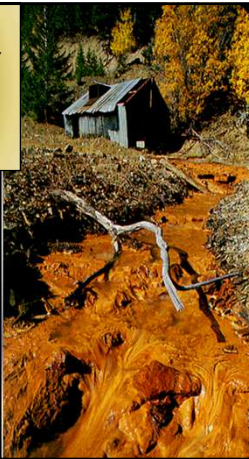


**Minerals, Mining & the Environment**  
9-4, 20.1, 20.2



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**Outline**

- Earth Processes and Minerals
  - Rock Cycle
- Earth Resources
- Environmental Effects of Resource Extraction
  - Mining
    - Reclamation
- Geological Hazards

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**Our Earth is a Dynamic Planet**

- A Layered Sphere
  - Core - interior composed of dense, intensely hot metal, mostly iron. Generates magnetic field enveloping the earth.
  - Mantle - hot, pliable layer surrounding the core. Less dense than core.
  - Crust - cool, lightweight, brittle outermost layer. Floats on top of mantle.

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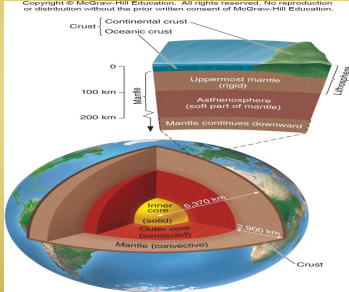
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## Earth's Cross Section



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## Tectonic Processes

- Upper layer of mantle contains convection currents that break overlying crust into a mosaic of **tectonic plates**.
  - Slide slowly across earth's surface
    - Ocean basins form where continents crack and pull apart.
    - **Magma** (molten rock) forced up through the cracks forms new oceanic crust that piles up underwater in **mid-ocean ridges**.

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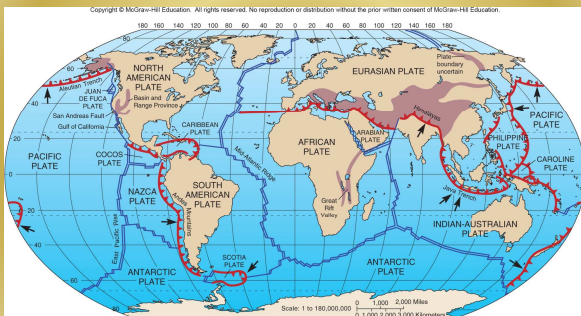
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## Tectonic Plates



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### Tectonic Processes

- Earthquakes are caused by grinding and jerking as plates slide past each other.
- Mountain ranges pushed up at the margins of colliding plates.
- When an oceanic plate collides with a continental landmass, the continental plate will ride up over the seafloor and the oceanic plate will **subduct** down into the mantle where it melts.
- Deep ocean trenches mark subduction zones.

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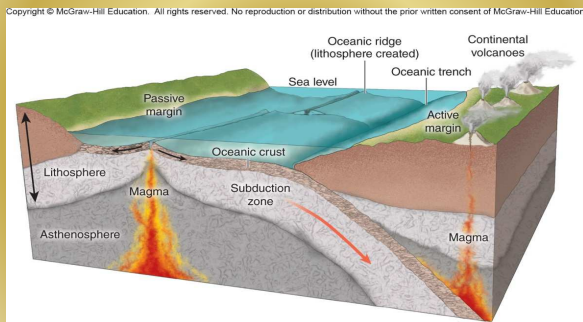
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### Tectonic Plate Movement



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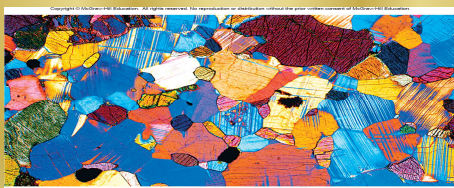
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### Rocks and Minerals

A **mineral** is a naturally occurring, inorganic, solid element or compound with a definite chemical composition and regular internal crystal structure.



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### Rock Types

- A **rock** is a solid, cohesive, aggregate of one or more minerals.
  - Each rock has a characteristic mixture of minerals, grain sizes, and ways in which the grains are mixed and held together.
- **Rock Cycle** - cycle of creation, destruction, and metamorphosis
  - Three major rock classifications:
    - Igneous
    - Sedimentary
    - Metamorphic

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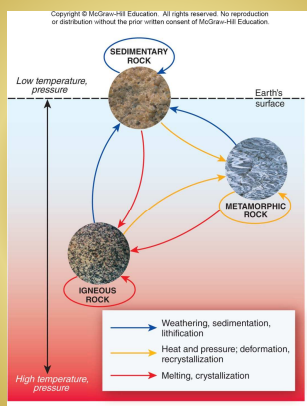
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### Rock Cycle




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### Igneous Rocks

- **Most common type of rock in Earth's crust.**
  - Solidified from magma extruded onto the surface from volcanic vents
    - Quick cooling of magma produces fine-grained rocks.
      - Basalt
    - Slow cooling of magma produces coarse-grained rocks.
      - Granite

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### Metamorphic Rock

- Preexisting rocks modified by heat, pressure, and chemical agents
  - Chemical reactions can alter both the composition and structure of rocks as they are metamorphosed.
    - Marble (from limestone)
    - Quartzite (from sandstone)
    - Slate (from mudstone and shale)

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### Weathering and Sedimentation

- **Mechanical weathering** - physical break-up of rocks into smaller particles without a change in chemical composition
- **Chemical weathering** - selective removal or alteration of specific components that leads to weakening and disintegration of rock
  - Oxidation
  - Hydrolysis
- **Sedimentation** - deposition of particles of rock transported by wind, water, ice, and gravity until they come to rest in a new location

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### Sedimentary Rock

- Deposited materials that remain in place long enough, or are covered with enough material for compaction, may again become rock. Examples: sandstone, shale
- Also can be formed from crystals that precipitate out of, or grow from, a solution. Example: halite
- Sedimentary rock can be shaped by erosion.
- Geomorphology is the study of the processes that shape the earth's surface and the structures they create.
- Humans shape the Earth's surface more than any other single geomorphic process except plate tectonics.

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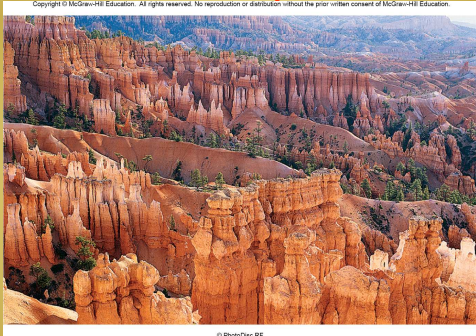
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## Sedimentary Rock



The sedimentary rock of Bryce Canyon National Park has been carved by erosion into tall spires.

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## Economic Geology

**Economic mineralogy is the study of minerals that are valuable for manufacturing.**

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**Table 14.2 Primary Uses of Some Major Metals Consumed in the United States**

Metal	Use
Aluminum	Packaging foods and beverages (38%), transportation, electronics
Chromium	High-strength steel alloys
Copper	Building construction, electric and electronic industries
Iron	Heavy machinery, steel production
Lead	Leaded gasoline, car batteries, paints, ammunition
Manganese	High-strength, heat-resistant steel alloys
Nickel	Chemical industry, steel alloys
Platinum-group	Automobile catalytic converters, electronics, medical uses
Gold	Medical, aerospace, electronic uses; accumulation as monetary standard
Silver	Electronics, jewelry

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## Economic Geology and Mineralogy

### Metals

**Metals consumed in greatest quantity by world industry (metric tons annually):**

- **Iron** (740 million)
- **Aluminum** (40 million)
- **Manganese** (22.4 million)
- **Copper and Chromium** (8 million ea)
- **Nickel** (0.7 million)

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### Non-Metal Mineral Resources

- **Gemstones and Precious Metals**
  - Their monetary value bankrupts despots, criminal gangs, terrorism, & inhumane labor conditions.
- **Sand and Gravel** - greatest volume and dollar value
  - Brick and concrete construction, paving, sandblasting
  - Glass production

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### Environmental Effects of Mineral Extraction

- Disturbance or removal of land surface
- 80,000 metric tons of dust
- >100 Toxic air pollutants
- Chemical and sediment runoff
  - When sulfide ores are exposed to air and water, they produce sulfuric acid.
- Vast quantities of ore must be crushed and washed to obtain small quantities of metal; enormous amounts of freshwater are thereby contaminated with acid, arsenic, & heavy metal.

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### Types of Mineral Extraction

- **Placer Mining** - hydraulically washing out metals deposited in streambed gravel by using water cannons to blast away stream beds
  - Destroys streambeds and fills water with suspended solids.
- **Underground mining** - tunneling into mineral seams is very dangerous
  - Tunnels can collapse.
  - Natural gas explosions
  - Water seeping into mine shafts dissolves toxic minerals and contaminates groundwater.
  - Fires in mines which burn for years

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### Types of Mineral Extraction



- Open pit or strip mining**
- 50% of U.S. coal is strip mined.
  - Creates huge holes in the earth which fill with contaminated groundwater.
  - Surface material is left in long ridges called spoil banks, because these do not contain topsoil, there often is no vegetation for many years.

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### Restoration of Extraction Sites

- **Surface Mining Control and Reclamation Act (1977)** requires better restoration of strip-mined lands, especially if land is classed as prime farmland.
  - Difficult and expensive
    - Complete reclamation often costs more than \$10,000 / hectare.

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### Mountaintop Removal

- Mining companies have recently begun to remove Appalachian coal via **mountaintop removal**.
- Ridge tops are removed to access a coal bed. The material from the ridge top is crushed and dumped into adjacent river valleys, burying streams in toxic substances.
- Environmental lawyers sued over violation of Clean Water Act.

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### Processing Ores

- Metals are extracted from ores by heating or treatment with chemical solvents.
  - **Smelting** - roasting ore to release metals
    - Major source of air pollution
  - **Heap-Leach Extraction** - crushed ore piled in large heaps and sprayed with a dilute alkaline cyanide solution which percolates through the pile to dissolve the gold
    - Effluent left behind in ponds can leak into surface water or groundwater.

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### Geologic Hazards

- **Asteroid impact** led to extinction of dinosaurs.
- **Floods** take the greatest number of lives, while
- **Wind** causes the most property damage.
- **Earthquakes** - sudden movements of the Earth's crust that occur along faults where one rock mass slides past another
  - Gradual movement - called creep or seismic slip
    - When friction prevents creep, stress builds up until eventually released with a sudden jerk.
    - Point at which first movement occurs is called the **epicenter**.

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### Earthquakes

- Worst death tolls from earthquake occur when construction is poor. Now buildings in earthquake zones are reinforced.
- Most seismically active region in U.S. is west coast.
- Largest earthquake recorded was in New Madrid, Missouri.
- Tsunami can be generated by earthquakes as we saw in 2011.

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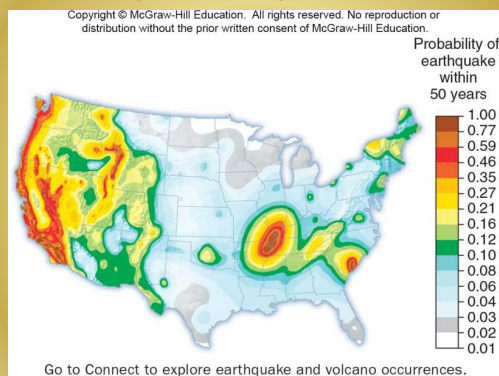
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### Seismic Map of Earthquake Risk in the US



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### Volcanoes

- Volcanoes and undersea magma vents are the sources of most of the Earth's crust.
  - Many of world's fertile soils are weathered volcanic material.
  - Nubes ardentes - deadly clouds of hot gas and ash like those that destroyed Pompeii, temperatures exceed 1000°C, they move at 60 mph and can kill in minutes.
  - Mudslides often accompany eruptions.
  - Volcanic dust and sulfur emissions reduce sunlight and temperature around the globe.

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### Landslides

- **Landslides are examples of mass wasting, in which geologic materials are moved downslope from one place to another.**
  - Can be slow and subtle or swift as in rockslides and avalanches
- **Road construction, forest clearing, cultivation, and building on steep, unstable slopes increase the frequency and damage done by landslides.**

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### Landslide in Pacific Palisades, California



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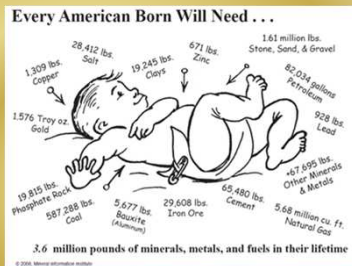
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## Why do we need mines?

- Houses
- Cars
- Toothpaste
- Plumbing
- Wiring
- Planes
- Electronics
- Jewelry
- Glass



If we can't grow it, it has to be mined!




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## What is mining?

○ Mining is extracting ore or minerals from the ground

○ When will a company mine?




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• **Minerals**, the building blocks of rocks, are pure inorganic solids




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**Language Arts:** *Research mineral deficiencies (anemia, scurvy, rickets)*

**Dig A Little Deeper  
Eat Your Broccoli**  
It contains **Selenium**, the *Brain Food*  
All Living Things Need The Fuel Provided by Minerals and Metals  
Life processes cannot occur without our world of inorganics.

There are 14 necessary mineral nutrients for plant growth. For human life, there are 7 necessary Macrominerals, 9 critical Microminerals and an abundance of other elements and minerals necessary for good health.

While our mineral intake represents only about 0.3 percent of our total intake of nutrients,

they are so potent and so important that without them we wouldn't be able to utilize the other 99.7 percent of foodstuffs, and would quickly perish.

For more information about minerals in society, go to:  
**Mineral Information Institute** [www.mii.org](http://www.mii.org)

**Social Studies:** *Foods you had for lunch — where did they come from?*

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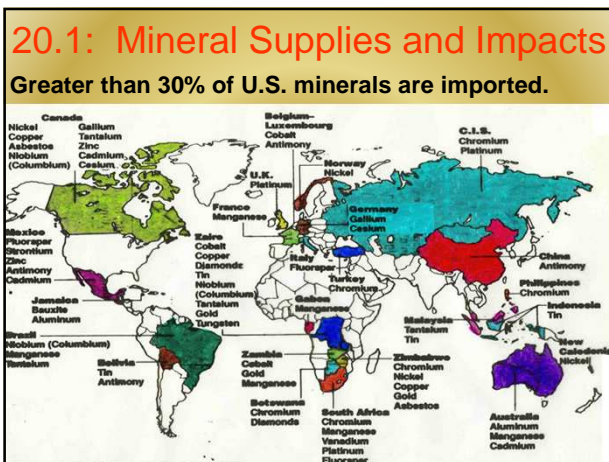
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**High-Grade Ore**

- Rocks that contain large enough quantities of minerals to be profitably mined

Iron Ore – iron atoms bonded with oxygen

Smelting

Solid Iron

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### Any mines near us?



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### So What are they mining?



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### What is the Sand and Gravel Used for?

- To make concrete. Concrete is Gravel + Sand + Cement (made from ash and limestone)
- for road construction
- for mixing with asphalt



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**"The Great Terrain Robbery:"**  
The 1872 Mining Law

- Mineral rights on Federal Land for \$5 / acre
- Pay no royalty for minerals extracted.
- No environmental protections



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**Before 1977, surface coal mining landowners had abandoned 1.1 million coal mine sites in the United States.**

- The Surface Mining Control and Reclamation Act (SMCRA), 1977, to regulate mining activity, rehabilitate abandoned mines, and protect society and the environment.
- The SMCRA required reclamation
- Created an Abandoned Mine Reclamation Fund to finance restoration of abandoned sites.

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SMCRA Required **Reclamation** which is maintaining water and air quality, minimizing flooding, erosion and damage to wildlife and aquatic habitats caused by surface mining



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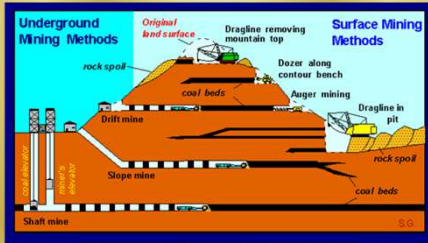
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## Types of Mines

- There are two main types of mines.
  - 1) Surface Mining
  - 2) Subsurface Mining



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## Surface Mining

- Mineral deposits are on or near the surface of the Earth and are removed.
- Accounts for 90% of mineral and rock resources and 60% of coal



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## Open Pit Mine

**Open-pit:** removes large, near surface deposits of minerals such as gold, iron and copper by digging a large hole.



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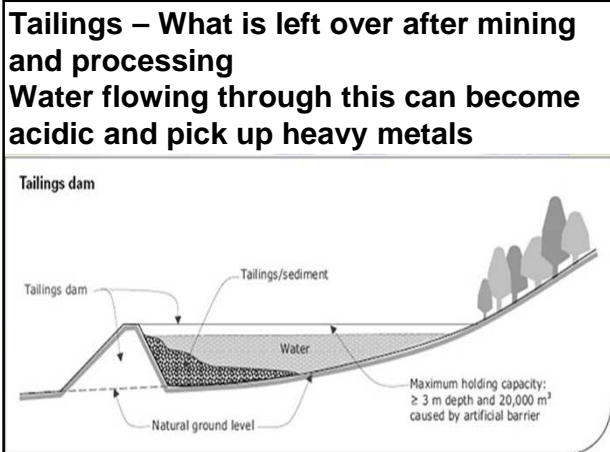
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**Dredging**

- Buckets and draglines scrape underwater deposits
- Minerals – gold in Ca. rivers

The photograph shows a large-scale dredging operation in a river. A long, narrow conveyor belt or dragline structure extends across the river, with buckets or draglines at the end. The water is dark, and the surrounding landscape is green. The text 'gty/m/ 135629585' and 'By Steven Kaufman' is overlaid on the image.

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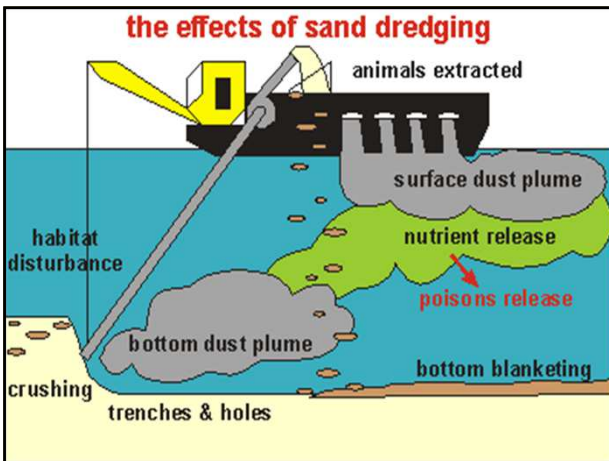
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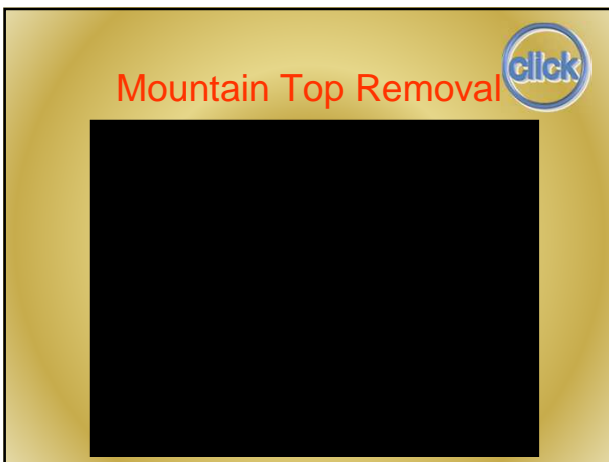
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**Strip Mining**

- Strips of land are removed to expose the coal deposit below.

undisturbed land

overburden

mineral seam

overburden seam

bench

high wall

pit

spoil banks

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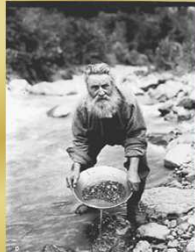
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## Placer Mining

- Using water to separate the heavier **ore** by density from the lighter sediments. Ex. Gold



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## Placer Mining



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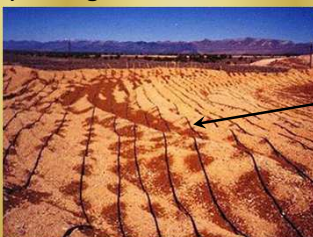
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## Heap-leach Extraction

- The mined ore is crushed
- put on an impermeable (plastic or clay) leach pad.
- Sprinklers/drip irrigation with **CYANIDE** is used.
- The solution percolates (2 months for gold/2 years for nickel) through then is collected



Cyanide solution

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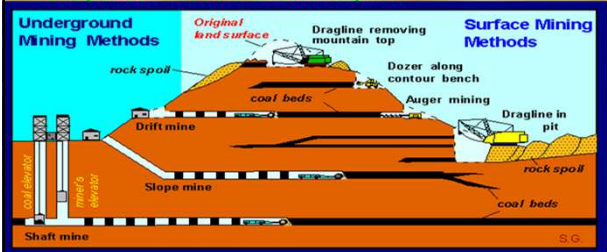
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## Subsurface Mining

- Mineral Deposits are located deep underground.
- Less environmental impact, but more dangerous to workers.
- Why less environmental impact?



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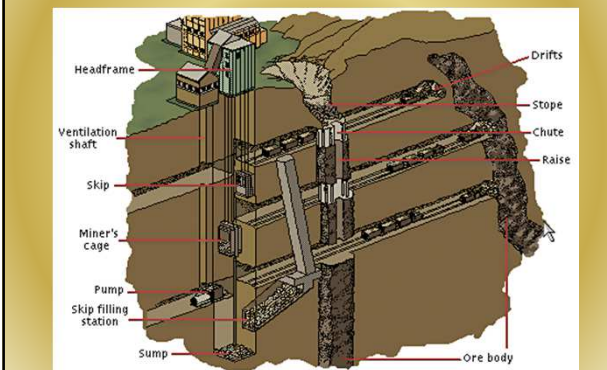
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**Shaft Mine:** A series of vertical and horizontal tunnels are dug to access minerals.



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## Centrailia, PA



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**Longwall mining – horizontally grinding up rock to expose/collect the coal.**



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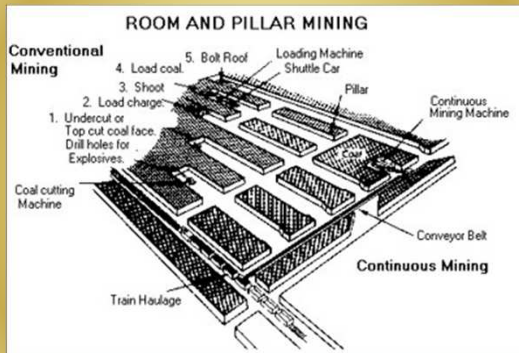
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**Clarence E. Butterworth**

- 1922 was forced to leave the 8<sup>th</sup> grade and go to work in a subsurface coal mine in PA.
- Worked in the mines until ran over by a coal digger in 1952.
- Developed black lung in the 1960's.



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### Acid Mine Drainage

- Sulfur is naturally found with coal and other minerals.
- Sulfur plus water makes H<sub>2</sub>SO<sub>4</sub> (Sulfuric Acid)
- This dissolved heavy metals out of the rock and creates acid mine drainage




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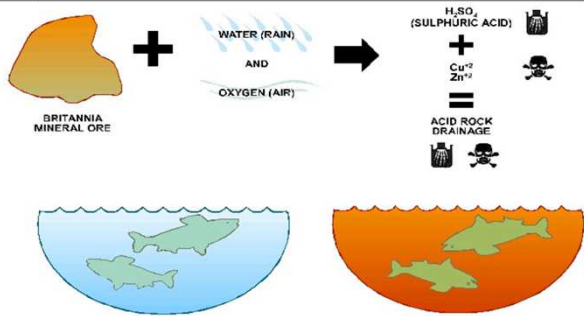
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### Acid Mine Drainage

Figure 1: Britannia Mine - What is Acid Mine Drainage?

The natural mineralization at Britannia contains metal sulphides which when exposed to air and water react to form a sulphuric acid solution containing dissolved metals. This mixture is known as Acid Rock Drainage or Acid Mine Drainage and can be very toxic to aquatic life.




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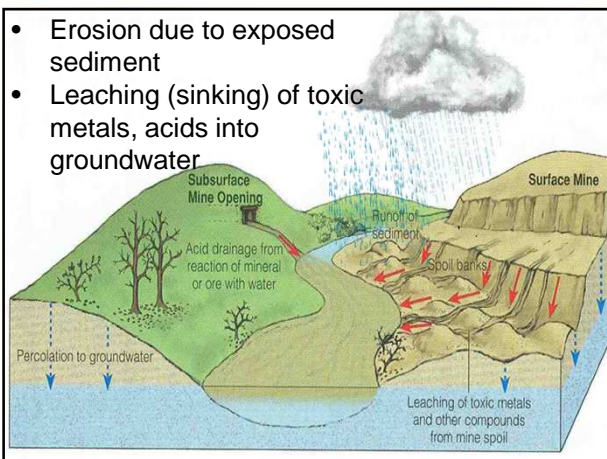
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- Erosion due to exposed sediment
- Leaching (sinking) of toxic metals, acids into groundwater




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**Antarctica may contain oil, natural gas, coal, and metals.**

**In 1991 a 50-year ban on mineral and oil exploration was enacted.**

**Why?**

The map shows the continent of Antarctica surrounded by the South Atlantic Ocean, South Pacific Ocean, and Indian Ocean. Key locations include the South Pole, Queen Maud Land, Wilkes Land, Marie Byrd Land, Ellsworth Land, and the Antarctic Peninsula. It also labels the Weddell Sea, Ross Sea, and Transantarctic Mountains. A legend identifies seals (Elephant, Weddell, Fur, Petrels) and penguins (Emperor, Adelle, Krill concentrations). It also shows the average minimum extent of summer icepack and the average maximum extent of winter icepack.

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**New Sources of Minerals?**

1. Finding new deposits is rare because its risky and very expensive.
2. Lower grade ores can now be extracted profitably due to improved techniques and technology.
3. Deep-ocean seabed mining is a future possibility.

Manganese nodules

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**Substitutes for Minerals**  
affordable? durable? practical?

- Ceramics and plastics are being developed as metal replacements with many advantages.
  - Harder, stronger, lighter, longer lasting

The diagram shows the components of a hip joint replacement: Acetabulum, Shell, Liner, Femoral Head, and Femoral Stem. The collage below shows various metal replacement parts with labels for 'Chemical Resistance', 'Friction & Wear', and 'Disinfectant Resistant'.

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Galena (ore of lead/silver)  
Mine and Marburg Virus at  
Python Cave in Uganda



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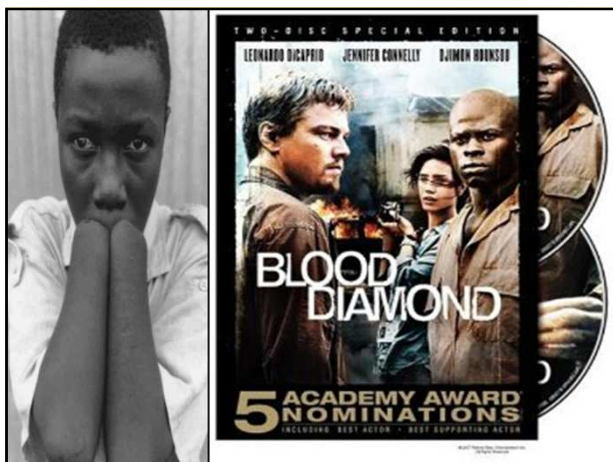
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