Chapter 14-Geology and Nonrenewable Mineral Resources- Part 2

Mining—Ores & Fuels

- Ores: Concentrated accumulations of minerals from which economically valuable materials can be extracted; typically metals contained in rocks.
- Metals: Elements with properties that allow them to conduct electricity and heat energy and perform other functions; e.g. magnetism. Copper, nickel, and aluminum are common examples of metals. They exist in varying concentrations in rock usually in association with elements such as sulfur, oxygen, and silicon.
- Fossil fuel: A fuel derived from biological material that became fossilized millions of years ago and deposited within sedimentary layers; e.g. coal, oil, and natural gas.
- Nuclear fuel: Fuels derived from radioactive materials that give off energy. Uranium, used generate electricity, is a nuclear fuel that is found in igneous, sedimentary and metamorphic deposits throughout the world.
- **Ore Formation**
  - Ores are formed by a variety of geologic processes.
  - **Hydrothermal deposits or veins**: Are distinct sheet like ore bodies of crystallized minerals; deposited in relatively high concentrations but within smaller areas of rock. This occurs when magma comes into contact with water, heating the water and creating a solution from which dissolved metals/minerals *precipitate* (*when a dissolved solid falls out of a liquid solution*).
  - **Disseminated deposits**: Disseminated ore is an ore containing small particles of valuable minerals (metals) that are spread quite uniformly throughout a large body of rock. Thus, disseminated deposits occur in large areas of rock, but are of low concentration. Large, disseminated deposits form significant sources of ore, e.g. porphyry copper deposits.
    - **Sulfide ores**: Sulfide ores contain large amounts of sulfide minerals. Sulfide minerals are compounds of sulfur and other elements.
      - Examples of sulfide minerals: zinc sulfide, lead sulfide, iron sulfide, copper sulfide, silver sulfide, molybdenum sulfide, arsenic trisulfide, copper iron sulfide, etc.
      - Igneous processes deposit sulfide ores in hydrothermal or disseminated deposits. These may occur in fracture zones in the crust in and around igneous bodies called batholiths, which cool and solidify to form the igneous rock granite.
      - Sulfide minerals are deposited as precipitates from aqueous solutions that contain soluble metals such as gold, silver, lead, zinc, pyrite, molybdenum, copper, arsenic, mercury, and cadmium, to name a few.
      - Chalcopyrite is a sulfide mineral with the chemical formula, $CuFeS_2$
      - Molybdenite is a sulfide mineral with the chemical formula, MoS_2
      - Therefore, large bodies of rock, such as granite—typical of mountain ranges—tend to contain large deposits of sulfide minerals and ore.
      - Sulfides are the most valuable minerals because they contain the metals that are most useful to our civilization.
    - **Oxides and hydroxides**
      - Oxides are compounds that combine metals or semi-metals and oxygen. Cuprite is a copper oxide mineral with the chemical formula, Cu_2O.
      - Hydroxides are similar to oxides, being metals combined with a hydroxyl ion rather than an oxygen. Malachite is a copper carbonate hydroxide mineral, with the formula $Cu_2CO_3(OH)_2$. Azurite is a copper carbonate hydroxide mineral with the formula, $Cu_3(CO_3)_2(OH)_2$.
      - Oxides and hydroxides often form at high temperatures beneath the Earth's surface in fracture zones where aqueous solutions evaporate and solid minerals precipitate out of solution.
    - **Unique/miscellaneous deposits:** Other deposits, such as banded iron formation (BIF) for example, were formed through unique biologic, atmospheric, and geologic interactions. The BIF layers were formed in seawater as the result of oxygen released by photosynthetic cyanobacteria. The oxygen then combined with dissolved iron in Earth's oceans to form insoluble iron oxides, which precipitated out and sunk to the ocean floor, forming a thin layer on the ocean floor, in-between layers of mud, which formed shale.

Chapter 14-Geology and Nonrenewable Mineral Resources- Part 2

Reserve: The known quantity of resources that can be economically recovered.
- Not all minerals are a found in all countries, and some countries have depleted their reserves of a particular mineral resource.
- For example, the United States has used up all of its reserves of nickel, and now must import it.
- Tantalum, a metal important in advanced electronics, has never existed in the U.S. and must be imported.
- Many of the *strategic metals* that the U.S. needs to maintain high-tech economy, such as manganese, cobalt, platinum, tungsten, titanium, niobium, coltan, lithium, and neodymium must be imported.
- Economic depletion: when it costs more than it is worth to find, extract, transport, and process the remaining deposits. At that point, there are five choices: recycle or reuse existing supplies, waste less, use less, find a substitute, or do without.
- Depletion time: The time it takes to use up a certain portion, usually 80%, of the reserves of a mineral at a given rate of use.

High-grade vs. low-grade ore and the environmental impact
- The environmental impacts from mining an ore are affected by its percentage of metal content, or grade. The more accessible and higher-grade ores are usually exploited first. As they become depleted, mining lower grade ores takes more money, energy, water, and other materials, and increases land disruption, mining waste, and pollution.
- Extracting lower grade ore can extend supplies of minerals. Technological advances in extracting and processing minerals have made it possible to extract lower grade ores. For example, in 1900 the average copper ore mined in the U.S. was about 5% copper by weight; today that ratio is 0.5%.
- There are several important implications associated with mining lower grade ores. Less metal per unit of volume of ore means more ore must be extracted, which means:
    1. Increased cost of mining and processing larger volumes of ore.
    2. Increasing shortages of freshwater needed to mine and process some minerals, especially in arid and semi-arid areas, such as much of the western United States.
    3. Greater environmental impacts due to increased land disruption, waste material and pollution during the mining and processing of ores.

Supply and demand: An increase in the price of a scarce mineral can lead to increased supplies.
- A plentiful mineral resource is cheap when its supply exceeds its demand.
- When a resource becomes scarce, its price rises. This can encourage exploration for new deposits, stimulate the development of better mining technology, and make it profitable to mining lower grade ores.
- It can also encourage the search for substitute materials and promote resource conservation.

Excluding environmental costs from market prices is an underlying cause of environmental problems.
- Government subsidies to mining companies keep the price of minerals and fuels artificially low. Plus Government programs like superfund cover the cost of externalities such as cleaning up abandoned mine lands.
- If the minerals were brought to market at full cost pricing that includes the external costs the prices of minerals and fuels would be much higher and people would be forced to use less and it would be much more expensive to purchase advanced electronics like computers and cell phones.

Recycle: A more sustainable way to use nonrenewable mineral resources is to reuse or recycle them.
- Metals like aluminum and copper are 100% recyclable, meaning none is wasted in the recycling process.
- Recycling aluminum beverage cans and scrap aluminum produces 95% less air pollution and 97% less water pollution, and uses 95% less energy than mining and processing the aluminum ore.

Chapter 14-Geology and Nonrenewable Mineral Resources- Part 2

Mining—Extraction

- *"If you can't grow it, you have to mine it"*
- Mining is the extraction of valuable minerals or other geological materials from the earth.
- Mining take enormous amounts of energy and water and can disturb the land, erode the soil, produce solid waste and greenhouse gases, pollute the air, water and soil.
  - **Surface mining**
    - — Strip mining: Strip mining is most commonly used to mine coal and tar sands; usually on fairly flat terrain where the coal seam or ore body is relatively close to Earth's surface and parallel to it.
      - Overburden (or *gangue*): to access the coal seam or ore body the layers of vegetation, soil, and rock must first be removed, this material is referred to as *overburden.*
      - Layers of coal or tar sand are then excavated in long strips by massive cranes called dragline excavators and transported to and trains and or a processing facility in giant haul trucks.
      - The unwanted waste material, called mining ***spoils*** or ***tailings,*** is then used to fill in excavated area.
    - — Contour strip mining: Strip mining is used to extract resources from large flat areas, whereas ***contour strip mining*** is used in hilly or mountainous terrain, where the mineral outcrop usually follows the contour of the land. This method of extraction usually leaves behind terraces (giant steps) in mountainsides.
    - — Mountaintop removal: Mountaintop removal employs the same excavation techniques and equipment as strip mining.
      - This method is used where a coal seams wrap all the way around the mountaintop.
      - Layers of rock and dirt above and between the coal seams are removed.
      - Coal seams are removed with excess soil and rock placed in an adjacent valley; i.e. valley fill.
      - ***Valley fills***: Overburden are disposed of in adjacent valleys because the broken rock will not all fit back into the mining pit, and disposal alternatives are limited.
      - Mountain top removal replaces relatively steep topography with relatively flat terrain.
    - — Open-pit mining: Open-pit mining is the most common type of mining. It is used when a large ore body is relatively close to the surface but extends deep beneath the surface.
      - Open-pit mining is most often used to extract disseminated deposits, usually of metals contained in sulfide ores, such as copper; e.g. porphyry copper deposits.
      - Using large excavation equipment such as hydraulic shovels and haul trucks, a large pit is dug into the Earth as dirt, rock and ore are removed in a series of concentric circles, downward into the Earth; creating a series of giant steps called benches, usually in nine to thirty meter intervals.
      - Haul roads are built forming ramps on which haul trucks transport ore and waste rock to the surface where ore is processed and waste rock (a.k.a overburden and gangue) is dumped in waste rock piles (a.k.a spoils piles).
      - Leftover waste from processing the ore is called *tailings*. Tailings may be solid rock or in the form of slurry. Solid tailings are heaped in tailings piles, while slurry is pumped to a tailings impoundments or settling ponds.
      - In cases where the pit dips into the water table water must be constantly pumped out to avoid flooding, a process called dewatering.
      - Pit lakes usually form in the bottom of the open-pit mine after operations have been ceased; this water needs to be monitored and treated indefinitely.
  - **Subsurface/underground mining**
    - When the desired resource lies deep within the Earth, tunnels and shafts are dug into the ground to reach it.
    - This type of mining tends to be less efficient, more expensive, and more dangerous, but if the resource is extremely valuable (such as diamonds or platinum) or in high demand (like coal or base metals such as copper, lead, and iron), it may be financially worth it.
    - There is less surface destruction and waste rock produced than in surface mining, but it often is unsafe.
    - Tunnels, often referred to as adits, are horizontal and follow veins of metals like copper or gold or coal seams. Shafts are vertical and use elevators to transport miners, equipment and ore.
    - In cases where subsurface mining occurs below the water table water must be constantly pumped out to avoid flooding.

Chapter 14-Geology and Nonrenewable Mineral Resources- Part 2

- **Artisanal and small-scale mining**
  - An artisanal miner or small-scale miner is, in usually, a subsistence miner. They are not officially employed by a mining company, but rather work independently, mining or panning for gold using their own resources.
  - Artisanal and Small-Scale Mining occurs in approximately 80 countries worldwide. There are approximately 100 million artisanal miners globally. Artisanal and small-scale production supply accounts for 80% of global sapphire, 20% of gold mining and up to 20% of diamond mining.
  - **Placer mining**: The process of looking for minerals, metals, and precious stones in river sediments. Miners use the water to separate heavier items, such as diamonds, tantalum, and gold, from lighter items, such as sand and mud. The prospectors in the California gold rush in the mid 1800's were placer miners, and the technique is still used today by artisanal miners.
- **In situ leaching**
  - In-situ leaching (ISL), also called in-situ recovery (ISR) or solution mining, is a mining process used to recover minerals such as copper and uranium through boreholes drilled into a deposit, *in situ*. In situ leach works by artificially dissolving minerals occurring naturally in a solid state.
  - The process initially involves the drilling of holes into the ore deposit. Explosive or hydraulic fracturing may be used to create open pathways in the deposit for solution to penetrate.
  - Leaching solution is pumped into the deposit where it makes contact with the ore. The solution bearing the dissolved ore content is then pumped to the surface and processed.
  - This process allows the extraction of metals and salts from an ore body without the need for conventional mining involving drill-and-blast, open-cut or underground mining.
- Can we get more minerals from the ocean? Dredging the ocean floor, extracting minerals from seawater, and mining volcanic regions of the ocean floor are all potential sources of valuable minerals that may be explored as more readily available reserves become depleted.

Mining—Processing

- Processing coal: First it is washed to remove contaminants and impurities like rocks, ash, sulfur and other substances. Next the coal is screened for size, and then large pieces may be crushed or pulverized to a useful size and run through a roll crusher until all of the coal is fairly uniform in size.
- Processing ore:
  - There are many ways to process ore (remove the metal from the ore) the methods described below are the most well known traditional methods. However, many modern processing techniques, such as *electrowinning* and *froth flotation* have become prevalent and are used in combination with the methods described below.
  - *Crushing and grinding*: Ore usually contains less than 2% of the desired metal. The first stage in separating the metal from the ore is often crushing the ore into a fine powder in ball mills. Then the ore may be processed by smelting or chemical treatments (or other processes not described here).
  - *Smelting*: The process of using a blast furnace to apply heat to ore and melt out the desired metal.
    - It is used to extract many metals from their ores, including silver, iron, copper, and other metals.
    - Smelting uses heat and a chemical reducing or oxidizing agent to decompose the ore, recovering the desired metal, and driving off other elements as gases and/or leaving behind slag (glass-like substance composed mostly of silicon dioxide and other base metals).
    - Coke (not to be confused with soda or illicit drugs) is a carbon-based substance commonly used as a reducing agent; oxygen in air is a common oxidizing agent.
    - A metal whose ore is an oxygen compound (iron, zinc, or lead oxides) is heated (reduction smelting) in a blast furnace to a high temperature. The oxide combines with the carbon in the coke, escaping as carbon dioxide or carbon monoxide.
    - Other impurities are removed by adding flux (a mineral, such as calcium carbonate, added to help remove impurities), with which they combine to form slag.
    - If the ore is a sulfide mineral (copper, nickel, or cobalt sulfides) air or oxygen is introduced to oxidize the sulfur to sulfur dioxide and any iron to slag, leaving the metal.

Chapter 14-Geology and Nonrenewable Mineral Resources- Part 2

- *Chemical treatments*
  - Heap leaching is an industrial mining process used to extract metals such as copper, gold, and nickel from ore through a series of chemical reactions.
  - Chemicals such as cyanide and sulfuric acid are sprayed on the ore causing the desired metals to dissolve or leach into a solution and precipitate out through chemical processes.
    - — In cyanide heap leaching, gold ore is heaped into a large pile. Cyanide solution is then sprayed on the top of the pile. As the crushed ore is irrigated with a dilute cyanide solution, the cyanide percolates downward through the ore; the gold (Au) leaches out of the ore as it bonds with cyanide (CN) and collects in a liner at the bottom of the heap where it drains into a storage pond. This gold-cyanide solution ($Au(CN)^-_2$) is known as a "pregnant solution".

$$Au^+ (s) + 2\ CN^- (aq) \rightarrow Au(CN)^-_2 (aq)$$

    - — One common way to recover the gold from the "pregnant solution" is to add zinc powder. This causes a precipitation of gold as zinc (Zn) reacts with cyanide to form a compound.

$$2\ Au(CN)^-_2 (aq) + Zn (s) \rightarrow Zn(CN)^-_4 (aq) + 2\ Au (s)$$

    - — The gold extracted may be only 0.01% of the total ore processed.
    - — Liquid wastes containing cyanide and other toxins are stored in tailings pond/impoundments.
    - — Chemical treatments used to process ore use enormous volumes of water, which are often extracted from local sources such as surface or ground water.

Mining—Environmental Effects

- **Biodiversity**
  - Mining almost always requires the construction of roads, which cause habitat fragmentation. Additionally, the clearing of forest and other plant communities, for the mine itself, causes habitat loss.
  - Ongoing development and operation of a mine leads to soil erosion and sediment pollution in waterways.
  - Mining discharges can impair streams and watersheds. Sediment-laden runoff can result in increased turbidity and decreased oxygen in receiving waters, which in turn can result in loss of in-stream habitat for fish and other aquatic species. Sediment can kill fish directly, destroy spawning beds, suffocate fish eggs and bottom dwelling organisms, and block sunlight resulting in reduced growth of beneficial aquatic grasses.
  - Overall mining operations tend to result in a loss of biodiversity.
- **Hazardous waste**
  - The term hazardous waste has technically been defined by the U.S. Environmental Protection Agency to include any substance that is flammable, corrosive, reactive, or toxic. Mining wastes are toxic to plants, animals, and humans.
  - Mining operations produce staggering amounts of hazardous waste. Each year mining operations in the U.S. produce 1.5 billion metric tons of wastes; 95% of this is attributed to coal mining in the U.S.
  - *Valley fills*: In mountaintop removal, a practice common in West Virginia and Kentucky, waste rock such as *spoils and extra overburden*, are dumped in neighboring valleys, where they can burry, block or alter stream flow, cause water pollution, and lead to habitat degradation.
  - *Tailings*: The leftover material from processing the ore—finely ground solid ore or a liquid slurry, both called *tailings*— are usually acidic, contain toxic chemicals such as cyanide and heavy metals such as lead, zinc, arsenic, and cadmium.
    - **Effluent** is an outflowing of wastewater, in this case mine wastewater is contaminated with heavy metals and a has low pH (acidic). Because of rain and snow, water will accumulate around a closed mine site and eventually flow into the surrounding ecosystem. Therefore, mines must be prepared to treat the effluent before it flows into the environment.
    - Tailings must be stored, essentially forever, in tailings ponds or impoundments that are usually bound by a tailings dam; typically, an earth-fill embankment dam.
    - Tailings are treated in *settling ponds* where the water is chemically treated with heavy bases (such as sodium hydroxide) to increase the pH (reduce the acidity). Chemicals are also added to allow heavy metals to precipitate out of solution and sink to the bottom; hence the term settling ponds.
    - Tailings impoundments may contain extremely toxic chemicals, such as cyanide, or heavy metals. Birds and mammals that are drawn to the ponds in search of water are often poisoned and die. The ponds can leak, overflow, or the impoundment dam may fail causing catastrophic toxic floods.

Chapter 14-Geology and Nonrenewable Mineral Resources- Part 2

- **Acid mine drainage**
  - Acid mine drainage is one of the most serious environmental problems that the coal and metal mining industry is currently facing.
  - Acid mine drainage (AMD) refers to the outflow of acidic water from a mining site.
  - AMD impacts stream and river ecosystems by decreasing the pH of the water and leaching toxic heavy metals out of soil and rocks.
- **How acid mine drainage forms**
    - AMD is a serious problem with hard rock mining; particularly sulfide ore that contains metals such as gold, copper, lead, silver, and zinc. Pyrite, an iron sulfide, is abundant in sulfide ore and its waste rock and tailings. AMD is also a problem in coal mining due to the high concentration of the iron sulfide, pyrite, found in coal.
    - Ordinarily, these potentially toxic ores exist in huge quantities underground and are "locked away". However, once the rock is crushed and exposed to oxygen and the surface environment the surface area available for chemical reactions increases greatly, compared to undisturbed rock. This makes the ore more "chemically available" for acid forming reactions.
    - When rainwater flows through waste rock and tailings of sulfide ore (or coal waste rock) it reacts with oxygen in the air and pyrite in the rock to form sulfuric acid.

$$4\ FeS_2 + 15\ O_2 + 14\ H_2O \rightarrow 4\ Fe(OH)_3 + 8\ H_2SO_4$$

  - **Acid mine drainage – "Yellow Boy"**
    - When the acidic water reacts with rock that buffers it (increases its pH) and becomes less acidic, metals and other solids precipitate out of solution. One of these precipitates, known as "yellow boy", and can turn streams a distinctive red/orange/yellow color and can smother life in a streambed.
  - **Acid mine drainage – Heavy metals**
    - The solubility of metals increases with a decrease in pH. Therefore, as the water becomes more acidic it can leach metals out of rocks and soils.
    - This means that toxic heavy metals such as arsenic, copper, and lead can easily become dissolved into the water. As more toxic heavy metals dissolve into the water it becomes toxic to fish by disrupting metabolic and reproductive systems. Precipitation of these metals can destroy habitat needed by macro-invertebrates.
    - Furthermore, these heavy metals can bioaccumulate up through the food chain and contaminate drinking water supplies.
    - Because of their high degree of toxicity, arsenic, cadmium, chromium, lead, and mercury rank among the priority metals that are of public health significance. These metallic elements are considered systemic toxicants that are known to induce nervous and organ damage, even at lower levels of exposure.
  - **Acid mine drainage and its effects on biodiversity**
    - In some regions where mining is done, streams and rivers are considered dead, that is, all organisms in them have been destroyed by runoff from mine wastes and/or tailings.
    - By one estimate, 16,000 km of waterways in the Appalachian Mountains have been seriously polluted by runoff from mining activities.
  - **Reducing acid mine drainage**
    - To reduce acid mine drainage, modern mining operations are generally required to lay down an impervious barrier onto which waste rock and tailings will be piled. When the mine closes, the waste rock or tailings pile should be covered with an impervious layer, such as clay, that will reduce contact with precipitation and minimize surface runoff.
    - Also, affected streams can be treated with alkaline/basic substance that buffer/neutralize the pH, substances such as calcium carbonate ($CaCO_3$), sodium hydroxide ($NaOH$), sodium bicarbonate ($NaHCO_3$), anhydrous ammonia (NH_3). Lining streams with alkaline rocks, such as limestone, is a method used to buffer streams with low pH. When they have buffered the water sufficiently—and become coated with "yellow boy" and other heavy metals—they can be removed and replaced or simply just removed if the ecosystem has been restored.

Chapter 14-Geology and Nonrenewable Mineral Resources- Part 2

Depletion and pollution of water resources

- In an open pit-mine the ore body may extend well below the water table. To avoid flooding at the bottom of the pit, the water table must be lowered by constantly pumping out of the underground water table; a process called dewatering. This "drawdown" affects the amount of water available in underground aquifers.
- This phenomenon is often referred to as a *cone of depression*, where an actual depression of the water level in an aquifer occurs (in an unconfined aquifer/water table) around a well where excessive pumping has occurred.
- Because of the dry nature of the western United States, much of the agricultural, domestic, municipal, and industrial water supplies come from groundwater that is pumped from aquifers.
- The water in these aquifers is *recharged* or *replenished* by annual seasonal rain and snowmelt that percolate into the groundwater and eventually into aquifers.
- *If the drawdown, from dewatering exceeds the annual recharge, water sources in this arid region can go dry.*
- **Pit lakes**
  - When an open-pit mine closes and dewatering ceases the groundwater will flow into the pit creating a ***pit lake***. The water in the pit lake will likely become acidic and contaminated with heavy metals. Eventually, if left untreated the contaminated water will flow back into groundwater and eventually into aquifers resulting in negative impacts on aquatic and human life. One such scenario is the Berkeley Pit in Butte, Montana, a retired gold mine. It is slowly filling with acidic water, laden with heavy metals; the water will need to be treated, essentially forever, to avoid contaminating groundwater resources.
  - Pit lakes often contain extremely toxic chemicals, such as cyanide, or heavy metals.
  - Birds and mammals that are drawn to the ponds in search of water are often poisoned and die.
- **Mercury air and water pollution**
  - Air pollution is another looming environmental impact that brought on by gold mining.
  - Gold ores contain other metals, most notably mercury. Pure mercury is a liquid at room temperature, and is gasified easily during mining processes, sometimes reacting with other substances.
  - Mercury is released into the air from gold mines as either mercury vapor or bounded by tiny suspended particles.
  - Mercury is widely considered the most dangerous heavy metal because it is toxic to humans and moves freely through the environment. It is connected to various nervous system disorders and is known to impair brain development in fetuses and young children.
  - One of the most dangerous forms of mercury, methyl mercury, can bioaccumulate in the food chain.
  - In bodies of water downwind of gold mines in Nevada, Utah, and Idaho elevated levels of mercury have been detected, due to this, the states have posted fish consumption advisories.
- **Artisanal placer mining & mercury**
  - Mercury is a highly volatile metal that is it moves easily among air, soil, and water. Mercury is harmful to plants, and animals and can damage the central nervous system in humans; children are especially sensitive to the effects. Mercury is naturally occurring in gold ore and can enter air and water during industrial gold mining. Also, artisanal gold miners using placer mining extract gold from sediments using the mercury amalgamation method, which contaminates air and water.

Chapter 14-Geology and Nonrenewable Mineral Resources- Part 2

Mining—Health and Safety

- Traditional subsurface mining is dangerous; hazards include accidental burial (mine tunnel collapse), explosions, and fires.
- Inhalation of gases and particles over long periods can lead to occupational respiratory diseases such as asbestosis, a form of lung cancer, and black lung disease.
- Fatalities in open-pit mines: rare wall collapses or haul trucks running over hard-to-see smaller vehicles.
- Also, rare fatalities have occurred in mining processing and treatment facilities due to build up of gases, such as carbon dioxide, in buildings, creating anoxic conditions.

Mining—Important Legislation

- **Mining Law of 1872**: This law was written primarily to encourage development and settlement of the western United States; allowed individuals or companies to recover ores or fuels from federal lands and stake a claim. Contained few, if any provisions for environmental protection. To a certain extent the law did regulate the mining of silver, copper, and gold ores, as well as, fuels including natural gas and oils on public land.
- **Mineral Leasing Act of 1920**: Authorizes and governs leasing of public lands for developing of coal, petroleum, natural gas and other hydrocarbons, phosphates, and sodium in the United States. Prior to the act, these materials were subject to the mining claims under the General Mining Act of 1872.
- **The Surface Mining Control and Reclamation Act of 1977**: Regulates surface mining of coal and surface effects of subsurface coal mining. The act mandates that land be minimally disturbed during the mining process and reclaimed after mining is complete.
- **Clean Air Act:** The U.S. Environmental Protection Agency (EPA) sets emissions standards for all hazardous air pollutants through the National Ambient Air Quality Standards (NAAQS). NAAQS specifies the levels for certain air pollutants in order to protect public welfare. Specific standards for compliance and operational permitting apply to emissions for the mining activity.
- **Clean Water Act:** The Clean Water Act prohibits all pollution discharges into navigable waters, unless the "polluter" obtains a permit. Section 404 of the Clean Water Act (CWA) regulates the discharge of dredged and fill material into waters of the United States.
  - Section 404 sets environmental criteria that must be met for individuals or companies to receive a permit. In the case of mining, overburden and tailings should be classified as fill material and hazardous solid wastes. Additionally, any river, stream, or lake near a mining operation should be classified as a navigable body of water.
  - However, the definitions of these terms have been subject to legal debate since the 1980's and in that time many mining operations have been permitted under Section 404 of the CWA.
  - Mountaintop removal coal mining, the practice of valley fills in particular, has been a permitted and therefore legally acceptable practice in Appalachia.
  - The Clean Water Rule, proposed by the Obama administration in 2014, sought to clarify the legal jurisdiction of the federal government under the Clean Water Act; paying special attention to the definition of "navigable waters." In effect the Clean Water Rule would make the practice of valley fills illegal.
- **Superfund:** Congress established the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) in 1980.
  - CERCLA is informally called Superfund. It allows EPA to clean up contaminated sites. It also forces the parties responsible for the contamination to either perform cleanups or reimburse the government for EPA-led cleanup work.
  - When there is no viable responsible party, Superfund gives EPA the funds and authority to clean up contaminated sites.
  - Abandoned mine lands (AMLs) are those lands, waters and surrounding watersheds where extraction, beneficiation or processing of ores and minerals has occurred.
  - AMLs can pose serious threats to human health and the environment. The EPA conducts and supervises investigation and cleanup actions at a variety of mine sites.

Chapter 14-Geology and Nonrenewable Mineral Resources- Part 2

Mining—Reclamation

- To restore a disturbed ecosystem to a state similar to its original condition the original physical, chemical and biological conditions must be recreated.
- Reclamation after mining involves several steps:
  1) Fill in the hole or depression created that was created in the landscape.
  2) Reshape the land to the original contours to resemble the landscape that existed before mining began.
     a. To do this, mining companies must scrape off the topsoil that was on the land and put it aside at the beginning of the operation.
     b. This topsoil must be returned and spread over the landscape after refilling and contouring has been completed.
  3) The land must be replanted in order to recreate the communities of organisms that inhabited the land before mining. The vegetation planted on the site must be native to the area and foster the process of natural succession.
- Properly completed reclamation makes the soils physically stable so that erosion does not occur and water infiltration and retention proceed as they did before mining.
- The materials used in the reclamation must be relatively free of metals, acids, and other compounds that could potentially leach into nearby bodies of water.
  - Trapper Mine in Craig, Colorado a reclamation success story.
    - Two million tons of coal excavated per year
    - Mine operators meticulously saved topsoil
    - Re-contoured land to original shape and spread original topsoil
    - Planted native species of grasses and shrubs including native sagebrush
    - The Columbian sharp-tailed grouse, a threatened bird species, now inhabits the reclaimed land and has higher survival and fertility rates than in native habitats of other parts of Colorado.
    - Populations of elk, mule deer, and antelope have all increased on reclaimed land.