



4. SULPHIDES AND SULFOSELS

This class includes approximately 350 minerals.

THE SULPHIDES SUBCLASS

The class of sulfides and sulfosalts presents for the mining geologist one of the the most important parts of mineralogy, because it contains the basic ores of almost all metals: Ag, As, Bi, Cd, Co, Cu, Ge, Hg, Mn, Mo, Ni, Pb, Pt, Sb, Tl and Zn.

With sulfides, we classify similar but rarer minerals, which are selenides, tellurides, arsenides and antimonides.

The general formula is $A_m X_n$, where

- A = Ag, As, Bi, Cd, Co, Cu, Fe, Ge, Hg, Mn, Mo, Ni, Pb, Pt, Sb, Tl, and Zn
- X = **S** (for sulphides); **Se** (for selenides); **Te** (for tellurides); **As** (for arsenides); **Sb** (for antimonides).

The main minerals of the sulphide subclass are:

Argentite	Ag_2S	Cinnabar	HgS
Chalcocite	Cu_2S	Réalgar	AsS
Bornite	Cu_5FeS_4	Orpiment	As_2S_3
Galena	PbS	Stibine	Sb_2S_3
Sphalerite	ZnS	Bismuthinite	Bi_2S_3
Chalcopyrite	$CuFeS_2$	Pyrite	FeS_2
Stannite	Cu_2FeSnS_4	Cobaltite	$(Co,Fe)AsS$
Greenockite	CdS	Marcasite	FeS_2
Pyrrhotite	$Fe_{1-x}S$	Arsenopyrite	$FeAsS$
Niccolite	$NiAs$	Molybdenite	MoS_2
Millerite	NiS	Calaverite	$AuTe_2$
Pentlandite	$(Fe,Ni)S$	Sylvanite	$(Au,Ag)Te_2$
Covellite	CuS	Skutterudite	$(Co,Ni)As_3$
Digenite	Cu_2S		

4.1. Argentite

(Ag_2S)

Cubic

Sometimes in crystals: millimetric cubes and octahedrons. Also in aggregates reticulated or filiform, in coatings, crusts or arborescences, in grainy masses with compact. $D=7.3$ / $H = 2$ to 2.5. Malleable. Color: lead gray to black. Opaque. Glow metallic, tarnishing with weathering.



Argentite forms at temperatures $> 179^{\circ}\text{C}$. By cooling, it transforms into rhombohedral Acanthite Ag_2S .

Argentite or its polymorph (acanthite), is found in deposits veins. **Deposits:** Norway, Mexico, Utah/USA. Important silver ore.



4.2. ARSENOPYRITE (MISPICKEL) (Fe As S) Monoclinic

Often automorphic: prisms with a diamond section, short or elongated following c , sometimes following b ; vertical faces streaked parallel to c . Aggregates grainy. Fragile, irregular breakage.

$D = 6 / H = 5.5$. Bright metallic shine. Color silver white to steel gray plus white than marcasite. Blackish dust.

Frequent, the most common of the arsenaceous minerals. High temperature mineral.



4.3. BORNITE (Cu₅FeS₄) cubic

Crystals rarely well developed, deformed cubes. Generally in compact masses or in disseminated form

$D = 5, H = 3$. Imperfect cleavage conchoidal break. Color: reddish, iridescent colored Dust gray black. Opaque, metallic shine.

Deposits; In iron-poor copper deposits, in veins and in impregnations

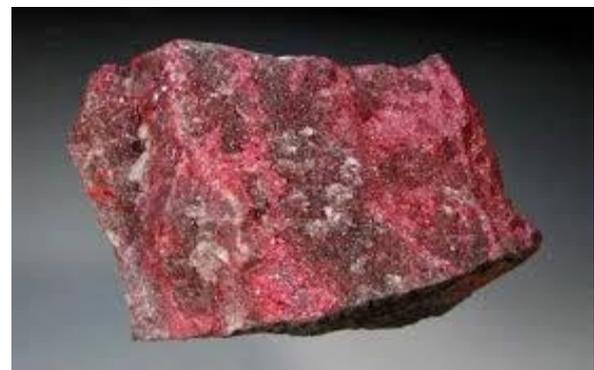


4.4. CINABER (HgS)

Rarely in crystals (maximum 2 to 5 cm): rhombohedral, sometimes flattened, twinned or in pseudo-hexagonal groups. Generally in inlays, crusts, coatings, compact to earthy masses.

D = 8.1; H = 1.5. Irregular breaks. Cleavage good. **Color:** red; browning by superficial alteration. Translucent in crystals. Adamantine luster, semi-metallic or earthy. **Main ore of mercury**

Rhombohedral



4.5. COVELLITE (Covellite) (CuS)

Very rare crystals: small hexagonal tablets. Most often in masses compact, earthy, in crust, in powdery coatings.

D = 4.6; H = 1.5 to 2. Conchoidal breakage. Perfect cleavage following lengthening.

Color: blue black. Opaque. Metallic, bold, matte shine. Dust: lead gray.

Mode of deposit: in the alteration zone of copper deposits. Important ore copper.

Hexagonal



4.6. CHALCOSINE (chalcocite) (Cu₂S) orthorhombic

Tabular and thick crystals, in short rods, rare. Most often in masses compact, also in disseminated form.

D=5.5-5.8; H = 2.5. Conchoidal breakage, imperfect cleavage.

Color: graylead to black with bluish reflections. Opaque; Metallic shine, tarnishing with alteration. Dark gray dust.

Mode of deposit: in vein deposits and impregnations. Important ore copper.



4.7. DIGENITE

(Cu₉S₅)

Cubic

Very rare in cubo-octahedrons. Generally massive, associated with covellite, chalcocite and bornite. Very lively metallic shine. Blue-black color.

4.8. CHALCOPYRITE

(Cu Fe S₂)

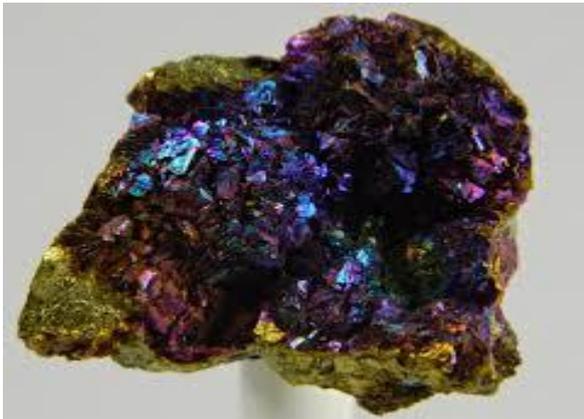
Quadratic

Etymology: from the Greek “chalcos”, copper: copper pyrite. Uncommon automorphic crystals (tetrahedrons). Generally masses finely grained. Shapeless grains or flakes. Uneven breakage.

D = 4.1 to 4.3; H = 3.5 to 4. Does not scratch glass (unlike pyrite). Opaque, metallic shine.

Golden yellow color, often tarnished or iridescent in blue, green, red, surface oxidation. Greenish black dust.

Frequently alters to covellite, chalcocite, malachite, copper sulfates.



Various deposits: Disseminated or segregated in eruptive rocks basic; diffuse high temperature impregnations; impregnations in silicified limestones (Katanga, Central Africa) sandstones or shales (“kupferschiefer” of Europe); Very common in vein hydrothermal deposits. **Main ore of copper.**

4.9. GALENA

(Pb S)

Cubic

Automorphic crystals in cubes (100) or cubo-octahedrons (100) and (111), with

accessory facets. Most often in crystalline masses with cleavages

trirectangular; or finely granular.

D = 7.6 / H = 2.5. Perfect cleavages. Opaque, metallic shine. Lead gray color.

Gray lead dust. Easily alterable into anglesite, cerussite, pyromorphite, etc. **Main ore of lead.**





One of the most widespread sulphides: Hydrothermal veins of all temperatures, especially hypo- and mesothermal (B.P.G.C). Clusters in limestones and dolomites. Syngenetic stratiform deposits

4.10. MARCASSITE

(FeS₂)

Orthorhombic

Tabular crystals, more rarely prismatic. More often in masses globular. Fibro-radiated, stalactitic. Twinned spearhead groups.

D = 5/ H = 6. Conchoidal breakage. Opaque, metallic shine. Yellow color of bronze with grayish or greenish reflections; whiter than pyrite on break fresh. Black to greenish brown dust.

Alteration easier than pyrite, with formation of whitish iron sulfates and sulfuric acid; Pseudomorphoses in limonite.

Deposits: Low temperature mineral from superficial deposits. Common but not in large masses. In certain epithermal deposits. In the rocks sedimentary (limestone, clays, carbon deposits), often in fibroradiated nodules. Sometimes used as a source of sulfur.

4.11. PYRRHOTITE Fe_{1-x}S Hexagonal (HT1[4]) or Monoclinic (BT2[5]). (0 < x < 0,2).

Quite rare crystals, in hexagonal tablets sometimes grouped in rosettes. Usually in compact masses.

D = 4.6 / H = 4. Fragile, conchoidal breakage. Opaque, metallic shine. Color bronze yellow with pink highlights. Brown patina. Gray-black dust. Dust attractable to the magnet (for varieties rich in sulfur). Very alterable, into sulfates then limonite. In basic eruptive rocks, with Pentlandite, chalcopyrite, sometimes chromite, platinum, either in disseminated grains or in large masses (Cu and Ni deposit of Sudbury - Canada).

Deposits: In deposits of contact metamorphism, notably limestones, associated with Scheelite. In hydrothermal deposits with blende, pyrite, galena, chalcopyrite.

Rarely used as a source of sulfur or iron.

4.12. PYRITE

(FeS₂)

Cubic

Often in cubes. Octahedrons and pentagonododecahedra are common. The faces of the cube are often ridged. It also comes in massive granular form.

D = 5/ H = 6. Uneven breakage. Opaque, bright metallic shine. Brass yellow color pale. Greenish-black dust. Easily alters to limonite, dull brown in color, often retaining its original form ("pseudomorphosis").

The most common of the sulphides, forms under all conditions of temperature: segregation in eruptive rocks dispersed in rocks eruptive and metamorphic; contact metamorphism deposits; impregnations diffuse and clustered, with mesothermal paragenesis; hydrothermal veins, in BPGC association; sedimentary rocks, in scattered crystals; common in fossil deposits and beds rich in organic matter.





4.13. SPHALERITE (BLENDE)

ZnS

Cubic

Crystals of complex shape, often tetrahedral. Usually in masses cleavable coarsely to finely granular. Perfect cleavages.

D = 3.5 to 4.2; H = 3.5 to 4. Transparent to almost opaque, adamantine luster to resinous. Yellow color (“honeyed” blende), brown, black. Yellow to brown dust.

Often contains Fe, Mn, Cd. Oxidizes to hemimorphite, smithsonite...

Deposits: Very widespread mineral. Hydrothermal vein or substitution deposits, with pyrite, galena

Note: **Wurtzite** is a hexagonal zinc sulphide (ZnS), of high temperature



4.14. STIBINE (Antimonite)

Sb₂S₃

Orthorhombic

Prisms elongated along c vertically streaked, often curved, needles sometimes in radiate groups, fibrous or finely grained masses.

D = 4.6; H = 2. Perfect cleavage. Opaque, bright metallic shine but tarnish in

blackish blue. Lead gray to black dust.

Alteration into yellow to yellow-green antimonites. A drop of KOH solution colors the stibnite orange.

Deposit modes: In low temperature hydrothermal veins, with quartz, barite, calcite, pyrite, cinnabar, gold. In the alternative roosts in the limestones or dolomites.

Main antimony ore: alloys, printing, etc....





THE SUBCLASS OF SULFOSELS

The subclass of sulfosalts is less important than that of sulfides. We group sulfo-arsenides, sulfo-antimonides of the following metals: Ag, Cu, Pb,

Sn, Bi, Fe.

The general formula is $A_m B_n X_n$, where

- A = Cu, Ag, Pb, Sn, Bi, Fe
- B = As, Sb
- X = S.

The main minerals are:

Pyrargirite	Ag_3SbS_3	Enargite	Cu_3AsS_4
Proustite	Ag_3AsS_3	Bournonite	$PbCuSbS_3$
Tetrahedrite	$Cu_{12}Sb_4S_{13}$	Jamesonite	$Pb_4FeSb_6S_{14}$
Tannantite	$Cu_{12}As_4S_{13}$		

-PROUSTITE Ag_3AsS_3 (*arsenic red silver*) **Rhombohedral**

Quite rare crystals, exceptionally large (10 cm); prisms, scalenohedra or acute rhombohedra. Generally grainy to compact masses, crusts or dendrites.

D = 5.57 / H = 2.5. Very fragile. Conchoidal breakage. Color: red-vermilion

cherry red when fresh. Becomes reddish black and opaque to light.

Adamantine radiance. Brownish red dust.

In paragenesis veins Ni, Co, Ag, As.

-BOURNONITE $PbCuSbS_3$ **Orthorhombic**

Pseudo-quadratic crystals, flattened. Often in compact masses, sometimes grainy.

D = 5.8/ H = 2.5-3. Fragile. Sub-conchoidal breakage. Color: lead gray plus or less tarnished. Opaque. Metallic shine. Gray dust.

In medium temperature hydrothermal deposits, with galena, sphalerite, chalcopryrite, quartz, barite, fluorite.

-GRAY COPPER: Solid solutions $Cu_{12}(As,Sb)_4S_{13}$, with two poles: Tetrahedrite $Cu_{12}Sb_4S_{13}$ and Tennantite $Cu_{12}Sb_4S_{13}$ Cubic.

Often in crystals: tetrahedra. Frequent macles. Also in masses compact or grainy.

D = 4.6 to 5.1 (increases with the percentage in Sb)/ H = 3 to 4.5 (increases with the percentage in As). Quite fragile. Conchoidal breakage. Steel gray to black color iron. Opaque. Metallic luster, sometimes shiny. Dust: olive black.

In medium temperature hydrothermal deposits.