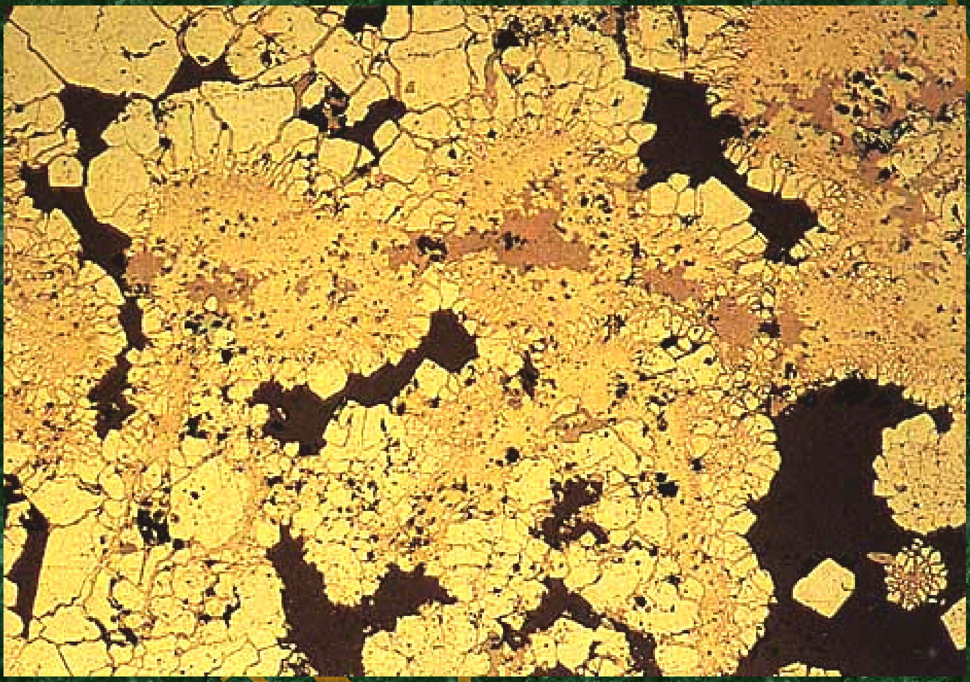
Masive sulfides

Location:	**Aarja, Semail Ophiolite. Oman** The massive sulphides lie between footwall basalts of the Geotimes Unit and hangingwall basalts of the Alley Unit, the latter are interpreted as having formed in a graben-like structure between seamounts. Both mineralogically and texturally, Aarja is different from Lasail and Bayda, for its ore carries few oxide minerals but a greater abundance of bornite and marcasite. It displays abundant collomorphic pyrite and there is little evidence for chalcopyrite replacement of sulphides.
Major Minerals:	Pyrite, chalcopyrite, bornite, sphalerite
Minor Minerals:	Marcasite, tennantite, anomalous bornite
Trace Minerals:	Include bravoite, galena, native gold
Textures:	Collomorphic textures between the iron, iron-copper and zinc sulphides are dominant. Fine-scale optical (and chemical) zoning of sphalerite is present. There is very little replacement of sphalerite by chalcopyrite, but pyrite is replaced by chalcopyrite and bornite. Sphalerite carries rare tennantite and galena inclusions
References:	Ixer et al., 1984, 1986; Haymon et al., 1984

Pyrite, chalcopyrite, bornite and haematite. Aarja, Oman

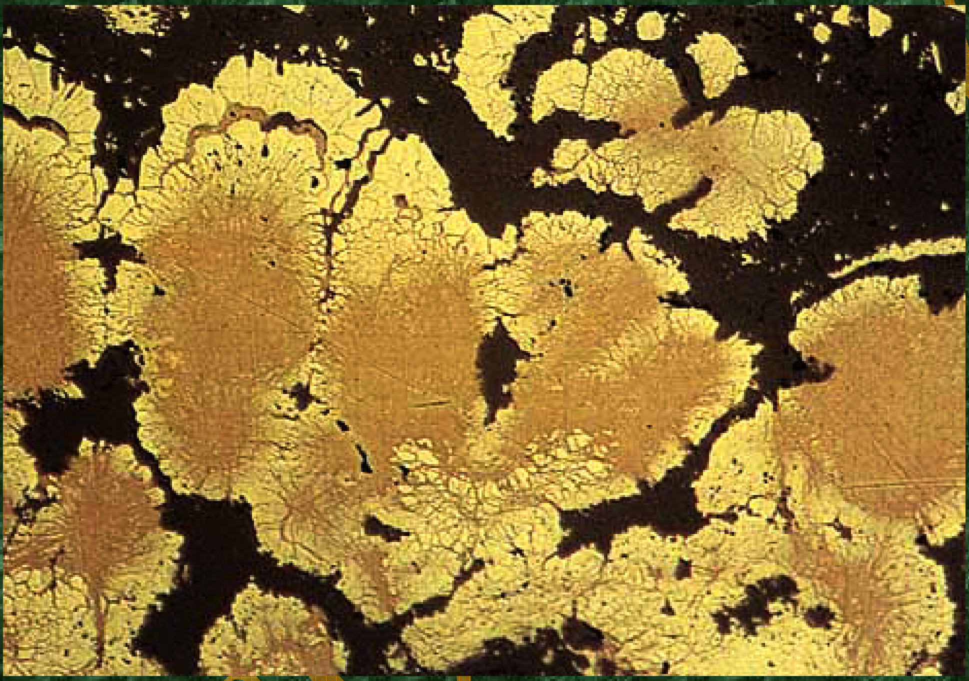


250µm

Radiating aggregates of pyrite (light yellow-white, top left) have been extensively replaced by copper-iron sulphides, but locally are unreplaced (top left). The cores to most of the aggregates are now chalcopyrite (yellow, centre) and bornite (brown, centre top) with rare haematite (blue, centre left, top right) laths. Minor amounts of relict pyrite are visible within the copper-iron sulphides (centre right). Quartz (black) is the gangue.

Polished block, plane polarized light, x 80, air

Bornite, pyrite and chalcopyrite. Aarja, Oman

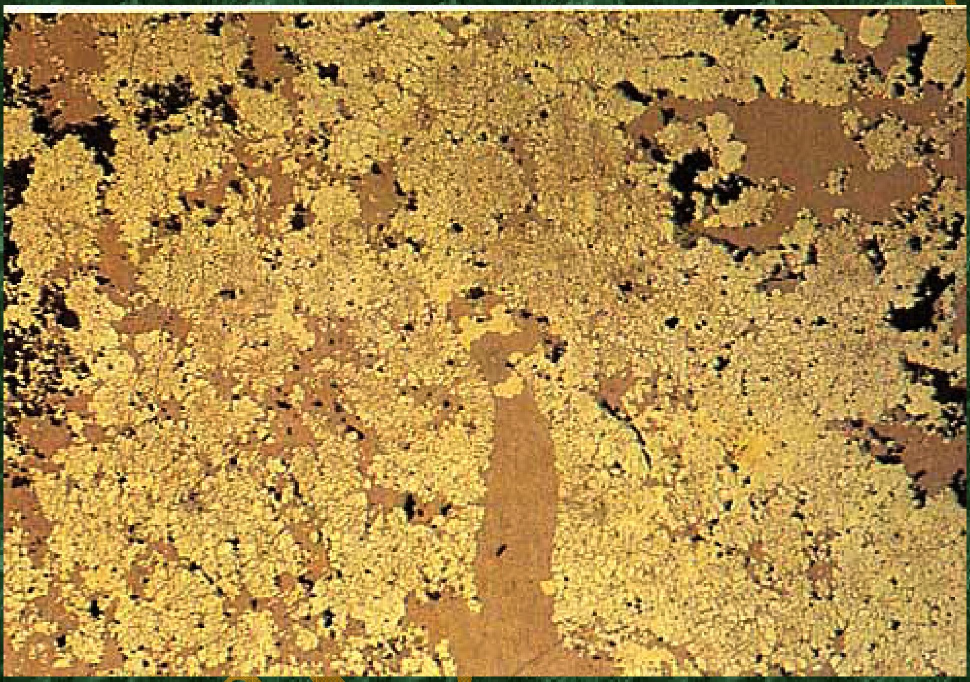


250µm

Radiating pyrite aggregates (light yellow-white, centre top) have been fractured and cemented by quartz (top centre). They have been extensively replaced by bornite (brown, centre), which locally is intergrown with minor amounts of chalcopyrite (yellow, centre left). In the cores of the original pyrite aggregates, where bornite replacement is complete, there is an almost total absence of relict pyrite. Bands of bornite (top left) between pyrite are probably fracture infilling rather than replacement. Quartz (grey) is the gangue.

Polished thin section, plane polarized light, x 80, air

Bornite, pyrite and chalcopyrite. Aarja, Oman

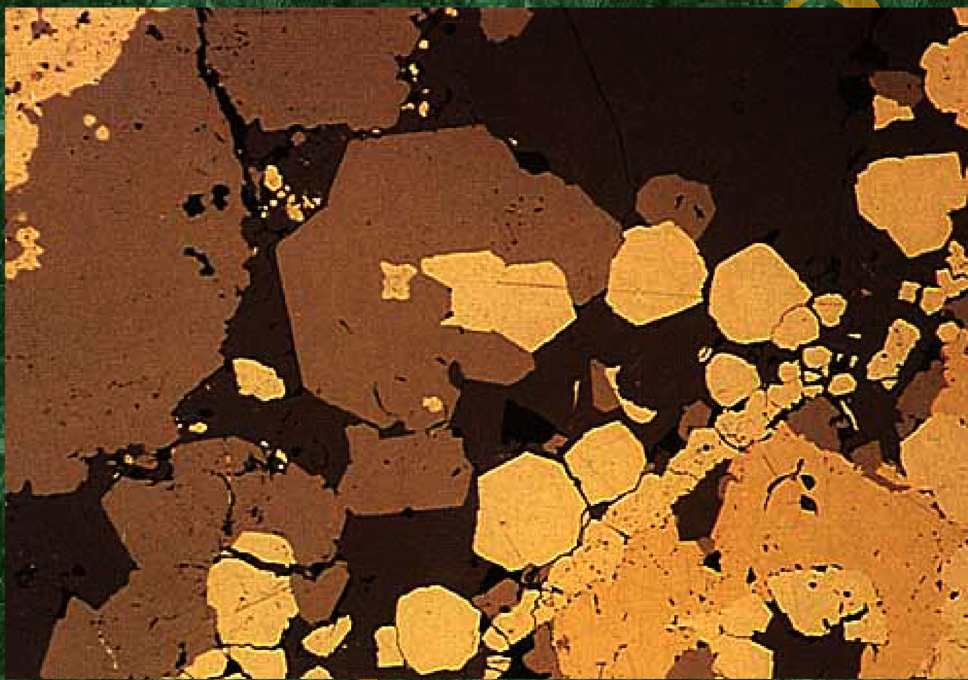


250µm

Fine-grained radiating pyrite (yellow-white, bottom right) is extensively replaced by bornite (centre top) to give lower reflectance cores to the 'pyrite'. Coarser-grained bornite (brown, top right) is intergrown with chalcopyrite (yellow, centre) and cements pyrite aggregates. Black areas are polishing pits.

Polished block, plane polarized light, x 80, air

Sphalerite, pyrite and chalcopyrite. Aarja, Oman

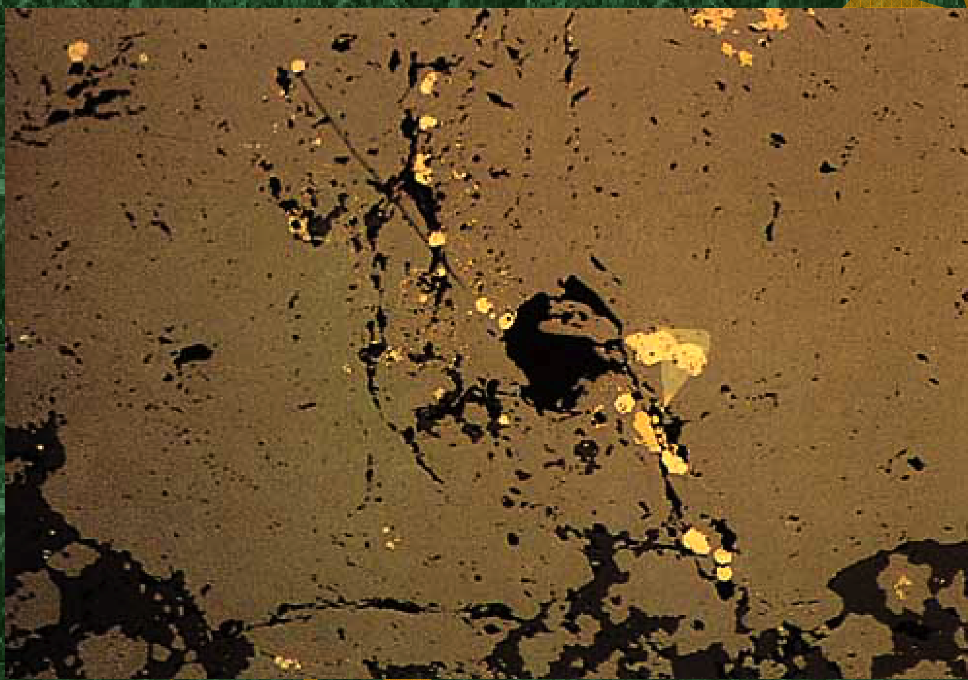


250µm

Sphalerite (grey, top left) forms botryoidal aggregates upon poorly crystalline pyrite (light yellow, top left). Euhedral sphalerite crystals (centre) have a hexagonal-looking morphology suggesting that they were initially wurtzite. Coarse discrete pyrite crystals are unzoned and euhedral (centre), whereas fine crystals within a northeast-oriented vein have lower reflectance cores. Chalcopyrite (yellow, bottom right) is intergrown with pyrite and rimmed by sphalerite. The sphalerite is free of chalcopyrite disease. Quartz is dark grey, black areas are polishing pits.

Polished block, plane polarized light, x 80, air

Sphalerite, chalcopyrite, pyrite and tennantite. Aarja, Oman



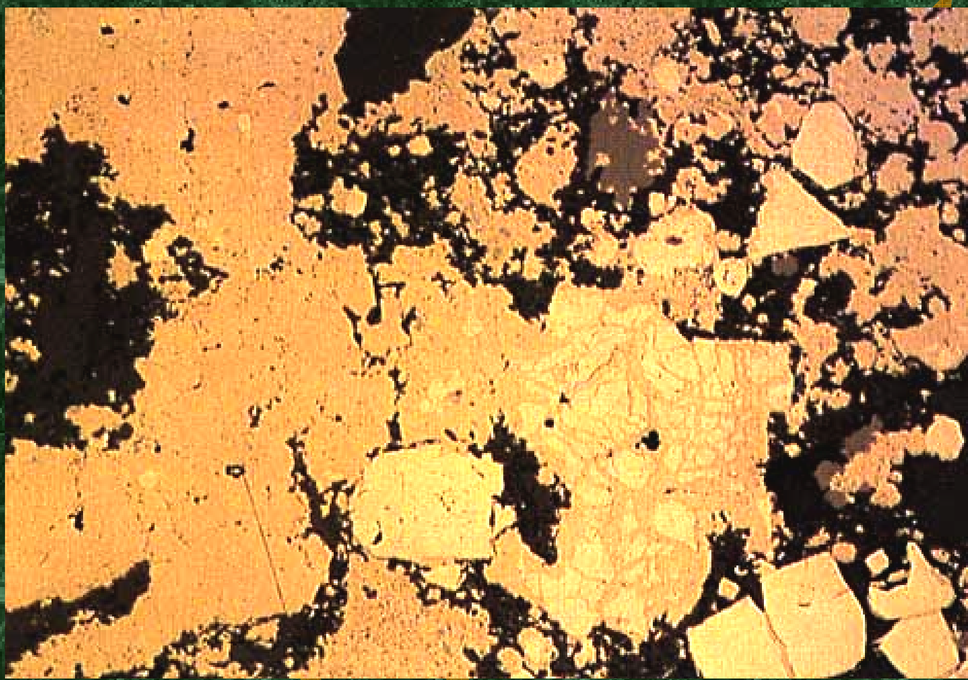
250µm

Sphalerite (grey), the main phase, encloses irregular chalcopyrite (yellow, top right) and fine chalcopyrite inclusions (centre) but is essentially free of chalcopyrite disease. Small euhedral pyrite crystals (pale yellow-white, centre) lie in a discontinuous veinlet cutting sphalerite. A triangular inclusion of tennantite (green-blue, centre right) is associated with chalcopyrite and two pyrite crystals. Quartz is dark grey, black areas are polishing pits.

Polished block, plane polarized light, x 80, air

Location:	**Çeyeli-Madenkoy deposit. Turkey** Volcanogenic massive sulphides and associated stringer zones are found in the Eastern Black Sea metallogenic province of northeastern Turkey within submarine basic to intermediate volcanics of Cretaceous to Tertiary age. The deposits have been affected by the Alpine orogeny. The deposits have many features in common with Kuroko ores, notably they are stratabound within acidic lavas and pyroclastics. The massive ores are overlain by iron-rich cherts, or iron- and manganese-rich sediments and underlain by a stockwork (stringer) zone. The ores are fine-grained or brecciated and show primary bedding structures. The main sulphate gangue is baryte. The (Çeyeli deposit lies within pyroclastic units close to the top of the Dacitic Series and is overlain by purple tuffs and basalts. It comprises massive copper-zinc ores (black ore) and stockwork copper-pyrite ores. Quartz, baryte, calcite and clay minerals are the main gangue.
Major Minerals:	Chalcopyrite, pyrite, sphalerite, locally bornite
Minor Minerals:	Tetrahedrite group minerals, galena, marcasite, covelline
Trace Minerals:	Include native gold and numerous sulphosalts
Textures:	Fine-grained ore has extensive rhythmical precipitation of pyrite-bornite-chalcopyrite-silica. Coarse-grained ore also has extensive rhythmical precipitation of sphalerite-galena-chalcopyrite-tetrahedrite associated with baryte, or shows complex intergrowths of sphalerite-galena-tetrahedrite-chalcopyrite-bornite-pyrite. Pyrite is replaced along its cleavage by chalcopyrite, and sphalerite has chalcopyrite disease. Sphalerite encloses fine- to coarse grained tetrahedrite inclusions
References:	Alton, 1978; Guy et al., 1983; Akinci, 1984

Chalcopyrite, pyrite and sphalerite. Çeyeli, Turkey

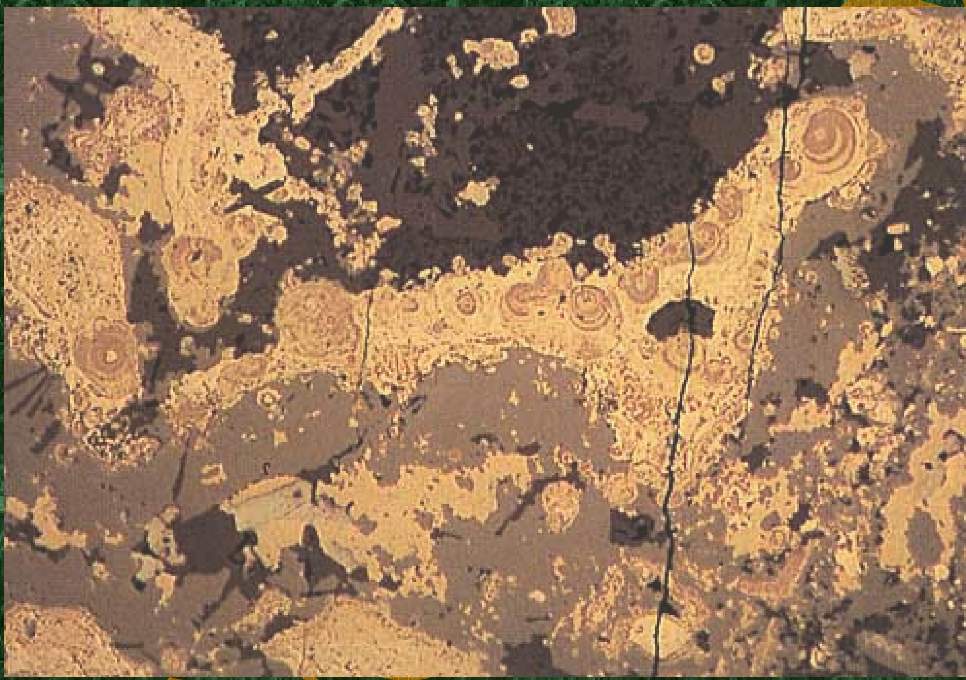


250µm

Pyrite (pale yellow-white, high reflectance) forms euhedral crystals with thin chalcopyrite rims (bottom right) and is extensively replaced by chalcopyrite (yellow, centre right) in a characteristic texture found in many volcanogenic deposits. Euhedral to subhedral sphalerite (light grey) overgrows chalcopyrite (right centre).

Polished block, plane polarized light, x 80, air

Sphalerite, chalcopyrite, pyrite, bornite and galena. Çeyeli, Turkey

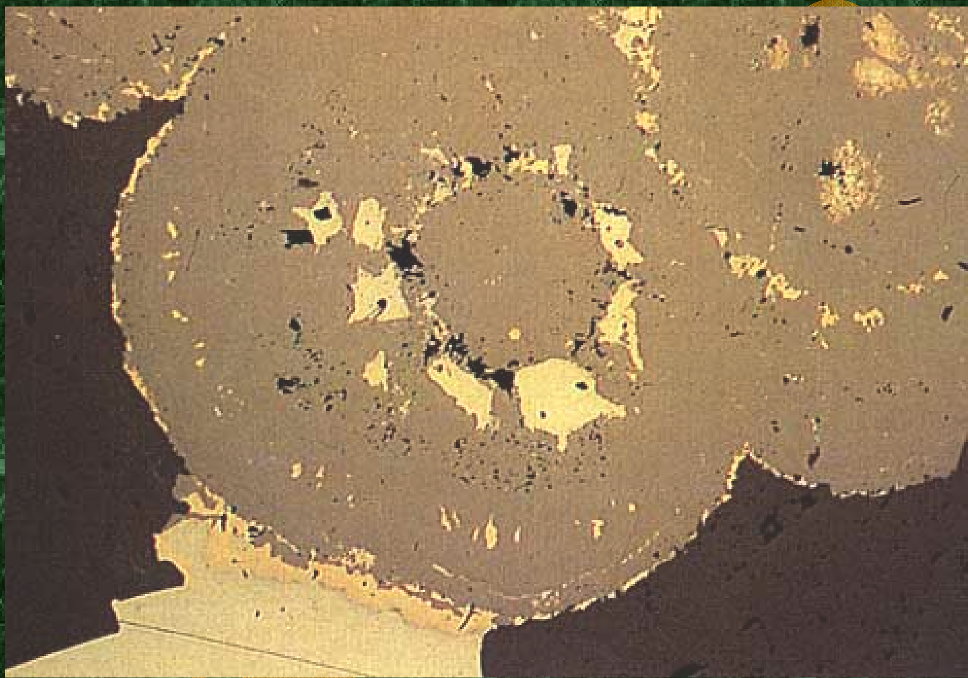


250µm

Concentrically banded bornite (brown, centre) and chalcopyrite (yellow, centre) are intergrown with poorly crystalline pyrite (pale yellow-white, centre top) which shows variations in reflectance and surface colour due to differences in crystallinity (top left) and degree of replacement by chalcopyrite (bottom left). Coarse-grained chalcopyrite (centre bottom) is intergrown with galena (blue-white, centre bottom) about sphalerite (light grey, centre), which is free of fine-grained inclusions. Silicates and sulphates (dark greys) constitute the gangue.

Polished block, plane polarized light, x 80, air

Sphalerite, galena, chalcopyrite and pyrite. Çeyeli, Turkey



250µm

Reniform sphalerite (light grey, centre) is interbanded with galena (white, centre bottom) and chalcopyrite (yellow) in successive growth rings. Chalcopyrite in the centre of the right sphalerite has replaced poorly crystalline pyrite (white, top right). Chatcopyrite can be seen to have higher relief than galena (bottom left). The gangue (dark grey) is sulphate. Black areas are polishing pits.

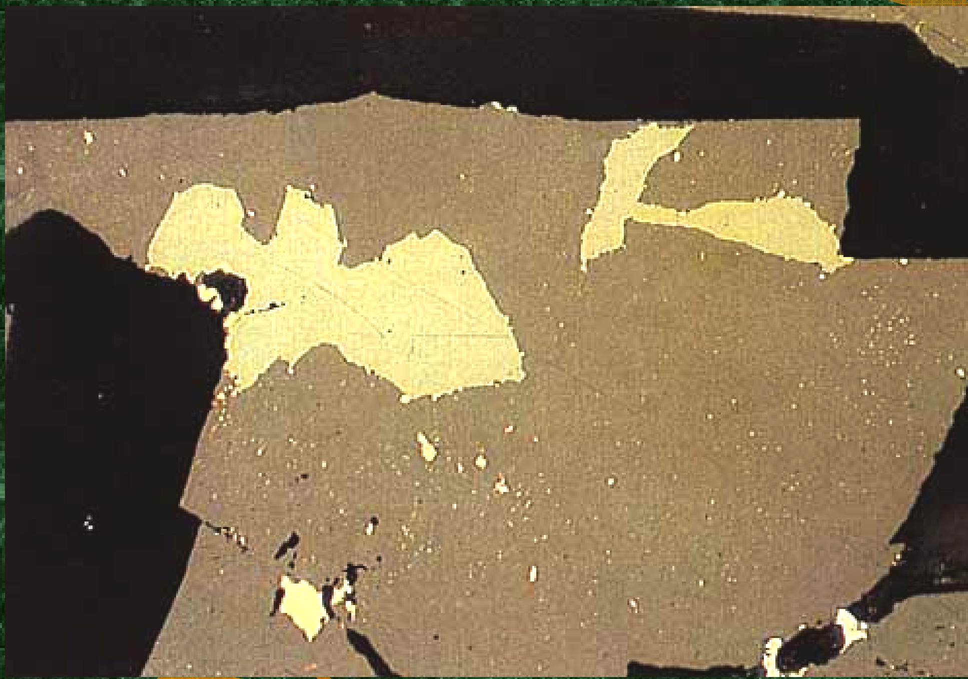
Polished block, plane polarized light, x 80, air

Chalcopyrite and sphalerite. Çeyeli, Turkey

Very finely banded ore comprising fine-grained chalcopyrite (yellow) and sphalerite (grey). Thin veinlets parallel with the layering carry coarse-grained chalcopyrite and sphalerite (top right). The individual minerals can be resolved at higher magnifications.

Polished block, plane polarized light, x 80, air

Sphalerite, tetrahedrite group mineral, chalcopyrite and galena. Çeyeli, Turkey

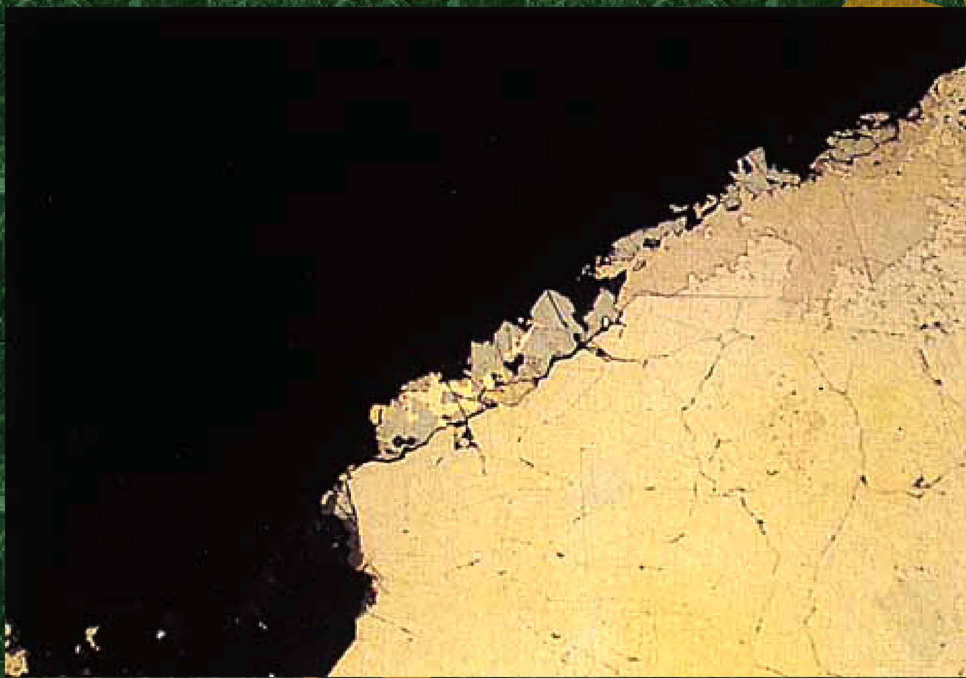


125µm

Sphalerite (grey) shows a slight variation in reflectance and very faint reddish internal reflections (both very difficult to see) due to submicroscopic inclusions of tetrahedrite (right centre). Coarse-grained tetrahedrite (green-blue, centre left) is also present within sphalerite as is chalcopyrite (yellow, bottom left). A minor amount of galena (white) lies in the gangue between sphalerite crystals (bottom right).

Polished block, plane polarized light, x 160, oil

Pyrite, chalcopyrite, galena, marcasite and native gold. Çeyeli, Turkey



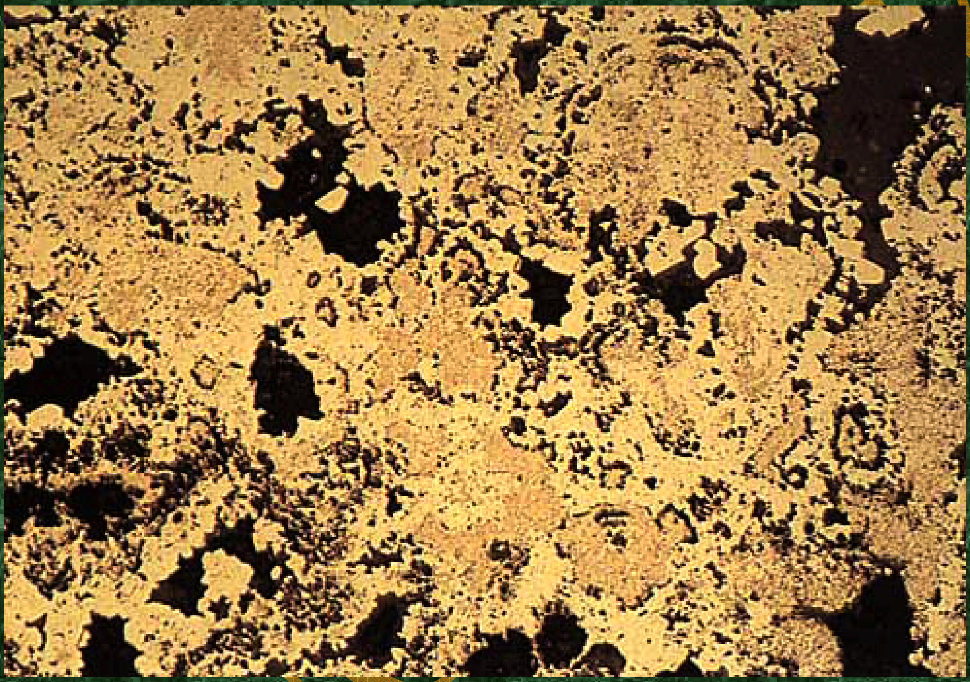
125µm

Marcasite (light blue-white, bottom right) rhombs form the cores to pyrite crystals (light yellow-white, right), which are replaced by chalcopyrite (top right). One marcasite crystal (bottom right) is twinned and shows faint bireflectance and reflection pleochroism (grey to blue-grey). Pyrite is rimmed and replaced by chalcopyrite (yellow), which itself has a galena rim (blue-grey, centre). Native gold (light yellow, high reflectance, centre) is intergrown with galena. The low reflectance and blue-grey colour of galena against native gold is characteristic. The black area is resin-

Polished block, plane polarized light, x 160, oil

Location:	**Galapagos Mound sulphides. Pacific Ocean** Massive sulphide mounds are associated with inactive vents lying along the Galapagos Rift. The sulphides are pyrite-chalcopyrite-dominated, unlike those found along 21'N, and share many similarities with massive sulphide ores found within ophiolite volcanic sequences. Opal and gypsum are the main non-sulphides.
Major Minerals:	Pyrite, chalcopyrite
Minor Minerals:	Marcasite, sphalerite/wurtzite
Trace Minerals:	Include pyrrhotite, haematite, tetrahedrite group minerals, galena, cubanite, covelline, blaubleibender covelline
Textures:	The chimney-like 'ores' have an inner chalcopyrite-rich core and pyrite - rich rim. Collomorphic pyrite is intergrown with marcasite. Euhedral pyrite encloses small chalcopyrite, isocubanite, wurtzite/sphalerite, haematite and galena inclusions along growth zones. Zinc sulphide has the habit of wurtzite and carries chalcopyrite inclusions. Chalcopyrite occurs as void infillings and is altered to covelline. Lamellae of pyrrhotite show extensive alteration to pyrite and marcasite
References:	Schrader et al., 1980; Malahoff, 1982; Oudin, 1982; Skirrow and Coleman, 1982; Malahoff et al., 1983

Pyrite and marcasite. Galapagos Mound, Pacific Ocean



250µm

Radiating aggregates of poorly crystalline pyrite (browner, lower reflectance, centre) form cores to euhedral or subhedral pyrite (yellow-white, centre right) which is intergrown with minor marcasite (blue-white, higher reflectance, top centre) in voids.

Polished block, plane polarized light, x 80, air

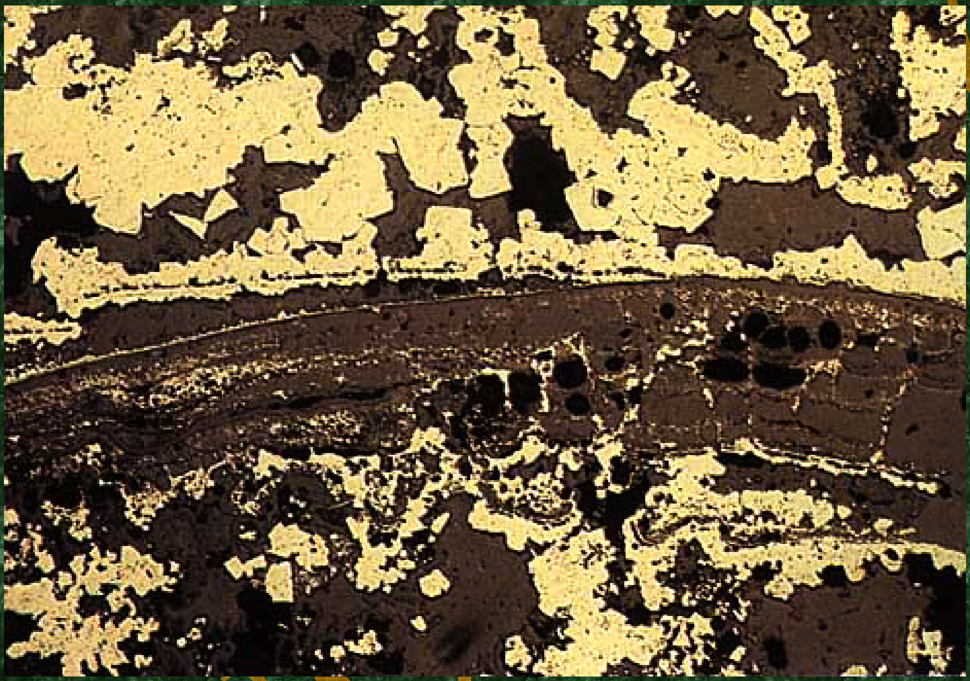
Pyrite and marcasite. Galapagos Mound, Pacific Ocean

500µm

Radiating, botryoidal, poorly crystalline pyrite (brown, lower reflectance, bottom centre) is overgrown by euhedral to subhedral pyrite (yellow-white, higher reflectance, centre bottom) and minor marcasite (white, centre bottom left). The east-west linear feature is an organic structure-a worm tube? that is partially infilled by pyrite (centre). Dark grey areas are matrix and resin (bottom left).

Polished block, plane polarized light, x 40, air

Pyrite. Galapagos Mound, Pacific Ocean

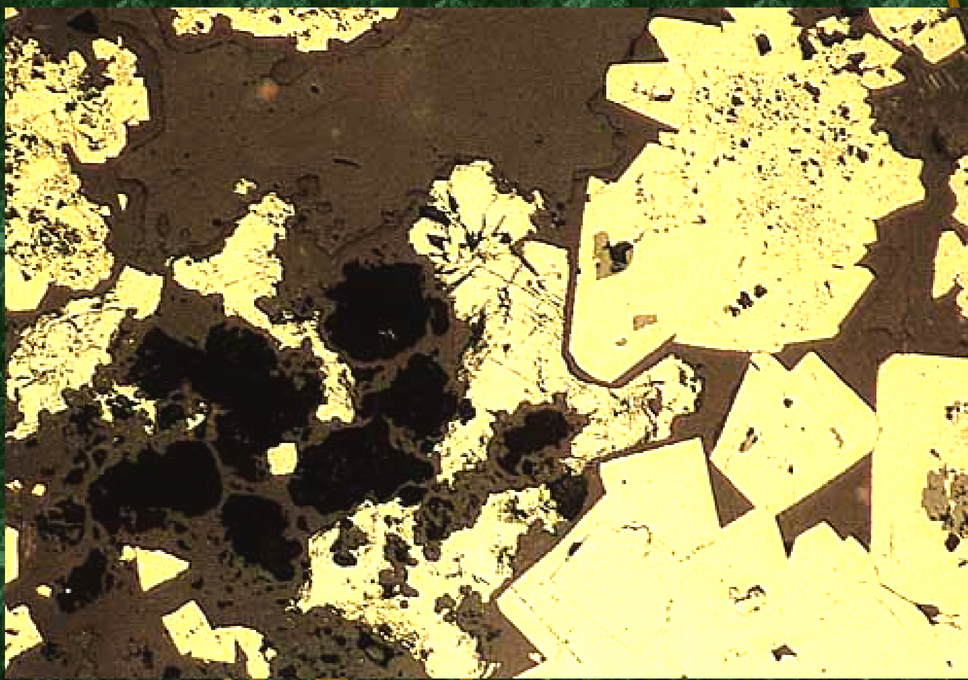


500µm

Euhedral to subhedral pyrite (yellow-white) is banded, as seen by slight variations in reflectance (top left). A large organic structure is partially infilled by very fine-grained pyrite (left and right centre) which has picked out some of the internal structure. Black areas are polishing pits.

Polished block, plane polarized light, x 40, air

Pyrite, marcasite and sphalerite. Galapagos Mound, Pacific Ocean

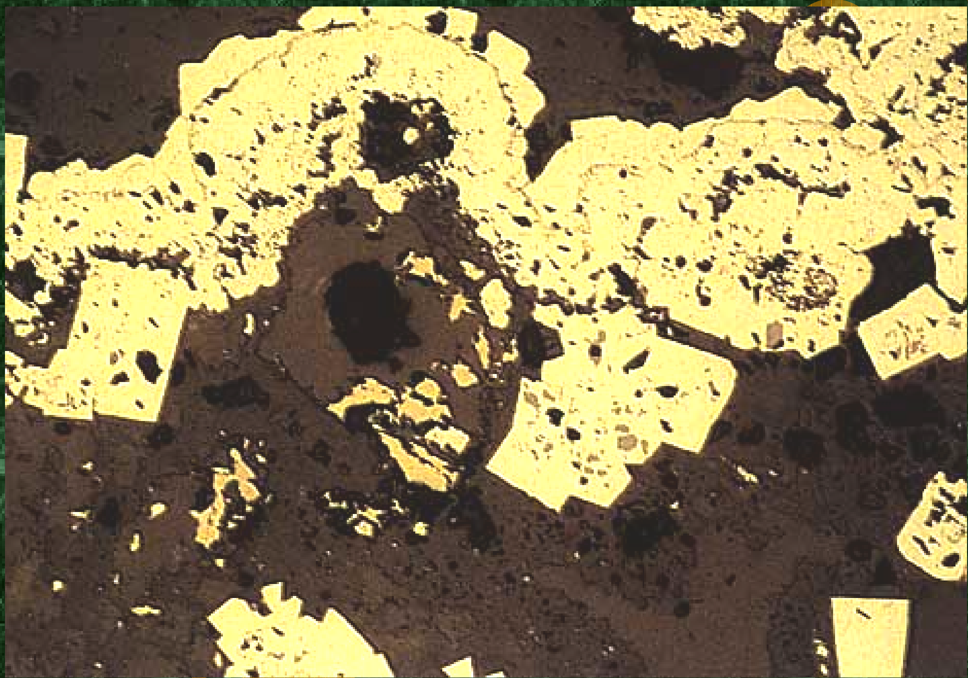


250µm

Pyrite (light yellow) forms euhedral crystals, many with poorly crystalline cores (top right), or irregular banded poorly crystalline aggregates (brown-white, lower reflectance, top left). A thin rim of silica (grey, top left) encloses pyrite. Subhedral to euhedral sphalerite (light grey, bottom right) inclusions occur in pyrite. Radiating crystals of marcasite (white, centre) surround pyrite and show incipient alteration to limonite along growth zones. Black areas are polishing pits.

Polished block, plane polarized light, x 80, air

Pyrite, marcasite, chalcopyrite and sphalerite. Galapagos Mound, Pacific Ocean

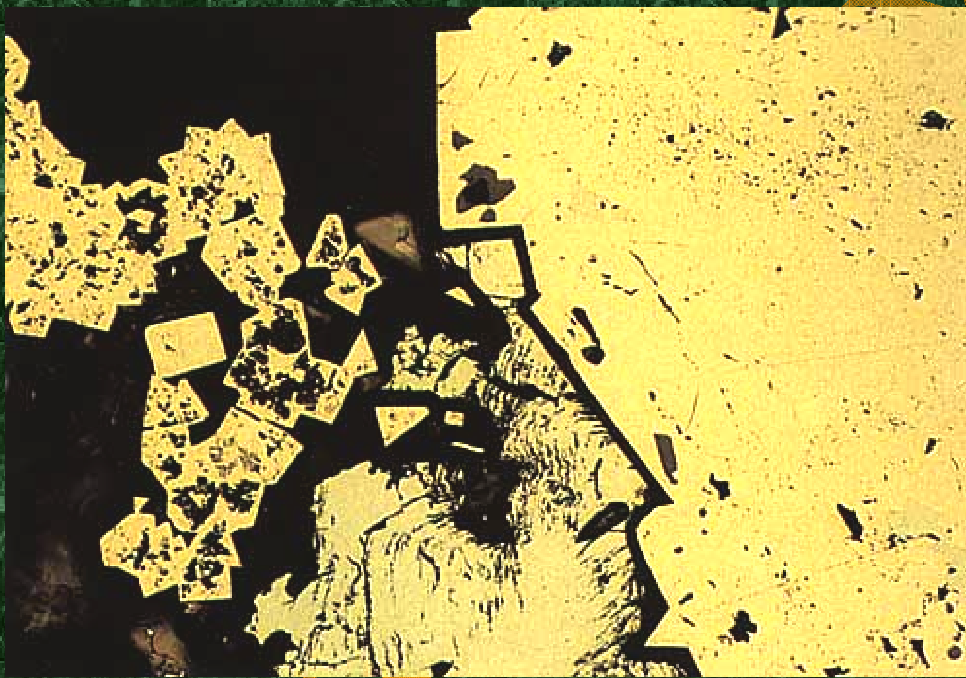


250µm

Pyrite (light yellow-white) forms euhedral crystals (centre) which contain small sphalerite (light grey, centre right) inclusions or is interbanded with marcasite (blue-white, higher reflectance than pyrite, centre top, top right). The lower reflectance growth bands within the pyrite-marcasite intergrowths are either due to very fine-grained pyrite or the presence of small non-sulphide inclusions. Anhedral chalcopyrite (yellow, centre) is present within the silica matrix. Black areas are polishing pits.

Polished block, plane polarized light, x 80, air

Pyrite, marcasite and sphalerite. Galapagos Mound, Pacific Ocean



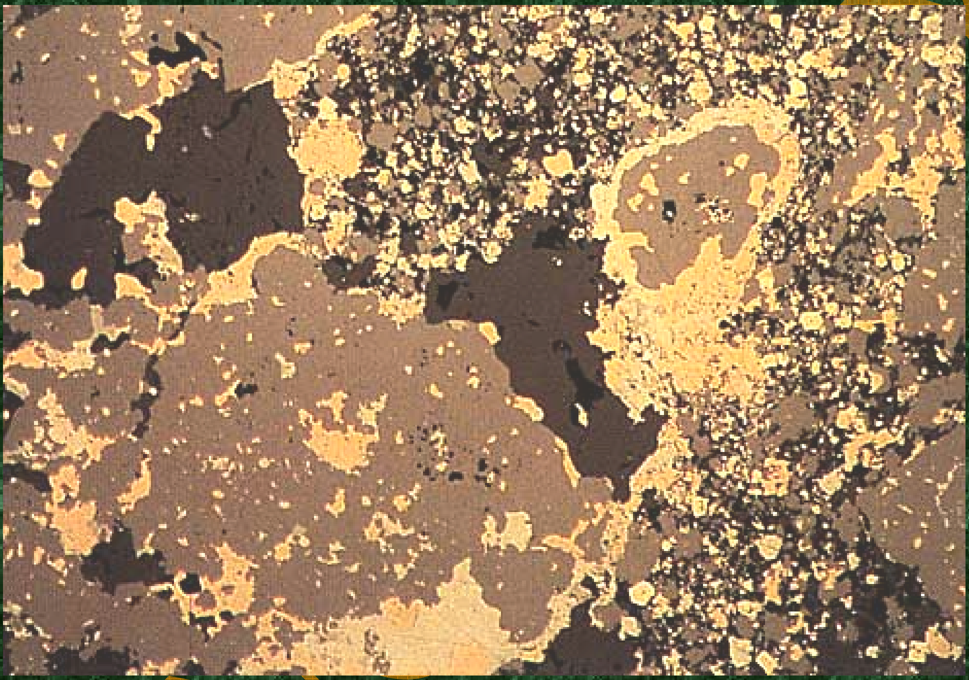
125µm

Pyrite (light yellow) forms euhedral crystals enclosing non sulphides (black, top right) and minor sphalerite (light grey, centre right). Marcasite (blue-green white, bottom centre) occurs as inclusions within the large pyrite (centre right) but also surrounds it. The main marcasite (bottom centre) shows incipient alteration to limonite; this alteration is crystallographically controlled along growth zones. Smaller euhedral pyrite crystals (left) contain abundant non-sulphide inclusions (black) and minor sphalerite (centre left).

Polished block, plane polarized light, x 160, oil

Location:	**Kuroko ore. Ainai Mine, Akita Prefecture, Japan** Ainai Mine lies within the Furutobe Caldera which is part of the Miocene Hokuroku Basin. This basin is the most important Kuroko district of the Green Tuff region of Japan.
Major Minerals:	Pyrite, chalcopyrite, sphalerite, galena, tetrahedrite group minerals
Minor Minerals:	Bonite
Trace Minerals:	Include stromeyerite, electrum, argentite, native silver, bournonite, boulangerite, djurleite, haematite, magnetite
Textures:	The ores show soft sediment deformation, including flame textures and slumping in addition to undeformed graded bedding. Collomorphic textures are common between sulphides, as are recrystallization textures. There is extensive replacement of pyrite and sphalerite by chalcopyrite (chalcopyrite disease)
References:	Ishikawa and Yanagisawa, 1974; Urabe and Sato, 1978

Sphalerite, chalcopyrite, galena, tetrahedrite and pyrite. Ainai Mine, Akita Prefecture, Japan

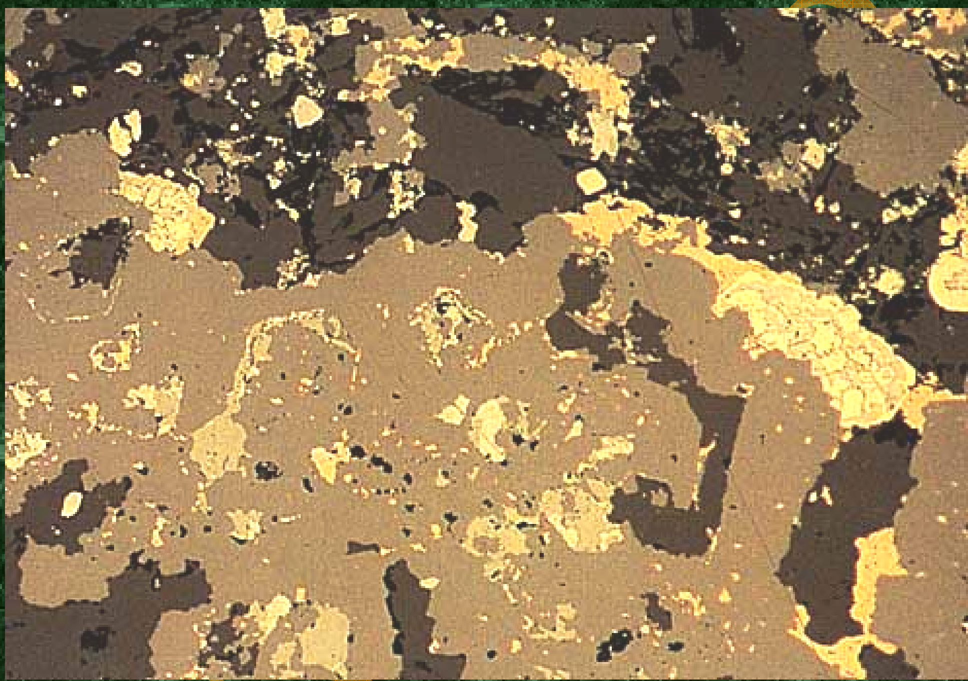


250µm

Coarse-grained sphalerite (light grey) is the main sulphide and is rimmed by chalcopyrite (yellow, centre right) and galena (white, bottom centre, top right). The galena carries small inclusions of tetrahedrite (grey, lower reflectance, centre right), which are difficult to see, and euhedral pyrite (centre right). Small euhedral pyrite cubes (light yellow, bottom right) are associated with small galena and chalcopyrite crystals within sphalerite (top and bottom right). Gangue phases are grey.

Polished block, plane polarized light, x 80, air

Sphalerite, chalcopyrite, tetrahedrite, galena and pyrite. Ainai Mine, Akita Prefecture, Japan

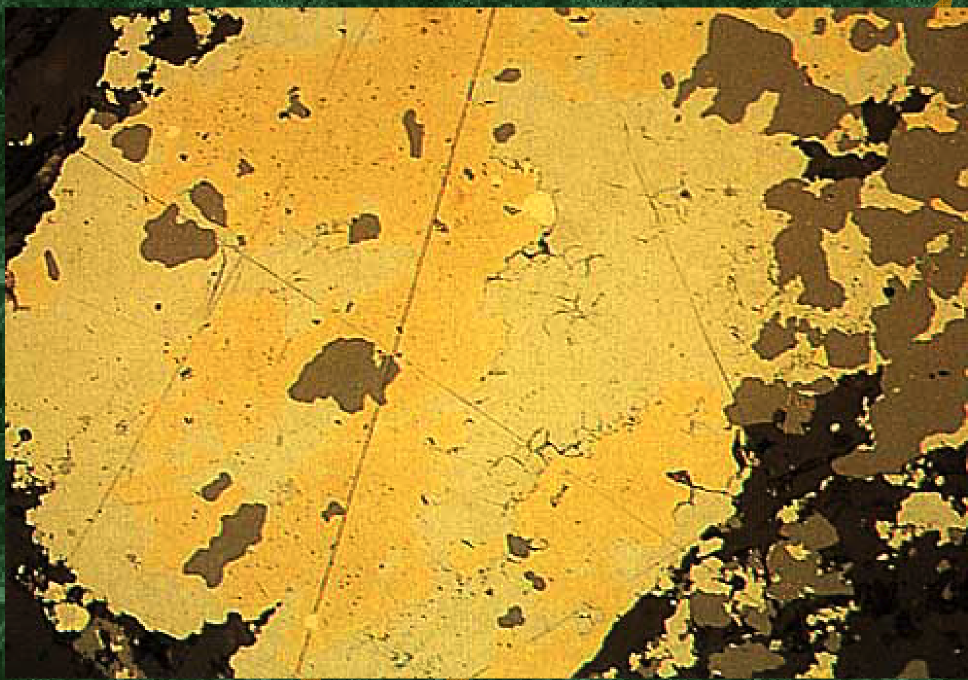


250µm

Coarse-grained sphalerite (light grey, centre) crystals carry tetrahedrite (green-grey, bottom centre), chalcopyrite (yellow, centre) and galena (white, centre) inclusions. Many of the inclusions can be seen to be associated with crystal boundaries of the sphalerite; this is especially true of fine-grained tetrahedrite (left centre). Chalcopyrite, galena and pyrite form incomplete rims around sphalerite (top left), where most of the pyrite has been replaced by galena (right centre). Much of the tabular gangue (grey, top centre) is baryte. Galena looks blue and darker against pyrite (right centre) but white and lighter against tetrahedrite within sphalerite (centre).

Polished block, plane polarized light, x 80, air

Galena, chalcopyrite, sphalerite and pyrite. Ainai Mine, Akita Prefecture, Japan

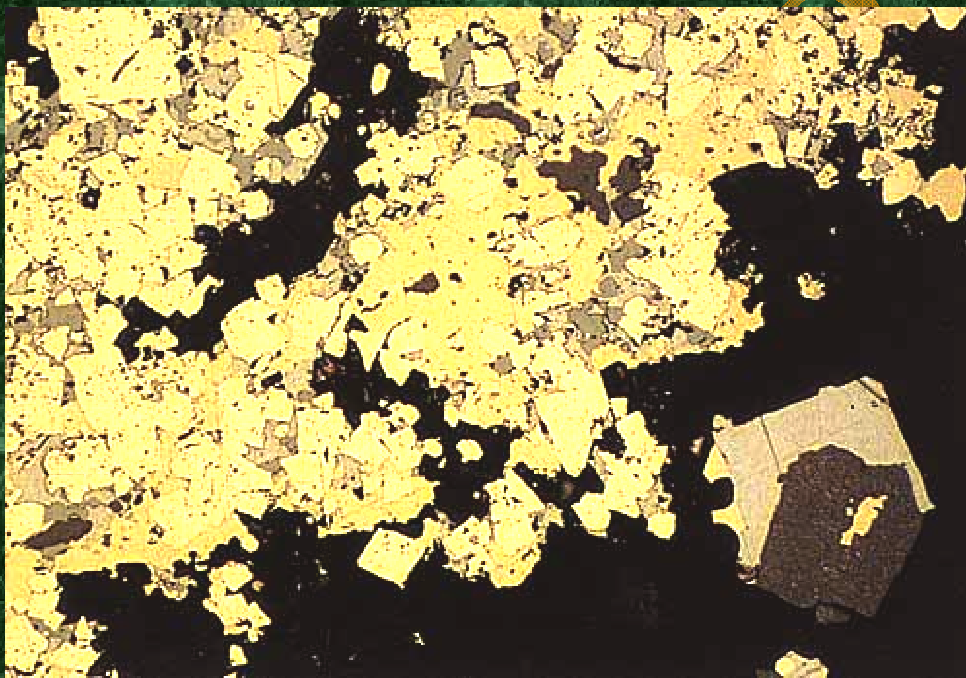


70µm

Repolished after etching. Galena (blue-white) forms complex intergrowths with chalcopyrite (yellow, centre) and sphalerite (light grey, right). Small subhedral pyrite crystals (light yellow-white, centre top) show high reflectance. Etching has shown the galena to comprise small polygonal crystals with 120' angles (centre top, centre bottom). Very small tetrahedrite crystals occur within galena (light grey, higher reflectance than sphalerite, left centre).

Polished block, plane polarized light, x 280, air

Pyrite, chalcopyrite, galena, sphalerite and tetrahedrite. Ainai Mine, Akita Prefecture, Japan

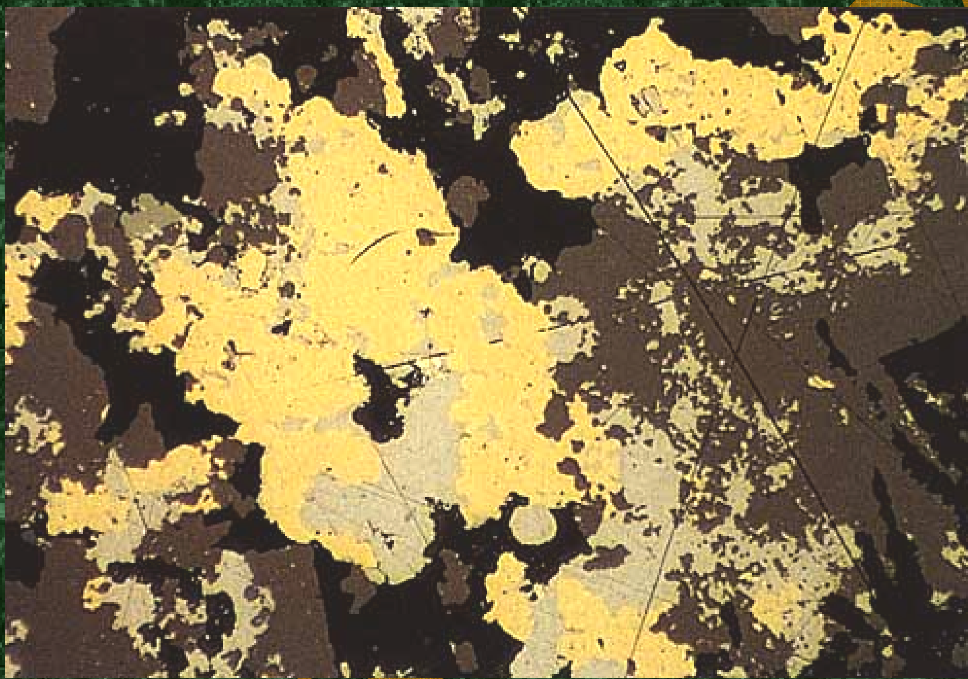


125µm

Euhedral pyrite (light yellow-white, left) is intergrown with chalcopyrite (yellow, centre), galena (light blue-white, centre right) and tetrahedrite (green-blue, lower reflectance, harder than galena, centre right) and minor sphalerite (grey, centre top). A coarse-grained subhedral crystal of sphalerite (right bottom) encloses chalcopyrite and is itself enclosed within euhedral galena. Gangue phases are black.

Polished block, plane polarized light, x 160, oil

Sphalerite, chalcopyrite, galena, tetrahedrite and native metal. Ainai Mine, Akita Prefecture, Japan

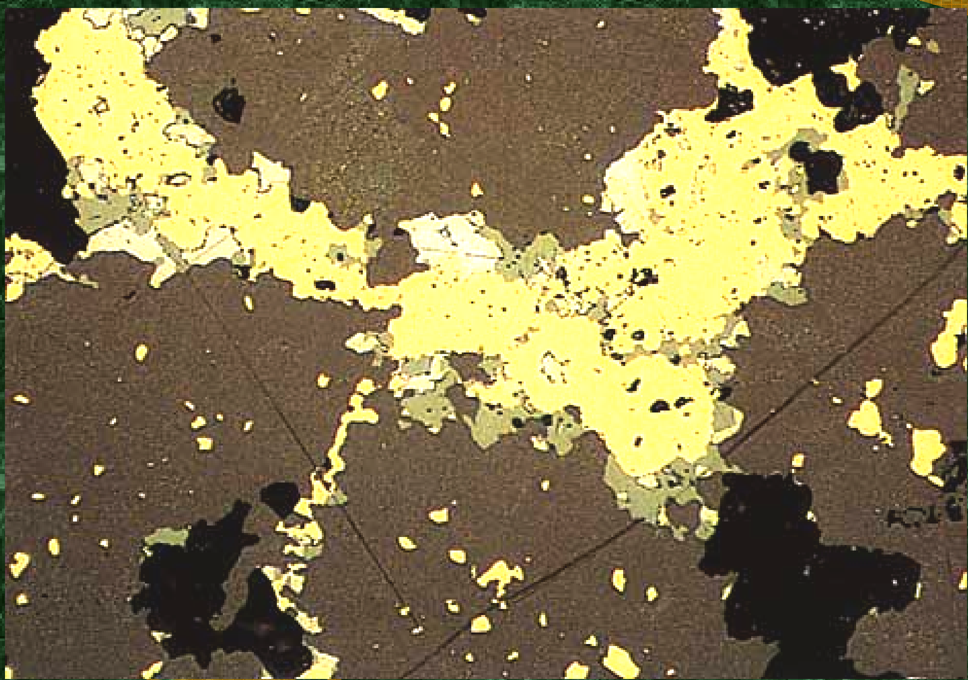


125µm

An unidentified native metal (cream-white, high reflectance, centre) occurs within galena (light blue-white, centre bottom) which has complex intergrowths with chalcopyrite (yellow, centre) and sphalerite (grey, centre right). A single crystal of tetrahedrite (green-blue, centre top left) is present. The sphalerite is inclusion-free. Gangue phases are black and include lath-shaped baryte (bottom right).

Polished thin section, plane polarized light, x 160, oil

Sphalerite, chalcopyrite, tetrahedrite and galena. Ainai Mine, Akita Prefecture, Japan



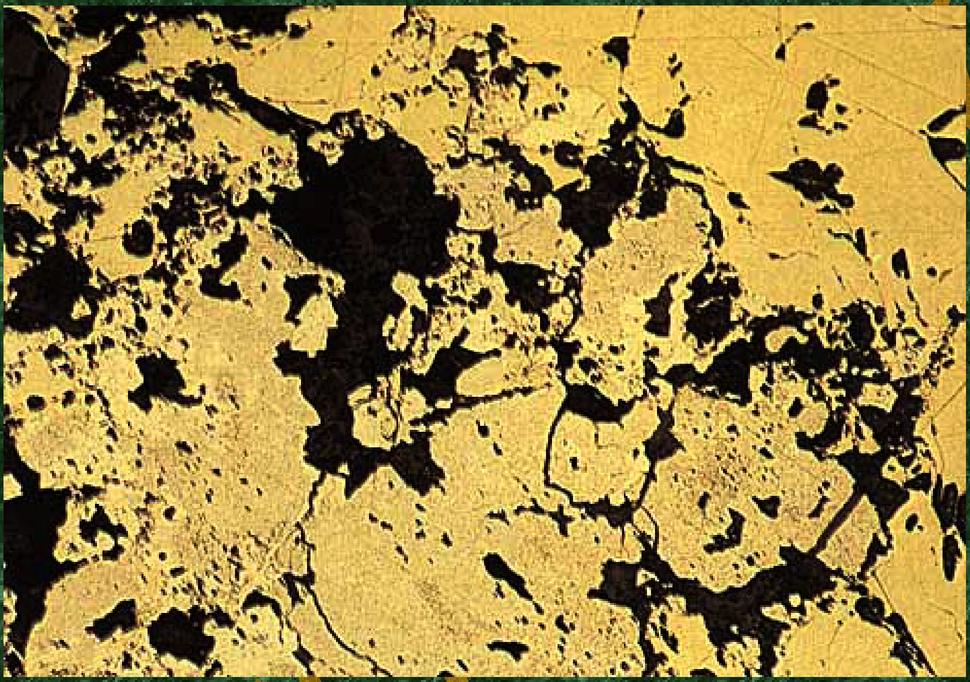
125µm

Large sphalerite (grey) crystals are separated by intergrown chalcopyrite (yellow, centre), galena (white, centre) and tetrahedrite (green-blue, centre). Tetrahedrite and galena form rims about chalcopyrite. Chalcopyrite inclusions within sphalerite are both irregular in shape (bottom centre) and submicroscopic where they change the surface colour of the sphalerite (light blue-grey diffuse areas, top centre). Faint reddish-grey areas in sphalerite (centre top) are also due to submicroscopic inclusions, probably of tetrahedrite, which are known to give sphalerite red internal reflections. Black areas are gangue phases.

Polished block, plane polarized light, x 160, oil

Location:	**Lasail and Bayda, Semail Ophiolite. Oman** Lasail and Bayda formed in the short time interval between the eruption of footwall basalts (Geotimes Unit) formed along a marginal basin spreading axis and a hangingwall lava unit (Lasail Unit) associated with an off-axis seamount.
Major Minerals:	Pyrite, chalcopyrite, magnetite, haematite
Minor Minerals:	Sphalerite, marcasite
Trace Minerals:	Include sphene, bornite, pyrrhotite, carrollite, cubanite, molybdenite, mackinawite, native gold
Textures:	Optical zoning of pyrite (related to the cobalt content) is common. Minor amounts of cobaltian pyrite are associated with carrollite in chalcopyrite. Inclusions of mixed pyrrhotite-chalcopyrite and pyrrhotite-chalcopyrite-cubanite occur within euhedral pyrite and are due to the breakdown of iss. Both pyrite and sphalerite are extensively replaced by chalcopyrite, pyrite along its cleavage, and sphalerite along twin planes and grain boundaries
References:	Haymon et al., 1984; Ixer et al., 1984, 1986; Haymon and Koski, 1985

Chalcopyrite and pyrite. Lasail, Oman

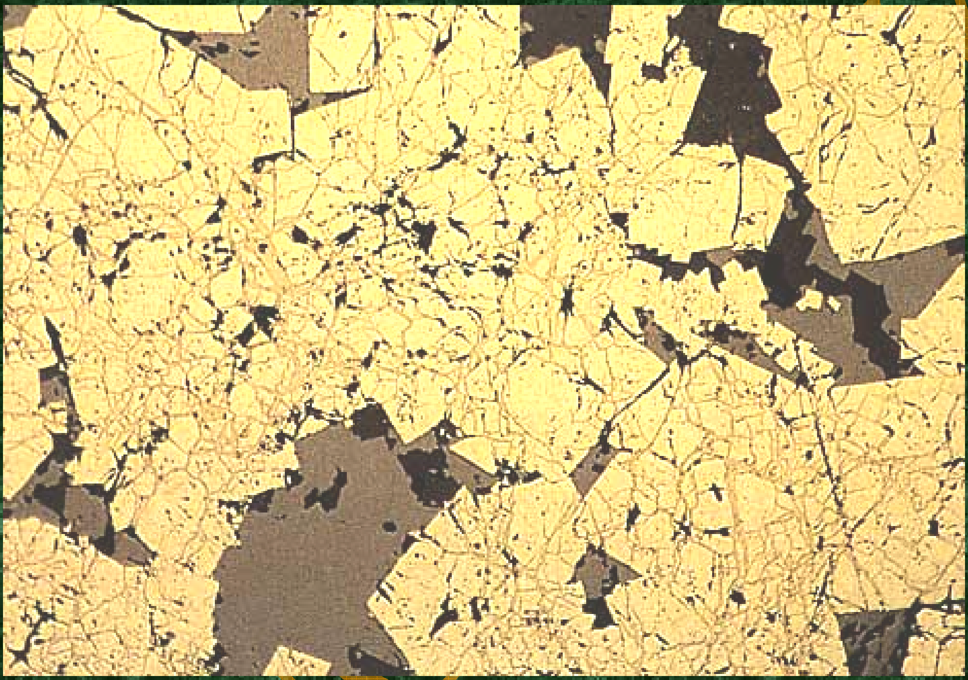


250µm

Chalcopyrite (yellow, right) surrounds poorly crystalline, fine-grained pyrite (brown, bottom centre) which has well crystalline margins (pale yellow-white, centre). The fine-grained nature of pyrite lowers its reflectance and gives a characteristic brown surface colour. The fine pyrite could be primary or altered pyrrhotite, but here it is probably primary. The gangue phases (dark grey) are silicates.

Polished block, plane polarized light, x 80, air

Pyrite, chalcopyrite and sphalerite. Bayda, Oman

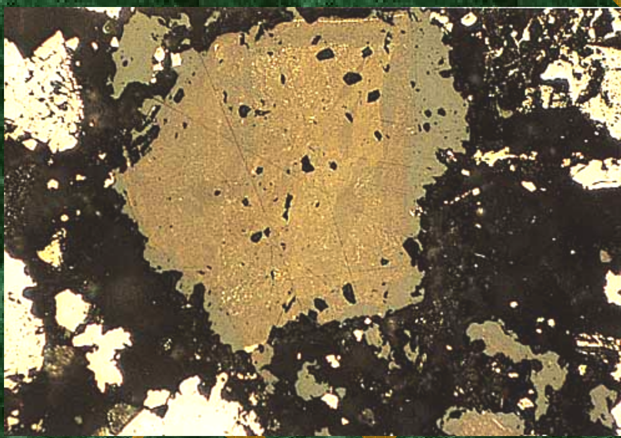


250μm

Euhedral pyrite (light yellow-white) crystals are extensively replaced by chalcopyrite (yellow) along the (100) cleavage directions of pyrite. Although pyrite is fractured, much of the chalcopyrite is replacing, rather than cementing, pyrite. Sphalerite (light grey, bottom centre) overgrows pyrite as small subhedral crystals (right centre) and is inclusion-free. Quartz is the main gangue phase (dark grey, top centre).

Polished block, plane polarized light, x 80, air

Sphalerite, pyrite and chalcopyrite. Bayda, Oman

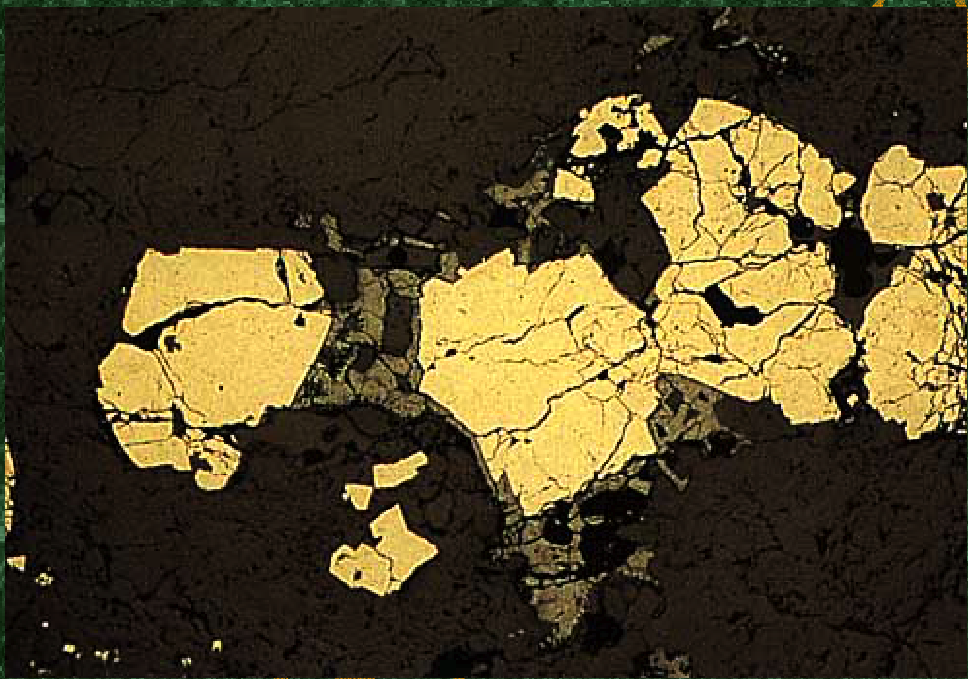


125μm

Euhedral to poorly crystalline pyrite (light yellow-white, left) surrounds sphalerite (centre) which has suffered extensive replacement by chalcopyrite; this is an extreme example of chalcopyrite disease. The replacement of sphalerite by very fine-grained chalcopyrite is crystallographically controlled, following growth zones and poorly defined twinning. The differences in surface colour (orange to purple) are due to orientation effects of the fine chalcopyrite inclusions. Under crossed polars the anisotropy effects are enormous. The outer margin of the sphalerite (grey, top left) is chalcopyrite-free and belongs to a later generation of sphalerite. Quartz (dark grey with internal reflections) is the gangue.

Polished block, plane polarized light, x 160, oil

Pyrite and haematite. Lasail, Oman



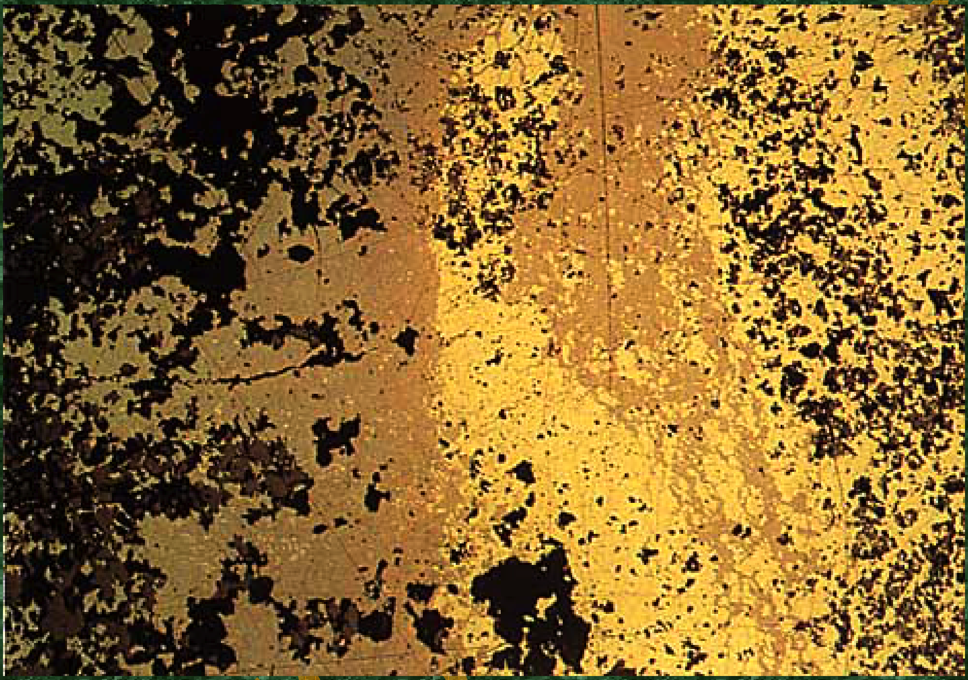
125µm

Euhedral pyrite (light yellow, centre) is fractured and surrounded by aggregates of fine-grained, often botryoidal, haematite (light green-grey, centre left). The differences in reflectance and surface colour (bottom centre) between the core and margin of the haematite aggregates are due to variations in grain size of individual haematite crystals. The coarser crystals on the margin have a slightly higher reflectance. Quartz (dark grey) is the gangue.

Polished block, plane polarized light, x 160, air

Location:	**Sulphide chimneys. East Pacific Rise, 21°N. Pacific Ocean** At 21°N along the spreading axis, zinc-rich chimneys comprise an inner wurtzite-rich core with a copper-iron sulphide-rich margin, whereas copper-rich chimneys have an inner chalcopyrite or iss core (isocubanite) passing out into a copper-iron sulphide rim. Anhydrite, opal, baryte and magnesium silicates are the major non-sulphide components of the 'ores'.
Major Minerals:	Wurtzite, sphalerite, chalcopyrite, pyrite, bornite, chalcocite, isocubanite
Minor Minerals:	Anomalous bornite, covelline, pyrrhotite, marcasite, digenite
Trace Minerals:	Include galena, valleriite, haematite, magnetite, tennantite, lead-silver sulphosalts
Textures:	Chimneys show mineralogical zoning from core to rim and alteration on their rims. Worm tubes are present. Compositionally zoned wurtzite forms hexagonal crystals with epitaxial chalcopyrite along growth zones. Much wurtzite has inverted to sphalerite. Chalcopyrite is collomorphic to euhedral and is successively replaced by bornite, digenite, chalcocite and covelline. lsocubanite is rimmed by chalcopyrite. Pyrrhotite forms hexagonal crystals or thin laths as part of the 'black smoke'. It is extensively replaced by pyrite and marcasite. Pyrite is collomorphic and intergrown with marcasite or forms discrete euhedral crystals
References:	Hekinian et al. 1980; Oudin, 1981, 1983a; Styrt et al., 1981; Haymon and Kastner, 1981; Goldfarb et al., 1983; Hannington et al., 1986; Caye et al., 1988

Chalcopyrite, bornite. chalcocite. East Pacific Rise, Pacific Ocean

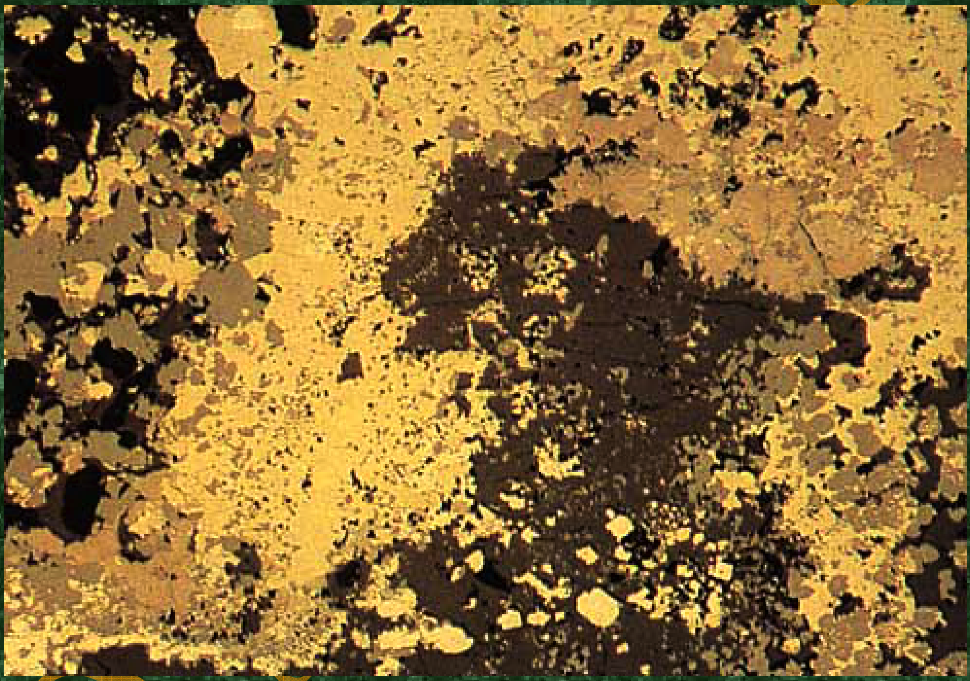


500µm

A section from the core (right) to margin (left) of a copper-rich chimney. The inner part of the chimney comprises chalcopyrite (yellow, right) which is intergrown with, and rimmed by, bornite (pink-brown, centre). Bornite alters in turn to a blue copper sulphide, chalcocite (left margin), via a series of copper-iron sulphides of intermediate compositions. Black areas are non-sulphides.

Polished block, plane polarized light, x 40, air

Chalcopyrite, sphalerite, bornite, pyrite and covelline. East Pacific Rise, Pacific Ocean

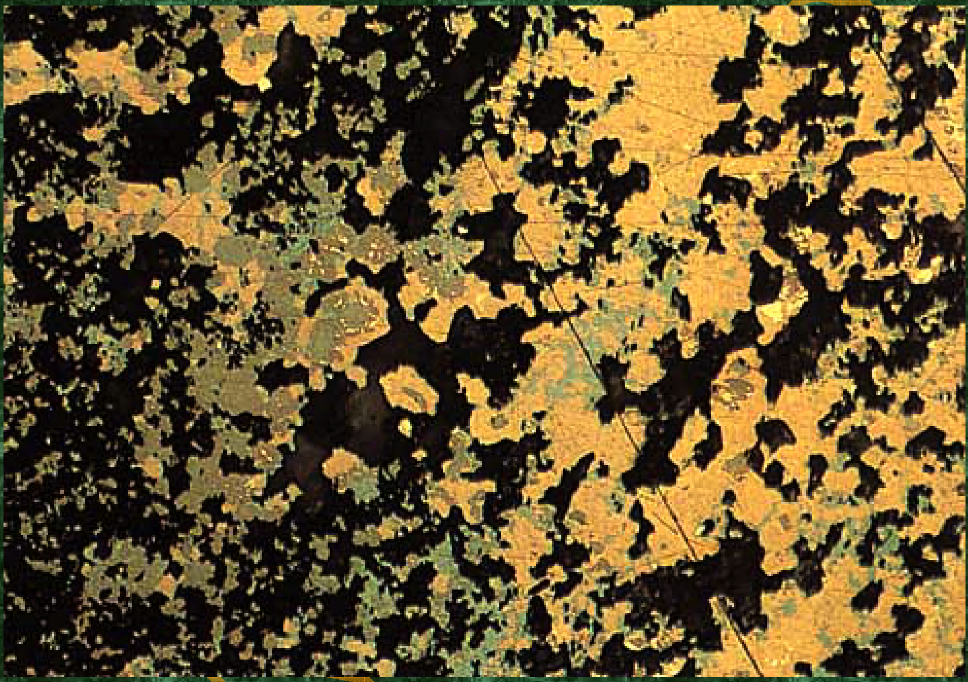


250µm

Chalcopyrite (yellow, top) is rimmed by bornite (pink brown, centre top) and by euhedral to subhedral sphalerite (light grey, left). Minor amounts of pyrite (white, highest reflectance) occur within chalcopyrite (top left) or within the matrix (bottom, centre). Trace amounts of covelline (blue) have replaced bornite (centre top) but are difficult to see at this magnification.

Polished block, plane polarized light, x 80, air

Bornite, sphalerite, chalcocite, pyrite and chalcopyrite. East Pacific Rise, Pacific Ocean

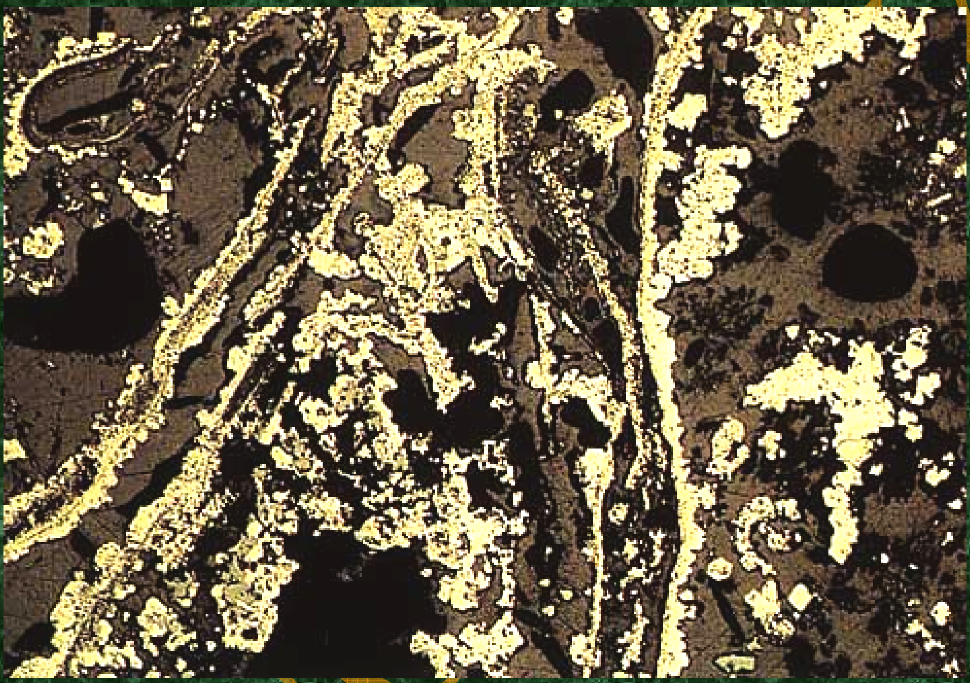


125µm

Bornite (pink-brown, right) passes into an area rich in sphalerite (light grey, left). Bornite contains rare, small pyrite (white, high reflectance, centre right) crystals and is altering to blue copper sulphide, chalcocite (centre right). Sphalerite (centre left) carries very small yellow chalcopyrite inclusions (centre) and also is being replaced by chalcocite. Black areas are non-sulphides.

Polished block, plane polarized light, x 160, oil

Pyrite and sphalerite. East Pacific Rise, Pacific Ocean

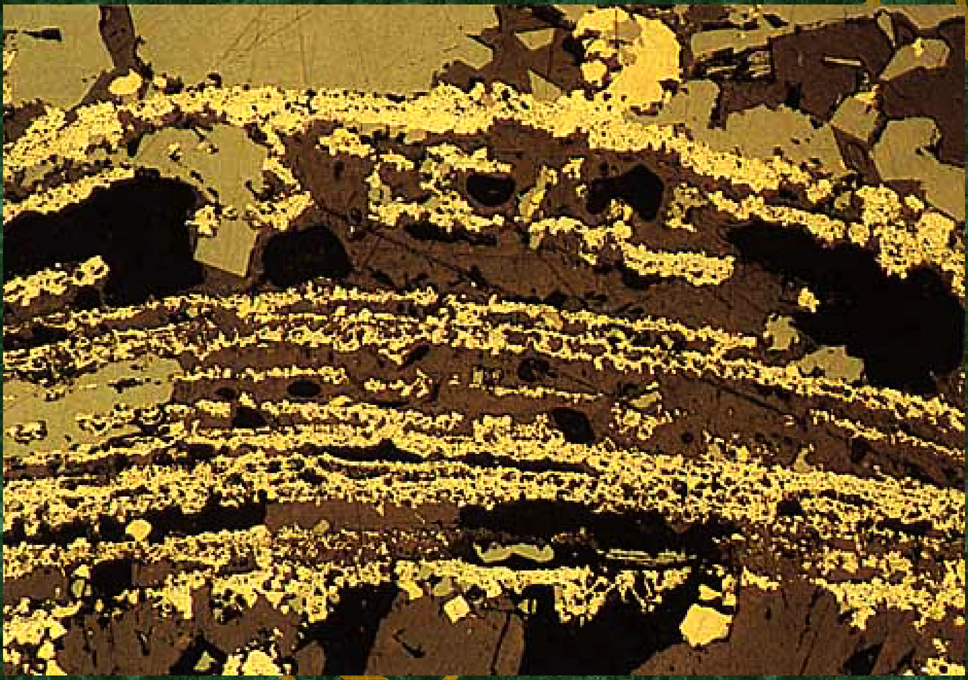


500µm

A series of roughly linear organic structures (worm tubes?) are associated with the nucleation and crystallization of poorly crystalline pyrite (brown, lower reflectance, centre) and more euhedral pyrite (yellow-white, right), much of which overgrows the poorly crystalline pyrite. Minor amounts of sphalerite (light grey, bottom left) are intergrown with pyrite. Black areas are polishing pits.

Polished block, plane polarized light, x 40, air

Pyrite, sphalerite and chalcopyrite. East Pacific Rise, Pacific Ocean



500µm

A transverse section through an organic structure (worm tube?) which has poorly crystalline to euhedral pyrite (light yellow-white) associated with it. Euhedral to subhedral sphalerite (light grey, top) is intergrown with minor amounts of chalcopyrite (yellow, top centre). Black areas are polishing pits, dark grey areas are non-sulphides (bottom).

Polished block, plane polarized light, x 40, air

Sphalerite, chalcopyrite and pyrrhotite. East Pacific Rise, Pacific Ocean

250µm

The outer margin of a zinc-rich chimney. Sphalerite (grey) is coarse-grained and has inclusion-free cores but minor chalcopyrite (yellow) on its margin. Smaller sphalerite crystals have a hexagonal morphology (centre right) suggesting wurtzite rather than sphalerite was originally precipitated. Fine-grained pyrrhotite laths (brown, left), which have largely altered to pyrite and marcasite, are precipitated 'black smoke'. Black areas are polishing pits.

Polished block, plane polarized light, x 80, air