-site will probably be more cost-effective. This does not eliminate the problem, since refined metals and maybe industrial minerals will have to be shipped, too.

Solar generators or nuclear energy could provide the electrical power necessary for all the operations needed in space mining.



An artist and space architect's concept of a habitat on Mars.

Hauling, crushing, and screening all depend on gravity to some extent, so these steps need modification for smaller cosmic bodies with less gravity. Enclosed circuits using magnetic, electric, or pneumatic (air pressure) transport may solve the problem, or previously unforeseen technology may be developed. Flotation processes will face the similar challenges of low gravity, limited water, and exposure to the hazards of space.

High cost is the main concern for any space operation. Today it would take billions of dollars to explore, mine, and ship mere ounces of materials to Earth. Instead of bringing the minerals to Earth, space mining might best be applied as what is called "in situ resource utilization," where materials are found, extracted, processed, and used right at the site. Mined materials would be used for constructing and maintaining space stations or human settlements in near and deep space.

Even so, interplanetary mining remains an expensive proposition. Only space-faring nations with the incentive and economic means could plan such ventures.

Mining Landfills

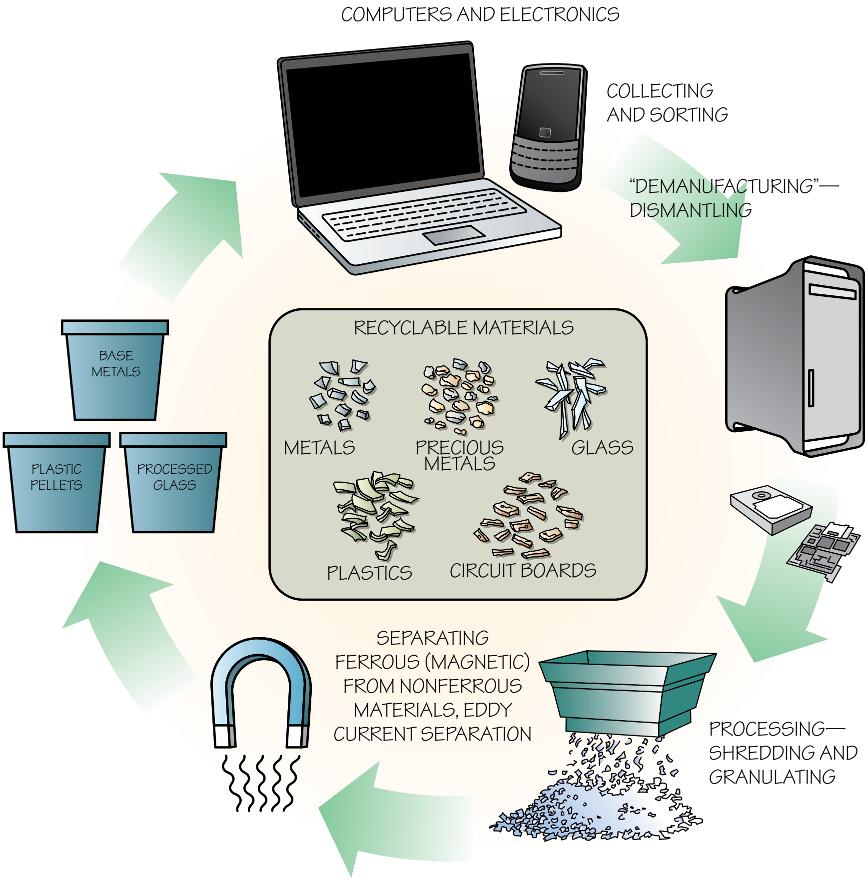
You are finished with an electronic device that no longer works and is too costly to repair. Everything we use has a life expectancy—the time when it becomes obsolete, it no longer performs its intended function, or it isn't needed anymore. The item enters the *waste stream:* the flow of waste from its point of origin through its treatment to its disposal. What we toss out may end up in a sanitary landfill, waste incinerator, recycling center, or open-air dump.

According to the U.S. Environmental Protection Agency, for every million cell phones recycled, we recover 35,274 pounds of copper, 772 pounds of silver, 75 pounds of gold, and 33 pounds of palladium. Recovering these metals saves energy and reduces the extraction of raw metals from Earth.

Many cities and towns have recycling programs. Most people are familiar with curbside recycling—we put recyclable household items (typically paper, plastics, glass, and aluminum) in a bin and take them to the curb, and municipal sanitation workers haul them to a recycling facility for sorting and distribution. Some communities have recycling centers where citizens drop off their recyclables. Once sorted and separated into different categories, the recyclables can be used to make new products.

Not all recycling centers accept electronic waste. Before you decide to throw out any electronic devices, check the municipal policy in your area. More and more centers now recycle electronics, from cell phones and laptops to TVs and other electronic devices. After sorting, the devices are dismantled and processed. Many of them contain contaminants such as lead, cadmium, and beryllium, which require special handling and disposal or recycling. Many metals, such as gold, silver, platinum, palladium, copper, tin, and zinc, can be recovered in recycling. Glass and plastics also are recovered and recycled.

These recycled materials—no longer destined for landfills or incinerators—are recovered and used to create new products. Garden furniture, license plate frames, nonfood containers, replacement auto parts, art, and jewelry are among the many types of goods produced from recycled materials. Rechargeable batteries are recycled into other rechargeable battery products.



Recycling Electronic Goods

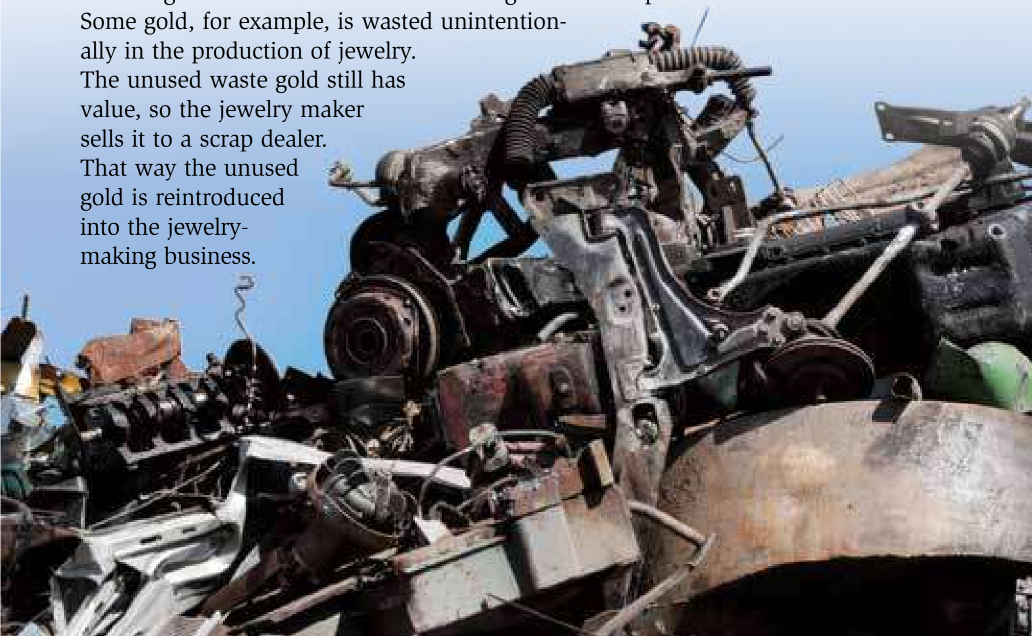
It's always best to recycle whatever you can. Most Americans know the expression "Reduce, Reuse, Recycle," but do most of us really do that?

Recycling Metals

Most metals remain usable even after the products that use them have reached the end of their lifespan. Recycling metals saves the energy that is used to separate them from their ores. Also, the hauling of the recycled objects is usually shorter than from distant mined sources, further saving energy and the materials used in mining.

Worldwide demand for metals grows steadily at 1 to 3 percent annually. Even this apparently slow growth rate means additions must continually be made to the metal supply. New supplies come from new mine developments, expansions of existing operations, increased recycling, or all three.

Typically called scrap metal, recycled metal is categorized as either new or old scrap. *New scrap* comes from pre-consumer sources generated from the manufacturing of different products. Some gold, for example, is wasted unintentionally in the production of jewelry. The unused waste gold still has value, so the jewelry maker sells it to a scrap dealer. That way the unused gold is reintroduced into the jewelry-making business.



We are able to account for about 85 percent of all the gold ever mined. About 15 percent is lost, mainly in electronics because the amount of gold in each device is too tiny to be recovered economically. The rest of the world's mined gold is held as heirloom jewelry, coins, and gold bullion (bars or ingots).

Old scrap comes from post-consumer supplies generated when an item has reached the end of its usefulness. Cast-off jewelry, dental gold (gold teeth), and the gold components of unwanted electronics are good examples of old-scrap gold. Copper is another commonly recycled metal. A third or more of annual consumption comes from recycled scrap copper.

Other metals typically recycled at scrap yards include aluminum, brass, lead, silver, platinum, iron, steel, and zinc. Most of these are recycled by manufacturers as new scrap. Much of the old scrap is rescued from the waste stream and recycled by individuals committed to salvaging such materials.

Recycling one aluminum can saves enough energy to run a TV for three hours.
Source: Can Manufacturers Institute

Sanitary landfills will probably be one source of minerals in the future. Metals and other materials could be extracted from them, processed, and refined for reuse.

"Recycling" Landfills

Except for the items that people conscientiously recycle and reuse, the vast majority of material entering the waste stream is picked up as municipal waste and placed in sanitary landfills. Waste in landfills is buried between layers of earth and isolated from the environment until it breaks down biologically, chemically, and physically.

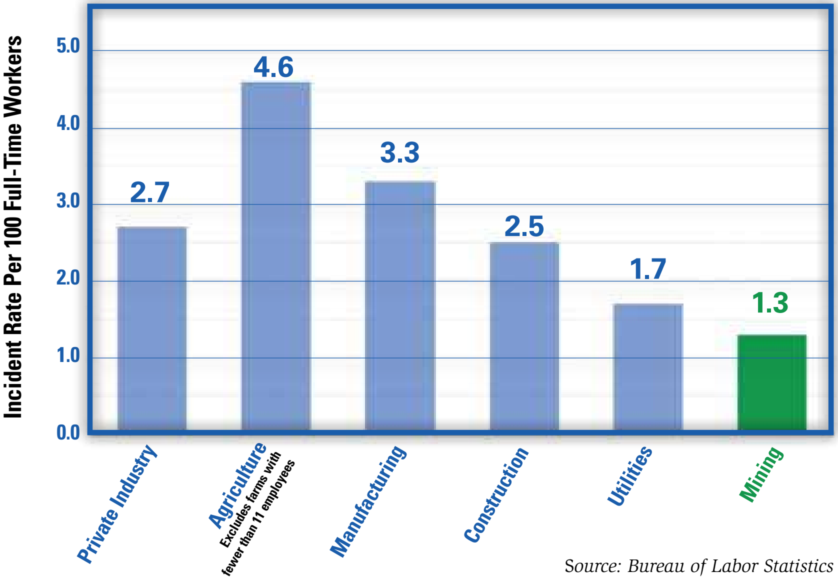
Mining municipal landfills will require special skills and techniques to protect air, water, and soil from contamination. Care will be needed to restore or reclaim the sites for uses such as farming, forestry, recreation (golf courses, public parks, zoos, ball fields, etc.), or industrial parks for factories and other businesses.

Most of the consumer waste in landfills still has value. How could we recycle everything? Organics (substances of plant or animal origin) could serve as compost and be used as fuel. Solids such as plastics could become fuels or the basis for new products. Glass could be recycled for new glass or energy-saving insulation. One innovation is to use glass fibers with cement to form a stronger type of concrete.


HARD HAT
LIGHT
METHANE
DETECTOR
HEARING PRO-
TECTION
SAFETY GOGGLES
REFLECTION TAPE
BATTERY
FOR LIGHT
SELF RESCUER
GLOVES
SNUG COVERALLS
STEEL-TOED
BOOTS
ANKLE STRAP

Health and Safety in Mines

At one time, mining was the most dangerous occupation in the United States. Improvements in mining engineering, education and training, government regulation, and industry leadership together with decreasing community tolerance for mining incidents have led to a significant reduction in mining incidents and disasters. Today, mining is among the safest industries as measured by nonfatal injury rates (see chart below).



Source: Bureau of Labor Statistics

2021 nonfatal occupational injury and illness rates for the private-sector industry

Making mines healthier and safer places to work is the responsibility of everyone involved—mine owners and workers, federal and state government regulators, equipment manufacturers and material suppliers, trainers and educators. Operating a safe mine requires careful planning to ensure that all facets of mining—production, processing, maintenance, training, emergency response, etc.—follow all applicable laws and regulations. The U.S. Mine Safety and Health Administration (MSHA) and state agencies enforce mine health and safety laws and regulations.

The industry strives continually to improve safety. Many companies working with the National Mining Association have launched the CORESafety program to do just that. It plans to optimize mine safety by improving mine engineering, work processes, and working conditions.

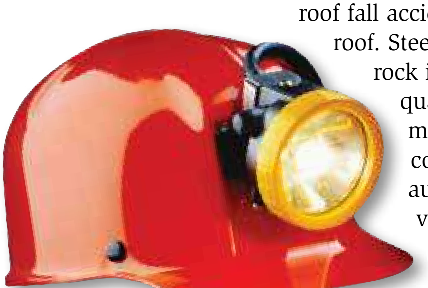
Tools for Mine Health and Safety

It is difficult to eliminate all risk from mining, so the focus is on managing risk at an acceptable level—for miners, management, government, and society. Some tools and techniques used in American mines to this end include hazard identification and risk assessment, personal protective equipment, environmental monitoring, and the introduction of automation for mining equipment.

Hazard Identification and Risk Assessment

"Being prepared" in mining means to anticipate and understand mine risks. What is the likelihood that something will go wrong, and what is likely to happen if it does? Examples include the potential for gas or dust explosions in underground coal mines, mine wall collapses, fires, and equipment striking a miner.

Experts believe it is more effective to eliminate hazards where they occur. An example is using roof bolts to prevent roof fall accidents by holding up an underground mine roof. Steel rods, 4 to 16 feet long, anchor the roof rock in place. Ventilation systems help ensure air quality. When coal rock releases flammable methane gas, ventilation dilutes its concentration. Large fans on the surface and auxiliary fans inside the mine provide ventilation throughout underground tunnels and shafts to accomplish this.



Personal Protective Equipment

Miners wear personal protective equipment to guard against injury. A hard hat protects the head; safety glasses protect eyes; earplugs or earmuffs minimize exposure to noise; gloves protect hands; and hard-toed boots minimize the risk of foot injury from impact, slip/trip, pinch, heat and cold, etc. Where needed, respirators protect against inhaling harmful dust, fumes, or gases.

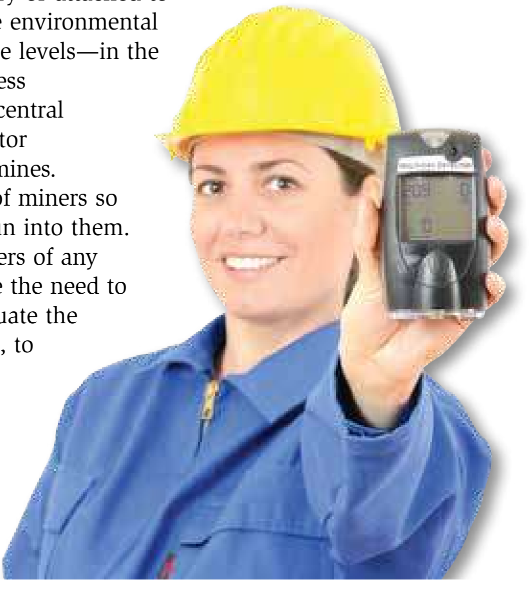
Underground miners carry a "self-rescue device" for protection from smoke and toxic gases, such as carbon monoxide, when escaping in the event of fire or explosion.

Environmental Monitoring Technology

Different instruments, often handheld devices, detect harmful and flammable gases, dust, fumes, noise, or radiation, and ensure that adequate oxygen is present. Some monitor many gases at the same time. Others measure airflow in the ventilation system.

Instruments may be stationary or attached to mobile equipment. They measure environmental factors—such as carbon monoxide levels—in the mine, relying on telemetry (wireless communication) to send data to central control stations. Computers monitor ventilation fans in underground mines. Other devices track the position of miners so that mobile equipment doesn't run into them.

Detection systems warn miners of any developing fire. Alarms announce the need to take action. It may mean to evacuate the mine or, in an underground mine, to seek shelter in a refuge chamber. GPS networks help surface mines pinpoint equipment and help isolate hazards as they occur.



Remote Control and Automation

Computer technology has radically improved mine safety and health. Many mining machines are remotely controlled to keep the miner from exposure to moving parts, dust, noise, unstable ground, etc. The introduction of robotics is helping miners reduce exposure to unnecessary risks. Some surface mines now use haul trucks that run without a driver, using satellite navigation and robotics.

Automated mining operations can be monitored from safe, clean control rooms like this, reducing unnecessary risks for operators.

Automation and robotics will increasingly be used as mines become less accessible to human miners. Applications include very thin or very deep deposits.

Mines & Quarries— Keep Out!

Mines and quarries are not like caverns open to the public for tours and recreation. Every year accidents on mine properties injure or kill dozens of people. Active mines are dangerous even for highly trained workers, and are regularly inspected for hazardous conditions. Active sites hold many risks to unaccompanied visitors—entering them without permission is considered trespassing.

Because abandoned mine properties are not inspected, they pose even greater hazards. Toxic, or explosive gases may be there if not properly ventilated. Tripping and falling is common, as abandoned mines are unlit with no guardrails: unseen vertical mine shafts may extend hundreds of feet into lower levels of the mine. And cave-ins can result from missing or deteriorating support structures.

Other dangers include discarded explosives which can become unstable and explode, and toxic chemicals which may leak from old containers. Deep bodies of water in mines are unsafe for drinking or swimming, and potentially laden with poisonous chemicals. Wild animals often inhabit abandoned mines, too, and they might not react kindly to intrusion!

Above ground, diving into quarry ponds is extremely risky as water depth can vary greatly. And you may not see disposed equipment and cables below the surface. If you encounter them underwater, you could get entangled or seriously injured.

Finally, riding dirt bikes and four-wheelers, hiking, or otherwise trespassing on mine property is dangerous and illegal. Unmarked high walls, steep cliffs and unseen shafts pose major hazards.

Learning More About Staying Safe

“Stay Out – Stay Alive” is a partnership of federal and state agencies, private groups, and businesses around the country that educate citizens about risks in abandoned mines. Go to AbandonedMines.gov, managed by the Bureau of Land Management, for more information.

Find out if your state mining agency or other organization has a public-awareness program to warn people about the dangers in abandoned mine sites and quarries. The Mine Safety and Health Administration (MSHA) maintains a list of state mining agencies on its web site, MSHA.gov. Check there, or with your state’s department of public safety, for more information.


Scouting America's Summit Bechtel Family National Scout Reserve in West Virginia has successfully been reclaimed and converted from an underground coal mining site to a recreational area enjoyed by thousands.

Sustainability in Mining

Sustainability relates to harvesting resources in ways that do not squander them or permanently damage the environment. A sustainable lifestyle or society meets today's needs without using up natural resources for future generations.

Recycling is a way to make minerals "partially renewable."

Mining in Society

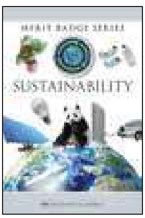
By now, you know how important mining is in our society. You have learned the old saying of miners: "If it can't be grown, it has to be mined." Mining provides, directly or indirectly, many of the raw materials needed to sustain life and maintain civilization. Unlike raw materials that are grown, the products of mining are *not* renewable. The mineral resources available to us are limited by our ingenuity to find and recover them safely.

Renewable resources can be replenished or replaced over time and measured in human terms, such as within generations. An example is growing new trees for lumber after harvesting the site by logging.

Metallic, most forms of energy, and industrial minerals, however, are nonrenewable resources. They cannot be replenished at rates that match human timeframes. Minerals require vast stretches of geologic time to concentrate them in deposits suitable for mining.

Mining directly affects the natural environment while working to meet the needs of a modern global economy. In this way, the job of mining is unique. The industry must find and extract mineral resources, while keeping in mind that sustainability calls for meeting the needs of future generations and conserving the environment. That means balancing the demand for products and materials with good stewardship of the land.

The U.S. Environmental Protection Agency was formed in 1970. Scouting America introduced the Environmental Science merit badge in 1972 to teach Scouts about conservation and care of the environment. In 1977, Congress passed the Surface Mining Control and Reclamation Act to regulate the environmental impacts of mining. In 1983, the United Nations appointed the World Commission on Environment and Development to unite member countries in pursuing sustainable development.



For more about sustainability and renewable resources, see the *Sustainability* merit badge pamphlet.

When it comes to sustainability, most mining operations face these challenges:

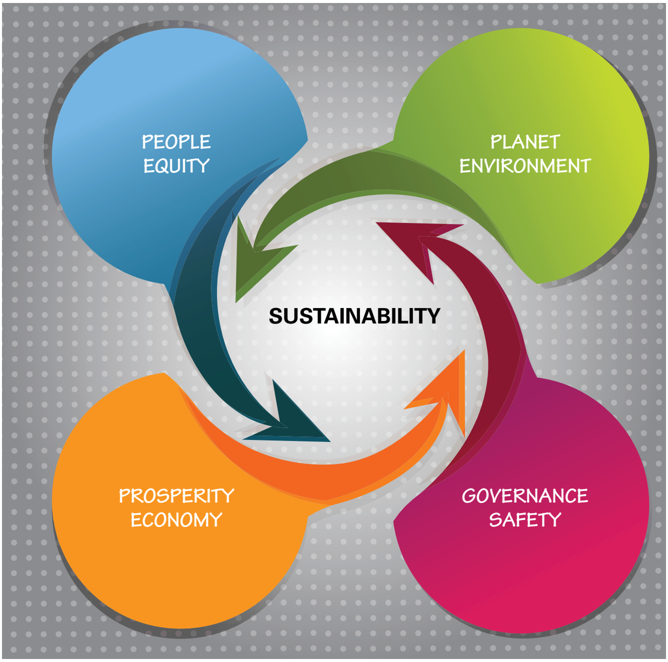
- Dwindling mineral resources have forced operations to move nearer to areas that are environmentally or culturally sensitive, or more densely populated.
- Population growth has moved people closer to existing mining operations.
- New mineral resources tend to be found in remote locations, often in undeveloped countries.
- Greater environmental awareness among the public, elected officials, and the media have brought mining operations under closer scrutiny.

A Framework for Sustainability

The *Sustainability* merit badge pamphlet shows a model of the three P's—people, prosperity, and the planet—tied to the three E's—equity (fairness), economy, and environment. In mining, a fourth ethical component—governance, or safety—can be added to the mix. Each essential element depends on the other. Improvements in one area often come at the expense of another. Consider each element in the framework and how the elements interact.

People and Community

A mining company is made up of people—its workers, as well as its customers and neighboring communities. Responsible companies recognize community (people) priorities while planning, when mining, and during reclamation.



Sustainability and mining

For example, when planning a new coal mine in southwest Pennsylvania, the mine company met with more than 200 citizen groups to explain how the mine would be a good neighbor. In another instance, the geologist for a new stone quarry near Washington, D.C., explained the geology and rocks to 20,000 second-graders. Through them, he reached their parents, who initially opposed the mine. As a result, local opposition ended 18 months later. Treating people fairly is important to maintaining a positive footing.

Planet and Environment

Earth provides essential resources for life. Without air to breathe, food to eat, and water to drink, we would not survive. Other resources add convenience and comfort to our lives. As our quality of life improves, few of us would want to go back to the way things were before we had cars, paved roads, electricity, indoor plumbing, and cell phones.

Mineral resources can be wasted by poor mining methods. Responsible companies respect the environment by using and producing resources wisely. They take into account environmental impacts in each stage of the mine's life.

Water and air used by mineral processing operations are subject to strict environmental regulation. The goal is to reduce the effects of mining operations to balance the benefits that society receives from the mined resources. Mineral processing plants treat water to remove solid or dissolved substances before releasing water into the environment. Water is treated so that it is not cloudy; it has a neutral pH (not acidic or basic); and impurities are below natural levels of local streams. Other equipment removes dust, toxic gases, and other compounds to prevent them from entering surrounding air.

Interactions

People, businesses, and the environment are all essential parts of sustainability; they interact. Responsible mining companies recognize these interactions and know how to be good neighbors and stewards of the land. As a Scout, think about how you can make a difference through the Scout Law and principles of sustainability. Consider these examples of how a Scout is:

Trustworthy. Sustainability starts with you. As a young leader, you can help by recycling and by advocating low-impact solutions to everyday issues.

Loyal. Demonstrate sustainability by reminding others how we share limited resources.

Helpful. Make a difference in your family and community—and help our world—by using only what you need.

Clean. Respect our world and the valuable resources we consume every day. Set an example by disposing of all waste properly, using less, and protecting resources more.

Land reclaimed for recreational use

Mine Land Reclamation

Mine land reclamation is a part of sustainability. Before mining begins, the condition of the land is assessed. Land use, watersheds, topography, and wildlife habitat are considered. The future effect of mining on each is determined, and plans are made to restore the land. One goal of mine land reclamation is to return the land to as good or better condition than it was before mining began. In this way, reclamation is similar to Scouting's Leave No Trace Seven Principles and the Outdoor Code.

Oftentimes land uses change after mining. The goal is to prepare the land for better use. For example, the King Coal Highway being built across southern West Virginia links surface mine reclamation sites together to complete the construction of the highway. When mining is finished, the highway will need only the road surface constructed, saving millions of dollars.

Land reclaimed for commercial and residential use

Mine reclamation efforts in progress

To restore mine land or improve the land to beneficial use, steps are taken to preserve qualities that have special value, such as topsoil and vegetation. Reclamation begins with stockpiling topsoil. Then the topsoil is planted with native vegetation to help prevent erosion of the stockpile and preserve native plant species. This topsoil is then spread over the disturbed land when mining ends.

The mining industry takes mine land reclamation and restoration seriously. The industry sees how stewardship of the land, from which it draws its livelihood and wealth, adds great value to communities. It also helps enrich the public's understanding of the reclamation and restoration process.

Land reclaimed for use as an airport

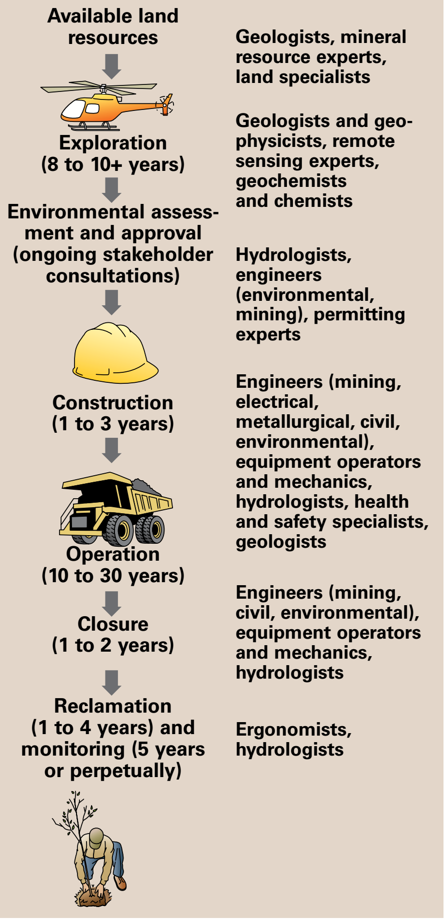

WASHO CREEK OVERLOOK
FROM THIS SPOT YOU CAN SEE MINING AND FORESTRY PRACTICES IN THE HEADWATERS OF THE WASHO CREEK DRAINAGE.
BARITE MINE
BOTH SURFACE AND UNDERGROUND MINING METHODS HAVE BEEN USED TO EXTRACT BARITE SINCE 1956. THE ORE IS TRUCKED TO A MILL IN CANADA FOR PROCESSING. BARITE ORE IS GROUND INTO A FINE POWDER FOR USE IN PAINT AND AS A WEIGHTING AGENT FOR WELL DRILLING.
TIMBER HARVEST
THREE METHODS OF HARVESTING TIMBER CAN BE SEEN:
SHELTERWOOD -MANY TREES ARE LEFT AFTER HARVEST WHICH PROVIDE SHADE FOR NEW TREE SEEDLINGS.
SEEDTREE -ONLY A FEW TREES REMAIN WHICH PROVIDE A SEED SOURCE TO START A NEW FOREST.
CLEARCUT -NO TREES ARE LEFT, AS THEY ARE NOT DESIRABLE OR NEEDED TO START A NEW FOREST.
THE METHOD USED AIDS IN MEETING LAND MANAGEMENT OBJECTIVES FOR WILDLIFE, WATERSHED, VISUAL VALUES, ETC. AS WELL AS TO ENHANCE THE REGENERATION OF TREES.

Careers in Mining

When most people think about what a miner does, the first image that springs to mind is the miner heading underground with a headlamp, hardhat, simple tools, and a lunch pail. Or you may think about the shovel operator, haul-truck driver, or someone working a bulldozer or front-end loader. These images have triggered the imaginations of artists and writers who have passed them down to us over time.

A career in the mining industry includes many more occupations than these. The cycle of developing mineral resources has many parts, and all offer interesting, well-paying career opportunities.

Mine workers take satisfaction in knowing they provide essential minerals and fuels that benefit society. Discovering and providing the minerals that increase our standard of living, minimizing environmental impacts, and contributing to a safe work situation are all benefits of a mining career. A mining career offers the prospect of travel, the challenge of working with advanced technology, and the opportunity for career advancement with increased responsibilities.



This illustration shows the sequence of events in mining and related careers.
Source: Mineral Resources Education Program of British Columbia

Mining Personnel

An operating mine might be in a remote location, along with the operations office and any connected processing plant. The division offices and company headquarters, however, or technical support are generally located in a large town or city.

Some positions in mining are paid hourly. People working in the mine itself are mostly equipment operators. Those working at a surface mine include drillers and blasters; dragline, shovel, and excavator operators; front-end loader and bulldozer operators; haul-truck drivers; and support personnel. In an underground mine, workers operate cutting machines, shuttle cars, roof bolters, scoops, longwall shearers, jumbo drills, loaders, haul trucks, belt conveyors, trains, and other mobile equipment.

The workers at a processing plant operate equipment for crushing and screening; physical and chemical procedures, especially in metal mines; haulage and mobile equipment; lab work; mapping and surveying; and other tasks. These are supported by software specialists, mechanics, welders, machinists, electricians, general laborers, and equipment manufacturers.

Technical Personnel

The minimum educational requirement for technical workers typically is a high school diploma. An associate degree or trade school education will help the worker meet requirements for positions of greater responsibility and higher pay. An example is the electrical certification required for an underground electrician, who is paid more than a typical laborer in a coal mine. Underground professionals tend to earn more than their counterparts in surface mining. Many trade skills are obtained through programs provided by the mining company in combination with on-the-job training or community colleges.

John Llewellyn Lewis (1880–1969) was an American leader of organized labor. From 1920 to 1960 he served as president of the United Mine Workers of America. He also worked to establish the Congress of Industrial Organizations, organizing millions of industrial workers in the 1930s. Under his leadership, coal miners won high wages, an eight-hour work day, good pensions, and good medical benefits.

The creation of the UMWA Welfare and Retirement Fund was perhaps his greatest legacy. The fund helped establish eight regional hospitals and many medical clinics in Appalachian coal country. In 1964, President Lyndon Johnson awarded Lewis the Presidential Medal of Freedom, the highest civilian decoration in the country, recognizing his many contributions to the labor movement.

Professional Personnel

Many different kinds of professionals are needed to explore for minerals and to mine them; to plan new operations; or to manage a mine. Mining professionals include geologists, mining and geological engineers, metallurgists, civil engineers, mine managers, and environmental specialists. These positions require a college degree, and in some cases, graduate degrees.

Professional personnel evaluate the mineral or ore deposit for its economic potential. They create mining plans based on those evaluations. Scientists and engineers work together to plan and build the processing plant(s) needed to treat the ore or rocks after they are hauled out of the mine.

It takes many thousands of people to mine all the minerals and fuels we rely on and use. Mining provides above-average income to miners; pays taxes to local, state, and federal governments; and often works with local communities to improve the quality of life for its neighbors.

Careers Supporting the Mining Industry

Equipment manufacturers and service companies support the mining industry, too. A wide variety of products is delivered to mines, ranging from office supplies to explosives, to heavy equipment. Service companies may provide security for the mine site; workers for short-term maintenance positions such as welders, mechanics, and electricians; and consulting engineers for almost every aspect of mining and processing.

There are careers in regulating the mining industry on local, state, or federal levels. These include health and safety inspectors, reclamation and water quality technicians and inspectors, and environmental quality experts.

Herbert Clark Hoover (1874–1964), was a mining engineer and scholar before he became the 31st president of the United States (1929–1933). His mining career began in 1897, in the gold fields of Western Australia. He later traveled to the Far East, where he worked for the Chinese Bureau of Mines as chief engineer and then as general manager of the Chinese Engineering and Mining Corporation. Hoover became an independent mining consultant in 1908, setting up offices worldwide. His mining ventures brought him wealth, but he was also famous as a published scholar. For example, he and his wife, Lou, were responsible for translating Agricola's *De Re Metallica*, which remains in print today.

Mining Resources

Scouting Literature

Archaeology, Composite Materials, Energy, Engineering, Environmental Science, Geology, Surveying, and *Sustainability* merit badge pamphlets

With your parent or guardian's permission, visit Scouting America's official retail site, **scoutshop.org**, for a complete list of merit badge pamphlets and other helpful Scouting materials and supplies.

Books

Cumming, John, ed. *Mining Explained,* 11th ed. The Northern Miner, 2012.

Lagomarsino, James. *The Ultimate Guide to Rocks and Minerals*. Parragon Books Ltd., 2011.

Prinz, Martin, George Harlow, and Joseph Peters, eds. *Simon and Schuster's Guide to Rocks and Minerals.* Simon and Schuster Inc., 1978.

Industry Organizations

American Exploration & Mining Association
miningamerica.org

National Mining Association
nma.org

Society for Mining, Metallurgy, and Exploration
smenet.org

Web-Based Resources

Ground Rules—Caterpillar Inc.
youtube.com/catgroundrules

Mineralogical Society of America
min4kids.org

Minerals Education Coalition
mineralseducationcoalition.org

NASA STEM Engagement
nasa.gov/stem

USGS National Minerals Information Center
usgs.gov/centers/nmic

USGS Mineral Resources Program
usgs.gov/energy-and-minerals/mineral-resources-program

Acknowledgments

Scouting America is grateful to staff members of the Society for Mining, Metallurgy, and Exploration, who so graciously gave of their time, expertise, and other resources to assist us with the *Mining in Society* merit badge and pamphlet.

Revision Team (2023): Stan Krukowski (chair), Oklahoma Geological Survey (retired); Dan Alexander, West Virginia University; Joe Hirschi, Southern Illinois University; Pam Wilkinson, University of Arizona; Charlie Zimmerman, Caterpillar Inc.

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Mining in Society Advisory Panel (2014): John Murphy (chair), University of Pittsburgh; Dan Alexander, West Virginia University; Rick Derry, BLM; Mark Jorgensen, CH2M Hill Inc.; Frank McAllister, Retired mining executive; Robert Robinson, Shannon & Wilson; Brian Shaffer, Alpha Natural Resources.

Special thanks to the following for their tremendous support: Frank McAllister; Bill Francart; Stan Perks; Dave Kanagy, Executive Director, SME; Rio Tinto Kennecott Utah Copper; Aaron Young; the students and faculty of Department of Mining Engineering, University of Utah; the SME Student Chapter, CONSOL Energy; WAAIME; and the many members of SME not listed here.

The Society for Mining, Metallurgy & Exploration (SME) and the Minerals Education Coalition (MEC) worked with Scouting America to develop the Mining in Society merit badge, including the requirements, pamphlet, badge design, and other materials. In our ongoing efforts to help Scouts learn about the mining industry and its impact on their lives, we're pleased to provide a resource page for those earning the badge, their merit badge counselors, and others:

SME FOUNDATION

MEC

MINERALS EDUCATION COALITION

mineralseducationcoalition.org/scouts

Have questions? Contact us at mec@smenet.org

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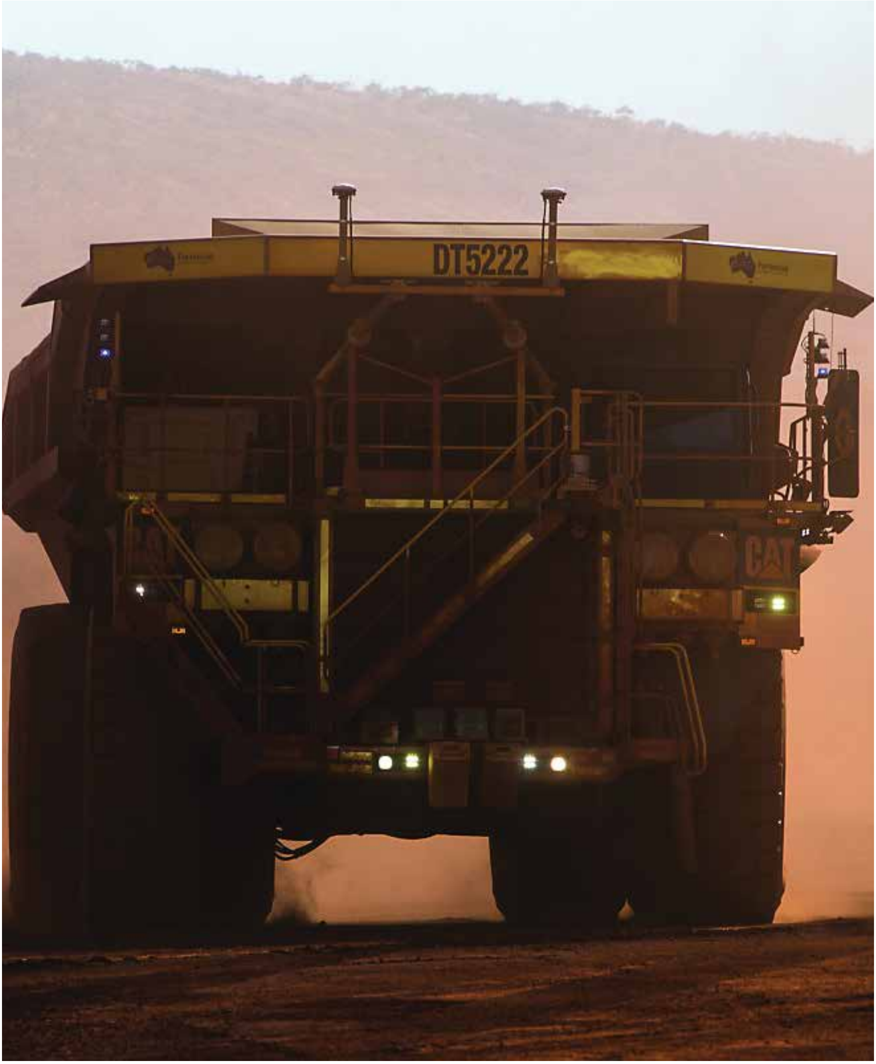
Notes



An autonomous mining haul truck designed to improve safety on mine sites in operation in Australia.