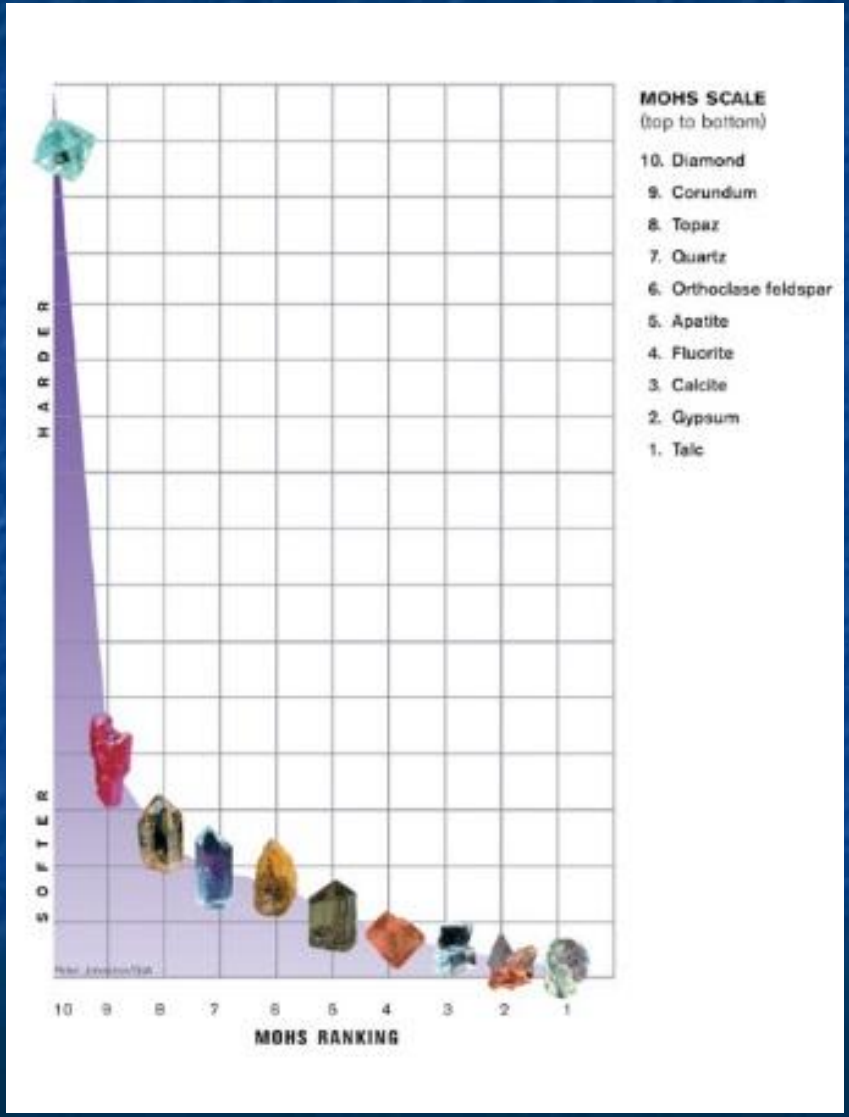
Chapter 12
Mineral and Rock Resources

Mineral And Rock Resources

- "If it can't be grown, it must be mined."
- Mineral – naturally occurring inorganic solid where individual atoms are arranged in an orderly manner (have a crystalline structure). May be one type of atom only or a compound. 4,000 different types in Earth.
- Rock – assemblage of one or more minerals
- Mineral resource - rock, mineral, or element with physical or chemical property useful to humans

Mohs Relative Hardness Scale

- Qualitative and quantitative hardness of common minerals
- See Figure 12.2 Page 364.



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Resources

TABLE 12.1 Average yearly per capita consumption rates of various mineral resources in the United States.

	Mineral Resource	U.S. Yearly Per Capita Consumption	Percent of All Mineral Resources
	Stone, sand, and gravel	22,060 lb (10,015 kg)	88
	Cement	940 lb (427 kg)	3.7
Nonmetals	Salt	400 lb (182 kg)	1.6
	Phosphate rock	302 lb (137 kg)	1.2
	Clays	276 lb (125 kg)	1.1
	Iron	425 lb (193 kg)	1.7
	Aluminum	77 lb (35 kg)	0.31
	Copper	17 lb (7.7 kg)	0.067
Metals	Lead	11 lb (5.0 kg)	0.044
	Zinc	10 lb (4.5 kg)	0.040
	Gold	.029 oz (.89 g)	0.00001
	All other minerals	674 lb (306 kg)	2.7
	Total	**25,192 lb (11,437 kg)**	**100%**

Source: Mineral Information Institute, 2012.

Minerals and People

TABLE 12.2 Applications and properties of selected metallic and nonmetallic mineral resources.

Metallic and Nonmetallic Mineral Resources	Important Applications	Key Physical and Chemical Properties
Gold (Au)	Electronics, jewelry, currency, bullion	Electrical conductor, noncorrosive, malleable
Silver (Ag)	Electronics, jewelry, photographic films	Electrical conductor, malleable
Copper (Cu)	Electrical wiring, plumbing, coins, alloys	Electrical conductor, malleable
Lead (Pb)	Batteries, solder, bullets, weights	High density, soft, low melting point
Zinc (Zn)	Rust-proofing steel, paint, alloys, coins	Corrosion resistant
Iron (Fe)	Iron, steel, yellow to brown pigments	High strength
Aluminum (Al)	Aluminum metal, chemicals	Lightweight, high strength, corrosion resistant
Titanium (Ti)	White pigment, metal for aircraft, ships, human joint replacements	Lightweight, high strength
Graphite (C)	Dry lubricant, graphite compounds, pencil leads	Extremely soft
Diamond (C)	Cutting tools, gemstones	Extremely hard
Quartz (SiO_2)	Glass, sand for mortar and cement, watch crystals	Transparent, hard, chemically resistant
Calcite ($CaCO_3$) (limestone)	Main ingredient of Portland cement, concrete, agricultural lime	Chemically reactive
Gypsum ($CaSO_4$ $2H_2O$)	Sheetrock (dry wall), plaster of Paris	Low density
Kaolinite clay	Paper filler/coating, filler and extender in paint, rubber, plastics, cosmetics, and medicine, ceramics	Extremely soft, white color, absorbant

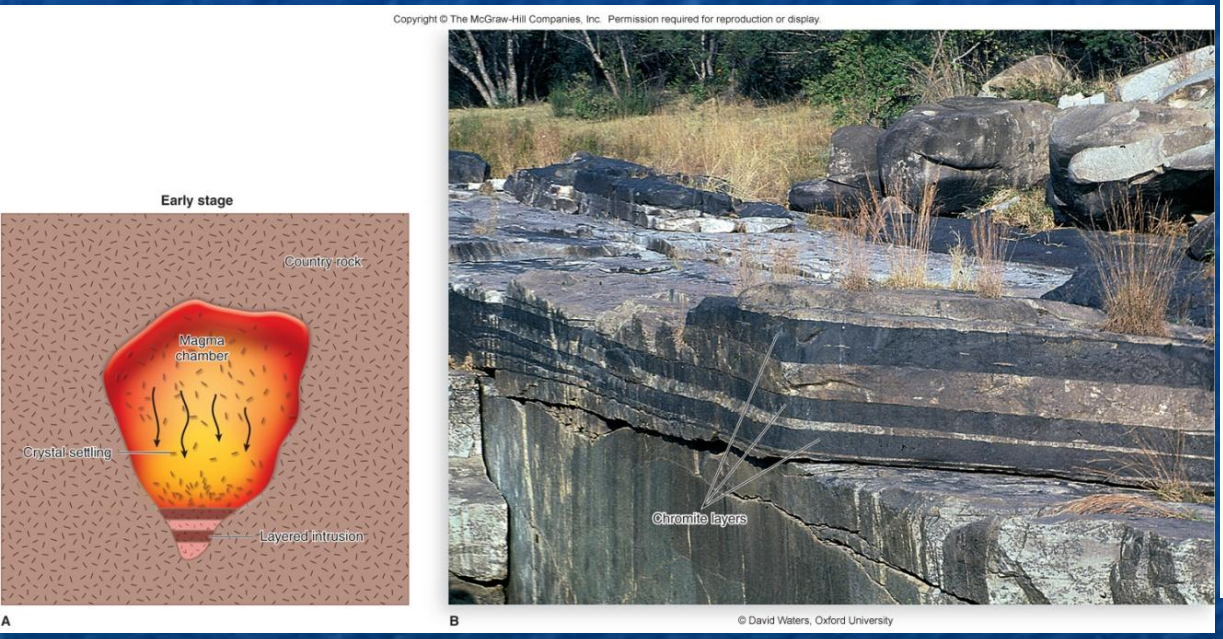
Economic Mineral Deposits

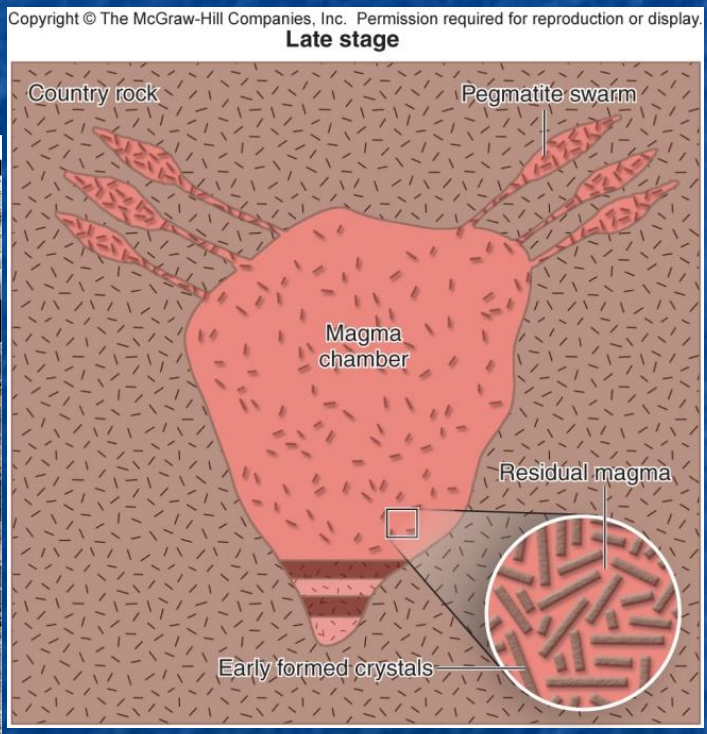
- Enrichment factor – degree to which mineral is concentrated above its average concentration in crust
- Ore deposits – body or rock or sediment with high enough concentration to mine minerals
  - High grade
  - Low grade
- Total Mineral Reserves – all known deposits economically to mine

Geology of Mineral Resources

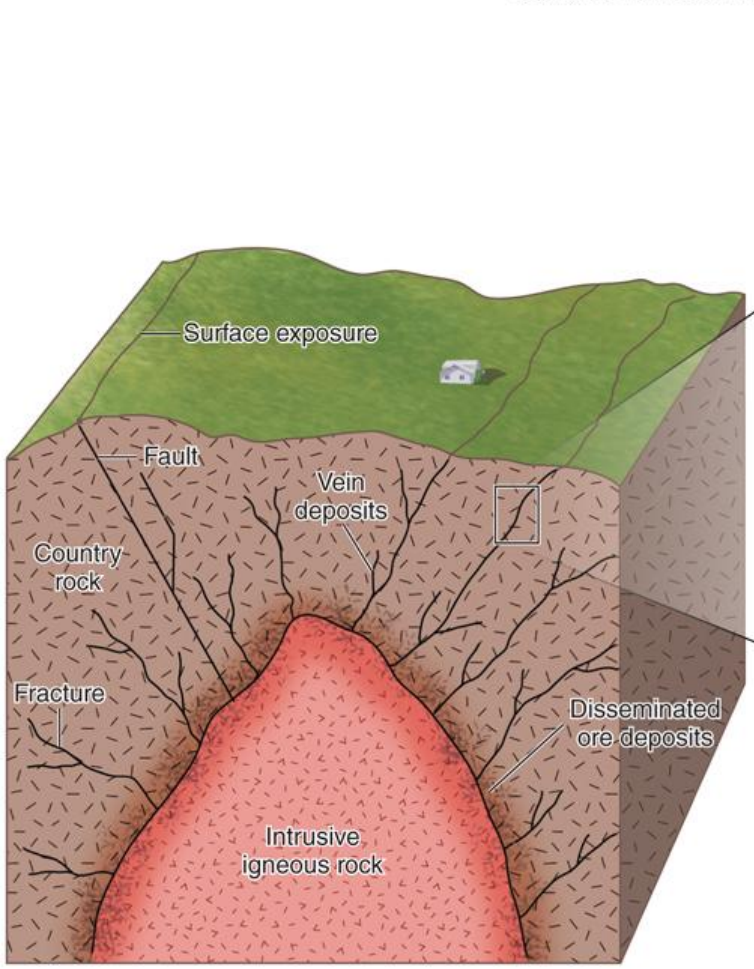
- Igneous Processes
  - Diamond pipes – associated with unusual type of igneous rock (Kimberlite)
  - Intrusive deposits
    - Layered intrusions – crystal settling, dense early forming minerals settle to bottom of magma chamber forming layers
  - Hydrothermal deposits – minerals that crystallize from enriched fluids
    - Disseminated deposits – low grade, dispersed
    - Massive sulfide deposits – hydrothermal fluids discharge from mid-oceanic ridges

Intrusive Deposits





Hydrothermal Deposits



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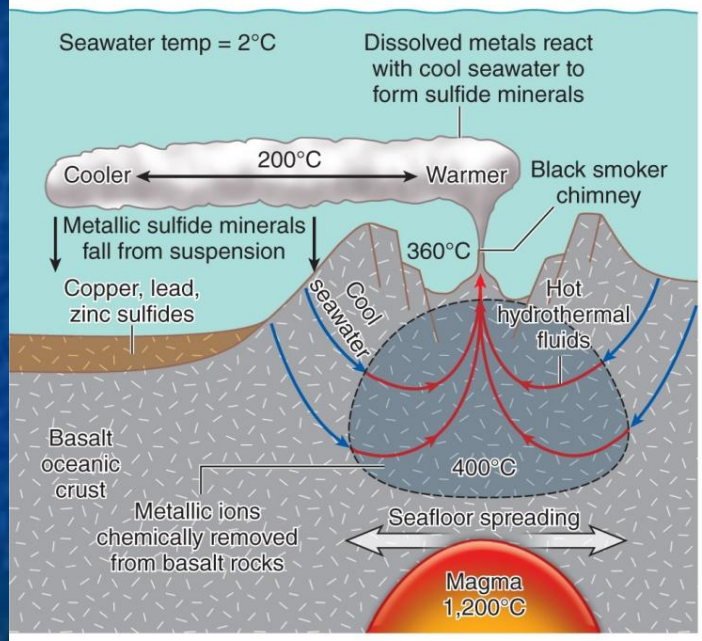
Massive Sulfide Deposits



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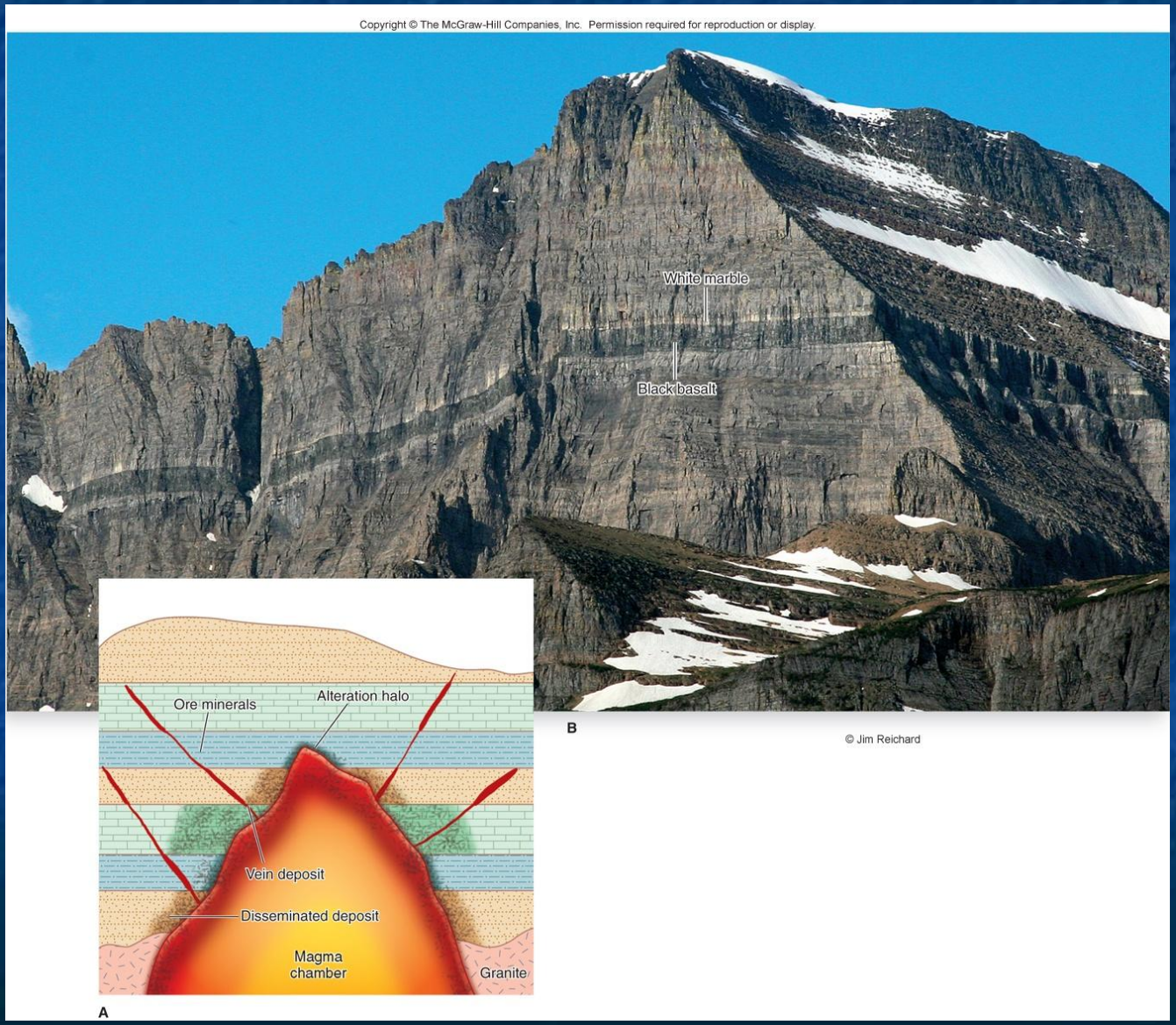
B NOAA

Geology of Mineral Resources

- Metamorphic processes – deep subsurface physical and chemical changes
  - Regional metamorphism – rocks are buried deeply or involved in mountain building event exposing them to high heat and pressure.
    - Ex. – shale into slate or production of marble from limestone
  - Contact metamorphism – rising magma comes into contact with rocks exposing them to high temperatures but not pressure

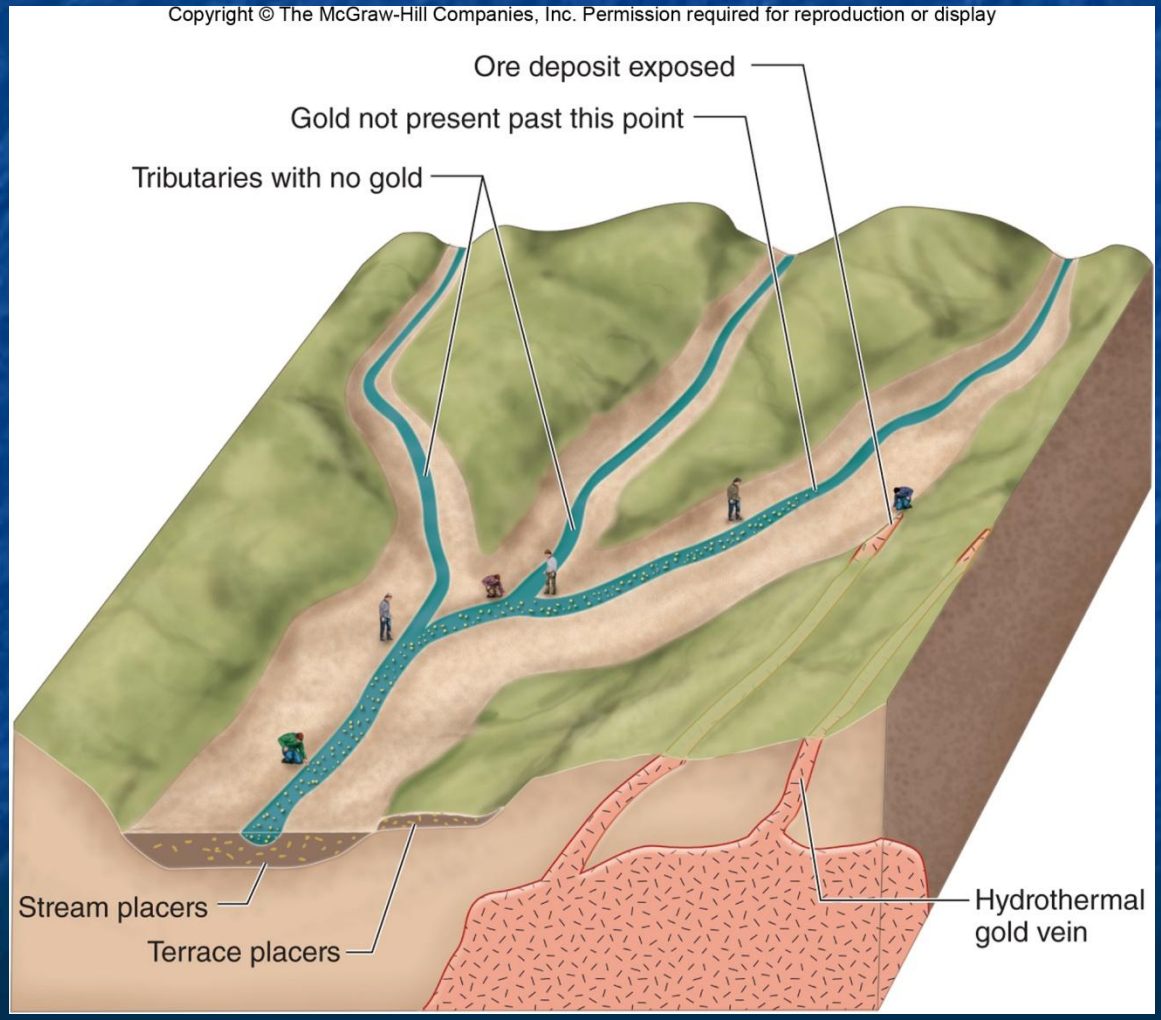
Contact Metamorphism



Geology of Mineral Resources

- Sedimentary processes – tend to concentrate certain types of minerals
  - Placer deposits – minerals resistant to weathering end up in sediment load of streams and hydraulically sorted forming concentrations. For ex., gold, platinum, tin, titanium.

Placer Deposits



More Sedimentary Processes

- Residual weathering products – secondary weathering products results in release of ions. Bauxite to obtain Al, laterite for making bricks
- Banded iron deposits – ability to mine process iron ore helped make Industrial Revolution possible.
- Evaporates – formed when minerals and salts precipitate out of highly saline solution and form layers of chemical sedimentary rock
- Phosphorites – phosphates from skeletal remains of marine organisms

Banded Iron Deposits

- Iron used in making steel for use in making machines, trucks, trains, ships, bridges support structures for bridges
- Large portion in alternating layers of quartz and iron oxide minerals
- Formed 2 – 1 billion years ago as iron began precipitating out of shallow seas. As plant life and free O_2 levels increased, iron oxide minerals formed, fell out of suspension forming large deposits

Two Types of Evaporites

1. Marine – minerals reflect chemical composition of seawater (Cl and Na ions)
   - Halite, gypsum, KCl, $CaCl_2$
   - Used as raw materials for chemicals, processing and preserving food
   - Impermeable evaporate beds as subsurface confining layers and accumulating of oil and gas
2. Non-Marine – borate and nitrates
   - Boron for glass and ceramics and lightweight metal alloys

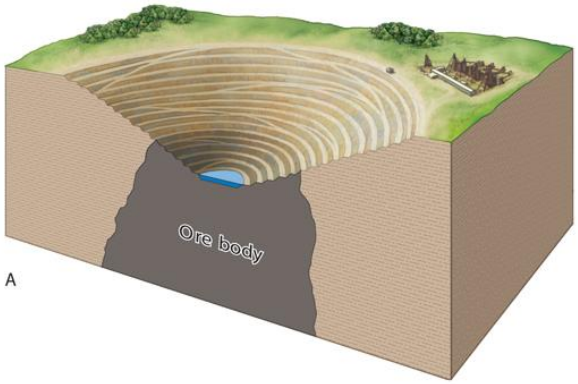
Phosphorites

- Phosphorus important plant nutrient
- Result from chemical weathering of rocks then transported to water bodies and accumulates
- Aquatic organisms extract Ca and P to form their bones, teeth, shells

Mining & Processing of Minerals

- Mining Techniques
  - Surface mining
    1. Open pit – terraced down slope to reduce mass wasting
    2. Strip – minerals in layers, include mountain top removal
  - Underground – shafts and tunnels, dangerous, fatal disease silicosis from exposure to silica dust
  - Placer – dredging water bodies and hydraulic sorting

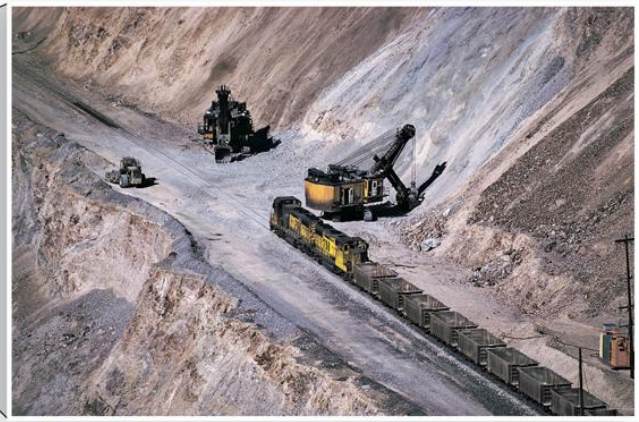
Open Pit Mining



A

B

R.D. Ramsey, Utah State Univ.



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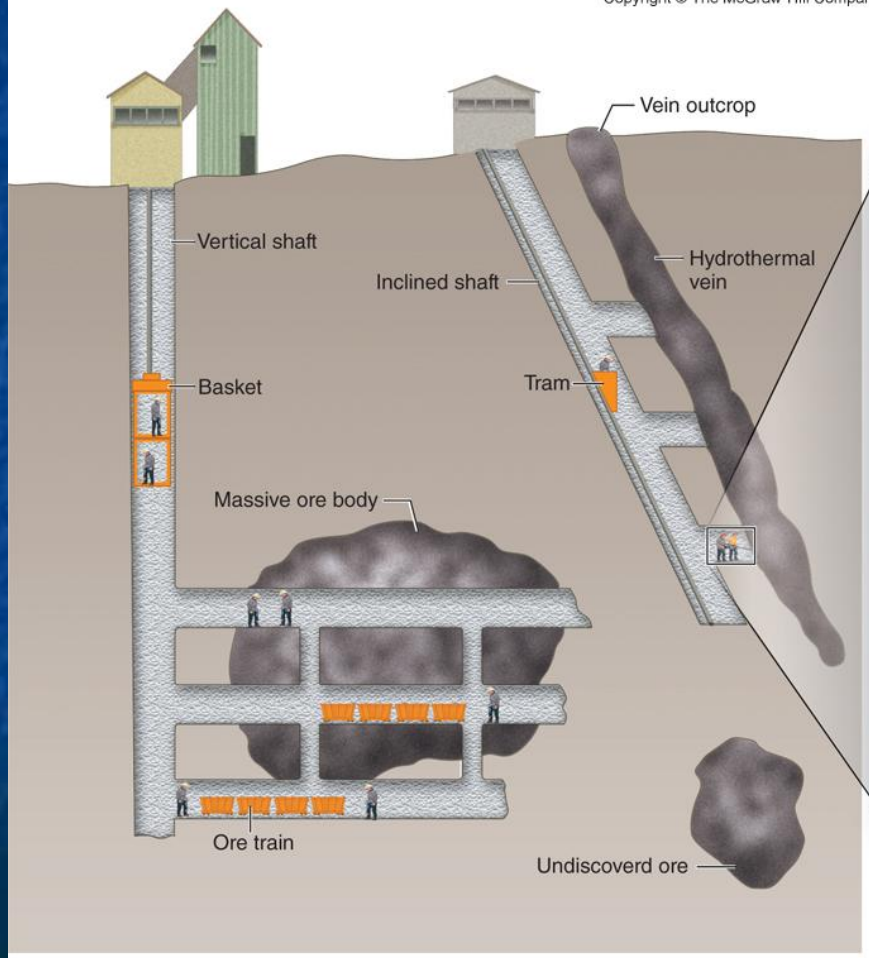
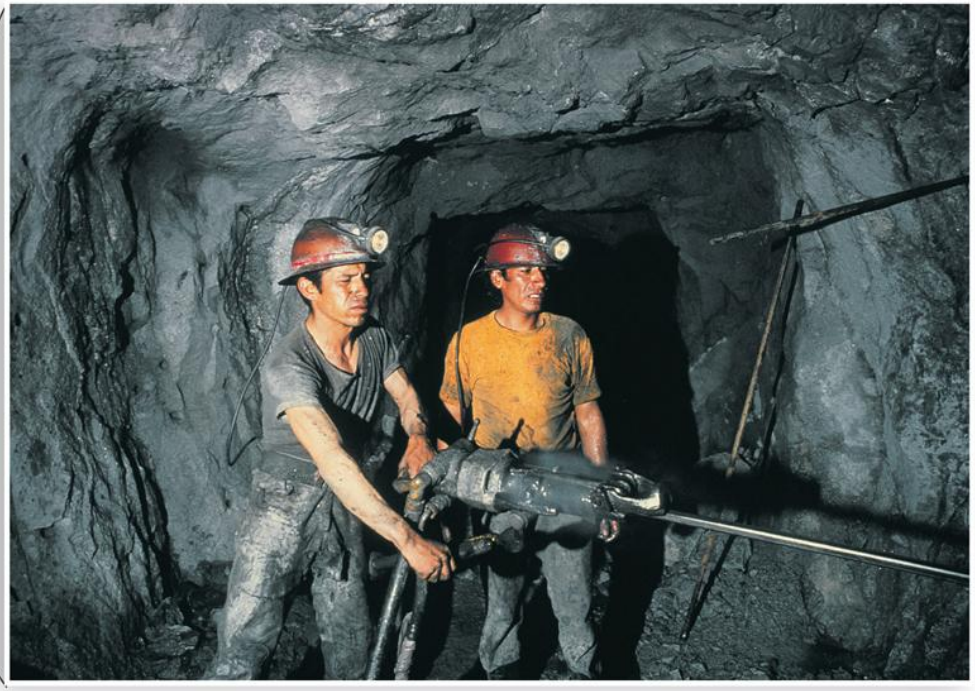
Underground Mining





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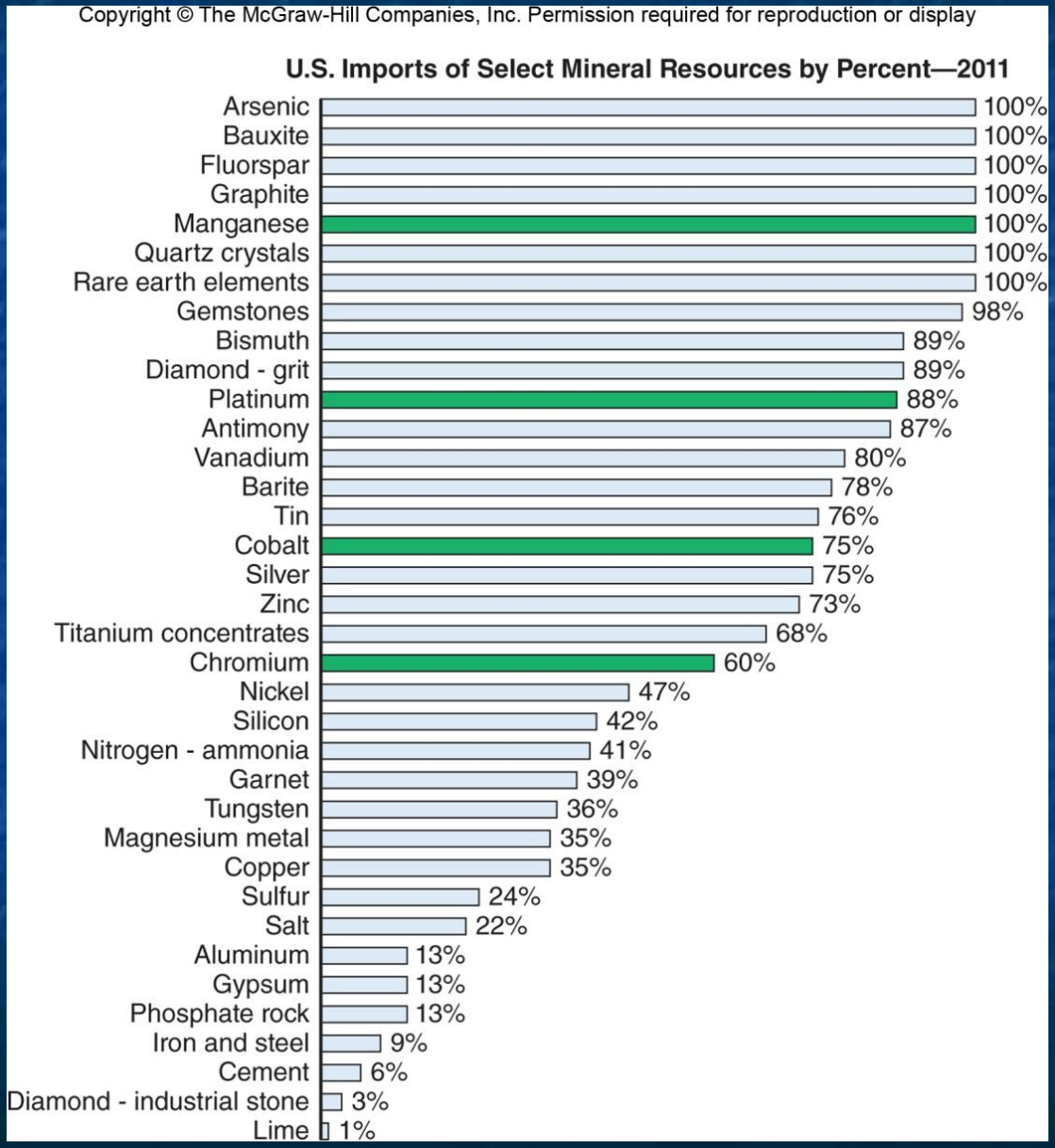
Mining & Processing of Minerals

- Mineral processing
  - Physical separation – crushing and using screens or sieves
  - Smelting – heating minerals and breaking chemical bonds to extract pure copper or other minerals. Limestone smelted to transfer calcite into lime.
  - Leaching – solution permeates through crushed ore to initiate chemical reaction; cyanide may be used

Distribution & Supply of Mineral Resources



Supply of Mineral Resources

- Not evenly distributed
  - Strategic minerals – critical, large amounts imported in U.S., important for civilian and defense industries
- Meeting future demand – consider population growth, life span of a mine
- Recycling
- Reusing

Supply of Mineral Resources

TABLE 12.4 World mineral production and projected lifetime of estimated reserves. Reserves represent mineral deposits that are economical to extract under current conditions.

Mineral	2010 Production (thousands of metric tons)	2010 Reserves (thousands of metric tons)	Estimated Life of Reserves (years)
Iron ore	2,800,000	170,000,000	61
Aluminum ore (bauxite)	220,000	29,000,000	132
Phosphate rock	191,000	71,000,000	372
Gypsum	148,000	n/a	
Chromium	24,000	n/a	
Copper	16,100	690,000	43
Manganese	14,000	630,000	45
Zinc	12,400	250,000	20
Titanium concentrates	6,700	690,000	103
Lead	4,500	85,000	19
Nickel	1,800	80,000	44
Tin	253	4,800	19
Cobalt	98	7,500	77
Silver	24	530	22
Gold	2.7	51	19
Platinum group	0.4	66	165

Source: Data from U.S. Geological Survey Mineral Commodity Summaries, 2012.

Supply of Mineral Resources

TABLE 12.5 Metal recycling rates in the United States. Although manganese is a strategic metal used in steel, it is not economical to recover and is not listed.

Mineral Resource	2009 Supply (thousands of metric tons)	2009 Recycling of Old & New Scrap (thousands of metric tons)	Percent Recycled
Iron and Steel	69,100	53,100	77
Aluminum	5,840	2,710	46
Copper	2,210	774	35
Lead	1,380	1,110	81
Zinc	1,170	273	23
Chromium	160	141	88
Nickel	173	80	46
Tin	82	13	16

Source: Data from U.S. Geological Survey Minerals Yearbook, 2009.

Environmental Impacts & Mitigation

- General Mining Act 1872 – "1872 Mining Law." Governs mining of precious metals. Allows mining to take precedence over all other land uses.
- Clean Air Act 1970 – minimized pollution caused by mining and processing plants
- Clean Water Act 1972 – water ways should be fishable and swimmable

Environmental Impacts & Mitigation

- Toxic heavy metals and acid drainage
- Increases acidity

A Silverton, Colorado
Philip L. Verplanck, U.S. Geological Survey

B Jerome, Arizona
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Environmental Impacts & Mitigation

- Processing of ores – can release toxins into environment; impermeable layers in holding tanks may develop leak
  - Dam failure in Romania in 2000 released 260 million gal of contaminated fluid
  - Dam failure in 2006 in China caused fatal landslide; poisoned water supplies
  - 1992 cyanide heap-leaching leaks Summitville, CO
- Collapse and subsidence – underground mines
- Abandoned mine hazards
- Smelting releases sulfur and metal ions forming acid rain

Environmental Impacts & Mitigation

- Constructed wetlands to treat acid mine waters
- Superfund – Government trust fund
  -program to fund clean up of hazards

Case Study 12.1 Asbestos: A Miracle Fiber Turned Deadly

- Asbestos – fibrous minerals resistant to heat and chemical break down
- Widespread use during Industrial Revolution
- Insulation, fireproofing, ceiling and floor tiles, home products
- 1960s studies discovered human health problems from exposure in the 30s and 40s
- Human lungs cannot expel fibers
- 1972 OSHA began regulating exposure levels
- 1989 EPA banned its use in most commercial products