

## II. SULPHIDES, SELENIDES, TELLURIDES, ARSENIDES, ANTIMONIDES

The sulphides, etc., fall into two Groups according to the character of the positive element.

- I. Sulphides, Selenides, Tellurides of the Semi-metals.
- II. Sulphides, Selenides, Tellurides, Arsenides, Antimonides of the Metals.

### I. Sulphides, etc., of the Semi-Metals

This section includes one distinct group, the Stibnite Group, to which orpiment is related; the other species included stand alone.

#### REALGAR.

Monoclinic. Axes  $a : b : c = 1.4403 : 1 : 0.9729$ ;  $\beta = 66^\circ 5'$ .  
 $mm''$ ,  $110 \wedge 1\bar{1}0 = 105^\circ 34'$ .  $rr'$ ,  $012 \wedge 0\bar{1}2 = 47^\circ 57'$ .

Crystals short prismatic; striated vertically. Also granular, coarse or fine; compact; as an incrustation.

Cleavage:  $b(010)$  rather perfect. Fracture small conchoidal. Sectile. H. = 1.5–2. G. = 3.56. Luster resinous. Color aurora-red or orange-yellow. Streak varying from orange-red to aurora-red. Transparent — translucent.

**Comp.** — Arsenic monosulphide,  $AsS = \text{Sulphur } 29.9, \text{ arsenic } 70.1 = 100$ .

**Pyr., etc.** — In the closed tube melts and gives a dark red liquid when hot and a reddish yellow solid when cold; in the open tube (if heated very slowly) sulphurous fumes, and a white crystalline sublimate of arsenic trioxide. B.B. on charcoal burns with a blue flame, emitting arsenical and sulphurous odors. Soluble in caustic alkalis.

**Artif.** — Realgar is frequently noted as a sublimation product from furnaces roasting ores of arsenic. Crystals are produced when arsenic sulphide is heated in a sealed tube with a solution of sodium bicarbonate.

**Obs.** — Realgar occurs usually in veins associated with silver and lead ores. It has been found in volcanic regions as a sublimation product. It has also been noted as a deposit from hot spring waters. It is often associated with orpiment. It occurs at Felsöbánya, Kapnik and Nagyg, Hungary; Allchar, Macedonia. Binnental, Switzerland, in dolomite. In the United States, at Mercur, Utah; in the Norris Geyser Basin, Yellowstone Park, as a deposition from the hot waters. Found at the Monte Cristo mining district, Snohomish Co., Washington; the name *realgar* is from the Arabic, *Rahj al ghâr*, *powder of the mine*.

**Use.** — Was used in fireworks to give a brilliant white light when mixed with saltpeter and ignited. The artificial material is now used for this purpose.

#### ORPIMENT.

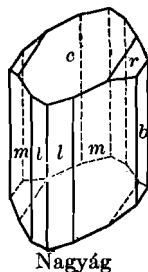
Monoclinic. Axes  $a : b : c = 0.596 : 1 : 0.665$ ,  $\beta = 90^\circ 41'$ .

Crystals small, rarely distinct. Usually in foliated or columnar masses; sometimes with reniform surface.

Cleavage:  $b(010)$  highly perfect, cleavage face vertically striated;  $a(100)$  in traces; gliding-plane  $c(001)$ . Sectile. Cleavage laminae flexible, inelastic. H. = 1.5–2. G. = 3.4–3.5. Luster pearly on  $b$  (cleavage); elsewhere resinous. Color lemon-yellow of several shades; streak the same, but paler. Subtransparent — subtranslucent.

**Comp.** — Arsenic trisulphide,  $As_2S_3 = \text{Sulphur } 39.0, \text{ arsenic } 61.0 = 100$ .

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Nagyág

**Pyr., etc.** — Same as for realgar, p. 357.

**Diff.** — Distinguished by its fine yellow color, pearly luster, easy cleavage, and flexibility when in plates.

**Artif.** — Orpiment has been synthesized by heating solutions of arsenic with ammonium sulphocyanate in a sealed tube; also by the treatment under pressure of arsenic acid with hydrogen sulphide.

**Obs.** — Occurs under same conditions as realgar with which it is commonly associated. It is found in Hungary at Tajowa in small crystals, in foliated and fibrous masses at Moldowa, in metalliferous veins at Kapnik and Felsöbánya; with realgar at Allechar, Macedonia. A large deposit occurred near Julamerk in Kurdistan. Occurs in fine crystals at Mercur, Utah. Among the deposits of the Steamboat Springs, Nevada; also with realgar in the Yellowstone Park.

The name orpiment is a corruption of its Latin name auripigmentum, "golden paint," given in allusion to the color, and also because the substance was supposed to contain gold.

**Use.** — For a pigment, in dyeing and in a preparation for the removal of hair from skins. The artificial material is largely used as a substitute for the mineral.

**Stibnite Group**

|                     |            |                                |
|---------------------|------------|--------------------------------|
|                     |            | <i>a</i> : <i>b</i> : <i>c</i> |
| <b>Stibnite</b>     | $Sb_2S_3$  | 0·9926 : 1 : 1·0179            |
| <b>Bismuthinite</b> | $Bi_2S_3$  | 0·9679 : 1 : 0·9850            |
| <b>Guanajuatite</b> | $Bi_2Se_3$ | 1 : 1 approx.                  |

The species of the Stibnite Group crystallize in the orthorhombic system and have perfect brachypinacoidal cleavage, yielding flexible laminæ.

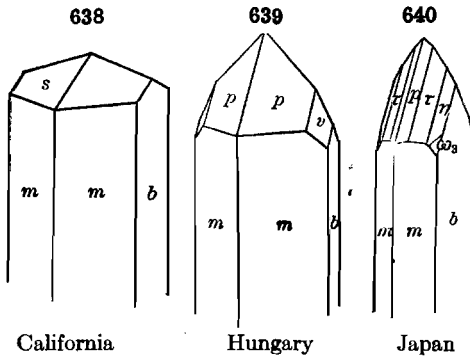
The species orpiment is in physical properties somewhat related to stibnite, but is monoclinic in crystallization. Groth notes that in a similar way, the oxide,  $As_2O_3$ , is monoclinic in claudetite, while the corresponding compound,  $Sb_2O_3$  (valentinite), is orthorhombic.

**STIBNITE.** Antimonite, Antimony Glance.

Orthorhombic. Axes *a* : *b* : *c* = 0·9926 : 1 : 1·0179.

|   |  |
|---|--|
| $mm'''$ , 110 $\wedge$ $\bar{1}\bar{1}0$ = 89° 34'. | $bv$ , 010 $\wedge$ 121 = 35° 8'.      |
| $pp'$ , 111 $\wedge$ $\bar{1}\bar{1}1$ = 71° 24½'.  | $b\eta$ , 010 $\wedge$ 353 = 40° 10½'. |
| $ss'$ , 113 $\wedge$ $\bar{1}\bar{1}3$ = 35° 52½'.  | $b\tau$ , 010 $\wedge$ 343 = 46° 33'.  |
| $ss'''$ , 113 $\wedge$ $\bar{1}\bar{1}3$ = 35° 36'. | $bp$ , 010 $\wedge$ 111 = 54° 36'.     |

Crystals prismatic; striated or furrowed vertically; often curved or twisted (cf. p. 188). Common in confused aggregates or radiating groups of acicular crystals; massive, coarse or fine columnar, commonly bladed, less often granular to impalpable.



Cleavage: *b* (010) highly perfect. Slightly sectile. Fracture small sub-conchoidal. H. = 2. G. = 4·52–4·62. Luster metallic, highly splendent on cleavage or fresh crystalline surfaces. Color and streak lead-gray, inclining to steel-gray; subject to blackish tarnish, sometimes iridescent.

**Comp.** — Antimony trisulphide,  $Sb_2S_3$  = Sulphur 28·6, antimony 71·4 = 100. Sometimes auriferous, also argentiferous.

**Pyr., etc.** — Fuses very easily (at 1), coloring the flame greenish blue. In the open tube sulphurous ( $SO_2$ ) and antimonial (chiefly  $Sb_2O_3$ ) fumes, the latter condensing as a white

sublimate which B.B. is non-volatile. On charcoal fuses, spreads out, gives sulphurous fumes, and coats the coal white with oxide of antimony; this coating treated in R.F. volatilizes and tinges the flame greenish blue. When pure, perfectly soluble in hydrochloric acid; in nitric acid decomposed with separation of antimony pentoxide.

**Diff.** — Distinguished (*e.g.*, from galena) by cleavage, color, softness; also by its fusibility and other blowpipe characters. It is harder than graphite. Resembles sometimes certain of the rarer sulphantimonites of lead, but yields no lead coating on charcoal.

**Micro.** — In polished section shows white color like galena with a smooth surface. Darkens with  $\text{HNO}_3$  and aqua regia; with KOH turns orange-yellow to reddish brown.

**Artif.** — Stibnite, like orpiment, has been artificially produced by heating in a sealed tube, a solution of antimony with ammonium sulphocyanate; also by passing hydrogen sulphide at a red heat over compounds of antimony.

**Obs.** — Stibnite has been noted in deposits of sulfataric origin but usually has apparently been deposited from alkaline solutions in intimate association with quartz. It is found in beds or veins in granite and gneiss, often accompanied with various other antimony minerals produced by its alteration. Also associated in metalliferous deposits with sphalerite, galena, cinnabar, barite, quartz; sometimes accompanies native gold.

Stibnite is the most common ore of antimony and is found in quantity in many countries but has never been extensively mined in the United States. In Europe it has been found in notable deposits at Wolfsberg, Harz Mts.; at Bräunsdorf near Freiberg in Saxony; at the Caspari mine near Arnsberg, Westphalia; in Hungary at Felsöbánya, Kremnitz and Kapnik; at various points in France. Groups of large splendid crystals have come from the antimony mines in the Province of Iyo, island of Shikoku, Japan. Important deposits are located in southern China, particularly in the Province of Hunan. Mexico and Chile produce considerable antimony ore.

In the United States the more important deposits are in Cal., on Telescope Peak in the Panamint Range, in Kern County and in the eastern part of San Benito County. Nev. has several deposits, mostly in the northwest section.

**Use.** — The most important ore of antimony.

**Metastibnite.** — An amorphous brick-red deposit of antimony trisulphide,  $\text{Sb}_2\text{S}_3$ , occurring with cinnabar and arsenic sulphide upon siliceous sinter at Steamboat Springs, Washoe Co., Nev.

**BISMUTHINITE.** Bismuth Glance.

Orthorhombic. Rarely in acicular crystals.  $mm''$ ,  $110 \wedge 110 = 88^\circ 8'$ . Usually massive, foliated or fibrous.

Cleavage:  $b(010)$  perfect. Somewhat sectile.  $H. = 2$ .  $G. = 6.4-6.5$ . Luster metallic. Streak and color lead-gray, inclining to tin-white, with a yellowish or iridescent tarnish. Opaque.

**Comp.** — Bismuth trisulphide,  $\text{Bi}_2\text{S}_3 = \text{Sulphur } 18.8$ , bismuth  $81.2 = 100$ . Sometimes contains a little copper and iron.

**Pyr., etc.** — Fusibility = 1. In the open tube sulphurous fumes, and a white sublimate which B.B. fuses into drops, brown while hot and opaque yellow on cooling. On charcoal at first gives sulphurous fumes; then fuses with spitting, and coats the coal with yellow bismuth oxide; with potassium iodide and sulphur gives a yellow to bright red coating of bismuth iodide. Dissolves readily in hot nitric acid, and a white precipitate of a basic salt falls on diluting with water.

**Artif.** — Bismuthinite has been produced artificially by treating the volatilized chloride of bismuth with hydrogen sulphide; in crystals by heating bismuth sulphide in a sealed tube with an alkaline sulphide.

**Micro.** — In polished section shows white color like galena with a smooth surface, with  $\text{HNO}_3$  blackens, leaving a rough surface; with aqua regia slowly turns brown.

**Obs.** — Found in Cornwall, England, at Carrock Fells, Redruth, etc.; in France at Meymac, Corrèze; in Saxony at Schneeberg and Altenberg; in Hesse at Bieber; in Hungary at Rézbánya and Oravicza; in Sweden at Riddarhyttan; in Bolivia at San Baldamero near Sovata and in the Chorolque and Tazna districts. Occurs in the United States in Beaver Co., Utah; in Rowan and Jackson Cos., N. C.; at Wicks, Jefferson Co., Mon.; Delaware Co., Pa.; Haddam, Conn.

**Use.** — An ore of bismuth.

**Guanajuatite.** Frenzelite. Bismuth selenide,  $\text{Bi}_2\text{Se}_3$ , sometimes with a small amount of sulphur replacing selenium. In acicular crystals; also massive, granular, foliated or fibrous. Cleavage:  $b(010)$  distinct.  $H. = 2.5-3.5$ .  $G. = 6.25-6.62$ . Luster metallic.

Color bluish gray. From the Santa Catarina mine, near Guanajuato, Mexico. Noted from Salmon, Idaho.

#### TETRADYMITÉ.

Rhombohedral. Crystals small, indistinct. Commonly in bladed forms foliated to granular massive.

Cleavage: basal, perfect. Laminae flexible; not very sectile. H. = 1·5–2; soils paper. G. = 7·2–7·6. Luster metallic, splendid. Color pale steel-gray.

**Comp.** — Consists of bismuth and tellurium, with sometimes sulphur and a trace of selenium; the analyses for the most part afford the general formula  $\text{Bi}_2(\text{Te}, \text{S})_3$ .

**Var.** — 1. *Free from sulphur.*  $\text{Bi}_2\text{Te}_3$  = Tellurium 48·1, bismuth 51·9. G. = 7·642 from Dahlonga. Var. 2. *Sulphurous.*  $2\text{Bi}_2\text{Te}_3 \cdot \text{Bi}_2\text{S}_3$  = Tellurium 36·4, sulphur 4·6, bismuth 59·0 = 100. This is the more common variety and includes the *tetradymite* in crystals from Schubkau.

**Pyr.** — In the open tube a white sublimate of tellurium dioxide, which B.B. fuses to colorless drops. On charcoal fuses, gives white fumes, and entirely volatilizes; tinges the R.F. bluish green; coats the coal at first white ( $\text{TeO}_2$ ), and finally orange-yellow ( $\text{Bi}_2\text{O}_3$ ); some varieties give sulphurous and selenous odors.

**Obs.** — Occurs in Hungary at Schubkau near Schemnitz at Rézbánya and Orawitza; at Carrock Fells, Cumberland, England. Occurs on Liddell Creek, Kaslo river, West Kootenay, British Columbia. In the United States, in Va., at the Whitehall gold mines, Spottsylvania Co.; in Davidson Co., N. C., and in the gold washings of Burke and McDowell counties, etc.; near Dahlonga, Ga.; in Mon. At the Montgomery mine and near Bradshaw, Ariz. Named from *τετραδύμος*, *fourfold*, in allusion to complex twin crystals sometimes observed.

**Grünlingite.** —  $\text{Bi}_4\text{TeS}_3$ . Massive. One distinct cleavage. Color, gray. G. = 7·321. From Cumberland, England. *Orueticite* is a similar mineral,  $\text{Bi}_5\text{TeS}_4$ , from Serrania de Ronda, Spain.

**Joséite.** — A bismuth telluride (Te 80 p. c., also S and Se). G. = 7·9. San José, Brazil.

**Wehrlite.** — A foliated bismuth telluride (Te 30 p. c.) of doubtful formula. G. = 8·4. Deutsch-Pilsen, Hungary.

#### MOLYBDENITE.

Crystals hexagonal in form, tabular, or short prisms slightly tapering and horizontally striated. Commonly foliated, massive or in scales; also fine granular.

Cleavage: basal eminent. Laminae very flexible, but not elastic. Sectile. H. = 1–1·5. G. = 4·7–4·8. Luster metallic. Color pure lead-gray; a bluish gray trace on paper. Opaque. Feel greasy.

**Comp.** — Molybdenum disulphide,  $\text{MoS}_2$  = Sulphur 40·0, molybdenum 60·0 = 100.

**Pyr., etc.** — In the open tube sulphurous fumes and a pale yellow crystalline sublimate of molybdenum trioxide ( $\text{MoO}_3$ ). B.B. in the forceps infusible, imparts a yellowish green color to the flame; on charcoal the pulverized mineral gives in O.F. a strong odor of sulphur dioxide and coats the coal with crystals of molybdic oxide, yellow while hot, white on cooling; near the assay the coating is copper-red, and if the white coating be touched with an intermittent R.F., it assumes a beautiful azure-blue color. Decomposed by nitric acid, leaving a white or grayish residue.

**Diff.** — Much resembles graphite in softness and structure (see p. 347), but has a bluer trace on paper and readily yields sulphur fumes on charcoal.

**Artif.** — Molybdenite has been made artificially by adding molybdic oxide to a fused mixture of potassium carbonate and sulphur; also by heating a mixture of molybdates and lime in an atmosphere of hydrochloric acid and hydrogen sulphide.

**Micro.** — In polished section shows grayish white color with smooth surface. Unaffected by reagents.

**Obs.** — Generally occurs embedded in, or disseminated through, granite, gneiss, zircon-syenite, granular limestone, and other crystalline rocks. At Arendal and Laurvik in Norway; Altenberg, Saxony; Zinnwald and Schlaggenwald, Bohemia; near Miask, Ural Mts.; Chessy in France; in Italy, on island of Sardinia; Carrock Fells, in Cumberland; at several of the Cornish mines. In large crystals at Kingsgate, Glen Innes, N. S. W.

In Me. at Blue Hill Bay; in Conn., at Haddam, in gneiss; in Ver., at Newport; in N. H., at Westmoreland; in N. Y., two miles southeast of Warwick; in N. J., at Franklin; in Pa., in Chester, near Reading and at Frankford; near Concord, Cabarrus Co., N. C.; in quartz vein at Crown Point, Wash. Molybdenite has been mined in various places in Ariz., Col., Nev., Mon., Tex., Utah, etc. In Canada, at St. Jérôme, Quebec; in large crystals in Renfrew county, Ontario; also in Aldfield township, Pontiac Co., Quebec.

Named from *μόλυβδος*, *lead*; the name, first given to some substances containing lead, later included graphite and molybdenite, and even some compounds of antimony. The distinction between graphite and molybdenite was established by Scheele in 1778-79.

**Use.** — An important ore of molybdenum.

**Tungstenite.** — Probably  $WS_2$ . Earthy or foliated. Color and streak, dark lead-gray.  $H. = 2.5$ .  $G. = 7.4$ . Found at Emma mine, Salt Lake Co., Utah.

**Patronite.** Rizopatronite. — Complex composition, containing large amounts of a vanadium sulphide, perhaps  $VS_4$ . Amorphous. Color black. Occurs in a complex mixture of mineral substances among which are *quisqueite* and *bravoite*, at Minasragra, Peru.

## II. Sulphides, Selenides, Tellurides, Arsenides, Antimonides of the Metals

The sulphides of this second section fall into four divisions depending upon the proportion of the negative element present. These divisions with the groups belonging to them are as follows:

### A. Basic Division

#### B. Monosulphides, Monotellurides, etc., $R_2S$ , $RS$ , etc.

1. *Galena Group.* Isometric-normal.
2. *Chalcocite Group.* Orthorhombic.
3. *Sphalerite Group.* Isometric-tetrahedral.
4. *Cinnabar — Wurtzite — Millerite Group.* Hexagonal and rhombohedral.

### C. Intermediate Division

Embraces Melonite,  $Te_2S_3$ ; Bornite,  $5Cu_2S.Fe_2S_3$ ; Linnæite,  $CoS.Co_2S_3$ ; Chalcopyrite,  $Cu_2S.Fe_2S_3$ ; etc.

#### {D. Disulphides, Diarsenides, etc., $RS_2$ , $RAs_2$ , etc.

1. *Pyrite Group.* Isometric-pyritohedral.
2. *Marcasite Group.* Orthorhombic.

### A. Basic Division

The basic division embraces several rare basic compounds of silver, copper or nickel chiefly with antimony and arsenic. Of these the crystallization of dyscrasite and maucherite only is known.

#### DYSCRASITE.

Orthorhombic. Axes  $a : b : c = 0.5775 : 1 : 0.6718$ . Crystals rare, pseudohexagonal in angles ( $mm''$ ,  $110 \wedge 1\bar{1}0 = 60^\circ 1'$ ) and by twinning. Also massive. Fracture uneven. Sectile.  $H. = 3.5-4$ .  $G. = 9.44-9.85$ . Luster

metallic. Color and streak silver-white, inclining to tin-white; sometimes tarnished yellow or blackish. Opaque.

**Comp.** — A silver antimonide, including  $\text{Ag}_3\text{Sb} = \text{Antimony } 27.1$ , silver  $72.9 = 100$ , and  $\text{Ag}_6\text{Sb} = \text{Antimony } 15.7$ , silver  $84.3 = 100$ , and perhaps other compounds.

Analyses vary widely, some conforming also to  $\text{Ag}_2\text{Sb}$ ,  $\text{Ag}_4(\text{Sb},\text{As})_3$ , etc. By some authors classed with chalcocite.

**Pyr., etc.** B.B. on charcoal fuses (1.5) to a globule, coating the coal with white antimony trioxide and finally giving a globule of almost pure silver. Soluble in nitric acid, leaving antimony trioxide.

**Obs.** — Occurs near Wolfach, Baden; Andreasberg in the Harz Mts., Germany; Allemont, France. Noted at Cobalt, Ontario, Canada. Also from Mexico and Chile. Named from *δυσκρασις*, a bad alloy.

**HUNTILITE, ANIMIKITE.** The ores from Silver Islet, Lake Superior, apparently contain a silver arsenide (*huntilite*,  $\text{Ag}_3\text{As}?$ ) and perhaps also a silver antimonide (*animikite*,  $\text{Ag}_3\text{Sb}?$ ), the latter probably a mixture.

**Horsfordite.** A silver-white, massive copper antimonide, probably  $\text{Cu}_6\text{Sb}$  (Sb 24 p. c.). G. = 8.8. Asia Minor, near Mytilene.

**Domeykite.** — Copper arsenide,  $\text{Cu}_3\text{As}$ . Reniform and botryoidal; also massive, disseminated. G. = 7.2-7.75. Luster metallic. Color tin-white to steel-gray, readily tarnished. From several Chilean mines; also Zwickau, Saxony. In North America, with niccolite at Michipicoten Island, Lake Superior. Microscopic examination shows this mineral to be an intimate mixture of two unknown constituents. Usually identical with algodonite.

**Mohawkite.** — Like domeykite,  $\text{Cu}_3\text{As}$ , with Ni and Co. Massive, fine granular to compact. Color gray with faint yellow tinge; tarnishes to dull purple. H. = 3.5. Brittle. G. = 8.07. Microscopic examination shows it to be a mixture. From Mohawk mine, Keweenaw Co., Mich. *Ledouxite* from the Mohawk mine said to be  $\text{Cu}_4\text{As}$  has been shown to be a mixture.

**Algodonite.** Copper arsenide,  $\text{Cu}_6\text{As}$  (As 16.5 p. c.); G. = 7.62. Resembles domeykite. From Chile; also Lake Superior. Microscopic examination shows this mineral to be a mixture of two constituents.

**Whitneyite.** Copper arsenide,  $\text{Cu}_9\text{As}$  (As 11.6 p. c.). G. = 8.4-8.6. Color pale reddish white. From Houghton Co., Mich.; Sonora, Lower California.

**Chilenite.** Perhaps  $\text{Ag}_5\text{Bi}$ . Copiapo, Chile.

**COCINERITE.** Copper, silver sulphide,  $\text{Cu}_4\text{AgS}$ . Massive. Color silver-gray, tarnishing black, H = 2.5. G. = 6.1. From Cocinera mine, Ramos, San Luis Potosi, Mexico.

**Stützite.** A rare silver telluride ( $\text{Ag}_4\text{Te}?$ ). Probably from Nagyág, Transylvania.

**Rickardite.**  $\text{Cu}_4\text{Te}_3$ . Massive. H. = 3.5. G. = 7.5. Color deep purple, dulling on exposure. Fusible. Found at Vulcan, Col.

**Maucherite.**  $\text{Ni}_3\text{As}_2$ . Tetragonal. Habit, square tabular. H. = 5. G. = 7.83. Color reddish silver-white tarnishing to gray copper-red. Streak blackish gray. Easily fusible. From Eisleben, Thuringia. The furnace product, *placodine*, is identical with *maucherite*.

## B. Monosulphides, Monotellurides, etc., $\overset{\text{I}}{\text{R}}_2\text{S}$ , $\overset{\text{II}}{\text{RS}}$ , ETC.

|                     |   |                         |                   |                                   |
|---------------------|---|-------------------------|-------------------|-----------------------------------|
|                     |   | <b>1. Galena Group.</b> | Isometric.        |                                   |
| <b>Galena</b>       | PbS   |                         | <b>Argentite</b>  | $\text{Ag}_2\text{S}$             |
| Also,               | $(\text{Pb},\text{Cu}_2)\text{S}$ , $(\text{Cu}_2,\text{Pb})\text{S}$ |                         | Jalpaite          | $(\text{Ag},\text{Cu})_2\text{S}$ |
| <b>Altaite</b>      | PbTe  |                         | <b>Hessite</b>    | $\text{Ag}_2\text{Te}$            |
| <b>Clausthalite</b> | PbSe  |                         | <b>Aguilarite</b> | $\text{Ag}_2\text{Se}$            |
| <b>Naumannite</b>   | $(\text{Ag}_2,\text{Pb})\text{Se}$                                    |                         |                   |                                   |

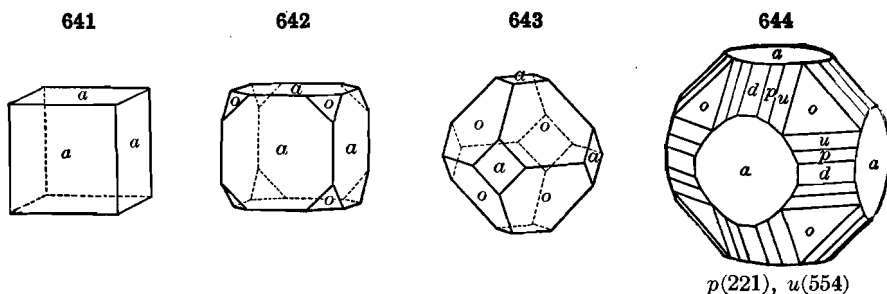
The following, known only in massive form, probably also belong here:

|                     |   |                   |   |
|---------------------|---|-------------------|---|
| <b>Berzelianite</b> | $\text{Cu}_2\text{Se}$                      | <b>Zorgite</b>    | $(\text{Pb},\text{Cu}_2,\text{Ag}_2)\text{Se}?$ |
| <b>Lehrbachite</b>  | $(\text{Pb},\text{Hg}_2)\text{Se}$          | <b>Crookesite</b> | $(\text{Cu},\text{Tl},\text{Ag})_2\text{Se}$    |
| <b>Eucairite</b>    | $\text{Cu}_2\text{Se}.\text{Ag}_2\text{Se}$ |                   |   |

The GALENA GROUP embraces a number of monosulphides, etc., of the related metals, silver, copper, lead, and mercury. These crystallize in the normal class of the isometric system, and several show perfect cubic cleavage. These characters are most distinctly exhibited in the type species, galena.

**GALENA. GALENITE. Lead glance.**

Isometric. Commonly in cubes, or cubo-octahedrons, less often octahedral. Also in skeleton crystals, reticulated, tabular. Twins: tw. pl.  $o(111)$ , both contact- and penetration-twins (Figs. 401, 404, p. 165), sometimes repeated; twin crystals often tabular  $\parallel o$ . Also other tw. planes giving polysynthetic tw. lamellæ. Massive cleavable, coarse or fine granular, to impalpable; occasionally fibrous or plumose.



Cleavage: cubic, highly perfect; less often octahedral. Fracture flat subconchoidal or even.  $H. = 2.5-2.75$ .  $G. = 7.4-7.6$ . Luster metallic. Color and streak pure lead-gray. Opaque.

**Comp.** — Lead sulphide,  $PbS = \text{Sulphur } 13.4, \text{ lead } 86.6 = 100$ . Often contains silver, and occasionally selenium, zinc, cadmium, antimony, bismuth, copper, as sulphides; besides, also, sometimes native silver and gold.

**Var.** — 1. *Ordinary*. (a) Crystallized; (b) somewhat fibrous and plumose; (c) cleavable, granular coarse or fine; (d) crypto-crystalline. The variety with octahedral cleavage is rare; in it the usual cubic cleavage is obtained readily after heating to  $200^\circ$  or  $300^\circ$ ; the peculiar cleavage may be connected with the bismuth usually present. One variety showing octahedral cleavage contained a small amount of tellurium.

2. *Argentiferous*. All galena is more or less argentiferous, and no external characters serve to distinguish the kinds that are much so from those that are not. The silver is detected by cupellation, and may amount from a few thousandths of one per cent to one per cent or more; when mined for silver it ranks as a *silver ore*.

3. Containing arsenic, or antimony, or a compound of these metals, as impurity. Here belong *bleischweif* from Claustal, Harz Mts., with  $0.22 \text{ Sb}$ , and *steinmannite* from Pibram, Bohemia, with both arsenic and antimony.

**Pyr.** — In the open tube gives sulphurous fumes. B.B. on charcoal fuses, emits sulphurous fumes, coats the coal yellow near the assay ( $PbO$ ) and white with a bluish border at a distance ( $PbSO_3$ , chiefly), and yields a globule of metallic lead. Decomposed by strong nitric acid with the separation of some sulphur and the formation of lead sulphate.

**Diff.** — Distinguished, except in very fine granular varieties, by its cubic cleavage; the color and the high specific gravity are characteristic; also the blowpipe reactions.

**Micro.** — In polished section shows white color with smooth surface usually showing triangular pits. With  $HNO_3$  blackens; with  $FeCl_3$  becomes bright, iridescent.

**Artif.** — Crystallized galena has been formed in numerous ways. In nature it is apparently commonly formed by hydrochemical reactions perhaps similar to the following laboratory methods: galena was produced by allowing a mixture of lead chloride, sodium bicarbonate and a solution of hydrogen sulphide to remain in a sealed tube for several months.

Pyrite or marcasite heated with a solution of lead chloride will produce galena; a solution of lead nitrate when heated with ammonium sulphhydrate will yield galena. Galena is frequently observed in furnace slags.

**Obs.** — One of the most widely distributed of the metallic sulphides. Occurs in beds and veins, both in crystalline and uncrystalline rocks. Very commonly found together with zinc ores in connection with limestone rocks. It is often associated with pyrite, marcasite, sphalerite, chalcocopyrite, arsenopyrite, etc., in a gangue of quartz, calcite, barite or fluorite, etc.; also with cerussite, anglesite, and other salts of lead, which are frequent results of its alteration. It is also common with gold, and in veins of silver ores.

A few of the notable localities at which galena has been found are as follows:

At Freiberg in Saxony in veins in gneiss; at Claustal and Neudorf, etc., in the Harz Mts., and at Pfibram in Bohemia, it forms veins in clay slate; similarly in Styria; in limestone at Bleiberg, Carinthia; in Silesia, Prussia; at Gonderbach near Laasphe, Westphalia; at Schemnitz, Kapnik, etc., Hungary; Joachimstal, Bohemia; at Poullaouen and Huelgoet, Brittany, France; in Moresnet district in Belgium; in province of Cagliari, Sardinia; in Spain, in granite at Linares, also in Catalonia, Grenada, and elsewhere; in veins through the graywacke of Leadhill, Scotland, and the contact hornstones of Cornwall; filling cavities in the limestone of Derbyshire, Cumberland, and the northern districts of England, associated with calcite, dolomite, fluorite, barite, witherite, calamine and sphalerite; in many places in Australia, Chile, Bolivia, Peru, etc.

Extensive deposits of this ore in the United States exist in Missouri, Illinois, Iowa, and Wisconsin. The ore occurs usually filling cavities or chambers in stratified limestone, of different periods, from Silurian to Carboniferous. It is associated with sphalerite, smithsonite, calcite, pyrite, etc. The Missouri mines are situated in three districts in the southern part of the state, (1) Southeastern, chiefly in St. Francis, Washington and Madison counties, (2) Central, (3) Southwestern or Joplin district, the latter producing chiefly zinc. Other districts in the upper Mississippi Valley are found in southwestern Wis., eastern Iowa and northwestern Ill. Also occurs in N. Y., at Rossie, St. Lawrence Co., in crystals with calcite and chalcocopyrite; in Pa., at Phoenixville and elsewhere. In Col., at Leadville and Aspen, there are productive mines of argentiferous galena, also at Georgetown, the San Juan district and elsewhere. Mined for silver in the Cur d'Alene region in Idaho; at the Park City and Tintic districts in Utah.

The name galena is from the Latin *galena* ( $\gamma\alpha\lambda\acute{\eta}\eta$ ), a name given to lead ore or the dross from melted lead.

**Use.** — The most important ore of lead and frequently a valuable ore of silver.

**CYPROPLUMBITE.** A massive mineral, from Chile, varying in characters from galena to those of chalcocite and covellite; composition,  $\text{Cu}_2\text{S}\cdot 2\text{PbS}$ (?). Material classed here from Butte, Mon., gave formula,  $5\text{Cu}_2\text{S}\cdot \text{PbS}$ . *Alisonite* is massive, deep indigo-blue quickly tarnishing; corresponds to  $3\text{Cu}_2\text{S}\cdot \text{PbS}$ . From Mina Grande, Chile. Whether these and similar minerals represent definite homogeneous compounds, or only ill-defined alteration-products, is uncertain, and if so it is not clear whether they should be classed with isometric galena or with orthorhombic chalcocite.

**Altaite.** Lead telluride,  $\text{PbTe}$ . Rarely in cubic or octahedral crystals, usually massive with cubic cleavage.  $G. = 8.16$ . Color tin-white, with yellowish tinge tarnishing to bronze-yellow. From the Altai Mts., with hessite; Coquimbo, Chile; Cal., Col., British Columbia.

**Clausthalite.** Lead selenide,  $\text{PbSe}$ . Commonly in fine granular masses resembling galena. Cleavage: cubic.  $G. = 7.6-8.8$ . Color lead-gray, somewhat bluish. From Claustal, Harz Mts., Germany; Cacheuta mine, Mendoza River, Argentina. *Tilkerodite* is a cobaltiferous variety.

**Naumannite.** — Silver-lead telluride  $(\text{Ag}_2\text{Pb})\text{Se}$ . In cubic crystals; also massive, granular, in thin plates. Cleavage: cubic.  $G. = 8.0$ . Color and streak iron-black. From Tilkerode in the Harz Mts., Germany.

**ARGENTITE.** Silver Glance.

Isometric. Crystals often octahedral, also cubic; often distorted, frequently grouped in reticulated or arborescent forms; also filiform. Massive; embedded; as a coating.

Cleavage:  $a(100)$ ,  $d(110)$  in traces. Fracture small subconchoidal. Perfectly sectile.  $H. = 2-2.5$ .  $G. = 7.20-7.36$ . Luster metallic. Color and streak blackish lead-gray; streak shining. Opaque.

**Comp.** — Silver sulphide,  $\text{Ag}_2\text{S} = \text{Sulphur } 12.9, \text{ silver } 87.1 = 100$ .



**Pyr., etc.** In the open tube gives off sulphurous fumes. B.B. on charcoal fuses with intumescence in O.F., emitting sulphurous fumes, and yielding a globule of silver.

**Diff.** — Distinguished from other sulphides by being readily cut with a knife; also by yielding metallic silver on charcoal.

**Micro.** — In polished section shows grayish white color with a smooth surface which is easily scratched. Turns brown with  $\text{HNO}_3$ , KCN and  $\text{FeCl}_3$ ; with conc. HCl tarnished iridescent by fumes and blackened by acid.

**Artif.** — Argentite is very easily prepared artificially and in numerous ways. Sulphur, sulphur dioxide or hydrogen sulphide will act upon metallic silver or any of its common compounds, either in solution or as solids, to produce silver sulphide.

**Obs.** — Found at Freiberg, etc., Saxony; Andreasberg, Harz Mts., Germany; Schemnitz, Hungary; Joachimstal, Bohemia; Kongsberg, Norway; Sardinia. In South America at silver mines in Chile, Peru and Bolivia. In Mexico in the states of Chihuahua, Guanajuato, etc. Important ore at Comstock Lode, Tonapah, etc., Nev.; Aspen, Leadville, etc. Col. Found at Port Arthur on north shore of Lake Superior.

**Use.** — An important ore of silver.

JALPAITE is a cupriferos argentite from Jalpa, Mexico.

**Hessite.** — Silver telluride,  $\text{Ag}_2\text{Te}$ . Isometric. Usually massive, compact or fine-grained. Cleavage indistinct. Somewhat sectile. H. = 2.5–3. G. = 8.31–8.45. Color between lead-gray and steel-gray. From the Altai Mts.; at Nagyág, Bótes and Rézbánya in Transylvania; Chile near Arqueros, Coquimbo. In Mexico at San Sebastian, Jalisco. In the United States, Calaveras Co., Cal.; Boulder Co., Col.; Utah. This species also often contains gold and thus graduates toward petzite.

**Petzite.** —  $(\text{Ag},\text{Au})_2\text{Te}$  with Ag : Au = 3 : 1. Massive; granular to compact. Slightly sectile to brittle. H. = 2.5–3. G. = 8.7–9.02. Color steel-gray to iron-black; tarnishing. From Nagyág, Transylvania; Kalgoorlie, West Australia; Yale District, British Columbia; Col.; Poverty Hill, Tuolumne Co., and elsewhere, Cal.

**Aguilarite.** Silver selenide,  $\text{Ag}_2\text{S}$  and  $\text{Ag}_2(\text{S},\text{Se})$ . In skeleton dodecahedral crystals. Sectile. G. = 7.586. Color iron-black. From Guanajuato, Mexico.

**Berzelianite.** Copper selenide,  $\text{Cu}_2\text{Se}$ . In thin dendritic crusts and disseminated. G. = 6.71. Color silver-white, tarnishing. From Skrikerum, Sweden; Lehrbach, in the Harz Mts., Germany.

**Lehrbachite.** Selenide of lead and mercury,  $\text{PbSe}$  with  $\text{HgSe}$ . Massive, granular. G. = 7.8. Color lead-gray to iron-black. From Lehrbach, in the Harz Mts., Germany.

**Eucairite.**  $\text{Cu}_2\text{Se}, \text{Ag}_3\text{Se}$ . Massive, granular. G. = 7.50. Color between silver-white and lead-gray. From the Skrikerum copper mine, Sweden; also Chile.

**Zorgite.** — Selenide of lead and copper in varying amounts. Perhaps a mixture. Massive, granular. G. = 7–7.5. Color dark or light lead-gray. From the Harz Mts., Germany; Cacheuta, Argentina.

**Crookesite.** Selenide of copper and thallium, also silver (1–5 p. c.),  $(\text{Cu},\text{Tl},\text{Ag})_2\text{Se}$ . Massive, compact. G. = 6.9. Luster metallic. Color lead-gray. From the mine of Skrikerum, Sweden.

**Umangite.**  $\text{CuSe}, \text{Cu}_2\text{Se}$ . Massive, fine-granular to compact. H. = 3. G. = 5.620. Color dark cherry-red. From La Rioja, Argentina.

## 2. Chalcocite Group

|                     |  | <i>a</i> : <i>b</i> : <i>c</i> |
|---------------------|--|--------------------------------|
| <b>Chalcocite</b>   | $\text{Cu}_2\text{S}$                        | 0.5822 : 1 : 0.9701            |
| <b>Stromeyerite</b> | $\text{Ag}_2\text{S}, \text{Cu}_2\text{S}$   | 0.5822 : 1 : 0.9668            |
| <b>Sternbergite</b> | $\text{Ag}_2\text{S}, \text{Fe}_4\text{S}_5$ | 0.5832 : 1 : 0.8391            |
| Frieseite           |  | 0.5970 : 1 : 0.7352            |
| <b>Acanthite</b>    | $\text{Ag}_2\text{S}$                        | 0.6886 : 1 : 0.9944            |

The species of the CHALCOCITE GROUP crystallize in the orthorhombic system with a prismatic angle approximating to  $60^\circ$ ; they are hence pseudo-hexagonal in form, especially when twinned. The group is parallel to the Galena Group, since  $\text{Cu}_2\text{S}$  appears in isometric form in cuproplumbite and  $\text{Ag}_2\text{S}$  also in argentite. Some authors include dyscrasite here (see p. 361).

**CHALCOCITE.** Copper Glance. Redruthite.

Orthorhombic. Axes  $a : b : c = 0.5822 : 1 : 0.9701$ .

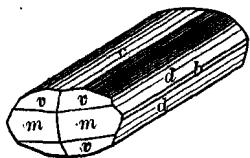
$$mm''', 110 \wedge \bar{1}\bar{1}0 = 60^\circ 25'$$

$$dd', (021) \wedge 0\bar{2}1 = 125^\circ 28'$$

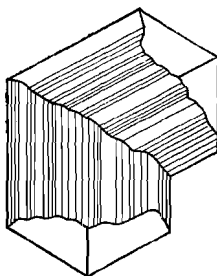
$$cp, 001 \wedge 111 = 62^\circ 35\frac{1}{2}'$$

$$pp''', 111 \wedge \bar{1}\bar{1}1 = 53^\circ 3\frac{1}{2}'$$

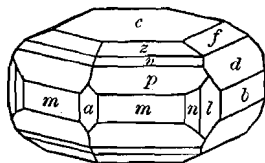
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Crystals pseudo-hexagonal in angle, also by twinning (tw. pl.  $m(110)$ ). Often massive, structure granular to compact and impalpable.

Cleavage:  $m(110)$  indistinct; etching of orientated crystals develops cleavages parallel to the three pinacoids. Fracture conchoidal. Rather sectile.  $H. = 2.5-3$ .  $G. = 5.5-5.8$ . Luster metallic. Color and streak blackish lead-gray, often tarnished blue or green, dull. Opaque.

**Comp.** — Cuprous sulphide,  $Cu_2S =$  Sulphur 20.2, copper 79.8 = 100. Sometimes iron in small amount is present, also silver.

**Pyr., etc.** — In the open tube gives sulphurous fumes. B.B. on charcoal melts to a globule, which boils with spitting; the fine powder roasted at a low temperature on charcoal, then heated in R.F., yields a globule of metallic copper. Soluble in nitric acid.

**Diff.** — Resembles argentite but much more brittle; bornite has a different color on the fresh fracture and becomes magnetic B.B.

**Micro.** — In polished section shows grayish or bluish white color with smooth surface. With  $HNO_3$  effervesces and etches, turning more or less blue, and develops cleavage directions; with KCN blackens and etches.

**Artif.** — Chalcocite has been prepared artificially by heating the vapors of cuprous chloride and hydrogen sulphide or by the treatment of cupric oxide with hydrogen sulphide; also by the heating of cupric solutions with ammonium sulphocyanate in a sealed tube.

**Obs.** — Chalcocite is an important ore of copper. It is usually secondary in its origin, being found in the upper, enriched portions of copper veins. It is commonly associated with chalcopyrite, bornite, pyrite, cuprite, malachite, azurite, etc.

Cornwall affords splendid crystals, especially the districts of Saint Just, Camborne, and Redruth (*redruthite*). Occurs at Joachimstal, Bohemia; Tellemarken, Norway; compact and massive varieties in Siberia; Saxony; Mte. Catini mines in Tuscany; Mexico; South America.

In the United States, Bristol, Conn., has afforded large and brilliant crystals; also found at Simsbury and Cheshire; at Schuyler's mines, N. J.; in Nev., in Washoe, Humboldt, Churchill and Nye counties; at Clifton, Ariz.; in Mon., massive at Butte in great amounts. Notable deposit at Kennecott, Copper River District, Alaska. Found in Canada, with chalcopyrite and bornite at the Acton mines and elsewhere in the province of Quebec.

**Use.** — An important ore of copper.

**Stromeyerite.**  $(Ag,Cu)_2S$ , or  $Ag_2S.Cu_2S$ . Rarely in orthorhombic crystals, often twinned. Commonly massive, compact.  $H. = 2.5-3$ .  $G. = 6.15-6.3$ . Luster metallic. Color and streak dark steel-gray. From the Zmeinogorsk mine, Siberia; Silesia; also Chile, Zacatecas, Mexico; Cobalt, Ontario; the Heintzelman mine in Ariz.; Col.

**Chalmersite.**  $Cu_2S.Fe_4S_8$ . Orthorhombic. Axial ratio near that of chalcocite. In thin elongated prisms vertically striated. Twins common with  $m(110)$  as tw. pl. resembling chalcocite.  $H. = 3.5$ .  $G. = 4.7$ . Color brass- to bronze-yellow. Strongly magnetic. From the Morro Velho gold mine, Minas Geraes, Brazil.

**STERNBERGITE**

Orthorhombic. Crystals tabular ||  $c(001)$ . Commonly in fan-like aggregations; twins, tw. pl.  $m(110)$ . Cleavage:  $c(001)$ , highly perfect. Thin laminæ flexible, like tin-foil.  $H. = 1-1.5$ .  $G. = 4.215$ . Luster metallic. Color pinchbeck-brown. Streak black. Opaque.

**Comp.** —  $AgFe_2S_3$  or  $Ag_2S.Fe_4S_5$  = Sulphur 30.4, silver 34.2, iron 35.4 = 100.

**Obs.** — Occurs with pyrargyrite and stephanite at Joachimstal, Bohemia, and Johanngeorgenstadt, Saxony.

**FRIESEITE.** Near sternbergite. In thick tabular crystals.  $H. = 2.5$ ;  $G. = 4.22$ . Color dark gray. Composition  $Ag_3FeS_8$ . Occurs with marcasite at Joachimstal, Bohemia.

**Acanthite.** Silver sulphide,  $Ag_2S$ , like argentite. In slender prismatic crystals (orthorhombic). Sectile.  $G. = 7.2-7.3$ . Color iron-black. Occurs at Joachimstal, Bohemia; also at Freiberg and Schneeberg, Saxony; at Rico, Col.

It has been suggested that acanthite may be only argentite in distorted isometric crystals.

**Sphalerite Group.** RS. Isometric-tetrahedral

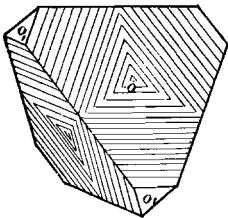
|                        |          |                    |          |         |
|------------------------|----------|--------------------|----------|---------|
| <b>Sphalerite</b>      | ZnS      | <b>Onofrite</b>    | Hg(S,Se) |         |
| <b>Metacinnabarite</b> | HgS      | <b>Alabandite</b>  | MnS      |         |
| Guadalcazarite         | (Hg,Zn)S | <b>Coloradoite</b> | HgTe     | Massive |
| <b>Tiemannite</b>      | HgSe     |                    |          |         |

The SPHALERITE GROUP embraces a number of sulphides, selenides, etc., of zinc, mercury, and manganese. These are isometric-tetrahedral in crystallization.

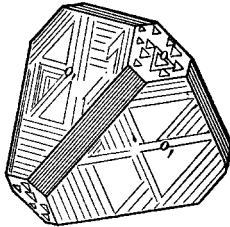
**SPHALERITE, ZINC BLENDE or BLENDE.** Black-Jack, Mock-Lead, False Galena.

Isometric-tetrahedral. Often in tetrahedrons. Twins common: tw. pl.

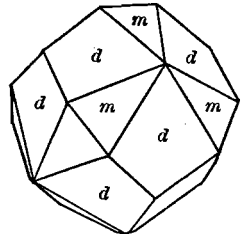
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$m = (311)$

$o(111)$ ; twinning often repeated, sometimes as polysynthetic lamellæ. Commonly massive cleavable, coarse to fine granular and compact; also foliated, sometimes fibrous and radiated or plumose; also botryoidal and other imitative shapes. Cryptocrystalline to amorphous, the latter sometimes as a powder.

Cleavage: dodecahedral, highly perfect. Fracture conchoidal. Brittle.  $H. = 3.5-4$ .  $G. = 3.9-4.1$ ; 4.063 white, N. J. Luster resinous to adamantine. Color commonly yellow, brown, black; also red, green to white, and when pure nearly colorless. Streak brownish to light yellow and white. Transparent to translucent. Refractive index high:  $n = 2.3692$ .

**Comp.** — Zinc sulphide,  $ZnS$  = Sulphur 33, zinc 67 = 100. Often containing iron and manganese, and sometimes cadmium, mercury and rarely lead

and tin. Also sometimes contains traces of indium, gallium and thallium; may be argentiferous and auriferous.

**Var. — 1. Ordinary.** Containing little or no iron; from colorless white to yellowish brown, sometimes green;  $G. = 4.0-4.1$ . The red or reddish brown transparent crystallized kinds are sometimes called *ruby blende* or *ruby zinc*. The massive cleavable forms are the most common, varying from coarse to fine granular; also cryptocrystalline. *Schalenblende* is a closely compact variety, of a pale liver-brown color, in concentric layers with reniform surface; galena and marcasite are often interstratified. The fibrous forms are chiefly wurtzite. A soft white amorphous form of zinc sulphide occurs in Cherokee Co., Kan.

**2. Ferriferous: Marmatite.** Containing 10 p. c. or more of iron; dark-brown to black;  $G. = 3.9-4.05$ . The proportion of FeS to ZnS varies from 1 : 5 to 1 : 2, and the last ratio is that of the *christophite* of Breithaupt, a brilliant black sphalerite from St. Christophe mine, at Breitenbrunn, having  $G. = 3.91-3.923$ .

**3. Cadmiferous: Příbramite, Przibramite.** The amount of cadmium present in any sphalerite thus far analyzed is less than 5 per cent.

**Pyr., etc. —** Difficultly fusible. In the open tube sulphurous fumes, and generally changes color. B.B. on charcoal, in R.F., gives a coating of zinc oxide, which is yellow while hot and white after cooling. If cadmium is present a reddish brown coating of cadmium oxide will form first. With cobalt solution the zinc oxide coating gives a green color when heated in O.F. Most varieties, after roasting, give with borax a reaction for iron. Dissolves in hydrochloric acid with evolution of hydrogen sulphide.

**Diff. —** Varies widely in color and appearance, but distinguished by the resinous luster in all but deep black varieties; usually exhibits distinct cleavage; nearly infusible B.B.; yields a zinc oxide coating on charcoal.

**Micro. —** In polished section shows a gray color with smooth surface. Transparent, yellow to brown with oblique illumination. With  $HNO_3$  becomes slowly brown, often showing crystal structure; with aqua regia effervesces and blackens.

**Artif. —** Sphalerite has been artificially formed by heating zinc solutions in hydrogen sulphide inclosed in a sealed tube; also by passing hydrogen sulphide over heated zinc chloride.

**Obs. —** Sphalerite is the most important ore of zinc. It occurs in both crystalline and sedimentary rocks, being especially common in the limestones, where it often occurs as beds of considerable size. It is frequently associated with galena, also with chalcopyrite, pyrite, barite, fluorite, siderite, etc. Commonly found with silver ores. Of the two forms of zinc sulphide, sphalerite is the form which crystallizes below  $1020^\circ$  while wurtzite is deposited at higher temperatures. Zinc sulphide is deposited from alkaline solutions as sphalerite; from acid solutions both forms are deposited, the amount of sphalerite increasing with the temperature while that of wurtzite increases with the acidity of the solution.

Some of the chief localities for crystallized sphalerite are: Alston Moor in Cumberland and at St. Agnes and elsewhere in Cornwall, England; Andreasberg and Neudorf in the Harz Mts., Freiberg, and other localities in Saxony; Příbram, and Schlackenwald in Bohemia; Kapnik, Schemnitz and Felsőbánya, in Hungary; Nagyág and Rodna in Transylvania; the Binnental in Switzerland, isolated crystals of great beauty, yellow to brown, in cavities of dolomite. A beautiful transparent variety yielding large cleavage masses is brought from Picos de Europa, Santander, Spain, where it occurs in a brown limestone. A similar variety with golden brown to green colors from Chivera mine, Cannanea, Mexico. Large crystals from Ani copper mines, Ugo, Japan. Fibrous varieties (see wurtzite) are obtained at Příbram; Geroldseck in Baden; Raibl, Carinthia; also in Cornwall. The original *marmatite* is from Marmato near Popayan, Italy.

The important zinc ore districts of the United States in which sphalerite is the chief zinc mineral are found in Missouri, Colorado, Montana, Wisconsin, Idaho and Kansas. Some localities noteworthy for the specimens they have produced are as follows: In Conn., at Roxbury. In N. J., a *white* variety (*cleiophane*) at Franklin Furnace. In Pa., at the Wheatley and Perkiomen lead mines, in crystals; near Friedensville, Lehigh Co., a grayish waxy variety. In Ill., near Rosiclare, with galena and calcite; at Marsden' diggings, near Galena, in stalactites, with crystallized marcasite, and galena; at Warsaw. In Wis., at Mineral Point, in fine crystals. In Ohio, at Tiffin. In Mo., in beautiful crystallizations with galena, marcasite and calcite at Joplin and other points in the southwestern part of the state; the deposits here occur in limestone and are of great extent and value; also in adjoining parts of Kan. In Col., at many places.

Named *blende* because, while often resembling galena, it yielded no lead, the word in German meaning *blind* or *deceiving*. *Sphalerite* is from  $\sigma\phi\alpha\lambda\epsilon\pi\omicron\varsigma$ , *teacherous*.

**Use. —** The most important ore of zinc.

**Metacinnabarite.** Mercuric sulphide, HgS. In composition like cinnabar, but occurs in black tetrahedral crystals; also massive. G. = 7.7. In Cal., from the Reddington mine, Lake county, with cinnabar, quartz and marcasite; and from San Joaquin, Orange Co. Found also at Idria in Austria.

**Guadalcazarite.** Near metacinnabarite, but contains zinc (up to 4 p. c.). Guadalcazar, Mexico. Probably a mixture.

**Tiemannite.** Mercuric selenide, HgSe. Isometric-tetrahedral. Commonly massive; compact. G. = 8.19 Utah; 8.30-8.47 Claustal. Luster metallic. Color steel-gray to blackish lead-gray. Streak nearly black. Occurs at Claustal in the Harz Mts.; Cal., in the vicinity of Clear lake; Marysvale, Piute Co., Utah.

**Onofrite.** Hg(S,Se) with Se = 4.5 to 6.5 p. c. San Onofre, Mexico; Marysvale, Utah.

**Coloradoite.** Mercuric telluride, HgTe. Massive. Conchoidal fracture. H. = 2.5. G. = 8.07 (Kalgoorlie). Color iron-black. Originally found sparingly in Colorado. Rather abundant at the Kalgoorlie district, West Australia. Material called *kalgoorlite* is a mixture of coloradoite and petzite.

**Alabandite.** Manganese sulphide, MnS. Isometric-tetrahedral; usually granular massive. Cleavage: cubic, perfect. G. = 3.95-4.04. Luster submetallic. Color iron-black. Streak green. Occurs at Nagyág, Transylvania; Kapnik, Hungary; Mexico; Peru; crystallized and massive on Snake River, Summit county, Col.; Tombstone, Ariz.

**Oldhamite.** Calcium sulphide, CaS. In pale brown spherules with cubic cleavage in the Busti meteorite. Also noted in Allegan meteorite.

**PENTLANDITE.**

Isometric. Massive, granular. Cleavage: octahedral. Fracture uneven. Brittle. H. = 3.5-4. G. = 5.0. Luster metallic. Color light bronze-yellow. Streak light bronze-brown. Opaque. Not magnetic.

**Comp.** — A sulphide of iron and nickel, (Fe,Ni)S. In part, 2FeS.NiS = Sulphur 36.0, iron 42.0, nickel 22.0 = 100.

**Obs.** — Occurs with chalcopyrite near Lillehammer, Norway. Also from Sudbury, Ontario, where it is intimately associated with nickeliferous pyrrhotite. It can be distinguished from the latter by its cleavage.

**4. Cinnabar-Wurtzite-Millerite Group.** Rhombohedral or Hexagonal

|               |   |                            |                     |                        |
|---------------|---|----------------------------|---------------------|------------------------|
| Cinnabar      | HgS                                     | Rhombohedral-Trapezohedral | <sup>c</sup> 1.1453 |                        |
| Covellite     | CuS                                     |                            | 1.1466              |                        |
| Greenockite   | CdS                                     | Hexagonal-Hemimorphic      | <sup>c</sup> 0.8109 | or <sup>c</sup> 0.9364 |
| Wurtzite      | ZnS                                     | "                          | 0.8175              | 0.9440                 |
| Millerite     | NiS                                     | Rhombohedral               |                     | 0.9883                 |
| Niccolite     | NiAs                                    | "                          | 0.8194              | 0.9462                 |
| Breithauptite | NiSb                                    | "                          | 0.8586              | 0.9915                 |
| Arite         | Ni(Sb,As)                               |                            |                     |                        |
| Pyrrhotite    | Fe <sub>11</sub> S <sub>12</sub> , etc. | Hexagonal                  | 0.8701              | 1.0047                 |
| Troilite      | FeS                                     |                            |                     |                        |

This fourth group among the monosulphides includes several subdivisions, as shown in the scheme above, and the relations of the species are not in all cases perfectly clear. It is to be noted that the sulphides of mercury and zinc, already represented in the sphalerite group, appear here again.

If, as suggested by Groth, the prominent pyramids of wurtzite, greenockite, etc., be made pyramids of the second series (e.g.,  $x = 1122$ , instead of 1011), then the values of  $c$  in the second column are obtained, which correspond to millerite. The form of several of these species, however, is only imperfectly known. A rhombohedral form for greenockite has been suggested.

**CINNABAR.**

Rhombohedral-trapezohedral. Axis  $c = 1.1453$ .

$$rr', 1011 \wedge \bar{1}011 = 87^\circ 23'.$$

$$ii', 4045 \wedge \bar{4}045 = 78^\circ 0\frac{1}{2}'.$$

$$cr, 0001 \wedge 1\bar{0}\bar{1}1 = 52^\circ 54'.$$

Crystals usually rhombohedral or thick tabular in habit, rarely showing trapezohedral faces; in rhombohedral penetration twins; also acicular prismatic. In crystalline incrustations, granular, massive; sometimes as an earthy coating.

Cleavage:  $m(10\bar{1}0)$  perfect. Fracture subconchoidal, uneven. Somewhat sectile.  $H. = 2-2.5$ .  $G. = 8.0-8.2$ . Luster adamantine, inclining to metallic when dark-colored, and to dull in friable varieties. Color cochineal-red, often inclining to brownish red and lead-gray. Streak scarlet. Transparent to opaque. Optically +. Indices:  $\omega_r = 2.82$ ,  $\epsilon_r = 3.14$ . See Art. 394.

**Var.** — 1. *Ordinary*: either (a) *crystallized*; (b) *massive, granular embedded or compact*; bright red to reddish brown in color; (c) *earthy* and bright red. 2. *Hepatic*. Of a liver-brown color, with sometimes a brownish streak, occasionally slaty in structure, though commonly granular or compact.

**Comp.** — Mercuric sulphide,  $HgS = \text{Sulphur } 13.8, \text{mercury } 86.2 = 100$ . Usually impure from the admixture of clay, iron oxide, bitumen.

**Pyr.** — In the closed tube alone a black sublimate of mercuric sulphide, but with sodium carbonate one of metallic mercury. Carefully heated in the open tube gives sulphurous fumes and metallic mercury, which condenses in minute globules on the cold walls of the tube. B.B. on charcoal wholly volatile, but only when quite free from gangue.

**Diff.** — Characterized by its color and vermilion streak, high specific gravity (reduced, however, by the gangue usually present), softness; also by the blowpipe characters (*e.g.*, in the closed tube). Resembles some varieties of hematite and cuprite.

**Artif.** — Cinnabar has been produced artificially by several methods which are, however, in general modifications of the two following types: (1) When the black mercury sulphide formed by the direct union of mercury and sulphur is sublimed, cinnabar is the product; (2) the black sulphide when treated with solutions of alkaline sulphides is converted into cinnabar. In general cinnabar is formed under alkaline conditions and metacinnabarite under acidic conditions.

**Obs.** — Cinnabar is the only common mineral of mercury and with rare exceptions constitutes the ore of the metal. It occurs in veins filling fissures and cavities in rocks which are commonly sedimentary in character, being often slates, shales, sandstones or limestones. While infrequently occurring in igneous rocks such rocks are commonly near by and are thought to have been the source of the metal. Cinnabar is deposited from hot alkaline solutions or as the result of solfataric action. Pyrite and marcasite, sulphides of copper, stibnite, realgar, gold, etc., are associated minerals; calcite, quartz or opal, also barite, fluorite, are gangue minerals; a bituminous mineral is common.

The most important European deposits are at Almaden in Spain, and at Idria in Carniola, where it is usually massive; also at Bakmut in southern Russia. Crystallized at Moschellandsberg and Wolfstein in the Palatinate and at the mines of Mt. Avala, near Belgrade, Servia; at Ripa in Tuscany; at Alsósajó, Hungary; in the Ural Mts., the Nerchinsk region in Transbaikalia; in large twinned rhombohedrons from Province of Kweichow, China; Japan; Mexico; Huancavelica, Peru; Chile.

In the United States forms extensive mines in Cal., the most important at New Almaden and the vicinity, in Santa Clara Co.; also at Altoona, Trinity Co.; it is now forming by solfataric action at Sulphur Bank, Cal., and Steamboat Springs, Nev.; has been found in southern Utah; important deposits occur in Brewster Co., Texas; also mined in Nev. and Ariz.

The name cinnabar is supposed to come from India, where it is applied to the red resin, dragon's blood. The native cinnabar of Theophrastus is true cinnabar; he speaks of its affording quicksilver. The Latin name of cinnabar, *minium*, is now given to red lead, a substance which was early used for adulterating cinnabar, and so got at last the name.

Only comparatively few localities have furnished the mineral in quantity.

**Use.** — The most important ore of mercury.

## COVELLITE.

Monoclinic? Pseudohexagonal through twinning. Crystals usually thin hexagonal plates. Often massive.

Cleavage: basal, perfect.  $H. = 1.5-2$ .  $G. = 4.6$ . Luster submetallic to resinous. Color indigo-blue or darker. Often shows fine purple color when moistened with water. Streak lead-gray to black. Opaque.

Comp. — Cupric sulphide,  $CuS = \text{Sulphur } 33.6, \text{ copper } 66.4 = 100$ .

**Pyr., etc.** — Fusible at 2.5 yielding sulphurous fumes. After roasting and moistening with hydrochloric acid gives azure-blue flame. Much sulphur in C.T.

**Micro.** — In polished section shows blue color with smooth surface. With KCN becomes instantly deep violet which rubs off, leaving a yellow coating and rough surface.

**Artif.** — Covellite has been prepared artificially by heating in sealed tubes a cupric solution with ammonium sulphocyanate and by heating sphalerite in a solution of copper sulphate.

**Obs.** — Covellite is a mineral of secondary origin found in the enriched portions of copper sulphide veins, associated with chalcocite, bornite, etc. Found in small amounts in many places. Noteworthy localities are as follows: various places in Germany; in exceptional crystals at Bor in Timoker Kreis, Servia; on the lavas of Vesuvius; in Chile; Province of Rikuchu, Japan. In the United States at the Butte district, Mon.; Summitville, Col.; La Sal district, Utah; Kennecott, Alaska, etc.

## GREENOCKITE.

Hexagonal-hemimorphic. Rarely in hemimorphic crystals; also as a coating.

Cleavage:  $a(11\bar{2}0)$  distinct,  $c(0001)$  imperfect. Fracture conchoidal. Brittle.  $H. = 3-3.5$ .  $G. = 4.9-5.0$ . Luster adamantine to resinous. Color honey-, citron-, or orange-yellow. Streak between orange-yellow and brick-red. Nearly transparent. Optically +.  $\omega = 2.506, \epsilon = 2.529$ .

Comp. — Cadmium sulphide,  $CdS = \text{Sulphur } 22.3, \text{ cadmium } 77.7 = 100$ .

**Pyr., etc.** — In the closed tube assumes a carmine-red color while hot, fading to the original yellow on cooling. In the open tube gives sulphurous fumes. B.B. on charcoal, either alone or with soda, gives in R.F. a reddish brown coating. Soluble in hydrochloric acid, affording hydrogen sulphide.

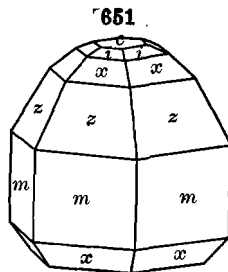
**Artif.** — Greenockite has been prepared artificially in several ways. Precipitated cadmium sulphide when fused with potassium carbonate and sulphur produced greenockite crystals; also when cadmium sulphate, calcium fluoride and barium sulphide were fused together. Greenockite is formed when cadmium oxide is heated in sulphur vapor.

**Obs.** — Occurs with prehnite at Bishopton, Renfrewshire, and elsewhere in Scotland. At Příbram in Bohemia, as a coating on sphalerite; similarly at other points; so too in the United States near Friedensville, Pa., and in the zinc region of southwestern Mo.; in Marion Co., Ark., it colors smithsonite bright yellow; noted at Franklin, N. J. Not uncommon as a furnace product.

**Use.** — An ore of cadmium.

**Wurtzite.** Zinc sulphide,  $ZnS$ , like sphalerite, but in hemimorphic hexagonal crystals; also fibrous and massive.  $G. = 3.98$ . Color brownish black. See under sphalerite, p. 368, for the conditions of its formation. From a silver-mine near Oruro in Bolivia; Portugal; at Mies, Bohemia; Peru. In crystals with sphalerite and quartz at the "Original Butte" mine, Butte, Mon. In crystals from Joplin, Mo.; from near Frisco, Beaver Co., Utah.

The massive fibrous forms of "Schalenblende" occur at Příbram, Bohemia; Liskeard, Cornwall, etc. Other forms, from Stolberg, Wiesloch, Altenberg, Germany, are in part wurtzite, in part sphalerite.



**MILLERITE.** Capillary Pyrites.

Rhombohedral. Usually in very slender to capillary crystals, often in delicate radiating groups; sometimes interwoven like a wad of hair. Also in columnar tufted coatings, partly semi-globular and radiated. The rhombohedron (01 $\bar{1}$ 2) is a gliding plane and artificial twins may be formed.

Cleavage perfect parallel to (10 $\bar{1}$ 1) and (01 $\bar{1}$ 2). Fracture uneven. Brittle; capillary crystals elastic. H. = 3-3.5. G. = 5.3-5.65. Luster metallic. Color brass-yellow, inclining to bronze-yellow, with often a gray iridescent tarnish. Streak greenish black.

**Comp.** — Nickel sulphide, NiS = Sulphur 35.3, nickel 64.7 = 100.

**Pyr., etc.** In the open tube sulphurous fumes. B.B. on charcoal fuses to a globule. When roasted, gives with borax and salt of phosphorus a violet bead in O.F., becoming gray in R.F. from reduced metallic nickel. On charcoal in R.F. the roasted mineral gives a coherent metallic mass, attractable by the magnet. Most varieties also show traces of copper, cobalt, and iron with the fluxes.

**Artif.** — Crystals of millerite have been formed artificially by treating under pressure a solution of nickel sulphate with hydrogen sulphide.

**Obs.** — Found at Joachimstal and Příbram in Bohemia; in Germany at Johanngeorgenstadt and Freiberg, Saxony; Wissen, Prussia; in Cornwall, England.

In the United States, at Antwerp, N. Y., in cavities in hematite; in Lancaster Co., Pa., at the Gap mine, in thin velvety coatings of a radiated fibrous structure. With calcite, dolomite and fluorite, forming delicate tangled hair-like tufts, in geodes in limestone, often penetrating the calcite crystals, at St. Louis, Mo.; similarly near Milwaukee, Wis. At Orford, Quebec.

**Use.** — An ore of nickel.

**BEYRICHITE.** NiS like millerite, but with lower specific gravity (4.7). Laspeyres considers all millerite as formed by paramorphism from beyrichite. Found in Westerwald, Rhine-Prussia.

**HAUCHECORNITE.** Perhaps Ni(Bi,Sb,S). In tabular tetragonal crystals. H. = 5. G. = 6.4. Color light bronze-yellow. From Hamm a. d. Sieg, Germany.

**NICCOLITE.** Copper Nickel.

Hexagonal. Crystals rare. Usually massive, structure nearly impalpable; also reniform, columnar; reticulated, arborescent. Fracture uneven. Brittle. H. = 5-5.5. G. = 7.33-7.67. Luster metallic. Color pale copper-red. Streak pale brownish black. Opaque.

**Comp.** — Nickel arsenide, NiAs = Arsenic 56.1, nickel 43.9 = 100. Usually contains a little iron and cobalt, also sulphur; sometimes part of the arsenic is replaced by antimony, and then it graduates toward breithauptite. The intermediate varieties have been called *arite*.

**Pyr., etc.** — In the closed tube on intense ignition gives a faint sublimate of arsenic. In the open tube a sublimate of arsenic trioxide, with a trace of sulphurous fumes, the assay becoming yellowish green. On charcoal gives arsenical fumes and fuses to a globule, which, treated with borax glass, affords, by successive oxidation, reactions for iron, cobalt, and nickel; the antimonial varieties give also reactions for antimony. Soluble in aqua regia.

**Obs.** — Accompanies cobalt, silver and copper ores in Germany in the Saxon mines of Annaberg, Schneeberg, Mansfield, etc.; also in Thuringia, Hesse, and in Styria; at Alloumont, Dauphiné, at Balen in the Basses Pyrenées, France (*arite*); at the Ko mines in Nordmark, Sweden; occasionally in Cornwall, Chile; abundant at Mina de la Rioja, Oriocha, Argentina. In the United States, sparingly at Franklin Furnace, N. J., Silver Cliff, Col. In Canada, at Cobalt, Ontario.

**Use.** — An ore of nickel.

**TEMISKAMITE.** Described as having composition Ni<sub>4</sub>As<sub>3</sub>, has been shown to be a mixture of *niccolite*, *maucherite* and a little *cobaltite*.

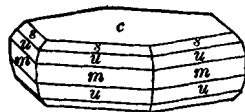
**Breithauptite.** Nickel antimonide, NiSb. Rarely in hexagonal crystals; usually massive, arborescent, disseminated. G. = 7.54. Color light copper-red. From Andreasberg in the Harz Mts., Germany.



**PYRRHOTITE.** Magnetic Pyrites.Hexagonal.  $c = 0.8701$ .

$$\begin{aligned} cs, 0001 \wedge 10\bar{1}1 &= 45^\circ 8'. \\ cu, 0001 \wedge 40\bar{4}1 &= 76^\circ 0'. \\ cy, 0001 \wedge (20^\circ 0'20\bar{3}) &= 81^\circ 30\frac{1}{2}'. \end{aligned}$$

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Twins: tw. pl.  $s(10\bar{1}1)$ , with vertical axes nearly at right angles (Fig. 418, p. 167). Distinct crystals rare, commonly tabular; also acute pyramidal with faces striated horizontally. Usually massive, with granular structure.

Parting:  $c(0001)$ , sometimes distinct. Fracture uneven to subconchoidal. Brittle.  $H. = 3.5-4.5$ .  $G. = 4.58-4.64$ . Luster metallic. Color between bronze-yellow and copper-red, and subject to speedy tarnish. Streak dark grayish black. Magnetic, but varying much in intensity; sometimes possessing polarity.

**Comp.** — Ferrous sulphide containing variable amounts of dissolved sulphur. Analyses show variation from  $Fe_5S_8$  to  $Fe_{16}S_{17}$ . Often also contains nickel.  $Fe_5S_8 =$  Sulphur 39.6, iron 60.4 = 100. (Cf. Art. 473, p. 323.)

Pyrrhotite differs from troilite in containing more or less of dissolved sulphur, while troilite, occurring in meteorites where there is always an excess of iron, may form the pure monosulphide.

**Pyr., etc.** — Unchanged in the closed tube. In the open tube gives sulphurous fumes. On charcoal in R.F. fuses to a black magnetic mass; in O.F. is converted into red oxide, which with fluxes gives only an iron reaction when pure, but many varieties yield small amounts of nickel and cobalt. Decomposed by hydrochloric acid, with evolution of hydrogen sulphide.

**Diff.** — Distinguished by its peculiar reddish bronze color; also by its magnetic properties.

**Micro.** — In polished section shows a cream color with a shiny and pitted surface. With hot HCl tarnishes quickly, giving bright colors, then blackens and dissolves; with aqua regia effervesces, becomes iridescent in center of drop and brown at the edge.

**Artif.** — Pyrrhotite has been synthesized by the direct union of iron and sulphur and also when pyrite is heated in an atmosphere of hydrogen sulphide at  $550^\circ$ . Pyrrhotite exists in two crystalline modifications, hexagonal at ordinary temperatures and orthorhombic above  $138^\circ$ .

**Obs.** — Occurs at Kongsberg, Modum, Kristiania, etc., in Norway; Falun, Sweden; Andreasberg in the Harz Mts., Germany; Schneeberg, Saxony; Leoben and Lavantal, Carinthia; Minas Geraes in Brazil, in large tabular crystals; the lavas of Vesuvius; Cornwall.

In North America, in Me., at Standish with andalusite; in Ver., at Stafford, etc. In N. Y., near Diana, Lewis Co.; Orange Co.; at Tilly Foster mine, Brewsters. In Pa., at the Gap mine, Lancaster Co., nickeliferous. In Tenn., at Ducktown mines, abundant. In Canada, in large veins at St. Jérôme, Elizabethtown, Ontario; large deposit mined for nickel at Sudbury, Ontario.

Named from *πυρρότης*, reddish.

**Use.** — Often becomes a valuable ore of nickel.

**Troilite.** Ferrous sulphide,  $FeS$ , occurring in nodular masses and in thin veins in many iron meteorites.  $G. = 4.75-4.82$ . Color tombac-brown. Considered to be the end member of the pyrrhotite series. See above.

### C. Intermediate Division

**Polydymite.** A nickel sulphide, perhaps  $Ni_4S_6$ . In octahedral crystals; frequently twinned.  $G. = 4.54-4.81$ . Color gray. From Grünau, Westphalia, Germany.

**Synchodymite.** Essentially  $(Co,Cu)_4S_6$ . Isometric, in small steel-gray octahedrons. From the Siegen district, Germany.

The following species are sometimes regarded as Sulpho-salts, namely, Sulpho-ferrites, etc.

**BORNITE.** Peacock Ore. Purple Copper Ore. Variegated Copper Ore. Erubescite.

Isometric. Habit cubic, faces often rough or curved. Twins: tw. pl.  $o(111)$ , often penetration-twins. Crystals rare. Usually massive, structure granular or compact.

Cleavage:  $o(111)$ , in traces. Fracture small conchoidal, uneven. Brittle.  $H. = 3$ .  $G. = 4.9-5.4$ . Luster metallic. Color between copper-red and pinchbeck-brown on fresh fracture, speedily iridescent from tarnish. Streak pale grayish black. Opaque.

**Comp.** — A sulphide of copper and iron.  $Cu_5FeS_4$ . Copper 63.3, iron 11.1, sulphur 25.6 = 100.

The mineral often contains small amounts of chalcocite, etc., and therefore shows considerable variation in its percentage composition, giving from 50 to 70 p. c. of copper and 15 to 6.5 p. c. of iron.

**Pyr., etc.** — In the closed tube gives a faint sublimate of sulphur. In the open tube yields sulphurous fumes. B.B. on charcoal fuses in R.F. to a brittle magnetic globule. The roasted mineral gives with the fluxes the reactions of iron and copper, and with soda a metallic globule. Soluble in nitric acid with separation of sulphur.

**Diff.** — Distinguished (*e.g.*, from chalcocite) by the peculiar reddish color on the fresh fracture and by its brilliant tarnish; B.B. becomes strongly magnetic.

**Micro.** — In polished section shows a pinkish brown color with smooth surface. With  $HNO_3$  becomes quickly golden-brown with effervescence.

**Artif.** — Bornite has been obtained by fusing pyrite, copper and sulphur together; by heating a mixture of cuprous, cupric and ferric oxides in hydrogen sulphide at  $100^\circ$  to  $200^\circ$ .

**Obs.** — Bornite is often a primary mineral of magmatic origin, being frequently found in igneous rocks. It is also often a secondary mineral, occurring with chalcocite, etc., in the enriched portions of copper sulphide veins. It is usually associated with other copper ores, and is a valuable ore of copper. Crystalline varieties are found in Cornwall, called by the miners "horse-flesh ore." Occurs massive at Ross Island, Killarney, Ireland; Monte Catini, Tuscany; the Mansfeld district, Germany; in Norway, Sweden, Siberia, Silesia, and Hungary. It is the principal copper ore at some Chilian mines; also common in Peru, Bolivia, and Mexico.

In the United States, found at the copper mine in Bristol, Conn.; massive at Mahoopeny, near Wilkesbarre, Pa.; in western Idaho; Butte, Mon., etc. A common ore in Canada, at the Acton and other mines.

Named after the mineralogist Ignatius von Born (1742-1791).

**Use.** — An ore of copper.

**Linnæite.** A sulphide of cobalt,  $Co_3S_4 = CoS.Co_2S_3$ , analogous to the spinel group. Also contains nickel (*var. siegenite*). Commonly in octahedrons; also massive.  $H. = 5.5$ .  $G. = 4.8-5$ . Color pale steel-gray, tarnishing copper-red. Occurs at Bastnaes, etc., Sweden; Müsen, near Siegen, Prussia; at Siegen (*stegenite*), in octahedrons. In the United States at Mine la Motte, Mo.; Mineral Hill, Md.

**Daubréelite.** An iron-chromium sulphide,  $FeS.Cr_2S_3$ , occurring with troilite in some meteoric irons. Color black.  $G. = 5.01$ .

**CUBANITE.** Described as an iron-copper sulphide, perhaps  $CuFe_2S_4 = CuS.Fe_2S_3$ . Examination of specimens from several localities show it to be a mixture of pyrite or pyrrhotite with chalcopyrite.

**CARROLITE.** A copper-cobalt sulphide,  $CuCo_2S_4 = CuS.Co_2S_3$ . Isometric; rarely in octahedrons. Usually massive.  $G. = 4.85$ . Color light steel-gray, with a faint reddish hue. From Carroll Co., Md., near Finksburg. Probably linnæite with intergrown bornite and chalcopyrite.

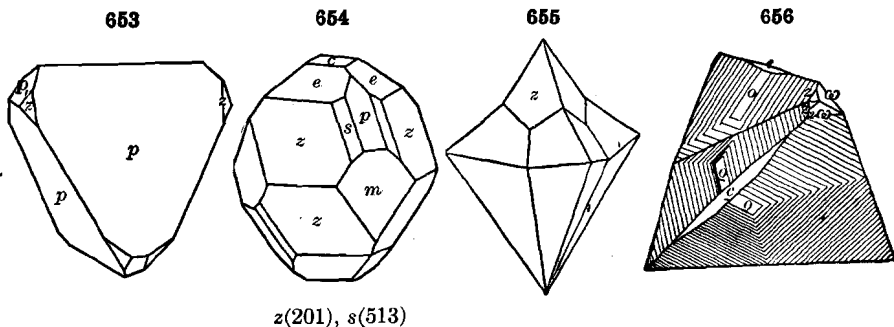
**Badenite.**  $(Co,Ni,Fe)_2(As,Bi)_3$ . Massive granular to fibrous.  $G. = 7.1$ . Metallic. Color steel-gray. Fusible. From near Badeni-Ungureni, Neguletzul valley, Roumania.

**CHALCOPYRITE.** Copper Pyrites. Yellow Copper Ore.

Tetragonal-sphenoidal. Axis  $c = 0.98525$ .

$pp', 111 \wedge \bar{1}\bar{1}1 = 108^\circ 40'$ .  $pp, 111 \wedge \bar{1}\bar{1}1 = 70^\circ 7\frac{1}{2}'$ .  $ce, 001 \wedge 101 = 44^\circ 34\frac{1}{2}'$ .

Crystals commonly tetrahedral in aspect, the sphenoidal faces  $p(111)$  large, dull or oxidized;  $p,(1\bar{1}1)$  small and brilliant. Sometimes both forms equally developed, and then octahedral in form. Twins: (1) tw. pl.  $p(111)$ ,



resembling spinel-twins (Fig. 417, p. 167); sometimes repeated as a five-ling (Fig. 655). (2) Tw. pl. and comp.-face  $e(101)$  (Fig. 656,) often in repeated twins. (3) Tw. pl.  $m(110)$ , tw. axis  $c$ , complementary penetration twins. Often massive, compact.

Cleavage:  $z(201)$ , sometimes distinct;  $c(001)$ , indistinct. Fracture uneven. Brittle.  $H. = 3.5-4$ .  $G. = 4.1-4.3$ . Luster metallic. Color brass-yellow; often tarnished or iridescent. Streak greenish black. Opaque.

**Comp.** — A sulphide of copper and iron,  $\text{CuFeS}_2 = \text{Sulphur } 35.0$ , copper  $34.5$ , iron  $30.5 = 100$ . Analyses often show variations from this formula, often due to mechanical admixture of pyrite.

Sometimes auriferous and argentiferous; also contains traces of selenium and thallium.

**Pyr., etc.** — In the closed tube often decrepitates, and gives a sulphur sublimate, in the open tube sulphurous fumes. On charcoal fuses to a magnetic globule; the residue moistened with hydrochloric acid and then touched with blowpipe flame gives intense blue flame color. Decomposed by nitric acid giving free sulphur and a green solution; ammonia in excess changes the green color to a deep blue, and precipitates red ferric hydroxide.

**Diff.** — Distinguished from pyrite by its inferior hardness and deeper yellow color. Resembles gold when disseminated in minute grains in quartz, but differs in being brittle and in having a black streak; further it is soluble in nitric acid.

**Micro.** — In polished section shows a bright brass-yellow color with smooth surface. With hot  $\text{HNO}_3$  tarnishes and dissolves. Unaffected by KCN, differing from gold.

**Artif.** — Chalcopyrite has been artificially prepared (1) by fusing pyrite and copper sulphide together; (2) by gently heating cupric and ferric oxides in an atmosphere of hydrogen sulphide.

**Obs.** — Chalcopyrite is the most common and important mineral containing copper. It is commonly of primary origin and from it, by various alteration processes, many other copper minerals are derived. It has repeatedly been observed as an original constituent of igneous rocks and the ultimate source of the copper of our ore deposits is to be found in rocks of this type. It occurs widely disseminated in metallic veins and nests in gneiss and crystalline schists, also in serpentine rocks; often intimately associated with pyrite, also with siderite, tetrahedrite, etc., sometimes with nickel and cobalt sulphides, pyrrothite, etc. Observed coated with tetrahedrite crystals in parallel position, also as a coating over the latter. Frequently associated with sphalerite, its crystals often lying with parallel orientation upon the latter mineral.

Chalcopyrite is so widely distributed as an ore mineral that it is possible to mention here only those occurrences which are exceptional either because of their size or because of the quality of the minerals found in them.

It is the principal ore of copper at the Cornwall mines; there associated with cassiterite, galena, bornite, chalcocite, tetrahedrite, sphalerite. At Falun, Sweden, it occurs in large masses embedded in gneiss. At Rammelsberg, near Goslar in the Harz Mts., Germany, it

forms a bed in argillaceous schist; occurs with nickel and cobalt ores in the Kupferschiefer of Mansfield. In Germany the Kurprinz mine at Freiberg affords well-defined crystals; also Horhausen, Dillenburg, Neudorf, Müsen. Common elsewhere as at Mte. Catini in Tuscany; Rio Tinto, Spain; in New South Wales; Chile; Japan, etc.

In the United States it is found in large crystals associated with quartz at Ellenville, N. Y.; in exceptional crystals at the French Creek mines, Chester Co., Pa., associated with pyrite, magnetite, etc.; in Mo., with sphalerite at Joplin; at various localities in Gilpin and other counties in Col. The most important sulphide deposits of copper in many of which chalcopyrite is the chief ore are found in the states of Arizona, Montana, Utah, Alaska, Nevada, New Mexico, California, and Tennessee.

In Canada there are important copper deposits in British Columbia, Ontario and Quebec, Use. — The most important ore of copper.

Named from χαλκός, *brass*, and *pyrites*, by Henckel (1725).

#### D. Disulphides, Diarsenides, etc.

The disulphides, diarsenides, etc., embrace two distinct groups. The prominent metals included are the same in both, viz.: iron, cobalt and nickel. The groups present, therefore, several cases of isodimorphism, as is shown in the lists of species below. These sulphides are all relatively *hard*, H. = 5-6; they hence strike fire with a steel, and this has given the familiar name *pyrites* applied to most of them. The color varies between pale brass-yellow and tin-white.

##### *Pyrite Group.* $RS_2, RAs_2, RSb_2$ . Isometric-pyritohedral

|                           |                               |                     |  |
|---------------------------|-------------------------------|---------------------|--|
| <b>Pyrite</b>             | $FeS_2$                       | <b>Gersdorffite</b> | $NiS_2.NiAs_2$                           |
| <b>Arsenoferrite</b>      | $FeAs_2$                      | <b>Corynite</b>     | $NiS_2.Ni(As,Sb)_2$                      |
| <b>Cobaltnickelpyrite</b> | $(Co,Ni,Fe)S_2$               | <b>Ullmannite</b>   | $NiS_2.NiSb_2$ (isometric-tetartohedral) |
| <b>Hauerite</b>           | $MnS_2$                       |                     |  |
| <b>Smaltite</b>           | $CoAs_2$ , also $(Co,Ni)As_2$ | <b>Sperrylite</b>   | $PtAs_2$                                 |
| <b>Chloanthite</b>        | $NiAs_2$ , also $(Ni,Co)As_2$ | <b>Laurite</b>      | $RuS_2?$                                 |
| <b>Cobaltite</b>          | $CoS_2.CoAs_2$                |                     |  |

##### *Marcasite Group.* $RS_2, RAs_2$ , etc. Orthorhombic

|                       |                          | $a : b : c$         | $110 \wedge 1\bar{1}0$ | $101 \wedge \bar{1}01$ |
|-----------------------|--------------------------|---------------------|------------------------|------------------------|
| <b>Marcasite</b>      | $FeS_2$                  | 0.7662 : 1 : 1.2342 | 74° 55'                | 116° 20'               |
| <b>Löllingite</b>     | $FeAs_2$                 | 0.6689 : 1 : 1.2331 | 67° 33'                | 123° 3'                |
| Leucopyrite           | $Fe_3As_4$               |                     |                        |                        |
| <b>Arsenopyrite</b>   | $FeS_2.FeAs_2$           | 0.6773 : 1 : 1.1882 | 68° 13'                | 120° 38'               |
| Danaite               | $(Fe,Co)S_2.(Fe,Co)As_2$ |                     |                        |                        |
| <b>Safflorite</b>     | $CoAs_2$                 |                     |                        |                        |
| <b>Rammelsbergite</b> | $NiAs_2$                 |                     |                        |                        |
| <b>Glaucodot</b>      | $(Co,Fe)S_2.(Co,Fe)As_2$ | 0.6942 : 1 : 1.1925 | 69° 32'                | 119° 35'               |
| <b>Alloclasite</b>    | $(Co,Fe)(As,Bi)S$        |                     |                        |                        |
| <b>Wolfachite</b>     | $NiS_2.Ni(As,Sb)_2$      |                     |                        |                        |

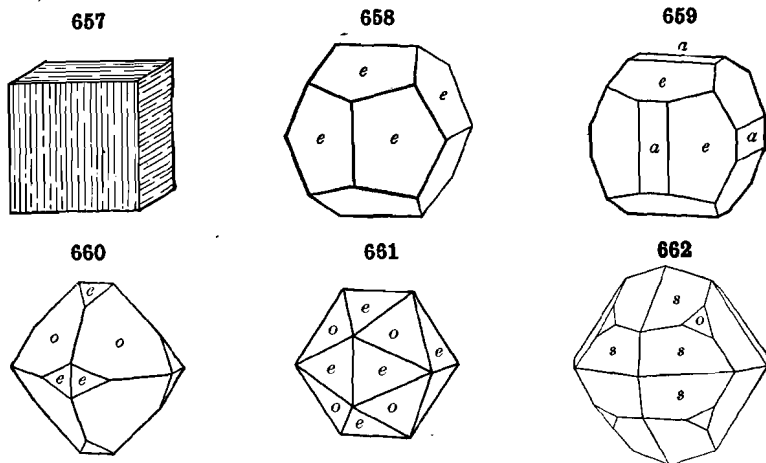
The PYRITE GROUP includes, besides the compounds of Fe, Co, Ni, also others of the related metals Mn and Pt. The crystallization is isometric-pyritohedral.

The species of the MARCASITE GROUP crystallize in the orthorhombic system with prismatic angles of about 70° and 110° and a prominent macrodome of about 60° and 120°. Hence fivefold and sixfold repeated twins are common with several species, in the one case the prism and in the other the macrodome named being the twinning-plane.

*Pyrite Group*

**PYRITE.** Iron Pyrites.

Isometric-pyritohedral. Cube and pyritohedron  $e(210)$  the common forms, the faces of both often with striations  $\parallel$  edge  $a(100)/e(210)$ , due to oscillatory combination of these forms and tending to produce rounded faces; pyritohedral faces also striated  $\perp$  to this edge; octahedron also common. See Figs. 657-662, also Figs. 133-138, pp. 65, 66. Twins: tw. ax. = a crystal axis, usually penetration-twins with parallel axes (Fig. 407, p. 166); rarely contact-twins. Frequently massive, fine granular; sometimes subfibrous radiated; reniform, globular, stalactitic.



Cleavage:  $a(100)$ ,  $o(111)$ , indistinct. Fracture conchoidal to uneven. Brittle.  $H. = 6-6.5$ .  $G. = 4.95-5.10$ ; 4.967 Traversella, 5.027 Elba. Luster metallic, splendent to glistening. Color a pale brass-yellow, nearly uniform. Streak greenish black or brownish black. Opaque.

**Comp.** — Iron disulphide,  $FeS_2 =$  Sulphur 53.4, iron 46.6 = 100.

Nickel, cobalt, and thallium, and also copper in small quantities, sometimes replace part of the iron, or else occur as mixtures; selenium is sometimes present in traces. Gold is sometimes distributed invisibly through it, auriferous pyrite being an important source of gold. Arsenic is rarely present, as in octahedral crystals from French Creek, Pa. (0.2 p. c. As).

**Pyr., etc.** — Easily fusible, (2.5-3). Becomes magnetic on heating and yields sulphur dioxide. Gives an abundant sublimate of sulphur in the closed tube. Insoluble in hydrochloric acid. The fine powder is completely soluble in strong nitric acid.

**Diff.** — Distinguished from chalcopyrite by its greater hardness and paler color; in form and specific gravity different from marcasite, which has also a whiter color.

**Micro.** — In polished section shows a cream color with a scratched and dull surface. With  $HNO_3$  effervesces slowly becoming faintly brown.

**Alteration.** — Pyrite readily changes by oxidation to an iron sulphate or to the hydrated oxide, limonite, with sulphuric acid set free. Crystals of pyrite which have been changed on their surfaces to limonite are common. This change may continue until the original mineral has completely disappeared. Large masses of pyrite lying near the surface may be altered to a cellular mass of limonite — the *iron gossan* of the miners — while the sulphuric acid set free travels downward and enters into various important reactions with the unaltered minerals below. The alteration of pyrite to limonite may be continued until hematite is formed.

**Obs.** — Experiments show that pyrite is formed in neutral or alkaline solutions and at high temperatures. Marcasite, on the other hand, is deposited from acid solutions and

is stable only at temperatures below 450° C. These sulphides can be formed through the action of hydrogen sulphide, although the reducing action of carbonaceous materials may also at times be of importance. Pyrite occurs in rocks of all ages and types, being most common in the metamorphic and sedimentary rocks, but it is also frequently found as a minor accessory constituent of igneous rocks. When disseminated in the rocks it usually occurs in small crystals, cubes, octahedrons, pyritohedrons, etc., but in veins it may occur in crystals or with a granular or radiating massive structure. At times it is in nodular or concretionary forms.

Pyrite is very widespread in its occurrence, being the most common sulphide mineral. At times it is found in very large amounts and is mined for its sulphur content or because it contains small amounts of some valuable metal, like copper, gold, etc. It is frequently found in crystals with a fine luster. Some of the more notable localities for its occurrence are given below.

Important commercial deposits of pyrite are found in Norway, Germany, France, Italy, Spain and Portugal. The mines at Rio Tinto, Spain, are especially noteworthy. The mineral has been mined in the United States in Louisa and Prince William Cos., Va.; in St. Lawrence Co., N. Y.; at Davis, Mass., etc. The following localities furnish exceptionally fine crystallized specimens: Cornwall, England; Traversella and Brosso, Piedmont Italy; Island of Elba; Ardennes, France, in distorted cubes; Minden, Prussia, in interpenetration twins; in various localities in Bohemia, Hungary, Germany, Sweden, etc.; at Firmeza, Cuba; at French Creek, Pa., in pyramids with apparently tetragonal or orthorhombic symmetry; at Rossie and Scoharie, N. Y.; Roxbury, Conn.; Franklin, N. J.; Gilpin Co. and at Leadville, Col.; Bingham Canyon, Utah.

The name pyrite is derived from *πυρ*, fire, and alludes to the sparks formed when the mineral is struck with a hammer; hence the early name *pyrites*, p. 376.

Use. — Pyrite often carries small amounts of copper or gold and becomes an important ore of these metals. It is also mined for its sulphur content which is used in the form of sulphur dioxide (used in the preparation of wood pulp for manufacture into paper), as sulphuric acid (used for many purposes, especially in the purification of kerosene and in the preparation of mineral fertilizers), and as the ferrous sulphate, copperas (used in dyeing, in inks, as a wood preservative, and as a disinfectant).

**Bravoite** (Fe,Ni)S<sub>2</sub>. Contains nearly 20 per cent nickel. In small grains and crystal fragments, apparently octahedral. Pale yellow with a faint reddish tarnish. Occurs disseminated through the vanadium ores at Minasragra, Peru.

**Cobaltnickelpyrite.** Iron sulphide with about 20 per cent cobalt and nickel, (Co,Ni,Fe)S<sub>2</sub>. In minute pyritohedral crystals. Steel-gray color. Gray-black streak. H. = 5. G. = 4.716. Found at Müsen, Germany.

**Arsenoferrite.** Iron arsenide, probably FeAs<sub>2</sub>. Isometric-pyritohedral. In small crystals. Color dark brown. Fine splinters transparent with ruby-red color. From the Binnental, Switzerland.

**Hauerite.** — Manganese disulphide, MnS<sub>2</sub>. In octahedral or pyritohedral crystals; also massive. G. = 3.46. Color reddish brown or brownish black. From Kalinka, Hungary; Raddusa, Catania, Sicily.

#### SMALTITE-CHLOANTHITE.

Isometric-pyritohedral. Commonly massive; in reticulated and other imitative shapes.

Cleavage: *o*(111) distinct; *a*(100) in traces. Fracture granular and uneven. Brittle. H. = 5.5–6. G. = 6.4 to 6.6. Luster metallic. Color tin-white, inclining, when massive, to steel-gray, sometimes iridescent, or grayish from tarnish. Streak grayish black. Opaque.

**Comp.** — SMALTITE is essentially cobalt diarsenide, CoAs<sub>2</sub> = Arsenic 71.8, cobalt 28.2 = 100. CHLOANTHITE is nickel diarsenide, NiAs<sub>2</sub> = Arsenic 71.9, nickel 28.1 = 100.

Cobalt and nickel are usually both present, and thus these two species graduate into each other, and no sharp line can be drawn between them. Iron is also present in varying amount; the variety of chloanthite containing much iron has been called *chathamite*. Further sulphur is usually present, but only in small quantities. Many analyses do not conform even approximately to the formula RAs<sub>2</sub>, the ratio rising from less than 1 : 2 to 1 : 2.5 and nearly 1 : 3, thus showing a tendency toward skutterudite (RAs<sub>3</sub>), perhaps due to either molecular or mechanical mixture. Microscopic examination of polished specimens shows

probable zoning of different members of the group. Material known as *keweenawite* is a mixture of smaltite, niccolite and domeykite.

Much that has been called smaltite is shown by the high specific gravity to belong to the orthorhombic species safflorite.

**Pyr., etc.** — In the closed tube gives a sublimate of metallic arsenic; in the open tube a white sublimate of arsenic trioxide, and sometimes traces of sulphur dioxide. B.B. on charcoal gives a coating of  $As_2O_3$ , the arsenical odor, and fuses to a globule, which, treated with successive portions of borax-glass, affords reactions for iron, cobalt, and nickel.

**Obs.** — Usually occurs in veins, accompanying ores of cobalt or nickel, and ores of silver and copper; also, in some instances, with niccolite and arsenopyrite. Found at the Saxon mines; Joachimstal, Bohemia; Wheal Sparnon, Cornwall; Riechelsdorf, Hesse, Germany; Tunaberg, Sweden; Allemont, Dauphiné, France; Cobalt, Ontario. In the United States, at Chatham, Conn., the *chathamite* occurs in mica slate, with arsenopyrite and niccolite; at Franklin Furnace, N. J.

**Use.** — Ores of cobalt and nickel.

### COBALTITE.

Isometric-pyritohedral. Commonly in cubes, or pyritohedrons, or combinations resembling common forms of pyrite. Also granular massive to compact.

Cleavage: cubic, rather perfect. Fracture uneven. Brittle.  $H. = 5.5$ .  $G. = 6-6.3$ . Luster metallic. Color silver-white, inclined to red; also steel-gray, with a violet tinge, or grayish black when containing much iron. Streak grayish black.

**Comp.** — Sulpharsenide of cobalt,  $CoAsS$  or  $CoS_2.CoAs_2 =$  Sulphur 19.3, arsenic 45.2, cobalt 35.5 = 100.

Iron is present, and in the variety *ferrocobaltite* in large amount.

**Pyr., etc.** — Unaltered in the closed tube. In the open tube gives sulphurous fumes, and a crystalline sublimate of arsenic trioxide. B.B. on charcoal gives off sulphur and arsenic oxides, and fuses to a magnetic globule; with borax a cobalt-blue color. Soluble in warm nitric acid, with the separation of sulphur.

**Obs.** — Occurs at Tunaberg and Hakansbö in Sweden; at the Nordmark mines; also at Skutterud in Norway; at Schladming, Styria; Siegen in Westphalia; Botallack mine, near St. Just, in Cornwall; Khetri mines, Rajputana, India; Cobalt, Ontario, Canada.

**Use.** — An ore of cobalt.

**Gersdorffite.** Sulpharsenide of nickel,  $NiAsS$  or  $NiS_2.NiAs_2$ . Iron, and sometimes cobalt, replace more or less of the nickel. Isometric-pyritohedral; usually massive.  $H. = 5.5$ .  $G. = 5.6-6.2$ . Color silver-white to steel-gray. From Loos, Sweden; the Harz Mts., and Lobenstein, Reuss-Schleiz, Germany; Schladming, Styria; Sudbury and Algoma districts, Ontario; Rossland, British Columbia.

CORYNITE is near gersdorffite, but contains also antimony. Probably represents a mixture. From Olsa, Carinthia.

**Willyamite.** —  $CoS_2.NiS_2.CoSb_2.NiSb_2$ . Cleavage cubic. Color tin-white to steel-gray. Broken Hill mines, New South Wales.

**Villamaninite.** Sulphide of  $Cu,Ni$  with smaller amounts of  $Co,Fe$ .  $H = 4.5$ .  $G. = 4.4-4.5$ . Color, iron-black. In irregular groups of cubo-octahedral crystals and in radiating nodular masses. In dolomite from Cármenes district, near Villamanfn, Prov. León, Spain.

**Ullmannite.** Sulphantimonide of nickel,  $NiSbS$  or  $NiS_2.NiSb_2$ ; arsenic is usually present in small amount. Isometric-tetartohedral; both pyritohedral and tetrahedral forms occur. Usually massive, granular.  $H. = 5-5.5$ .  $G. = 6.2-6.7$ . Color steel-gray to silver-white. Occurs in the mines of Siegen, Prussia; Lölling, Carinthia (tetrahedral); Monte Narba, Sarrabus, Sardinia (pyritohedral).

**KALLILITE.**  $Ni(Sb,Bi)S$  or  $NiS_2.Ni(Sb,Bi)_2$ . Massive, color light bluish gray. From the Friedrich mine near Schönstein a. d. Sieg, Germany.

**Sperrylite.** — Platinum diarsenide,  $PtAs_2$ . In minute cubes, or cubo-octahedrons with at times small pyritohedral or diploid faces.  $H. = 6-7$ .  $G. = 10.6$ . Luster metallic. Color tin-white. Streak black. Found at the Vermillion mine, 22 miles west of Sudbury, Ontario, Canada; also in Macon Co., N. C. Found associated with covellite at the Rambler mine, Medicine Bow Mts., Wyo. This is the only known native compound of platinum.

**Laurite.** Sulphide of ruthenium and osmium, probably essentially  $RuS_2$ . In minute octahedrons; in grains.  $H. = 7.5$ .  $G. = 6.99$ . Luster metallic. Color dark iron-black. From the platinum washings of Borneo. Also reported from Oregon.

**Skutterudite.** Cobalt arsenide,  $CoAs_2$ . Isometric-pyritohedral. Also massive granular. Cleavage:  $a(100)$ , distinct.  $H. = 6$ .  $G. = 6.72-6.86$ . Color between tin-white and pale lead-gray. From Skutterud, Norway; the Turtmantal, Switzerland.

**NICKEL-SKUTTERUDITE.**  $(Ni,Co,Fe)As_2$ . Massive, granular. Color gray. From near Silver City, N. M.

**BISMUTO-SMALTITE.**  $Co(As,Bi)_2$ . A skutterudite containing bismuth. Color tin-white.  $G. = 6.92$ . Zschorlau, near Schneeberg, Saxony.

### Marcasite Group

For the list of species and their relations, see p. 376.

**MARCASITE.** White iron pyrites.

Orthorhombic. Axes  $a : b : c = 0.7662 : 1 : 1.2342$ .

$mm'''$ ,  $110 \wedge 110 = 74^\circ 55'$ .

$h'$ ,  $011 \wedge 0\bar{1}1 = 101^\circ 58'$ .

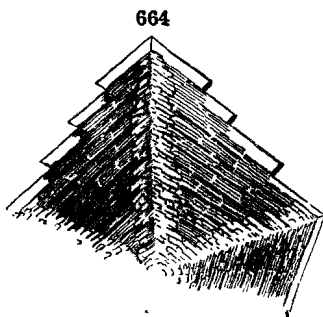
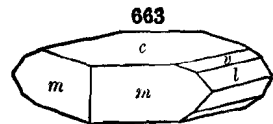
$ee'$ ,  $101 \wedge \bar{1}01 = 116^\circ 20'$ .

$cs$ ,  $001 \wedge 111 = 63^\circ 46'$ .

Twins: iw. pl.  $m(110)$ , sometimes in stellate fivelings (Fig. 436, p. 169,

cf. Fig. 664); also tw. pl.  $e(101)$ , less common, the crystals crossing at angles of nearly  $60^\circ$ . Crystals commonly tabular  $\parallel c(001)$ , also pyramidal; the brachydomes striated  $\parallel$  edge  $b(010)/c(001)$ . Often massive; in stalactites; also globular, reniform, and other imitative shapes.

Cleavage:  $m(110)$



Folkestone

rather distinct;  $l(011)$  in traces. Fracture uneven. Brittle.  $H. = 6-6.5$ .  $G = 4.85-4.90$ . Luster metallic. Color pale bronze-yellow, deepening on exposure. Streak grayish or brownish black. Opaque.

**Comp.** — Iron disulphide, like pyrite,  $FeS_2 =$  Sulphur 53.4, iron 46.6 = 100. Arsenic is sometimes present in small amount.

**Var.** — The varieties named depend mainly on state of crystallization. *Radiated*: Radiated; also the simple crystals. *Cockscomb Pyrite*: Aggregations of flattened twin crystals in crest-like forms. *Spear Pyrite*: Twin crystals, with re-entering angles a little like the head of a spear in form. (Fig. 664.) *Capillary*: In capillary crystallizations.

**Pyr., etc.** — Like pyrite. Very liable to decomposition, more so than pyrite.

**Diff.** — Resembles pyrite, but has a lower specific gravity, and the color when fresh (e.g., after treatment with acid) is paler; when crystallized easily distinguished by the forms. More subject to tarnish and final decomposition than pyrite.

Marcasite can be distinguished chemically from pyrite by the following methods. When both minerals are finely powdered and treated with a little concentrated nitric acid, first in the cold and later, after vigorous action has ceased, by warming, it will be found that in the case of pyrite the greater part of the sulphur of the mineral has been oxidized and taken into solution as sulphuric acid, while in the case of marcasite most of the sulphur has separated in a free state. The Stokes method, which can be used quantitatively to determine the amounts of the two minerals in a mixture, depends upon the difference in their behavior when boiled with a standard solution of ferric sulphate. In the case of pyrite about 52 per cent of the sulphur is oxidized to sulphuric acid, while with marcasite only about 12 per cent is oxidized.

**Micro.** — In polished sections shows a cream color with a scratched and dull surface. With  $HNO_3$  slowly turns brown to black with effervescence.



**Alteration.** — Marcasite being relatively unstable is easily altered. Specimens often disintegrate with the formation of ferrous sulphate and sulphuric acid. It also alters to pyrite, limonite, etc.

**Obs.** — Marcasite is a much more unstable compound than pyrite and is formed under comparatively limited conditions. Experiments have shown that it is deposited at temperatures below 450° C. and in acid solutions. The higher the temperature the more acid must the solution contain. At ordinary temperatures marcasite may be deposited from nearly neutral solutions. Marcasite is formed in general under surface conditions, while in deep veins where the minerals are deposited from ascending hot and usually alkaline waters only pyrite is found.

Marcasite occurs abundantly at Littmitz near Carlsbad, Bohemia. Found at several localities in the Harz Mts., Germany. In its cockscomb form occurs at Tavistock in Devonshire and as Spear Pyrites in the chalk-marl between Folkestone and Dover, England. In the United States a notable locality is at Galena, Ill., where it occurs in stalactites with concentric layers of sphalerite and galena. In fine crystals at Mineral Point, Wis.; in crystals altered to limonite from Richland Co., Wis. Frequently associated with galena, sphalerite and dolomite from the Joplin district, Mo.

The word *marcasite*, of Arabic or Moorish origin (and variously used by old writers, for bismuth, antimony), was the name of common crystallized pyrite among miners and mineralogists in later centuries, until near the close of the eighteenth. It was first given to this species by Haidinger in 1845.

**Löllingite.** Essentially iron diarsenide,  $FeAs_2$ , but passing into  $Fe_3As_4$  (*leucopyrite*); also tending toward arsenopyrite ( $FeAsS$ ) and safflorite ( $CoAs_2$ ). Bismuth and antimony are sometimes present. Usually massive. H. = 5-5.5. G. = 7.0-7.4 chiefly, also 6.8. Luster metallic. Color between silver-white and steel-gray. Streak grayish black. Occurs in the Lölling-Hüttenberg district in Carinthia. Found also sparingly in a number of other districts.

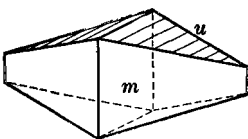
GEYERITE is near löllingite, but contains sulphur; from Geyer, Saxony.

**ARSENOPYRITE, or MISPICKEL.**

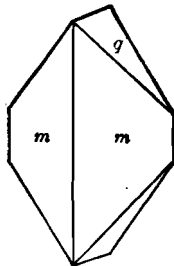
Orthorhombic. Axes  $a : b : c = 0.6773 : 1 : 1.1882$ .

|           |  |
|-----------|--|
| $mm'''$ , | $110 \wedge 110 = 68^\circ 13'$ .        |
| $ee'$ ,   | $101 \wedge \bar{1}01 = 120^\circ 38'$ . |
| $uu'$ ,   | $014 \wedge 0\bar{1}4 = 33^\circ 5'$ .   |
| $nn'$ ,   | $012 \wedge 0\bar{1}2 = 61^\circ 26'$ .  |
| $qq'$ ,   | $011 \wedge 0\bar{1}1 = 99^\circ 50'$ .  |

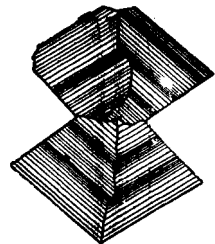
665



666



667



Twins: tw. pl.  $m(110)$ , sometimes repeated like marcasite (Figs. 667 and 437, p. 109);  $e(101)$  cruciform twins, also trillings (Figs. 432, 433, p. 169). Crystals prismatic  $m(110)$  or flattened vertically by the oscillatory combination of brachydomes. Also columnar, straight, and divergent; granular, or compact.

Cleavage:  $m(110)$  rather distinct;  $c(001)$  in faint traces. Fracture uneven. Brittle. H. = 5.5-6. G. = 5.9-6.2. Luster metallic. Color silver-white, inclining to steel-gray. Streak dark grayish black. Opaque.

**Comp.** — Sulpharsenide of iron,  $FeAsS$  or  $FeS_2.FeAs_2 =$  Arsenic 46.0, sul-

phur 19.7, iron 34.3 = 100. Part of the iron is sometimes replaced by cobalt, as in the variety *danaite* (3 to 9 p. c. Co).

**Pyr., etc.** — In the closed tube may give at first a little yellow sulphide of arsenic and then a conspicuous sublimate of metallic arsenic which is of bright gray crystals near the heated end and of a brilliant black amorphous deposit farther away. In the open tube gives sulphurous fumes and a white sublimate of arsenic trioxide. B.B. on charcoal gives arsenical fumes and a magnetic globule. Decomposed by nitric acid with the separation of sulphur.

**Diff.** — Characterized by its hardness and tin-white color; closely resembles some of the sulphides and arsenides of cobalt and nickel, but identified, in most cases easily, by its blowpipe characters. Löllingite does not give a decided sulphur reaction.

**Micro.** — In polished sections shows a white color with scratched and dull surface. With  $\text{HNO}_3$  darkens quickly through iridescent colors to brown, showing rough surface.

**Obs.** — Found principally in crystalline rocks, its usual mineral associates being ores of silver, lead, and tin, also pyrite, chalcopyrite, and sphalerite. Abundant at Freiberg, etc., in Saxony; at Andreasberg, Harz Mts., Germany; Sala, Sweden; Skutterud, Norway; at several points in Cornwall. In crystals in the Binnental, Switzerland. Crystals of *danaite* from Sulitjelma, Finland.

In the United States, in N. H., in gneiss, at Franconia (*danaite*). In Conn., at Mine Hill, Roxbury, with siderite. In crystals at Canton, Ga.; Leadville, Col. In twin crystals in quartz ore veins at Deloro, Hastings Co., Ontario.

The name *mispickel* is an old German term of doubtful origin. *Danaite* is from J. Freeman Dana of Boston (1793-1827), who made known the Franconia locality.

**Use.** — An ore of arsenic.

**Safflorite.** Like smaltite, essentially cobalt diarsenide,  $\text{CoAs}_2$ . Form near that of arsenopyrite. Usually massive. H. = 4.5-5. G. = 6.9-7.3. Color tin-white, soon tarnishing. From Germany at Schneeberg, Saxony; Bieber, Hesse; Wittichen, Baden; from Tunaberg, Sweden.

**Rammelsbergite.** Essentially nickel diarsenide,  $\text{NiAs}_2$ , like chloanthite. Crystals resembling arsenopyrite; also massive. G. = 6.9-7.2. Color tin-white with tinge of red. Occurs at Schneeberg, Saxony, and at Riechelsdorf, Hesse, Germany.

**Glaucodot.** Sulpharsenide of cobalt and iron,  $(\text{Co,Fe})\text{AsS}$ . In orthorhombic crystals (axes, etc., p. 376). Also massive. H. = 5. G. = 5.90-6.01. Luster metallic. Color grayish tin-white. Occurs in the province of Huasco, Chile; at Hakansbö, Sweden. Named from  $\gamma\lambda\alpha\upsilon\kappa\acute{o}\varsigma$ , *blue*, because used for making smalt.

**ALLOGLASITE.** Probably glaucodot containing bismuth and other impurities. Commonly in columnar to hemispherical aggregates. H. = 4.5. G. = 6.6. Color steel-gray. From Orawitza, Hungary.

**Wolfachite.** Probably  $\text{Ni}(\text{As,Sb})\text{S}$ , near corynite. In small crystals resembling arsenopyrite; also columnar radiated. H. = 4.5-5. G. = 6.372. Color silver-white to tin-white. From Wolfach, Baden, Germany.

**Melonite.** A nickel telluride,  $\text{NiTe}_2$ . In indistinct granular and foliated particles. Color reddish white, with metallic luster. From the Stanislaus mine, Cal.; probably also in Boulder Co., Col. Found at Worturpa, New South Wales.

The following species are tellurides of gold, silver, etc.

**SYLVANITE.** Graphic Tellurium.

Monoclinic.  $a : b : c = 1.6339 : 1 : 1.1265$ ;  $\beta = 89^\circ 35'$ . Often in branching arborescent forms resembling written characters; also bladed and imperfectly columnar to granular.

Cleavage:  $b(010)$  perfect. Fracture uneven. Brittle. H. = 1.5-2. G. = 7.9-8.3. Luster metallic, brilliant. Color and streak pure steel-gray to silver-white, inclining to yellow.

**Comp.** — Telluride of gold and silver  $(\text{Au,Ag})\text{Te}_2$  with  $\text{Au} : \text{Ag} = 1 : 1$ ; this requires: Tellurium 62.1, gold 24.5, silver 13.4 = 100.

**Pyr., etc.** — When a little of the powdered mineral is heated in concentrated sulphuric acid a reddish violet color is given to the solution. When treated with nitric acid is decomposed leaving residue of rusty colored gold. A few drops of hydrochloric acid added to this

solution yield an abundant precipitate of silver chloride. In the open tube gives a white sublimate of tellurium dioxide which near the assay is gray; when treated with the blowpipe flame the sublimate fuses to clear transparent drops. B.B. on charcoal fuses to a dark gray globule, covering the coal with a white coating, which treated in R.F. disappears, giving a bluish green color to the flame; after long blowing a yellow, malleable metallic globule is obtained.

**Obs.** — With gold, at Offenbánya, Transylvania; also at Nagyág. With calaverite at Kalgoorlie district, West Australia. In Cal., Calaveras Co., at the Melones and Stanislaus mines. In Boulder Co., at Cripple Creek and elsewhere in Col. Named from Transylvania, where first found, and in allusion to *sylvanium*, one of the names at first proposed for the metal tellurium.

**Use.** — An ore of gold

**Krennerite.** A telluride of gold and silver (Au,Ag)Te<sub>2</sub> like sylvanite. In prismatic crystals (orthorhombic), vertically striated. G. = 8.353. Color silver-white to brass-yellow. From Nagyág, Transylvania; Cripple Creek, Col.

**Calaverite.** A gold telluride, AuTe<sub>2</sub> with small amounts of silver. Monoclinic. In small lath-shaped crystals striated parallel to their length. Massive granular to crystalline. H. = 2.5. G. = 9.043. Color silver-white with often a faint yellow tinge. Tests similar to those for sylvanite with smaller amount of silver showing. Occurs with petzite at the Stanislaus mine, Calaveras county, Cal. An important gold ore at the Cripple Creek district, Col. Found elsewhere in that state. Occurs abundantly at Kalgoorlie, West Australia.

**Muthmannite.** (Ag,Au)Te. In tabular crystals usually elongated in one direction. One perfect cleavage parallel to elongation. H. = 2.5. Color bright brass-yellow, on fresh fracture gray-white. Probably from Nagyág, Transylvania. *Empressite*, AgTe, from the Empress-Josephine mine, in the Kerber Creek District, Col., is probably a gold-free variety. Massive. H. = 3-3.5. G. = 7.5. Color pale bronze.

**Nagyagite.** A sulpho-telluride of lead and gold; some analyses show also about 7 p. c. of antimony which was probably due to impurities. Orthorhombic. Crystals tabular || *b*(010); also granular massive, foliated. Cleavage: *b* perfect; flexible. H. = 1-1.5. G. = 6.85-7.2. Luster metallic, splendid. Streak and color blackish lead-gray. Opaque. From Nagyág, Transylvania; and at Offenbánya. Reported from Colorado and Tararu Creek, New Zealand.

### Oxysulphides

Here are included Kermesite, Sb<sub>2</sub>S<sub>2</sub>O, and Voltzite, Zn<sub>5</sub>S<sub>4</sub>O.

**Kermesite.** Pyrostibite. Antimony oxysulphide, Sb<sub>2</sub>S<sub>2</sub>O or 2Sb<sub>2</sub>S<sub>3</sub>.Sb<sub>2</sub>O<sub>3</sub>. Monoclinic. Usually in tufts of capillary crystals. Cleavage: *a*(100) perfect. H. = 1-1.5. G. = 4.5-4.6. Luster adamantine. Color cherry-red.

Results from the alteration of stibnite. Occurs at Malaczka, Hungary; Bräunsdorf, Saxony; Allemont, Dauphiné, France. At South Ham, Wolfe Co., Quebec, Canada; with native antimony and stibnite at the Prince William mine, York Co., New Brunswick.

Named from *kermes*, a name given (from the Persian *qurmizq*, crimson) in the older chemistry to red amorphous antimony trisulphide, often mixed with antimony trioxide.

**Voltzite.** Zinc oxysulphide, Zn<sub>5</sub>S<sub>4</sub>O or 4ZnS.ZnO. In implanted spherical globules. H. = 4-4.5. G. = 3.66-3.80. Color dirty rose-red, yellowish. Occurs near Pontgibaud, Puy-de-Dôme, France; Joachimstal, Bohemia; Marienberg, Saxony, Germany.

## III. SULPHO-SALTS

I. Sulpharsenites, Sulphantimonites, Sulphobismuthites.

II. Sulpharsenates, Sulphostannates, etc.

### I. Sulpharsenites, Sulphantimonites, etc.

In these sulpho-salts, as further explained on p. 320, sulphur takes the place of the oxygen in the commoner and better understood oxygen acids (as carbonic acid, H<sub>2</sub>CO<sub>3</sub>, sulphuric acid, H<sub>2</sub>SO<sub>4</sub>, phosphoric acid, H<sub>3</sub>PO<sub>4</sub>, etc.).

The species included are salts of the sulpho-acids of trivalent *arsenic*, *antimony* and *bismuth*. The most important acids are the ortho-acids,