

## 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          | O <sup>2-</sup>   |
| • Hydroxides      | (OH) <sup>-</sup> |

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 ( $\text{FeS}_2$ )

- 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 ( $\text{CuFeS}_2$ ) 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 ( $\text{ZnS}$ ) 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 hi oxygen environments)

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

Hematite ( $\text{Fe}_2\text{O}_3$ ) and Magnetite ( $\text{Fe}_3\text{O}_4$ ) are Fe (iron) ores

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

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

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

- Grows in octahedra
- **Magnetic** (parallel alignment of unpaired electrons in  $\text{Fe}^{2+}$  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  $\text{AlO(OH)}$
  - diasporite  $\text{AlO(OH)}$
  - 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