Ores and Economic Minerals

An ore is anything that can be mined from the Earth at a profit; most ores contain metals.

Ore is formed by Concentration of low-abundance Elements

- 99% of the Earth’s crust is made up of O, Si, Al, Fe, Ca, Na, K, Mg, and Ti (major elements)
- Many other elements are useful in modern society
- Concentration of these elements in average crust is very small (all together they’re only 1%)
- Geologic processes must concentrate these elements hundreds to thousands of times to make ore

Most Ore Minerals belong to these four non-silicate Mineral Groups

- Native Elements none
- Sulfides S
- Oxides O²⁻
- Hydroxides (OH)⁻

Native Elements

- Metals - metallic bonds, metallic luster
- Semimetals - have some, but not all, properties of metals: arsenic, antimony and bismuth
- Nonmetals - covalent bonding, lack metallic properties
Principal Native Metals

- Gold (Au)
- Silver (Ag)
- Copper (Cu)
- Platinum (Pt, rarest and most valuable)
- All have cubic arrangement of atoms
- Habits: massive, leaf, wire-like, arborescent

Gold

Copper Crystal, very unusual

Native Non-metals

- Sulfur (S)
- Graphite (C)
  - Low pressure polymorph of Carbon
- Diamond (C)
  - High pressure polymorph of Carbon >30kbar
  - Formed deep in the Earth’s mantle >90km
  - Brought to the surface by violent, explosive igneous eruptions of magmas called kimberlites

Diamond
uncut octahedron, ~1cm

Cut Diamonds

Graphite
• H=1-2, streak black
• Is formed of flat hexagonal, honeycomb-like sheets of covalently-bonded Carbon atoms
• The sheets are held together by very weak van der Waals bonds, accounts for very low hardness
• Pencil lead is a mixture of graphite and very fine clay

Note difference between diamond and graphite structures

Common Sulfide Minerals
(reduced, formed in low oxygen environments)

Pyrite (FeS$_2$)

• Grows in cubes, striated cubes, octahedra and sometimes a special form called the pyritohedron with 6 pairs of 5-sided faces

• Brass-yellow color and relatively high hardness (6-6.5) are characteristic

Chalcopyrite (CuFeS$_2$) is the most important ore mineral of Copper

• More coppery or tarnished brassy-yellow color than Pyrite
• Greenish-black streak and lower hardness, 3.5

Sphalerite (ZnS) is the most important ore mineral of zinc

• Resinous luster, but may be black
• Brown or yellow streak

Tends to sparkle from reflections off many perfect cleavages
Galena (PbS) is the most important ore mineral of Pb (lead)

- High specific gravity, even for an opaque, metallic mineral, \( G = 7.6 \), "hefty"
- Lead-gray color, metallic luster
- Cubic growth forms
- Perfect cubic cleavage

Common Oxide Minerals
(oxidized, formed in high oxygen environments)

- Magnetite (Fe\(_3\)O\(_4\)), two Fe\(^{3+}\), one Fe\(^{2+}\)
- Hematite (Fe\(_2\)O\(_3\)), both Fe\(^{3+}\), completely oxidized
- Zincite (ZnO)
- Franklinite (ZnFe\(_2\)O\(_4\))
- Pyrolusite (MnO\(_2\))
- Chromite (FeCr\(_2\)O\(_4\))
- Cassiterite (SnO\(_2\))

Hematite (Fe\(_2\)O\(_3\)) and Magnetite (Fe\(_3\)O\(_4\)) are Fe (iron) ores

**Hematite (Fe\(^{3+}\)\(_2\)O\(_3\)) - completely oxidized**

- Comes in 2 varieties: specular (micaceous with sparkly metallic luster) and earthy (dull), both have a red streak
- Non-magnetic

**Magnetite (Fe\(^{3+}\)\(_2\)Fe\(^{2+}\)O\(_4\))**

- Grows in octahedra
- **Magnetic** (parallel alignment of unpaired electrons in Fe\(^{2+}\) when formed in Earth’s magnetic field)

Hematite and Magnetite occur together with red chert in BIFs*
Common Hydroxide Minerals

- Goethite \( \text{FeO(OH)} \)
- Al hydroxides
  - gibbsite \( \text{Al(OH)}_3 \)
  - boehmite \( \text{AlO(OH)} \)
  - diaspore \( \text{AlO(OH)} \)
- together these make up bauxite (actually a rock name, multiple minerals), the most important Al ore

Mineral Associations

- Very helpful for identifying minerals
- Certain minerals very commonly occur together
- Sulfide minerals like pyrite and chalcopyrite, sphalerite and galena
- Oxide and hydroxide minerals like hematite and magnetite