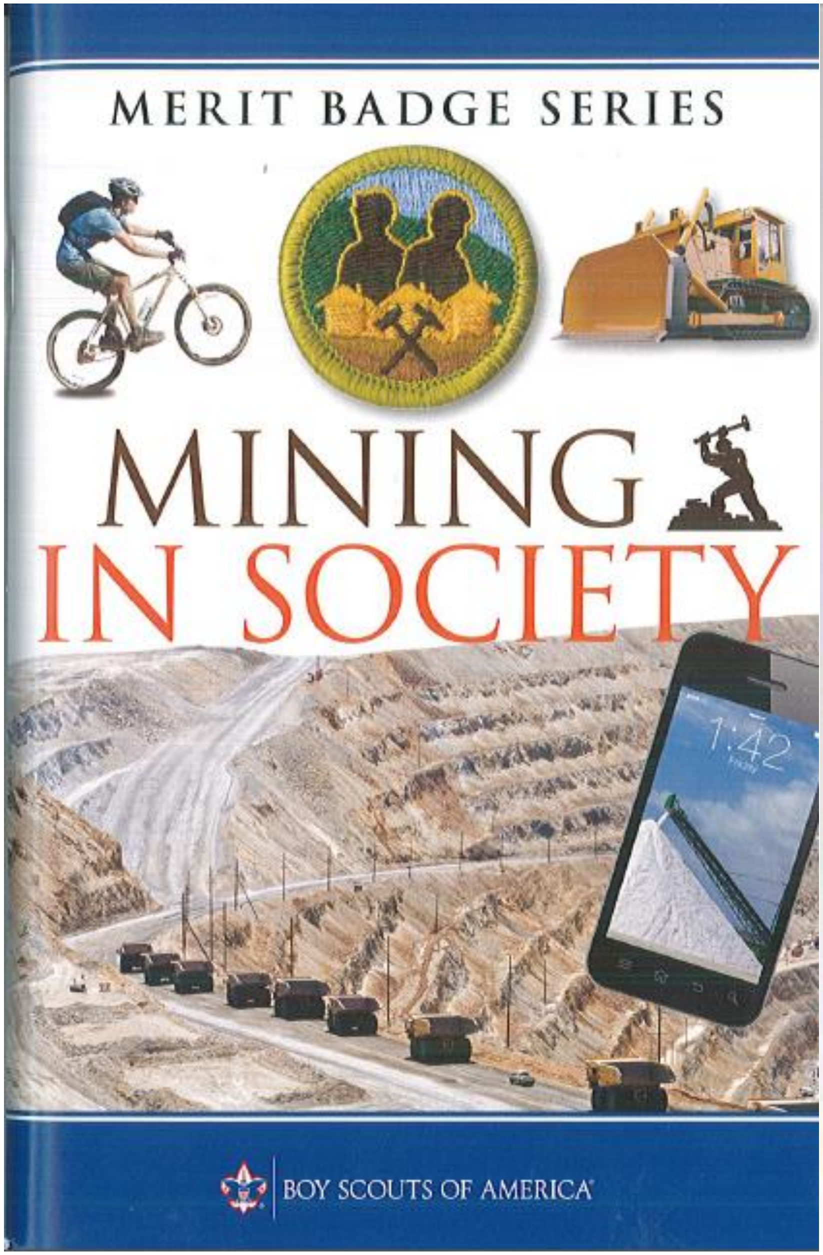

BOY SCOUTS OF AMERICA
MERIT BADGE SERIES

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"

BOY SCOUTS OF AMERICA

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 1a, determine the countries where those minerals can be found, and discuss what you learned with 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 are used in mine rescues.
4. Discuss with your counselor the dangers someone might encounter at an abandoned mine. Include information about the "Stay Out—Stay Alive" program.
5. Do ONE of the following:
   a. With your parent'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

2014 Printing

   b. With your parent'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'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.
   d. With your parent'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.

*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 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 safety equipment.

b. Explain reclamation as it is used in mining and how mine reclamation pertains to Scouting's no-trace principles.

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 the BSA Summit Bechtel Family National Scout Reserve from a mine site to its current role.

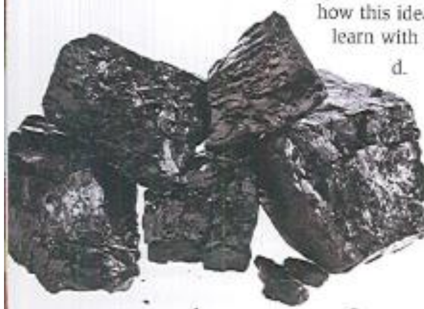
7. Do ONE of the following:

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 learn 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 learn with your counselor.

d. With your parent'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.

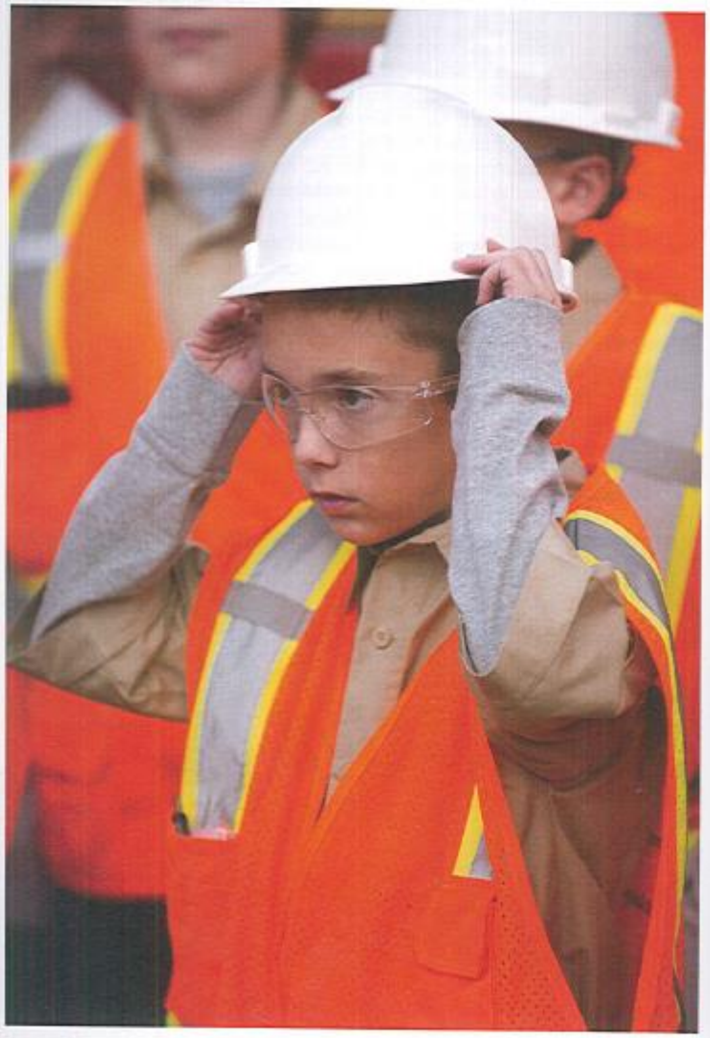


8. Do ONE of the following:

a. With your parent's and counselor's approval, meet with 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's permission and counselor's approval, visit a career academy or community college 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 from the earth that are valuable in creating products and services that people find useful.

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 from minerals that were mined from the 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.

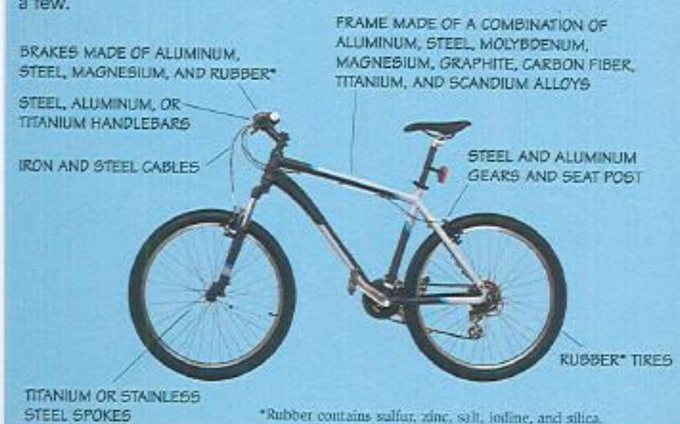
What's in Your Smartphone?
Producing a typical smartphone calls for the following metals and elements found in minerals: aluminum, antimony, beryllium, cadmium, carbon, chromium, cobalt, copper, gallium, gold, indium, iron, lanthanum, lead, lithium, manganese, mercury, neodymium, nickel, nitrogen, oxygen, 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, a car has about 34 minerals and metals, and a smart phone requires 30 minerals and metals—all were extracted from the earth.

Mining produces coal for generating electricity, and as a raw material for many industrial processes. Uranium for nuclear power is also mined. Even the devices needed to harness solar and wind energy are made from minerals that come from mining.

Minerals in Your Everyday Life

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



*Rubber contains sulfur, zinc, salt, iodine, and silica.

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 the 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 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, which is used to make steel. Fossil fuels, such as coal, are energy minerals, and so is uranium, which provides power by the heat from radioactive decay.
- *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, and pumice.

Glass was first discovered and used in the Bronze Age.

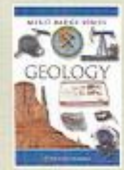
Your home is built of mineral products that were mined. Are the outside walls of your home or apartment made of brick, stone, or aluminum siding? All had to come from a mine at one stage or another. In a typical home, the inside walls are wall-board made of gypsum. The foundation is concrete with crushed stone in it, and the roofing shingles contain fine crushed stone. Windows are 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. To learn more, visit the website of the Minerals Education Coalition at www.MineralsEducationCoalition.org/MiningInSocietyMB.

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.

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 the metal; its properties made it so significant in human history.

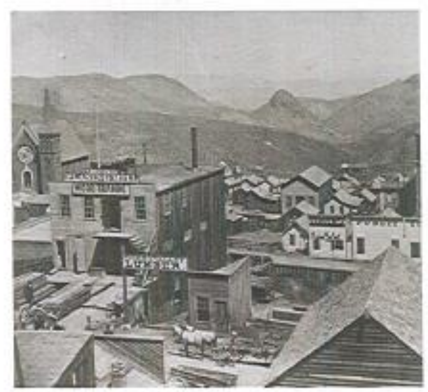
With technological advances came the Iron Age, when iron and steel became extensively used, especially for cutting tools. Smelted iron was hammered into the desired shape to make steel swords and other weapons and tools.

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).



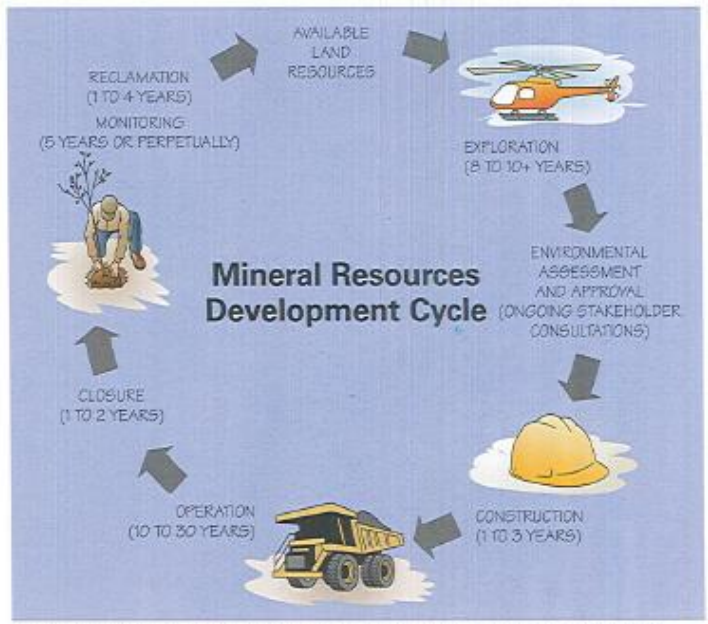
Because legal battles were waged over claims ownership, the U.S. Congress in 1866 passed the first law to govern how Americans could prospect and mine on federal public lands. Then in 1872, Congress passed the General Mining Act, which is still in effect today.

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. An *ore* is a type of rock that contains minerals of value, especially metals. 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 lava, which occurs on or near the surface as volcanic eruptions or lava flows.
- Sedimentary rocks form when particles eroded from older rocks are transported, deposited, and compressed into new rock. Examples are sandstone and shale. Sedimentary rocks may contain the remains of dead organisms (coal is made of fossil plants; limestone is made from the skeletons of sea creatures). Rock salt is a chemical sedimentary rock: the salt forms a solid when seawater evaporates.
- 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, nonmetallic, nonfuel mineral. It can be any hard igneous, metamorphic, or sedimentary rock.

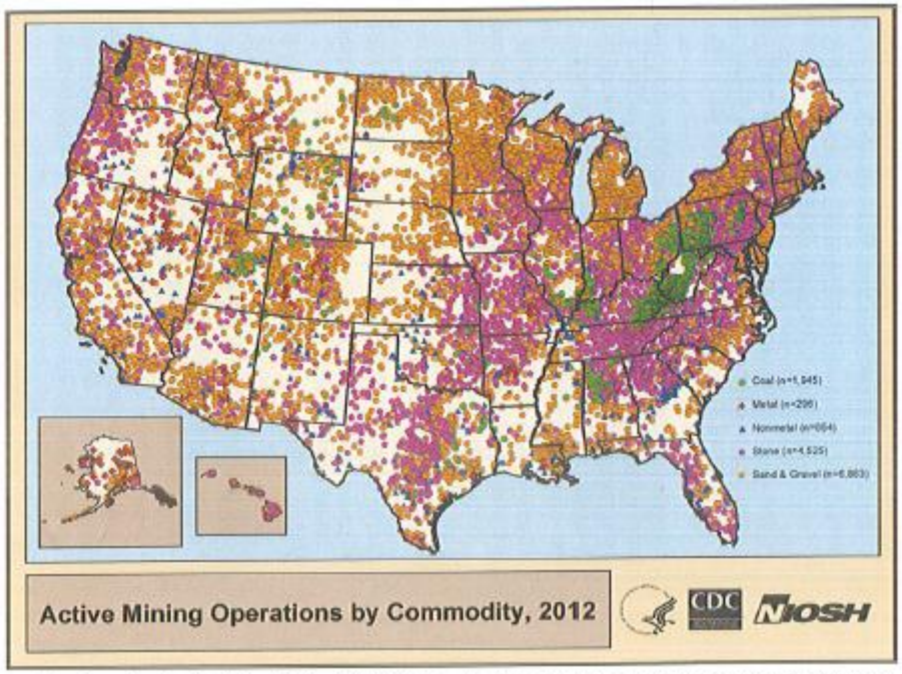
Important Minerals Used Every Day

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.

Here is a review of some common minerals: 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 active mines in the United States in 2010, illustrates how widespread mining is in this country. The land seems to be covered by the 14,000 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.

- 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 sedimentary rock formed mostly from the shells of marine organisms. Because oceans have covered much of Earth's surface, limestone is abundant. It is made mostly of the mineral *calcite* (calcium carbonate). 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 about 73 million metric tons of cement was produced at 98 plants in 35 states in 2012. Cement plants are found across the country.

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, plastics, and ceramics such as sinks and toilets. Bentonite is sticky 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 40 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 35 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 a few metals with its own distinctive color. 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* or mixtures with other metals. Copper is widely used in electrical wiring, electronics, water pipes and tubing, and as gutters and roofing material.

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.

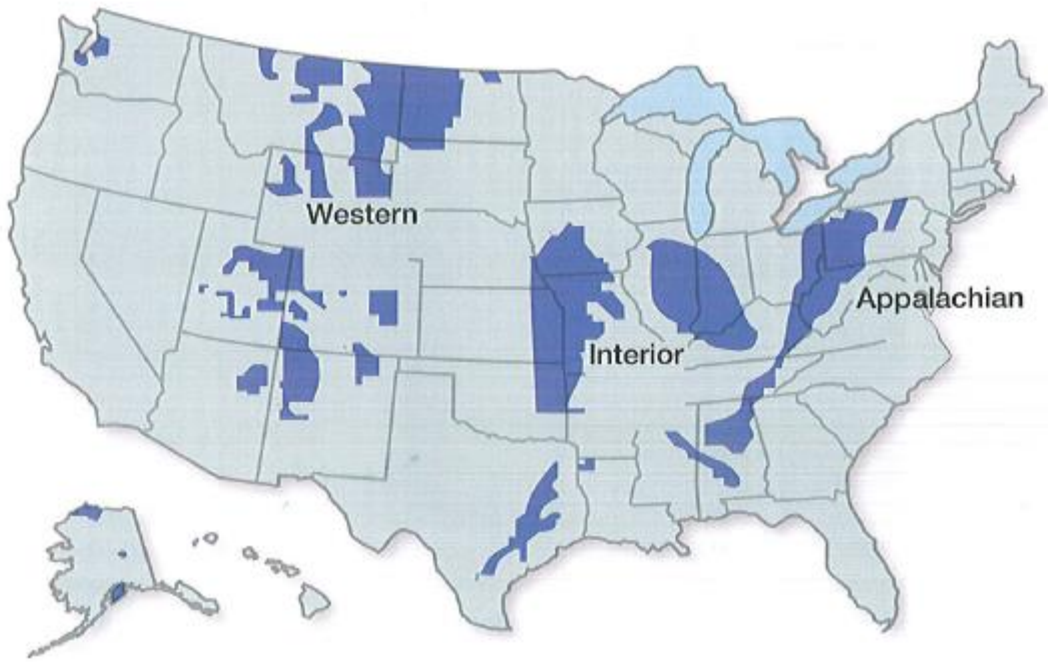
Some of the largest mines in the world today are copper mines. The metal is in high demand because of its wide variety of uses, and the search for large deposits never ends. As civilization depends more on electricity and electronic technology, the demand for copper will continue.

Gold. Gold is produced at about 50 hard rock mines from what are called *lodes* (ore deposits), a few large *placer* mines in river deposits (all in Alaska), and many smaller placer mines (mostly in Alaska and the western United States). In addition, a small amount of gold is recovered when mining silver and when processing metals such as copper, lead, and zinc. The United States exports gold, and in 2012, the country produced 230 metric tons of gold, ranking third after China and Australia. More than 99 percent of the gold produced in the United States comes from only 30 mines. Most U.S. gold production is from large open-pit mines in Nevada.

Gold is used mostly in jewelry and the arts—these account for about 66 percent of gold production. Another 12 percent goes into dental fillings. Gold is a good conductor that does not corrode, making it reliable for electronics and other electrical uses—these account for 5 percent of gold production. The remaining 17 percent is used as bullion (gold bars) for investment, money, medicine, glassmaking, and awards and medallions.

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	Bauxite, laterite soils; (converted to alumina first)	China, Brazil, Indonesia	Lightweight metal parts of all types
Antimony	Stibnite	China	Flame retardant, lead alloys (batteries), chemicals
Beryllium	Beryl and bertrandite	USA, China	Electronics, defense applications, nonsparking tools
Chromium	Chromite	South Africa, Kazakhstan	Stainless steel, electroplating
Cobalt	Cobaltite	Republic of Congo, Zambia	Superalloys, chemicals
Copper	Copper sulfides	Chile, China, Peru, USA	Electrical applications, building construction
Gallium	From bauxite and sphalerite	China, Germany, Kazakhstan, Ukraine	Electronics
Gold	Native metal in lode and placer deposits	China, USA, Australia, Russia, South Africa	Jewelry, dentistry, electronics
Indium	From zinc ores	China, Canada, Japan, South Korea	Liquid crystal displays (LCDs)
Iron	Hematite and magnetite	China, Australia, Brazil, India	Wrought iron, cast iron, steel
Lead	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	Igneous rock and brine (salt) deposits	Australia, Chile, China	Ceramics and glass, batteries
Manganese	Pyrolusite	South Africa, USA, China, Gabon	Steelmaking, pig iron production
Molybdenum	Molybdenite, from copper and tungsten ores	China, USA, Chile, Peru	Iron and steelmaking, superalloys, lubricants
Nickel	Pentlandite, laterite deposits	Philippines, Indonesia, Russia, Australia, Canada	Stainless steel, superalloys
Palladium	Native metal in alluvial deposits, copper and nickel ores	USA, South Africa, Russia, Zimbabwe, Canada	Catalytic converters, petroleum refining, dentistry, jewelry
Platinum	Native metal in alluvial deposits, copper and nickel ores	USA, South Africa, Russia, Zimbabwe, Canada	Catalytic converters, petroleum refining, jewelry, laboratory equipment
Silver	Ores of copper, copper-nickel, lead, and lead-zinc	Mexico, China, Peru	Electronics, coins and medals, photography
Tantalum	Tantalite, coltan ores	Rwanda, Mozambique	Electronic components, alloys, superalloys
Titanium	Rutile, ilmenite	Australia, South Africa, Canada, China, USA	White pigments, welding rods, alloys, airplane parts
Tungsten	Wolframite, scheelite	China, Russia, Canada	Tungsten carbide, tungsten metal wire, alloys
Zinc	Sphalerite	China, Australia, Peru, USA	Galvanizing, zinc-based alloys, brass and bronze

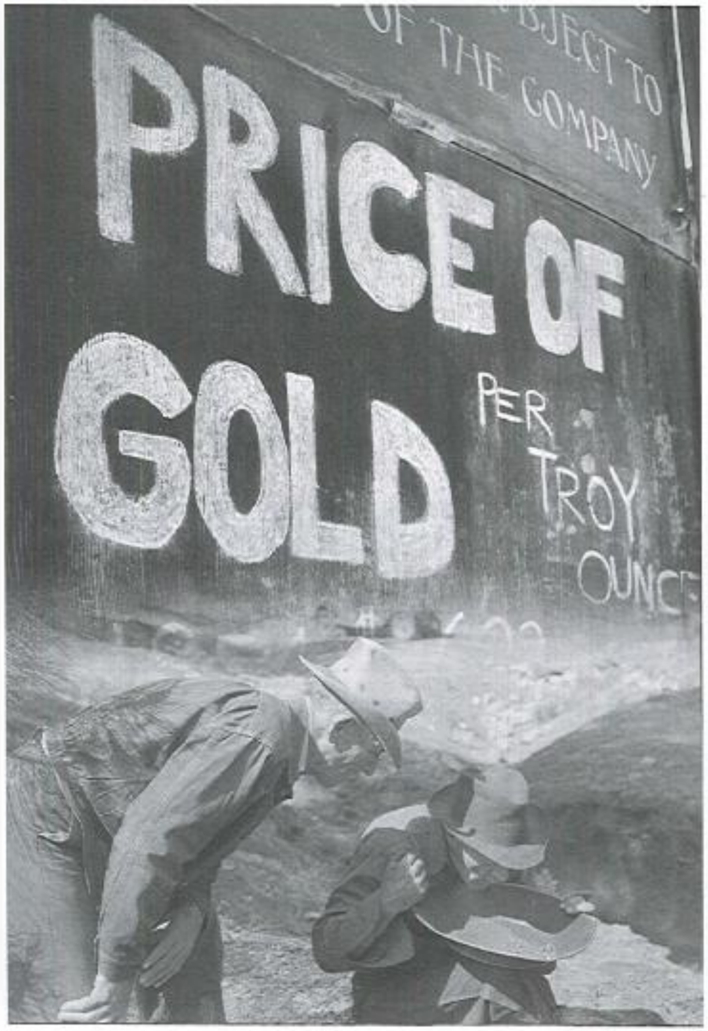
Industrial Minerals

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
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; power plant waste	China, Iran, Thailand, Spain	Wallboard, plaster, retardant in cement, soil amendment
Iodine	Caliche, oil-field brine, seaweed	Chile, Japan, USA	Medicine, catalysis in plastics, nutrition, liquid crystal displays
Perlite	Igneous (volcanic) rock	USA, Greece, Turkey, Japan	Building construction products, fillers, horticultural, filter aids
Phosphate	Sedimentary rock	China, USA, Morocco, Russia	Fertilizer, animal feed supplements, food additives
Potash	Sedimentary (evaporite) rock	Canada, Russia, Belarus, China	Fertilizer, chemicals

Mineral	Ore (Mineral or Rock)	Major Sources	Major Uses
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



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 his trusty mule. With his pick and shovel, off he would go 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.

The prospector would follow the gold upstream, panning every so often, seeking the "mother lode," or major ore deposit. When he stopped finding gold in the sediments, he would backtrack to locate where the gold was entering the stream, narrowing his search. Traditionally, once found, a miner 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. Satellites collect and process 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, 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 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 weak 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.

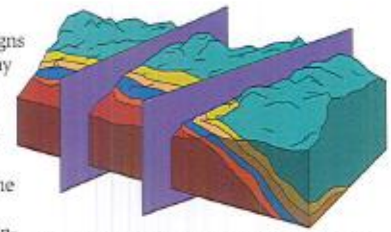
Land ownership is an important consideration. The exploration team needs to avoid trespassing (exploring on land without authorization). Local government offices have records of land ownership as well as information on who owns the mineral rights.

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.

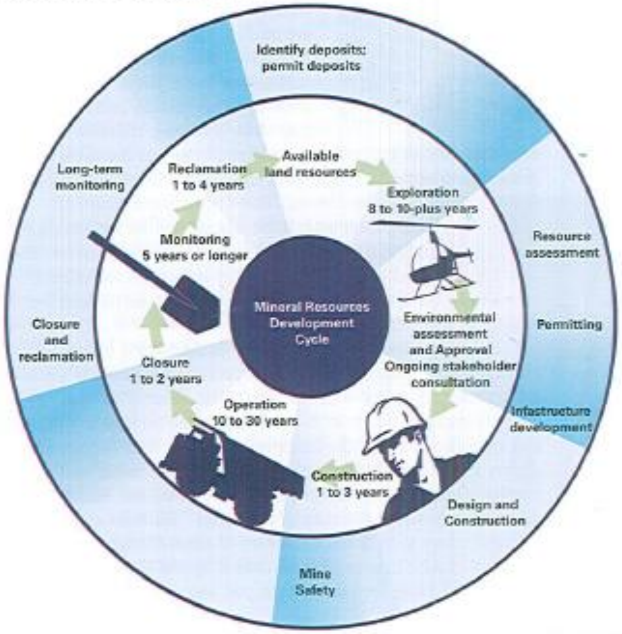
The Major Steps in Exploration

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 examining the surface, 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.

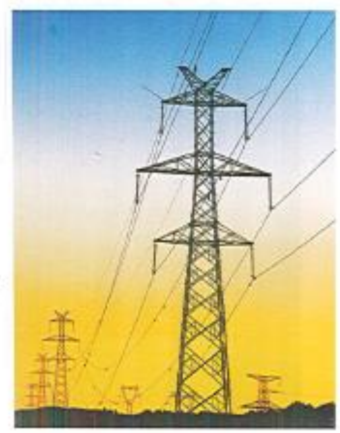
Different states may require additional information as well as recording the claim with the county and state where the claim is located. More information about staking mining claims can be found at the Bureau of Land Management website, www.blm.gov. (See "Mining Resources" in this pamphlet.)

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.



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.

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

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

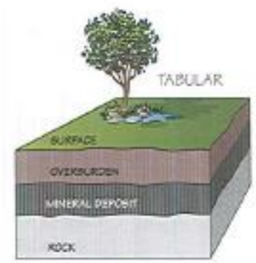
The type of mine is determined by the size and shape of the mineral deposit, how deep it is, and the kind of rock that surrounds it. The main types of mineral deposits include *tabular*, *massive*, *vein*, and *placer*.

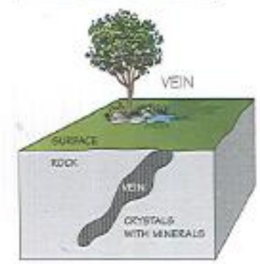
Tabular. The mineral deposit is basically horizontal and fairly uniform in thickness, like a slab or countertop. It can be at the surface or thousands of feet below. Examples of minerals found in tabular deposits are bituminous and lignite coal, limestone, salt, and trona (sodium carbonate or soda ash).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

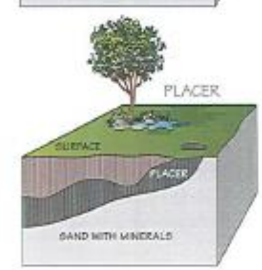
Massive. The mineral deposit lies within a large rock formation and is usually hundreds of feet thick and thousands of feet wide. It can be at the surface or thousands of feet below. Massive mineral deposits include metals like gold, silver, copper, lead, and zinc.

Vein. 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. 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. *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.

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.

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


BLAST-HOLE DRILL


RUBBER-TIRE LOADER


DOZER


EXPLOSIVES FOR BLASTING


LOADING SHOVEL


GRADER

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

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. Under-ground 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.

Photos provided courtesy of Joy Global Inc. and/or its affiliates

CONTINUOUS MINER

TRANSPORT VEHICLE

BLAST-HOLE DRILL

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*.

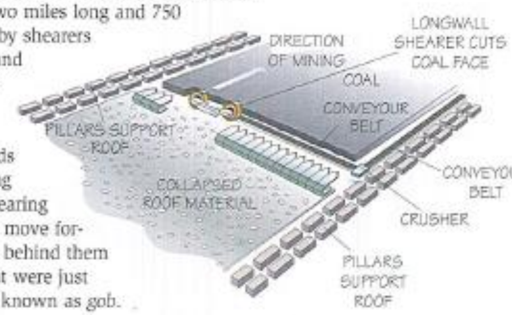
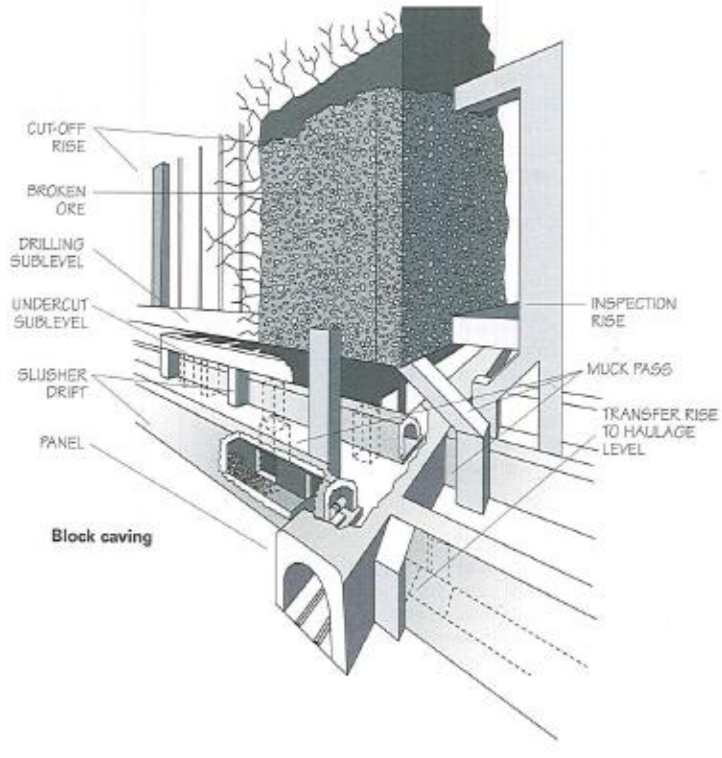


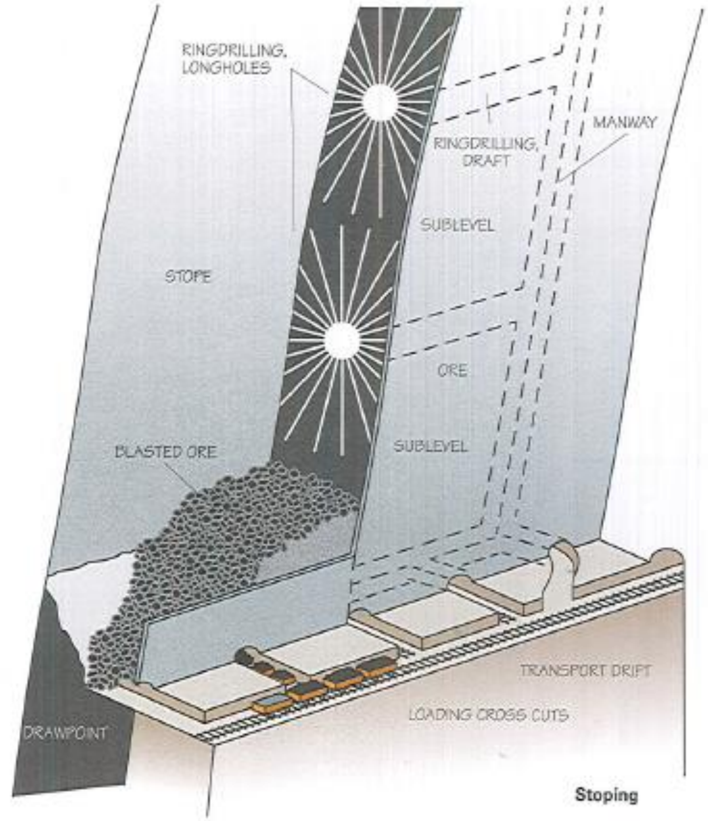
Photo provided courtesy of Joy Global Inc. and/or its affiliates

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.