
U3A Geology
Sulphide class

Introduction

- The sulphide class also includes the arsenides, tellurides, selenides, and the antimonides.
- arsenides are compounds of arsenic with more electropositive elements
- telluride minerals are Au-Ag-Te minerals that have the tellurium anion Te^{2-}
- selenides are chemical compounds containing a Se^{2-} ion
- antimonides are compounds of Sb with more electropositive elements. The antimonide ion is Sb^{3-}

Stibnite (Sb_2S_3)

- Stibnite (also called antimonite) is the most important source of the metalloid antimony
- it occurs in hydrothermal deposits commonly associated with realgar, orpiment, cinnabar, gold, galena and pyrite
- significant deposits of stibnite are located in Hunan Province (China), Shikoku (Japan), Idaho (USA) and Australia
- stibnite is used in the manufacture of matches, fireworks and percussion caps, antimony is used to harden lead e.g. bullets, type
- historically, the Romans used stibnite for making colourless glass and eye cosmetics

Stibnite – gold association

- Sb is a useful indicator element for the presence of gold
- stibnite occurs as a major sulphide in some gold deposits
- in Victoria, stibnite–gold deposits are common in the Melbourne zone of the Lachlan Fold Belt but not in the Bendigo-Ballarat zone
- Victorian stibnite-Au deposits include Costerfield, Nagambie, Clonbinane, Big River, Kevington and the Woods Point district
- Costerfield is a Sb-Au deposit containing the ore mineral aurostibite ($AuSb_2$) and abundant stibnite

Stibnite

Crystal system: orthorhombic

Colour: lead-grey

Habit: slender prismatic

Streak: grey to black

Lustre: metallic

Cleavage: 1 perfect

Hardness: 2

S.G.: 4.52 -4.62

Remarks: horizontal striations

stibnite

Molybdenite (MoS_2)

- Molybdenite is a greasy, platy mineral similar in appearance to graphite
- occurs in high temperature hydrothermal ore deposits associated with minerals that include pyrite, chalcopyrite, fluorite (CaF_2), scheelite ($CaWO_4$), wolframite ($FeWO_4$) and quartz
- molybdenite occurs in disseminated molybdenite deposits and porphyry Cu deposits e.g. in the Andes
- extremely soft with a metallic lustre
- most important ore mineral of molybdenum, commonly alloyed with iron to form a steel variant also used as a lubricant

Molybdenite

Crystal system: hexagonal

Colour: lead-grey

Habit: platy, greasy

Streak: greyish-black

Lustre: metallic

Cleavage: 1 perfect

Hardness: 1 – 1.5

S.G.: 4.7

molybdenite

Cinnabar (HgS)

- Cinnibar is the chief ore mineral of mercury
- commonly occurs as a vein-filling mineral with realgar (AsS), orpiment (As_2S_3), pyrite, marcasite and stibnite
- the major source of cinnabar is the Almaden mine in Spain
- this mine was exploited from Roman times until 1991 → cinnabar mined for its vermillion pigment and mercury content
- cinnabar is toxic requiring precautions for the toxic mercury component. Mining in the Almaden mine was regarded as being akin to a death sentence. Miners were slaves and convicts

Cinnabar

Crystal system: hexagonal

Colour: red

Habit: fine-grained granular, massive

Streak: scarlet

Lustre: admantine to dull

Cleavage: 3 perfect

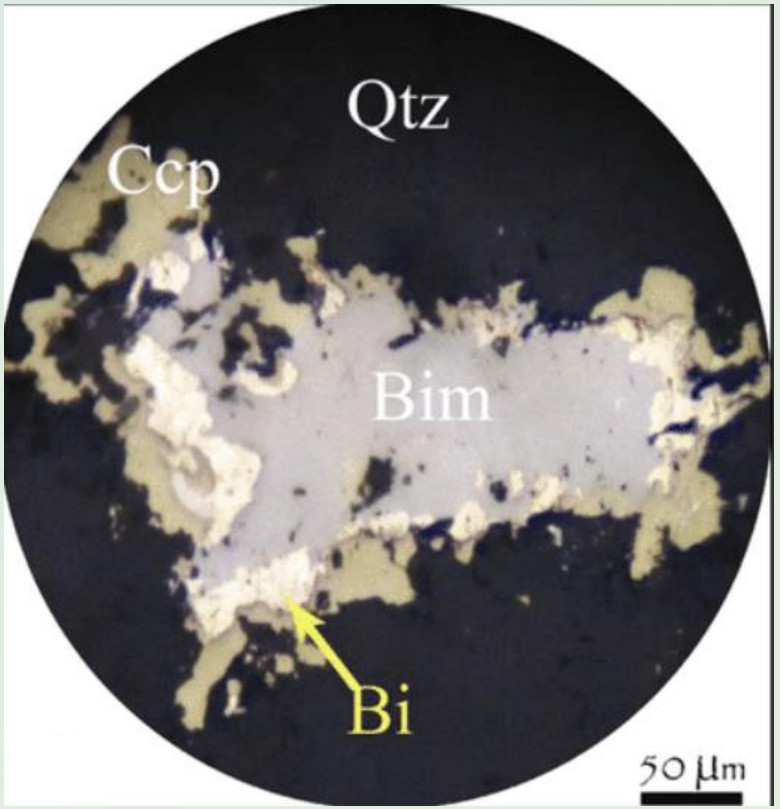
Hardness: 2.5

S.G.: 8.1

cinnabar

Bismuthinite (Bi_2S_3)

- Bismuthinite is an important ore of bismuth
- it occurs in hydrothermal veins with tourmaline-bearing Cu veins associated with granite, in some high temperature Au deposits and volcanic exhalation deposits
- associated minerals include native Bi, arsenopyrite, stannite, galena, pyrite, chalcopyrite, tourmaline, wolframite, cassiterite



Bismuthinite replacing bismuth (polished section)

Bismuthinite

Crystal system: orthorhombic

Colour: lead-grey to tin white

Habit: slender prismatic to acicular, massive

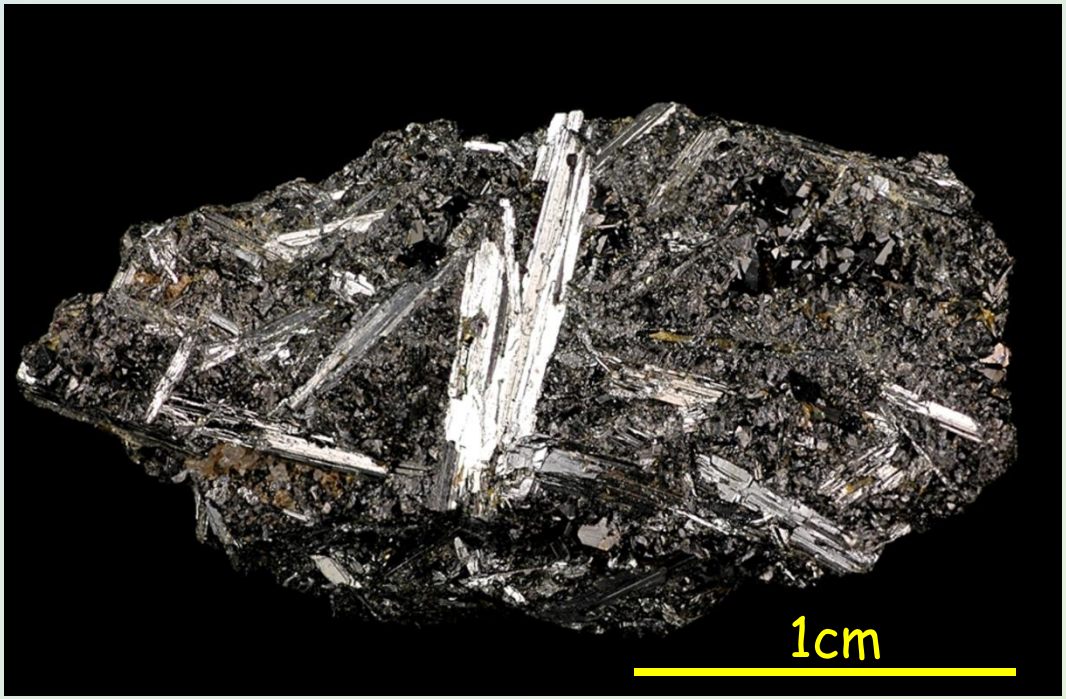
Streak: lead-grey

Lustre: admantine to dull

Cleavage: 3 perfect

Hardness: 2

S.G.: 6.78



bismuthinite

Stannite (Cu_2FeSnS_4)

- Stannite → Sn sulphide ore mineral comprising approximately 28% Sn, 30% Cu, 13% Fe and 30% S
- occurs in Sn-bearing hydrothermal vein deposits containing chalcopyrite, sphalerite, arsenopyrite, pyrite, cassiterite (SnO_2) and wolframite ($FeWO_4$)
- minor component of cassiterite sulphide ores in NW Tasmania e.g. Mt Bischoff, Cleveland and Renison Bell
- also found with other Sn minerals in veins in Cornwall, UK and Bolivia

Stannite

Crystal system: tetragonal

Colour: steel-grey to iron black

Habit: granular, massive

Streak: black

Lustre: metallic

Cleavage: indistinct

Hardness: 4

S.G.: 4.3-4.5

Stannite

Arsenides

- Arsenides are compounds of arsenic with more electropositive elements
- many arsenides are binary compounds with other metals
- the most important minerals of arsenic are arsenopyrite (FeAsS) and the sulphides orpiment (As_2S_3) and realgar (AsS)
- primary arsenides occur in lodes or veins more or less directly connected with igneous intrusions
- realgar and orpiment are characteristic of oxidized portion of such deposits

Realgar (AsS)

- Realgar → arsenic sulphide with a characteristic red-orange colour
- most commonly occurs as a low temperature vein mineral associated with other As and Sb minerals
- also occurs in volcanic sublimations and hot springs
- realgar disintegrates on long exposure to light to form orpiment
- used by ancient Greeks to make medicine called "bull's blood' and as red paint pigment by the Romans
- small amounts of realgar are used in the making of realgar wine in China → traditionally consumed at the Dragon Boat Festival

Realgar

Crystal system: monoclinic

Colour: red to orange

Habit: short prismatic crystals, granular, earthy

Streak: red to orange

Lustre: resinous

Cleavage: 1 good

Hardness: 1.5 - 2

S.G.: 3.5

realgar

Orpiment (As_2S_3)

- Orpiment is a deep-coloured orange-yellow arsenide found in volcanic fumaroles, low temperature hydrothermal veins and hot springs
- yellow orpiment is sensitive to light and degrades into arsenic oxides that are soluble and migrate into surrounding environment
- orpiment was once used as a pigment in artworks, medicines and other applications
- early physicians in China used small doses of arsenic as a drug to treat a variety of diseases even though it is toxic
- modern usage → hair removal in India also in tanning

Orpiment

Crystal system: monoclinic

Colour: lemon-yellow to brown-yellow

Habit: usually in foliated or columnar masses

Streak: yellow

Lustre: pearly, admantine

Cleavage: 1 good

Hardness: 1.5 - 2

S.G.: 3.5

orpiment

Arsenpyrite (FeAsS)

- Arsenopyrite → Fe-As sulphide commonly associated with gold mineralisation and a useful indicator of gold-bearing reefs
- it is the most abundant arsenic-bearing mineral
- crystal habit, hardness, density and garlic odour when struck with metal are diagnostic
- arsenopyrite is found in high temperature hydrothermal veins, in pegmatites and associated with contact metamorphism and metasomatism. Rare in igneous rocks
- arsenopyrite often oxidises to form scoradite $FeAsO_4.2H_2O$

Arsenopyrite

Crystal system: monoclinic

Colour: silver or tin-white

Habit: usually massive

Streak: black

Lustre: metallic

Cleavage: poor

Hardness: 5.5 – 6

S.G.: 6 – 6.2

arsenopyrite

Cobaltite (Co,Fe)AsS)

- Cobaltite → arsenide mineral composed of Co, As and S with Fe commonly present
- occurs in high-temperature hydrothermal deposits and contact metamorphic rocks
- associated with magnetite, sphalerite, chalcopyrite, titanite and calcite
- it is found chiefly in Sweden, Norway, Germany, Cornwall, Canada, Chile, Australia, Democratic Republic of Congo and Morocco
- Australian deposits occur in e.g. Broken Hill, NSW; Cloncurry, Qld; Murrin Murrin, WA

Cobaltite

Crystal system: orthorhombic

Colour: silver-white inclined to red

Habit: cubes or pyritohedra with striated faces

Streak: greyish-black

Lustre: metallic

Cleavage: pseudocubic perfect

Hardness: 5.5

S.G.: 6.33

cobalt pyritohedron

Nickeline (NiAs)

- Nickeline → mineral consisting primarily of Ni arsenide
- contains approximately 43.9% Ni and 56.1% As
- small amounts of S, Fe are usually present and sometimes As is largely replaced by Sb
- formed by hydrothermal alteration of ultramafic rocks and associated ore deposits
- associated minerals include pentlandite, pyrrhotite and arsenopyrite
- eastern flank of the Widgiemooltha Dome in WA contains nickeline from altered pentlandite-pyrite-pyrrhotite assemblages

Nickeline

Crystal system: hexagonal

Colour: pale copper-red

Habit: massive, reniform, columnar

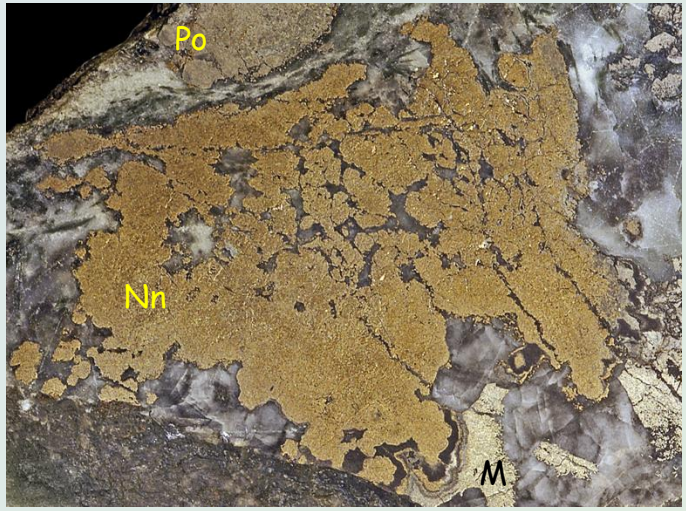
Streak: brownish-black

Lustre: metallic

Cleavage: imperfect

Hardness: 5 - 5.5

S.G.: 7.78



nickeline

Skutterudite $(Co,Ni)As_3$

- Skutterudite → relatively rare arsenide that is an ore mineral for both Co and Ni
- rarely the main ore mineral, usually an accessory
- occurs in medium and high temperature hydrothermal veins with other Ni and Co minerals
- similar to galena but does not have characteristic galena cleavage
- occurs with common sulphides arsenopyrite, pyrite, pyrrhotite, chalcopyrite and molybdenite
- the cobaltian species usually alters to erythrite $[Co_3(AsO_4).8H_2O]$

Skutterudite

Crystal system: cubic

Colour: tin-white to silver-grey

Habit: usually massive

Streak: black

Lustre: metallic

Cleavage: indistinct

Hardness: 5.5 - 6

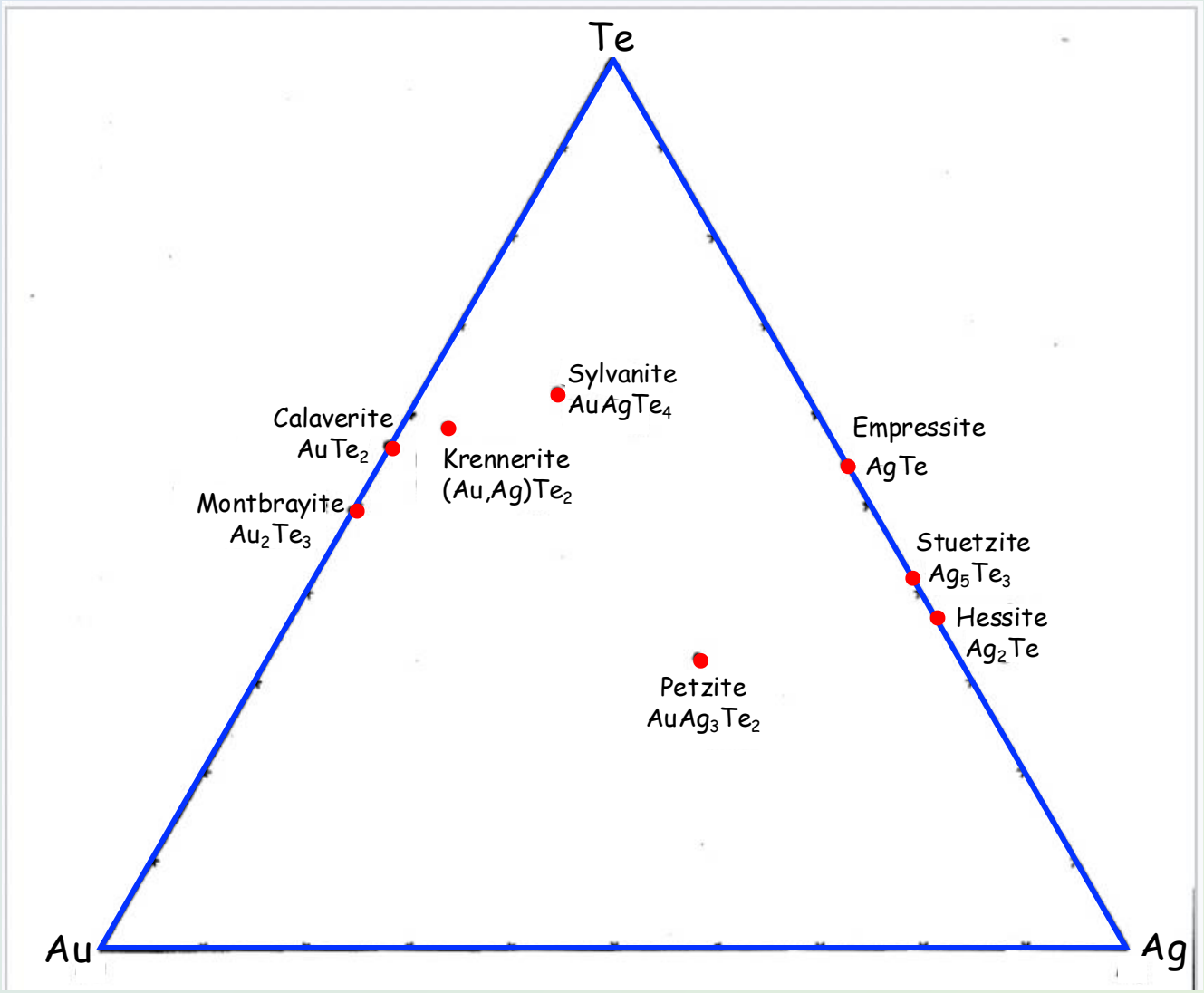
S.G.: 6.5

skutterudite

Tellurides

- Tellurides → Au-Ag-Te minerals that contain the tellurium anion Te^{2-} as a main component
- they are similar to sulphides and are grouped with them in both the Dana and Strunz classification systems
- some 70-75% of Au in the Golden Mile deposits around Kalgoorlie, WA occurs as native gold, 20% occurs as tellurides
- a small number of Au deposits (mostly but not exclusively epithermal) contain exploitable Au-Ag-Te
- tellurides are also known from many Archaean and Proterozoic orogenic deposits

Au-Te-Ag Ternary diagram



Calaverite ($AuTe_2$)

- Calaverite is an uncommon telluride of Au with approximately 3% of Au replaced by Ag
- calaverite can be dissolved in hot sulphuric acid, leaving a spongy mass of Au in a red solution of tellurium
- calaverite most commonly found in low temperature veins
- occurrences include Cripple Creek, Colorado; Rouyn district, Quebec; Emperor Mine Fiji and Golden Mile Kalgoorlie, WA.
- in the Kalgoorlie gold rush 1893, large amounts of calaverite were mistaken for fool's gold and used for building materials and for infilling potholes and ruts when later identified led to second gold rush (1896) and excavation of streets

Calaverite

Crystal system: monoclinic

Colour: light yellow to pinkish white

Habit: bladed or lath-like, massive

Streak: green to yellow-grey

Lustre: metallic

Cleavage: none

Hardness: 2.5 - 3

S.G.: 9.1 – 9.3

platy calaverite crystals

Krennerite (Au_3AgTe_8)

- Krennerite is one of the rarest tellurides, crystallising in the orthorhombic crystal system
- it can contain variable amounts of Ag in the structure with Au being substituted by up to 24% Ag
- occurs in epithermal veins with other tellurides (petzite, sylvanite, hessite)
- decomposes under surface conditions releasing films of native gold
- occurs in Au mines in Colorado (Cripple Creek), Roumania (Sacarimb) and Fiji (Emperor mine)

Krennerite

Crystal system: orthorhombic

Colour: silver-white

Habit: vertically striated crystals

Streak: greenish-grey

Lustre: highly metallic

Cleavage: 1 perfect

Hardness: 2

S.G.: 8.62

Sylvanite ($AuAgTe_4$)

- Sylvanite → most common telluride mineral
- structurally similar to calaverite but contains Ag in its structure in addition to Au
- if less than 13.4% Ag is replaced by Au → no longer classified as sylvanite but rather as calaverite
- found in Transylvania ((Romania), East Kalgoorlie (WA), Cripple Creek (Colorado), Rouyen district (Quebec), Emperor mine (Fiji)
- associated with native Au, fluorite, rhodochrosite, pyrite, acanthite
- most commonly found in low-temperature, hydrothermal vein deposits

Sylvanite

Crystal system: orthorhombic

Colour: silver-grey, silver-white

Habit: tabular, skeletal or bladed crystals

Streak: steel grey

Lustre: metallic

Cleavage: 1 perfect

Hardness: 1.5 - 2

S.G.: 8.2

sylvanite

Selenides

- Selenides → chemical compounds containing the Se anion with oxidation -2, similar to sulphides
- the parent inorganic selenide is H_2Se
- many Se minerals are known, Se partially substitutes for the S ion in many sulphide minerals
- the degree of substitution is only of commercial interest for Cu sulphide minerals
- selenide minerals include ferroselite ($FeSe_2$) and umangite (Cu_3Se_2)

Ferroselite ($FeSe_2$)

- Ferroselite → Fe selenide precipitated under reducing conditions in anoxic environments
- found in Rocky Mountains, Colorado, USA in association with shale deposits
- its association with low temperature assemblages indicate that its minimum temperature of formation is quite low

Ferroselite

Crystal system: orthorhombic

Colour: steel grey, silver-white

Habit: acicular prismatic

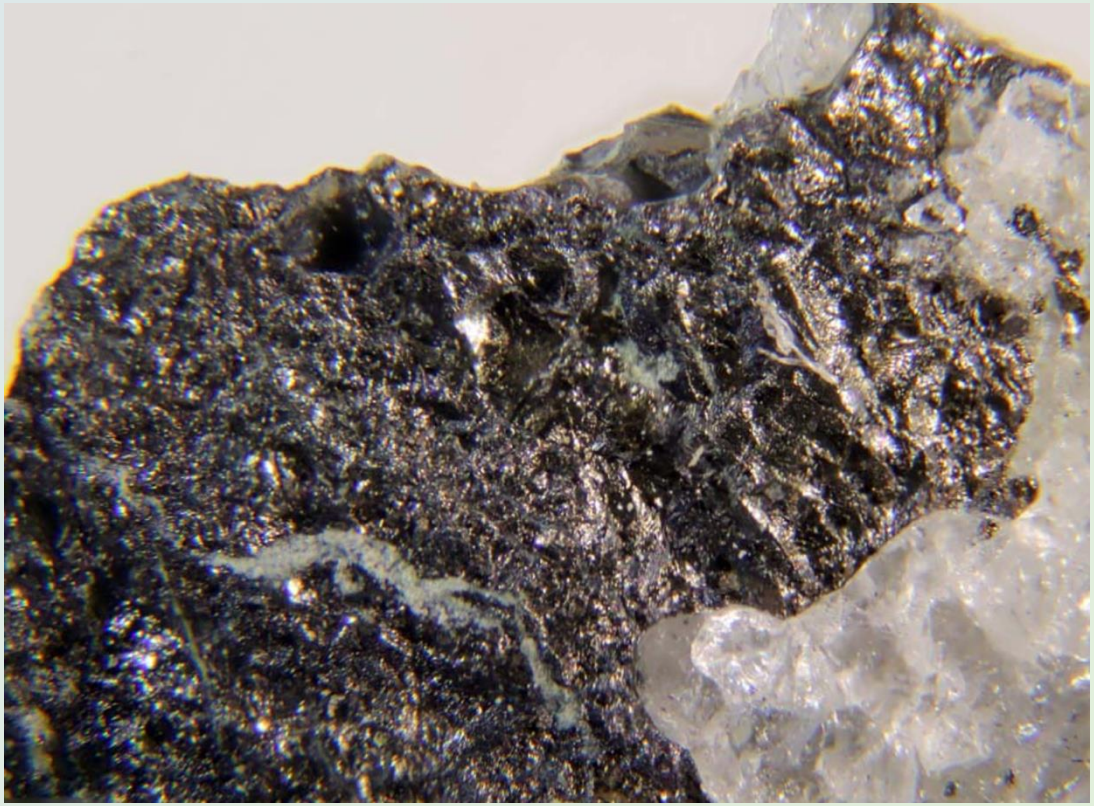
Streak: black

Lustre: metallic

Cleavage: none

Hardness: 6 – 6.5

S.G.: 7.2



ferroselite

Umangite (Cu_3Se_2)

- Blue to red-coloured Cu selenide that occurs with Cu sulphides and other selenides in hydrothermal veins
- occurs in small grains or fine granular aggregates
- mineral deposits are found in Argentina, Germany and Sweden
- alters to malachite when weathered

Umangite

Crystal system: tetragonal

Colour: red, bluish red-black

Habit: massive, granular

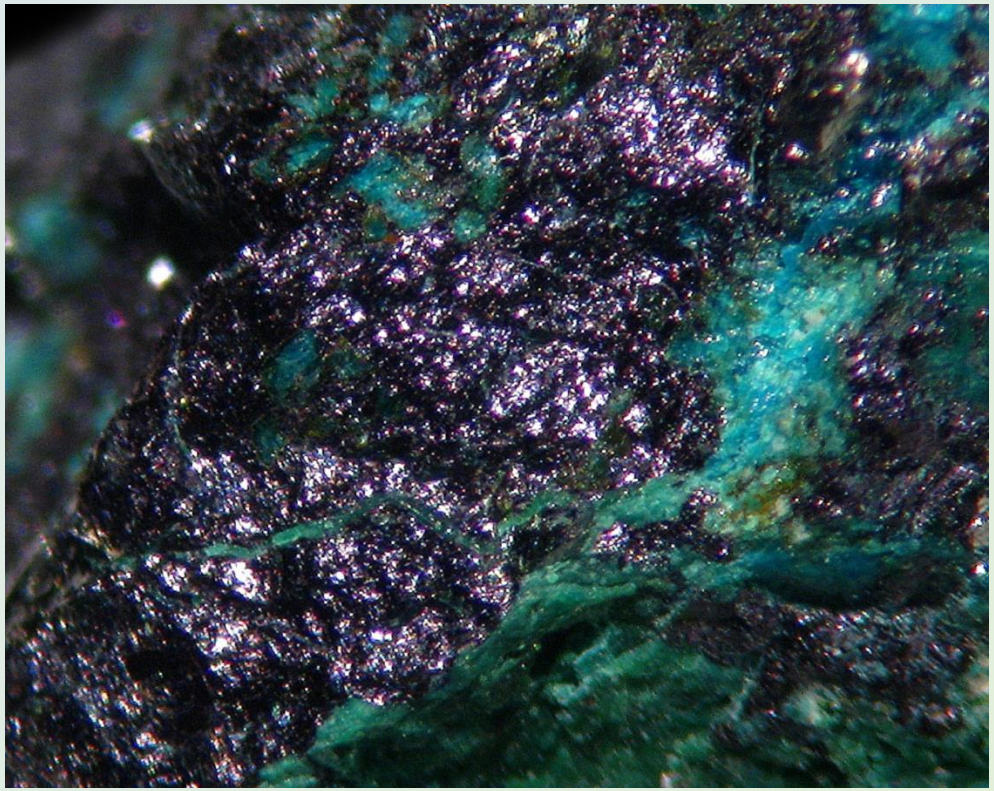
Streak: black

Lustre: metallic

Cleavage: 2 distinct at 90°

Hardness: 3

S.G.: 5.62 – 6.78



umangite

Sulpho-antimonides

- Sulpho-antimonides → compound of antimony with more electropositive elements and S
- the antimonide ion is Sb^{3-}
- the most common of these minerals are tetrahedrite, bournonite and Jamesonite that are normally present as trace accessory minerals in some hydrothermal vein deposits

Tetrahedrite [$(Cu,Fe)_{12}Sb_4S_{13}$]

- Tetrahedrite → Cu-Sb sulpho-antimonide
- other elements substitute in the structure, mainly Zn with less commonly Ag, Hg and Pb
- the name is derived from distinctive tetrahedron shaped crystals
- Bi also substitutes for Sb
- occurs in low to moderate temperature veins and contact metamorphic deposits

Tetrahedrite

Crystal system: cubic

Colour: flint-grey to iron-black

Habit: massive, granular, tetrahedral crystals

Streak: grey to black

Lustre: metallic

Cleavage: none

Hardness: 3.5 – 4.5

S.G.: 4.4 – 5.1

Tetrahedrite with chalcopyrite and sphalerite, Casapalca Mine, Peru

Bournonite ($PbCuSbS_3$)

- Bournonite → trithioantimonite of Pb and Cu
- crystals of bournonite → generally tabular
- forms in medium temperature hydrothermal deposits
- commonly occurs with galena, tetrahedrite, sphalerite, chalcopyrite, stibnite, quartz and Jamesonite ($Pb_4FeSb_6S_{14}$)
- accessory mineral in some Au deposits

Bournonite

Crystal system: orthorhombic

Colour: steel-grey to iron-black

Habit: prismatic to tabular

Streak: steel-grey to iron-black

Lustre: brilliant to dull

Cleavage: one imperfect

Hardness: 2.5 - 3

S.G.: 5.7 – 5.9

Bournonite,

St Laurent-Le Minier, France