A classification scheme for ore deposits

There are many different way of categorizing ore deposits, and the best classification schemes are probably those that remain as independent of genetic linkage as possible these are: Igneous, Metamorphic, and Sedimentary ore deposits (Fig 1, a, b)

Einaudi, (2000), stated that all mineral deposits can be classified into three types based on process, namely ***magmatic deposits, hydrothermal deposits, and surfacial deposits formed by surface and groundwater.***

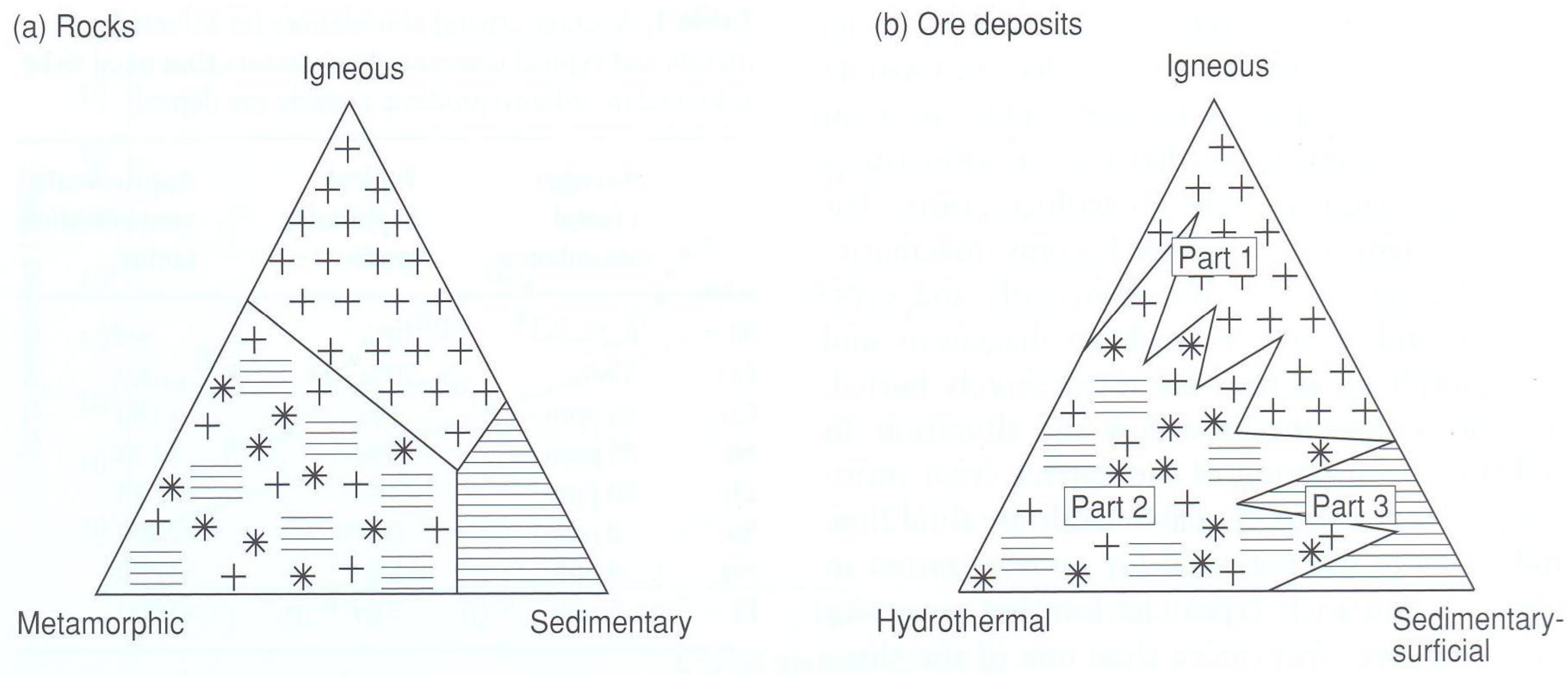


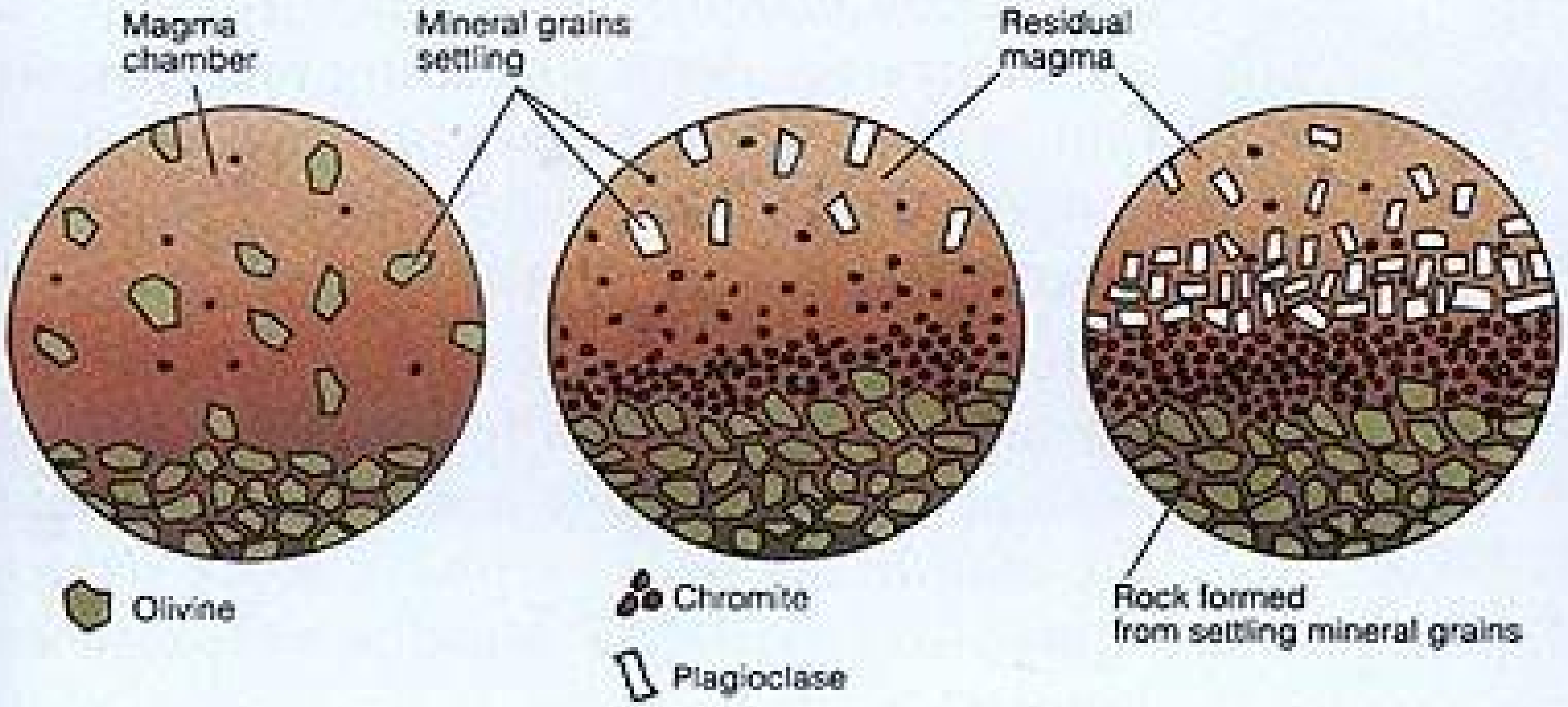
Fig 1 classification of the principle rock types (a) and an analogous, but much simplified, classification of ore deposit types (b) photograph show interplay between ore forming processes

Magmatic Ore Deposits

Magmatic ore deposits are those which are formed during crystallization of a magma, deep underground. The host rock for the mineralization can range from ultramafic to felsic. The deposit can consist of massive ores in some cases, and disseminations of rare minerals in others. In the case of more massive ores, there are three primary means of concentrating minerals of value during the formation of these deposits (Fig. 3.38):

- ***gravitational settling***
- ***differentiation***
- ***immiscible separations***

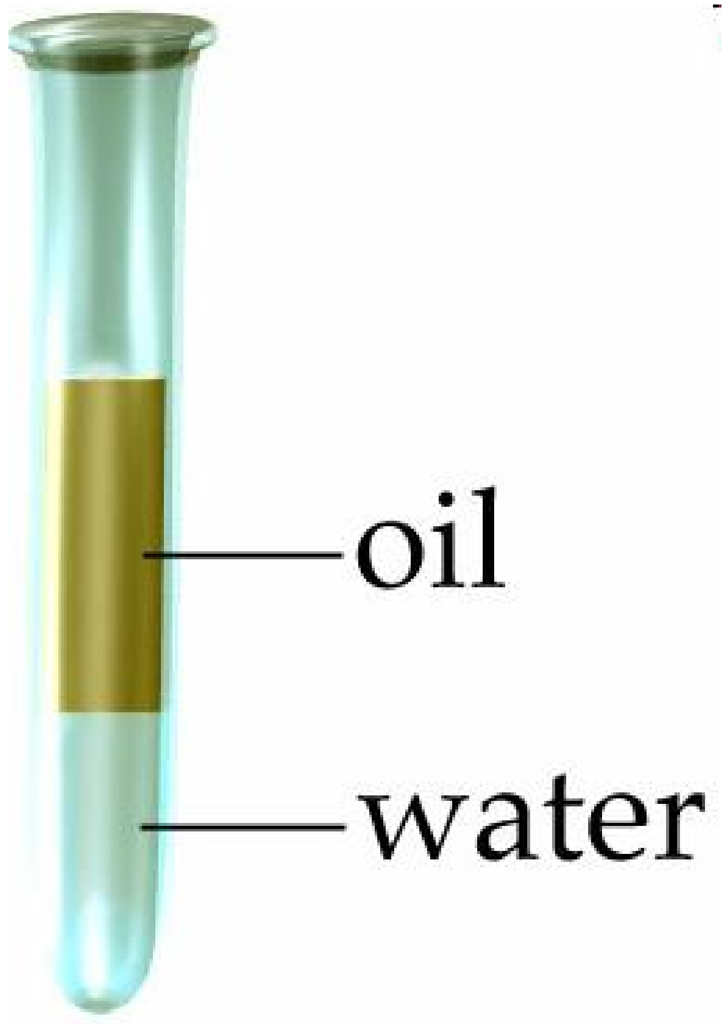
Formation of magmatic mineral deposit by crystal settling



A. Grains of three minerals settle at different rates and produce three rock types of different composition.

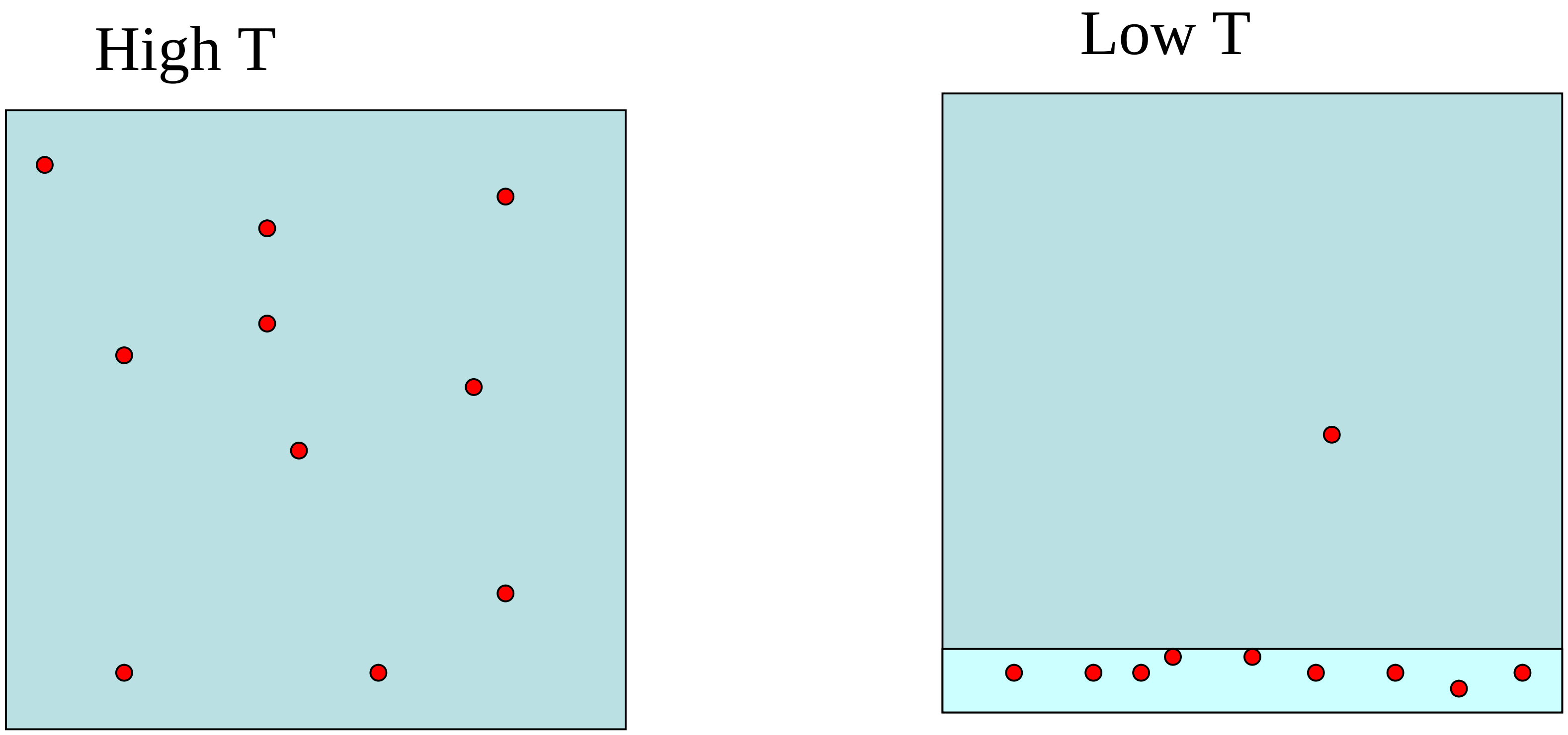
Figure 3.38 from: Skinner, Brian J. and Stephen C. Porter (1995) The Dynamic Earth, 3rd ed. New York: John Wiley & Sons, Inc., p.109.

immiscible separations



Oil and water don’t mix …

- As magmas cool, they can split into two liquids of different composition and density.
  - One of these liquids is the silica-rich melt. It has the most volume
  - The other, typically much smaller in volume, can be rich in metal oxides, sulfides or carbonates.



Desirable element • preferentially concentrated into low-volume melt

- **Types of Immiscible Melts**

- Oxide melts can be rich in Fe (Fe_2O_3, hematite) and Ti ($FeTiO_3$, ilmanite).

- Sulfide melts can be rich in Ni, Cu, and the platinum-group elements, in addition to iron sulfur (FeS, pyrrhotite).

- Carbonate melts can be rich in niobium, tantalum, rare earths, copper, thorium, and phosphorous.

What make a viable mineral deposit?

Table 1 **average crustal abundance for selected metal and typical concentration factors that need to be achieved in order to produce a viable ore deposits (From Evan, A.M, 1993)**

Note: 1 ppm is the same as 1 gt $^{-1}$

Elements	Average Crutal abundance	Typical exploitable grade or \ *(Av.minimum exploitable grade)*	Approximate concentration factor
Al	8.20%	30 %	* 4
Fe	5.60%	50 %	* 10
Cu	55 ppm	1 %	* 180
Ni	75 ppm	1 %	* 130
Zn	70 ppm	5 %	* 700
Sn	2 ppm	0.5 %	* 2500
Au	4 ppb	5 gt $^{-1}$	* 1250
Pt	5 ppb	5 gt $^{-1}$	* 1000

Terminology:

Ore: any naturally occurring material from which a mineral or aggregate of value can be extracted at profit.

To be ore must be ,

1-Payable, 2- Involve economic consideration, 3- involving geologic consideration.

Economic Consideration:

- Mineral exploration
- Economic evaluation
- Mine development
- Mine extraction
- Ore dressing
- Smelting
- Refining
- Marketing
- Power supplies
- 10-Eqipments cost
- 11-water supplies
- 12-Transport metal cost

Gangue minerals: Usually worthless, non metallic minerals of a deposit that may be:

Introduced minerals, b- The inclosing rocks c- are discarded in the treatment of the ore

Economic minerals: Are natural resources which, once extracted and used, are not renewable.

Grade: The concentration of an element in a mineral deposit is termed grade usually expressed as % or in ppm

Cut-off grade: The lowest percentage at which deposits can be economically worked is termed cut-off grade.

Tenor: The grade or amount of commodity actually present

Factors controlling cut-off grade limit:

A-Geological factor, B-Geochemical factors, C-Other factors

The point B and C depend on the following factors:

1-By product

2-Undesirable substance

3-Mineralogical form

4-Grain size and shape

5-Size and shape of ore body

6-Mineral characters

The other factors controlling the classification of Cut-off grade are:

- 1-Commodity price
- 2-Cost of capital
- 3-Location
- 4-Environmental consideration
- 5-Taxation
- 6-Political factors

Syngenetic: refers to ore deposits that form at the same time as their host rocks.

Epigenetic: refers to ore deposits that form after their host rocks.

Hypogene: refers to mineralization caused by ascending hydrothermal solution.

Supergene: refers to mineralization caused by descending solutions. Generally refers to the enrichment process accompanying the weathering and oxidation of sulfide and oxide ores at or near the surface.

Metallogeny: the study of genesis of mineral deposits, with emphasis on their relationship in space and time to geological features of the Earths crust.

Metallotect: any geological, tectonic, lithological, or geochemical feature that has played a role in the concentration of one or more elements in the Earths crust.

Metallogeneic Epoch: a unit of geologic time favorable for deposition of ores or characterized by a particular assemblage of deposit types.

Metallogenic Province: a region characterized by a particular assemblage of mineral deposit type.

Epithermal: hydrothermal ore deposits formed at shallow depth (less than 1500 m) and fairly low temperature (50-200 ˚C)

Mesothermal: hydrothermal ore deposits formed at intermediate depth (1500 – 4500 m) and temperature 200 - 400˚C)

Hypothermal: hydrothermal ore deposits formed at substantial depth (grater than 4500 m) and elevated temperature (400-600 ˚C)

Periodic table of the elements:

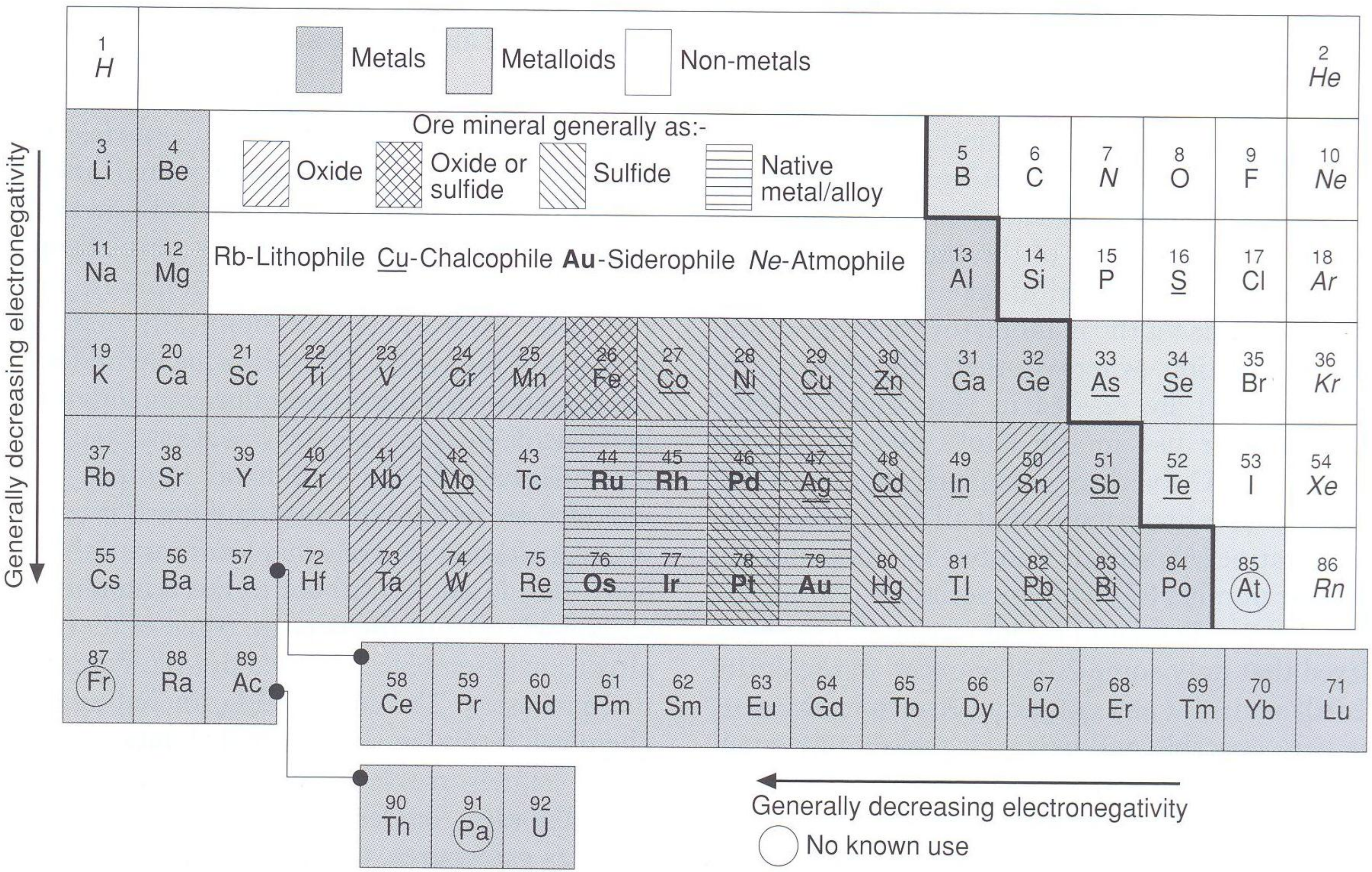


Fig 2 Periodic table showing the 92 geologically relevant elements classified on the basis of their rock and mineral associations (From Robb, 2005)

Common Ore and Gangue mineral

1- Native element

Metals	Non-Metals
Gold - Au	Sulfur – S
Silver - Ag	Diamond – C
Platinum - Pt	Graphite - C
Palladium - Pd	
Copper - Cu	

2- Halides

- **Halite – NaCl**
- **Sylvite – Kcl**
- **Chloragyrite –AgCl**
- **Fluorite - CaF2**
- **Atacmite Cu2 Cl(OH)3**

3- Sulfide and Sulfo-salts

Sulfide	**Sulfo-salt**
Chlcocite – Cu_2S	Tetrahedrite – $(Cu,Ag)_{12}$ Sb4 S_{13}
Bornite – Cu_5FeS_4	Tennanite – $(Cu,Ag)_{12}$ As_4 S_{13}
Galena – PbS	Energite – Cu_3 AsS_4
Sphalerite – ZnS	
Chlcopyrite – $CuFeS_2$	
Phrhotite – Fe_{1-x} S	
Pentlandite – $(Fe,Ni)_9$ S_8	
Millerite – NiS	
Covellite - CuS	
Cinnabar – HgS	
Pyrite – FeS_2	

4- Oxides:

Oxides	**Hydroxide (or Oxyhydroxide)**
Cuprite- Cu2O	
Hematite – Fe2O3	Geothite FeO(OH)
Illminite – FeTiO3	Gibbsite – Al(OH)3
Hercynite – FeAl2O4	Boehemite – MnO(OH)
Gahnite – ZnAl2O4	
Magnetite – Fe3O4	
Chromite – FeCr2O4	
Rutile – TiO2	
Anatase – TiO2	
Pyrlucite –MnO2	
Casseterite – SnO2	
Uraninite – UO2	
Thorianite – ThO2	