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Computerized Database of the Optical Properties of the Opaque Minerals
[Compiled From "Tables For Microscope Identification of Ore Minerals",
by Uytenbogaardt and Burke]

by

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This database was last revised in January, 1989. The database consists of the optical and pertinent physical properties of 288 opaque minerals. These properties are: 1, chemical composition*; 2 and 3, reflected light color and tints (in air)*; 4 and 5, reflected light color and tints (in oil)*; 6, bireflectance*; 7, anisotropy*; 8, crystallographic class*; 9, percent reflectance in green light (540nm)*; 10, Vickers Hardness Number; 11, possible internal reflections; 12, polishing hardness; and 13, a brief listing of common associations and textures. The database can be searched on those properties that are starred.

The database was written with Filemaker Plus™ and is compatible with Filemaker 4™ and Filemaker II™ also. It was created on a Macintosh Plus™ but will also run on the Macintosh SE™, II™, and IIx™.
Computerized Database of the Optical Properties of the Opaque Minerals

[Compiled From "Tables For Microscopic Identification of Ore Minerals", by Uytenbogaardt and Burke]

This open file report arose from frustrations which I have perpetually encountered in attempting to identify those small grains of gray- (or white-, or yellow-, etc) reflecting minerals under the microscope. Almost without exception, the texts and tables most commonly available to aid the ore microscopist in his quest for identity (sic), fail to group the opaque minerals by their most distinctive, most obvious, and certainly most easily described characteristic - their color! The Delft punch card system (Kühnel et al., 1982) sorts the minerals by their color in reflected light, but it is somewhat expensive and not commonly available. The software described here allows one to sort through the 260 odd minerals listed and extract only those fitting the observed property(ies).

The data compiled here were taken, almost verbatim, from "Tables for Microscopic Identification of Ore Minerals" by W. Uytenbogaardt and E. A. J. Burke (1971). Supplemental data were taken from Picot and Johan (1982) and Criddle and Stanley 1986); citations from these references are noted in the individual records by (P&J) and (QDF2), respectively. The data were compiled using Filemaker Plus™ with each mineral and its characteristic properties listed as a separate record.

A typical record is shown below:

**Mineral Name:** Pyrite

**Chem. Comp.:** Fe.S2

**Crystall.:** cubic

**Color:** yellow

**Tint:** white cream

**Color (oil):**

**Tint (oil):**

**Bireflectance:** nil

2
**Anisotropy:** often weakly to distinctly anisotropic, blue-green to orange-red

%R: 54 hi  \hspace{1cm} \textbf{VHN:} 913-2056

**Int'l Reflects:**

Polish. Hard.: >aspy, cobaltite; slt>marc, hem; <sperrylite, laurite, cassiterite

**Comments:** Generally idiomorphic, coarser grains showing rect or square outlines; also coarse grained aggregates of xl fragments, coarse grained sphere-like aggregates, fine grained idiomorphic, fine-grained skeletal, very fine grained spherical (often with colloidal texture); cleavages // to (100), (311), and (111) may be visible; twinning lamellae rare; zoning not uncommon; higher Co, Ni, or Cu contents result in pinkish, reddish, or violet tints; may also contain significant quantities of Au or As or Sb; p. 206; 791.

Although the table is comparatively self-explanatory, a brief discussion of the information in each field and how the different fields can be used to group the minerals is appropriate. Manipulations are described in terms of the capabilities of Filemaker Plus™.

**Mineral Name** - the name of the mineral whose properties are listed in that record.

The "FIND" command can be used to bring up the record of a specific mineral by typing its name in this field.

**Chem. Comp.** - the chemical composition of the mineral, as given by Uytenbogaardt and Burke (1971). While searching, Filemaker Plus™ will find only those items that are preceded by punctuation (i.e., spaces, commas, periods, parentheses, etc.). Therefore, it was necessary to insert periods within the chemical formulas of the minerals to permit this field to be searched for minerals containing a particular element or group of elements. This search procedure is not without some idiosyncrasies. Searching for sulfides by specifying the letter "S" in this field will find all sulfides; it will also find all antimonides (Sb), selenides (Se), and other elements which start with a
capital S. With the present version of Filemaker Plus™, this must be endured; perhaps a future version will be more selective.

Crystall. - simply the crystallographic system the mineral belongs to; listed as cubic, hexagonal, hexagonal-rhombohedral, tetragonal, orthorhombic, monoclinic, or triclinic. The file may be searched for any of these.

Color - this is the color of the mineral as listed in Uytenbogaardt and Burke (1971). This field categorizes the minerals as white, gray, blue, red, yellow, brown, green, orange, violet, black, cream, and pink. Because color is subjective, more than one color is often listed in this field; red listed with pink or orange, for instance. Uytenbogaardt and Burke (1971) also report the color of most minerals in comparison to commonly associated minerals. This information was not included in this compilation. If one is observing a yellow mineral, simply search this field for yellow minerals and Filemaker Plus™ will extract them from the database. Again, however, specifying more than one color will find only minerals whose color fields list both colors, not either color.

Tint - faint color deviations from the dominant color of the mineral. Search as for color. "Blu" will find both blue and bluish.

Color (oil) and Tint (oil) - lists those colors when they differ noticeably from the color of the mineral in air.

Bireflectance - degree of bireflectance is listed as nil, weak, distinct, strong, and v strong. Color variations shown by the mineral in different orientations are described. This field is most easily searched for degree of bireflectance, color descriptions being extremely subjective and affected by the kind and quality of microscope being used.
Anisotropy - degree of anisotropy is listed as isotropic, weak, distinct, strong, and v strong. Colors shown by the mineral under crossed polars are described. This field is most easily searched for degree of anisotropy.

%R - this field lists the percent reflectance in air at 540nm, or as close to this wavelength as published values permit. Because the reflectance of anisotropic minerals varies with orientation, the reflectance is often given as a range of values. Because Filemaker Plus™ will not search for a range, this field also contains a text modifier. Reflectance is categorized as v low (0 to 10%), low (10 to 30%), mod (30 to 50%), hi (50 to 70%), and v hi (>70%); this field can be searched using these modifiers.

Intl Reflects. - any internal reflections that the mineral may display are listed here. This field is most conveniently searched by color.

Polish. Hard. - the polishing hardness of the mineral in comparison to those minerals with which it is frequently in contact is listed here. This field, because it usually contains so few comparative hardnesses, is not suitable for searching. An unknown mineral may clearly have a lower polishing hardness than pyrite, but if that comparison is not listed in this field for the unknown mineral, as "<py", then a search of this field would not find it.

Comments - this field lists the typical form of the mineral, describes what, if any, twinning or cleavage may occur, and describes any other characteristic features of the mineral. This field does not list the common associates of the mineral, nor its common position in the paragenetic sequence. That information can be found in either Uytenbogaardt and Burke (1971) (the first page number listed) or Ramdohr (1980) (the second page number listed).

The "Comments" field is actually two three-line fields pasted together. This limits the contents of each of the fields to about 240 characters. This
limiting will facilitate the transport of this information into a different
database, should that be desirable. Details concerning such transport can be
found in the Filemaker Plus™ manual, and probably within the manual of
the destination database, as well.

Filemaker Plus™ has a host of features that the user may find helpful.
Furthermore, users can modify the database in any way they wish. Information can be
added to a field, and minerals can be added to the database. The compilation currently
contains about one-half of the minerals listed in Uytenbogaardt and Burke (1971). If you
would like a copy of the database, please send me a 3.5 inch microfloppy disk and I will
send you the database. I am also very interested in receiving comments or suggestions
from future users.

Finally, this effort was reviewed by B.F. Leonard of the U.S. Geological Survey.
His comments and suggestions, based on a lifetime of observing ore minerals in reflected
light and struggling with the problems of their identification, was literally invaluable. Only
a few individuals are around who possess Ben's expertise, and there are even fewer who
would have been as thorough and as encouraging as Ben was. My sincerest thanks.

REFERENCES
Griddle, A.J., and Stanley, C.J., editors, 1986, the quantitative data file for ore minerals of
the Commission on Ore Microscopy of the International Mineralogical Association,
Recherches Géologiques et Minières, Orléans, France, and Elsevier Scientific
Uytenbogaardt, W. and Burke, E.A.J., 1971, Tables for microscopic identification of ore
ABBREVIATIONS USED IN THE COMPILATION

Aspy - arsenopyrite
Bn - bornite
Cc - chalcopyrite
Cov - covellite
Cpy - chalcopyrite
Degs - degrees
Ft - faint
Gn - galena
Hem - hematite
Hexa - hexagonal
Ilm - ilmenite
IR - internal reflection
Lt - light
Marc - marcasite
Mod - moderate
Moly - molybdenite
Mono - monoclinic
Mt - magnetite
Ortho - orthorhombic
Pent - pentlandite
Pleo - pleochroism
Po - pyrrhotite
Py - pyrite
Rect - rectangular
Rhombo - rhombohedral (trigonal)
Sl - sphalerite
Slt - slightly
Ten - tennantite
Tet - tetrahedrite
V - very
XI - crystal
Xlites - crystallites
Xln - crystalline
Mineral Name: Acanthite (see Argentite)  
Chem. Comp.: Ag$_2$S  
Crystall.: mono  
Color: gray  
Tint: light green  
Color (oil): "smudgy gray"  
Tint (oil): distinctly green  
Bireflectance: weak (oil)  

Anisotropy: distinct with good polish  

%R: 33-37 mod  
VHN: 20-61  

Int'l Reflects.:  

Polish. Hard.: <cc, gn; one of the softest minerals known.  

Comments: Very soft; argentite (cubic) is stable phase above 177°C; p. 34; 471

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Mineral Name: Aeschynite (eschynite)  
Chem. Comp.: (Ce,Nd,Th,Y)(Ti,Nb)$_2$O$_6$  
Crystall.: ortho  
Color: gray  
Tint:  
Color (oil):  
Tint (oil):  
Bireflectance: nil  

Anisotropy: isotropic (metamict)  

%R: < columbite (<15) low  
VHN: 593-754  

Int'l Reflects.: weak dark brown  

Polish. Hard.:  

Comments: Generally prismatic, sometimes tabular or lamellar; usually metamict; associated with pegmatitic or magmatic hydrothermal veins; may occur with zircon, minerals of the betafite group, muscovite, biotite, Ti-oxides, pyrochlore, columbite, sphene, corundum, or arfvedsonite; all data from pp. 489-496 of Vlasov (1966).
Mineral Name: Aguilarite

Chem. Comp.: Ag₄Se.S

Crystall.: ortho <-133C-> cubic

Color: gray

Tint: green

Color (oil): 

Tint (oil): not observable or very weak

Birefringence: v weak, shades of gray; sometimes isotropic

%R: 35 mod VHN: 25-35

Int'l Reflects.: v low

Polish. Hard.: v low

Comments: Accompanied and replaced by argentite, electrum, stephanite, pearcite, and Cu- and Ag-selenides; p. 218; 478.

Mineral Name: Aikinite


Crystall.: ortho

Color: white

Tint: cream

Color (oil): distinctly pink, yellow

Tint (oil): distinct, creamy white to white or light brown

Birefringence: strong, blue-gray-white to pinkish-gray-white to white

%R: 39-46 mod VHN: 165-246

Int'l Reflects.: >gn;~bismuthinite, gn-bismuthinite; <bouronite

Polish. Hard.: >gn;~bismuthinite, gn-bismuthinite; <bouronite

Comments: Forms idiomorphic acicular or columnar xls; may occur in bundles of prismatic xls; perfect cleavage // (010); sharp extinction, some orientations with deep indigo blue color; p. 292; 738.
Mineral Name: Alabandite
Chem. Comp.: Mn.S
Crystall.: cubic
Color: gray
Tint: 
Color (oil): 
Tint (oil): 
Bireflectance: 
Anisotropy: isotropic

%R: 25 low
VHN: 138-266
Int’l Reflects.: brownish / dark green
Polish. Hard.: <sl

Comments: idiomorphic xls and coarse aggregates; lamellar twinning common; p. 124; 642

Mineral Name: alpha-Vredenburgite
Chem. Comp.: (Mn,Fe)3.O4
Crystall.: tetragonal
Color: gray
Tint: 
Color (oil): 
Tint (oil): 
Bireflectance: weak, shades of gray
Anisotropy: distinct, gray to black

%R: 18-20 low
VHN: 
Int’l Reflects.: 

Polish. Hard.: <bixbyite, braunite

Comments: Occurs as irregular masses, commonly as definite pseudomorphs after bixbyite; marked lamellar parting; no cleavage; p. 346; 943.
Mineral Name: Altaite  
Chem. Comp.: Pb.Te

Crystall.: cubic
Color: bright white  
Color (oil): high %R in oil
Bireflectance: isotropic

%R: 71 v hi

VHN: 34-57

Int'l Reflects.: white to bluish and blue gray; strong and abundant

Comments: v. high reflectivity (oil); may be included in gn; usually as granular aggregates of xenomorphic xls; may be as tiny idiomorphic disseminations in gn; p. 240; 661.

Mineral Name: Anatase  
Chem. Comp.: Ti.O2

Crystall.: tetragonal
Color: gray  
Color (oil):

Bireflectance: v weak

%R: 20 low

VHN: 576-623

Int'l Reflects.: white to bluish and blue gray; strong and abundant

Comments: Occurs as idiomorphic xls and as rounded grains; replaces ilmenite; p. 178; 1010.
Mineral Name: Andorite
Chem. Comp.: Pb(Ag,Cu)Sb₃S₆ (gen’l)

Crystall.: ortho
Color: white
Color (oil): gray
Tint: yellow
Bireflectance: weak (air), distinct on grain boundaries in oil

Anisotropy: distinct, gray green to gray blue, violet gray or pinkish gray

%R: 30 mod
VHN: 140-206
Int’l Reflects.: red (rare)

Polish. Hard.: >pyrargyrite, stibnite; slt<semseyite; ~jamesonite; <bournonite; <<sl, stannite

Comments: Occurs as idiomorphic prismatic xls and as aggregates of rounded grains; lamellar twinning very common, often in different directions; a parquet-like texture may result; p. 260; 742.

Mineral Name: Anglesite
Chem. Comp.: PbSO₄

Crystall.: 
Color: dark gray
Color (oil): darker
Tint: 
Bireflectance: none

Anisotropy: none

%R: v low
VHN: 
Int’l Reflects.: probably common?

Polish. Hard.: low, like cerrusite

Comments: Cerrusite is v similar but shows pleo and anisotropy; common as fine-grained and rhythmic encrustations on gn, often with interlayered secondary gn; cleavage is scarcely visible in polished section; p. 1109.
Mineral Name: Antimony                   Chem. Comp.: Sb (usually contains some As)

Crystall.: hexagonal

Color: white

Tint: 

Color (oil): Tint (oil):

Bireflectance: weak

Anisotropy: distinct, yellowish gray, brownish, bluish gray

%R: 70-75 v hi

VHN: 45-135

Int'l Reflects.: >stibnite; <dyscrasite, stibarsenic, arsenic

Comments: Commonly occurs as fine-granular aggregates; idiomorphic cube-like xls rarely occur enclosed in gn; cleavage commonly visible; twinning lamellae, often polysynthetic, usually occur; p. 76; 373.

Mineral Name: Argentite (see Acanthite)                   Chem. Comp.: Ag2.S

Crystall.: cubic

Color: gray

Tint: light green

Color (oil): "smudgy gray" Tint (oil): distinctly green

Bireflectance: weak (oil)

Anisotropy: distinct with good polish

%R: 33-37 mod

VHN: 20-61

Int'l Reflects.: <cc, gn; one of the softest minerals known.

Comments: The stable Ag2S phase above 177°C; p. 34; 471.
Mineral Name: Argentopyrite

Chem. Comp.: Ag.Fe\textsubscript{2}.S\textsubscript{3}

Crystall.: ortho

Color: gray or white

Tint: yellow

Color (oil): darker

Tint (oil):

Birefringence: distinct, pale yellow to brownish or grayish yellow

Anisotropy: strong, light greenish yellow, pink, red-brown (P&J)

\%R: 27-37 mod (P&J; QDF2) VHN: 250-252

Int'l Reflects:

Polish. Hard.: >po; <py

Comments: Pseudo-hex xls; intricate intergrowths of xls; with py, argentite, po; lamellar twinning present; p. 268; 639

Mineral Name: Arsenic

Chem. Comp.: As (usually contains some Sb)

Crystall.: hexagonal

Color: white

Tint: tarnishes in air in one day

Color (oil):

Tint (oil):

Birefringence: distinct in oil, grayish white with a yellow tint to light bluish gray

Anisotropy: v distinct, steel gray, yellow gray or dark gray tints

\%R: 47 to 56 hi (P&J &QDF2) VHN: 57-167

Int'l Reflects:

Polish. Hard.: >>Bi; >Ag, Sb; slt>dyscrasite, stibarsenic

Comments: May show a fine to coarse xln texture; smaller grains tending to be equigranular, coarser xls showing a plume- or sheaf-like appearance; usually shows a colloform texture with concentric layers or spheroids with radiated texture; idiomorphic xls may occur as an alteration product of geocronite; a basal cleavage is often visible; twinning lamellae very common; zonal colloform textures are developed by exposure to air for some days; p. 84; 365.
**Opaque Mineral Optics**

**Mineral Name:** Arsenopyrite  
**Chem. Comp.:** Fe.As.S

- **Crystall.:** mono  
- **Color:** white  
- **Tint:** cream pink  
- **Bireflectance:** weak, but noticeable  
- **Anisotropy:** strong, blue, green, reddish brown-yellow  
- **%R:** 51-52 hi  
- **VHN:** 715-1354  
- **Int'l Reflects.:**  
- **Polish. Hard.:** >>skutterudite, loellingite, magnetite; slt>glaucozot; <cobaltite, pyrite  
- **Comments:** Usually idiomorphically developed with characteristic rhomb-shaped sections, also skeleton-shaped, hypidiomorphic granular, elongated (in spherulites), fine-grained, or extremely fine grained; cleavage commonly absent; lamellar twinning very common; zonal texture not uncommon; p. 190; 863.

**Mineral Name:** Aurostibite  
**Chem. Comp.:** Au.Sb2

- **Crystall.:** cubic  
- **Color:** white  
- **Tint:** pink  
- **Bireflectance:** nil  
- **Anisotropy:** isotropic  
- **%R:** 61 hi  
- **VHN:** 248-262  
- **Int'l Reflects.:**  
- **Polish. Hard.:** >Au  
- **Comments:** Occurs as angular xenomorphic grains; no apparent cleavage; practically always associated with Au, often as a reaction product between Au and stibnite; p. 72; 824.
**Mineral Name:** Awaruite  
**Chem. Comp.:** (Ni,Fe)  
**Crystall.:** cubic  
**Color:** white  
**Tint:** green?  
**Color (oil):** nil  
**Bireflectance:** nil  
**Anisotropy:** isotropic

### Physicochemical Properties

- **%R:** 60-61 hi  
- **VHN:** 209-420  

**Comments:** Always occurs in serpentinized rocks, commonly as coarse granular aggregates; also as veins in mt and silicates; mostly occurs as rounded grains; may form skeletal xls or elongated tabular grains, and reniform or botryoidal aggregates, sometimes with alternating layers of Cu; rarely observed as tiny needles or as almost perfect cubes a few microns across; p. 128; 356.

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**Mineral Name:** Baumhauerite  
**Chem. Comp.:** Pb12.As16.S36  
**Crystall.:** triclinic  
**Color:** white  
**Tint:** pink brown  
**Color (oil):** nil  
**Tint (oil):** blue green  
**Bireflectance:** distinct  
**Anisotropy:** distinct to strong, remarkable blue gray color in lightest position

### Physicochemical Properties

- **%R:** 34-39 mod  
- **VHN:** 128-182  

**Comments:** Often occurs as granular aggregates; twins // (100) very common; p. 300; 751.
Mineral Name: Benjamite  
Chem. Comp.: Pb2(Ag,Cu)2.Bi4.S9  
Crystall.: mono  
Color: white  
Tint: yellow  
Color (oil):  
Tint (oil):  
Bireflectance: weak, distinct in oil  
Anisotropy: strong, blue to pale brown  
%R: 41-42 mod  
VHN: 161-194  
Int'l Reflects.:  
Polish. Hard.:  
Comments: Irregular and spindle-shaped aggregates; no cleavage; intergrowths with empeclite; p. 284; 747.

Mineral Name: Berthierite  
Chem. Comp.: Fe.Sb2.S4  
Crystall.: mono  
Color: white gray  
Tint: pink brown  
Color (oil):  
Tint (oil):  
Bireflectance: strong, brownish pink, gray white, white  
Anisotropy: v strong, blue, gray white, brown, pinkish brown  
%R: 36-41 mod  
VHN: 67-126  
Int'l Reflects.:  
Polish. Hard.: ~stibnite, pyrargyrite; <<sl  
Comments: Radial texture with fibrous or spathic form; needle-like xls, sometimes as aggregates; forms oriented intergrowths with stibnite and myrmekitic ones with cpy; sharp extinction; p. 48; 724.
Mineral Name: Berzelianite

Chem. Comp.: Cu(2-x)Se

Crystal.: cubic

Color: pale blue or white  Tint: blue; rapidly tarnishes to dark blue

Color (oil):  Tint (oil): distinctly blue

Bireflectance: nil

Anisotropy: isotropic

%R: 28 low  VHN: 22-99

Int'l Reflects.: ~clausthalite

Comments: Similar to cc.; color deepens to indigo blue soon after preparation; may contain oriented inclusions of klockmannite; p. 216; 467.

Mineral Name: Betekhtinite

Chem. Comp.: Pb2(Cu,Fe)21.S15

Crystal.: ortho

Color: white  Tint: yellow cream

Color (oil):  Tint (oil):

Bireflectance: distinct, light cream to yellow cream

Anisotropy: strong, dark gray black to dark yellow brown to dark blue green

%R: >gn mod  VHN:

Int'l Reflects.: >bn

Comments: Occurs as tabular, long prismatic, or needle-like xls; may form granular aggregates; alters to bn and gn; p. 94.
Mineral Name: Birnessite

Chem. Comp.: \(\text{Mn}^{4+}, \text{Mn}^{2+}(O, OH)_2\) may contain minor Ca, Mg, Na, K

Crystall.: ?

Color: gray

Tint: 

Color (oil): 

Tint (oil):

Bireflectance: weak

Anisotropy: weak to distinct, gray shades; undulatory extinction

\(\%R\): ~25 low

\(\text{VHN}\): no data

Int'l Reflects.: 

Polish. Hard.: >ranceite

Comments: Occurs as reniform or botryoidal masses; only found as supergene or secondary mineral; p. 352.

Mineral Name: Bismuth

Chem. Comp.: \(\text{Bi}\) (may contain some Te or As)

Crystall.: hexagonal

Color: white

Tint: cream pink (after quickly tarnishing) brown

Color (oil): 

Tint (oil): 

Bireflectance: weak but distinct, creamy white to creamy grayish white

Anisotropy: distinct to strong

\(\%R\): 60-65 hi

\(\text{VHN}\): 10-26

Int'l Reflects.: 

Polish. Hard.: <bismuthinite and all other minerals which may accompany it

Comments: A basal cleavage may be visible; commonly polysynthetically twinned, often with parquet-like or feather-like appearance; p.36; 374.
Mineral Name: Bismuthinite
Chem. Comp.: Bi2.S3

Crystal.: ortho
Color: white
Tint:
Color (oil): gray white
Tint (oil): blue
Bireflectance: weak to distinct, creamy white, bluish gray white, gray white

Anisotropy: v strong, slate gray to yellowish brown or gray violet
%R: 38-59, mod to hi
VHN: 67-216

Int'l Reflects.: slt>emplектite; <cpy; ~gn

Comments: Lighter, with less bireflectance and anisotropy than stibnite, with which it forms a solid solution; straight extinction, large xls commonly show undulatory extinction; usually radial-fibrous form; cleavage // (010) not uncommon; lamellar twinning or "spindle-like" texture reported; p. 66; 710.

Mineral Name: Bixbyite
Chem. Comp.: (Mn,Fe)2.O3

Crystal.: cubic
Color: gray
Tint: cream yellow

Color (oil):
Tint (oil):

Bireflectance: usually not present, sometimes v weak in oil

Anisotropy: isotropic, sometimes weak anomalous anisotropism
%R: 23 low
VHN: 882-1168

Int'l Reflects.: >hausmannite; ~braunite; or<hollandite, depending on orientation of hollandite

Comments: Occurs as well-developed idiomorphic xls and as granular aggregates; cleavage // (111) may be distinct; coarse lamellar twinning, sometimes forming a regular network not uncommon; zoning occurs; p. 352; 959.
Mineral Name: Bornhardtite
Chem. Comp.: Co3. Se4

Crystall.: cubic
Color: white
Tint: pink
Color (oil):
Tint (oil):

Bireflectance:
Anisotropy: isotropic

%R: no data
VHN:

Int'l Reflects.:

Polish. Hard.:

Comments: Idiomorphic xls; intergrown with trog talite, hastite, clausthalite; p. 220; 702.

Mineral Name: Bornite
Chem. Comp.: Cu5. Fe. S4

Crystall.: cubic
Color: lt brown - orange
Tint: pink; rapidly tarnishes to purple
Color (oil): darker
Tint (oil):

Bireflectance: usually v. weak (tarnishes quickly)

Anisotropy: weak to distinct; usually visible

%R: 26 low
VHN: 68-124

Int'l Reflects.:

Polish. Hard.: >cc, gn; slightly <cpy

Comments: Other brown minerals have stronger pleo; po is much harder; commonly occurs as aggregates of rounded grains; idiomorphic xls very rare; often twinned; two cleavages often visible; zonal texture not observed; p. 88; 487
Mineral Name: Boulangerite

Crystall.: mono
Color: white Tint: blue green
Color (oil): much darker Tint (oil):
Bireflectance: distinct, gray white or white with a bluish green tint to darker green gray
Anisotropy: strong, light tan to brown to bluish gray
%R: 38-42 mod VHN: 90-182 (?)
Int'l Reflects.: rare, red
Polish. Hard.: slt<gn; <bournonite

Comments: Usually as granular or fibrous aggregates or as needle-shaped or tabular xls; cleavage or twinning or zonal texture not observed; polarization colors more variegated in air than in oil (in contrast to jamesonite); bireflectance weaker than for jamesonite; p. 272; 770.

Mineral Name: Bournonite
Chem. Comp.: (2.PbS)(Cu2S)(Sb2.S3)

Crystall.: ortho
Color: white Tint: gray blue green
Color (oil): Tint (oil):
Bireflectance: weak (air), visible only on grain boundaries; distinct (oil), bluish green white to olive brown white
Anisotropy: distinct (oil), pale blue, greenish gray, brownish yellow, dark brown, purplish
%R: 35-39 mod VHN: 132-213
Int'l Reflects.: >boulangerite, jamesonite, stibnite; slt>gn; <cpy, tet, sl
Polish. Hard.: >bournonite, slt, <cyp, tet, sl

Comments: Usually as aggregates of polygonal grains; no cleavage; twinning after (110) very common and characteristic, parquet-like pattern common; p. 68; 734.
Mineral Name: Braggite
Chem. Comp.: (Pt,Pd,Ni)S

Crystall.: tetragonal
Color: white
Tint: cream violet
Color (oil): Tint (oil):
Bireflectance: distinct (oil), bluish tints

Anisotropy: strong, blue to brown, similar to arsenopyrite

%R: 35 mod
VHN: 742-1030

Int'l Reflects.: slt>Pt, cooperite, stibiopaladinite; <<sperrylite

Comments: Occurs as idiomorphic tabular xls; twinning rare; alternating layers and myrmekitic intergrowths with Pt; p. 330; 695.

---

Mineral Name: Brannerite
Chem. Comp.: (U,Th,Ca)(Ti,Fe)2.O6

Crystall.: mono
Color: gray
Tint: Usually metamict
Color (oil): Tint (oil):
Bireflectance: Usually metamict

Anisotropy: Usually metamict

%R: 17 low
VHN: 387-907

Int'l Reflects.: brownish gray or grayish white in coarse xls; blue-gray to bluish white to dark brown & yellowish in fine xls;

Polish. Hard.: Slit-Pt, cooperite, stibiopaladinite; <<sparrylite

Comments: Occurs as idiomorphic columnar, prismatic, or needle-shaped xls, or as aggregates of these; also as rounded or irregularly shaped grains; twinning or cleavage not observed; practically always contains very small laths of po and exsolution or alteration bodies of anatase; may show a characteristic dusting of radiogenic gn; p. 196; 1043.
Mineral Name: Braunite

Chem. Comp.: MnMn$_6$(O$_8$/SiO$_4$)

Crystal.: tetragonal

Color: gray

Tint: brown

Color (oil): Tint (oil):

Bireflectance: weak but distinct in oil, shades of dark gray

Anisotropy: weak but distinct, brownish gray to slate blue

%R: 20-22 low

VHN: 280-1187

Int’l Reflects.: dark brown to deep red, rare

Polish. Hard.: slt>mt; slt<bixbyite; <most sections of hollandite

Comments: Usually forms compact or finely granular masses, hypidiomorphic xls or well-developed xls resembling octahedrons; cleavage not observed, twinning rare; zonal texture may occur; p.350; 962.

---

Mineral Name: Bravoite (see Cattierite, Vaesite)

Chem. Comp.: (Fe, Ni, Co)S$_2$

Crystal.: cubic

Color: cream brown

Tint: pink violet

Color (oil): Tint (oil):

Bireflectance: nil

Anisotropy: isotropic

%R: 31-52 mod to hi

VHN: 668-1535

Int’l Reflects.: slt>pent; ~po

Comments: Zonal texture very common due to compositional variations; zones may differ in color and H; high Ni coincides with low reflectivity; Cattierite is the Co end member and Vaesite the Ni endmember of the complete solution series; Cattierite is pinkish (pinkish violet in oil), and Vaesite is gray; p. 132; 809.
Mineral Name: Breithauptite
Chem. Comp.: NiSb

Crystall.: hexagonal
Color: pink
Tint: violet
Color (oil): Tint (oil):
Bireflectance: strong, light pinkish to bright pinkish violet
Anisotropy: bluish green, bluish gray, violet-red
%R: 37-48 mod
VHN: 412-584

Int'l Reflects.: slt<niccolite; <rammelsbergite, safflorite, skutterudite; <cobaltite, aspy, glaucodot

Comments: Can be confused only with niccolite; commonly allotriomorphic granular, also idiomorphic; no cleavage or twinning; zonal texture very common; p. 148; 624.

Mineral Name: Briartite
Chem. Comp.: Cu2(Fe,Zn)Ge.S4

Crystall.: tetragonal
Color: gray
Tint: blue
Color (oil): Tint (oil):
Bireflectance: not observable
Anisotropy: weak to distinct (oil), gray green and reddish tints
%R: 28 low
VHN:

Int'l Reflects.: =cpy

Comments: May show lighter and darker colored zones; polysynthetic twinning visible in oil, in parallel laths in two directions perpendicular to each other; p.90; 548.
**Opaque Mineral Optics**

**Mineral Name:** Calaverite  
**Chem. Comp.:** Au,Te₂

- **Crystall.:** mono  
- **Color:** white  
- **Tint:** cream yellow

**Color (oil):**  
**Tint (oil):**

**Bireflectance:** weak to distinct, light yellow white to light yellow brown

**Anisotropy:** weak to distinct, grayish red, green, greenish brown (or light gray to dark gray with brownish tints)

- **%R:** 64 hi  
- **VHN:** 198-237

**Int'l Reflects.:**

**Polish. Hard.:** >pyrargyrite, sylvanite; sl<gn; <krennerite

**Comments:** Usually occurs as idiomorphic needle-shaped xls sometimes radially developed, penetrating the other tellurides, or as irregular lath-shaped xls; cleavage generally absent; multiple twinning may occur; p. 240; 431.

---

**Mineral Name:** Carrollite  
**Chem. Comp.:** Co₂.Cu.S₄

- **Crystall.:** cubic  
- **Color:** white  
- **Tint:** creamy (pink)

**Color (oil):**  
**Tint (oil):**

**Bireflectance:** nil

**Anisotropy:** isotropic

- **%R:** 43 mod  
- **VHN:** 351-566

**Int'l Reflects.:**

**Polish. Hard.:** ~linnaeite group (siegenite, polydymite)

**Comments:** Occurs as euhedral, subhedral, and anhedral grains; p. 146; 697.
Mineral Name: Cassiterite

Chem. Comp.: Sn.O2

Crystall.: tetragonal

Color: gray

Tint:

Color (oil):

Tint (oil):

Bireflectance: distinct, light to dark gray

Anisotropy: very distinct, gray to dark gray (in oil, masked by internal reflections)

%R: 11-12 low

VHN: 811-1532

Int'l Reflects.: light yellow or whitish to yellow brown, abundant

Polish. Hard.: very high

Comments: Occurs in coarse grained xls, intergrown xls or irregular grains, often beautifully zoned; in very fine grained aggregates acicularly developed, sometimes with radiated texture (pinwheel-like clusters); banded; as colloform aggregates; prismatic cleavage occasionally visible; twinning very common; p. 208; 1013.

Mineral Name: Cattierite (see Bravoite, Vaesite)

Chem. Comp.: Co.S2 (may contain some Ni and Cu)

Crystall.: cubic

Color: pink

Tint:

Color (oil): pink violet

Tint (oil): pink

Bireflectance: nil

Anisotropy: isotropic

%R: 33 mod

VHN: 953-1113

Int'l Reflects.: sl>s1; >siegenite

Polish. Hard.: Forms granular intergrowths with a linnaeite-group mineral; larger xls may show a perfect cubic cleavage; p. 134; 809,816.
Mineral Name: Cerargyrite group  
Chem. Comp.: Ag.Cl to Ag.Br

Crystal.: cubic  
Color: dull gray to  
Color (oil):  
Bireflectance: isotropic

Anisotropy: isotropic

%R: ~11%? Ramdohr  
VHN:  
Int'l Reflects.: common  
Polish. Hard.: ~acanthite

Comments: Forms shells, crusts and fracture fillings, also beautiful idiomorphic xls; often replaces Ag; p. 1110.

Mineral Name: Cerrusite  
Chem. Comp.: PbCO3

Crystal.: pseudohexagonal  
Color: gray  
Color (oil): darker  
Bireflectance: strong,

Anisotropy: strong, but obscured by internal reflections

%R: ~12  
VHN:  
Int'l Reflects.: bright and abundant  
Polish. Hard.: ~or > gn

Comments: Weathering product of gn and other Pb-bearing sulfides; gn cleavage is often preserved; strong pleo and aniso are characteristic (cf anglesite); p. 1108.
**Opaque Mineral Optics**

**Mineral Name:** Chalcocite  
**Chem. Comp.:** Cu2.S

**Crystall.:** ortho (>103°C hex)  
**Color:** white  
**Color (oil):** white  
**Bireflectance:** v weak if present

**Tint:** blue to gray  
**Tint (oil):** blue gray

**Anisotropy:** weak to distinct (emerald green to light pink); parallel extinction

%R: 30-33 mod  
VHN: 58-98

**Int'l Reflects.:**

**Polish. Hard.:** < argentite; < cov, bn; ~ gn, digenite

**Comments:** Chalcocite formed above 103°C is generally coarse-grained and shows intergrowths with digenite; lamellar twinning common; p. 58; 441.

---

**Mineral Name:** Chalcophanite  
**Chem. Comp.:** (Zn,Mn,Fe)Mn3.O7(3.H2O)

**Crystall.:** triclinic  
**Color:** white gray  
**Color (oil):**

**Bireflectance:** v strong, bright white to dark gray  
**Bireflectance (oil):**

**Tint:** v strong, white and gray-white tints

%R: 10-27 v low to low  
VHN: 71-194

**Int'l Reflects.:** intense carmine to deep red is common in Zn-rich; Zn-poor has none

**Polish. Hard.:** low

**Comments:** Occurs as aggregates of tabular xls and as radiating blades; as tiny prismatic xls in secondary Mn ores; also as crypto-xln colloform bands or layers which line or fill cavities in earlier Mn oxides; p. 344; 1085.
**Opaque Mineral Optics**

**Mineral Name:** Chalcopyrite  
**Chem. Comp.:** Cu.Fe.S2  
**Crystall.:** tetragonal  
**Color:** brassy yellow  
**Tint:** green  
**Color (oil):** yellow (darker)  
**Tint (oil):** green  
**Bireflectance:** weak; rare  
**Anisotropy:** weak, but recognizable in oil, gray-blue and greenish yellow  
**%R:** 45 mod  
**VHN:** 174-219  
**Int'l Reflects.:**  
**Polish. Hard.:** >gn; <sl, po, pent  
**Comments:** Twinning very common; lamellae may be differentially developed; very small grains similar to Au; millerite lighter and more cream; may show inclusions of valleriite, cubanite, mackinawite, stannite, sphalerite, or tetrahedrite; p. 92; 526.

**Mineral Name:** Chalcostibite  
**Chem. Comp.:** (Cu2S)(Sb2.S3)  
**Crystall.:** ortho  
**Color:** white  
**Tint:** pink gray  
**Color (oil):**  
**Tint (oil):**  
**Bireflectance:** distinct (oil), creamy white to light brown  
**Anisotropy:** distinct, pinkish, greenish gray, bluish gray  
**%R:** 36-44 mod  
**VHN:** 183-287  
**Int'l Reflects.:** pale red, rare  
**Polish. Hard.:** >Ag; slt<cpy, sl  
**Comments:** Anisotropy more vivid than for bournomite; occurs as allotriomorphic grains, rarely as tabular prismatic xls; cleavage // (001) commonly visible; may show triangular pits; forms intergrowths with enargite; p. 86; 717.
<table>
<thead>
<tr>
<th>Mineral Name</th>
<th>Chromite</th>
<th>Cinnabar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chem. Comp.</td>
<td>(Fe,Mg)(Cr, Al,Fe)2.O4</td>
<td>Hg.S</td>
</tr>
<tr>
<td>Crystall.</td>
<td>cubic</td>
<td>hexagonal</td>
</tr>
<tr>
<td>Color</td>
<td>dark gray</td>
<td>white gray</td>
</tr>
<tr>
<td>Color (oil)</td>
<td>nil</td>
<td>gray</td>
</tr>
<tr>
<td>Bireflectance</td>
<td>nil</td>
<td>distinct (pinkish to yellowish)</td>
</tr>
<tr>
<td>Anisotropy</td>
<td>isotropic, may show anomalous anisotropism</td>
<td>distinct (commonly masked by IR's)</td>
</tr>
<tr>
<td>%R</td>
<td>12-13 low</td>
<td>24-30 low</td>
</tr>
<tr>
<td>VHN</td>
<td>1036-2000</td>
<td>51-98</td>
</tr>
<tr>
<td>Int'l Reflects.</td>
<td>red-brown, very common</td>
<td>intense red</td>
</tr>
<tr>
<td>Polish. Hard.</td>
<td>&gt;mt, hem</td>
<td>slt&gt;Sb, metacinnabar; &lt;&lt;cuprite</td>
</tr>
</tbody>
</table>

**Comments:**

Chromite: Usually forms homogeneous rounded idiomorphic xls or coarsely xln aggregates; cataclastic texture very common; cleavage commonly not visible, in some specimens distinct; twinning not obs; zonal texture not uncommon; p. 174; 946.

Cinnabar: Somewhat similar to proustite, or proustite is brighter and more bluish; idiomorphic and granular aggregates; idiomorphic xls; commonly as granular aggregates; p. 78; 673.
Mineral Name: Clausthalite
Chem. Comp.: Pb,Se
Crystall.: cubic
Color: bright white
Color (oil): similar
Tint (oil):
Bireflectance:
Anisotropy: isotropic
%R: 50 hi
VHN: 46-72
Int’l Reflects.: 
Polish. Hard.: <<gn; slt > tiemannite
Comments: Forms a complete solid solution with galena; lighter color next to galena; cubic cleavage less perfect than gn, but triangular pits may occur; commonly as allotriomorphic grains, sometimes as colloform aggregates; no indication of zoning or twinning; p. 220; 659.

Mineral Name: Cobaltite
Chem. Comp.: (Co,Fe)As.S
Crystall.: ortho
Color: white
Color (oil):
Tint (oil):
Bireflectance: weak, white to pinkish white
Anisotropy: weak to distinct, blue gray and brown color shades
%R: 56 hi
VHN: 948-1367
Int’l Reflects.: >>skutterudite, loellingite; >aspy; <py
Polish. Hard.: Commonly as idiomorphic xls, also skeletons or allotriomorphic aggregates; cleavage in coarser grains; twinning lamellae often visible; zoning occurs; p. 192; 827.
**MINERAL OPTICS**

**Mineral Name:** Coffinite

**Chem. Comp.:** \( U(SiO_4)_{1-x}(OH)_x \)

**Crystall.:** tetragonal

**Color:** gray

**Tint:**

**Color (oil):**

**Tint (oil):**

**Bireflectance:** v weak

**Anisotropy:** appears isotropic

**%R:** 7-10 v low

**VHN:** 236-333

**Int'l Reflects.:** brownish tints, rare and weak

**Polish. Hard.:** <=pitchblende

**Comments:**

Occurs as idiomorphic xls with tetragonal outlines, or as submicroscopic aggregates, in colloform textures; may form veinlets, surrounded by carbonaceous material; forms botryoidal encrustations; occurs as intergranular films between quartz and fluorite; as inclusions in niccolite; p. 196; 1097.

---

**Mineral Name:** Cohenite

**Chem. Comp.:** \((Fe,Ni,Co)3.C\)

**Crystall.:** ortho

**Color:** white

**Tint:** cream

**Color (oil):**

**Tint (oil):**

**Bireflectance:** weak but distinct

**Anisotropy:** weak but distinct

**%R:** no data

**VHN:**

**Int'l Reflects.:**

**Polish. Hard.:** >>pearlite; >iron, po; <schreibersite

**Comments:**

Terrestrial cohenite forms fine-lamellar intergrowths with iron, so called pearlite; p. 142; 358.
Mineral Name: Coloradoite
Chem. Comp.: Hg. Te

Crystal.: cubic
Color: gray

Color (oil): Tint (oil):

Bireflectance:
Anisotropy: isotropic
%R: 34 mod
VHN: 23-35

Int'l Reflects.:<calaverite and sylvanite; usually >petzite

Polish. Hard.: <calaverite and sylvanite; usually >petzite

Comments: Similar to petzite; cleavage not observed; included in and molded by granular hessite; practically always associated with Au; p. 234; 524.

Mineral Name: Columbite-Tantalite
Chem. Comp.: (Fe,Mn)(Nb,Ta)2.O6

Crystal.: ortho
Color: white gray

Color (oil): Tint (oil):

Bireflectance:
Anisotropy: distinct, straight extinction
%R: 15-18 low
VHN: 240-1021

Int'l Reflects.: distinct; Mn = yellow-brown, Fe = deep-red

Polish. Hard.: very high; ~tapiolite

Comments: Usually occurs as euhedral xls and as granular aggregates; cleavage // (100) may be distinct, // (010) less distinct; twinning rare, zonal texture may occur; p. 202; 1039.
Mineral Name: Cooperite
Chem. Comp.: PtS
Crystal.: tetragonal
Color: brown
Tint: orange pink
Color (oil): coffee brown to olive brown
Bireflectance: v weak, only visible in oil on grain boundaries
Anisotropy: strong (oil), gray pink to gray green
%R: 39 mod  
VHN: 505-588
Int'l Reflects.:  
Polish. Hard.: <Pt; <<sperrylite
Comments: Xenomorphic grains and prismatic xls; simple and polysynthetic twinning; intergrowths with Pt, sperrylite, and braggite; p. 322; 696.

Mineral Name: Copper
Chem. Comp.: Cu (may contain some Ag or As)
Crystal.: cubic
Color: pink
Tint: soon tarnishing brown (ish)
Color (oil):  
Tint (oil):  
Bireflectance: nil
Anisotropy: isotropic
%R: 65 hi (QDF2)  
VHN: 48-143
Int'l Reflects.:  
Polish. Hard.: >cc; <cuprite
Comments: Occurs coarse- and fine-grained (as concretions), with allotriomorphic or panidiomorphic texture, as xl aggregates; supergene Cu may show a dendritic or spear-like form; cleavage not observed; after etching a lamellar twinning is always visible; zonal texture not uncommon; p.116; 308.
**Opaque Mineral Optics**

**Mineral Name:** Coronadite  
**Chem. Comp.:** Pb<=2.Mn8.O16

- **Crystall.:** tetragonal  
- **Color:** white  
- **Color (oil):**  
- **Tint:** gray  
- **Tint (oil):**  
- **Bireflectance:** distinct

**Anisotropy:** strong, white to dark gray to dark brown; straight extinction; cross sections appear isotropic  
**%R:** 27-33 low to mod  
**VHN:** 327-357

**Int'l Reflects.:**

**Polish. Hard.:**

**Comments:** Occurs as platy xls, arranged in sheaf-like aggregates; cleavage often distinct; twinning, polysynthetic and mosaic-like, often occurs; p. 356; 1036.

---

**Mineral Name:** Cosalite  
**Chem. Comp.:** (2.PbS)(Bi2.S3)

- **Crystall.:** ortho  
- **Color:** white  
- **Color (oil):**  
- **Tint:** pink gray  
- **Tint (oil):**  
- **Bireflectance:** distinct, light creamy white to darker greenish gray

**Anisotropy:** weak, pinkish yellow, bluish or violet gray  
**%R:** 43 mod  
**VHN:** 74-161

**Int'l Reflects.:**

**Polish. Hard.:** sLt>gn

**Comments:** Occurs as minute needle-shaped xls and fibers or as short-prismatic xls, often forming bundle or sheaf-like aggregates; also as granular aggregates; cleavage very rare; twinning not observed; p. 286; 778.
Mineral Name: Covellite

Chem. Comp.: Cu.S

Crystall.: hexagonal

Color: indigo blue

Tint:

Color (oil): deeper blue

Tint (oil):

Bireflectance: bluish white to deep blue; oil, blue gray to purple-violet red

Anisotropy: v strong, fiery orange to reddish brown

%R: 7 to 24 v low to low

VHN: 59-129

Int'l Reflects.:

Polish. Hard.: >>argentite; slt<gn; >cpy; ~cc

Comments: Alteration product of many Cu-sulfides; Blableibender means blue-remaining and refers to its behavior in oil; usually occurs as idiomorphic tabular xls; perfect basal cleavage; no twinning or zoning observed; p. 54; 676.

Mineral Name: Crednerite

Chem. Comp.: Cu.Mn.O2

Crystall.: mono

Color: white

Tint: cream

Color (oil):

Tint (oil):

Bireflectance: v strong, white or yellowish white to gray

Anisotropy: strong and vivid, white to yellowish white to light gray to violet gray; undulatory extinction

%R: 24-35 low to mod

VHN:

Int'l Reflects.:

Polish. Hard.:

Comments: p. 356; 906.
**Mineral Name:** Cryptomelane  
**Chem. Comp.:** A<=2B8.O16  
A=chiefly K, some Na and Ba;  
B=chiefly Mn4+, some

**Crystall.:** mono (pseudotetragonal)  
**Color:** white brown gray  
**Tint:** tan blue  
**Color (oil):**  
**Tint (oil):** distinct

**Anisotropy:** strong, shades of gray; crypto-xln is isotropic  
%R: 27 low  
**VHN:** 325-1048

**Int'l Reflects.:**  
**Polish. Hard.:** varying, fibrous masses show very low hardness  
**Comments:** With pyrolusite commonest of the Mn minerals; occasionally occurs as well-developed fibrous or acicular xls; usually forms very fine-grained masses, less commonly botryoidal masses; also as colloform layers concentric with, or alternating with, layers of pyrolusite or nsutite; p. 354; 1030.

---

**Mineral Name:** Cubanite  
**Chem. Comp.:** Cu.Fe2.S3

**Crystall.:** ortho  
**Color:** gray or brown  
**Tint:** creamy, pink, yellow  
**Color (oil):** darker  
**Tint (oil):** distinct, cream gray / lt brown gray (oil)

**Anisotropy:** strong, rose brown to deep blue gray  
%R: 40 mod  
**VHN:** 150-264

**Int'l Reflects.:**  
**Polish. Hard.:** slt>cpy; <=sl; <<po

**Comments:** Intimately intergrown with bn, po, and cpy; lamellar shape; occurs as irregular granular or polygonal aggregates; commonly occurs as exsolution lamellae in cpy; p. 96; 630.
Mineral Name: Cubic Cubanite

Chem. Comp.: Cu.Fe2.S3?

Crystal.: cubic

Color: brown

Tint: pink

Color (oil): Tint (oil):

Bireflectance:

Anisotropy: isotropic

%R: 35 mod

VHN:

Int'l Reflects.:

Polish. Hard.: >cpy; <po

Comments: Can be confused with cubanite and po; occurs intergrown with ortho. cubanite; as fine rims on exsolution bodies of ortho. cubanite in cpy; often replaces ortho. cub. with development of parallel fissures from volume decrease; p. 96; 545.

Mineral Name: Cuprite

Chem. Comp.: Cu2.O

Crystal.: cubic

Color: gray

Tint: blue

Color (oil): much darker

Tint (oil): distinctly bluish

Bireflectance: weak, visible on close examination

Anisotropy: strong (anom), deep gray blue to olive green (masked in oil by internal reflections)

%R: 25-30 low

VHN: 179-218

Int'l Reflects.: deep red, always visible

Polish. Hard.: >cpy, Cu, tenorite; <goethite

Comments: Occurs as idiomorphic xls and in earthy form, which may be intimately associated; cleavage // (111) rarely visible; no twinning; p. 118; 893.
Mineral Name: Cuprobismutite

Chem. Comp.: Cu.Bi.S2

Crystall.: mono

Color: white

Tint: cream pink

Bireflectance: distinct, white to gray-white with a creamy tint

Anisotropy: distinct

%R: 37-41 mod

VHN:

Int'l Reflects.: 

Polish. Hard.: 

Comments: Occurs as tiny prismatic xls elongated // b; and as massive grains; associated with cpy, wolframite, cassiterite, gn, tet, emplectite, aikinite, benjaminite, berryite, tetradymite, and bismuthinite; p. 294; 718. (Optical data from P&J).

Mineral Name: Cylindrite


Crystall.: ortho

Color: white

Tint: gray creamy

Bireflectance: distinct, creamy white to bluish gray white

Anisotropy: distinct, dark blue-black to yellow white

%R: 28-31 low to mod

VHN: 31-131

Int'l Reflects.: 

Polish. Hard.: slt>franckeite; <cpy, sl, stannite

Comments: Transverse sections show a concentric texture with layers of different thicknesses; these appear as twin lamellae in longitudinal sections, that approach each other at the end of the xls; franckeite may occur between the layers; cross sections exhibit a spherulitic cross between crossed polars; may show radial twinning; p.316; 748.
Mineral Name: Davidite

Chem. Comp.: (Fe, Ce, U, La)2(Ti, Fe, Cr, V)5O12

Crystall.: hexagonal
Color: gray
Color (oil): not present
Tint: brown
Tint (oil): not present

Bireflectance: not present
Anisotropy: usually metamict

%R: 15-20 low
VHN: 693-890

Int'l Reflects.: deep brown, rare
Polish. Hard.: ~ilm; <hem, rutile

Comments: Occurs as rounded grains or as tabular xls; may form colloform textures; cleavage // (0001); p. 174; 1004.

Mineral Name: Delafossite

Chem. Comp.: Cu.Fe.O2

Crystall.: hexagonal
Color: brown
Color (oil): gray brown
Tint: rose red yellow
Tint (oil): pink yellow

Bireflectance: see colors
Anisotropy: distinct to strong, bluish gray; straight extinction

%R: 20-25 low
VHN:

Int'l Reflects.: <cuprite, goethite
Polish. Hard.: <cuprite, goethite

Comments: Forms aggregates of subparallel xls, also sheaf-like or coarse laminated aggregates, or very fine grained inclusions in goethite, etc., with concentric or botryoidal texture and then very similar to tenorite; cleavage may be visible; basal sections appear isotropic; p. 116; 903.
Mineral Name: Diaphorite  
Chem. Comp.: \((4.\text{PbS})(3.\text{Ag2S})(3.\text{Sb2.S3})\)  
Crystall.: mono  
Color: white  
Bireflectance: distinct on grain boundaries, white to lemon-gray  
Anisotropy: weak to distinct, brownish gray to dull purplish gray; oblique extinction  
%R: 38 mod  
VHN: 197-242  
International Reflects.:  
Polish. Hard.: <gn (VHN implies that it should be considerably harder than gn)  
Comments: Aggregates of rounded or slightly elongated grains; well-developed twinning is generally present and diagnostic; p. 264; 745.

Mineral Name: Digenite  
Chem. Comp.: \(\text{Cu}(1.765)\text{S-Cu}(1.79)\text{S}\)  
Crystall.: cubic  
Color: clear blue  
Bireflectance:  
Anisotropy: isotropic  
%R: 21 low  
VHN: 56-83  
International Reflects.:  
Polish. Hard.: ~cc, gn  
Comments: Octahedral cleavage often visible; often exsolves cc or cov; p. 60; 441.
**Mineral Name:** Djurleite  
**Chem. Comp.:** Cu1.96.S  

- **Crystall.:** ortho  
- **Color:** white  
- **Color (oil):**  
- **Bireflectance:** v weak  
- **Anisotropy:** weak

**Bireflectance:** v weak

%R: ~30 low  

**Comments:** Similar to cc; cannot exist above 93°C; breaks down to hexagonal cc and high digenite; p. 60; 441.

**Mineral Name:** Dufrenoysite  
**Chem. Comp.:** (2.PbS)(As2.S3)

- **Crystall.:** mono  
- **Color:** white  
- **Color (oil):**  
- **Bireflectance:** distinct, only on grain boundaries and twin lamellae  
- **Anisotropy:** strong, brownish violet to dark green  

%R: 37-41 mod  

**Int'l Reflects.:** may occur, dark red  

**Comments:** Occurs as idiomorphic and xenomorphic grains; abundant polysynthetic twins of varying width; p. 302; 752.
Mineral Name: **Dyscrasite**  
**Chem. Comp.**: Ag₃Sb  
**Crystal**: ortho  
**Color**: white  
**Tint**:  
**Color (oil)**: grayer  
**Tint (oil)**:  
**Bireflectance**: weak, white to creamy white  
**Anisotropy**: weak to distinct  
%R: 62-65 hi  
VHN: 152-178  
**Int'l Reflects.**:  
**Polish. Hard.**: >>gn; slt>Ag and Sb; slt<As, cpy  
**Comments**: May occur idiomorphically (with prismatic, square, or rhombic sections) or allotriomorphically; cleavage rarely visible; usually untwinned; irregular jig-saw twinning occurs; p. 84; 407

Mineral Name: **Electrum**  
**Chem. Comp.**: (Au,Ag) 25% and more Ag  
**Crystal**: cubic  
**Color**: white cream  
**Tint**: cream yellow  
**Color (oil)**:  
**Tint (oil)**:  
**Bireflectance**: nil  
**Anisotropy**: isotropic (improper polishing may impart strong anomalous anisotropy)  
%R: 66 hi  
VHN: 34-44  
**Int'l Reflects.**:  
**Polish. Hard.**: see at gold  
**Comments**: Occurrence similar to that of gold; commonly as irregular grains of different size and as veinlets; p. 72.
Mineral Name: Emplectite

Chem. Comp.: Cu.Bi.S2

Crystallic.: ortho

Color: white

Tint: cream yellow

Color (oil): Tint (oil):

Bireflectance: distinct (oil), blue-green, light greenish or creamy

Anisotropy: strong, brown to bluish, dark violet

%R: 36-42 mod

VHN: 158-249

Int'l Reflects.:

Polish. Hard.: >>bismuth

Comments: Darker and more yellowish than bismuthinite, reddish brown tint next to other Cu-Bi sulfides; usually in fibrous or needle-like xls or aggregates; cleavage // (001) may be visible; twinning occurs; p. 294; 719.

Mineral Name: Enargite-Stibioenargite (Famatinite)

Chem. Comp.: Cu3(As,Sb)S4

Crystallic.: ortho

Color: gray or brown

Tint: pink

Color (oil): darker gray

Tint (oil): brown, violet, pink

Bireflectance: weak, distinct (oil) - grayish pink (yellow tint), pinkish gray, grayish violet

Anisotropy: strong - bluish, greenish, reddish, and orange tints

%R: 25 low

VHN: 133-383

Int'l Reflects.: deep red may occur

Polish. Hard.: >gn, bn, cc, chalcostibite, cpy; ~tet, luzonite; <sl

Comments: Hardness and anisotropy are characteristic; stibioenargite, "famatinite", is much rarer; as prismatic xls and allotriomorphic or rounded grains; (110) cleavage nearly always visible; usually untwinned (stress twinning may occur); often shows zonal texture when etched; p. 110; 583.
Mineral Name: Eskebornite  
Chem. Comp.: Cu. Fe. Se2  
Crystall.: hexagonal  
Color: lt yellow  
Tint: brown  
Color (oil): much darker  
Tint (oil):  
Bireflectance: distinct, especially along grain edges (oil), yellowish white to brassy yellow  
Anisotropy: strong, but without pronounced colors, grayish white with yellowish or greenish tints  
%R: 24-35 low to mod  
VHN: 141-202  
Int'l Reflects.:  
Polish. Hard.: slt > clausthalite, naumannite, tiemannite, umangite, klockmannite; << cpy  
Comments: With selenides; softer than po; good basal cleavage, sections // (0001) may show triangular pits; wedge-shaped deformation twins may occur; p. 222; 613.

Mineral Name: Eskolaite  
Chem. Comp.: Cr2.O3  
Crystall.: hexagonal  
Color: gray  
Tint:  
Color (oil): gray  
Tint (oil): blue  
Bireflectance: distinct in oil on grain boundaries and twin lamellae  
Anisotropy: strong, (air) gray blue and greenish, (oil) gray to brownish gray  
%R: 19-21 low  
VHN: 2077-3200  
Int'l Reflects.: emerald green  
Polish. Hard.: > chromite  
Comments: Usually occurs as euhedral, tabular, or prismatic xls; weak zoning may be visible on the darker outer parts of the xls; p. 212; 968.
Mineral Name: Eucairite

Chem. Comp.: alpha (Cu2.Se)(Ag2Se)

Crystall.: ortho - pseudotetragonal

Color: white  
Tint: yellowish

Color (oil):  
Tint (oil): creamy yellow

Bireflectance: distinct (oil), creamy yellow with a pinkish brown tint to white with a greenish yellow tint

Anisotropy: strong, olive brown to steel blue with a purplish tint

%R: 37 mod (P&J & QDF2)  
VHN: 79-90

Int'l Reflects.:  
Polish. Hard.: >klockmannite; ~clausthalite

Comments: Similar to naumannite; usually granular; no evidence of cleavage, twinning or zoning; forms myrmekitic intergrowths with klockmannite and umangite; occurs as needles in umangite; p. 224; 484.

Mineral Name: Ferberite

Chem. Comp.: Fe.W.O4

Crystall.: mono

Color: gray  
Tint: 

Color (oil): gray  
Tint (oil): cream yellow

Bireflectance: not observable

Anisotropy: distinct, greenish yellow to dark gray

%R: 16-19 low (P&J)  
VHN: 387-418

Int'l Reflects.:  
Polish. Hard.: ~ wolframite

Comments: May occur in large xls or in concentric aggregates with radial texture; cleavage may be distinct; p. 186.
**Opaque Mineral Optics**

**Mineral Name:** Ferroselite

**Chem. Comp.:** FeSe₂

- **Crystall.:** ortho
- **Color:** cream
- **Tint:** pink
- **Color (oil):**
- **Tint (oil):** weak to distinct, creamy to white with pinkish tints
- **Bireflectance:** weak to distinct, creamy to white with pinkish tints
- **Anisotropy:** distinct to strong, greenish gray to lilac

- **%R:** 47-50 mod
- **VHN:** 700-933

**Int'l Reflects.:**

**Polish. Hard.:** <<py

**Comments:** Occurs as idiomorphic prismatic to needle-like xls or aggregates; perfect cleavage // to elongation; twinning // (101); occurs as inclusions in eskebornite; p. 228; 845.

**Mineral Name:** Franckeite


- **Crystall.:** triclinic
- **Color:** white
- **Tint:** gray
- **Color (oil):**
- **Tint (oil):** weak, gray white to gray white with a brown tint
- **Bireflectance:** weak, gray white to gray white with a brown tint
- **Anisotropy:** distinct, light brownish gray to dark gray

- **%R:** 27-34 low to mod
- **VHN:** 13-108

**Int'l Reflects.:**

**Polish. Hard.:** slt>gn; <teallite; <<sl

**Comments:** May form tabular xls, prisms, fibers (with feathery appearance) or spheroidal aggregates with radial texture; cleavage // (010) often visible; displacement twins distinguish it from teallite; wedge-shaped twins also occur; p. 316; 747.
Mineral Name: Franklinite
Chem. Comp.: (Zn,Fe,Mn)(Fe,Mn)2O4

Crystall.: cubic

Color: gray

Color (oil): 

Bireflectance: nil

Anisotropy: isotropic

%R: 18 low

VHN: 667-847

Int'i Reflects.: deep red, abundant in oil

Polish. Hard.: >zincite

Comments: Cleavage may be distinct; twinning // (111) and (100) and zoning occur; forms oriented intergrowths with magnetite, hematite, gahnite, or other spinels, or hetaerolite; p. 342; 940.

Mineral Name: "Freibergite"
Chem. Comp.: Ag-tetrahedrite

Crystall.: cubic

Color: gray

Color (oil): 

Bireflectance: nil

Anisotropy: isotropic

%R: 30 mod

VHN: 252-375

Int'l Reflects.: brownish red

Polish. Hard.: >Ag sulfosalts;

Comments: Cleavage rarely visible; freibergite in the strict sense has been redefined as having more Ag than Cu in atoms; p. 106.
Mineral Name: Freieslebenite

Chem. Comp.: \((4.\text{PbS})(2.\text{Ag}_2\text{S})(\text{Sb}_2\text{S}_3)\)

Crystall.: mono

Color: white gray

Tint:

Color (oil):

Tint (oil): yellow

Bireflectance: weak

Anisotropy: distinct, without color effects

%R: 35 mod

VHN: 85-140

Int'l Reflects.:<gn ? (not in clear agreement with VHN)

Comments: Irregular aggregates of xls with idiomorphic boundaries; cleavage in two directions, // (110) and (001) may be visible; synthetic twinning // (110) occurs; observed as small inclusions in gn, which is distinctly reddish (oil) in comparison; p. 264; 744.

Mineral Name: Frohbergite

Chem. Comp.: \(\text{Fe}_2\text{Te}_2\)

Crystall.: ortho

Color: pink red

Tint: purple lilac

Color (oil):

Tint (oil):

Bireflectance: v weak in oil, visible only on grain boundaries

Anisotropy: strong, orange red to inky blue

%R: 45 mod

VHN: 250-297

Int'l Reflects.: >cpy; <tet

Comments: Occurs as inclusions in Au, petzite, cpy, melonite; cleavage and twinning not observed; p. 244; 858.
Mineral Name: Froodite  
Chem. Comp.: Pd.Bi2

Crystall.: mono

Color: gray  
Tint:

Color (oil):  
Tint (oil):

Bireflectance:

Anisotropy: strong, light to dark gray

% R: 50 mod  
VHN:

Int'l Reflects.:  

Polish. Hard.:  

Comments: Occurs in the As and Pd-Cu-rich Ni-ores of Sudbury; p. 330; 826.

Mineral Name: Fulöppite  

Crystall.: mono

Color: white  
Tint:

Color (oil):  
Tint (oil):

Bireflectance:

Anisotropy: distinct, bluish green to reddish brown

% R: 32-42 mod (P&J & QDF2)  
VHN:

Int'l Reflects.:  

Polish. Hard.:  

Comments: No cleavage; occurs as clusters or as irregularly intergrown xls associated with needles of zinkenite, with sl, dolomite and sulfur; p. 272; 762.
Mineral Name: Galena

Chem. Comp.: Pb.S

Crystal.: cubic

Color: bright white

Tint: pink

Color (oil): darker

Tint (oil):

Bireflectance:

Anisotropy: isotropic; weak anomalous anisotropy sometimes

%R: 44 mod

VHN: 56-116

Int'l Reflects.: >>argentite; >proustite, covellite; ~cc;<bn, cpy, tet

Comments: Triangular pits characteristic; similar to clausthalite; as idiomorphic cubes; as granular aggregates and as skeletal xls; very often developed with crystallographic boundaries; perfect cubic (100) cleavage is nearly always visible; twinning caused by mechanical deformation or pressure may occur; zonal texture not uncommon, may be brought out by etching; p.64; 646.

Mineral Name: Galenobismutite

Chem. Comp.: (PbS)(Bi2.S3)

Crystal.: ortho

Color: white

Tint: cream

Color (oil):

Tint (oil):

Bireflectance: strong, yellowish white to pinkish gray or bluish gray

Anisotropy: strong, yellow to dark brown

%R: 42 mod

VHN: 88-150

Int'l Reflects.: <<cpy

Comments: Usually as radial aggregates of fibrous and feathery xls, intergrown with bismuthinite; cleavage // c and perpendicular to c may be visible; may show simple or polysynthetic twinning; p. 286; 777
Mineral Name: Gallite

Chem. Comp.: Cu.Ga.S2

Crystall.: tetragonal

Color: gray

Tint: brown violet

Color (oil): Tint (oil):

Bireflectance: distinct on grain boundaries, brownish gray to violet gray

Anisotropy: distinct, gray-blue tints

%R: 21 low

VHN: 446-471

Int'l Reflects.: 

Polish. Hard.: >gn, renierite; slt>germanite;

Comments: Lighter gray than sl; harder than tn; exsolution bodies in sphalerite and germanite; common associate of germanite; twinned // (112) and (111), also lamellar; p. 112; 542.

Mineral Name: Geikielite

Chem. Comp.: Mg.Ti.O3

Crystall.: hexagonal -rhombohedral

Color: gray

Tint: brown (less brown than ilm)

Color (oil): Tint (oil):

Bireflectance: distinct

Anisotropy: strong, pinkish brown to dark brown, more vivid than ilmenite

%R: 12-15 low

VHN: 560-930

Int'l Reflects.: orange red, more common than ilmenite

Polish. Hard.: slt>ilm

Comments: Occurs as irregular to rounded grains; may contain exsolution lamellae of mt; forms solid solution with ilmenite; p. 176; 980.
**Mineral Name:** Geocronite  
**Chem. Comp.:** (27.PbS)(7(Sb,As)2.S3)  
**Crystall.:** mono  
**Color:** white  
**Tint:** blue green  
**Color (oil):**  
**Tint (oil):**  
**Bireflectance:** weak (air) only on grain boundaries; (oil) light yellow white to greenish white  
**Anisotropy:** distinct, light gray to dark gray, bluish gray or steel blue, creamy tan to brownish gray; oblique extinction  
**%R:** 38-42 mod  
**VHN:** 95-206  
**Int'l Reflects.:**  
**Polish. Hard.:** >boulangerite; ~franckeite  
**Comments:** Occurs as tabular xls and as granular aggregates; rounded grains not uncommon; cleavage may be visible; twinning lamellae very common and characteristic; usually developed in one direction (as distinct from bournonite), exactly //; p. 274; 774.

---

**Mineral Name:** Germanite  
**Chem. Comp.:** Cu3(Ge,Fe)S4  
**Crystall.:** cubic  
**Color:** gray  
**Tint:** pink or violet  
**Color (oil):** more colored  
**Tint (oil):**  
**Bireflectance:**  
**Anisotropy:** isotropic  
**%R:** 20-26 low  
**VHN:** 372-450  
**Int'l Reflects.:**  
**Polish. Hard.:** slt<ten; >gn  
**Comments:** Similar to enargite, luzonite, and bornite; as fine-granular aggregates; common with ten, gn, and enargite; may be distinctly zoned or mottled; p. 106; 572.
Mineral Name: Gersdorffite  
Chem. Comp.: (Ni,Co,Fe)As.S  
Crystall.: cubic  
Color: white  
Tint: yellow pink cream  
Color (oil):  
Tint (oil):  
Bireflectance: nil  
Anisotropy: isotropic  
%R: 47-54 mod to hi  
VHN: 520-907  
Int'l Reflects.:  
Polish. Hard.: >linnaeite; ~skutterudite, ullmannite, loellingite; <<py, aspy  
Comments: Commonly forms idiomorphic xls often showing zonal texture (etching); also as skeletal xls, or as fine grains with irregular boundaries; cleavage // (100) nearly always distinct and typical; triangular pits not uncommon; twin lamellae have been observed; p. 158; 833.

Mineral Name: Getchellite  
Chem. Comp.: As.Sb.S3  
Crystall.: mono  
Color: white gray  
Tint: gray blue  
Color (oil):  
Tint (oil):  
Bireflectance: distinct in oil  
Anisotropy: weak, obscured by internal reflections  
%R: 26-27 low  
VHN: 30-50  
Int'l Reflects.: strong, blood red  
Polish. Hard.: ~orpiment  
Comments: Perfect cleavage // (001); p. 42; 704.
### OPAQUE MINERAL OPTICS

<table>
<thead>
<tr>
<th>Mineral Name:</th>
<th>Glaucodot</th>
<th>Chem. Comp.:</th>
<th>(Co,Fe)As.S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystall.:</td>
<td>ortho</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color:</td>
<td>white</td>
<td>Tint:</td>
<td>cream</td>
</tr>
<tr>
<td>Color (oil):</td>
<td></td>
<td>Tint (oil):</td>
<td></td>
</tr>
<tr>
<td>Bireflectance:</td>
<td>weak</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anisotropy:</td>
<td>distinct</td>
<td></td>
<td></td>
</tr>
<tr>
<td>%R:</td>
<td>45-50 mod</td>
<td>VHN:</td>
<td>841-1277</td>
</tr>
<tr>
<td>Int'l Reflects.:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polish. Hard.:</td>
<td>slit&lt;aspy; &lt;cobaltite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comments:</td>
<td>More bluish, with weaker bireflectance and anisotropic color effects than aspy; commonly idiomorphically developed, often showing inclusions; cleavage in two directions may be distinct, // (001) and (110); occurs as inclusions in skeletal xls of cobaltite; p. 190; 871.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mineral Name:</th>
<th>Goethite</th>
<th>Chem. Comp.:</th>
<th>alpha - Fe.O.OH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystall.:</td>
<td>ortho</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color:</td>
<td>gray dull to bright</td>
<td>Tint:</td>
<td>blue</td>
</tr>
<tr>
<td>Color (oil):</td>
<td></td>
<td>Tint (oil):</td>
<td></td>
</tr>
<tr>
<td>Bireflectance:</td>
<td>weak, in oil more distinct but often masked by internal reflections</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anisotropy:</td>
<td>distinct, gray-blue, gray-yellow, brownish, greenish gray; masked in oil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>%R:</td>
<td>15-20 low</td>
<td>VHN:</td>
<td>525-1010</td>
</tr>
<tr>
<td>Int'l Reflects.:</td>
<td>brownish yellow or reddish brown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polish. Hard.:</td>
<td>~lepidocrocite; &lt;mt, maghemite, ilmenite, hem</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comments:</td>
<td>Principal constituent of most limonites; colloform texture and spherulitic aggregates very common; banding or intimate intergrowths with hematite and ilvaite occur; the centers of zoned grains often have highest %R; p. 160; 1071.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Mineral Name: Gold
Chem. Comp.: Au (May contain Ag, Pd, Cu, Bi, Pt, Hg, Rh)

Crystall.: cubic
Color: yellow
Tint: bright golden
Color (oil):
Tint (oil):
Bireflectance: nil

Anisotropy: isotropic
%R: 66 hi
VHN: 41-94

Int'l Reflects.: >gn; <tet, sl; <<cpy

Comments: The color changes with varying metal content; the different phases do not only occur as separate grains but are frequently intergrown with each other in intricate patterns; rarely occurs as euhedral pentagonal or dodecahedral xls but normally as isolated grains of different size, as fine veinlets, skeletal grains, clustered, sheaf-like masses, pseudohexagonal xls, fine acicular, as xl aggregates, in colloidal form, or as solid solution in pyrite, aspy, and sl; forms rims on py, cpy, and gn; p. 70; 321.

Mineral Name: Graphite
Chem. Comp.: C

Crystall.: hexagonal - rhombohedral
Color: brown v dark
Tint:
Color (oil): orange to black
Tint (oil):
Bireflectance: v strong, brownish to almost black (in air bluish gray)

Anisotropy: v strong, straw-yellow to dark brown or violet-gray; basal sections appear isotropic
%R: 5-20 v low to low
VHN: 7-12

Int'l Reflects.: <<cpy; <moly

Comments: Forms small plates, blades or laths, and sheaf-like aggregates; rarely radial-fibrous shells; the basal cleavage in usually well-visible; twinning and zonal texture not observed; parallel displacements and curved or wave-like texture very common; p. 104; 384.
Mineral Name: Gratonite


Crystall.: hexagonal

Color: white

Tint: pink

Color (oil): 

Tint (oil): 

Bireflectance: v weak, visible only on grain boundaries

Anisotropy: distinct, but weaker than any other lead-silver sulfosalt; straight extinction

%R: 33-34 mod

VHN: 123-156

Int’l Reflects.: red, rarely visible

Polish. Hard.: ~gn, slt<jordanite

Comments: Always occurs in sheaf-like aggregates of idiomorphic xls; cross-sections may have hexagonal or trigonal outlines; zonal texture may occur; p. 298; 757.

Mineral Name: Greenockite

Chem. Comp.: Cd.S

Crystall.: hexagonal

Color: light gray

Tint: blue

Color (oil): med gray

Tint (oil): 

Bireflectance: nil

%R: 17 low

VHN: 52-91

Int’l Reflects.: abundant lt yellow, brownish red, blood-red

Polish. Hard.: <sl

Comments: Lighter and more bluish than sl; forms coatings on sl, py, franckeite, canfieldite; commonly associated with wurtzite; p. 124; 582.
<table>
<thead>
<tr>
<th>Mineral Name</th>
<th>Greigite</th>
<th>Chem. Comp.: Fe$_3$S$_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystall.</td>
<td>cubic</td>
<td></td>
</tr>
<tr>
<td>Color</td>
<td>white</td>
<td>Tint: cream</td>
</tr>
<tr>
<td>Color (oil)</td>
<td></td>
<td>Tint (oil):</td>
</tr>
<tr>
<td>Bireflectance</td>
<td>nil</td>
<td></td>
</tr>
<tr>
<td>Anisotropy</td>
<td>isotropic</td>
<td></td>
</tr>
<tr>
<td>%R</td>
<td>no data</td>
<td>VHN:</td>
</tr>
<tr>
<td>Int'l Reflects.:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polish. Hard.:</td>
<td>sli&gt;po</td>
<td></td>
</tr>
<tr>
<td>Comments</td>
<td>Very similar to bravoite and the linnaeite group; tends to form idiomorphic xls; no cleavage; p. 140; 697.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mineral Name</th>
<th>Groutite</th>
<th>Chem. Comp.: alpha MnOOH (may contain some Sb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystall.</td>
<td>ortho</td>
<td></td>
</tr>
<tr>
<td>Color</td>
<td>grayish white</td>
<td>Tint: brown</td>
</tr>
<tr>
<td>Color (oil):</td>
<td>Tint (oil):</td>
<td></td>
</tr>
<tr>
<td>Bireflectance:</td>
<td>distinct, lightest perpendicular to elongation</td>
<td></td>
</tr>
<tr>
<td>Anisotropy:</td>
<td>v strong, but no vivid colors; // elongation, dark violet-brown; perpendicular elongation, pale brownish gray</td>
<td></td>
</tr>
<tr>
<td>%R</td>
<td>13-19 (QDF2)</td>
<td>VHN: 613-813</td>
</tr>
<tr>
<td>Int'l Reflects.:</td>
<td>abundant in sections // (010) (oil), deep red-brown; rare in other sections</td>
<td></td>
</tr>
<tr>
<td>Polish. Hard.:</td>
<td>no data</td>
<td></td>
</tr>
<tr>
<td>Comments:</td>
<td>Ossurs as platy, tabular, wedge- or lens-shaped xls, or as radiating aggregates of platy xls; cleavage // to (010) and (100); p. 340; 1081.</td>
<td></td>
</tr>
</tbody>
</table>
Mineral Name: Guanajuatite  
Chem. Comp.: Bi$_2$(Se,S)$_3$

Crystall.: ortho  
Color: white  
Tint: cream pink  

Bireflectance: distinct (air), strong (oil), yellowish white to bluish gray white to pinkish white

Anisotropy: strong, color effects subdued, sharp extinction

%R: 55 hi  
VHN: 42-150

Comments: Lighter than paraguanajuatite, weaker anisotropy than bismuthinite; radiated or granular aggregates; also as idiomorphic xls; distinct cleavage in two directions; may be intergrown with clausthalite; p. 230; 714.

Mineral Name: Gudmundite  
Chem. Comp.: Fe$_2$Sb$_2$S$_4$

Crystall.: mono  
Color: white  
Tint: cream

Bireflectance: distinct, white (faint green) to pinkish cream to pinkish white

Anisotropy: strong, white, gray, green, blue, black, purple, pink, brown

%R: 41-57 mod to hi  
VHN: 588-683

Comments: Often forms idiomorphic, needle-shaped xls or xl aggregates; twinning very common; almost invariably associated with tet, gn, po, sulfosalts; forms regular or irregular intergrowths with po and Pb-Sb- or Cu-Sb-sulfosalts; occurs as decomposition product of tet; p. 130; 872.
Mineral Name: Hastite          Chem. Comp.: Co,Se2
Crystall.: ortho
Color: red violet          Tint: brown red
Color (oil): more vivid       Tint (oil): 
Bireflectance: distinct to strong, brown red to red violet

Anisotropy: strong, with vivid colors often in meat red tints
%R: no data       VHN:
Int'l Reflects.: 
Polish. Hard.: 
Comments: Forms idiomorphic xls, arranged in radial aggregates around a core of trog talite or Au, the whole included in clausthalite; lamellar twinning abundant; p. 226; 845.

Mineral Name: Hauchecornite          Chem. Comp.: (Ni,Co)9(Bi,Sb)2.S8
Crystall.: tetragonal
Color: brown yellow          Tint: gray cream
Color (oil):       Tint (oil):
Bireflectance: weak

Anisotropy: distinct to strong, brown and blue gray tints
%R: 40 mod       VHN:
Int'l Reflects.: 
Polish. Hard.: slt>millerite
Comments: Usually occurs as granular aggregates, seldom as idiomorphic tabular xls; no cleavage; p. 122; 403.
**Mineral Name:** Hauerite

**Chem. Comp.:** Mn\textsubscript{52}

**Crystall.:** cubic

**Color:** white gray

**Tint:** brown

**Color (oil):**

**Tint (oil):** nil

**Bireflectance:** nil

**Anisotropy:** isotropic

%R: 25 low

VHN: 485-508

**Int'l Reflects.:** always present; commonly red as in cuprite, or brownish red as in manganite

**Polish. Hard.:**

**Comments:** Generally as idiomorphic octahedral xls; cubic cleavage usually distinct; triangular pits may occur; associated with sulfur-rich clays in volcanic rocks; p. 162; 826.

---

**Mineral Name:** Hausmannite

**Chem. Comp.:** (Mn,Fe)Mn\textsubscript{2}O\textsubscript{4}

**Crystall.:** tetragonal

**Color:** gray

**Tint:** brown blue

**Color (oil):**

**Tint (oil):** distinct in oil, gray with a faint bluish tint to dark brownish gray

**Bireflectance:**

**Anisotropy:** strong, yellowish or yellowish brown, light gray, or bluish gray

%R: 17-21 low

VHN: 466-724

**Int'l Reflects.:** blood red, not uncommon

**Polish. Hard.:** >manganite, pyrolusite, cryptomelane; <jacobsite; <<bixbyite

**Comments:** Usually forms coarse-grained aggregates often with mosaic texture or well-developed xls, also as fine-grained veinlets replacing bixbyite; irregular twinning very common and characteristic, lamellae often intersecting each other and of unequal width and hardness, untwinned specimens rare but may occur; numerous fine scratches appear in the lightest bireflectant and anisotropic positions; p. 346; 955.
<table>
<thead>
<tr>
<th>Mineral Name</th>
<th>Heazlewoodite</th>
<th>Chemical Composition</th>
<th>Ni$_3$S$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystall.</td>
<td>hexagonal</td>
<td>Color</td>
<td>cream yellow</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tint</td>
<td>yellow</td>
</tr>
<tr>
<td>Bireflectance</td>
<td>v weak, visible on grain boundaries only (oil)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anisotropy</td>
<td>strong, lilac to grayish green</td>
<td></td>
<td></td>
</tr>
<tr>
<td>%R</td>
<td>53 hi</td>
<td>VHN</td>
<td>221-321</td>
</tr>
<tr>
<td>International Reflects.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polish, Hard.</td>
<td>slt&gt;cpy, bn; slt&lt; pent, awaruite, po; &lt; millerite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comments</td>
<td>Always occurs in serpentinized rocks, in a granular or interlocking mosaic texture; cleavage // (1011) may be visible; may show twin lamellae; p. 122; 405.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mineral Name</th>
<th>Hematite</th>
<th>Chemical Composition</th>
<th>Fe$_2$O$_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystall.</td>
<td>hexagonal - rhombohedral</td>
<td>Color</td>
<td>gray white</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tint</td>
<td>blue sometimes</td>
</tr>
<tr>
<td>Bireflectance</td>
<td>distinct, (in oil) yellowish white to grayish blue or brownish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anisotropy</td>
<td>v distinct, especially on twin boundaries, grayish blue to grayish yellow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>%R</td>
<td>26-30 low</td>
<td>VHN</td>
<td>739-1114</td>
</tr>
<tr>
<td>International Reflects.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polish, Hard.</td>
<td>&gt;&gt;goethite, lepidocrocite, mt; &gt;ilmenite; ~rutile; py; &lt; cassiterite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comments</td>
<td>Usually idiomorphically developed, tabular or thin tabular, also laminated, fibrous or as radiated aggregates of needle-shaped xls; two pseudo-cleavages often distinct. Lamellar twinning very common; often caused by strain, lamellae may occur in different systems and show transverse twinning, they may be curved, tapering off, showing alternating wedges; p. 198; 969.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Opaque Mineral Optics**

**Mineral Name:** Herzenbergite  
**Chem. Comp.:** Sn.S  
**Crystall.:** ortho  
**Color:** white  
**Tint:** gray  
**Color (oil):**  
**Tint (oil):**  
**Bireflectance:** weak, bluish to yellowish white  
**Anisotropy:** strong, bright to yellowish red / blue-violet  
%R: 42-44 mod  
VHN: 48-114  
**Int'l Reflects.:** (oil) red-brown  
**Polish. Hard.:**  
**Comments:** Very similar to teallite and franckeite; thin tabular xls in subparallel aggregates; zonal xls are common; p. 318; 669.

---

**Mineral Name:** Hessite  
**Chem. Comp.:** Ag2.Te  
**Crystall.:** mono <-155C-> cubic  
**Color:** gray white  
**Tint:** ft purple against gn  
**Color (oil):** gray  
**Tint (oil):** brown  
**Bireflectance:** distinct in oil; pinkish or brownish, to bluish  
**Anisotropy:** strong, dark gold brown or orange to dark blue gray or blue  
%R: 39-41 mod  
VHN: 24-44  
**Int'l Reflects.:**  
**Polish. Hard.:** lowest of all tellurides; >argentite; slt<altaite; <<gn, Au  
**Comments:** Occurs as rounded aggregates or as allotriomorphic xls, also as skeleton-shaped xls; cleavage not observed; high temperature form practically always displays inversion twin lamellae; inclusions in gn not rare; commonly intergrown with petzite and Au; p. 242; 421.
Mineral Name: Hetaerolite  
Chem. Comp.: Zn.Mn2.O4  
Crystall.: tetragonal  
Color: dark gray  
Color (oil):  
Bireflectance: weak to distinct  
Anisotropy: strong, yellowish and brownish gray  
%R: 13-18 low  
VHN: 585-813  
Int’l Reflects.: reddish brown, common and abundant  
Polish. Hard.: ~hausmannite  
Comments: Occurs as idiomorphic xls and as polygonal aggregates, also forms lamellar aggregates often with radiated texture or concentric intergrowths with chalcophanite; replaces manganite; "hydrohetaerolite" is very similar in all respects to hetaerolite; p. 338; 958.

Mineral Name: Heterogenite  
Chem. Comp.: Co.O.OH(H2O)  
Crystall.: hexagonal  
Color: white  
Color (oil): darker  
Bireflectance: v strong, creamy white to grayish brown  
Anisotropy: v strong, brown to gray, basal sections appear isotropic  
%R: 10-25 v low to low  
VHN:  
Int’l Reflects.:  
Polish. Hard.:  
Comments: Cleavage or parting often visible; basal sections show hexagonal outline and often a fine concentric texture; spherulites and radiated aggregates very common; central parts usually very fine-grained, coarsening outward; p. 162; 1081.
**Heteromorphite**

**Chem. Comp.**: \((7\text{PbS})(4\text{Sb}_2\text{S}_3)\)

**Crystal I.**: mono

**Color**: white

**Tint**: green

**Color (oil)**: Tint (oil):

**Bireflectance**: distinct to strong

**Anisotropy**: strong

**%R**: 37-41 mod

**VHN**: 137-187

**Comments**: Forms intergrowths with plagionite and semseyite; very similar to jamesonite; p. 274; 763.

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**Högbomite**

**Chem. Comp.**: (Fe,Mg)\(_6\)(Al,Fe)\(_{16}\).Ti.O\(_{32}\)

**Crystal I.**: hexagonal

**Color**: dark gray

**Tint**: Tint (oil):

**Bireflectance**: weak; in oil distinct on twin boundaries

**Anisotropy**: distinct, masked in oil by internal reflections

**%R**: 10 v low

**VHN**: 1048-1214

**Int'l Reflects.**: yellowish brown, abundant and strong

**Polish. Hard.**: slt>spinel; >ilmenite, mt

**Comments**: Forms small idiomorphic xls, basal sections show hexagonal outline; also occurs as tabular, prismatic, and barrel-shaped xls and as irregular grains; twinning very common; replacement product of spinel; p. 182; 998.
**Mineral Name:** Hollandite  
**Chem. Comp.:** (Ba<=2)R8.O16  
R=mainly Mn4+, also Mn2+,Fe, and Co

**Crystall.:** mono and pseudotetragonal  
**Color:** white  
**Tint:** yellowish  
**Color (oil):**  
**Tint (oil):** distinct (oil), white to light gray

**Bireflectance:** distinct (oil), white to light gray

**Anisotropy:** strong, gray to yellowish to pinkish white to bluish to violet-gray; basal sections are practically isotropic  
**%R:** 26-33 low to mod  
**VHN:** 272-1048

**Int'l Reflects.:**

**Polish. Hard.:** slt<bixbyite; most sections >>braunite

**Comments:** Forms well-developed prismatic or tabular xls, fibrous aggregates of needle-like xls, or coarse-grained and fine-grained, compact or botryoidal masses; cleavage commonly distinct; twinning may occur, similar to that of hausmannite or hematite; p. 356; 1035.

---

**Mineral Name:** Huebnerite  
**Chem. Comp.:** Mn.W.O4

**Crystall.:** mono  
**Color:** gray  
**Tint:** brown  
**Color (oil):**  
**Tint (oil):** distinct

**Bireflectance:** distinct

**Anisotropy:** strong

**%R:** <wolframite low  
**VHN:**

**Int'l Reflects.:** red, lighter than wolframite

**Polish. Hard.:** ~wolframite

**Comments:** Occurs as coarse, separate xls or as finely xln aggregates; zonal xls occur due to differences in Fe/Mn ratio; p. 186.
**Mineral Name:** Hutchinsonite

- **Chem. Comp.:** \((\text{Tl},\text{Pb})_2\text{As}_5\text{S}_9\)
- **Crystall.:** ortho
- **Color:** white
- **Tint:** gray blue
- **Color (oil):**
- **Tint (oil):** blue
- **Bireflectance:** weak, bluish violet-white to bluish white with a green tint
- **Anisotropy:** distinct to strong, violet to deep blue; in oil obscured by internal reflections; straight extinction
- **%R:** 30-31 mod
- **VHN:** 170-171
- **Int'l Reflects.:** carmine red
- **Polish. Hard.:**
- **Comments:** Radiating aggregates of needle-like xls; no twinning or zoning observed; good cleavage // (010); p. 298; 740.

**Mineral Name:** Idaite

- **Chem. Comp.:** \(\text{Cu}_3\text{Fe}_3\text{S}_4\)
- **Crystall.:** hexagonal
- **Color:** brown to orange
- **Tint:** red
- **Color (oil):** more vivid
- **Tint (oil):**
- **Bireflectance:** v. strong, reddish orange / red-brown / bright yellowish gray
- **Anisotropy:** v strong, vivid green to grayish green
- **%R:** 21-29 low
- **VHN:** 176-202
- **Int'l Reflects.:**
- **Polish. Hard.:** somewhat > cov
- **Comments:** Supergene, as alteration of bornite; hypogene, large hexagonal tabular xls; p. 56; 693.
**Mineral Name:** Ilvaite  

**Chem. Comp.:** CaFe2.Fe(OH/O/Si2O7)  

- **Crystall.:** ortho mono  
- **Color:** gray blue  
- **Tint:**  
- **Color (oil):** gray blue  
- **Tint (oil):**  
- **Bireflectance:** v strong (air), blue and gray; extreme (oil), dark red or reddish purple to gray or slightly bluish gray  
- **Anisotropy:** v strong (air), blue, pink, reddish orange (45 degs, fiery orange); (oil), dark blue, purplish red (45 degs, bluish orange)  
- **%R:** 8-9 v low  
- **VHN:** 703-1055  
- **Int'l Reflects.:** orange to brown to red, rare  
- **Polish. Hard.:** >>graphite; >sl; ~hem; >mt; <py  

**Comments:** Occurs as idiomorphic xls or as aggregates; also as hypidiomorphic grains; twinning rare, lamellae following two systems; p. 198; 1095.
**Mineral Name:** Indium  
**Chem. Comp.:** In  
**Crystall.:** tetragonal  
**Color:** white  
**Tint:** pink  
**Color (oil):**  
**Tint (oil):**  
**Bireflectance:** not present  
**Anisotropy:** weak  
**%R:** 90-95 v hi  
**VHN:** 130-159  
**Int'l Reflects.:**  
**Polish. Hard.:**  
**Comments:** Occurs in close association with native lead in greisenized and albitic granites; p. 104.

**Mineral Name:** Iridium  
**Chem. Comp.:** Ir (may contain up to 32% Os - see Osmiridium; and Ru and Pt)  
**Crystall.:** cubic  
**Color:** white  
**Tint:** bluish next to Pt; yellowish next to Os  
**Color (oil):**  
**Tint (oil):**  
**Bireflectance:** nil  
**Anisotropy:** isotropic  
**%R:** 82 v hi  
**VHN:** 681-743  
**Int'l Reflects.:**  
**Polish. Hard.:** >>Pt  
**Comments:** Only found as exsolution bodies in Pt; as rounded or octahedral grains, lamellae // (100) of Pt, worm-like; may contain in turn exsolutions of Pt; p. 328; 339.
Mineral Name: Iron  
Chem. Comp.: alpha - Fe (usually contains some Cr and Ni)

Crystall.: cubic  
Color: white  
Tint: gray blue

Color (oil):  
Tint (oil): nil

Bireflectance: nil

Anisotropy: isotropic

%R: 65 hi  
VHN: 116-288

Int’l Reflects.:  
Polish. Hard.: <mt, cohenite

Comments: Usually occurs as drop-like aggregations; intimate exsolution intergrowths with fine-lamellar cohenite, oriented // (111) of iron, are called pearlite; no cleavage, zoning or twinning were observed in natural terrestrial iron; p. 128; 353.

Mineral Name: Jacobsite  
Chem. Comp.: (Mn,Fe,Mg)(Fe, Mn)2.O4

Crystall.: cubic  
Color: brown gray  
Tint: rose pink brown

Color (oil):  
Tint (oil): nil

Bireflectance: nil

Anisotropy: isotropic

%R: 20 low  
VHN: 690-875

Int’l Reflects.: deep red, may occur; more common with increasing Mn content

Polish. Hard.: ~mt; slt<braunite

Comments: Forms polygonal grains, rounded idiomorphic xls and fine grained aggregates; twinning and cleavage not observed; p. 248; 943.
Opaque Mineral Optics

Mineral Name: Jalpaite

Chem. Comp.: Ag3.Cu.S2

Crystal.: tetragonal

Color: white gray

Tint: green?

Color (oil): Tint (oil):

Bireflectance: weak, only visible in oil, brownish gray to gray

Anisotropy: distinct, blue green and light green; stronger than acanthite, less pronounced than stromeyerite and mckinstryite

%R: 30 low

VHN: 23-30

Int'l Reflects.: 

Polish. Hard.: ~argentite; <gn

Comments: Forms lamellated and granular aggregates; good prismatic cleavage; occurs intergrown with acanthite or pearcite, and as inclusions in gn and sl; difficult to distinguish from acanthite; p. 38; 486.

Mineral Name: Jamesonite


Crystal.: mono

Color: white

Tint: ft green, especially in contact with gn

Color (oil): Tint (oil):

Bireflectance: strong, bright white with a slt yellow-green tint

Anisotropy: strong, gray, tan, brown, light blue, dark blue; basal sections are nearly isotropic

%R: 37-41 mod

VHN: 67-126

Int'l Reflects.: Bi-jamesonite has red

Polish. Hard.: <gn

Comments: Occurs as needle-shaped xls and in aggregates of these; cleavage perpendicular to elongation usually visible; twinning lamellae very common developed // elongation; p. 48; 765.
**Mineral Name:** Jarosite  
**Chem. Comp.:** $X\text{Fe}_3\{(\text{OH})_6\text{SO}_4\}_2$, where $X = \text{K or Na, NH}_4, \text{Ag, or 1/2Pb}$

**Crystall.:** rhombohedral  
**Color:**  
**Color (oil):**  
**Tint:**  
**Tint (oil):**  
**Bireflectance:** strong

**Anisotropy:**

$\%R$:  
**VHN:**

**Int'l Reflects.:** common, nearly colorless

**Polish. Hard.:**

**Comments:** In gossan of pyritic ore deposits; may accumulate in the rhythmically banded limonitic crusts of cpy and py; p. 1111.

---

**Mineral Name:** Jordanite  
**Chem. Comp.:** $(27\text{PbS})(7\text{As}_2\text{S}_3)$

**Crystall.:** mono  
**Color:** white  
**Color (oil):**  
**Tint:** faint green  
**Tint (oil):**

**Bireflectance:** distinct, white to yellowish gray white to faint greenish gray white

**Anisotropy:** strong, dark gray, yellowish gray, greenish gray, dark brownish gray

$\%R$: 37-41 mod  
**VHN:** 149-204

**Int'l Reflects.:**

**Polish. Hard.:** sgt>semseyite, gratonite; ~gn

**Comments:** Idiomorphic grains rare; usually as concentric or botryoidal masses with undulatory extinction and weak anisotropy; layers may alternate with gn; cleavage may be present; regular twinning very common; p. 302; 754.
Mineral Name: Joseite-A and Joseite-B
Chem. Comp.: A: Bi(4+x)Te(1-x)S2
            B: Bi(4+x)Te(2-x)S
            x = 0 to 0.3
Crystall.: hexagonal
Color: white
Tint: yellow; B is slightly lighter than A
Color (oil): Tint (oil): yellow stronger
Bireflectance: not present
Anisotropy: weak, gray to yellow gray, distinct in sections // c; air, lt pinkish gray to dark brownish gray; oil, light gray to slate gray with a pink tint; basal sections appear isotropic
%R: A=49-53; B=52-58
VHN: 29-87
Int'l Reflects.: slt < tetradymite; < bismuthite
Polish. Hard.: very high
Comments: Forms platy xls; perfect basal cleavage; a "spindle"-like texture, due to folding has been observed; p. 236; 439.

Mineral Name: Karelianite
Chem. Comp.: V2.O3
Crystall.: hexagonal
Color: gray brown
Tint: green brown
Color (oil): Tint (oil): weak
Bireflectance: weak
Anisotropy: strong, reddish brown to gray
%R: 18 low
VHN: 1790
Int'l Reflects.: very high
Polish. Hard.: very high
Comments: Forms prismatic xls; contains inclusions of po, cpy, py; p. 212; 969.
Mineral Name: Kermesite  
Chem. Comp.: Sb₂S₂O

Crystallography: triclinic or monoclinic

Color: gray  
Tint: blue

Color (oil):  
Tint (oil):

Bireflectance: distinct, bluish gray-white to brownish gray-white (P&J)

Anisotropy: strong, violet to blue green; in oil masked by internal reflections

%R: 25-32 low (P&J & QDF2)  
VHN: 36-99

Int'l Reflects.: intense, deep-red with a violet tint

Polish. Hard.: 

Comments: Occurs as irregular grains or as radiated aggregates; also as single needle-like xls; produced as alteration of stibnite; p. 42; 715.

---

Mineral Name: Kesterite  
Chem. Comp.: Cu₂Sn.Zn.S₄

Crystallography: tetragonal

Color: gray  
Tint:

Color (oil):  
Tint (oil):

Bireflectance: not present

Anisotropy: weak

%R: 25 low (QDF2)  
VHN: 328-348 (QDF2)

Int'l Reflects.: 

Polish. Hard.: ~stannite

Comments: Zn-analog of stannite; may be identical to the "stannite (?) II) of Ramdohr (1944); occurs as exsolution and replacement intergrowths with stannite and "hexastannite"; it is replaced by cassiterite; p. 310; 548.
Mineral Name: Klockmannite

Chem. Comp.: Cu-Se

Crystall.: hexagonal

Color: gray

Tint: green blue

Color (oil):

Tint (oil):

Bireflectance: v. strong, grayish brown (violet) / bluish gray

Anisotropy: v. strong, creamy white to orange; (brownish blue to fiery orange)

%R: 12-36 low to mod

VHN: 57-86

Int'l Reflects.:

Polish. Hard.: ~umangite; <eucairite

Comments: Basal cleavage common; commonly replaces umangite and eucairite; twinning not observed; p. 222; 681.

Mineral Name: Kobellite-Tintinaite

Chem. Comp.: (5.PbS)(4(Bi><Sb)2.S3)

Crystall.: ortho

Color: white

Tint: yellow green

Color (oil):

Tint (oil):

Bireflectance: distinct, greenish white to violet gray

Anisotropy: distinct, steel gray to gray brown; apparently straight extinction

%R: 37-45 mod

VHN: 69-173

Int'l Reflects.:

Polish. Hard.: >>bismuth; slt<gn

Comments: Occurs as granular aggregates and as radial aggregates of columnar and needle-like xls; good cleavage // (010) (// elongation); twinning not uncommon; p. 290; 780.
Mineral Name: Kotulskite  
Chem. Comp.: Pd(Te,Bi)\(_{1-2}\)

Crystall.: hexagonal

Color: cream yellow  
Tint:

Color (oil):  
Tint (oil):

Bireflectance: distinct, light cream to slightly darker grayish cream

Anisotropy: strong, gray or brownish to dark blue gray

%R: 59-64 hi  
VHN: 236

Int'l Reflects.: 

Polish. Hard.: >cpy; ~michenerite; <pent, moncheite, merenskyite

Comments: Cleavage not observed; forms intergrowths with moncheite, michenerite, and merenskyite; p. 332; 838.

Mineral Name: Krennerite  
Chem. Comp.: Au.Ag.Te\(_4\)

Crystall.: ortho

Color: white  
Tint: cream

Color (oil):  
Tint (oil):

Bireflectance: weak, yellowish creamy to same with violet-gray tint

Anisotropy: strong, light gray, yellow, brown; no definite extinction

%R: 72 v hi  
VHN: 36-130

Int'l Reflects.: 

Polish. Hard.: silt>petzite, pyrargyrite; >sylvanite, calaverite

Comments: Idiomorphic thin tabular xls are rare; cleavage in two directions, less perfect than for sylvanite; multiple twinning may occur; p. 252; 430.
Mineral Name: Laurite

Chem. Comp.: Ru.S2

Crystall.: cubic

Color: white

Tint: blue gray

Color (oil): blue gray

Tint (oil): blue gray

Bireflectance: nil

Anisotropy: isotropic

%R: 42-43 mod

VHN: 1393-2167

Int'l Reflects.:

Polish. Hard.: highest of all sulfides

Comments: Occurs as diamond-shaped inclusions in chromite; replaced by platinum; p. 322; 820.

Mineral Name: Lautite

Chem. Comp.: Cu.As.S

Crystall.: ortho

Color: white to gray

Tint: brown to pink

Color (oil): brown to pink

Tint (oil): brown to pink

Bireflectance: weak; only at grain boundaries in oil; brownish pink to bluish

Anisotropy: distinct, bluish green or bluish violet to violet-brown

%R: 27-32 low to mod

VHN: 142-147

Int'l Reflects.: v weak

Polish. Hard.: <<enargite;<arsenic

Comments: Similar to enargite, but less anisotropic; rather commonly twinned; always occurs as xenomorphic aggregates; p. 68; 525. (P&J)
Mineral Name: Lead

Chem. Comp.: Pb (may contain some Ag or Sb)

Crystall.: cubic

Color: white

Color (oil):

Tint:

Tint (oil):

Bireflectance: nil

Anisotropy: isotropic

%R: 60-65 hi

VHN: 4-6

Int'l Reflects.: very low

Comments: Tarnishes rapidly, becoming black; usually occurs as granular aggregates and as dendritic, skeletal xls; twinning may occur; p. 36; 337.

Mineral Name: Lengenbachite


Crystall.: triclinic

Color: white

Color (oil):

Tint:

Tint (oil):

Bireflectance: nil

Anisotropy: distinct on grain boundaries

%R: 34-37 mod

VHN: 29-40

Int'l Reflects.: very low

Comments: Aggregates of foliated grains; twinning lamellae may occur; p. 300; 754.
Mineral Name: Lepidocrocite

Chem. Comp.: gamma - Fe.O.OH

Crystal.: ortho

Color: white gray  Tint: gray

Color (oil):  Tint (oil): blue green

Birefringence: weak to distinct, stronger than for goethite

Anisotropy: strong, shades of gray

%R: 15-25 low  VHN: 147-782

Int'l Reflects.: reddish, less abundant than in goethite

Polish. Hard.: < goethite

Comments: Usually occurs as thin plates or tabular xls in goethite; often associated with mt and hem; also in intergrowths called "limonite"; p. 160; 1076.

Mineral Name: Lillianite

Chem. Comp.: (3.PbS)(Bi2.S3)

Crystal.: ortho

Color: white  Tint: creamy

Color (oil):  Tint (oil): 

Birefringence: distinct (oil), creamy white to darker and less creamy

Anisotropy: distinct, more in air than in oil

%R: 45 mod  VHN: 120-195

Int'l Reflects.: 

Polish. Hard.: silt>Ag

Comments: Usually occurs as aggregates of tabular, needle-like or platy xls; unstable and readily decomposes to gn, bismuthinite, and argentite or to galenobismutite and gn or to cosalite and gn; a prominent cleavage is present; p. 286; 781.
**Mineral Name:** Linnaeite  
**Chem. Comp.:** Co3.S4  
**Crystall.:** cubic  
**Color:** white  
**Tint:** cream (pink, brown, yellow)  
**Color (oil):**  
**Tint (oil):** nil  
**Bireflectance:** nil  
**Anisotropy:** isotropic  
**%R:** 45-50 mod  
**VHN:** 351-566  
**Int'l Reflects.:**  
**Polish. Hard.:** >>cpy; >sl, po; ~skutterudite; <gersdorffite; << aspy  
**Comments:** Occurs as idiomorphic xls and as anhedral grains; cleavage or parting // (100) commonly visible; twinning and zonal texture not observed; p. 146; 697.

**Mineral Name:** Lithiophorite  
**Chem. Comp.:** (Al,Li)Mn.O2(OH)2  
**Crystall.:** mono  
**Color:** white dark gray  
**Tint:**  
**Color (oil):**  
**Tint (oil):**  
**Bireflectance:** v strong (oil), white to dark gray  
**Anisotropy:** v strong, black to white, sometimes with a steel-blue tint  
**%R:** 10-20 low  
**VHN:** 60-100  
**Int'l Reflects.:**  
**Polish. Hard.:** >>crypto-xln cryptomelane; <pyrolusite  
**Comments:** Usually occurs as fine-grained masses, sheet-like coatings, botryoidal crusts and colloform layers; rarely as pseudohexagonal xls; mica-like cleavage; p. 344; 1038.
### Liveingite

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mineral Name</strong></td>
<td>Liveingite</td>
</tr>
<tr>
<td><strong>Chem. Comp.</strong></td>
<td>Pb₁₉.As₁₃.S₂₈</td>
</tr>
<tr>
<td><strong>Crystall.</strong></td>
<td>mono</td>
</tr>
<tr>
<td><strong>Color</strong></td>
<td>white</td>
</tr>
<tr>
<td><strong>Tint</strong></td>
<td>brown green (faint) against gn</td>
</tr>
<tr>
<td><strong>Color (oil)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Tint (oil)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Bireflectance</strong></td>
<td>nil</td>
</tr>
<tr>
<td><strong>Anisotropy</strong></td>
<td>distinct</td>
</tr>
<tr>
<td><strong>%R</strong></td>
<td>34-36 mod</td>
</tr>
<tr>
<td><strong>VHN</strong></td>
<td>173-1183</td>
</tr>
<tr>
<td><strong>Int'l Reflects.</strong></td>
<td>rather rare, clear red</td>
</tr>
<tr>
<td><strong>Polish. Hard.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Comments</strong></td>
<td>Shows no twinning; forms prismatic needles; p. 300; 751.</td>
</tr>
</tbody>
</table>
Mineral Name: Loellingite  
Chem. Comp.: Fe.As$_2$

Crystal.: ortho  
Color: white  
Tint: yellow  

Color (oil):  
Tint (oil):  

Bireflectance: weak to distinct, white or bluish white to yellowish white  

Anisotropy: v strong, bright orange-yellow to reddish brown to pale brown to blue to pale slaty blue to green  

%R: 55 hi  
VHN: 368-1048

Int'l Reflects.:  

Polish. Hard.: >>cpy, sl; slt>po, safflorite, rammelsbergite; ~gersdorffite; slt<mt; << aspy

Comments: Zoned coarse xls may occur, not as common as for rammelsbergite or safflorite; usually forms idiomorphic xls, radiated aggregates, or fine-grained massive aggregates, also as skeleton-shaped aggregates, thin crusts (e.g. enclosing arsenic spheroids), or as interlocking masasics with safflorite; cleavage not observed; twinning, simple or compound, very common; p. 156; 854.

Mineral Name: Lorandite  
Chem. Comp.: Tl.As.S$_2$

Crystal.: mono  
Color: white gray  
Tint: blue  

Color (oil):  
Tint (oil):  

Bireflectance: weak, but noticeable  

Anisotropy: strong, obscured by abundant internal reflections  

%R: 31-33 mod  
VHN: 39-57

Int'l Reflects.: dark red

Polish. Hard.: >realgar, metacinnabar; <cinnabar

Comments: Much lighter than realgar; cleavage visible only in large xls; twinning not observed; replaces raguinitite; p. 44; 732.
Mineral Name: Ludwigite (see Vonsenite)  
Chem. Comp.: (Mg,Fe)2(Fe,Al)B.O5

Crystall.: ortho  
Color: gray blue  
Tint: 
Color (oil): much darker  
Tint (oil): blue more intense

Bireflectance: strong (Mg-rich), gray to brownish gray; very strong (Mg-poor), bluish, gray to brownish gray
Anisotropy: strong; Mg-rich, gray to black; Mg-poor, dark blue to bright pinkish gray

%R: 8-10 v low  
VHN: 537-1486

Int'l Reflects.: Mg-rich, faint reddish brown

Polish. Hard.: >lepidocrocite; ~mt

Comments: Occurs as single prisms, clusters of prisms and radiating aggregates of minute fibers; lamellar twinning is rarely visible in sections // c; p. 164; 1094.

Mineral Name: Luzonite-Stibiolumonite  
Chem. Comp.: Cu3(As,Sb)S4

Crystall.: tetragonal  
Color: It brown to yellow  
Tint: pink or orange

Color (oil): Tint (oil): yellow orange to violet red

Bireflectance: distinct to strong (oil) - light orange brown to grayish violet

Anisotropy: v. strong, dark brown, grayish green,

%R: 25-27 low  
VHN: 205-397

Int'l Reflects.: 

Polish. Hard.: >gn,bn, cpy; slt >tet;~enargite; ~sl

Comments: Colors brighter than enargite; ubiquitous lamellar twinning; forms irregular, rounded and isometric grains; cleavage not observed; concentric textures with enargite occur; p. 110; 588.
Mineral Name: Mackinawite  
Chem. Comp.: Fe (Ni,Co,Cu,Cr)S  
Crystall.: tetragonal  
Color: gray  
Tint: pink red  
Color (oil):  
Tint (oil):  
Bireflectance: distinct to strong, pinkish gray to gray  
Anisotropy: v. strong, grayish white to dark gray or black  
%R: 22-45 low to mod  
VHN: 52-181  
Int'l Reflects.:  
Polish. Hard.: ~po  
Comments: As idiomorphic xls, exsolved from pent, po, cpy, and cubanite, and as alteration; no bronze or brown colors as for vallerite; anisotropy decreases markedly after a few weeks; idiomorphic xls; perfect basal cleavage; reaction rims between cpy and po; p. 140; 683.

Mineral Name: Maghemite  
Chem. Comp.: gamma - Fe2.O3  
Crystall.: cubic  
Color: gray  
Tint: blue  
Color (oil):  
Tint (oil):  
Bireflectance: nil  
Anisotropy: isotropic  
%R: 26 low  
VHN: 357-988  
Int'l Reflects.: brownish red, very rare  
Polish. Hard.: slt>mt; <<hem  
Comments: Formed by oxidation of mt, all stages in the oxidation of mt into maghemite may occur in nature, which may explain the differences in VHN; p. 170; 1000.
Mineral Name: Magnetite

Chem. Comp.: Fe3.O4

Crystall.: cubic

Color: gray

Tint: brown (pink w/ Ti)

Color (oil):

Tint (oil):

Bireflectance: nil

Anisotropy: isotropic

%R: 21 low

VHN: 440-1100

Int'l Reflects.: 

Polish. Hard.: >>po; commonly <ilmenite; <braunite, <<hematite

Comments: Usually as euohedral xls, tabular xls may be pseudomorphs after hematite, also forms irregular strings and granular aggregates, rarely colloform aggregates; cleavage commonly not distinct; lamellar twinning // (111) and zonal texture not uncommon; p. 168; 911.

Mineral Name: Magnetoplumbite

Chem. Comp.: Pb(Fe,Mn,Al,Ti)12.O19

Crystall.: hexagonal

Color: gray

Tint:

Color (oil):

Tint (oil):

Bireflectance: v weak

Anisotropy: distinct only in oil

%R: 22-24 low

VHN: 841-868

Int'l Reflects.: very rare, even in oil

Polish. Hard.: 

Comments: Occurs as idiomorphic barrel-shaped xls; replaced by hematite; p. 184; 966.
Opaque Mineral Optics

**Mineral Name:** Maldonite  
**Chem. Comp.:** Au2.Bi

- **Crystall.:** cubic  
- **Color:** white to cream  
- **Tint:** green (cf Bi)

- **Color (oil):**  
- **Tint (oil):** blue (cf Bi)

- **Bireflectance:** nil

- **Anisotropy:** isotropic

- **%R:** 50-60 hi  
- **VHN:**

- **Int'l Reflects.:**

- **Polish. Hard.:** >>Bi;>gn, Au

- **Comments:** Supply of Bi causes disintegration to a myrmekitic intergrowth of Bi and Au; the associated Bi has no twin lamellae; p. 72; 336.

---

**Mineral Name:** Manganite  
**Chem. Comp.:** gamma - Mn.O2

- **Crystall.:** mono  
- **Color:** gray  
- **Tint:** brown

- **Color (oil):**  
- **Tint (oil):** weak to strong (oil), light grayish brown, dark brownish gray, darker with olive tint

- **Bireflectance:** strong // elongation; yellowish, bluish gray, dark violet-gray

- **Anisotropy:**

- **%R:** 15-21 low  
- **VHN:** 367-803

- **Int'l Reflects.:** blood red, very common

- **Polish. Hard.:** <hausmannite, jacobsite, braunite, mt; <<pyrolusite

- **Comments:** Forms prismatic xls or lamellar xl aggregates sometimes with radiated texture; cleavage // (010) and (110) often distinct, especially in cross sections; twinning lamellae very common; p. 342; 1079.
**Opaque Mineral Optics**

**Mineral Name:** Manganosite  
**Chem. Comp.:** Mn.O

- **Crystall.:** cubic
- **Color:** gray  
- **Tint:** green
- **Color (oil):**  
- **Tint (oil):** nil
- **Bireflectance:** nil
- **Anisotropy:** isotropic
- **%R:** 14 low  
- **VHN:** 314-325
- **Int'l Reflects.:** always present, emerald green on fresh surfaces, red appearing with time

**Polish. Hard.:**

**Comments:** Commonly occurs as granular aggregates; forms oriented intergrowths with zincite or periclase; replaced by pyrochroite; p. 338; 897.

---

**Mineral Name:** Marcasite  
**Chem. Comp.:** Fe.S2

- **Crystall.:** ortho
- **Color:** white yellow  
- **Tint:** yellow
- **Color (oil):**  
- **Tint (oil):** strong, brownish white to bluish greenish gray
- **Bireflectance:** strong, blue to green-yellow to purplish to violet-gray
- **Anisotropy:** strong, blue to green-yellow to purplish to violet-gray
- **%R:** 47-53 mod to hi  
- **VHN:** 762-1561
- **Int'l Reflects.:**

**Polish. Hard.:** >po; commonly <py but > gel-pyrite

**Comments:** Commonly shows colloform texture; forms alternating layers with py or crusts on gel-pyrite; idiomorphic, lath-shaped xls less common; radiated aggregates may occur; cleavage may be distinct; twinning(both coarse and fine lamellar) and zonal texture very common; whiter than py; p. 204; 839.
<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Matildite (=Schapbachite)</td>
<td>Ag.Bi.S2+Pb.S</td>
<td>hexagonal</td>
<td>white</td>
<td>pink</td>
<td>white</td>
<td>yellow</td>
<td>weak in oil: yellowish white / ft greenish white</td>
<td>strong, lt to dark gray</td>
<td>44 mod</td>
<td>68-91</td>
<td>slt&gt;gn; &lt;cpy</td>
<td>Common exsolution textures with gn; always with gn; complete solid solution with gn above 215C; lamellar twinning; p. 282; 665.</td>
</tr>
<tr>
<td>Mawsonite</td>
<td>Cu(2+x)Fe.Sn(1-x)S10</td>
<td>tetragonal</td>
<td>orange</td>
<td>brown</td>
<td>v. strong</td>
<td>lt orange/orange/brown</td>
<td>v. strong; bright straw yellow to prussian blue to dark grayish blue</td>
<td>25 low</td>
<td>166-210</td>
<td>&lt;~bn</td>
<td>Much brighter than bn, especially in oil; no cleavage or twinning observed; as rounded or irregular inclusions in bn; as reaction rims between cassiterite and bn; p. 90; 575.</td>
<td></td>
</tr>
</tbody>
</table>
**Mineral Name:** Mckinstryite  
**Chem. Comp.:** Cu.8+x.Ag1.2-x.S  
**Crystall.:** ortho  
**Color:** white gray  
**Tint:** gray blue  
**Color (oil):**  
**Tint (oil):** distinct  
**Bireflectance:** strong, gray, pale grayish blue, light tan  
**Anisotropy:** distinct  
**%R:** 30-35 mod  
**VHN:** 60  
**Int'l Reflects.:**  
**Polish. Hard.:**  
**Comments:** Occurs as coarse-grained aggregates of intergrown xls; forms intergrowths with jalpaite; p. 44; 484.

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**Mineral Name:** Melonite  
**Chem. Comp.:** NiTe2 - forms a SS with merenskyite (may contain some Se)  
**Crystall.:** hexagonal  
**Color:** pink cream  
**Tint:** cream pink  
**Color (oil):**  
**Tint (oil):**  
**Bireflectance:** v weak, O more creamy, E more pinkish  
**Anisotropy:** distinct, grayish mauve to yellowish brown; straight extinction  
**%R:** 57-62 hi (QDF2)  
**VHN:** 46-59 (QDF2)  
**Int'l Reflects.:**  
**Polish. Hard.:** usually =>cpy; >Au, krennerite; sometimes <=Au and < montbrayite  
**Comments:** Occurs as isolated euohedral or subhedral xls enclosed in krennerite, altaitie or montbrayite, with or without partial rims of petzite; because of its softness it is often deformed and exhibits wavy extinction; p. 252; 420.
Mineral Name: Meneghinite


Crystall.: ortho

Color: white

Tint: blue

Color (oil): Tint (oil):

Bireflectance: weak, white (brownish yellow) to grayish white (reddish or faint greenish)

Anisotropy: strong, light tan, brown, blue gray; straight extinction

%R: 40-46 mod

VHN: 113-183

Int'l Reflects.: rare, red

Polish. Hard.: slt<gn; <cpy

Comments: Occurs as acicular or needle-like idiomorphic xls and as granular aggregates; one perfect cleavage // (010); twinning and parquet-like texture have been observed (resembling jamesonite); zonal texture not observed; anisotropy stronger than jamesonite and boulangerite; bireflectance much weaker than for jamesonite; p. 50; 772.

Mineral Name: Merenskyite

Chem. Comp.: (Pd,Pt)(Te,Bi)2

Crystall.: hexagonal - rhombohedral

Color: white

Tint: cream

Bireflectance: weak to distinct, white (creamy tint) to light grayish white

Anisotropy: distinct to strong, dark brown to light greenish gray

%R: 63-65 hi

VHN: 

Int'l Reflects.: >cpy, kotulskite; <pent

Polish. Hard.: >cpy, kotulskite; <pent

Comments: Pd endmember of series, moncheite is the Pt endmember; forms a solid solution series with melonite; occurs intergrown with kotulskite; p. 332; 838.
Mineral Name: Metacinnabar  
Chem. Comp.: Hg.S

Crystall.: cubic  
Color: white  
Tint: gray

Color (oil): much darker  
Tint (oil): brown

Bireflectance: v. weak on grain boundaries if present

Anisotropy: isotropic

%R: 28 low  
VHN: 73-161

Int'l Reflects.: <cinnabar; tet-tn

Comments: Twin lamellae almost always present; very often intergrown with cinnabar, which has distinct anisotropy; p. 78; 521.

Mineral Name: Metastibnite  
Chem. Comp.: Sb2.S3

Crystall.: noncrystalline

Color: white  
Tint: blue

Color (oil): none  
Tint (oil): none

Bireflectance: distinct (air), in oil masked by internal reflections

%R: mod, <stibnite  
VHN: 

Int'l Reflects.: intense, deep-red

Comments: Commonly with colloform texture, which is more distinct under crossed nicols; darker and lower %R than stibnite; p. 44; 709.
Mineral Name: Miargyrite  
Chem. Comp.: Ag,Sb,S2

Crystal.: mono  
Color: white  
Tint:

Color (oil): much darker  
Tint (oil): gray sometimes blue

Bireflectance: strong, white / It bluish gray / gray

Anisotropy: strong, lt gray / blue gray / brownish, often masked by internal reflections

%R: 30-35 mod  
VHN: 88-130

Int'l Reflects.: deep red

Polish. Hard.: slt>pyrargyrite;<gn, stephanite; << freibergite

Comments: v. similar to freibergite, polybasite, pyrargyrite, and stephanite; granular aggregates; twinning has been observed; p. 262; 662.

Mineral Name: Michenerite  
Chem. Comp.: (Pd,Pt)Bi,Te

Crystal.: cubic  
Color: white  
Tint: gray

Color (oil):  
Tint (oil):

Bireflectance: nil

Anisotropy: isotropic

%R: 56 hi  
VHN:

Int'l Reflects.:

Polish. Hard.: >cpy; ~kotulskite; <moncheite

Comments: With hessite, maucherite, moncheite, kotulskite; p. 324; 825.
opaque mineral optics

Mineral Name: Millerite
Chem. Comp.: Ni.S

Crystall.: rhombo

Color: pure yellow
Tint: cream

Color (oil): similar
Tint (oil):

Bireflectance: distinct (oil), grayish yellow / bright yellow

Anisotropy: strong, lemon-yellow / iris-blue / violet; straight, but incomplete extinction

%R: 51-56 hi

VHN: 192-376

Int'l Reflects.:

Polish. Hard.: >cpy;<sl, pent, linnaeite

Comments: Distinguished from other yellow minerals by hardness (cpy) and anisotropy (py); basal sections appear isotropic; radiated or bundle-like aggregates of needle-shaped xls; cleavage // to (1011) commonly visible; p. 122; 626.

Mineral Name: Minium
Chem. Comp.: Pb3.O4

Crystall.: tetragonal

Color: gray
Tint: normally blue, pink yellow from internal reflections

Color (oil): weak, yellowish-gray to orange gray to gray blue
Tint (oil):

Bireflectance: weak, yellowish-gray to orange gray to gray blue

Anisotropy: obscured by internal reflections

%R: 20 low

VHN:

Int'l Reflects.: pink and yellow, abundant and strong

Polish. Hard.: <gn, lithargite, massicotite

Comments: Generally extremely fine-grained; replaces and forms pseudomorphs after gn and cerrusite; p. 50.
**Opaque Mineral Optics**

**Mineral Name:** Molybdenite  
**Chem. Comp.:** Mo.S2

- **Crystall.:** rhombohedral-hexagonal  
- **Color:** white to dull gray  
- **Tint:** blue

**Color (oil):** Tint (oil):  
**Bireflectance:** v. strong, white to dull blue gray

**Anisotropy:** v strong, white with pinkish tint, dark blue (characteristic)

- **%R:** 22-42 low to mod  
- **VHN:** 16-101

**Int'l Reflects.:**

- **Polish. Hard.:** in fine-grained aggregates slt>cpy; <graphite

**Comments:** Often more or less curved plates or xls with undulatory extinction; may show colloform texture; forms rosette-shaped aggregates; cleavage // (0001) nearly always visible; Parallel displacement very common, often producing a twinning-like texture; polysynthetic twinning of primary origin is indicated by marked variations in polarization effects in sections // c; observed as minute inclusions in many sulfides; p. 103; 874.

---

**Mineral Name:** Moncheite  
**Chem. Comp.:** (Pt,Pd)(Te,Bi)2

- **Crystall.:** hexagonal
- **Color:** white gray  
- **Tint:** gray

**Color (oil):** Tint (oil):  
**Bireflectance:** weak to distinct

**Anisotropy:** distinct to strong, light yellowish brown to dark brown

- **%R:** 53-59 hi  
- **VHN:**

**Int'l Reflects.:**

- **Polish. Hard.:** >kotulskite; michenerite; ~pent; <cpy

**Comments:** Pt end member of a series, the Pd member is merenskyite; distinct cleavage // (0001); generally as blebs or fine laths; forms intergrowths with michenerite, kotulskite, ferroplatinum; p. 332; 838.
Mineral Name: Montbrayite
Chem. Comp.: Au2.Te3

Crystall.: triclinic
Color: white

Tint: cream

Color (oil): weak

Tint (oil): weak

Bireflectance: weak to distinct, light gray, light yellow-brown, blue-gray

%R: 64 hi

VHN: 198-228

Comments: Occurs as coarse, solid mosaics with optically continuous areas, often several mm in width; cleavage occurs, no evidence of twinning; p. 238; 435.

Mineral Name: Montroseite
Chem. Comp.: (V,Fe)O.OH

Crystall.: ortho
Color: white gray

Tint: strong, bright grayish yellow to dark brown

Color (oil): weak

Tint (oil): weak

Bireflectance: 15-17 low (P&J)

VHN: 266-300

Comments: Occurs as bladed xls; replaces karelianite; p. 100; 1081.
Opaque Mineral Optics

Mineral Name: Murdochite

Crystall.: cubic
Color: gray
Color (oil): nil
Tint: yellow brown
Tint (oil):
Bireflectance: nil
Anisotropy: isotropic
%R: 17 low
VHN: 519-657
Int'l Reflects.: 

Polish. Hard.: slt>plattnerite

Comments: Occurs as euhedral xls; twinning not uncommon, zonation always present; octahedral cleavage has been observed; p. 166; 906.

Mineral Name: Nagyagite

Crystall.: tetragonal
Color: gray
Color (oil): weak, gray to brownish gray
Tint: slt purple
Tint (oil):
Bireflectance: distinct, light gray (bluish) to dark brownish or greenish gray in sections which transverse the cleavage; no definite extinction; sections // to cleavage near isotropic
%R: 39-43 mod (P&J) VHN: 60-94 (QDF2)
Int'l Reflects.: 

Polish. Hard.: slt>sylvanite

Comments: Usually occurs as thin-tabular laminated xls, often bent; perfect cleavage // (010); polysynthetic twinning may occur in sections // (010); with Au and other tellurides; p. 236; 433.
Mineral Name: Naumannite

Chem. Comp.: beta-Ag2Se <-133C->
alpha-Ag2Se

Crystall.: ortho <133C> cubic

Color: gray
Tint: green

Color (oil): much darker
Tint (oil): weak (oil), brownish gray to darker greenish gray-brown

Bireflectance: distinct, light to dark gray

%R: ~35 mod
VHN: 27-56

Int'l Reflects.:<clausthalite

Comments: Usually shows traces of cubic cleavage, probably due to parting associated with the alpha-beta inversion; mimetic twinning may be very distinct; may form myrmekitic intergrowths with clausthalite; p. 224; 478.

Mineral Name: Niccolite

Chem. Comp.: Ni.As

Crystall.: hexagonal

Color: pink to lt brown
Tint: yellow or brown

Color (oil): similar, less white
Tint (oil): strong, yellowish pink to brownish pink to light pink

Bireflectance: v. strong, yellowish, grayish green, violet-blue, bluish gray; straight, but incomplete extinction; basal sections appear isotropic

%R: 48-53 mod to hi
VHN: 308-533

Int'l Reflects.:

Polish. Hard.: »Ag; »cpy; »breithauptite, po; <rammelsbergite, skutterudite; »loellingite, py

Comments: Pink colors and hardness are distinctive; chevron-like twinning may occur; sometimes forms concentric aggregates, often with radiated texture; idiomorphic xls and cross-shaped twins also occur; forms pseudo-eutectic intergrowths with po, cpy, and maucherite; p. 150; 615.
MINERAL OPTICS

Mineral Name: Nickel
Chem. Comp.: Ni

Crystal.: cubic
Color.: white
Bireflectance: nil

Tint: blue

Anisotropy: isotropic
%R: 63 hi
VHN: 186-210

Int'l Reflects.: <heazlewoodite

Polish. Hard.: <heazlewoodite

Comments: Occurs as euhedral grains (cubes) in heazlewoodite; also as anhedral "spider-like" irregular masses in the intergranular spaces of heazlewoodite aggregates; p. 122; 362.

Mineral Name: Nsutite
Chem. Comp.: Mn1-xMnx.O2-2x(OH2x)

Crystal.: hexagonal
Color.: white

Tint: cream

Bireflectance: crypto-xln aggregates are isotropic; coarse xls, distinct, white gray to dark gray

Anisotropy: strong, light and dark gray
%R: 30-40 mod
VHN: 350-1288

Int'l Reflects.: >pyrolusite

Polish. Hard.: >pyrolusite

Comments: Occurs as coarse-grained xls resembling pyrolusite, or as crypto-xln aggregates; nsutite shows shrinkage cracks in fine-grained colloform aggregates, which may be caused by transition from Mn-nsutite to nsutite; may form fan-like aggregates of fine fibers; p. 358; 1029.
Mineral Name: Orcelite

Chem. Comp.: Ni(5-x)As2

Crystallographic:
- hexagonal

Color: brown bronze

Tint: pink

Bireflectance: weak (weaker than niccolite or breithauptite)

Anisotropy: distinct to strong, green and violet tints

%R: 49 (QDF2)  
VHN: no data

Comments: Shows a lamellar structure; only observed in serpentinized rocks; occurs as inclusions in awaruite; may contain inclusions of pentlandite; p. 148; 399.

Mineral Name: Oregonite

Chem. Comp.: Ni2.Fe.As2

Crystallographic:
- hexagonal

Color: white

Tint: pinkish cream (P&J)

Bireflectance: weak

Anisotropy: weak, only visible at grain boundaries

%R: 49-50 mod  
VHN: 605-635

Comments: Occurs as aggregates of rounded to oval grains, as crusts around niccolite; p. 142; 400.
Mineral Name: Orpiment

Chem. Comp.: As$_2$S$_3$

Crystall.: mono

Color: gray

Tint:

Color (oil): much darker

Tint (oil):

Bireflectance: strong (air), white to dull gray to dull gray white, in oil darker with reddish tint

Anisotropy: strong, masked by internal reflections

%R: 25 low

VHN: 22-58

Int’l Reflects.: abundant and intense, white to light yellow

Polish. Hard.: slt $>$ realgar

Comments: May occur as needle-formed or tabular xls masses, often sheaf-like or radiating, but usually as alteration product around realgar; forms oriented intergrowths with realgar; p. 40; 890.

---

Mineral Name: Osmium

Chem. Comp.: Os (Os content $>$ 80%)

Crystall.: hexagonal

Color: white

Tint: against Pt it is bluish gray

Color (oil): Tint (oil):

Bireflectance: not present

Anisotropy: strong, vivid orange red tints

%R: 62 (QDF2)

VHN: no data

Int’l Reflects.: 

Polish. Hard.: v hi

Comments: As tiny tabular or elongated hexagonal xls; often enclosed within Pt or as small lamellae within Pt; p. 334; 350.
**Opaque Mineral Optics**

**Mineral Name:** Owhyeeite  
**Chem. Comp.:** Pb5.Ag2.Sb6.S15

- **Crystall.:** ortho  
- **Color:** grayish white  
- **Tint:** green olive  
- **Color (oil):**  
- **Tint (oil):**  
- **Bireflectance:** distinct, greenish to olive gray-white; not as strong as for jamesonite  
- **Anisotropy:** v strong, straw or brownish white, grayish white and pale blue-gray to dark blue just before extinction; straight extinction  
- **%R:** 38-45 (P&J)  
- **VHN:** 98-129

**Int'l Reflects.:**

**Polish. Hard.:** >=pyrargyrite; ~boulangerite; slt<gn?; <<tet  

**Comments:** Like jamesonite, it is fibrous; occurs as acicular and fusiform xls; also as irregular fine-grained aggregates; triangular pits may occur in poorly polished grains; cleavage // (001) in prismatic sections; occasionally twinned // elongation; p. 268; 745.

---

**Mineral Name:** Palladium  
**Chem. Comp.:** Pd

- **Crystall.:** cubic  
- **Color:** white  
- **Tint:** cream  
- **Color (oil):**  
- **Tint (oil):**  
- **Bireflectance:** nil  
- **Anisotropy:** isotropic  
- **%R:** ~70 v hi  
- **VHN:**

**Int'l Reflects.:**

**Polish. Hard.:** <Pt  

**Comments:** Occurs as small octahedral single xls and as xenomorphic grains; forms rims around Pt-sulfides embedded in Pt; p. 326; 338.
Mineral Name: Paraguanajuatite
Chem. Comp.: Bi$_2$(Se,S)$_3$
Crystall.: hexagonal - rhombohedral
Color: gray white
Tint:
Color (oil): pink
Bireflectance: strong (oil), lighter to darker slightly bluish gray
Anisotropy: v distinct, but practically no color effects
%R: 45 mod
VHN: 30-160
Int'l Reflects.:
Polish. Hard.: <guanajuatite
Comments: Darker than guanajuatite and with pinkish tint in oil; occurs as lamellar bodies, granular or curved; forms pseudomorphs after guanajuatite; cleavage // (0001) is perfect; p. 228; 714.

Mineral Name: Pararammelsbergite
Chem. Comp.: Ni.As$_2$
Crystall.: ortho
Color: white
Tint:
Color (oil): yellowish to bluish white
Bireflectance: v weak to distinct (oil), yellowish to bluish white
Anisotropy: strong, usually without the bluish colors of rammelsbergite
%R: 56-58 hi
VHN: 673-824
Int'l Reflects.:
Polish. Hard.: >niccolite; <Ni-skutterudite, loellingite
Comments: Usually forms tabular xls with rectangular transverse sections, occasionally radial subrectangular xls or mosaics of interlocking grains; cleavage may be visible; twinning rare and not lamellar; zonal texture occurs; whiter than associated white arsenides, including rammelsbergite; p. 154; 860.
Mineral Name: Parkerite (see shandite; p. 62)  
Chem. Comp.: $\alpha - \text{Ni}_3(\text{Bi,Pb})_2\text{S}_2$

Crystal.: monoclinic  
Color: white  
Tint: cream mauve  

Color (oil):  
Tint (oil):  

Bireflectance: distinct, creamy white to grayish creamy white  

Anisotropy: strong, greenish gray to yellowish brown or slate-blue to salmon pink  

$\% R$: 44-48 mod  
VHN: 111-142  

Int'l Reflects.:  

Polish. Hard.: slt< or ~gn

Comments: Usually occurs as xenomorphic grains; also as irregular rounded and subhedral particles; as veinlets and stringers; usually polysynthetically twinned, especially well visible in oil; may be crossed by less pronounced transverse lamellae; notched cleavage traces; p. 62; 404.

Mineral Name: Patronite  
Chem. Comp.: V.S2

Crystal.: mono  
Color: gray  
Tint: brown  

Color (oil):  
Tint (oil): yellowish  

Bireflectance: v strong, light gray to yellowish gray to brown  

Anisotropy: v strong, light gray to blue green in oil, no color effects in air  

$\% R$: ~20 low  
VHN:  

Int'l Reflects.:  

Polish. Hard.:  

Comments: Forms aggregates of very fine short prismatic needle-like xls; basal cleavage is present; twinning not observed; p. 38; 887.
Mineral Name: **Pavonite**

**Chem. Comp.:** $(\text{Ag}_2\text{S})(\text{Bi}_2\text{S}_3)$

**Crystall.:** mono

**Color:** white gray

**Color (oil):**

**Tint:** gray pink blue

**Tint (oil):** stronger tints

**Bireflectance:** distinct (air) to strong (oil), white, white with a grayish pink tint, bluish gray white

**Anisotropy:** strong, pale to intense blue and light tan to brown

%R: 42 mod

**Int'l Reflects.:**

**Polish. Hard.:** ~cpy; <sl

**Comments:** Occurs as tiny bladed xls; cleavage is present; p. 282; 716.

---

Mineral Name: **Penroseite**

**Chem. Comp.:** $(\text{Ni,Co,Cu})\text{Se}_2$

**Crystall.:** cubic

**Color:** white

**Color (oil):** much darker

**Tint:** brown

**Tint (oil):** olive green

**Bireflectance:** nil

**Anisotropy:** isotropic

%R: 35 mod

**Int'l Reflects.:**

**Polish. Hard.:** >cpy

**Comments:** Cleavage // (100) may be visible; zonal texture very common; p. 218; 818.
Mineral Name: Pentlandite  
Chem. Comp.: (Fe,Ni)\(_9\).S\(_8\)  
Crystal.: cubic  
Color: white or yellow  
Tint: cream  
Color (oil):  
Tint (oil):  
Bireflectance: isotropic  
%R: 40-55 mod to hi  
VHN: 202-303  
Int'l Reflects.:  
Polish. Hard.: >cpy;~<po  
Comments: May have good cleavage; associated with cpy and po; idiomorphic or xenomorphic xls; flame-like segregations, and feather-like, finger-like, or star-like bodies in po; also with cpy and cubanite; p. 130; 497.

Mineral Name: Perovskite-group  
Chem. Comp.: (Ca,Na, REE)(Ti,Nb)O\(_3\)  
Crystal.: pseudocubic  
Color: dark gray  
Tint:  
Color (oil): dark gray  
Tint (oil): blue  
Bireflectance: nil  
Anisotropy: nil  
%R: 15 low  
VHN: 490-895  
Int'l Reflects.: white to brown, strong and always present  
Polish. Hard.: > or ~mt  
Comments: Usually occurs in alkaline rocks or carbonatites as idiomorphic cubic or octahedral xls, sometimes rounded or with curious or allotriomorphic texture; cleavage in fine-grained material not observable; complicated lamellar twinning always present, may be visible by the internal reflections; very difficult to identify in polished section; p. 182; 1004.
Mineral Name: Petzite  
Chem. Comp.: Ag₃Au₂Te₂

Crystall.: cubic  
Color: white gray  
Color (oil): nil  
Bireflectance: nil  
Anisotropy: isotropic  
%R: 37 mod  
VHN: 35-74  
Int'l Reflects.:  

Polish. Hard.: <sylvanite, coloradoite, hessite, altaite, calaverite  
Comments: Cubic cleavage less perfect than for gn; triangular pits may occur; p. 234; 424.

Mineral Name: Pitchblende  
Chem. Comp.: UO₂

Crystall.: cubic  
Color: shades of gray  
Color (oil): nil  
Bireflectance: nil  
Anisotropy: isotropic  
%R: 10-15 low  
VHN: 314-803  
Int'l Reflects.: dark brown and yellow brown  

Polish. Hard.: variable  
Comments: Pitchblende high in UO₂ takes a good polish, homogeneous, comparatively hard; pitchblende high in UO₃ (oxidation product of above) polishes poorly, has a rough surface, and is comparatively soft. Occurs in great variety of forms, showing all gradations such as: botryoidal, colloform, cellular, dendritic, spherulitic, oolitic, ring-like, brecciated, or vein forms; concentric or circular cross sections commonly show radiating cracks; 194; 1050.
Mineral Name: Plagionite  
Crystall.: mono  
Color: white  
Tint: gray  
Color (oil):  
Tint (oil):  
Bireflectance: distinct, white or light gray to brownish pink  
Anisotropy: distinct, pinkish, brownish, blue; oblique extinction  
%R: 35-38 mod  
VHN: 120-165  
Int'l Reflects.: dark red, occasionally visible  
Polish. Hard.:  
Comments: May occur as tabular xls or as coatings; forms aggregates of needle-shaped or prismatic grains; cleavage observable only in coarse-grained specimens; p. 276; 762.

Mineral Name: Platinum  
Chem. Comp.: Pt  
Crystall.: cubic  
Color: white  
Tint: cream  
Color (oil):  
Tint (oil):  
Bireflectance: nil  
Anisotropy: isotropic  
%R: ~70 v hi  
VHN: 297-339 (QDF2)  
Int'l Reflects.:  
Polish. Hard.: >sl; <po  
Comments: Commonly forms irregular xenomorphic grains, seldom idiomorphic xls; zonal texture not uncommon; may contain exsolution bodies of iridium; p. 326; 340.
<table>
<thead>
<tr>
<th>Mineral Name</th>
<th>Chem. Comp.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plattnerite</strong></td>
<td><strong>Pb,O₂</strong></td>
</tr>
<tr>
<td><strong>Crystal.</strong></td>
<td>tetragonal</td>
</tr>
<tr>
<td><strong>Color</strong></td>
<td>gray</td>
</tr>
<tr>
<td><strong>Color (oil):</strong></td>
<td>Tint:</td>
</tr>
<tr>
<td><strong>Bireflectance</strong></td>
<td>weak, distinct on grain boundaries, gray to blue gray</td>
</tr>
<tr>
<td><strong>Anisotropy</strong></td>
<td>distinct in xln material, blue to greenish</td>
</tr>
<tr>
<td>%R:</td>
<td>17-18 low</td>
</tr>
<tr>
<td><strong>VHN</strong></td>
<td>490-642</td>
</tr>
<tr>
<td><strong>Int'l Reflects.</strong></td>
<td>reddish brown, abundant</td>
</tr>
<tr>
<td><strong>Polish. Hard.</strong></td>
<td>&gt;&gt; all associated minerals</td>
</tr>
<tr>
<td><strong>Comments</strong></td>
<td>Occurs as short needle-like xls; p. 162; 1021.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mineral Name</th>
<th>Chem. Comp.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plumboferrite</strong></td>
<td><strong>(PbO)(Fe₂.O₃)</strong></td>
</tr>
<tr>
<td><strong>Crystal.</strong></td>
<td>hexagonal</td>
</tr>
<tr>
<td><strong>Color</strong></td>
<td>gray</td>
</tr>
<tr>
<td><strong>Color (oil):</strong></td>
<td>Tint (oil):</td>
</tr>
<tr>
<td><strong>Bireflectance</strong></td>
<td>not observable</td>
</tr>
<tr>
<td><strong>Anisotropy</strong></td>
<td>weak</td>
</tr>
<tr>
<td>%R:</td>
<td>15-20 low</td>
</tr>
<tr>
<td><strong>VHN</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Int'l Reflects.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Polish. Hard.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Comments</strong></td>
<td>Occurs as rounded grains; two cleavages visible; prismatic and // (0001); twinning rare; p. 184; 967.</td>
</tr>
</tbody>
</table>
**Mineral Name:** Polybasite and Pearceite (and Polydymite)  
**Chem. Comp.:** \((\text{Ag}, \text{Cu})_2(\text{As}, \text{Sb})_2 \text{S}_n\)  \(\text{Ni}_3 \text{S}_4\)

**Crystal I.:** mono-pseudohexagonal  
**Color:** gray  
**Tint:** green brown  
**Color (oil):**  
**Tint (oil):**

**Bireflectance:** distinct (oil), greenish to dark gray with a violet blue-gray tint  
**Anisotropy:** distinct (air), strong (oil), blue, gray, green, and yellowish colors  
**%R:** 30-35mod  
**VHN:** 108-164  
**Int'l Reflects.:** deep-red nearly always visible

**Polish. Hard.:** >argentite; ~pyrargyrite; <stephanite; << ten

**Comments:** Idiomorphic pseudohexagonal plates and tablets; sometimes arranged in subparallel and rosette-like groups; cleavage // (001); basal sections may appear isotropic; p. 262; 729.

---

**Mineral Name:** Polydymite  
**Chem. Comp.:** \(\text{Ni}_3 \text{S}_4\)

**Crystal I.:** cubic  
**Color:** white  
**Tint:** yellow  
**Color (oil):**  
**Tint (oil):**

**Bireflectance:** nil  
**Anisotropy:** isotropic  
**%R:** 46 mod  
**VHN:** 437-444  
**Int'l Reflects.:**

**Polish. Hard.:** ~other minerals of the linnaeite group

**Comments:** Idiomorphic xls; no twinning or zonal texture; p. 146; 697.
**Mineral Name:** Proustite  
**Chem. Comp.:** \((3\text{Ag}_2\text{S})(\text{As}_2\text{S}_3)\)

- **Crystall.:** hexagonal  
- **Color:** gray  
- **Tint:** blue  
- **Color (oil):**  
- **Tint (oil):**  
- **Bireflectance:** strong; air, white (yellowish) to bluish gray (darker); oil, grayish blue (brownish) to grayish blue (darker)  
- **Anisotropy:** strong, in oil masked by internal reflections

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>%R</td>
<td>25-28 low</td>
</tr>
<tr>
<td>VHN</td>
<td>50-156</td>
</tr>
</tbody>
</table>

**Int'l Reflects.:** scarlet-red, always visible

**Polish. Hard.:** ~pyrargyrite

**Comments:** Occurs as irregular grains, as allotriomorphic aggregates or as idiomorphic needle-shaped xls; twinning and zonal texture may occur; p. 258; 783.

---

**Mineral Name:** Pseudobrookite  
**Chem. Comp.:** \(\text{Fe}_2\text{Ti.O}_5\)

- **Crystall.:** ortho  
- **Color:** gray  
- **Tint:**  
- **Color (oil):**  
- **Tint (oil):**  
- **Bireflectance:** weak  
- **Anisotropy:** distinct

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>%R</td>
<td>15 low</td>
</tr>
<tr>
<td>VHN</td>
<td></td>
</tr>
</tbody>
</table>

**Int'l Reflects.:** reddish yellow

**Polish. Hard.:** <rutile

**Comments:** Sometimes idiomorphically developed; occurs intergrown with hematite formed by oxidation of ilmenite and titanomagnetite; p. 178; 1046.
**Opaque Mineral Optics**

**Mineral Name:** Psilomelane (romanachite)  
**Chem. Comp.:** A3X6Mn8O16  
A= Ba, Mn, Al, Fe, Si, etc  
X=(O, OH)6 with OH=5

**Crystall.:** ortho  
**Color:** white gray  
**Tint:** blue gray  
**Color (oil):**  
**Tint (oil):**  
**Bireflectance:** strong, almost white to dull gray to bluish gray

**Anisotropy:** strong, white to gray; straight extinction

**%R:** 15-30 low  
**VHN:** 203-813

**Int'l Reflects.:** brown, occasionally visible

**Polish. Hard.:** fine-grained form hard; coarse-grained commonly <coarse-grained Mn minerals

**Comments:** Common Mn mineral, only pyrolusite and cryptomelane are encountered more frequently; forms finely xln aggregates or minute acicular xls not unlike fine-grained pyrolusite; most commonly botryoidal masses sometimes consisting of concentric layers, which layers may also contain pyrolusite or cryptomelane; also irregular or cellular masses; rarely long prismatic xls; p. 354; 1030.

---

**Mineral Name:** Pyrargyrite  
**Chem. Comp.:** (3.Ag2S)(Sb2.S3)

**Crystall.:** hexagonal  
**Color:** gray  
**Tint:** blue (violet)  
**Color (oil):**  
**Tint (oil):**  
**Bireflectance:** distinct to strong, no great color differences

**Anisotropy:** strong, pale to dark gray, in oil masked by internal reflections

**%R:** 28-31 low to mod  
**VHN:** 50-156

**Int'l Reflects.:** Intense, carmine-red

**Polish. Hard.:** >>argentite;>polybasite; <stephanite, gn, and most other accompanying minerals

**Comments:** Occurs as idiomorphic xls, and as aggregates of irregular grains; often twinned and with zonal texture; internal reflections less pronounced than in proustite; p. 258; 785.
Opaque Mineral Optics

Mineral Name: Pyrite
Chem. Comp.: FeS2

Crystall.: cubic
Color: yellow

Tint: white cream

Color (oil): 
Tint (oil):

Bireflectance: nil

Anisotropy: often weakly to distinctly anisotropic, blue-green to orange-red

%R: 54 hi
VHN: 913-2056

Int’l Reflects.: 

Polish. Hard.: >aspy, cobaltite; slt>marc, hem; <sperrylite, laurite, cassiterite

Comments: Generally idiomorphic, coarser grains showing rect or square outlines; also coarse grained aggregates of xl fragments, coarse-grained sphere-like aggregates, fine-grained idiomorphic, fine-grained skeletal, very fine grained spherical (framboidal); cleavages // to (100), (311), and (111) may be visible; twinning lamellae rare; zoning not uncommon; higher Co, Ni, or Cu contents result in pinkish, reddish, or violet tints; may also contain significant quantities of Au or As or Sb; p. 206; 791.

Mineral Name: Pyrochlore group
Chem. Comp.: A2B2X7;

A=Ca,Na,U,REE,Fe,Th,Mn,
Mg,Sr,K,Ba,Pb,Bi,Cs,Sb.

Crystall.: cubic
Color: dark gray

Tint: 

Color (oil): 
Tint (oil):

Bireflectance: nil

Anisotropy: isotropic

%R: 12-16 low
VHN: 173-916

Int’l Reflects.: colorless to dark brown, always present

Polish. Hard.: <columbite

Comments: Usually occurs as single, idiomorphic xls; rarely as aggregates; fairly often partially or completely metamict; zoning very common; twinning rare, spinel law // (111); p.188; 1046.
Mineral Name: Pyrolusite  
Chem. Comp.: beta - Mn.O2

**Crystall.:** tetragonal

**Color:** white  
**Tint:** cream

**Color (oil):**  
**Tint (oil):** cream

**Bireflectance:** distinct, yellowish white to distinctly darker white gray

**Anisotropy:** v. strong, yellowish to dark brown to greenish blue to slate gray; straight extinction

%R: 30-36 mod  
VHN: 76-1500

**Int'l Reflects.:**

**Polish. Hard.:** depending on orientation and type of xl aggregates, may be as high as braunite

**Comments:** Occurs as coarse-grained euhedral tabular to prismatic xls; commonly fine-grained showing intersecting irregular prisms, also massive or in radiated xls; banded texture not uncommon; cleavage // (110) usually distinct in coarse xls; twinning, single and lamellar, may occur; p. 358; 1025.

---

Mineral Name: Pyrrhotite  
Chem. Comp.: Fe.S

**Crystall.:** hexagonal - mono

**Color:** cream brown  
**Tint:** pink

**Color (oil):** brown  
**Tint (oil):**

**Bireflectance:** very distinct to strong, brownish creamy to reddish brown

**Anisotropy:** v.strong, yellow-gray, greenish gray, or grayish blue

%R: 34-39 mod  
VHN: 230-390

**Int'l Reflects.:**

**Polish. Hard.:** >>cpy; >sl; ~pent, niccolite; <<aspy, py

**Comments:** Hardness and lively anisotropy distinctive; cubanite softer; cleavage, especially in altered specimens; pentlandite exsolutions common; twinning and zonal texture not uncommon; p. 138; 592.
Mineral Name: Rammelsbergite
Chem. Comp.: Ni.As2

Crystall.: ortho
Color: white
Tint: yellow
Color (oil): Tint (oil):
Bireflectance: weak to distinct (oil), yellowish white to bluish white

Anisotropy: strong, pinkish, brownish, bluish, and greenish

%R: 60 hi
VHN: 459-830

Int'l Reflects.: ~minerals of the skutterudite-series, niccolite; slt<safflorite, loellingite;<aspy, cobaltite, glaucodot

Comments: Forms compact or fine-grained aggregates or mosaics of interlocking grains; zonal spherulitic and radiated textures very common, in the latter case with fibrous or bladed xls; skeletal xls also occur; cleavage // (110) rarely visible; simple and lamellar twinning very common; shows intergrowths with niccolite and with minerals of the skutterudite-series; whiter than other Ni-Co-Fe arsenides; p. 154; 852.

Mineral Name: Ramsdellite
Chem. Comp.: gamma - Mn.O2

Crystall.: ortho
Color: white yellow
Tint: yellow
Color (oil): Tint (oil):
Bireflectance: distinct to strong (oil), yellowish white to more grayish

Anisotropy: strong, yellow-brown to dark gray

%R: 12-33 low to mod
VHN: 93-1200

Int'l Reflects.: deep violet red (oil), very common

Polish. Hard.: <pyrolusite

Comments: May show diamond-shaped cross sections; commonly as small patches of fine-grained fibrous and easily cleavable xls; cleavage // (110) and (010); olive to brownish tint against pyrolusite; p. 352; 1028.
**Mineral Name:** Rathite I  
**Chem. Comp.:** (Pb,Tl)3As4(As,Ag)S10

**Crystall.:** mono  
**Color:** white  
**Tint:**  
**Color (oil):**  
**Tint (oil):** distinct on twin lamellae  
**Bireflectance:**  
**Anisotropy:** very strong, olive-green to yellow to violet-blue to blue  
**%R:** 34-39 mod  
**VHN:** 159-163  
**Int’l Reflects.:** very common, brown to clear red  
**Polish. Hard.:**  
**Comments:** Polysynthetic twinning; cleavage // (010) often distinct; p. 300; 752.

---

**Mineral Name:** Realgar  
**Chem. Comp.:** As.S

**Crystall.:** mono  
**Color:** gray  
**Tint:**  
**Color (oil):** much darker  
**Tint (oil):** weak but distinct, reddish gray to bluish gray  
**Bireflectance:**  
**Anisotropy:** strong, but masked by internal reflections  
**%R:** 20-21 low  
**VHN:** 47-660  
**Int’l Reflects.:** abundant and intense, yellowish red  
**Polish. Hard.:** <orpiment; <<stibnite  
**Comments:** Usually occurs interstitial to other ore minerals; as inclusions in orpiment; forms striated intergrowths with orpiment; p.41; 889.
Mineral Name: Renierite
Chem. Comp.: (Cu,Fe,Ge,Zn)S

Crystall.: tetragonal
Color: orange brown  
Tint: distinct; orange to bronze with a violet tint
Color (oil):  
Tint (oil):
Bireflectance: distinct to strong, easily visible in oil; yellow-brown to dark brown or grayish yellow to bluish gray
%R: 23-25 low  
VHN: 295-425

Int'l Reflects.:  
Polish. Hard.: <-cpy; >bn; <ten

Comments: Similar to bornite, but doesn't tarnish; occurs as granular aggregates and as idiomorphic xls in cpy, gn, sl, ten, bn, and cc; polysynthetic and parquet-like twinning have been observed; p. 90; 574.

Mineral Name: Rickardite
Chem. Comp.: Cu(2-x)Te

Crystall.: tetragonal
Color: red purple  
Tint: red violet blue
Color (oil):  
Tint (oil):
Bireflectance: v strong, bight pinkish red to purplish blue-gray

Anisotropy: v strong, canary yellow to deep brown red, fiery orange, white blue-gray, dark blue; basal sections appear isotropic
%R: 12-20 low (QDF2)  
VHN: 72-85 (QDF2)

Int'l Reflects.:  
Polish. Hard.: low, but >wessite, Bi-tellurides

Comments: May show a complex pattern of polysynthetic twinning along two sets of planes probably at right angles to each other; occurs as exsolution lamellae in two sets in vulcanite; forms coatings on Te; p. 242; 416.
Mineral Name: Robinsonite  

Crystall.: triclinic  
Color: white  
Tint: blue green  
Color (oil): darker  
Tint (oil): darker colors  
Bireflectance: distinct, gray white or white with a bluish green tint to greenish gray

Anisotropy: strong, light tan to brown to bluish gray

%R: 38-42 mod  
VHN: 118-123  
Int'l Reflects.: rare, red

Polish. Hard.:  
Comments: Occurs as inclusions in boulangerite; p. 276; 764.

Mineral Name: Rutile  
Chem. Comp.: Ti.O2

Crystall.: tetragonal  
Color: gray  
Tint: ft blue  
Color (oil):  
Tint (oil):  
Bireflectance: distinct in oil,

Anisotropy: strong, colors usually masked by the internal reflections

%R: 20-24 low  
VHN: 933-1280  
Int'l Reflects.: white, yellowish, brown, reddish brown, brownish violet, green; strong and abundant

Polish. Hard.: >ilmenite; <hematite, cassiterite

Comments: Often idiomorphically developed; in minute needle-shaped xls arranged // crystallographic directions of original host minerals; cleavage often distinct; lamellar twinning very common; p. 180; 1005.
Opague Mineral Optics

Mineral Name: Safflorite
Chem. Comp.: (Co,Fe,Ni)As₂
Crystall.: ortho
Color: white
Tint: blue gray
Color (oil): Tint (oil): v weak, bluish to grayish
Bireflectance: strong, highly variable polarization colors
%R: 55-60 hi
VHN: 430-988
Int'l Reflects.: >Skutterudite-series; ~niccolite; <loellingite; <cobaltite, glaucodot
Comments: Usually shows concentric or radiated textures forming alternating zones with other minerals (such as niccolite, glaucodot, skutterudite, etc.); also tubercle-like textures; occurs as aggregates of idiomorphic xls; cleavage not observed; twinning very common and typical (star-shaped or compound trillings); p. 156; 848.

Mineral Name: Samarskite
Chem. Comp.: (Fe,Y,U)₂(Nb,Ti,Ta)₂O₇
Crystall.: orthorhombic
Color: lt gray
Tint: creamy
Color (oil): Tint (oil): nil
Bireflectance: isotropic
%R: 14.8 to 16.6 low
VHN: 736-897
Int'l Reflects.: faint reddish brown
Comments: Generally prismatic, sometimes lamellar or needles; cleavage indistinct; forms intergrowths with columbite; common in granite pegmatites; may occur with columbite, monazite, biotite, muscovite, garnet, tourmaline, magnetite, topaz, phenakite, sphene, zircon, etc.; all data from pp. 526-534 of Vlasov (1966).
**Mineral Name:** Samsonite  
**Chem. Comp.:** (2.Ag2S)(MnS)(Sb2.S3)  
**Crystall.:** mono  
**Color:** gray  
**Tint:** blue  
**Color (oil):**  
**Tint (oil):**  
**Bireflectance:** distinct, olive green gray to blue gray  
**Anisotropy:** weak, greenish gray to purple  
**%R:** 28 low  
**VHN:** \( \text{Int'l Reflects.}: \) deep red, very common  
**Comments:** Occurs as single xls and as radial aggregates; triangular pits may occur; twinning not observed; very similar to pyrargyrite; p. 260; 790.

**Mineral Name:** Sartorite  
**Chem. Comp.:** (PbS)(As2.S3)  
**Crystall.:** mono  
**Color:** white  
**Tint:**  
**Color (oil):**  
**Tint (oil):**  
**Bireflectance:** weak  
**Anisotropy:** distinct, gray-blue to yellowish gray  
**%R:** 35-39 mod  
**VHN:** 194-197  
**Int'l Reflects.:** very common, deep-red  
**Comments:** Abundantly twinned // (100); commonly broad lamellae of equal width; p. 302; 750.
Mineral Name: Scheelite

Chem. Comp.: Ca.W.O4

Crystal I.: tetragonal

Color: gray white

Tint:

Color (oil): much darker

Tint (oil):

Bireflectance: not observable

Anisotropy: distinct, but highly masked by internal reflections

%R: 10 v low

VHN: 285-464

Int’l Reflects.: abundant, white

Polish. Hard.: <wolframite

Comments: Replaces wolframite or is interstitial to it; the replacing scheelite may show a pale yellow internal reflection; p. 184; 1093.

Mineral Name: Schirmerite


Crystal I.: orthorhombic

Color: white

Tint: cream

Color (oil): weak, visible at grain boundaries

Tint (oil):

Bireflectance: weak, visible at grain boundaries

Anisotropy: weak, visible at grain boundaries

%R: 42-47 mod (P&J)

VHN: 150-206*

Int’l Reflects.:

Polish. Hard.:

Comments: Granular aggregates of elongated grains; cleavage may be visible; p. 282; 746.

**Mineral Name:** Selenium

**Chem. Comp.:** Se

**Crystall.:** hexagonal - rhombohedral

**Color:** white

**Tint:**

**Color (oil):** darker

**Tint (oil):** brown gray

**Bireflectance:** v strong (air), creamy white to brownish; (oil) bluish gray white to dull brown

**Anisotropy:** v strong, green to greenish gray, vivid

**%R:** 25-35 low to mod

**Int'l Reflects.:**

**VHN:**

**Polish. Hard.:** <clausthalite, gn

**Comments:** Forms acicular xls or aggregates; occurs as a decomposition product of selenides, forming bundles of xls, single prismatic xls, and gel-textures; a lamellar structure occurs; often included in clausthalite; p. 224; 382.

---

**Mineral Name:** Seligmannite

**Chem. Comp.:** $(2\text{PbS})(\text{Cu}_2\text{S})$

**Crystall.:** ortho

**Color:** white gray

**Tint:**

**Color (oil):**

**Tint (oil):** pink

**Bireflectance:** weak, distinct on twin lamellae

**Anisotropy:** strong, brown to green to greenish blue

**%R:** 36-40 mod

**VHN:** 149-167

**Int'l Reflects.:**

**Polish. Hard.:** slt>gn; <<ten

**Comments:** Usually forms xenomorphic grains; needle-like idiomorphic grains in stromeyerite; commonly polysynthetically twinned; parquet-like twinning occurs, similar to bournonite; anisotropy stronger than bournonite; p. 304; 734.
### Mineral Name: Semseyite

**Chem. Comp.**: (9.\(\text{PbS}\))(4.\(\text{Sb}_2\text{S}_3\))

- **Crystall.**: mono
- **Color**: white
- **Tint**: green yellow
- **Color (oil)**: Tint (oil):
- **Bireflectance**: distinct, white with a yellow-green tint to greenish gray
- **Anisotropy**: strong, light gray to bluish gray to brown to dark gray
- **%R**: 40 mod
- **VHN**: 109-173
- **Int'l Reflects.**:
- **Polish. Hard.**: <gn
- **Comments**: Occurs as lath-like or prismatic coarsely xln aggregates, or as fine granular aggregates; cleavage oblique to the elongation of the grains; twinning or zonal texture not observed; p. 276; 764.

### Mineral Name: Siegenite

**Chem. Comp.**: (Ni,Co)\(3\text{.S}_4\)

- **Crystall.**: cubic
- **Color**: white
- **Tint**: cream slt pink
- **Color (oil)**: Tint (oil):
- **Bireflectance**: nil
- **Anisotropy**: isotropic
- **%R**: 45 mod
- **VHN**: 336-579
- **Int'l Reflects.**:
- **Polish. Hard.**: ~linnaeite, <cattierite
- **Comments**: Occurs as idiomorphic xls and as irregular grains; cubic cleavage not always visible; p. 146; 697.
<table>
<thead>
<tr>
<th>Mineral Name: Silver</th>
<th>Chem. Comp.: Ag (may contain minor amounts of Au, Hg, As, Sb, Pt, Ni, Pb, and Co)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystall.: cubic</td>
<td></td>
</tr>
<tr>
<td>Color: white cream</td>
<td>Tint: cream (tarnishes quickly to creamier or pinkish tints)</td>
</tr>
<tr>
<td>Color (oil):</td>
<td></td>
</tr>
<tr>
<td>Bireflectance: nil</td>
<td></td>
</tr>
<tr>
<td>Anisotropy: isotropic</td>
<td></td>
</tr>
<tr>
<td>%R: 90-95 v hi</td>
<td>VHN: 40-118</td>
</tr>
</tbody>
</table>

**Int'l Reflects.:**

**Polish. Hard.:** >>proustite; >gn; slt <dyscrasite; < As, tet; <<sl

**Comments:** Twinning and zoning not uncommon; cleavage not observed; occurs as dendrites, as skeleton- or cross-shaped xls surrounded by niccolite, rammelsbergite, or Ni-skutterudite; as irregular masses, as disseminated grains or leaves; as tubercle-like grains, as inclusions in other minerals; p. 74; 313.

<table>
<thead>
<tr>
<th>Mineral Name: Sinnerite</th>
<th>Chem. Comp.: Cu1.4. As0.9. S2.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystall.: triclinic</td>
<td></td>
</tr>
<tr>
<td>Color: gray white</td>
<td>Tint: yellow brown (against gn)</td>
</tr>
<tr>
<td>Color (oil):</td>
<td>Tint (oil):</td>
</tr>
<tr>
<td>Bireflectance: nil</td>
<td></td>
</tr>
<tr>
<td>Anisotropy: distinct, gray-brown to gray blue</td>
<td></td>
</tr>
<tr>
<td>%R: 30-32 mod</td>
<td>VHN: 357-390</td>
</tr>
</tbody>
</table>

**Int'l Reflects.:**

**Polish. Hard.:**

**Comments:** Under crossed nicols abundant twinning is visible which is remotely similar to that of aspy; p. 68; 571.
**Mineral Name:** Skutterudite-series

**Chem. Comp.:** (Co,Ni,Fe)As_{3-x}

**Crystall.:** cubic

**Color:** white

**Tint:** cream gray blue

**Color (oil):**

**Tint (oil):**

**Bireflectance:** nil

**Anisotropy:** isotropic

**%R:** 53 hi

**VHN:** 268-974

**Int'l Reflects.:**

**Polish. Hard.:** Ferroan>Cobaltian>Nickelian; H with respect to rammelsberite, niccolite, safflorite, linnaeite varies with composition; all members >maucherite; < loellingite, ullmannite,

**Comments:** Cleavage may be distinct, on cobaltian skutterudite rare; twinning not observed; differences in H may be sufficient to distinguish texture in composite xls; pure skutterudite commonly forms homogeneous idiomorphic xls; zonal xls may occur; all other members form coarse xls with very fine zonal texture, or zonal intergrowths with other members of the series or with rammelsbergite or safflorite; xl aggregates not uncommon; p. 152; 881.

---

**Mineral Name:** Smithite

**Chem. Comp.:** Ag.As.S_{2}

**Crystall.:** mono

**Color:** white

**Tint:**

**Color (oil):** white

**Tint (oil):** blue

**Bireflectance:** distinct, bluish white to bluish gray in oil

**Anisotropy:** distinct, but obscured by internal reflections

**%R:** 40 mod

**VHN:**

**Int'l Reflects.:** strong and abundant, bright orange

**Polish. Hard.:** <proustite

**Comments:** Occurs as fine-bladed, tabular xls, sometimes pseudohexagonal; nearly indistinguishable from trechmannite; p. 266; 726.
**Mineral Name:** Smythite  
**Chem. Comp.:** Fe$_3$S$_4$

<table>
<thead>
<tr>
<th>Crystall.</th>
<th>hexagonal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>cream</td>
</tr>
<tr>
<td>Tint</td>
<td>pink</td>
</tr>
<tr>
<td>Color (oil)</td>
<td></td>
</tr>
<tr>
<td>Tint (oil)</td>
<td></td>
</tr>
<tr>
<td>Bireflectance</td>
<td>strong, grayish yellow to reddish brown</td>
</tr>
<tr>
<td>Anisotropy</td>
<td>strong, yellow to blue gray</td>
</tr>
<tr>
<td>%R</td>
<td>35 mod</td>
</tr>
<tr>
<td>VHN</td>
<td></td>
</tr>
</tbody>
</table>

**Int'l Reflects.:**

**Polish. Hard.:**

**Comments:** Occurs as clusters of very fine patches in radial, more rarely in parallel, arrangement; perfect basal cleavage; very similar to po, but has stronger bireflectance; p. 140; 612.

---

**Mineral Name:** Sperrylite  
**Chem. Comp.:** Pt.As$_2$

<table>
<thead>
<tr>
<th>Crystall.</th>
<th>cubic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>white</td>
</tr>
<tr>
<td>Tint</td>
<td></td>
</tr>
<tr>
<td>Color (oil)</td>
<td></td>
</tr>
<tr>
<td>Tint (oil):</td>
<td>cream blue</td>
</tr>
<tr>
<td>Bireflectance</td>
<td>nil</td>
</tr>
<tr>
<td>Anisotropy</td>
<td>isotropic</td>
</tr>
<tr>
<td>%R</td>
<td>56 hi</td>
</tr>
<tr>
<td>VHN:</td>
<td>960-1277</td>
</tr>
</tbody>
</table>

**Int'l Reflects.:**

**Polish. Hard.:** >>Pt; >braggite, geversite; ~py; <laurite, hollingworthite

**Comments:** Usually as idiomorphic cubic xls; cleavage // (100) occasionally visible; no twinning or zoning observed; forms intergrowths, sometimes myrmekitic, with Pt and magnetite; p. 324; 821.
Mineral Name: Sphalerite

Chem. Comp.: ZnS

Crystal.: hextetrahedral

Color: gray

Tint:

Color (oil): dark gray

Tint (oil):

Bireflectance: isotropic

Anisotropy: isotropic

%R: 18 low

VHN: 128-276

Int'l Reflects.: red and orange; sometimes white

Polish. Hard.: <po,mt;> cpy, tet-ten

Comments: Similar to alabandite; lower %R than magnetite (oil); cleavage // (110) commonly visible in coarse grains; lamellar twinning and zonal texture common; p. 126; 506.

Mineral Name: Spinel-series (spinel, hercynite, almandine)

Chem. Comp.: Mg or Fe or Mn or Zn, Al2O4

Crystal.: cubic

Color: gray

Tint:

Color (oil):

Tint (oil):

Bireflectance: nil

Anisotropy: isotropic

%R: 7 v low

VHN: 861-1650

Int'l Reflects.: abundant and intense, colourless to various shades of green and brown

Polish. Hard.: very high

Comments: Usually as idiomorphic xls, also massive, coarse-granular to compact and as irregular or rounded embedded grains; twinning lamellae // (111) may be visible; p. 210; 906.
<table>
<thead>
<tr>
<th>Mineral Name: Stannite</th>
<th>Chem. Comp.: Cu₂Fe₃Sn₄S₁₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystal: tetragonal</td>
<td></td>
</tr>
<tr>
<td>Color: gray</td>
<td>Tint: brown or green</td>
</tr>
<tr>
<td>Color (oil): darker</td>
<td>Tint (oil):</td>
</tr>
<tr>
<td>Bireflectance: distinct, light brown to brownish olive-green</td>
<td></td>
</tr>
</tbody>
</table>

Anisotropy: distinct (violet-gray, slate green, bluish, yellowish brown)

%R: 26-29 low  VHN: 140-326

Int'l Reflects.:>cp;~tetrahedrite;<sl

Polish. Hard.: >cp; ~tetrahedrite; <sl

Comments: Zonal or spotty mottling common; similar to tet-ten; very fine compound twinning common; may have triangular cleavage pits; p. 312; 549.

<table>
<thead>
<tr>
<th>Mineral Name: Stannite Jaune</th>
<th>Chem. Comp.: Cu₂⁺Sn₁⁻ₓFe₄S₁₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystal: tetragonal</td>
<td></td>
</tr>
<tr>
<td>Color: brown yellow</td>
<td>Tint: yellow orange brown</td>
</tr>
<tr>
<td>Color (oil):</td>
<td>Tint (oil):</td>
</tr>
<tr>
<td>Bireflectance: strong, yellowish to orange brown</td>
<td></td>
</tr>
</tbody>
</table>

Anisotropy: strong, reddish, bluish and greenish tints

%R: 23-25 low  VHN:  

Int'l Reflects.:>bn

Polish. Hard.: >bn

Comments: Stannite jaune is yellow stannite, an intermediate member of the stannite-idaite series; occurs as exsolution lamellae in stannite; also as reaction rims between cpy and stannite, and between cassiterite and bn; p. 310.
Mineral Name: Stephanite

Chem. Comp.: \((5\text{Ag}_2\text{S})(\text{Sb}_2\cdot\text{S}_3)\)

Crystal: ortho

Color: gray

Tint: pink violet

Color (oil): Tint (oil):

Birefringence: weak, gray, gray with a brownish pink tint, pink

Anisotropy: strong (oil), dark violet to dull grayish green; sharp extinction; basal sections appear isotropic

\%R: 25-30 low

VHN: 31-124

Int'l Reflect.: 

Polish. Hard.: >>argentite; >polybasite and pyrargyrite; <tet

Comments: Occurs as columnar xls and xenomorphic aggregates; fine compound twinning is not uncommon; p. 256; 727.

Mineral Name: Sternbergite

Chem. Comp.: Ag.\text{Fe}_2.\text{S}_3

Crystal: ortho

Color: brown

Tint:

Color (oil): darker

Tint (oil):

Birefringence: distinct, light to dark brown (P&J)

Anisotropy: strong, vivid bluish and reddish to lilac (P&J)

\%R: 24-37 low to mod (P&J & VHN: 31-44

Int'l Reflect.: 

Polish. Hard.: >bismuth; ~pyrargyrite, proustite; slt< argyropyrite, < gn, Ag

Comments: Occurs as thin tabular xls, mostly of pseudo-hexagonal outlines due to interpenetrating twinning; sometimes very fine-grained; perfect basal cleavage // (001), better than for argentopyrite; memetic twinning very common; somewhat darker than po; p. 268; 639.
Mineral Name: Stibnite                                      Chem. Comp.: Sb2S3

Crystal: ortho

Color: white gray                                      Tint: gray

Color (oil):                                           Tint (oil):

Bireflectance: strong, dull gray white, brownish gray, pure white

Anisotropy: v. strong, blue, gray white, brown, pinkish brown

%R: 31-47 mod                                      VHN: 42-153

Int'l Reflects:

Polish. Hard.: >orpiment, realgar; ~berthierite, gn, bournonite; <<cpy

Comments: Irregular granular masses or as radiated aggregates; pressure twins, crumpling lamellae, and deformation very common; may show fine growth-zoning; p. 42; 705.

Mineral Name: Stilleite                                Chem. Comp.: ZnSe

Crystal: cubic

Color: gray                                           Tint:

Color (oil):                                           Tint (oil):

Bireflectance: nil

Anisotropy: isotropic

%R: ~30 low                                         VHN:

Int'l Reflects.: deep gray, rare

Polish. Hard.: >tet

Comments: Occurs as xenomorphic inclusions in linnaeite and Se-vae site; twin lamellae may be observed; p. 216; 520.
Mineral Name: Stromeyerite

Chem. Comp.: Cu.Ag.S

Crystall.: ortho

Color: dull white

Tint: faint gray violet

Color (oil): violet pink tint stronger

Tint (oil): violet pink tint stronger

Bireflectance: weak (air); strong (oil) - grayish brown / cream / ft bluish green

Anisotropy: strong - blue / deep violet

%R: 26-30 low

VHN: 27-62

Int’l Reflects.: Needle-like idiomorphic xls are rare; an oleander-leaf texture is not uncommon; often late; with cc and silver; p. 52; 481.

Mineral Name: Sulfur

Chem. Comp.: S

Crystall.: ortho or mono

Color: gray

Tint:

Color (oil): much darker

Tint (oil):

Bireflectance: distinct in air, in oil masked by internal reflections

Anisotropy: distinct in air, in oil masked by internal reflections

%R: 10-15 low

VHN: 24-66

Int’l Reflects.: white to light yellowish, abundant and intense

Polish. Hard.: very low

Comments: Usually fine-granular; easily recognized; an alteration product of sulfides; p. 40; 381.
Mineral Name: Sylvanite

Chem. Comp.: Au.Ag.Te4

Crystall.: mono

Color: white

Tint: cream

Color (oil):

Tint (oil):

Bireflectance: distinct, creamy white to creamy brown

Anisotropy: strong, light bluish gray to dark brown

%R: 50-58 hi

VHN: 60-250

Int’l Reflects.:

Polish. Hard.: >>argentite, hessite; >altaite, Bi-tellurides; slt>nagyagite; <pyrargyrite

Comments: Often forms skeleton-shaped xls; cleavage // (010) perfect, // (100) less distinct; polysynthetic twinning is always present; p. 248; 426.

Mineral Name: Talnakhite

Chem. Comp.: Cu.Fe.S2

Crystall.: cubic

Color: dark yellow

Tint: pink

Color (oil):

Tint (oil):

Bireflectance: nil

Anisotropy: isotropic

%R: 39 mod

VHN:

Int’l Reflects.:

Polish. Hard.:

Comments: Occurs as intergrowths with fine plates and mesh structures of cpy; fills the spaces between these plates and mesh structures; p. 94.
Mineral Name: Tapiolite

Chem. Comp.: (Fe,Mn)(Ta,Nb)2.O6

Crystall.: tetragonal

Color: white gray

Tint: blue gray

Bireflectance: distinct to strong

Anisotropy: strong, slaty gray to red-brown or dark blue to greenish gray

%R: 16-18 low

VHN: 796-1132

Int’l Reflects.: red or red-brown, not abundant

Polish. Hard.: > or = columbite

Comments: Twin lamellae // (011) always present; occurs as reaction rims in columbite, as exsolution bodies in the form of fine needles in cassiterite; p. 202; 1042.

Mineral Name: Teallite

Chem. Comp.: Pb.Sn.S2

Crystall.: ortho

Color: white

Tint: cream pink

Bireflectance: weak, white to yellowish

Anisotropy: v distinct, lt-brownish-dk gray / steel blue / violet

%R: 40-47 mod

VHN: 31-125

Int’l Reflects.: 

Polish. Hard.: >franckite; <<sl

Comments: Coarse laths, radiating aggregates; basal cleavage; polysynthetic twinning; wave-like textures and twinning occur; p. 318; 670.
**Mineral Name:** Tellurium  
**Chem. Comp.:** Te (may contain some Se, Au, Ag, or Fe)  
**Crystall.:** hexagonal  
**Color:** white  
**Tint:** gray cream  
**Color (oil):**  
**Tint (oil):**  
**Bireflectance:** distinct, white to brownish gray  
**Anisotropy:** strong, bluish and brownish grays, similar to stibnite but not so bright  
\[\%R: \text{57-69 hi (P&J)} \quad \text{VHN: 25-87} \]  
**Int'l Reflects.:**  
**Polish. Hard.:** <empressite, montbrayite, krennerite, calaverite; >sylvanite, tellurobismuthite, altaite  
**Comments:** Occurs as prismatic or acicular xls and as dense columnar, sometimes fine-grained masses; cleavage occasionally observed; twinning not observed; p. 246; 383.

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**Mineral Name:** Tellurobismuthite  
**Chem. Comp.:** Bi$_2$Te$_3$  
**Crystall.:** hexagonal  
**Color:** white  
**Tint:** cream pink  
**Color (oil):**  
**Tint (oil):**  
**Bireflectance:** v weak, creamy to grayish white  
**Anisotropy:** distinct, gray or grayish blue to yellowish gray  
\[\%R: \text{64 hi} \quad \text{VHN: 32-93} \]  
**Int'l Reflects.:**  
**Polish. Hard.:** >tetradymite  
**Comments:** Forms exsolution intergrowths with tetradymite; may occur as idiomorphic inclusions in cpy; perfect cleavage // (0001); lamellar twinning has been observed; p. 250; 436.
**Tennantite**

**Chem. Comp.:** Cu$_2$As$_4$S$_{13}$ (minor Ag, Fe, Sb, Zn not rare)

**Crystal.:** cubic

**Color:** gray

**Tint:** blue or green

**Bireflectance:**

**Anisotropy:** isotropic

**%R:** 27-31 low to mod

**VHN:** 251-425

**Int'l Reflects.:** various shades of red

**Polish. Hard.:** >>gn; ~cpy;

**Comments:** Forms myrmekitic intergrowths with gn, stromeyerite, cpy, py, pyrargyrite; cleavage not always discernible; p. 108; 549.

---

**Tenorite**

**Chem. Comp.:** CuO

**Crystal.:** mono

**Color:** gray white

**Tint:**

**Color (oil):** much darker

**Tint (oil):** brown cream

**Bireflectance:**

**Anisotropy:** strong, creamy to brownish to yellowish gray

**%R:** 20-25 low

**VHN:** 203-254

**Int'l Reflects.:**

**Polish. Hard.:** >cc; <cuprite, goethite

**Comments:** Forms sheaves of acicular xls, concentric aggregates, fine grained mosaics or pseudomorphic; lamellar twinning not uncommon; p. 118; 899.
**Opaque Mineral Optics**

**Mineral Name:** Tetradymite  
**Chem. Comp.:** Bi$_2$.Te$_2$.S  
**Crystall.:** hexagonal  
**Color:** white  
**Tint:** cream or light yellow  
**Color (oil):**  
**Tint (oil):**  
**Bireflectance:** weak, greenish tints  
**Anisotropy:** distinct, bluish gray or yellow gray, (perhaps with pinkish or brownish tints)  
**%R:** 53-60 hi (P&J & QDF2)  
**VHN:** 30-44 (QDF2)  
**Int'l Reflects.:**  
**Polish. Hard.:** <tellurobismutite, wehrlite>  
**Comments:** Chemically similar to joseite and grünlingite; may show anhedral texture; a "spindle"-like texture occurs due to folding; forms idiomorphic needle-shaped xls with straight extinction and hexa cross sections; perfect basal cleavage is always present; fine lamellar twinning is rarely visible; p. 248; 436.

**Mineral Name:** Tetrahedrite  
**Chem. Comp.:** Cu$_{12}$.Sb$_4$.S$_{13}$  
**Crystall.:** cubic (minor Ag, As, Bi, Fe, Hg, Pb, Te, Zn not rare)  
**Color:** light gray  
**Tint:** olive green or brown  
**Color (oil):**  
**Tint (oil):**  
**Bireflectance:**  
**Anisotropy:** isotropic  
**%R:** 31-33 mod  
**VHN:** 251-425  
**Int'l Reflects.:** brown red  
**Polish. Hard.:** >>gn;~cpy;  
**Comments:** Cleavage not always distinct; zonal texture may be developed by etching; distinguished from stephanite, polybasite, miargyrite by isotropy; much lighter than sl in oil; p. 108; 562.
<table>
<thead>
<tr>
<th>Mineral Name:</th>
<th>Thorianite</th>
<th>Chem. Comp.:</th>
<th>(Th,U,Ce)O₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystall.:</td>
<td>cubic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color:</td>
<td>gray</td>
<td>Tint:</td>
<td>darker than uraninite</td>
</tr>
<tr>
<td>Color (oil):</td>
<td></td>
<td>Tint (oil):</td>
<td></td>
</tr>
<tr>
<td>Birefringence:</td>
<td>nil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anisotropy:</td>
<td>isotropic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>%R:</td>
<td>15 low</td>
<td>VHN:</td>
<td>920-1235</td>
</tr>
<tr>
<td>Int'l Reflects.:</td>
<td>red and yellow brown, often visible in oil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polish. Hard.:</td>
<td>&gt;uraninite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comments:</td>
<td>Usually occurs as cubic xls, as rounded grains in alluvial deposits, or as aggregates of these; also as rounded or irregularly shaped grains; twinning or cleavage not observed; p. 196; 1070.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mineral Name:</th>
<th>Tiemannite</th>
<th>Chem. Comp.:</th>
<th>Hg-Se</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystall.:</td>
<td>cubic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color:</td>
<td>white, gray</td>
<td>Tint:</td>
<td>delicate brown</td>
</tr>
<tr>
<td>Color (oil):</td>
<td>much darker</td>
<td>Tint (oil):</td>
<td>distinctly brown</td>
</tr>
<tr>
<td>Birefringence:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anisotropy:</td>
<td>isotropic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>%R:</td>
<td>~30 mod</td>
<td>VHN:</td>
<td>26-39</td>
</tr>
<tr>
<td>Int'l Reflects.:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polish. Hard.:</td>
<td>&lt;clausthalite;&lt;&lt;gn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comments:</td>
<td>Allotriomorphic grains, sometimes enclosed by clausthalite; p. 216; 523.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Mineral Name:** Titanomagnetite  
**Chem. Comp.:** Fe(1-x)Fe(2-2x)Ti(x)O4  
**Crystall.:** cubic  
**Color:** white gray  
**Color (oil):** brown  
**Tint:** brown  
**Tint (oil):**  
**Bireflectance:** nil  
**Anisotropy:** isotropic  
**%R:** 17 low  
**VHN:** 715-734  
**Int'l Reflects.:**  
**Polish. Hard.:** slt>mt  
**Comments:** Homogeneous Ti-mt is only formed by rapid cooling of a high temperature solid solution of mt with ilm or ulvospinelle; p. 168.

**Mineral Name:** Todorokite  
**Chem. Comp.:** (H2O,...)<=2(Mn,...)<=8(O,OH)16  
**Crystall.:** mono  
**Color:** pale gray  
**Color (oil):**  
**Tint:**  
**Tint (oil):**  
**Bireflectance:** weak, shades of gray with yellowish or brownish tints  
**Anisotropy:** strong, white to gray, undulatory extinction  
**%R:** 20-23 low  
**VHN:**  
**Int'l Reflects.:**  
**Polish. Hard.:**  
**Comments:** Occurs as columnar aggregates, fine fibrous and as irregular masses with botryoidal or layered structure; also as fan- or sheaf-like aggregates of radiating fibers or acicular xлитes; cleavage perpendicular to the basal plane and parallel to the elongation; p. 350; 1084.
Mineral Name: Trogtalite
   Chem. Comp.: Co.Se2
   Crystall.: cubic
   Color: violet blue
   Tint: pink
   Color (oil): nil
   Tint (oil): nil
   Bireflectance: nil
   Anisotropy: isotropic
   %R: 41 mod (P&J)
   VHN:
   Int'l Reflects.:
   Polish. Hard.: very hard
   Comments: Occurs as idiomorphic grains in clausthalite; often radially enveloped by hastite and bornhardtite; p. 218; 819.

Mineral Name: Tungstenite
   Chem. Comp.: W.S2
   Crystall.: hexagonal
   Color: white gray
   Tint: blue
   Color (oil): nil
   Tint (oil): nil
   Bireflectance: v strong, white to dull gray with a dark bluish tint
   Anisotropy: v strong, pinkish white to dark blue
   %R: 18-36 (P&J)
   VHN: 15 (on basal sections only)
   Int'l Reflects.:
   Polish. Hard.: >gn
   Comments: Impossible to distinguish from molybdenite; occurs as fine scaly aggregates; also as inclusions in safflorite and skutterudite; basal sections have ~50%R; p. 102; 880.
**Mineral Name:** Ullmannite

**Chem. Comp.:** Ni.Sb.S

**Crystall.:** cubic

**Color:** white

**Tint:**

**Color (oil):**

**Tint (oil):** blue gray

**Bireflectance:** nil

**Anisotropy:** isotropic

**%R:** 45 mod

**VHN:** 460-560

**Int'l Reflects.:**

**Polish. Hard.:** >linnaeite; ~gersdorffite; <<py

**Comments:** Commonly idiomorphically developed; cleavage // (100) often visible; triangular pits may occur, but more rare than in gersdorffite; zonal texture occurs; p. 158; 836.

---

**Mineral Name:** Ulvöspinel

**Chem. Comp.:** Fe2.Ti.O4

**Crystall.:** cubic

**Color:** brown

**Tint:**

**Color (oil):**

**Tint (oil):**

**Bireflectance:** nil

**Anisotropy:** isotropic

**%R:** 18 low (P&J)

**VHN:**

**Int'l Reflects.:**

**Polish. Hard.:** >mt

**Comments:** Rarely as idiomorphic octahedral xls; usually as very fine exsolution bodies in Ti-rich mt, // to (100) and (110) of the mt; these mts may also contain exsolution lamellae of spinel and ilmenite; p. 170; 923.
**Mineral Name:** Umangite  
**Chem. Comp.:** Cu$_3$.Se$_2$

**Crystall.:** tetragonal  
**Color:** violet  
**Tint:** brown red  
**Color (oil):** nearly red  
**Tint (oil):**

**Bireflectance:** v strong, bright violet red to greenish blue-gray

**Anisotropy:** v strong, (air) orange red to orange yellow; (oil) yellow to dark orange; extinction parallels the cleavage directions

**%R:** 13-16 low  
**VHN:** 77-112

**Int'l Reflects.:**

**Polish. Hard.:** ~klockmannite

**Comments:** Always xenomorphic; forms massive or fine-grained aggregates of needle-like and granular xls; two cleavage directions, poorly developed; polysynthetic twinning often wedge-shaped, in several directions; may contain lamellae or veinlets of klockmannite; p. 222; 681.

---

**Mineral Name:** Uraninite  
**Chem. Comp.:** U.O$_2$

**Crystall.:** cubic  
**Color:** gray  
**Tint:** brown  
**Color (oil):** much darker  
**Tint (oil):**

**Bireflectance:** nil

**Anisotropy:** isotropic

**%R:** 17 low  
**VHN:** 625-929

**Int'l Reflects.:** v dark brown or reddish brown, not uncommon

**Polish. Hard.:** very high, >mt; <or=py

**Comments:** Forms well-developed xls; cleavage // (100) and (111) may be visible; twinning // (111) often occurs; zonal texture very common, may be evident by oriented inclusions; p. 194; 1050.
Mineral Name: Vaesite (see Bravosite, Cattierite)  
Chem. Comp.: Ni₂S₂ (may contain some Co and Cu)  
Crystall.: cubic  
Color: gray  
Tint: nil  
Color (oil):  
Tint (oil):  
Bireflectance: nil  
Anisotropy: isotropic  
%R: 31 mod  
VHN: 773-856  
Int'l Reflects.:  
Polish. Hard.: no data  
Comments: Ni end member of the bravosite series; occurs as octahedral and cubic xls, and as aggregates; may show cubic cleavage almost as perfect as that of gn; formed by alteration of Ni-skutterudite and other Ni-sulfides and -arsenides; p. 134; 809,815.

Mineral Name: Valleriite  
Chem. Comp.: Cu₆Fe₂S₄(Mg,Al,Fe)(OH)₂  
Crystall.: hexagonal  
Color: brown  
Tint: bronze  
Color (oil):  
Tint (oil):  
Bireflectance: v. strong, creamy bronze / grayish pink-violet / bluish gray  
Anisotropy: v strong, white to gray bronze  
%R: 14-20 low  
VHN: 30  
Int'l Reflects.:  
Polish. Hard.: <or= graphite (Ramdohr)  
Comments: Needle, thread, myrmekite, lath, bleb, star inclusions in cpy, po, and pent; also occurs as fine-laminated or pisolitic aggregates; p. 98; 683.
**Mineral Name:** Villamaninite  
**Chem. Comp.:** (Cu,Ni,Co,Fe)S2

- **Crystall.:** cubic  
- **Color:** gray  
- **Tint:** idiomorphic (red violet), nodular (blue violet)  
- **Color (oil):**  
- **Bireflectance:** nil  
- **Anisotropy:** isotropic  
- **%R:** 25-30 low  
- **VHN:** 440-710  
- **Int'l Reflects.:**  
- **Polish. Hard.:** >>cpy; >penroseite; ~linnaeite; <bravoite, py  
- **Comments:** Idiomorphic form is Cu-rich, whereas the Cu-poor form is nodular; nodular form often surrounds the idiomorphic, the two separated by a rim of bravoite; p. 144; 816.

**Mineral Name:** Violarite  
**Chem. Comp.:** (Ni,Fe)3.S4

- **Crystall.:** cubic  
- **Color:** white  
- **Tint:** violet cream  
- **Color (oil):**  
- **Bireflectance:** nil  
- **Anisotropy:** isotropic  
- **%R:** 42 mod  
- **VHN:** 241-458  
- **Int'l Reflects.:**  
- **Polish. Hard.:** >cpy, sl; ~pent; slt<bravoite, po; <<aspy, py  
- **Comments:** Cubic and octahedral cleavage commonly well-developed; twinning and zonal texture not observed; usually as alteration product, often with bravoite, of pentlandite or millerite; alteration commonly starts along cleavages; p. 132; 697.
Mineral Name: Vonsenite (see Ludwigite)  
Chem. Comp.: (Fe,Mg)2(Fe,Al)B2O5

Crystal.: ortho  
Color: gray brown blue  Tint: pinkish

Color (oil): darker  Tint (oil): colors more intense

Bireflectance: v strong (air), blue or blue gray to brownish gray to brown or pinkish brown; colors darker in oil

Anisotropy: v strong, blue to pink to reddish brown to fiery orange @ 45 degrees

%R: 10-15 v low to low  VHN: 707-1003

Int'l Reflects.: 

Polish. Hard.: ~mt; <hem

Comments: Occurs as aggregates of polygonal to subrounded grains; sometimes as lath- wedge- and diamond shaped xls, commonly with rounded corners; locally broad twin lamellae may be visible; p. 164; 1094.

---

Mineral Name: Vrbaite  

Crystal.: ortho  
Color: white gray  Tint: blue

Color (oil):  Tint (oil):

Bireflectance: ?

Anisotropy: distinct, blue or bluish green to reddish yellow

%R: 30-33 mod  VHN: ?

Int'l Reflects.: abundant, red

Polish. Hard.: >chalcothallite; <<cuprite

Comments: Anisotropy not as strong as lorandite; occurs as single grains, and as inclusions in chalcothallite; p. 46; 732.
**Mineral Name:** Vulcanite  
**Chem. Comp.:** Cu,Te

- **Crystall.:** ortho
- **Color:** yellow white blue  
  **Tint:** yellow white blue
- **Color (oil):**  
  **Tint (oil):**
- **Bireflectance:** v strong, bright yellow or yellow white to medium blue
- **Anisotropy:** v strong, brilliant yellow white, grayish yellow white, yellow orange, gray; extinction // cleavage and elongation of laths
  - %R: 15-68! low to hi (QDF)  
  - **VHN:** 34-40 (QDF2)

**Int'l Reflects.:**

- **Polish. Hard.:** no data

**Comments:** Occurs as elongated irregular laths or as equidimensional grains; two cleavages, one // elongation and the other at right angles; extremely thin twinning occurs at 45° to the prominent cleavage; may be secondary; p. 244; 419.

---

**Mineral Name:** Vysotskite  
**Chem. Comp.:** (Pd,Pt,Ni)S

- **Crystall.:** tetragonal
- **Color:** white  
  **Tint:** blue
- **Color (oil):** distinct (oil), grayish blue to grayish lilac  
  **Tint (oil):**
- **Bireflectance:** distinct, bluish and brownish
  - %R: 45 mod  
  - **VHN:**

**Int'l Reflects.:**

- **Polish. Hard.:** high

**Comments:** Occurs as well-formed prismatic xls; p. 330; 695.
Mineral Name: Wairauite  
Chem. Comp.: Co.Fe  
Crystall.: cubic  
Color: white  
Color (oil): Tint (oil): nil  
Bireflectance: nil  
Anisotropy: isotropic  
%R: 54 hi  
VHN: 185-329  
Int'l Reflects.: = awaruite  
Comments: Occurs as euhedral xls with cubic or octahedral forms in serpentines; closely associated with awaruite, with which it forms zoned grains; p. 128; 357.

Mineral Name: Wittichenite  
Chem. Comp.: (3.Cu2S)(Bi2.S3)  
Crystall.: ortho  
Color: gray  
Color (oil): Tint (oil): cream brown  
Bireflectance: weak, only visible at grain boundaries  
Anisotropy: distinct (oil), dull brown colors  
%R: 33-36 mod (P&J & QDF2)  
VHN: 161-216  
Int'l Reflects.: = bismuth; >emplectite; ~cc; <cpy, tet, ten,  
Comments: Commonly coarse granular; also as acicular and elongated rectangular euhedra; no cleavage or twinning; p. 292; 721.
## Opaque Mineral Optics

**Mineral Name:** Wolframite  
**Chem. Comp.:** (Fe,Mn)WO₄

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystall.</td>
<td>mono</td>
</tr>
<tr>
<td>Color</td>
<td>gray</td>
</tr>
<tr>
<td>Tint (oil)</td>
<td>faint brown or yellow</td>
</tr>
<tr>
<td>Birefringence</td>
<td>weak to distinct at twin boundaries, gray to brownish gray</td>
</tr>
<tr>
<td>Anisotropy</td>
<td>weak to distinct, yellow to gray, sometimes with a violet or green tint</td>
</tr>
<tr>
<td>%R</td>
<td>16-19 low</td>
</tr>
<tr>
<td>VHN</td>
<td>258-657</td>
</tr>
<tr>
<td>Polish. Hard.</td>
<td>&gt;mt, scheelite; &lt;=py, aspy, cassiterite</td>
</tr>
<tr>
<td>Comments</td>
<td>Forms tabular idiomorphic xls, irregular grains also occur; zoning occurs (growth zones), sometimes with scheelite; cleavage often distinct in two directions; twinning very common; p. 186; 1087.</td>
</tr>
</tbody>
</table>

**Mineral Name:** Woodruffite  
**Chem. Comp.:** (Zn,H₂O)₈·(Mn,Zn...)₈·(O,OH)₁₆

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystall.</td>
<td>monoclinic</td>
</tr>
<tr>
<td>Color</td>
<td>gray</td>
</tr>
<tr>
<td>Tint (oil)</td>
<td>yellow</td>
</tr>
<tr>
<td>Birefringence</td>
<td>distinct, gray to yellowish gray</td>
</tr>
<tr>
<td>Anisotropy</td>
<td>v distinct</td>
</tr>
<tr>
<td>%R</td>
<td>26 low</td>
</tr>
<tr>
<td>VHN</td>
<td>744</td>
</tr>
<tr>
<td>Polish. Hard.</td>
<td></td>
</tr>
<tr>
<td>Comments</td>
<td>Occurs as very fine grains; alteration product of franklinite; p. 352; 1084.</td>
</tr>
</tbody>
</table>
**Mineral Name:** Wuestite  
**Chem. Comp.:** FeO  
**Crystall.:** cubic  
**Color:** gray  
**Tint:** greenish against mt  
**Color (oil):**  
**Tint (oil):**  
**Bireflectance:** nil  
**Anisotropy:** isotropic  
**%R:** 18 low (QDF2)  
**VHN:**  
**Int'l Reflects.:**  
**Polish. Hard.:** ~magnetite

**Comments:** Occurs with magnetite, hematite, goethite and iron as curved bodies in a tuff breccia; also with magnetite and hematite in a natural coke; p. 166; 898.

---

**Mineral Name:** Wulfenite  
**Chem. Comp.:** Pb.Mo.O4  
**Crystall.:** tetragonal  
**Color:** gray  
**Tint:**  
**Color (oil):**  
**Tint (oil):**  
**Bireflectance:** weak, distinct in oil  
**Anisotropy:** obscured by the internal reflections  
**%R:** 17 low  
**VHN:** 211-233  
**Int'l Reflects.:** colorless, yellow and orange-yellow, strong and abundant  
**Polish. Hard.:** <descloizite

**Comments:** Occurs as idiomorphic xls and as aggregates in the oxidation zone; p. 144.
Mineral Name: Wurtzite

Chem. Comp.: Zn.S

Crystall.: hexagonal

Color: gray, like sl

Tint:

Color (oil): dark gray

Tint (oil):

Bireflectance:

Anisotropy: nil

%%%%: 18 low

VHN: 146-264

Int'l Reflects.: abundant yellow-brown

Polish. Hard.: like sl

Comments: Distinguishable from sl only by X-ray; p. 126; 577.

---

Mineral Name: Xanthoconite-Pyrostilpnite

Chem. Comp.: (3.Ag2S)((As,Sb)2.S3)

Crystall.: mono

Color: gray

Tint: blue

Color (oil):

Tint (oil):

Bireflectance: similar to proustite-pyrargyrite

Anisotropy: similar to proustite-pyrargyrite

%R: low

VHN:

Int'l Reflects.: yellowish or yellowish brown

Polish. Hard.: ~proustite and pyrargyrite

Comments: Differs from proustite and pyrargyrite only in internals; p. 258; 789.
Opaque Mineral Optics

Mineral Name: Zincite

Chem. Comp.: Zn.O

Crystal.: hexagonal

Color: brown

Tint: pink

Color (oil): Tint (oil):

Bireflectance: masked by the internal reflections

Anisotropy: " " "

%R: 10 v low

VHN: 150-318

Int'l Reflects.: abundant, yellowish or red

Polish. Hard.: <<frankinite

Comments: Occurs as rounded and xenomorphic grains; cleavage // (0001) may be distinct in not well polished sections; forms oriented intergrowths with hausmannite and manganosite; p. 162; 896.

Mineral Name: Zinkenite

Chem. Comp.: (PbS)(Sb2S3) or (6PbS)(7Sb2.S3)

Crystal.: hexagonal

Color: white gray

Tint:

Color (oil): Tint (oil):

Bireflectance: weak, but perceptible

Anisotropy: distinct, light gray to dark gray; straight extinction

%R: 38-43 mod

VHN: 123-207

Int'l Reflects.: rare, dark red

Polish. Hard.: 

Comments: Occurs as felted masses of tiny acicular or hair-like xls; as coatings; as vein- and fracture-fillings; or as radial fibrous aggregates; p. 278; 761.