If it didn’t grow,  
it came from a mine...  

Mineral Resources

This section:

• What are mineral resources?
• What are they used for?
• Where do we find them?
• What is an ore?
• How do ores form?
• Is ore formation related to plate tectonics?

What is a mineral resource?!  

• Some definitions:
  – Any element, compound, mineral or rock 
    concentrated in a form that can be extracted 
    to obtain a commodity of value.
  
  – A concentration of naturally occurring material 
    (solid, liquid, or gas) in or on the Earth’s crust 
    in a form that can now (or potentially) be 
    extracted at a profit.

Non-Metallic Mineral Resources

• Non-Metallic Mineral Resources
  – Agriculture Industry (phosphates, nitrates, sodium 
    chloride, sulfur)
  – Construction (sand, gravel, clay, gypsum, limestone)
  – Ceramics/Abrasives (feldspar, quartz, clay, diamond, 
    pumice, garnet, corundum)

• Metallic Mineral Resources
  – Abundant metals (Iron, Aluminum, Magnesium, 
    Manganese, Titanium)
  – Scarce metals (Copper, Lead, Zinc, Chromium, Nickel, 
    Gold, Silver)
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Why do you think so much stone and gravel is used?

Non-Metallic Mineral Resources

- Natural Aggregate
  - Made up of natural gravel, crushed gravel-sized rock fragments or sand.
  - Has many uses, but most common is in construction.
  - The construction of a typical interstate highway can require as much as 20,000 tons per lane mile!!

Table 12.1 A Few of the Mineral Products in a Typical American Home

<table>
<thead>
<tr>
<th>Category</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building materials</td>
<td>Sand, gravel, stone, brick (clay), cement, steel, aluminum, asphalt, glass</td>
</tr>
<tr>
<td>Plumbing and wiring materials</td>
<td>Iron and steel, copper, brass, lead, cement, asbestos, glass, tile, plastic</td>
</tr>
<tr>
<td>Insulating materials</td>
<td>Rock, wool, fiberglass, gypsum (plaster and wallboard)</td>
</tr>
<tr>
<td>Paint and wallpaper</td>
<td>Mineral pigments (such as iron, zinc, and titanium) and fillers (such as talc and asbestos)</td>
</tr>
<tr>
<td>Plastic floor, tiles, other plastics</td>
<td>Mineral fillers and pigments, petroleum products</td>
</tr>
<tr>
<td>Appliances</td>
<td>Iron, copper, and many rare metals</td>
</tr>
<tr>
<td>Furniture</td>
<td>Synthetic fibers made from minerals (mainly coal and petroleum products); steel springs; wood finished with rottenstone polish and mineral varnish</td>
</tr>
<tr>
<td>Clothing</td>
<td>Natural fibers grown with mineral fertilizers; synthetic fibers made from minerals (mainly coal and petroleum products)</td>
</tr>
<tr>
<td>Food</td>
<td>Grown with mineral fertilizers; processed and packaged by machines made of metals</td>
</tr>
<tr>
<td>Drugs and cosmetics</td>
<td>Mineral chemicals</td>
</tr>
<tr>
<td>Other items</td>
<td>Windows, screens, light bulbs, porcelain fixtures, china, utensils, jewelry: all made from mineral products</td>
</tr>
</tbody>
</table>

Metallic Mineral Resources

- Most scarce and/or abundant metals come from ores.
- An ore is a rock in which a valuable metal occurs in high concentrations.

**The Difference Between Rock and Ore:**
Ore Deposits are Extreme Local Enrichments of Metal

**TABLE 12.3 Approximate Concentration Factors of Selected Metals Necessary before Mining Is Economically Feasible**

<table>
<thead>
<tr>
<th>Metal</th>
<th>Average Concentration (%)</th>
<th>Percent in Ore</th>
<th>Approximate Concentration Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>0.00000004</td>
<td>0.001</td>
<td>2,500</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.00001</td>
<td>0.1</td>
<td>10,500</td>
</tr>
<tr>
<td>Lead</td>
<td>0.0015</td>
<td>4</td>
<td>2,500</td>
</tr>
<tr>
<td>Copper</td>
<td>0.005</td>
<td>0.4 to 0.8</td>
<td>80 to 160</td>
</tr>
<tr>
<td>Iron</td>
<td>5</td>
<td>20 to 69</td>
<td>4 to 14</td>
</tr>
<tr>
<td>Aluminum</td>
<td>8</td>
<td>35</td>
<td>4</td>
</tr>
</tbody>
</table>

Data from U.S. Geological Survey Professional Paper 820, 1973
Although normal geologic processes form ores, ore deposits are rare in space and time.

Where do ores come from?

- Igneous, Sedimentary, and Metamorphic processes create minerals/rocks.

- More rarely: igneous, sedimentary, and metamorphic processes create ores.

Ore Deposit Formation

- Hydrothermal (hot fluids)
- Igneous
- Sedimentary
- Weathering (cold fluids)
Hydrothermal Deposits

- Groundwater flows through rocks heated by igneous magmas
  - Heated
  - Dissolves metals
  - Cu, Ag, Au

- Fluids re-deposit metals in concentrated form along veins and throughout ore body.

Porphyry Copper - Disseminated

Vein Copper Sulfides - higher concentrations
Porphyry Copper

- High tonnage (1.7 billion tons)
- Low grade ore (< 0.7% Cu)

Cu concentrated in this granite 100x normal crustal abundance.

Cu sulfide minerals concentrated in veins 1000-6000x normal crustal abundance

Hydrothermal Deposits

Black Smokers and massive sulfide deposits

Hot seawater leaches metals

Igneous - Crystal Settling

Dense minerals crystallizing in magma, settle to the bottom of magma chamber.

- Chromium, Platinum, Nickel, Copper

Igneous - Crystal Settling

Chromite layers in the Bushveld Igneous Complex, South Africa

Chromite is the ore mineral for chromium.
Igneous - Disseminated Deposits

- Kimberlite pipes
  - Long, thin pipelike bodies of igneous rock that originate 150-200 km deep in mantle.
  - Rapid, explosive rise of magma thru crust, punches circular hole and creates a tuff ring.
  - Magma carries pieces of mantle rock to surface...and sometimes diamonds!

Igneous - Disseminated Deposits

A diamond mine from the air

Richest mines in Kimberley, South Africa yield only one carat of diamond for every 5 m³ mined!

Sedimentary - Evaporite Deposits

- From precipitation of salts in shallow marine basins or saline lakes (in arid climates).
- Salts of sodium (halite), potassium (sylvite), calcium (gypsum), boron (borax), etc.

Evaporite Deposits of North America
Sedimentary - Placer Deposits

River transport and accumulation of dense minerals: gold, garnet, diamond, etc.

Blocks of ore fall down and break up.

Grains are sorted by river current.

Sedimentary - Placer Deposits

Gold nuggets

Weathering - Residual Deposits/Secondary Enrichment
Leaching of soluble metals by migrating groundwater (cool)

Weathering - Residual Deposits/Secondary Enrichment

Residual ore Ex: Bauxite (Aluminum)

Enrichment Zone Ex: Uranium

Leached zone

Secondary enrichment zone

Time 1

Time 2