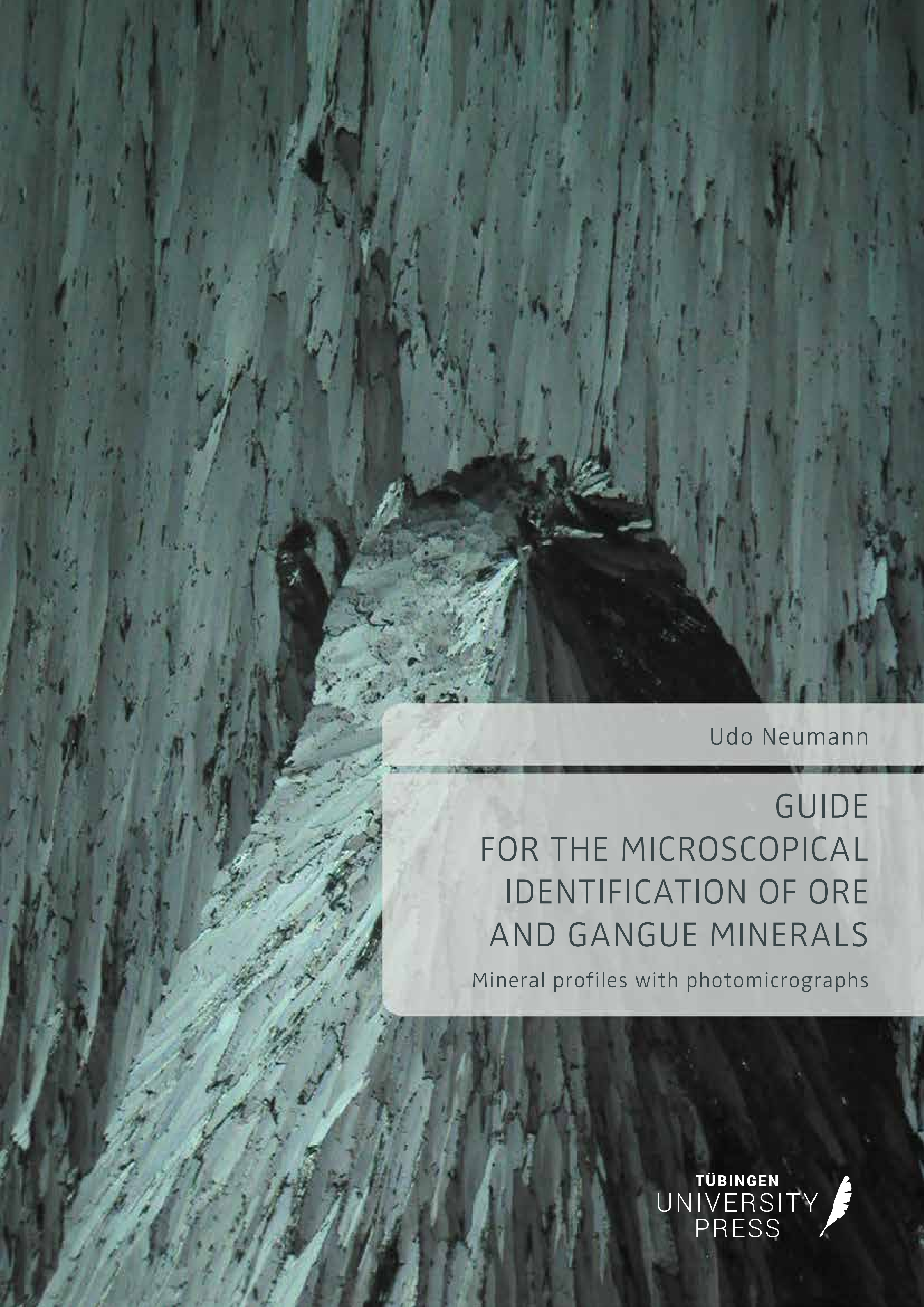


Udo Neumann

# GUIDE FOR THE MICROSCOPICAL IDENTIFICATION OF ORE AND GANGUE MINERALS

Mineral profiles with photomicrographs

TÜBINGEN UNIVERSITY PRESS

GUIDE
FOR THE MICROSCOPICAL IDENTIFICATION
OF ORE AND GANGUE MINERALS

Udo Neumann

# Guide for the microscopical identification of ore and gangue minerals

Mineral profiles with photomicrographs

TÜBINGEN UNIVERSITY PRESS

**Bibliografische Information der Deutschen Nationalbibliothek**
Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie, detaillierte bibliografische Daten sind im Internet über http://dnb.d-nb.de abrufbar.



Die Online-Version dieser Publikation ist auf dem Repositorium der Universität Tübingen verfügbar unter:
http://hdl.handle.net/10900/97483
http://nbn-resolving.de/urn:nbn:de:bsz:21-dspace-974837
http://dx.doi.org/10.15496/publikation-38866

2. Auflage Tübingen University Press 2020
Universitätsbibliothek Tübingen
Wilhelmstr. 32
72074 Tübingen
tup@ub.uni-tuebingen.de
www.tuebingen-university-press.de

ISBN (Hardcover): 978-3-947251-06-3
ISBN (PDF): 978-3-947251-12-4

Umschlaggestaltung: Susanne Schmid, Universität Tübingen
Fotos Cover und Innenteil: Udo Neumann
Satz, Layout und Bildnachbearbeitung: Sandra Binder, Universität Tübingen
Druck und Bindung: Pro BUSINESS digital printing Deutschland GmbH
Printed in Germany

# CONTENT

# PART A

## 1. INTRODUCTION

Starting with the initial publications of Campbell & Knight (1905, 1906), the use of reflected polarized light for the observation of ore minerals and other opaque phases is now established as an essential method in earth sciences and materials science. It is a valuable part of the characterisation and interpretation of all kind of metallic ores in science and industry. In addition, reflected light microscopy is also used for the investigation of concretes, ceramics, metals/alloys, archaeological artefacts and in coal petrography.

The microscopical identification of opaque and translucent mineral phases is the first step during careful investigation of usually fine-grained ores, followed by the more important interpretation of the textural and structural features. Since ore mineral identification is in part also possible by using expensive and time-consuming table-top REM, µ-XRD and other sophisticated methods, the main purpose of microscopy is the observation of the intergrowths of different minerals and phases.

The interpretation of the ore fabric is essential in establishing a mineralogical paragenetic sequence and in consequence for the understanding of the often very complex ore genesis. In practice, selecting the ideal mineral processing technique for ores requires a) understanding the mineral content including the distribution of minor metals as possible by-products and more importantly b) determining the manifold mineral intergrowths in the raw ores for the optimal mineral liberation.

This guide includes optical properties for important ore and gangue minerals as well as photomicrographs of their typical appearances, textures, and assemblages.

Its initial purpose was to be a hand-out script for the students attending my geosciences courses at the University of Tübingen. Therefore, you might find some German expressions and content here and there. This guide is primarily designed as additional material for students and does not replace reading a textbook of ore microscopy!

The basics of reflected-light microscopy and the profiles of about twenty of the most common ore minerals are the subject of the undergraduate course »Introduction to ore microscopy«, whereas the whole suite of about 130 minerals is studied in the graduate course »Ore petrology and ore microscopy«.

For the theoretical understanding of the principles and basics in reflected light microscopy please refer to the classical textbooks, such as Craig & Vaughan (1994), Mücke (1989, in German), and Bauman & Leeder (1991, in German).

Much more information about ore minerals can be found in the «bible« for ore microscopists from Paul Ramdohr (1975, in German, and 1980, in English), although his books are not designed for beginners. See the bibliography for additional publications.

Because ore microscopy is often an observation of qualitative optical properties and of textural features, students and scientists depend on a combination of detailed descriptions of the minerals (»mineral profiles«) and photomicrographs of their typical appearance. There are many publications concerning ore microscopy, but a practical, useful combination of valid mineral descriptions and photomicrographs is still missing, very expensive, or out of print.

Each ore and gangue mineral is presented on facing pages, with four or more photomicrographs on the right and the mineral profile on the left side.

Time-consuming quantitative measurements of the reflectance and the Vickers hardness provide us with the two basic parameters for the qualitative microscopy but are not applicable to standard microscopical investigations of ore mineralisations or non-ore rocks. However, in order to investigate an unknown phase by comparing it to a well-known mineral, these semi-quantitative parameters are important.

The values of reflectance and hardness are only two of many parameters which can be used for the identification of a mineral or a phase in artificial products, such as slags. Other important diagnostic criteria, such as internal reflections, twinning, texture, structure, or the mineral association/paragenesis, are in many cases far more helpful for the identification.

In order to be familiar with these features it is essential to have sufficient practice with many polished sections as possible. The faint optical differences especially in reflectance and in colour impression are a main obstruction for the beginner and often disillusioning. Therefore, I will stress the importance of using oil immersion objectives (see under Reflectance) and the other diagnostic parameters.

To identify an unknown mineral, it may be convenient for beginners to start with only a few selected properties, such as reflectance, bireflectance, and internal reflections. Check out tables I-V to help identify unknown minerals in combination with the mineral association. For a quick identification of gangue minerals see table 8.6.

Although scanning electron microscope (SEM) and electron microprobe analysis (EMPA) are routinely used for studying unknown phases today, the first step in analysing natural minerals or artificial phases is the microscopical investigation! To cite Louis J. Cabri (1987): »Without a proper understanding and use of a microscope and microscopic methods, the most sophisticated investigation is for naught. Let us hope that this message will be noted and remembered!«

The selection of mineral profiles and photomicrographs in this guide is restricted to the different ores and minerals available to the author. A large number of them are from the Schwarzwald (Black Forest) in SW-Germany since our group in Tübingen around Gregor Markl is intensively and extensively studying a variety of mineralisations in that region. Some readers will miss some selenides, tellurides, and PGE minerals, whereas other minerals in this guide might be of minor general significance.

In preparing these mineral profiles the following main references were used, especially Craig & Vaughan (1994), Criddle & Stanley (1993), Mücke (1989), Ramdohr (1980), and Uytenbogaardt & Burke (1985).

## 2. ACKNOWLEDGMENTS

First and foremost, I would like to thank Arno Mücke in Göttingen for the very stimulating discussions during many hours of research and teaching, and for the permission to modify his unpublished mineral profiles («Erkennungskarten«). Without him I would never have reached the deepest understanding of ore microscopy.

Many thanks also to the preparation staff, Peter Meyer, Göttingen, and Simone Schafflick and Indra Gill-Kopp, both Tübingen. Without their excellent work in preparing polished sections the exact descriptions and good photomicrographs of the minerals would not have been possible. I am also grateful to the many students I have had the last 30 years. Their interests in ore microscopy and ore geology stimulated my affords to present a user friendly guide for the identification of ore minerals in the microscope.

I am also very grateful to Manuel Scharrer for his review of the guide, and to him and Tatjana Epp for their readiness to help with and to teach in many of my exercise courses. Finally, I am particularly indebted to Amélie Stephan for her meticulous review of the English draft.

# 3. CHECK-LIST FOR ORE MICROSCOPY

You will need to have a clean, polished section. If necessary, manually polish the section with MgO powder. Then check the ore microscope (see Fig. 1) following these steps:

- Connect the lamp to the transformer (power cable in?).
- Switch on the transformer carefully step by step to high power:
  - Is there light on the microscope stage (use a piece of white paper for double-check)?
- Check the opaque illuminator:
  - Is the blue filter inserted?
  - Is the polariser inserted?
  - Are both the illuminator diaphragms (field F and aperture A) open?
- Make sure the analyser and other optical devices are not in the light path.
- Start with a low magnification objective (5x, red ring) for the first overview.

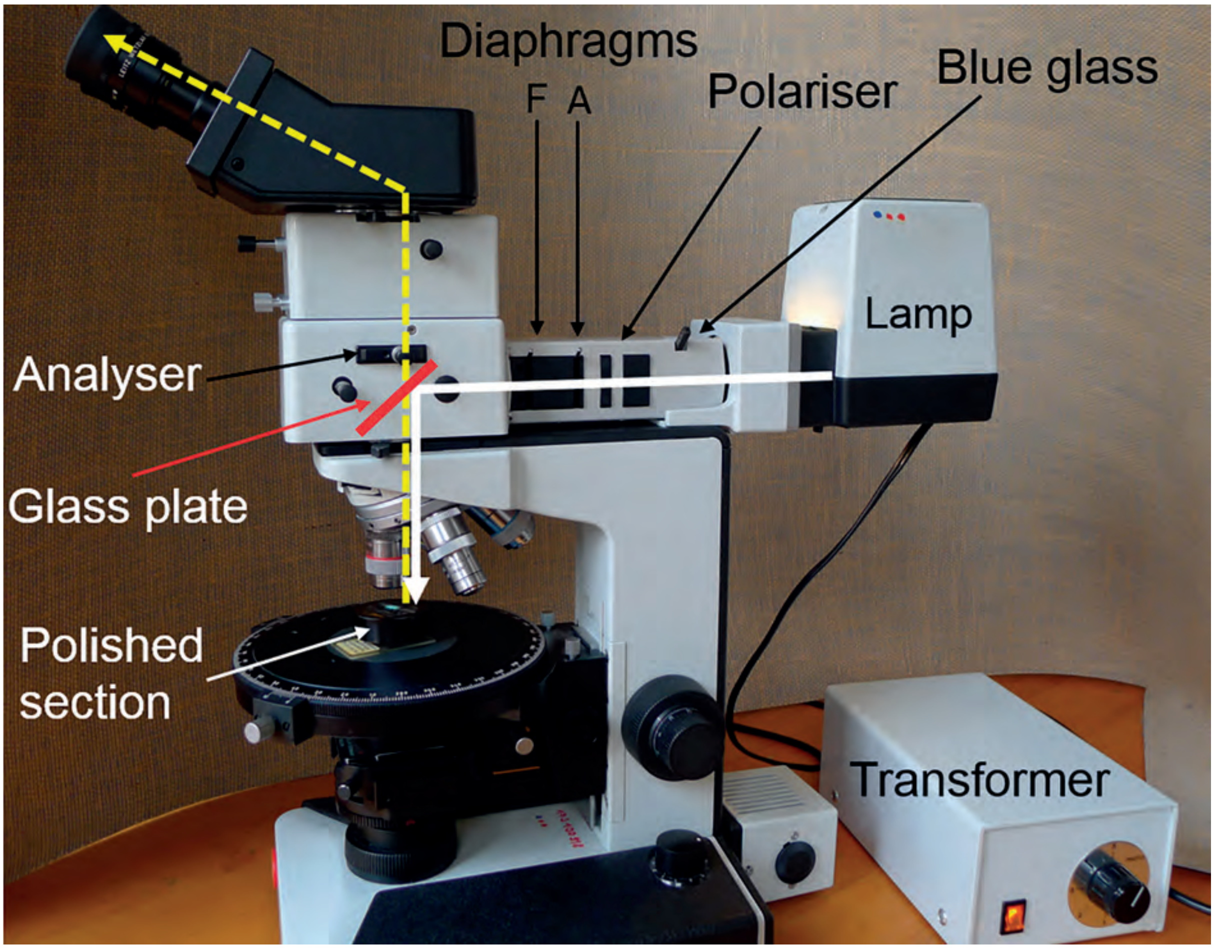



**Figure 1:** Microscope Leica Laborlux 12 Pol S for reflected and transmitted light microscopy. Diaphragm F = field diaphragm (»Leuchtfeldblende«), A = aperture diaphragm (»Aperturblende«). White line: Path of light from the lamp to the surface of the polished section; yellow line: Path of reflected light from the polished section to the eye.

# 4. EXPLANATION OF TERMINOLOGY

## 4.1. MINERAL NAME AND FORMULA

International used mineral name (also German names or synonyms) and simplified mineral formula.

## 4.2. VHN (VICKERS HARDNESS NUMBER)

Micro indentation hardness (Vickers Hardness Numbers) according to literature. The listed values are mainly compiled from Criddle & Stanley (1993) or estimated from other hardness measurements.

For most minerals the numbers are rounded due to compensate for inaccuracies while preparing and measuring the material. They are listed for a general comparison.

Because most users do not have the means to perform exact quantitative measurements, it is thus helpful to estimate the relative hardness of minerals.

An easy and quick way to get a first impression of the hardness of an unknown mineral is to check the polishing hardness and the scratch hardness, the presence of scratches.

During polishing of the section the hard minerals are more resistant to abrasion than the softer ones, leading to a kind of topography, where the hard grains stand above the surface of the softer grains, presenting a polishing relief. Under the microscope this relief between hard and soft minerals is visible as a black boundary line (see photos 23, 101, 370 and 465). Grain boundaries between similar hard grains are hard to detect and very thin. They are much thicker and easier to see, if the minerals show strongly differing hardness. The relief will be more distinct and visible after repeated polishing, because the softer minerals will be worn away quicker than the hard ones.

To determine the polishing hardness, it is recommended to bring the grain boundary line into focus and slightly close the aperture diaphragm. Then change the distance between objective and sample by lowering the microscope stage, the surface will get out of focus. During this operation a bright shining contour light line, the so-called Kalb line, will appear, which will move into the direction of the softer mineral. With this method it is possible to compare the relative hardness of adjacent minerals. Be aware that most minerals exhibit a more or less strong anisotropism of hardness (see sphalerite, photo 508), which is not (!) related to optical anisotropism! This is notably a problem for the quantitative measurements.

The extent of the scratching depends on the varying hardness of minerals. This is referred to as the scratch hardness. In general, soft minerals will show many broad and deep scratches whereas hard minerals may exhibit only few fine ones. To compare the scratch hardness, it is useful to look for scratches that extend across boundaries between different minerals, where the scratch varies in thickness or even disappears (see photo 25).

## 4.3. CRYSTAL SYSTEM

- tric. = triclinic
- mcl. = monocline
- o'rh. = orthorhombic
- trig. = trigonal
- tetr. = tetragonal
- hex. = hexagonal
- cub. = cubic.
- ps. = pseudo.

## 4.4. REFLECTANCE (R)

Quantitative reflectance values (R in %) in air and oil at 546 nm wavelength according to Criddle & Stanley (1993) unless otherwise noted. Some reflectance values (of low reflecting minerals) were calculated from refractive index n, others are rough approximations by the author. Be aware that published reflectance measurements usually have a large margin of error up to 5-10% due to measurement inaccuracies, the quality of the polished surface, tarnishing effects, varying chemical composition (solid solutions), and the presence of micro inclusions and internal reflections!

The reflectance (brightness) is a characteristic mineral property which is used in quantitative and qualitative ore microscopy.

Physically the reflectance of a phase depends on two parameters:

- Refraction (refractive index n) and
- Absorption (absorption coefficient k).

Minerals with low R values (non-metallics) only show weak absorption. Their absorption coefficient k is in general very small (< 0.03; mostly around $10^{-7}$) and can be negligible in the Fresnel equation. For these minerals $R_{air}$ is only a function of n:

$$R_{air} = \frac{(n-1)^2}{(n+1)^2}$$

With this equation you can calculate R values for minerals with small k directly from published refractive indices (n).

If the mineral is more opaque and has sufficiently high absorption (k > 0.03), the Beer'sche equation is valid.

Because R also depends on the medium (air, water, or oil) in which reflection takes place, the refractive index of the medium (N = refractive index of the medium, N = 1 for air, N = 1.518 for oil) has to be included in the final Fresnel equation:

$$R = \frac{(n-N)^2 + k^2}{(n+N)^2 + k^2}$$

From this equation it becomes apparent that using oil immersion (N = 1.518 instead of 1.000) the reflectance of a given mineral is reduced.

Because the expressions (n - N) and (n + N) change depending on the medium used, R is especially reduced for minerals with low values of k, whereas R of stronger absorbing minerals with higher k is less strongly reduced.

For the identification of minerals, it is not necessary to measure the exact values of the reflectance R. Beginning students should instead learn how to recognize a few very important and frequent ore minerals with their known R at first glance, to estimate the R values of the unknown minerals. These ore ‚standards' are pyrite, arsenopyrite, chalcopyrite, pyrrhotite, fahlore, galena, sphalerite, hematite, magnetite, ilmenite, and rutile.

Because reflectance values in oil immersion are often not measured and/or published, the following diagram (Fig. 2) can be used for the rough estimation of $R_{oil}$ from the published values of $R_{air}$. This data is compiled from data published by Criddle & Stanley (1993). Many optical properties of ore minerals are better visible and more distinctive with the help of oil immersion objectives. What are the advantages of immersion against «normal« air objectives?

1. Small differences in reflectance of two minerals are more obvious in oil than in air because the relative difference is enhanced.
2. The change of reflectance of an anisotropic mineral in different orientations – the bireflectance – is stronger in oil (see anisotropic factor A).
3. Most minerals are only very weakly or not coloured when observed in air. By using immersion objectives, the colour impressions of the minerals and the reflection pleochroism of a single mineral are strongly enhanced!

The general reduction of R using oil immersion objectives is highly valuable and very useful for the mineral identification. Two minerals which have small differences in their R values in air are hardly to distinguish, whereas the same small difference in oil is more pronounced and easier to see. The reason is that the perceptibility of R differences does not depend of the absolute difference in R but on the relative difference.

The absolute difference of 1% in R is hardly to detect between two minerals with $R_{air}$ of 21%, resp. 20% (relative difference = 5%), but easy to distinguish for two minerals in oil with $R_{oil}$ of 6%, resp. 5% (relative difference = 18%), or even better with $R_{oil}$ of 2%, resp. 1% (here relative difference = 66%). The same is true for the differences of minerals exhibiting bireflectance (see under $A_{oil}$, below).

Therefore, oil objectives (and of course days, weeks, even years of practice) will help to recog-

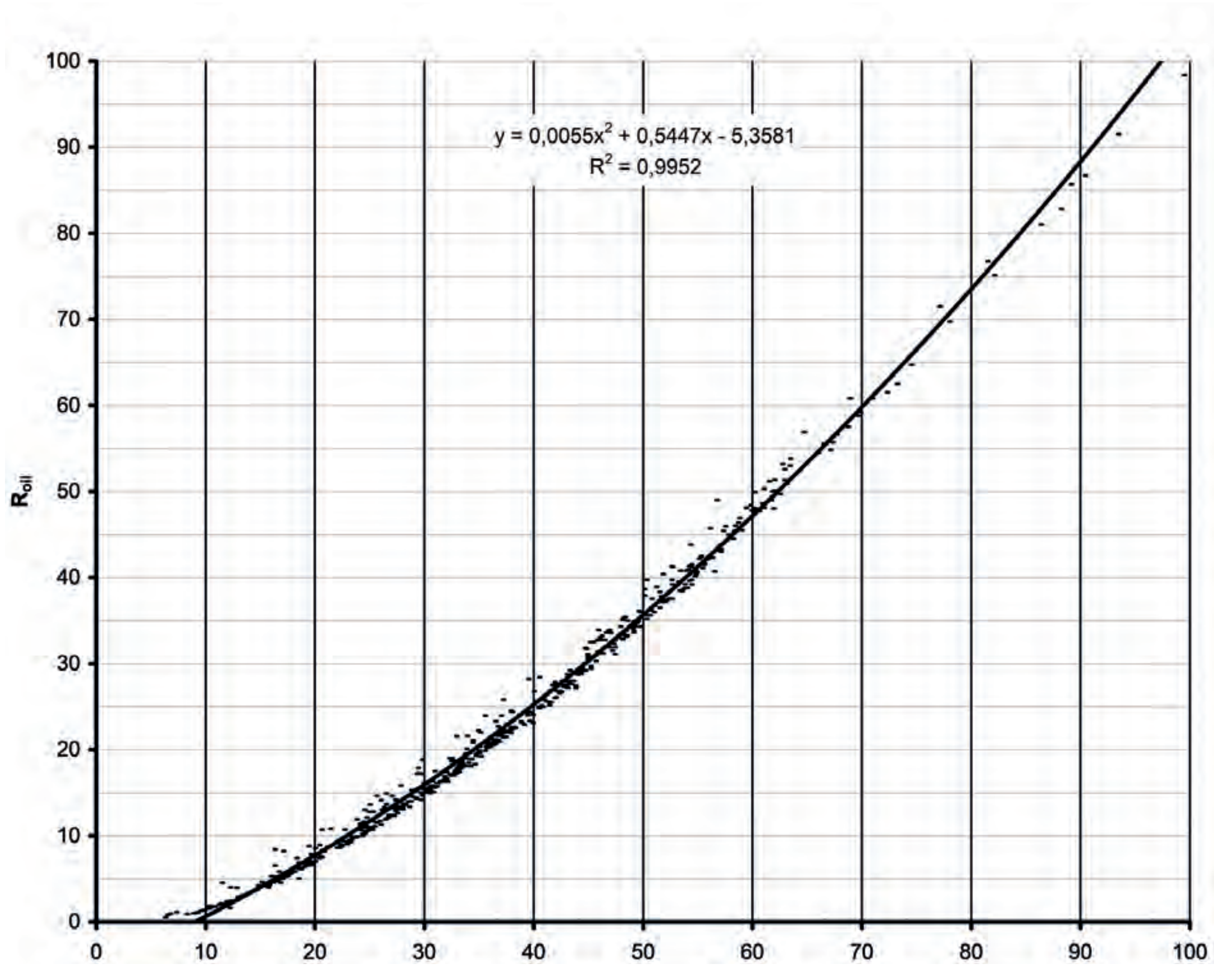



**Figure 2:** Diagram for the calculation of Roil from published Rair (data compiled from Criddle & Stanley, 1993)

nize the faint differences in reflectance and colour impression (»colour tint«) and thus to identify the minerals. This very simple tool is recommended for all practical courses and especially for the beginners, as already mentioned before by many professionals:

Ramdohr (1980): »It has to be emphasized over and over again that whoever shuns the use of oil immersion misses an important diagnostic tool and will never see hundreds of details described in this book.« (p. 293).

Craig & Vaughan (1981): »The presence of immersion medium (oil or water) reduces the reflectance of the minerals, but enhances colour differences, reduces diffuse light scattering, and generally permits the observation of weak anisotropism and bireflectance.« (p. 8).

Uytenbogaardt & Burke (1985): »Therefore, oil immersion is recommended here as a standard way for studying polished sections.« (Page VIII).

Gierth (1989): »Bei diesem (Polarisationsmikroskop) ist aber zumindest Eines unerläßlich: ein Objektiv für Ölimmersion in der Maßstabszahl zwischen 10x bis 20x; denn viele Beobachtungen sind eben nur bei Ölimmersion möglich.« (p. 1).

These observations are by no means new, but in many geoscience institutes today it is more or less common for some reasons (availability, price) to use ore microscopes without oil objectives.

Because immersion objectives have very short working distances, they should be used with care, especially when focussing on the polished surface of the section!

## 4.5. COLOUR IMPRESSION (CI)

Colour impressions in the mineral profiles are only given for oil immersion because the colour intensity of a mineral is generally increased – therefore more easily visible – using immersion objectives.

For anisotropic minerals the colour impressions correspond to the orientation of R ($R_o$, $R_e$, $R_1$, $R_2$ etc.) in the line above.

The selected blue filter and intensity of illumination should be kept constant for colour comparisons. For the detection of faint colour tints avoid colourful minerals in the direct neighbourhood of the unknown phase.

The impression of a mineral in reflected light appears with colour if the refractive index n and the absorption index k – and consequently the reflectance R – varies with different wavelengths, the dispersion of optical constants. If R is a function of (λ) → minerals will have a colour impression.

Measuring the R values of a mineral for different wavelengths gives a curve which represents the mineral`s specific spectral dispersion. Tabulated R values as a function of wavelength and the curve of dispersion can be found in Criddle & Stanley (1993). Minerals with nearly horizontal curves of dispersion show only non-coloured «colour« impressions ranging from white to black depending on R. These achromatic CI were subdivided in this guide from white – greyish white – whitish grey – grey – greyish black to black in order of decreasing R values.

If the value of R is different for special wavelengths, the minerals inherit some degree of colour. In ore microscopy these colours of the reflected light are named colour impressions (CI) to distinguish them from the mineral specific colour seen macroscopically or in transitted light. For example: the colour impression (CI) for hematite is whitish grey whereas the colour in transitted light is red which can be seen in the ore microscope as internal reflections, IR, see below.

Because the colour impressions of minerals in air are in most cases not strong and luscious, it is very helpful to use an oil immersion objective. If you are in doubt whether the mineral has a faint colour tint or not, take a look at a nearby sheet of white paper to standardize your impression by white balancing of your eyes.

Minerals with strong CI were described only by colour, some with the addition of another colour tint. For less strong coloured minerals each colour impression is preceded by white or grey, depending on the overall reflectance, e.g. whitish blue, greyish brown. If the colour is not easily visible, this colour tint is added to the CI usually from white to grey, e.g. white tint yellow.

Although we are able to distinguish many fine colour tints, we are unfortunately not able to find the right terms for these colour nuances. In addition, every person has their own kind of seeing and naming colours, so that publishing the «right« name for a colour in the minerals profile is impossible. Scanning different ore microscopy books and tables shows that the colour impressions listed in them are not comprehensible and far from uniform, especially for the colours of anisotropic effects. The readers are encouraged to use and/or add their own impressions («looks like my washed-out pink polo shirt«). The faint colour impressions of pyrrhotite are such an example, cream rose – white tint yellow brown. It is easier and more convenient to declare it to be «tombac«, a kind of bronze. Every ore microscopy expert will know what you are talking about.

Beyond being subjective colour impressions can be influenced by:

- surrounding strong coloured minerals
- R (if < 25 % in oil more a less with grey tints)
- chemical composition for solid solutions
- grain orientation of anisotropic minerals
- surface quality of the polished section
- kind of objective (air – oil), and
- lamp and the filter.

I would like to stress again that the colour impression is only one of many useful criteria to identify a mineral and should therefore not be overrated.

## 4.6. BIREFLECTANCE (BR AND RPL) IN OIL

Colour impression and/or reflectance of anisotropic minerals can vary under plane-polarized light without analyser due to the orientation of the mineral grain/crystal and as the stage of the microscope is rotated.

During rotation of the microscope stage anisotropic minerals show – as a function of their crystallographic orientation – variable optical effects with a maximum and a minimum every 90° and consequently the same effect all 180°. This bireflectance is generally the sum of two different effects, the changing of colour impression and reflectance. Reflection pleochroism (Rpl) means the colour impression of a mineral varies according to the position of the crystal to the polariser. Bireflection (BR, often also called bireflectance) means the mineral shows different reflectance values ($R_a$, $R_b$, $R_c$, $R_o$, $R_e$).

BR < Rpl: Minerals show mainly Rpl and less BR
BR ~ Rpl: Minerals show BR as well as Rpl
BR > Rpl: Minerals show mainly BR.

Minerals are either optical isotropic (cubic minerals) or anisotropic. The degree of the bireflectance of anisotropic minerals is

1. specific for a given mineral, i.e. the effects vary strongly from mineral to mineral
2. dependent on the orientation of a mineral grain. An anisotropic mineral/crystal can show effects ranging from the maximum differences to not variable effects in its isotropic (basal) section depending on the orientation of the optical indicatrix to the section surface.

Having this in mind it is logical to look for a grain in a polycrystalline aggregate with the strongest visible differences of reflectance and/or colour impression in the two adjacent positions (maxima and minima). This is easy for minerals with variable reflectance values but not as simple for minerals with only differences in colour impression.

If there is only one grain in the polished section and you see a weak bireflectance, then you know for sure that this mineral is not isotropic, but it is not possible to classify the BR (at least weak, but may be stronger in more optimal orientation). If this single grain shows no effects it is even worse, because you cannot decide whether it is an isotropic mineral or a basal section of an anisotropic mineral.

The mineral-specific effects of anisotropism with uncrossed polars are listed for their optimal orientation and grouped according to the seven main types of strength and the proportion of the three sub-types of BR vs. Rpl. See also tables 8.1-8.3.

As already mentioned above, the differences in BR and Rpl are much easier to see with the use of oil immersion objectives. The enhanced effects can be calculated from the anisotropic factor $A_{air}$ and $A_{oil}$.

## 4.7. ANISOTROPIC FACTOR $A_{OIL}$

The anisotropic factor (A) for oil immersion is the relative bireflectance of a mineral calculated with the following equation:

$$A = 100^* (R_{max} - R_{min})/(½^*(R_{max} + R_{min})).$$

The relative bireflectance is – in contrast to the absolute bireflectance – analogue to the visual impression, this is valid specifically for BR but not for Rpl.

The contrast factor Kf can be calculated by $Kf = A_{oil}/A_{air}$. It is obvious that the relative bireflection is much stronger using oil immersion objectives.

## 4.8. ANISOTROPISM EFFECTS UNDER CROSSED POLARS (AEXPOL)

Variable optical effects of the mineral under plane polarized light and crossed polars can be seen when the sample is rotated.

AExPol are variations in brightness and/or colour of an anisotropic mineral grain in an optimal orientation if the specimen is rotated. There should be four positions, each 90° apart, where the mineral grain shows minimum brightness or maximum darkness – called normal position – and four positions where the grain shows maximum brightness – called 45°- or diagonal position.

In general, minerals with low reflectance – and with low absorption – show no or only weak anisotropic colour effects under crossed polars, i.e. most oxides, while minerals with high reflectance can exhibit colours under crossed polars, especially under not precisely crossed polars.

The classification of AExPol is based primarily on the brightness in the 45°-position from very strong to very weak effects, which can further be subdivided depending on whether these effects are associated with a colour, a colour tint or no colour. The terms extremely strong, very strong, strong, distinct, weak, and very weak are used to describe the intensity of anisotropism (brightness).

To find the best grain orientation for the description of AExPol you have to find a grain which has the highest bireflection or reflection pleochroism (Rpl). This grain will also exhibit the largest differences between normal and 45°-position under crossed polars.

Optimum conditions for the observation of anisotropism effects under crossed polars are an intensive light source (always remove the blue filter!), objectives with low aperture/magnification (less than 40/50x), and the optimal grain orientation with the maximum variation between extinction and 45°-position.

Effects of weak anisotropism are better detected shifting the analyser a few degrees off the exactly crossed position to the polariser (named not precisely crossed polars) and by observing the sample using oil immersion.

Comparing the published colours for minerals leaves a frustrating impression. They are rarely identical or characteristic for a specific mineral and can vary very strongly from author to author. The reason for this potpourri is based on the different technical parameters used by these authors. In particular, the position of the polariser to the glass plate and the position of analyser to the polariser is important because tiny misfits from the ideal position(s) can lead to unreproducible effects.

The colours observed under crossed polars are not comparable with the interference colours in transmitted light microscopy. Instead, they are a combination of difficult to handle parameters.

These mixed colours are the sum of the

1. Rotation of the plane of polarisation and the formation of elliptic polarized light during the reflection of the incoming light
2. Dispersion of the refractive indices and of the absorption coefficients
3. Nature of the incoming light, which should be parallel, 100% linear polarised, and perpendicular to the surface of the section
4. Position of the analyser to the polariser
5. Position of the polariser to the glass plate (or prism)
6. Type of objective.

Points 1 and 2 are depending on the grain orientation and therefore controlled by material specific constants. Their co-action controls whether the mineral shows any colours under crossed polars. In contrast, points 3-6 are only technical factors. Disregarding these factors can lead to quite different effects and colours under crossed polars.

For reproducible and precise effects be aware of the following aspects:

1. Because the light intensity under crossed polars is only a few per mille from the light without the analyser, it is important to remove the blue filter and to use a powerful light source. Note: The new LED illumination requires no daylight filter since the LED already provides a light temperature of around 4500 K. But be aware that the illumination with white light-emitting diodes (WLED) and RGB diodes give a modified »white« colour spectrum compared to the halogen lamps, leading to more colourful anisotropism effects, which are not mentioned in the mineral profiles!
2. The objectives should be stress-free (labelled P or Pol), and should have a small aperture, i.e. ob-

jective with a magnification power of less than 40/50x. Slightly close the aperture diaphragm.
3. Precise orientation of the sample surface perpendicular to the axis of the microscope. Rotate the sample during multiple pressing with the section press.
4. The section must have a perfect polishing. Otherwise many tiny scratches will lighten the grains and produce an atypical anisotropism (in German: Kratzeranisotropie) which is not mineral specific.
5. The polariser must be oriented parallel to the glass plate and the analyser must be exactly 90° rotated from the polariser. This is of course only possible if the polars can be rotated.

A main division in the mineral profiles is made for the AExPol depending on whether the polar are precisely crossed (90°) or not. The adjustment of the polars is very delicate in respect to reproducible results. The optical differences between ideal and not exactly crossed polars are less obvious only for minerals with low R, which is dominated mainly by n, e.g. ilmenite, or for very bright minerals, which show non-coloured effects, e.g. molybdenite, mackinawite. Minerals with colourful AExPol are very sensible for the adjustment of the polars (see below).

Important to note: If a mineral shows a colour effect under crossed polars, this colour or colour tint is identical at each 45°-position only if the polars are exactly crossed and in the ideal position, 0°, 90°, respectively. When the analyser is not perfectly crossed with 90° to the polariser, you will see two different effects – in colour and brightness – in adjacent diagonal positions. This is especially pronounced for minerals, which have high absorption indices. In short: After the reflection of light on anisotropic minerals the two vibration directions of the wave R1 and R2 differ in amplitude and/or in phase, creating elliptically polarized light where the major axis of the ellipse is rotated.

In general, two methods can be used to perform an exact crossing of the polars.

1. With the help of an isotropic mineral, e.g. galena or magnetite. After adjusting of the polariser (if possible E-W) insert the analyser and adjust it until the mineral is as dark/black as possible.
2. With the help of highly reflecting, anisotropic minerals which show colour effects under crossed polars, e.g. arsenopyrite (see photos 26 and 27), marcasite, or nickeline. These minerals have different anisotropic effects in adjacent 45°-positions if the polars are not exactly crossed. Prior to the observation, a precise orientation of the sample surface perpendicular to the axe of the microscope is needed. Then, if possible, rotate the polariser into the 0° position and insert the analyser. During rotation of the stage, the mineral should show equal optical effects in all four 45°-positions. If you observe differences in colour and/or brightness move the analyser in one direction and observe the effects during rotation of the stage. If the differences are now stronger, you have to move the analyser into the other direction until the 45°-positions show optical identity. In sum, move the analyser until all four diagonal positions show very similar or at best identical effects. Now the polariser is in the ideal position and the analyser is precisely crossed 90°.

In general, with exactly crossed polars the overall field of view is generally dark and the effects are less colourful and much darker than those under slightly uncrossed polars.

## 4.9. EXTINCTION

Additional features accompanying the position with minimum brightness, the «normal« position, may be used for the identification of minerals. These are straight and uneven extinction, or the mineral grain shows complete, incomplete or undulate extinction just like in transmitted light. If the reflectance of a mineral is controlled by high absorption (k-values) these minerals often show incomplete extinction position, i.e. they are not completely black. In some cases, the normal position is slightly coloured, especially if the analyser is not exactly crossed.

## 4.10. INTERNAL REFLECTIONS (IR)

Important features for mineral identification are internal reflections (IR), which can be seen in minerals with a reflectance of $R_{air}$ less than ~40% ($R_{oil}$ < ~25%).

Internal reflections are diffuse patches of light most often near fractures, cleavage planes, inclusions, and grain boundaries which are produced in minerals that are not completely opaque in transmitted light. These are minerals with low reflectance and more important with low absorption. That is the reason why the low reflecting graphite shows no IR. Due to its high absorption graphite is opaque even in very thin flakes.

The colour of the IR corresponds to the macroscopic colour of the mineral. The frequency and intensity of IR depend on grain size, amount of fractures or inclusions, and in some cases on the chemical composition, e.g. in rutile, cassiterite or sphalerite.

IR are more obviously recognized if the surface reflectance of the mineral is low, and/or if the polars are crossed. Intensity and amount of IR increase using an immersion objective, crossing the polars and rotating the grain into the normal position, decreasing the overall brightness of the other optical effects. In transparent minerals the numerous IR often mask and hide the anisotropism effects, e.g. anatase, cinnabar. Gangue minerals with their very low reflectance always show abundant IR, even under uncrossed polars. The colour of the IR can sometimes be used for their identification, e.g. epidote vs. garnet or biotite vs. muscovite.

Unfortunately, the intensity of the IR also depends on the grain size and the amount of discontinuity planes of the mineral (in German: Unstetigkeitsflächen). For example, large hematite grains only rarely exhibit IR, whereas fine-grained hematite aggregates are full of red IR. The IR of some minerals also vary in colour and intensity due to the variable content of minor elements. Iron-poor varieties of rutile, sphalerite, and cassiterite are full of yellow-white to colourless IR, whereas the iron-rich one's exhibit only few and dark brown IR.

A classification of internal reflections with the typical minerals is compiled in table 8.4. See also table 8.6 for gangue minerals.

## 4.11. TWINNING

Crystal twinning – the oriented intergrowth of two or more crystals of the same mineral – is an important mineral-specific parameter. It can be very helpful for the mineral identification and even for the genetic interpretation of a mineralisation.

The typical twinning of a given mineral is classified due to the mode (orientation and form) and frequency. Be aware that the twinning of a mineral can vary due to different parameters like primary growth, secondary transformations or deformations, and – very important – due to the crystal orientation.

In general, the easiest way to observe twinning is crossing the polars with a slightly uncrossed analyser. The twinning is of course dependent on the orientation of the anisotropic grain. In a specific position these twins can be missing, i.e. if the orientation of the single lamellae system is parallel to the surface of the section, so it is advisable to scan different grain orientations for the characteristic twinning.

The type of twinning is a result of the mineral formation process.

We distinguish three types:

1. growth twinning
2. inversion twinning
3. deformation twinning.

Twin formation during initial growth shows twinning after relative simple rules with generally one more or less straight twin boundary. Prominent examples are safflorite (star-like triplets), loellingite, rutile, cassiterite and marcasite.

Inversion twinning due to phase transformation is characterized by many adjoining lamellae (polysynthetic twinning). These fine lamellae are similar and parallel in certain mineral areas or domains but not in parallel arrangement in the whole grain. The lamellae are lens- or spindle-like and build up an interlaced network. Typical examples are chalcopyrite, bornite and stannite. The formation results from the inversion of a high-temperature modification into the low-temperature one. If an inversion twinning is visible, this feature can be used as geothermometer for the estimation of minimum formation temperatures.

Deformation twins, mechanical induced twinning, are similar to inversion twins, showing also unequal and lamellar but rarely spindle-like twins. They are accompanied by bending, cataclasis, crumpled lamellae (in German: »Zerknitterungslamellen«) and beginning recrystallization features. Examples are hematite, ilmenite, rutile, hausmannite, sphalerite, pyrrhotite, chalcopyrite, nickeline, stibnite and graphite.

### 4.12. FURTHER OBSERVATIONS

The morphology of crystals, cleavages, exsolution features and the intergrowth with other minerals, as well as structure and texture phenomena can be very useful for the identification and interpretation of complex ores. The user is strongly advised to consider these additional parameters beside the above mentioned optical parameters.

### 4.13. FORM, HABIT, TEXTURES

In many rocks and ores, the minerals exhibit their typical appearance with respect to the crystal morphology in form and habit (anhedral-euhedral, isometric, tabular, acicular, etc.), zoning, occurrence of exsolution bodies, and typical replacement, deformation and intergrowth features. For the mineral identification and the interpretation of the ore genesis it is very important and helpful to look carefully for these features. See tables 8.5 and 8.7.

### 4.14. CLEAVAGE (#)

Minerals with good cleavages in hand specimens do not necessary show this feature in polished section. The polishing process has great influence on the visibility of cleavage planes, seen as oriented fine black lines on the mineral surface. Powerful polishing can create many cleavages and deformation pits, whereas a careful polishing process can even eliminate all cleavage features by smearing over the cleavage fissures in soft minerals. Nevertheless, if a mineral shows cleavage planes, it can be an important feature for the identification.
In many ores and rocks, galena, pyrrhotite and minerals with sheet-like crystal structure, e.g. graphite, valleriite, molybdenite, can easily be identified by their typical cleavage features. The triangular black pits in galena are commonly visible and very typical.

### 4.15. PARAGENESIS (ASSOCIATION)

An important feature for the mineral identification are those minerals which are often in paragenesis (co-genetic phases) or in association (not co-genetic) with this mineral. Good knowledge of the most important assemblages is of valuable help for the identification of unknown minerals and should not be underestimated. See also table 8.5 and 8.7.

### 4.16. DIAGNOSTIC FEATURES

These are the most important criteria for the identification of a given mineral in the ore microscope.

### 4.17. NOTES, DRAFTS

Further important information and space for your own drawings and notes.

# 5. SOME ABBREVIATIONS USED IN THIS GUIDE

| Abbr. | Explanation |
|---|---|
| $A_{oil}$ | Intensity of bireflectance in oil (the anisotropic factor) |
| AExPol | Anisotropism effects with precisely crossed polars:<br>intensity and colours (in oil) |
| AExPol (~) | Anisotropism effects with analyser rotated a few degrees (~ 2-5°) from its ideal position: intensity and colours (in oil) |
| BR and Rpl | Bireflection and reflection pleochroism (in oil) |
| BR ~ Rpl | BR as strong as reflection pleochroism |
| BR > Rpl | BR more pronounced than reflection pleochroism |
| BR < Rpl | BR less pronounced than reflection pleochroism |
| CI | Colour impression (in oil) |
| EB | Exsolution bodies |
| Formula (abbr.) | Simplified mineral formula (abbreviation after Whitney & Evans (2010), and Fontboté (2006)) |
| IR | Internal reflections:<br>Occurrence and colour in oil |
| \|\| Pol | Uncrossed polars (only one polariser) |
| x Pol | Precisely crossed polars |
| x Pol (~) | Not exactly crossed polars (with ~ 2-5° from the ideal position) |
| R (in % at 546 nm) | Reflectance values in air/oil (mainly after Criddle & Stanley (1993) unless otherwise noted, see below).<br>[1]: after Uytenbogaardt & Burke (1985)<br>[2]: after Ramdohr (1980) |
| VHN | Vickers Hardness Number (values mainly after Criddle & Stanley (1993) or estimated from Mohs hardness) |
| # | Cleavage, or cleavage after ... |
| X/XX | Crystal/Crystals |

# 6. MINERAL ABBREVIATIONS (MODIFIED AFTER WHITNEY & EVANS (2010) AND FONTBOTÉ (2006))

| Abbr. | Name | Abbr. | Name | Abbr | Name |
|---|---|---|---|---|---|
| ab | albite | cct | chalcocite | gru | grunerite |
| act | actinolite | cer | cerussite | gy | gypsum |
| adr | andradite | chl | chlorite (group) | hbl | hornblende |
| afs | alkali feldspar | chr | chromite | hc | hercynite |
| all | allanite | cin | cinnabar | hm | hematite |
| alm | almandine | cob | cobaltite | hsm | hausmannite |
| alu | alunite | cp | chalcopyrite | ill | illite |
| amp | amphibole (group) | cpx | clinopyroxene | ilm | ilmenite |
| an | anorthite | crn | corundum | ilv | ilvaite |
| and | andalusite | cub | cubanite | iss | intermediate ss |
| ang | anglesite | cup | cuprite | jm | jamesonite |
| anh | anhydrite | cv | covellite | kam | kamacite (a-FeNi) |
| ank | ankerite | dg | digenite | kao | kaolinite |
| ant | anatase | di | diopside | ky | kyanite |
| ap | apatite (group) | dia | diamond | lin | linnaeite |
| asp | arsenopyrite | dol | dolomite | lm | limonite |
| aug | augite | el | electrum | lo | loellingite |
| az | azurite | eng | enargite | mal | malachite |
| bar | barite | ep | epidote | mc | microcline |
| bdy | baddeleyite | fa | fayalite | mgh | maghemite |
| bio | biotite | fh | fahlore (tnt-td) | mgs | magnesite |
| bn | bornite | fl | fluorite | mic | mica (group) |
| boul | boulangerite | fo | forsterite | mlr | millerite |
| brc | brucite | fsp | feldspar (group) | mm | montmorillonite |
| brk | brookite | gg | gangue | mnz | monazite |
| bxb | bixbyite | gn | galena | mol | molybdenite |
| cal | calcite | goe | goethite | mrc | marcasite |
| car | carrollite | gr | graphite | ms | muscovite |
| cas | cassiterite | grs | grossular | mss | monosulfide ss |
| cb | carbonate (group) | grt | garnet (group) | mt | magnetite |

contd.

| Abbr. | Name | Abbr. | Name | Abbr | Name |
|---|---|---|---|---|---|
| ne | nepheline | ram | rammelsbergite | tae | taenite |
| nk | nickeline | rds | rhodochrosite | td/ttr | tetrahedrite |
| ol | olivine (group) | rlg | realgar | tlc | talc |
| opx | orthopyroxene | rt | rutile | tnr | tenorite |
| or | orthoclase | sa | sanidine | tnt | tennantite |
| orp | orpiment | sch | scheelite | trm | tremolite |
| phl | phlogopite | scp | scapolite (group) | tro | troilite |
| plag | plagioclase | sd | siderite | ttn | titanite |
| pn | pentlandite | ser | sericite | tur | tourmaline |
| po | pyrrhotite | sfs | sulfosalts (class) | urn | uraninite |
| pph | pyrophanite | sk | skutterudite | usp | ulvöspinel |
| pr | proustite | sph | sphalerite | wf | wolframite (fb-hub) |
| prl | pyrophyllite | spl | spinel | wo | wollastonite |
| prv | perovskite | srp | serpentine (group) | wur | wurtzite |
| psb | pseudobrookite | ss | solid solution | wus | wuestite |
| px | pyroxene (group) | stbn | antimonite = stibnite | zeo | zeolite (group) |
| py | pyrite | stbn | stibnite | zrn | zircon |
| pyrg | pyrargyrite | stlb | stilbite | | |
| qz | quartz | str | strontianite | | |

## 7. REFERENCES

**Baumann, L. & Leeder, O. (1991):** Einführung in die Auflichtmikroskopie.- Deutscher Verlag für Grundstoffindustrie GmbH, Leipzig, 408 p. (out of print)

**Cabri, L.C. (1987):** The mineralogy of precious metals: new developments and metallurgical implications - Presidential address. - Can. Mineral., 25, 1-7

**Craig, J.R. & Vaughan, D. J. (1994):** Ore microscopy and ore petrography.- Second edition, Wiley-Interscience, NY, 448 p.

**Criddle, A. J. & Stanley, C. J. (1993):** The quantitative data file for ore minerals.- Third edition, Chapman & Hall, London, 64 p. + 635 tables.

**Criddle, A. J. & Stanley, C. J. (2017):** Quantitative Data File for reflectance values of minerals. Online: http://nrmima.nrm.se/Copy%20of%20COMwavelengths.xls (last visit: 23.04.2018) (but R values listed only for air).

**Fontboté, L. (2006):** Recommended abbreviations for studies on ore deposits. - https://www.unige.ch/sciences/terre/research/Groups/mineral_resources/opaques/ore_abbreviations.php (last visit: 18.05.2019)

**Gierth, E. (1989):** Leitfragen zur Bestimmung von Erzmineralien im Anschliff.- Clausthaler Tektonische Hefte, 25, Second edition, Verlag E. Pilger, Cl.-Zellerfeld, 131 p. (out of print)

**Ineson, P. R.(1989):** Introduction to Practical Ore Microscopy. - Longman, 192 p.

**Ixer, R. A. & Duller, P. R. (1998):** Virtual Atlas of Opaque and Ore Minerals in their Associations. - http://www.atlas-of-ore-minerals.com. (last visit: 16. 05. 2019)

**Marshall, D., Anglin, C. & Mumin, H. (2004):** Ore Mineral Atlas. – Geol. Ass. Canada Mineral Deposits Division, 112 p.

**Mücke, A. (1989):** Anleitung zur Erzmikroskopie mit einer Einführung in die Erzpetrographie.- Enke Verlag, Stuttgart, 187 p. (out of print)

**Picot, P. & Johan, Z. (1982):** Atlas of ore minerals.- Elsevier, Amsterdam, 458 p.

**Pracejus, B. (2015):** The ore minerals under the microscope.- Atlases in Geoscience, 3, Elsevier, 1118 p.

**Ramdohr, P. (1975):** Die Erzmineralien und ihre Verwachsungen. – 4., bearbeitete und erweiterte Auflage, Akademie-Verlag, Berlin, 1277 p. (out of print)

**Ramdohr, P. (1980):** The ore minerals and their intergrowths.- English Translation of the 4th Edition in two volumes, Pergamon Press, Oxford/London, total 1205 p. (out of print)

**Spry, P. G. & Gedlinski, B. L. (1987):** Tables for the determination of common opaque minerals.- Economic Geology Publishing Company, New Haven, 52 p.

**Uytenbogaardt, W. & Burke, E. A. J. (1985):** Tables for microscopic identification of ore minerals.- 2nd revised edition, Dover Publ., Inc. New York, 430 p.

**Vaughan, D. J. (2006)(Ed.):** Sulfide Mineralogy and Geochemistry.- Rev. Mineral. Geochem., Vol. 61, 714 p.

**Whitney, D. L. & Evans, B. W. (2010):** Abbreviations for names of rock-forming minerals. – Amer. Min., 95, 185–187.

**http:**//webmineral.com: The Mineralogy Database contains 4714 individual mineral species descriptions (2017) with links and a comprehensive image library.

**http:**//www.mindat.org: World's largest open database of minerals, rocks, and meteorites.

**http:**//nrmima.nrm.se//imalist.htm: IMA mineral list with 5488 valid minerals (June 2019).

**http:**//rruff.info: RRUFF Project website containing an integrated database of Raman spectra, X-ray diffraction and chemistry data for minerals.

# 8. TABLES

## 8.1. COLOUR IMPRESSION – REFLECTANCE – BR (WITH OIL IMMERSION)

| I. Minerals WITHOUT colour impression (white to black) in oil | | | |
|---|---|---|---|
| R | BR/Rpl not visible to very weak | BR/Rpl weak to distinct | BR/Rpl strong to extremely strong |
| > 50% | Silver 91<br>Platinum 59<br>Osmium > 48 | Antimony 64-69 | |
| 50-35% | Iron 45<br>Gersdorffite 31 to 43<br>Clausthalite 37 | Rammelsbergite 43-48<br>Tetradymite 41-48 | |
| 35-25% | Galena 28 | | |
| 25-18% | | Pyrolusite 23-30<br>Jordanite 23-25<br>Franckeite 21-22<br>Teallite 18-20 | Bismuthinite 22-34 |
| 18-10% | | Hematite 12-16 | Ramsdellite 9-25<br>Manganomelane 14-23 |
| 10-5% | Alabandite 8.8<br>Anatase 6.6-6.8<br>Wurtzite 5 to 6<br>Sphalerite 5.0 to 5.4 | Pseudobrookite 6-6.5 | Mackinawite 5.2-28.4<br>Molybdenite 7.8-24.1<br>Rutile 6.9-9.3<br>Lithiophorite 2-8 |
| < 5% | Pyrolusite 4.9<br>Baddeleyite 3.1. - 3.3<br>Thorianite 3<br>Chromite 2 to 3<br>Scheelite 1.4 - 1.5<br>Spinel 0.4 to 3<br>Barite 0.2 | Zircon 1.4-1.8 | Lepidocrocite 2.0-6.2<br>Titanite 1.3-2.0<br>Cassiterite 1.8-2.4<br>Cerussite 0.8-2.5<br>Malachite 0.2-1.3<br>Siderite 0.1-1.1<br>Calcite 0.0-0.2 |

Explanation:
3-5 means: minimal R-maximal R
3 to 5 means: R of mineral varies from 3 to 5% due to solid solutions
All R values above 10% are rounded

## 8.2. COLOUR IMPRESSION – REFLECTANCE – BR (WITH OIL IMMERSION)

### II. Minerals with WEAK colour impression (tint) in oil

| R | BR/Rpl not visible to very weak | BR/Rpl weak to distinct | BR/Rpl strong to extremely strong |
|---|---|---|---|
| > 50% | | Allargentum 59-59.5 | |
| 50-35% | Pararammelsb. 45-47<br>Skutterudite 39 to 41<br>Pentlandite 37<br>Cobaltite 36<br>Maucherite 35-36 | Bismuth 48-56<br>Dyscrasite 48-51<br>Cementite 40-42<br>Safflorite 39-40<br>Loellingite 38-41<br>Arsenopyrite 37-38<br>Arsenic 37-42 | |
| 35-25% | Ullmannite 33<br>Violarite 33 | Schapbachite 27-33<br>Teallite 28-29 | |
| 25-18% | Chalcocite 18 | Boulangerite 23-28<br>Emplectite 22-27<br>Bournonite 19-21 | Jamesonite 21-29 |
| 18-10% | Vaesite 17<br>Acanthite 15 to 16<br>Fahlore 15 to 17<br>Pyrostilpnite 14-15<br>Tiemannite 15<br>Kesterite 11-12 | Djurleite 16-17<br>Polybasite 15-17<br>Pearceite 14-17<br>Cuprite 12-13<br>Enargite 11-15<br>Stannoidite 11-14 | Nsutite 16-22<br>Miargyrite 16-18<br>Cinnabar 10-14<br>Orpiment 10-13 |
| 10-5% | Wuestite 7.0<br>Braunite 6.4-7.0<br>Magnetite 5 to 8<br>Tit-Magnetite 5 to 6<br>Pseudorutile ~ 7 | Realgar 6-8<br>Iscorite 5-6<br>Ferro-Columbite 5.0-5.4 | Hausmannite 4.8-7.4<br>Marokite 4.5-6.4<br>Valleriite 1.6-10.7<br>Graphite 0.5-15 |
| < 5% | Pitchblende 3 to 4<br>Pyrochlore 2 to 5 | Goethite 4.3-6.0 | Manganite 3.5-7.5 |

Explanation:
3-5 means: minimal R-maximal R
3 to 5 means: R of mineral varies from 3 to 5% due to solid solutions
All R values above 10% are rounded

## 8.3. COLOUR IMPRESSION – REFLECTANCE – BR (WITH OIL IMMERSION)

### III. Minerals with DISTINCT TO STRONG colour impression in oil

| R | BR/Rpl not visible to very weak | BR/Rpl weak to distinct | BR/Rpl strong to extremely strong |
|---|---|---|---|
| > 50% | Gold 72<br>Copper 57 | | |
| 50-35% | Pyrite 39 | Millerite 38-44<br>Marcasite 34-42 | Breithauptite 24-35 |
| 35-25% | Chalcopyrite 34 | Nickeline 33-38 | Berthierite 22-27 |
| 25-18% | Bravoite 20 | Pyrrhotite 23-28<br>Emplectite 22-27 | Cubanite 24-28<br>Mückeite 24<br>Stibnite 16-33 |
| 18-10% | Metacinnabar 11<br>Bornite 10<br>Maghemite 10 | Stephanite 14-15<br>Pyrargyrite 13-15<br>Stannite 13-14<br>Stannoidite 11-14<br>Proustite 10-13 | Sternbergite 11-23<br>Imiterite 13-17<br>Luzonite 12-14<br>Kermesite 11-15 |
| 10-5% | Digenite 8.6<br>Jacobsite 8<br>Bixbyite 9.3 | | Tenorite 7.6-13.1<br>Spionkopite 6.1-12.3<br>Yarrowite 1.8-11.1 |
| < 5% | | Wolframite 4.1-4.8 | Ilmenite 4.9-6.7<br>Covellite 0.9-9.9<br>Ilvaite 1-2 |

Explanation:
3-5 means: minimal R-maximal R
3 to 5 means: R of mineral varies from 3 to 5% due to solid solutions
All R values above 10% are rounded

## 8.4. CLASSIFICATION OF INTERNAL REFLECTIONS (IR) WITH EXAMPLES (IN OIL)

| | rare | occasional | frequent | abundant |
|---|---|---|---|---|
| **I. Red IR** | Boulangerite<br>Braunite<br>Hematite (coar-se-grained)<br>Tennantite<br>Pyrophanite<br>Jacobsite<br>Chalcophanite<br>Plagionite<br>Enargite | Livingstonite<br>Polybasite/Perceite<br>Sphalerite (Fe-rich)<br>Hausmannite<br>Manganite (bloodred)<br>Franklinite<br>Rutile (Fe-rich)<br>Wolframite<br>Miargyrite | Kermesite<br>Proustite<br>Hematite (fine-grained)<br>Rutile<br>Mn-Wolframite | Realgar (yellowred)<br>Cuprite (bloodred)<br>Getchellite (bloodred)<br>Cinnabar<br>Zincite (light red) |
| **II. Brown IR** | Cassiterite (Fe-rich)<br>Chromite (Mg-Al-)<br>Columbite (Fe-Nb-)<br>Sphalerite (Fe-rich)<br>Uraninite, Braunite | Hetaerolite | Hoegbomite<br>Lepidocrocite (brownish red)<br>Titanite (Fe-rich) | Goethite<br>Baddeleyite |
| **III. Orange IR** | Geikielite | | Rutile | Manganotantalite<br>Realgar |
| **IV. Yellow IR** | Geikielite | Hetaerolite | Titanite<br>Zincite<br>Sphalerite (Fe-poor)<br>Cassiterite (Fe-poor) | Greenockite<br>Orpiment<br>Pyrochlore |
| **V. Green IR** | | Alabandite<br>Sphalerite (yellow green) | Hercynite<br>Manganosite | Malachite |
| **VI. Blue IR** | | | | Azurite<br>Anatase (white blue)<br>Galaxite |
| **VII. White or colourless IR** | | | | Titanite<br>Rutile (Fe-free)<br>Scheelite, Zircon<br>Cassiterite (Fe-free)<br>Sphalerite (Fe-free) |

## 8.5. COMMON INTERGROWTHS OF SOME IMPORTANT MINERALS (HOST – GUESTS)

| Host | Guest |
|---|---|
| **Bornite** | Chalcopyrite, fahlore, linnaeite |
| **Braunite** | Hausmannite, hematite |
| **Cassiterite** | Rutile, ilmenite, columbite |
| **Chalcopyrite** | Sphalerite, cubanite, pyrrhotite, fahlore, bornite, stannite, mackinawite, chalcopyrrhotite, briartite, gallite, renierite |
| **Chalcocite** | Bornite, digenite, chalcopyrite |
| **Chromite** | Ilmenite, hematite, rutile, escolaite |
| **Cinnabar** | Metacinnabar |
| **Columbite** | Uraninite, ilmenite, rutile |
| **Corundum** | Hematite |
| **Cubanite** | Chalcopyrite |
| **Digenite** | Chalcopyrite, bornite, covellite |
| **Fahlore** | Chalcopyrite |
| **Galena** | Schapbachite, tetradymite, argentite, polybasite, cosalite, ... |
| **Graphite** | Molybdenite |
| **Hematite** | Ilmenite, corundum |
| **Hausmannite** | Jacobsite |
| **Ilmenite** | Hematite, rutile, corundum, spinel, magnetite |
| **Jacobsite** | Hausmannite |
| **Linneite** | Chalcopyrite, millerite |
| **Magnetite** | Ilmenite, hematite, hercynite, ulvite, spinel, geikielite |
| **Pentlandite** | Chalcopyrite, linnaeite, mackinawite |
| **Pyrrhotite** | Pentlandite, chacopyrite, cubanite, mackinawite |
| **Rutile** | Hematite, ilmenite, cassiterite |
| **Sphalerite** | Chalcopyrite, pyrrhotite, fahlore, stannite, mackinawite |
| **Spinel** | Magnetite, ilmenite |
| **Stannite** | Sphalerite, chacopyrite, cubanite, fahlore, stannoidite |

## 8.6. IMPORTANT PROPERTIES OF COMMON GANGUE MINERALS

| Gangue | $R_{air}/R_{oil}$ [%] | Optical properties | Other properties |
|---|---|---|---|
| | **calculated from n** | **IR: Internal reflections**<br>**BR: Bireflection** | **#: cleavage**<br>**XX: crystals** |
| **Calcite** | 4-6/0.0-0.3 | strong BR, white IR | #! polysynth. twinning |
| **Siderite** | 5-9/0.1-1.1 | extremly strong BR | #; common alteration to iron-oxihydroxides |
| **Quartz** | 4.6/0 | no BR, white IR | no #; many flincs! Hardness |
| **Feldspar** | 4.3 to 4.8/0 | unclear, many IR | #; with alteration minerals (clays) |
| **Mica** | 5 to 7/0 to 0.2 | BR; biotite: brown IR | # after one direction, tabular, bladed |
| **Kaolinite, clay minerals** | 5/0 to 0.3 | often »opaque«-like appearance | very fine flakes |
| **Garnet** | 6 to 9/0.4 to 1.2 | yellow-brown IR | no #, isometric habit, VHN |
| **Amphibole/ Pyroxene** | 5 to 7/0.1 to 0.3 | greenish-brown IR | typ. # |
| **Olivine** | 6 to 8/0.2 to 0.7 | colourless, no BR | no #, occ. with spinels |
| **Fluorite** | 3.2/0 | one of the darkest minerals, in part violet | # {111}, many flincs |
| **Barite** | 5.9/0.1 | no BR | # (001), tabular XX |

## 8.7. FORM, HABIT, TEXTURES (PHOTOS SHOWING THE CHARACTERISTIC FEATURES)

| Feature | Photo number |
|---|---|
| **Habit, form of grains** | |
| Isometric habit: cubic, octaedric, granular, rounded | 49, 77,105, 117, 120, 184, 195, 269, 308, 429, 439, 444, 511, 512, 551 |
| Twodimensional habit: tabular, bladed, elongated, flaky | 24, 37-40, 44, 45, 121, 133, 221, 222, 237, 361, 389, 545, 553 |
| Onedimensional habit: prismatic, acicular, needle-shaped, fibrous | 16, 41, 69, 83, 205, 281, 284, 325, 534 |
| Skeletal | 52, 55, 261, 265, 319, 403, 499, 585, 587 |
| Spherulitic (spheroidal), radial | 29, 207, 277, 289, 326, 338, 445, 472, 589 |
| Concentrically banded | 164, 233, 293, 295, 513-516, 563 |
| Botryoidal-reniform (collomorph) | 21, 92, 185, 189, 375, 405-408, 431, 433 |
| Oolitic | 88, 465 |
| Feathery-flowery | 334 |
| Zoned grains | 78, 90, 113, 268, 316, 323, 324, 402, 432, 441, 488, 510, 516, 522, 563, 599 |
| Growth twins | 33, 49, 89, 137, 155, 225, 275, 297, 481, 485, 486, 508 |
| **Cooling features (exsolution bodies and inversion twinning)** | |
| Lamellar EB (discs, oleander leaf, plates) | 139, 145, 148, 236, 241, 242, 244, 247, 251, 313, 388, 484 |
| Irregular, dispersed EB | 5, 194, 313, 409, 459, 525 |
| Myrmekitic-graphic EB | 67, 98 |
| Star-like, flame-like EB | 398, 399 |
| Inversion twinning | 66, 69, 75, 76, 100, 104 |
| **Intergrowth textures** | |
| Ophitic, intersertal, interlocked | 231, 395, 450,, 497, 591 |
| Myrmekitic, symplectitic | 121,168, 190, 513, 519, 548 |
| Poikiloblastic (sieve-like, idioblastic) | 87, 167, 184, 308, 400, 439, 441, 494, 509 |
| Disseminated | 102, 291 |
| Rimmed | 511, 512 |
| Amoeboid | 279 |
| Spongy cellular/boxy cellular | 139, 140, 497 |
| Atoll-like | 105, 106 |

| | |
|---|---|
| **Replacement textures** | |
| Filiform, graphic | 93, 128, 272, 305, 355, 453, 539 |
| Cellular, island shaped, boxwork | 97, 107, 198, 349, 359, 403, 404, 466, 537, 538 |
| Skeleton-shaped | 55 |
| Cusp-and-caries | 11, 12, 31, 65, 185, 571 |
| Lamellar (along cleavage or crystal planes) | 15, 86, 92, 95, 156, 191, 229, 317, 322, 372, 454, 495, 521, 536, 541, 555, 561, 565, 571 |
| Zonal | 432, 502, 504 |
| Atoll-like | 438 |
| Cement-shaped | 200, 312 |
| Pseudomorph | 135, 208, 238, 331, 420, 422, 424, 440, 447, 448, 460, 479, 573, 595 |
| **Deformation-related textures** | |
| Cataclastic, brecciated, broken | 50, 69, 107, 108, 203, 235, 348, 437, 468, 529 |
| Translation lamellae, pressure twins | 85, 103, 134, 179, 239, 240, 249, 370, 452, 533 |
| Bending | 177, 361, 456 |
| Planar alignment | 221, 222 |

# PART B

# MINERAL PROFILES AND PHOTOMICROGRAPHS OF COMMON ORE AND GANGUE MINERALS

# Acanthite/Argentite (in German: Silberglanz)

**Mineral name:** Acanthite/Argentite
**Formula:** $Ag_2S$
**VHN:** 20-60
**Crystal System:** mcl. (cub.)

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 30.4 | $R_2$ = 31.2 | $R_{(air)}$ after[1] |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = ~15 | $R_2$ = ~16 | $R_{(oil)}$ estimated |
| **Colour impression** | **(in oil)** | greyish white<br>tint olive | greyish white | |
| **BR ~ Rpl** | **(in oil)** | weak | | $A_{oil}$ = 6 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | weak without colour | weak with colour tint |
| **Colour:** | **in 45° position** | grey | grey tint violet – greyish olive brown |
| | **... in other positions** | grey tint brown | olive brown – greyish violet |
| **Extinction position** | | impure, brownish black | |
| **Mode of extinction** | | imperfect due to many scratches | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | argentite – acanthite: complex lamellar to irregular twinning | |
| | **frequency** | always, when inversion from argentite, missing in formation at T < 179°C | |

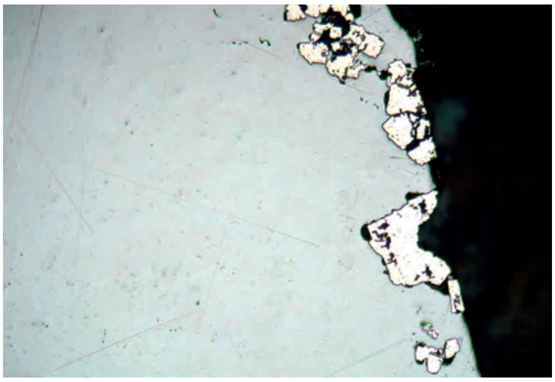
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | euhedral crystals, polygonal aggregates, earthy to spongy masses, as exsolution bodies \|\| {100} in galena; very soft |
| **Paragenesis** | silver, gn, fahlore, proustite, pyrargyrite, uraninite, py, cp, cv, sph, cerussite |
| **Diagniostic features** | rapid tarnishing, many scratches |

## Notes, drafts

[1] after Uytenbogaardt & Burke (1985).
Inversion from the high-temperature modification argentite at 179°C forms twinned acanthite.
Untwinned acanthite crystallizes below 179°C.
BR and AExPol are more distinct after some time of light etching!

## 1 **Acanthite, pyrite –** Gnade Gottes (prob. near Brod), Bohemia, Czech Republic



Acanthite aggregate (light grey) beside small pyrites.

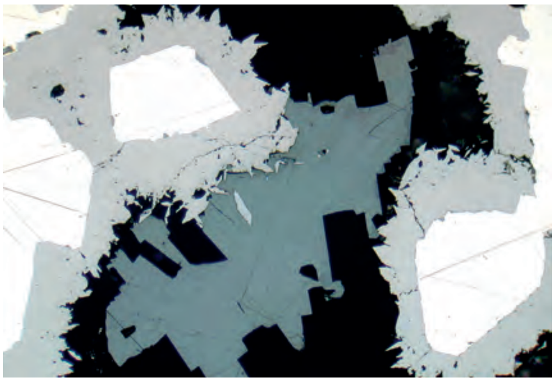
Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D120_01
Section: AS1063

## 2 **Acanthite, pyrite –** Gnade Gottes (prob. near Brod), Bohemia, Czech Republic

As above, with crossed polars (but not exactly crossed) showing complex twinning of acanthite due to inversion from the cubic high temperature modification argentite.

Obj.: 10 ×
Polars: × Pol (~)
Photo width: 1.4 mm
Photo No.: D120_02
Section: AS1063

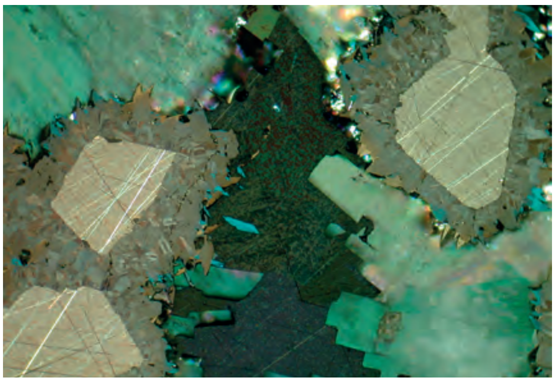
## 3 **Acanthite, silver, ram, lo –** Nieder-Beerbach, Odenwald, Germany



Acanthite (medium grey) between silver crystals (white), which are surrounded by rammelsbergite and loellingite (both light grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D184_22
Section: MB25

## 4 **Acanthite, silver, ram, lo –** Nieder-Beerbach, Odenwald, Germany



As above, with crossed polars. Note the light AExPol of silver due to numerous tiny scratches.

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D184_23
Section: MB2

# Alabandite (in German: Alabandin)

**Mineral name:** Alabandite
**Formula:** MnS

**VHN:** 240
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | R = 22.3 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | R = 8.8 | |
| **Colour impression** | **(in oil)** | grey | against sph: lighter grey |
| **BR Rpl** | **(in oil)** | -- | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | in each position dark | |
| **Colour:** | **in 45° position** | black | |
| | **... in other positions** | black | |
| **Extinction position** | | black | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | yellow green - olive green | |
| **(IR)** | **frequency** | common - frequent | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

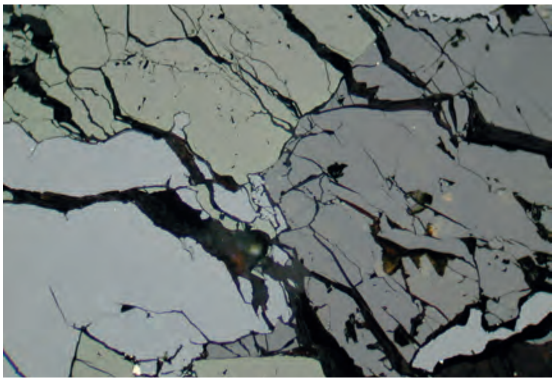
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | EB of po, cp, mackinawite |
| **Paragenesis** | jacobsite, sphalerite, chalcopyrite, mackinawite |
| **Diagniostic features** | green IR, EB |

## Notes, drafts

Rare mineral! Similar to SPHALERITE!

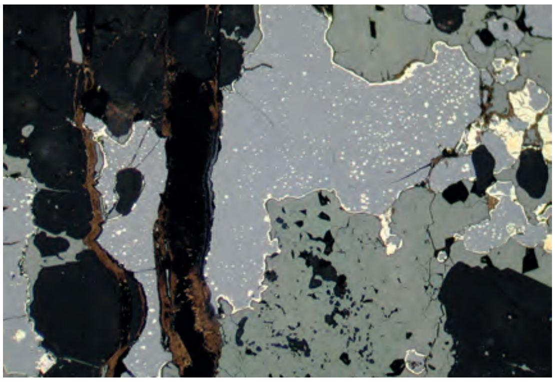
## 5 Alabandite, jacobsite, sph – Noda Tamagawa, Japan



Grain of alabandite (left, light grey) with sphalerite (right, medium grey), and jacobsite (upper part, olive).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D13_13
Section: AS215

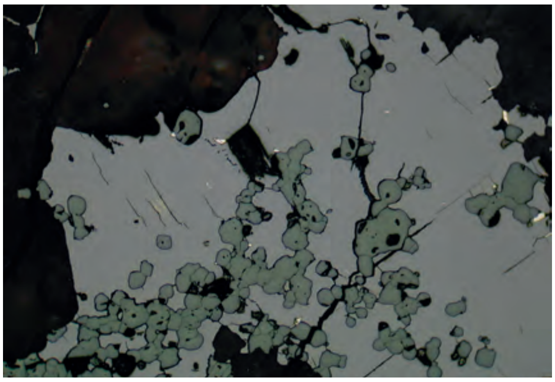
## 6 Alabandite, jacobsite, cp, valleriite – Noda Tamagawa, Japan



Alabandite with tiny EB of chalcopyrite, surrounded by jacobsite (olive to green). Younger veinlets of valleriite (bronze).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D13_14
Section: AS215

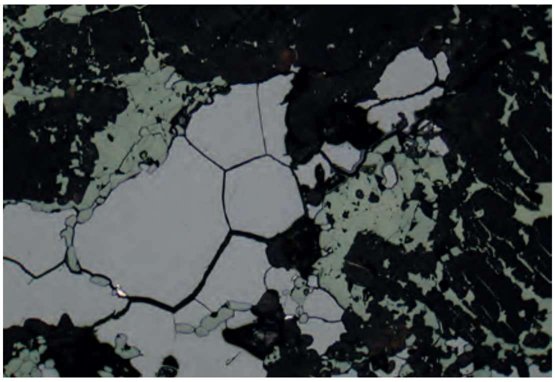
## 7 Alabandite, jacobsite – Noda Tamagawa, Japan



Alabandite (grey) with good cleavage and light yellow green IR; small grains of jacobsite (green).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D103_05
Section: AS214

## 8 Alabandite, jacobsite – Noda Tamagawa, Japan



Equigranular alabandite grains (light grey) surrounded by jacobsite (green), which replaces garnet (nearly black).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D103_03
Section: AS214

# Allargentum

**Mineral name:** Allargentum
**Formula:** $Ag_6Sb$

**VHN:** 170-200
**Crystal System:** hex.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1 = 69.5$ | $R_2 = 70.9$ | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1 \sim 59$ | $R_2 \sim 59.5$ | $R_{(oil)}$ estimated |
| **Colour impression** | **(in oil)** | yellowish white | yellowish white | rapid tarnishing |
| **BR ~ Rpl** | **(in oil)** | weak | | $A_{oil} = 1$ |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | distinct without colour | strong with colour |
| **Colour:** | **in 45° position** | light grey | greyish brown |
| | **... in other positions** | brown | orange yellow - blue - purple |
| **Extinction position** | | bluish black | |
| **Mode of extinction** | | straight | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | lamellar after one or two direction; partly spindle-like | |
| | **frequency** | frequent | |

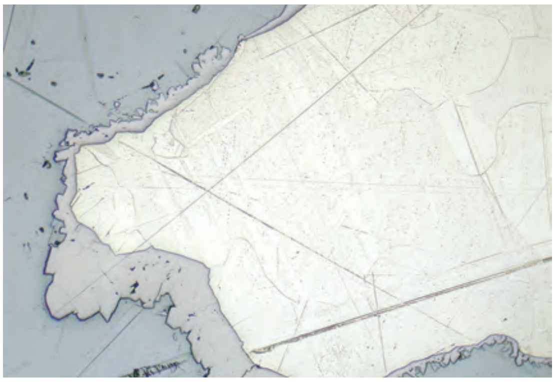
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | equigranular, colloform; spindle-shaped EB of silver, overgrown by gersdorffite or loellingite; irregular fractures, no # (hackly/jagged fracture) |
| **Paragenesis** | native silver, dyscrasite, gersdorffite, loellingite |
| **Diagniostic features** | AExPol, no #, rapid tarnishing, paragenesis, many scratches |

## Notes, drafts

Occasional with low As-content. Similar to SILVER and DYSCRASITE.

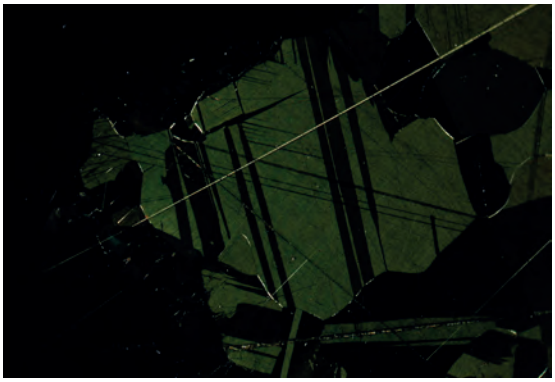
## 9 Allargentum, loellingite, galena – Wenzel mine, Schwarzwald, Germany



Massive allargentum (centre with twinned grains, BR) with thin rim of loellingite in groundmass of galena (grey, left part of photo).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D185_16
Section: SSW16

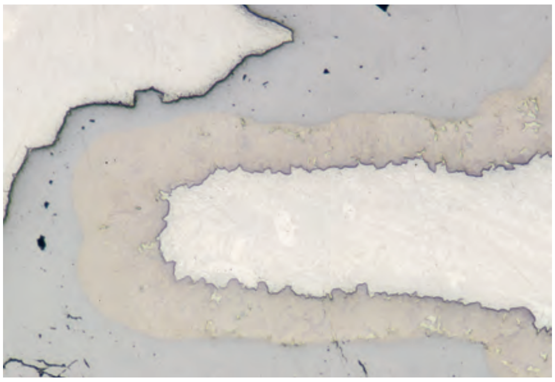
## 10 Allargentum, loellingite, galena – Wenzel mine, Schwarzwald, Germany



As above with crossed polars. Lamellar twinning of allargentum is clearly visible.

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D185_17
Section: SSW16

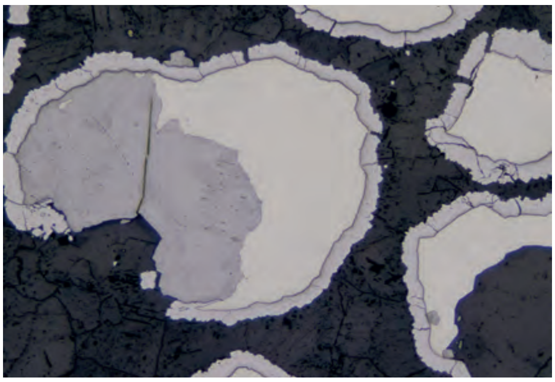
## 11 Allargentum, breithauptite, nk – Wenzel mine, Schwarzwald, Germany



Replacement of allargentum (centre to right side of photo, lamellar twinning, weak BR) by mixture of breithauptite (through Sb-diffusion in direct contact to allargentum, more violet than nickeline) plus nickeline (shades of orange); gersdorffite (light grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: 84_07
Section: Wenzel17

## 12 Allargentum, galena, calcite – Wenzel mine, Schwarzwald, Germany



Round aggregates of allargentum with gersdorffite rim (light grey) in part replaced by galena (medium grey) and calcite (dark grey).

Obj.: 2,5 × oil
Polars: || Pol
Photo width: 3.8 mm
Photo No.: 85_02
Section: Wenzel5

# Amphibole

**Mineral name:** Amphibole
**Formula:** $Ca_2(Mg,Fe)_5[(OH)_2|Si_8O_{22}]$

**VHN:**
**Crystal System:** mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_x \sim 5.9$ | $R_z \sim 6.6$ | calculated from $n_x$, $n_z$ |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_x \sim 0.2$ | $R_z \sim 0.3$ | calculated from $n_x$, $n_z$ |
| **Colour impression** | **(in oil)** | »black« (but light IR!) | »black« (but light IR!) | |
| **BR ~ Rpl** | **(in oil)** | very weak – weak | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | not visible | not visible |
| **Colour:** | **in 45° position** | masked by IR | masked by IR |
| | **... in other positions** | | |
| **Extinction position** | | masked by IR | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | greenish, brownish, rare bluish | |
| **(IR)** | **frequency** | common | |
| **Twinning** | **mode** | none | |
| | **frequency** | -- | |

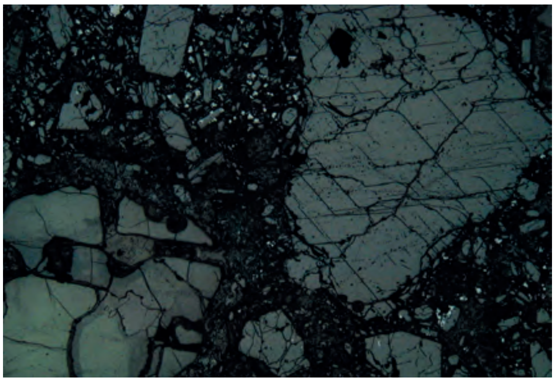
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | granular to euhedral XX, good # (amphibole-typical) |
| **Paragenesis** | cpx, ol, feldspar, qz, mt, po, ... |
| **Diagniostic features** | low R, amphibole-typical # |

## Notes, drafts

Optical properties are varying with composition!

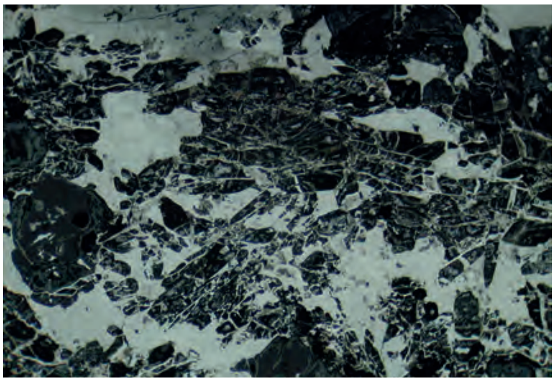
## 13 Amphibole, olivine – Bürzlen, Urach volcanic field, SW-Germany



Amphibole crystal (with perfect #) and broken olivine grains (lower left part, without #) in olivine nephelinite.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D56_28
Section: Xeno5

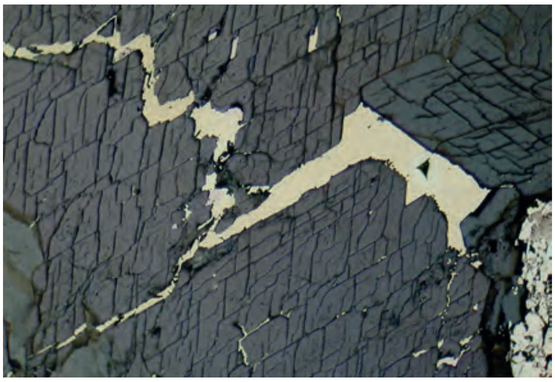
## 14 Amphibole, garnet, manganomelane – Ungwan Mallam Ayuba, Nigeria



Groundmass of garnet and amphibole crystals (with #) is replaced by fine-grained manganomelane, lithiophorite, and limonite (white to medium grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D152_27
Section: AS238

## 15 Amphibole, cp, po – Horbach, Schwarzwald, Germany



Chalcopyrite and minor pyrrhotite replacing amphibole crystal along cleavage planes and fractures.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D196_22
Section: AS3197

## 16 Crocidolite, qz, mt, hm – BIF from Hamersley Range, Australia

Quartz with asbestiform crocidolite and euhedral magnetite (partly with hematite).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D107_24
Section: S1197A

# Anatase

**Mineral name:** Anatase (ant)
**Formula:** $TiO_2$
**VHN:** 600-700
**Crystal System:** tetr.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o = 19.5$ | $R_e = 19.1$ | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o = 6.8$ | $R_e = 6.6$ | |
| **Colour impression** | **(in oil)** | grey | grey | many IR! |
| **BR > Rpl** | **(in oil)** | very weak | | $A_{oil} = 3$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | very weak | very weak |
| **Colour:** | **in 45° position** | masked by IR | masked by IR |
| | **... in other positions** | | |
| **Extinction position** | | -- | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | colourless, bluish white | |
| **(IR)** | **frequency** | predominant | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

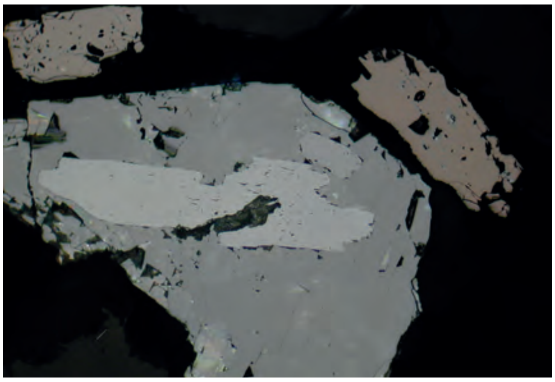
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | euhedral to anhedral, rounded grains; usually small. Intergrown with rutile and pseudobrookite, replaces ilmenite |
| **Paragenesis** | ilmenite, rutile, hematite, magnetite, biotite |
| **Diagniostic features** | IR; similar to rutile (but rutile has strong BR and $R_e > R_o$) |

## Notes, drafts

Similar to SPHALERITE (which has a sulfide paragenesis) and RUTILE (see under rutile, p. 262).

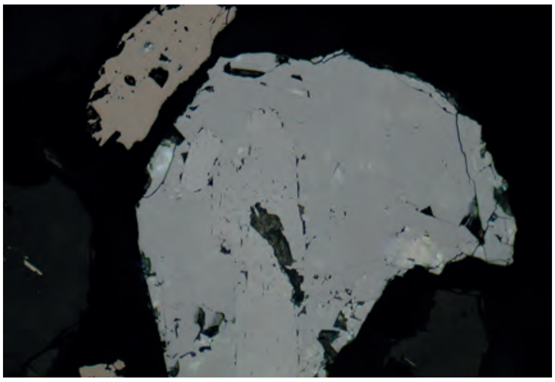
## 17 **Anatase, rutile, ilmenite –** Placer near Neualbenreuth, Oberpfalz, Germany



Rutile crystals (light grey) surrounded and partly replaced by anatase (medium grey), two elongated ilmenite grains (brown).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D110_01
Section: AS140

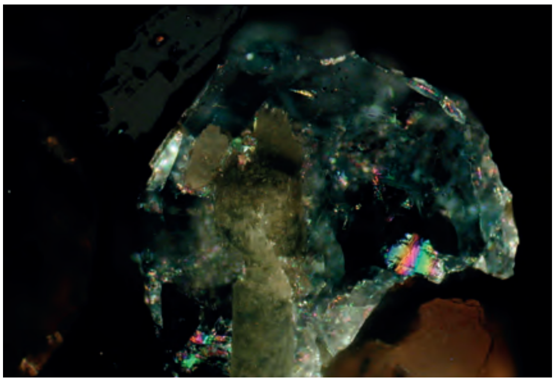
## 18 **Anatase, rutile, ilmenite –** Placer near Neualbenreuth, Oberpfalz, Germany



As above, now 90° rotated. Note reflectance of rutile now equals reflectance of anatase.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D110_02
Section: AS140

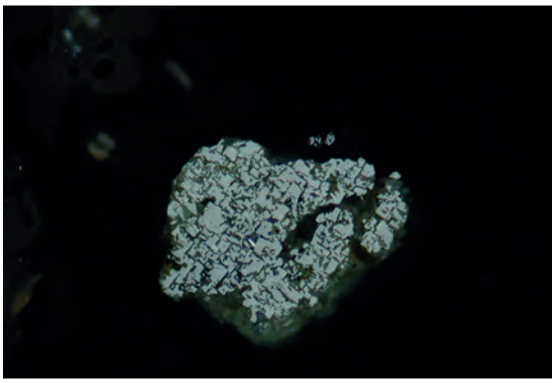
## 19 **Anatase, rutile, ilmenite –** Placer near Neualbenreuth, Oberpfalz, Germany



As above, with crossed polars. Anatase with colourless to bluish internal reflections in contrast to rutile with yellow IR.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D110_07
Section: AS140

## 20 **Anatase –** Placer near Neualbenreuth, Oberpfalz, Germany



Fine-grained aggregate of anatase pseudomorph after unknown phase.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D109_28
Section: AS140

# Arsenic (in German: ged. Arsen)

**Mineral name:** Arsenic
**Formula:** As

**VHN:** 70-170
**Crystal System:** trig.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 55.7 | $R_{e'}$ = 51.6 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 42.1 | $R_{e'}$ = 37.1 | |
| **Colour impression** | **(in oil)** | white (tint yellow) | white tint blue | against galena: cream |
| **BR ~ Rpl** | **(in oil)** | distinct | | $A_{oil}$ = 12 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong with colour tint | strong with colour tint |
| **Colour:** | **in 45° position** | yellowish brown | light grey – yellowish grey |
| | **... in other positions** | | dark grey |
| **Extinction position** | | black | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | complex to lamellar twinning, pressure-twin lamellae | |
| | **frequency** | frequent | |

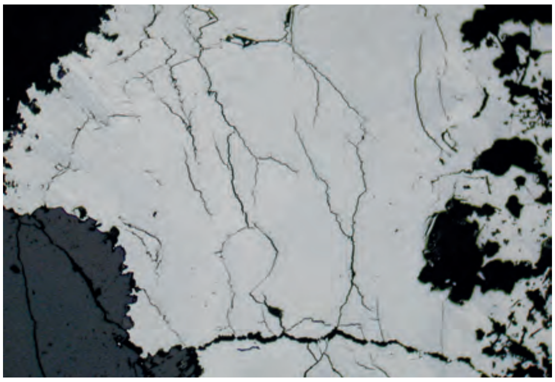
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | fine- to coarse-grained aggregates, in colloform bands, plume- or sheaf-like crystals; perfect basal cleavage \|\| (0001) |
| **Paragenesis** | wurtzite, skutterudite, rammelsbergite, bismuth, silver, arsenopyrite, ... |
| **Diagniostic features** | very rapid tarnishing to blue and brown! |

## Notes, drafts

The strong tarnishing cannot be rubbed off with paper (only wet polishing with MgO); after months or years most of the arsenic is altered and completely destroyed! For taking photomicrographs you can use only fresh polished section (don't wait more than 2-3 days!).
Position with CI = white tint blue and minimum R is not $R_o$ as noted in Criddle & Stanley!

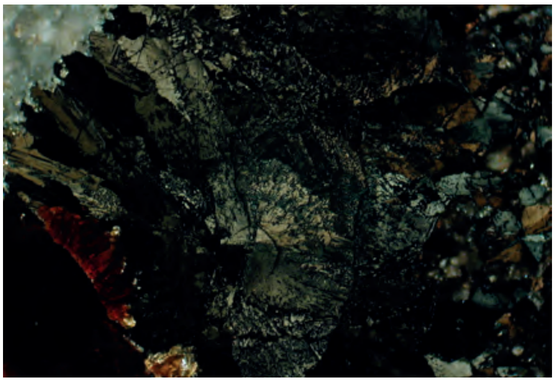
## 21 **Arsenic, wurtzite –** Michael im Weiler, near Lahr, Schwarzwald, Germany



Colloform aggregate of arsenic with coarse-grained outer part (in this area with visible BR). Lower left side of photo: wurtzite (dark grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D112_04
Section: L-4

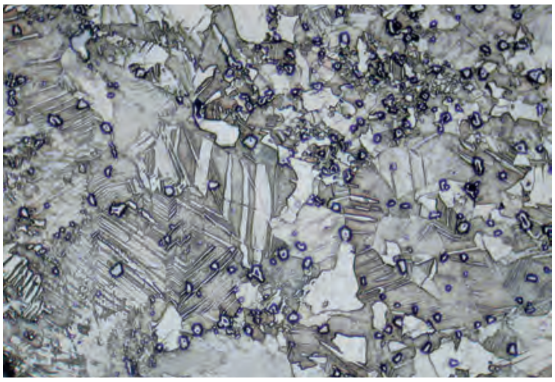
## 22 **Arsenic, wurtzite –** Michael im Weiler, near Lahr, Schwarzwald, Germany



As above, with crossed polars.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D112_02
Section: L-4

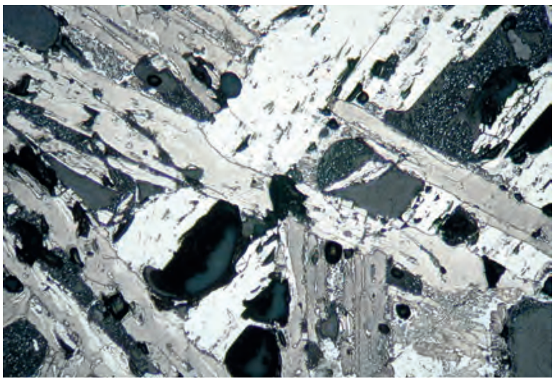
## 23 **Arsenic, allargentum –** Nieder-Beerbach, Odenwald, Germany



Lamellar twinned grains of arsenic showing bireflection and relief due to light etching and strong, repeated polishing. Small inclusions of kutinaite ($Ag_6Cu_{17}As_7$) plus allargentum with high relief.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D165_27
Section: CHe12

## 24 **Arsenic –** Slag from Wiesloch, Baden, Germany



Ophitic network of arsenic laths in an artificial slag.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D46_03
Section: 15S9A

# Arsenopyrite (in German: Arsenkies)

**Mineral name:** Arsenopyrite (asp)
**Formula:** FeAsS
**VHN:** 760-1200
**Crystal System:** mcl./tric.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in % (for 546 nm)** | $R_a$ = 52.3 | $R_b$ = 51.9 | $R_c$ = 51.9 |
| **$R_{(oil)}$ in % (for 546 nm)** | $R_a$ = 37.6 | $R_b$ = 37.3 | $R_c$ = 37.2 |
| **Colour impression (in oil)** | white tint yellow | white tint cream | white tint bluish |
| **BR < Rpl (in oil)** | weak to distinct | | $A_{oil}$ = 1 |

## Observations with crossed polars (AExPol in oil)

| | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|
| **Anisotropism intensity/colour** | very weak with colour | distinct with colour |
| **Colour: in 45° position** | bluish grey | yellow brown - turquoise blue |
| **... in other positions** | grey, bluish | reddish brown |
| **Extinction position** | grey black | olive black |
| **Mode of extinction** | incomplete without colour | |
| **Internal reflections (IR) colour** | -- | |
| **frequency** | -- | |
| **Twinning mode** | complex (lamellar twinning in two directions; domains) | |
| **frequency** | very common | |

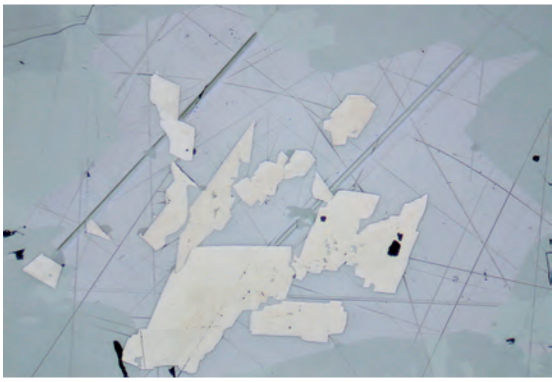
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | very common as euhedral, rhomb-shaped crystals, often with strong relief to other sulfides; no #, but abundant cataclastic fractures |
| **Paragenesis** | pyrite, gold, gn, sph, po, and many more |
| **Diagniostic features** | grain shape, AExPol (»Felderteilung«, domain formation), cataclasis, hardness |

## Notes, drafts

Very variable As:S-ratio from 1.22 to 0.82!
As-rich phases are monoclinic (ps.orh.); others: triclinic!
Similar minerals: LOELLINGITE, SAFFLORITE, PYRITE, MARCASITE

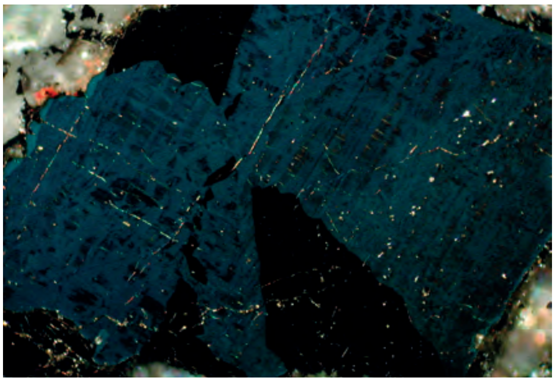
## 25 **Arsenopyrite, galena, geocronite** – Sala, Västmanland, Sweden



Typical rhomb-shaped crystals of arsenopyrite crystals in galena (grey white) and geocronite (greenish grey, outer parts of photo). Note the varying intensity of scratches in the three minerals due to different hardness.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D22_29
Section: AS2877

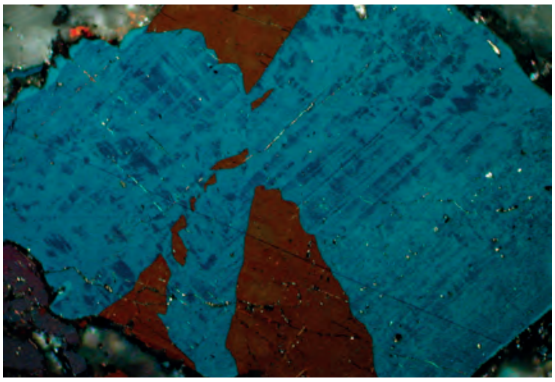
## 26 **Arsenopyrite** – Hällefors, Sweden



Weak anisotropism of arsenopyrite under perfect crossed polars. Intensity varies due to »Felderteilung« (probably caused by different As/S ratio).

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.5 mm
Photo No.: D219_25
Section: AS101

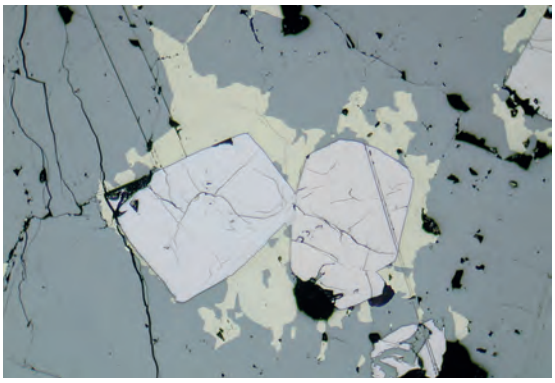
## 27 **Arsenopyrite** – Hällefors, Sweden



As above, but here with slightly uncrossed polars: arsenopyrite exhibits distinct anisotropism with brownish yellow and turquoise blue colours.

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.5 mm
Photo No.: D219_28
Section: AS101

## 28 **Arsenopyrite, cp, tnt** – Bräunsdorf, Saxony, Germany



Rhomboidal crystals of arsenopyrite with distinct reflection pleochroism (white – white tint yellow) in chalcopyrite (light yellow), and tennantite (grey). Note the cataclastic fractures of arsenopyrite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D130_05
Section: AS1745

# Azurite

**Mineral name:** Azurite (az)
**Formula:** $Cu_3[OH \mid CO_3]_2$

**VHN:** ~160
**Crystal System:** mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 7.1 | $R_2$ = 8.6 | calculated from n |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 0.4 | $R_2$ = 0.9 | calculated from n |
| **Colour impression** | **(in oil)** | grey (with blue IR) | grey (with blue IR) | |
| **BR > Rpl** | **(in oil)** | strong | | $A_{oil}$ = 77 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong | strong |
| **Colour:** | **in 45° position** | masked by IR | masked by IR |
| | **... in other positions** | | |
| **Extinction position** | | -- | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | deep blue | |
| **(IR)** | **frequency** | predominant | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

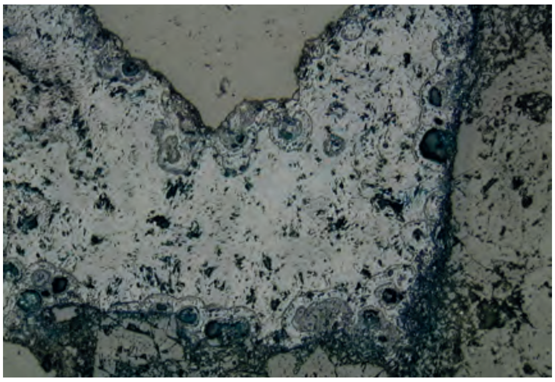
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | tabular, spherical to radial fibrous aggregates |
| **Paragenesis** | fahlore, luzonite, enargite, malachite |
| **Diagniostic features** | blue IR, BR |

## Notes, drafts

Azurite forms almost exclusively from fahlore, enargite, and luzonite.

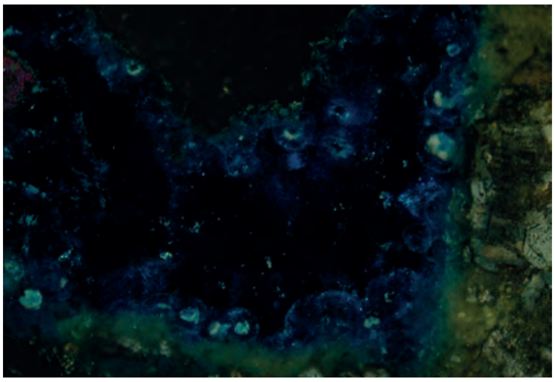
## 29 **Azurite, qz –** Ühlingen, Waldshut, Schwarzwald, Germany



Spherical aggregates of azurite (light grey) pore filling between quartz (medium grey) in Buntsandstein.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D80_11
Section: DK1

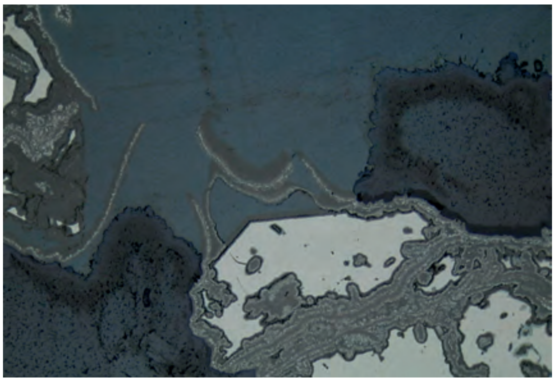
## 30 **Azurite, qz –** Ühlingen, Waldshut, Schwarzwald, Germany



As above, with crossed polars; showing blue IR of azurite.

Obj.: 10 ×
Polars: × Pol
Photo width: 1.4 mm
Photo No.: D80_12b
Section: DK1

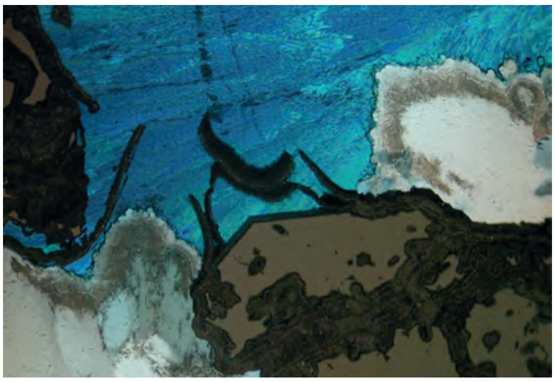
## 31 **Azurite, tennantite –** Neubulach, Schwarzwald, Germany



Alteration of tennantite (light grey) by different secondary copper minerals (various shades of grey, chalcocite, covellite, ...), which are themselves replaced by youngest azurite (grey with light blue internal reflections).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D176_27
Section: JH3

## 32 **Azurite, tennantite –** Neubulach, Schwarzwald, Germany



As above, now with crossed polars.

Obj.: 10 × oil
Polars: × Pol
Photo width: 1.4 mm
Photo No.: D176_26
Section: JH3

# Baddeleyite

**Mineral name:** Baddeleyite
**Formula:** $ZrO_2$

**VHN:** ~1100
**Crystal System:** mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 13.4 | $R_2$ = 13.7 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 3.1 | $R_2$ = 3.3 | |
| **Colour impression** | **(in oil)** | grey | grey | |
| **BR > Rpl** | **(in oil)** | weak | | $A_{oil}$ = 6 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | weak without colour | weak without colour |
| **Colour:** | **in 45° position** | grey | grey |
| | **... in other positions** | masked by IR | masked by IR |
| **Extinction position** | | masked by IR | |
| **Mode of extinction** | | masked by IR | |
| **Internal reflections** | **colour** | yellow brown to dark brown | |
| **(IR)** | **frequency** | predominant | |
| **Twinning** | **mode** | simple, and polysynthetic deformation twins after more than one direction | |
| | **frequency** | common | |

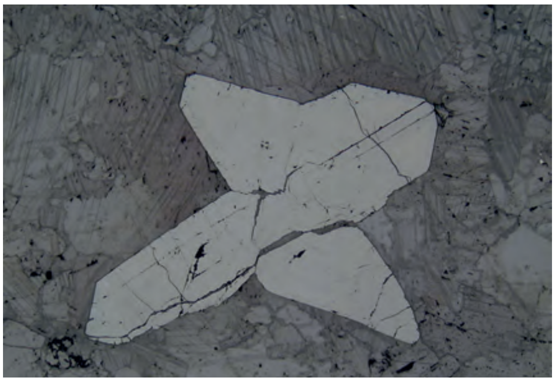
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | botryoidal and colloform masses, tabular crystals after {100}, cleavage || {001} (then parallel elongation of XX). Replacement by zirkelite. |
| **Paragenesis** | mt, zirconolith, zirkelite, apatite, carbonates, valleriite, serpentine |
| **Diagniostic features** | paragenesis |

## Notes, drafts

CI often with tint yellow due to IR.
Zirkelite ($(Ca,Th,Ce)Zr(Ti,Nb)_2O_7$) is slightly darker and shows red brown IR

## 33 **Baddeleyite, carbonate –** Carbonatite Pit, Phalaborwa, RSA



Baddeleyite twin within carbonate groundmass.

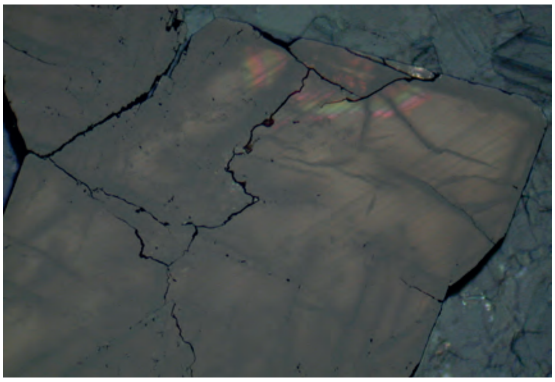
Obj.: 5 ×
Polars: || Pol
Photo width: 2.8 mm
Photo No.: D195_17
Section: SL 98

## 34 **Baddeleyite, carbonate –** Carbonatite Pit, Phalaborwa, RSA

As above with crossed polars.

Obj.: 5 ×
Polars: × Pol
Photo width: 2.8 mm
Photo No.: D195_18
Section: SL 98

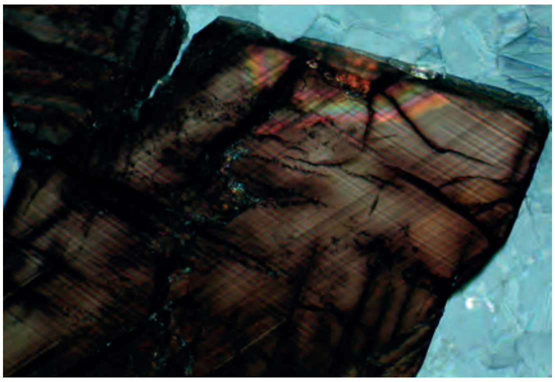
## 35 **Baddeleyite, carbonate –** Carbonatite Pit, Phalaborwa, RSA



Euhedral baddeleyite with visible internal reflections and fine lamellar twinning.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D195_24
Section: SL 98

## 36 **Baddeleyite, carbonate –** Carbonatite Pit, Phalaborwa, RSA



As above with crossed polars. Fine lamellar twinning after two directions.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D195_23
Section: SL 98

# Barite (in German: Baryt, Schwerspat)

**Mineral name:** Barite (bar)
**Formula:** $BaSO_4$

**VHN:** ~170
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_a = R_b = 6.0$ | $R_c = 5.8$ | calculated from n |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_a = R_b = 0.2$ | $R_c = 0.2$ | calculated from n |
| **Colour impression** | **(in oil)** | black (but light IR!) | black (IR!) | |
| **BR ~ Rpl** | **(in oil)** | -- | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

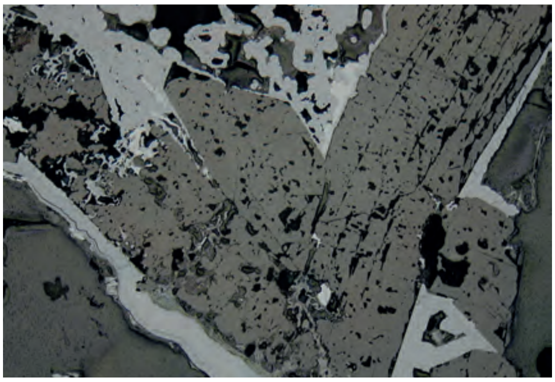
| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | not visible | not visible |
| **Colour:** | **in 45° position** | masked by IR | masked by IR |
| | **... in other positions** | | |
| **Extinction position** | | masked by IR | |
| **Mode of extinction** | | masked by IR | |
| **Internal reflections** | **colour** | white - colourless | |
| **(IR)** | **frequency** | predominant | |
| **Twinning** | **mode** | none | |
| | **frequency** | -- | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | large, tabular XX, perfect cleavage \|\| (001) |
| **Paragenesis** | fluorite, qz, gn, sph, py, hm, ... |
| **Diagniostic features** | #, tabular habit, no BR |

## Notes, drafts

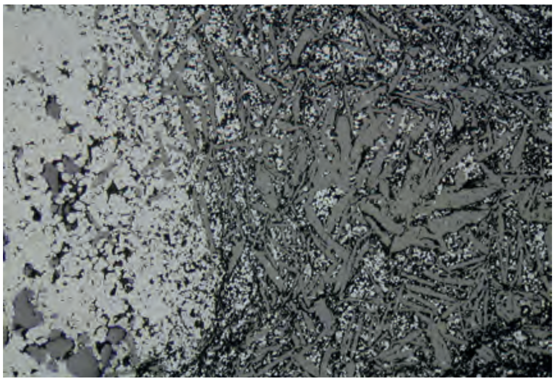
## 37 Barite, goethite, hematite – Otto mine near Schottenhöfe, Schwarzwald,Germany



Plates of barite (medium grey, cleavage) overgrown by hematite (light grey) and goethite (slightly darker than hematite).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D69_22
Section: AS3248

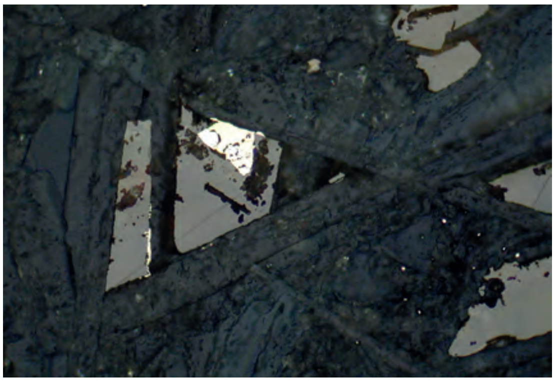
## 38 Barite, quartz, sph – Prominent Hill, SE Coober Pedy, S-Australia



Barite plates (medium grey) intergrown with sphalerite (light grey); some quartz grains in sphalerite.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D67_13
Section: AS3598

## 39 Barite, sph, py, cp – Bleiche, Waldshut, Schwarzwald, Germany



Barite plates (dark grey with various IR) enclosing sphalerite (light grey), pyrite, and chalcopyrite (nearly white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D79_26
Section: DK-14

## 40 Barite, lm, mn-oxides – Otto mine near Schottenhöfe, Schwarzwald, Germany

Barite plate (dark with IR) with younger botryoidal limonite (medium grey, partly with brown IR) and feathery manganomelane (light grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D69_28
Section: AS3248

# Berthierite

**Mineral name:** Berthierite
**Formula:** $FeSb_2S_4$
**VHN:** 100-200
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 36.6 | $R_2$ = 42.0 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 21.6 | $R_2$ = 26.8 | $R_2$ \|\| elongation [001] |
| **Colour impression** | **(in oil)** | brownish pink | greyish white | |
| **BR < Rpl** | **(in oil)** | strong | | $A_{oil}$ = 22 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong without colour | strong with colour tint |
| **Colour:** | **in 45° position** | greyish white (impure) | tint turquois - white |
| | **... in other positions** | | brownish grey, bluish grey |
| **Extinction position** | | black | |
| **Mode of extinction** | | straight, undulatory | |
| **Internal reflections** | **colour** | --- | |
| **(IR)** | **frequency** | | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

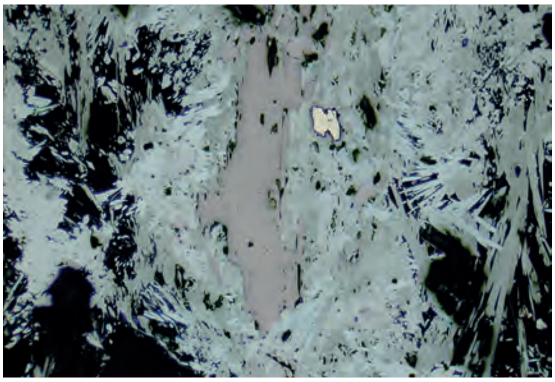
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | tabular-needle-like XX, fibrous, in part oriented intergrown with or replaced by stibnite; decomposition into pyrite+stibnite. # is not visible. |
| **Paragenesis** | stibnite, po, py, asp, cp, gudmundite |
| **Diagniostic features** | CI, paragenesis |

## Notes, drafts

$R_1$ is similar to PYRRHOTITE (but more dark brown)!

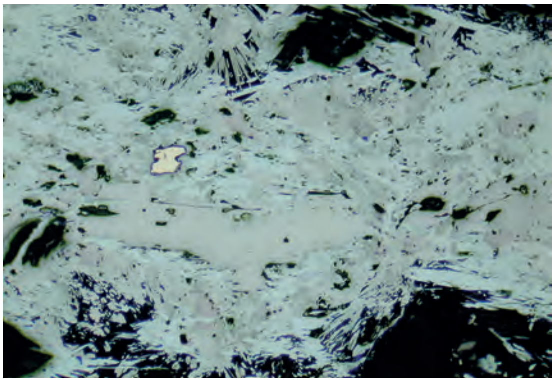
## 41 Berthierite, stibnite, pyrite – Schneeberg, Saxony/Germany (?)



Lath of berthierite (brownish) replaced and surrounded by stibnite (greyish-white needles), and pyrite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D183_09
Section: AS1017

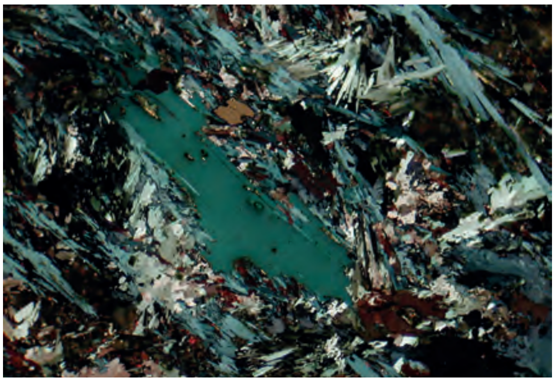
## 42 Berthierite, stibnite, pyrite – Schneeberg, Saxony/Germany (?)



As above, but 90° rotated, shows $R_{max}$ of berthierite || elongation.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D183_08
Section: AS1017

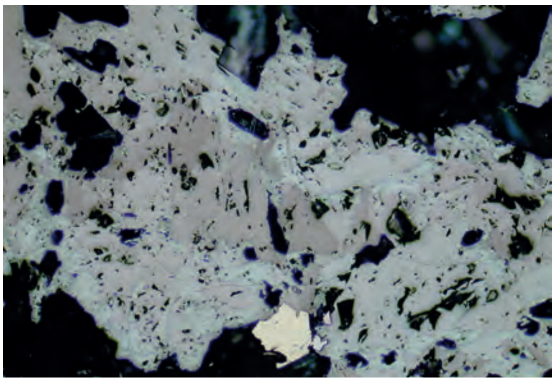
## 43 Berthierite, stibnite, pyrite – Schneeberg, Saxony/Germany (?)



As above, with (not exactly) crossed polars. Berthierite shows turquoise colours of anisotropism.

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D183_11
Section: AS1017

## 44 Berthierite, stibnite, pyrite – Schneeberg, Saxony/Germany (?)



Aggregate of berthierite laths (brownish) replaced and surrounded by stibnite (greyish white needles); one pyrite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D183_12
Section: AS1017

# Biotite

**Mineral name:** Biotite (bio)
**Formula:** $K(Fe,Mg)_3[(OH,F)_2|AlSi_3O_{10}]$

**VHN:** ~<100
**Crystal System:** mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| $R_{(air)}$ in % | (for 546 nm) | $R_x = 5.3$ | $R_y = R_z = 6.0$ | calculated from n |
| $R_{(oil)}$ in % | (for 546 nm) | $R_x = 0.1$ | $R_y = R_z = 0.2$ | calculated from n |
| Colour impression | (in oil) | dark grey (but IR!) | dark grey (IR!) | |
| BR > Rpl | (in oil) | strong | | $A_{oil} = 67$ |

## Observations with crossed polars (AExPol in oil)

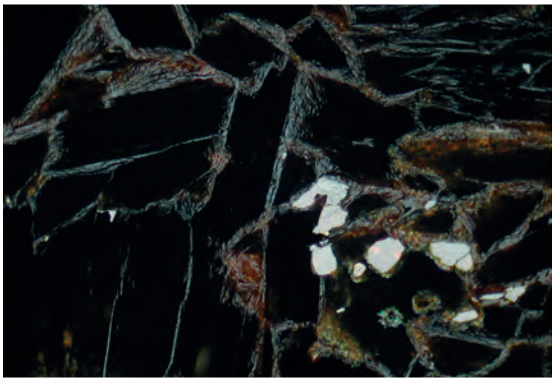
| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| Anisotropism intensity/colour | | visible | visible |
| Colour: | in 45° position | light grey; occasional the normal interference colours are visible | light grey |
| | ... in other positions | | |
| Extinction position | | masked by IR | |
| Mode of extinction | | -- | |
| Internal reflections | colour | yellow brown to dark brown | |
| (IR) | frequency | common | |
| Twinning | mode | -- | |
| | frequency | -- | |

## Further observations

| | |
|---|---|
| Form, habit, textures, cleavage ... | large, tabular XX, bended aggregates; perfect cleavage \|\| (001) |
| Paragenesis | zircon, rutile, ilmenite, goe, mt, qz, feldspar, chlorite |
| Diagniostic features | perfect #, tabular habit |

## Notes, drafts

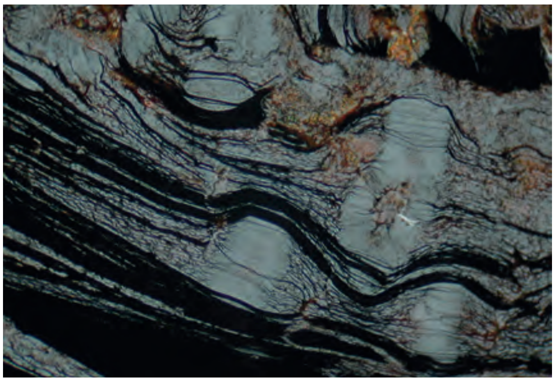
## 45 Biotite, rutile – Radium Hill, Olary Prov., S-Australia



Tabular crystals of biotite (black) with alteration rims of limonite (medium grey). Some rutile grains (light grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D78_29
Section: AS3519

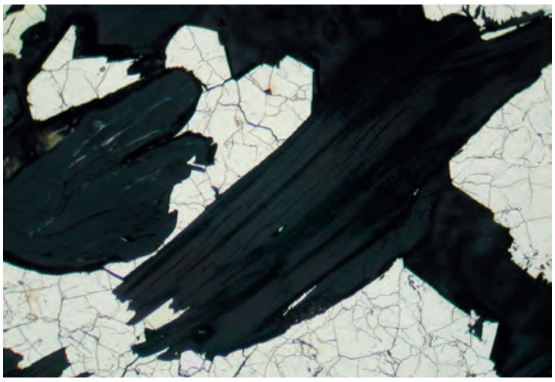
## 46 Biotite, limonite – Radium Hill, Olary Prov., S-Australia



Flakes of biotite fanned out (by stacks of clay mineral now replaced by limonite) and intergrown with limonite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D79_03
Section: AS3519

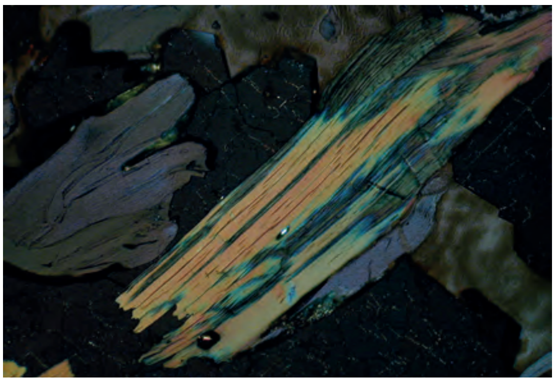
## 47 Chlorite, biotite, cobaltite – Ram, Blackbird, Idaho, USA



Flakes of chlorite (left side) with relicts of biotite (centre), both in cobaltite (white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D113_19
Section: R-06-04/1234.0

## 48 Chlorite, biotite, cobaltite – Ram, Blackbird, Idaho, USA



As above, with crossed polars. Note the violet-blue interference colours of chlorite replacing biotite, which has various interference colours. This is reflected light!

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D113_18
Section: R-06-04/1234.0

# Bismuth (in German: ged. Wismut)

**Mineral name:** Bismuth
**Formula:** Bi (± As, Te)
**VHN:** <20
**Crystal System:** trig.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 59.8 | $R_{e'}$ = 67.2 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 47.8 | $R_{e'}$ = 55.7 | |
| **Colour impression** | **(in oil)** | white tint rose (brown) | whitish cream | |
| **BR ~ Rpl** | **(in oil)** | | | $A_{oil}$ = 15 |

## Observations with crossed polars (AExPol in oil)

| | | | |
|---|---|---|---|
| | | **Precisely crossed polars** | **Not precisely crossed polars** |
| **Anisotropism intensity/colour** | | strong with colour tint | strong with colour tint |
| **Colour:** | **in 45° position** | greyish white tint olive | greyish white – yellow olive |
| | **… in other positions** | | |
| **Extinction position** | | grey black, scratches | |
| **Mode of extinction** | | brownish black, scratches | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | polysynthetic, spindle-shaped after more than one direction; and coarse | |
| | **frequency** | abundant | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | dendritic, euhedral or droplet-like inclusions in Co-Ni-arsenides (partly with »frost splitting« cracks) |
| **Paragenesis** | Co-Ni-arsenides, asp, scheelite, bismuthinite … |
| **Diagniostic features** | very low hardness, scratches, dark tarnishing, BR, paragenesis, texture |

## Notes, drafts

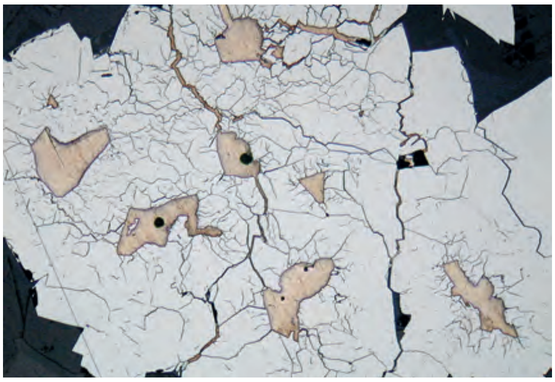
Native bismuth is an extensively very common native element.
Maucherite has no BR and is less coloured; Breithauptite is more rose.

## 49 Bismuth, safflorite, sk – Neuglück, Wittichen, Schwarzwald, Germany

Euhedral crystal of native bismuth showing simple and lamellar twinning; in groundmass of skutterudite and safflorite.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.5 mm
Photo No.: D215_22
Section: TÜ8

## 50 Bismuth, skutterudite – Mackenheim, Odenwald, Germany



Anhedral native bismuth (cream) surrounded by skutterudite (white). Note the fracturing of skutterudite due to the expanding during crystallisation of liquid bismuth with the formation of radial cracks (+dV!).

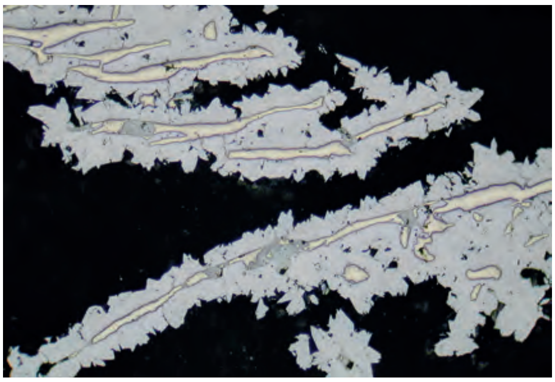
Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D167_10
Section: CHe22

## 51 Bismuth, safflorite – Ore boulder from Dom-Insel, Wroclaw, Poland

Anhedral bismuth (»Easter Bunny« in cream with scratches) enclosed by safflorite (white, some star-like twins).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D81_31
Section: AS3515

## 52 Bismuth, bismuthinite, rammelsbergite – Schneeberg, Saxony, Germany



Skeletal bismuth (cream-white, highest R), partly replaced by bismuthinite (medium grey), and later encrusted by rammelsbergite (nearly white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D82_07
Section: AS1762

# Bismuthinite (in German: Bismuthinit, Wismutglanz)

**Mineral name:** Bismuthinite
**Formula:** $Bi_2S_3$
**VHN:** 70-210
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_a$ = 43.8 | $R_b$ = 37.1 | $R_c$ = 49.0 |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_a$ = 29.1 | $R_b$ = 22.0 | $R_c$ = 33.6 |
| **Colour impression** | **(in oil)** | greyish white tint blue | grey | whitish cream |
| **BR > Rpl** | **(in oil)** | strong | | $A_{oil}$ = 42 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong with faint colour tint | strong with faint colour tint |
| **Colour:** | **in 45° position** | white tint yellow | grey – white tint yellow |
| | **... in other positions** | | brownish |
| **Extinction position** | | black, brown | |
| **Mode of extinction** | | straight, often undulatory in large XX | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | translation twins and crumpled lamellae | |
| | **frequency** | occasional | |

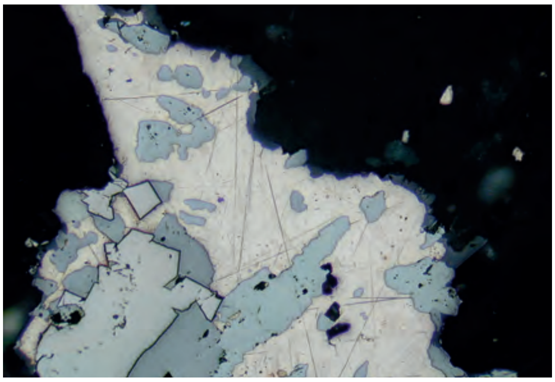
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | often in large lath-like XXs with perpendicular cracks; needles to fibrous XX; often replacing bismuth; # \|\| to longer elongation {010} common |
| **Paragenesis** | bismuth, cassiterite, stannite, wolframite, scheelite, molybdenite |
| **Diagniostic features** | paragenesis with native bismuth, # |

## Notes, drafts

# of EMPLECTITE is perpendicular to elongation of crystals.
$R_c$ of bismuthinite is || elongation.

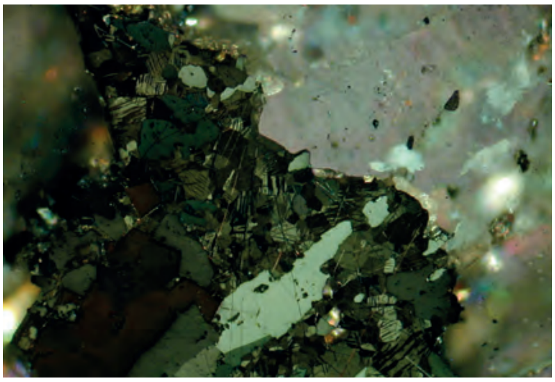
## 53 Bismuthinite, bismuth, asp – Stuhlskopf, BLZ, Schwarzwald



Replacement of bismuthinite (grey, BR) by native bismuth (cream). Euhedral pyrite with relief against bismuth and bismuthinite (lower left part).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D60_28
Section: WP303KL

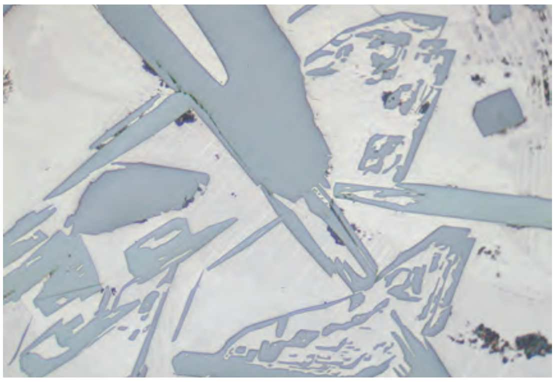
## 54 Bismuthinite, bismuth, asp – Stuhlskopf, BLZ, Schwarzwald



Same as above, with crossed polars, showing strong anisotropism of bismuthinite and lamellar twinning of native bismuth.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D60_29
Section: WP303KL

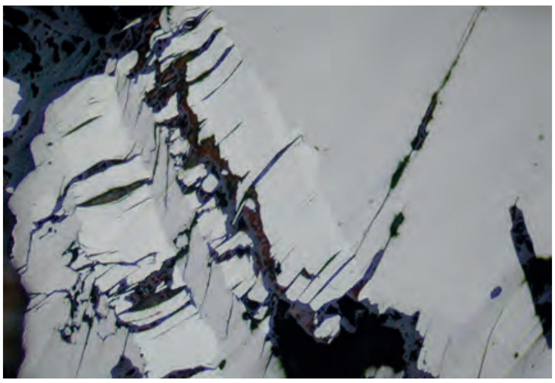
## 55 Bismuthinite, bismuth – Locality unknown



Skeletal relicts of bismuthinite (greyish) in native bismuth.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D193_29
Section: KB0

## 56 Bismuthinite, – El Teniente, Chile



Fractured and twinned bismuthinite grain (BR, medium to light grey) with cleavage planes.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D193_20
Section: KB72

# Bixbyite

**Mineral name:** Bixbyite
**Formula:** $Mn_2O_3$

**VHN:** 900
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 22.8 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 9.3 | |
| **Colour impression** | **(in oil)** | greyish yellow olive | |
| **BR Rpl** | **(in oil)** | -- | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | in each position dark | in each position dark |
| **Colour:** | **in 45° position** | black | black |
| | **... in other positions** | | |
| **Extinction position** | | -- | -- |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | -- (fine lamellar twinning is typical for anisotropic sitaparite) | |
| | **frequency** | -- | |

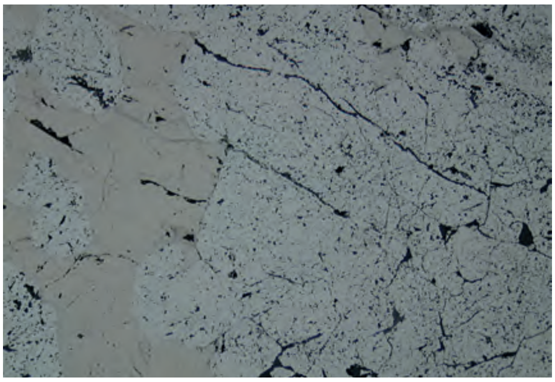
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | usually in euhedral XX, often replaced by braunite+hematite |
| **Paragenesis** | braunite, hematite, manganomelane, pyrolusite |
| **Diagniostic features** | very similar to jacobsite |

## Notes, drafts

Sitaparite $(Mn,Fe,Ca)_2O_3$: not cubic, weak BR and AExPol.

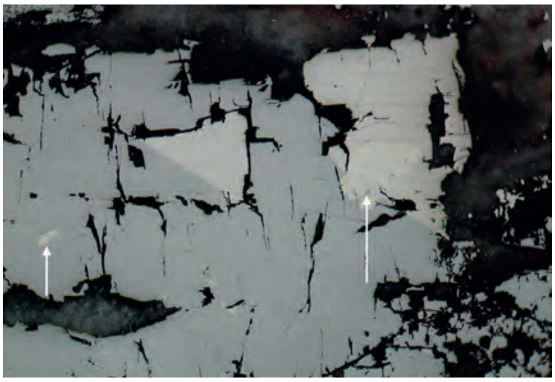
## 57 Bixbyite, hollandite – Ultevis, Sweden



Bixbyite (yellow brown) with porous hollandite (greyish white), and few little braunites (medium grey).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D133_22
Section: AS216

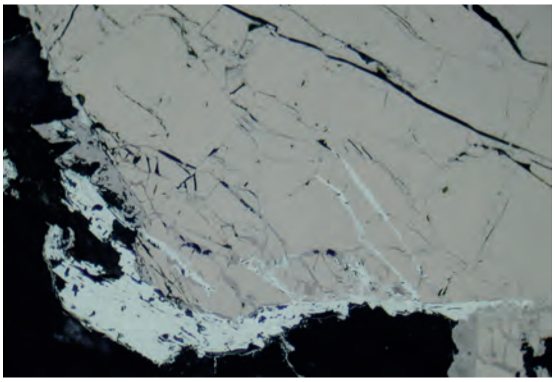
## 58 Bixbyite, hausmannite – Sailauf, Hesse, Germany



Large grain of hausmannite (with strong BR and scratches) with inclusions of bixbyite (arrows; yellowish grey; slightly higher R than hausmannite).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D60_10
Section: S61

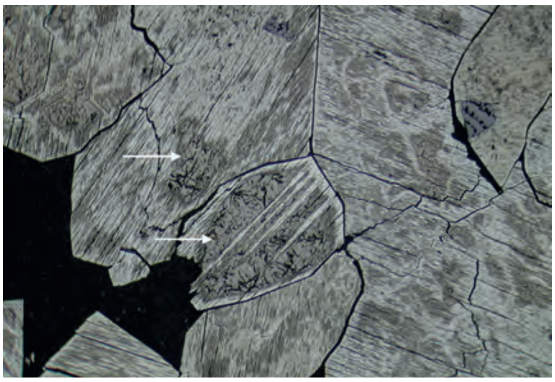
## 59 Bixbyite, braunite, hematite– Ultevis, Sweden



Bixbyite grain partly altered into braunite (medium grey) plus hematite (whitish grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D133_28
Section: AS216

## 60 Bixbyite, pyrolusite, braunite – Haut Poirot, Vosges, France



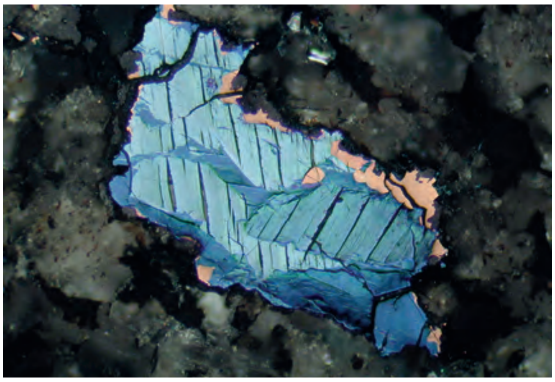
Pyrolusite crystals with relictic core of bixbyite (arrows; veined by pyrolusite), and braunite (medium grey). Note dark patches (unknown composition) in pyrolusite as relicts of former bixbyite (present in the centre of photo).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D138_04
Section: JD03

# Blue-remaining covellite
## (in German: Blaubleibender Covellin)

Mineral profiles for blue-remaining covellite:
see under Spionkopite (p. 280) and Yarrowite (p. 316)

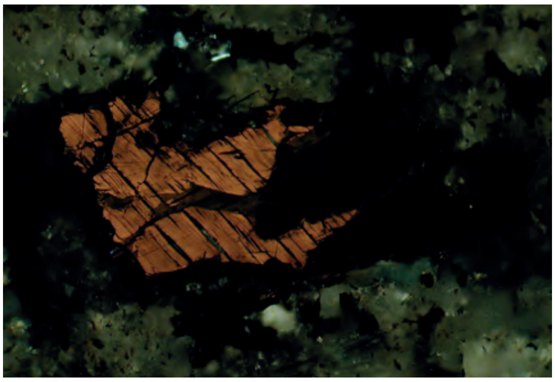
## 61 Spionkopite, bornite – Kesebol, Sweden



Spionkopite (shades of blue) with strong BR and distinct cleavage, surrounded by bornite (light brown).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D06_08
Section: AS1649

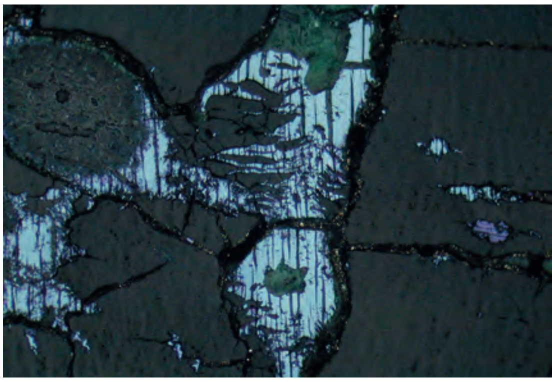
## 62 Spionkopite, bornite – Kesebol, Sweden



As above, with crossed polars.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D06_09
Section: AS1649

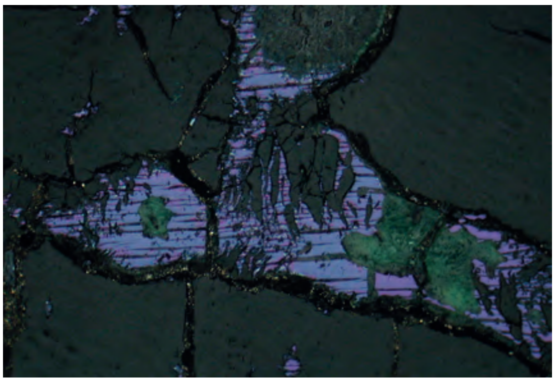
## 63 Yarrowite, malachite – Frankenberg, Hesse, Germany



Yarrowite (light blue, with $R_{max}$) with cleavage planes, in part replaced by malachite (green IR).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D148_11
Section: AS3554

## 64 Yarrowite, malachite – Frankenberg, Hesse, Germany



As above, 90° rotated. $R_{min}$ of yarrowite is much darker and bluish with a faint violet tint.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D148_10
Section: AS3554

# Bornite (in German: Bornit, Buntkupferkies)

**Mineral name:** Bornite (bn)
**Formula:** α-$Cu_5FeS_4$
**VHN:** 90-100
**Crystal System:** o'rh. (ps.tetr.)

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in % (for 546 nm)** | 21.3 | | |
| **$R_{(oil)}$ in % (for 546 nm)** | 10.4 | | |
| **Colour impression (in oil)** | orange brown (tint violet) | older sections: tarnishing → violet brown | |
| **BR Rpl (in oil)** | not visible | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|
| **Anisotropism intensity/colour** | extremely weak without colour | weak with faint colour tint |
| **Colour: in 45° position** | grey | grey brown - grey black |
| **... in other positions** | grey | |
| **Extinction position** | black | |
| **Mode of extinction** | perfect, straight | |
| **Internal reflections (IR) colour** | -- | |
| **frequency** | -- | |
| **Twinning mode** | twisted, oleander-leaf twinning (if β-bornite); rare translation twins | |
| **frequency** | occasional | |

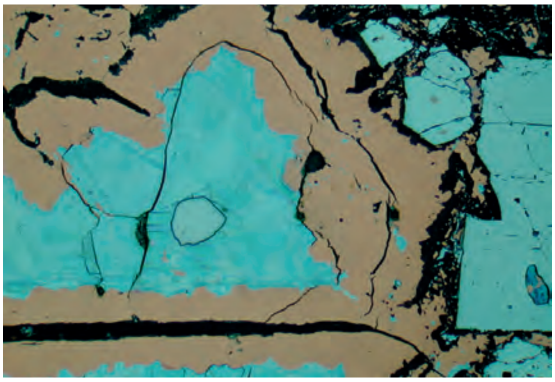
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | often anhedral, rounded grains. EB of cp (spindles) or digenite. Decomposition into cp, and network of idaite lamellae |
| **Paragenesis** | chalcopyrite, cct, cv, dg, py, mt, valleriite, sph |
| **Diagniostic features** | CI, twinning |

## Notes, drafts

Varying composition of high-temperature β-bornite-ss (>265°C, cubic)
$Bn_{ss1}$: »Brown bornite«, Cu/Fe = <5.0, (Cu+Fe)/S > 1.5 (no tarnishing), and
$Bn_{ss2}$: »Purple bornite«, Cu/Fe = >5.0, (Cu+Fe)/S < 1.5 (rapid tarnishing)
(see: Ciobanu et al. (2017): Ore Geology Rev., 81, 1218-1235).
Between 200 and 265°C: (metastable) »intermediate bornite«.

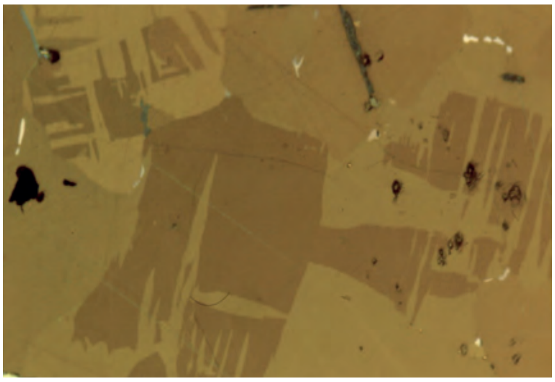
## 65 Bornite, digenite, annilite, hem, mt – Kesebol, Sweden



Cusp-and-caries replacement of digenite/annilite (bluish) by bornite (orange-brown). Hematite in centre of digenite and on the right side of photo (here pseudomorph after magnetite).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D06_05
Section: AS1641

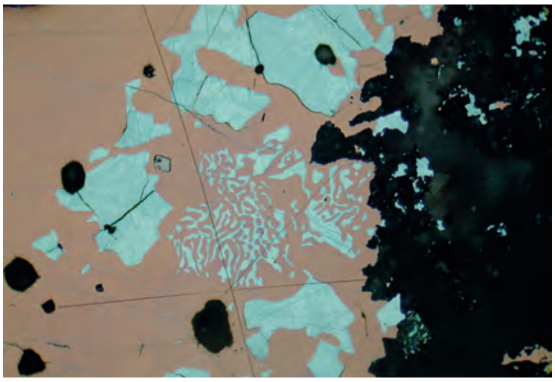
## 66 Bornite – Dognacska (Dognecea), W-Romania



Oleander-leaf shaped twinning of bornite. Not exactly crossed polars!

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.5 mm
Photo No.: A81_05
Section: AS1064

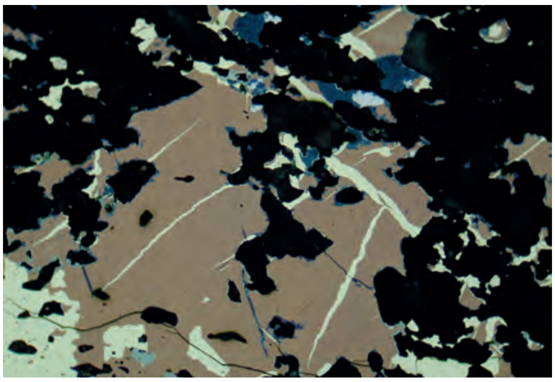
## 67 Bornite, digenite – Kesebol, Sweden



Myrmecitic intergrowth of bornite (brown) and digenite (light blue).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D06_22
Section: AS1650

## 68 Bornite, chalcopyrite, yarrowite – La Plata mine, Chiriboga, Ecuador



Bornite with chalcopyrite veinlets, in part replaced by yarrowite (deep blue). Minor fahlore (greenish grey) and galena (whitish grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D95_14
Section: AS3103

# Boulangerite

**Mineral name:** Boulangerite (boul)
**Formula:** $Pb_5Sb_4S_{11}$

**VHN:** 90-180
**Crystal System:** mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 37.4 | $R_2$ = 41.8 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 23.0 | $R_2$ = 27.6 | |
| **Colour impression** | **(in oil)** | whitish grey tint olive | whitish grey | |
| **BR ~ Rpl** | **(in oil)** | distinct | | $A_{oil}$ = 9 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | distinct without colour | distinct without colour |
| **Colour:** | **in 45° position** | greyish white | greyish white – greyish white |
| | **... in other positions** | light blue, rose white | greyish white tint rose and blue |
| **Extinction position** | | black | |
| **Mode of extinction** | | perfect, undulatory | |
| **Internal reflections** | **colour** | red | |
| **(IR)** | **frequency** | rare | |
| **Twinning** | **mode** | -- (»twinned boulangerite« = jamesonite) | |
| | **frequency** | -- | |

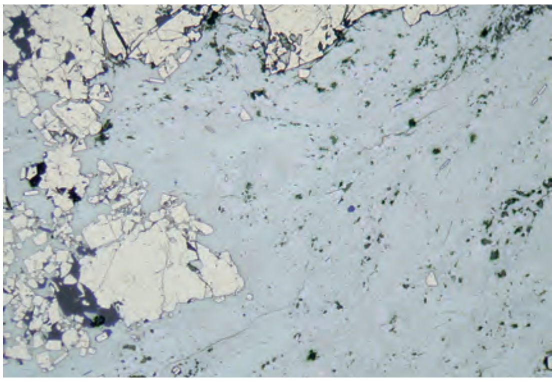
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | needle-shaped \|\| [001] or platy \|\| (100), fibrous, often in sub-parallel groups; # not observed; may be replaced by galena, fahlore, bournonite. |
| **Paragenesis** | galena, silver minerals, jamesonite, tetrahedrite |
| **Diagniostic features** | against stibnite much less anisotropic; weaker BR than jamesonite |

## Notes, drafts

$R_1$ ⊥ elongation, $R_2$ || elongation!
In contrast to similar JAMESONITE: no visible #, bluish AExPol. $R_2 < R_{Galena}$!

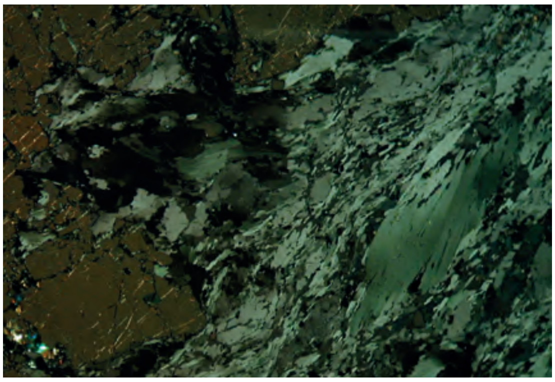
## 69 Boulangerite, pyrite – Strassegg, Styria, Austria



Aggregate of elongated boulangerites (light grey) around and in between cataclastic pyrite.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D15_22
Section: AS196

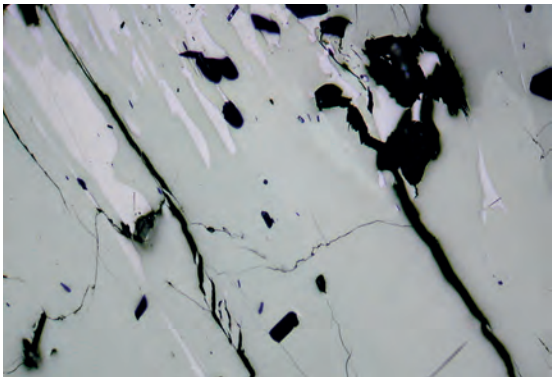
## 70 Boulangerite, pyrite – Strassegg, Styria, Austria



As above, with crossed polars. Boulangerite with undulatory extinction.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D15_23
Section: AS196

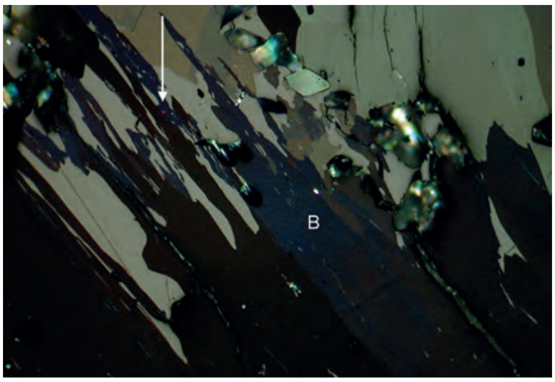
## 71 Boulangerite, jamesonite, galena – Sala, Västmanland County, Sweden



Nearly invisible intergrowth of elongated crystals of boulangerite (right side) with jamesonite (left part of photo). Distinct higher reflecting elongated relicts of galena (greyish white, upper part).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D94_02
Section: AS245

## 72 Boulangerite, jamesonite, galena – Sala, Västmanland County, Sweden




As above, with crossed polars. Note the bluish colour and one red internal reflection (arrow) of boulangerite (B).

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D94_05
Section: AS245

# Bournonite

**Mineral name:** Bournonite
**Formula:** $PbCuSbS_3$

**VHN:** 170-205 (on (010))
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_a$ = 35.6 | $R_b$ = 34.0 | $R_c$ = 35.5 |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_a$ = 20.7 | $R_b$ = 18.9 | $R_c$ = 20.4 |
| **Colour impression** | **(in oil)** | grey | grey tint olive | grey (tint blue) |
| **BR ~ Rpl** | **(in oil)** | distinct | | $A_{oil}$ = 9 |

## Observations with crossed polars (AExPol in oil)

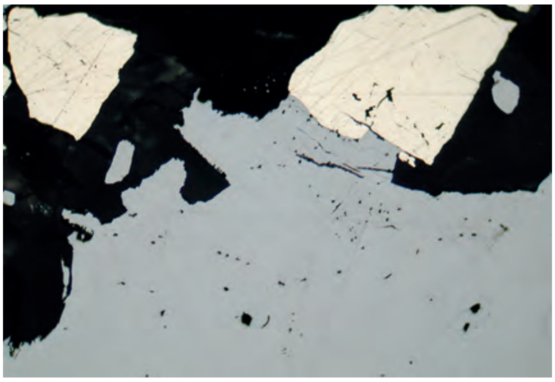
| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | weak with colour tint | weak with colour |
| **Colour:** | **in 45° position** | grey tint yellow olive | yellow olive – grey tint turquoise |
| | **... in other positions** | turquoise | yellow green, blue |
| **Extinction position** | | brownish black | |
| **Mode of extinction** | | perfect | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | polysynthetic in (110); ~ 90° in basal sections, parqueted twins, partly bended | |
| | **frequency** | abundant and characteristic | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | commonly polygonal grains, rounded inclusions in galena or fahlore; grains size varies strong from µm to cm. |
| **Paragenesis** | galena, fahlore, Ag-minerals, jamesonite |
| **Diagniostic features** | parquet-like twinning, isometric grains (unlike boulangerite, jamesonite) |

## Notes, drafts

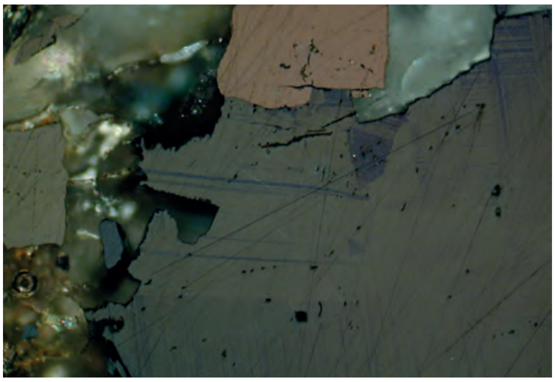
## 73 **Bournonite, pyrite –** Apollo, Raubach, Westerwald, Germany



Bournonite (medium grey, faint BR) and pyrite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D94_25
Section: AS3592

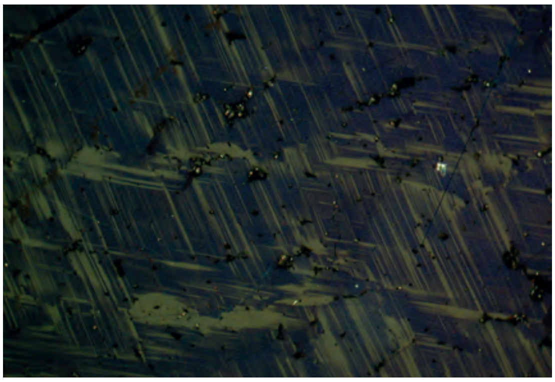
## 74 **Bournonite, pyrite –** Apollo, Raubach, Westerwald, Germany



As above, with crossed polars. Polysynthetic twinning of bournonite.

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D94_26
Section: AS3592

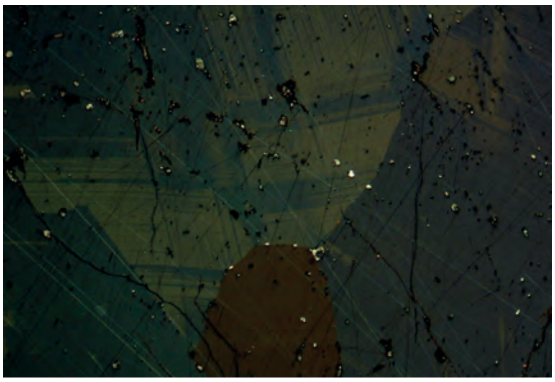
## 75 **Bournonite –** Locality unknown



Typical parquet-like twinning of bournonite after two directions.

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D13_20
Section: AS1006

## 76 **Bournonite, pyrite –** Obernberg am Brenner, Tyrol, Austria



Polysynthetic twinning of bournonite (parquet-like twinning).

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D64_19
Section: AS3585

# Braunite

**Mineral name:** Braunite
**Formula:** $Mn^{2+}Mn_6^{3+}[O_8|SiO_4]$

**VHN:** 920-1200
**Crystal System:** tetr.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 18.9 | $R_{e'}$ = 19.9 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 6.4 | $R_{e'}$ = 7.0 | |
| **Colour impression** | **(in oil)** | grey (tint brown) | grey tint brown | |
| **BR ~ Rpl** | **(in oil)** | weak | | $A_{oil}$ = 9 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | very weak without colour | very weak without colour |
| **Colour:** | **in 45° position** | greyish black | dark grey – black |
| | **... in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | perfect | |
| **Internal reflections** | **colour** | brown | |
| **(IR)** | **frequency** | very rare | |
| **Twinning** | **mode** | simple {112}, no lamellae | |
| | **frequency** | very rare | |

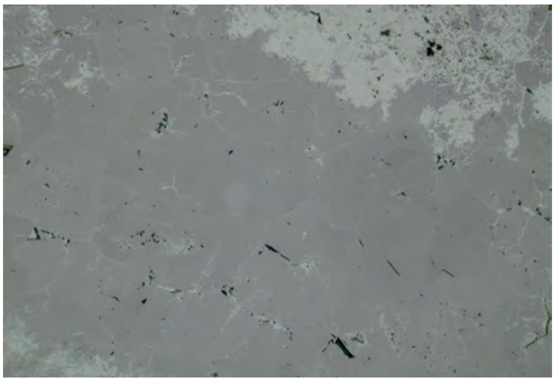
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | equigranular aggregates, often euhedral and zoned, often porous grain centre. # \|\| {112} |
| **Paragenesis** | other Mn-minerals |
| **Diagniostic features** | paragenesis, very weak anisotropism, similar to mt |

## Notes, drafts

~[3 $Mn_2O_3$ * 1 $MnSiO_3$].
For $Mn^{2+}$: Ca, Fe; for $Mn^{3+}$: Al, Fe, Si.
Varying composition due to substitution of $Si^{4+} + Mn^{2+} \leftrightarrow 2Mn^{3+} \rightarrow [(3+x)Mn_2O_3 * (1-x)MnSiO_3]$ with x ~ 0.0-0.3

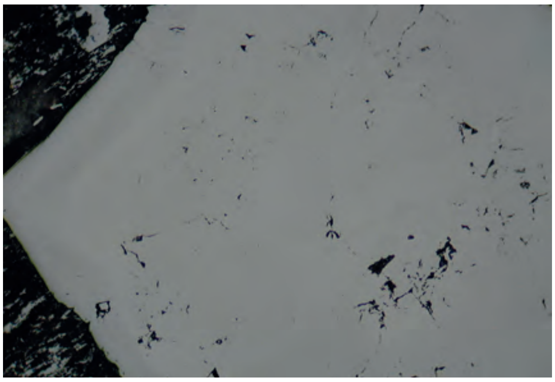
## 77 **Braunite, manganomelane –** Oberröthenbach, Schwarzwald, Germany



Equigranular braunite aggregates partly replaced by manganomelane (light grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D91_16
Section: IR19a

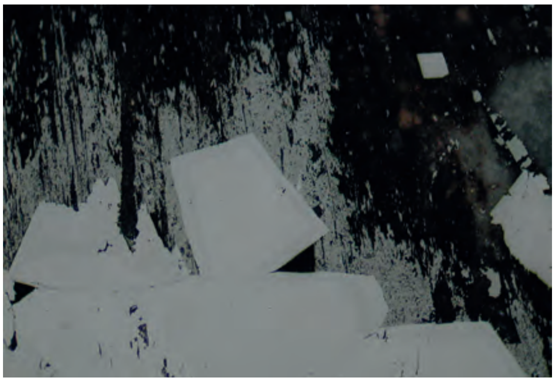
## 78 **Braunite –** Sailauf, Spessart, Germany



Euhedral crystal of braunite showing sharp zonation (slightly darker rim and irregular core zoning).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D60_12
Section: S61

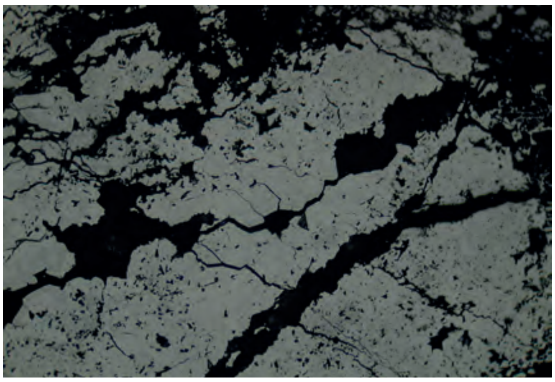
## 79 **Braunite, manganite –** Sailauf, Spessart, Germany



Zoned braunite crystals surrounded by younger anhedral manganite aggregates.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D60_06
Section: S61

## 80 **Braunite –** Fallota near Bivio, Grisons, Switzerland



Aggregate of fine zoned braunites.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D38_11
Section: F3.2

# Breithauptite

**Mineral name:** Breithauptite
**Formula:** NiSb

**VHN:** 400-600
**Crystal System:** hex.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 47.2 | $R_{e'}$ = 38.2 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 35.2 | $R_{e'}$ = 24.5 | |
| **Colour impression** | **(in oil)** | light pinkish | pinkish violet | |
| **BR ~ Rpl** | **(in oil)** | strong | | $A_{oil}$ = 36 |

## Observations with crossed polars (AExPol in oil)

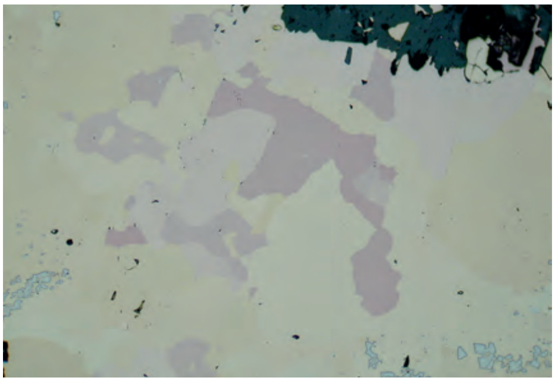
| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | very strong with colour tint | very strong with colours |
| **Colour:** | **in 45° position** | light greenish yellow | yellow green – bluish grey |
| | **... in other positions** | | other colours |
| **Extinction position** | | black | |
| **Mode of extinction** | | perfect | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | isolated granular or euhedral grains; rare tabular XX, core of arsenide rosettes. Often replaced by nickeline; no # |
| **Paragenesis** | nickeline, gersdorffite, safflorite, maucherite, ullmannite, silver, Ag-minerals |
| **Diagniostic features** | intensive colour, stronger BR and AExPol than nickeline |

## Notes, drafts

## 81 Breithauptite, nickeline – »Ontario«, Canada



Several grains of breithauptite (shades of rose-violet) in part replaced by nickeline (light to medium orange).

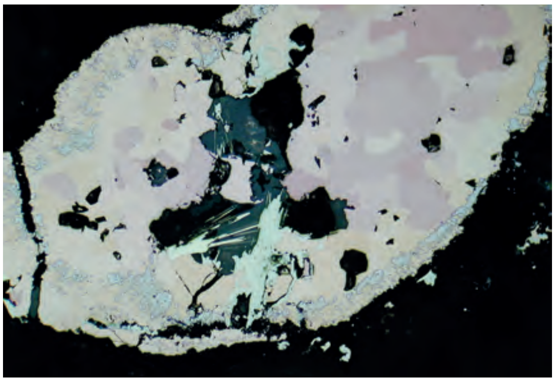
Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D94_21
Section: AS3432

## 82 Breithauptite, nickeline – »Ontario«, Canada

As above, with crossed polars. Breithauptite shows yellow green to bluish grey AExPol.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D94_22
Section: AS3432

## 83 Breithauptite, nickeline, millerite – »Ontario«, Canada



Rounded aggregate of breithauptite (violet tones), nickeline (orange colours), needle-like millerite (light yellow), and small outer zone with tiny crystals of cobaltite (strong relief).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D133_06
Section: AS3432

## 84 Breithauptite, nickeline, millerite – »Ontario«, Canada

As above, with crossed polars.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D133_07
Section: AS3432

# Calcite

**Mineral name:** Calcite
**Formula:** $CaCO_3$

**VHN:** ~ 80
**Crystal System:** trig.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 6.1 | $R_e$ = 3.8 | calculated from n |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 0.2 | $R_e$ = 0.0 | calculated from n |
| **Colour impression** | **(in oil)** | grey black (but light IR!) | black (but light IR!) | |
| **BR > Rpl** | **(in oil)** | very strong | | $A_{oil}$ = 133 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong without colour | strong without colour |
| **Colour:** | **in 45° position** | grey, masked by IR | grey – grey, masked by IR |
| | **... in other positions** | | |
| **Extinction position** | | masked by IR | |
| **Mode of extinction** | | masked by IR | |
| **Internal reflections** | **colour** | white – colourless – multi-coloured (interference colours!) | |
| **(IR)** | **frequency** | predominant | |
| **Twinning** | **mode** | polysynthetic after one or two direction (occ. bended) | |
| | **frequency** | abundant | |

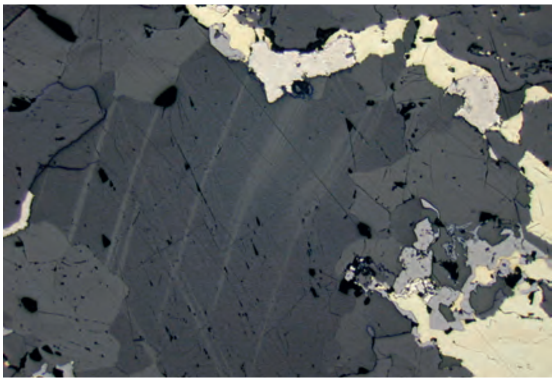
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | anhedral to euhedral gangue mineral;<br>cleavage \|\| {10–11} perfect. |
| **Paragenesis** | other gangue minerals, sphalerite, galena, pyrite |
| **Diagnostic features** | low R, very strong BR and AExPol |

## Notes, drafts

Dolomite, magnesite, and ankerite are very similar.

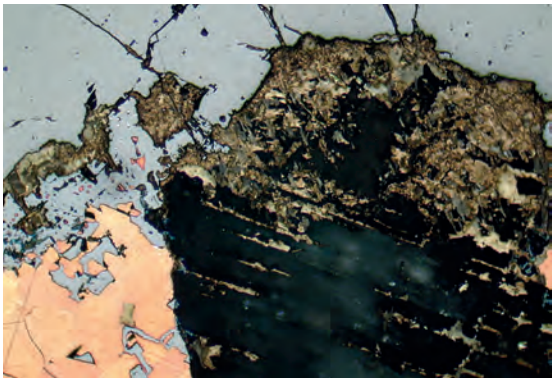
## 85 Calcite, cp, po – Artenberg quarry, Steinach, Schwarzwald, Germany



Calcite with polysynthetic twinning, partly bended. Note strong bireflection! Associated with chalcopyrite (yellow), pyrrhotite (cream), and pyrite (yellow white).

Obj.: 2.5 ×
Polars: || Pol
Photo width: 4.5 mm
Photo No.: D03_09
Section: AS3468

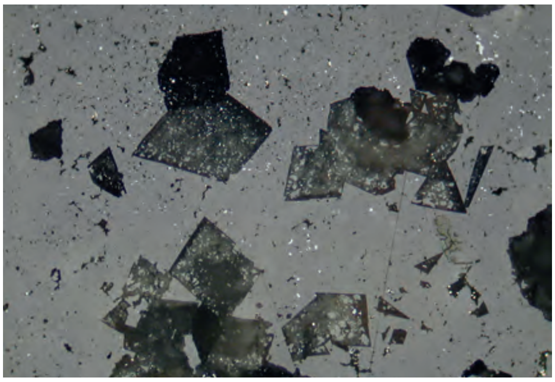
## 86 Calcite, valleriite, bn, mt – Phalaborwa, RSA



Valleriite (shades of yellowish brown) replaces calcite (dark grey, black with internal reflections) along twin boundaries or cleavage planes. Magnetite (grey) and bornite (orange).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D09_13
Section: AS1817

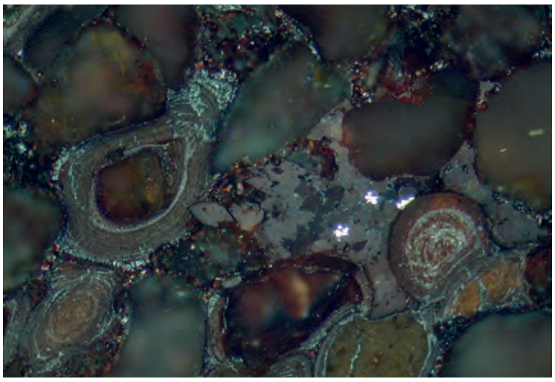
## 87 Calcite, sph, gn – Tara mine, Navan, Co. Meath, Ireland



Co–precipitation (?) of euhedral calcite (dark grey) with sphalerite (grey, groundmass and as inclusion in cal), and tiny galena (white). Some quartz crystals (black).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D67_17
Section: AS3596

## 88 Calcite, qz, py, limonite – Wasseralfingen, Aalen, Germany



Oolitic iron ore with limonite ooids (partly with hematite) and quartz clasts (dark grey, internal reflections) in groundmass of younger calcite (rhombs, BR!) and some pyrite (white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D62_17
Section: AS3597

# Cassiterite (in German: Cassiterit, Zinnstein)

**Mineral name:** Cassiterite (cas)
**Formula:** $(Sn,Fe)O_2$
**VHN:** 1240–1470
**Crystal System:** tetr.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 10.7 | $R_{e'}$ = 12.2 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 1.8 | $R_{e'}$ = 2.4 | |
| **Colour impression** | **(in oil)** | dark grey | (lighter) grey | |
| **BR > Rpl** | **(in oil)** | strong | | $A_{oil}$ = 29 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | weak without colour | weak without colour |
| **Colour:** | **in 45° position** | dark grey, often masked by IR | grey – grey, often masked by IR |
| | **… in other positions** | | |
| **Extinction position** | | masked by IR | |
| **Mode of extinction** | | masked by IR | |
| **Internal reflections** | **colour** | brown (Fe-rich) to white (Fe-poor) | |
| **(IR)** | **frequency** | rare to predominant | |
| **Twinning** | **mode** | simple & coarse ((101) »Visiergraupen«); polysynthetic in one direction | |
| | **frequency** | frequent; occasional | |

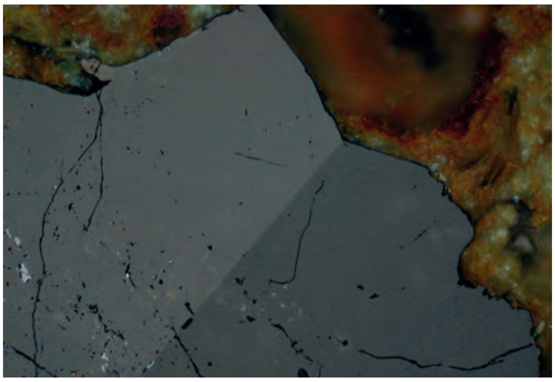
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | high T.: coarse, isometric grains; low-T.: colloform to fibrous (»Holzzinn«); zoning often visible by IR, pores, and EB (columbite, rutile, wolframite, …) |
| **Paragenesis** | columbite, rt, wolframite, stannite, cp |
| **Diagnostic features** | twinning, paragenesis, hardness; resembles titanite and other gangue minerals! |

## Notes, drafts

Similar to TITANITE.

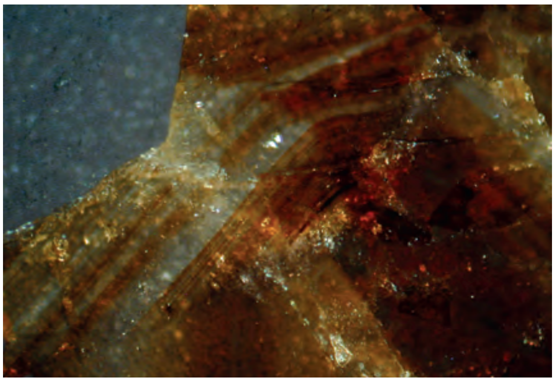
## 89 **Cassiterite –** Igla Tin mine, Al Baḩr al Aḩmar, Egypt



Cassiterite twin showing strong BR.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D69_18
Section: AS3139

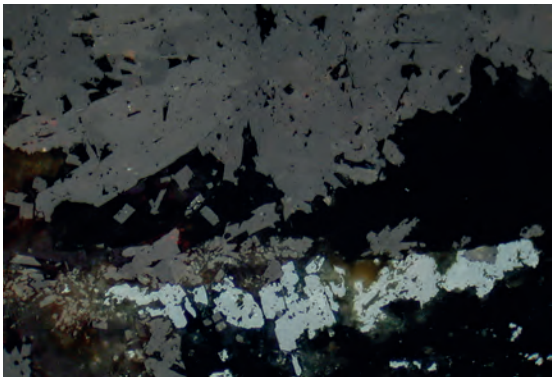
## 90 **Cassiterite –** Punta Santa Vittoria, Fluminimaggiore, Sardinia, Italy



Zoned cassiterite with different coloured internal reflections due to varying iron content of cassiterite.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D69_17
Section: AS1561

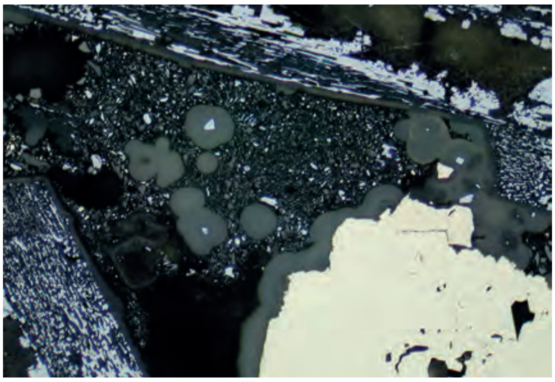
## 91 **Cassiterite, anatase, tourmaline –** Cornwall, England



Elongated cassiterites (medium grey with BR) beside tourmaline (nearly black), and anatase (light grey, lower part of photo).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D184_10
Section: MD175

## 92 **Cassiterite, pyrite, galena –** Potosi, Bolivia



Colloform cassiterite (»Holzzinn«) around galena (white) and anhedral pyrite (yellowish white). Both, cassiterite and galena, are alteration products of primary teallite (structure relicts of tabular crystals in the upper and left side of photo).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D109_12
Section: AS1024

# Cerussite

**Mineral name:** Cerussite
**Formula:** $PbCO_3$

**VHN:** ~ 160
**Crystal System:** o'rh., ps. hex.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_a = 8.2$ | $R_b = R_c = 12.2$ | calculated from n |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_a = 0.8$ | $R_b = R_c = 2.5$ | calculated from n |
| **Colour impression** | **(in oil)** | grey | grey | |
| **BR > Rpl** | **(in oil)** | very strong | | $A_{oil} = 88$ |

## Observations with crossed polars (AExPol in oil)

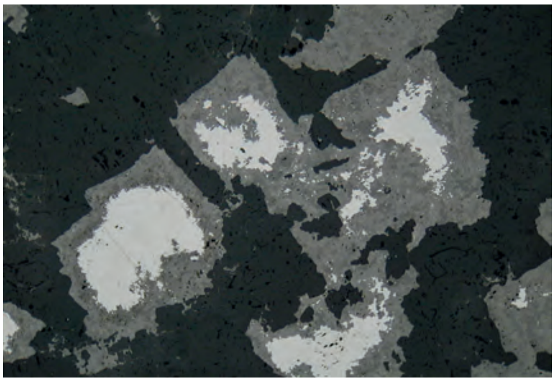
| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | very strong; masked by IR | very strong; masked by IR |
| **Colour:** | **in 45° position** | masked by IR | masked by IR |
| | **... in other positions** | | |
| **Extinction position** | | masked by IR | |
| **Mode of extinction** | | masked by IR | |
| **Internal reflections** | **colour** | white with coloured borders | |
| **(IR)** | **frequency** | predominant | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | weathering product of galena and other Pb-bearing sulfides; often as pseudomorphs; no # visible |
| **Paragenesis** | galena, fahlore, cp, anglesite, silver, covellite |
| **Diagnostic features** | very strong BR, paragenesis |

## Notes, drafts

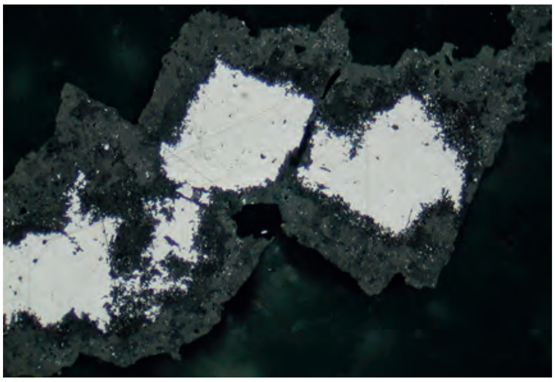
## 93 Galena, anglesite, cerussite, qz – Sodmine, Eastern Desert, Egypt



Galena crystals replaced by cerussite (BR, shades of grey) in quartz matrix (dark grey).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D99_18
Section: AS3141

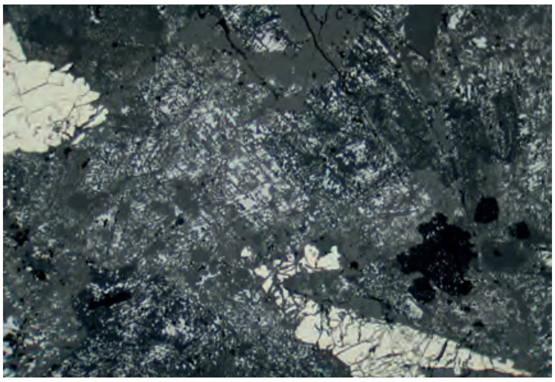
## 94 Galena, anglesite, cerussite, qz – Sodmine, Eastern Desert, Egypt



Alteration of galena crystals. First alteration phase is anglesite (dark grey) amoring relitic galena (greyish white). Both are rimmed by the second alteration phase: cerussite (BR, shades of grey); quartz matrix.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D100_16
Section: AS3141

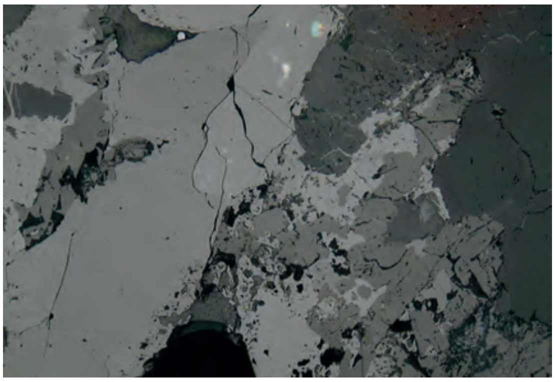
## 95 Cerussite, galena, gersdorffite – Katzensteig, Schwarzwald, Germany



Replacement of galena by cerussite (greyish, strong BR!) along parallel cleavage planes of galena; two large grains of gersdorffite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D74_03
Section: SN40

## 96 Cerussite, quartz, barite – Sodmine, Eastern Desert, Egypt



Large cerussite grains (BR, light grey, some IR) and smaller barite crystals (medium grey); with quartz (darker grey, right side).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D99_19
Section: AS3141

# Chalcocite (in German: Chalkosin, Kupferglanz)

**Mineral name:** Chalcocite (cct)
**Formula:** $Cu_2S$
**VHN: 80-90**
**Crystal System:** mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_a$ = 33.4 | $R_b$ = 33.4 | $R_c$ = 33.2 |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_a$ = 18.3 | $R_b$ = 18.1 | $R_c$ = 17.9 |
| **Colour impression** | **(in oil)** | whitish grey tint blue | whitish grey tint blue | whitish grey tint blue |
| **BR ~ Rpl** | **(in oil)** | very weak | | $A_{oil}$ = 2 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | very weak with colour tint | very weak with colour tint |
| **Colour:** | **in 45° position** | brownish black | dark brown – brownish black |
| | **... in other positions** | brownish black | brownish black |
| **Extinction position** | | black | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | common | |
| **Twinning** | **mode** | pseudomorph after high chalcocite: polysynthetic, spindle-shaped | |
| | **frequency** | absent – common (depends on formation temperature) | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | with myrmekitic exsolution bodies of bornite (and vice versa) |
| **Paragenesis** | covellite, digenite, djurleite, cp, bn, goethite |
| **Diagnostic features** | not as blue as digenite, paragenesis |

## Notes, drafts

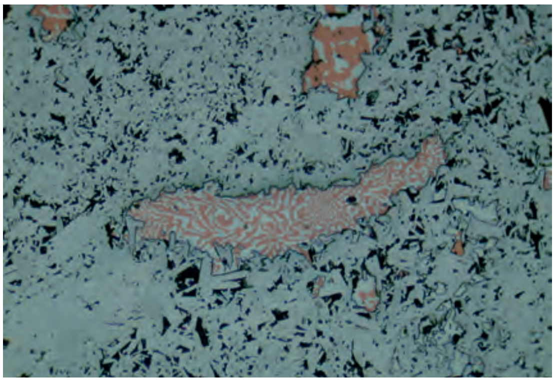
CI and RV vary due to polishing and contents of Fe, Mn, Ag, Se, and Te.
Former high chalcocite (hex.) is always present as low chalcocite (mcl.), T of inversion ~ 103-90 °C (Fleet, 2006; Rev. Mineral. Geochem., 61, 365-419).
Djurleite ($Cu_{1.96}S$) is similar in colour and reflectance (but has no polysynthetic, spindle-shaped twins).

## 97 Chalcocite, pyrite – Wheel Turner mine, Mt. Painter, Australia

Secondary chalcocite (bluish grey) replacing pyrite in the cementation zone (boxwork structure).

Obj.: 5 ×
Polars: || Pol
Photo width: 2.8 mm
Photo No.: D197_26
Section: WT80E

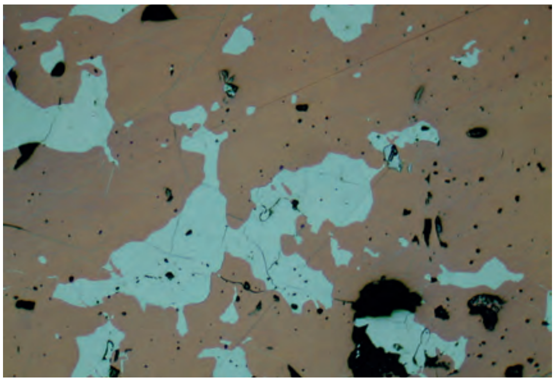
## 98 Chalcocite, bornite, hematite – Prominent Hill, SE Coober Pedy, S-Australia



Myrmecitic intergrowths of chalcocite and bornite (centre and upper part of photo) enclosed by platy hematite (grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D137_26
Section: WT80E

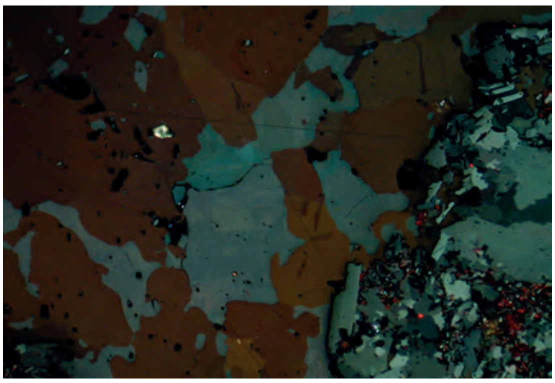
## 99 Chalcocite, bornite – Prominent Hill, SE Coober Pedy, S-Australia



Fine irregular intergrowth of chalcocite (bluish grey) with bornite (orange brown).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D137_28
Section: AS3589

## 100 Chalcocite, bornite – Prominent Hill, SE Coober Pedy, S-Australia



As above, with not perfect crossed polars. Note twinning of chalcocite due to the inversion of high-chalcocite to low-chalcocite.

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D137_30
Section: AS3589

# Chalcopyrite (in German: Chalkopyrit, Kupferkies)

**Mineral name:** Chalcopyrite (cp)
**Formula:** $Cu^{1+}Fe^{3+}S_2$
**VHN:** 180-200
**Crystal System:** tetr.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 45 | | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 34 | | |
| **Colour impression** | **(in oil)** | yellow | against gold: yellow green | |
| **BR ~ Rpl** | **(in oil)** | extremely weak to absent | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | very weak with faint colour tint | weak with colour |
| **Colour:** | **in 45° position** | black grey with brown tint | light brown – black brown |
| | **... in other positions** | | yellow olive – grey with blue tint |
| **Extinction position** | | black tint brown | |
| **Mode of extinction** | | incomplete | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | oleander-leaf-like {102}; and polysynthetic in 2 directions {112} resp. | |
| | **frequency** | rare (inversion twins); and occasional (deformation twins) resp. | |

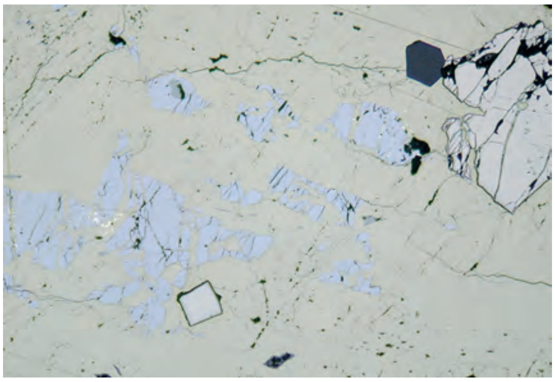
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | very often anhedral; often as inclusion in sphalerite and pyrite; # is rare. EB of cubanite, mackinawite, sphalerite, and stannite; as EB in bornite, stannite |
| **Paragenesis** | sphalerite, stannite, py, po, cub, mackinawite, cv |
| **Diagnostic features** | yellow CI, anhedral grains form, paragenesis; selective tarnishing |

## Notes, drafts

High temperature cp formation from *intermediate solid solution* ıss ((Cu, Fe, Zn, Sn)S)
Above 557° C: cubic high-temperature phase.
*Chalcopyrite-disease*: Tiny anhedral cp grains in sphalerite as the result of an infiltration of Cu-rich fluids in Fe-bearing sphalerite.
Cp with unexsolved $Cu_2S$-content shows rapid tarnishing!

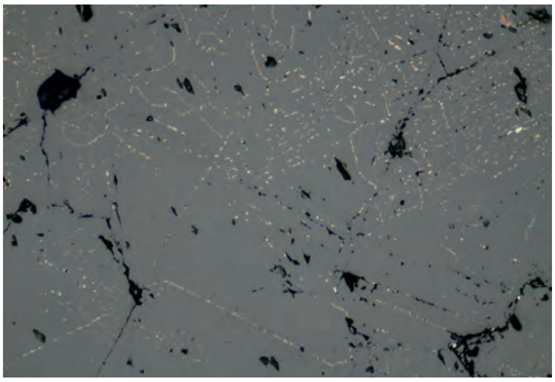
## 101 Chalcopyrite, gersdorffite, py, gold – Mitterberg, Salzburg, Austria



Groundmass of chalcopyrite (yellow) with pyrite crystals (yellowish white, relief) and gersdorffite (greyish white). Late gold impregnation (light yellow, left side) between fractured gersdorffite grains.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D16_03
Section: AS143

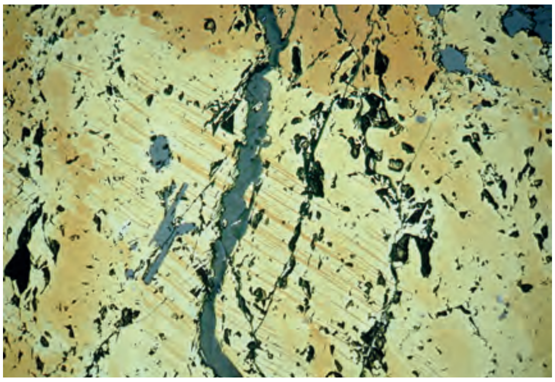
## 102 Chalcopyrite, sphalerite – Pfunderer Berg, S-Tyrol, Italy



»Chalcopyrite disease«: Infiltration of Fe-bearing sphalerite by Cu-rich fluids producing tiny grains of $CuFeS_2$ in ZnS. This is not an exsolution texture!

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D46_21
Section: AS3576

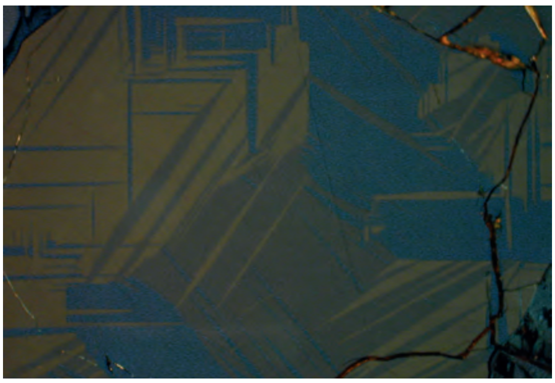
## 103 Chalcopyrite – W-Sonora, Tucson, AZ, USA



Deformation twins of chalcopyrite visible due to different strong tarnishing.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D90_04
Section: AS1780

## 104 Chalcopyrite – Calamita, Elba, Italy



Chalcopyrite with oleander-leaf like twinning due to inversion.

Obj.: 20 × oil
Polars: × Pol ( ~ )
Photo width: 0.7 mm
Photo No.: D107_06
Section: AS3144

# Chromite

**Mineral name:** Chromite (chr)
**Formula:** (Fe,Mg)(Cr,Al,Fe)$_2$O$_4$

**VHN:** 1300-1800
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 10 to 15 | depending on chemistry | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 2 to 3 | magnesiochromite: 2.5 % | |
| **Colour impression** | **(in oil)** | dark grey | | |
| **BR Rpl** | **(in oil)** | -- | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | homogeneous dark | |
| **Colour:** | **in 45° position** | black | |
| | **... in other positions** | | |
| **Extinction position** | | -- | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | brown | |
| **(IR)** | **frequency** | rare (and only at rims and fractures) | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

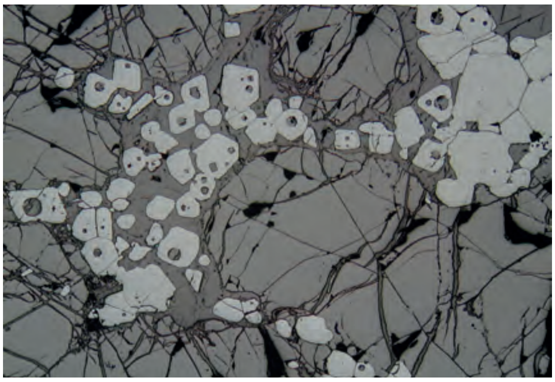
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | coarse, rounded aggregates, often fractured by cataclasis, zoning; commonly rimmed by magnetite; rare EB of ilmenite; no # |
| **Paragenesis** | magnetite, ilmenite, PGE minerals, Mg-silicates |
| **Diagnostic features** | paragenesis, brown IR, no #, hardness |

## Notes, drafts

Similar to MAGNETITE and SPHALERITE.

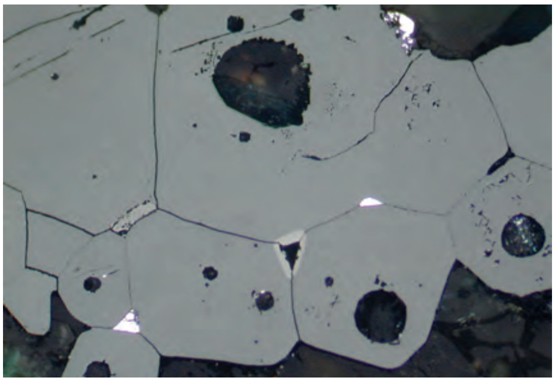
## 105 Chromite, olivine – Rhum, Scotland



Anhedral atoll-structured chromite cumulates (medium grey) around olivine grains (dark grey).

Obj.: 5 ×
Polars: || Pol
Photo width: 2.8 mm
Photo No.: D128_27
Section: AS1818

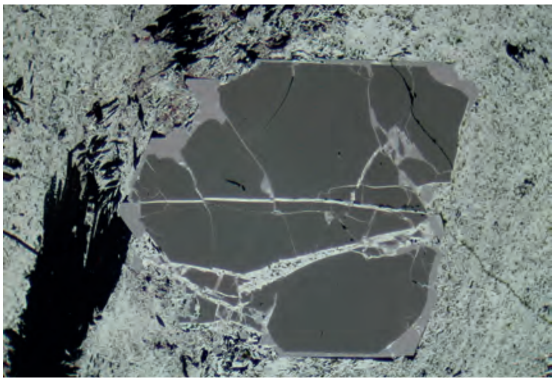
## 106 Chromite, mt, PGM – Rhum, Scotland



Polygonal chromite aggregates in triple-junction configuration. Tiny ilmenite exsolution bodies and early silicates in chromite. Between chromite grains (esp. in triple junctions) enrichment of magnetite (light grey rims) and unknown PGE-minerals (white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D25_14
Section: AS1818

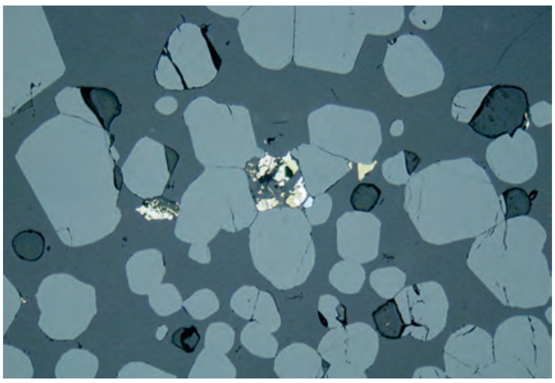
## 107 Chromite, mt, hm – Rzanovo, Kavardaci, Republic of North Macedonia



Serpentinized podiform chromite deposit with euhedral, cataclastic Cr-spinel. Fractured core of chr (grey) is partly corroded, replaced and rimmed by mt (lighter brownish grey). Late formation of hm (light greyish white) in the groundmass (also penetrating and replacing mt).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D181_01
Section: AS109

## 108 Chromite, cp, pn, laurite, Pt – UG2, Karee mine, Bushveld Complex, RSA



Euhedral to rounded grains of chromite (medium grey) with laurite (whitish yellow), (Pt,Fe) alloy (white), pentlandite (cream), and chalcopyrite (dark yellow).

Obj.: 10 × oil
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D218_13
Section: AS8919a

# Cinnabar (in German: Cinnabarit, Zinnober)

**Mineral name:** Cinnabar (cin)
**Formula:** HgS

**VHN:** 80-160
**Crystal System:** trig.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 24.1 | $R_{e'}$ = 29.0 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 10.1 | $R_{e'}$ = 14.0 | |
| **Colour impression** | **(in oil)** | grey tint violet | grey (tint green) | |
| **BR > Rpl** | **(in oil)** | strong | | $A_{oil}$ = 32 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | distinct with colour | distinct with colour |
| **Colour:** | **in 45° position** | greyish olive | greyish olive |
| | **... in other positions** | | |
| **Extinction position** | | masked by IR | |
| **Mode of extinction** | | masked by IR | |
| **Internal reflections** | **colour** | red | |
| **(IR)** | **frequency** | abundant (often visible with one polar) | |
| **Twinning** | **mode** | coarse/simple; rare translation twins | |
| | **frequency** | rare | |

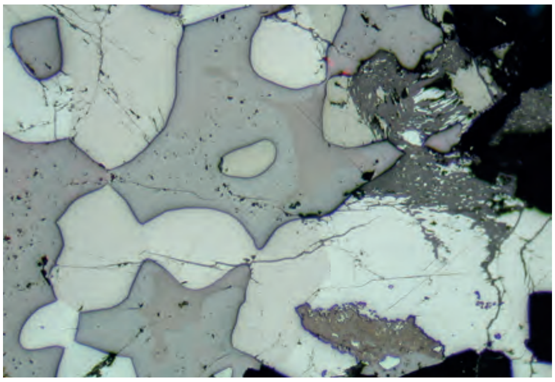
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | predominant equigranular, foam structure, rarely interlocked grains; cleavage \|\| {10-10} rather perfect |
| **Paragenesis** | metacinnabar, stibnite, py, mrc, asp, realgar, orpiment ... |
| **Diagnostic features** | IR, paragenesis, many scratches |

## Notes, drafts

Similar to CUPRITE.

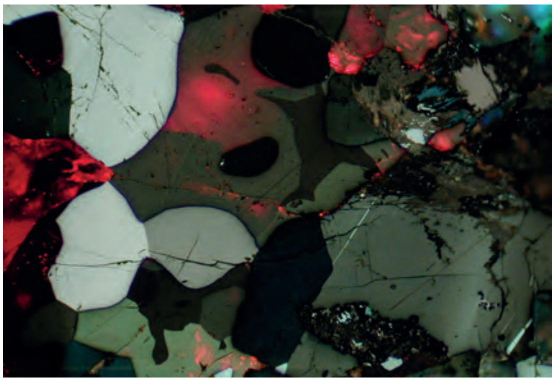
### 109 Cinnabar, metacinnabar, stibnite – Çirakman tepe, Ladik, Turkey



Anhedral grains of cinnabar (medium grey, some red IR) replacing metacinnabar (greyish brown relicts in cinnabar), intergrown with stibnite (white to light grey, partly with alteration to Sb-oxihydroxides).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D32_05
Section: AS154

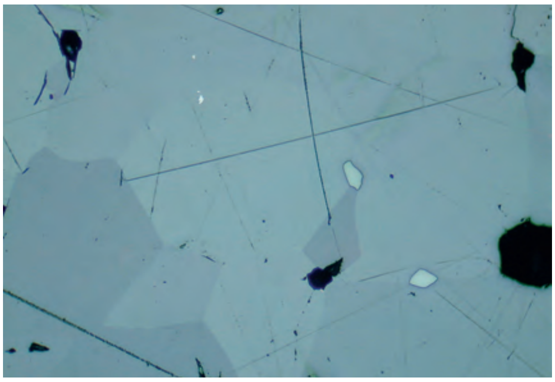
### 110 Cinnabar, metacinnabar, stibnite – Çirakman tepe, Ladik, Turkey



As above, with crossed polars. Red internal reflections and distinct anisotropism of cinnabar; stibnite grains show strong effects (left side).

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D32_06
Section: AS154

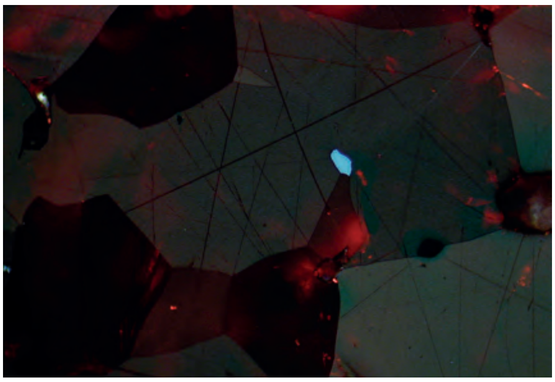
### 111 Cinnabar, stibnite, arsenopyrite – Çirakman tepe, Ladik, Turkey



Cinnabar grains (different grey tones due to BR, some scratches) with triple junction grain boundaries. Two small stibnite grains (light grey), and tiny arsenopyrite inclusions in cinnabar (upper left part of photo).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D213_29
Section: AS155

### 112 Cinnabar, stibnite – Çirakman tepe, Ladik, Turkey



As above, with crossed polars. Note the different visibility of AExPol versus IR in the cinnabar grains. One stibnite grain shows maximum anisotropism (bluish white).

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D213_28
Section: AS155

# Clinopyroxene

**Mineral name:** Clinopyroxene (cpx)
**Formula:** $(Ca,Mg,Fe)_2Si_2O_6$

**VHN:** ~ 600
**Crystal System:** mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_x$ ~ 6.3 | $R_z$ ~ 7.3 | calculated from $n_x$, $n_z$ |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_x$ ~ 0.3 | $R_z$ ~ 0.5 | calculated from $n_x$, $n_z$ |
| **Colour impression** | **(in oil)** | »black« (but IR!) | »black« (but IR!) | |
| **BR > Rpl** | **(in oil)** | distinct | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | not visible | not visible |
| **Colour:** | **in 45° position** | masked by IR | masked by IR |
| | **… in other positions** | | |
| **Extinction position** | | masked by IR | |
| **Mode of extinction** | | masked by IR | |
| **Internal reflections** | **colour** | white – colourless – brownish | |
| **(IR)** | **frequency** | predominant | |
| **Twinning** | **mode** | lamellar after one direction | |
| | **frequency** | occasional | |

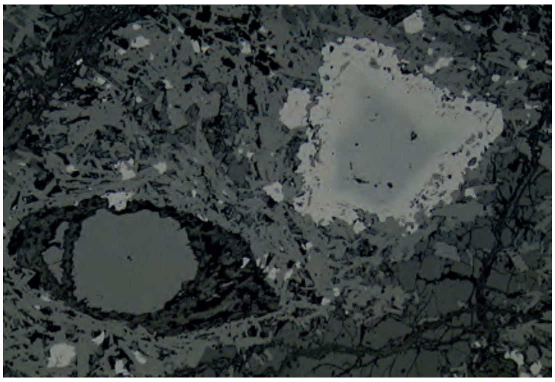
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | granular to euhedral, prismatic, zoning; # planes with 90° |
| **Paragenesis** | other rock-forming minerals, mt, po |
| **Diagnostic features** | low R, pyroxene typical # |

## Notes, drafts

Optical properties are varying with composition!

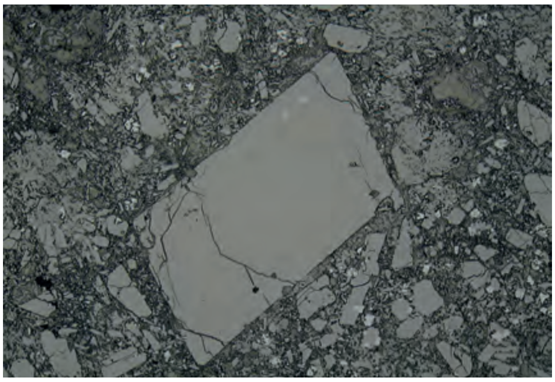
## 113 Clinopyroxene, olivine, spinel – Hohenstoffeln, Hegau, Germany



Zoned spinel (dark core of Al-Cr-spinel with lighter rim of magnetite) and relict of olivine crystal in fine-grained groundmass of pyroxene and magnetite.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D135_14
Section: AS2874

## 114 Clinopyroxene, mt – Bürzlen, Urach volcanic field, SW-Germany



Clinopyroxene crystal with small magnetite inclusions (light grey) in olivine nephelinite.

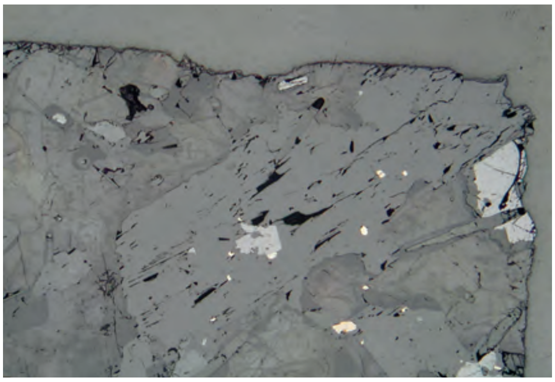
Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D99_01
Section: Xeno1b

## 115 Aegirine augite, sphalerite – Ilimaussaq, Greenland

Green prismatic aegirine augites with sphalerite crystal (light grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D122_17
Section: BR9

## 116 Clinopyroxene, mt, po – Ilimaussaq, Greenland



Syenite with anhedral grain of pyroxene. Tiny inclusions of pyrrhotite and magnetite in cpx.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D122_03
Section: GM1331

# Cobaltite

**Mineral name:** Cobaltite (cob)
**Formula:** CoAsS
**VHN:** 1100-1300
**Crystal System:** o'rh. (ps. cub.)

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in %** **(for 546 nm)** | 50.7 | | |
| **$R_{(oil)}$ in %** **(for 546 nm)** | 36.4 | | |
| **Colour impression** **(in oil)** | white tint rose | more pink in older sections | |
| **BR < Rpl** **(in oil)** | very weak (visible at grain boundaries) | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | very weak with colour | weak with colour |
| **Colour:** | **in 45° position** | brownish grey, bluish grey | brown – bluish grey |
| | **... in other positions** | | |
| **Extinction position** | | brownish black | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | complex, partly polysynthetic, partly chess-board-like | |
| | **frequency** | frequent (in larger grains) | |

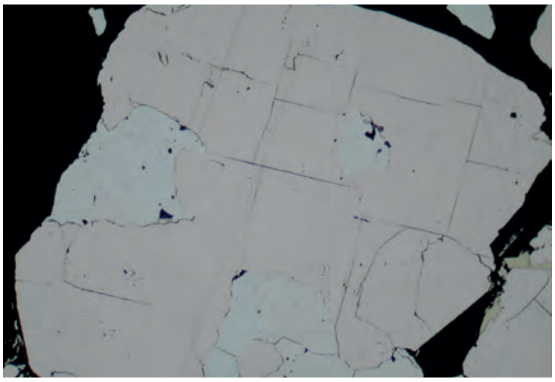
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | mostly euhedral large crystals, low temp. cobaltites show zoning (As/S). Perfect cleavage after {100}; also cataclastic textures. |
| **Paragenesis** | Co-Ni-arsenides, py, asp, skutterudite |
| **Diagnostic features** | euhedral form, hardness, twinning |

## Notes, drafts

CI is similar to $R_a/R_b$ of ARSENOPYRITE (white cream)

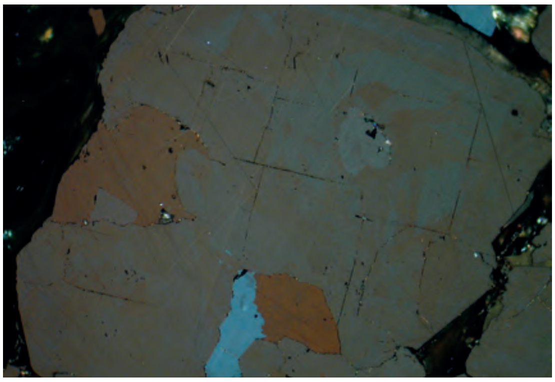
## 117 Cobaltite, asp – Blackbird, Idaho, USA



Crystal of cobaltite (tint rose, with #) intergrown with arsenopyrite (pure white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D112_24
Section: GH BB-15

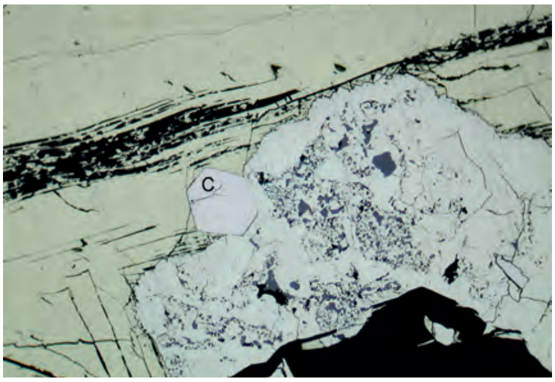
## 118 Cobaltite, asp – Blackbird, Idaho, USA



As above, with crossed polars. Note weak anisotropism of cobaltite! Arsenopyrite with stronger anisotropism in bluish and brownish colours.

Obj.: 20 × oil
Polars: × Pol ( ~ )
Photo width: 0.7 mm
Photo No.: D112_26
Section: GH BB-15

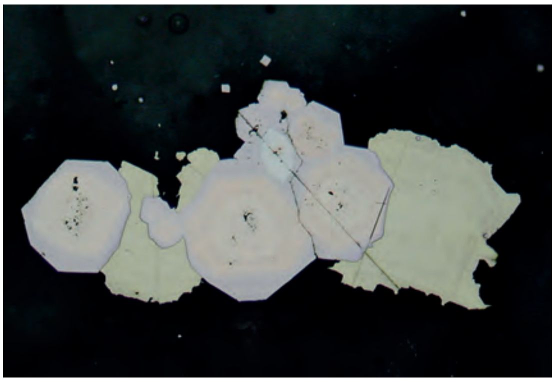
## 119 Cobaltite, cp, py, mt – Ram, Blackbird, Idaho, USA




Euhedral cobaltite (white tint rose, marked C) beside pyrite-magnetite intergrowth (formerly po). Chalcopyrite (yellow) with fabric relict of former lamellar cubanite (now dissolved, black).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D113_14
Section: R-06-04/1234.0

## 120 Cobaltite, py, cp, marcasite – Todtnauer veins, Schwarzwald, Germany



Small rim of cobaltite (white tint rose) around zoned pyrite crystals (whitish yellow) with chalcopyrite (yellow) and marcasite (nearly white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D89_01
Section: JST 24

# Cohenite (Cementite)

**Mineral name:** Cohenite (Cementite)
**Formula:** $(Fe,Ni)_3C$

**VHN:** ~ 600
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1 = 54$[2] | $R_2 = 56$[2] | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1 \sim 40$ | $R_2 \sim 43$ | calculated from $R_{air}$ |
| **Colour impression** | **(in oil)** | white tint rose | white tint yellow | all tints against iron |
| **BR ~ Rpl** | **(in oil)** | weak | | $A_{oil} = 5$ |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | weak with colour tint | weak with colour tint |
| **Colour:** | **in 45° position** | grey tint yellow | yellowish grey – dark grey (tint blue) |
| | **... in other positions** | dark grey | |
| **Extinction position** | | black | |
| **Mode of extinction** | | straight (to elongation) | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

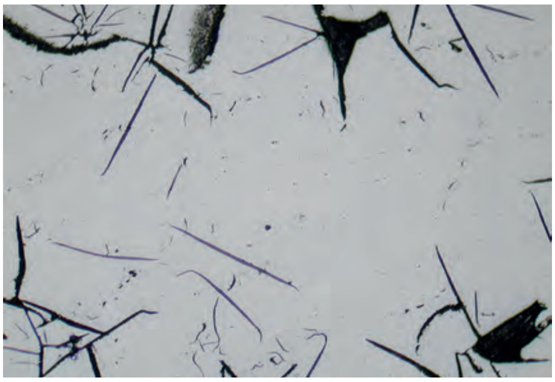
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | euhedral, myrmekitic or partly fine lamellar intergrowth with iron |
| **Paragenesis** | iron, graphite, mt, pn |
| **Diagnostic features** | paragenesis, AExPol |

## Notes, drafts

Artificial $(Fe, Ni)_3C$ is called CEMENTITE
$R_2$ of cohenite is very similar to R of IRON (α-ferrite), but the CI is more yellow.
[2] After RAMDOHR, 1980

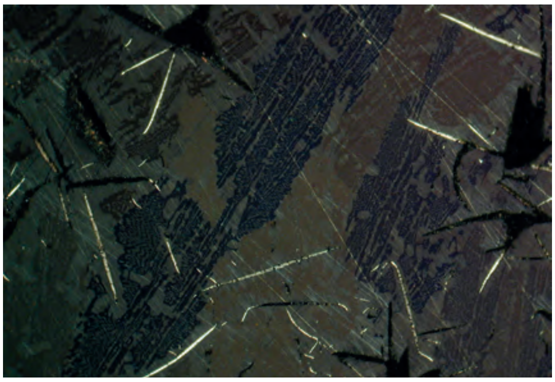
## 121 **Iron, gr, cementite –** Thyssen smelter Schwelgern, Duisburg, Germany



Technical α-iron (white) in myrmekitic intergrowth (»perlite«) with cohenite/ cementite ($Fe_3C$, with faint yellowish tint; invisible in photo!); graphite flakes (dark grey to black).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D86_29
Section: AS3531

## 122 **Iron, gr, cementite –** Thyssen smelter Schwelgern, Duisburg, Germany



As above, with crossed polars. Note the isotropic behaviour of iron (only dark grey and often associated with graphite) in contrast to weak anisotropism of cementite (dark grey, olive brown-brown), and the strong effects of graphite (nearly white).

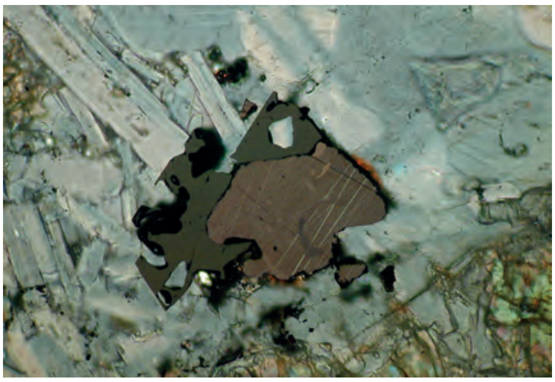
Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D86_31
Section: AS3531

## 123 **Iron, cohenite, ilmenite –** Khungtukun massif, Taimyr, Sibiria, Russia

Grain of terrestrial iron (white) with some round and wormlike inclusions of cohenite (slightly more yellow, nearly invisible in photo). Both surrounded by skeletal ilmenite (brownish grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D220_26
Section: AS3685

## 124 **Iron, graphite, cementite –** Khungtukun massif, Taimyr, Sibiria, Russia



As above, with crossed polars. Weak anisotropism of cementite is clearly visible.

Obj.: 20 × oil
Polars: × Pol ( ~ )
Photo width: 0.7 mm
Photo No.: D220_28
Section: AS3685

# Columbite

**Mineral name:** Columbite
**Formula:** $(Fe,Mn)(Nb,Ta)_2O_6$

**VHN:** 650–750
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 17.4 (14.6)* | $R_2$ = 16.8 (13.7)* | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 5.4 (3.7)* | $R_2$ = 5.0 (3.3)* | |
| **Colour impression** | **(in oil)** | grey tint brown | greyish brown | |
| **BR ~ Rpl** | **(in oil)** | weak (Ta-rich: distinct) | | $A_{oil}$ = 8 (11) |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | weak without colour | weak without colour |
| **Colour:** | **in 45° position** | grey | grey |
| | **... in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | perfect, straight, partly mosaic | |
| **Internal reflections** | **colour** | red-orange (Mn-rich: yellow brown) | |
| **(IR)** | **frequency** | Nb-rich: rare and dark; Ta-rich: frequently and lighter | |
| **Twinning** | **mode** | simple \|\| {201} ps.hexagonal | |
| | **frequency** | rare | |

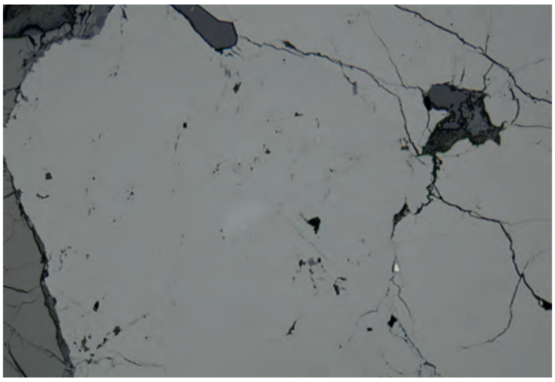
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | euhedral XX (tabular \|\| (100)), also granular. EB of cas, ilm, rt, uraninite, as EB in cas; # not visible |
| **Paragenesis** | cassiterite, ilmenite, rutile, uraninite, tapiolith |
| **Diagnostic features** | weak AExPol, IR, paragenesis |

## Notes, drafts

WOLFRAMITE is similar, but has less IR and visible #.
* for Ferro-columbite $(Fe, Mn)Nb_2O_6$, and Mangano-Tantalite $MnTa_2O_6$ resp.

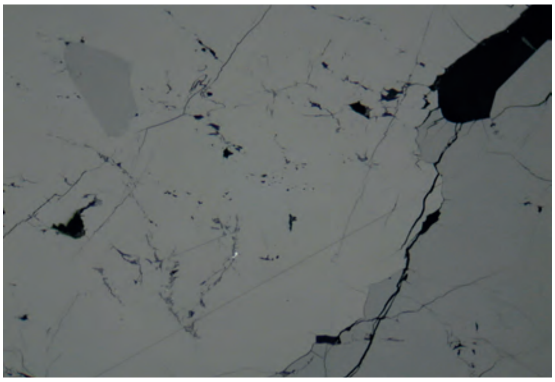
## 125 Columbite – Tveit, Iveland, Norway



Large columbite grain enclosing a small columbite grain in different orientation with higher reflectivity. The very weak bireflection of columbite in air is only visible at grain boundaries.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D86_13
Section: AS3452

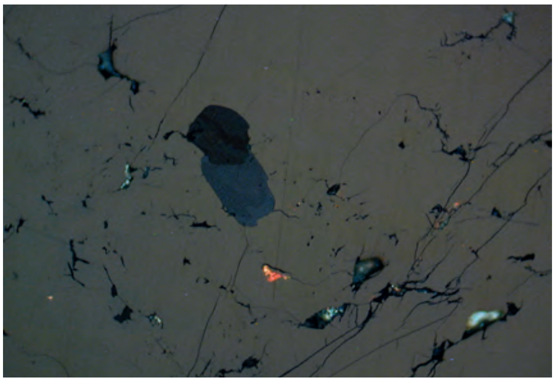
## 126 Columbite – Tveit, Iveland, Norway



Same section as above. With oil immersion objective the bireflection of columbite is apparently stronger and easy visible.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D86_14
Section: AS3452

## 127 Columbite – Tveit, Iveland, Norway



As above, with crossed polars. Weak anisotropism and orange IR are visible.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D86_17
Section: AS3452

## 128 Columbite – Giles prospect, S-Spargoville, Coolgardie, Australia

Patchy alteration or replacement of primary pegmatitic columbite (grey) by younger columbite (slightly darker).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D90_24
Section: AS3621

# Copper (in German: ged. Kupfer)

**Mineral name:** Copper
**Formula:** (Cu,Ag,As)

**VHN:** 80-100
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 64.6 | | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 56.9 | | |
| **Colour impression** | **(in oil)** | white orange | tarnishing to brown | |
| **BR Rpl** | **(in oil)** | -- | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | anisotropism due to scratches | anisotropism due to scratches |
| **Colour:** | **in 45° position** | in each position homogeneous light | in each position homogeneous light |
| | **... in other positions** | | |
| **Extinction position** | | greyish violet | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

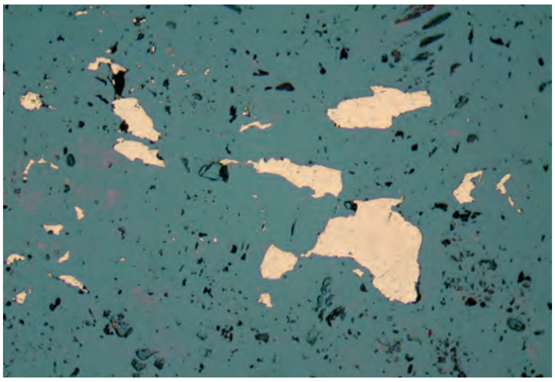
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | coarse- to fine-grained aggregates, dendritic or spear-like crystals, zoning due to Ag or As content; many scratches |
| **Paragenesis** | cuprite, tenorite, chalcocite, enargite, bornite, pyrrhotite, iron, magnetite |
| **Diagnostic features** | R, CI, scratches, paragenesis |

## Notes, drafts

Native copper grains in older sections are strongly tarnished or completely oxidized!

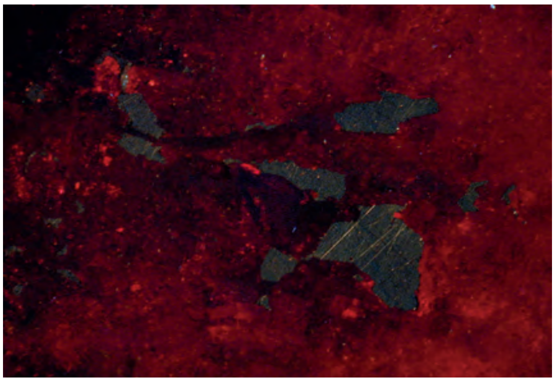
## 129 Copper, cuprite – Locality unknown



Replacement of native copper (light orange) by cuprite (grey, with red IR).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D43_23
Section: AS3547

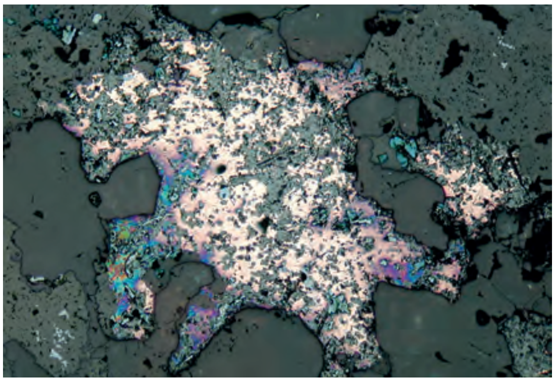
## 130 Copper, cuprite – Locality unknown



As above, with crossed polars. Cuprite with abundant red IR, copper with anisotropism due to numerous scratches.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D43_25
Section: AS3547

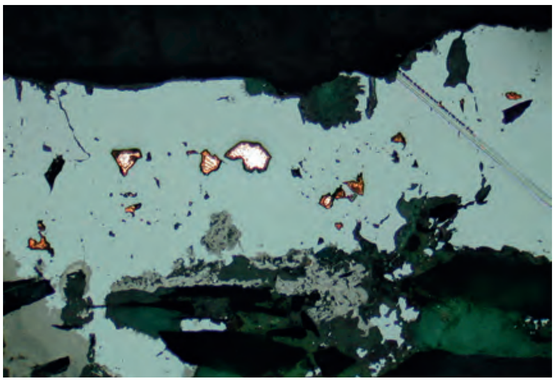
## 131 Copper – Tsumeb, Namibia



Copper (partly tarnished) intergrown with carbonates and quartz (strong relief).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D05_13
Section: AS2508

## 132 Copper, cup, tnr, mal – British Empire Mine, Wheel Turner, S-Australia



Relicts of native copper in cuprite (grey), which itself is replaced by tenorite (brownish grey), and malachite (green IR).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D197_21
Section: BEM-375

# Covellite (in German: Covellin)

**Mineral name:** Covellite (cv)
**Formula:** »CuS« = $[Cu_3^{1+}(S_2)^{2-}S^{2-\bullet}]^a$

**VHN:** 50-140
**Crystal System:** hex.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| $R_{(air)}$ in % (for 546 nm) | $R_o = 6.6$ | $R_{e'} = 23.7$ | |
| $R_{(oil)}$ in % (for 546 nm) | $R_o = 0.9$ | $R_{e'} = 9.9$ | |
| **Colour impression** (in oil) | violet | greyish blue tint violet | |
| **BR ~ Rpl** (in oil) | extremely strong | | $A_{oil} = 166$ |

## Observations with crossed polars (AExPol in oil)

| | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|
| **Anisotropism intensity/colour** | very strong with colour | very strong with colour |
| **Colour:** in 45° position | light orange | orange – orange |
| ... in other positions | light orange | |
| **Extinction position** | black | |
| **Mode of extinction** | perfect, undulatory | |
| **Internal reflections** colour | -- | |
| **(IR)** frequency | -- | |
| **Twinning** mode | deformation twins and translations (crumpled lamellae, »Zerknitterungslamellen«) | |
| frequency | common | |

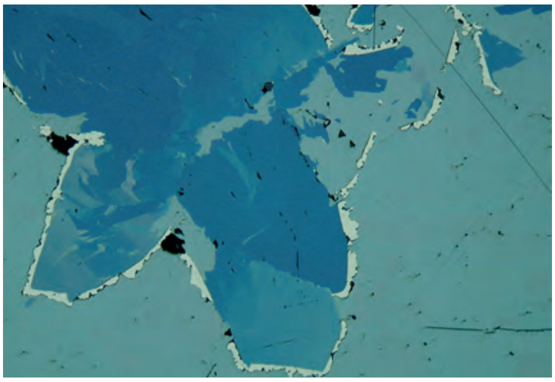
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | platy to blade-like forms, often radial aggregates, replacing other Cu-sulfides and galena, pyrite; perfect # \|\| {0001} |
| **Paragenesis** | chalcocite, chalcopyrite, fahlore, bornite, enargite, pyrite |
| **Diagnostic features** | CI, Rpl, AE\|\|Pol |

## Notes, drafts

Covellite without violet CI in oil → Yarrowite or Spionkopite (»Blaubleibender Covellin«)
[a]: Covellite is a natural occuring superconductor ($T_c < 1.63K$) and accommodates Cu only in the 1+ oxidation state due to S-S bonds!).
$^\bullet$ in the formula is an electron »hole« delocalised through the lattice.
See: Di Benedetto et al. (2006), EJM, 18, 283-287.

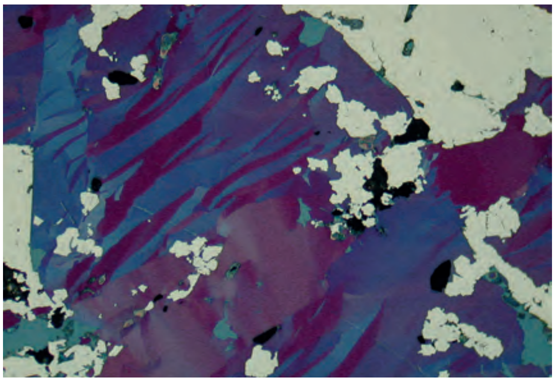
## 133 Covellite, digenite, py – Bor, Serbia



Former euhedral crystals of covellite (dark blue, BR!) rimmed by pyrite (yellowish white). Both were replaced in part by digenite (greyish blue).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D42_11
Section: AS3545

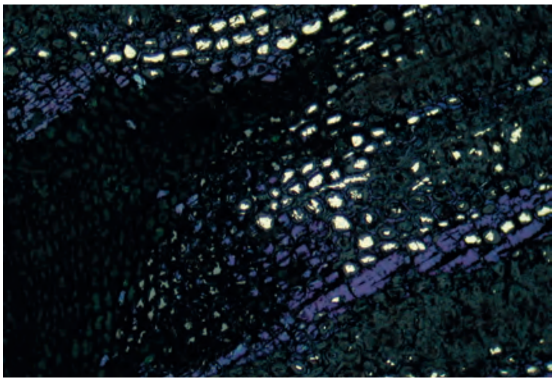
## 134 Covellite, digenite, py – Bor, Serbia



Strong reflection pleochroism of covellite in oil immersion with blue and violet lamellae. Formation of crumpled lamellae due to deformation (»Zerknitterungslamellen«); pyrite (yellowish white), and small digenites (bluish).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D50_09
Section: AS113

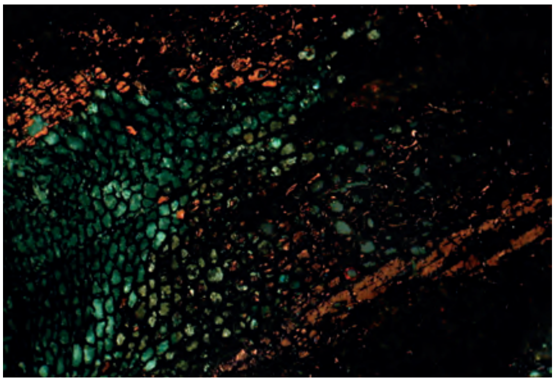
## 135 Covellite, py, malachite – Frankenberg, Hesse, Germany



Cell wood structure replaced by covellite (violet), pyrite (yellow), and malachite (dark grey, left side of photo).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D54_20
Section: AS3554

## 136 Covellite, py, malachite – Frankenberg, Hesse, Germany



As above with crossed polars. Cell wood structure replaced by covellite (orange AExPol!), pyrite (black), and malachite (green internal reflections).

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D54_19
Section: AS3554

# Cubanite

**Mineral name:** Cubanite (cub)
**Formula:** $CuFe_2S_3$

**VHN:** 150–260
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 35.4 | $R_2$ = 39.4 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 23.9 | $R_2$ = 28.2 | |
| **Colour impression** | **(in oil)** | yellowish brown | cream-white | (→cp: with bluish tint) |
| **BR ~ Rpl** | **(in oil)** | strong | | $A_{oil}$ = 16 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | weak with colour | distinct with colour |
| **Colour:** | **in 45° position** | bluish grey | greyish turquois – brownish orange |
| | **… in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | perfect, straight | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | 1. polysynthetic \|\| {001}; 2. simple \|\| {110} triplets | |
| | **frequency** | 1. often; 2. frequently | |

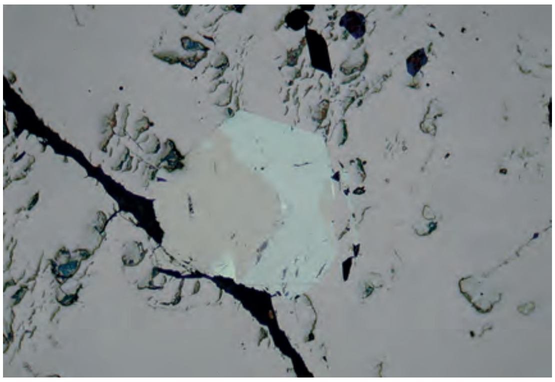
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | often anhedral as inclusion in cp and po; elongated, tabular XX; complex twinning due to inversion from isocubanite. |
| **Paragenesis** | cp, po, mackinawite |
| **Diagnostic features** | CI, twinning, paragenesis with cp, similar to po |

## Notes, drafts

T > 250°C: Isocubanite (cub.; synonym: Chalcopyrrhotite) with $R_{oil}$ ~ 23 %

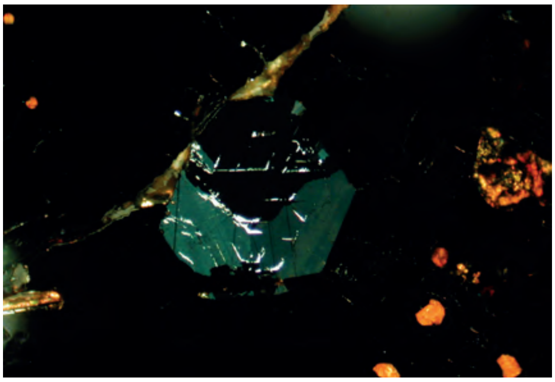
## 137 Cubanite, pyrrhotite, mackinawite – Gryhytthan, Sweden



Triplet-twin of cubanite (with Rpl and BR) in pyrrhotite. Small inclusions of mackinawite (dark grey and white) in cubanite are clearly visible.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D26_07
Section: AS160

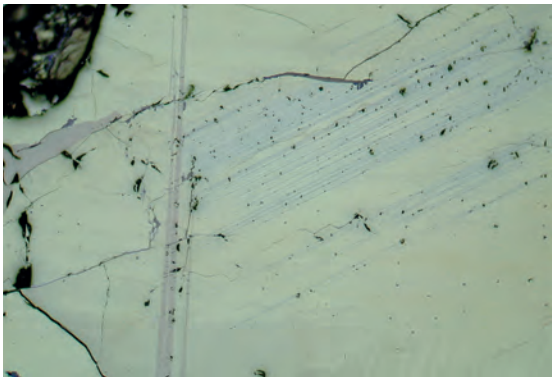
## 138 Cubanite, pyrrhotite, mackinawite – Gryhytthan, Sweden



As above, with crossed polars. Note the strong anisotropism of mackinawite.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D26_05
Section: AS160

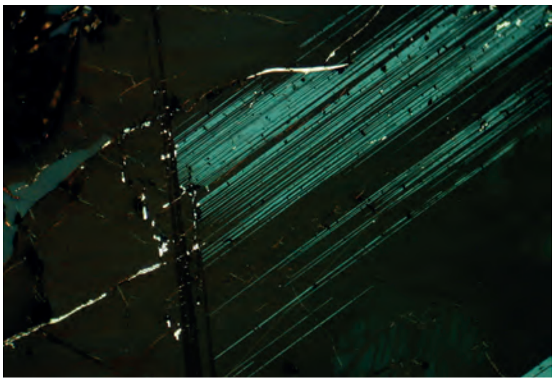
## 139 Cubanite, chalcopyrite, mackinawite – Talnakh, Russia



Fine lamellae of cubanite (bluish grey - brownish grey) in chalcopyrite. Veinlets filled with secondary mackinawite (dark grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D27_10
Section: AS3062

## 140 Cubanite, chalcopyrite, mackinawite – Talnakh, Russia



As above, with crossed polars. White stringers are mackinawi-te.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D27_11
Section: AS3062

# Cuprite

**Mineral name:** Cuprite (cup)
**Formula:** $Cu_2O$
**VHN:** 180-220
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 26.0 | $R_2$ = 27.9 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 11.8 | $R_2$ = 13.1 | |
| **Colour impression** | **(in oil)** | grey tint green | grey | → Cu: greyish blue |
| **BR ~ Rpl** | **(in oil)** | distinct | | $A_{oil}$ = 10 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | weak without colour | distinct with colour |
| **Colour:** | **in 45° position** | weak brightening | light blue - light olive green |
| | **... in other positions** | | |
| **Extinction position** | | masked by IR | -- |
| **Mode of extinction** | | masked by IR | |
| **Internal reflections** | **colour** | red | |
| **(IR)** | **frequency** | abundant | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

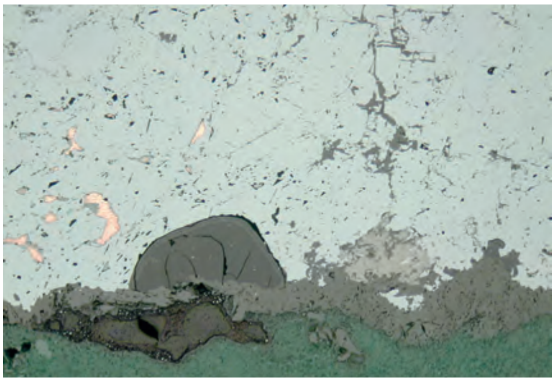
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | euhedral to anhedral XX, needle-like, interlocked; replaces copper, chalcocite and is replaced by tenorite and secondary Cu-silicates/-carbonates. Good # \|\| {111}. |
| **Paragenesis** | copper, tenorite, delafossite, malachite, chalcocite, limonite, cp |
| **Diagnostic features** | red IR, paragenesis |

## Notes, drafts

Most cuprites are anisotropic (probably due to polishing effects). Similar to CINNABAR.

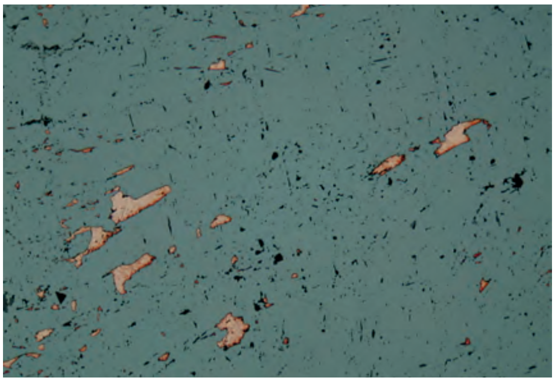
## 141 Cuprite, copper, tenorite – Locality unknown



Cuprite (light grey) with inclusions of native copper (light orange), partly replaced by tenorite (brownish grey), and secondary brochantite (green IR, lower part of photo).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D58_30
Section: AS3548

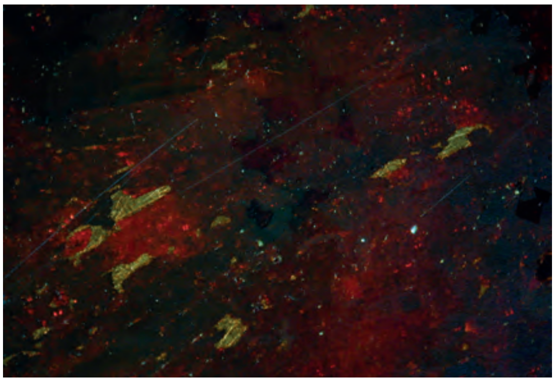
## 142 Cuprite, copper – Locality unknown



Native copper in cuprite (here grey with blue tint against copper). Note faint cleavage planes after {111}.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D42_03
Section: AS3547

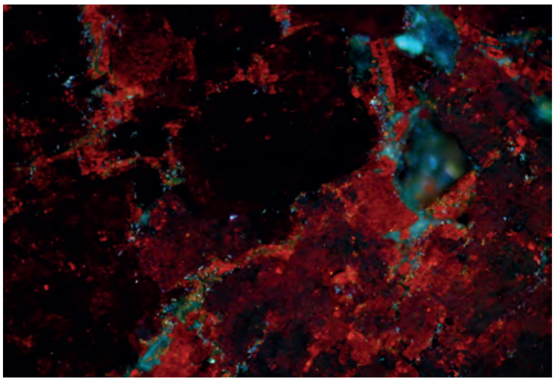
## 143 Cuprite, copper – Locality unknown



As above, with crossed polars. Note the distinct anisotropism of cuprite and the red IR. Copper with anisotropism due to scratches (»Kratzeranisotropie«).

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D42_05
Section: AS3547

## 144 Cuprite – Locality unknown



Red internal reflections and distinct anisotropism of cuprite.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D85_19
Section: AS3548

# Digenite

**Mineral name:** Digenite (dg)
**Formula:** $Cu_{1.8+x}S$ ($Cu_9S_5$)

**VHN:** 90-110
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 21.9 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 8.6 | |
| **Colour impression** | **(in oil)** | greyish blue | |
| **BR Rpl** | **(in oil)** | -- | $A_{oil}$ = 0 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | homogeneous dark | homogeneous dark |
| **Colour:** | **in 45° position** | black | greyish black |
| | **... in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | lamellar, more than one direction (spinel law) | |
| | **frequency** | frequently | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | anhedral, often replacing py, enargite, djurleite, anilite, bornite; »zerfallener Digenit« = mixture of djurleite+anilite |
| **Paragenesis** | chalcocite, cv, djurleite, anilite, bn |
| **Diagnostic features** | stronger blue and dull than chalcocite |

## Notes, drafts

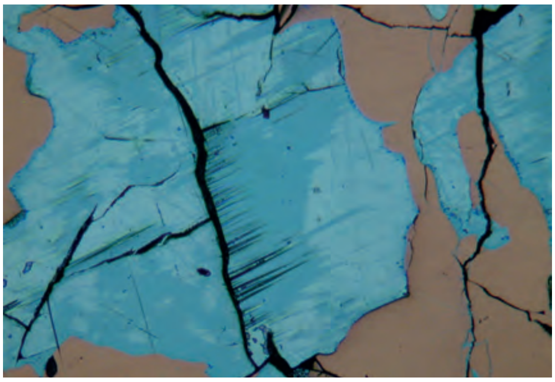
The Cu-S-system is quite complex with different phases/formulae/structures!
Cubic T-Digenite (low-digenite) stable between 83-76° C. Anilite ($Cu_{1.75}S$) has a similar optic.
See: Fleet (2006): Rev. Mineral Geochem. 61, 365-419, and Will et al. (2002): EJM, 14, 591-598.

## 145 Digenite, chalcocite, covellite – Bor, Serbia

Digenite (blue) with oriented fine lamellae of chalcocite (bluish grey) replacing covellite (violet) and pyrite (white yellow).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D50_10
Section: AS113

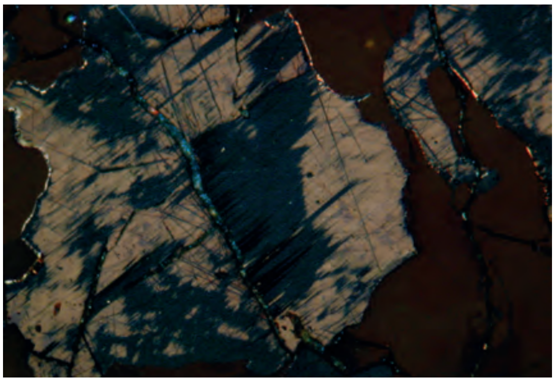
## 146 Digenite, anilite – Kesebol, Sweden



Digenite (blue) intergrown with anilite (light blue), penetrated by younger bornite (brown). See also photo no. 65.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D06_10
Section: AS1649

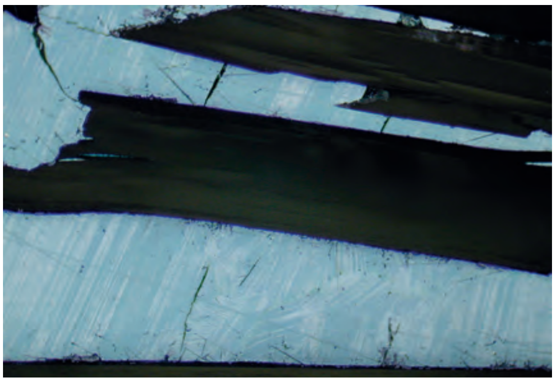
## 147 Digenite, anilite – Kesebol, Sweden



As above, with crossed polars. Digenite is almost black, anilite with strong anisotropism.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D06_17
Section: AS1649

## 148 »Zerfallener«, lamellar digenite – Amdalsverk, Norway



Separated biotite laths (greenish grey) partly replaced by lamellar intergrowth of anilite (medium blue) and djurleite (light greyish blue) formed by the low-temperature decomposition of former digenite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D05_21
Section: AS1646

# Djurleite

**Mineral name:** Djurleite
**Formula:** $Cu_{1.96}S$ ($Cu_{31}S_{16}$)

**VHN:** 70-80
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 31.7 | $R_2$ = 32.7 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 16.6 | $R_2$ = 17.4 | |
| **Colour impression** | **(in oil)** | grey (tint blue) | grey | similar to chalcocite! |
| **BR ~ Rpl** | **(in oil)** | very weak | | $A_{oil}$ = 5 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | extremely weak without colour | weak with colour |
| **Colour:** | **in 45° position** | brownish grey | greyish orange – dark brown |
| | **... in other positions** | brownish grey | impure bluish grey |
| **Extinction position** | | black | |
| **Mode of extinction** | | straight | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | lamellar twins after one direction (\|\| elongation)s | |
| | **frequency** | common | |

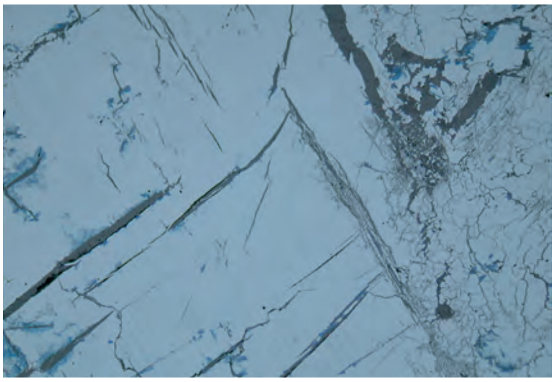
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | massive-granular, prismatic-tabular XX, some with # \|\| elongation |
| **Paragenesis** | covellite, chalcocite, goethite, malachite |
| **Diagnostic features** | R, paragenesis, lamellar twinning, lower R than chalcocite |

## Notes, drafts

Stable only below ~ 93° C. Bluish tint of CI varies depending on polishing process.
Very similar to CHALCOCITE!

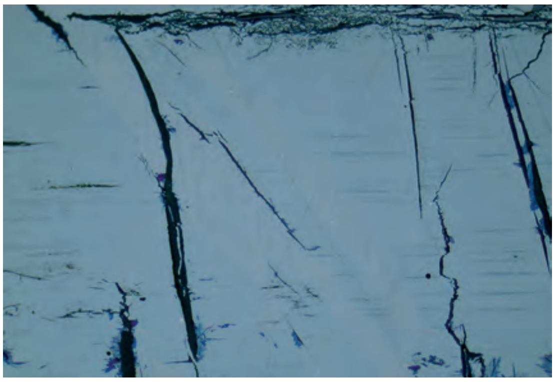
## 149 Djurleite, covellite – Dome Rock Mine, S-Australia



Large crystal of djurleite with cleavages and alteration cracks. Replacement by covellite (blue).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D159_10
Section: AS3550

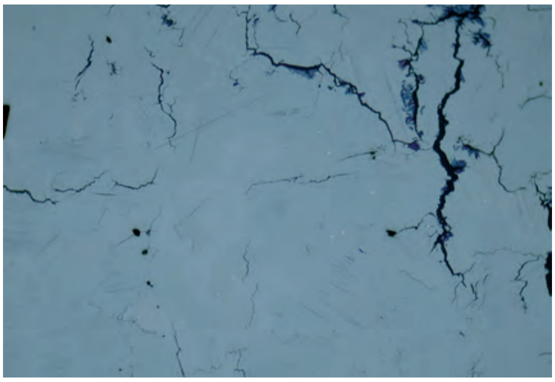
## 150 Djurleite, covellite – Dome Rock Mine, S-Australia



Part of photo above, now with oil immersion. Due to the weak bireflection a lamellar twinning of djurleite is visible (NW-SE).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D159_11
Section: AS3550

## 151 Djurleite, covellite – Dome Rock Mine, S-Australia



Granular, interlocked aggregate of djurleite with crackle-like alteration and newly formed covellite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D159_15
Section: AS3550

## 152 Djurleite, covellite – Dome Rock Mine, S-Australia

As above, with crossed polars.

Obj.: 20 × oil
Polars: × Pol ( ~ )
Photo width: 0.7 mm
Photo No.: D159_14
Section: AS3550

# Dyscrasite

**Mineral name:** Dyscrasite
**Formula:** $Ag_{3+x}Sb_{1-x}$

**VHN:** ~ 150-180
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 60.1 | $R_2$ = 62.7 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 47.9 | $R_2$ = 51.2 | |
| **Colour impression** | **(in oil)** | white cream | white | |
| **BR ~ Rpl** | **(in oil)** | weak | | $A_{oil}$ = 7 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | weak with colour tint | distinct with colour |
| **Colour:** | **in 45° position** | grey impure (tint yellow brown) | orange brown – yellow green – blue violet |
| | **… in other positions** | brownish grey | |
| **Extinction position** | | black | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | few irregular or saw tooth-like {110}, also spindle-like twins | |
| | **frequency** | occasional | |

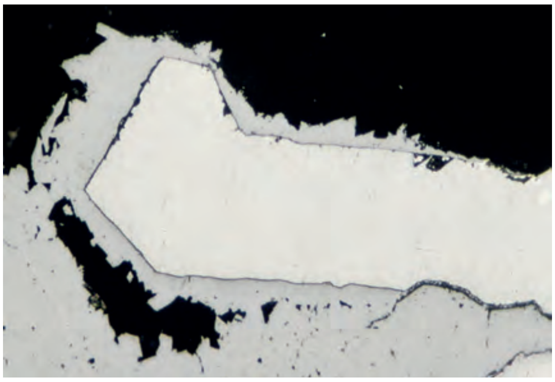
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | euhedral, granular, isometric, occasional large XX; well-developed # {001}+{011} |
| **Paragenesis** | allargentum, native silver, gn |
| **Diagnostic features** | paragenesis, twinning, # |

## Notes, drafts

Dyscrasite formula: $x \leq 0.2$. Similar to ALLARGENTUM.

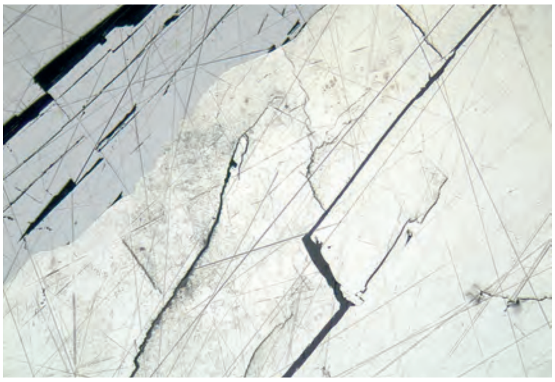
## 153 Dyscrasite, sk – Wenzel mine, Schwarzwald, Germany



Euhedral crystal of dyscrasite rimmed by skutterudite and safflorite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: A86_19
Section: Wenzel792

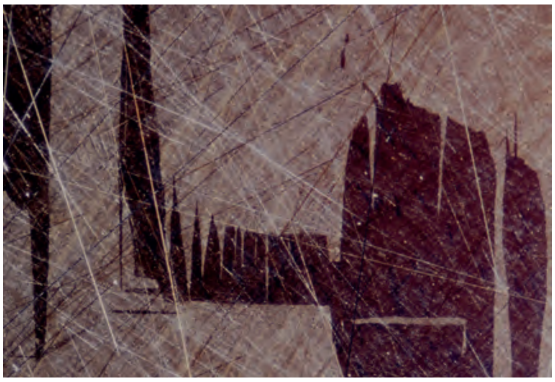
## 154 Dyscrasite, galena – Wenzel mine, Schwarzwald, Germany



Dyscrasite (white) with cleavage beside galena (greyish white with perfect #).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D185_19
Section: SSW7

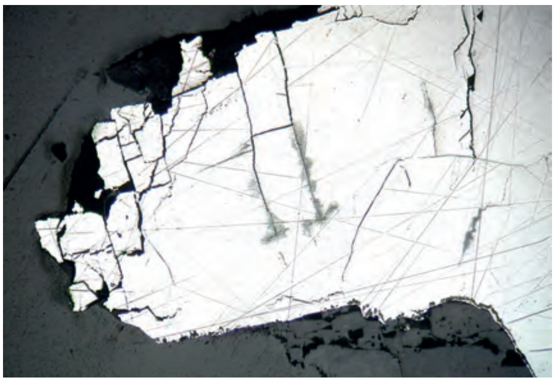
## 155 Dyscrasite – Pribram, Czech Republic



Saw tooth-like complex twinning of dyscrasite.

Obj.: 20 × oil
Polars: × Pol ( ~ )
Photo width: 0.5 mm
Photo No.: A87_27
Section: AS1125

## 156 Dyscrasite – Wenzel mine, Schwarzwald, Germany



Single crystal of dyscrasite with distinct cleavage (pathway for alteration with tiny silver grains and greyish tarnishing).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D185_18
Section: SSW7

# Emplectite

**Mineral name:** Emplectite
**Formula:** $CuBiS_2$

**VHN:** 160-230
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1 = 37.3$ | $R_2 = 42.2$ | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1 = 21.9$ | $R_2 = 26.9$ | $R_2$ = \|\| elongation |
| **Colour impression** | **(in oil)** | greyish white tint brown | greyish white tint olive | |
| **BR ~ Rpl** | **(in oil)** | distinct | | $A_{oil} = 20$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong with colour tint | strong with colour |
| **Colour:** | **in 45° position** | light grey with tint yellow green | light yellow – bluish |
| | **... in other positions** | | dark violet brown |
| **Extinction position** | | black | |
| **Mode of extinction** | | straight, undulatory | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | simple | |
| | **frequency** | rare | |

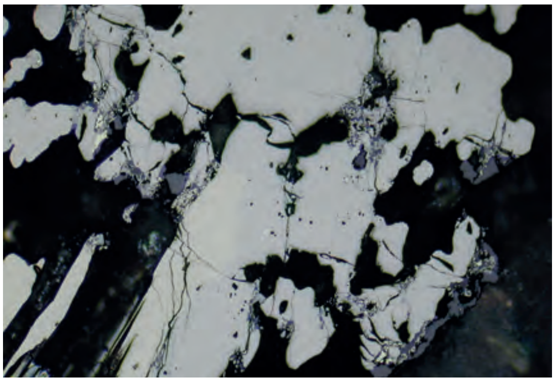
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | fibrous, needle-like XX (\|\| [001], rare flattened \|\| {010}; replaced by wittichenite. # \|\| (001) (bismuthinite has # \|\| {010}) |
| **Paragenesis** | bismuthinite, wittichenite, bismuth, cp, ... |
| **Diagnostic features** | paragenesis |

## Notes, drafts

Low temperature phase (< 320° C) of $CuBiS_2$ (> 320° C: Cuprobismutite)
CI against BISMUTHINITE: more yellow-olive
BR orientation in UYTENBOGAARDT & BURKE (1985) is incorrect!

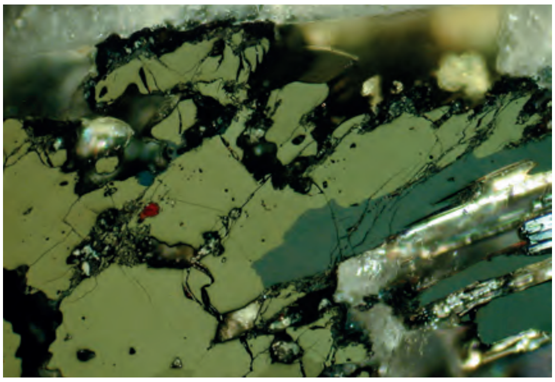
## 157 **Emplectite –** Grube Daniel im Gallenbach, Wittichen, Schwarzwald



Emplectite with distinct bireflection.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D141_12
Section: AS3647

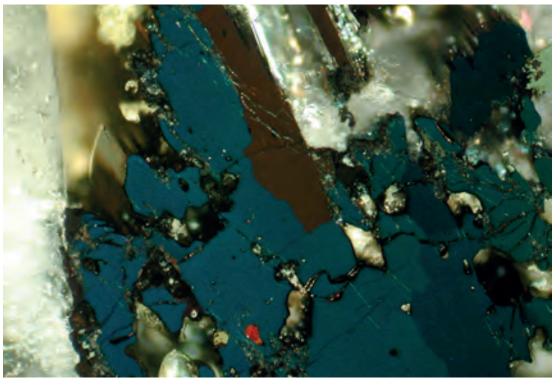
## 158 **Emplectite –** Grube Daniel im Gallenbach, Wittichen, Schwarzwald



Yellow green anisotropism effects of emplectite.

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D141_15
Section: AS3647

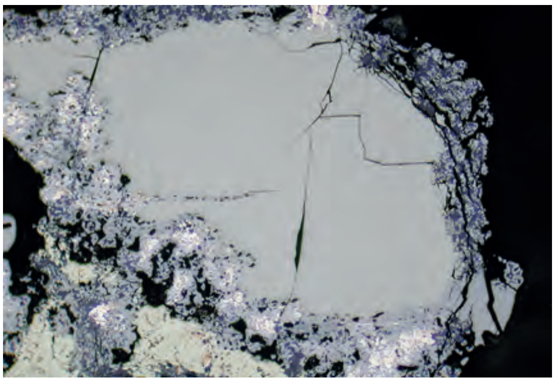
## 159 **Emplectite –** Grube Daniel im Gallenbach, Wittichen, Schwarzwald



As above, but 90° rotated.

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D141_14
Section: AS3647

## 160 **Emplectite, wittichenite, bismuth, cp –** Wittichen, Schwarzwald



Large grain of emplectite (greyish white tint yellow) decomposes to a mixture of native bismuth (tiny white grains) plus wittichenite (medium grey), and chalcopyrite (yellow).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D141_18
Section: AS3647

# Enargite

**Mineral name:** Enargite (eng.)
**Formula:** $Cu^{1+}_3(As,Sb)^{5+}S_4$

**VHN:** 130–380
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_a$ = 24.2 | $R_b$ = 25.2 | $R_c$ ≈ 28 |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_a$ = 10.9 | $R_b$ = 11.6 | $R_c$ ≈ 15 |
| **Colour impression** | **(in oil)** | grey tint violet | grey tint brown | greyish cream |
| **BR ~ Rpl** | **(in oil)** | distinct | | $A_{oil}$ = 6 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong with colour | strong with colour |
| **Colour:** | **in 45° position** | greyish yellow | greyish yellow – reddish brown |
| | **… in other positions** | reddish brown | greyish blue, red brown |
| **Extinction position** | | black | |
| **Mode of extinction** | | straight | |
| **Internal reflections** | **colour** | deep red | |
| **(IR)** | **frequency** | very rare | |
| **Twinning** | **mode** | single lamellae and ps. hex. triplets || {320}, deformations twins may occur | |
| | **frequency** | very rare (i.e. in ore from Bor, Serbia) | |

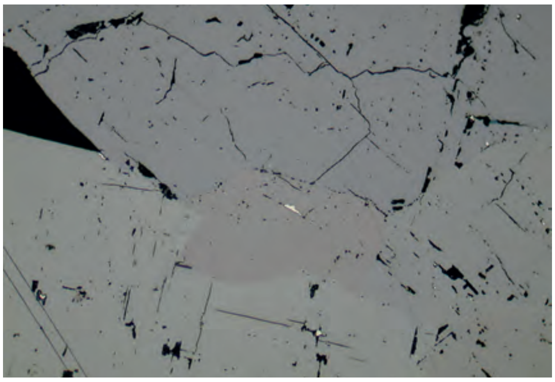
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | stubby prismatic XX, anhedral to rounded grains, paramorph after luzonite (partly || twin lam. of luzonite); # {110} often visible |
| **Paragenesis** | luzonite, tnt, py, cp |
| **Diagnostic features** | paragenesis, luzonite is more orange brown and always twinned |

## Notes, drafts

A copperthioarsenat with $As^{5+}$!
O'rh. Sb-endmember: Stibioenargite (»Famatinite«): $Cu_3SbS_4$
Dimorph with LUZONITE – stibioluzonite (tetr.); Sb-free enargite formed > 280°C
(POSFAI & BUSECK (1998): AM 83, 373-382).
Transformation to tennantite (gives a »porous tennantite«) or to tennantite with tiny chalcopyrite inclusions (so called »yellow tennantite«).

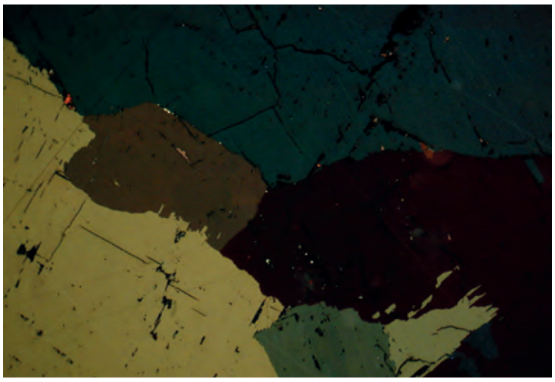
## 161 Enargite, pyrite – »Colorado«, USA



Reflection pleochroism of enargite; note the good cleavage of enargite grains. One tiny inclusion of pyrite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D115_12
Section: AS3635

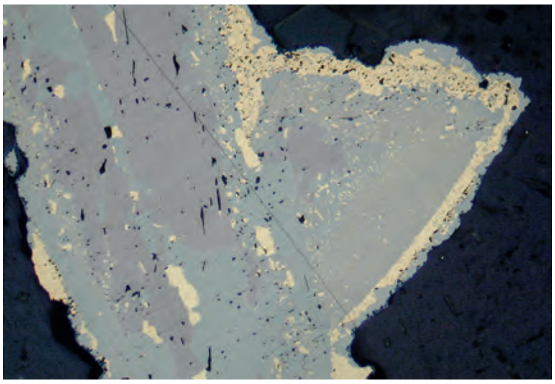
## 162 Enargite, pyrite – »Colorado«, USA



As above, with (not exactly) crossed polars. Enargite shows no twinning (in contrast to luzonite).

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D115_14
Section: AS3536

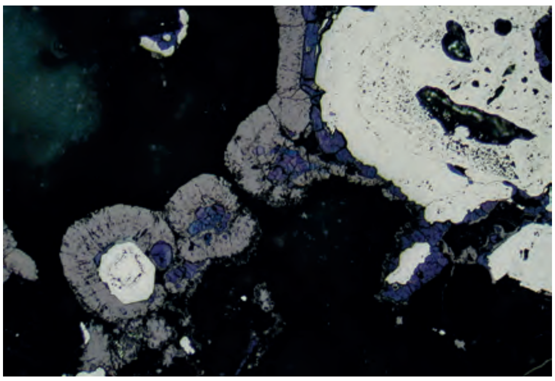
## 163 Enargite, tennantite, cp – Clara mine, Oberwolfach, Schwarzwald, Germany



Relicts of former euhedral enargite crystals (tint violet) replaced by a mixture of tennantite (grey) plus chalcopyrite (yellow). Note: The »yellow fahlore« in triangle on the right side is a very fine-grained myrmekitic mixture of fahlore with chalcopyrite. This »yellow fahlore« is rimmed by chalcopyrite and fahlore.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D204_23
Section: MK35

## 164 Enargite, py, cv – Mahoni prospect, Lombok, Indonesia



Aggregates of anhedral enargite around zoned pyrite (white) and covellite (blue-violet).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D91_10
Section: AS3624

# Fahlore (Tennantite – Tetrahedrite; in German: Fahlerz)

**Mineral name:** Fahlore (tnt-td)
**Formula:** $(Cu,Ag,Fe)_{12}(As,Sb,Bi)_4S_{13}$

**VHN:** 300-380
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | tennantite: ~ 30 | tetrahedrite: ~ 32 |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | ~ 15 | ~ 17 |
| **Colour impression** | **(in oil)** | grey tint green | grey tint brown(olive) |
| **BR Rpl** | **(in oil)** | -- | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | in each position dark | in each position dark |
| **Colour:** | **in 45° position** | black | black |
| | **... in other positions** | | |
| **Extinction position** | | -- | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | red | |
| **(IR)** | **frequency** | absent to common (high As content) | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

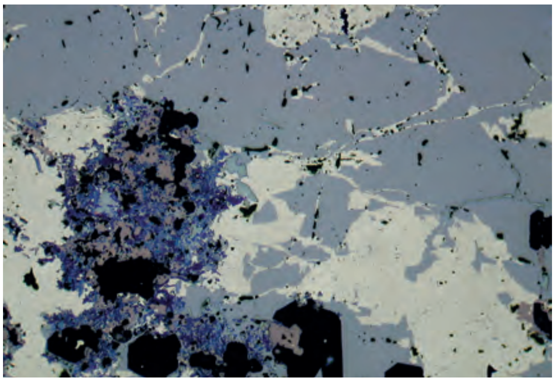
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | mostly anhedral; occasionally as inclusion in galena, no # |
| **Paragenesis** | galena, chalcopyrite, sphalerite, stannite, sulfosalts |
| **Diagnostic features** | R, CI, paragenesis |

## Notes, drafts

General formula: $[(Cu, Ag)^{[3]}{}_6[Cu^{1+},Zn,Fe,Hg,Ge,Mn,Cu^{2+}]^{[4]}{}_6]$ $[(Sb,As,Bi)^{[3]}{}_4]$ $[S^{[4]}{}_{12}S^{[6]}]$
TETRAHEDRITE: Sb-rich fahlore, TENNANTITE: As-rich fahlore.

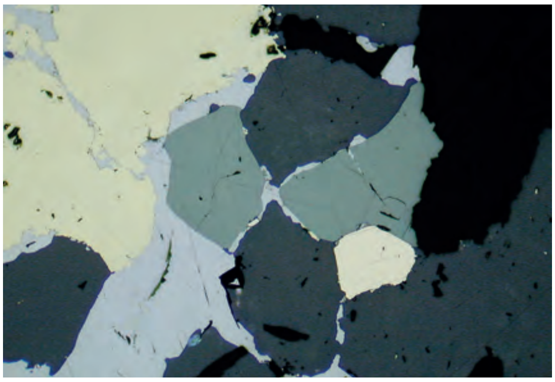
## 165 Fahlore, cp, luzonite, cov – Clara mine, Oberwolfach, Schwarzwald, Germany



Fahlore (grey) penetrated and replaced by chalcopyrite (yellow). Luzonite (brownish) is transformed into covellite (blue-violet).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D54_06
Section: AS3578

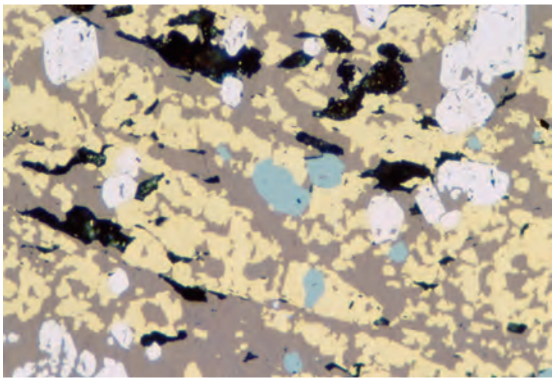
## 166 Tennantite, sph, gn, cp, py – Boliden, Sweden



Isometric grains of greenish fahlore (here tennantite), together with sphalerite (dark grey), pyrite (whitish yellow), and chalcopyrite (yellow). Younger galena (greyish white) in fractures and on grain boundaries.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D93_03
Section: WT5 176-5

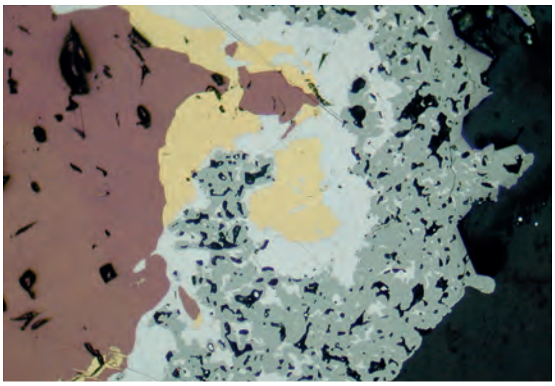
## 167 Tennantite, bn, py, cp – La Plata mine, Chiriboga, Ecuador



Small grains of anhedral fahlore (greenish grey) and euhedral pyrite (white) in complex intergrowth of bornite (brown) with chalcopyrite (yellow).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: A69_18
Section: AS3101

## 168 Fahlore, bn, cp, gn, qz – Detzeln, S-Schwarzwald, Germany



Fahlore-carbonate-myrmekite enclosing galena (greyish white), chalcopyrite (yellow), and bornite (orange violet).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D79_21
Section: DK-11

# Feldspar (in German: Alkalifeldspat)

**Mineral name:** (Alkali) Feldspar (fsp)
**Formula:** $(K,Na)AlSi_3O_8$

**VHN:** ~ 800-900
**Crystal System:** mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_x = 4.3$ | $R_z = 4.4$ | calculated from $n_x$, $n_z$ |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_x = 0.0$ | $R_z = 0.0$ | calculated from $n_x$, $n_z$ |
| **Colour impression** | **(in oil)** | »black« (but light IR!) | »black« (but light IR!) | |
| **BR Rpl** | **(in oil)** | -- | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

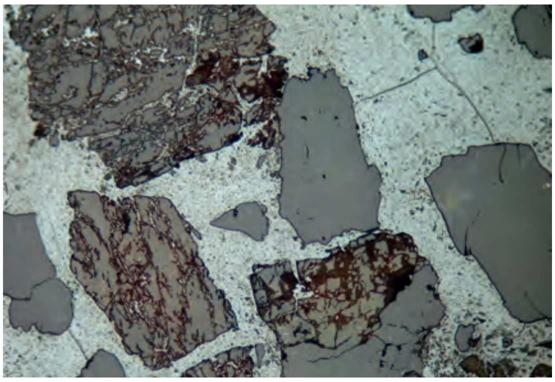
| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | not visible | not visible |
| **Colour:** | **in 45° position** | masked by IR | masked by IR |
| | **... in other positions** | | |
| **Extinction position** | | masked by IR | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | white – colourless | |
| **(IR)** | **frequency** | predominant | |
| **Twinning** | **mode** | simple | |
| | **frequency** | occasional; common | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | granular to euhedral XX, often altered to clay minerals with dusty appearance (not as clear as quartz); # after two directions |
| **Paragenesis** | qz, sericite, clay minerals, hematite, other rock-forming minerals |
| **Diagnostic features** | low R, no BR, # |

## Notes, drafts

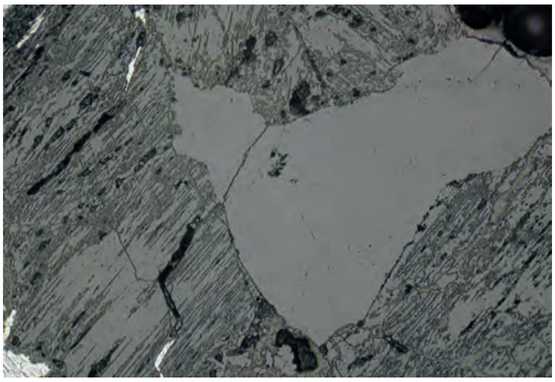
## 169 Alkali feldspar, quartz, limonite – Vrábce, Czech Republic



Sandstone with relicts of feldspar (anhedral grains with numerous cracks) and quartz in a matrix of limonite (medium grey).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D41_18
Section: 3-6

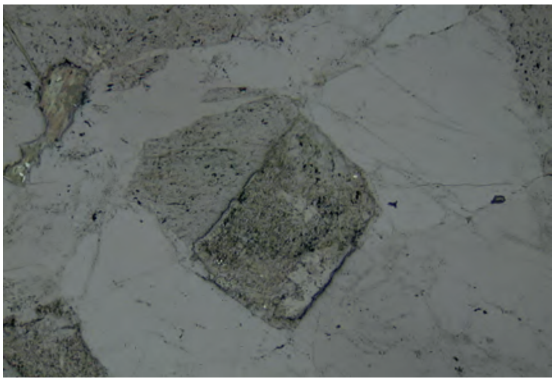
## 170 Alkali feldspar, quartz – Oberröthenbach, Schwarzwald, Germany



Feldspar (with cleavage and alteration features), quartz, and tiny pyrolusite (nearly white).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D104_31
Section: IR 31b

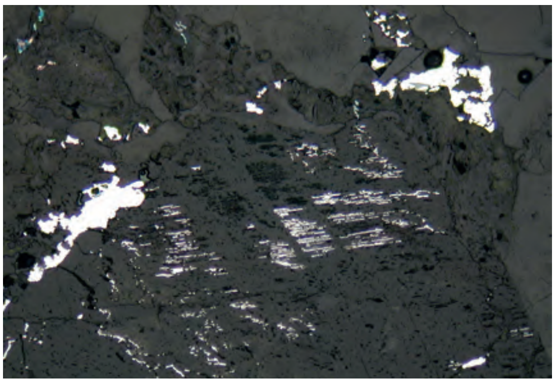
## 171 Alkali feldspar, qz, bio – Grube Anton, Heubachtal, Schwarzwald, Germany



Crystal of alkali feldspar enclosed in quartz. Biotite flake (upper left).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D139_04
Section: WIT2

## 172 Alkali feldspar, silver, quartz – Wittichen, Schwarzwald, Germany



Precipitation of silver (white) in pores between quartz and feldspar, and along the cleavage plains of large feldspar grain.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D187_09
Section: KHF55

# Fluorite (in German: Fluorit, Flussspat)

**Mineral name:** Fluorite (fl)
**Formula:** $CaF_2$
**VHN:** ~ 180
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 3.2 | calculated from n |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 0.0 | calculated from n |
| **Colour impression** | **(in oil)** | black (but IR!) | |
| **BR Rpl** | **(in oil)** | -- | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

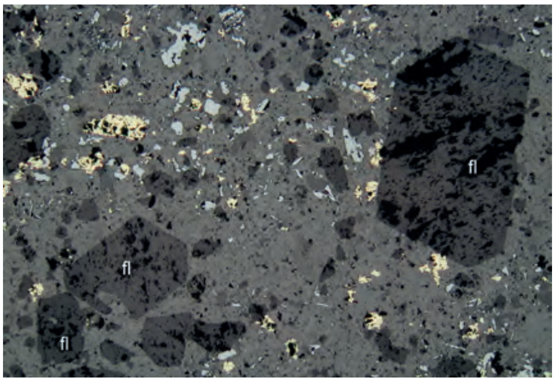
| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | isotropic | isotropic |
| **Colour:** | **in 45° position** | many IR | many IR |
| | **... in other positions** | | |
| **Extinction position** | | -- | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | white, violet | |
| **(IR)** | **frequency** | predominant | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | euhedral to anhedral grains; many fluid inclusions (mostly rectangular morphologies, in contrast to the more round flincs in quartz!)); perfect # \|\| {111} |
| **Paragenesis** | barite, qz, gn, sph, pitchblende |
| **Diagnostic features** | very low R, isotropic, perfect cleavage |

## Notes, drafts

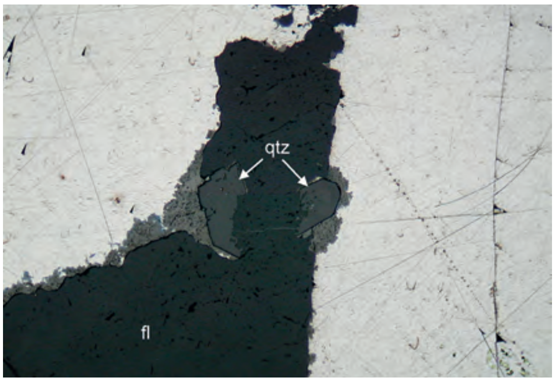
## 173 Fluorite, carbonate, hm, cp – Olympic Dam, Australia




Euhedral to anhedral crystals of fluorite (fl, dark grey with black cleavage pits) in matrix of carbonate (medium grey), hematite (light grey), and chalcopyrite (yellow).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D101_22
Section: OD664

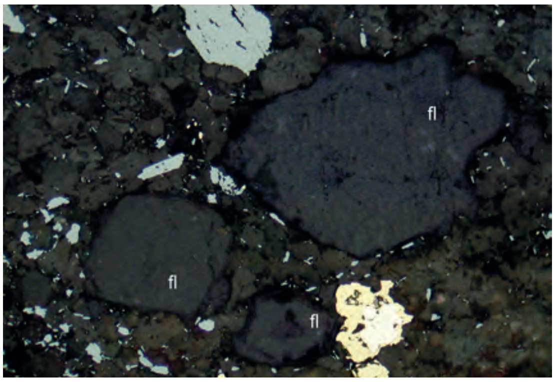
## 174 Fluorite, galena, quartz – Jenigi, Egypt




Fluorite vein (fl, dark grey to black) in galena (greyish white) parting a quartz crystal (qz, medium grey) and cerussite (light grey).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D99_20
Section: AS3140

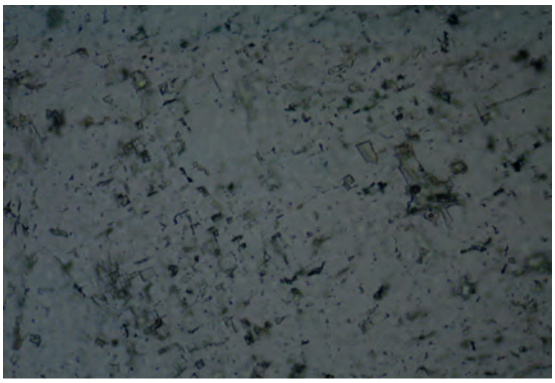
## 175 Fluorite, carbonate, hm, cp – Olympic Dam, Australia




Clasts of fluorite (fl, with violet rim) in matrix of carbonate, hematite (light grey), and chalcopyrite plus pyrite (lower right of photo).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D102_26
Section: OD662

## 176 Fluorite – Clara mine, Oberwolfach, Schwarzwald, Germany



Large fluorite crystal showing tiny fluid inclusions with rectangular morphology.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D204_19
Section: MK35

# Franckeite

**Mineral name:** Franckeite
**Formula:** ~ $Pb_5Sn_2FeSb_2S_{14}$

**VHN:** 30-100
**Crystal System:** tric.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 35.6 | $R_2$ = 37.5 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 20.7 | $R_2$ = 22.1 | |
| **Colour impression** | **(in oil)** | greyish white | greyish white tint yellow | |
| **BR ~ Rpl** | **(in oil)** | weak | | $A_{oil}$ = 7 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | distinct with colour tint | distinct with colour |
| **Colour:** | **in 45° position** | light grey tint brown | grey tint blue – greyish yellow |
| | **... in other positions** | brown, greyish blue | yellow brown, greyish blue |
| **Extinction position** | | greyish black | |
| **Mode of extinction** | | straight, undulatory | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | translation twins \|\| (001); also perpendicular to elongation | |
| | **frequency** | frequent | |

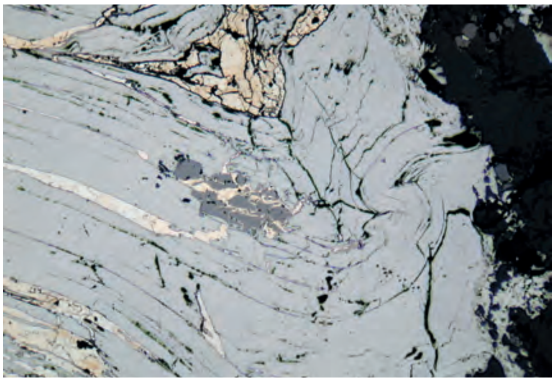
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | tabular, radial fibrous, EB of po, as thin lamellae in cylindrite; # \|\| {010} |
| **Paragenesis** | stannite, gn, sphalerite, py, mrc, teallite, cylindrite |
| **Diagnostic features** | #, translation twins, low BR, little darker and less yellow than teallite |

## Notes, drafts

XX are often bended due to translation in (001). Cylindrite has stronger BR and different morphology.

## 177 Frankeite, pyrite, wurtzite – Oruro, Bolivia



Bended laths of franckeite (with perfect cleavage) intergrown with pyrite/marcasite (various white-yellow colours due to tarnishing) and wurtzite (medium grey, centre).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D109_13
Section: AS1018

## 178 Frankeite, pyrite, wurtzite – Oruro, Bolivia

As above, with crossed polars.

Obj.: 10 ×
Polars: × Pol (~)
Photo width: 1.4 mm
Photo No.: D109_15
Section: AS1018

## 179 Frankeite – Oruro, Bolivia

Tabular franckeite crystals showing deformation features like twinning and crumpled lamellae (»Zerknitterungslamellen«).

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D109_25
Section: AS1019

## 180 Frankeite – Oruro, Bolivia

Crumpled lamellae and undulatory extinction of franckeite.

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D109_16
Section: AS1018

# Gahnite

**Mineral name:** Gahnite
**Formula:** $(Zn,Fe,Mg)Al_2O_4$

**VHN:** 1900-2400
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | R = 8.4 | calc. from n = 1.82 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | R = 0.8 | | |
| **Colour impression** | **(in oil)** | dark grey | | |
| **BR Rpl** | **(in oil)** | -- | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | isotropic, masked by IR | isotropic, masked by IR |
| **Colour:** | **in 45° position** | masked by IR | masked by IR |
| | **... in other positions** | | |
| **Extinction position** | | -- | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | bluish or greenish white | |
| **(IR)** | **frequency** | abundant | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

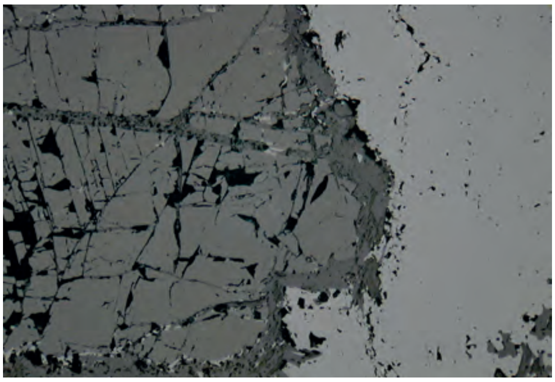
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | octahedral crystals; occasionally replaced by sphalerite, as EB in franklinite; distinct # \|\| {111} |
| **Paragenesis** | sph, ilm, rt, py, cas, po, asp |
| **Diagnostic features** | IR, paragenesis |

## Notes, drafts

Similar to ALABANDITE.

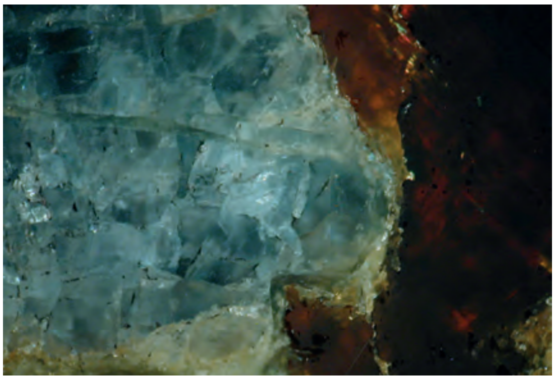
## 181 Gahnite, sphalerite – Mina Victoria, Bossost, N-Spain



Gahnite (left side) with visible cleavage planes beside sphalerite (right side).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D92_19
Section: AS3611

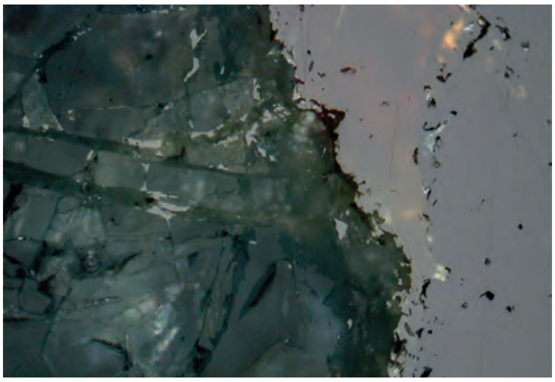
## 182 Gahnite, sphalerite – Mina Victoria, Bossost, N-Spain



As above, with crossed polars. Note the bluish IR of gahnite, and the brown IR of sphalerite.

Obj.: 10 ×
Polars: × Pol
Photo width: 1.4 mm
Photo No.: D92_20
Section: AS3611

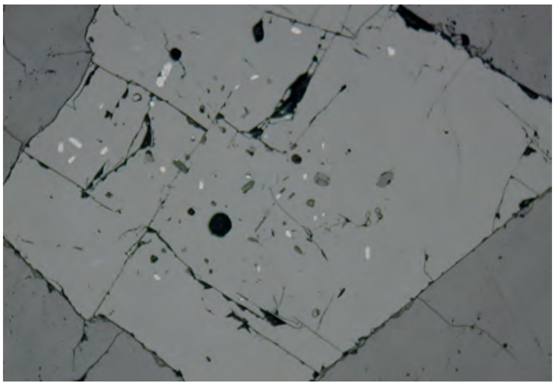
## 183 Gahnite, sphalerite – Mina Victoria, Bossost, N-Spain



In oil immersion now strongly reduced reflectance (0.8%) of gahnite (left; with bluish white IR). Sphalerite on the right shows some brown IR.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D92_22
Section: AS3611

## 184 Gahnite, ilmenite, gangue – 9-Mile-Mine, Broken Hill, NSW, Australia



Euhedral crystal of gahnite with tiny inclusions of rounded ilmenites and gangue minerals.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D128_12
Section: AS3522

# Galena/Galenite (in German: Galenit, Bleiglanz)

**Mineral name:** Galena/Galenite (gn)
**Formula:** PbS
**VHN:** 60-100
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 43.0 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 28.0 | |
| **Colour impression** | **(in oil)** | greyish white | |
| **BR Rpl** | **(in oil)** | -- | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | homogeneous dark | homogeneous dark |
| **Colour:** | **in 45° position** | black | grey black |
| | **… in other positions** | | |
| **Extinction position** | | -- | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | (only visible after etching) | |
| | **frequency** | -- | |

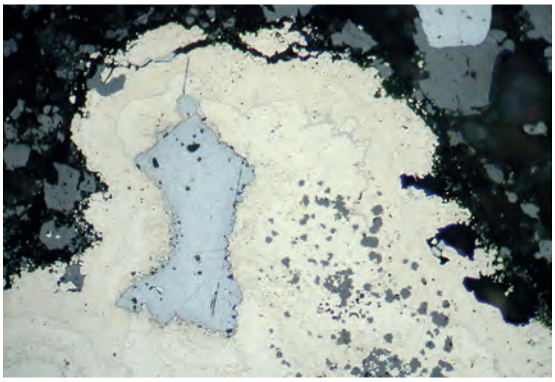
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | euhedral – anhedral, EB of miargyrite and schapbachite, inclusions of Ag-minerals and sulfosalts; # \|\|{100} → triangular pits (characteristic, but not with perfect polish!) |
| **Paragenesis** | sphalerite, chalcopyrite, marcasite, bravoite, Ag-minerals |
| **Diagnostic features** | cleavage, low polishing hardness, scratches |

## Notes, drafts

Similar to ULLMANNITE (ullmannite has higher R, more often visible zoned).

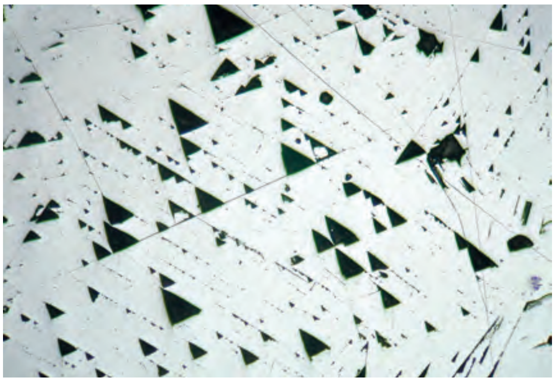
## 185 Galena, pyrite, sphalerite – Rammelsberg, Harz, Germany



Anhedral relict of galena (greyish white) replaced and surrounded by colloform and zoned pyrite (yellow-white) and sphalerite (grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D67_22
Section: AS3598

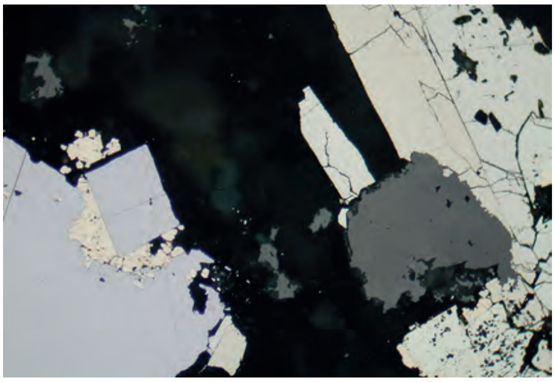
## 186 Galena – Balya, Turkey



Galena with characteristic triangular pits along cleavage lines || {100}.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D32_13
Section: AS156

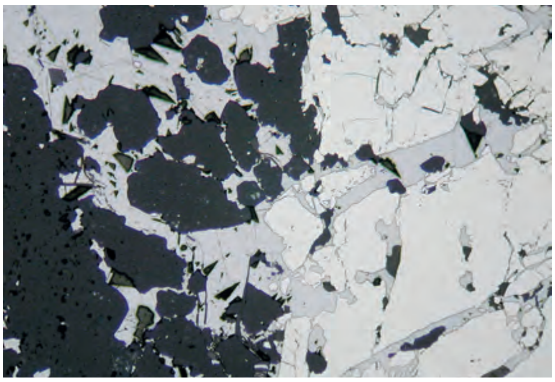
## 187 Galena, pyrite, marcasite, sphalerite – Tepla, Slovenia



Left side: Galena intergrown with pyrite (white yellow). Right side: Marcasite plates (light yellow) accompanied with sphalerite (medium grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D58_02
Section: AS3501

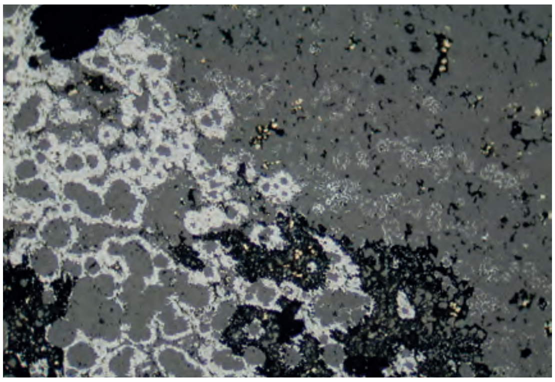
## 188 Galena, asp, qz – Hällefors, Sweden



Galena (greyish white, triangular pits) replacing arsenopyrite rhombs (nearly white) and quartz (dark grey).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D69_02
Section: AS101

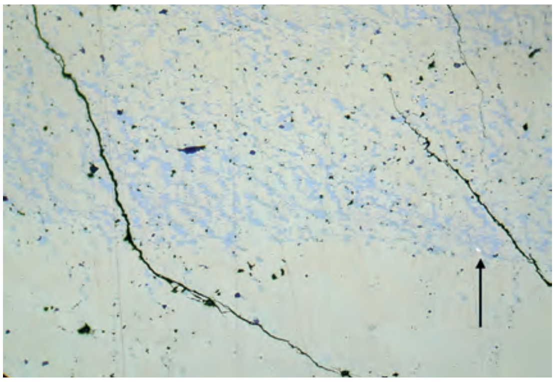
## 189 Galena, sph, py – Tara Mine, Navan, Co. Meath/Ireland



Colloform aggregates of galena (light grey) and sphalerite (medium grey) with tiny pyrite grains.

Obj.: 20 oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D67_15
Section: AS3596

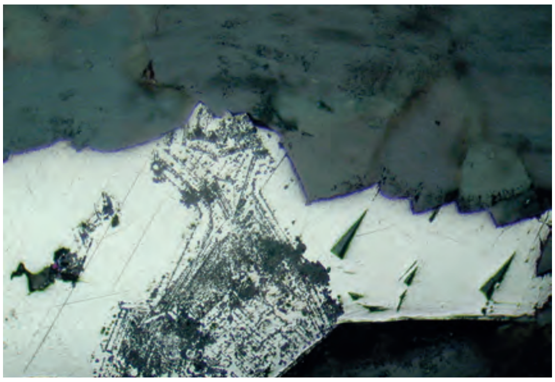
## 190 Galena, cp, gold – Rammelsberg, Harz, Germany



Very fine and complex intergrowth of galena (light grey) with chalcopyrite (yellow) and gold (arrow, light yellow).

Obj.: 20x oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D37_26
Section: AS3507

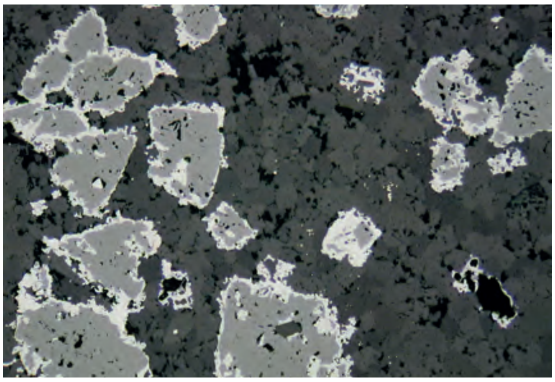
## 191 Galena – Riggenbach, Schwarzwald, Germany



Zoning of galena, visible due to oriented replacement by gangue mineral.

Obj.: 20x oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D70_01
Section: BO43

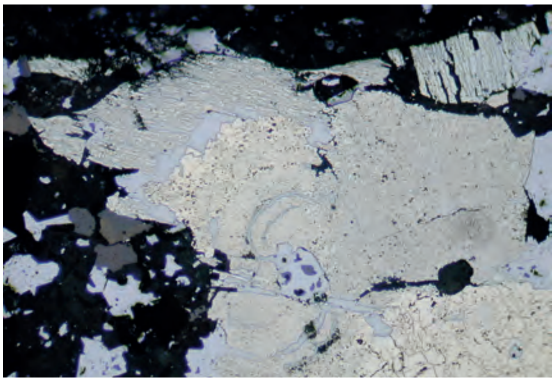
## 192 Galena, sph, cb – Aselfingen, Schwarzwald, Germany



Galena (light grey) replacing sphalerite crystals (medium grey), both in carbonate groundmass (shades of dark grey, BR).

Obj.: 10x
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D80_02
Section: without No

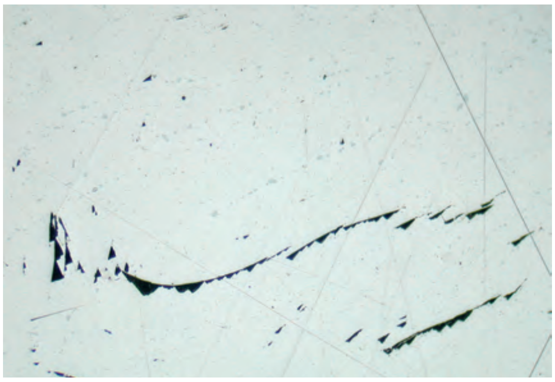
## 193 Galena, py, mrc, sph – Grube Geyer, Saxony, Germany



Bird-eyes structure with fine-grained marcasite and pyrite (central part of photo) is in part replaced by galena (greyish white). Small sphalerites in the left part of photo.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D30_10
Section: AS1758

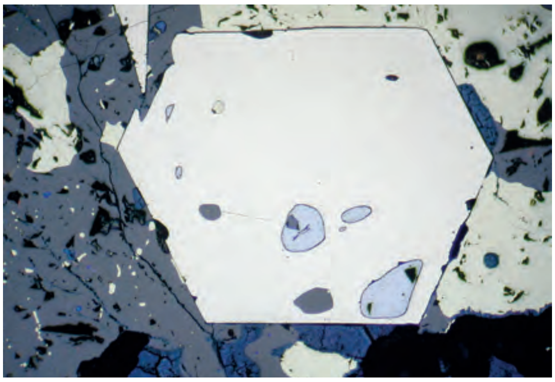
## 194 Galena, py, mrc, po – Locality unknown



Galena with tiny exsolution bodies of bournonite (slighty darker than galena). Some deformed cleavage planes with triangular pits.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D161_24
Section: TÜ43

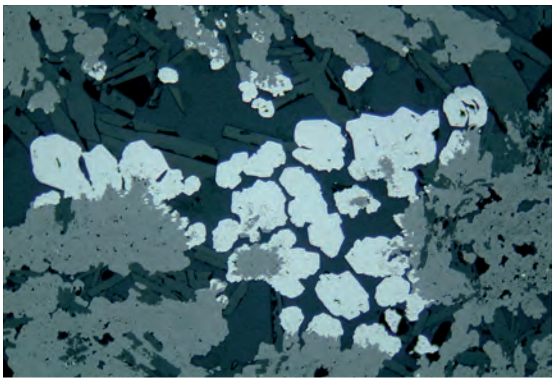
## 195 Galena, py, cp, sph, cv – Zlaté Hory, Okres Jeseník, Czech Republic



Euhedral crystal of pyrite with round inclusions of galena (greyish white) and sphalerite (grey). Groundmass of chalcopyrite (yellow), sphalerite (grey with cp inclusions), and covellite (violet-blue).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D84_10
Section: AS2553

## 196 Galena, sph – Black smoker, Manus basin, Pacific Ocean



Sphalerite (and/or wurtzite) overgrown by galena (greyish white).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D213_18
Section: AS3652

# Garnet (in German: Granat)

**Mineral name:** Garnet
**Formula:** $(Fe,Mn)_3(Al,Fe)_2[(SiO_4)_3]$

**VHN:** ~1400
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 9 to 6 | depending on composition | calculated from n |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 1.2 to 0.4 | | calculated from n |
| **Colour impression** | **(in oil)** | dark grey | | |
| **BR Rpl** | **(in oil)** | -- | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

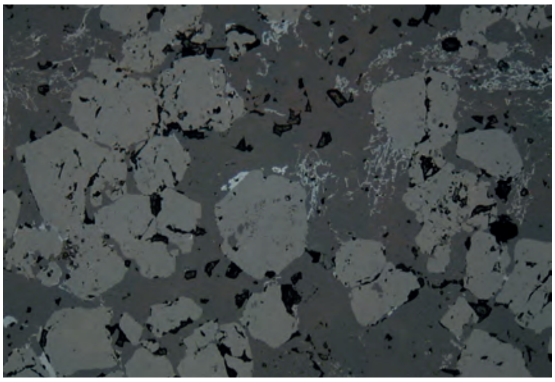
| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | isotropic | -- |
| **Colour:** | **in 45° position** | masked by IR | |
| | **... in other positions** | | |
| **Extinction position** | | -- | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | from colourless, white to yellow, orange, brown, red; (Cr-garnet: green) | |
| **(IR)** | **frequency** | predominant | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | isometric habit, no #, many inclusions (rt, ilm, mt, cb, po) |
| **Paragenesis** | amphibole, px, qz, ep, mt, ilm, rt, goe, manganomelane |
| **Diagnostic features** | habit, no #, IR, hardness |

## Notes, drafts

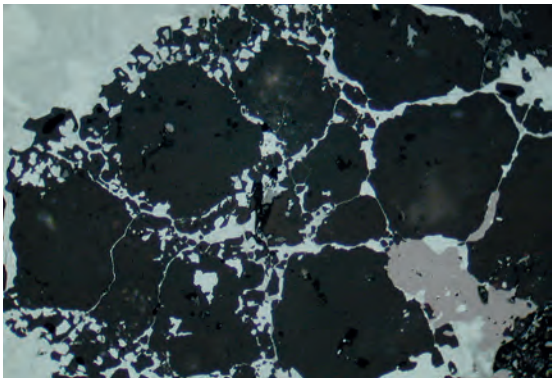
## 197 Garnet, ilm, amp, cb – Ungwan Mallam Ayuba, Kaduna, N-Nigeria



Subhedral crystals of garnet (medium grey) surrounded by some ilmenites (light grey) and amphiboles (dark grey), which are partly replaced along cleavage planes by manganomelane (light grey). Note: tiny, slightly darker inclusions of carbonate (BR!) in garnet.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D84_18
Section: AS249

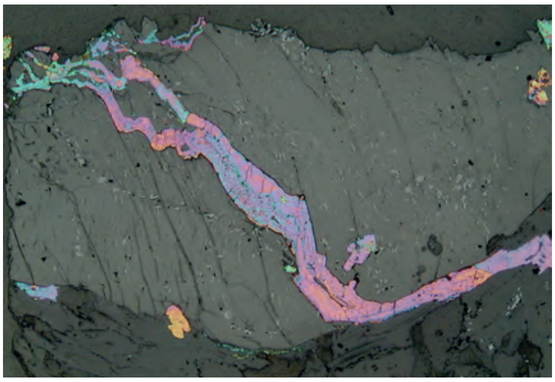
## 198 Garnet, ilm, manganomelane – Ungwan Mallam Ayuba, Kaduna, N-Nigeria



Garnet grains with beginning alteration to manganomelane (greyish white). Ilmenite in lower right part of photo. Note: tiny carbonate inclusions (black to dark grey → BR!) as pre-metamorphic relicts in garnet.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D13_24
Section: AS239

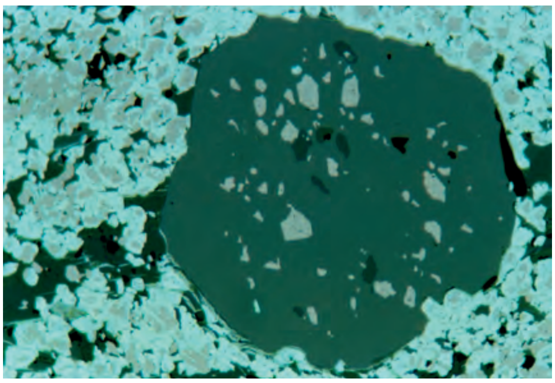
## 199 Garnet, ilmenite, pyrite – Grandfontaine, Vosges, France



Large deformed grain of garnet (medium grey) with tiny inclusions of ilmenite (slightly lighter). Younger vein with pyrite (colours due to strong tarnishing).

Obj.: 5 ×
Polars: || Pol
Photo width: 2.6 mm
Photo No.: D52_02
Section: AS2566

## 200 Garnet, mt, hem, carbonate – Rostock, Namibia



Garnet porphyroblast with inclusions of magnetite (light brown), quartz (dark grey) and carbonate (grey) in groundmass of magnetite/martite and mica. Note that only groundmass magnetites show martitization.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.0 mm
Photo No.: A81_03
Section: AS182

# Gersdorffite

**Mineral name:** Gersdorffite
**Formula:** (Ni,Co)AsS

**VHN:** 520-910
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| $R_{(air)}$ in % | (for 546 nm) | 57 (to 46) | | |
| $R_{(oil)}$ in % | (for 546 nm) | 43 (to 31) | depending on composition | |
| Colour impression | (in oil) | white (tint yellow) | slow tarnishing | |
| BR Rpl | (in oil) | -- | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| Anisotropism intensity/colour | | homogeneous dark | homogeneous dark |
| Colour: | in 45° position | black | brownish black |
| | ... in other positions | | |
| Extinction position | | -- | -- |
| Mode of extinction | | -- | |
| Internal reflections | colour | -- | |
| (IR) | frequency | -- | |
| Twinning | mode | -- | |
| | frequency | -- | |

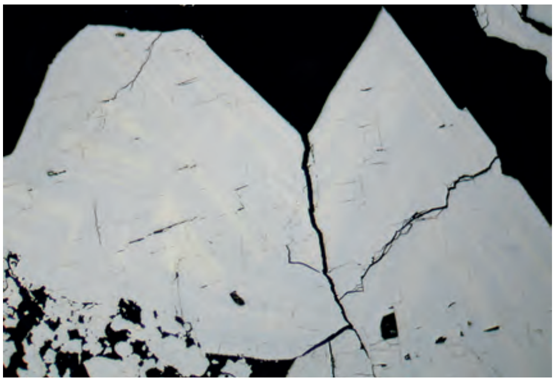
## Further observations

| | |
|---|---|
| Form, habit, textures, cleavage ... | euhedral XX ({100}+{111}), often zoned (Co, Fe; As/S; Sb);<br># \|\| {100} → triangular pits (less often than in galena) |
| Paragenesis | Co-, Ni-sulfides, -sulfarsenides and -arsenides |
| Diagnostic features | euhedral XX, #, hardness |

## Notes, drafts

Similar to ULLMANNITE.

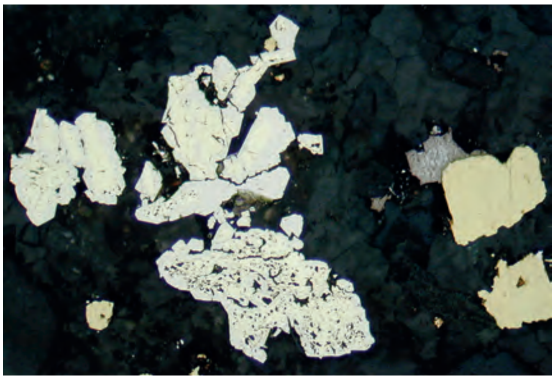
## 201 Gersdorffite – Siegen, Germany



Zoned euhedral gersdorffite crystals (white - yellowish white) with tiny cleavage trails.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D31_17
Section: AS1747

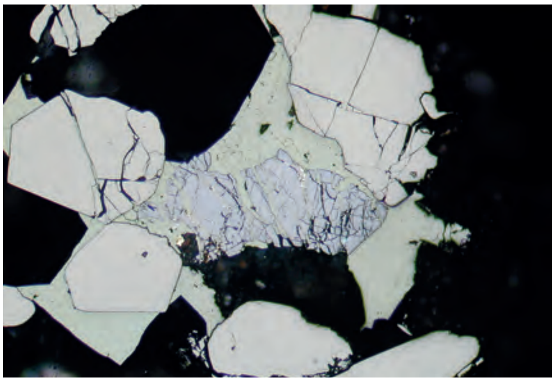
## 202 Gersdorffite, py, cp – Holzbruck near St. Wilhelm, S-Schwarzwald, Germany



Gersdorffite (upper left part, yellow-white) accompanied by porous pyrite; chalcopyrite (yellow).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D74_01
Section: SN36

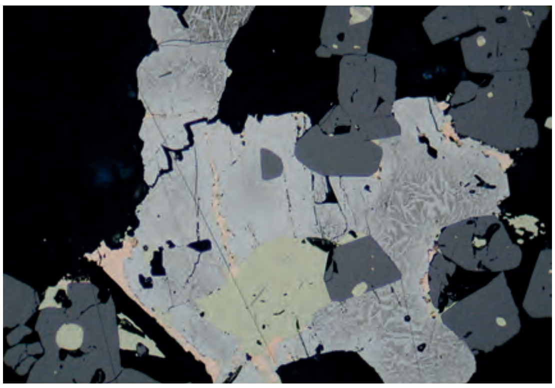
## 203 Gersdorffite, gold, cp, py – Mitterberg, Mühlbach, Salzburg, Austria



Cataclastic broken gersdorffite (greyish white, centre) with tiny fillings of gold (light yellow); in groundmass of chalcopyrite (yellow) plus pyrite crystals.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D16_06
Section: AS143

## 204 Gersdorffite, cp, mt, nickeline – Moran mine, Kambalda, W-Australia



Slightly tarnished gersdorffite grains (whitish grey) enclosing chalcopyrite (yellow, with minor mackinawite), some younger nickeline (orange), and magnetite (grey, with rounded inclusions of cp+cb).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D211_14
Section: S-710-1

# Goethite (in German: Goethit, Nadeleisenerz)

**Mineral name:** Goethite (goe)
**Formula:** α-FeOOH

**VHN:** 660-800
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_a$ = 18.3 | $R_b$ = 15.6 | $R_c$ = 17.7 |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_a$ = 6.0 | $R_b$ = 4.3 | $R_c$ = 5.6 |
| **Colour impression** | **(in oil)** | grey | grey (tint brown) | grey tint blue |
| **BR ~ Rpl** | **(in oil)** | weak to strong (only larger crystals) | | $A_{oil}$ = 33 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | distinct without colour | distinct without colour |
| **Colour:** | **in 45° position** | grey | grey – greyish black |
| | **... in other positions** | | |
| **Extinction position** | | often masked by IR, black | |
| **Mode of extinction** | | perfect | |
| **Internal reflections** | **colour** | yellow brown; also yellow, brown or orange | |
| **(IR)** | **frequency** | abundant | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

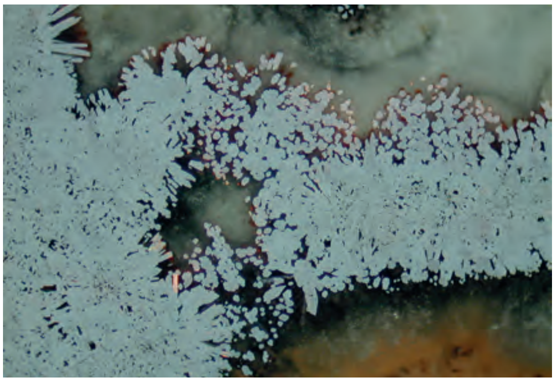
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | tabular, platy, concentric shell-like, fine crystalline to colloform, »Glaskopf« aggregates; weathering product of almost all iron minerals |
| **Paragenesis** | lepidocrocite, hematite, manganomelane, and other Fe minerals |
| **Diagnostic features** | IR, texture, paragenesis |

## Notes, drafts

Opt. features = f (crystallinity, grain size, porosity, polish, $H_2O$- content and composition (Al, Mn)).
Mixed with other Fe-(Mn)-oxihydroxides as alteration/weathering/oxidation product of Fe-bearing minerals in fine- to cryptocrystalline masses (called LIMONITE, »Brauner Glaskopf«).
Often pseudomorph after primary Fe-rich minerals (like pyrite or siderite).

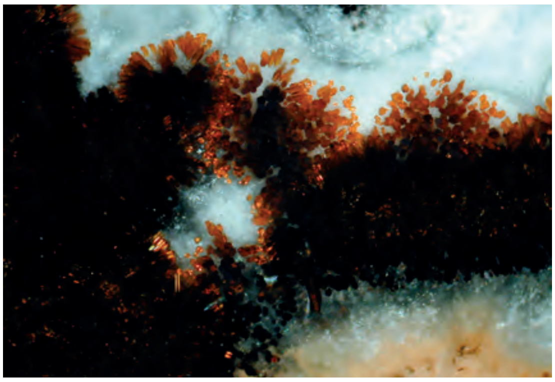
## 205 Goethite – Ahnet-Mouydir, Hoggar Massif, Algeria



Euhedral crystals of goethite showing bireflection and some yellow brown internal reflections.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D34_20
Section: A188/3

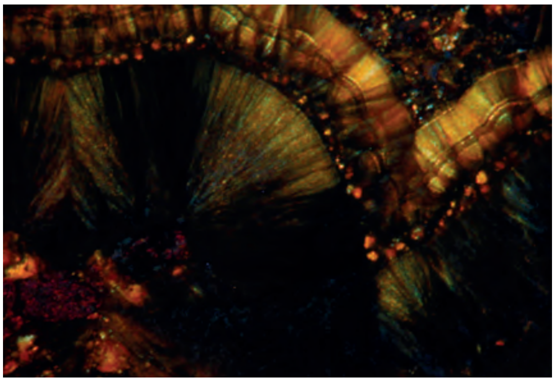
## 206 Goethite – Ahnet-Mouydir, Hoggar Massif, Algeria



As above, with crossed polars; yellow brown internal reflections.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D34_20
Section: A188/3

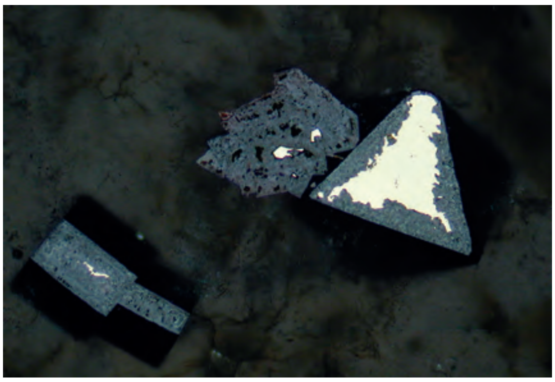
## 207 Goethite – The Pinnacles, near Broken Hill, Australia



Colloform goethite with yellow to orange brown internal reflections.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D01_21
Section: AS3525

## 208 Goethite, py – Stuhlskopf, Schwarzwald, Germany



Pseudomorph replacement of pyrite crystals by goethite (limonite).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D61_05
Section: FP43-1

# Gold

**Mineral name:** Gold
**Formula:** (Au,Ag)

**VHN:** 30-60
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| $R_{(air)}$ in % | (for 546 nm) | 77 | $Au_{80}Ag_{20}$: 84.0 | |
| $R_{(oil)}$ in % | (for 546 nm) | 71 | $Au_{80}Ag_{20}$: 79.4 | |
| Colour impression | (in oil) | yellow | Ag-rich: white yellow | |
| BR Rpl | (in oil) | -- | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| Anisotropism intensity/colour | | anisotropism due to scratches | anisotropism due to scratches |
| Colour: | in 45° position | greenish black due to scratches | greenish black |
| | ... in other positions | »Kratzeranisotropie« | »Kratzeranisotropie« |
| Extinction position | | -- | |
| Mode of extinction | | -- | |
| Internal reflections | colour | -- | |
| (IR) | frequency | -- | |
| Twinning | mode | -- | |
| | frequency | -- | |

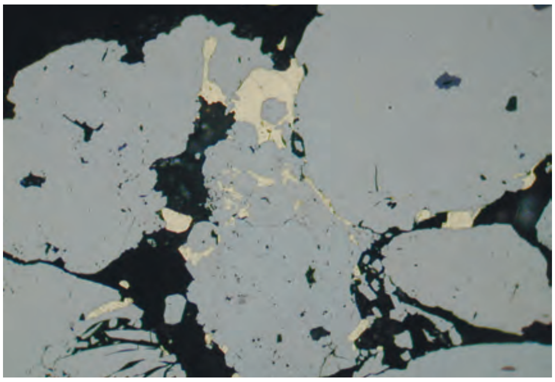
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | anhedral grains, dendritic; rare in large aggregates, i.e. often tiny grains! Zoning (Au-Ag) |
| **Paragenesis** | arsenopyrite, tellurides, stibnite, limonite, clausthalite, py, bismuthinite |
| **Diagnostic features** | high reflectance and bright yellow colour, poor polishing, »Kratzeranisotropie« |

## Notes, drafts

6 % Pd reduces $R_{oil}$ of gold to 50 %!
Be aware that other yellow minerals (such as pyrite, arsenopyrite, chalcopyrite) appear very dull, greyish-yellow or dirty yellowish-green, if in direct contact to gold grains.

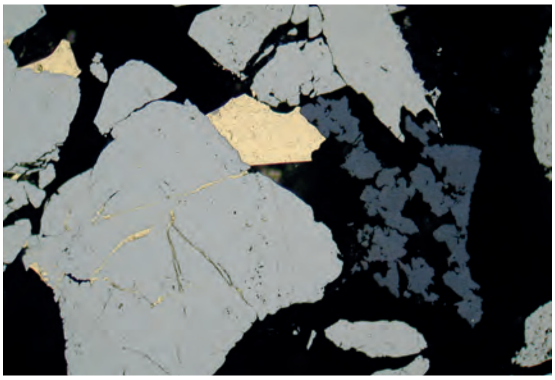
## 209 Gold, pyrite – Witwatersrand, RSA



Mobilized gold (light yellow) in rounded and partly fractured grains of pyrite (greyish yellow).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D83_09
Section: AS3472

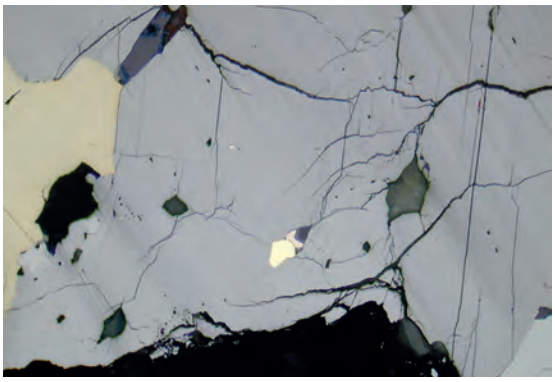
## 210 Gold, pyrite, rutile – Witwatersrand, RSA



Pyrite grains (greyish yellow) with small veinlets of gold. Larger isolated gold particles and rutiles (dark grey) between pyrite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D96_06
Section: AS3472

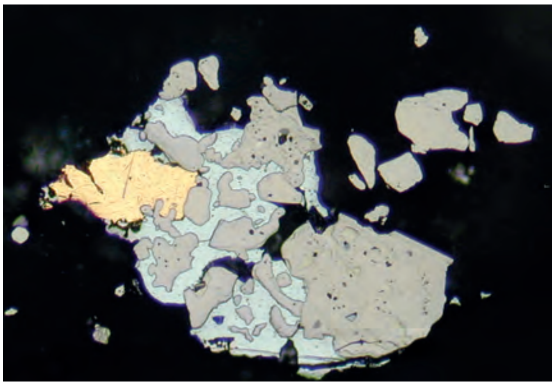
## 211 Gold, bismuth, bismuthinite, cp – El Teniente, Chile



Large bismuthinite (good cleavage) with an inclusion of gold (whitish yellow) and bismuth (in direct contact to gold; slightly darker). Chalcopyrite (yellow) on the left side of photo.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D193_19
Section: KB72

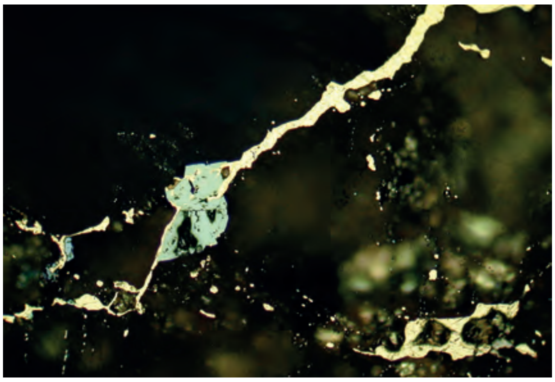
## 212 Gold, tellurium, pyrite – Kochbulak, Uzbekistan



Anhedral gold (yellow) in association with native tellurium (white), both around anhedral pyrite grains (brownish grey). High-sulfidation epithermal gold deposit.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D135_10
Section: AS3056

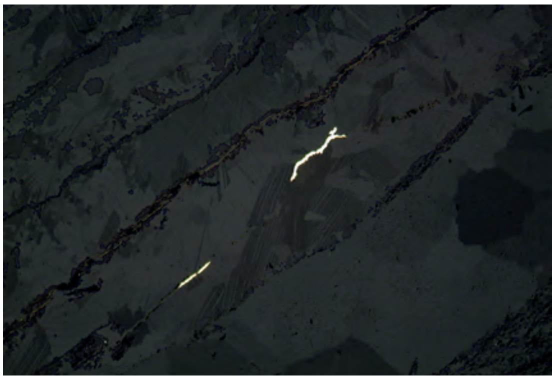
## 213 Gold, chalcopyrite – Ashanti mine, Obuasi, Ghana



Gold veinlet in quartz with small grains of chalcopyrite (greenish grey).

Obj.: 20x oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D96_03
Section: AS120

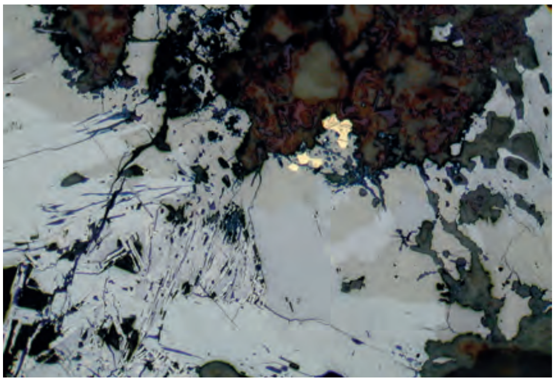
## 214 Gold, carbonate – Goldhausen, near Korbach, Kellerwald, Germany



Tiny gold flakes in carbonate-rich matrix (note BR and twinning).

Obj.: 10x
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D105_18
Section: AS111

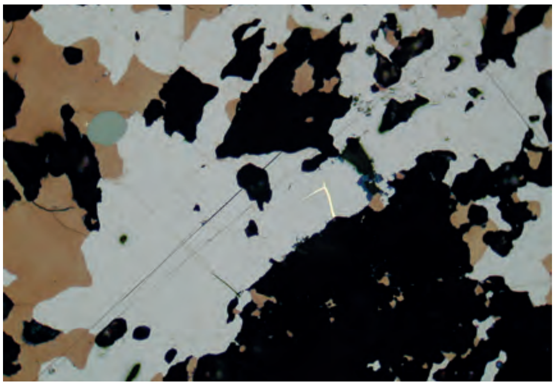
## 215 Gold, emplectite, bismuthinite – Stuhlskopf, Schwarzwald, Germany



Small gold grains beside emplectite (brownish grey), bismuthinite (grey), and secondary Bi-minerals (yellow to reddish-brown, upper part of photo).

Obj.: 20x oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D60_16
Section: Kindler11

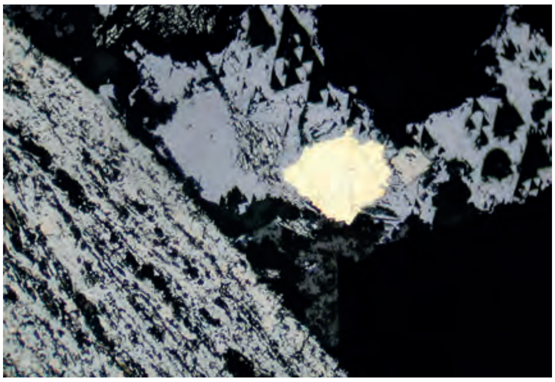
## 216 Gold, galena, bornite, fahlore – La Plata-Mine, Chiriboga, Ecuador



Galena (light grey) with tiny veinlets of gold (yellow): Bornite (orange brown), rounded fahlore (greenish grey), and gangue (black).

Obj.: 20x oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D95_15a
Section: AS3103

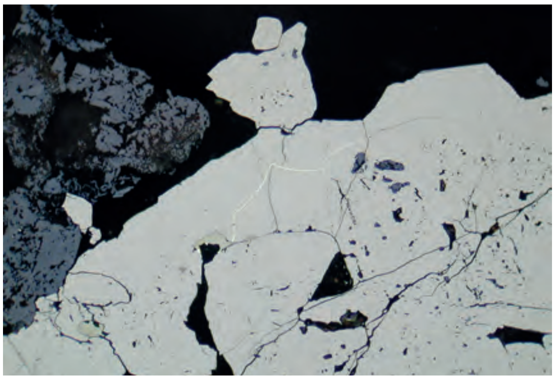
## 217 Gold, gn, py, mrc – Felsenloch, BLZ, Schwarzwald, Germany



Large grain of gold (electrum $Au_{70}Ag_{30}$) associated with pyrite (cube at right side of gold), and galena (light grey). On the left side of photo large crystal of former pyrrhotite, now transformed to pyrite plus marcasite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D190_25
Section: CH54

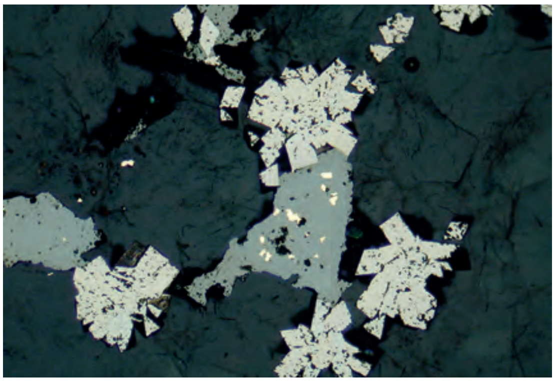
## 218 Gold, py, cp, rt – Val Toppa, Pieve Vergonte, N-Italy



Thin veinlet of gold in pyrite (which includes rutile and chalcopyrite). Left side: rutile.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D203_16
Section: AS119

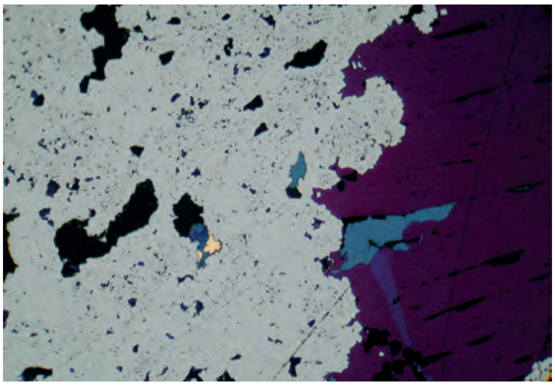
## 219 Gold, fahlore, asp, qz – Hoberg, Schwarzwald, Germany



Gold inclusions in fahlore (grey), surrounded by arsenopyrite (beige), and younger quartz. Note that quartz incorporated the existing gold inclusions (upper left side) of the fahlore after its replacement.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D207_17
Section: GL-Ho1

## 220 Gold, pyrite, covellite, dig – Bor, Serbia



Groundmass of pyrite with inclusion of gold (light yellow) and digenite (+cv). Large covellite crystal (violet) is replaced in part by pyrite and digenite (blue).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.4 mm
Photo No.: D214_19
Section: AS3545

# Graphite

**Mineral name:** Graphite (gr)
**Formula:** C
**VHN:** 7-12
**Crystal System:** hex.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o = 26$ | $R_{e'} = 6$ | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o = 15$ | $R_{e'} = 0.5$ | |
| **Colour impression** | **(in oil)** | light grey tint yellow | dark grey tint brown | |
| **BR ~ Rpl** | **(in oil)** | extremely strong | | $A_{oil} = 187$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | very strong with colour tint | very strong with colour |
| **Colour:** | **in 45° position** | white with yellow tint | light yellow – light yellow |
| | **... in other positions** | | |
| **Extinction position** | | olive black | |
| **Mode of extinction** | | straight, undulatory, disperse | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | translations and crumpled lamellae | |
| | **frequency** | very common | |

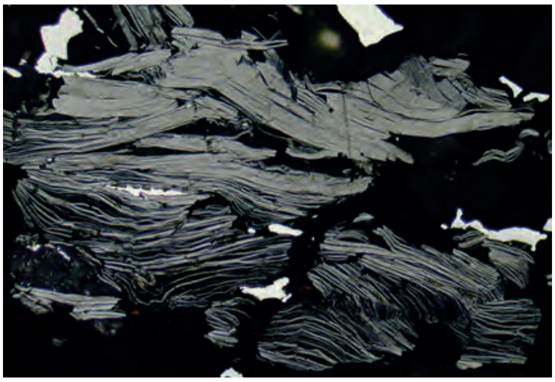
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | often flaky, platy, tabular; # perfect \|\| (0001) |
| **Paragenesis** | manifold; often in metamorphic ores |
| **Diagnostic features** | BR, AExPol, in all positions not transparent → no IR! |

## Notes, drafts

Valleriite is very similar to graphite (see fig. 571, 572)!
Molybdenite is much brighter!

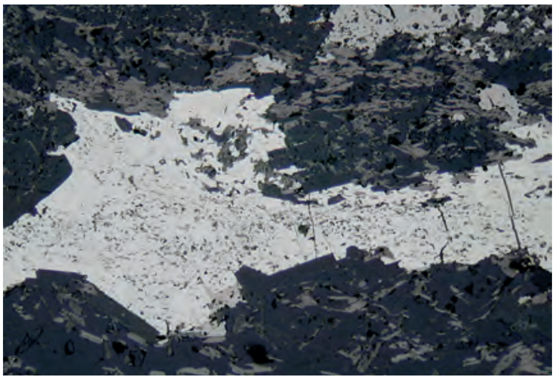
## 221 Graphite, po – Kropfmühl, Passau, Germany



Sub-parallel flakes of graphite (grey) with pyrrhotite (light cream). Graphite flakes in position with highest reflectance.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D07_10
Section: AS1054b

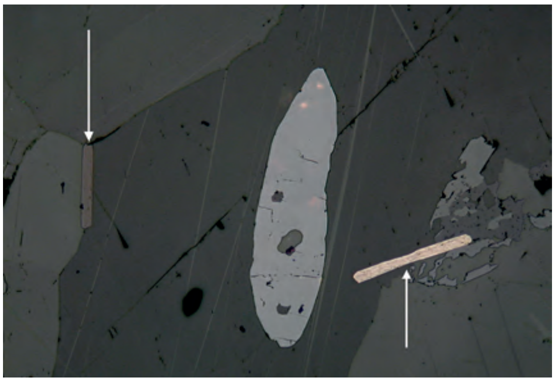
## 222 Graphite, py – Skrammelfallsgruvan, Norberg, Sweden



Aligned graphite plates (brownish grey) in and around pyrite (light yellow).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D46_13
Section: AS3572

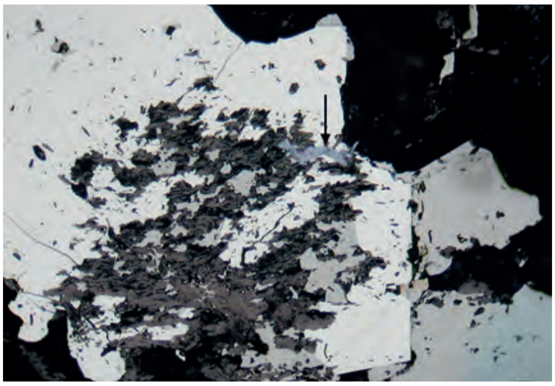
## 223 Graphite, ttn, carbonate – Kropfmühl, Passau, Germany



Two crystals of graphite (arrows) showing the strong bireflection. The lath on the left side is nearly as dark as the carbonate matrix (BR!, twinning). Elongated grain of titanite (light grey) in the centre.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D14_08
Section: AS1055a

## 224 Graphite, molybdenite, py – Skrammelfallsgruvan, Norberg, Sweden



Graphite flakes (brownish grey) intergrown with molybdenite (lighter bluish grey, arrow) enclosed in pyrite and pyrrhotite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D46_17
Section: AS3572

# Hausmannite

**Mineral name:** Hausmannite (hsm)
**Formula:** $Mn_3O_4$

**VHN:** 430-570
**Crystal System:** tetr..

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 20.2 | $R_{e'}$ = 16.3 | $R_{e'}$ = 13.3(*) |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 7.4 | $R_{e'}$ = 4.8 | $R_{e'}$ = 3.0(*) |
| **Colour impression** | **(in oil)** | grey tint blue | grey tint brown (moiré) | |
| **BR ~ Rpl** | **(in oil)** | strong | | $A_{oil}$ = 43 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong with colour tint | strong with colour tint |
| **Colour:** | **in 45° position** | whitish yellow | greyish yellow – grey tint blue |
| | **... in other positions** | moiré effect | |
| **Extinction position** | | grey black | |
| **Mode of extinction** | | not perfect | |
| **Internal reflections** | **colour** | red | |
| **(IR)** | **frequency** | frequently | |
| **Twinning** | **mode** | polysynthetic after more than one direction {101} | |
| | **frequency** | always visible | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | often euhedral {111}), very often replaced by pyrolusite along cracks |
| **Paragenesis** | pyrolusite, bixbyite, braunite |
| **Diagnostic features** | twinning, moiré effect, paragenesis, red IR |

## Notes, drafts

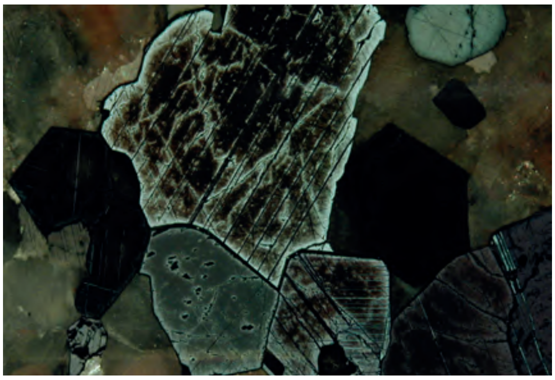
(*) after Jarosch (1987); Mineral. Petrol., 37, 15-23.

## 225 **Hausmannite –** Jakobsberg, Sweden

Euhedral crystals of hausmannite with twins lamellae showing characteristic moiré appearance in the position of minimum reflectance.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D13_08
Section: AS212

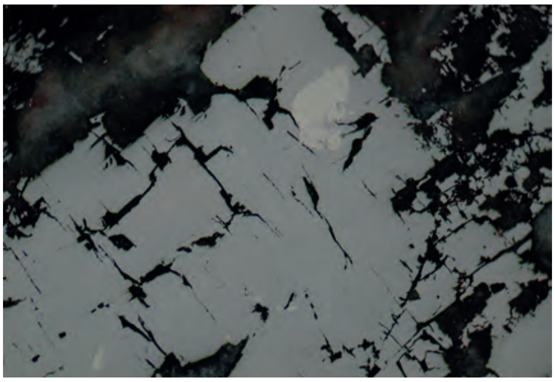
## 226 **Hausmannite –** Jakobsberg, Sweden



Hausmannite with twinning and different strong anisotropism.

Obj.: 5 ×
Polars: × Pol
Photo width: 2.8 mm
Photo No.: D15_21
Section: AS212

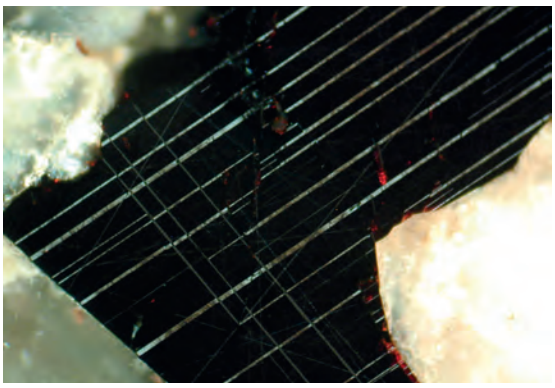
## 227 **Hausmannite, bixbite –** Sailauf quarry, Spessart, Germany



Hausmannite (medium grey, BR!) with inclusions of bixbyite (yellowish grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D60_10
Section: S61

## 228 **Hausmannite –** Jakobsberg, Sweden



Lamellar twinned hausmannite with red internal reflections.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D13_06
Section: AS212

# Hematite (in German: Hämatit, Eisenglanz)

**Mineral name:** Hematite (hm)
**Formula:** α-$Fe_2O_3$

**VHN:** 900
**Crystal System:** trig.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 30.0 | $R_{e'}$ = 26.4 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 15.9 | $R_{e'}$ = 12.4 | $R_o$ \|\| elongation |
| **Colour impression** | **(in oil)** | white grey | white grey | |
| **BR > Rpl** | **(in oil)** | distinct | | $A_{oil}$ = 28 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | distinct without colour | distinct with colour tint |
| **Colour:** | **in 45° position** | grey | grey tint green – grey |
| | **… in other positions** | grey tint green | |
| **Extinction position** | | black | |
| **Mode of extinction** | | perfect, undulatory | |
| **Internal reflections** | **colour** | deep red (»blood red«) | |
| **(IR)** | **frequency** | abundant to rare (depending on grain size) | |
| **Twinning** | **mode** | polysynthetic after more than one direction (trellis-work fence, »Jägerzaun«) | |
| | **frequency** | rare (in magmatites), common (in metamorphosed ores) | |

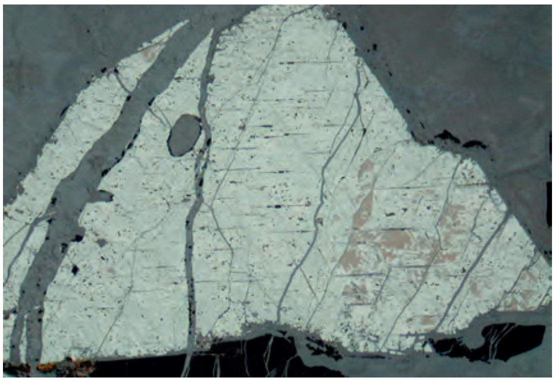
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | lens-shaped or tabular XX; martite: hem pseudomorph after mt \|\|{111}; EB of ilmenite (corundum, rutile) or as hematite-EB in ilmenite |
| **Paragenesis** | magnetite, ilmenite, rutile, goethite, pyrite |
| **Diagnostic features** | paragenesis, red IR (in small grains) |

## Notes, drafts

»cubic hematite« = see MAGHEMITE (γ-$Fe_2O_3$).
ILMENOHEMATITE ($Fe_2O_3$ + $FeTiO_3$)-SOLID SOLUTION has R < 30-26/15-12.

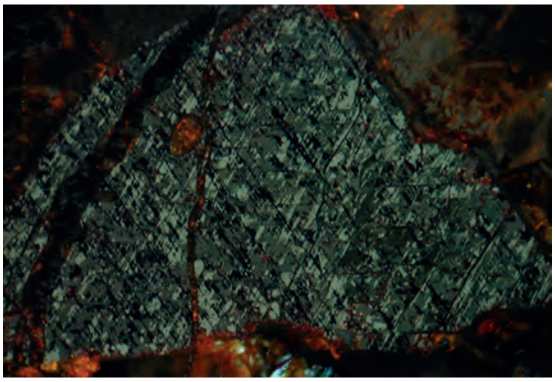
**229 Hematite, mt, martite, goe –** The Pinnacles, near Broken Hill, Australia



Magnetite (brownish grey relicts) with strong martitization (martite; greyish white lamellae of hematite) surrounded and penetrated by younger goethite (grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D67_07
Section: AS3525

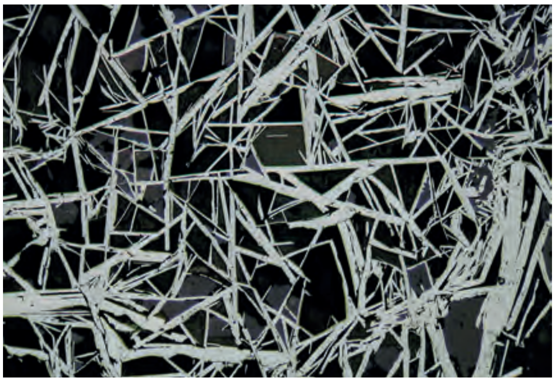
**230 Hematite, mt, martite, goe –** The Pinnacles, near Broken Hill, Australia



Same as above with crossed polars. Three sets of oriented hematite lamellae (120°) are easy visible. Numerous internal reflections of goethite, but only few red internal reflection of hematite.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D67_08
Section: AS3525

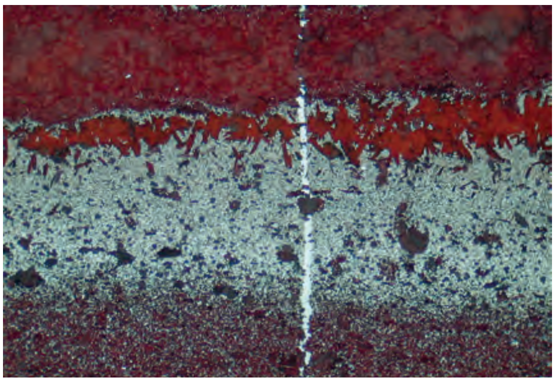
**231 Hematite –** Terra Nera, Elba, Italy



Thin tabular hematite showing an ophitic network (»sperriges Gefüge«).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D50_17
Section: AS3162

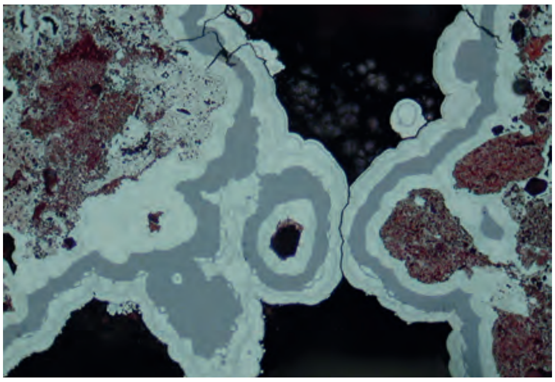
**232 Hematite, qz, carbonate –** Mamatwan, Kuruman, RSA



Layer of medium grained hematite (light grey) with carbonate grains (dark grey) surrounded by layers of hematite plus silicates (light red internal reflections!) or carbonates (upper part with medium red IR). N-S trending hematite veinlet (whitish grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D10_07
Section: M1

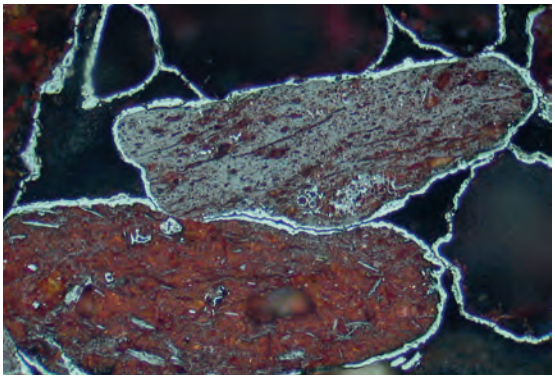
## 233 Hematite, goethite – W of Erg Teganet, Ahnet-Mouydir area, Algeria



Colloform intergrowth of hematite (light grey) and goethite (medium grey) around clasts of hematite-bearing sediments (grey to red).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D20_01
Section: A235

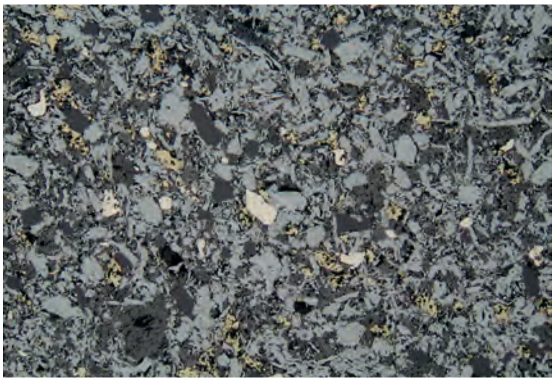
## 234 Hematite, mt– E of Jebel Bagline, Ahnet-Mouydir area, Algeria



Sandstone with hematite coated clasts of sediment (centre), metamorphic rock (lower part, with tiny plates of graphite), and quartz grains (black).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D21_07
Section: A316/3

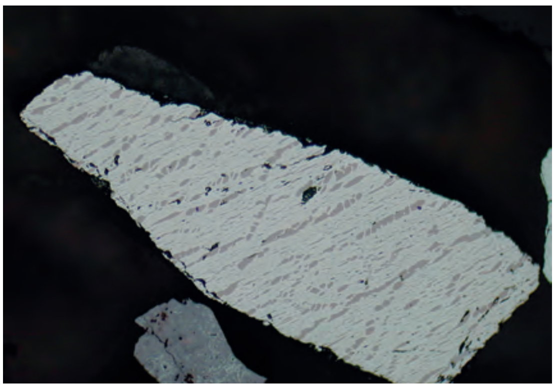
## 235 Hematite, cp, py – Olympic Dam, Australia



Breccia of hematite (medium grey), chalcopyrite (yellow), and pyrite (whitish yellow) in groundmass of carbonate.

Obj.: 5 ×
Polars: || Pol
Photo width: 2.8 mm
Photo No.: D101_21
Section: OD653

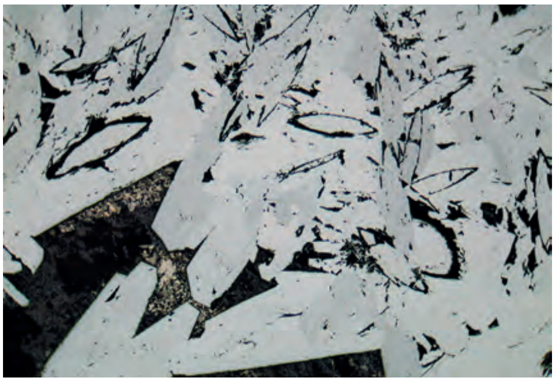
## 236 Ilmenite-hematite – Sardes, Turkey



Placer sample with hematite grain showing tiny exsolution bodies of ilmenite (called »ilmenite-hematite«).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D106_17
Section: AS146

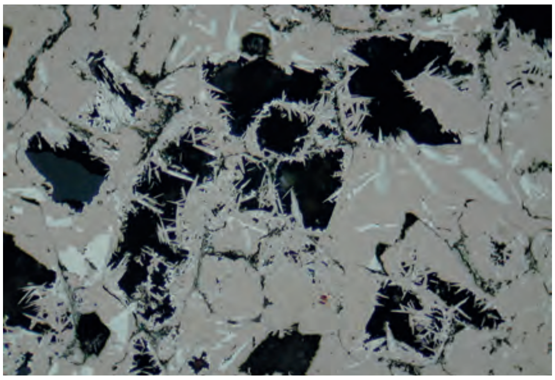
## 237 **Hematite –** Otto mine, Schottenhöfe, Schwarzwald, Germany



Hematite phantom crystals with lens-shaped cores and lath-like rims.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D69_21
Section: AS3250

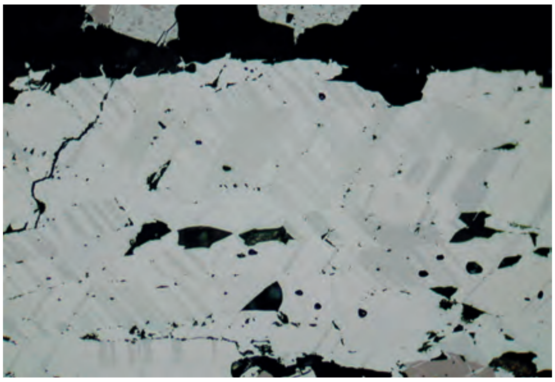
## 238 **Hematite, mt –** Calamita, Elba, Italy



Mushketoffite: Magnetite (brownish grey) pseudomorph after hematite platelets (relicts are visible).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D84_06
Section:  A3142

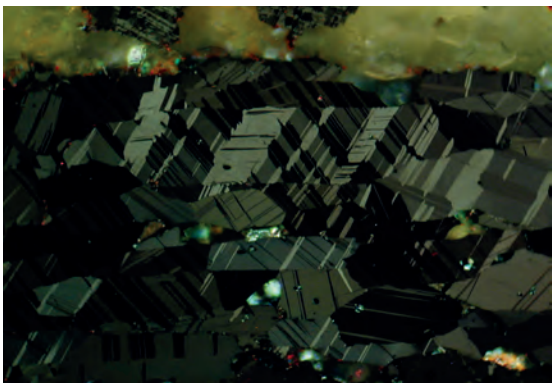
## 239 **Hematite –** Wadi Mubarak, Eastern Desert, Egypt



Hematite with typical twinning (»Jägerzaun« – trellis-work fence) due to deformation/metamorphism. Twinning lamellae are oriented approx. 45° to the shistosity planes of the ore.

Obj.: 5 ×
Polars: || Pol
Photo width: 2.8 mm
Photo No.: D68_02
Section: AS177

## 240 **Hematite –** Wadi Mubarak, Eastern Desert, Egypt



As above with crossed polars. Note the almost complete absence of red internal reflections!

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D68_05
Section: AS177

# Ilmenite

**Mineral name:** Ilmenite (ilm)
**Formula:** $FeTiO_3$
**VHN:** 560-700
**Crystal System:** trig.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 19.2 | $R_{e'}$ = 16.4 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 6.7 | $R_{e'}$ = 4.9 | |
| **Colour impression** | **(in oil)** | greyish brown<br>or only grey (tint brown ) | brown<br>often only greyish brown | |
| **BR ~ Rpl** | **(in oil)** | strong | | $A_{oil}$ = 31 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | distinct without colour | distinct without colour |
| **Colour:** | **in 45° position** | grey | grey – grey (tint green) |
| | **… in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | straight | |
| **Internal reflections** | **colour** | only due to high Mn-content (pyrophanite = $MnTiO_3$): red | |
| **(IR)** | **frequency** | rare | |
| **Twinning** | **mode** | polysynthetic after more than one direction | |
| | **frequency** | occasional | |

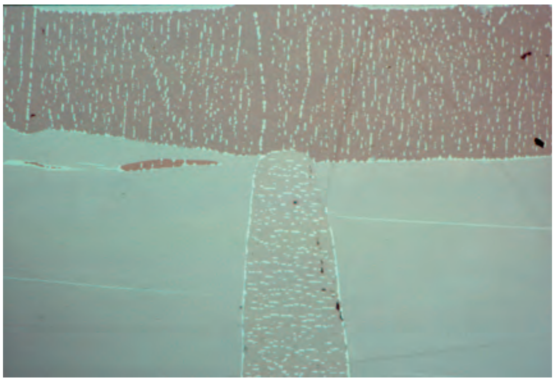
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | elongated, lens- or tabular-shaped grains; often as EB in magnetite and hematite; often replaced/rimmed by »leached ilmenite« and (pseudo)rutile |
| **Paragenesis** | magnetite, hematite (also as EB), rutile, titanite |
| **Diagnostic features** | CI, paragenesis |

## Notes, drafts

Mn-ilmenite: pyrophanite, Mg-ilmenite: geikielite.
HEMOILMENITE ($FeTiO_3$ + $Fe_2O_3$)-SOLID SOLUTION has R > 20-17/8-5.
Optical features varying distinct with contents of $Fe_2O_3$, MnO, and MgO.
Alteration of ilmenite forms »leached ilmenite« (partly oxidized ilmenite with vacancies) and PSEUDORUTILE.

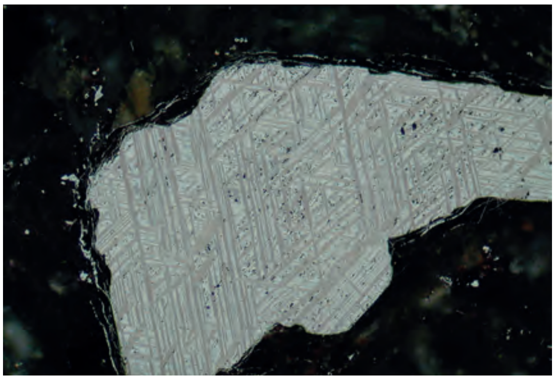
## 241 Ilmenite, rutile – Neils Valley, Jos plateau, Nigeria



Two large crystals of (hematite-)ilmenite in perpendicular orientation exhibiting the strong bireflectance (darker brown vs. grey with brownish tint, lighter) and tiny exsolution bodies of hematite. In the lower part of photo large grain of rutile (light grey) with small twin lamellae.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: BR1
Section: AS134

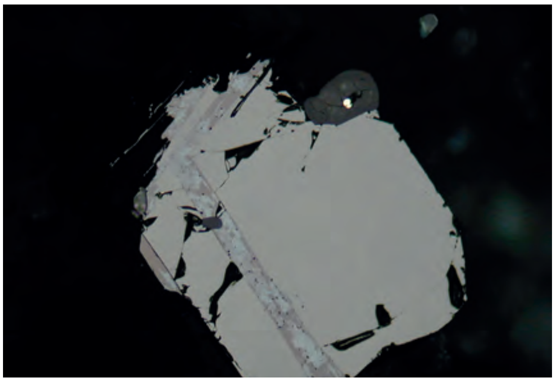
## 242 Ilmenite, martite – Rhyolite of unknown locality



Unaltered ilmenite lamellae (brownish grey) in martitized magnetite (grey white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D57_01
Section: LW-44

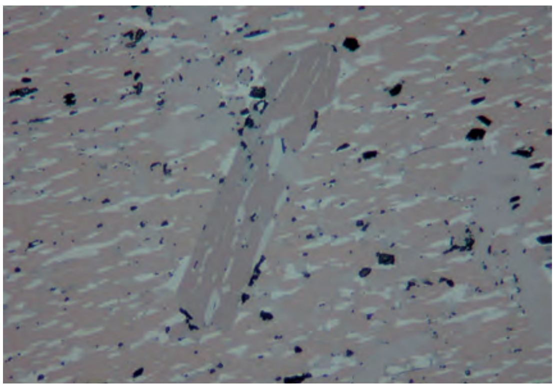
## 243 Ilmenite, mt, hm, rt – Åmli, S-Norway



Sandwich-type ilmenite-magnetite. Ilmenite (brownish grey) is patch-like oxidized into a fine mixture of hematite and rutile (light grey tones). Magnetite with tiny elongated exsolution bodies of spinel (dark grey). Zircon crystal (dark grey) with pyrite inclusion.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D52_14a
Section: AS173

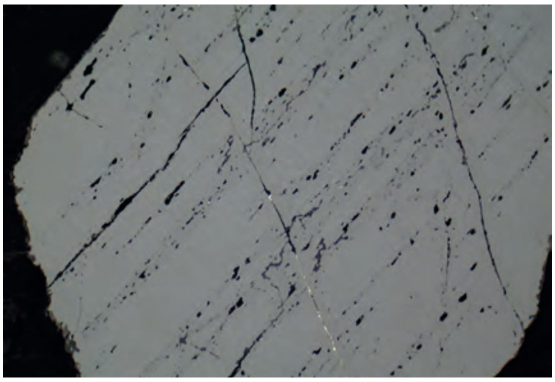
## 244 Hematite-ilmenite, rutile – Radium Hill, Olary Prov., S-Australia



Hematite-ilmenite: Ilmenite (matrix and one tabular crystal in brownish grey, BR!) with exsolution disks of light grey hematite. Intergrown with rutile (medium grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D01_31
Section: AS3519

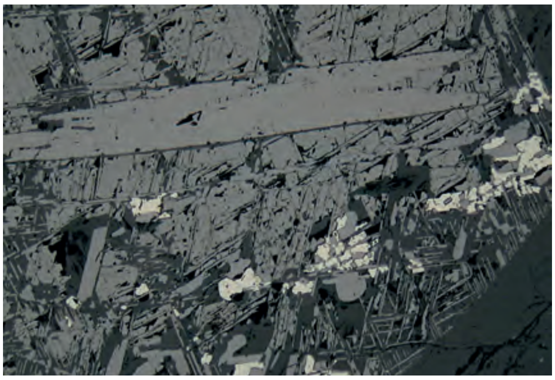
## 245 Hematite-ilmenite, cp – Railway gravel near Iberville, P. Q., Canada



Ilmenite (medium grey) with tiny elongated hematite exsolution bodies (light grey). These hematites are missing in part of the ilmenite along lamellar inclusion-rich zones and beside fractures (which are partly filled with chalcopyrite).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.4 mm
Photo No.: D97_01a
Section: AS1563

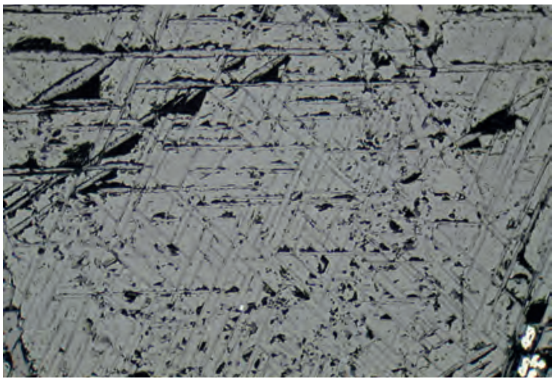
## 246 Ilmenite, mt, py – »Corsica«



Large ilmenite lath in ground-mass of trellis-type ilmenite-magnetite. Much of the magnetite is replaced by gangue and pyrite (white yellow), leaving a trellis-type network of ilmenite lamellae.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D52_20
Section: AS264

## 247 Ilmenite, mt – »Corsica«



Fine ilmenite lamellae in trellis-type intergrowth parallel {111} of magnetite.

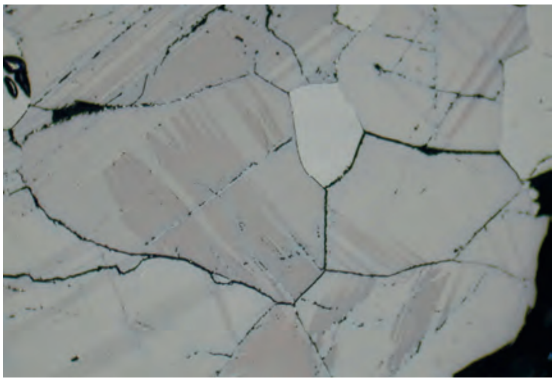
Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D37_29
Section: AS264

## 248 Ilmenite – »Corsica«

Relicts of trellis-type ilmenite lamellae and granular ilmenite grains. The groundmass magnetite is completely replaced by silicates.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D153_06
Section: AS264

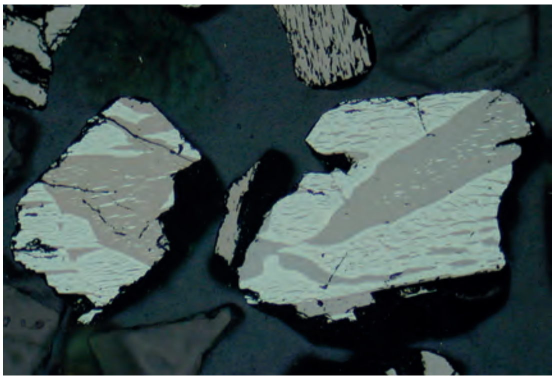
## 249 Ilmenite, mt, pseudorutile – Otanmäki, Kajaani, Finland



Deformation twinning within ilmenite grains, some magnetite (slightly higher R). Minor formation of pseudorutle (bluish grey) along cracks.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D195_15
Section: AS1647

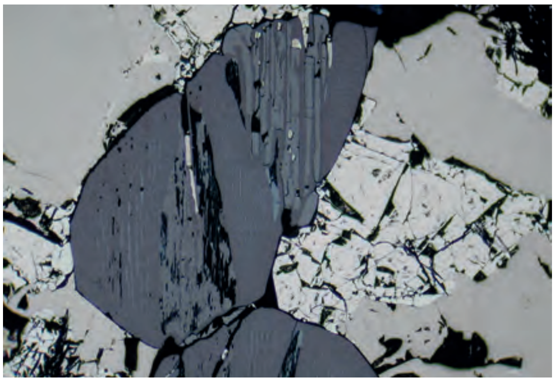
## 250 Hematite-ilmenite, ilmenite-hematite – Placer near Porto Anchel, Mexico



Complex exsolution feature of hematite-ilmenite (ilmenite with hematite-EB) with ilmenite-hematite (hematite with ilmenite-EB).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D141_19
Section: AS246

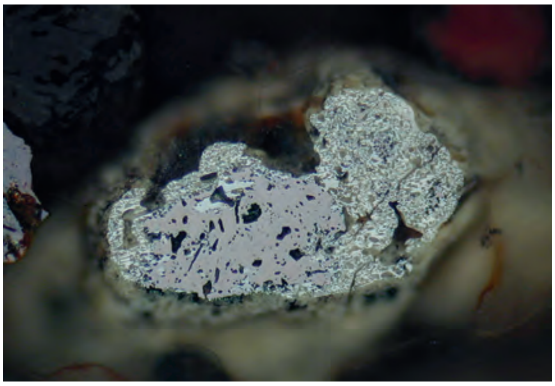
## 251 Ilmenite, mt – Flat mine, Evje, S-Norway



Grain of hematite-ilmenite (brownish grey ilmenite matrix with tiny bluish grey plates of hematite-EB) intergrown with elongated to skeletal magnetite (medium grey). The grain is surrounded by pyrrhotite and pentlandite (highest R).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.6 mm
Photo No.: D141_25a
Section: AS2563

## 252 Ilmenite, rutile, anatase – Sardes, Turkey



Formation of fine-grained mixture of rutile plus anatase (»leucoxene«) as an alteration product around ilmenite (greyish brown).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D106_18
Section: AS146

# Ilvaite

**Mineral name:** Ilvaite (ilv)
**Formula:** $CaFe^{2+}_2Fe^{3+}[OH|O|Si_2O_7]$

**VHN:** 700-1055
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1 = 10$ | $R_2 = 8$ | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1 = 2$ | $R_2 = 1$ | |
| **Colour impression** | **(in oil)** | grey tint yellow | dark blue | |
| **BR < Rpl** | **(in oil)** | very strong | | $A_{oil} = 66$ |

## Observations with crossed polars (AExPol in oil)

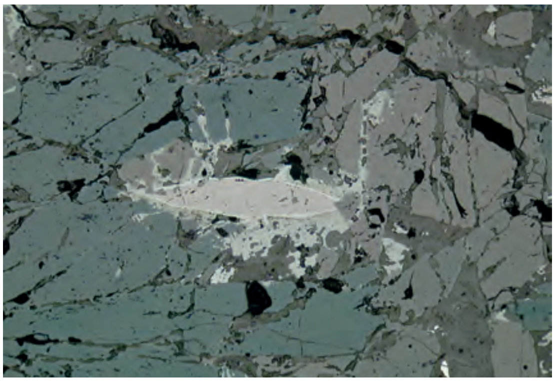
| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong with colour | strong with colour |
| **Colour:** | **in 45° position** | orange brown | orange brown – brownish orange |
| | **… in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | straight | |
| **Internal reflections** | **colour** | yellow to red | |
| **(IR)** | **frequency** | rare (at rims) | |
| **Twinning** | **mode** | simple | |
| | **frequency** | rare | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | euhedral tabular XX and anhedral aggregates;<br>replaces mt; alteration to goethite |
| **Paragenesis** | magnetite, hematite, ilmenite, Ca-Mg-silicates, goethite, po, py |
| **Diagnostic features** | Rpl, AExPol |

## Notes, drafts

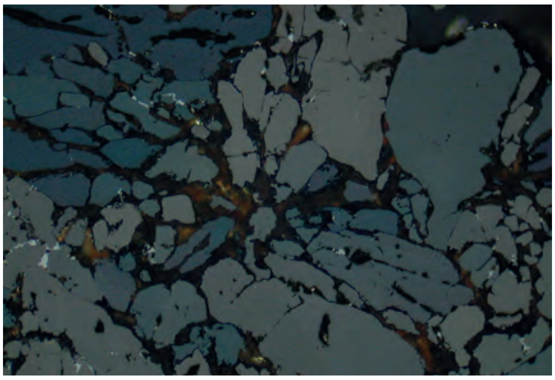
## 253 Ilvaite, magnetite, hematite – Calamita, Elba, Italy



Different oriented ilvaite crystals (bluish grey to grey) surrounding a lens-like magnetite crystal (light brownish grey), which is rimmed by hematite (whitish grey). Late alteration product is limonite (medium grey).

Obj.: 10 × oil
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D14_21
Section: AS3136

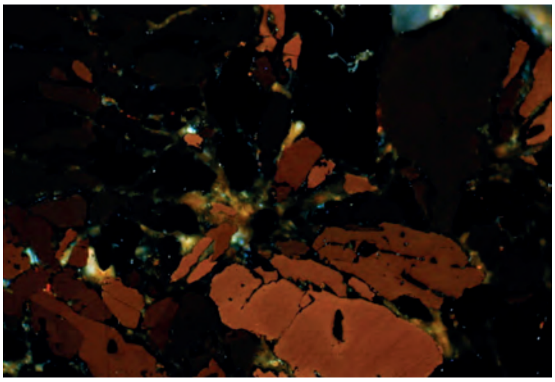
## 254 Ilvaite – Calamita, Elba, Italy



Reflection pleochroism of ilvaite grains (different colour impressions from grey tint yellow to greyish blue).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D83_25
Section: AS3142

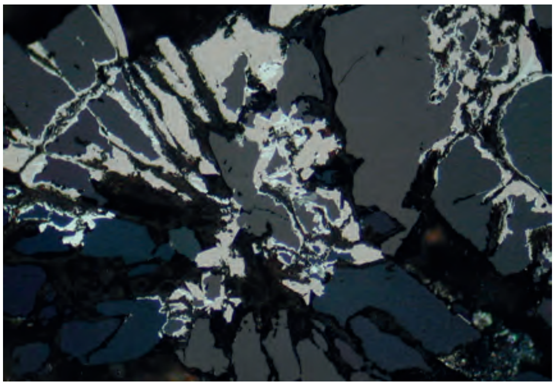
## 255 Ilvaite – Calamita, Elba, Italy



Same as above, with crossed polars. Ilvaite with characteristic orange anisotropism colours.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D83_29
Section: AS3142

## 256 Ilvaite, mt, hm – Calamita, Elba, Italy



Ilvaite partly replaced by magnetite (greyish brown) and hematite (light grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D84_04
Section: AS3142

# Imiterite

**Mineral name:** Imiterite
**Formula:** $Ag_2HgS_2$

**VHN:** 80-140
**Crystal System:** mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 29.4 | $R_2$ = 32.0 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ ~ 13 | $R_2$ ~ 17 | $R_{(oil)}$ estimated (*) |
| **Colour impression** | **(in oil)** | brownish grey | greyish blue | |
| **BR ~ Rpl** | **(in oil)** | strong | | $A_{oil}$ = 27 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong with colour | strong with colour |
| **Colour:** | **in 45° position** | greyish blue | light greyish blue – grey tint brown |
| | **... in other positions** | brownish grey, olive | orange, yellow olive, blue |
| **Extinction position** | | dark brownish grey | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | orange red | |
| **(IR)** | **frequency** | rare | |
| **Twinning** | **mode** | lamellar (one direction) | |
| | **frequency** | very rare | |

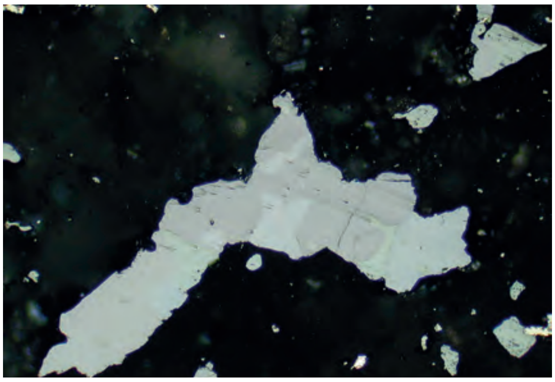
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | euhedral to anhedral crystals;<br>no #. |
| **Paragenesis** | acanthite, silver, polybasite, cinnabar, cp, sph, gn, asp |
| **Diagnostic features** | Rpl, AExPol |

## Notes, drafts

(*) $R_{oil}$ data (14-13 %) from Walenta & Hess (1985); Aufschluss, 36, 209-215, are probably too low.

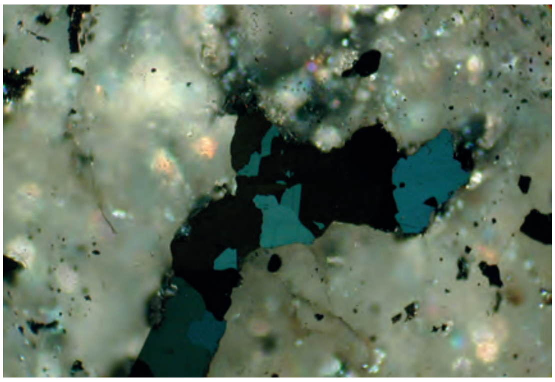
## 257 Imiterite, argentite – Imiter, Morocco



Anhedral grains of imiterite (BR, medium greyish brown to light grey) intergrown with argentite (grey tint green).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D177_26
Section: BA1308

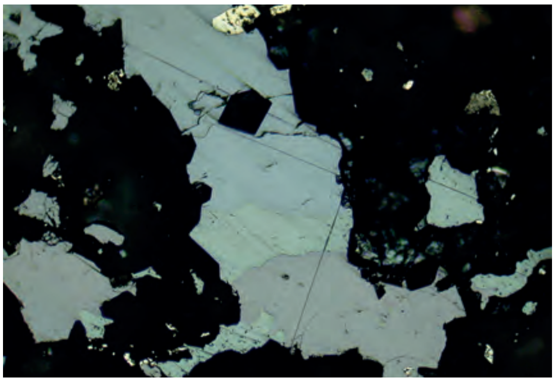
## 258 Imiterite, argentite – Imiter, Morocco



As above, with crossed polars. Note blue anisotropism colours of imiterite.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: AS177_27
Section: BA1308

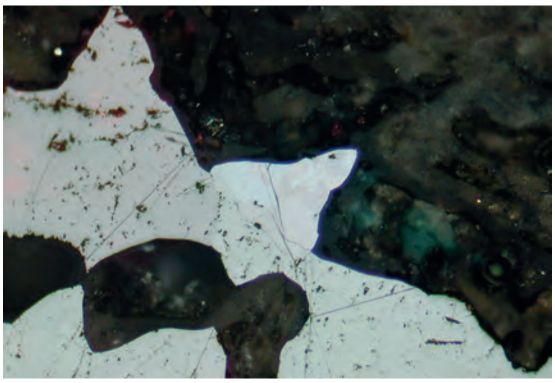
## 259 Imiterite, argentite, asp – Imiter, Morocco



Argentite (greyish green) enclosed by two grains of imiterite (upper part: light grey tint blue, lower part: grey tint brown).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D181_16
Section: BA1308

## 260 Imiterite, cinnabar – Çirakman tepe, Ladik, Turkey



Polycrystalline aggregate of imiterite (centre of photo, grey tint brown to light grey) beside cinnabar (medium grey, poor polishing, in part with red IR).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D32_08
Section: AS154

# Iron (in German: ged. Eisen)

**Mineral name:** Iron (α-Ferrite)
**Formula:** α-Fe
**VHN:** 110-160
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 58.1 | | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 45.2 | | |
| **Colour impression** | **(in oil)** | white | against cohenite: tint blue | |
| **BR Rpl** | **(in oil)** | -- | | $A_{oil}$ = 0 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | homogeneous dark | homogeneous dark |
| **Colour:** | **in 45° position** | black | greyish black |
| | **... in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | not visible | |
| | **frequency** | -- | |

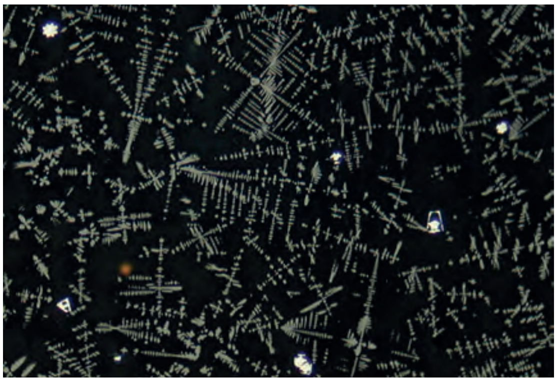
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | droplets, sponge-like, skeletal grains; EB of cohenite ($Fe_3C$), oriented intergrown with mt or wuestite |
| **Paragenesis** | cohenite (=cementite), wuestite, mt, iscorite, graphite |
| **Diagnostic features** | paragenesis, similar to platinum but darker; cohenite is more yellow |

## Notes, drafts

Terrestrial formation of iron is rare, but often in meteorites and in artificial products.
See also under: Cohenite.
Meteoritic iron with < 6 wt.% Ni = α-(Fe, Ni) = Kamacite
Meteoritic iron with > 6 wt.% Ni = γ-(Fe, Ni) = Taenite (artificial: austenite)

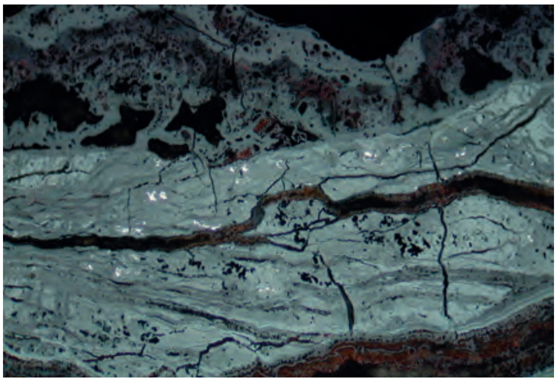
## 261 Iron, wuestite – Weil im Schönbuch, Stuttgart, Germany



Artificial medieval slag with tiny iron crystals (»hopper« and star-like, white), and skeletal wuestite aggregates (medium grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D85_29
Section: AS3512

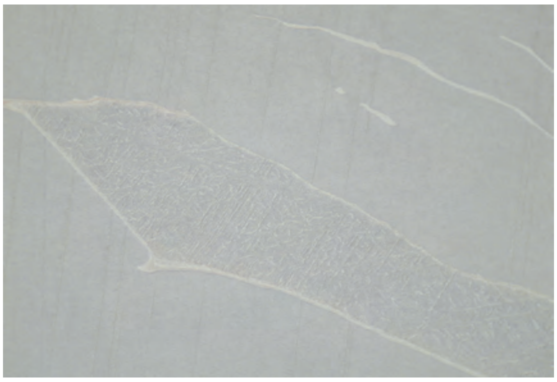
## 262 Iron, limonite – Quadra Island, B. C., Canada



Old iron rope oxidized by sea water. Remnants of α-iron (white) in a mixture of different iron-oxihydroxides (shades if medium grey with some brown IR).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D51_30
Section: AS3534

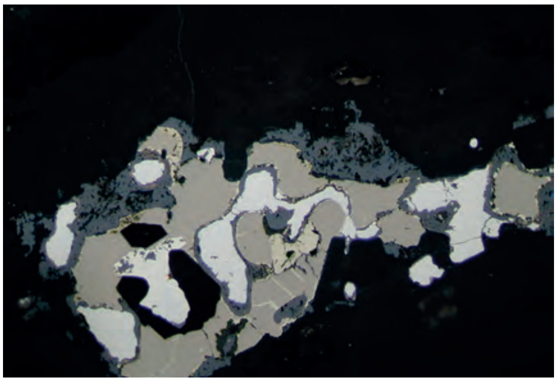
## 263 Iron (kamacite, taenite) – Iron meteorite Gibeon



Broad lamellae of kamacite (matrix, with fine Neumann bands = mechanical, plate-shaped twin lamellae) enclosing elongated plessite (= mixture of kamacite + taenite). Thin rims of pure taenite (light yellowish white) are bordering the plessite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D215_10
Section: AS3649

## 264 Iron, po, pn, cp, wuestite, gr – Khungtukun massif, Taimyr, Sibiria, Russia



Formation of terrestrial iron (white) due to reduction of pyrrhotite (brownish cream), which is intergrown with chalcopyrite (yellow) and pentlandite (cream). At the contact between iron and pyrrhotite small grains of wuestite (medium grey). Graphite flake in the upper part of photo.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D221_01
Section: AS3686

# Iscorite

**Mineral name:** Iscorite (Silicoferrite)
**Formula:** $Fe_5^{2+}Fe_2^{3+}SiO_{10}$

**VHN:** --
**Crystal System:** mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1 = 16$ | $R_2 = 17$ | estimated |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1 = 5$ | $R_2 = 6$ | estimated |
| **Colour impression** | **(in oil)** | grey tint blue | grey tint brown | |
| **BR < Rpl** | **(in oil)** | distinct | | $A_{oil} = 18$ |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | weak with colour tint | distinct with colour |
| **Colour:** | **in 45° position** | grey tint orange | greyish brown – yellow brown (lighter) |
| | **... in other positions** | orange brown | orange, yellow olive, blue |
| **Extinction position** | | black | |
| **Mode of extinction** | | perfect, straight | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

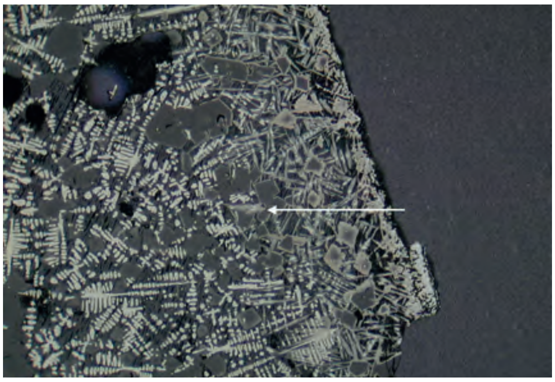
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | tabular, elongated, dendritic crystals in iron slags |
| **Paragenesis** | wuestite, mt, olivine |
| **Diagnostic features** | BR; in iron slags with wuestite, mt, and iron |

## Notes, drafts

$R_2$ || elongation.
Crystallization product of iron-rich and $SiO_2$-poor melts, cooling under slightly oxid. conditions.
Ref.: Nell & van den Berg (1988): Trans. Inst. Min. Metall., 97, C53-C60. Rose et al. (1990): J. Hist. Metall., 24, 27-32.

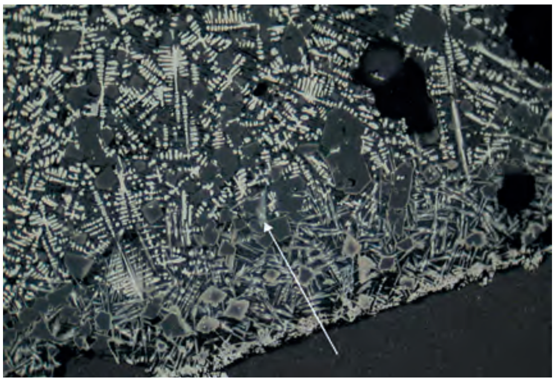
## 265 Iscorite, mt, wuestite, spinel – Medieval slag, Schalkstetten, N of Ulm, Germany



Iron slag with tiny tabular crystals of iscorite (medium grey tint brown, centre-right part of photo, arrow), skeletal magnetites and wuestites (left side) between zoned euhedral spinels (dark grey, with light magnetite rim).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D110_15
Section: AS3513

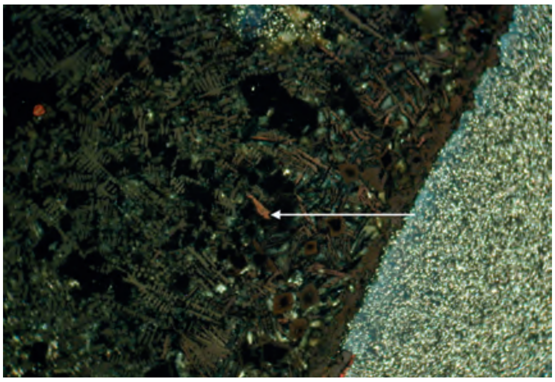
## 266 Iscorite, mt, wuestite, spinel – Medieval slag, Schalkstetten, N of Ulm, Germany



As above, but section 90° rotated. Iscorite now medium grey tint blue (arrow).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D110_13
Section: AS3513

## 267 Iscorite, mt, wuestite, spinel – Medieval slag, Schalkstetten, N of Ulm, Germany



Enlarged part from above, with crossed polars. Note distinct orange anisotropism of iscorite.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.4 mm
Photo No.: D110_16
Section: AS3513

## 268 Iscorite, mt, wuestite, spinel – Medieval slag, Schalkstetten, N of Ulm, Germany

Zoned spinel crystals intergrown with tiny lamellar iscorites (medium grey) and dendritic wuestite (light grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.4 mm
Photo No.: D110_21
Section: AS3513

# Jacobsite (in German: Jakobsit)

**Mineral name:** Jacobsite
**Formula:** $(Mn,Fe,Mg)(Fe,Mn)_2O_4$

**VHN:** 660-710
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | ~ 21 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | ~ 8 | |
| **Colour impression** | **(in oil)** | olive – olive brown – greyish olive | due to composition |
| **BR Rpl** | **(in oil)** | -- | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | homogeneous dark | homogeneous dark |
| **Colour:** | **in 45° position** | black | |
| | **... in other positions** | | |
| **Extinction position** | | -- | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | red | |
| **(IR)** | **frequency** | rare | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

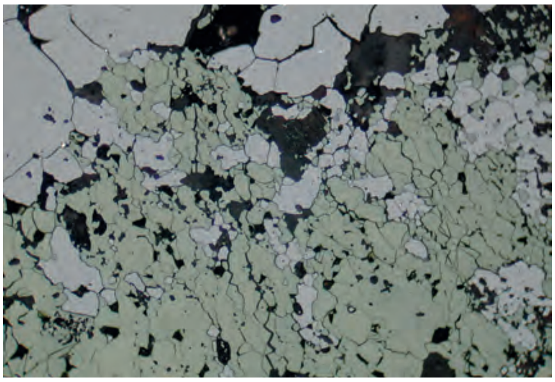
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | granular, edge-rounded aggregates, often cataclasis; frequently zoned and patchy coloured |
| **Paragenesis** | limonite, pyrolusite, hematite |
| **Diagnostic features** | CI, similar to braunite (which is not greenish, but anisotropic) |

## Notes, drafts

Jacobsite with more than 54 % $Mn_3O_4$ → EB of HAUSMANNITE.
Anisotropic jacobsite = Iwakiite ($MnFe_2O_4$; tetr.)
See: MATSUBARA ET AL. (1979): Mineral J. (Tokyo), 9, 383-391.

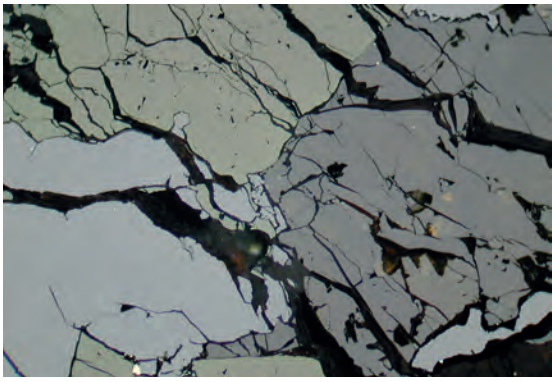
## 269 Jacobsite, alabandite – Noda Tamagawa, Iwate, Japan



Equigranular aggregate of jacobsite (greyish olive, zoning) with alabandite (grey) in complex pyrometasomatic Mn-ore.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D13_11
Section: AS215

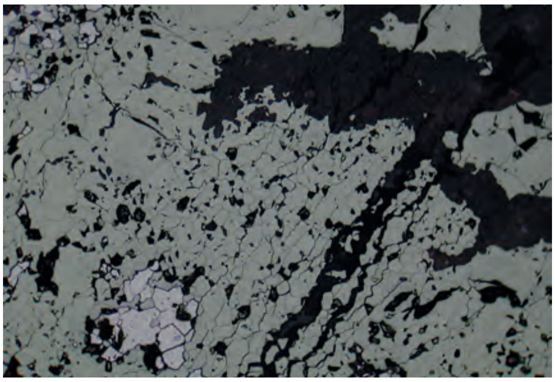
## 270 Jacobsite, alabandite, sph – Noda Tamagawa, Iwate, Japan



Jacobsite (greenish grey, upper and lower part), alabandite (light grey), and sphalerite (medium grey, partly with yellow brown IR).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D13_13
Section: AS215

## 271 Jacobsite, alabandite – Noda Tamagawa, Iwate, Japan



Granular aggregate of jacobsite (greenish grey) with few alabandite (light grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D103_02
Section: AS214

## 272 Jacobsite – Mina Barnabe, Bahia, Brazil

Jacobsite with spongy alteration rim.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D103_16
Section: AS218

# Jamesonite

**Mineral name:** Jamesonite (jm)
**Formula:** $Pb_4FeSb_6S_{14}$

**VHN:** 60-90
**Crystal System:** mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 36.4 (⊥ c) | $R_2$ = 44.2 (\|\| c) | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 20.8 (⊥ c) | $R_2$ = 28.8 (\|\| c) | |
| **Colour impression** | **(in oil)** | greyish tint olive | grey white tint (yellow) green | |
| **BR ~ Rpl** | **(in oil)** | distinct – strong | | $A_{oil}$ = 32 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | distinct with colour tint | distinct with colour tint |
| **Colour:** | **in 45° position** | grey tint yellow | grey tint yellow – dark grey |
| | **... in other positions** | | brown violet |
| **Extinction position** | | black | |
| **Mode of extinction** | | perfect, undulatory | |
| **Internal reflections** | **colour** | orange red | |
| **(IR)** | **frequency** | very rare | |
| **Twinning** | **mode** | polysynthetic in one direction \|\| (100), always \|\| elongation of X | |
| | **frequency** | predominant | |

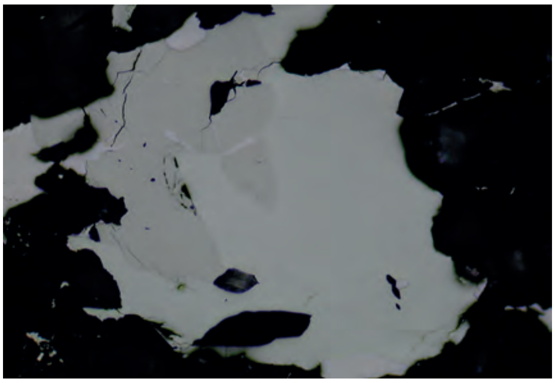
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | single X or bunches of needle-like XX without head planes, fibrous aggr. (»Feder-Erz«), compact masses; # (001) ⊥ to elongation, in part additional # \|\| elongation. |
| **Paragenesis** | gn, sph, asp, Ag-minerals, fahlore |
| **Diagnostic features** | CI, twinning \|\| elongation |

## Notes, drafts

In contrast to similar BOULANGERITE: #, no bluish AExPol, $R_2 > R_{Galena}$!

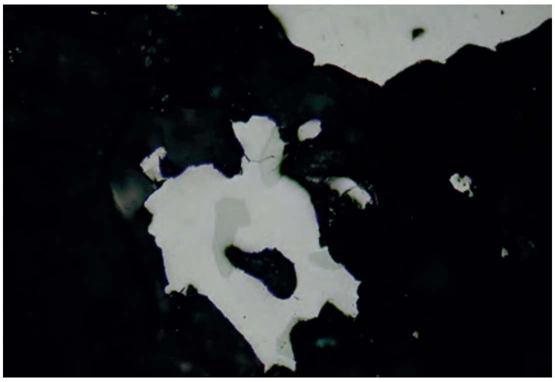
## 273 Jamesonite, galena – Sala silver mine, Västmanland County, Sweden



Granular jamesonite (with BR) with small relicts of galena (greyish white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D93_26
Section: AS245

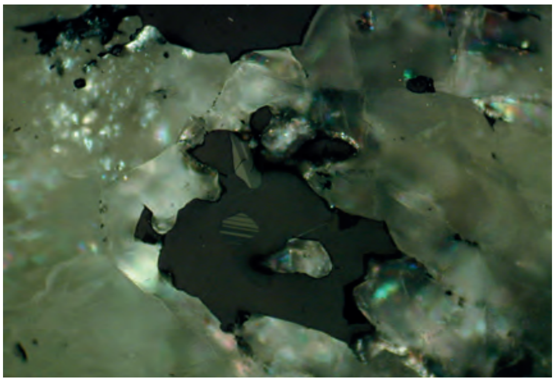
## 274 Jamesonite, galena – Sala silver mine, Västmanland County, Sweden



Galena grain with two slightly darker jamesonite inclusions.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D94_08
Section: AS245

## 275 Jamesonite, galena – Sala silver mine, Västmanland County, Sweden



As above, with crossed polars. Note twinning within the two inclusions of jamesonite.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D94_09
Section: AS245

## 276 Jamesonite, boulangerite – Sala silver mine, Västmanland County, Sweden

Jamesonite (lower right part of photo; reddish brown with faint twinning) beside boulangerite (bluish AExPol). See also photo no. 71 and 72!

Obj.: 20 × oil
Polars: × Pol (~!)
Photo width: 0.7 mm
Photo No.: D94_14
Section: AS245

# Jordanite

**Mineral name:** Jordanite
**Formula:** $Pb_{14}As_6S_{23}$

**VHN:** 110-140
**Crystal System:** mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 38.1 | $R_2$ = 40.6 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 22.6 | $R_2$ = 25.1 | |
| **Colour impression** | **(in oil)** | greyish white (tint green) | greyish white | |
| **BR ~ Rpl** | **(in oil)** | distinct | | $A_{oil}$ = 10 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | weak without colour | distinct without colour |
| **Colour:** | **in 45° position** | grey | light grey – dark grey |
| | **... in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | undulatory | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | polysynthetic after (001) | |
| | **frequency** | common | |

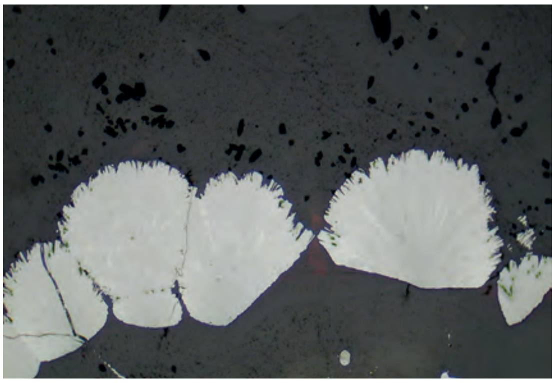
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | rare euhedral elongated XX, often concentric to colloform masses; # \|\| (010) |
| **Paragenesis** | intergrown with schalenblende, galena, gratonite, other Pb-As-sulfosalts |
| **Diagnostic features** | paragenesis |

## Notes, drafts

Visually, $R_2$ (in oil) is very similar to $R_{Galena}$.

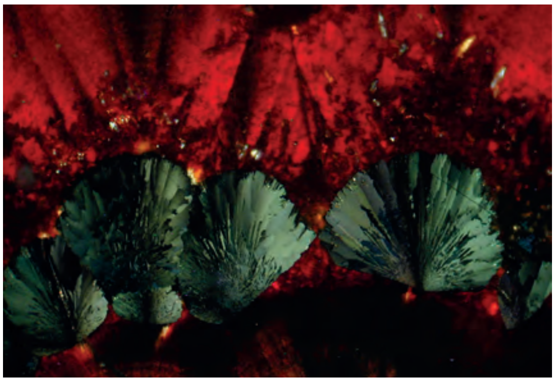
## 277 Jordanite, sphalerite – Michael im Weiler, Schwarzwald, Germany



Reniform aggregates of subparallel platy jordanite crystals (light grey) surrounded by sphalerite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D213_07
Section: KS1376

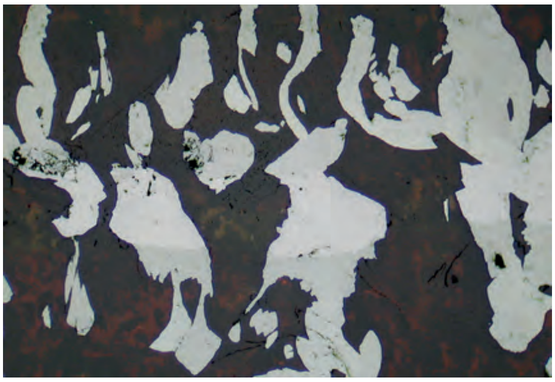
## 278 Jordanite, sphalerite – Michael im Weiler, Schwarzwald, Germany



As above, with crossed polars. Jordanite with undulatory extinction; sphalerite with deep red internal reflections.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D213_08
Section: KS1376

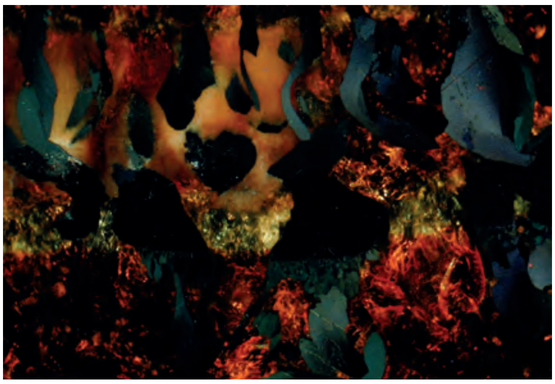
## 279 Jordanite, galena, sphalerite – Michael im Weiler, Schwarzwald, Germany



Irregular masses of jordanite (light grey) above and below a galena-rich layer (slightly more white), all in a groundmass of schalenblende.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D212_27
Section: KS1376

## 280 Jordanite, galena, sphalerite – Michael im Weiler, Schwarzwald, Germany



As above, with crossed polars. Note the undulatory extinction of jordanite, and the yellow to orange-red internal reflections of schalenblende.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D212_28
Section: KS1376

# Kermesite

**Mineral name:** Kermesite
**Formula:** $Sb_2S_2O$

**VHN:** 30-90
**Crystal System:** tric., ps. mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_a$ = 25.1 | $R_b$ = 30.4 | $R_c$ = 25.9 |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_a$ = 10.7 | $R_b$ = 15.1 | $R_c$ = 11.3 |
| **Colour impression** | **(in oil)** | greyish olive | greyish blue | grey |
| **BR < Rpl** | **(in oil)** | strong | | $A_{oil}$ = 35 |

## Observations with crossed polars (AExPol in oil)

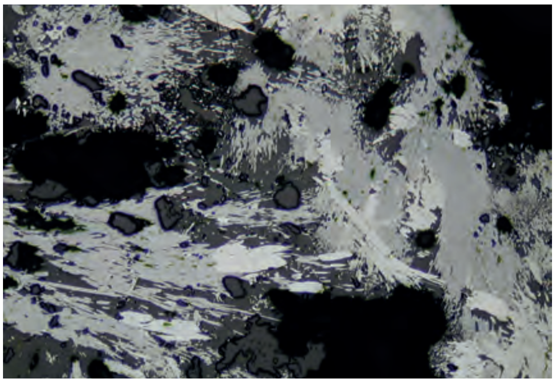
| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | distinct with colour tint | distinct with colour |
| **Colour:** | **in 45° position** | grey tint yellow | greyish blue – greyish yellow (lighter) |
| | **... in other positions** | greenish blue – blue violet | |
| **Extinction position** | | black | |
| **Mode of extinction** | | straight | |
| **Internal reflections** | **colour** | red violet | |
| **(IR)** | **frequency** | abundant | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | typical radial fibrous aggregates after [010];<br>oxidation product of stibnite (but no pseudomorphs!) |
| **Paragenesis** | stibnite |
| **Diagnostic features** | red violet IR, habit, paragenesis |

## Notes, drafts

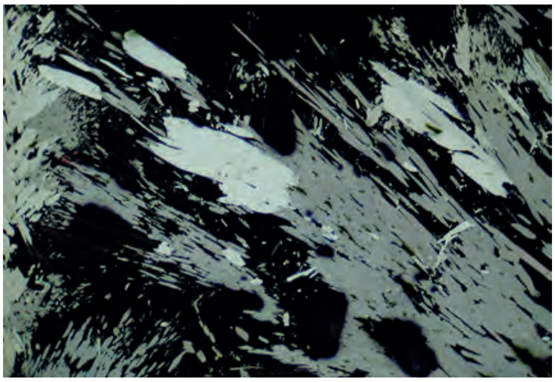
### 281 **Kermesite, stibnite –** Bräunsdorf, Saxony, Germany (?)



Kermesite (slightly darker than stibnite) around stibnite needles (centre of photo, greyish white – white).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D99_21
Section: AS1017

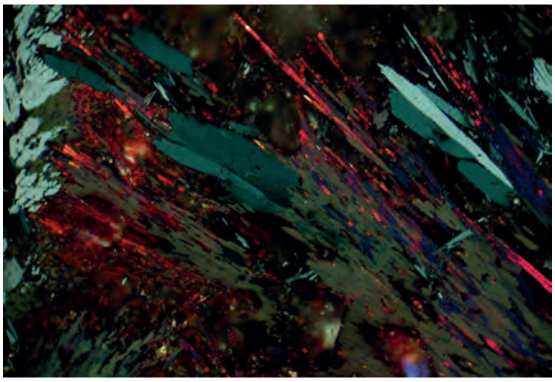
### 282 **Kermesite, stibnite –** Bräunsdorf, Saxony, Germany (?)



Kermesite needles (medium grey) with elongated stibnites (greyish white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D99_22
Section: AS1017

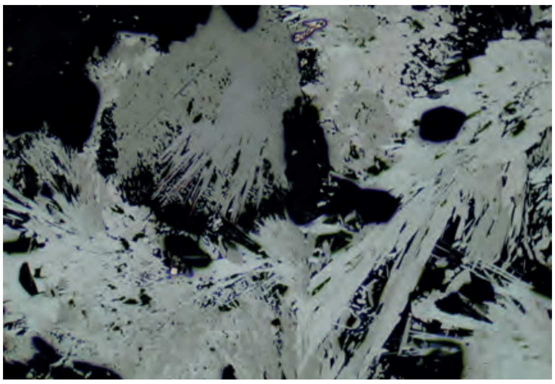
### 283 **Kermesite, stibnite –** Bräunsdorf, Saxony, Germany (?)



As above, with crossed polars. Kermesite with characteristic red IR, and stibnite with strong AExPol.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D99_24
Section: AS1017

### 284 **Kermesite, stibnite –** Bräunsdorf, Saxony, Germany (?)



Kermesite needles in different orientation (upper left part) surrounded by stibnite needles.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D99_26
Section: AS1017

# Kesterite

**Mineral name:** Kesterite
**Formula:** β-$Cu_2(Zn,Fe)SnS_4$

**VHN:** ~ 340
**Crystal System:** tetr., ps. cubic

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 25.6 | $R_{e'}$ = 24.8 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 11.5 | $R_{e'}$ = 10.9 | |
| **Colour impression** | **(in oil)** | grey tint olive | grey tint olive | |
| **BR > Rpl** | **(in oil)** | very weak | | $A_{oil}$ = 5 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | very weak without colour | weak without colour |
| **Colour:** | **in 45° position** | dark grey | impure dark grey |
| | **... in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | straight | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

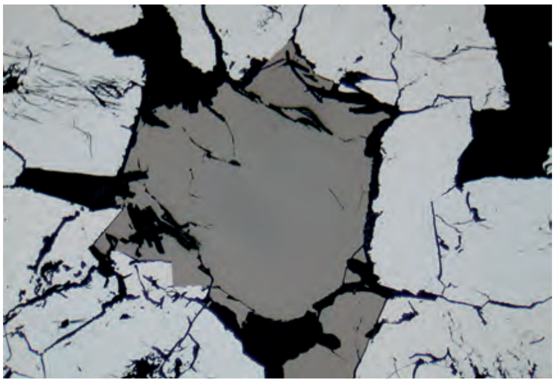
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | euhedral to anhedral grains intergrown with stannoidite, stannite and other sulfides |
| **Paragenesis** | stannite, stannoidite, asp, wolframite, cassiterite |
| **Diagnostic features** | paragenesis |

## Notes, drafts

Fe-rich Kesterite: Ferrokesterite (often described as isostannite)

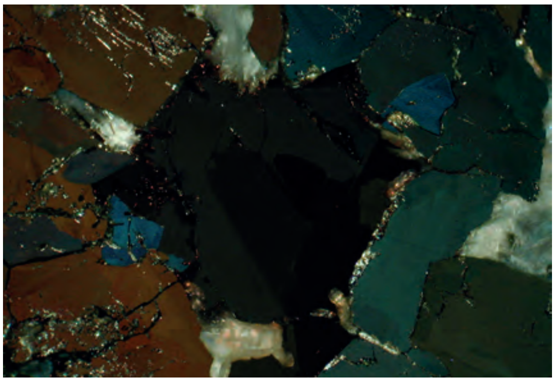
### 285 Kesterite, asp – St. Michaels Mount, Cornwall, England



Large grain of kesterite (grey) enclosed by arsenopyrite (white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D155_24
Section: AS3627

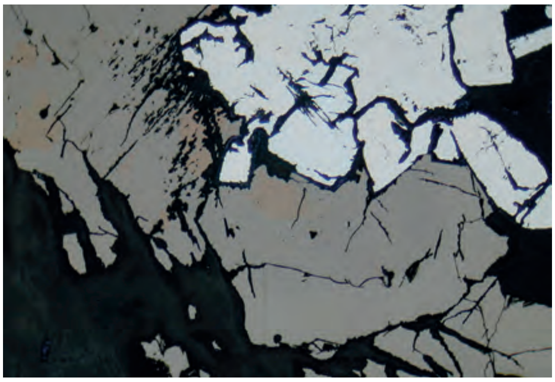
### 286 Kesterite, asp – St. Michaels Mount, Cornwall, England



As above with crossed polars; weak anisotropism is visible.

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D155_25
Section: AS3627

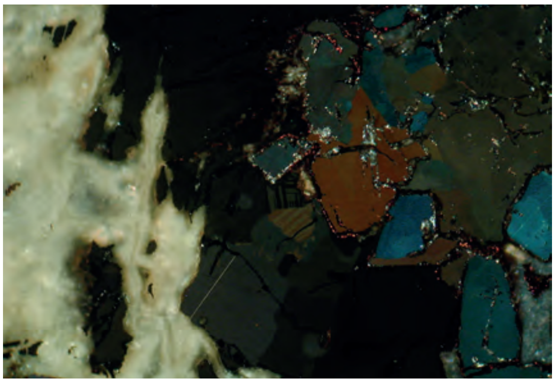
### 287 Kesterite, stannoidite, asp – St. Michaels Mount, Cornwall, England



Kesterite (grey) with relicts of stannoidite (orange brown), and arsenopyrite (white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D155_27
Section: AS3627

### 288 Kesterite, stannoidite, asp – St. Michaels Mount, Cornwall, England



As above with crossed polars showing weak anisotropism of kesterite and distinct anisotropism of stannoidite with spindle-like lamellae (centre of photo).

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D155_26
Section: AS3627

# Lepidocrocite (in German: Lepidokrokit, Rubinglimmer)

**Mineral name:** Lepidocrocite
**Formula:** γ-FeOOH

**VHN:** ~ 400
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1 = 11.6$ | $R_2 = 18.4$ | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1 = 2.0$ | $R_2 = 6.2$ | |
| **Colour impression** | **(in oil)** | dark grey – black (dull) | white grey tint blue | |
| **BR > Rpl** | **(in oil)** | extremly strong | | $A_{oil} = 102$ |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong without colour | strong without colour |
| **Colour:** | **in 45° position** | white | white – white |
| | **… in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | perfect | |
| **Internal reflections** | **colour** | brownish red, seldom reddish yellow or brown;<br>not as brilliant red as in hematite | |
| **(IR)** | **frequency** | common | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

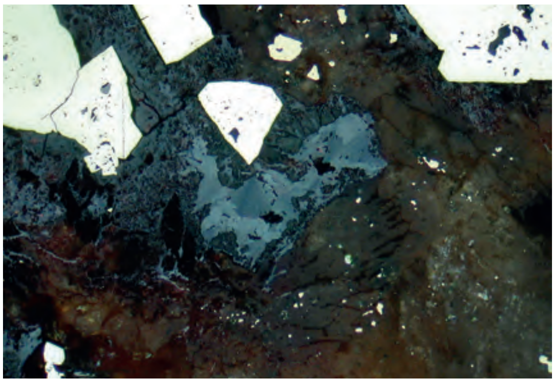
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | thin tablets, tabular, radial aggregates;<br>often intergrown with goethite |
| **Paragenesis** | together with goethite as oxidation product of Fe-sulfides |
| **Diagnostic features** | strong BR and AExPol, brownish red IR |

## Notes, drafts

Extensively common, intensively less abundant than goethite.
The similar LITHIOPHORITE has no IR!

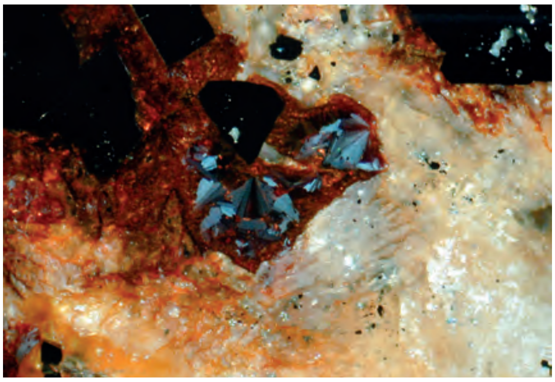
## 289 Lepidocrocite, py, cp, carbonate – Rotgülden mine, Salzburg, Austria



Equigranular aggregate of Pyrite and chalcopyrite (upper part) in association with fan-shaped lepidocrocite (varying shades of grey → strong BR, central part). Carbonate groundmass with goethite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D22_16
Section: AS3536

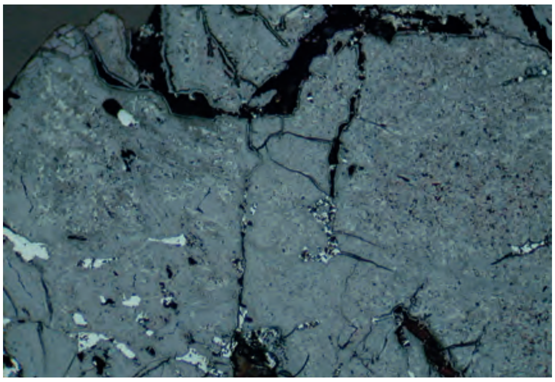
## 290 Lepidocrocite – Rotgülden mine, Salzburg, Austria



As above, with crossed polars. Strong anisotropism of fan-shaped lepidocrocite (with some red internal reflections!) surrounded by goethite (many orange-brown IR).

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D22_18
Section: AS3536

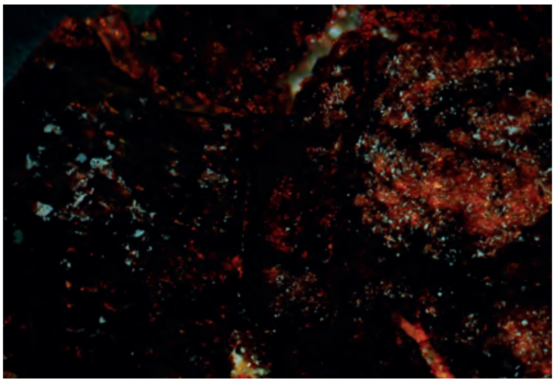
## 291 Lepidocrocite, goethite – Stuhlskopf, Schwarzwald, Germany



Fine-grained mixture of goethite and lepidocrocite with minor hematite (light grey). Small grains of goethite and lepidocrocite are difficult to identify with uncrossed polars (but see next photo!).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D61_03
Section: FP43-1

## 292 Lepidocrocite, goethite – Stuhlskopf, Schwarzwald, Germany



As above, now with crossed polars. Lepidocrocite exhibits strong anisotropism (light grey to white), whereas anisotropism of goethite is weak and mainly masked by abundant internal reflections (varying yellow-brown).

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D61_02
Section: FP43-1

# Lithiophorite

**Mineral name:** Lithiophorite
**Formula:** $LiAl_2Mn_3O_9 * H_2O$

**VHN:** 60-100
**Crystal System:** mcl., ps. hex.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1 = 20.4$ | $R_2 = 9.8$ | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1 \sim 8$ | $R_2 \sim 1.5$ | estimated |
| **Colour impression** | **(in oil)** | grey white (tint blue) | grey black (tint brown) | |
| **BR > Rpl** | **(in oil)** | extremly strong | | $A_{oil} = 137$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong without colour | very strong without colour |
| **Colour:** | **in 45° position** | white | white – white |
| | **... in other positions** | Co-rich: whitish rose | |
| **Extinction position** | | black | |
| **Mode of extinction** | | perfect, undulatory | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

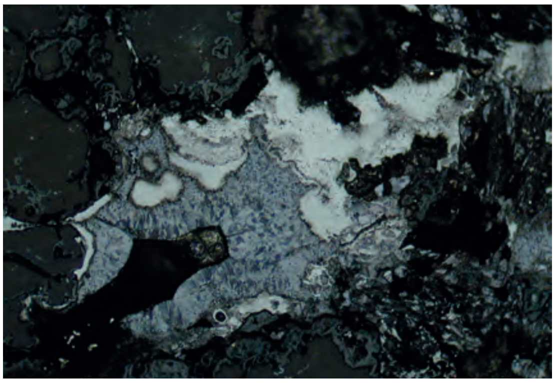
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | fibrous, needle-like, garben-like aggregates, often zoned, replaces Mn-silicates and other Mn-minerals |
| **Paragenesis** | other Mn-minerals |
| **Diagnostic features** | paragenesis, AExPol, BR |

## Notes, drafts

Li → Co, Ni, Cu, and Pb.
CI varies with composition (> 1-2 % CoO → greyish rose), higher CoO content (called »asbolane«) → pink.
The similar LEPIDOCROCITE has internal reflections!

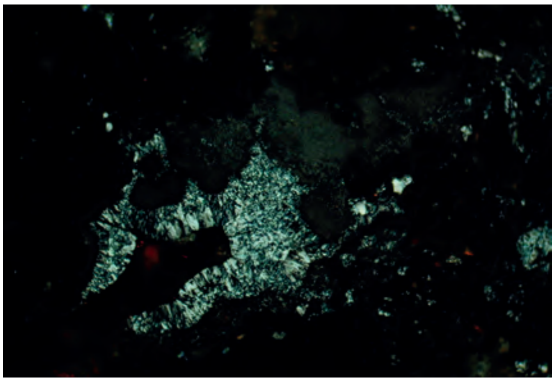
## 293 Lithiophorite, manganomelane – Ungwan Mallam Ayuba, N-Nigeria



Fine-grained lithiophorite aggregate (medium to dark bluish grey) intergrown with manganomelane (light grey); both replacing Mn-rich amphibole and spessartite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D13_09
Section: AS238

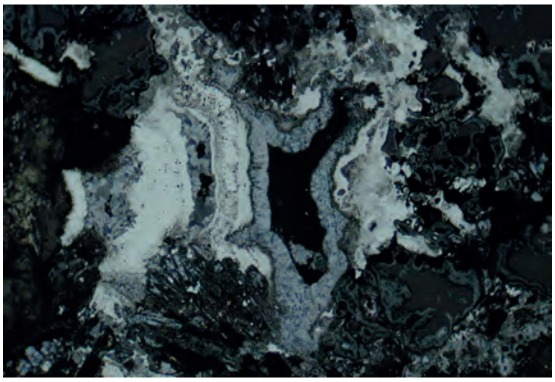
## 294 Lithiophorite, manganomelane – Ungwan Mallam Ayuba, N-Nigeria



As above, with crossed polars. Very strong anisotropism of lithiophorite is easy visible.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D13_10
Section: AS238

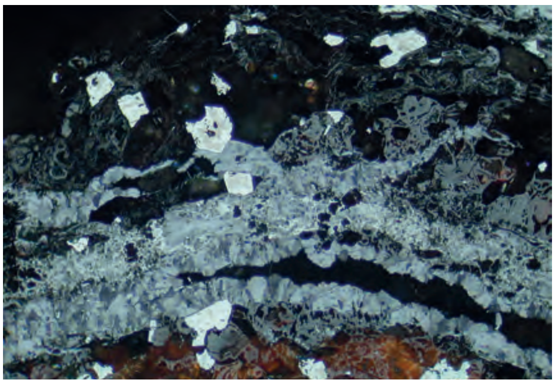
## 295 Lithiophorite, manganomelane – Ungwan Mallam Ayuba, N-Nigeria



Rhythmic layering of lithiophorite (BR) and manganomelane (highest R) as alteration product of garnet (upper left and lower right part of photo) and amphibole (lower centre of photo).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D13_28
Section: AS238

## 296 Lithiophorite, mt, hm – Ruwan Doruwa, Kaduna, N-Nigeria



Layers of lithiophorite (BR; light to medium grey) with limonite (medium grey), and magnetite crystals (with beginning martitization).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D133_11
Section: AS241

# Loellingite

**Mineral name:** Loellingite (lo)
**Formula:** $FeAs_2$
**VHN:** 860-920
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 53.4 | $R_2$ = 55.5 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 38.4 | $R_2$ = 41.6 | |
| **Colour impression** | **(in oil)** | whitish yellow | white tint blue | |
| **BR < Rpl** | **(in oil)** | distinct (stronger than safflorite) | | $A_{oil}$ = 8 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong without colour | strong with colour |
| **Colour:** | **in 45° position** | light grey | greyish yellow – greyish blue |
| | **... in other positions** | greyish white tints of yellow/blue | yellow brown – blue |
| **Extinction position** | | greyish black | |
| **Mode of extinction** | | not perfect, straight, patchy | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | twins and triplets \|\|{110} (swallowtail, »Schwalbenschwanz«); polysynthetic \|\|{011} | |
| | **frequency** | common; rare | |

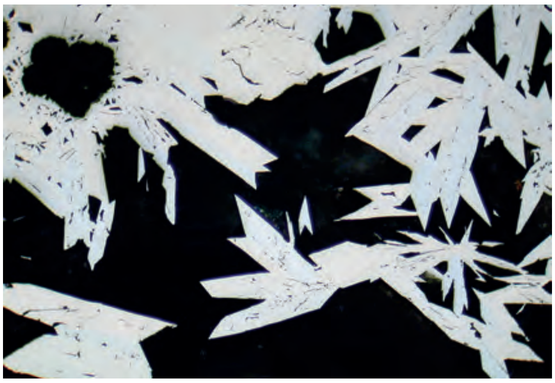
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | often euhedral tabular XX, radial aggr., rare (visible) zoning; |
| **Paragenesis** | asp, nk, bismuth, gersdorffite, skutterudite |
| **Diagnostic features** | similar to safflorite but without orange brown AExPol and less zoned |

## Notes, drafts

Be aware of the complete solid solution loellingite – safflorite.
Similar to ARSENOPYRITE and SAFFLORITE!

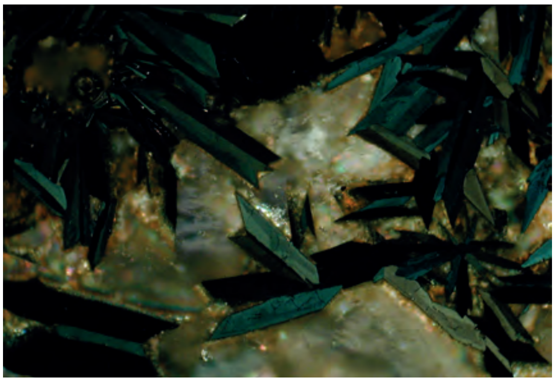
## 297 Loellingite – Nieder-Beerbach, Odenwald, Germany



Elongated crystals of loellingite with swallowtail (»Schwalbenschwanz«) twinning (indeed triplets) with distinct reflection pleochroism.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D172_26
Section: CHe11

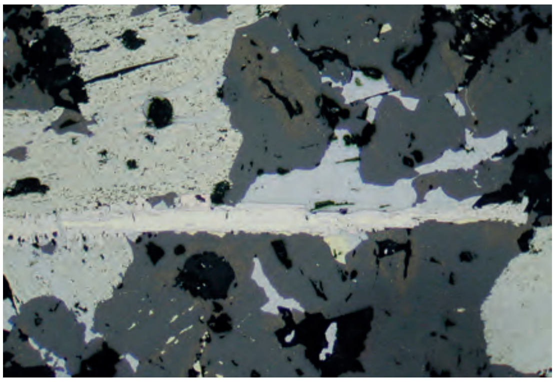
## 298 Loellingite – Nieder-Beerbach, Odenwald, Germany



As above, with crossed polars showing strong anisotropism of loellingite (stronger than for asp).

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D172_27
Section: CHe11

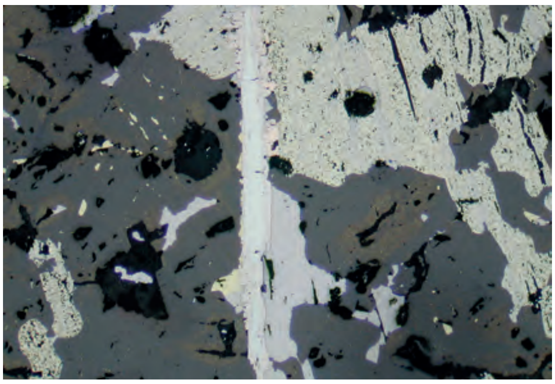
## 299 Loellingite, asp, sph, gn – Geyer mine, Saxony, Germany



Elongated crystals of loellingite (core, whitish yellow) overgrown by arsenopyrite (white rim), in sphalerite (showing cp-disease), galena (greyish white), and complex pseudomorph of pyrite plus galena after pyrrhotite (left side of photo).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D30_14
Section: AS1758

## 300 Loellingite, asp, sph, gn – Geyer mine, Saxony, Germany



As above, but 90° rotated. The colour impression of loellingite is now white tint blue.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D30_15
Section: AS1758

# Luzonite

**Mineral name:** Luzonite – Stibioluzonite
**Formula:** $Cu^{1+}{}_{3}(As,Sb)^{5+}S_{4}$

**VHN:** 200-400
**Crystal System:** tetr.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1 = 24.5$ | $R_2 = 27.3$ | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1 = 12.2$ | $R_2 = 14.0$ | |
| **Colour impression** | **(in oil)** | greyish yellow | orange brown | |
| **BR < Rpl** | **(in oil)** | strong | | $A_{oil} = 14$ |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong without colour | strong wit colour tint |
| **Colour:** | **in 45° position** | light grey | light grey tint yellow – very dark grey |
| | **... in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | straight to morphology, oblique to the twin planes | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | complex, fine lamellar twinning after two or three directions | |
| | **frequency** | always, typical | |

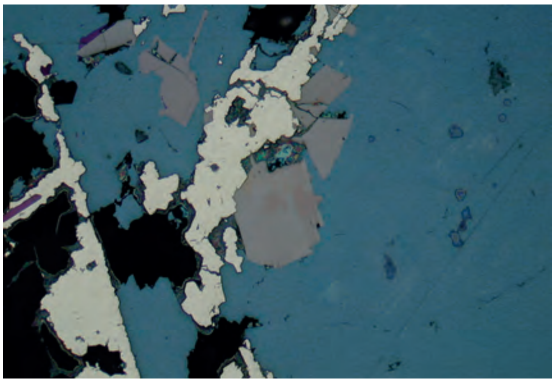
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | often paramorphic transformation to enargite, twinning, occasional zoned; no #! |
| **Paragenesis** | enargite, pyrite, chalcopyrite, fahlore, sphalerite |
| **Diagnostic features** | orange CI, twinning, AExPol |

## Notes, drafts

More orange brown than the similar ENARGITE.

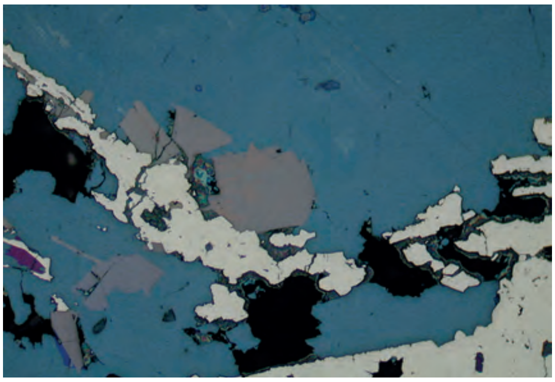
## 301 Luzonite, enargite, digenite, py – Bor, Serbia



Enargite (greyish) replacing luzonite (more brown, relicts of twinning is visible); pyrite with covellite, and digenite (with small chalcocite lamellae).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D50_05
Section: AS113

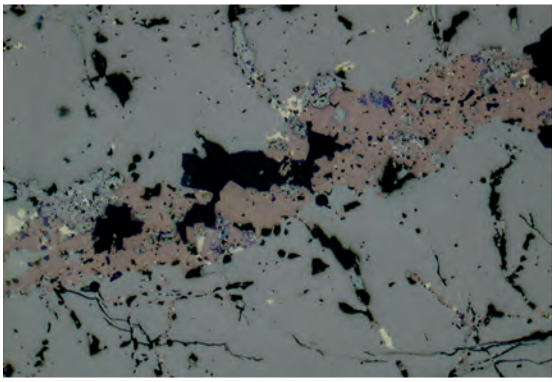
## 302 Luzonite, enargite, digenite, py – Bor, Serbia



As above, but 90° rotated. Enargite now with lower reflectance than luzonite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D50_06
Section: AS113

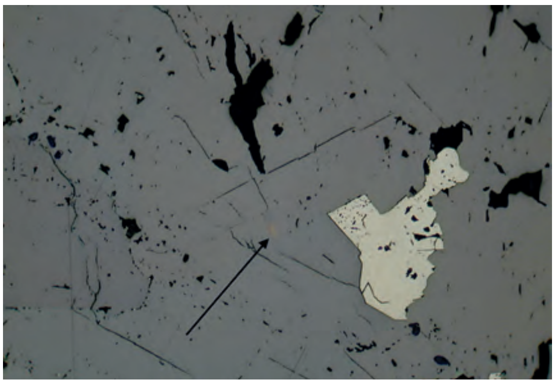
## 303 Luzonite, fahlore, cp – Clara mine, Oberwolfach, Schwarzwald, Germany



Luzonite (brown colours) in fahlore (grey), plus chalcopyrite and covellite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D54_09
Section: AS3578

## 304 Luzonite, enargite, py – »Colorado«, USA



Tiny inclusion of luzonite (orange brown – red brown; arrow in centre of picture) surrounded by enargite (greyish), pyrite (whitish yellow).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D115_11
Section: AS3635

# Mackinawite

**Mineral name:** Mackinawite
**Formula:** $(Fe,Ni,Co)_{1+x}S$

**VHN:** 50-180
**Crystal System:** tetr.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 40.4 | $R_{e'}$ = 16.2 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 28.4 | $R_{e'}$ = 5.2 | |
| **Colour impression** | **(in oil)** | greyish white tint rose | grey | |
| **BR ~ Rpl** | **(in oil)** | extremely strong | | $A_{oil}$ = 138 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | very strong with colour tint | very strong with colour tint |
| **Colour:** | **in 45° position** | white tint yellow | white tint yellow – whitish grey |
| | **... in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | straight, perfect, undulatory | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | lamellar | |
| | **frequency** | occasional (Mooihoek deposit) | |

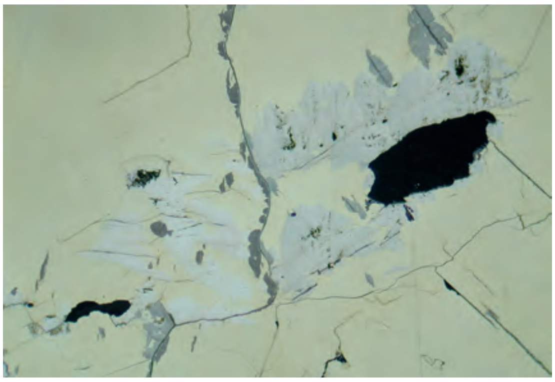
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | tabular to anhedral flakes and usually very small (some µm); as EB in iron-rich cp, together with cubanite |
| **Paragenesis** | cp, pn, py, cub, maucherite |
| **Diagnostic features** | BR, AExPol, paragenesis, small grain size (!) |

## Notes, drafts

x in formulae max. 0.08. Similar to MOLYBDENITE.

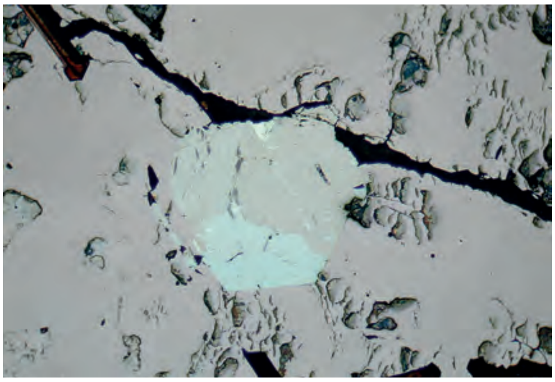
## 305 Mackinawite, cp – Phalaborwa, RSA



Groundmass of chalcopyrite (yellow, with #!) with small N-S veinlet of mackinawite, and extended areas of replacement features with mackinawite in different orientations (BR from nearly white to medium grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D200_16
Section: U2-130

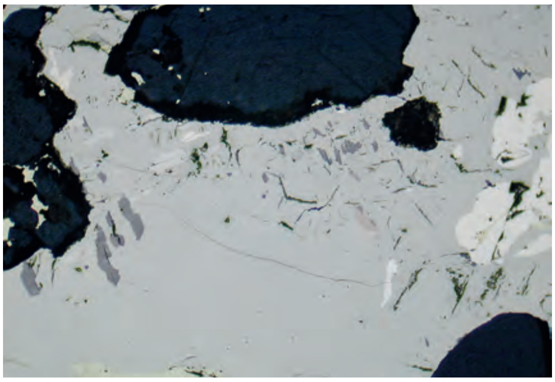
## 306 Mackinawite, cubanite, po, cp – Gryhytthan, Sweden



Cubanite triplet with small flame-like inclusions of mackinawite (medium grey) and chalcopyrite, within pyrrhotite (poor polishing.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D26_03
Section: AS160

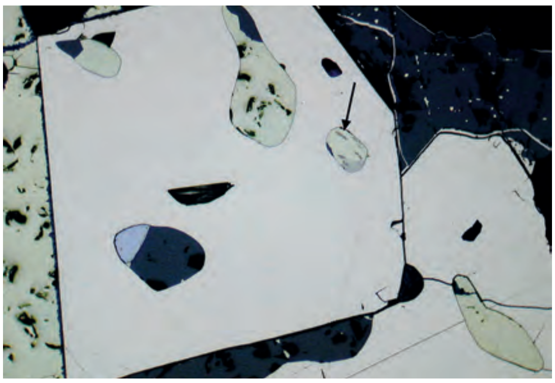
## 307 Mackinawite, cubanite, po, cp, py – Phalaborwa, RSA



Oriented mackinawite laths (white to dark grey) and two small pyrrhotite inclusions (reddish brown) within large cubanite grain (light grey). Chalcopyrite (lower left) and tiny pyrites.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D200_19
Section: U2-130

## 308 Mackinawite, py, cp – Zlaté Hory, Okres Jeseník, Czech Republic



Euhedral pyrite with rounded inclusions of gn+sph (lower left part), cp+sph, and cp+cub+ mackinawite (right part of pyrite). The flame-like inclusions of mackinawite (in cp) are distinct darker than cubanite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D84_13
Section: AS2553

# Maghemite

**Mineral name:** Maghemite (mgh)
**Formula:** $(Fe^{3+}_{0.67}\square_{0.33})Fe_2O_4$

**VHN:** ~ 400
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in %** **(for 546 nm)** | 24.4 | | |
| **$R_{(oil)}$ in %** **(for 546 nm)** | 10.3 | | |
| **Colour impression** **(in oil)** | bluish grey | against mt: greyish blue | |
| **BR Rpl** **(in oil)** | -- | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|
| **Anisotropism intensity/colour** | homogeneous dark | |
| **Colour:** **in 45° position** | black | |
| **... in other positions** | | |
| **Extinction position** | -- | |
| **Mode of extinction** | -- | |
| **Internal reflections** **colour** | brownish red (colour between hm and goethite) | |
| **(IR)** **frequency** | very rare | |
| **Twinning** **mode** | -- | |
| **frequency** | -- | |

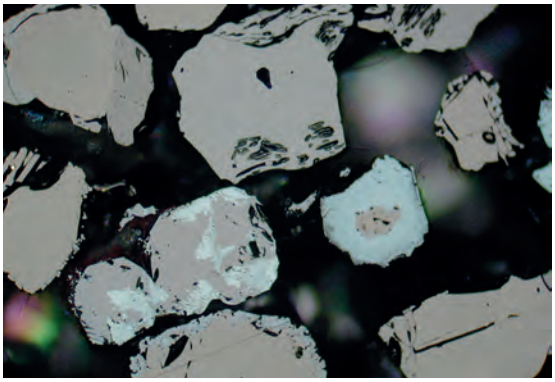
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | irregular, net- to cloud-like pseudomorphs after mt; alteration to hematite |
| **Paragenesis** | mt, hm, goe, lepidocrocite |
| **Diagnostic features** | CI, plus paragenesis with magnetite or hematite |

## Notes, drafts

Titanomaghemite $(Ti^{4+}_{0.5}\square_{0.5})Fe^{3+}_2O_4$) has higher R and does not alter to hematite.
»Kenomagnetite«: Name for relicts of lacunar spinel formed as a transitional stage phase (between magnetite and maghemite) during hematitization of magnetite
(first introduced 1969 by Kullerud et al., see MORRIS (1980), Econ. Geol., 75, 184-209).

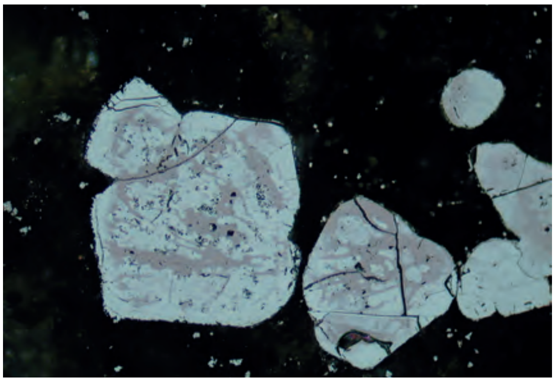
## 309 Maghemite, mt, hm – Placer sample from Milos island, Greece



Magnetite grains (brownish grey) rimmed and replaced by maghemite (bluish grey, centre) or by hematite (whitish grey, grains on left side). Upper part of photo: ilmenite (with BR).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D08_10
Section: AS139

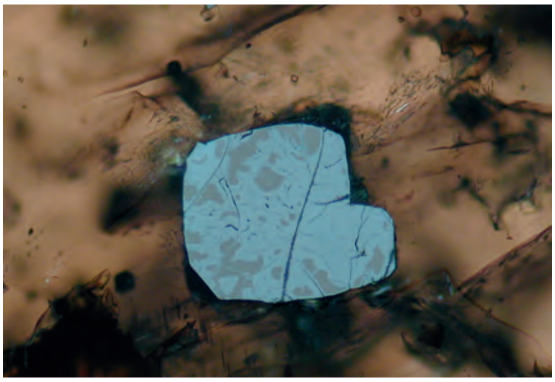
## 310 Maghemite, mt – Locality unknown



Irregular replacement of magnetite (brownish grey) by maghemite (bluish grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D53_15
Section: 9-2-2

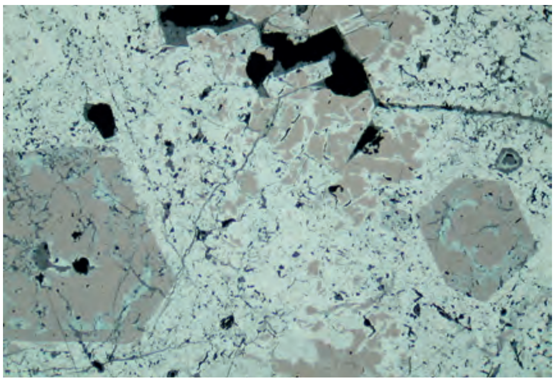
## 311 Maghemite, mt – Locality unknown



Transformation of magnetite into maghemite (combined transmitted and reflected light). Matrix of clinopyroxene.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D53_25
Section: 8-6-3

## 312 Maghemite, mt, hm – Calamita, Elba, Italy



Complex oxidation process of magnetite. Main magnetite groundmass is replaced by hematite (greyish white), whereas two "fresh" magnetite crystals (left and right side of photo) show an internal irregular zone of maghemite (bluish white) replacements.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D14_14
Section: AS2600

# Magnetite – Ti-Magnetite

**Mineral name:** (Ti-)Magnetite (mt)
**Formula:** $[Fe^{2+}]_{1+x}[Fe^{3+}]_{2-2x}[Ti^{4+}]_xO_4$

**VHN:** 500-550
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 20 | Ti-Mt: 16 to 17 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 8 | Ti-Mt: 5 to 6 | Mg-Ferrite: 5.9 % |
| **Colour impression** | **(in oil)** | grey (often with brownish or yellow tint) | Ti-Mt: grey tint brownish pink | |
| **BR Rpl** | **(in oil)** | -- | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | homogeneous dark (*) | sometimes very weak without colour |
| **Colour:** | **in 45° position** | black | greyish black |
| | **... in other positions** | | |
| **Extinction position** | | -- | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

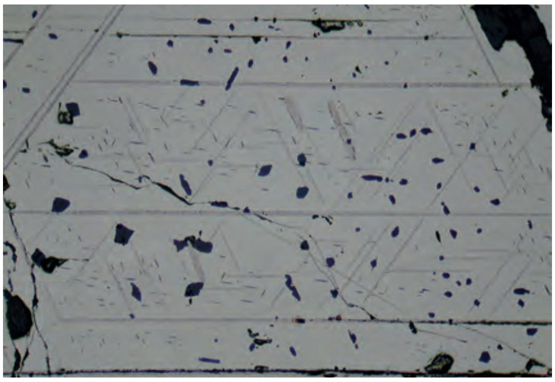
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | euhedral grains common; EB of ilmenite, ulvite, spinel etc. Zoning with Cr-/Al-/Mg-rich cores; often with beginning martitization (→ hem); no # |
| **Paragenesis** | hematite, ilmenite, spinel, chromite, pyrite |
| **Diagnostic features** | paragenesis, martitization, no IR, no # |

## Notes, drafts

CI and R are varying with composition (Ti, Mn, Cr, Al, Si).
Ti-rich end member ($Fe_2TiO_4$) = Ulvöspinel (Ulvite).
(*) Anisotropic magnetite (cloth-texture) probably results from exsolution of minute ilmenite lamellae.
Visible fine zoning (very thin delicate zones!) is typical for $SiO_2$-rich magnetite in pyrometasomatic ores.
»Kenomagnetite«: see maghemite.

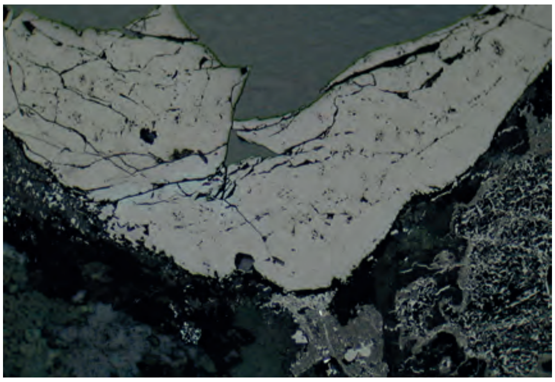
## 313 Magnetite, ilm, spl, – Krzemianka, Suwalki-Intrusion, NE-Poland



Magnetite host with exsolution of a) trellis-type lamellae of ilmenite (brownish grey) and b) minute exsolution bodies of different oriented spinels (black, lens shaped or isometric), c) tiny spinel blebs bordering larger trellis-type ilmenites, indicating the younger age of these spinels.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D25_12
Section: AS198

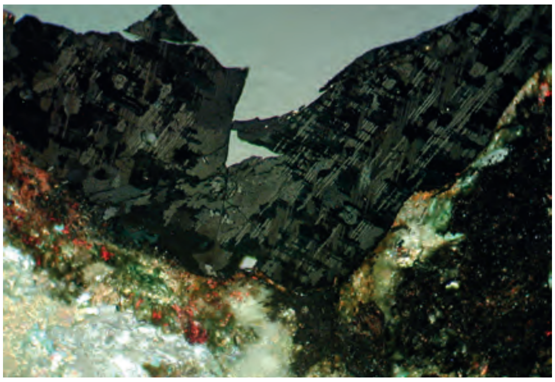
## 314 Magnetite, ilm, cloth-texture – Ilimaussaq, Greenland



Magnetite in cloth-type texture with fine exsolution bodies of ilmenite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D154_02
Section: GM1852

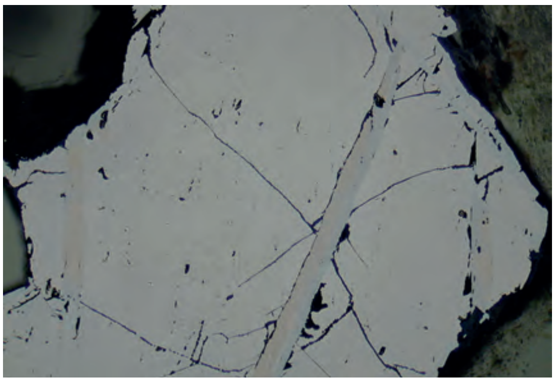
## 315 Magnetite, ilm, cloth-texture – Ilimaussaq, Greenland



As above with crossed polars. Note the distinct anisotropism of the cloth-texture.

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D154_05
Section: GM1852

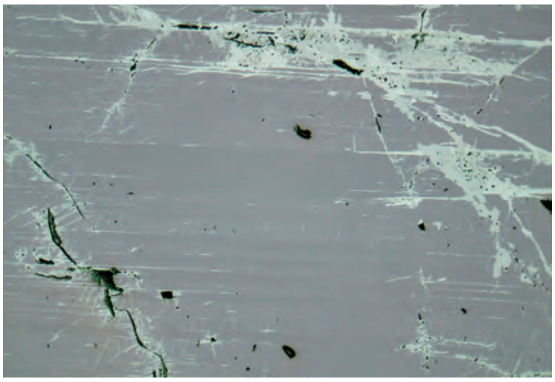
## 316 Magnetite, ilm – Ganawuri Complex, Jos Plateau, Nigeria



Magnetite with large ilmenite lamella (right side, partly altered to leached ilmenite, grey) and tiny trellis-type exsolution bodies of ilmenite, in addition to the scarcely visible cloth-texture.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D25_20
Section: AS324

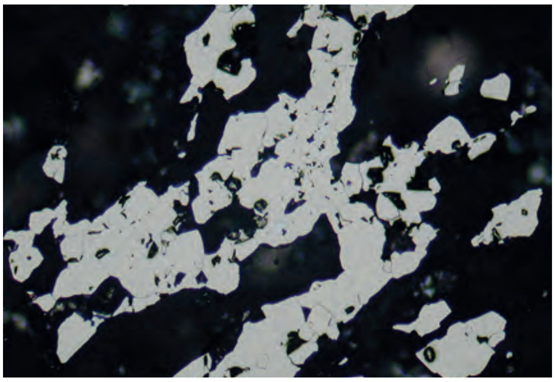
## 317 Magnetite, hm – Wheel Turner mine, Mt. Painter, Australia



Magnetite with lamellae visible by slightly different reflectance (greyish brown), in part (esp. along lamellae contacts) replaced by hematite. In this case the reduced reflectance of magnetite is caused by silica-enrichment.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D87_09
Section: WT7

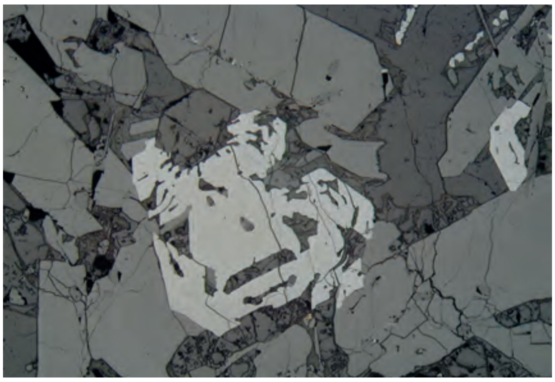
## 318 Magnetite, rutile – Kiruna, Sweden



Anhedral aggregates of magnetite (grey) with tiny inclusions of rutile (slightly higher R).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D25_01
Section: AS1742

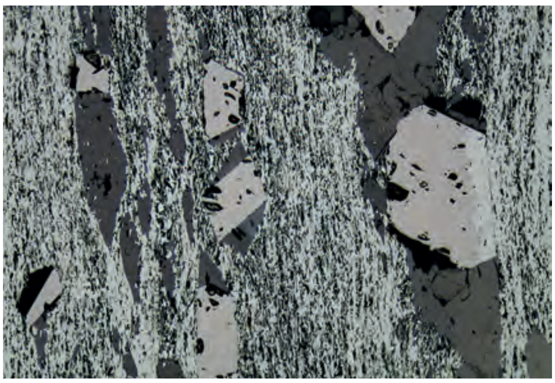
## 319 Ti-Magnetite, cpx, nepheline – Hohenstoffeln, Hegau, Germany



Skeletal crystal of titanomagnetite ("Hopper"-crystal) in nepheline groundmass (dark grey) with large cpx crystals (medium grey).

Obj.: 5 ×
Polars: || Pol
Photo width: 2.8 mm
Photo No.: D43_12
Section: AS2873

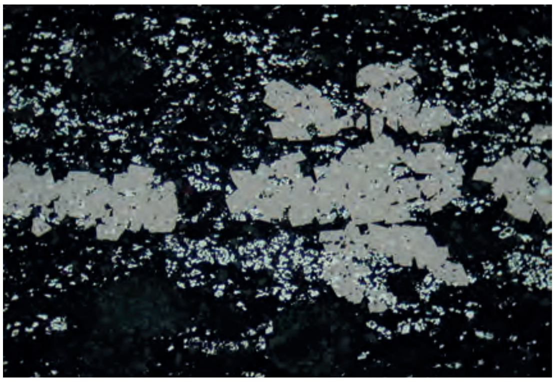
## 320 Magnetite, hm, qz – Maria Schneegrube, Bergstadt, Moravia, Czech Republic



Metamorphic ore with rotated magnetite crystals in fine-grained groundmass of hematite and quartz. Note the newly formed quartz in the pressure shadows of the magnetites.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D105_07
Section: AS2540

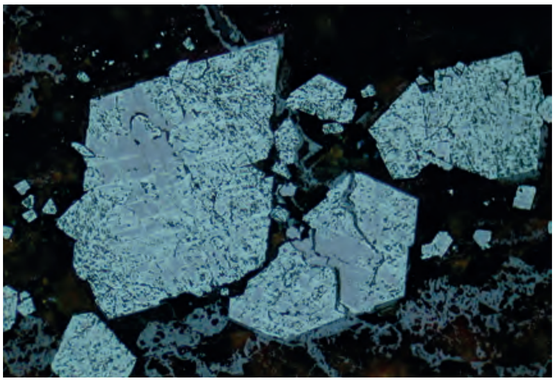
### 321 Magnetite, hm, carbonate – BIF, Mamatwan mine, Hotazel, RSA



Banded iron formation: Fine-grained groundmass of »primary« hematite (light grey) and carbonate (dark grey) with larger crystals of younger (diagenetic?) magnetite (including hematite and carbonate relicts).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D17_17
Section: M4

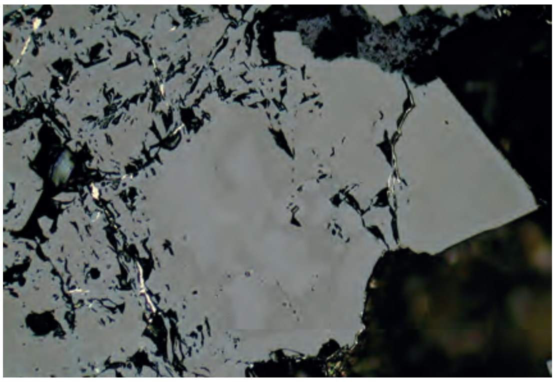
### 322 Magnetite, hematite, goethite – BIF, Hamersley Range, Australia



Euhedral crystals of magnetite (violet-grey »kenomagnetite«) which show advanced transformation into hematite (martitization); some goethite (grey) between the magnetite grains.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D214_14
Section: BIF5

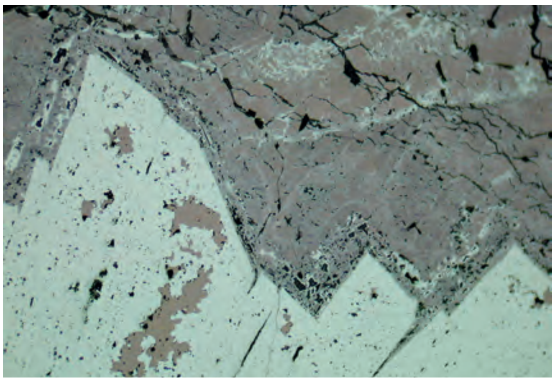
### 323 Magnetite, pyrite – San Leone, Sardinia, Italy



Patchy zoned magnetite (medium grey) with small veinlets of pyrite (light yellow) in pyrometasomatic ore.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D179_22
Section: AS204

### 324 Magnetite, hematite – Lakovica near Bucim, Macedonia



Pyrometasomatic ore with relicts of unzoned magnetite I (brown) in large hematite I laths (whitish grey) which are themselves overgrown by delicately zoned magnetite II (which is in part replaced by younger hematite II).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D105_14
Section: AS125

# Malachite

**Mineral name:** Malachite (mal)
**Formula:** $Cu_2[(OH)_2 | CO_3]$

**VHN:** ~ 160
**Crystal System:** mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 7.7 | $R_2$ = 9.8 | calculated from n |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 0.2 | $R_2$ = 1.3 | calculated from n |
| **Colour impression** | **(in oil)** | grey (with green IR) | grey (with green IR) | |
| **BR > Rpl** | **(in oil)** | extremely strong | | $A_{oil}$ = 147 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong | strong |
| **Colour:** | **in 45° position** | masked by IR | masked by IR |
| | **... in other positions** | | |
| **Extinction position** | | -- | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | various shades of green | |
| **(IR)** | **frequency** | predominant | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

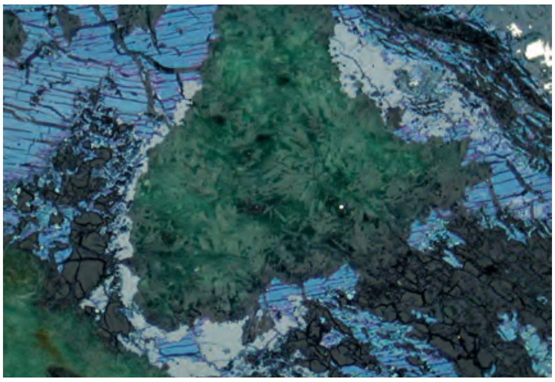
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | tabular, spherical to radial fibrous aggregates |
| **Paragenesis** | other Cu minerals, barite, quartz, and azurite |
| **Diagnostic features** | green IR, BR |

## Notes, drafts

Similar to many Cu-sulfates (with usually weak BR).

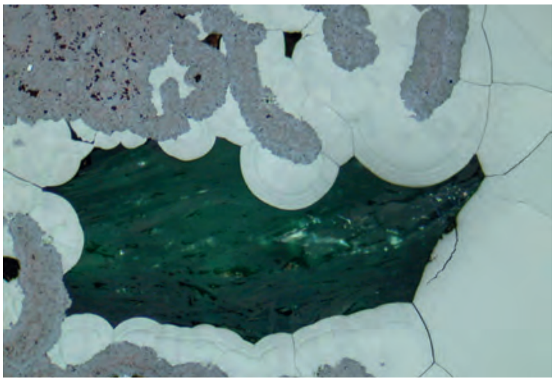
## 325 **Malachite, yarrowite, cv, fh –** Frankenberg, Hesse, Germany



Tiny needles of malachite (green IR) replacing fahlore (grey), yarrowite (blue) and covellite (violet).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D95_22
Section: AS3554

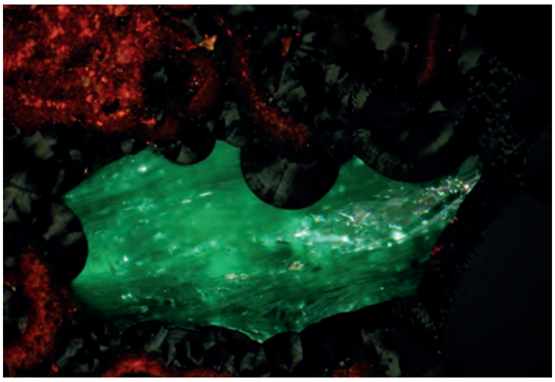
## 326 **Malachite, hm, goe –** Yudnamutana Gorge, N. Flinders Range, S-Australia



Green internal reflections of radial fibrous malachite in cavity with colloform hematite (light grey) and goethite (medium grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D198_01
Section: YT-287

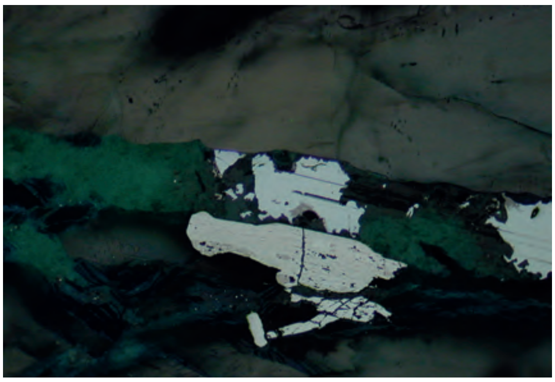
## 327 **Malachite, hm, goe –** Yudnamutana Gorge, N. Flinders Range, S-Australia



As above, with crossed polars.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D198_02
Section: YT-287

## 328 **Malachite, hm, ilm, cuprite –** British Empire Mine, Mt. Painter, S-Australia



Tabular crystal of hematite (greyish brown; with ilmenite exsolution bodies) beside cuprite (centre of photo, grey), and malachite (greenish).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D87_19
Section: BEM375neu

# Manganite

**Mineral name:** Manganite
**Formula:** γ-MnOOH

**VHN:** 630-740
**Crystal System:** mcl., ps. o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_a \sim 17$ | $R_b = 14.1$ | $R_c = 20.5$ |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_a \sim 5$ | $R_b = 3.5$ | $R_c = 7.5$ |
| **Colour impression** | **(in oil)** | grey tint brown | grey tint olive | grey |
| **BR > Rpl** | **(in oil)** | strong | | $A_{oil} = 73$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong with colour tint | strong with colour tint |
| **Colour:** | **in 45° position** | greyish yellow | greyish yellow – grey tint blue |
| | **... in other positions** | | brownish grey |
| **Extinction position** | | black | |
| **Mode of extinction** | | straight, perfect, also undulatory | |
| **Internal reflections** | **colour** | red – reddish brown | |
| **(IR)** | **frequency** | rare – common | |
| **Twinning** | **mode** | simple \|\| {011} | |
| | **frequency** | occasional | |

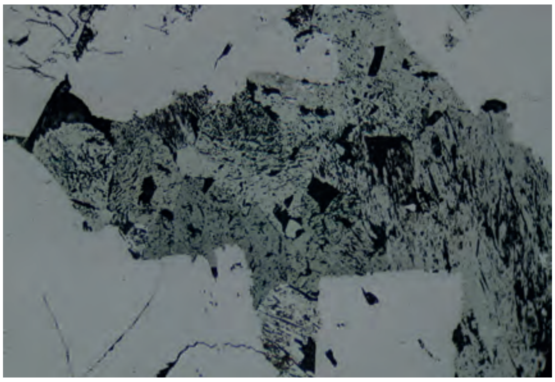
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | usually large elongated XX, often broken; replacement by pyrolusite; perfect # \|\| {010} |
| **Paragenesis** | pyrolusite, braunite, bixbyite, hollandite, hausmannite, manganomelane |
| **Diagnostic features** | replacement by pyrolusite, perfect #, similar to hausmannite |

## Notes, drafts

$R_c$ || elongation. $R_a$ ~ isotropic section

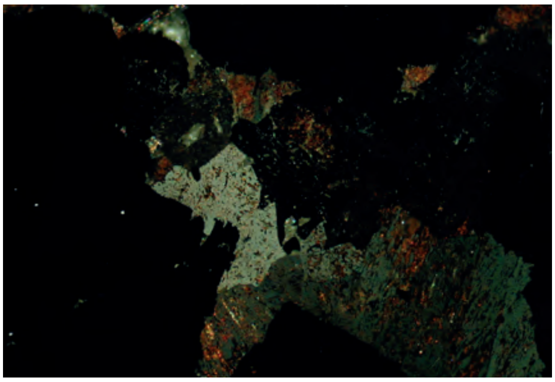
## 329 Manganite, braunite – Sailauf quarry, Spessart, Germany



Porous grains of manganite (centre, distinct bireflection!) within braunite aggregate.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D60_02
Section: S61

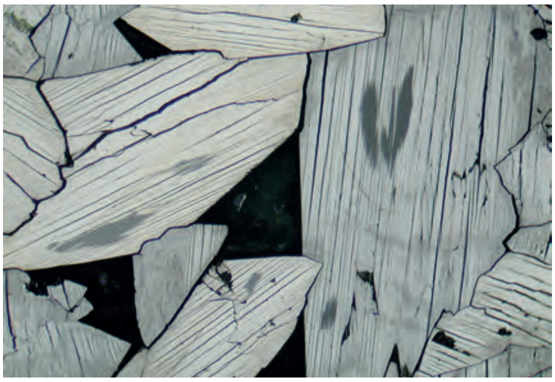
## 330 Manganite, braunite – Sailauf quarry, Spessart, Germany



As above, with crossed polars. Manganite exhibits reddish brown internal reflections.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D60_04
Section: S61

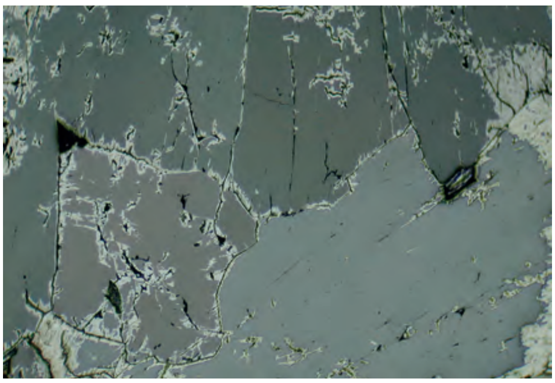
## 331 Manganite, pyrolusite – Broken Hill, NSW, Australia



Manganite (medium to dark grey) is replaced by oriented pyrolusite (medium to light yellowish grey). This pseudomorph of pyrolusite after manganite is characterized by typical cracks ||(010)).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D33_04
Section: AS217

## 332 Manganite – Haut-Poirot, Vosges, France



Manganite crystals with distinct Rpl and BR. Replacement by pyrolusite (whitish yellow) starts at grain boundaries.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D138_21
Section: JD06

# Manganomelane (cryptomelane – romanèchite)

**Mineral name:** Manganomelane (C.-R.)*
**Formula:** $(K,Ba)_{<2}Mn_8O_{16} * xH_2O$

**VHN:** 600-900 (500-700)
**Crystal System:** mcl. or o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ ~ 39 (31) | $R_2$ ~ 28 (23) | R estimated |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ ~ 22 to 24 (16) | $R_2$ ~ 13 to 15 (10) | R estimated |
| **Colour impression** | **(in oil)** | white (greyish white) | greyish white (grey tint brown) | |
| **BR > Rpl** | **(in oil)** | strong (strong) | | $A_{oil}$ = ~50 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | distinct (strong) without colour | distinct (strong) without colour |
| **Colour:** | **in 45° position** | greyish white | greyish white – grey |
| | **... in other positions** | R.: near ext.pos. olive brown | |
| **Extinction position** | | black | |
| **Mode of extinction** | | perfect | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

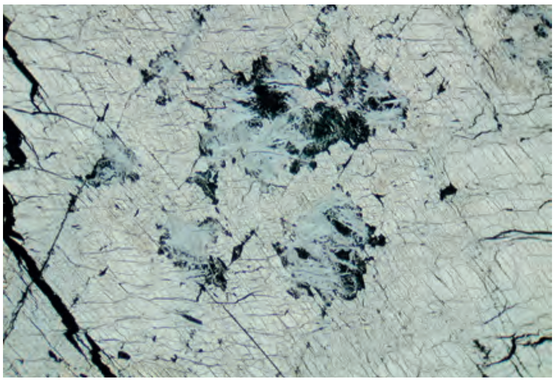
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | fibrous, needle-like XX, botryoidal masses of acicular XX; often fine-grained and intergrown with other Mn-minerals |
| **Paragenesis** | pyrolusite, lithiophorite, goethite, nsutite, and primary Mn-minerals |
| **Diagnostic features** | morphology, paragenesis, alteration product of $Mn^{2+}$-minerals |

## Notes, drafts

$R_{Rom} < R_{Cry}$
(C.-R.)*: Cryptomelane – (Romanèchite values in parentheses). Romanèchite is often named hollandite.
Optical properties are varying with composition and grain size!

## 333 Manganomelane, ramsdellite, pyrolusite – Mistake mine, Arizona, USA



Secondary formation of manganomelane needles (light grey to medium grey BR!) in pyrolusite (yellowish white).

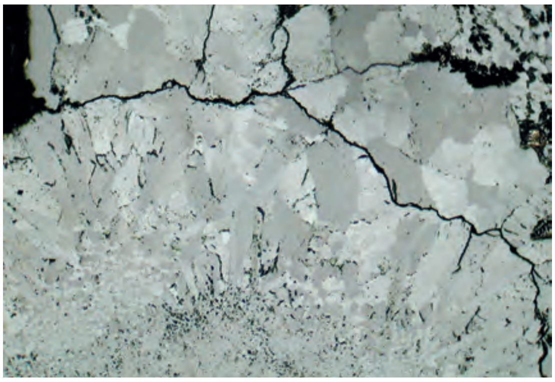
Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D13_15
Section: AS132

## 334 Manganomelane, goe – Otto mine, Schottenhöfe, Schwarzwald, Germany

Plates and needles of Ba-rich manganomelane (whitish grey) within goethite (grey, partly with brown IR) from an altered hydrothermal barite vein.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: AS3248
Section: D69_29

## 337 Romanèchite (hollandite) – Clara mine, Schwarzwald, Germany



Large crystals of Ba-rich manganomelane with distinct BR (note the brownish tint for $R_{min}$).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D103_13
Section: AS2177

## 336 Romanèchite (hollandite) – Clara mine, Schwarzwald, Germany

As above, with crossed polars. Strong anisotropism effects of manganomelane are typical.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D103_14
Section: AS2177

# Marcasite (in German: Markasit)

**Mineral name:** Marcasite (mrc)
**Formula:** $FeS_2$
**VHN:** 760-1560
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1 = 49.1$ | $R_2 = 56.2$ | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1 = 34.3$ | $R_2 = 42.3$ | |
| **Colour impression** | **(in oil)** | white cream tint brown | white tint turquoise | |
| **BR ~ Rpl** | **(in oil)** | distinct | | $A_{oil} = 20$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | distinct with colour | distinct with colour |
| **Colour:** | **in 45° position** | yellow green | light grey yellow – turquoise |
| | **... in other positions** | different shades of green | brownish, green |
| **Extinction position** | | black | |
| **Mode of extinction** | | perfect, undulatory (if deformed) | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | polysynthetic after one direction; and coarse after (110) | |
| | **frequency** | common | |

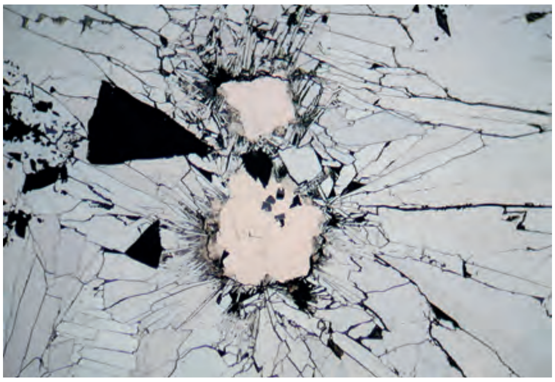
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | partly very fine-grained, colloidal, tabular crystals; not stable above 240° C → pyrite; replaces pyrrhotite (bird eyes-formation); # \|\| {101} distinct |
| **Paragenesis** | pyrite, pyrrhotite, galena, sphalerite |
| **Diagnostic features** | green AExPol, CI, paragenesis |

## Notes, drafts

Similar to ARSENOPYRITE, LOELLINGITE, and SAFFLORITE.

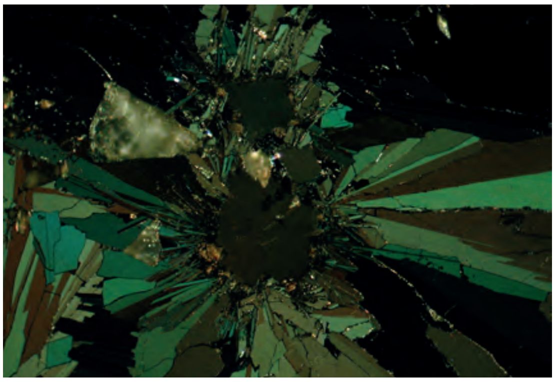
## 337 **Marcasite, py –** Tepla, Slovenia



MVT ore with pyrite (yellowish white) overgrown by tabular marcasite crystals.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D57_27
Section: AS3501

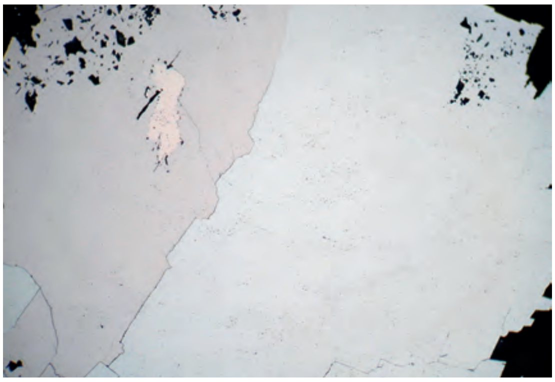
## 338 **Marcasite, py –** Tepla, Slovenia



Same as above, with crossed polars.
Note the typical green (and brownish) colours of marcasite with crossed polars.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D57_28
Section: AS3501

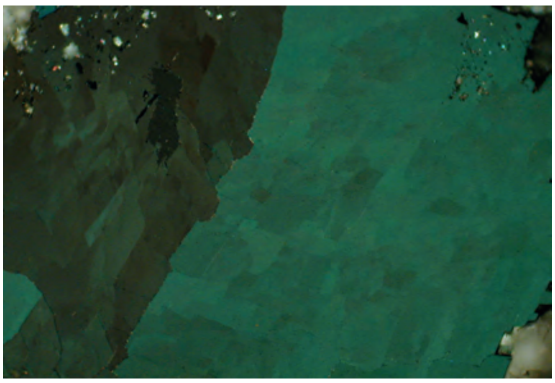
## 339 **Marcasite, py –** Tepla, Slovenia



Two grains of marcasite (Rpl and BR visible) with small inclusion of pyrite (yellowish white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D57_31
Section: AS3501

## 340 **Marcasite, py –** Tepla, Slovenia



Same as above, with crossed polars.
Note the undulatory extinction of marcasite.

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D57_33
Section: AS3501

# Marokite

**Mineral name:** Marokite
**Formula:** $CaMn_2O_4$
**VHN:** ~ 800
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 16.0 | $R_2$ = 18.6 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 4.5 | $R_2$ = 6.4 | |
| **Colour impression** | **(in oil)** | grey tint rose | grey tint olive – yellow | |
| **BR < Rpl** | **(in oil)** | strong | | $A_{oil}$ = 36 |

## Observations with crossed polars (AExPol in oil)

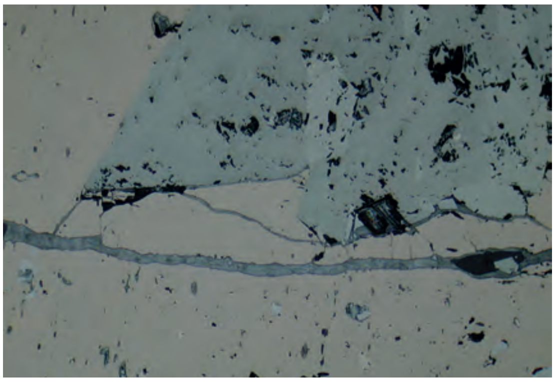
| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong with colour | strong with colour |
| **Colour:** | **in 45° position** | yellowish green | olive green – greenish grey |
| | **… in other positions** | violet grey | |
| **Extinction position** | | black | |
| **Mode of extinction** | | not straight (after Ramdohr) | |
| **Internal reflections** | **colour** | red | |
| **(IR)** | **frequency** | frequent | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | coarse-grained or prismatic XX;<br># perfect \|\| {100}, good \|\| {001} |
| **Paragenesis** | hausmannite, lithiophorite, braunite, pyrolusite, manganomelane |
| **Diagnostic features** | Rpl, AExPol |

## Notes, drafts

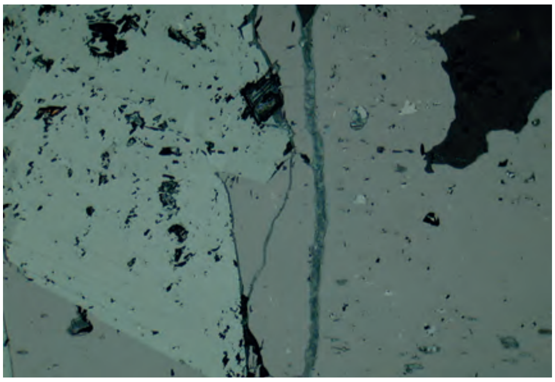
## 341 Marokite, hausmannite, lithiophorite – Tachgagalt, Morocco



Grey porous hausmannite (upper part) with marokite ($R_{max}$ = lighter than R of hausmannite). Small veinlet of lithiophorite (E-W, medium grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D133_14
Section: AS232

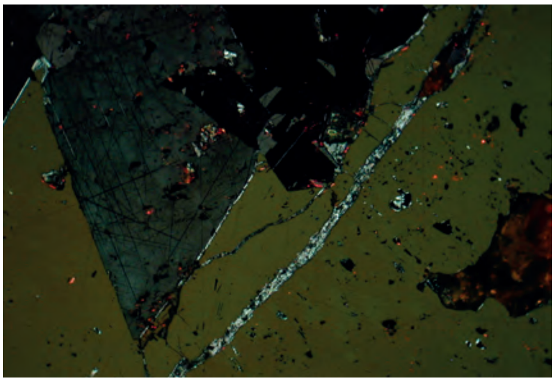
## 342 Marokite, hausmannite, lithiophorite – Tachgagalt, Morocco



As above, but 90° rotated. $R_{min}$ of marokite now darker than R of hausmannite (grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D133_15
Section: AS232

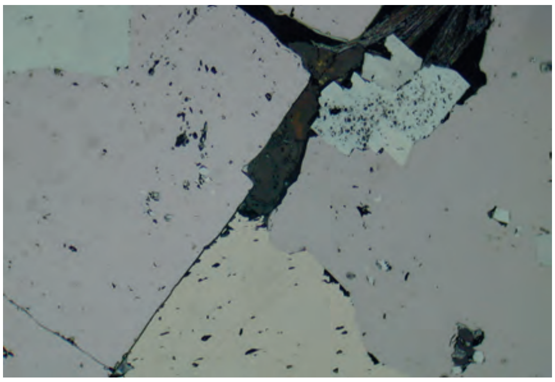
## 343 Marokite, hausmannite, lithiophorite – Tachgagalt, Morocco



As above, with crossed polars. Note the yellowish green AExPol of marokite with some red IR. Hausmannite (with twinning and red IR), and veinlet of lithiophorite (very strong AExPol).

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D133_17
Section: AS232

## 344 Marokite, hausmannite – Tachgagalt, Morocco



Small greyish hausmannite cubes (upper right part) beside large marokite crystals, which show strong reflection pleochroism (grey tint rose – grey tint olive yellow – grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D133_20
Section: AS232

# Maucherite

**Mineral name:** Maucherite
**Formula:** $Ni_{11}As_8$

**VHN:** 620-720
**Crystal System:** tetr.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1 = 48.4$ | $R_2 = 49.6$ | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1 = 35.0$ | $R_2 = 36.0$ | |
| **Colour impression** | **(in oil)** | white tint ochre | white (impure) | |
| **BR ~ Rpl** | **(in oil)** | extremely weak | | $A_{oil} = 2$ |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | very weak with colour | very weak with colour |
| **Colour:** | **in 45° position** | brownish black | brown – light brown |
| | **... in other positions** | | |
| **Extinction position** | | greyish black | |
| **Mode of extinction** | | not perfect | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | polysynthetic | |
| | **frequency** | occasional | |

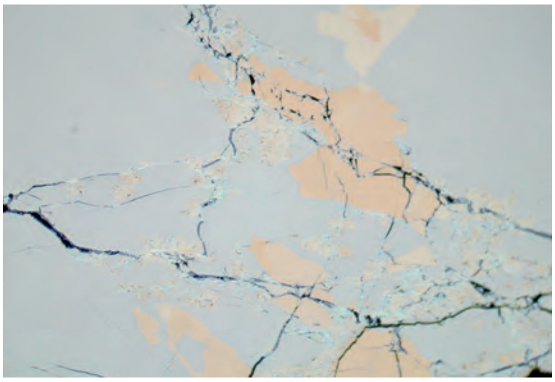
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | massive or anhedral elongated XX, replaces nickeline and vice versa |
| **Paragenesis** | Co-Ni-arsenides, esp. nickeline |
| **Diagnostic features** | very weak BR and AExPol, paragenesis |

## Notes, drafts

CI against nickeline more greyish.

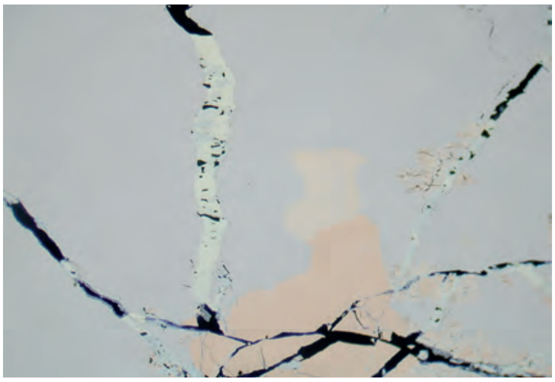
## 345 Maucherite, nickeline – Sangershausen, Hesse, Germany



Maucherite (greyish) with relicts of nickeline (shades of orange).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D12_12
Section: AS1000

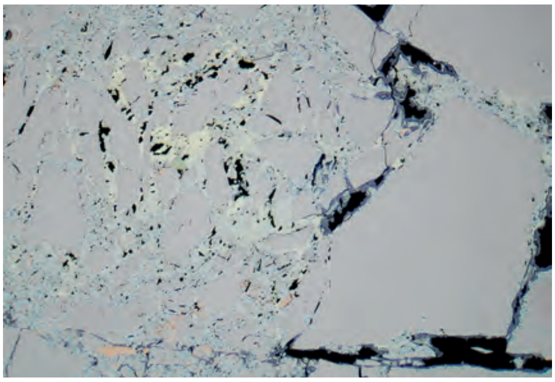
## 346 Maucherite, nickeline – Sangershausen, Hesse, Germany



Maucherite (groundmass) with small veinlet of millerite (light yellow), and nickeline (orange).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D12_13
Section: AS1000

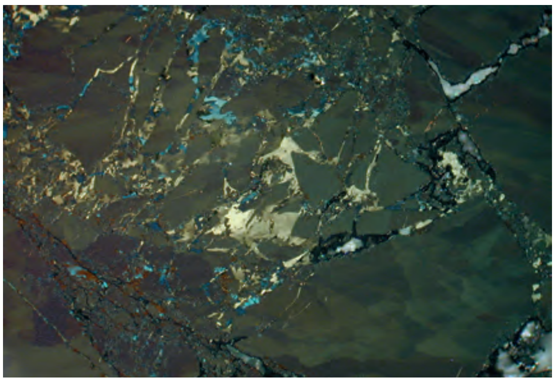
## 347 Maucherite, nickeline – Sangershausen, Hesse, Germany



Maucherite with tiny relicts of nickeline, and small veinlets filled with younger millerite (light yellow).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D98_22
Section: AS1000

## 348 Maucherite, nickeline – Sangershausen, Hesse, Germany



As above, with crossed polars. Weak, partly undulatory anisotropism of maucherite. Note strong anisotropism of millerite.

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D98_23
Section: AS1000

# Metacinnabar (in German: Metacinnabarit)

**Mineral name:** Metacinnabar
**Formula:** α-HgS
**VHN:** ~ 100
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 25.2 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 11.2 | |
| **Colour impression** | **(in oil)** | brownish grey | |
| **BR Rpl** | **(in oil)** | -- | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | very weak without colour | very weak without colour |
| **Colour:** | **in 45° position** | greyish black | greyish black |
| | **... in other positions** | | |
| **Extinction position** | | greyish black | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | polysynthetic after more than one direction (\|\| {111}+{211}) often bended | |
| | **frequency** | frequent | |

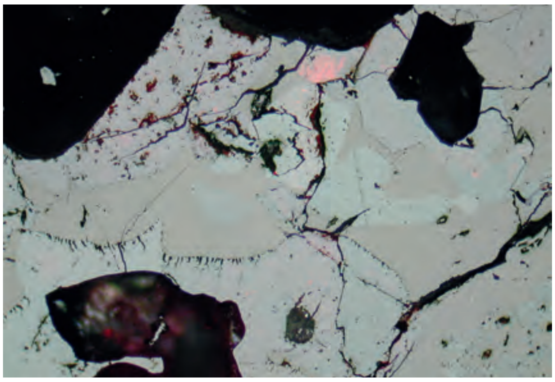
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | granular, anhedral aggregates;<br>replacement by cinnabar (along twin lamellae, if present) |
| **Paragenesis** | cinnabar |
| **Diagnostic features** | CI, paragenesis |

## Notes, drafts

Similar to Hg-FAHLORE (schwazite), which is really isotropic, and has no twins.

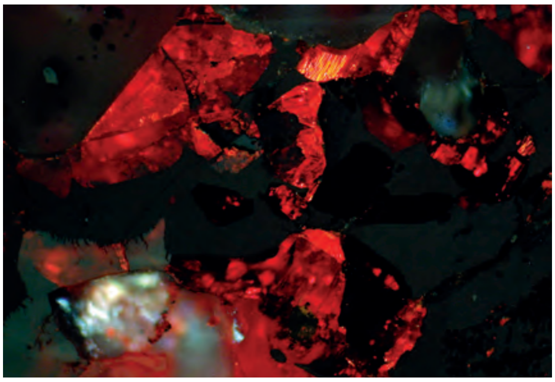
## 349 Metacinnabar, cinnabar – Çirakman tepe, Ladik, Turkey



Relicts of metacinnabar (brownish grey) in cinnabar (grey with red IR).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D32_03
Section: AS154

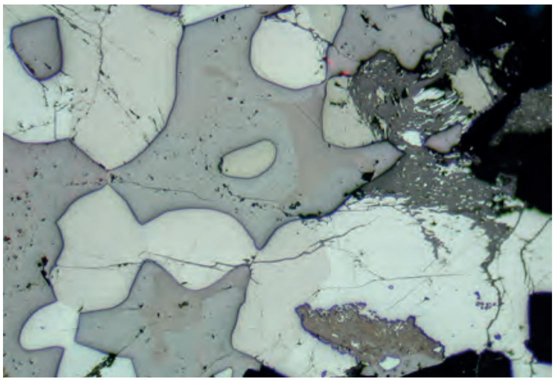
## 350 Metacinnabar, cinnabar – Çirakman tepe, Ladik, Turkey



As above, with crossed polars. Metacinnabar is not completely black.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D32_04
Section: AS154

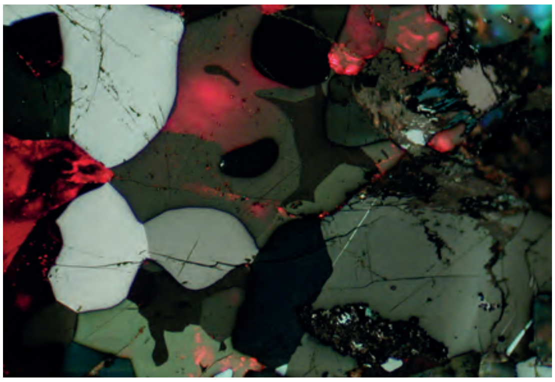
## 351 Metacinnabar, cinnabar, stibnite – Çirakman tepe, Ladik, Turkey



Relicts of metacinnabar (brownish grey) in cinnabar (grey, some red IR); anhedral stibnite (partly altered).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D32_05
Section: AS154

## 352 Metacinnabar, cinnabar, stibnite – Çirakman tepe, Ladik, Turkey



As above, with crossed polars.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D32_06
Section: AS154

# Miargyrite

**Mineral name:** Miargyrite
**Formula:** $AgSbS_2$

**VHN:** 100-130
**Crystal System:** mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1 = 31.4$ | $R_2 = 34.2$ | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1 = 16.1$ | $R_2 = 18.2$ | |
| **Colour impression** | **(in oil)** | grey tint blue | grey tint rose cream | also grey moiré |
| **BR < Rpl** | **(in oil)** | strong | | $A_{oil} = 12$ |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong without colour | strong with colour tint |
| **Colour:** | **in 45° position** | light grey | yellowish grey |
| | **... in other positions** | | often masked by IR |
| **Extinction position** | | often masked by IR | dark bluish violet |
| **Mode of extinction** | | often undulatory | |
| **Internal reflections** | **colour** | raspberry red (similar to pyrargyrite, proustite) | |
| **(IR)** | **frequency** | common (but less intensive and less common than in pyrargyrite) | |
| **Twinning** | **mode** | polysynthetic | |
| | **frequency** | very rare | |

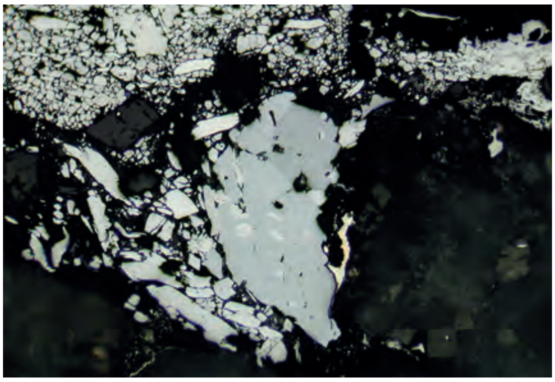
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | granular or thick tabular XX |
| **Paragenesis** | pyrostilpnite, sph, tetrahedrite, asp, gn, other Ag-minerals |
| **Diagnostic features** | strong Rpl, AExPol, IR |

## Notes, drafts

In comparison to PYRARGYRITE more white; against GALENA: lower R and more greenish brown.

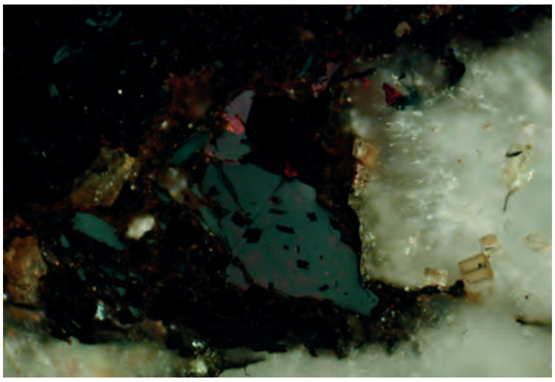
## 353 Miargyrite, jamesonite, cassiterite – Oruro, Bolivia



Aggregate of miargyrite (centre, light grey, BR) with inclusions of euhedral jamesonite (white). Main mass is jamesonite; some isolated small cassiterite crystals (dark grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D109_17
Section: AS1018

## 354 Miargyrite, jamesonite, cassiterite – Oruro, Bolivia



As above, with crossed polars. Red internal reflections of miargyrite are visible.

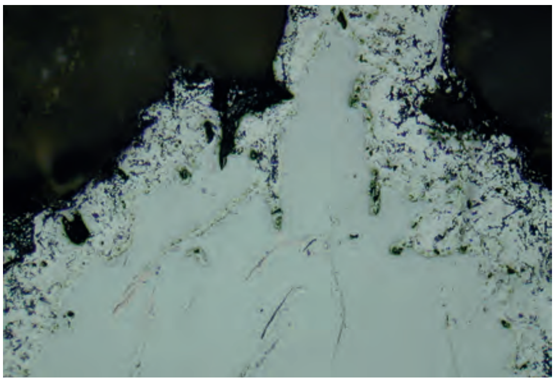
Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D109_19
Section: AS1018

## 355 Miargyrite, argentite – Flammeck, Glottertal, Schwarzwald, Germany

Replacement of miargyrite (light grey, $R_{max}$) by argentite (slightly darker, porous).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D196_18
Section: AS274

## 356 Miargyrite, argentite – Flammeck, Glottertal, Schwarzwald, Germany



As above, but 90° rotated. Miargyrite (medium grey, with $R_{min}$) is now slightly darker than argentite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D196_17
Section: AS274

# Millerite

**Mineral name:** Millerite (mir)
**Formula:** NiS

**VHN:** 190-380
**Crystal System:** trig.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 50.0 | $R_{e'}$ = 54.2 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 37.9 | $R_{e'}$ = 43.8 | |
| **Colour impression** | **(in oil)** | yellow tint green | whitish yellow | |
| **BR ~ Rpl** | **(in oil)** | distinct | | $A_{oil}$ = 14 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong with colour tint | strong with colour |
| **Colour:** | **in 45° position** | light yellow white | light ochre – light greyish blue |
| | **... in other positions** | light olive | ochre – blue |
| **Extinction position** | | brownish black | |
| **Mode of extinction** | | perfect, partly undulatory | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | polysynthetic after more than one direction | |
| | **frequency** | occasional | |

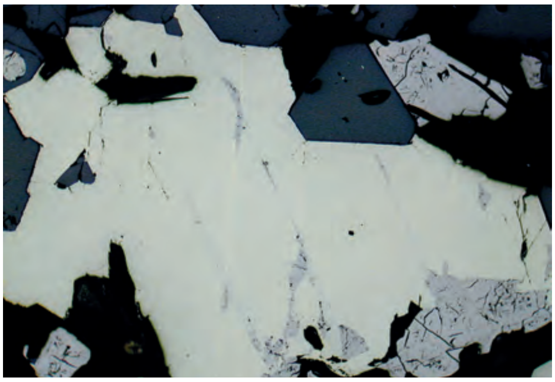
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | radiated to bundle-like aggr. of needle-shaped XX, rarely granular; # commonly visible |
| **Paragenesis** | pentlandite, py, gersdorffite, linneite, nickeline, maucherite |
| **Diagnostic features** | yellow CI and strong AExPol |

## Notes, drafts

Hydrothermal alteration of PENTLANDITE gives millerite + pyrite.

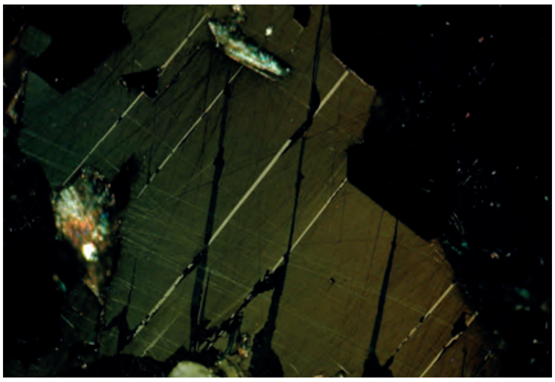
## 357 Millerite, violarite, spinel – Long Victor mine, Kambalda, Australia



Millerite with fine twinning; violarite (light grey, bottom right), and euhedral spinel (dark grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D90_27
Section: AS3617

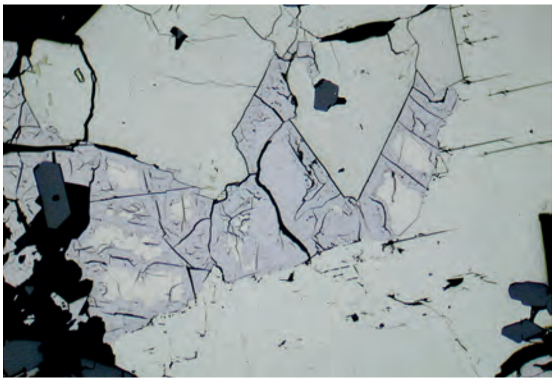
## 358 Millerite, violarite, spinel – Long Victor mine, Kambalda, Australia



As above, with crossed polars. Strong AExPol und twinning of millerite.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D90_28
Section: AS3617

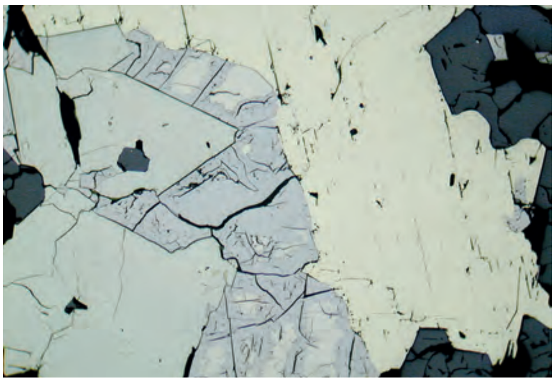
## 359 Millerite, py, pn, violarite – Long Victor mine, Kambalda, Australia



Millerite (lower right part of photo, $R_{min}$, #) with euhedral pyrite crystals (upper part of photo). Relicts of pentlandite (cream, mainly replaced by light grey violarite) between pyrite and millerite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D90_30
Section: AS3617

## 360 Millerite, py, pn, violarite – Long Victor mine, Kambalda, Australia



As above, but 90° rotated. Millerite (right part of photo, $R_{max}$, #) with pyrite and pentlandite (replaced by violarite).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D90_29
Section: AS3617

# Molybdenite (in German: Molybdänit, Molybdänglanz)

**Mineral name:** Molybdenite (mol)
**Formula:** $MoS_2$
**VHN:** 20-30 (on (001))
**Crystal System:** trig.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in % (for 546 nm)** | $R_o = 38.6$ | $R_{e'} = 19.5$ | $R_o$ \|\| elongation |
| **$R_{(oil)}$ in % (for 546 nm)** | $R_o = 24.1$ | $R_{e'} = 7.8$ | |
| **Colour impression (in oil)** | greyish white | grey (tint olive) | |
| **BR > Rpl (in oil)** | extremely strong | | $A_{oil} = 102$ |

## Observations with crossed polars (AExPol in oil)

| | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|
| **Anisotropism intensity/colour** | very strong with colour tint | very strong with colour tint |
| **Colour: in 45° position** | white (tint yellow) | white (tint yellow) - white |
| **... in other positions** | violet tints | violet tints |
| **Extinction position** | greyish black | |
| **Mode of extinction** | not perfect, undulatory | |
| **Internal reflections (IR) colour** | -- | |
| **frequency** | -- | |
| **Twinning mode** | twisted and bended »twins«, crumpled lamellae | |
| **frequency** | often | |

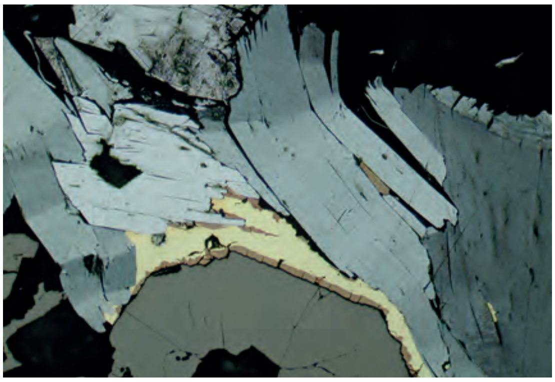
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | tabular, flaky, often bended and twisted;<br># \|\| {0001} always visible |
| **Paragenesis** | cp, cas, asp, graphite |
| **Diagnostic features** | BR (!), AExPol, low hardness |

## Notes, drafts

Similar to MACKINAWITE (which has in general smaller grain size!).

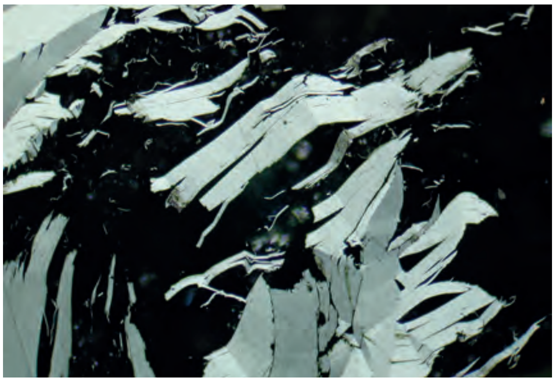
## 361 Molybdenite, cp, bn, mt – Oravicza, Romania



Chalcopyrite (yellow) as youngest mineral beside older molybdenite (white – grey) and magnetite (dark grey); note the reaction rim of bornite (brown) between magnetite and chalcopyrite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D06_24
Section: AS1009

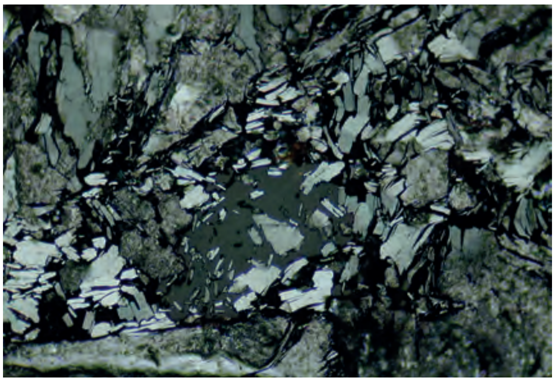
## 362 Molybdenite – Oravicza, Romania



Flakes of molybdenite, partly bended.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D06_25
Section: AS1009

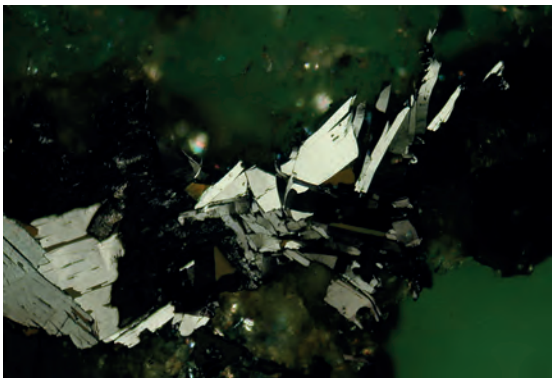
## 363 Molybdenite, cassiterite – Locality unknown



Flakes of molybdenite (white to grey) around cassiterite (dark grey, in centre).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D161_12
Section: TÜ11

## 364 Molybdenite – Ocna de Fier, Caraș-Severin, Banat, Romania



Undeformed flakes of molybdenite under crossed polars showing the very strong anisotropism.

Obj.: 10 ×
Polars: × Pol
Photo width: 1.4 mm
Photo No.: D93_13
Section: AS1009

# Mückeite

**Mineral name:** Mückeite
**Formula:** $CuNi(Bi,Sb)S_3$

**VHN:** 140-170
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 39 | $R_2$ = 34 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ ~ 24 | $R_2$ ~ 24 | estimated |
| **Colour impression** | **(in oil)** | yellow-brown | grey tint olive | |
| **BR << Rpl** | **(in oil)** | strong | | $A_{oil}$ ~ 0 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | distinct strong with colours | distinct with vivid colours |
| **Colour:** | **in 45° position** | greyish yellow | blue – olive yellow |
| | **... in other positions** | light grey blue, orange brown | greyish green, orange |
| **Extinction position** | | black | |
| **Mode of extinction** | | straight | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

## Further observations

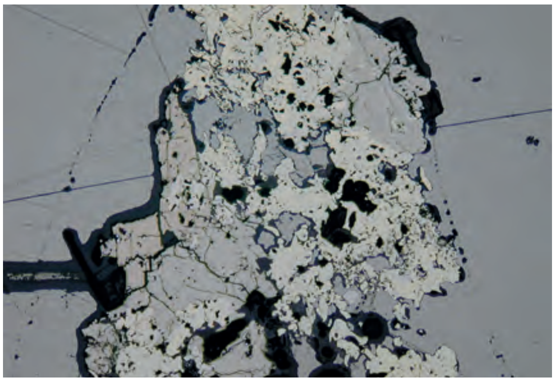
| | |
|---|---|
| **Form, habit, textures, cleavage ...** | euhedral to subhedral crystals, tabular to {010}, elongated along [001]; # || (010) perfect, || (001) good; replaces lapieite. |
| **Paragenesis** | millerite, polydymite, bismuthinite, aikinite, lapieite |
| **Diagnostic features** | Rpl, AExPol, paragenesis |

## Notes, drafts

$R_2$ || elongation and #.
$R_1$ in oil is visually not very different from $R_2$! (~ slightly lighter than $R_{min}$ of bismuthinite)

PS: Not a common ore mineral, but in honour of my teacher Arno Mücke!

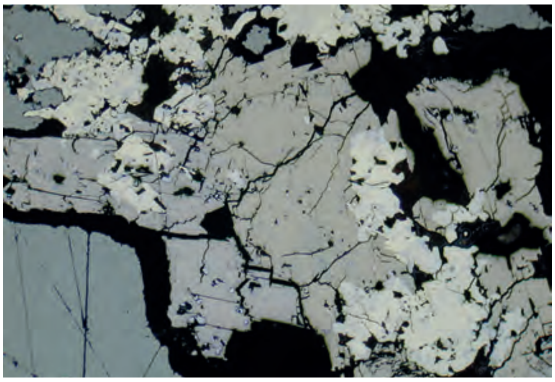
## 365 Mückeite, millerite, bismuthinite – Grüne Au, Siegerland, Germany



Complex intergrowth of elongated mückeite crystals (medium grey) with millerite (yellow). Background on left and right side is carbon coating from EMPA analysis.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D04_03
Section: AS126

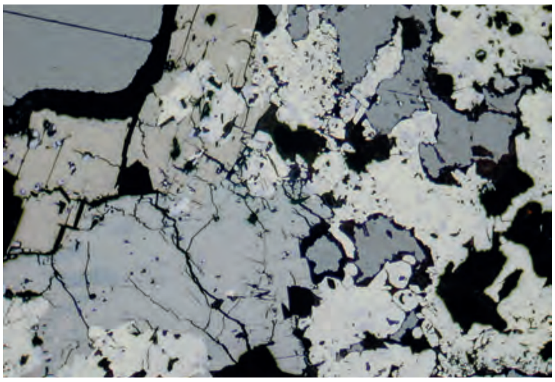
## 366 Mückeite, millerite, bismuthinite – Grüne Au, Siegerland, Germany



Distinct refection pleochroism of mückeite (yellow brown to grey tint green), intergrown with millerite (yellow), and some tiny bismuthinites.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D186_20
Section: AS126

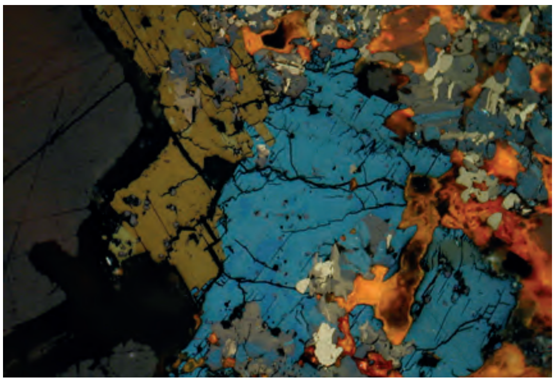
## 367 Mückeite, millerite, bismuthinite – Grüne Au, Siegerland, Germany



As above, but 90° rotated.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D04_04
Section: AS126

## 368 Mückeite, millerite, bismuthinite – Grüne Au, Siegerland, Germany



As above, but with (not exactly) crossed polars showing vivid anisotropism colours of mückeite.

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D186_21
Section: AS126

# Nickeline, Niccolite (in German: Nickelin, Rotnickelkies)

**Mineral name:** Nickeline (Niccolite, nk)
**Formula:** NiAs
**VHN:** 310-530
**Crystal System:** hex.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 51.4 | $R_{e'}$ = 46.1 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 38.4 | $R_{e'}$ = 33.2 | |
| **Colour impression** | **(in oil)** | whitish orange | white orange brown | |
| **BR ~ Rpl** | **(in oil)** | distinct | | $A_{oil}$ = 14 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | distinct with colour | strong with colour |
| **Colour:** | **in 45° position** | turquoise blue | greyish orange – turquoise blue |
| | **… in other positions** | bluish grey | light blue, orange brown |
| **Extinction position** | | nearly black | |
| **Mode of extinction** | | straight, undulatory | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | polysynthetic after more than one direction; also simple growth twins | |
| | **frequency** | occasional; rare | |

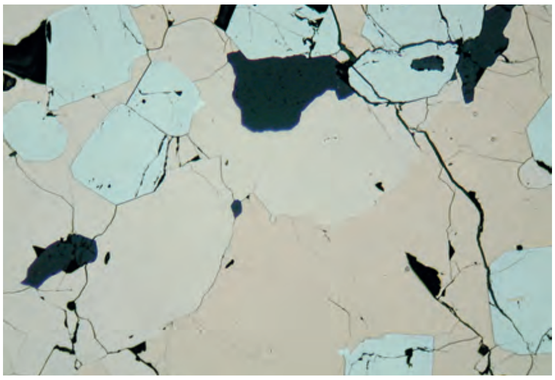
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | common anhedral, granular, radial aggr., dendritic, cataclasis, often lamellar, black alteration products (parallel to #) |
| **Paragenesis** | Co-Ni-arsenides, bismuth, Ag-minerals |
| **Diagnostic features** | CI (maucherite has no BR and is less orange coloured), AExPol |

## Notes, drafts

CI of BREITHAUPTITE is much more violet.

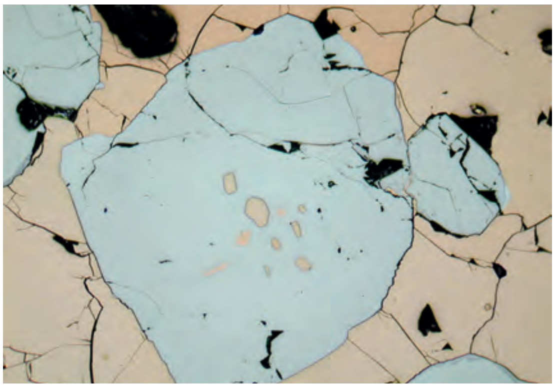
## 369 Nickeline, gersdorffite – Zinkwand-Schöttern, Lungau, Carinthia, Austria



Nickeline (orange brown, BR) with gersdorffite crystals (greyish white).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D98_01
Section: AS1759

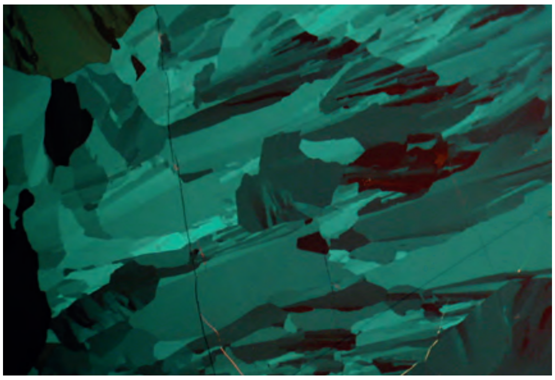
## 370 Nickeline, gersdorffite – Zinkwand-Schöttern, Lungau, Carinthia, Austria



Large gersdorffite crystal (greyish white) with numerous inclusions of nickeline. Note the thickness variation of the relief boundaries of nickeline grains against the gersdorffite matrix. The different orientation of the nickeline inclusions exhibit hardness anisotropism from 310-530. Gersdorffite grain has VHN ~ 530.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D98_11
Section: AS1759

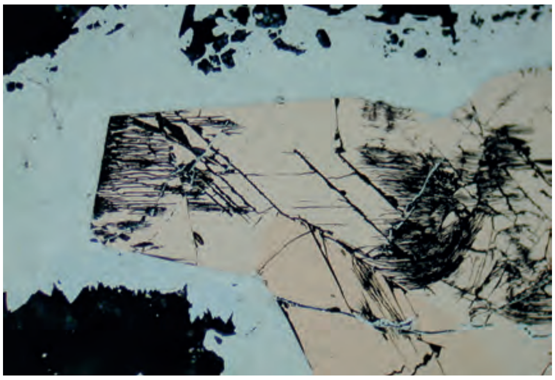
## 371 Nickeline – Sangershausen, Hesse, Germany



Turquoise colours of nickeline under crossed polars; with deformation twins.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D12_16
Section: AS1000

## 372 Nickeline, safflorite – Nentershausen, Hesse, Germany



Euhedral crystal of nickeline (orange brown) with lamellar alteration features parallel cleavage, encrusted by safflorite (whitish).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D142_11
Section: AS163

# Nsutite

**Mineral name:** Nsutite
**Formula:** γ-($Mn^{4+}$,$Mn^{3+}$)(O,OH)$_2$

**VHN:** ~ 1100
**Crystal System:** hex.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ ~ 38 | $R_{e'}$ ~ 32 | estimated |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ ~ 22 | $R_{e'}$ ~ 16 | estimated |
| **Colour impression** | **(in oil)** | greyish white | grey | |
| **BR > Rpl** | **(in oil)** | strong | | $A_{oil}$ ~ 32 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | distinct with colour tint | distinct with colour tint |
| **Colour:** | **in 45° position** | greyish white tint rose yellow | greyish white tint yellow – white tint blue |
| | **… in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | perfect, undulatory | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

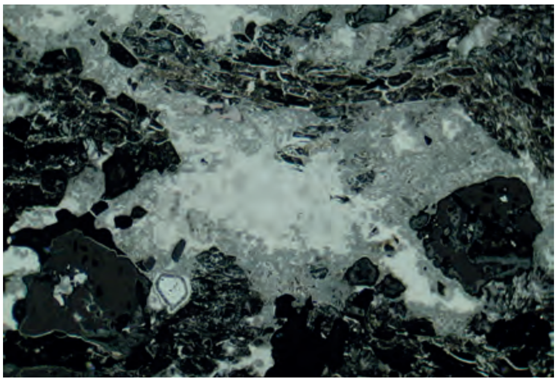
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | only spherical, very fine fibres, rhythmical crusts, rare coarse grains; often replacing manganomelane and vice versa. |
| **Paragenesis** | maganomelane, pyrolusite, rhodochrosite |
| **Diagnostic features** | form, CI against manganomelane more yellow |

## Notes, drafts

Common alteration product of Mn-rich carbonates. Similar to MANGANOMELANE (stronger BR).

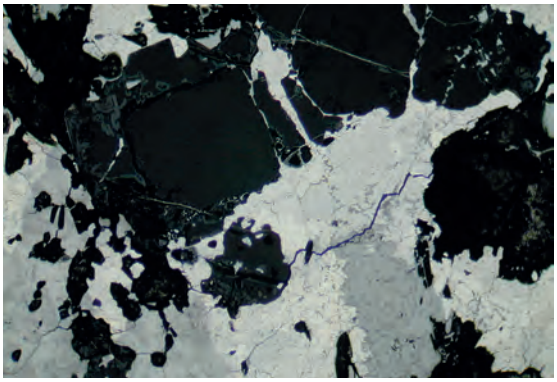
## 373 Nsutite, maganomelane, lm – Ungwan Mallam Ayuba, Kaduna, N-Nigeria



Nsutite (centre, colloform) enclosed by limonite (medium grey, lower left: vug with manganomelane plus limonite. Relicts of amphibole (upper part) and little altered garnet crystals (lower left and right).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D13_27
Section: AS238

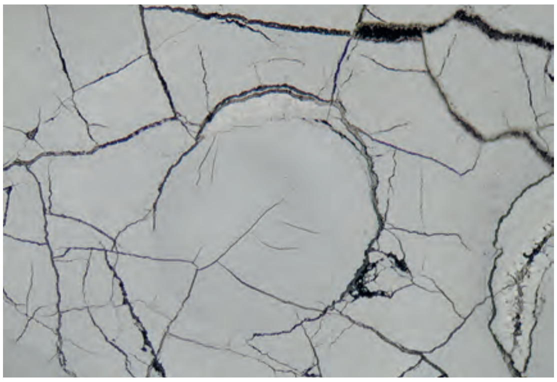
## 374 Nsutite, maganomelane, pyrolysite – Ungwan Mallam Ayuba, N-Nigeria



Nsutite (lower left part of photo) intergrown with pyrolusite (yellowish white, highest R), and manganomelane (light grey, lower right). All three phases replace amphiboles and garnets.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D13_29
Section: AS238

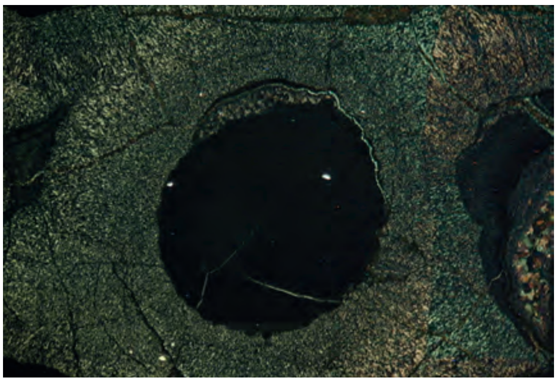
## 375 Nsutite – Nsuta, Ghana



Colloform aggregate of nsutite with numerous cracks.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D103_09
Section: AS213

## 376 Nsutite – Nsuta, Ghana



As above, with crossed polars. Note the nearly isotropic behaviour of the very fine-grained nsutite in the centre.

Obj.: 10 ×
Polars: × Pol
Photo width: 1.4 mm
Photo No.: D103_11
Section: AS213

# Olivine

**Mineral name:** Olivine (ol)
**Formula:** $(Mg,Fe)_2SiO_4$

**VHN:** ~ 1300
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_x$ = 5.9 | $R_z$ = 6.3 | calculated from $n_x$, $n_z$ |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_x$ = 0.2 | $R_z$ = 0.2 | calculated from $n_x$, $n_z$ |
| **Colour impression** | **(in oil)** | »black« (but light IR!) | »black« (but light IR!) | |
| **BR Rpl** | **(in oil)** | -- | | $A_{oil}$ = 0 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | not visible | not visible |
| **Colour:** | **in 45° position** | masked by IR | masked by IR |
| | **... in other positions** | | |
| **Extinction position** | | masked by IR | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | white – colourless | |
| **(IR)** | **frequency** | predominant | |
| **Twinning** | **mode** | none | |
| | **frequency** | -- | |

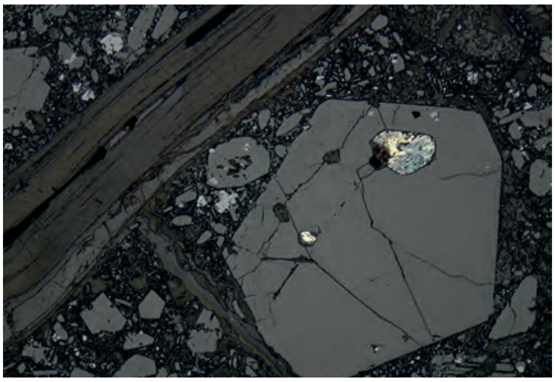
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | granular to euhedral, with melt or sulfide inclusions, alteration to serpentine; no #. |
| **Paragenesis** | pyroxene, plagioclase, chromite, spinel, po, cp |
| **Diagnostic features** | low R, no BR, no # |

## Notes, drafts

Magmatic olivine often with pyrrhotite and/or spinel inclusions.

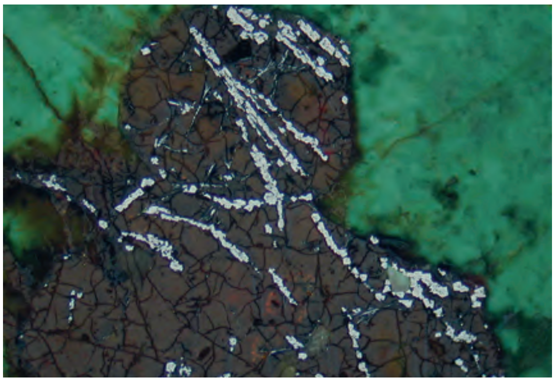
## 377 Olivine, phlogopite – Bürzlen, Urach volcanic field, SW-Germany



Mantle xenolith with olivine (note round sulfide inclusions, partly oxidized), and large tabular phlogopite

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D56_30
Section: Xeno5

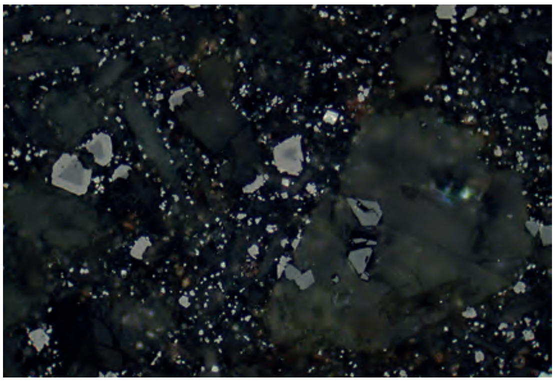
## 378 Olivine, magnetite – Ganawuri complex, Jos Plateau, Nigeria



Alteration and oxidation of fayalite-rich olivine (reddish grey) resulting in the formation of younger magnetite (light grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D25_19
Section: AS3245

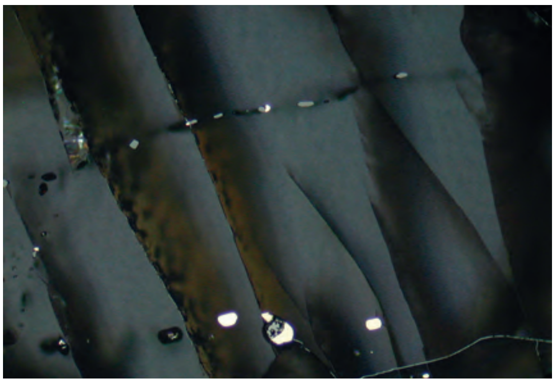
## 379 Olivine, spinel, mt – Gutenberger Steige, Urach, SW-Germany



Large anhedral crystal of olivine (right part of photo) with inclusions of euhedral, unzoned spinels (medium grey). Matrix with cpx, ol, melilite, perovskite, tiny magnetites and some larger zoned spinels with magnetite-rich rim.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D134_32
Section: AS3291

## 380 Olivine, spinel, troilite – Meteorite Brahin (pallasite)



Large, cracked olivine crystal from the Brahin pallasite with inclusions of spinel (medium grey, upper trail), and troilite (nearly white, lower trail).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D148_24
Section: 9031055

# Orpiment (in German: Auripigment)

**Mineral name:** Orpiment (orp)
**Formula:** $As_2S_3$
**VHN:** 20-50
**Crystal System:** mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_a$ = 17.0* | $R_b$ = 22.4* | $R_c$ = 25.2* |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_a$ = 5.1* | $R_b$ = 8.9* | $R_c$ = 11.0* |
| **Colour impression** | **(in oil)** | dark grey tint red | dark grey velvet | grey white |
| **BR > Rpl** | **(in oil)** | extremely strong | | $A_{oil}$ = 74 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong without colour | strong without colour |
| **Colour:** | **in 45° position** | but usually masked by IR | but usually masked by IR |
| | **... in other positions** | | |
| **Extinction position** | | masked by IR | |
| **Mode of extinction** | | masked by IR | |
| **Internal reflections** | **colour** | white to yellow (lemon yellow) | |
| **(IR)** | **frequency** | abundant | |
| **Twinning** | **mode** | translations twins, bended | |
| | **frequency** | frequent | |

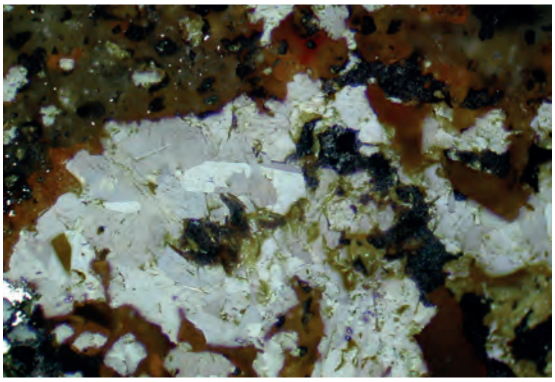
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | needle-like or tabular (010) XX, tufted, radial fibrous, crusts, replaces realgar; # \|\| (010) always visible |
| **Paragenesis** | realgar, arsenic, marcasite, gelpyrite |
| **Diagnostic features** | paragenesis, yellow IR, low hardness, # |

## Notes, drafts

* calculated from $n_a$, $n_b$, and $n_c$ (2.4, 2.8, and 3.02, resp.)

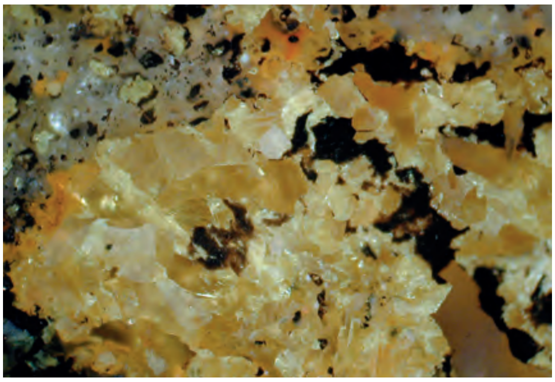
## 381 Orpiment – Allchar, Macedonia



Orpiment with distinct bireflection and yellow IR.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D10_16
Section: AS106

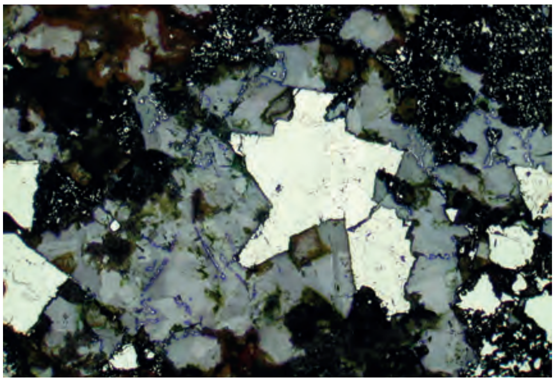
## 382 Orpiment – Allchar, Macedonia



As above, with crossed polars.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D10_ 17
Section: AS106

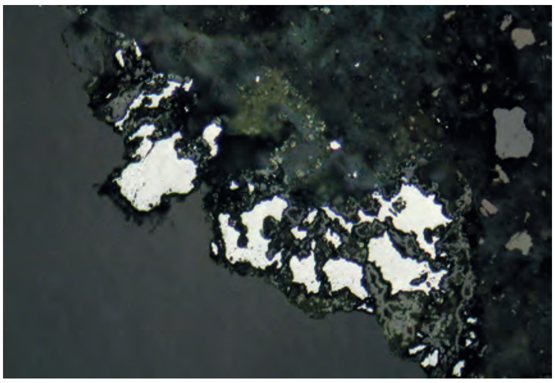
## 383 Orpiment, marcasite – Allchar, Macedonia



Marcasite (light yellow) enclosed by orpiment (greyish).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D10_18
Section: AS106

## 384 Orpiment, arsenic – Michael im Weiler, near Lahr, Schwarzwald, Germany



Alteration of arsenic (white) to orpiment (grey to yellow).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D112_18
Section: L-4

# Osmium (Iridosmium)

**Mineral name:** Osmium (Iridosmium)
**Formula:** (Os,Ir,Ru)
**VHN:** ~ 700-1000
**Crystal System:** hex.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ ~ 62 | $R_2$ ~ 62 | for $Os_{85}Ir_{12}Ru_2$ |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ ~ 47 | $R_2$ ~ 49 | |
| **Colour impression** | **(in oil)** | white | white | tint blue against Pt |
| **BR ~ Rpl** | **(in oil)** | very weak | | $A_{oil}$ = 2 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | weak with colour | distinct with colour |
| **Colour:** | **in 45° position** | reddish brown | yellow red |
| | **… in other positions** | | |
| **Extinction position** | | brownish black | |
| **Mode of extinction** | | straight | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

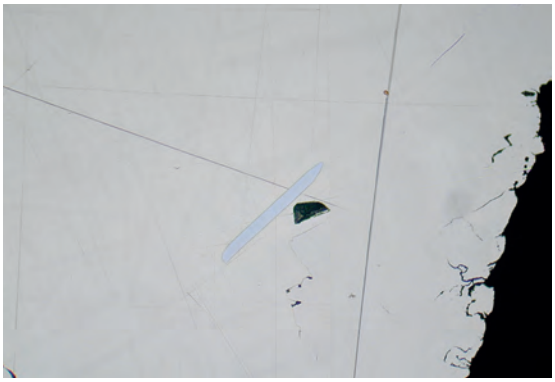
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | granular, tabular, often as EB \|\| {111} in platinum |
| **Paragenesis** | platinum, iridium, chromite, Pt-Fe-alloys |
| **Diagnostic features** | paragenesis, AExPol, |

## Notes, drafts

Reflectivity = f (chemistry), after Criddle & Stanley (1993):
for $Os_{53}Ir_{40}Ru_5$: R = 63-66/51-54
for $Ir_{63}Os_{29}Ru_7$: R = 73/63

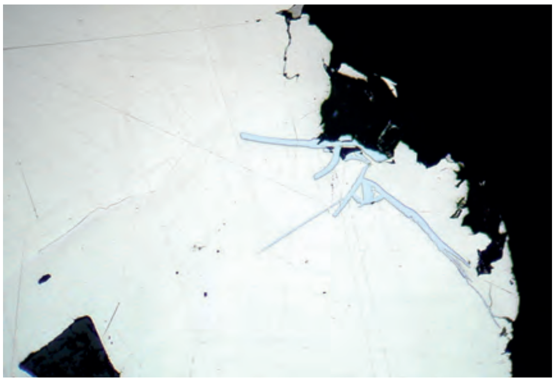
## 385 Iridosmium, platinum – Ural (prob. Nishe Tagilsk nugget)



Platelet of iridosmium (bluish white) in platinum groundmass.

Obj.: 20× oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D180_17
Section: AS1043

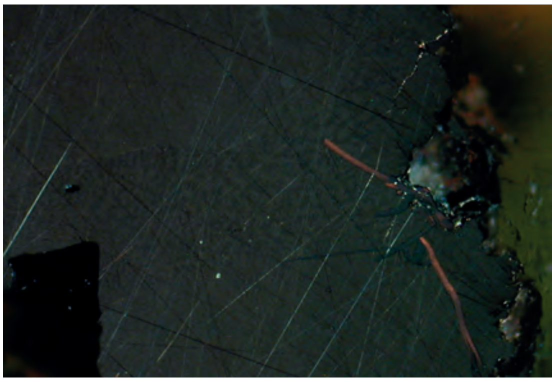
## 386 Iridosmium, platinum, chr – Ural (prob. Nishe Tagilsk nugget)



Elongated crystals of iridosmium (bluish white) in platinum. Lower left part shows chromite.

Obj.: 20× oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D180_08
Section: AS1043

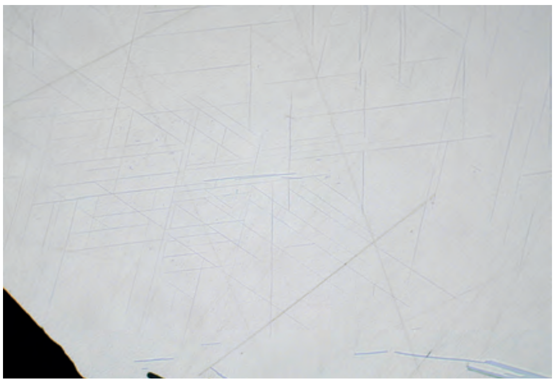
## 387 Iridosmium, platinum – Ural (prob. Nishe Tagilsk nugget)



As above, with crossed polars. Note: red-orange AExPol of iridosmium.

Obj.: 20× oil
Polars: × Pol
Photo width: 0.5 mm
Photo No.: D180_10
Section: AS1043

## 388 Iridosmium, platinum – Ural (prob. Nishe Tagilsk nugget)



Platinum nugget with small tablets of exsolved iridosmium || {111} of platinum. Digital modified photo with enhanced image contrast.

Obj.: 20× oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D180_14
Section: AS1043

# Pararammelsbergite

**Mineral name:** Pararammelsbergite
**Formula:** $NiAs_2$
**VHN:** 680-810
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 58.9 | $R_2$ = 59.7 (\|\| elongation) | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 45.5 | $R_2$ = 46.8 (\|\| elongation) | |
| **Colour impression** | **(in oil)** | white tint blue | white tint yellow | |
| **BR ~ Rpl** | **(in oil)** | weak | | $A_{oil}$ = 3 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | weak with colour | distinct with colour |
| **Colour:** | **in 45° position** | ochre brown | light ochre – orange brown – greenish grey |
| | **... in other positions** | no bluish colours | |
| **Extinction position** | | brownish black | |
| **Mode of extinction** | | straight, perfect | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | simple | |
| | **frequency** | rare | |

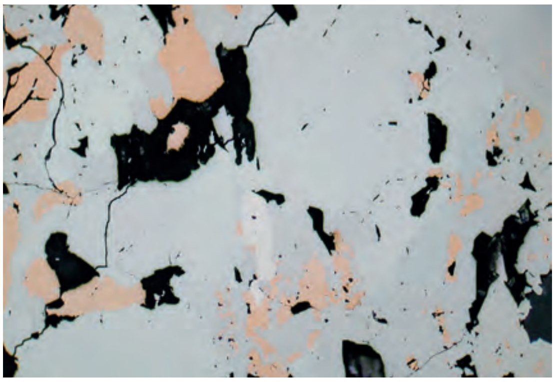
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | tabular XX and anhedral grains; often replaces skutterudite and nickeline |
| **Paragenesis** | rammelsbergite, safflorite, nickeline |
| **Diagnostic features** | no lamellar twinning, no bluish AExPol, form |

## Notes, drafts

After Ramdohr and own observations the lightest of all Ni-Co-arsenides.

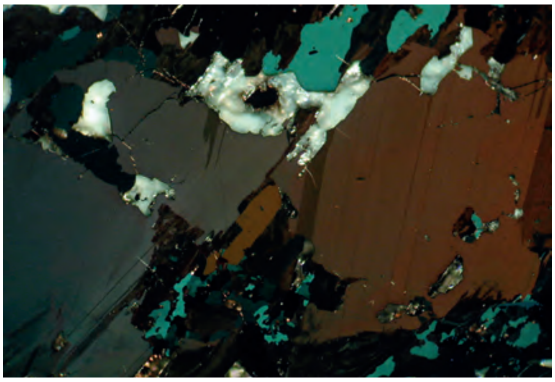
## 389 Pararammelsbergite, ram, nk – Boussmassse mine, Bou Azzer, Morocco



Pararammelsbergite crystal (centre of photo; whitish grey), surrounded by rammelsbergite (slightly darker), and nickeline (orange).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D99_05
Section: AS3571

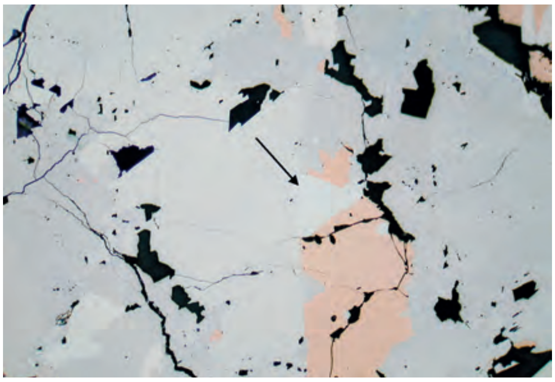
## 390 Pararammelsbergite, ram, nk – Boussmassse mine, Bou Azzer, Morocco



As above, with crossed polars.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D99_07
Section: AS3571

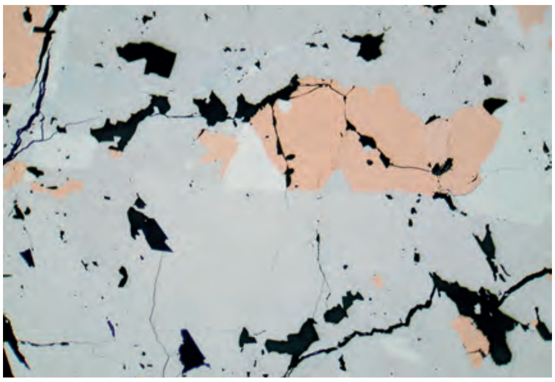
## 391 Pararammelsbergite, ram, nk – Boussmassse mine, Bou Azzer, Morocco



Pararammelsbergite crystal (arrow, triangle crystal in the centre of photo; CI and R very similar to rammelsbergite), surrounded by rammelsbergite (main mass), and nickeline (orange).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D99_17
Section: AS3571

## 392 Pararammelsbergite, ram, nk – Boussmassse mine, Bou Azzer, Morocco



As above, but 90° rotated. Pararammelsbergite crystal is now clearly visible (centre of photo; R now higher against rammelsbergite), surrounded by rammelsbergite (main mass), and nickeline (orange).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D99_16
Section: AS3571

# Pearceite

**Mineral name:** Pearceite
**Formula:** $(Ag,Cu)_{16}(As,Sb)_2S_{11}$

**VHN:** 140-160
**Crystal System:** trig.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 32.2 | $R_{e'}$ = 29.1 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 17.1 | $R_{e'}$ = 14.4 | $R_o$ \|\| elongation |
| **Colour impression** | **(in oil)** | grey tint violet blue | grey tint green | |
| **BR < Rpl** | **(in oil)** | distinct | | $A_{oil}$ = 17 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong with colour | strong with colour |
| **Colour:** | **in 45° position** | green | light yellow green – dark bluish green |
| | **... in other positions** | | brown, violet blue |
| **Extinction position** | | black | |
| **Mode of extinction** | | straight, undulatory | |
| **Internal reflections** | **colour** | red | |
| **(IR)** | **frequency** | frequent (Sb-pearceite: absent; higher Cu-content: less IR) | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

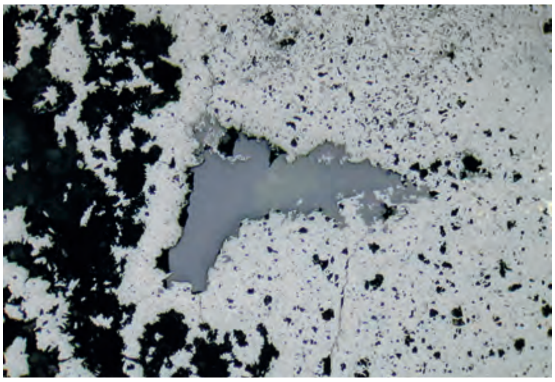
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | euhedral pseudo hexagonal-plates, subparallel and rosette-like.<br># \|\| (001) |
| **Paragenesis** | other silver minerals, safflorite, tennantite |
| **Diagnostic features** | CI, AExPol, poor polishing (many scratches) |

## Notes, drafts

Polybasite: formula as pearceite but with Sb > As.

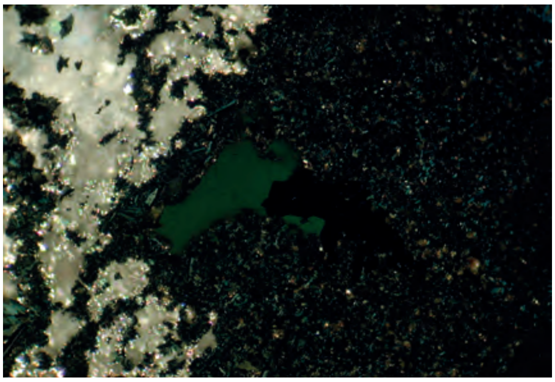
## 393 **Pearceite, safflorite –** Nieder-Beerbach, Odenwald, Germany



Pearceite with strong Rpl (grey tint green to violet grey) in fine-grained safflorite matrix (greyish white); some tiny silver (white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D145_23
Section: CHe26A

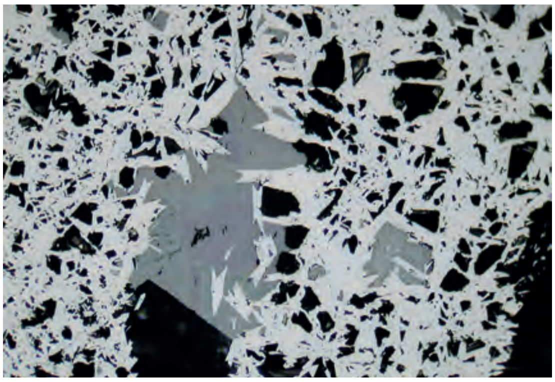
## 394 **Pearceite, safflorite –** Nieder-Beerbach, Odenwald, Germany



As above, with crossed polars. Typical greenish AExPol of pearceite.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D145_24
Section: CHe26A

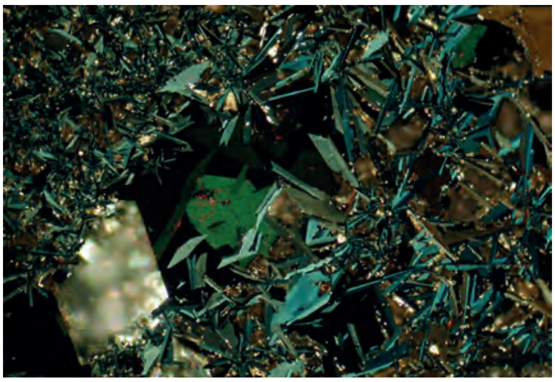
## 395 **Pearceite, lo, argentite, silver –** Nieder-Beerbach, Odenwald, Germany



Pearceite (Rpl!) with argentite (greenish grey grain in lower right side of photo with tiny silver spots) surrounded by twinned loellingite crystals (white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D146_13
Section: CHe26B

## 396 **Pearceite, lo, argentite, silver –** Nieder-Beerbach, Odenwald, Germany



As above, with crossed polars.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D146_14
Section: CHe26B

# Pentlandite

**Mineral name:** Pentlandite (pn)
**Formula:** $(Ni,Fe)_9S_8$

**VHN:** 270-290
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 48.9 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 37.2 | |
| **Colour impression** | **(in oil)** | white cream | (against pyrite: less yellow) |
| **BR Rpl** | **(in oil)** | -- | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | homogeneous dark | homogeneous dark |
| **Colour:** | **in 45° position** | grey black (tint violet) | grey black tint violet |
| | **... in other positions** | | |
| **Extinction position** | | -- | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

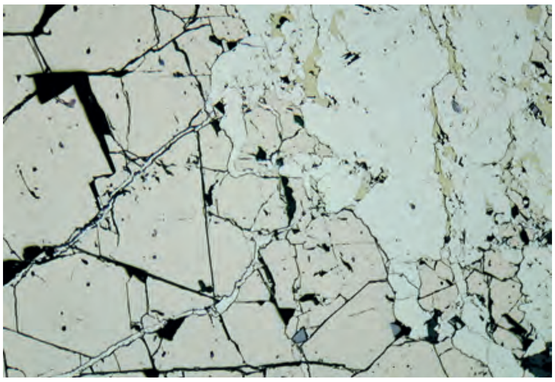
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | anhedral grains, or flame-like EB \|\| (0001) in pyrrhotite, excess Fe → mackinawite-EB; distinct # \|\| {111}! |
| **Paragenesis** | pyrrhotite, violarite, bravoite, chalcopyrite, millerite, spinel, mt, chr |
| **Diagnostic features** | octahedral #, flame-like EB, paragenesis with pyrrhotite! |

## Notes, drafts

Pentlandite is similar to PYRITE (but pn has distinct #!!)
Co-pentlandite: $(Co, Ni, Fe)_9S_8$

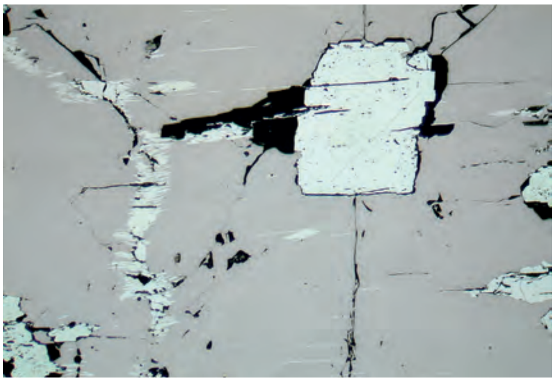
## 397 Pentlandite, py, cp – Victor South mine, Kambalda, Australia



Pentlandite (cream, with typical #), partly replaced by pyrite (nearly white) and chalcopyrite (yellow).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D91_03
Section: AS3613

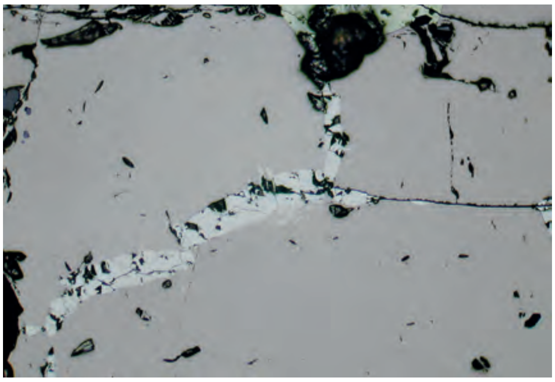
## 398 Pentlandite, po, py – Horbach, Schwarzwald, Germany



Flame-like pentlandite (creamy white) in pyrrhotite; euhedral pyrite (yellowish white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D26_10
Section: AS2562

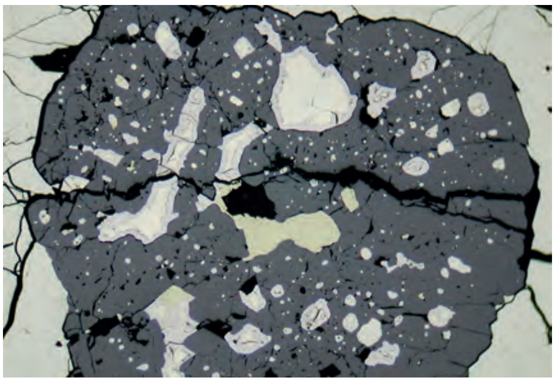
## 399 Pentlandite, po – Sudbury, Ontario, Canada



Granular and flame-like pentlandite along grain boundaries of pyrrhotite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D26_12
Section: AS1760

## 400 Pentlandite, violarite, spl, cp – Gill orebody, Kambalda, W-Australia



Large spinel with many inclusions of pentlandite (rimmed by violarite) and chalcopyrite (yellow).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D91_01
Section: AS3617

# Perovskite

**Mineral name:** Perovskite (prv)
**Formula:** $Ca(Ti,Nb)O_3$

**VHN:** 1000
**Crystal System:** o'rh. (ps. cub.).

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 16.6 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 4.9 | |
| **Colour impression** | **(in oil)** | grey (tint blue) | |
| **BR Rpl** | **(in oil)** | -- | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | not visible | |
| **Colour:** | **in 45° position** | masked by IR | |
| | **... in other positions** | | |
| **Extinction position** | | masked by IR | |
| **Mode of extinction** | | masked by IR | |
| **Internal reflections** | **colour** | colourless – brown | |
| **(IR)** | **frequency** | always | |
| **Twinning** | **mode** | lamellar twinning, and complex | |
| | **frequency** | abundant but rarely visible in polished sections | |

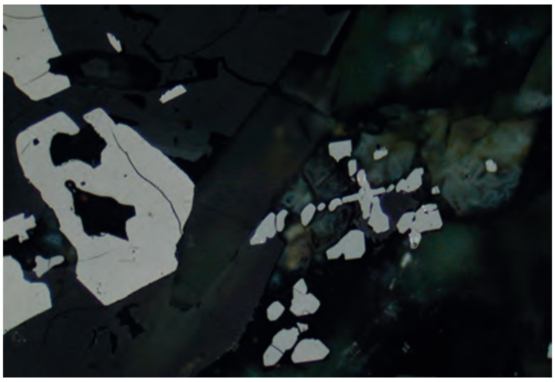
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | euhedral to anhedral crystals; intergrown with ilmenite or mt; often replaced by rutile or anatase |
| **Paragenesis** | mt, ilm, rt |
| **Diagnostic features** | paragenesis |

## Notes, drafts

CI and R varying with composition; very similar to SPHALERITE and TITANITE (BR!)
Perovskite with Nb > Ti is named latrappite.

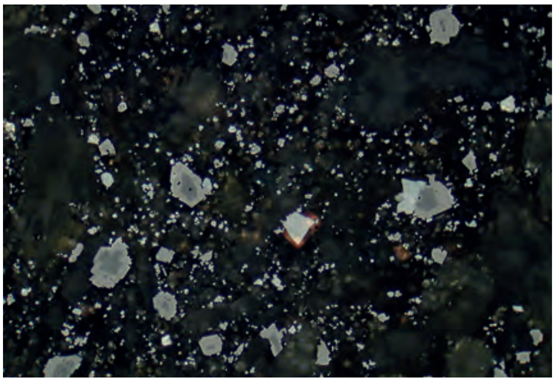
## 401 Perovskite, magnetite – Nephelinite from Hohenstoffeln, Hegau, Germany



Skeletal aggregate of perovskite (right side of photo) with white IR. Left side: magnetite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D153_20
Section: AS2873

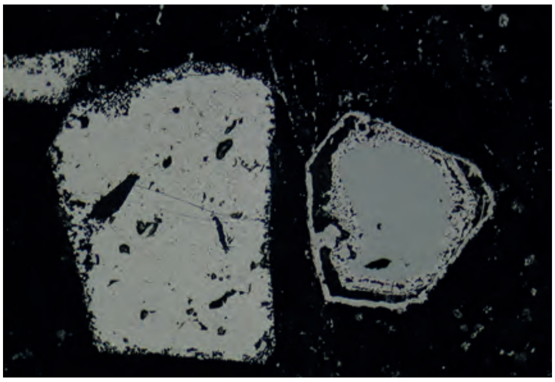
## 402 Perovskite, spinel, mt – Nephelinite from Urach volcanic field, SW-Germany



Zoned spinel grains (spinel core with magnetite rim) and tiny perovskite crystals (higher R, white IR) in groundmass of cpx and nepheline.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D134_30
Section: AS 3291

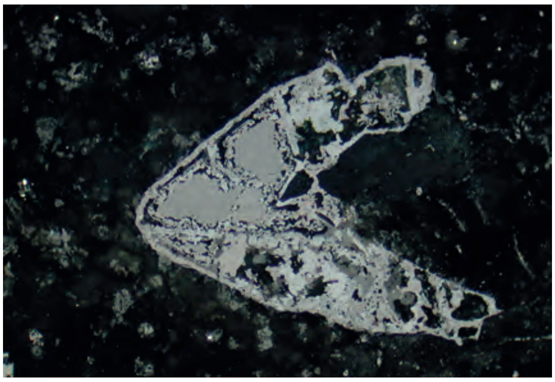
## 403 Perovskite, mt, ilm – Tamazeght complex, Morocco



Right side: Perovskite crystals (medium grey) rimmed and replaced by ilmenite. Left side: Magnetite with ulvite exsolutions in »cloth-texture«.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D155_04
Section: TMZ29

## 404 Perovskite, rt, ilm – Tamazeght complex, Morocco



Perovskite twin (relict on the left side of the upper twin crystal) replaced by a mixture of ilmenite (greyish brown) and rutile (light grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D155_06
Section: TMZ29

# Pitchblende (in German: Pechblende, Uraninit)

**Mineral name:** Pitchblende (Uraninite)
**Formula:** $UO_2$
**VHN:** 500-550
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 13 to 14 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 3 to 4 | |
| **Colour impression** | **(in oil)** | grey tint brown | |
| **BR Rpl** | **(in oil)** | -- | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

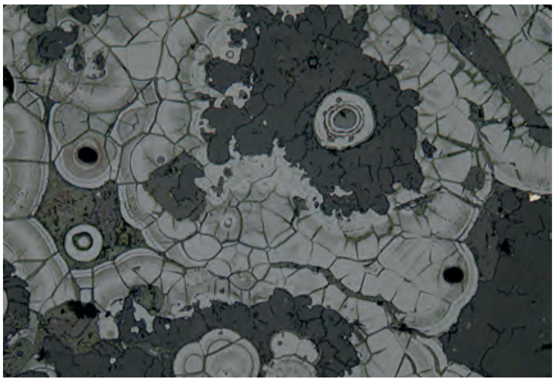
| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | homogeneous dark | |
| **Colour:** | **in 45° position** | black | |
| | **... in other positions** | | |
| **Extinction position** | | -- | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | dark brown | |
| **(IR)** | **frequency** | rare | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | rare euhedral XX (uraninite s. s.), more often colloform, botryoidal or globular aggr., irregular shrinkage cracks, often filled with younger minerals (galena!), zoning |
| **Paragenesis** | gn, py, hm, thorianite, barite, coffinite |
| **Diagnostic features** | rhythmic texture, cracks, radioactive halo, galena inclusions |

## Notes, drafts

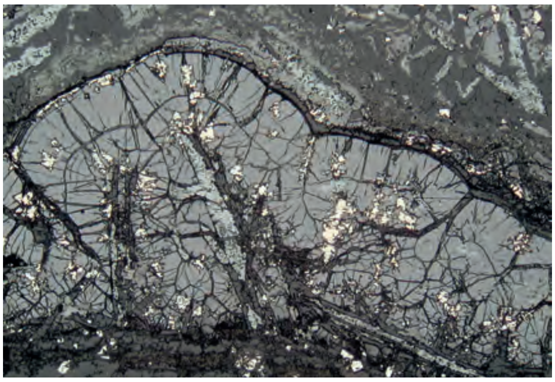
## 405 Pitchblende – Menzenschwand, Schwarzwald, Germany



Concentric masses of colloform pitchblende.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D81_01
Section: M31

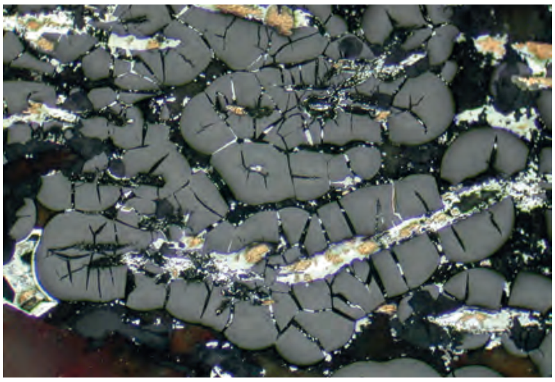
## 406 Pitchblende, hematite, py – Menzenschwand, Schwarzwald, Germany



Colloform pitchblende overgrowing tabular hematite (light grey, probably pseudomorph after primary barite), pyrite.

Obj.: 5 ×
Polars: || Pol
Photo width: 2.8 mm
Photo No.: D72_03
Section: A2

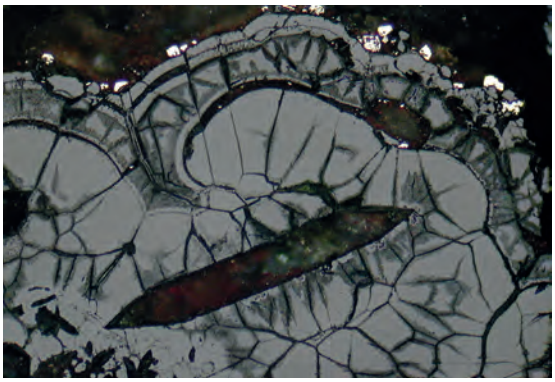
## 407 Pitchblende, bismuth, bismuthinite – Wittichen, Schwarzwald, Germany



Colloform pitchblende (grey) overgrowing skeletal bismuth (yellow tarnishing colours) which is partly altered to bismuthinite (white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D185_27
Section: SW120

## 408 Pitchblende, barite, py – Menzenschwand, Schwarzwald, Germany



Pitchblende on euhedral barite tablet, small pyrites.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D81_09
Section: M31

# Platinum (in German: ged. Platin)

**Mineral name:** Platinum
**Formula:** (Pt,Fe)
**VHN:** 300-400
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| $R_{(air)}$ in % | (for 546 nm) | 70 | | |
| $R_{(oil)}$ in % | (for 546 nm) | 59 | depending on composition | |
| Colour impression | (in oil) | white | against IrOs: tint yellow | |
| BR Rpl | (in oil) | -- | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|
| Anisotropism intensity/colour | homogeneous dark | homogeneous dark |
| Colour: in 45° position ... in other positions | in each position homogeneous grey | in each position homogeneous grey |

| | | |
|---|---|---|
| Extinction position | | grey |
| Mode of extinction | | -- |
| Internal reflections | colour | -- |
| (IR) | frequency | -- |
| Twinning | mode | -- (along {111}, only visible after etching) |
| | frequency | -- |

## Further observations

| | |
|---|---|
| Form, habit, textures, cleavage ... | often irregular grains or as EB. Can show extremely fine tabular EB of IrOs \|\| {111} and/or granular EB of iridium. |
| Paragenesis | Ir, IrOs, chromite, po, sperrylite |
| Diagnostic features | high R, paragenesis |

## Notes, drafts

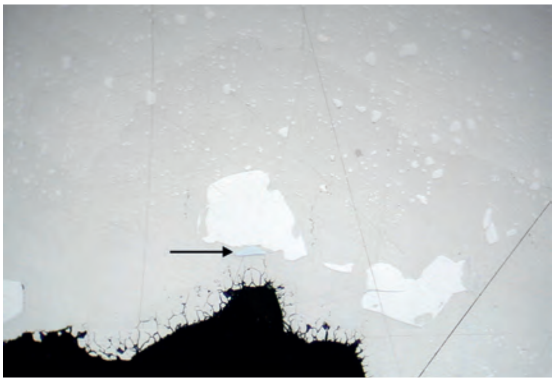
Always with small iron content (4-21 %).
$Pt_{80}Fe_{20}$ has $R_{air}$ = 60 % (Toma & Murphy (1977), Can. Min., 15, 59-69).

## 409 Platinum, iridium, – Ural (prob. Nishne Tagilsk nugget)

Tiny exsolution bodies of iridium (slightly lighter and more white) in platinum.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D180_12
Section: AS1043

## 410 Platinum, iridium, iridosmium – Ural (prob. Nishne Tagilsk nugget)



Numerous tiny and some large exsolution bodies of iridium (nearly white) in platinum. Small lath of iridosmium (bluish white) below iridium grain in centre of photo (arrow).

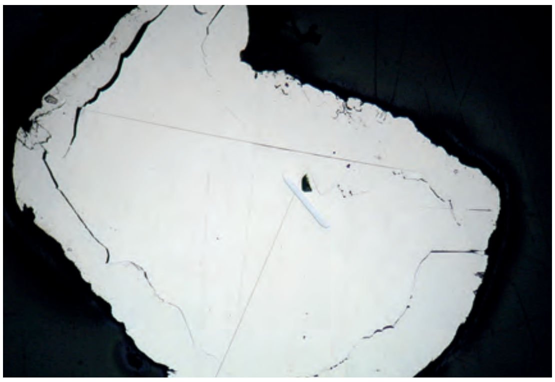
Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D180_13
Section: AS1043

## 411 Platinum, iridosmium – Ural (prob. Nishne Tagilsk nugget)

Wedge-shaped alteration features at platinum rim following extremely fine tablets of iridosmium (slightly darker than Pt, NW-SE direction).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D180_16
Section: AS1043

## 412 Platinum, iridosmium – Ural (prob. Nishne Tagilsk nugget)



Digital modified photo (with enhanced image contrast). Small tabular iridosmium within a large platinum grain, which shows a lamellar internal texture and a prominent darker rim.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D180_04
Section: AS1043

# Proustite

**Mineral name:** Proustite
**Formula:** $Ag_3AsS_3$

**VHN:** 50-150
**Crystal System:** trig.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 27.7 | $R_{e'}$ = 24.2 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 13.1 | $R_{e'}$ = 10.4 | |
| **Colour impression** | **(in oil)** | greyish blue tint brown | greyish blue | |
| **BR ~ Rpl** | **(in oil)** | distinct | | $A_{oil}$ = 23 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong with colour tint | strong with colour |
| **Colour:** | **in 45° position** | greyish yellow | grey – greyish yellow |
| | **... in other positions** | masked by IR | turquoise, violet |
| **Extinction position** | | masked by IR | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | red to yellow | |
| **(IR)** | **frequency** | frequent – abundant | |
| **Twinning** | **mode** | coarse & simple; lamellar deformation twins | |
| | **frequency** | occasional – frequent | |

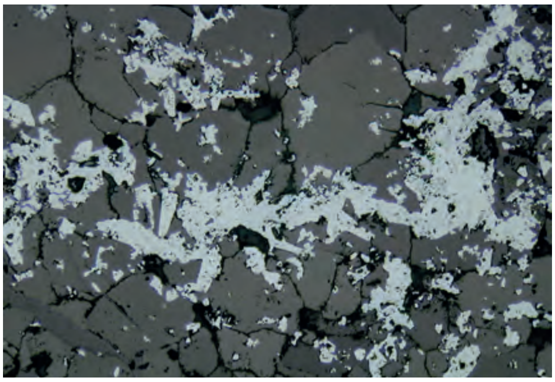
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | often perfect tabular to needle-shaped XX; irregular grains; no #! |
| **Paragenesis** | other Ag-sulfosalts, galena, native bismuth, arsenic, rammelsbergite |
| **Diagnostic features** | CI, light etching (within hours!), red IR; very similar to pyrargyrite! |

## Notes, drafts

Only limited miscibility with PYRARGYRITE ($Ag_3SbS_3$).

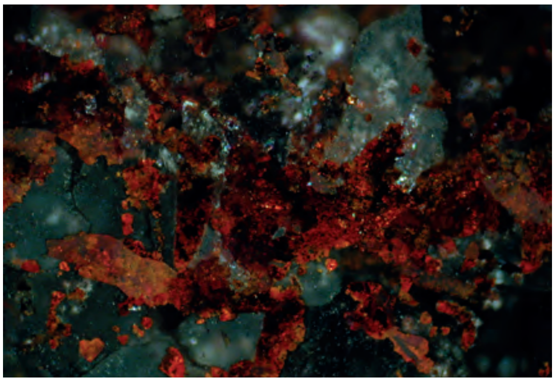
## 413 Proustite, calcite – Nieder-Beerbach, Odenwald, Germany



Proustite (light grey) embedded in isometric calcite grains.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D151_02
Section: CHe25

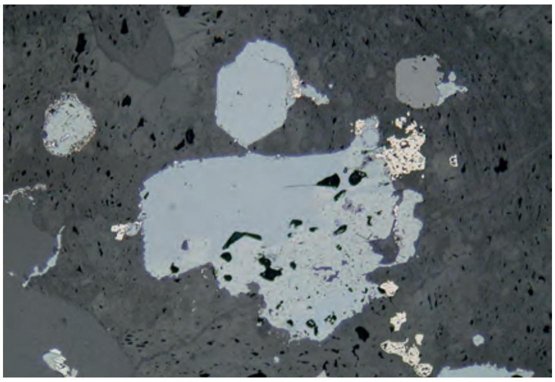
## 414 Proustite, calcite – Nieder-Beerbach, Odenwald, Germany



Numerous red internal reflections of proustite. Some crystals show anisotropism. Detail from photo above.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D151_12
Section: CHe25

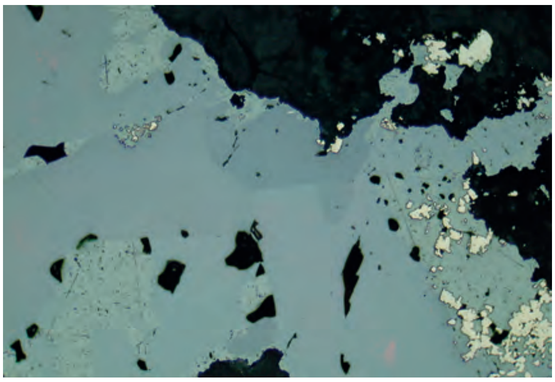
## 415 Proustite, acanthite, pyrite – Jachymov (Joachimsthal), Czech Republic



Proustite (larger grain in centre and above) partly replaced by acanthite (right side with stippled surface; tint green). Small pyrite grains.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D156_14
Section: AS3629

## 416 Proustite, acanthite, pyrite – Jachymov (Joachimsthal), Czech Republic



As above, now with oil immersion. Bireflection of proustite is distinct, some red IR are visible. Acanthite (greyish green, poor polishing) and pyrite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D156_21
Section: AS3629

# Pseudobrookite

**Mineral name:** Pseudobrookite (psb)
**Formula:** $Fe_2TiO_5$
**VHN:** ~1000
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1 = 18.4$ | $R_2 = 19.2$ | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1 = 6.0$ | $R_2 = 6.5$ | |
| **Colour impression** | **(in oil)** | grey | grey | |
| **BR > Rpl** | **(in oil)** | weak | | $A_{oil} = 8$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | weak without colour | weak without colour |
| **Colour:** | **in 45° position** | grey | grey |
| | **... in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | perfect | |
| **Internal reflections** | **colour** | reddish brown to orange | |
| **(IR)** | **frequency** | abundant | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

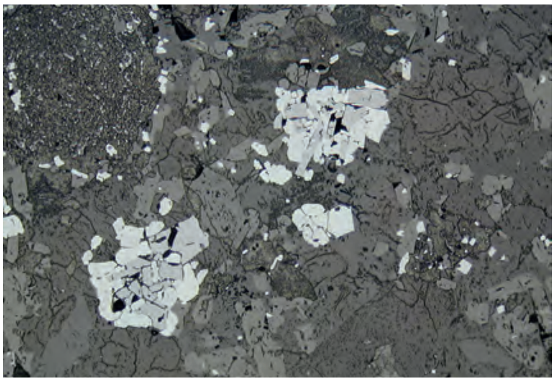
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | often euhedral, tabular columnar XX;<br>decomposition into rutile + hematite |
| **Paragenesis** | intergrown with hm (oxidation of ilm+titanomagnetite), ilm, rt, mt |
| **Diagnostic features** | similar to rutile (which has stronger BR, AExPol), IR, paragenesis |

## Notes, drafts

High-temperature formation due to oxidation of titanomagnetite.

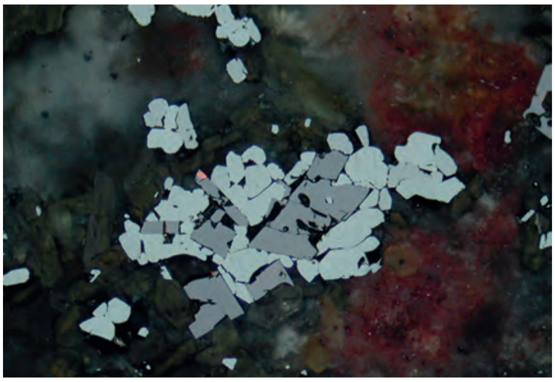
## 417 Pseudobrookite, hm – Katzenbuckel, Odenwald, Germany



Pseudobrookite tablets (medium grey) intergrown with hematite (light grey) in nepheline syenite matrix.

Obj.: 5 ×
Polars: || Pol
Photo width: 2.8 mm
Photo No.: D24_02
Section: Kb42

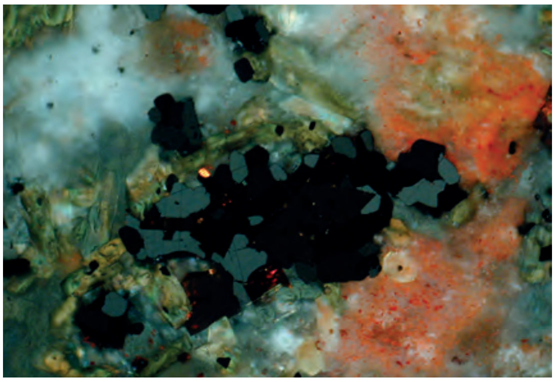
## 418 Pseudobrookite, hm – Katzenbuckel, Odenwald, Germany



Pseudobrookite tablets (medium grey, some red IR) intergrown with hematite (light grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D24_04
Section: Kb42

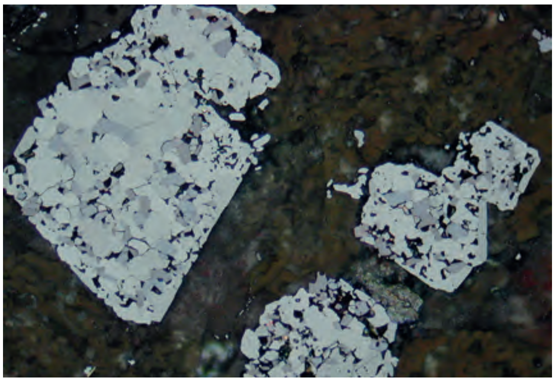
## 419 Pseudobrookite, hm – Katzenbuckel, Odenwald, Germany



As above, with crossed polars. Pseudobrookite with reddish brown to orange IR.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D24_07
Section: Kb42

## 420 Pseudobrookite, hm – Katzenbuckel, Odenwald, Germany



Pseudobrookite plus hematite pseudomorph after euhedral crystals of magnetite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D24_13
Section: Kb42

# Pseudorutile

**Mineral name:** Pseudorutile
**Formula:** ~ $Fe_2^{3+}Ti_3O_9$

**VHN:** ~ 130
**Crystal System:** hex.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | R ~ 19-20 | (estimated) | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | R ~ 7-8 | depends of composition | |
| **Colour impression** | **(in oil)** | bluish grey | | |
| **BR Rpl** | **(in oil)** | not visible | | $A_{oil}$ = 0 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | not visible to weak | not visible to weak |
| **Colour:** | **in 45° position** | greyish black | greyish black |
| | **... in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | brownish to reddish-brown | |
| **(IR)** | **frequency** | rare (in Fe-poor pseudorutiles) | |
| **Twinning** | **mode** | ---- | |
| | **frequency** | | |

## Further observations

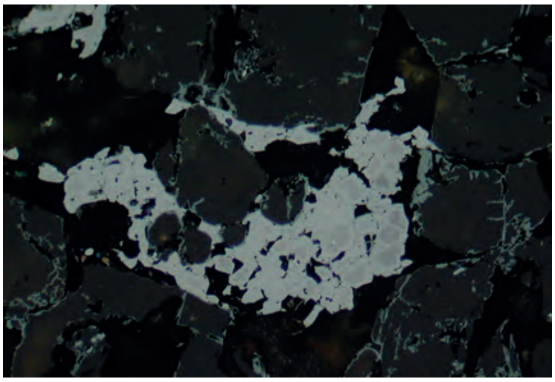
| | |
|---|---|
| **Form, habit, textures, cleavage ...** | Intermediate product during alteration of ilmenite to rutile, replacing primary ilmenite (or »leached ilmenite«), often with relicts of unaltered ilmenite |
| **Paragenesis** | ilmenite, »leached ilmenite«, rutile, magnetite, goethite |
| **Diagnostic features** | alteration product of ilmenite and leached ilmenite |

## Notes, drafts

General formulae $Fe_{2-y}^{3+}Ti_3O_{9-3y}(OH)_{3y}$ with y = 0-2 (pseudorutile: y = 0; leucoxene: y = 2)*.

* see: Mücke & Chaudhuri (1991): Ore Geology Rev., 6, 25-44.

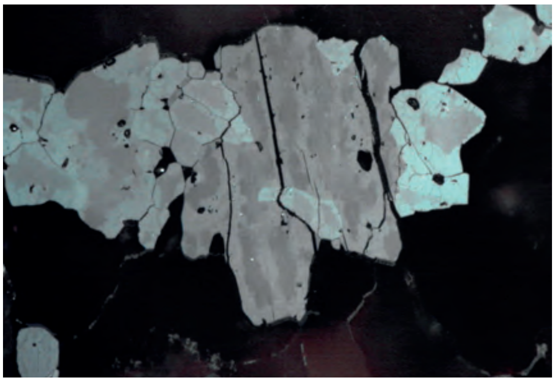
## 421 Leached ilmenite, pseudorutile, grt – Ungwan Mallam Ayuba, N-Nigeria



Aggregates of ilmenite (medium grey with brown tint) with rims of leached ilmenite and pseudorutile (lighter grey); matrix of garnets with limonite rim.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D84_20
Section: AS249

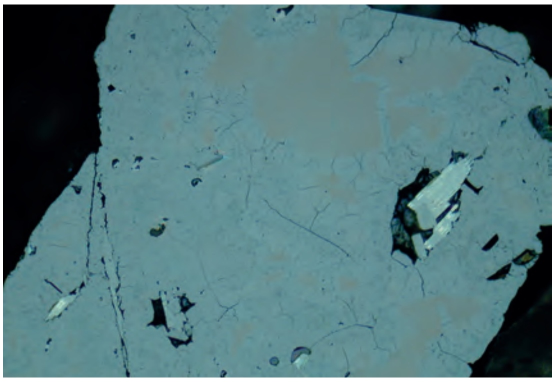
## 422 Ilm, leached ilmenite, pseudorutile – Tudun Kudu Hill, Kaduna, N-Nigeria



Replacements of ilmenite (core of grains, medium brownish grey) by leached ilmenite (lighter brownish grey) and finally by pseudorutile (light grey without brown tint, many cracks).

Obj.: 40 × oil
Polars: || Pol
Photo width: 0.3 mm
Photo No.: A02_02
Section: TK1_3

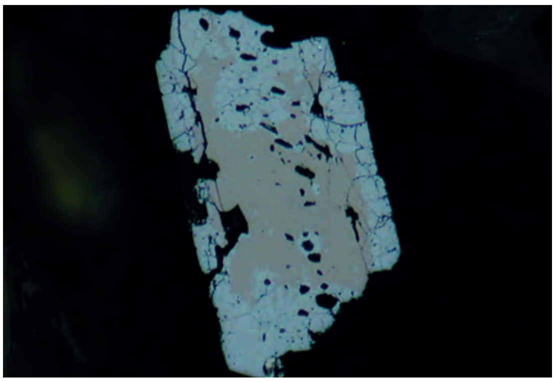
## 423 Ilmenite, pseudorutile, rt – Placer from Neualbenreuth, Bavaria, Germany



Relict of ilmenite (brownish grey) within pseudorutile (bluish grey, many cracks); new crystallized large rutile (light grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D149_27
Section: AS140

## 424 Ilmenite, pseudorutile – Placer from Neualbenreuth, Bavaria, Germany



Alteration of ilmenite (brownish grey) to pseudorutile (bluish grey, many cracks).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.4 mm
Photo No.: D109_26
Section: AS 140

# Pyrargyrite

**Mineral name:** Pyrargyrite (pyrg)
**Formula:** $Ag_3SbS_3$

**VHN:** 50-150
**Crystal System:** trig.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 30.4 | $R_{e'}$ = 28.5 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 15.0 | $R_{e'}$ = 13.3 | |
| **Colour impression** | **(in oil)** | greyish blue (tint olive) | greyish blue | |
| **BR ~ Rpl** | **(in oil)** | weak | | $A_{oil}$ = 12 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | weak with colour tint | weak with colour tint |
| **Colour:** | **in 45° position** | greyish yellow | grey – greyish yellow |
| | **... in other positions** | | turquoise, violet |
| **Extinction position** | | black | |
| **Mode of extinction** | | perfect | |
| **Internal reflections** | **colour** | red | |
| **(IR)** | **frequency** | frequent | |
| **Twinning** | **mode** | simple; lamellar deformation twins | |
| | **frequency** | occasional – frequent | |

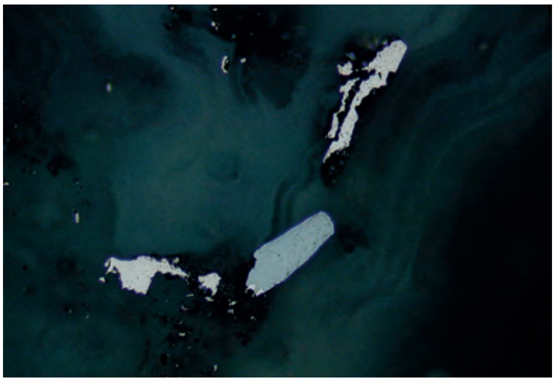
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | very often perfect single crystals; occasionally as irregular interlocked grains; limited solid solution with $Ag_3AsS_3$ (proustite); no # |
| **Paragenesis** | other Ag-sulfosalts, galena, bismuth |
| **Diagnostic features** | greyish blue CI, red IR, paragenesis |

## Notes, drafts

Monocline modification of $Ag_3SbS_3$ = see PYROSTILPNITE.

### 425 Pyrargyrite, gn, chalcedony – Todtnau, Schwarzwald, Germany



Pyrargyrite crystal (medium grey, centre of photo) partly replaced by galena (light grey) in matrix of chalcedony.

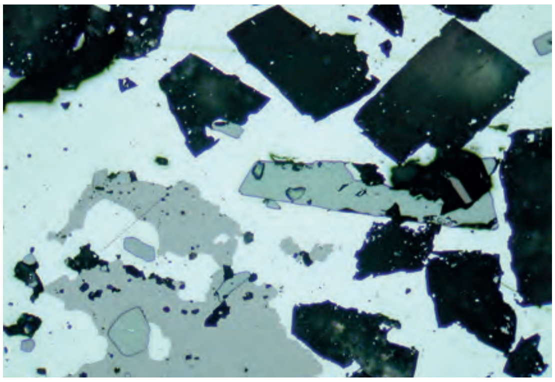
Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D89_08
Section: JSt1

### 426 Pyrargyrite, gn, chalcedony – Todtnau, Schwarzwald, Germany

As above, with crossed polars. Red internal reflections of pyrargyrite are visible.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D89_09
Section: JSt1

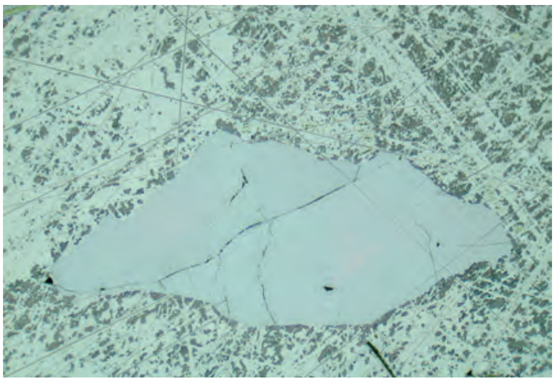
### 427 Pyrargyrite, clausthalite, tiemannite – Tilkerode, Harz, Germany



Euhedral pyrargyrite in clausthalite (light grey) beside carbonate (black) and tiemannite (brownish grey, in part replaced by clausthalite).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D32_15
Section: AS1752

### 428 Pyragyrite, acanthite – Gnade Gottes, Bohemia, Czech Republic



Pyrargyrite within strongly tarnished acanthite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D120_19
Section: AS1063

# Pyrite

**Mineral name:** Pyrite (py)
**Formula:** $FeS_2$

**VHN:** ~1500-1600
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 53.7 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 39.2 | |
| **Colour impression** | **(in oil)** | white yellow | |
| **BR Rpl** | **(in oil)** | -- | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | homogeneous dark | occasionally weak with colour tint |
| **Colour:** | **in 45° position** | black | grey with impure colours (olive, yellow ...) |
| | **... in other positions** | | |
| **Extinction position** | | -- | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

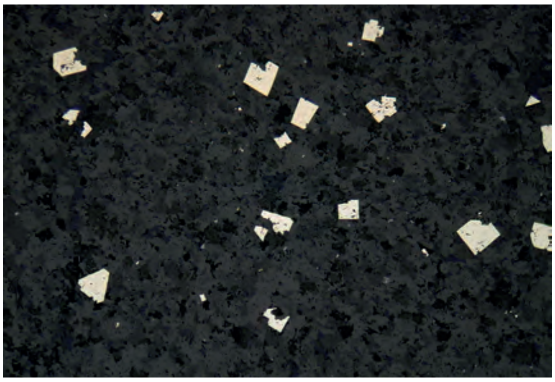
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | very often as euhedral crystals, tiny crystal clusters in »framboids«; locking older minerals (e.g. po, cp) as relicts, often replaces po. Only rare # \|\| {100}! |
| **Paragenesis** | po (e.g. bird eyes), asp, mrc, cp, gold, and many more |
| **Diagnostic features** | form, cataclasis, many inclusions, hardness |

## Notes, drafts

One of the most common sulfides in rocks.
Other elements → weak anisotropism (Se, As) or → different R/CI (Ni, Co, Cu, Ag)
Ni-rich pyrite = bravoite (CI more brownish, violet).

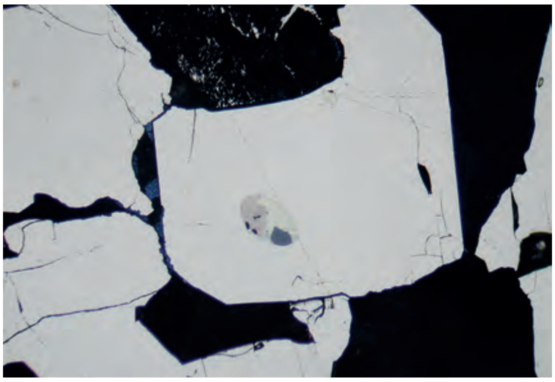
## 429 Pyrite, carbonate, cp – Sulphur Spring, Soannesville Group, W-Australia



VMS mineralization with small cubes of pyrite in fine-grained groundmass of carbonate (and minor cp).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D179_16
Section: MW3
(KCD26 core)

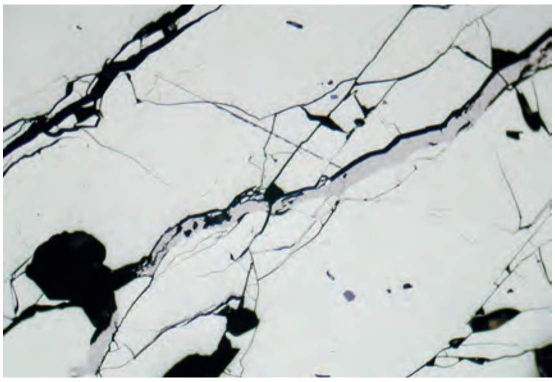
## 430 Pyrite, cp, po, sph, cub – Zlaté Hory, Okres Jeseník, Czech Republic



Large grain of pyrite with oval inclusion of chalcopyrite (yellow), pyrrhotite (light brown), sphalerite (dark grey), and cubanite (light grey)

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D28_25
Section: AS2553

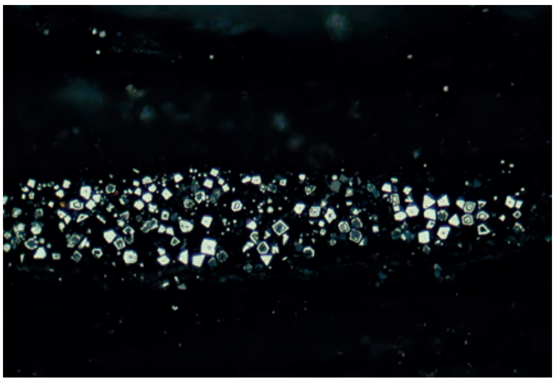
## 431 Pyrite, bravoite – Gill orebody, Kambalda, W-Australia



Small veinlet of bravoite (slightly brownish white) in cataclastic pyrite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D127_28a
Section: AS3617

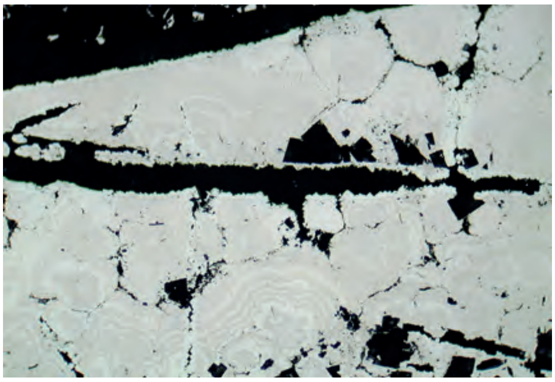
## 432 Pyrite – Goldhausen, Korbach, Hesse, Germany



Zoned euhedral pyrite crystals partly replaced by limonite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D105_21
Section: AS111

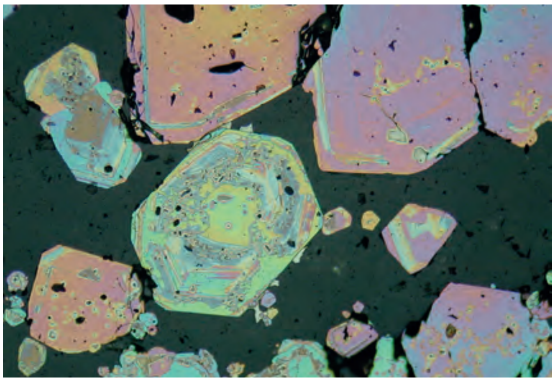
## 433 Pyrite, barite – Detzeln, NE Waldshut, SW-Germany



Colloform pyrite with fine zoning (digital enhanced contrast of photo), replacing tabular barites (black).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D79_28
Section: DK-14

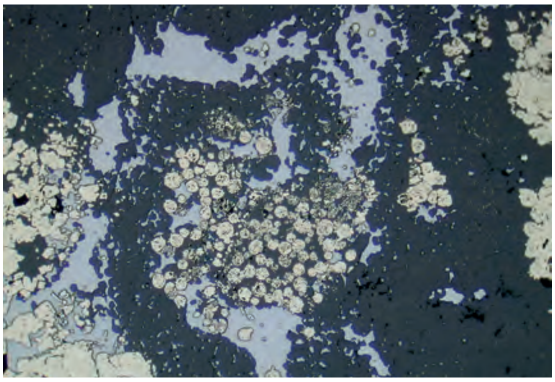
## 434 Pyrite – Kocbulak, Usbekistan



Tarnishing of pyrite in older sections often show fine delicate zonings, which are not observable in fresh polished sections!

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D208_06
Section: AS3057

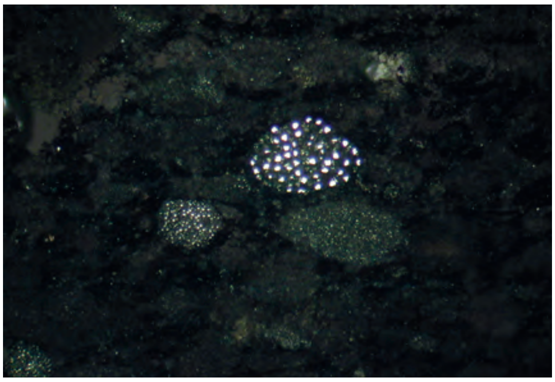
## 435 Pyrite, gn, sph – Rammelsberg, Harz, Germany



Framboidal pyrite (yellow white) within sphalerite (dark grey), and galena (medium grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D169_11
Section: AS3508

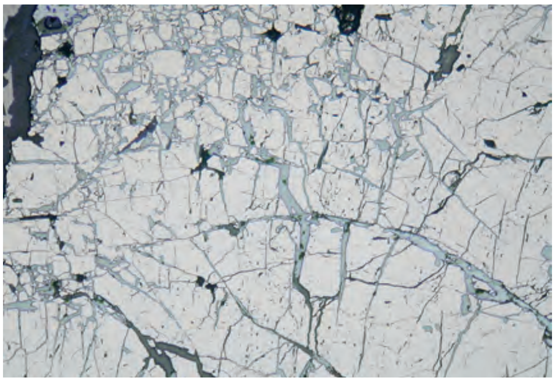
## 436 Pyrite – Sebkha Mekkerhane, Hoggar Massif, Algeria



Agglomerates of tiny pyrite cubes in organic rich sediment. These more or less round pyrite concentrations are called »framboids« indicating possible bacterial sulfate reduction (BSR) and sulfide precipitation (starting with mackinawite).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D29_06
Section: A106/1

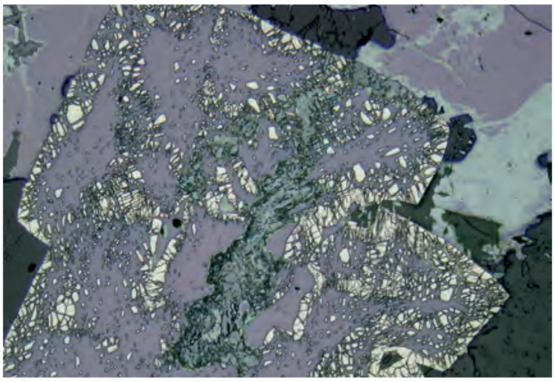
## 437 Pyrite, boulangerite – Strassegg, Styria, Austria



Deformed grain of pyrite with replacement features of younger boulangerite along cleavage planes (usually rare in pyrite).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D194_16
Section: AS196

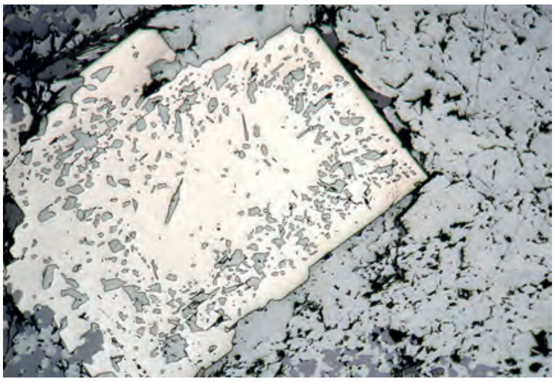
## 438 Pyrite, bornite – Wittichen, Schwarzwald, Germany



Selective replacement of euhedral pyrite cube (light yellow relicts) by bornite (violet). Bornite is in part replaced by chalcocite (bluish grey)

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D157_22
Section: MM17

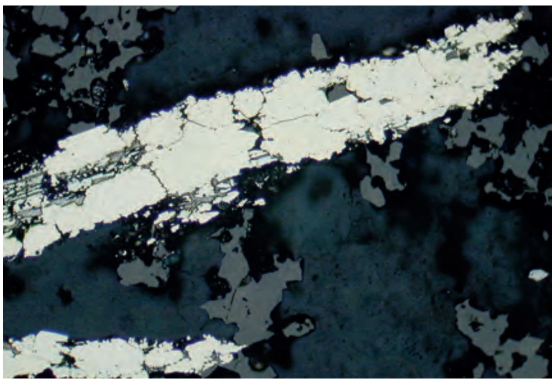
## 439 Pyrite, boulangerite, sph – Cleary Hill, Livengood, Alaska, USA



Poikilobastic crystal of pyrite enclosing boulangerite is surrounded by sphalerite and boulangerite.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D64_09
Section: AS3584

## 440 Pyrite, mrc, sph – Wilsbach, Münstertal, Schwarzwald, Germany



Agglomerate of pyrite grains (plus marcasite) pseudomorph after elongated pyrrhotite crystal. Some sphalerite grains (grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D73_13
Section: Bo69a

# Pyrochlore

**Mineral name:** Pyrochlore
**Formula:** $(Na,Ca,U)_2(Nb,Ta,Ti)_2(O,OH)_7$

**VHN:** 300-600
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 15 to 12 | | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 5 to 2 | depends on composition | |
| **Colour impression** | **(in oil)** | grey (tint brown) | | |
| **BR Rpl** | **(in oil)** | -- | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | isotropic | |
| **Colour:** | **in 45° position** | masked by IR | |
| | **... in other positions** | | |
| **Extinction position** | | masked by IR | |
| **Mode of extinction** | | | |
| **Internal reflections** | **colour** | yellow – orange – red – brown | |
| **(IR)** | **frequency** | always | |
| **Twinning** | **mode** | simple || (111) spinel law | |
| | **frequency** | rare | |

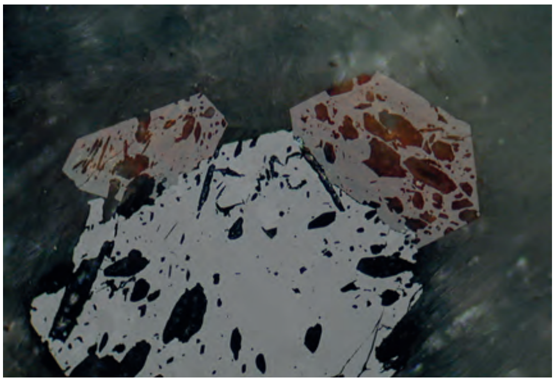
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | euhedral single crystals (rare aggregates), very often zoned and poikiloblastic; frequent alteration features and intergrown with other Nb-Ta-W-phases |
| **Paragenesis** | Nb-Ta-minerals, cassiterite, magnetite, carbonates, fluorite |
| **Diagnostic features** | euhedral, zoned crystals |

## Notes, drafts

U-rich members show higher R. Similar to SPHALERITE.

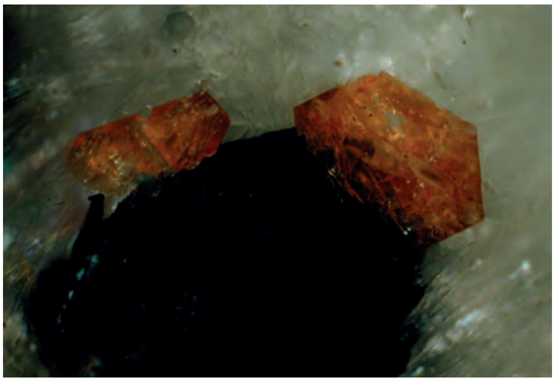
## 441 Pyrochlore, magnesioferrite – Badberg, Kaiserstuhl, Germany



Euhedral pyrochlore crystals (medium grey with IR) on magnesioferrite (light grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D97_16
Section: AS1577

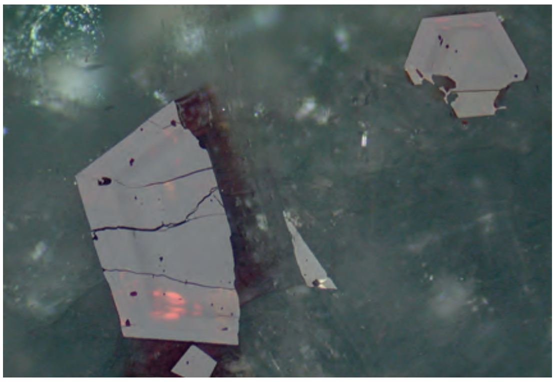
## 442 Pyrochlore, magnesioferrite – Badberg, Kaiserstuhl, Germany



As above, with crossed polars.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D97_19
Section: AS1577

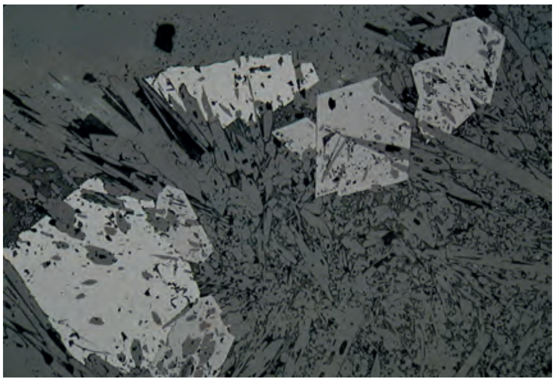
## 443 Pyrochlore, carbonate – Badberg, Kaiserstuhl, Germany



Fine zoning of pyrochlore crystals (red IR) with replacement features; in carbonate groundmass.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D97_12
Section: AS1577

## 444 Pyrochlore, mt, ap, carbonate – Badberg, Kaiserstuhl, Germany



Poikiloblastic crystals of pyrochlore (medium grey; centre and upper right part of photo) and two magnesioferrite crystals (left side, slightly lighter) in carbonate-apatite(needles) groundmass.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D97_06
Section: AS1577

# Pyrolusite

**Mineral name:** Pyrolusite
**Formula:** β-$MnO_2$

**VHN:** ~ 100-1500*
**Crystal System:** tetr.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 38 | $R_{e'}$ = 45 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 23 | $R_{e'}$ = 30 | $R_e$ =\|\| elongation |
| **Colour impression** | **(in oil)** | greyish white | whitish yellow | |
| **BR ~ Rpl** | **(in oil)** | distinct | | $A_{oil}$ = 29 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong with colour | strong with colour |
| **Colour:** | **in 45° position** | white-yellow | light yellow – greyish tint yellow |
| | **... in other positions** | yellow brown | brown, bluish grey |
| **Extinction position** | | grey black | |
| **Mode of extinction** | | not perfect, undulatory, patchy | |
| **Internal reflections** | **colour** | -- (pseudo IR due to fine cracks) | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | simple \|\| {011}, twins and triplets | |
| | **frequency** | occasional | |

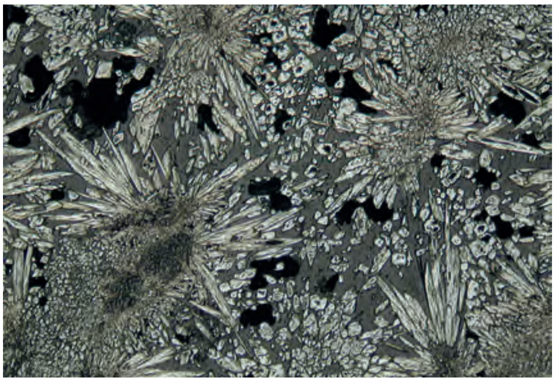
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | coarse-grained euhedral to prismatic XX, finegrained, massive, banded texture; often pseudomorph after manganite (often as relicts), then many cracks \|\| (010). |
| **Paragenesis** | manganomelane, manganite, nsutite, ramsdellite, braunite, hematite |
| **Diagnostic features** | high R (for oxides), paragenesis, parallel cracks |

## Notes, drafts

Typical oxidation product of MANGANITE. $R_o$ of pyrolusite is very similar to R of NSUTITE.
Section ⊥ c (= ⊥ elongation, with $R_o$) is much harder and shows a better polish,
whereas sections || c (= || elongation) seem to reflect much lower due to poor polishing!
→ occasionally $R_o$ in sections ⊥ c is visual higher than $R_e$ and $R_o$ in sections || elongation!
* VHN strongly depends on orientation, polishing, and type of aggregate!

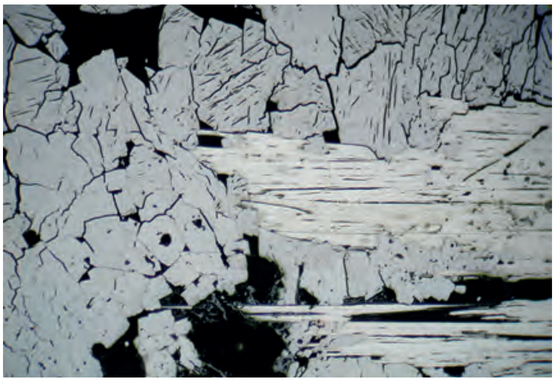
## 445 **Pyrolusite –** Rappenloch, Schwarzwald, Germany



Radial growth of euhedral crystals of pyrolusite (whitish yellow).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D116_09
Section: KH-16

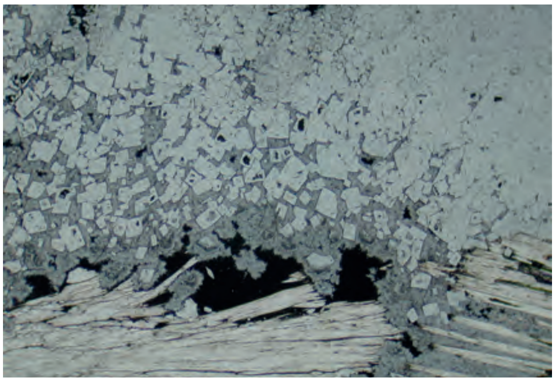
## 446 **Pyrolusite –** Oberröthenbach, Schwarzwald, Germany



Pyrolusite with distinct bireflection from whitish yellow (|| elongation) to greyish white (⊥ longation).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D91_15
Section: IR-19a

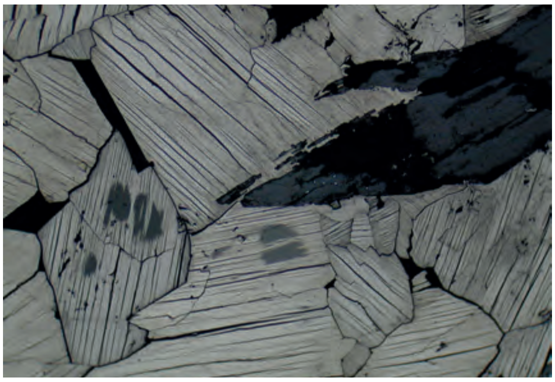
## 447 **Pyrolusite, lithiophorite –** Farallon Negro, Prov. Catamarca, Argentinien



Euhedral pyrolusite crystals surrounded by fine-grained lithiophorite (medium grey). Pyrolusite in the upper part as cross sections with $R_o$, in the lower part longitudinal sections with $R_e$ (colour more yellow).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D143_21
Section: AS225

## 448 **Pyrolusite, manganite, wolframite –** Broken Hill, Australia



Manganite relicts (medium to dark grey) in newly formed pyrolusite (pseudomorph after manganite with typical cracks ||(010)). One large wolframite crystal (dark grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D103_20
Section: AS217

# Pyrostilpnite

**Mineral name:** Pyrostilpnite
**Formula:** $Ag_3SbS_3$

**VHN:** 95-115
**Crystal System:** mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** (for 546 nm) | $R_1 = 29.7$ | $R_2 = 30.1$ | | |
| **$R_{(oil)}$ in %** (for 546 nm) | $R_1 = 14.6$ | $R_2 = 14.8$ | | |
| **Colour impression** (in oil) | grey tint blue | grey tint blue | | |
| **BR ~ Rpl** (in oil) | very weak | | $A_{oil} = 1$ | |

## Observations with crossed polars (AExPol in oil)

| | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|
| **Anisotropism intensity/colour** | very weak without colour | weak without colour |
| **Colour:** in 45° position | grey (masked by IR) | grey (masked by IR) |
| **... in other positions** | | |
| **Extinction position** | black, but masked by IR | |
| **Mode of extinction** | -- | |
| **Internal reflections (IR)** colour | yellow – orange brown | |
| **(IR)** frequency | frequent | |
| **Twinning** mode | lamellar parallel elongation, in part bended | |
| frequency | occasional | |

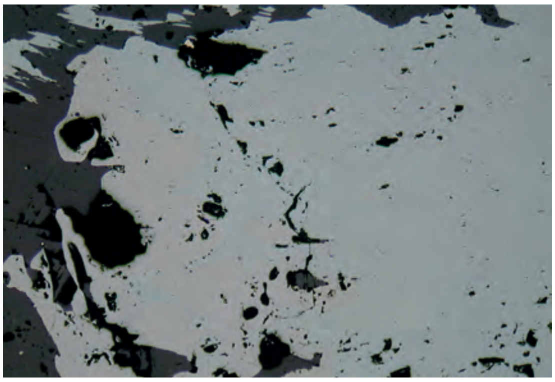
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | tabular, prismatic || [001], sub parallel radiating blade- to needle-like crystals. # || (010) |
| **Paragenesis** | pyrargyrite, miargyrite, silver, other Ag-minerals |
| **Diagnostic features** | IR, #, paragenesis |

## Notes, drafts

trig. modification of $Ag_3SbS_3$ = PYRARGYRITE (with more bluish CI).

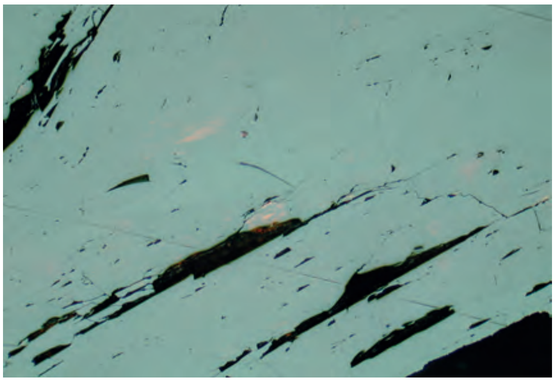
## 449 **Pyrostilpnite, stephanite –** Wenzel mine (?), Schwarzwald, Germany



Pyrostilpnite (right side, grey) in contact with stephanite (left side, grey tint brown).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D126_24
Section: TÜ40

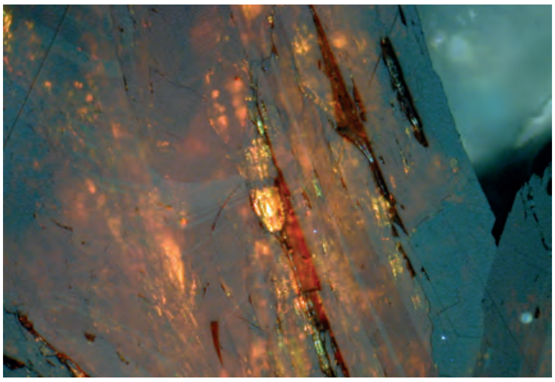
## 450 **Pyrostilpnite –** Wenzel mine (?), Schwarzwald, Germany



Pyrostilpnite laths with some orange IR and good #.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D126_29
Section: TÜ40

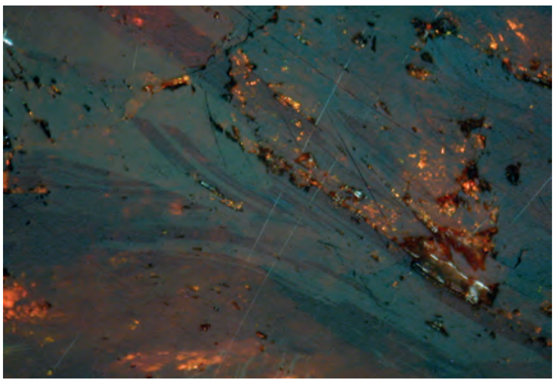
## 451 **Pyrostilpnite –** Wenzel mine (?), Schwarzwald, Germany



As above, with crossed polars. Note weak greyish anisotropism beside light yellow-orange IR.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D126_30
Section: TÜ40

## 452 **Pyrostilpnite –** Wenzel mine (?), Schwarzwald, Germany



Fine lamellar twinning, in part bended.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D126_26
Section: TÜ40

# Pyrrhotite (in German: Pyrrhotin, Magnetkies)

**Mineral name:** Pyrrhotite (po)
**Formula:** $Fe_{1-x}S$ (x = 0.1 - 0.2)
**VHN:** 260-410
**Crystal System:** mcl./hex.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1/R_o$ = 35 to 37 | $R_2/R_{e'}$ = 40 to 42 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1/R_o$ = 23 to 24 | $R_2/R_{e'}$ = 27 to 29 | |
| **Colour impression** | **(in oil)** | white tint yellow brown | cream rose | so called »tombak colour« |
| **BR ~ Rpl** | **(in oil)** | distinct | | $A_{oil}$ = 18 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | distinct without colour | distinct with colour |
| **Colour:** | **in 45° position** | grey | greyish turquoise – greyish red brown |
| | **… in other positions** | | greyish brown – green |
| **Extinction position** | | greyish black | |
| **Mode of extinction** | | incomplete | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | translation twins, and due to inversion | |
| | **frequency** | rare – frequent | |

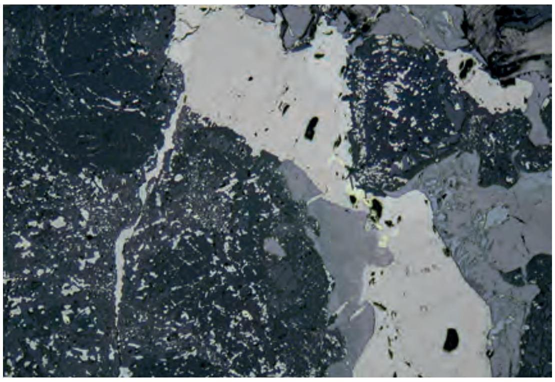
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | anhedral aggregates, distinct # after one direction; often as inclusion in pyrite, supergene bird eyes-formation (hypogene: → mt+py). EB of pn-»flames« |
| **Paragenesis** | py, mrc, cp, cub, mackinawite, pn, mt |
| **Diagnostic features** | CI not easy to describe (»tombak«), #, paragenesis, bird eyes-formation |

## Notes, drafts

»Fresh« troilite (FeS): more yellow brown, slightly higher R, but rapid tarnishing (hours!).
Pyrrhotite grains are often (submicroscopic) lamellar intergrowths of two or more po-subtypes.

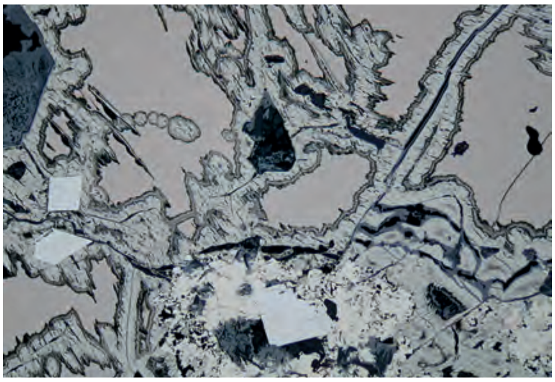
## 453 Pyrrhotite, ilm, rt, graphite – Rimella-Gula, Val Sessia, N-Italy



Late formation of pyrrhotite (brownish cream) replacing gangue minerals and older Fe-Ti-minerals (ilm→rt→ttn) and graphite (upper right part of photo).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D16_19
Section: AS135

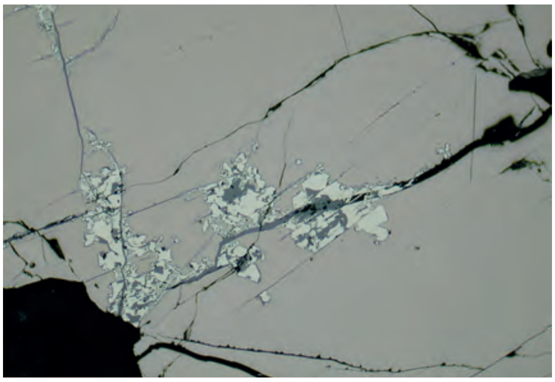
## 454 Pyrrhotite, py, asp – Calamita, Elba, Italy



Typical alteration of pyrrhotite along cracks and cleavage planes leading to the formation of pyrite/marcasite (whitish yellow) plus Fe-sulfates (dark grey). So called »bird eyes structure«. Euhedral arsenopyrite (white) and recrystallized pyrite (yellowish white, lower part of photo).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D14_11
Section: AS1054a

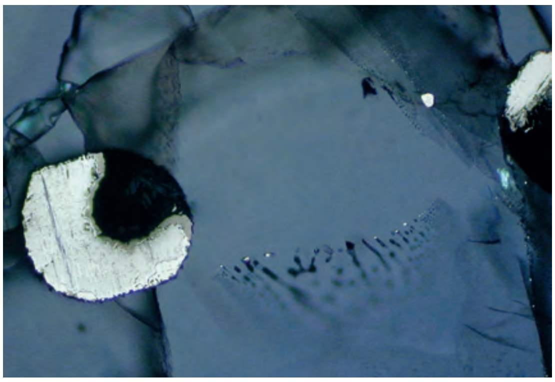
## 455 Pyrrhotite, py, mt – Kropfmühl, Passau, Germany



Beginning transformation/oxidation of pyrrhotite (brownish grey) to pyrite (whitish yellow) plus magnetite (medium grey) following fractures in po.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D90_10
Section: AS1054a

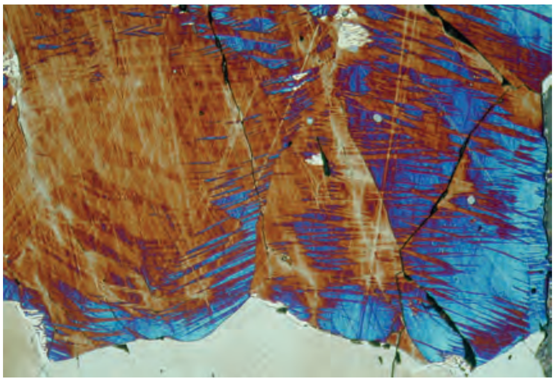
## 456 Pyrrhotite, pn, py, ol – Kunzenbrühl, Urach volcanic field, SW-Germany



Sulfidic melt inclusions in olivine from nephelinitic rock. Former mss is decomposed into pyrrhotite plus pentlandite (as exsolution in po) and minor pyrite (light rim). Note the trail of secondary sulfide melt inclusions (below and right side of large inclusion).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D213_17
Section: Xeno6

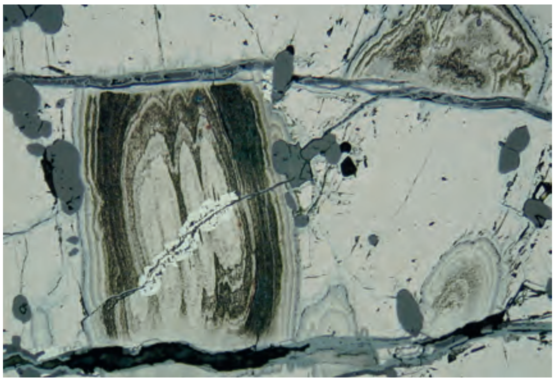
## 457 Pyrrhotite, pn – Victor South Mine, Kambalda, W-Australia



Different tarnishing effects of lamellar pyrrhotite with tiny pentlandites grains and flames at grain boundaries.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D188_24
Section: AS3614

## 458 Pyrrhotite, py – Mte. Frerone, Adamello, Italy



Pyrrhotite with bird-eyes structure and small newly formed pyrite crystals along crack within large bird-eye.

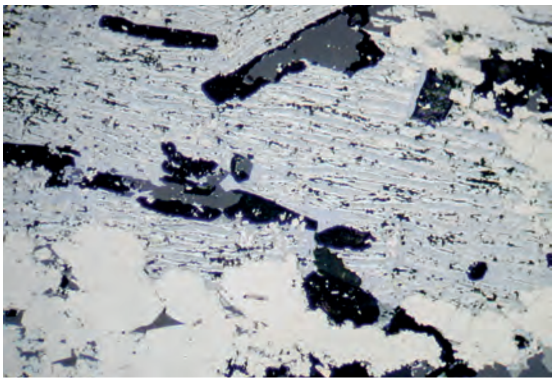
Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D206_25
Section: AS1056

## 459 Sph, po, gn, cp – Broken Hill, Australia

Tiny pyrrhotite exsolution bodies in sphalerite (resembling chalcopyrite disease!). One small veinlet of chalcopyrite (yellow), larger po grains and younger galena (greyish white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D92_28
Section: AS3622

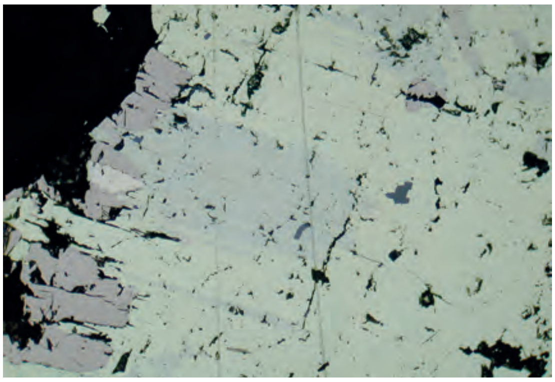
## 460 Po, py, mrc, gn – Wilsbach, Münstertal, Schwarzwald, Germany



Pseudomorph of marcasite (nearly white), galena (greyish white between marcasite) and pyrite (whitish yellow) after large po (small lath as relict in pyrite). The perfect cleavage of former pyrrhotite is still visible giving directions to mrc formation. Galena is the youngest mineral.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D73_07
Section: BO69a

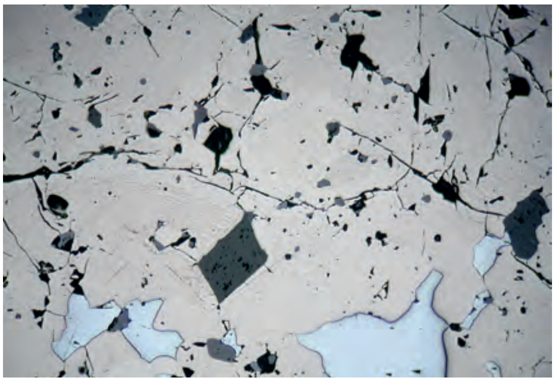
## 461 Pyrrhotite, pn, cp, cub – Phalaborwa, RSA



Pyrrhotite (brown, left side of photo) intergrown with pentlandite (cream) and chalcopyrite (yellow) plus lamellar cubanite (light grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D201_19
Section: MT-33

## 462 Pyrrhotite, gn – Tsumeb, Namibia



Hexagonal pyrrhotite as relicts in monocline pyrrhotite (slightly higher reflectance), in contact with galena (light grey). Digital modified photo with enhanced image contrast.

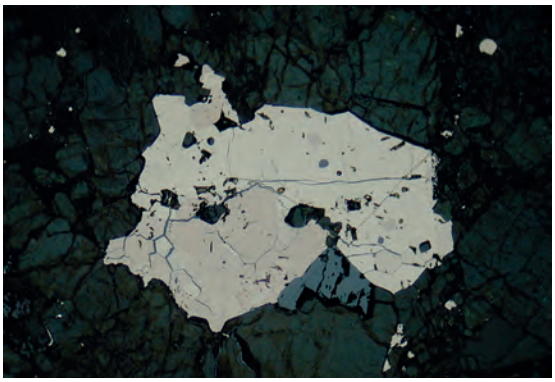
Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D169_26
Section: AS2507

## 463 Troilite, iron, iron oxihydroxides – Meteorite Brahim (pallasite)

Troilite with some darker lamellae beside native iron (white) and iron oxihydroxides (shades of grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D148_23
Section: 9031055

## 464 Troilite, spl – Meteorite (unknown locality)



Large grain of troilite (with visible BR) beside spinel (grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D161_01
Section: Me2677

# Quartz (in German: Quarz)

**Mineral name:** Quartz (qz)
**Formula:** $SiO_2$
**VHN:** 725
**Crystal System:** trig.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 4.6 | $R_e$ = 4.7 | calculated from n |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 0.1 | $R_e$ = 0.1 | calculated from n |
| **Colour impression** | **(in oil)** | »black« (but light IR!) | »black« (but light IR!) | |
| **BR Rpl** | **(in oil)** | -- | | $A_{oil}$ = 0 |

## Observations with crossed polars (AExPol in oil)

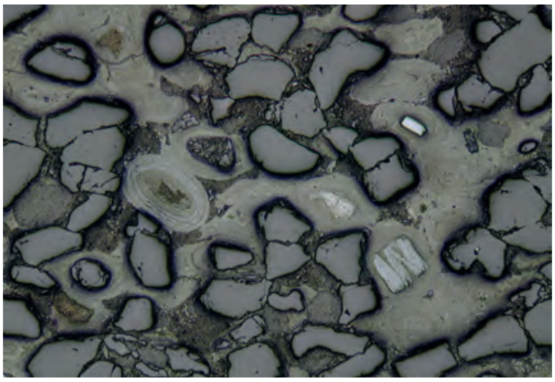
| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | not visible | not visible |
| **Colour:** | **in 45° position** | masked by IR | masked by IR |
| | **... in other positions** | | |
| **Extinction position** | | masked by IR | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | white – colourless | |
| **(IR)** | **frequency** | predominant | |
| **Twinning** | **mode** | none | |
| | **frequency** | -- | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | granular to euhedral, usually with many fluid inclusions; no # |
| **Paragenesis** | barite, fluorite, and many more |
| **Diagnostic features** | low R, no BR, hardness, no #; many fluid inclusions |

## Notes, drafts

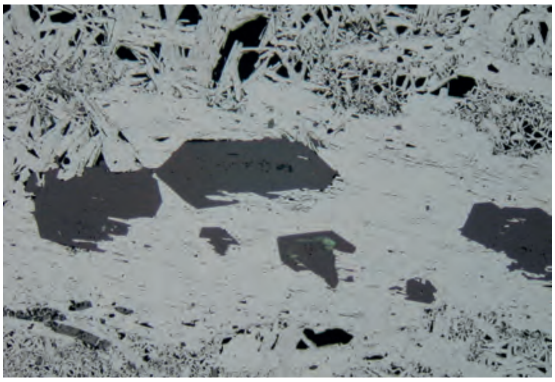
## 465 Quartz, limonite, rutile – Wasseralfingen, Aalen, SW-Germany



Oolitic iron ore with anhedral quartz clasts (note strong relief!) and limonitic ooids. Some ooids formed around cores of rutile (light grey, upper right part) or limonitic clays (medium grey stacks).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D62_32
Section: AS3597

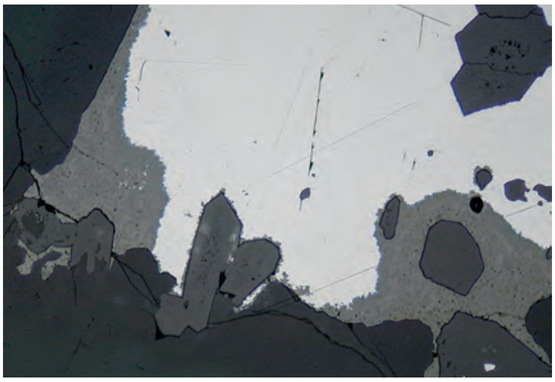
## 466 Quartz, hematite – Mt. Mulga Barite mine, Olary Pr., S-Australia



Euhedral quartz crystals partly replaced by hematite (greyish white).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D01_26
Section: AS3523

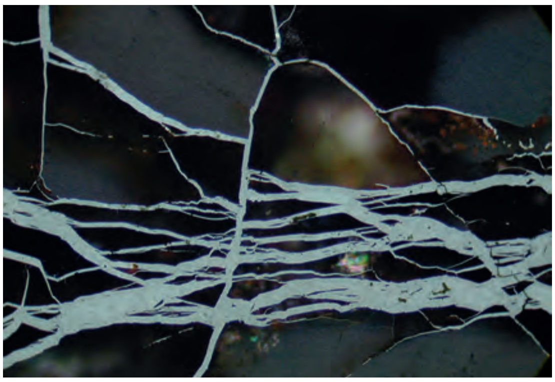
## 467 Quartz, fluorite, cerussite, galena – Jenigi, Egypt



Fluorite (left side and lower part of photo) is overgrown by euhedral quartz crystals (slightly lighter). Replacement of galena (white) by cerussite (medium grey).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D134_16
Section: AS3140

## 468 Quartz, goethite – The Pinnacles, near Broken Hill, NSW, Australia



Goethite crosscutting (not replacing!) fractured quartz grains (grey to black with light IR).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D67_05
Section: AS3525

# Rammelsbergite

**Mineral name:** Rammelsbergite (ram)
**Formula:** $NiAs_2$

**VHN:** 630-760
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1 = 56.8$ | $R_2 = 60.9$ | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1 = 43.1$ | $R_2 = 48.1$ | |
| **Colour impression** | **(in oil)** | white, impure (rose) | white | |
| **BR ~ Rpl** | **(in oil)** | weak | | $A_{oil} = 11$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | distinct with colour | distinct with colour |
| **Colour:** | **in 45° position** | greyish blue | greenish grey – blue – yellow brown |
| | **... in other positions** | | colourful |
| **Extinction position** | | impure grey | |
| **Mode of extinction** | | not perfect, undulatory | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | polysynthetic after more than one direction; also simple twins | |
| | **frequency** | abundant; frequent | |

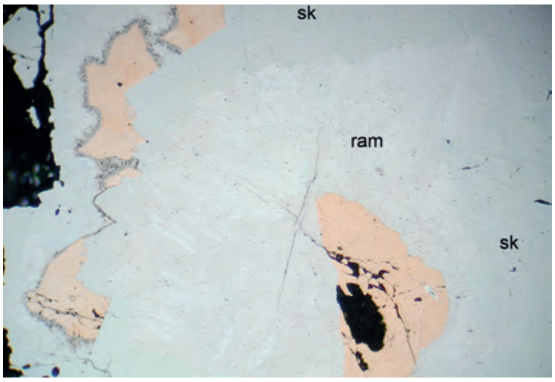
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | often as interlocked grains (< 1mm);<br>rare visible zoning (Ni – Co,Fe) |
| **Paragenesis** | Co-Ni-arsenides, bismuth |
| **Diagnostic features** | twinning, high R |

## Notes, drafts

Similar to PARARAMMELSBERGITE.

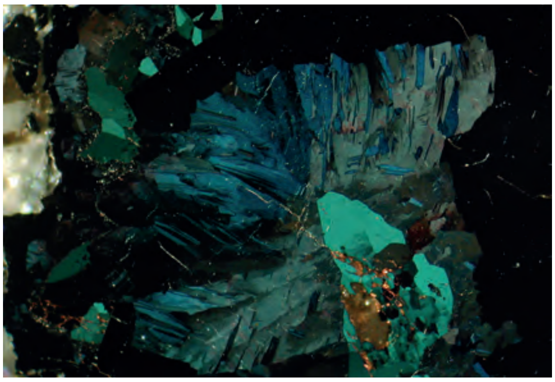
## 469 Rammelsbergite, nk, sk – Nentershausen, Richelsdorfer Gebirge, Germany




Rammelsbergite (ram; weak BR due to fine polysynthetic twinning) and skutterudite (sk) around older nickeline (orange). Rim of younger nickeline followed by outer rim of rammelsbergite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D142_07
Section: AS163

## 470 Rammelsbergite, nk, sk – Nentershausen, Richelsdorfer Gebirge, Germany



As above, with crossed polars (Not precisely crossed!). Here rammelsbergite shows greenish blue colours, whereas nickeline is turquoise.

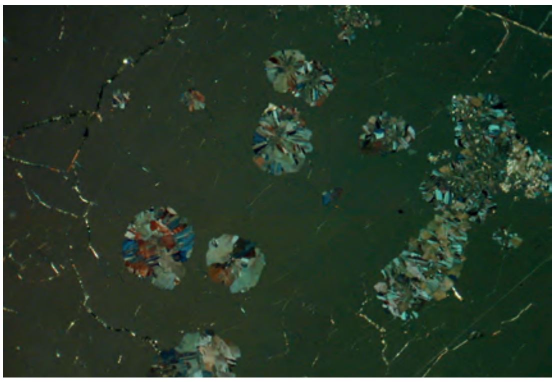
Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D142_09
Section: AS163

## 471 Rammelsbergite – Nieder-Beerbach, Odenwald, Germany

Characteristic lamellar twinning of rammelsbergite and anisotropism colours of brown and blue.

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D44_17
Section: AS1573

## 472 Rammelsbergite, skutterudite – Nieder-Beerbach, Odenwald, Germany



Spherical aggregates of rammelsbergite (vivid colours; twins) in skutterudite (dark).

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D44_24
Section: AS1573

# Ramsdellite

**Mineral name:** Ramsdellite
**Formula:** γ-$MnO_2$

**VHN:** ~ 100-1200*
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ ~ 40 | $R_2$ ~ 22 | estimated |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ ~ 25 | $R_2$ ~ 9 | estimated |
| **Colour impression** | **(in oil)** | greyish white | grey tint olive | |
| **BR ~ Rpl** | **(in oil)** | very strong | | $A_{oil}$ = 94 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong with colour tint | strong with colour tint |
| **Colour:** | **in 45° position** | white tint yellow | white tint yellow – white tint rose |
| | **... in other positions** | near ext.: violet tint | violet tint |
| **Extinction position** | | greyish black | |
| **Mode of extinction** | | not perfect, rare undulatory | |
| **Internal reflections** | **colour** | red | |
| **(IR)** | **frequency** | very rare | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

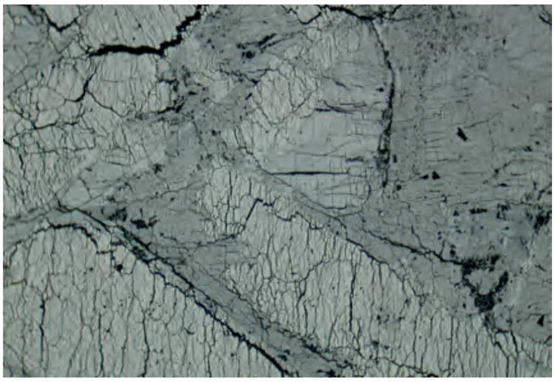
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | many crevasses, often replaced by pyrolusite |
| **Paragenesis** | pyrolusite, manganomelane, manganite, nsutite |
| **Diagnostic features** | paragenesis, BR, AExPol with violet tint |

## Notes, drafts

R distinct lower than R of (similar) PYROLUSITE.
* VHN strongly depends on orientation, polishing and type of aggregate!

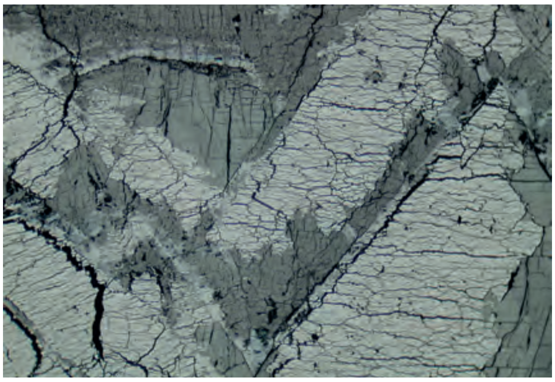
## 473 Ramsdellite, pyrolusite – Mistake mine, Arizona, USA



Replacement of pyrolusite (whitish yellow) by ramsdellite (medium grey, $R_{max}$).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D13_17
Section: AS132

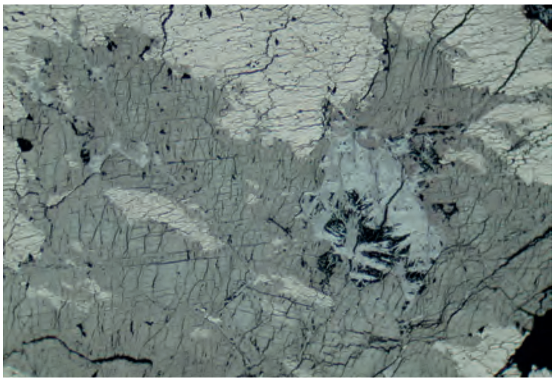
## 474 Ramsdellite, pyrolusite – Mistake mine, Arizona, USA



As above, 90° rotated. Ramsdellite now dark with $R_{min}$.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D13_16
Section: AS132

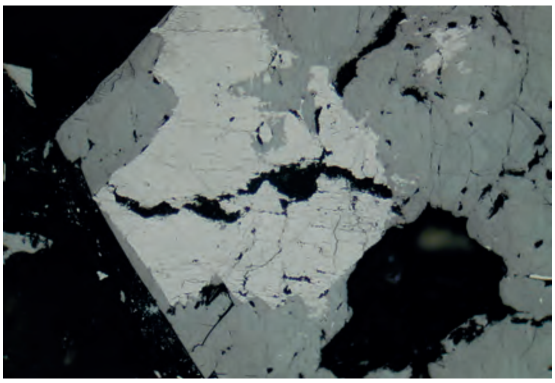
## 475 Ramsdellite, pyrolusite, manganomelane – Mistake mine, Arizona, USA



Pyrolusite, ramsdellite (medium grey), and newly formed manganomelane fibres (light grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D13_18
Section: AS132

## 476 Ramsdellite, pyrolusite – Mistake mine, Arizona, USA



Strong contrast of reflectance between pyrolusite (whitish yellow) and ramsdellite (medium grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D13_19
Section: AS132

# Realgar

**Mineral name:** Realgar (rlg)
**Formula:** $As_4S_4$

**VHN:** 50-60
**Crystal System:** mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_a$ = 19(*) | $R_c$ = 21(*) | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_a$ = 6.4(*) | $R_c$ = 8(*) | |
| **Colour impression** | **(in oil)** | grey (tint red) | grey (tint blue) | |
| **BR > Rpl** | **(in oil)** | distinct | | $A_{oil}$ = 22 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | masked by IR – not visible | masked by IR – not visible |
| **Colour:** | **in 45° position** | masked by IR | masked by IR |
| | **… in other positions** | | |
| **Extinction position** | | masked by IR | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | yellow-red | |
| **(IR)** | **frequency** | abundant | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

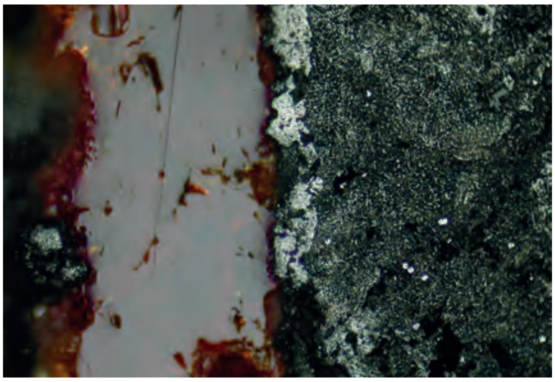
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | granular aggr., crusts, and euhedral; replaced by and oriented intergrowths with orpiment |
| **Paragenesis** | orpiment, arsenic, stibnite, marcasite, asp, lorandite, tennantite, loellingite |
| **Diagnostic features** | paragenesis, IR |

## Notes, drafts

(*) R calculated from $n_a$ and $n_c$ (2.538, and 2.704, resp.)

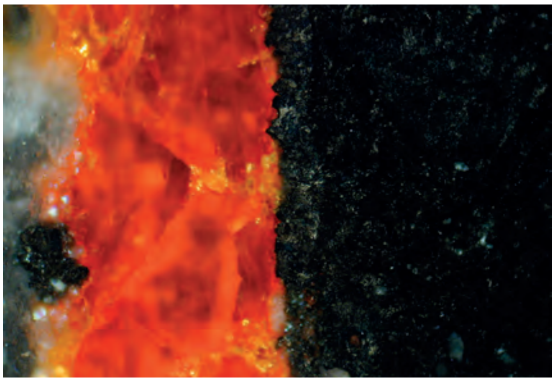
## 477 **Realgar, arsenic –** Michael im Weiler, Schwarzwald, Germany



Massive realgar beside native arsenic (in part strongly tarnished).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D125_16
Section: BW102

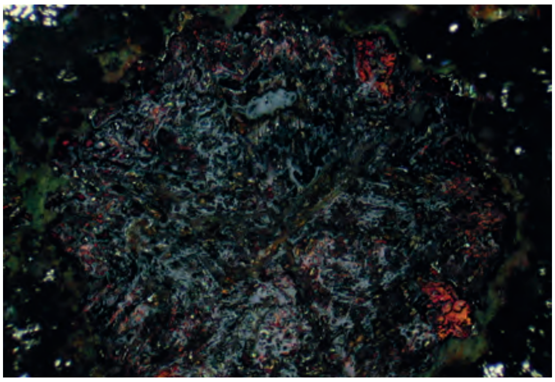
## 478 **Realgar, arsenic –** Michael im Weiler, Schwarzwald, Germany



As above, with crossed polars.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D125_17
Section: BW102

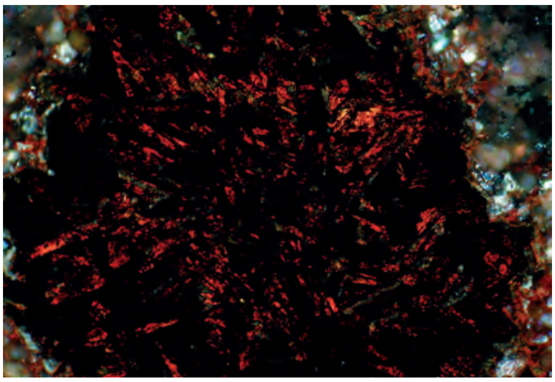
## 479 **Realgar, arsenic –** Allchar, S-Macedonia



Realgar pseudomorph after native arsenic.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D194_26
Section: AS108

## 480 **Realgar, arsenic –** Allchar, S-Macedonia



As above, with crossed polars.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D100_03
Section: AS108

# Rutile

**Mineral name:** Rutile (rt)
**Formula:** $TiO_2$
**VHN:** 900-980
**Crystal System:** tetr.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 19.7 | $R_{e'}$ = 23.1 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 6.9 | $R_{e'}$ = 9.3 | |
| **Colour impression** | **(in oil)** | grey | light grey (tint blue) | |
| **BR ~ Rpl** | **(in oil)** | strong | | $A_{oil}$ = 29 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | weak without colour | distinct without colour |
| **Colour:** | **in 45° position** | grey | grey – grey |
| | **... in other positions** | | |
| **Extinction position** | | often masked by IR | |
| **Mode of extinction** | | straight | |
| **Internal reflections** | **colour** | white (Fe-poor) – yellow orange – brown red (Fe-rich) | |
| **(IR)** | **frequency** | abundant – common – occasional | |
| **Twinning** | **mode** | polysynthetic after more than 1 direction; and coarse | |
| | **frequency** | common | |

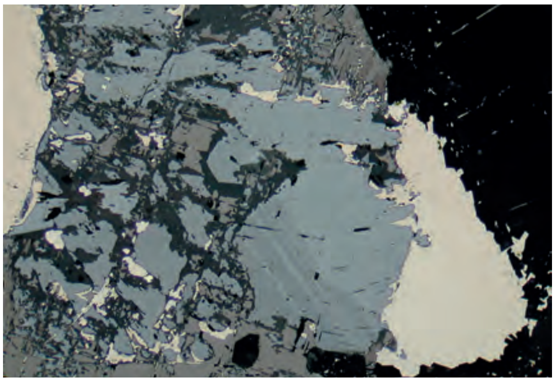
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | often anhedral crystals; as fine-grained product of ilmenite alteration (»leucoxene«); mt/ilm decomposition → hematite + rutile (blitz-texture) |
| **Paragenesis** | ilm, hm, ttn, garnet, biotite, amphibole |
| **Diagnostic features** | BR, twinning; anatase has $R_{min}$ \|\| c-axis |

## Notes, drafts

Rutile is (meta-)stable at nearly all p/T-conditions!
In contrast to ANATASE, rutile has strong BR and $R_e > R_o \rightarrow R_{max}$ || c.

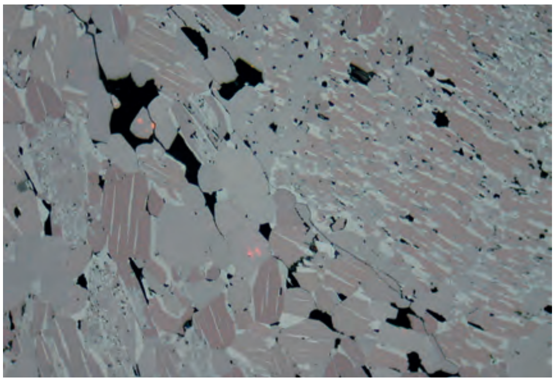
## 481 Rutile, ilm, ttn, po – Rimella-Gula, Val Sessia, Italy



Rutile (grey, with lamellar twinning) is replacing older ilmenite (brownish grey); titanite (dark grey) between ilm and rt; younger pyrrhotite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D16_23
Section: AS135

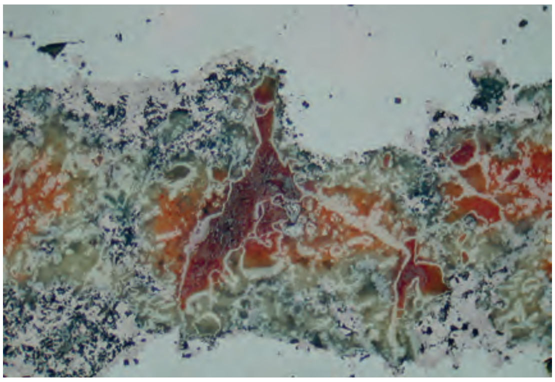
## 482 Rutile, hm, ilm – Radium Hill, Olary, S-Australia



Mixture of rutile (medium grey) and hematite-ilmenite (brown grains - BR! - with light grey exsolution bodies of hematite). Central rutile grain shows red internal reflection.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D01_30
Section: AS3519

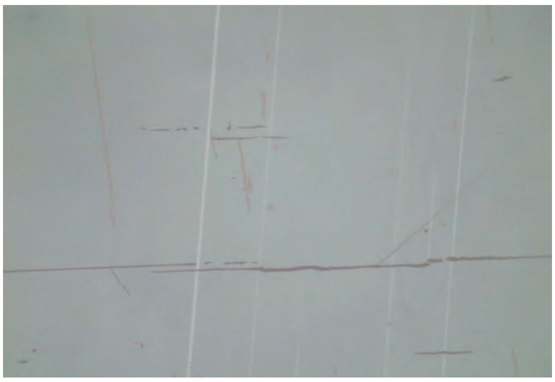
## 483 Rutile, ilm, anatase – Neils Valley, Jos Plateau, Nigeria



Ilmenite (brownish grey) cross-cutting rutile (upper and lower part of photo). Ilmenite is transformed into a mixture of fine-grained rutile, anatase, and goethite (so called "leucoxene").

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D23_19
Section: AS134

## 484 Rutile, ilm – Neils Valley, Jos Plateau, Nigeria



Rutile with small twins (N-S, grey – light grey) and exsolution lamellae of ilmenite (E-W and N-S, brownish grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D23_25
Section: AS134

# Safflorite

**Mineral name:** Safflorite
**Formula:** $(Co,Ni,Fe)As_2$

**VHN:** 790-880
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 54.1 | $R_2$ = 54.6 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 39.6 | $R_2$ = 40.2 | |
| **Colour impression** | **(in oil)** | white tint yellow | white tint blue | |
| **BR < Rpl** | **(in oil)** | weak | | $A_{oil}$ = 1.5 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | weak with colour tint | distinct with colour |
| **Colour:** | **in 45° position** | grey tint yellow | greyish yellow – greyish blue |
| | **… in other positions** | grey tint blue or brown | blue, orange brown |
| **Extinction position** | | greyish black | |
| **Mode of extinction** | | not perfect, patchy | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | needle-like, very often as star-like triplets | |
| | **frequency** | abundant | |

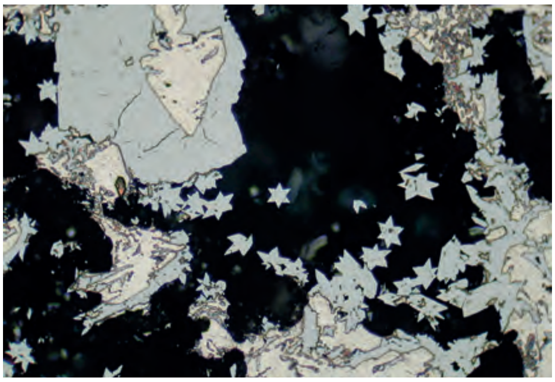
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | needle-like, prismatic, diamond-shaped, very often flame-like zoning; # distinct \|\|{100} |
| **Paragenesis** | Co-Ni-arsenides, bismuth |
| **Diagnostic features** | star-like triplets, flame-like zoning (AExPol) |

## Notes, drafts

The safflorite-structure stabilisation always requires the incorporation of Ni and Fe. Pure $CoAs_2$ is clinosafflorite (mcl., $R_{oil}$: 39-41 %; $A_{oil}$: 4.8). Similar to LOELLINGITE and ARSENOPYRITE.

## 485 Safflorite, bismuth, sk – Boulder from the Dom-Insel, Wrocław, Poland



Typical star-like triplets of safflorite. Native bismuth (light cream with pores) in skutterudite (upper left part of photo).

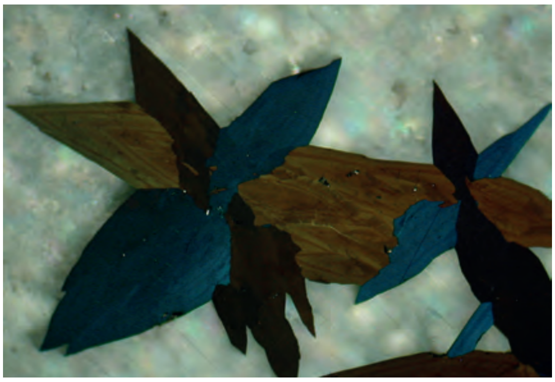
Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D86_12
Section: AS3515

## 486 Safflorite – Mackenheim, Odenwald, Germany

Star-like twinned safflorite with distinct refection pleochroism; small inclusion of bismuth in safflorite (left side).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D147_01
Section: CHe5

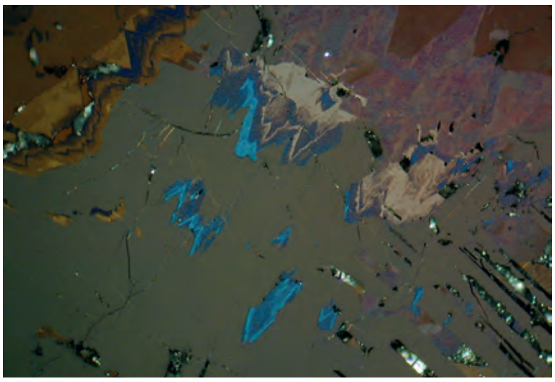
## 487 Safflorite, calcite – Mackenheim, Odenwald, Germany



Triplets of safflorite under not perfect crossed polars showing yellow brown and blue AExPol and faint flame-like zoning. Matrix: calcite.

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D146_26
Section: CHe23

## 488 Safflorite, skutterudite – Boussmasse, Bou Azzer, Morocco



Flame-like zoning in safflorite (bluish and yellow brown) partly replaced by skutterudite.

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D89_26
Section: AS3571

# Scheelite

**Mineral name:** Scheelite (sch)
**Formula:** $CaWO_4$
**VHN:** ~ 400
**Crystal System:** tetr.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 9.8 | $R_{e'}$ = 10.1 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 1.4 | $R_{e'}$ = 1.5 | |
| **Colour impression** | **(in oil)** | grey | grey | |
| **BR Rpl** | **(in oil)** | not visible | | $A_{oil}$ = 0 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | not visible (IR) | not visible (IR) |
| **Colour:** | **in 45° position** | masked by IR | masked by IR |
| | **... in other positions** | | |
| **Extinction position** | | masked by IR | |
| **Mode of extinction** | | masked by IR | |
| **Internal reflections** | **colour** | white – colourless – yellow | |
| **(IR)** | **frequency** | predominant | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | replaces wolframite (and vice versa), anhedral grains; good # {111} |
| **Paragenesis** | wolframite, asp, po, bismuth, molybdenite, Mn-oxides |
| **Diagnostic features** | paragenesis, UV-active |

## Notes, drafts

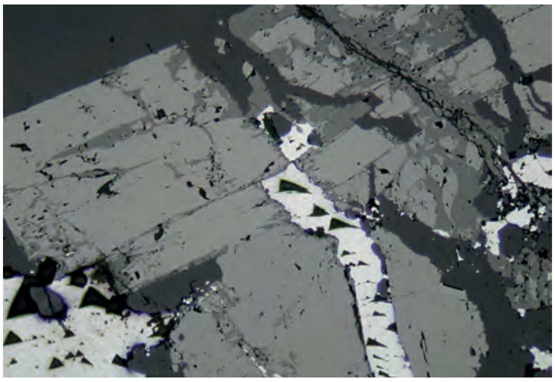
»gangue mineral optic«, thus often overlooked!

## 489 Scheelite, wolframite – Vignola-Falensina, Val Sugana, Trento, Italy

Large crystal of wolframite (medium grey) partly replaced by scheelite (left and lower side of photo; dark grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D64_07
Section: AS3583

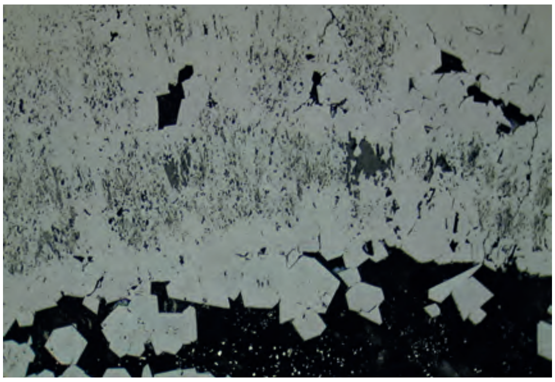
## 490 Scheelite, wolframite, gn – Vignola-Falensina, Val Sugana, Trento, Italy



Replacement of wolframite crystals (light grey) by scheelite (medium grey). Younger veinlet of galena (white).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D64_01
Section: AS3583

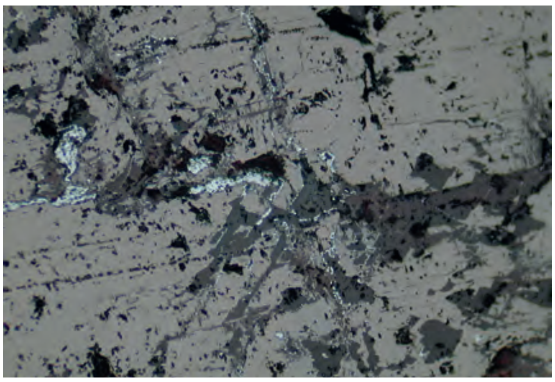
## 491 Scheelite, braunite – Silberbrünnle, Gengenbach, Schwarzwald, Germany



Small inclusions of anhedral to elongated scheelite (dark grey) in braunite (medium grey).

Obj.: 20 × oil
Polars: ||Pol
Photo width: 0.7 mm
Photo No.: D149_05
Section: AS3337

## 492 Scheelite, wf, hm – Eggberg, Bad Säckingen, Schwarzwald, Germany



Large crystal of wolframite (medium grey) partly replaced by scheelite (dark grey) plus hematite (nearly white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D196_05
Section: AS8413

# Siderite

**Mineral name:** Siderite (sid)
**Formula:** $FeCO_3$
**VHN:** ~ 190
**Crystal System:** trig.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 9.3 | $R_e$ = 5.5 | calculated from n |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 1.1 | $R_e$ = 0.1 | calculated from n |
| **Colour impression** | **(in oil)** | grey | black | |
| **BR > Rpl** | **(in oil)** | extremely strong | | $A_{oil}$ = 166 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong without colour | strong without colour |
| **Colour:** | **in 45° position** | light grey | light grey |
| | **… in other positions** | predominant IR | predominant IR |
| **Extinction position** | | masked by IR | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | white – yellow brown | |
| **(IR)** | **frequency** | predominant | |
| **Twinning** | **mode** | polysynthetic | |
| | **frequency** | occasional | |

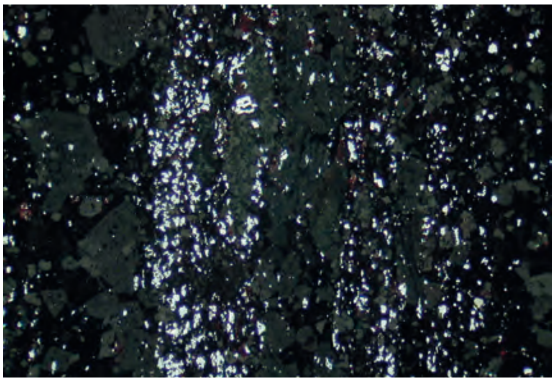
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | typical rhombohedral habit; often altered to Fe-oxihydroxides (limonite) along cleavage planes; perfect # |
| **Paragenesis** | goethite, hematite, other carbonates |
| **Diagnostic features** | #, paragenesis |

## Notes, drafts

Carbonate with strongest BR!

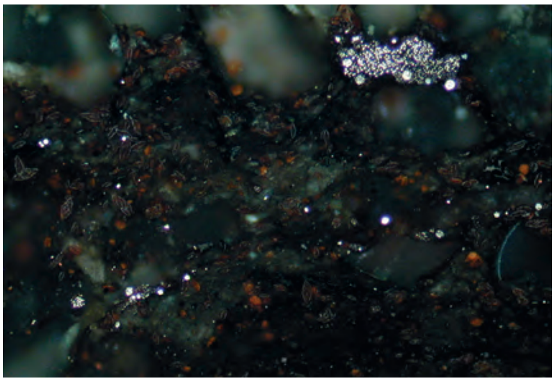
## 493 Siderite, hematite – Mamatwan mine, Kuruman, RSA



Idioblastic siderite crystals (medium grey) with iron silicates, quartz, and hematite (whitish grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D17_15
Section: M4

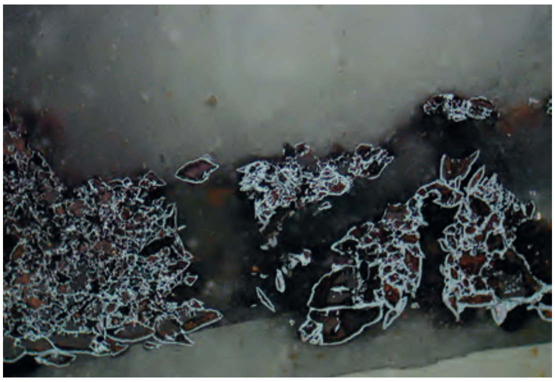
## 494 Siderite, pyrite – Wasseralfingen, Aalen, Germany



Siderite-rich layer with framboidal pyrite plus goethite; rounded quartz grains in the upper part.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D79_13
Section: Aa26

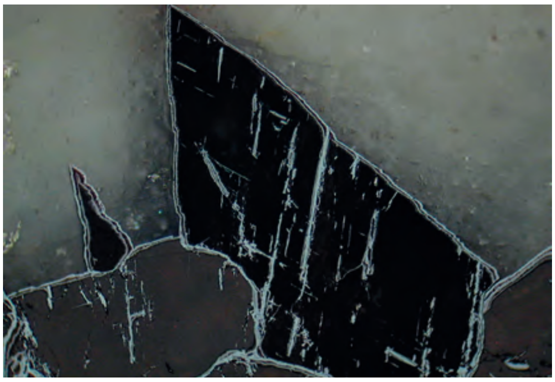
## 495 Siderite, limonite – Feld »Ludwig«, Hundsdorf, Kellerwald, Germany



Lenticular siderites rimmed and replaced by limonite (light grey). Milky quartz in upper and lower part of photo.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D96_11
Section: AS165

## 496 Siderite, limonite – Feld »Ludwig«, Hundsdorf, Kellerwald, Germany



Alteration of siderite (very strong BR!) along cleavage planes by limonite. Quartz in upper left and right part of photo.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D96_10
Section: AS165

# Silver (in German: ged. Silber)

**Mineral name:** Silver
**Formula:** Ag

**VHN:** 60-70
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in % (for 546 nm)** | with 0.9 % Sb: R = 93 | with 4 % Sb: R = 86 | |
| **$R_{(oil)}$ in % (for 546 nm)** | " R = 91 | " R = 81 | |
| **Colour impression (in oil)** | white | white | tarnishing! |
| **BR Rpl (in oil)** | -- | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|
| **Anisotropism intensity/colour** | anisotropism due to scratches | anisotropism due to scratches |
| **Colour: in 45° position** | many light scratches (»Kratzeranisotropie«) | homogeneous light grey with many scratches |
| **... in other positions** | | |
| **Extinction position** | -- | |
| **Mode of extinction** | -- | |
| **Internal reflections (IR) colour** | -- | |
| **frequency** | -- | |
| **Twinning mode** | -- | |
| **frequency** | -- | |

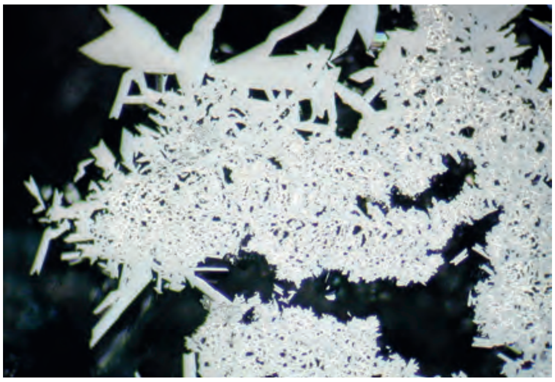
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | dendritic aggregates, skeletal crystals, cubes; fine-grained aggregates |
| **Paragenesis** | acanthite, fahlore, cp, allargentum, Co-minerals |
| **Diagnostic features** | very high R, rapid tarnishing, many scratches, poor polishing |

## Notes, drafts

Rapid tarnishing (to yellow, reddish, brown)!

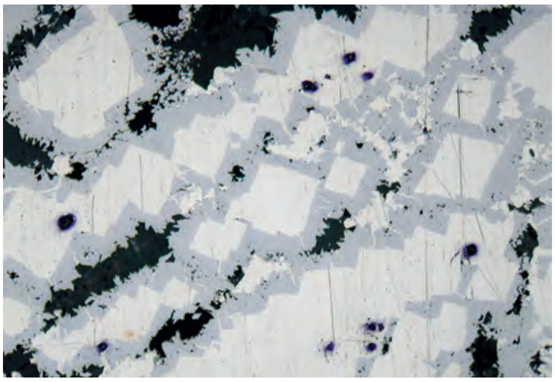
## 497 Silver, safflorite – Nieder-Beerbach, Odenwald, Germany



Silver (white) in sponge-like intergrowth with safflorite (greyish white with Rpl).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D145_07
Section: CHe 26a

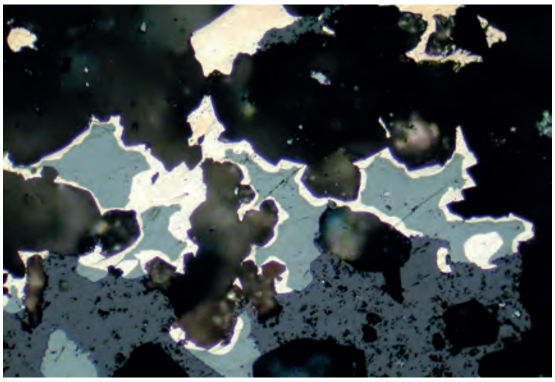
## 498 Silver, safflorite – Nieder-Beerbach, Odenwald, Germany



Skeletal silver as linear array of silver cubes (white) with interconnecting tiny silver veinlets in safflorite (whitish grey).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D146_12
Section: CHe26b

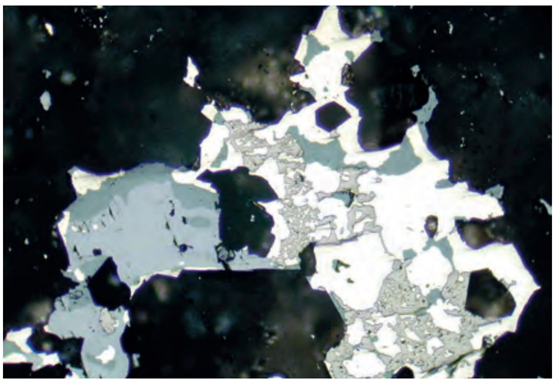
## 499 Silver, akanthite, sphalerite – Imiter, Morocco



Silver (white) overgrowing and replacing argentite (medium grey). Both replaced by sphalerite (dark grey, bottom of photo).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D181_20
Section: IM1308

## 500 Silver, argentite, galena, asp – Imiter, Morocco



Anhedral silver (nearly white) replacing arsenopyrite (dull greyish yellow relicts) and argentite (dark greenish grey). Galena (grey, left side of photo) is replaced by argentite (darker greenish grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D177_22
Section: IM1308

# Skutterudite

**Mineral name:** Skutterudite – Ni-Skutterrudite (sk)
**Formula:** $(Co,Ni,Fe)As_3$
**VHN:** 600-900
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | R = 54 to 56 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | R = 39 to 41 | |
| **Colour impression** | **(in oil)** | white tint cream | |
| **BR Rpl** | **(in oil)** | -- | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | homogeneous dark | isotropic,<br>some with weak anisotropism |
| **Colour:** | **in 45° position** | greyish black | medium grey |
| | **... in other positions** | occasionally greyish AExPol | |
| **Extinction position** | | black | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | often euhedral with fine zoning (varying Co-Ni-Fe); occasionally cracks due to breakdown of High-T-solid solution.<br>Alteration zones are strongly anisotropic! |
| **Paragenesis** | nickeline, bismuth, pararammelsbergite, and many more |
| **Diagnostic features** | very fine zoning, habit |

## Notes, drafts

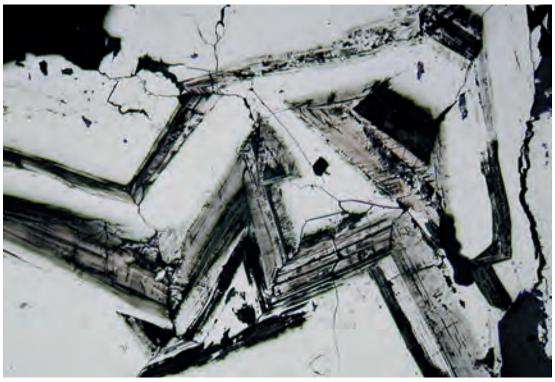
No As-deficiency (Schumer et al. (2017): AM102, 205-209). Zoned skutterudites formerly named »Speis-kobalt«. Solid solutions forming large XX with very fine, delicate zoning (differences in hardness, selective replacement).
Ferroskutterudite (with 5-8 wt. % Fe): $R_{air}$ = 57 % (Spiridonov & Gritsenko (2007), New Data on Minerals. Moscow, 42, 16-27).

## 501 Skutterudite, cobaltite, Bi, safflorite – Schneeberg, Saxony, Germany

Cubic crystal of skutterudite with cross-like inclusion of cobaltite plus bismuth. Safflorite crusts on bismuth.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D82_02
Section: AS1762

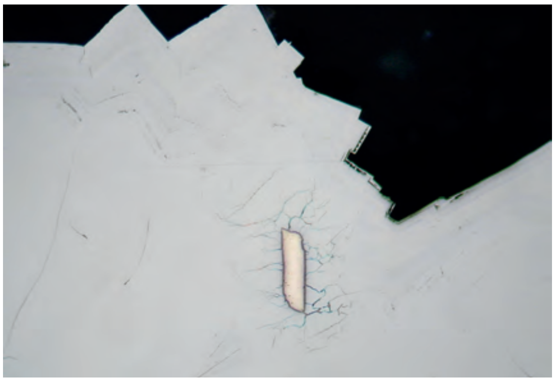
## 502 Skutterudite – Mackenheim, Odenwald, Germany



Zoned skutterudite crystals with selective zonal alteration features.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D147_10
Section: CHe4

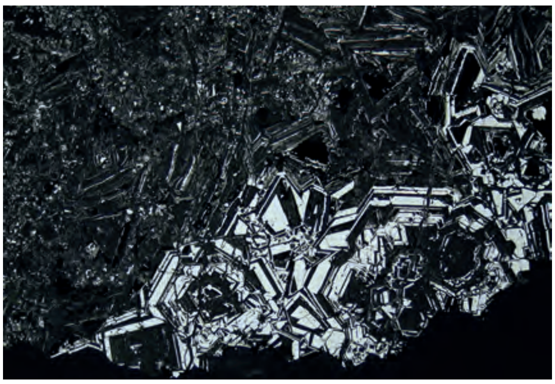
## 503 Skutterudite, bismuth – Neuglück, Wittichen, Schwarzwald, Germany



Zoned skutterudite with inclusion of bismuth (note cracks around bismuth). Digital modified photo with enhanced image contrast!

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D31_27
Section: TÜ9

## 504 Skutterudite, cb, qz – Bauhaus near Nentershausen, Richelsdorf, Germany



Sharp selective replacement of zoned skutterudite by gangue minerals (carbonate, quartz).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D144_21
Section: AS162

# Sphalerite (in German: Sphalerit, Zinkblende)

**Mineral name:** Sphalerite (sph)
**Formula:** (Zn,Fe)S
**VHN:** 200-220
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 17.0 | | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 5.0 | with 13 % Fe: 5.4 % | with 2.6 % Cd: 4.7 % |
| **Colour impression** | **(in oil)** | grey | | |
| **BR Rpl** | **(in oil)** | -- | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | homogeneous dark | homogeneous dark |
| **Colour:** | **in 45° position** | black or masked by IR | black or masked by IR |
| | **… in other positions** | | |
| **Extinction position** | | -- | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | white – yellow green – red brown – dark brown (with increasing Fe-content) | |
| **(IR)** | **frequency** | abundant – common – occasional – rare | |
| **Twinning** | **mode** | polysynthetic twinning (rarely observable on the basis of R/IR) | |
| | **frequency** | common | |

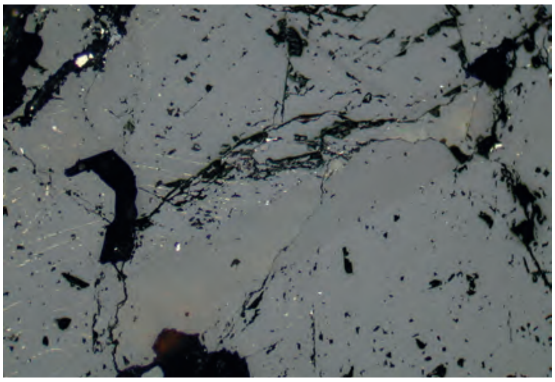
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | often in anhedral aggregates; chalcopyrite inclusions (chalcopyrite-disease); EB of stannite, pyrrhotite, cubanite. |
| **Paragenesis** | gn, cp, po, py, stannite, marcasite, wurtzite |
| **Diagnostic features** | chalcopyrite-disease, paragenesis |

## Notes, drafts

R depends on Fe-content (Fe-poor sphalerite has lower R and more light IR).
FeS-content of sphalerite can be used as geobarometer but only in paragenesis (!) with pyrrhotite + pyrite.
CHALCOPYRITE-DISEASE: Tiny inclusion of cp in sph (due to an infiltration of Cu-fluids in Fe-bearing sphalerite).
SCHALENBLENDE: see under WURTZITE.

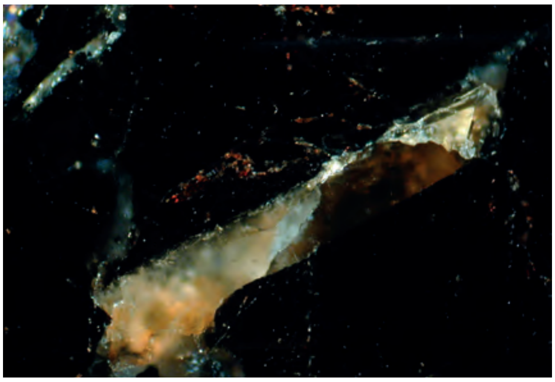
## 505 Sphalerite I + II, cp – Elisabeth mine, Pfunderer Berg, Tyrol, Italy



Aggregate of sphalerite I (grey) with »chalcopyrite disease« (left side of photo). Note the central part of sphalerite with no chalcopyrite inclusions and slightly lower reflectance (= Fe-poor sphalerite II).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D46_28
Section: AS3576

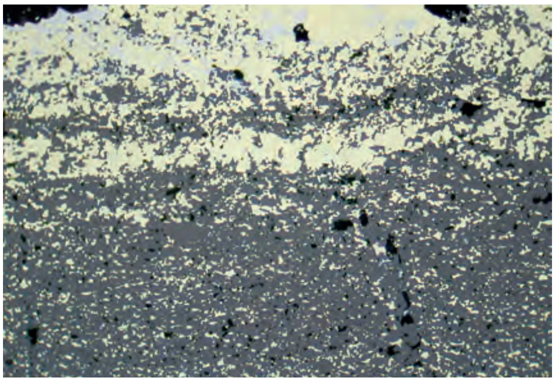
## 506 Sphalerite I + II, cp – Elisabeth mine, Pfunderer Berg, Tyrol, Italy



As above, with crossed polars. The central part with sphalerite II shows lighter and much more internal reflections (due to Fe-poor composition) than the surrounding sphalerite I with few brown IR.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D46_27
Section: AS3576

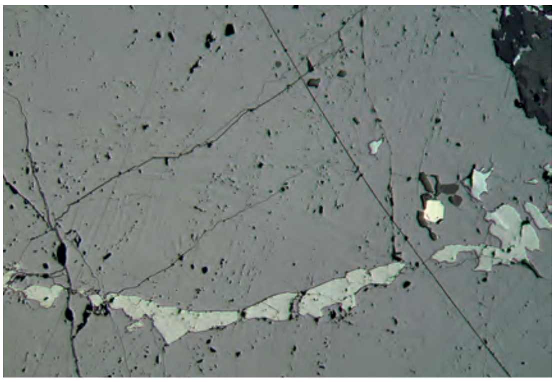
## 507 Sphalerite, gn, cp – Rammelsberg, Harz, Germany



Typical fine-grained ore from Rammelsberg with galena (nearly white), chalcopyrite (yellow) and sphalerite (grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D37_25
Section: AS3507

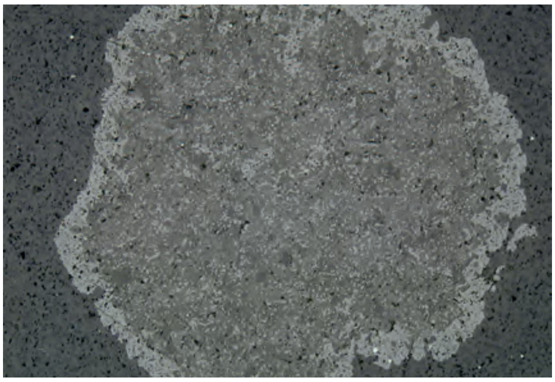
## 508 Sphalerite, fahlore, py – Fort Steel Mining Distr., B. C., Canada



Lamellar twinning of sphalerite! Visible only due to differences in polishing hardness and slightly inclined (!) mounting of the polished section. Small vein of fahlore (greenish grey), one pyrite.

Obj.: 5 ×
Polars: || Pol
Photo width: 2.8 mm
Photo No.: D09_06
Section: AS1744

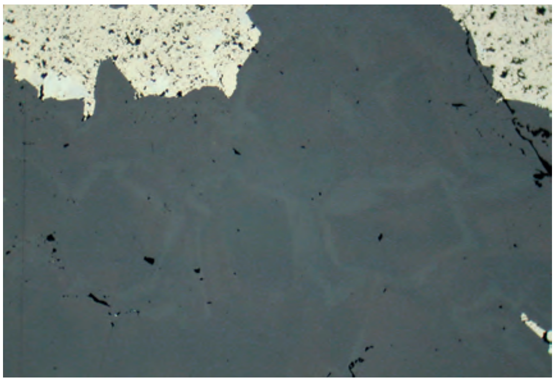
## 509 Sphalerite, carbonate – Dörrenzimmern, S-Schwarzwald, Germany



Poikiloblast of sphalerite in matrix of fine-grained carbonate.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D80_04
Section: DK II 47

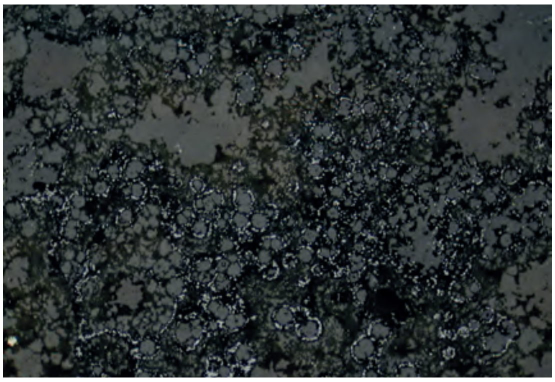
## 510 Sphalerite, py – Jachimov (Joachimsthal), Czech Republic



Compact aggregate of zoned sphalerite grains with dark cores and slightly lighter rims; pyrite (whitish yellow).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D156_24
Section: AS3629

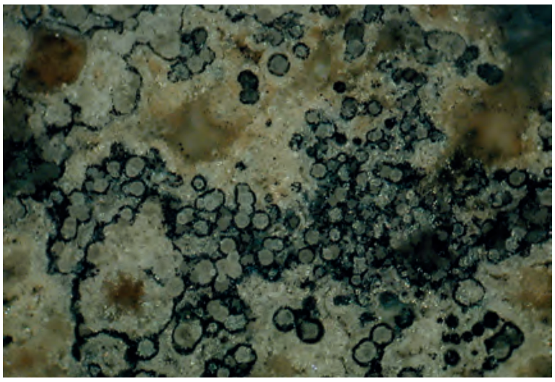
## 511 Sphalerite, gn, carbonate – Tara mine, Navan, Ireland



Fine-grained rounded aggregates of sphalerite (medium grey) rimmed by galena (white) in groundmass of carbonates (dark grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D83_18
Section: AS3596

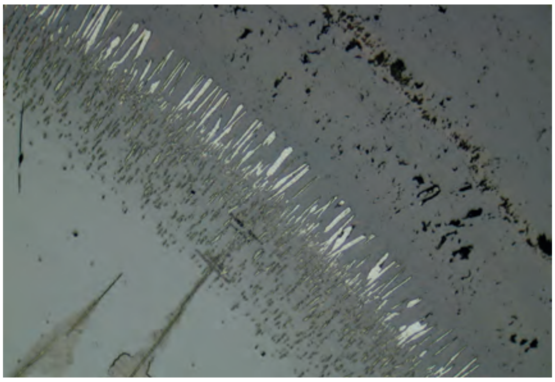
## 512 Sphalerite, gn, carbonate – Tara mine, Navan, Ireland



As above, with crossed polars. Note light yellow to colourless internal reflections of sphalerite due to the very low iron content.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D83_17
Section: AS3596

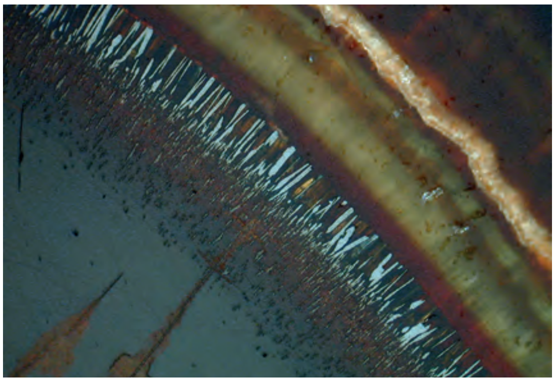
## 513 Sphalerite, wurtzite, jordanite – Michael im Weiler, Schwarzwald, Germany



Schalenblende: Rhythmic collomorph texture of sphalerite/wurtzite aggregate. In one band a co-precipitation of jordanite (light grey) occurred.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D169_03
Section: BW95

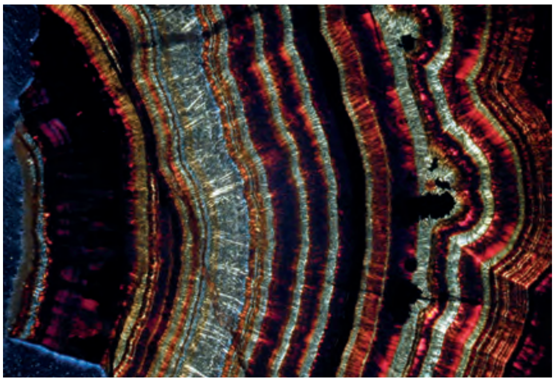
## 514 Sphalerite, wurtzite, jordanite – Michael im Weiler, Schwarzwald, Germany



As above, with crossed polars. Light bands of wurtzite with white-yellow IR and dark bands of sphalerite. Distinct anisotropism of jordanite crystals.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D169_02
Section: BW95

## 515 Sphalerite, wurtzite, jordanite – Michael im Weiler, Schwarzwald, Germany

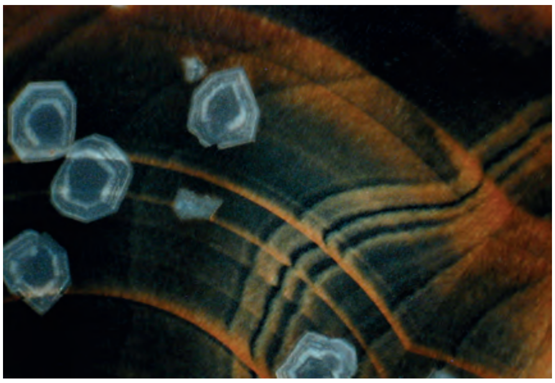


Schalenblende: Banded aggregate of sphalerite
(red bands: < 1 wt. % Fe)
and wurtzite
(white bands: < 0.1 wt. % Fe).
Minor jordanite (black).

Combined transmitted and reflected light under crossed polars!

Obj.: 2.5 ×
Polars: × Pol
Photo width: 5 mm
Photo No.: D175_06
Section: BW95

## 516 Sphalerite, quartz – Michael im Weiler, Schwarzwald, Germany



Complex banding of schalenblende with co-precipitation of euhedral, zoned quartz crystals.

Obj.: 10 ×
Polars: × Pol
Photo width: 1.4 mm
Photo No.: D168_31
Section: BW95

# Spinel

**Mineral name:** Spinel s. l. (spl)
**Formula:** $(Fe,Mg)(Al,Fe,Cr)_2O_4$

**VHN:** 860-1700
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 7 to 10 | depending on composition | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 0.4 to 3 | spinel s.s.: 0.4 % | |
| **Colour impression** | **(in oil)** | dark grey | | |
| **BR Rpl** | **(in oil)** | -- | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | homogeneous dark | |
| **Colour:** | **in 45° position** | black or masked by IR | |
| | **... in other positions** | | |
| **Extinction position** | | -- | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | colourless to greenish, rarely brownish | |
| **(IR)** | **frequency** | abundant | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

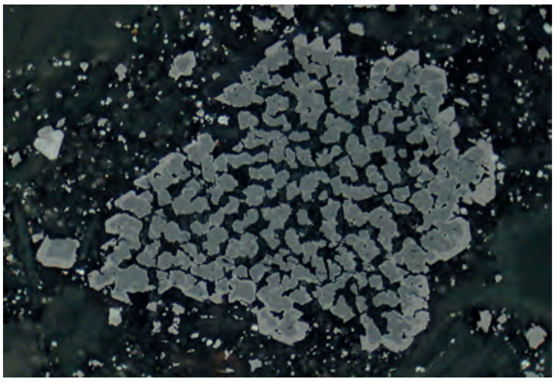
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | euhedral or idioblastic aggregates, often fractured by cataclasis; as EB in mt, or rimmed by mt. |
| **Paragenesis** | magnetite, ilmenite, corundum |
| **Diagnostic features** | paragenesis, IR, no #, hardness, R similar to R of gangue minerals |

## Notes, drafts

Cr-rich spinel: see CHROMITE
Hercynite $FeAl_2O_4$
Spinel s.s. $MgAl_2O_4$

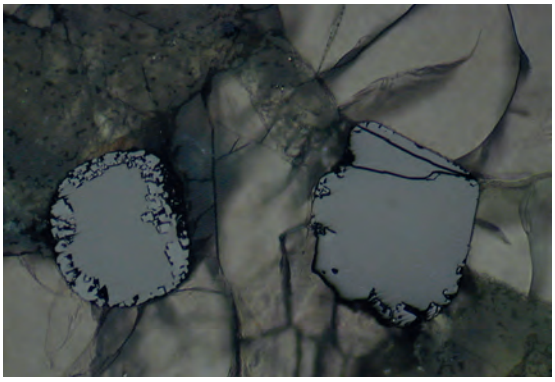
## 517 Spinel, mt, perovskite – Gutenberger Steige, Urach, B.-W., Germany



Kind of symplectitic spinel with Al-rich core (medium grey) and Fe-rich rim (Ti-mt). Groundmass with Ti-magnetite (in part with spinel core) and perovskite (light grey, left side of photo).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D134_26
Section: AS3291

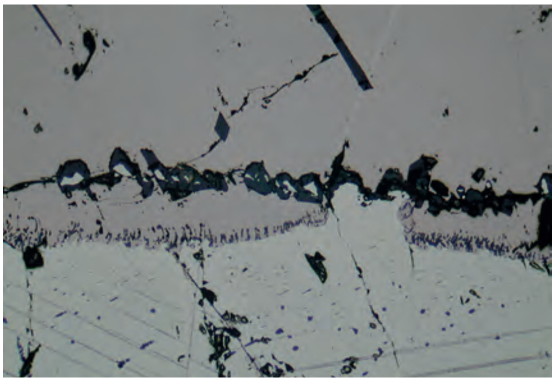
## 518 Spinel, mt, olivine, cpx – Bölle (Kunzenbrühl), Urach, B.-W., Germany



Right crystal: Euhedral crystal of spinel (Mg-Al(-Cr) spinel) almost entirely enclosed in olivine (light grey due to internal reflections).
Left crystal: Spinel with reaction rim of magnetite between olivine (some fractures, right side) and pyroxene (darker grey, upper left side).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D56_13
Section: Xeno6

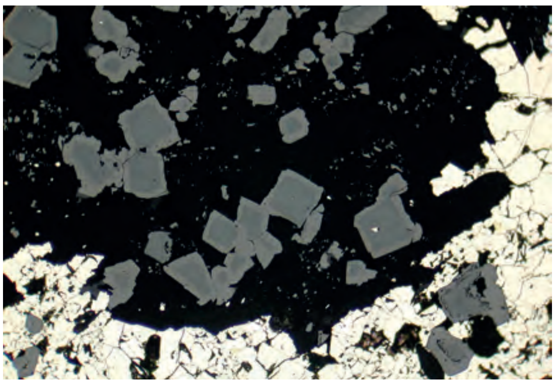
## 519 Spinel, magnetite, ilmenite – Krzemianka, Suwalki-Intrusion, Poland



Reaction zone between ilmenite (upper part) and Ti-magnetite (lower part). Ilmenite contains tiny spinels I (dark grey) in the outer zone and larger spinel II crystals (in part with magnetite relicts) in the inner subzone. Ti-magnetite with exsolution bodies of lamellar ilmenite and lensoid spinels.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D25_14
Section: AS198

## 520 Spinel, pentlandite, cp – McLeay mine, Kambalda, Australia



Zoned euhedral crystals of spinel with magnetite-rich rim, in part surrounded by pentlandite with minor chalcopyrite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D210_08
Section: S-LSU207_1

# Spionkopite

**Mineral name:** Spionkopite
**Formula:** $Cu_{39}S_{28}$

**VHN:** 120-160
**Crystal System:** hex.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 18.6 (15.5*) | $R_{e'}$ = 27.1 (20.6*) | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 6.1 | $R_{e'}$ = 12.3 | |
| **Colour impression** | **(in oil)** | blue | grey blue | |
| **BR > Rpl** | **(in oil)** | strong – distinct | | $A_{oil}$ = 68 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong with colour | very strong with colour |
| **Colour:** | **in 45° position** | light orange yellow | orange – orange |
| | **... in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | perfect, undulatory | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | translation twins | |
| | **frequency** | common | |

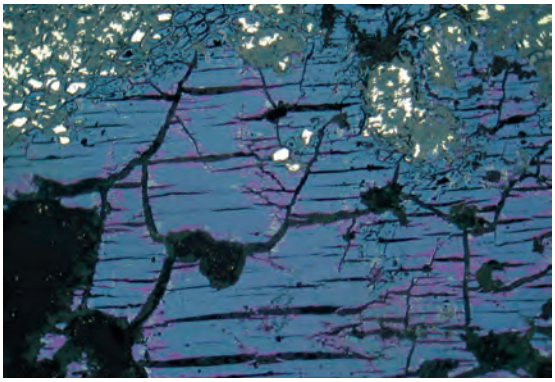
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | small platy- and tabular crystals;<br>lamellae replacement product of chalcocites |
| **Paragenesis** | chalcocite, covellite, djurleite, chalcopyrite, tennantite, magnetite, Co-pentlandite |
| **Diagnostic features** | CI, AE\|\|Pol , no violet tint like yarrowite |

## Notes, drafts

»Blaubleibender Covellin« is spionkopite or yarrowite, or both.
BR is less strong compared to yarrowite!
* R after Goble (1980), Can. Mineral., 18, 511-518.

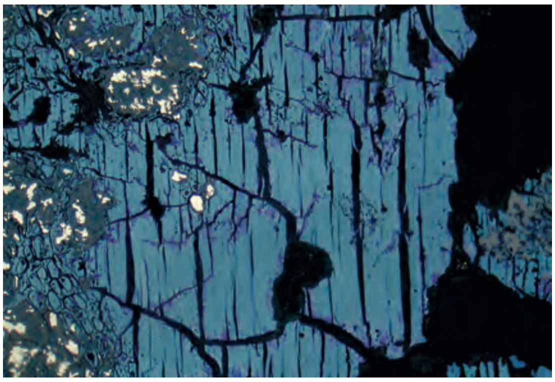
## 521 **Spionkopite, cv, cp –** Frankenberg, Hesse, Germany



Spionkopite ($R_{min}$ dark blue without violet tint) and distinct cleavage, surrounded and replaced by covellite (red violet).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D95_27
Section: AS3554

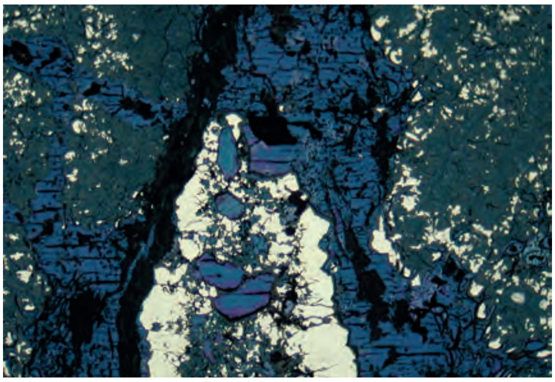
## 522 **Spionkopite, cv, cp –** Frankenberg, Hesse, Germany



As above, now 90° rotated. Now spionkopite with $R_{max}$ (note the only distinct BR in contrast to the strong BR of yarrowite).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D95_28
Section: AS3554

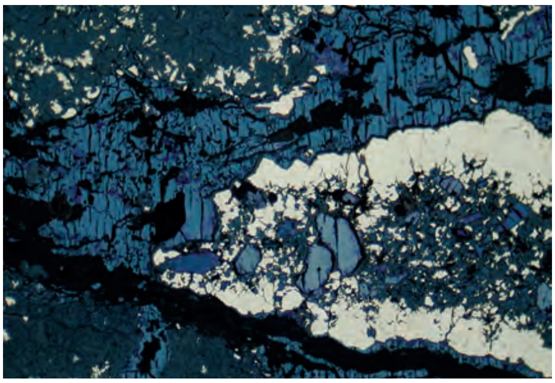
## 523 **Spionkopite, cv, cp –** Frankenberg, Hesse, Germany



Spionkopite ($R_{min}$ dark blue without violet tint) and distinct cleavage, surrounded and replaced by covellite (red violet). Relicts of chalcopyrite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D95_19
Section: AS3554

## 524 **Spionkopite, cv, cp –** Frankenberg, Hesse, Germany



As above, 90° rotated ($R_{max}$ of spionkopite now medium blue).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D95_20
Section: AS3554

# Stannite (in German: Stannit, Zinnkies)

**Mineral name:** Stannite
**Formula:** α-$Cu_2FeSnS_4$

**VHN:** 210-270
**Crystal System:** tetr.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1 = 27.7$ | $R_2 = 28.4$ | $R_2 \sim R_o$ |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1 = 13.4$ | $R_2 = 14.0$ | |
| **Colour impression** | **(in oil)** | brownish olive | grey tint green | |
| **BR < Rpl** | **(in oil)** | distinct | | $A_{oil} = 8$ |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | weak with colour | weak with colour |
| **Colour:** | **in 45° position** | violet blue | bluish violet – violet blue |
| | **... in other positions** | violet | violet |
| **Extinction position** | | greyish black | |
| **Mode of extinction** | | not perfect | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | very fine polysynthetic twinning (microcline-like); coarse twins | |
| | **frequency** | often; rare | |

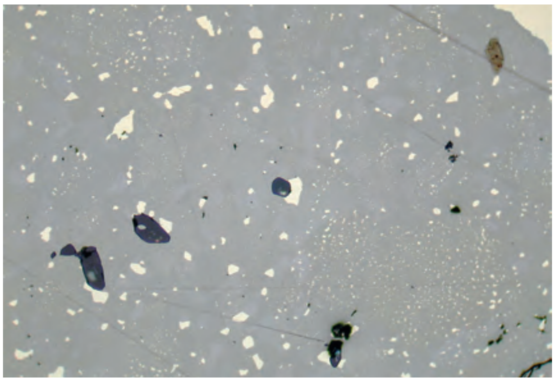
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | nearly never euhedral;<br>inclusions of sph and/or cp (tiny grains) due to exsolution |
| **Paragenesis** | cp, cas, sph, asp, py, fahlore, bismuth, bismuthinite, ... |
| **Diagnostic features** | CI, microcline-like twinning, EB of cp |

## Notes, drafts

Nearly always excess content of $CuFeS_2$ and ZnS (be aware of nano-inclusions!).
H-temperature $Cu_2FeSnS_4$ = isostannite (*stannite II* of Ramdohr) was synthetized by FRANZ (1971) und WANG (1982) between 420-500° C (but may be ferrokesterite due to the structural similarity). The observed polysynthetic twinning of stannite could be an inversion twinning(?).
See BONAZZI ET AL. (2003), Can Min, 41, 639-647.
See also: KESTERITE ($Cu_2ZnSnS_4$)

## 525 Stannite, cp, cas – Cornwall, England



Equigranular aggregate of stannite (various grey tones) with chalcopyrite exsolution bodies. Three rounded cassiterite grains in stannite.

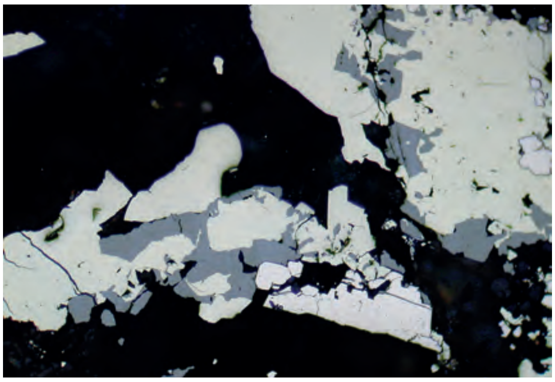
Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D09_18
Section: AS1020

## 526 Stannite, cp, cas – Cornwall, England

As above, with crossed polars. Typical violet blue anisotropism colours.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D09_21
Section: AS1020

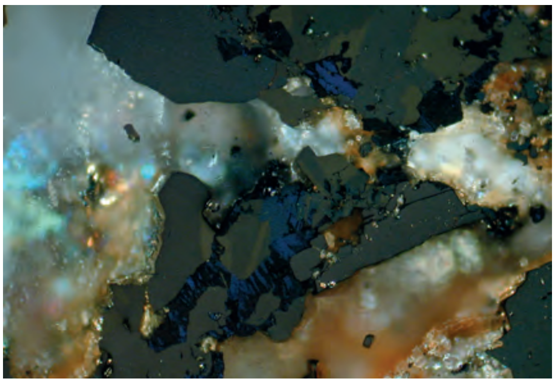
## 527 Stannite, cp, py – Neves-Corvo, Portugal



Stannite (medium grey) replacing chalcopyrite (whitish yellow), and pyrite (white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D149_07
Section: AS2174

## 528 Stannite, cp, py – Neves-Corvo, Portugal



As above, with crossed polars. Note: bluish AExPol.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D149_08
Section: AS2174

# Stannoidite

**Mineral name:** Stannoidite
**Formula:** $Cu_8(Fe,Zn)_3Sn_2S_{12}$

**VHN:** 180-270
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1 = 23.7$ | $R_2 = 27.3$ | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1 = 11.3$ | $R_2 = 13.6$ | |
| **Colour impression** | **(in oil)** | orange brown | yellow brown | (salmon brown) |
| **BR ~ Rpl** | **(in oil)** | distinct | | $A_{oil} = 19$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | distinct with colour | distinct with colour |
| **Colour:** | **in 45° position** | greyish orange – greyish yellow | orange – greyish yellow |
| | **... in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | straight | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | polysynthetic after 2 directions (similar to cp; Cornwall sample) | |
| | **frequency** | ? | |

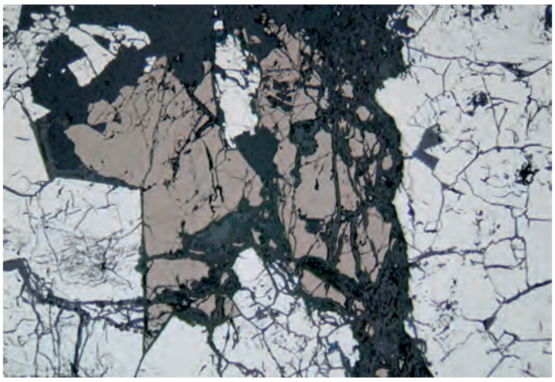
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | as EB in stannite or vice versa; reaction rim between cp and stannite |
| **Paragenesis** | kesterite, stannite, cp, bn, cas, mawsonite, chalcocite, tnt, asp, gn, enargite |
| **Diagnostic features** | CI, BR, paragenesis; similar to bornite (but stronger BR, AExPol) |

## Notes, drafts

CI compared with KESTERITE ($Cu_2ZnSnS_4$) is more orange; also stronger AExPol.

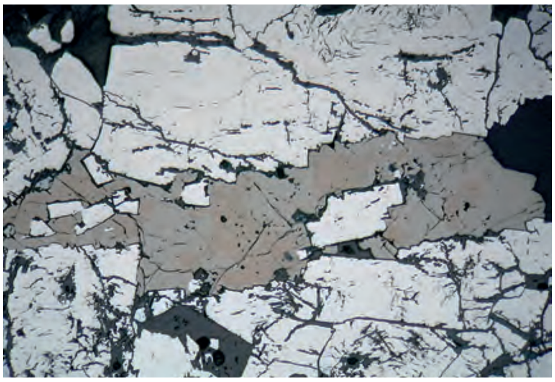
## 529 **Stannoidite, asp –** St. Michaels Mount, Cornwall, England



Stannoidite (brown) between cataclastic arsenopyrites.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D155_18
Section: AS3627

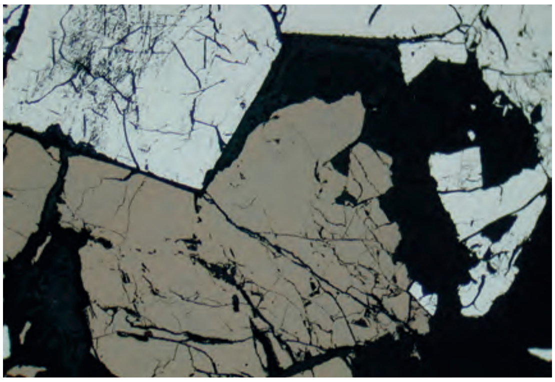
## 530 **Stannoidite, stannite, asp –** St. Michaels Mount, Cornwall, England



Stannoidite (brown) surrounded and partly replaced by stannite (greenish grey); arsenopyrite.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D155_16
Section: AS3627

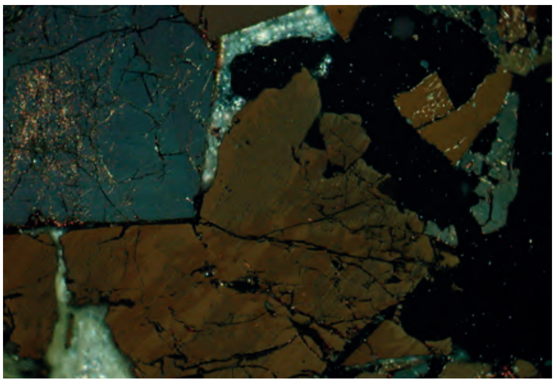
## 531 **Stannoidite, stannite, asp –** St. Michaels Mount, Cornwall, England



Stannoidite (brown) with tiny exsolution lamellae of stannite (not visible in photo); arsenopyrite (white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D155_19
Section: AS3627

## 532 **Stannoidite, stannite, asp –** St. Michaels Mount, Cornwall, England



As above, with crossed polars. Note polysynthetic twinning of stannoidite (centre of photo) and very fine lamellae of stannite (NE-SW, dark grey).

Digitally edited contrast and brightness.

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D155_21
Section: AS3627

# Stibnite (in German: Stibnit, Antimonit)

**Mineral name:** Stibnite (stbn)
**Formula:** $Sb_2S_3$
**VHN:** 70-80 (on (010))
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_a$ = 42.2 | $R_b$ = 31.1 | $R_c$ = 48.1 |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_a$ = 26.8 | $R_b$ = 16.1 | $R_c$ = 33.4 |
| **Colour impression** | **(in oil)** | grey white | grey tint olive brown | pure white |
| **BR ~ Rpl** | **(in oil)** | extremely strong | | $A_{oil}$ = 75 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong without colour | very strong with colour tint |
| **Colour:** | **in 45° position** | white | white tint blue – white tint rose |
| | **... in other positions** | rose brown, grey blue | brown, grey blue |
| **Extinction position** | | black | |
| **Mode of extinction** | | perfect, undulatory | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | spindle-shaped (lancet-shaped) deformation twins, and crumpled lamellae | |
| | **frequency** | rare – common | |

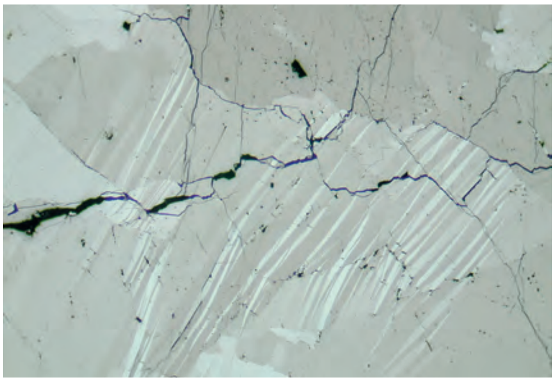
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | fibrous, acicular to tabular XX, also equigranular; in oxidation zones replacement by Sb-oxihydroxides; # \|\| {010} perfect |
| **Paragenesis** | cinnabar, metacinnabar, asp, gold, fahlore, As-minerals |
| **Diagnostic features** | BR, AExPol, translation twins, low hardness, paragenesis, # |

## Notes, drafts

$R_c$ is higher and more white compared to $R_2$ of similar BOULANGERITE.

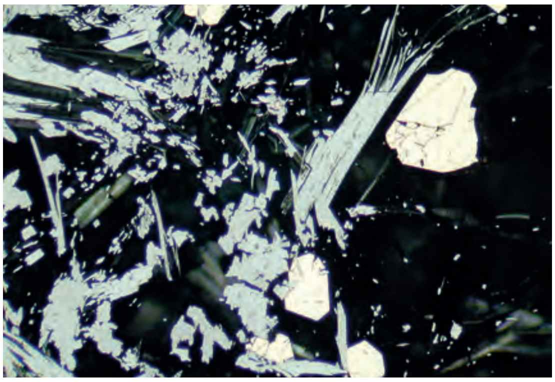
## 533 Stibnite – Pribram, Czech Republic



Strong bireflection of stibnite with bended deformation twins.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D32_30
Section: AS1003

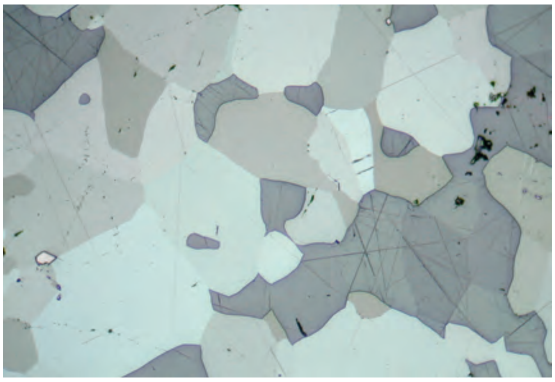
## 534 Stibnite, py – Schweizergrund near Sulzburg, Schwarzwald, Germany



Acicular to tufted crystals of stibnite in paragenesis with pyrite.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D33_24
Section: Metz357

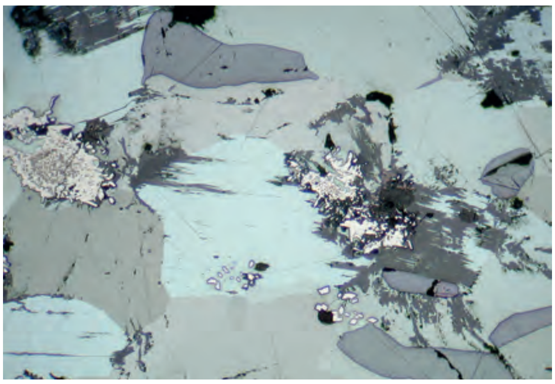
## 535 Stibnite, cinnabar – Çirakman tepe, Ladik, Turkey



Equigranular aggregate of stibnite (with strong BR) and cinnabar (medium grey with many scratches). One small crystal of arsenopyrite (white, lower left part).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D32_25
Section: AS155

## 536 Stibnite, cinnabar, asp – Çirakman tepe, Ladik, Turkey



Typical alteration of stibnite grains parallel cleavage plans to secondary Sb-minerals (dark grey). Few cinnabar grains (medium grey) and cluster of arsenopyrite, partly euhedral diamond-shaped.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D32_27
Section: AS155

# Teallite

**Mineral name:** Teallite
**Formula:** $PbSnS_2$

**VHN:** 60-120
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 42.5 | $R_2$ = 44.0 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 28.0 | $R_2$ = 29.1 | |
| **Colour impression** | **(in oil)** | greyish white tint yellow | cream white | |
| **BR ~ Rpl** | **(in oil)** | weak | | $A_{oil}$ = 4 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | distinct with colour | strong with colour |
| **Colour:** | **in 45° position** | greyish olive – grey tint blue | grey – greyish blue |
| | **... in other positions** | greyish violet near isotropic sec. | violet, olive |
| **Extinction position** | | greyish black | |
| **Mode of extinction** | | not perfect, straight \|\| elongation, undulatory | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | complex, and after (001), polysynthetic translations after (001) | |
| | **frequency** | occasional | |

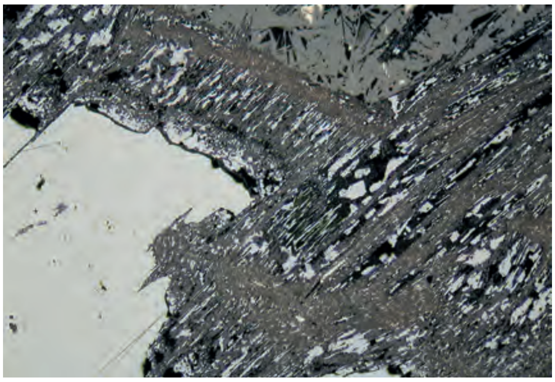
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | tabular XX \|\| (001), granular, radial aggregates, decomposition into gn + cas; # \|\| (001). |
| **Paragenesis** | galena, cassiterite, wurtzite, sphalerite, pyrite |
| **Diagnostic features** | paragenesis, texture |

## Notes, drafts

Isotropic section perpendicular to (001), i. e. in sections with #-planes.

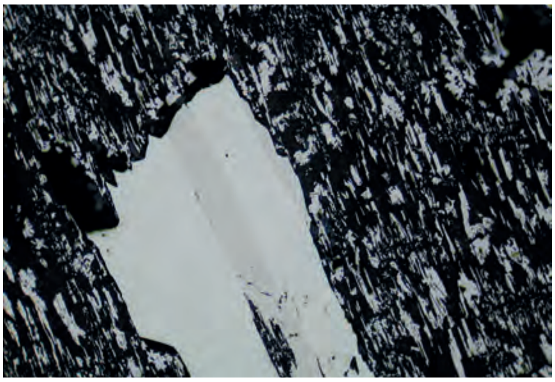
## 537 Teallite, gn, cas, wurtzite – Potosi, Bolivia



Large lath of teallite (lower left side) in part replaced by intimate mixture of galena (white) and cassiterite (dark grey). Upper part of photo wurtzite with pyrite.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D109_04
Section: AS1024

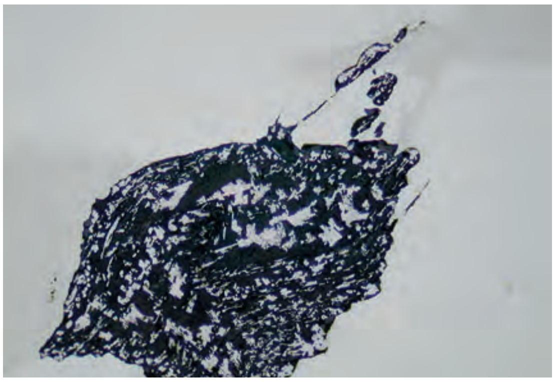
## 538 Teallite, gn, cas – Potosi, Bolivia



Large lath of twinned teallite (centre) in part replaced by intimate mixture of galena (white) and cassiterite (nearly black).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D109_05
Section: AS1024

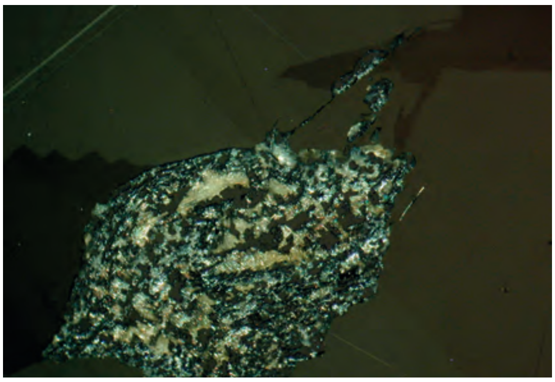
## 539 Teallite, gn, cas – Potosi, Bolivia



Intimate mixture of galena (white) and cassiterite (nearly black) surrounded by large crystal teallite (note bireflectance).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D109_09
Section: AS1024

## 540 Teallite, gn, cas – Potosi, Bolivia



As above, with crossed polars, showing distinct anisotropism of teallite, and light yellow internal reflections of cassiterite.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D109_11
Section: AS1024

# Tenorite (Melanocite)

**Mineral name:** Tenorite (Melanocite)
**Formula:** CuO

**VHN:** 190-130
**Crystal System:** mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 20.4 | $R_2$ = 27.5 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 7.6 | $R_2$ = 13.1 | |
| **Colour impression** | **(in oil)** | brownish grey | cream grey | |
| **BR ~ Rpl** | **(in oil)** | extremely strong | | $A_{oil}$ = 53 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong with colour tint | strong with colour tint |
| **Colour:** | **in 45° position** | yellow white | white yellow – bluish white |
| | **... in other positions** | | |
| **Extinction position** | | grey black, many scratches | |
| **Mode of extinction** | | not perfect, uneven | |
| **Internal reflections** | **colour** | brown | |
| **(IR)** | **frequency** | very rare (in samples from Vesuv) | |
| **Twinning** | **mode** | polysynthetic after more than one direction (\|\| elongation) | |
| | **frequency** | common | |

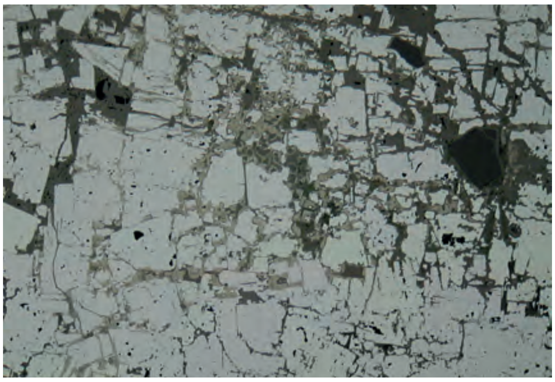
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | spherical, fibrous, botryoidal, skeletal, often fine-grained; replaces cuprite \|\| {111} of cuprite |
| **Paragenesis** | cuprite, copper, chrysocolla, malachite, goethite, paramelanocite, delafossite |
| **Diagnostic features** | CI, paragenesis |

## Notes, drafts

In comparison to delafossite poor # and less yellow in oil.
Paramelanocite: tetragonal modification of CuO (with lower R, many scratches).

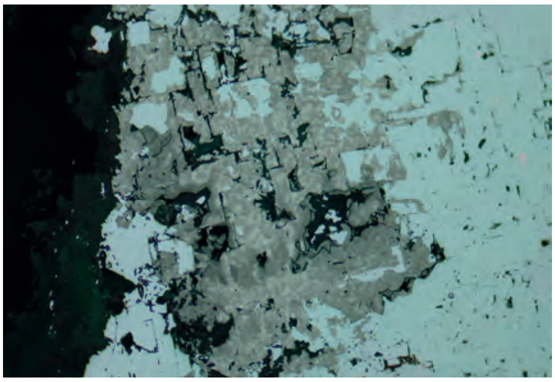
## 541 Tenorite, cuprite – Locality unknown



Secondary formation of tenorite (brownish grey) along the cleavage planes of cuprite (medium grey).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D85_04
Section: AS3548

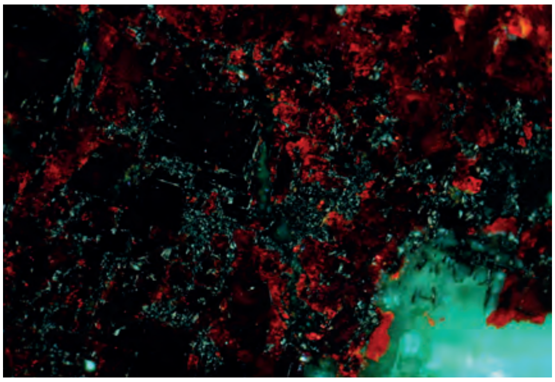
## 542 Tenorite, cuprite – Locality unknown



As above, with oil immersion objective. Note strong BR of tenorite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D05_27
Section: AS114

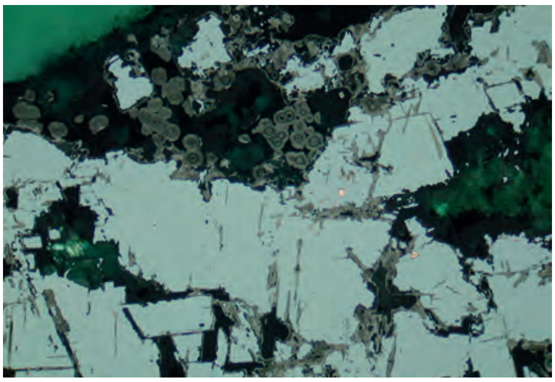
## 543 Tenorite, cuprite – Locality unknown



As above, with crossed polars. Note the strong anisotropism of tenorite and red IR of cuprite.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D85_11
Section: AS3548

## 544 Tenorite, cuprite – Locality unknown



Botryoidal aggregates of tenorite beside cuprite. Tiny inclusions of native copper (orange) in cuprite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D43_31
Section: AS3547

# Tetradymite

**Mineral name:** Tetradymite
**Formula:** $Bi_2Te_2S$
**VHN:** 30-45
**Crystal System:** trig.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o = 60.5$ | $R_{e'} = 54.8$ | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o = 47.7$ | $R_{e'} = 40.7$ | |
| **Colour impression** | **(in oil)** | white tint yellow | white | |
| **BR > Rpl** | **(in oil)** | distinct | | $A_{oil} = 16$ |

## Observations with crossed polars (AExPol in oil)

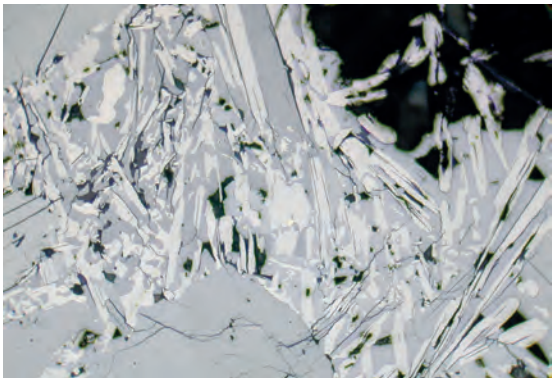
| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | distinct with colour tint | distinct with colour tint |
| **Colour:** | **in 45° position** | grey (tint brownish yellow) | bluish grey – greyish yellow |
| | **… in other positions** | | brownish yellow |
| **Extinction position** | | greyish black | |
| **Mode of extinction** | | straight, undulatory | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | lamellar twinning | |
| | **frequency** | rare | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | tabular and needle-like XX, also granular; # \|\| (0001) |
| **Paragenesis** | bismuthinite, emplectite, bismuth, fahlore |
| **Diagnostic features** | paragenesis |

## Notes, drafts

## 545 Tetradymite, bismuthinite – Stuhlskopf, Schwarzwald, Germany



Laths of tetradymite (nearly white) enclosed by bismuthinite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7mm
Photo No.: D182_13
Section: Kind11

## 546 Tetradymite, bismuthinite – Stuhlskopf, Schwarzwald, Germany

As above, with crossed polars. Grey tint brownish yellow anisotropism colours. Strong anisotropism of bismuthinite.

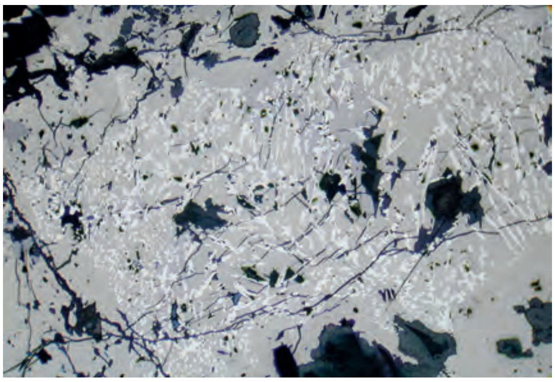
Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D182_14
Section: Kind11

## 547 Tetradymite, bismuthinite – Stuhlskopf, Schwarzwald, Germany

As above, now with (not exactly) crossed polars, resulting in more vivid anisotropism colours (bluish grey to greyish yellow).

Obj.: 20 × oil
Polars: × Pol (~)
Photo width: 0.7 mm
Photo No.: D182_15
Section: Kind11

## 548 Tetradymite, emplectite, fahlore – Stuhlskopf, Schwarzwald, Germany



Myrmekitic intergrowth of tetradymite (white) with emplectite (beige olive), rimmed by fahlore.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D182_17
Section: Kind11

# Thorianite

**Mineral name:** Thorianite
**Formula:** $(Th,U)O_2$

**VHN:** ~ 1100-1280
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 13 (to 16) | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 3 | |
| **Colour impression** | **(in oil)** | dark grey | |
| **BR Rpl** | **(in oil)** | -- | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | homogeneous dark | |
| **Colour:** | **in 45° position** | black | |
| | **... in other positions** | | |
| **Extinction position** | | -- | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | rare | |
| **(IR)** | **frequency** | red brown to yellow brown | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

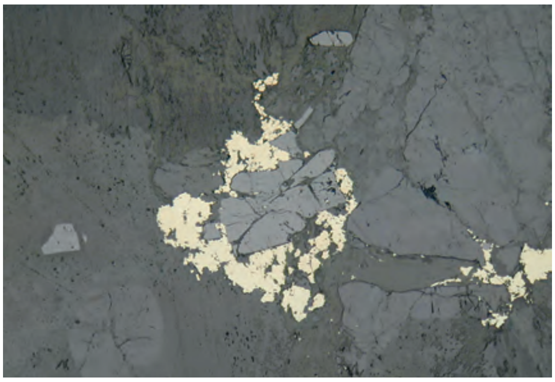
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | often in euhedral cubic crystals; rounded grains in placer, often zoned; cleavage \|\| {100}+{111} |
| **Paragenesis** | mt, ilm, cas, uraninite, sulfides |
| **Diagnostic features** | habit, paragenesis |

## Notes, drafts

R varies with U- and Ce-content.

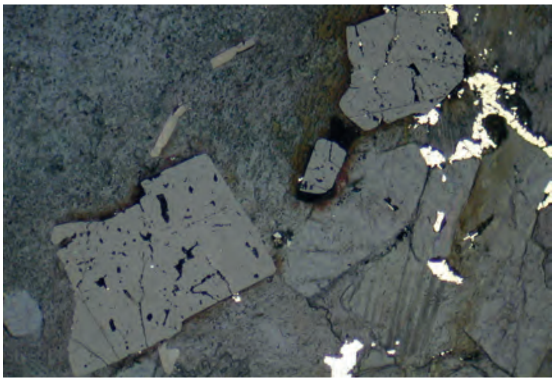
## 549 Thorianite, baddeleyite, cp – 2. Lift, PMC mine, Phalaborwa, RSA



Small thorianite crystal (left side of photo) in carbonatite, together with baddeleyite (centre, grey), and chalcopyrite (yellow).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D188_09
Section: 61

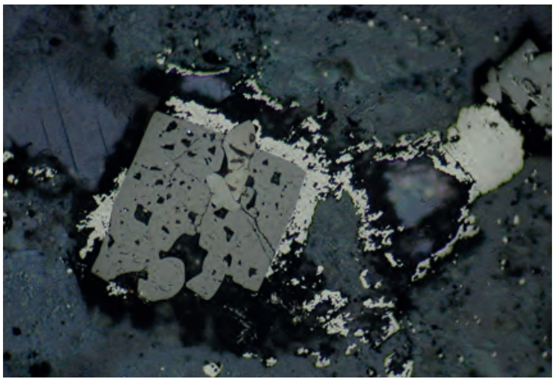
## 550 Thorianite, mt, cp – 2. Lift, PMC mine, Phalaborwa, RSA



Thorianite cubes (medium grey) beside prismatic baddeleyite (brownish grey, upper left part of photo), and chalcopyrite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D188_10
Section: 61

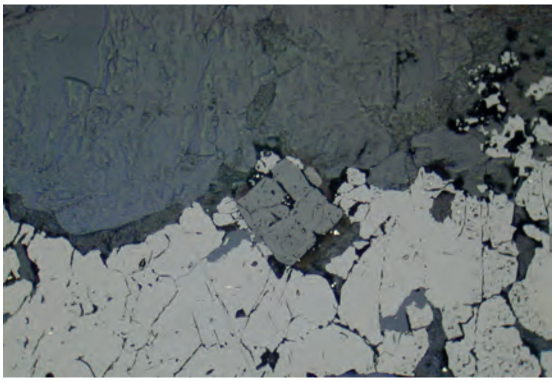
## 551 Thorianite, baddeleyite, mt – Phalaborwa, RSA



Euhedral thorianite with small baddeleyite crystals (slightly higher R), both surrounded by magnetite (light grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D201_12
Section: Albaradio

## 552 Thorianite, mt – 2. Lift, PMC mine, Phalaborwa, RSA



Thorianite cube (medium grey) partly enclosed by magnetite (light grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D188_11
Section: 61

# Titanite

**Mineral name:** Titanite (ttn)
**Formula:** $CaTi[O|SiO_4]$
**VHN:** 700-850
**Crystal System:** mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 9.5 | $R_2$ = 11.0 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 1.3 | $R_2$ = 2.0 | |
| **Colour impression** | **(in oil)** | black (but IR!) | greyish black (IR!) | |
| **BR > Rpl** | **(in oil)** | strong | | $A_{oil}$ = 42 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | strong without colour | strong without colour |
| **Colour:** | **in 45° position** | grey, masked by IR | grey – grey, masked by IR |
| | **... in other positions** | | |
| **Extinction position** | | masked by IR | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | white – yellow – brown (Fe-rich) | |
| **(IR)** | **frequency** | abundant – common | |
| **Twinning** | **mode** | polysynthetic after one direction | |
| | **frequency** | rare | |

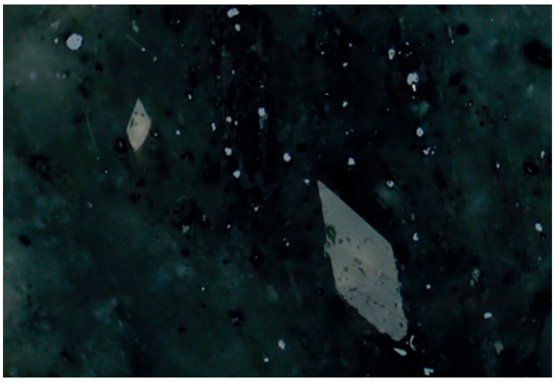
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | lens- or diamond-shaped grains, replaces ilmenite and rutile; often within biotite or amphiboles/pyroxenes. Good cleavage \|\| {110} |
| **Paragenesis** | ilmenite, rutile, anatase |
| **Diagnostic features** | paragenesis, habit |

## Notes, drafts

Similar to CASSITERITE (which is more often twinned).

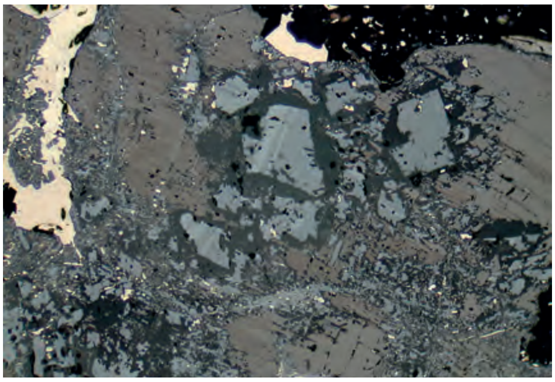
## 553 Titanite – Selberg, Quiddelbach, Hocheifel, Germany



Euhedral crystals of titanite in nephelinite. Large titanite shows lamellar twinning with displaced lamellae on the right side of the crystal.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D07_01
Section: AS1136

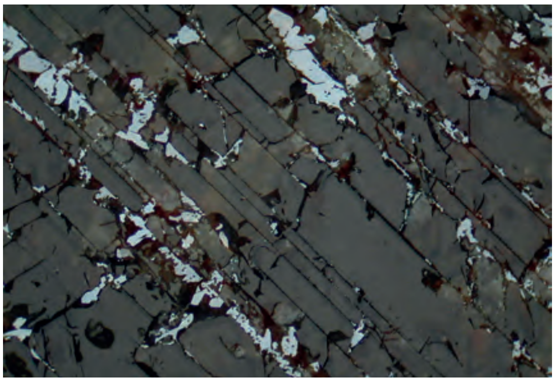
## 554 Titanite, rt, ilm, po – Rimella-Gula, Val Sessia, Italy



Titanite (grey, maximum reflectance $R_2$) as replacement product of rutile (lighter grey, twins), which replaces older ilmenite (brownish grey, twins); replacement by younger pyrrhotite (light cream).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D16_21
Section: AS135

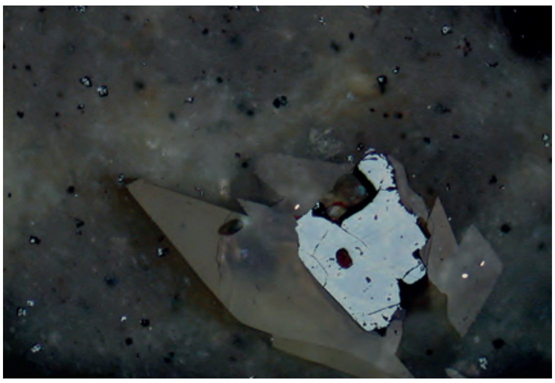
## 555 Titanite, rutile – Yudnamutana Gorge, N. Flinders Range, Australia



Large titanite crystal partly replaced by rutile (light grey) along cleavage planes.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D71_14
Section: JH60

## 556 Titanite, mt, ilmenohematite, po – Drachenfels, south of Bonn, Germany



Diamond-shaped grains of titanite (some with inclusions of pyrrhotite) around magnetite with ilmenohematite (light to medium grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D206_15
Section: AS1128

# Tourmaline (in German: Turmalin)

**Mineral name:** Tourmaline (tur)
**Formula:** $NaFe_3(Al,Fe)_6[(OH)_4(BO_3)_3Si_6O_{18}]$

**VHN:** ~ 1000
**Crystal System:** trig.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 5.9 | $R_e$ = 6.3 | calculated from n |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 0.2 | $R_e$ = 0.3 | |
| **Colour impression** | **(in oil)** | greyish black | greyish black | with IR colours! |
| **BR ~ Rpl** | **(in oil)** | weak/not visible | | $A_{oil}$ = 0 |

## Observations with crossed polars (AExPol in oil)

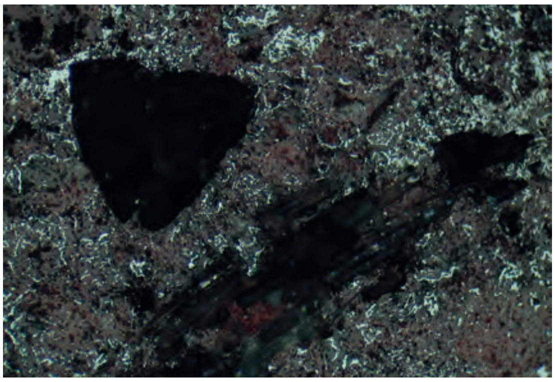
| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | very weak | weak |
| **Colour:** | **in 45° position** | in general masked by IR | |
| | **… in other positions** | | |
| **Extinction position** | | often masked by IR | |
| **Mode of extinction** | | straight | |
| **Internal reflections** | **colour** | from white over yellow, rose, blue, green to greyish black; often zoned | |
| **(IR)** | **frequency** | abundant | |
| **Twinning** | **mode** | simple | |
| | **frequency** | rare | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage …** | needle-like and prismatic XX with triangular head sections, colour zoning; no #, but cracks \|\| (0001) |
| **Paragenesis** | cassiterite, wolframite, asp, qz |
| **Diagnostic features** | habit, paragenesis, zoning |

## Notes, drafts

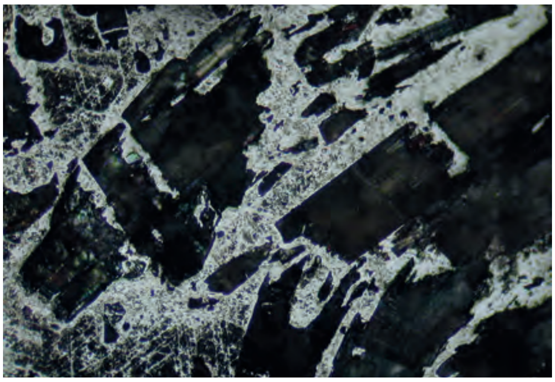
## 557 Tourmaline, sch, hm – Eggberg, Bad Säckingen, Schwarzwald, Germany



Two tourmaline crystals (nearly black) cut parallel and ⊥ to the c-axis in fine-grained groundmass of scheelite (reddish grey) and hematite (nearly white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D196_12
Section: AS270

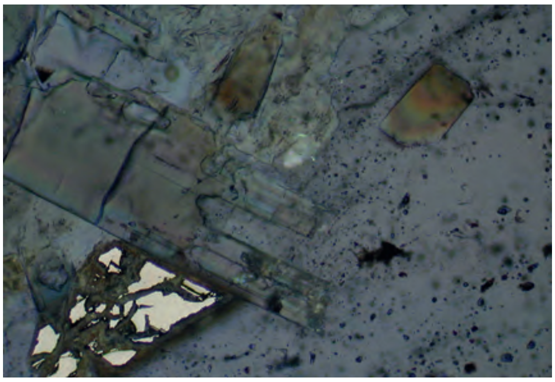
## 558 Tourmaline, hematite – Eggberg, Bad Säckingen, Schwarzwald, Germany



Broken crystals of dark tourmaline enclosed and replaced by hematite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D196_13
Section: AS270

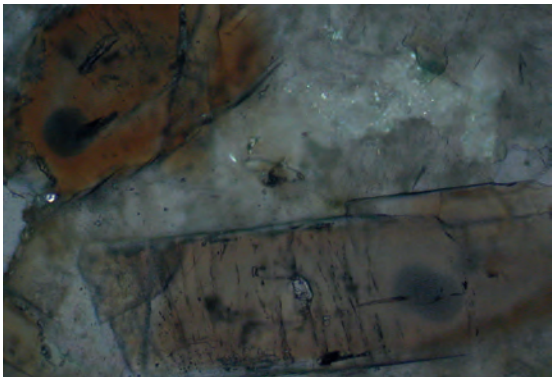
## 559 Tourmaline, kesterite, quartz – St. Michaels Mount, Cornwall, England



Corroded prisms of transparent tourmaline with visible interference colours in quartz groundmass; lower left: kesterite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D155_26
Section: AS3627

## 560 Tourmaline, quartz – St. Michaels Mount, Cornwall, England



Two reddish brown tourmalines crystals with colour zoning in quartz groundmass.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D155_30
Section: AS3627

# Ullmannite

**Mineral name:** Ullmannite
**Formula:** NiSbS

**VHN:** ~ 460-560
**Crystal System:** tric., ps.cub.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 47.3 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 32.8 | |
| **Colour impression** | **(in oil)** | white tint blue | |
| **BR Rpl** | **(in oil)** | -- | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | rarely very weak anisotropic | -- |
| **Colour:** | **in 45° position** | greyish | -- |
| | **... in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

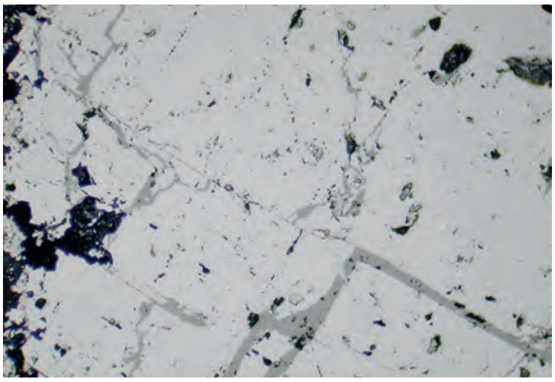
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | euhedral XX (cubes), occasional with zoning (Co, Fe, Bi, As).<br># \|\| {100} with (rare) triangular pits (less often than in gersdorffite). |
| **Paragenesis** | breithauptite, cp, gn, gold |
| **Diagnostic features** | CI, paragenesis |

## Notes, drafts

Rare mineral. Often as solid solution with GERSDORFFITE.

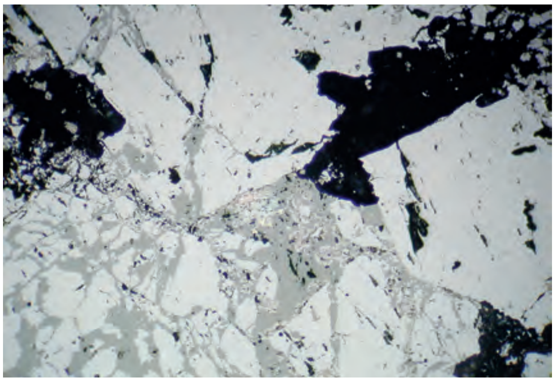
## 561 Ullmannite, tetrahedrite – Salchendorf, Siegerland, Germany



Large crystal of ullmannite with replacement by tetrahedrite along cleavage planes.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D134_06
Section: AS2878

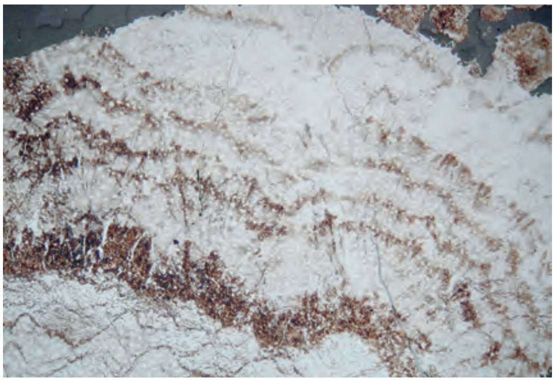
## 562 Ullmannite, td, Bi, bismuthinite, nk – Salchendorf, Siegerland, Germany



Cataclastic ullmannite with tetrahedrite (greenish grey), bismuth → bismuthinite, and tiny nickeline.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D134_05
Section: AS2878

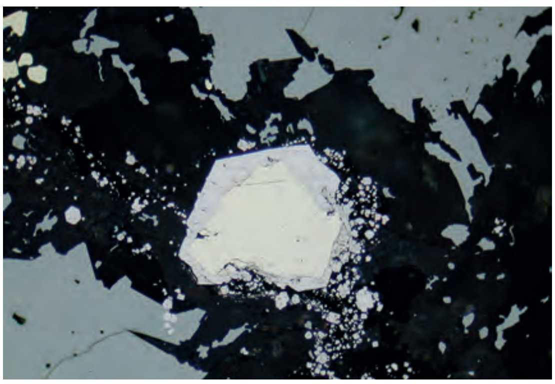
## 563 Ullmannite-Gersdorffite-ss – Grube Silberquelle, Siegerland, Germany



Different tarnishing effects of zoned ullmannite-gersdorffite solid solution.

Obj.: 5 ×
Polars: || Pol
Photo width: 2.8 mm
Photo No.: D149_02
Section: AS1757

## 564 Pyrite, ullmannite, tetrahedrite – Locality unknown



Anhedral pyrite (yellowish white) enclosed by euhedral ullmannite (white). Tiny cubes of ullmannite in gangue minerals beside larger tetrahedrite (medium grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D148_25
Section: AS1007

# Vaesite

**Mineral name:** Vaesite
**Formula:** $NiS_2$

**VHN:** ~ 800
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 31.8 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 17.4 | |
| **Colour impression** | **(in oil)** | brownish grey | |
| **BR Rpl** | **(in oil)** | -- | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | homogeneous dark | homogeneous dark |
| **Colour:** | **in 45° position** | black | black |
| | **... in other positions** | | |
| **Extinction position** | | -- | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

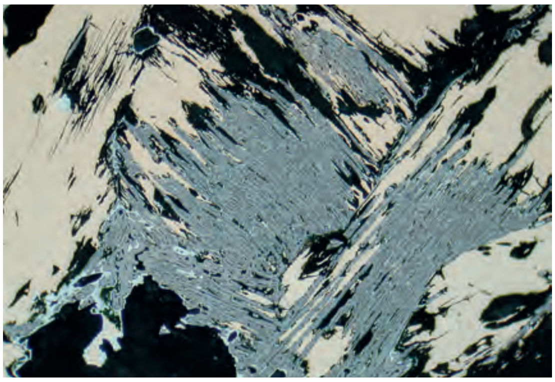
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | replacing nickeline and Ni-skutterudite, zoning may occur (Ni-Fe) |
| **Paragenesis** | nickeline, Ni-skutterudite, millerite, other Ni-As-S minerals |
| **Diagnostic features** | paragenesis |

## Notes, drafts

Bravoite (Ni-Pyrite, $(Ni,Fe)S_2$) R = >32/>18.

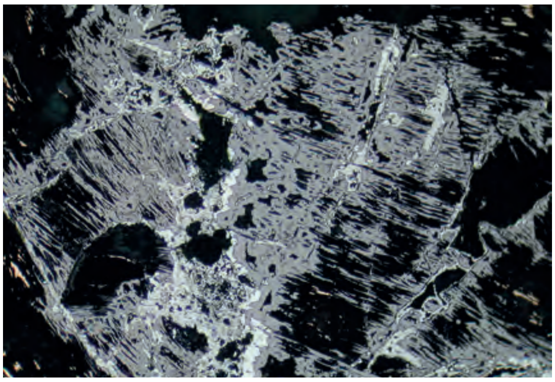
## 565 Vaesite, nickeline – Nentershausen, Hesse, Germany



Strong replacement of nickeline (yellow orange) by vaesite (medium grey) parallel the cleavage planes.

Obj.: 20× oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D142_26
Section: AS164

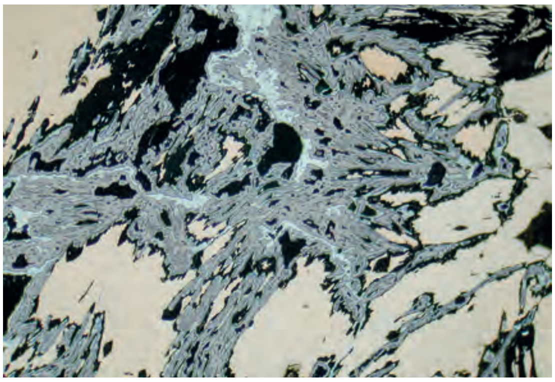
## 566 Vaesite, nickeline – Nentershausen, Hesse, Germany



Vaesite pseudomorph after nickeline.

Obj.: 20× oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D142_19
Section: AS164

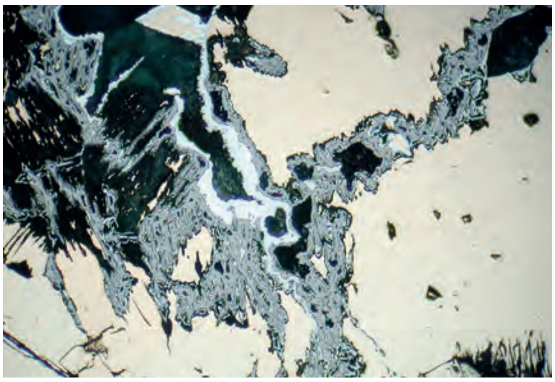
## 567 Vaesite, nickeline – Nentershausen, Hesse, Germany



Alteration of nickeline (yellow orange) by vaesite (brownish grey), plus veinlet and small rims of younger NiAs-phase (whitish grey).

Obj.: 20× oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D142_18
Section: AS164

## 568 Vaesite, nickeline – Nentershausen, Hesse, Germany



As photo above.

Obj.: 20× oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D142_16
Section: AS164

# Valleriite

**Mineral name:** Valleriite
**Formula:** $(Fe,Cu)_4S_4 * 3(Mg,Al)(OH)_2$

**VHN:** ~ 30
**Crystal System:** tric., ps. hex..

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 20.5 | $R_2$ = 10.3 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 10.7 | $R_2$ = 1.6 | |
| **Colour impression** | **(in oil)** | greyish yellow | grey (tint violet) | |
| **BR ~ Rpl** | **(in oil)** | extremely strong | | $A_{oil}$ = 147 |

## Observations with crossed polars (AExPol in oil)

| | | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|---|
| **Anisotropism intensity/colour** | | extremely strong with colour tint | extremely strong with colour tint |
| **Colour:** | **in 45° position** | white yellow | white yellow – white yellow |
| | **... in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | straight, perfect, undulatory | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | deformation twins | |
| | **frequency** | abundant | |

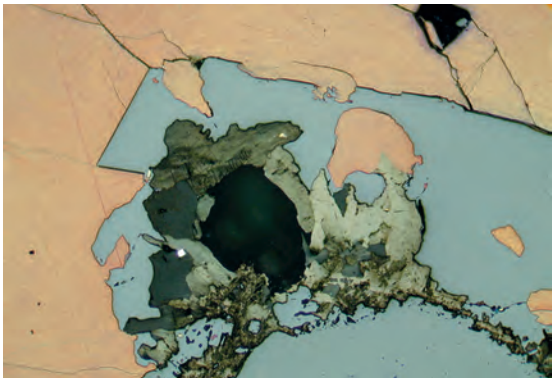
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | thin tabular flakes, spherulitic aggregates; replaces spinel, forsterite and bornite; perfect # \|\| {0001} |
| **Paragenesis** | cp, chr, mt, pn, po, bn, sperrylite |
| **Diagnostic features** | extreme BR and AExPol |

## Notes, drafts

Very similar to GRAPHITE (which $R_{e'}$ is slightly darker and $R_o$ is less yellow).

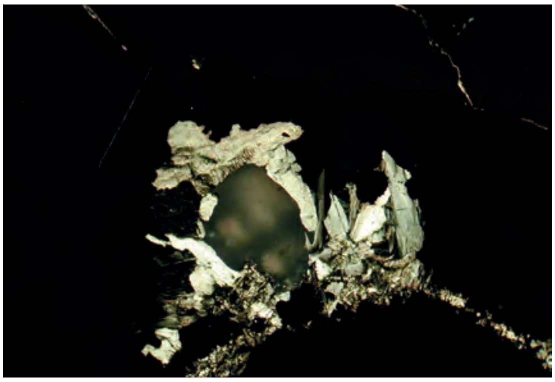
## 569 Valleriite, bornite, mt – Phalaborwa, RSA



Plates of valleriite (yellowish grey to dark grey, strong BR) and bornite (orange brown), both replacing magnetite (medium grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D09_15
Section: AS1817

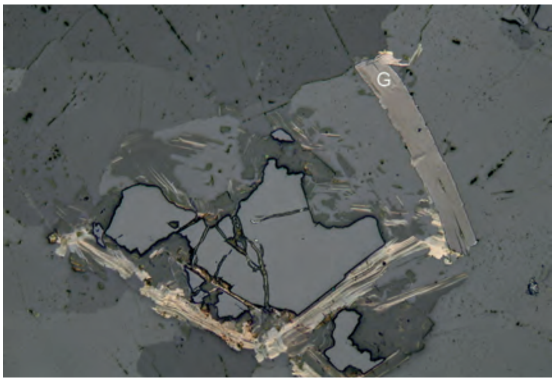
## 570 Valleriite, bornite, mt – Phalaborwa, RSA



As above, with crossed polars. Note the extremely strong anisotropism.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D09_16
Section: AS1817

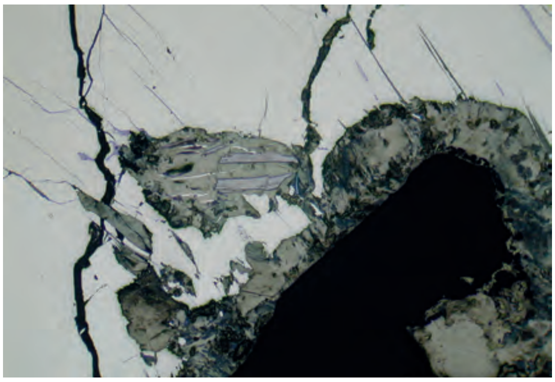
## 571 Valleriite, graphite, forsterite, carb – Kropfmühl, Passau, Germany




Fine lamellae of valleriite (yellowish grey, lower and left part of photo) as replacement product around serpentinized forsterite (crystal relict with strong relief) in carbonate groundmass (note bireflection!). One large flake of very similar graphite (right part, G) in contact to valleriite.

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D14_04
Section: AS1054a

## 572 Valleriite, graphite, po – Kropfmühl, Passau, Germany



Replacement of pyrrhotite (cream) by valleriite (yellowish grey to dark grey). Note the two large graphite flakes (horizontal tabular crystals, here with $R_o$; less yellow than valleriite) in main mass of valleriite. Forsterite (black) in lower right side of photo.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D215_16
Section: AS1054a

# Violarite

**Mineral name:** Violarite
**Formula:** $FeNi_2S_4$

**VHN:** 240-370
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| $R_{(air)}$ in % (for 546 nm) | 45.3 | | |
| $R_{(oil)}$ in % (for 546 nm) | 32.5 | | |
| Colour impression (in oil) | white cream | against pn: tint rose/violet | |
| BR Rpl (in oil) | -- | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

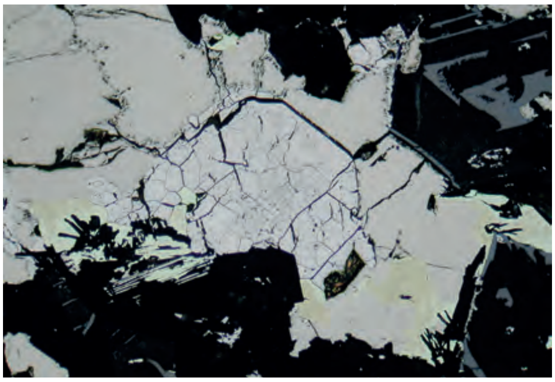
| | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|
| **Anisotropism intensity/colour** | homogeneous dark | homogeneous dark |
| **Colour:** in 45° position | black | black |
| ... in other positions | | |
| **Extinction position** | -- | |
| **Mode of extinction** | -- | |
| **Internal reflections (IR)** colour | -- | |
| frequency | -- | |
| **Twinning** mode | -- | |
| frequency | -- | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | commonly replacing pentlandite (partly pseudomorph), scarred-cracked; alteration product of pn, po and millerite |
| **Paragenesis** | pn, po, millerite |
| **Diagnostic features** | in association with other Ni-minerals |

## Notes, drafts

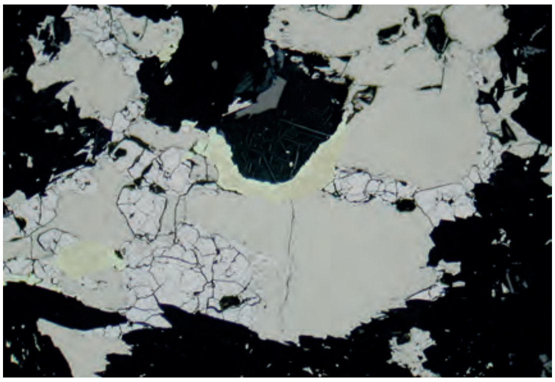
## 573 Violarite, po, cp – Sohland a. d. Spree, Germany



Violarite pseudomorph (centre) after euhedral pentlandite crystals. Pyrrhotite and chalcopyrite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D26_20
Section: AS3500

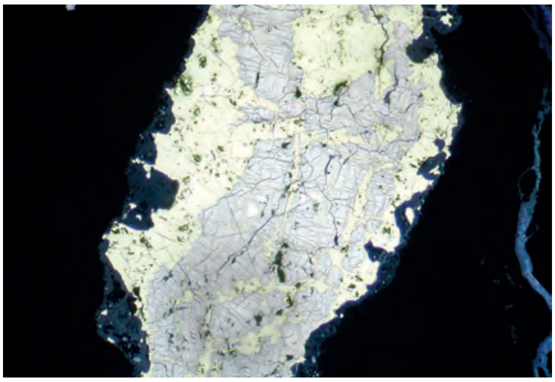
## 574 Violarite, pn, po, cp – Sohland a. d. Spree, Germany



Violarite completely replacing granular pentlandite, whereas flame-like pentlandite in pyrrhotite (centre of photo) is nearly unaltered. Some chalcopyrite (partly tarnished).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D26_22
Section: AS3500

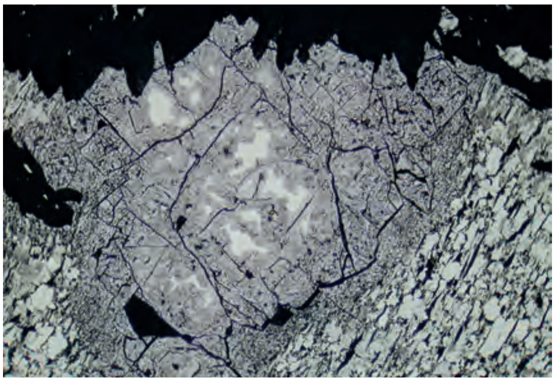
## 575 Violarite, cp, pn – Rote Wand, Bivio, Switzerland



Violarite (#, greyish white) with few relicts of pentlandite (higher reflectance, cream) replaced by chalcopyrite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D54_30
Section: WP_P05

## 576 Violarite, py, pn, – Horbach, Schwarzwald, Germany



Replacement of pentlandite (light cream) by violarite (greyish), surrounded by pyrite and marcasite (pseudomorph after pyrrhotite).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D169_20
Section: AS3197

# Wittichenite

**Mineral name:** Wittichenite
**Formula:** $Cu_3BiS_3$

**VHN:** 170-190
**Crystal System:** o'rh.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 33.3 | $R_2$ = 35.5 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 18.5 | $R_2$ = 20.3 | |
| **Colour impression** | **(in oil)** | impure grey (tint blue) | impure grey (tint brown) | |
| **BR ~ Rpl** | **(in oil)** | weak | | $A_{oil}$ = 9 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | very weak with colour tint | weak with colour tint |
| **Colour:** | **in 45° position** | dark bluish grey | light grey – greyish brown |
| | **... in other positions** | | grey rose |
| **Extinction position** | | black | |
| **Mode of extinction** | | straight | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

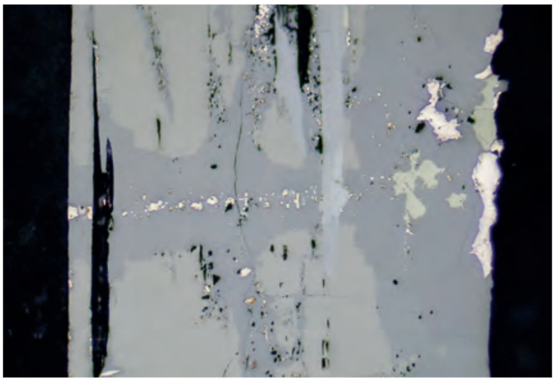
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | granular; prismatic crystals are rare (no needles), replacing emplectite; no #! |
| **Paragenesis** | emplectite, cuprobismutite, bismuth, tennantite, aikinite, cp, bornite |
| **Diagnostic features** | usually the darkest sulfosalt in the paragenesis |

## Notes, drafts

See Criddle & Stanley (1997): Mineral. Mag., 43, 109-113.

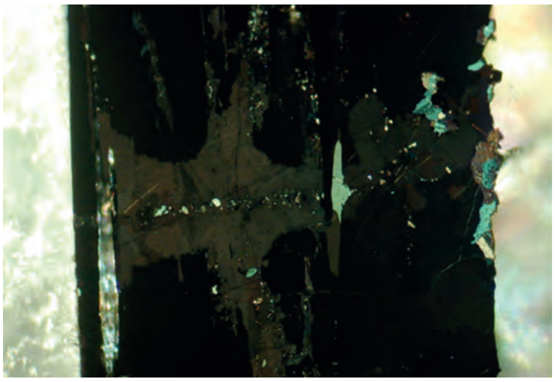
## 577 Wittichenite, emplectite, aikinite, bismuth – Wittichen, Schwarzwald



Emplectite (grey tint olive) with small aikinite needles ($PbCuBiS_3$, light grey) is replaced by wittichenite (medium grey) and bismuth (whitish); small chalcopyrites on the right side.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D158_10
Section: TÜ7

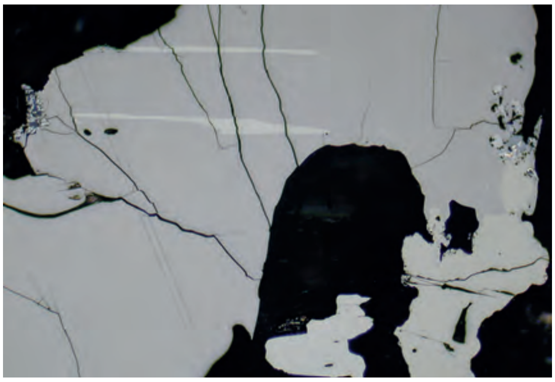
## 578 Wittichenite, emplectite, aikinite, bismuth – Wittichen, Schwarzwald



As above, with crossed polars. Weak anisotropism of wittichenite in light greyish brown colours.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D158_11
Section: TÜ7

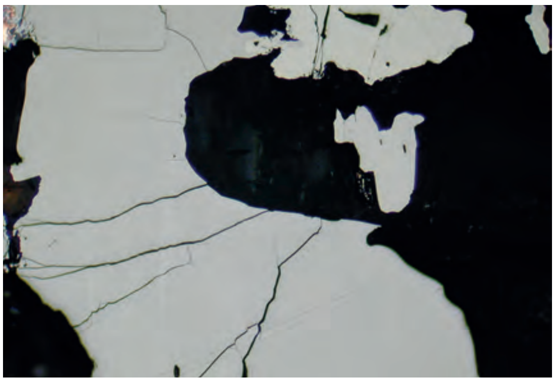
## 579 Wittichenite, emplectite – Daniel im Gallenbach, Wittichen, Schwarzwald



Two needles of emplectite (light grey) in wittichenite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D141_16
Section: TM112

## 580 Wittichenite, emplectite – Daniel im Gallenbach, Wittichen, Schwarzwald



As above, but 90° rotated. Now the two needles of emplectite show only little difference to wittichenite ($R_{empl} \sim R_{witt}$ = 22 vs. 20 %).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D141_17
Section: TM112

# Wolframite

**Mineral name:** Wolframite (wf)
**Formula:** (Fe,Mn)$WO_4$

**VHN:** 320-290
**Crystal System:** mcl.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_1$ = 15.2 | $R_2$ = 16.3 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_1$ = 4.1 | $R_2$ = 4.8 | |
| **Colour impression** | **(in oil)** | grey tint brown | grey tint yellow olive | |
| **BR ~ Rpl** | **(in oil)** | distinct | | $A_{oil}$ = 16 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | weak with colour tint | weak without colour |
| **Colour:** | **in 45° position** | greyish olive | grey – grey |
| | **... in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | perfect, distinctly inclined | |
| **Internal reflections** | **colour** | deep red (Mn-rich) to yellow brown (Fe-rich) | |
| **(IR)** | **frequency** | abundant to common | |
| **Twinning** | **mode** | simple + coarse || (100), never lamellar | |
| | **frequency** | abundant | |

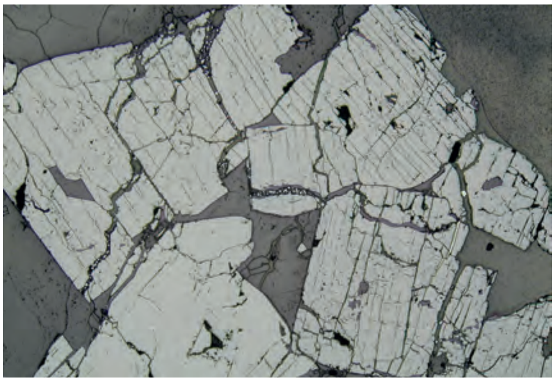
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | mainly as large tabular (100), lens-shaped XX with characteristic cross-fractures. # (010) perfect, replacements by scheelite |
| **Paragenesis** | scheelite, cas, qz, siderite |
| **Diagnostic features** | large XX with cross-fractures, inclined extinction, paragenesis |

## Notes, drafts

Similar to COLUMBITE.
Fe-rich wolframite: Ferberite; Mn-rich: Huebnerite.

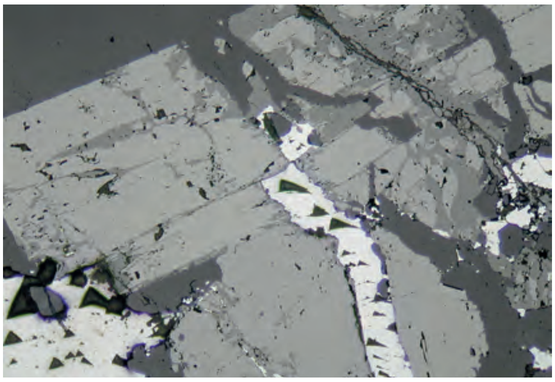
## 581 **Wolframite –** Neudorf, Harz, Germany



Large wolframite crystals (perfect cleavage || (010)).

Obj.: 5 ×
Polars: || Pol
Photo width: 2.8 mm
Photo No.: D09_02
Section: AS1564

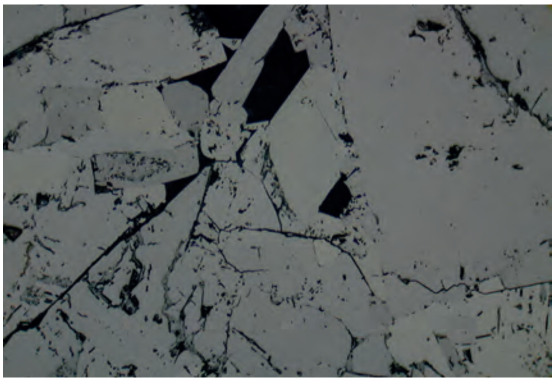
## 582 **Wolframite, scheelite, gn –** Vignola-Falensina, Val Sugana, Trentino, Italy



Broken euhedral plates of wolframite (light grey) partly replaced by scheelite (medium grey), and galena (white, triangular pits).

Obj.: 10 ×
Polars: || Pol
Photo width: 1.4 mm
Photo No.: D64_01
Section: AS3583

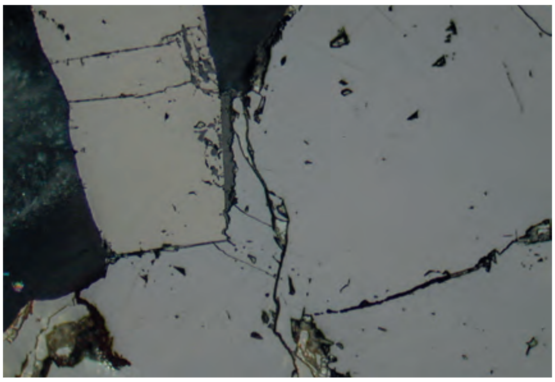
## 583 **Wolframite –** Vignola-Falensina, Val Sugana, Trentino, Italy



Aggregate of wolframite crystals showing distinct bireflection in oil.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D64_06
Section: AS3583

## 584 **Wolframite, sph, scheelite –** Vignola-Falensina, Val Sugana, Trentino, Italy



Tabular wolframite (left side, $R_{max,}$ grey tint yellow olive) with sphalerite (right side, pure grey), and scheelite (small elongated grain between wolframite and sph, darker grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D64_03
Section: AS3583

# Wuestite

**Mineral name:** Wuestite (wus)
**Formula:** $(Fe,Mg)_{1-x}O$

**VHN:** ~ 530
**Crystal System:** cub.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in %** **(for 546 nm)** | 18.5 | | |
| **$R_{(oil)}$ in %** **(for 546 nm)** | 7.0 | slightly less than mt | |
| **Colour impression** **(in oil)** | grey tint green | | |
| **BR Rpl** **(in oil)** | -- | | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | **Precisely crossed polars** | **Not precisely crossed polars** |
|---|---|---|
| **Anisotropism intensity/colour** | homogeneous dark | homogeneous dark |
| **Colour:** **in 45° position** | black | |
| **... in other positions** | | |
| **Extinction position** | -- | |
| **Mode of extinction** | -- | |
| **Internal reflections** **colour** | -- | |
| **(IR)** **frequency** | -- | |
| **Twinning** **mode** | -- | |
| **frequency** | -- | |

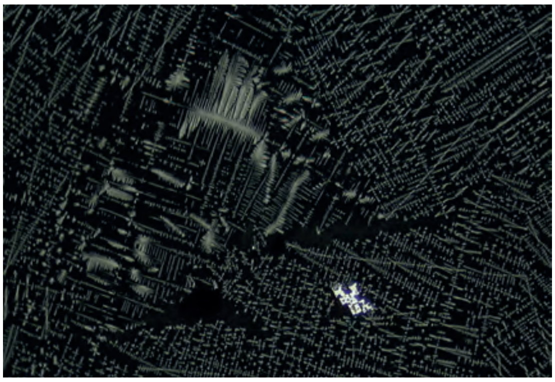
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | often intergrown with magnetite, zoning (Mg-Fe);<br>as EB in artificial mt |
| **Paragenesis** | iron, mt, fayalite |
| **Diagnostic features** | paragenesis with magnetite and iron |

## Notes, drafts

Typically found in artificial products (slags), T < 570° C → $Fe + Fe_3O_4$. Similar to MAGNETITE.
Rare in natural occurrences.

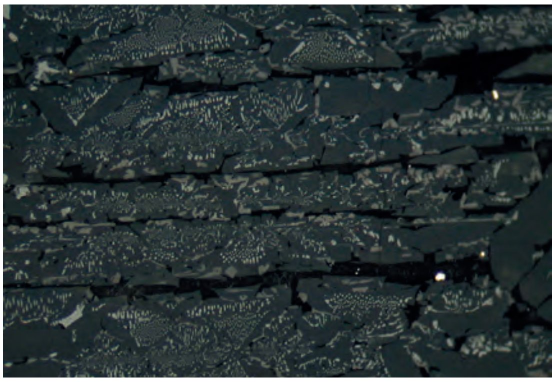
## 585 Wuestite, iron – Weil im Schönbuch, N of Tübingen, SW-Germany



Artificial iron slag with skeletal wuestite (grey tint green) and small grain of iron (white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D85_23
Section: AS3512

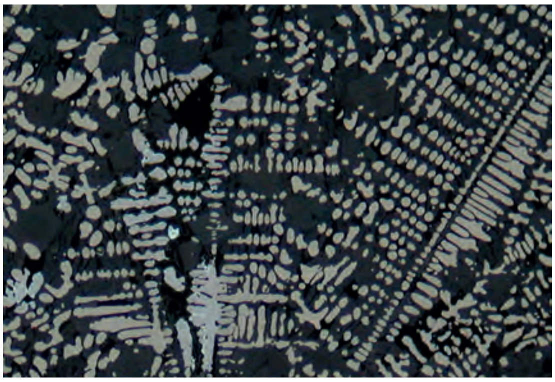
## 586 Wuestite, mt, iron – Locality unknown



Slag with tiny magnetites (slightly more bright, grey) and larger grains of wuestite (grey tint olive); few iron grains (white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D22_11
Section: ExIII/30

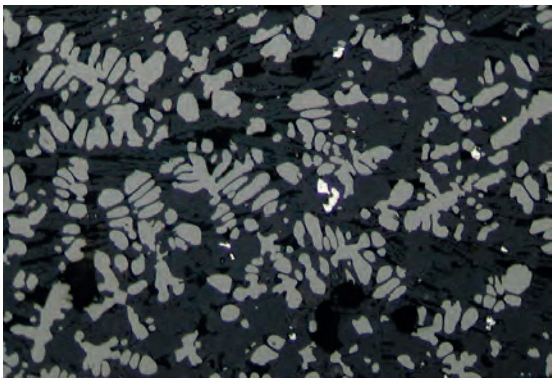
## 587 Wuestite, mt – Medieval slag, Schalkstetten, N of Ulm, Germany



Skeletal aggregates of magnetite (medium grey, lower left part of photo) with rims of hematite, and skeletal wuestite (grey tint olive).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.4 mm
Photo No.: D110_22
Section: AS3513

## 588 Wuestite, iron – Medieval slag, Schalkstetten, N of Ulm, Germany



Artificial iron slag with wuestite (grey) and iron (white) in silicate groundmass.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D224_02
Section: AS3513

# Wurtzite

**Mineral name:** Wurtzite (wur)
**Formula:** ZnS or $ZnS_{1-x}$ (*)

**VHN:** 150-260
**Crystal System:** hex.

## Observations with one polar (AE || Pol)

| | | | |
|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | 18 to 19 | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | 5 to 6 | |
| **Colour impression** | **(in oil)** | grey (tint blue) | |
| **BR Rpl** | **(in oil)** | not visible | $A_{oil} = 0$ |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | masked by internal reflections | |
| **Colour:** | **in 45° position** | not visible; rarely greyish | |
| | **... in other positions** | | |
| **Extinction position** | | not visible | |
| **Mode of extinction** | | -- | |
| **Internal reflections** | **colour** | yellow to dark brown | |
| **(IR)** | **frequency** | predominant | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- (in contrast to sphalerite) | |

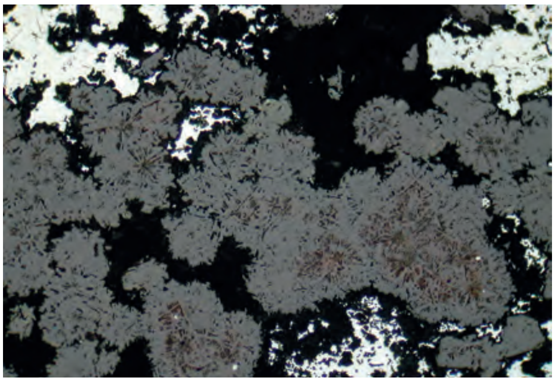
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | radial fibrous aggr. in concentric shells (»Schalenblende«), tabular, dendritic, zoning; replaces galena, teallite, carbonates; occasionally # \|\| (0001) |
| **Paragenesis** | sph, py, mrc, gn |
| **Diagnostic features** | form, #, very similar to sphalerite (but no twins)! |

## Notes, drafts

»SCHALENBLENDE«: Rhythmic banded aggregate of fine-grained SPHALERITE and wurtzite.
(*) see FLEET (2006), Rev. Mineral. Geochem., 61, 365-419.

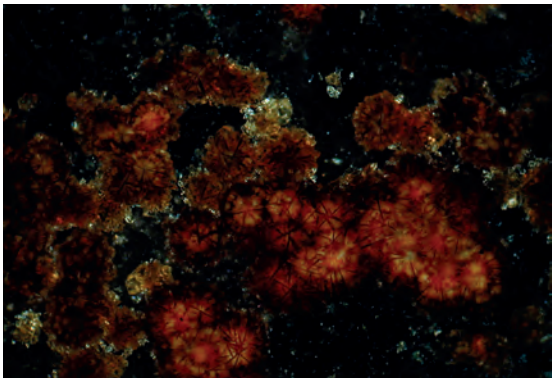
### 589 Wurtzite, arsenic – Michael im Weiler, near Lahr, Schwarzwald, Germany



Radial aggregates of needle-like crystals of wurtzite (medium grey) intergrown with arsenic (white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D112_20
Section: L-4

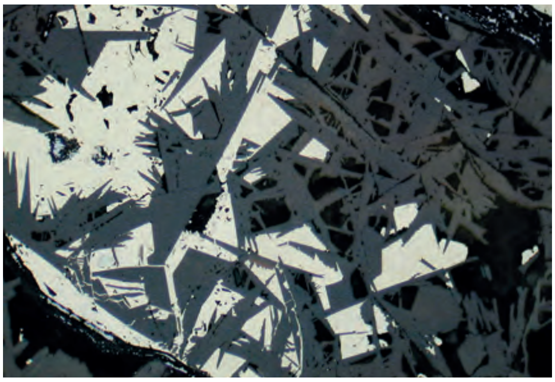
### 590 Wurtzite, arsenic – Michael im Weiler, near Lahr, Schwarzwald, Germany



As above, with crossed polars. Yellow brown to red internal reflections of wurtzite.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D112_19
Section: L-4

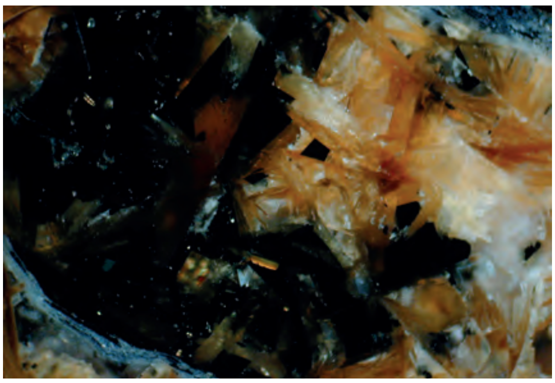
### 591 Wurtzite, py – Potosi, Bolivia



Ophitic network of wurtzite platelets (medium grey with some yellow brown IR) and pyrite.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D109_06
Section: AS1024

### 592 Wurtzite, py – Potosi, Bolivia



As above, with crossed polars.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D109_07
Section: AS1024

# Yarrowite

**Mineral name:** Yarrowite
**Formula:** $Cu_{1.12}S$ ($Cu_9S_8$)

**VHN:** 95-100
**Crystal System:** trig.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 10.2 (12.1*) | $R_{e'}$ = 25.3 (20.6*) | |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 1.8 | $R_{e'}$ = 11.1 | |
| **Colour impression** | **(in oil)** | blue tint violet | light blue | |
| **BR > Rpl** | **(in oil)** | extremely strong | | $A_{oil}$ = 143 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | very strong with colour | very strong with colour |
| **Colour:** | **in 45° position** | orange | light orange |
| | **... in other positions** | | |
| **Extinction position** | | black | |
| **Mode of extinction** | | perfect, undulatory | |
| **Internal reflections** | **colour** | -- | |
| **(IR)** | **frequency** | -- | |
| **Twinning** | **mode** | translation twins, kink banding | |
| | **frequency** | common | |

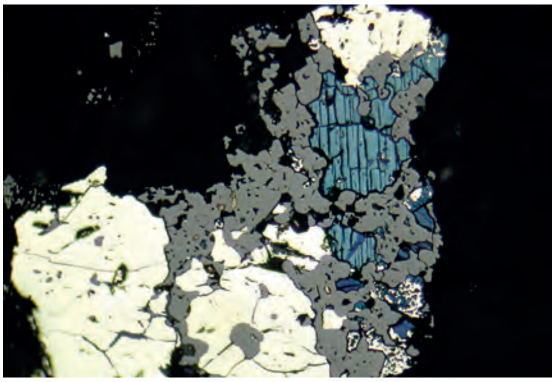
## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | platy tabular; perfect # \|\| {0001} |
| **Paragenesis** | anilite, djurleite, spionkopite, covellite, Cu-sulfides |
| **Diagnostic features** | stronger BR and AExPol than spionkopite, lower R with tint violet |

## Notes, drafts

»Blaubleibender covellite« after Fleet (2006), Rev. Mineral. Geoch., 61, p. 385.
Stability T < 157° C. Similar to spionkopite.
*: different R after Goble (1980), Can. Mineral.,18, 511-518.

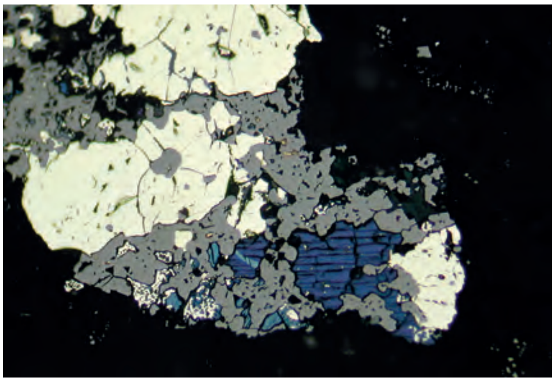
## 593 Yarrowite, mt, py, cp – Rhum, Scotland



Yarrowite (light blue, with $R_{max}$) with magnetite (grey), chalcopyrite (white yellow), and pyrite (white).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D25_17
Section: AS1818

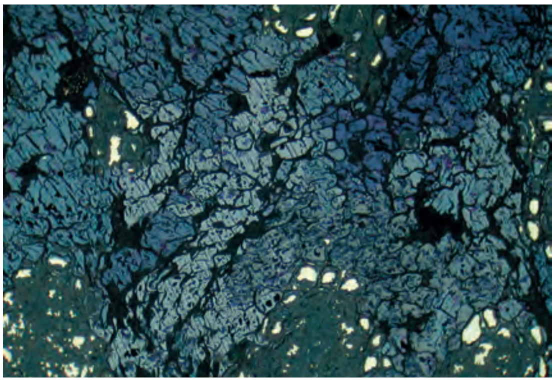
## 594 Yarrowite, mt, py, cp – Rhum, Scotland



As above, 90° rotated. $R_{min}$ of yarrowite now dark blue with faint violet tint.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D25_16
Section: AS1818

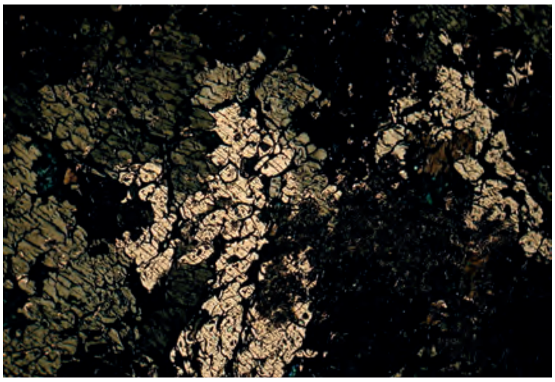
## 595 Yarrowite, cp – Frankenberg, Hesse, Germany



Yarrowite (different shades of blue) replaces chalcopyrite (light yellow) pseudomorph after plant structure.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.7 mm
Photo No.: D148_13
Section: AS3554

## 596 Yarrowite, cp – Frankenberg, Hesse, Germany



As above, with crossed polars.

Obj.: 20 × oil
Polars: × Pol
Photo width: 0.7 mm
Photo No.: D148_14
Section: AS3554

# Zircon (in German: Zirkon)

**Mineral name:** Zircon (zrn)
**Formula:** $ZrSiO_4$

**VHN:** ~ 1600
**Crystal System:** tetr.

## Observations with one polar (AE || Pol)

| | | | | |
|---|---|---|---|---|
| **$R_{(air)}$ in %** | **(for 546 nm)** | $R_o$ = 10.0 | $R_e$ = 10.9 | calculated from n |
| **$R_{(oil)}$ in %** | **(for 546 nm)** | $R_o$ = 1.4 | $R_e$ = 1.8 | calculated from n |
| **Colour impression** | **(in oil)** | grey | grey | |
| **BR ~ Rpl** | **(in oil)** | very weak (masked by IR) | | $A_{oil}$ = 25 |

## Observations with crossed polars (AExPol in oil)

| | | Precisely crossed polars | Not precisely crossed polars |
|---|---|---|---|
| **Anisotropism intensity/colour** | | not visible | not visible |
| **Colour:** | **in 45° position** | masked by IR | |
| | **... in other positions** | | |
| **Extinction position** | | masked by IR | |
| **Mode of extinction** | | masked by IR | |
| **Internal reflections** | **colour** | colourless to light brown | |
| **(IR)** | **frequency** | predominant | |
| **Twinning** | **mode** | -- | |
| | **frequency** | -- | |

## Further observations

| | |
|---|---|
| **Form, habit, textures, cleavage ...** | grains in older rocks show prominent zoning, and radioactive blasting cracks in the rim due to U- and Th-rich cores; columnar to rounded isolated grains. |
| **Paragenesis** | placer minerals, other silicate minerals |
| **Diagnostic features** | habit, zoning, hardness, cracks, high VHN |

## Notes, drafts

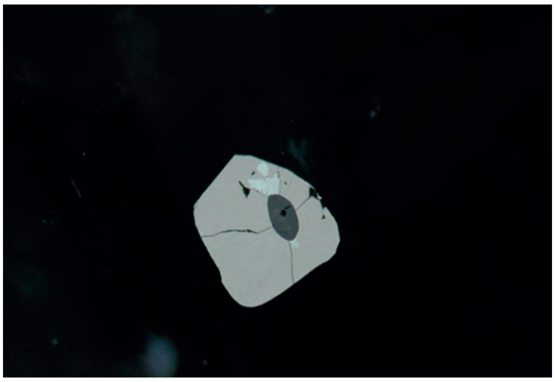
R similar to CASSITERITE, TITANITE, SCHEELITE, but higher than monazite and xenotime.
$R_e$ || elongation

## 597 Zircon, ilm, mt, rt, hm – Åmli, S-Norway

Zircon crystal (central right part) with tiny inclusion of sulfide, attached on large magnetite grain with ilmenite lamellae (sandwich-type, partly replaced by fine-grained mixture of rutile and hematite).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D179_28
Section: AS173

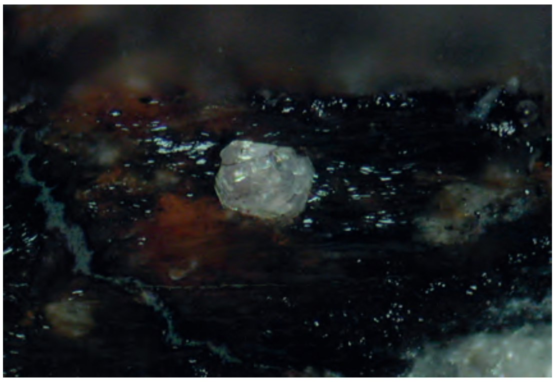
## 598 Zircon, ilm, rt, hm – Åmli, S-Norway



Oval-shaped inclusion of zircon (medium grey) inclusion in ilmenite (with hematite and rutile). Radial cracks in the surrounding ilmenite as radioactive effect of the U/Th content in the zircon.

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D179_29
Section: AS173

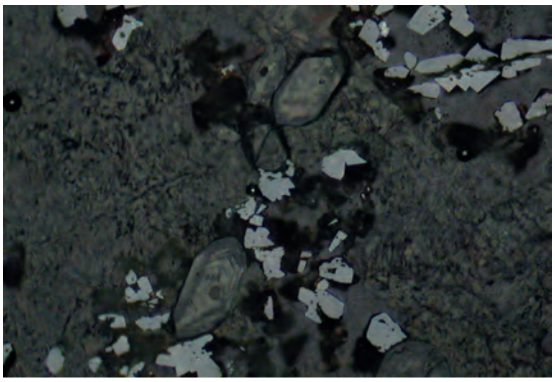
## 599 Zircon, biotite, rt – Oberröthenbach, Schwarzwald, Germany



Zoned zircon (light grey) in larger biotite with tiny inclusions of rutile (medium grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D104_30
Section: IR21a

## 600 Zircon, rutile – Clara mine, Oberwolfach, Schwarzwald, Germany



Two zoned euhedral zircon crystals (nearly transparent) beside numerous rutile grains (medium grey).

Obj.: 20 × oil
Polars: || Pol
Photo width: 0.5 mm
Photo No.: D58_22
Section: ASClara2.2

# GUIDE FOR THE MICROSCOPICAL IDENTIFICATION OF ORE AND GANGUE MINERALS

Reflected-light microscopy is an essential method in earth and materials sciences for the observation of opaque minerals in rocks, metallic ores, coals, and of synthetic phases in slags, cements, metalls/alloys and coal.

In contrast to other analytic investigations, ore microscopy does not only allow for the identification of many minerals but also enables the user to characterise their intergrowths and fabrics, resulting in the interpretation of their genesis and of the subsequent transformation processes, like alteration, replacement, exsolution and deformation.

This guide is intended to serve as an introduction and helpful resource for geosciences students and professionals in the industry for identifying important opaque minerals and some synthetic phases. It includes the optical properties of 130 ore and gangue minerals as well as at least four photomicrographs of their typical appearances, textures, and assemblages

ISBN 978-3-947251-07-0
9 783947 251070

TÜBINGEN
UNIVERSITY
PRESS