# Textures & Structures of ore Deposits

# Importance of study of ore textures:

1- Texture may provide evidence of the nature of the ore forming processes.

2- Textures in polymetallic ores reflect the stages of their development, i.e., their history .

Types of ore textures:

# I- PRIMARY GROWTH TEXTURES

Secondary textures

# II- REPLACEMENT TEXTURES

# III- COOLING TEXTURES

# IV- INVERSION TEXTURES

# V- DEFORMATION TEXTURES

# I- PRIMARY GROWTH TEXTURES

**A-Primary growth textures formed from magma:**

**B- Primary growth textures ormed by open space deposition:**

## A- Primary growth textures formed from magma:

- *** In plutonic rocks, most **oxide** minerals are ***euhedral*** to ***subhedral*** within and among the silicate minerals, e. g., chromite, magnetite and ilmenite in gabbroic host rocks

This is due to their refractory nature and higher temperature of formation which lead to little or no obstruction to the growth of their crystal faces.

- Simultaneous growth of ***subhedral*** ore- and silicate-minerals leads to formation of ***Poikilitic textures*** with variable interfacial angles (compare annealing textures).
- (Attention!!!, what about textures of **sulphide** minerals in plutonic igneous rocks?).

- *** In volcanic rocks, rapid cooling results in formation of***:***
- ***- Skeletal crystals*** in oxide-bearing rocks (e. g., ***ilmenite***)***.***
- ***- Round droplets*** in sulfide-bearing rocks (e. g., ***mixed*** or ***composite*** round crystals of pyrrhotiteFe1-xS, pentlandite (Fe,Ni)9S8 and chalcopyrite CuFeS2).

- B- ***<u>Primary growth textures of ore-minerals formed by open space deposition</u>***:

These textures are specific to minerals formed in open spaces, vugs and fractures.

- They are characterized by
- 1- ***Well-developed*** **crystal faces** in minerals that rarely have euhedral crystal forms (e. g., chalcopyrite), pyrite show rare octahedral crystal form than the common cube and pyritohedra.
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- 2- ***Growth zoning*** e. g., 1- sphalerite due to variation in Fe-content, 2- concentrically growth-zoned pyrite $FeS_2$-bravoite $(Fe, Ni, Co)S_2$ due to sequential deposition from Co- and Ni-bearing solutions.

- 3- ***Colloform growth banding***, e. g., sphalerite, pyrite, Fe-Mn oxides.The texture is formed due to initial deposition form a colloid or by successive banding of tiny fibrous crystals.

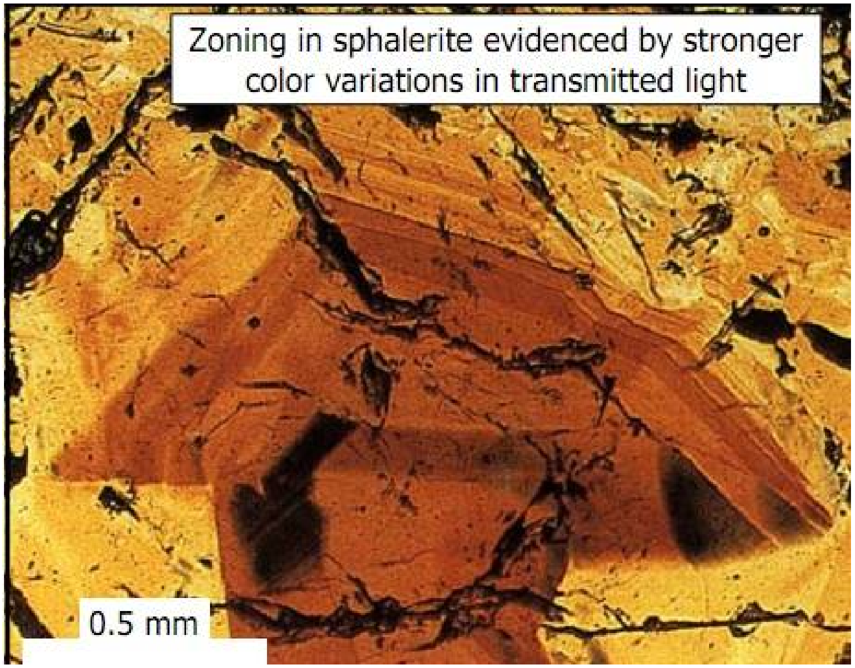
- 4- ***Comb structures*** (Formed by outward growth from fracture walls).
- 5- Symmetrical or rhythmical ***Crustification***, (inward deposition on fracture walls).

- 6- ***Breccia ore*** results from deformation of crustified veins during or after ore formation.

- 7- ***Fibrous (brush-like) texture*** is represented by complex masses of fibrous crystals radiating from multiple growth sites along an open facture.

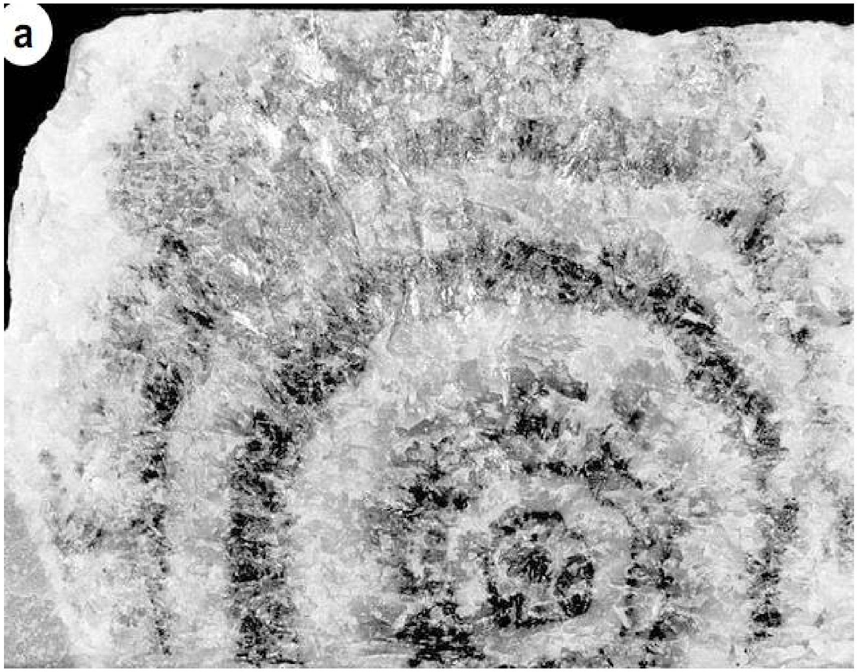
# ***Primary growth textures from open spaces***

***Growth zoning***



Zoning in sphalerite evidenced by stronger color variations in transmitted light

***Colloform growth banding***



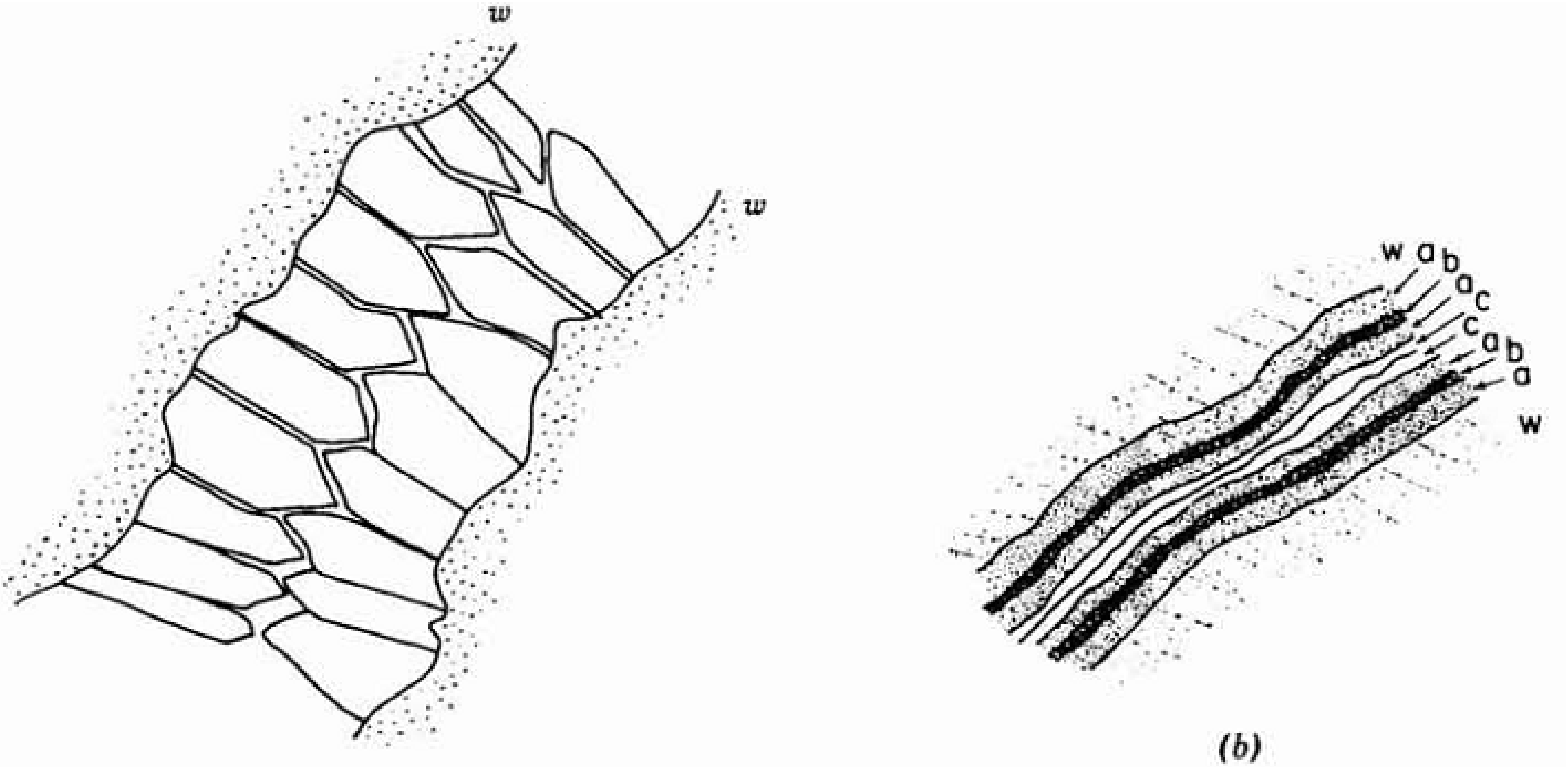
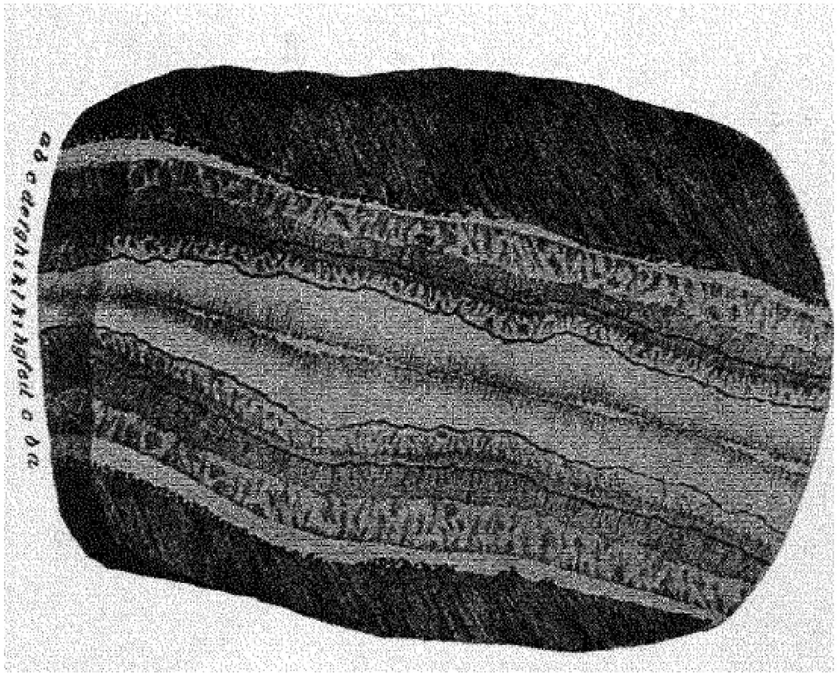


**FIGURE 7.6** (*a*) Comb structure showing growth of crystals outward from fracture walls. (*b*) Symmetrically crustified vein showing successive deposition of minerals inward from open fracture walls. This vein is also rhythmically crustified in showing the depositional sequences *a-b-a-c* (*w* = wall rock). Scale variable from millimeter to several meters across vein.

# crustification



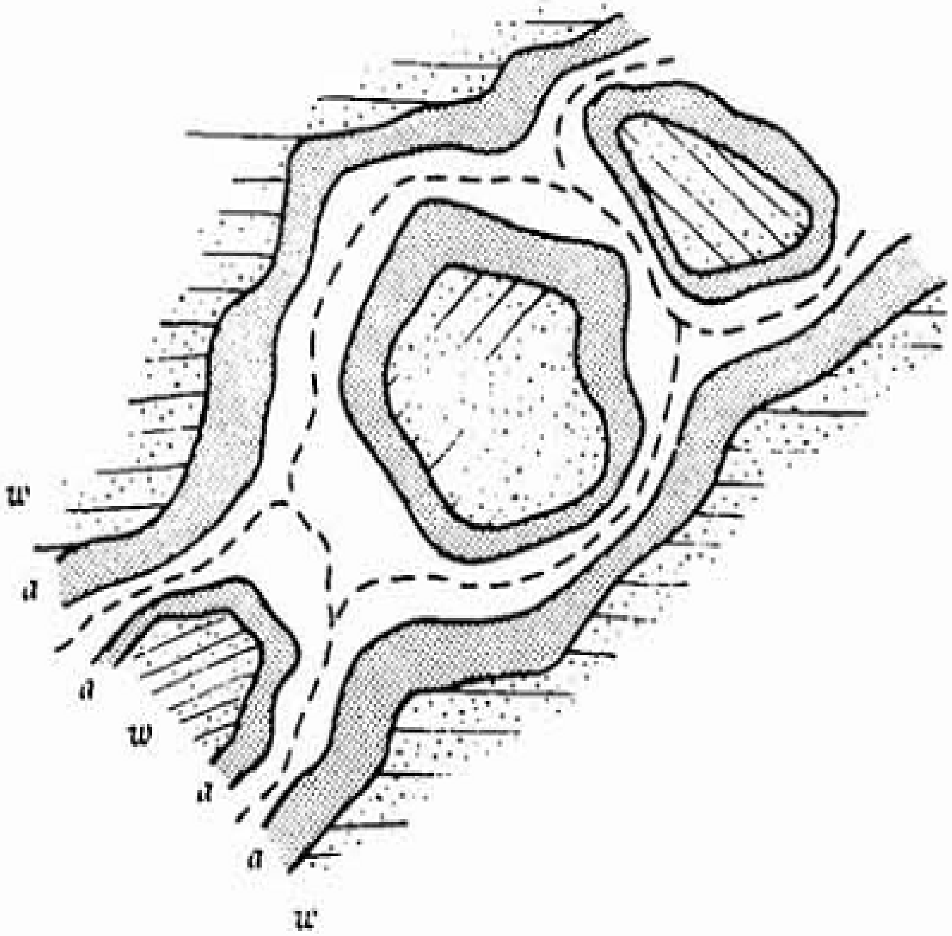
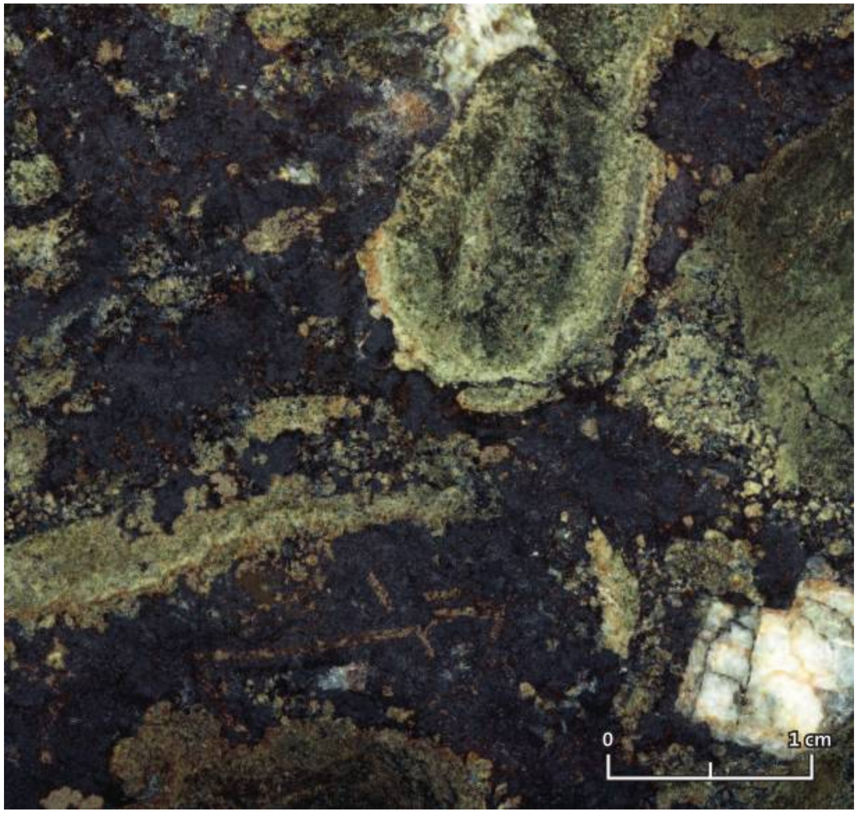


**FIGURE 7.7** Breccia ore showing successive deposition of minerals on breccia fragments and other wall rocks. Scale variable from wall rock fragments of millimeter to several meters across breccia fragments.

# Breccia ore



- **II- REPLACEMENT TEXTURES:**
- Replacement is the dissolving of one mineral and the simultaneous deposition of another mineral in its place, without change in volume or intervening development of appreciable open spaces.
- Replacement depends on 3 features of the mineral being replaced:
- i-The surfaces available for reaction.
- ii-The structure of both minerals (that baing replaced and the replacing).
- iii-The chemical composition of the original mineral and the reactive fluid.

- ***i- Crystal surface:***
- Replacement starts in *any channel or space through or between the mineral grains*. In the beginning, replacement is easily recognised where the original mineral is still visible even as remenant islands in more advanced stages. Here, it is interesting to remmember that the *remenant islands show optical continuity.* In completely replaced minerals only vestigial (inherited) structures such as typical morphology of the original mineral may indicate it, e.g., pyrrhotite laths now seen as pyrite and marcasite!

# How can we differentiate, Filling or replacement??

| Texture | Shape of the original phase surfaces | The surfaces on either Side of a fracture |
|---|---|---|
| Filing/injection | Leaves the original fractured surfaces intact. | Should match |
| Replacement | Consumes some of the original phase and tend to produce a rounding off of irregular surfaces | Do not match |

- ***ii- Crystal structure:***
- Structure can controls replacement due to:
- 1- the structure is responsible for the cleavage directions.
- 2- Different reaction suscibtibility at different crystallographic directions
- ***iii-Chemecal composition:***
- The new mineral retains the same cations of the original one with merely a chage in oxidation state or a change in anions.

* Change in oxidation state:

Magnetite $Fe^{2+}O.Fe^{3+}{}_2O_3 \Rightarrow$ Hematite $2Fe^{3+}{}_2O_3$ (martite),

Pentlandite $(Fe^{2+}, Ni^{2+})_9S_8 \Rightarrow$ Violarite $Fe^{2+}Ni^{3+}{}_2S_4$

* Change in anions:

Pyrite ($FeS_2$) $\Rightarrow$ Hematite ($Fe_2O_3$)

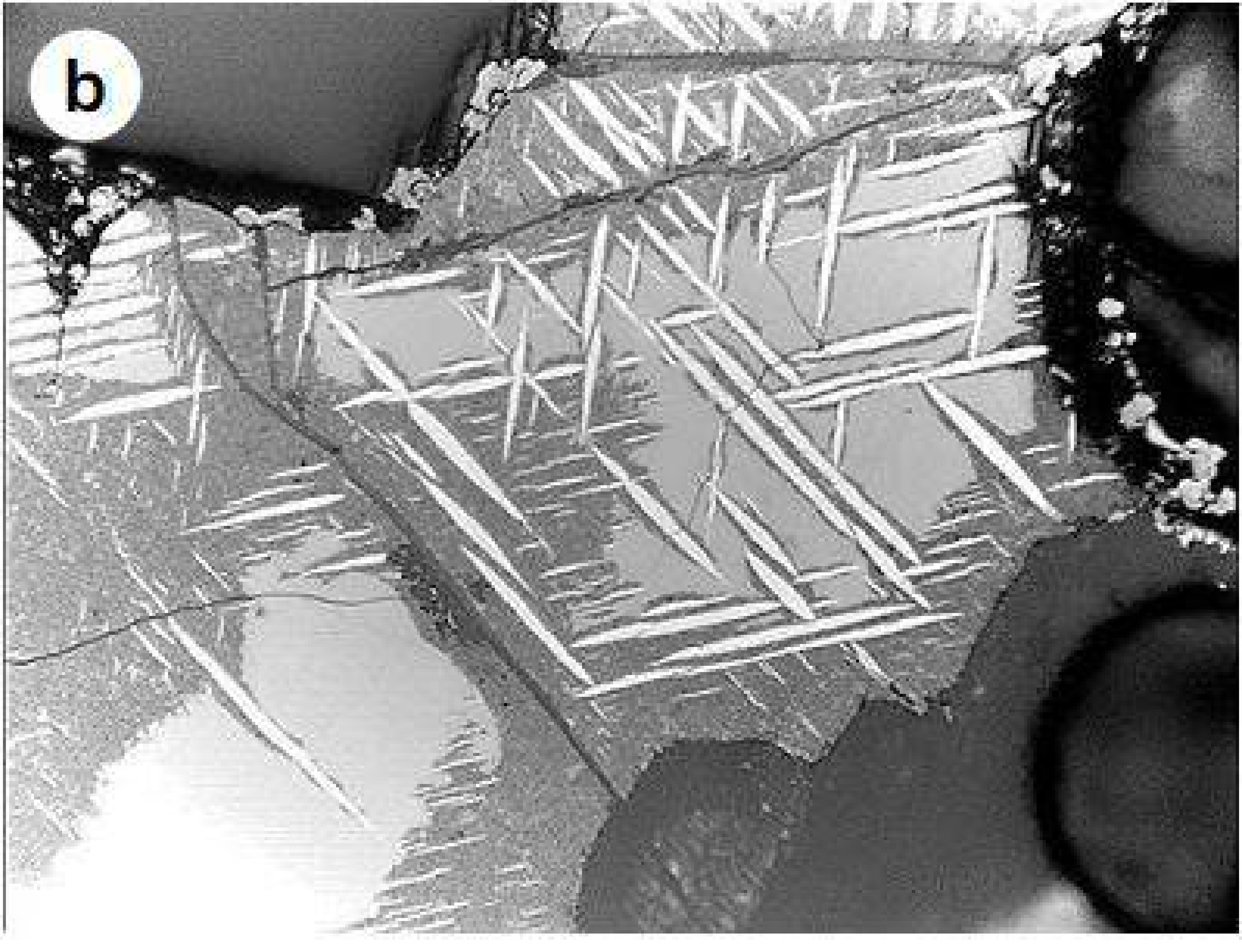
Galena ($PbS$) $\Rightarrow$ Anglesite ($PbSO_4$)

- Replacement may also *selectively* remove one cation while leaving another, e.g.,
- (1) the development of Covellite on the expense of Bornite or chalcopyrite:
- Bornite $Cu_5FeS_4 \Rightarrow$ covellite (CuS)
- Chalcopyrite $CuFeS_2 \Rightarrow$ covellite (CuS)
- The replacement or weathering of the Fe-Cu ores follows a particular direction in the Cu-Fe-S system so that Fe is removed before Cu, giving to:
- Chalcopyrite($CuFeS_2$) $\Rightarrow$ Bornite($Cu_5FeS_4$) $\Rightarrow$ Digenite($Cu_9S_5$) $\Rightarrow$ Chalcocite($Cu_2S$) $\Rightarrow$ Covellite (CuS)

- (2), the removal of Fe from pyrrhotite (by replacement or oxidation) results in increase in the S:Fe ratio, and the formation of monoclinic pyrrohtite (looks like flames along the margins of fractures), then pyrite and marcasite (as grains or colloform masses ‘birds eyes’.
- ** In both cases, the removed Fe, may leave the area in solution or may be precipitated as goethite.
- The exsolved hematite in ilminite may sometimes selectively removed increasing the ore grade.
- (Conversely),when Cu-rich fluid reacts with pyrite in fractures, chalcopyrite is formed .

- **III-COOLING TEXTURES:**
- These textures comprise annealing, exsolution and decomopsition
- 1- Annealing:
- Annealing is *the recrystallization* during cooling *to minimise the surface areas* of the grains and the interfacial tension by development of equant grains with ~120° interfacial (or dihedral) angles (this depends on the mineral types).
- Annealing is accompanied by re-equilibrium either by:
- A- Formation of zoned overgrowths on grains (may be through sorption of smaller grains), e.g., Formation of pyrite overgrowths on primary pyrite
- B- Homogenization of grains containing original (primary) growth zoning. (Sphalerite shows residual growth zoning at the crystal centers)

- *2*- Exsolution Texture*:*
- In exsolution, one phase is expelled from another, often in characteristic pattern.
- How does the exsolution process take place?
- This results from :1- Deffusion (of metal ions through a sulfide or oxide lattice), 2- Nucleation of crystallites, 3- Growth of crystallites or crystals.
- What does exsolution kinetically depend on?
- It depends on
- 1- Temperature,
- 2- Degree of supersaturation
- 3- concentration of impurities.
- What controls exsolution?
- The *similarities* of *crystal structure and chemical ponding* between the host and the phase to be exsolved, particularly the *matching of atomic arrangements in specific layers* resulting in *a shared planes of atoms*, frequently leading to crystallographically controlled (i.e., coherent) exsolution.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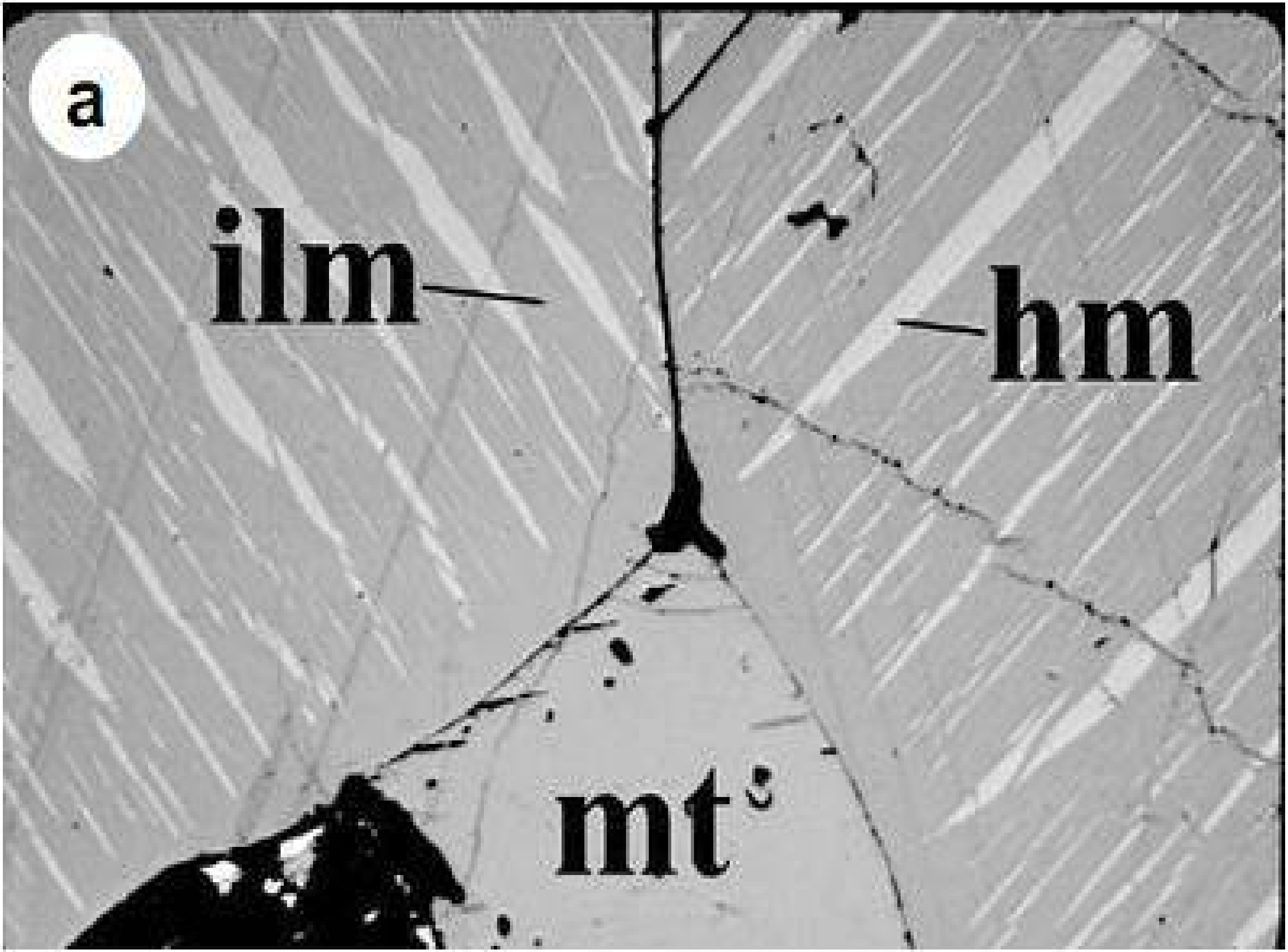
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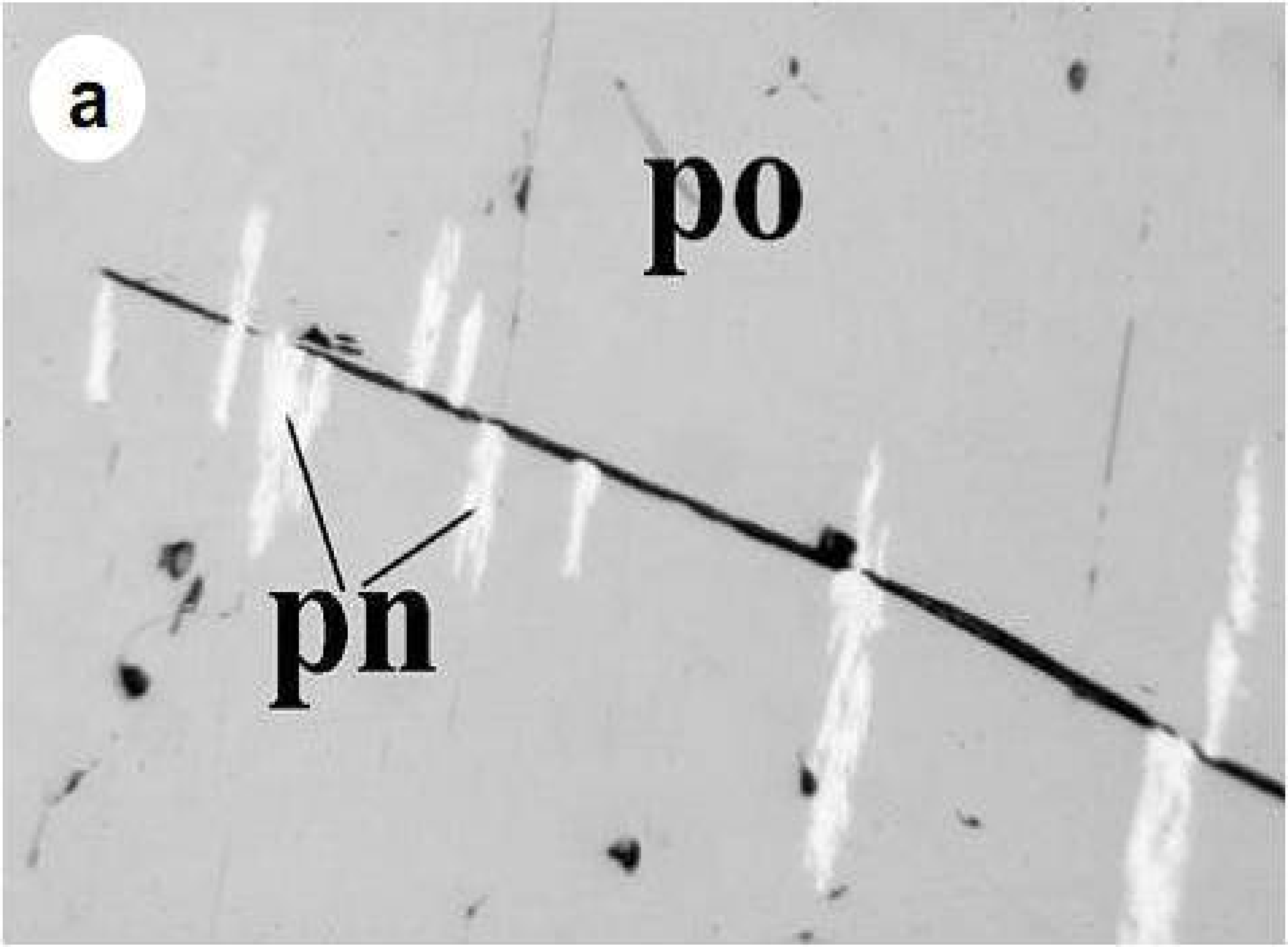
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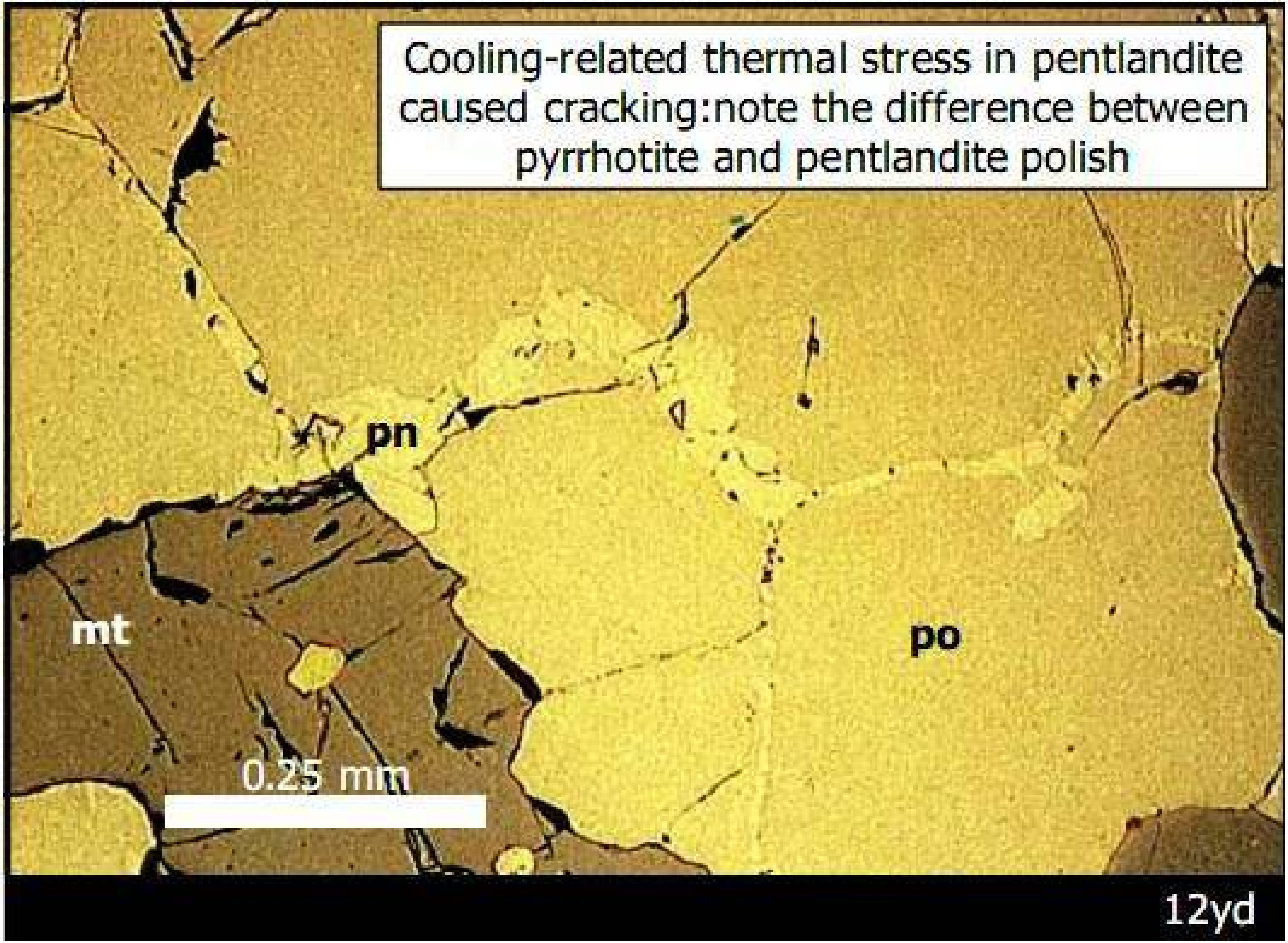
- Decrease in the interfacial energy during exsolution (through cooling) is accomplished by more equant forms of the exsolved phases. So, the early exsolved flames of pentlandite in pyrrhotite coalesce (with cooling) into irregular veinlets, which suffer fracturing due to higher thermal coefficient of pentlandite.

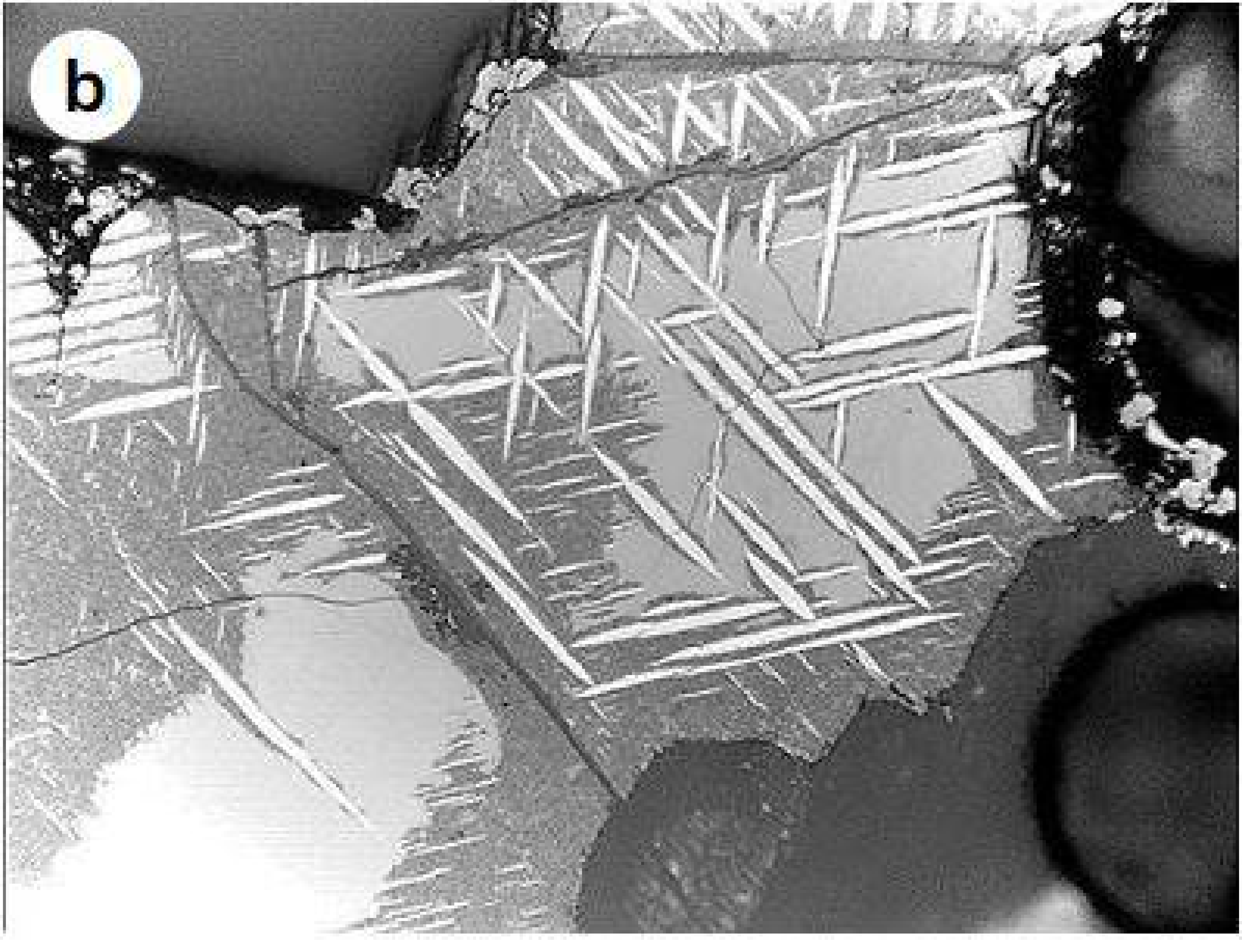


Cooling-related thermal stress in pentlandite caused cracking:note the difference between pyrrhotite and pentlandite polish

- How can we differentiate between replacement and exsolution??
- There is a depletion (thinning) in intersecting exsolution lamellae at the junction, while greater concentration of the replacing phase at sites of intrsection.
- Exsolution intergrowths of the FeTi oxides represent good and famous example.
- Chalcopyrite disease:

  This is a texture describes existence of fine chalcopyrite inclusions in sphalerite.

  In this texture, chalcopyrite occurs as very fine grains or rods (1-20 µm) randomly dispersed or crystallographycally arranged in rows within sphalerite.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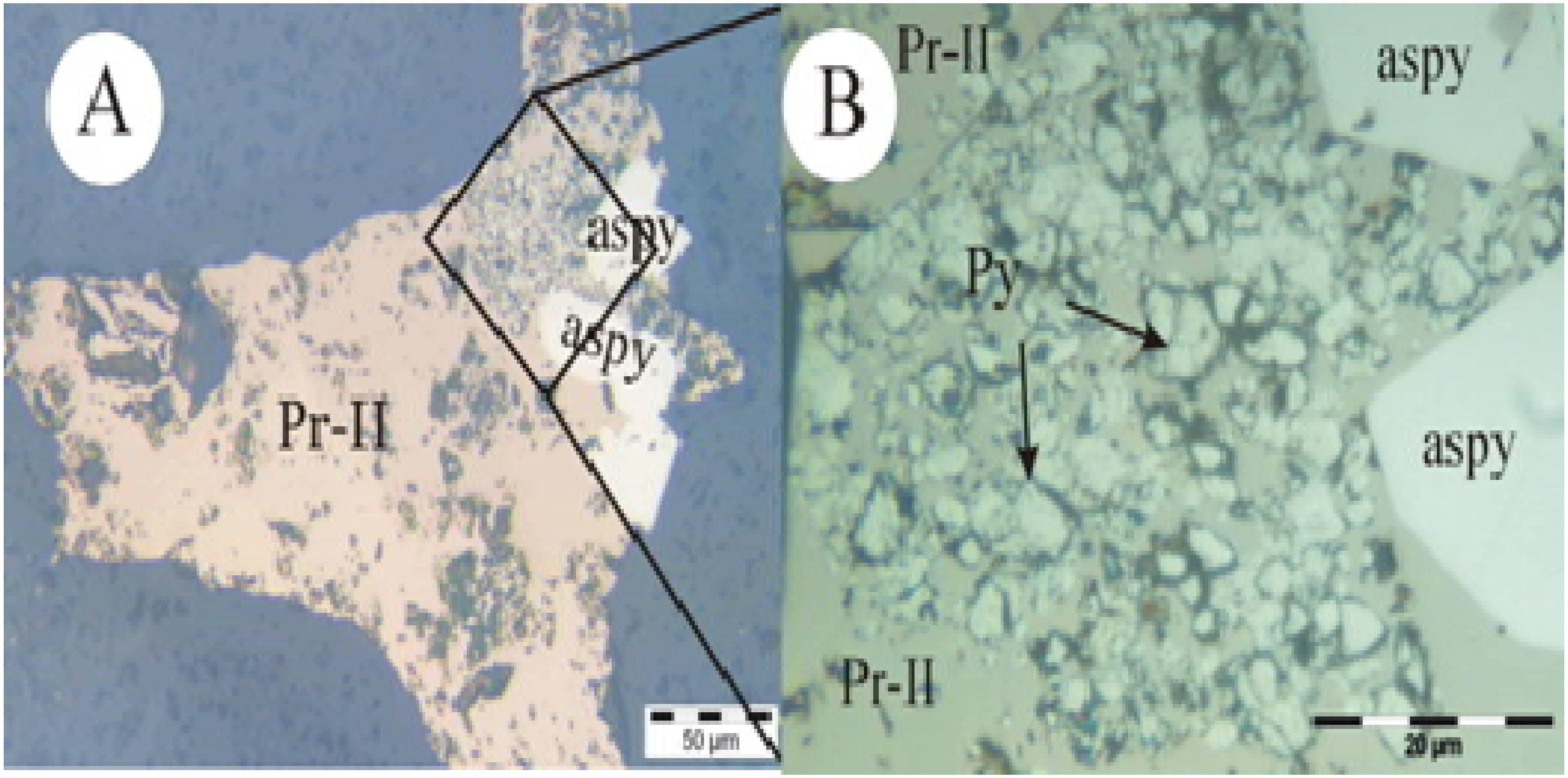
- Noncoherent exsolution

  It is an exsolution in which the structures of both phases are completely different or without crystallographic continuity across the interface between the phases.

- This is best ***represented by the case of pyrite-pyrrhotite equilibrium*** at high temperature (~ 400° C or more). Normally over 700° C pyrite does not exist and pyrrhotite is the only Fe-sulphide, but ***with cooling*** pyrite starts to exsolve (from pre-existing pyrrhotite). However, pyrite *tends to grow as euhedra* at the expense of the surrounding phases because of its **considerable force of crystallization**. Moreover, the structure of pyrite is different from that of pyrrhotite. Accordingly, the resulting pyrite occurs as individual grains (euhedral cubes) rather than exsolution lamellae.

# Noncoherent exsolution

# Develpoment of pyrite ($FeS_2$) on the expense of pyrrhotite ($Fe_{1-x}S$)

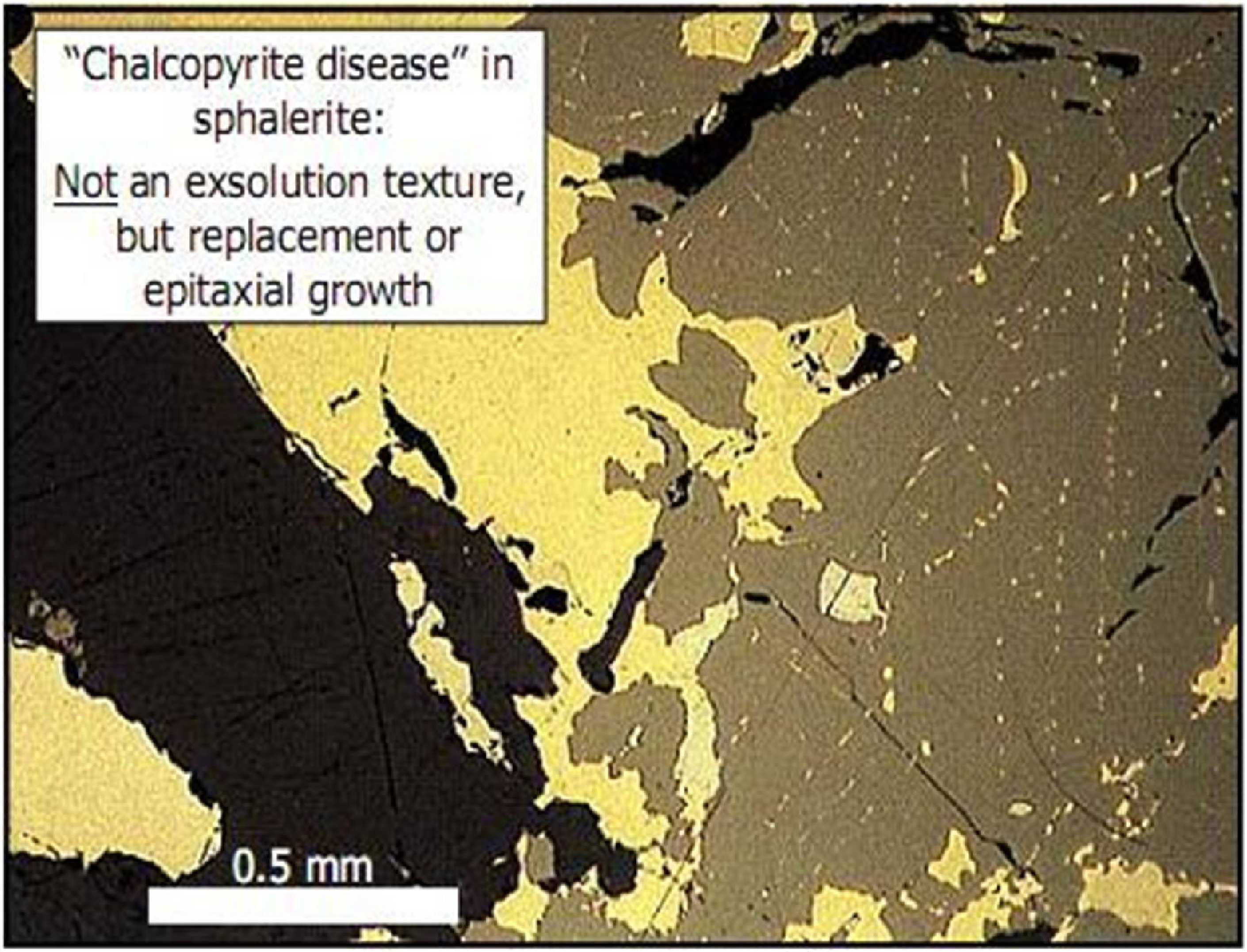


# •So Don’t Forget !

- Exsolution texture has *shared planes of atoms between the host and the exsolved mineral* due to *similarity* in *crystal structure and chemical ponding* between them, particularly the *matching of atomic arrangements in specific layers.*

# Chalcopyrite disease

Minute inclusions of chalcopyrite in sphalerite, likely with some arrangement.



- Chalcopyrite desease, exsolution or replacement???
- Experimental work showed that chalcopyrite does not dissolve in sphalerite in significant amounts unless temperatures are above 500° C. However, the chalcopyrite disease is present in the carbonate-hosted Zn-Pb ores which form at 100 -150° C, and in unmetamorphosed volcanogenic sulphides which form at 200 -300° C. Acordingly, chalcopyrite disease is not an exsolution. It is either formed by *epitaxial growth** during the sphalerite formation or by *replacement* by a Cu-rich fluid react with sphalerite after formation. During annealing (by metamorphism), the chalcopyrite may be redistributed when the sphalerite recrystallizes, so that it remains concentrated along the sphalerite grain boundaries.

- *3- Decomposition:*
- *There are two types,*
- 1- Eutectoidal breakdown 2- the breakdown of the central portion of a complete solid solution series.
- *1-Eutectoidal breakdown*: in which a mineral phase of higher temperature origin undergoes on cooling an abrupt change into two phases of distinctly different compositions.
- Examples:
- 1- Digenite $Cu_9S_5$, is not stable below 70° C, unless it contains ~ Fe and decomposes with cooling below this temperature to form a complex mixture of
- Anilite $Cu_7S_4$ + Djurleite $Cu_{1.97}S$ ,
- or Chalcocite $Cu_2S$ + Djurleite $Cu_{1.97}S$ (when the original fluid more rich in Cu).
- 2- High temp. Cu-Pb sulphide ⇒decomposition ⇒ galena (PbS) +chalcocite ($Cu_2S$)
- *2- Breakdown of the central portion of solid solution:*
- Ag, Bi, Pb homogeneous sulphide (solid solution) decomposition ⇒ larth-like intergrowths of *(matildite $AgBiS_2$ and galena PbS)*
- )

- **IV- INVERSION TEXTURES:**

- Inversion is the transformation of a mineral into another of the same composition but with a different structure. When the crystal morphology of the original mineral is retained the new one is known as paramorphous.

- *Argentite Ag2S (Cubic, high temp, stable over 180ºC) ⇒ acanthite Ag2S (Monoclinic, low temp, stable under 180ºC)

- *Digenite Cu9S5 (Hexagonal, high temp, stable over 70º C) ⇒ Chalcocite Cu2S (Monoclinc, low temp, stable under 70º C)

- *In some cases, inversion leads to change in volume*
- *** Marcasite ⇒ inversion ⇒⇒⇒ pyrite (2.6 % volume reduction) leaving characteristic small pores.
- *** Pyrrhotite ⇒ inversion (weathering) ⇒ pyrite or marcasite (30 % volume reduction)