MINERAL RESOURCES AND SOCIETY

Carlin Trend – gold deposit in north-central Nevada

- ⇒ Discovered in 1962
- ⇒ In 2002, 50 millionth ounce of gold mined
- ⇒ Gold Quarry Mine – largest of Newmont Gold Company several open pit mines
- ⇒ Recovering gold runs about $240 per ounce
- ⇒ Additional costs are in reclamation bond money
- ⇒ Mining should end sometime around 2030 with reclamation following
- ⇒ Keeping the mine dry requires water pumping now that the mine is pretty deep

"Every material used in modern industrial society is either grown in or derived from the Earth's natural mineral resources."

Mineral Resources are classified as metallic or nonmetallic

- ⇒ 94% of mineral use by weight is nonmetallic

<u>Mineral Abundances and Distribution</u>
A. Economic Mineral Concentration

Mineral Deposits: locally rich concentrations of minerals
Mineral Reserves: "sufficiently enriched" to be recovered with existing technology.

- ⇒ Metallic are called ores and the deposits are known as ore minerals

Concentration Factor: enrichment expressed as the ratio of the elements abundance in the deposit compared to its continental crust abundance average.

Concentration Factor Numbers

Table

- ⇒ High numbers generally correspond with rare things
- ⇒ Lower numbers occur with abundant minerals

97% of the Earth's Crust is made of: O, Si, Al, Fe, Na, Ca, K, Mg

Average Crustal Abundance: amount of a particular element/mineral in the crust

- ⇒ Most are a fraction
- ⇒ High-grade deposit – lots of the stuff
  Ex: Copper, Cu, (CA=0.0063%) - mineral deposit can be 2-4%
- ⇒ Low-grade deposit – minimal but still exploitable

B. Factors That Change Reserves

- ⇒ Fluctuations are due to: changing demand, discoveries of new deposits and changing technology

⇒ Classical example: Gold
  - 1968: $35 per troy ounce
  - 1970s: Federal government removed restrictions prohibiting private ownership of gold bullion
  - 1980: $800 per ounce → (cyanide heap – leaching technology)
  - 2003: $330 per ounce
  - Now: Over $1000 ounce

⇒ Environmental Consequences and Aesthetics
  - related to cyanide solution accidents
  - smelters – ore plants process concentrates and produce slag

Examples of Environmental Issues That Favored the Environment Over Mineral Exploitation
1) Agreement between Clinton and Crown Butler Mines in 1996
2) Two year moratorium on hard rock mining along mountain's Rocky Mountain Front
3) No surface coal mining in Fera Lake area of Kentucky

Many wares are based on natural resources:
⇒ Oil
⇒ Lapis Lazuli in Afghanistan

C. Distribution of Mineral Resources
Some minerals are formed by ubiquitous igneous processes, while others only form in a specific condition.
⇒ Result: unequal distribution
⇒ Gold and silver have founded civilizations

<u>Origins of Mineral Deposits</u>
Classification are based on genesis
1) Igneous Processes
   A. Intrusive Processes
      1. Pegmatites: Sources of granite minerals and Be, Li and gemstones
         → Black Hills of South Dakota (See Rocky Raccoon); Dunton, Maine and Brazil
      2. Crystal Setting: from magma cooling
         → Chromite in Alaska, Bushveld complex of South Africa
         →Bushveld: Cr, Ni, V, Platinum

   B. Disseminated Deposits: occur when a multitude of mineralized veins develop near the top of a large igneous intrusion
      → Most common – porphyry Cu deposits (Bingham Canyon, Utah
      → Kimberlite Pipes – famous for diamonds

   C. Hydrothermal Deposits: hot fluids associated with being near cooling magma – fluids deposit lodes
      →Gold-Quartz: occur together
      →Lead-Zinc-Silver

D. Volcanogenic Deposits: Vented from volcanic activity near the surface, such as the black smokers of the M.O.R.
   - → Produce massive sulfide deposits
   - →Cyprus – Latin meaning Cu

2) Sedimentary Processes
   A. Surficial Precipitation
      1. Chemical precipitates in shallow marine basins – Banded Iron Formations
         - → BIFs reflect oxygen revolution (Lake Superior)
      2. Marine Evaporites – K salts (Carlsbad, NM)
      3. Non-marine Evaporite- Carbonates, Borax, other salts (Searle's Lake and Trona, CA)

   B. Deep Ocean Precipitation: formed on ocean floor
      - → Our present technology does not allow us to exploit right now
      - → Mn, Fe and other hydroxides

   C. Placer Deposits: Concentrated by moving water (like a river)
      - → More dense materials, such as Au, Platinum and diamonds
      1. Alluvial placers – by rivers
      2. Bench placers – stream terrace deposit
      3. Beach placers – like Nome, Alaska
      4. Glacial outwash

3) Weathering Processes
   A. Lateritic: produced in warm/wet climates
      - → Since Fe and AL are relatively insoluble, they accumulate in soils
      - → Bauxite – aluminum ore
   B. Secondary Enrichment: ground water picks up goodies and will redeposit them in a lower deposit
      - → Typically improves grade of deposit

4) Metamorphic Processes
   A. Contact-Metamorphic (high T, low P) – related to hydrothermal mentioned above – W-Mo deposits
   B. Regional-Metamorphic (entire region) – Asbestos and Talc

<u>Mineral Resources</u>

1) Metallic Minerals
   A. Abundant Metals: Al, Fe, Mg, Mn, Titanium (0.1% by weight)
      - → Industrialized nations are the biggest consumers
   B. Scarce Metals (less than 0.1%)
      - → Most are in sulfide deposits
      - → Cu, Pb, Zn, Ni, Ag, Au
      - → Others: Co, Columbium, Cd, Tantalum, Antimony, Gallium

2) Non-metallic Mineral Reserves
   - ⇒ 94% of mineral resources
   - ⇒ Lots – entire book worth

A. Industrial Minerals
  - Sulfur and halite, diamond and corundum
  - Sulfur – most widely used, obtained as a by-product of petroleum refining or from the tops of salt domes.
  - Salt Domes: contain gypsum and anhydrite (all evaporites)
  - Salt: used to make chlorine gas, NaOH, de-icing highways, food, manufacturing steel and aluminum.
  - Sulfur: 80% for sulfuric acid for phosphate fertilizers
  - Diamond, corundum, Emery, Garnet are all industrial abrasives
  - Artificial diamonds manufactured from graphite are now 70% of market for abrasives
  - Natural diamonds come from Kimberlite (igneous ultramafic) – (South Africa, Ghana, Zaire, Botswana, Australia, Belarus, Yukutia, Canada's NW Territories)
  - US has replaced corundum and emery with synthetics (since we have very little reserves of this stuff)

B. Agricultural Minerals
  - With human population doubling every 40 years, food production will only increase
  - Phosphate: US, Morocco, Turkmenistan, Buryat
  - Potassium: US (evaporate beds of NM, OK, Kansas, Texas)

C. Construction Materials
  - 2/3 of US mined: aggregates (crushed stone, sand & gravel) 20 billion total
  - 80% aggregate used in road building
  - Clay (for bricks and tile), gypsum (drywall)
  - Per Dwelling: 114 tons of rock, sand and gravel

<u>Mineral Resources for the Future</u>

By dividing the known reserves of a resource by its projected rate of use, it is possible to calculate the number of years remaining until the resource is depleted.

⇒ First projected in the 1970's that we would run out of some stuff
⇒ Nowadays, not quite worried as much, although tables show some minerals are near their finish
⇒ US relies on other countries for many things: Figure 13.16
⇒ Discrepancies between Table 13.6 and Figure 13.16 are due to the fact that we do get some stuff back by recycling
⇒ Antarctica may eventually be a site of mineral exploitation
⇒ Collectively, 30% of minerals produced are recycled

<u>Mining and its Environmental Impacts</u>

"When the ores are washed, the water which has been used poisons the brooks and streams, and either destroys the fish or drives them away." - Agricola from De Re Metallica, 1550.

The General Mining Law of 1872 – allowed widespread mining without consideration of environmental impact. The law has been amended some 50 times in the last 140 years or so.

Three big changes to the 1872 Law are:

1) Mineral Lands Leasing Act of 1920: Government retains title to all federal lands possessing energy resources (oil, gas and coal) and assesses royalties on the profits from the lands leased by developers.
2) Beginning in 1992, claim maintenance fee of $100 per claim per year must be paid on claims staked under the 1872 Law in order for claims to remain valid.
3) Environmental Restrictions added in the 1970's and 1980's SMCRA (Surface Mining Control and Reclamation Act) of 1977
    - Reclamation of coal mined lands
    - Specifically for coal

Mining on federal lands follows NEPA of 1969 – (Natural Environmental Policy Act)

⇒ Mining companies must file an EIR (Environmental Impact Report)

Some SMCRA funds are utilized to help clean up metal mines

CERCLA of 1980 (Comprehensive Environmental Response, Compensation and Liability Act) – overseen by the EPA

⇒ Established superfund to clean up worst toxic/hazardous waste

Some states have enacted Stat Environmental Policy Acts (SEPA)

⇒ Vary a lot from state to state

⇒ CO – strong regulatory provisions relating to mine operation, environmental protection, reclamation bonding, inspections, emergency response, authority over mine operation.

⇒ AZ – did not have mine reclamation law until 1994, companies can wait as long as 17 years to reclaim land

⇒ MI – ranks sixth in production and has no mining law, No reclamation (voluntary only)

A. Impacts of Coal Mining

Types:

1) Contour Mining – typical in the hilly areas of the eastern US, where coal beds occur in outcrops along hillsides.
    → Spoil: used to backfill holes created
    → Hydro seeding – spraying seeds mixed with water, mulch, fertilizer, and line onto regarded soil.

2) Area Mining – used to mine coal in flat or gently rolling terrain
    → reclamation has resulted in good agricultural lands

3) Mountaintop Removal Mining – recovers coal at the tops of mountains
    → Biggest problem is the removal of the extra wasted rock
    → Contamination of rivers of carcinogenic chemicals
    → Issues are still in courts (violations of Clean Water Act)

B. Impacts of Underground Mining

Two most important effects of underground mining:

1) Subsidence
2) AMD – Acid Mine Drainage

AMD – sulfide in tailings reacts with water to form SO_2 which can then form sulfuric acid.

→ Acid releases other metals into the environment, like Cu, Zn, Fe and others at toxic levels into rivers, etc.

C. Impacts of Surface Mining

Dredging continues today – scooping of Earth materials below a body of water

Results in:

1) Washes away soil
2) Leaves behind big boulders
3) Damages biological systems
4) Scarification of land

Hydraulic Mining is rarely used nowadays

→ Use high pressure jet, called a monitor, against hillsides of alluvial deposits

→ Highly destructive to land

Still used outside the U.S. in Russia and Brazil

Mercury dissolved gold and silver to form an amalgam

In U.S., kept northern CA Rivers brown with sediment for 20 years.

⇒ 3 to 8 million pounds of Hg in ecosystem in U.S.

⇒ 100 tons into the Amazon each year

Strip Mining

⇒ Used when mining is close to the surface

⇒ Area is backfilled after mining

Open Pit Mining

⇒ Only practical way to extract many minerals when they occur in a large low-grade-ore deposit

⇒ Very damaging to environment

⇒ Bingham Canyon Copper Mine – Utah

- now a half mile deep

Impacts of Mineral Processing

Minerals need to be processed for use. This process requires concentrations of the mineral and then smelting.

Briefly, the concentration process requires

1) Crushing the ore into a fine powder
2) Classifying the crushed materials by particle size and sorting
3) Separating the desired components by flotation, gravity or some chemical method

Separation Methods

1) Flotation – widely used, especially for recovering sulfide –ore minerals such as lead, zinc and copper
   - → Stuff is treated with some hydrocarbon compound to make undesired stuff sink
   - → Skim off the goodies after pumping with air

2) Gravity Separation – used to collect high density ores like AU, Platinum group metals, W and tin
   - → Rockers, sluice boxes and dredges are all examples

3) Chemical Methods

   a. Leaching – typically sulfuric acid dissolves stuff but others are used too.
   - → For treating Cu-O ores (sulfuric acid)
   - → Other dissolving compounds: ammonia, cyclo hexane, bromine, chlorine, ethyl benzene, glycol, ethers, hydrazine, naphthalene, nitric acid, phenol, propylene, sulfuric acid, thiovrea, toluene, and xylem and →

   b. Cyanide (Cyanidization)
   - → Cyanide dissolves Au and Ag
   - → Captured on charcoal – comes out near pure
   - → Cyanide kills critters, especially birds
   - → Various techniques have been used to keep out critters
     - Plastic Sheets
     - Heavy Metal
     - Scary Flags
     - Nowadays – net/fence combo

Smelting

- ⇒ Notoriously bad for the environment
- ⇒ Release sulfur gasses
- ⇒ Mitigation has been good
- ⇒ Bingham Canyon Mine – Before 1995: 2,136kg (4700lbs)/hr
  Now: 91kg (200lbs)/hr

Mine Land Reclamation

After mining is completed, areas are back filled and reclaimed

A. Surface and Ground Water Protection
   - → 500/1500 abandoned coal mines are somewhere in the process of reclamation
   - → AMD – Acid Mine Drainage

   Control Measures for AMD
   1) Entrapment Ponds – add alkaline to neutralize
   2) Grading and Covering of acid-forming materials
   3) Backfilling underground mines with alkaline fly ash
   4) Utilizing wetlands and their vegetation

Bacteria Bioxidation – critters break down harmful components

- ⇒ Homestale Gold Min in Lead, SD

B. Mill and Smelter Waste Contamination
   - → Tailings thousands of times natural levels pollute water
   - → Big ones: Pb, As, Zn, Cd, Be
   - → EPA may monitor metal levels
   - → EPA removes stuff and puts it in a Constructed Repository Site

C. Revegetation and Wildlife Restoration
   - → Helps with erosion
   - → SMCRA minimum maintenance for east (5years), west (10years)
   - → Wildlife habitats are used

<u>The Future of Mining</u>
Are we running out? Not yet.

However, the costs of getting less accessible materials will be very damaging.
- ⇒ Other countries do not have environmental standards

A. Mining Legislation in the U.S.
   - → In general, pro-environmental
   - → 2003 – CA – State Mining and Geology Board
     - Required open pits to recontour land after reclamation
   - → NAFTA – North American Free Trade Act
     - Canadian Corp is suing U.S. over land in Mojave

<u>Case Studies</u>
13.1 Mining the CA Mother Lode

13.2 AMD and Earth Systems
- ⇒ All four spheres

13.3 Cleaning Up Historic Mining Sites in Co

13.4 The Mike Horse Mine – A Cleanup or Dilemma

13.5 Is a Company’s Word as Good as its Bond?