CHAPTER II- CLASSIFICATION OF MINERALS (THE NINE GROUPS)

II-1 NON-SILICATE MINERALS

Apart from silicates there are also non-silicate minerals. They are called **native elements, sulfides, sulfates, carbonates, halides, oxides and hydroxides and phosphates.**

II-1-1 NATIVE ELEMENTS

They are substances not chemically combined with other materials to form compounds. They are classified into two groups: Metals (Gold, silver, copper and platinum) and metalloids (Sulfur, graphite and diamond).

II-1-1-1 METALS

Metals have high electrical conductivity. Their structures are compact, they have a high density “d”, a low hardness “D”; they are ductile and malleable and do not exhibit sharp cleavage.

II-1-1-1-1 Native Gold (Au): An opaque mineral with a metallic luster. It is frequently in flakes, irregular grains in quartz (SiO_2).

- Cubic holohedron m3m. Face-centered cubic structure (c. f. c)

- hardness H = and malleable at high purity.

- Density D = 19.3, lowers to 15.5 with the Ag content (up to 20% electrum).

- Golden yellow (Pure) to light yellow (Au-Ag) color is found in primary deposits in hydrothermal veins. Especially in residual deposits.

II-1-1-1-2 Native silver (Ag):

Silvery white color, alters on contact with the atmosphere. It is an opaque mineral with a metallic sheen. It is a mineral soluble in nitric acid, it is the best conductor of electricity and heat.

- Cubic holohedron m3m, face-centered cubic structure (c. f. c).

- H = 2.5-3

- D = 10.5

- Oxidizes quickly

- Primary mineral of meso-and epithermal veins with Ni, Co and Bi.

- Secondary mineral in the oxidation zone of silver galena deposits.

II-1-1-1-3 Native copper (Cu): Its color varies from coppery red to light pinkish red on fresh surfaces, it changes to coppery brown. It is an opaque mineral with a metallic luster, it is soluble in nitric acid.

- Cubic holohedron m3m, face-centered structure (c. f. c).

- H = 2.5, malleable and ductile

- D = 9

- Alters into cuprite Cu2O, azurite Cu3(OH)2(CO3)2 and malachite Cu2(OH)2CO3

- Secondary mineral from the oxidation zones of copper deposits.

II-1-1-1-4 Platinum (Pt): silvery gray to white in color, generally found in the form of small grains or scales. It is slightly magnetic in the presence of iron impurities; it is soluble in all acids.

II-1-1-2 SUME METALS

II-1-1-2-1 Native sulfur (S)

- Orthorhombic holohedron mmm

- Frequently automorphic

- Conchoidal breakage

- Sulfur yellow to honey yellow color.

- H = 1.5 – 2.5; very fragile

- Breaks with a rustle on moderate heating due to its very poor thermal conductivity.

- D = 2 to 3.

- Frequently produced by reduction of gypsum $CaSO4.2H2O$ by organic matter in biochemical sedimentary deposits, it also comes from the condensate of volcanic fumaroles or deposits of sulphurous springs.

II-1-1-3 NON-METALS

There are two polymorphic forms of carbon in nature: diamond and graphite.

II-1-1-3-1 Diamond: (C)

- Cubic holohedron m3m

- Frequently automorphic

- Next perfect cleavage [111]

- Colorless or tinted with yellow, pink, blue.

- H = 10; the hardest of all known minerals.

- Fragile, (metallic shine)

- D = 3.5

- Primary mineral in kimberlites and their eclogite xenolites (or xenolites).

- Detrital mineral in diamondiferous placers because they are unalterable.

II-1-1-3-2 Graphite: (C)

- Hexagonal holohedron 6mm/m

- Quite rare automorphic crystals.

- Black or steel gray

- H = 1 to 2, bold feel

- D = 2.1 to 2.3.

- Primary mineral

- Primary accessory mineral in acidic eruptive rocks and in crystalline schists.

- Opaque mineral with metallic

- Opaque mineral with metallic term.

- Rubbed on the paper

- Rubbed on the paper, it leaves a gray mark.

II-1-2 HALIDES

II-1-2-1 Halite (NaCl)

- Cubic holohedron m3m

- Frequently automorphic:

- Cleavage (100)

- H = 2,

- Sub-conchoidal breakage

- D = 2.1 to 2.2

- Common mineral in sedimentary rocks formed by evaporation (evaporites). Very soluble in water

II-1-2-2 Fluorite (CaF_2)

- Cubic holohedron m3m

- Frequently automorphic: cubic (100)

- Also in cleavable masses

- Macle by penetration (111) very common

- Transparent to translucent, sheen, green or purple, rarely pink

- H = 4. Fragile

- D = 3.1 to 3.2

- Mineral frequently in pneu-matolytic deposits in Greisen (with cassiterite SnO_2, topaz, tourmaline etc., and thus in sedimentary rocks)

II-1-3 SULPHIDES AND SULSOSELS

From a chemical point of view, they are derivatives of hydrogen sulphide (HgS), most sulphides are characterized by a metallic luster.

II-1-3-1 Galena (PbS): It is lead gray in color, it is soluble in hydrochloric acid,

- Cubic holohedron m3m

- Often automorphic

- Perfect cleavage (100)

- Macle (111) frequent by adjoining and penetration

- Fresh shiny lead gray sections or cleavage with bluish reflections and matt gray aged surfaces

- H = 2.5 to 3. Fragile

- D = 7.2 to 7.6

- Main ore of lead

- Found mainly in mesothermal veins in paragenesis BPGC (Blende, pyrite, galena and chalcopyrite).

- On-site alteration of anglesite $PbSO_4$, cerussite $PbCO_3$ in the oxidation zones of lead deposits.

II-1-3-2 Blende or sphalerite (ZnS)

- Cubic hemihedral 43m

- Often automorphic

- Perfect cleavage (110)

- Frequent polysynthetic contact twins (111)

- Light yellow color (ZnS) to brown-black (Blende rich in Fe up to 27% is marmatite), red to green, gray and white, can also be colorless.

- Main ore of zinc

- Alteration in oxidized zone into smithsonite $ZnCO_3$ and hemi-morphilite Zn_4 $[(OH)_2 . Si_2O_7]$.H2O.

II-1-3-3 Gray copper: Cu_3 (As, Sb) S_{3-4} (± Ag, Zn):

Are sulfosalts constituting a continuous solid solution between tetrahedrite (Sb) and tennantite (As).

- Often automorphic

- Steel gray to iron black color

- Metallic shine

- H = 3 (Sb) to 4.5 (As). Quite fragile

- D = 4.6 (As) to 5.1 (Sb)

- Antimony-containing gray coppers alter into malachite and azurite.

II-1-3-4 Chalcopyrite: $CuFeS_2$

- Quite rarely automorphic

- No cleavage, irregular breakage

- Macle (111) quite like, polysynthetic

- On fresh break, metallic brass yellow color.

- H = 3.5. Fragile

- D = 4.1 to 4.3

- Opaque mineral in acidic or basic eruptive rocks.

II-1-3-5 Pyrite (FeS_2)

- Frequently automorphic

- No cleavage

- Sub-conchoidal breakage

- Metallic brass yellow color

- H = 6 to 6.5. Fragile

- D = 4.8 to 4.9

- Low temperature mineral in certain epithermal deposits but especially in sedimentary rocks (chalks and clays)

- It changes very easily in humid air to iron sulfate.

II-1-3-6 Molybdenite (MOS_2)

- Hexagonal holohedron 6mm/m

- Quite often automorphic but distorted

- Very easy (001) cleavage (between the sulfur layers)

- Bluish lead gray color

- Main molybdenum ore

- In pegmatitic, pneumatolytic and hypo-thermal SnO_2 and $FeWO_4$ deposits.

II-1-3-7 Stibine (Sb_2S_3)

- Orthorhombic holohedron mmm

- Frequently automorphic in very elongated crystals

- Perfect cleavage according to (010)

- Fresh break and steel gray section with a bright metallic sheen which turns blue at the beginning of alteration.

- H = 2

- D = 4.6 to 4.7

- Low temperature mineral. Essentially in deposits with barite $BaSO_4$ gangue, quartz or calcite.

- Often associated with cinnabar HgS, realgar AsS and orpiment As_2S_3.

II-1-4 OXIDES AND HYDROXIDES

These are minerals where the radical is (O_2-Oxide; OH-hydroxide), they are formed in surface conditions (atmospheric weathering, sedimentation). They are generally soft, poorly crystallized, with brown, ocher, red or black colors.

II-1-4-1 Magnetite (Fe_3O_4 (Oxide)

It is an important iron mineral, it is strongly magnetic, it attracts iron shot and deflects the needle of a compass.

- Cubic holohedron m3m, it is frequently automorphic
- Macle by contact or penetration (111) very common
- Opaque black color with semi-metallic shine
- H = 5.5 to 5.6
- Any breakage
- D = 5.2

Very common mineral: opaque accessories of eruptive rocks aids and on all basics.

In magmatic segregation deposits but also in pyro-meta-somatic deposits (mineralized skarns, Rare in sedimentary rocks)

It weathers into hematite FeO3 and limonite.

II-1-4-2 Hematite or oligist (Fe_2O_3) (Oxide)

It is known as "nothing ore", it can become magmatic when heated.

- Rhombohedral holohedron 3m
- Commonly automorphic
- Steel gray to iron black color for massive crystals
- Very lively metallic shine.
- H = 6.5
- Uneven breakage (No easy cleavage)
- D = 5.2 to 5.3
- Common mineral: Opaque accessory in many eruptive rocks and crystalline schists (hematite quartzites). It changes into limonite

II-1-4-3 Ilmenite ($FeTiO_3$) (Oxide)

It is iron black in color, an opaque mineral, with a metallic shine over time. It is soluble in concentrated hydrochloric acid, it is weakly magnetic.

II-1-4-4 Cassiterite (SnO2)

- Holohedral quadratic 4/m x mm, quite often automorphic

- Reddish or blackish brown, adamantine luster

- H = 6 to 7. 6 to 7.

- Irregular break

- D = 6.8 to 7.1

- Main ore of tin. Typically high temperature. Essentially linked to pegmatitic, pneumatolytic and hypothermal deposits in acidic eruptive rocks (granites). Virtually unalterable.

II-1-4-5 Limonite (FeO3.nH2) (Hydroxide)

Brownish yellow, brown or black in color, dissolves very slowly in acid.

II-1-5 CARBONATES

They are salts of carbonic acid, they have a light color: white, pink, gray, with the exception of copper carbonates which have a green or blue color. An important distinctive character is the reaction of carbonates with HCl, HNO_3, which causes various effervescences.

Among the carbonates are:

II-1-5-1 Calcite ($CaCO_3$)

It is very frequently automorphic: the facies of calcite are extremely diverse and involve a very great diversity of forms.

- Colorless (Icelandic Spar) or whitish (fluid inclusions), it also turns yellow, reddish, brown, black due to solid oxide inclusions

S metallic.

- Extremely common mineral in limestone, marble, cipolins but also is a gangue mineral of hydrothermal deposits, in the cavities and vacuoles of basaltic lavas;

- Effervescence with HCl.

II-1-5-2 Dolomite (Ca Mg CO_3)

It is white, gray-brown, perfect with yellowish, grayish, greenish, fragile shades. It dissolves slowly in cold diluted hydrochloric acid. It reacts with HCl less than calcite (Weak effervescence).

II-1-5-3 Aragonite ($CaCO_3$)

- Orthorhombic holohedron mmm

- Very rarely automorphic

- Colorless, gray or purplish more often

- Fairly common mineral: Mainly in fissures of volcanic rocks in salt-evaporitic deposits (with gypsum)

- In stable under ordinary conditions if it is free of Sr, transforms into calcite, a stable form.

II-1-5-4 Azurite (Cu_3 [$(CO_3)2(OH)_2$])

- Holohedral monoclinic 2/m, frequently automorphic. Facies very rich in form

- Very dark blue color. Translucent with stained glass shine; it is effervescently soluble in HCl

- H = 3.5 to 4

- Conchoidal breakage

- D = 3.7 to 3.9

- Frequent mineral from the oxidation zone of copper sulphide deposits

- Weathers to malachite and malachite copper and native copper.

II-1-5-5 Malachite Cu_2 [$CO_3(OH)_2$]

It is fibrous in shape and has a silky shine with a green color. It is soluble with effervescence in dilute hydrochloric acid.

- Holohedral monoclinic 2/m

- Rare isolated automorphic crystals

- Perfect cleavage (001)

- Translucent with glassy shine

- H = 4

- Irregular break

- D = 4

- Frequent mineral in the oxidation zones of copper sulphide and sulphosalt deposits

II-1-6 SULFATES AND TUNGSTATES

II-1-6-1 Sulfates

These are salts of sulfuric acid. They have a light color, faint in water.

II-1-6-1-1 Barite ($BaSO_4$)

- Orthorhombic holohedron mmm, often automorphic

- Perfect cleavage (001) and (110)

- Color: colorless, whitish, honey yellow to brown or reddish

- Vitreous to pearly shine

- H = 3 - 3.5, cleavage fracture

- D = 4.48

- Frequent mineral in meso-to-epithermal veins (often associated with quartz, galena, fluorite, carbonate gangues, etc.) and as cement.

II-1-6-1-2 Gypsum ($CaSO_4$-$2H_2O$)

- Holohedral monoclinic 2/m, frequently automorphic, perfect (010) cleavage (through layers of molecular water)

- Color: colorless, perfectly clear, grayish white

- Pearly shine on the cleavage (010)

- H = 1.5 - 2μ- Lamellar breakage

- D = 2.3

- Very common mineral: in evaporitic sedimentary rocks and salty marls in an arid climate where it crystallizes by rapid evaporation of brines.

- Also in the oxidation zone of sulphide deposits from carbonate surroundings.

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II-1-6-2 TUNGSTATES

II-1-6-2-1 Scheelite ($CaWO_4$)

Is quadratic hemihedral 4/m, it is quite rare automorphic

- It is often in grainy masses

- Difficult cleavage (111)

- Color: colorless, most often translucent milky white to grayish or yellowish

- Stony to greasy shine

- H = 4.5 to 5

- Irregular breakage

- D = 5.9 to 6.1

- Important tungsten ore. Found mainly in pyro-metasomatic contact deposits between acidic eruptive rocks and carbonate rocks (Skarns)

II-1-6-2-2 Wolframites (Fe, Mn) WO_4

It is monoclinic holohedron 2/m, quite often automorphic with numerous shapes

- Found in thick blades included in quartz

- Perfect cleavage (010)

- Colors: ferberite ($FeWO_4$) is coal black with sub-metallic luster, hubnerite ($MnWO_4$) is translucent yellow-brown to red-brown with internal reflections

- H = 4.5

- Irregular break except along the cleavage plane

- D = 7.1 (hubnerite) and 7.5 (forberite)

- Main tungsten ore: in pneumatolytic (greisens) and pegmatitic deposits as well as in hypothermal deposits.

II-1-7 PHOSPHATES, ARSENIATES AND VANADATES

II-1-7-1 Phosphates This group includes minerals whose colors are brilliant and with fine crystalline shapes. Phosphates, where the anionic radical $(PO4)^{3-}$, tetrahedron within which phosphorus can be replaced by vanadium $(VO4)^{3-}$ and arsenic $(AsO4)^{3-}$.

Phosphates are rare.

The phosphate minerals are:

II-1-7-1-1 Amblygonite (Li, Na) $AlPO_4$ (F, OH), Hardness (H)= 5.5-6, Density (D)= 3-3.31; perfect cleavage, white to grayish white color

II-1-7-1-2 Lazurite (Mg, Fe)$Al_2(PO4)_2(OH)_2$, Hardness (H)= 5.5-6, Density (D) = 3.1 indistinct cleavage, color blueII-1-7-1-3 Pyromophilite Pb5$(PO4)_3$Cl, Hardness (D)= 3.5-4; Density 6.5-7.2 Cleavage practically absent (green, orange, gray, brown).

II-1-7-1-4 Vivianite Fe_3 $(PO4)_2$. $8H_2O$, Hardness (H)= 1.5-2, Density (D)= 2.68. Perfect cleavage (Colorless when fresh)

II-1-7-1-5 Atunite Ca $(UO_2)_2(PO_4)_2$ .10-$12H_2O$, Hardness (H)= 2-2.5; Density (D)= 3-3,2. Basic cleavage (perfect (yellow to green color)).

II-1-7-1-6 Apatite $Ca_5(PO_4)$ (F, Cl, OH), Hardness (H)= 5; Density (D)= 3.18-3.2. Uneven, fragile breakage.

II-1-7-2 Arsenates

Arsenates contain arsenic, sulfur and oxygen ($AsSO_4$). Arsenates have a specific weight of 3-5, except numetite which, because of lead, has a specific weight of 7.0-7.3.

The arsenate minerals are:

II-1-7-2-1 Adamite $Zn_2AsO_4(OH)$, Hardness (H)= 3.5, Density (D)= 4.3-4.4, yellow-green (or yellow-green) color.

II-1-7-2-2 Annabergite $Ni_3(AsO_4)_2$. $8H_2O$, Hardness (H)=1.5-2.5, Density (D)= 3.07, perfect cleavage in white, gray, pole green or yellow green color.

II-1-7-2-3 Mimetite $Pb_5(AsO_4)_3Cl$, Hardness (H)=3.5-4, Density (D)= 7-7.3. No cleavage (Color yellow, orange, brown to white)

II-1-7-2-4 Chnoclase $Cu_3(AsO_4)(OH)_3$, Hardness (H)=2.5-3; Density (D)= 4.33. Perfect cleavage, dark greenish blue to greenish black.

II-1-7-3 Vanadates

Vanadates are another rare group, they contain vanadium and oxygen (VO_4).

-***Vanadinite*** $Pb_5(VO4)_3Cl$***:*** is probably the best known, its color is red. It is one of the main industrial ores of the metal vanadium and a minor source of lead.

II-1-7-3-1 Carnotite $K_2(UO_2)2V_2.O_8.3H_2O$, Hardness (H)= 2, Density (D)= 4.75. Perfect basal cleavage, bright yellow or greenish yellow in color.

II-1-7-3-2 Vanadinite $Pb_5(VO_4)_3Cl$, Hardness (H)= 3, Density (D)= 6.8, no cleavage, bright red to brownish red color.

II-1-7-3-3 Volborthite $Cu_3V_2O_7(OH)_2$. $2H_2O$, Hardness (H)= 3.5, Density (D)= 3.42. Perfect basal cleavage, green, yellow or brown in color.

II-1-8 THE BORATES

All borates contain Al^{3+}, Fe^{3+} and Mn_3 cations. Boron belongs to the number of fairly mobile elements in aqueous solutions containing components such as Cl, OH and especially F for which it has a great chemical affinity. The concentration and formation of boric compounds takes place in the products, residuals of various geological processes, partly in pegmatites and hydrothermal formations (ortho borates, borosilicates) but mainly in saline basins in drying areas enriched in boron .

It was found that at low temperatures B_2O_3 is likely to be eliminated by CO_2. During alteration, borates are replaced by carbonates.

Example :

II-1-8-1 Boracite $Mg_3B_7O_{13}Cl$

Anhydrous borates

II-1-8-2 Ascharite $MgHBO_3$

Example :

II-1-8-3 Borax $Na_2B_4O_7.\ 10H_2O$

Hydrated borates

II-1-8-4 Ulexite $NaCaB_5O_9.\ 8H_2O$

II-1-9 NITRATES

In the earth's crust, nitrogen exists in the form of complex ions: $[NO_3]$, $[NH_4]^+$. It is found in the gaseous state in the atmosphere.

Nitrates, salts of the strong acid NHO_3 (nitric acid), which are very soluble, are widespread in the current formations of hot desert countries.

The most important are the nitrates of the alkali metals K and Na. The nitrates of the alkaline earth metals Mg, Ca, and Ba are the least common.

Example :

II-1-9-1 Nitratine $NaNO_3$

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