Oxides

Cassiterite SnO_2

Cassiterite may contain minor amounts of Fe, Nb, Ta, Ti, W or Si.

Crystals

Tetragonal, with axial ratios a:c = 1:0.672. Crystals are commonly short prisms [001], with {110} and {100} prominent shapes. Faces in [10-1] and [001] are often striated. Twinning on {011} is very common, giving both contact and penetration twins. There is a poor {100} cleavage. D = 6.98-7.02, H = 6.5.

Polished section

Cassiterite is grey, somethimes appearing slightly brownish. With R_o = 11% and R_e = 12%, bireflectance is weak, but usually visible in granular aggregates and twinned grains. Cassiterite is darker than sphalerite and only slightly brighter than gangue minerals. Anisotropy is distinct in gray colours, but internal reflections, which are common and colourless to brown, often masks the anisotropy.

Cassiterite occurs as isolated prismatic to rounded crystals, geniculate (knee-like) twins or granular aggregates. Colloform aggregates containing colloidal haematite are known as "wood tin". Twinning is common, and cleavage traces are often present. Zonation of the Fe-content may be seen in crossed polars, because Fe absorbs the light in the internal reflections. VHN = 1240-1470.

Occurrence

Cassiterite is mainly found with wolframite, topaz, tourmaline, arsenopyrite, molybdenite, pyrrhotite and Bi-minerals in high-temperature hydrothermal veins, pegmatites, greisens, stockworks and dissemination associated with acid igneous rocks. It is found as a detritial heavy mineral in sediments (such as placer deposits of Malaysia) and in gossans over staniferous sulphide deposits. Wood tin is found in the secondary oxidation zone.

Distinguishing features

Compared with cassiterite: sphalerite is brighter, isotropic and softer; wolframite is slightly brighter and has fewer internal reflections; rutile is brighter.

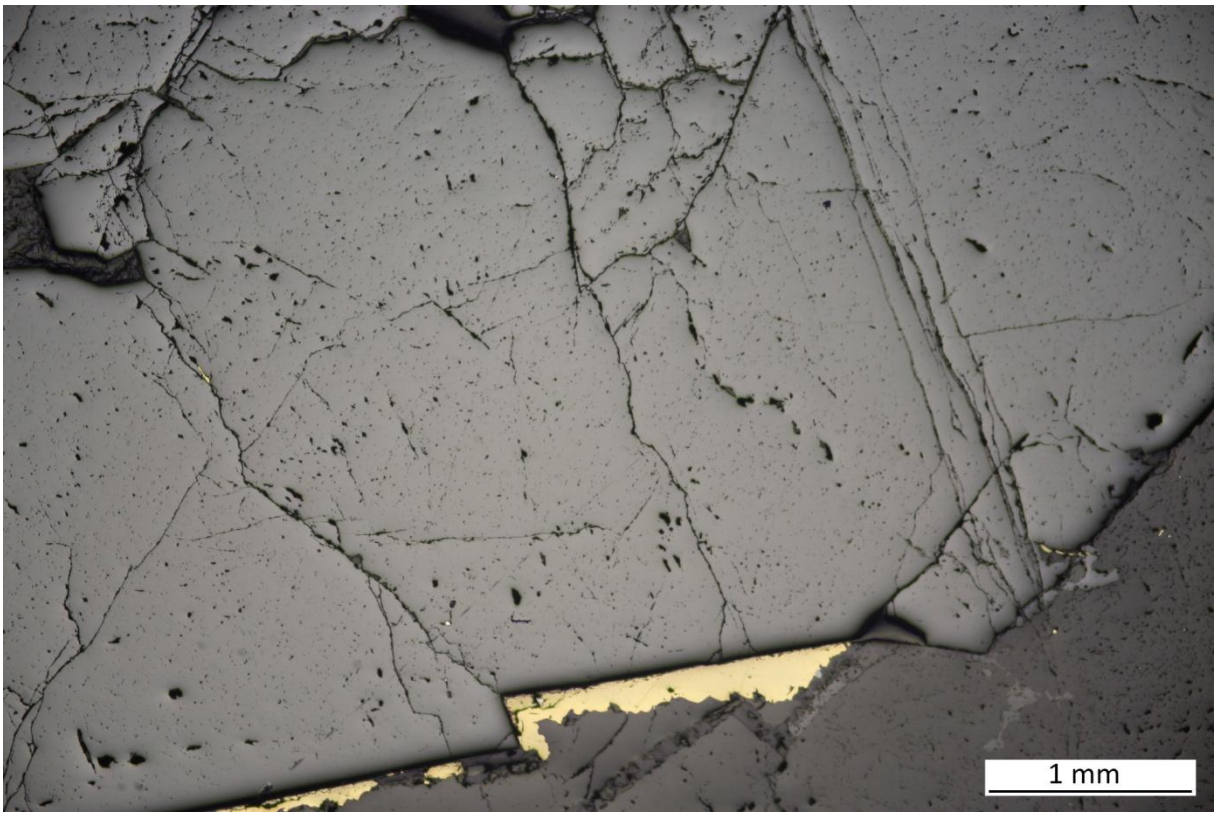

Fig. 1. Cassiterite (grey) with chalcopyrite (yellow), sample 68, PPL

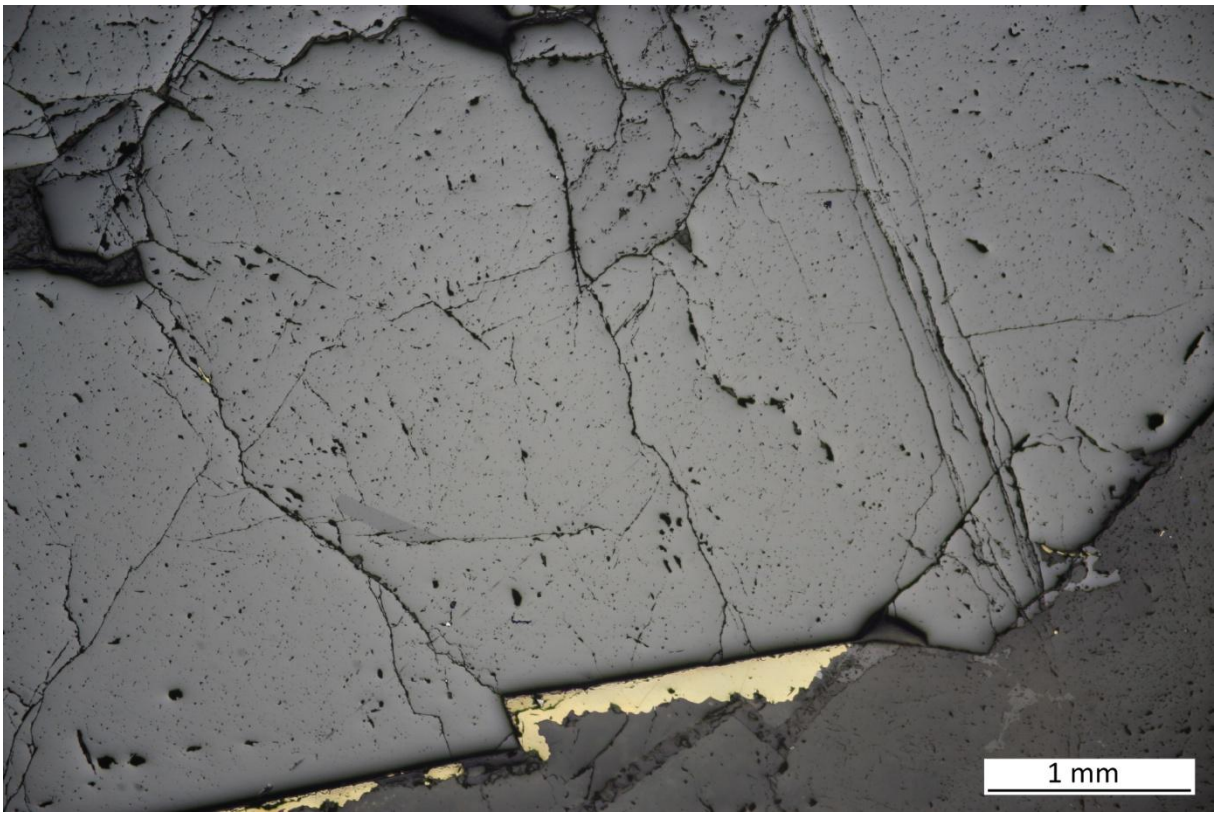

Fig. 2. Cassiterite (grey) with moderate anisotropy, surrounded by chalcopyrite (yellow), sample 68, XPL

Chromite $FeCr_2O_4$

Usually contains Mg and Al, chromite may contain minor amounts of Zn, V and Mn.

Crystals

Chromite is cubic, and is a member of the spinel group. Crystals are rare, but occur as octahedral modified by {001} faces. There is no cleavage. D = 5.1, H = 6.5.

Polished section

Chromite is opaque, except in very thin grain margins which are brownish in colour. Colour is grey, somethimes appearing slightly brownish. R = 13%, but varies with chemical composition. This reflectance value is significantly less than that of magnetite. Higher Fe and Cr contents increase R, but Al and Mg decrease R. Chromite as cubic mineral is usually isotropic. Fe-poor chromite may have scarce reddish-brown internal reflections.

Chromite is an accessory mineral in most peridotites and derived serpentinites. It occurs as rounded octahedral grains resembling droplets, interstitially in silicates, or as granular aggregates. Cataclastic texture is common. A zonation in reflectance, related to chemical zonation, can be observed. Marginal discoloration and alteration of grains may occur. Inclusions of Fe + Ti + O phases, e.g. rutile, may be present. VHN = 1270-1460.

Occurrence

Chromite is only abundant in certain mafic igneous rocks, especially large layered intrusions (e.g. the Bushveldt lopolith) as cumulates or possibly oxide-liquid segregations. It is found as podiform concentrations, possibly originally cumulates, in Alpine-type serpentinites, and also as a detritial heavy mineral in sedimentary and metamorphosed rocks. Chromite can occur as cores within magnetite grains. Fe-rich rims of chromites, commonly observed in serpentinites, are known as ferrit-chromite. The rims have a slightly higher reflectance than the chromite cores and are magnetic.

Distinguishing features

Compared with chromite: magnetite is brighter. These two minerals are similar unless direct comparison of brightness can be made, but magnetite is magnetic!

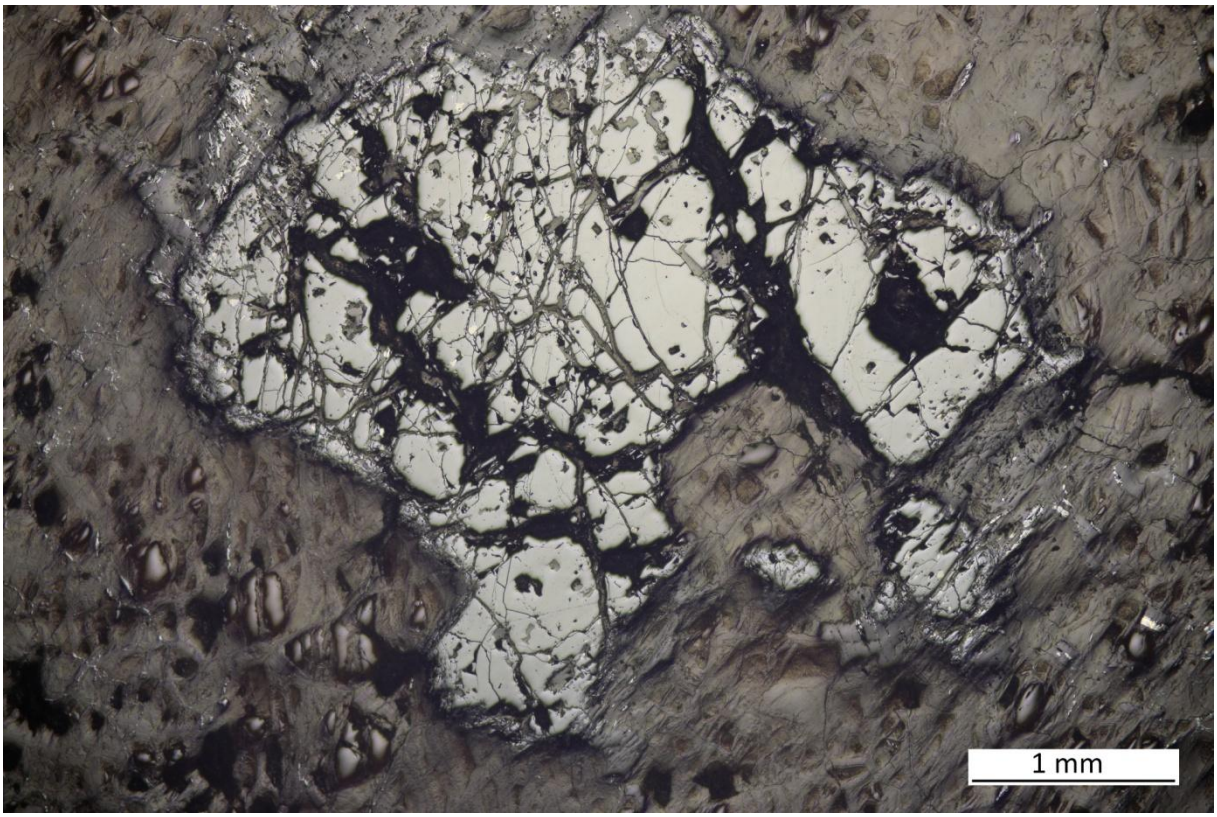

Fig. 3. Chromite grains (grey), sample 19, PPL

Haematite Fe_2O_3

Haematite is often titaniferous, there is a haematite-ilmenite solid solution.

Crystals

Haematite is trigonal, a:c = 1:1.3652, it usually occurs as tabular crystals {0001}, often in subparallel growths. Penetration twinning occurs on {0001} and lamellar twinning on {10-11}. There is no cleavage. D = 5.2, H = 6.5.

Thin section

Haematite is opaque, but deep red in very thin plates. It is uniaxial negative, with absorption *o>e.*

Polished section

Haematite is light grey and only weakly bireflecting, with R_o = 30% and R_e = 26%. It is much brighter than magnetite and ilmenite. Anisotropy is strong in bluish and brownish greys. The deep-red internal reflections are scarce except in very thin plates. Haematite coatings give a red coloration to internal reflections of transparent grains such as quartz.

Haematite occurs as idiomorphic tabular crystals and fibrous radiating aggregates. It is also found as microcrystalline colloform masses. Haematite is often intergrown with other Fe + Ti + O minerals and it occurs as lamellae in ilmenite. Haematite may contain lamellae of ilmenite or rutile. Lamellar twinning is common, and pseudo-cleavage consisting of elongate pits can be present. VHN= 1000-1100.

Occurrence

Haematite is found with other Fe-Ti-O minerals in igneous and metamorphic rocks as well as sedimentary rocks, especially banded iron formations. Haematite in veins may be primary, but it frequently forms by oxidation of other primary iron-bearing minerals.

Distinguishing features

Compared with haematite: stibnite has a distinct bireflectance, is softer and has a good cleavage; ilmenite is pinkish and darker; and cinnabar has abundant internal reflections and is softer.

Note

“Martite” is magnetite pseudomorphosed by an intergrowth of haematite.

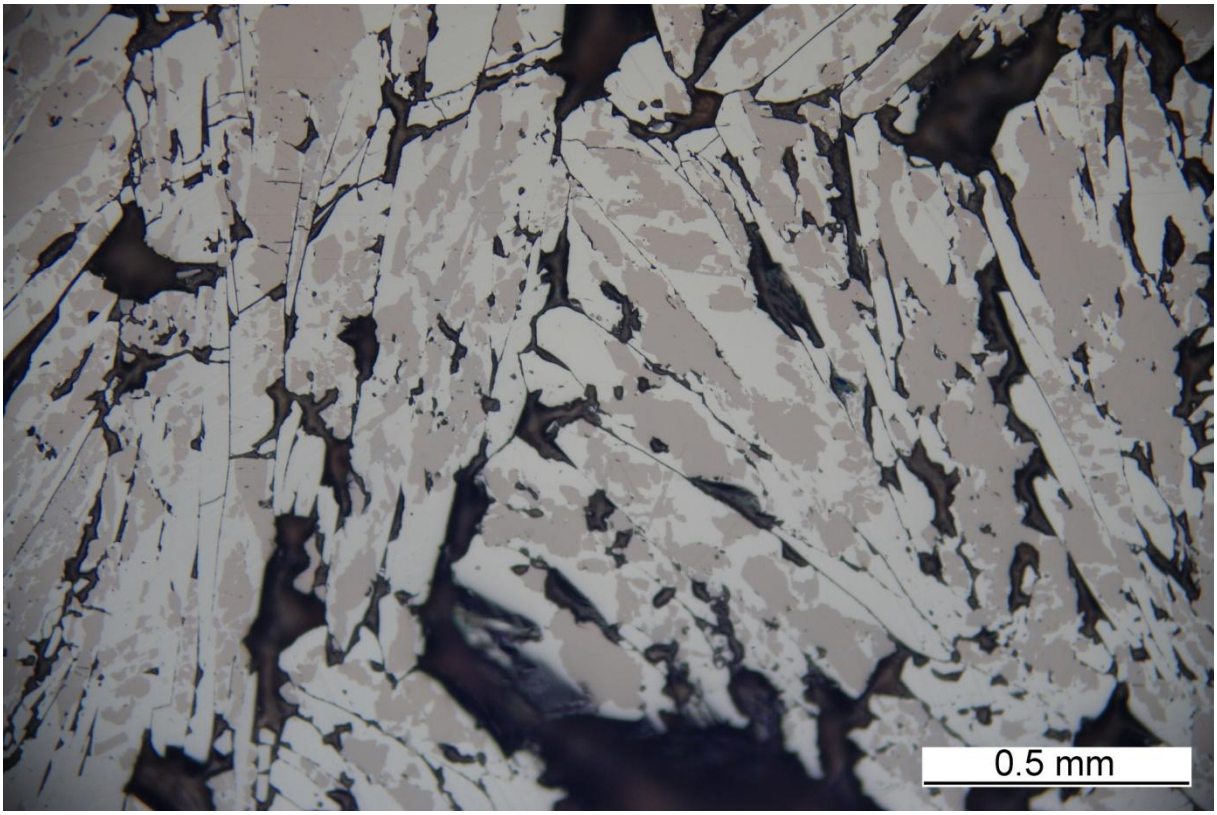

Fig. 4. Haematite tables (grey), partly pseudomorphosed by magnetite (darker grey), sample 17, PPL

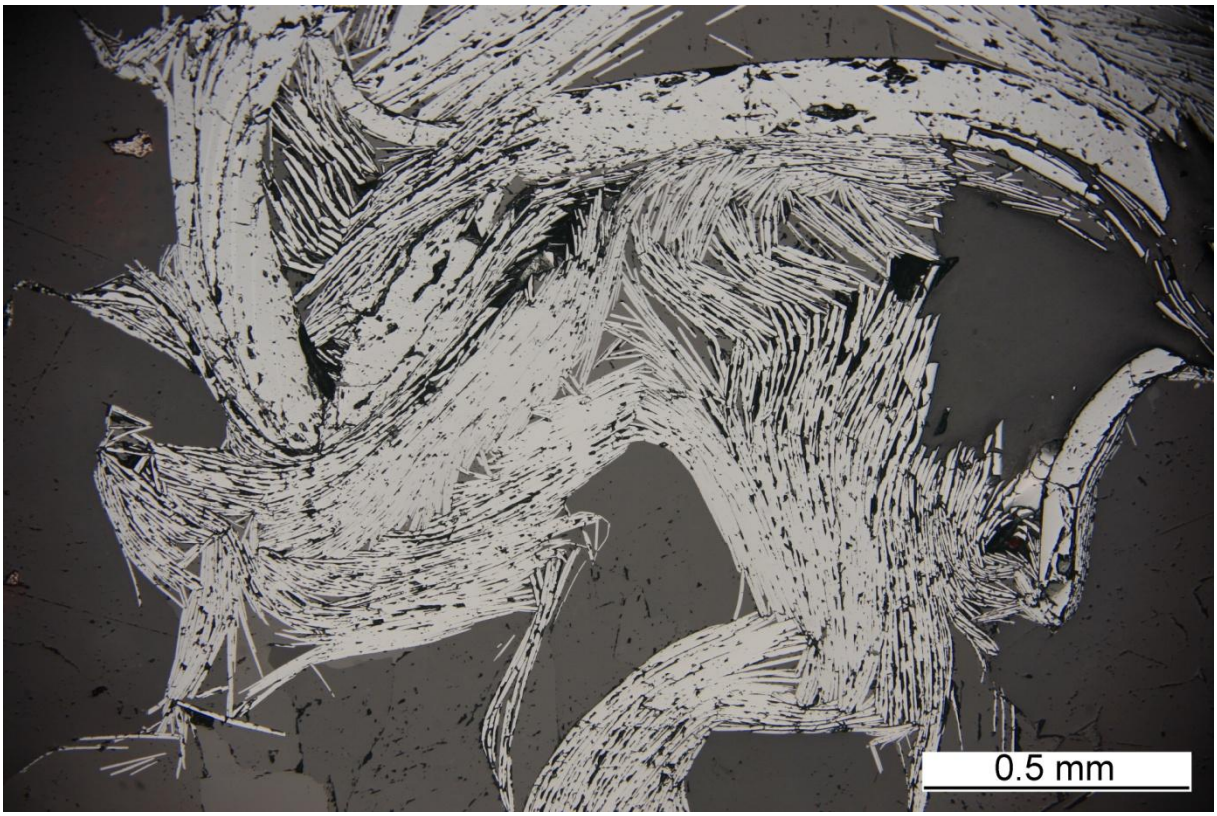

Fig. 5. Haematite (grey), sample 65, PPL

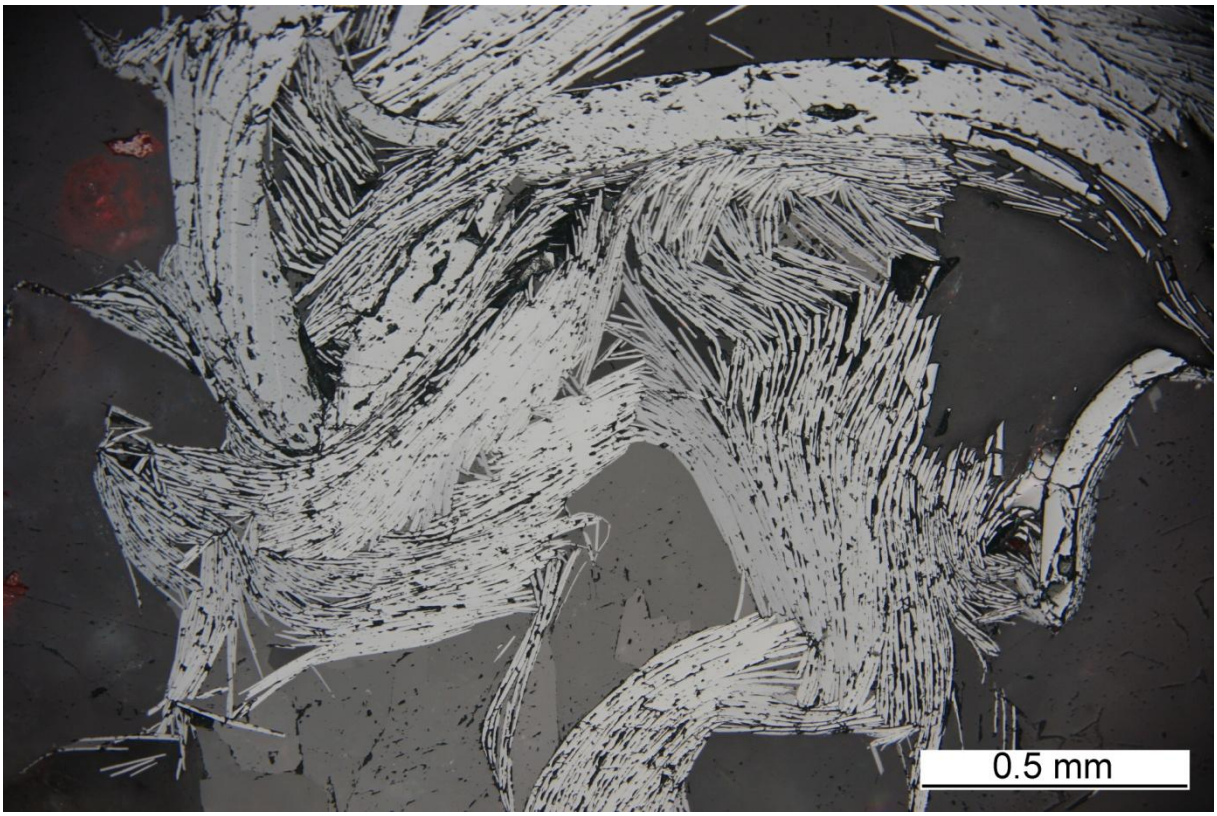

Fig. 6. Haematite (grey), with strong anisotropy, sample 65, XPL

Ilmenite $FeTiO_3$

Ilmenite can contain Mn or Mg, the magnesian end member is geikielite and the manganiferous end member is pyrophanite. It may also contain Fe^{3+}, which represents a solid solution towards haematite Fe_2O_3.

Crystals

Ilmenite is trigonal, isostructural with haematite, with a:c = 1:1.3846, and usually occurs as tabular {0001} crystals. Twinning occurs on {0001}, and multiple twinning on {10-11}. There is no cleavage, but there is a parting parallel to {10-11}. D = 4.7, H = 5.5.

Polished section

Ilmenite is slightly pinkish or brownish light grey, with a weak pleochroism. R_o = 20%, which is similar to magnetite, and R_e = 17%. Anisotropy is moderate, but is only distinct in some orientations; tints are greenish, bluish and brownish greys.

Ilmenite is sometimes idiomorphic, but is usually intergrown with other Fe + Ti + O minerals. It often contains lamellar inclusions of haematite or other Fe + Ti + O minerals. Occasionally, lamellar twins may be present, VHN = 560-700 varying with chemical composition.

Occurrence

Ilmenite is found with other Fe + Ti + O minerals in igneous rocks, especially of mafic composition, and in metamorphic rocks, rarely in hydrothermal veins and pegmatites. Detrital ilmenite is usually altered to leucoxene, which is enriched in TiO_2. It occurs in heavy-mineral concentrations. Mg-rich ilmenites occur in kimberlites, but also in contact metamorphosed rocks and dolomitic marbles.

Distinguishing features

Compared with ilmenite: magnetite is slightly brighter and usually bluish-grey in direct comparison, isotropic and strongly magnetic. Rutile shows anisotropy and abundant internal reflections.

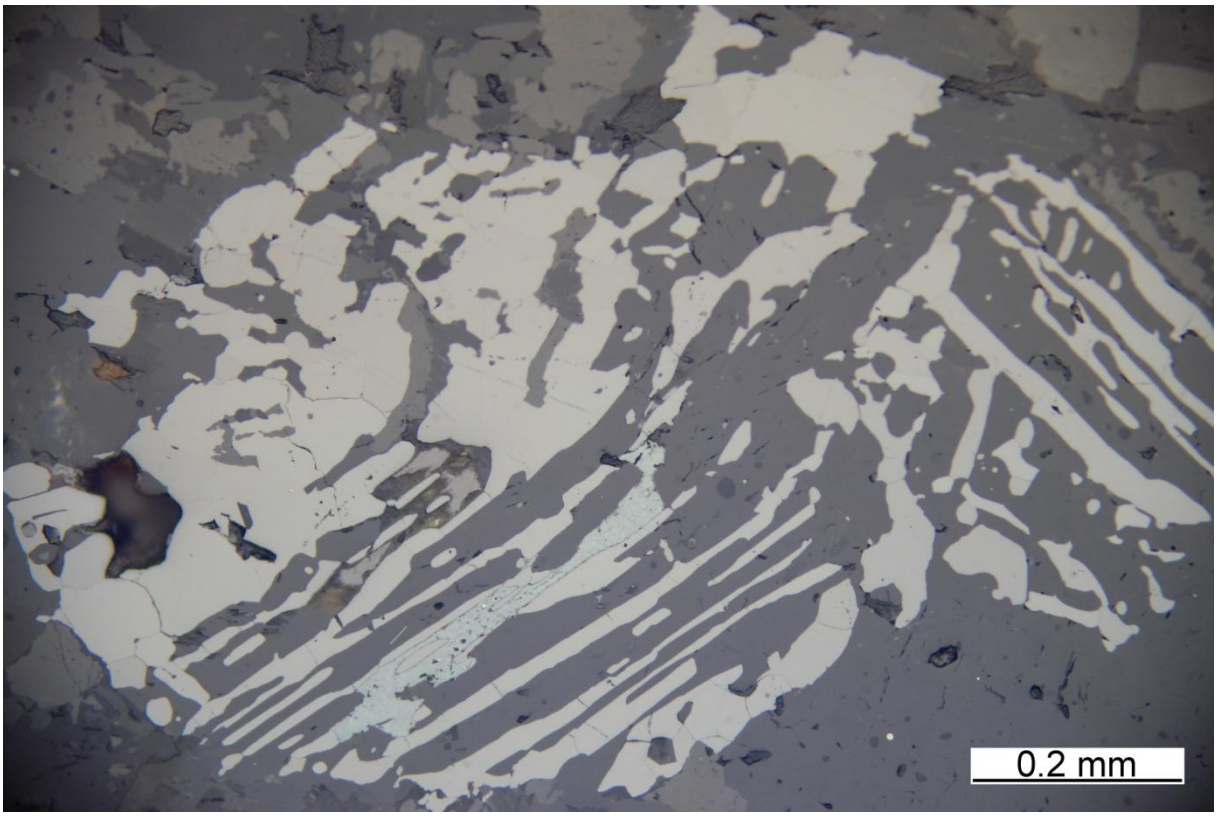

Fig. 7. Skeletal ilmenite (grey) in gabro, sample 1, PPL

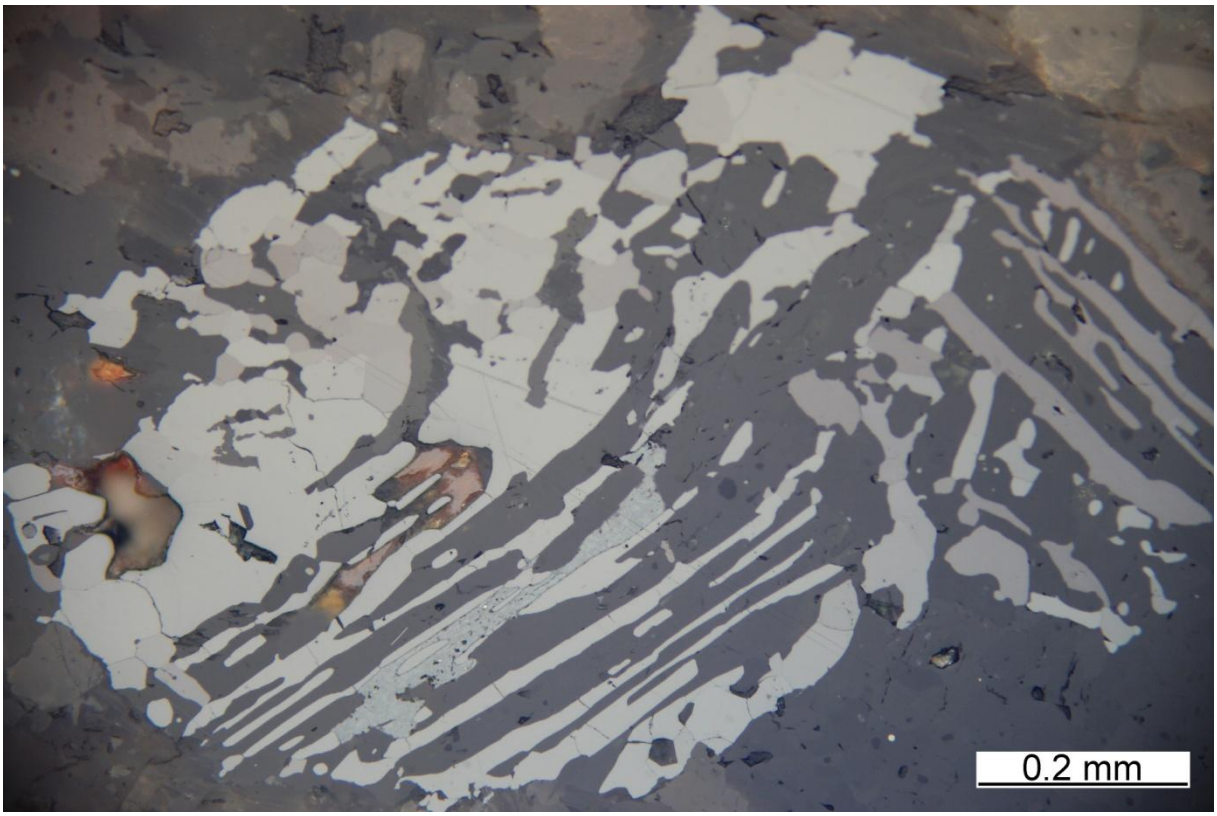

Fig. 8. Skeletal ilmenite (grey) with distinct anisotropy, gabro, sample 1, XPL

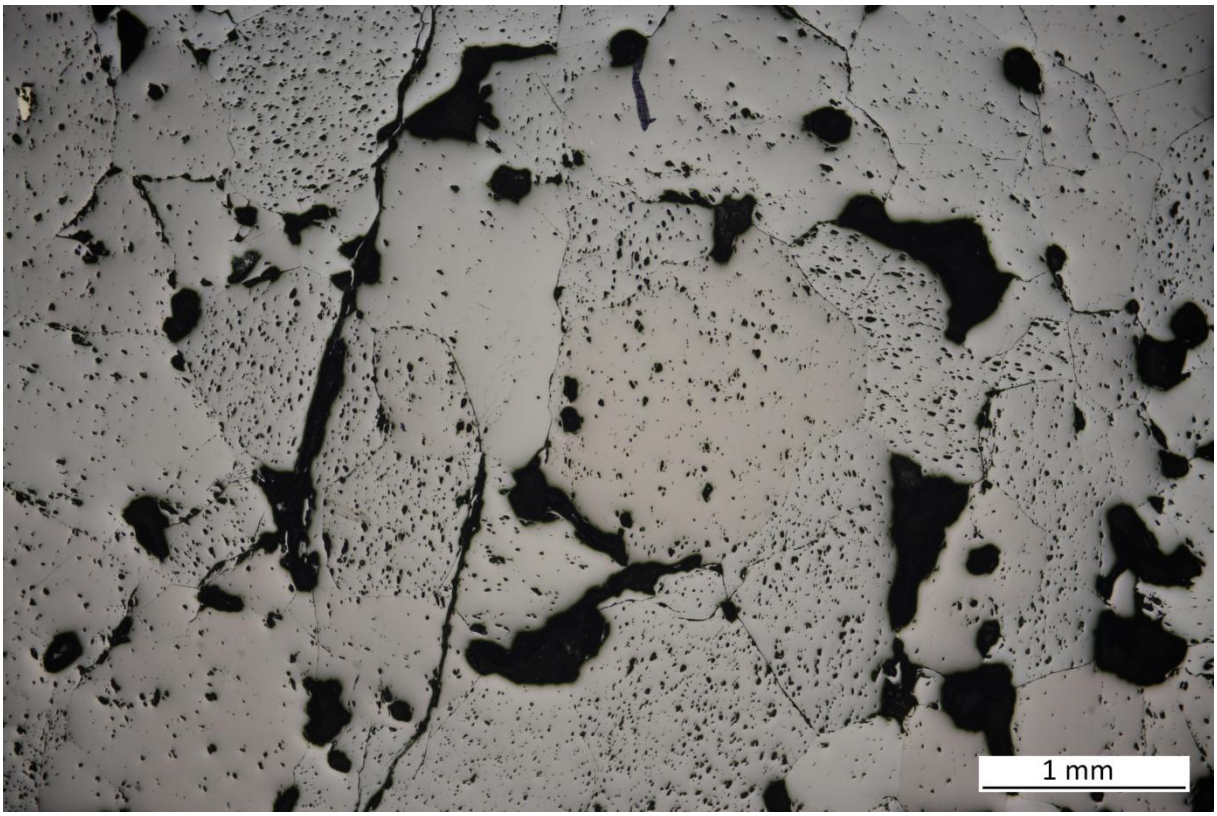

Fig. 9. Ilmenite aggregate (grey) with a weak pleochroism, sample 52, PPL

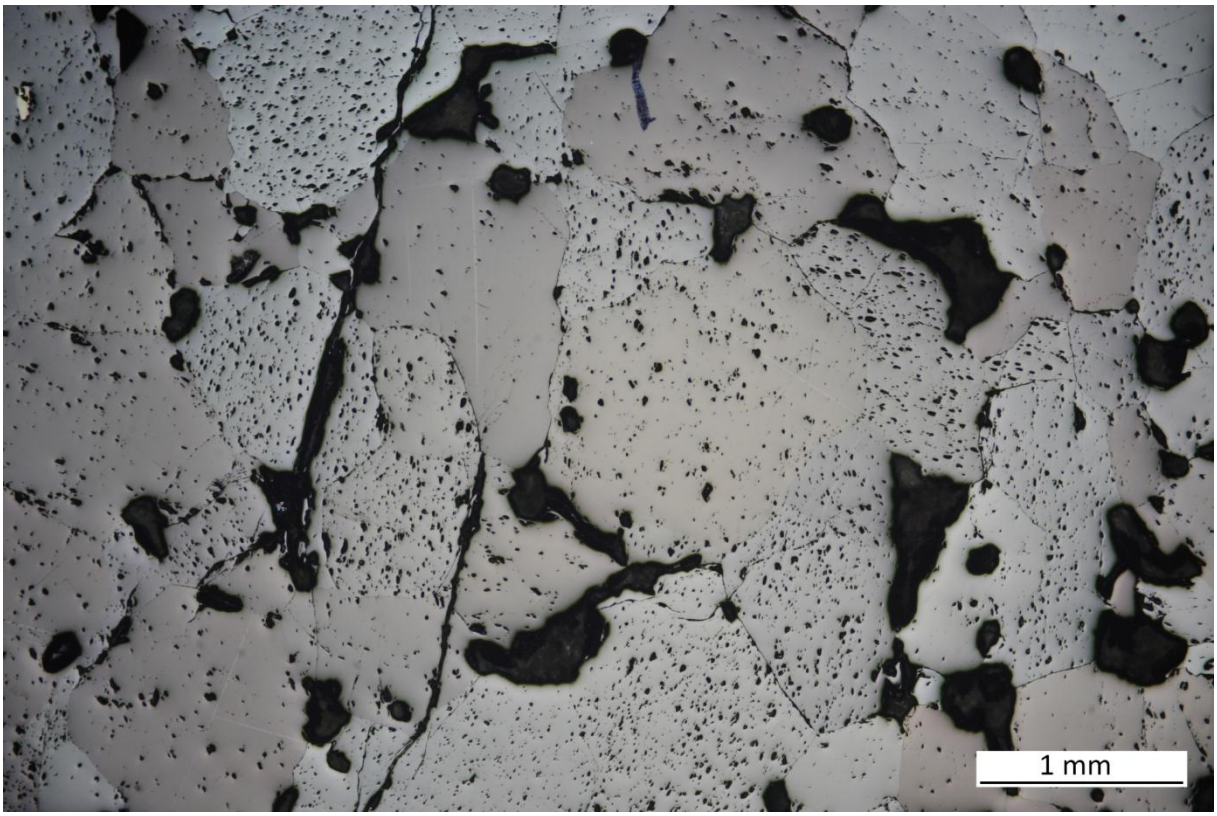

Fig. 10. Ilmenite aggregate (grey) with distinct anisotropy, sample 52, XPL

Magnetite Fe_3O_4

Magnetite often contain Ti, Cr or Mn. Titaniferous magnetite often contains ulvöspinel Fe_2TiO_4 in solid solution.

Crystals

Magnetite is an inverse spinelide. It is cubic commonly occurring as octahedral and combinations of the octahedron and rhombic dodecahedron. Twinning is common on {111} – the usual spinel twin. D = 5.2, H = 5.5.

Polished section

Magnetite is grey, somethimes with a brownish or pinkish tint indicative of titanium (ulvospinel is brownish grey). Reflectance R = 21%, making magnetite much darker than pyrite and haematite. Magnetite is isotropic, with good extinction.

It is often found as idiomorphic octahedral sections, but also as skeletal grains or granular aggregates. Lamellae of haematite are often in a triangular pattern. Lamellae and blebs of ilmenite in a fine “frosty” texture of ulvospinel in magnetite represent slowly cooled titaniferous magnetite. Also, exsolved lamellae and blebs of dark grey spinels may be present. VHN = 500-790.

Occurrence

Magnetite is usually found with other Fe + Ti + O minerals in igneous and metamorphic rocks and skarns. It also occurs as a heavy mineral in sediments and sedimentary rocks, and in high-temperature hydrothermal veins with sulphides. It represents reducing conditions relative to haematite.

Distinguishing features

Compared with magnetite: ilmenite is similar but often pinker and anisotropic; sphalerite is softer, usually has internal reflections and occurs in a different associations; chromite is very similar in isolation but is darker and can show internal reflections. A magnetitized needle may be used to confirm the magnetism of magnetite grains in polished section.

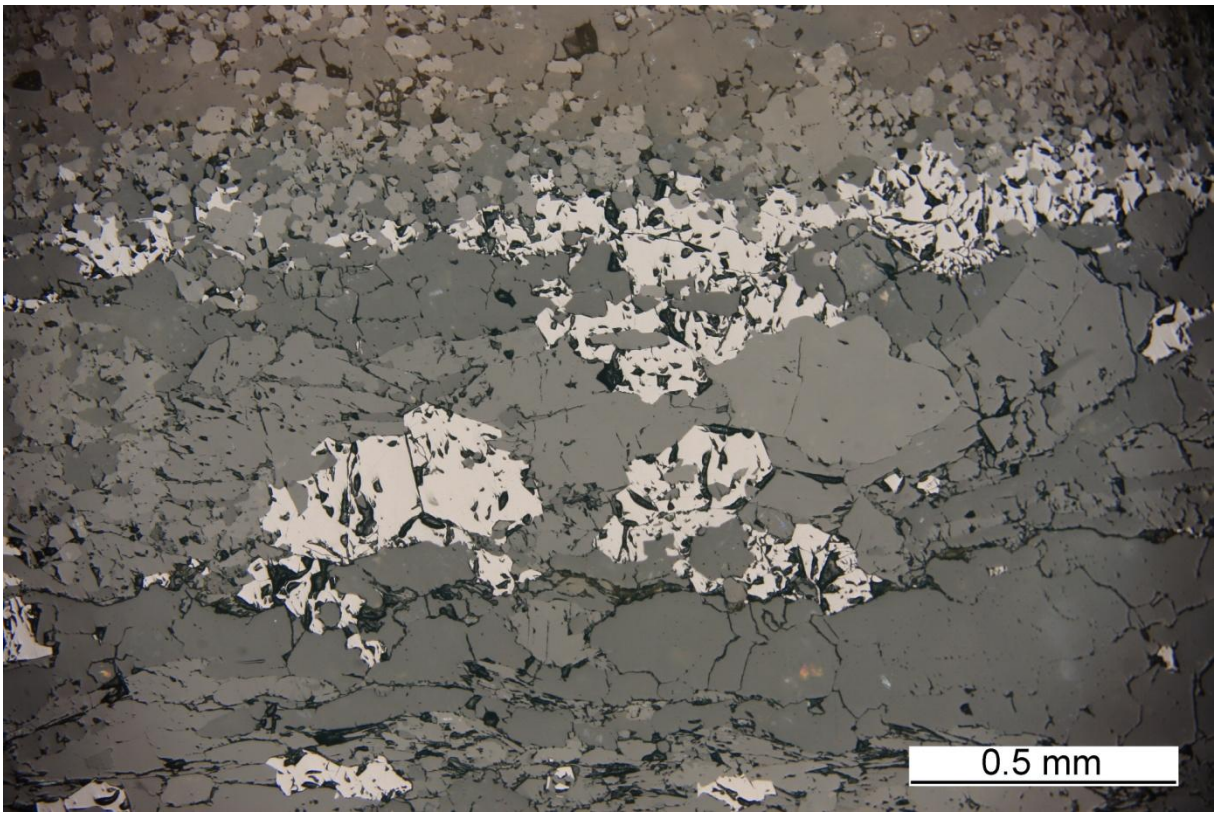

Fig. 11. Magnetite (grey) aggregates in banded iron ore, sample 92, PPL

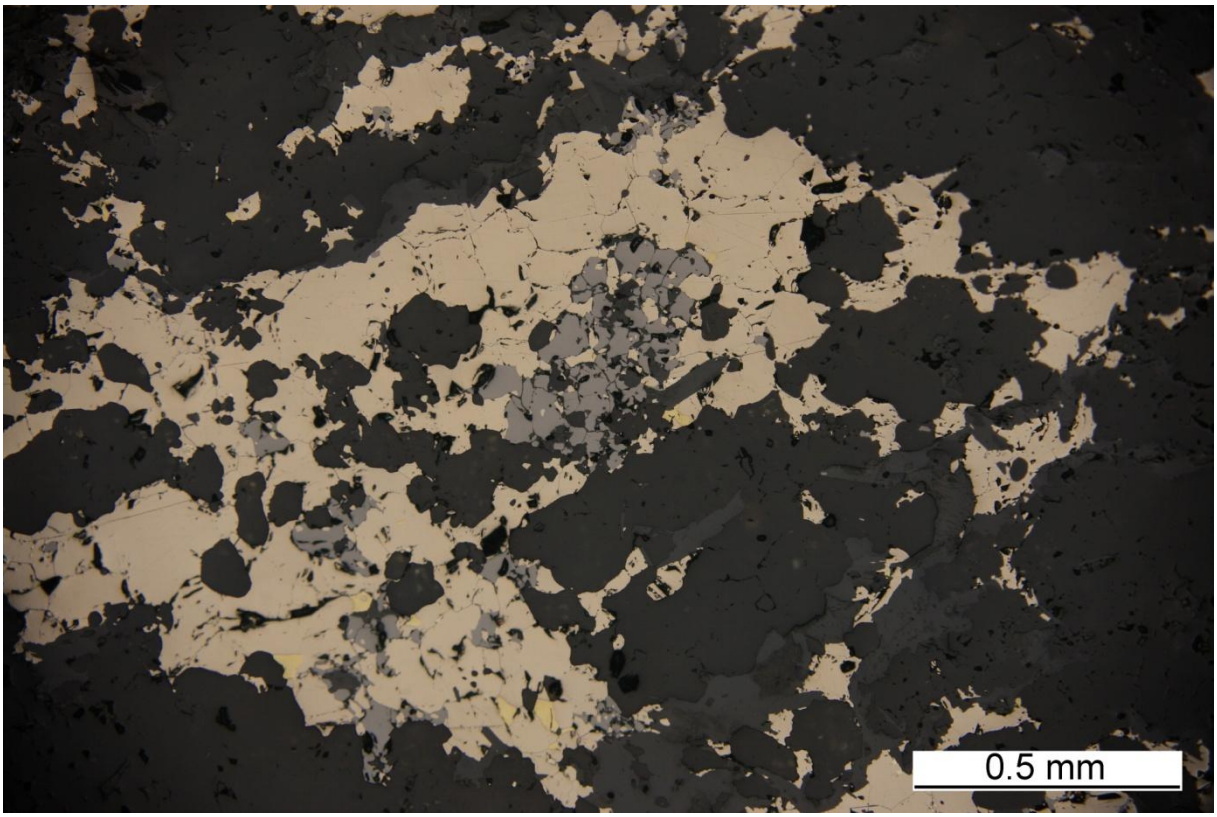

Fig. 12. Aggregates of magnetite (grey) in pyrrhotite (pinkish) with accessory chalcopyrite (yellow), sample Leiterberg, PPL

Rutile TiO_2

Rutile may contain minor amounts of Fe or Nb. The polymorphs anatase and brookite are almost identical to rutile in polished section.

Crystals

Rutile is tetragonal, with axial ratios a:c = 1:0.6442. Crystals are commonly prismatic [001], often slender to acicular. Twinning on {011} is common and is often repeated or geniculated. There is a distinct cleavage on {110} as well as a cleavage on {100}. D = 4.23-5.5, H = 6-6.5.

Polished section

Rutile is light grey with a slight bluish tint. R_o = 20% and R_e = 23%, bireflectance is weak, but usually visible. Rutile has about the same brightness as magnetite. It is strongly anisotropic in greys, but the anisotropy is often masked by abundant bright colourless yellow to brown internal reflections. In Fe-rich varieties, internal reflections are less abundant and reddish.

Rutile occurs as isolated prismatic to acicular crystals or as aggregates of crystals and in spongy porphyroblasts. It usually occurs as small grains. Simple and multiple twins are common. VHN = 890-970.

Occurrence

Rutile is associated with other Fe + Ti + O phases in pegmatites, igneous and metamorphic rocks. It is a heavy mineral in sediments. It is often produced from ilmenite on wall-rock alteration by hydrothermal solutions. Rutile occurs within quartz crystals as long thread-like crystals. The low-temperature TiO_2 polymorphs anatase and brookite have a similar occurrence to low-temperature varieties (forms) of rutile.

Distinguishing features

Compared with rutile: cassiterite tends to be more equant and is darker; haematite is whiter and brighter and rarely shows internal reflections; ilmenite is slightly pinkish and does not show internal reflections.

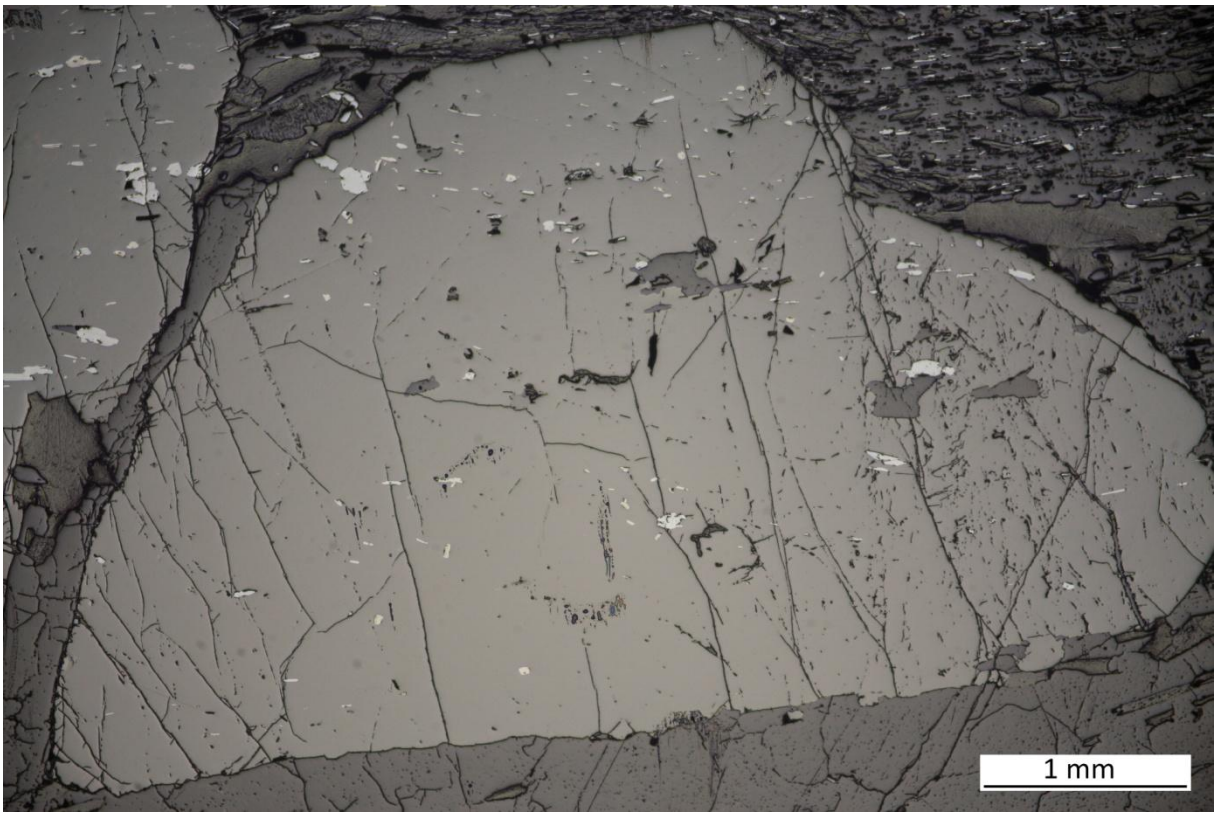

Fig. 13. Rutile crystals (grey) with a distinct cleavage, sample 7, PPL

Uraninite UO_2

The U is often replaced by Th, Pb or Ce. Natural uraninite is commonly oxidized to some extent to pitchblende UO_{2-3}. Thucolite is fragmental uraninite in polymerized carbonaceous material.

Crystals

Uraninite is cubic and rarely can occur as octahedral, cubes or dodecahedra. Twinning on {111} is rare. There is no cleavage. D = 9, H = 6.5.

Polished section

Uraninite is is grey, with R = 17%, similar to sphalerite. It is cubic and isotropic. Pitchblende is similar but slightly darker, with R = 16%. Scarce brown internal reflections may be observed in these minerals.

Uranium oxides commonly occur as spherical or botryoidal masses. Uraninite is well crystallized, but pitchblende varies in crystallinity and non-stoichiometry and tends to polish poorly. Composition zoning results in slight brightness and hardness changes. Shrinkage cracks occur in pitchblende. VHN = 780-840 (uraninite), 500-550 (pitchblende).

Occurrence

Uranium oxides are found in high-temperature pegmatitic to low-temperature hydrothermal vein and replacement deposits. There is an association with Ni + Co + Ag + Bi mineralization, with acid igneous rocks and with organic material in sedimentary rocks. Detrital uraninite is found in placer deposits with gold.

Distinguishing features

Compared with uraninite: magnetite is similar, but is magnetic. The uranium oxides are radioactive.

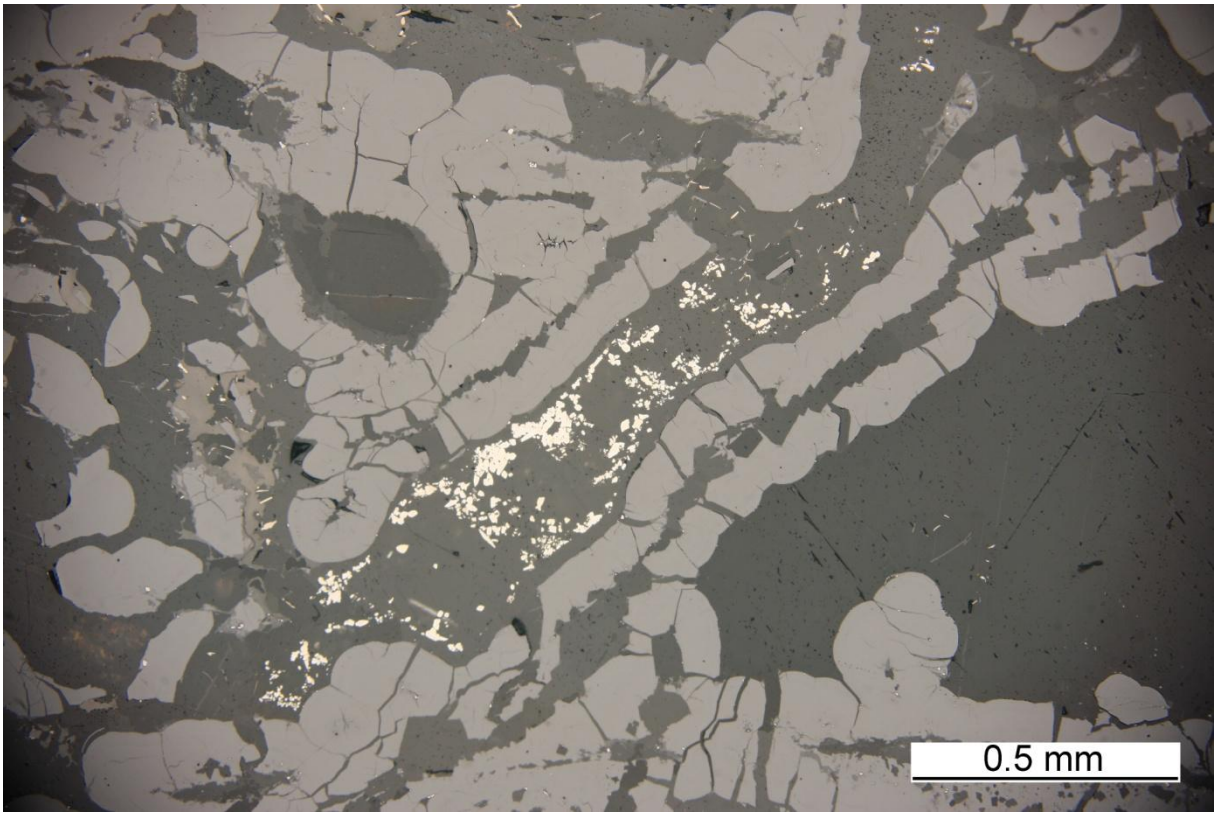

Fig. 14. Spherical aggregates of uraninite (grey), sample 128, PPL

Tungstates

Wolframite $(Fe,Mn)WO_4$

The iron end member is called ferberite and the manganese end member huebnerite.

Crystals

Wolframite is monoclinic, a:b:c = 0.839 : 1 : 0.876, β = 90°40′. It is usually prismatic [001]. Simple twinning is common and takes place on {100} and {023}. There is a perfect {010} cleavage and a parting on {100} and {101}.

Thin section

$n_\alpha = 2.150–2.269$

$n_\beta = 2.195–2.328$

$n_\gamma = 2.283–2.444$

$\delta = 0.133–0.175$

$2V_\gamma = 60°–70°$ + ve

OAP is perpendicular to (010)

D = 7.18–7.62 H = 5–5.5

Colour

Transparency decreases with an increase in the Fe content. Colour banding is due to a variation in the Fe : Mn ratio. Iron -rich wolframite is brownish red to dark green.

Pleochroism

Common, with α red, brown or yellow, β pale green to yellowish brown, and γ red, green or dark brown.

Habit

Elongate prismatic, often occurring as thin flat crystals.

Cleavage {010} perfect.

Relief Extremely high

Birefringence Extremely high, but colours are hidden by the mineral colour.

Polished section

Wolframite is slightly brownish grey. With R ≈ 16% it is slightly brighter than cassiterite. Bireflectance is weak. Anisotropy is moderate and distinct in bluish greys. Extinction is oblique. Reddish-brown internal reflections are common. Wolframite occurs as idiomorphic

tabular or bladed crystals with simple twinning. Zoning is enhanced by weathering. Cleavage traces may be observed. VHN = 320–390.

Occurrence

Wolframite is found in high-temperature hydrothermal veins and pegmatites, usually associated with quartz and Sn, Au and Bi minerals. It is associated with granitic rocks and greisenization. It is also found in placers with cassiterite. Scheelite $CaWO_4$ is a common associate and may replace wolframite. Scheelite is strongly fluorescent.

Distinguishing features

Compared with wolframite, cassiterite is darker and has more abundant internal reflections, while sphalerite is isotropic and is often associated with chalcopyrite.

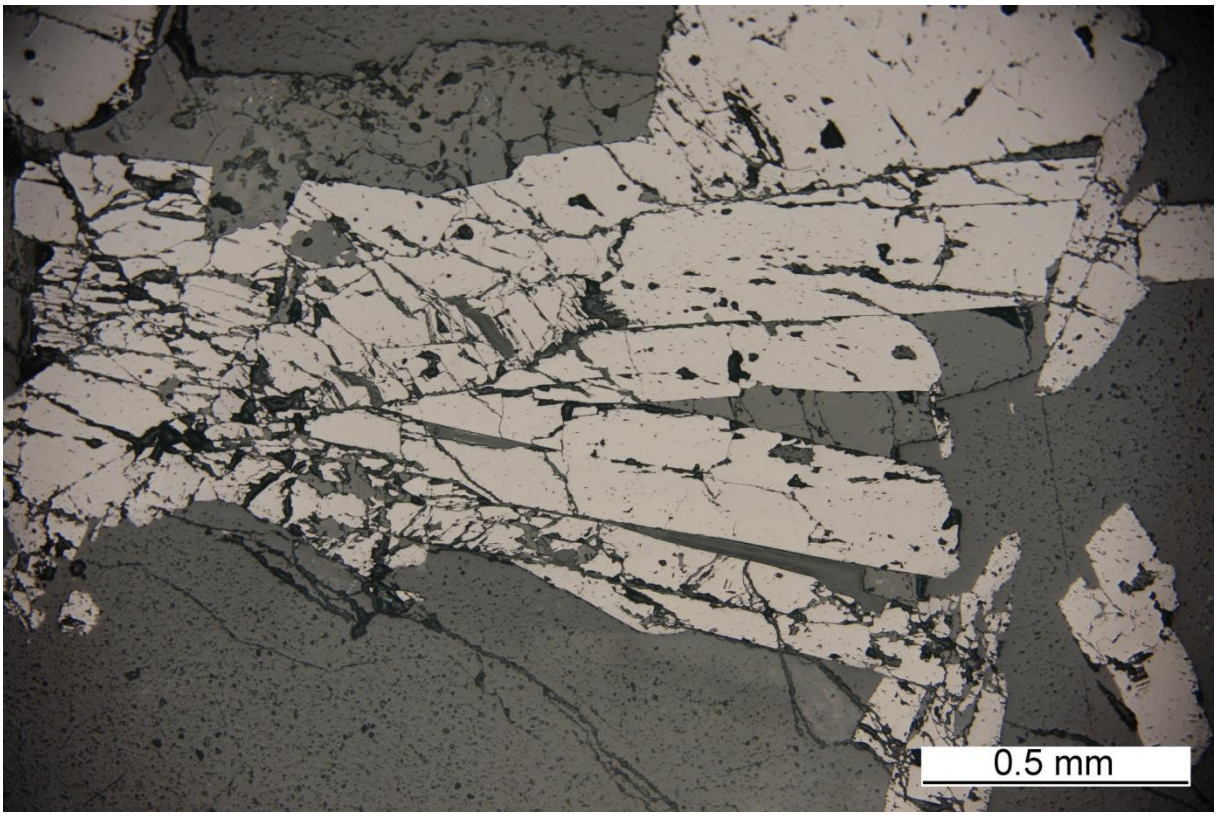

Fig. 15. Wolframite, sample 127, PPL

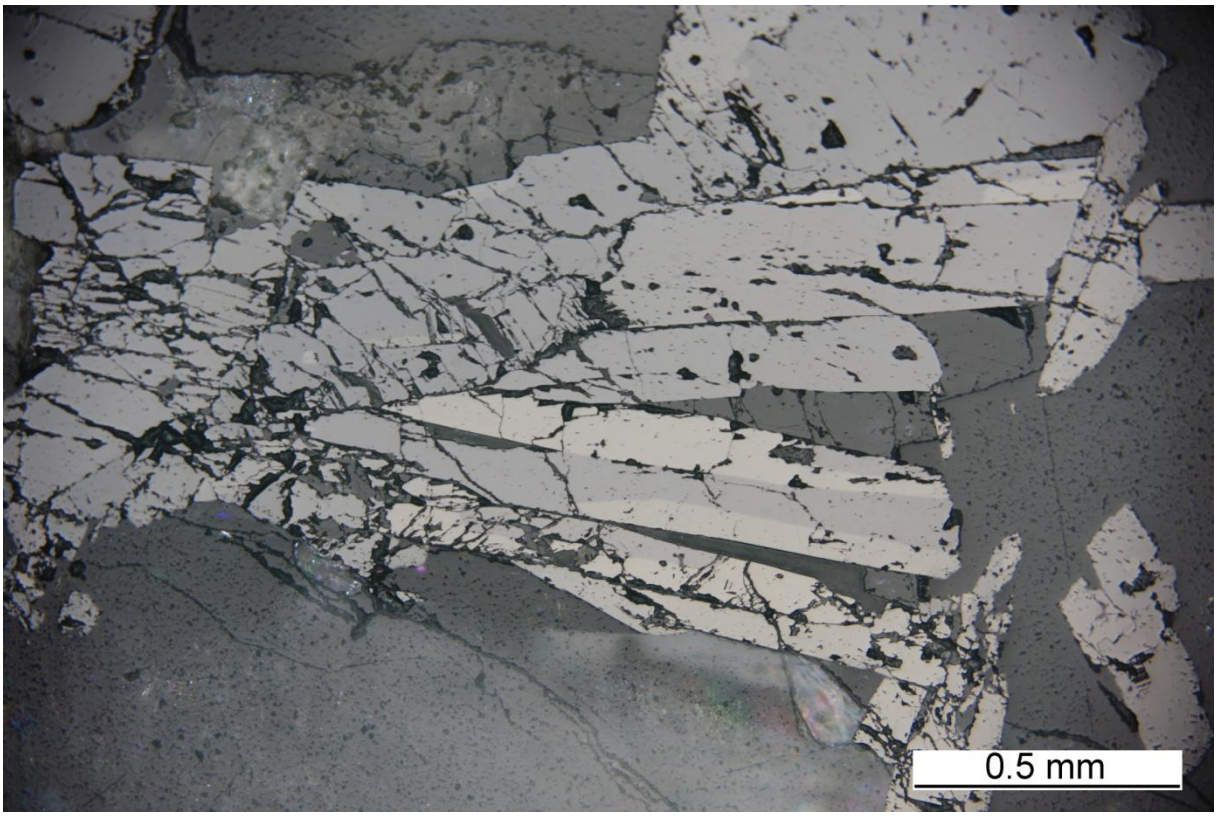

Fig. 16. Wolframite with moderate anisotropy, sample 127, XPL