



**PETROGRAFIA DE MINÉRIOS (GSA 0501)**

**PROPRIEDADES ÓPTICAS I**



**COR, PLEOCROÍSMO, REFLECTÂNCIA, ISOTROPIA, ANISOTROPIA...**

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# IMPORTANTES PROPRIEDADES ÓPTICAS DOS MINERAIS DE MINÉRIO

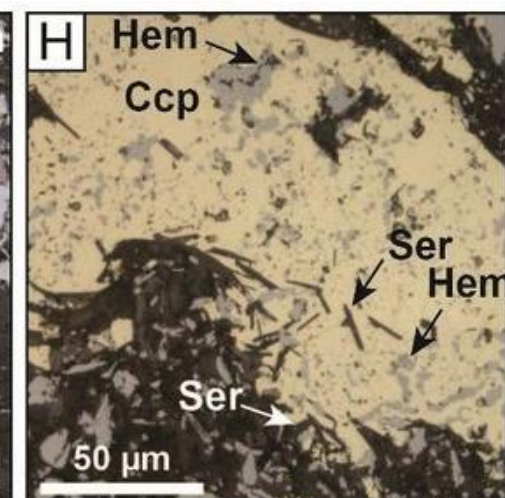
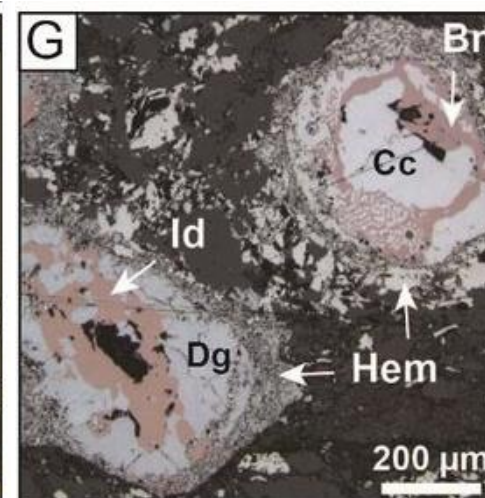
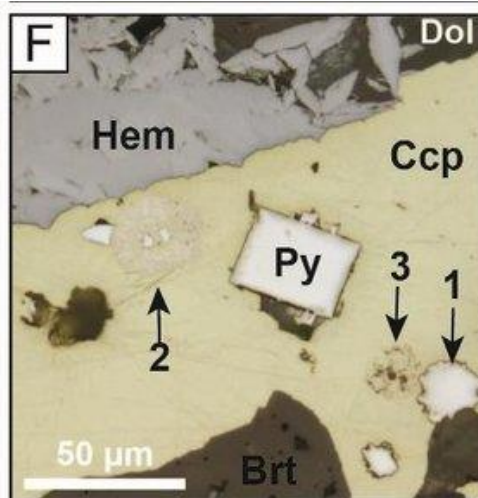
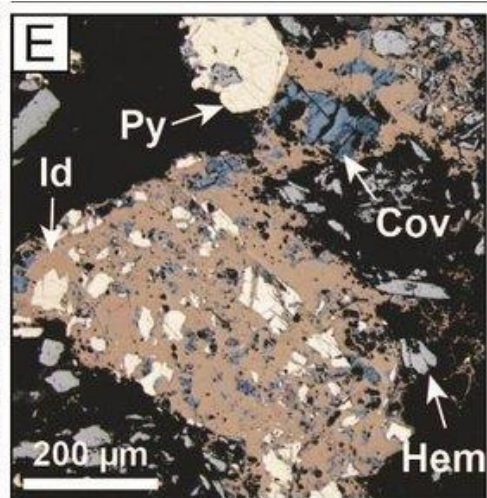
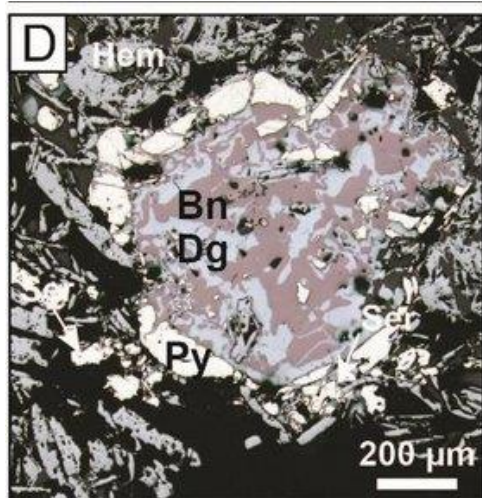
## LUZ REFLETIDA

### POLARIZADORES DESCRUZADOS

- ✓ Cor
- ✓ Pleocroísmo
- ✓ Reflectância (Brilho)
- ✓ Birreflectância

### POLARIZADORES CRUZADOS

- ✓ Isotropia
- ✓ Anisotropia
- ✓ Reflexões Internas

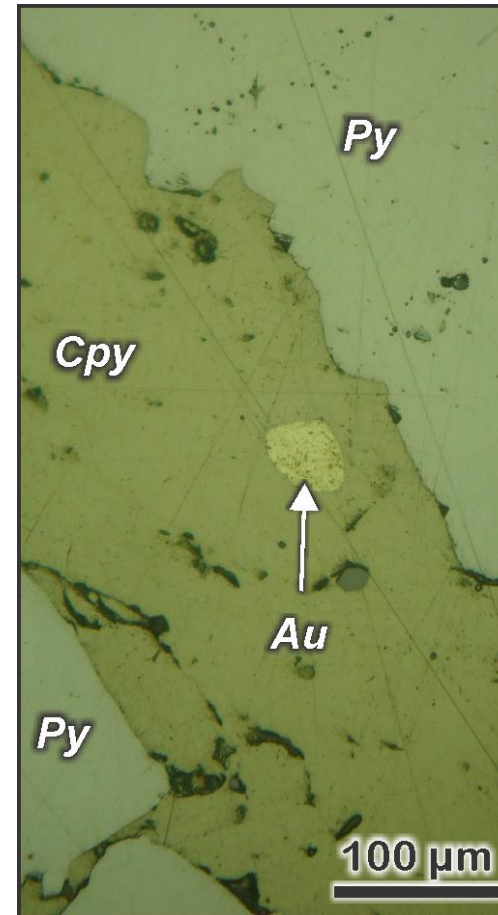
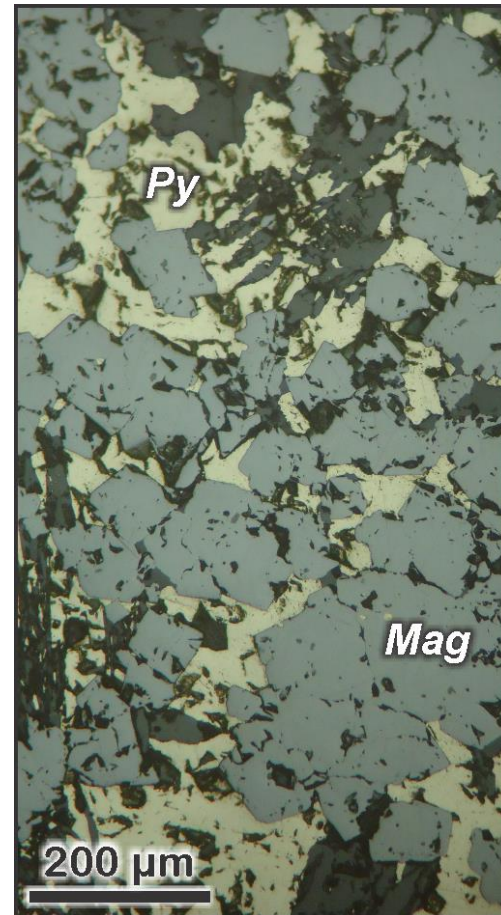
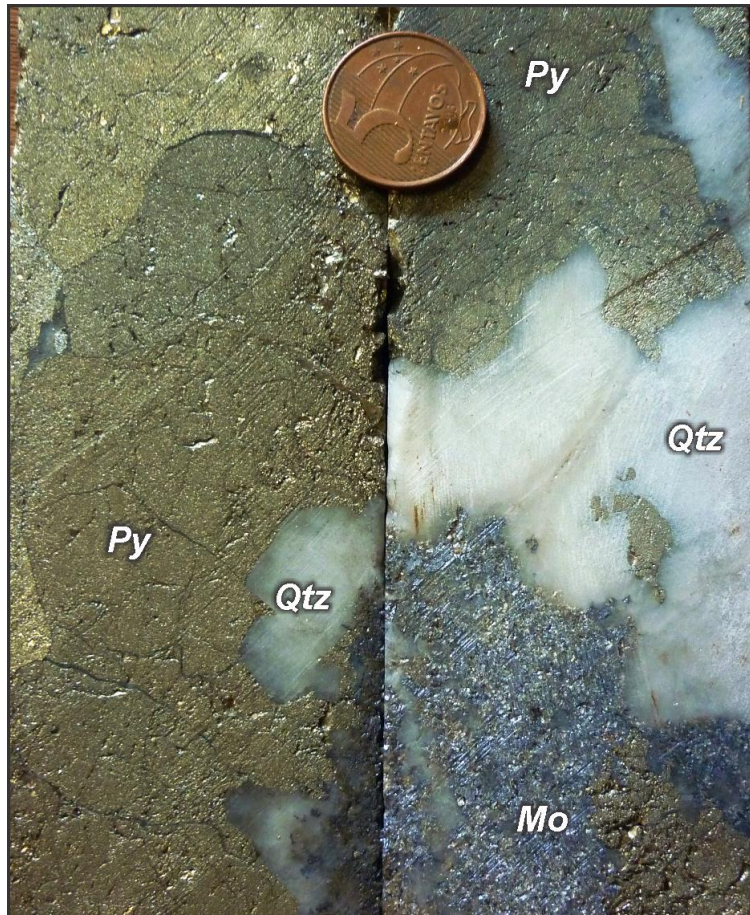




# PROPRIEDADES ÓPTICAS AOS POLARIZADORES DESCRUZADOS

## COR

Propriedade diagnóstica, mas cuja percepção pode variar em função dos diferentes minerais que podem estar no mesmo campo visual.



Podem variar em função:

- (1) composição química em que certos elementos são substituídos na rede cristalina;
- (2) interação com os minerais vizinhos/em contato.



# PROPRIEDADES ÓPTICAS AOS POLARIZADORES DESCRUZADOS

## COR

### GANGA MINERAL

A cor dependerá de seu índice de refração. Minerais com baixo índices de refração têm baixa capacidade de refletir a luz, e absorvem a maior parte da luz incidente.

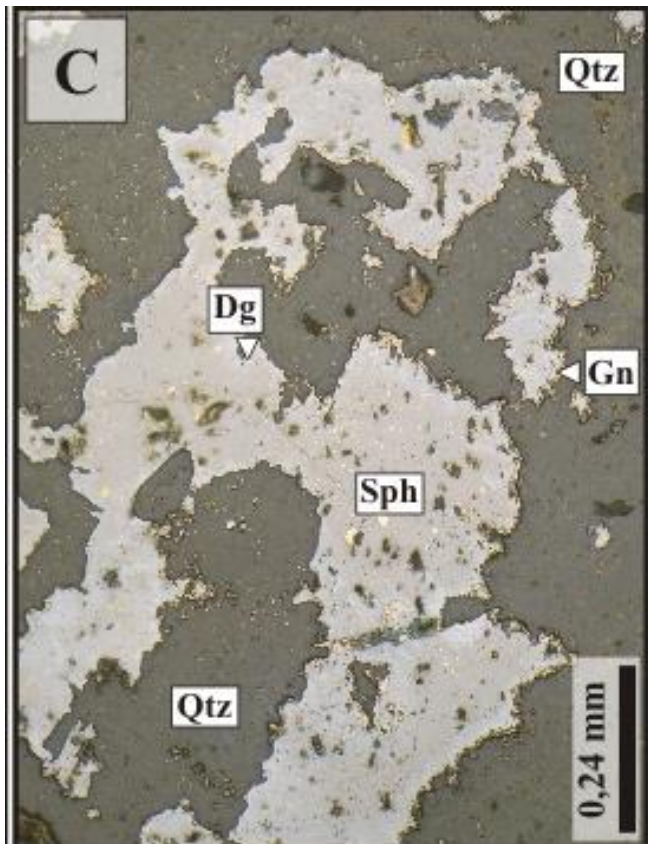
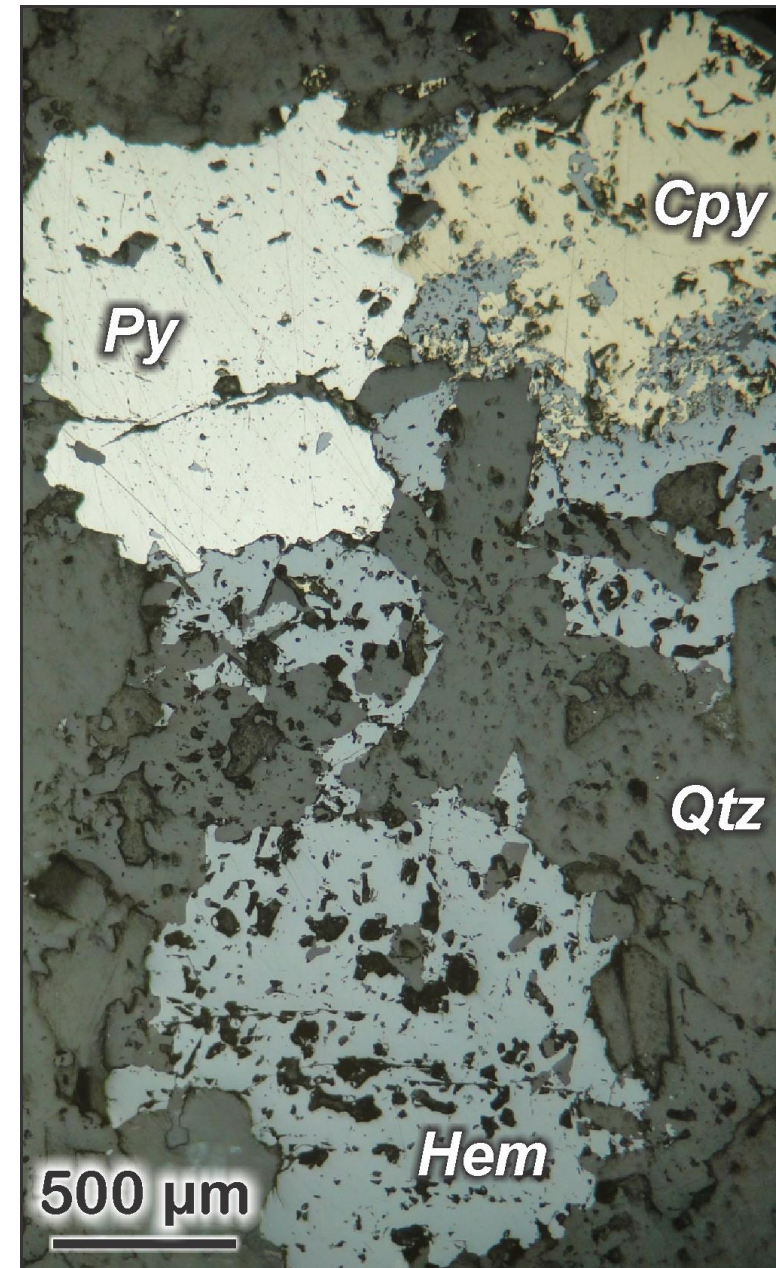
Zeólitas → quase negras

Calcita e quartzo → cinza escuro

Esfalerita → cinza claro

Alguns minerais opacos podem se parecer com a cor da ganga:

Esfalerita (ZnS) → cinza claro





# PROPRIEDADES ÓPTICAS AOS POLARIZADORES DESCRUZADOS

## COR

- Pode, entretanto, corresponder a uma propriedade que varia de investigador a investigador.

→ A mesma cor pode apresentar variações se descrita por diferentes investigadores.

*Ex. Pirrotita ( $Fe_{1-x}S$ ) → bronze claro, creme, vermelho pálido, marrom claro.*

Siglas:

Po: Pirrotita

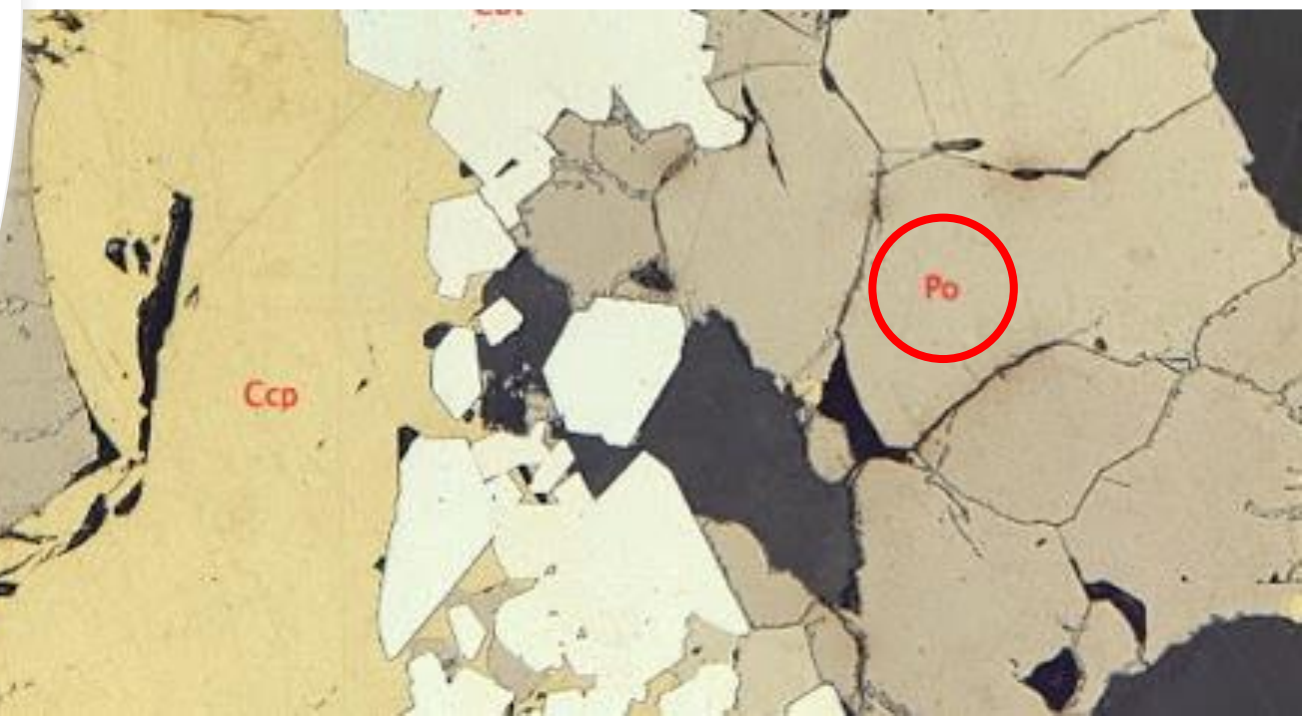
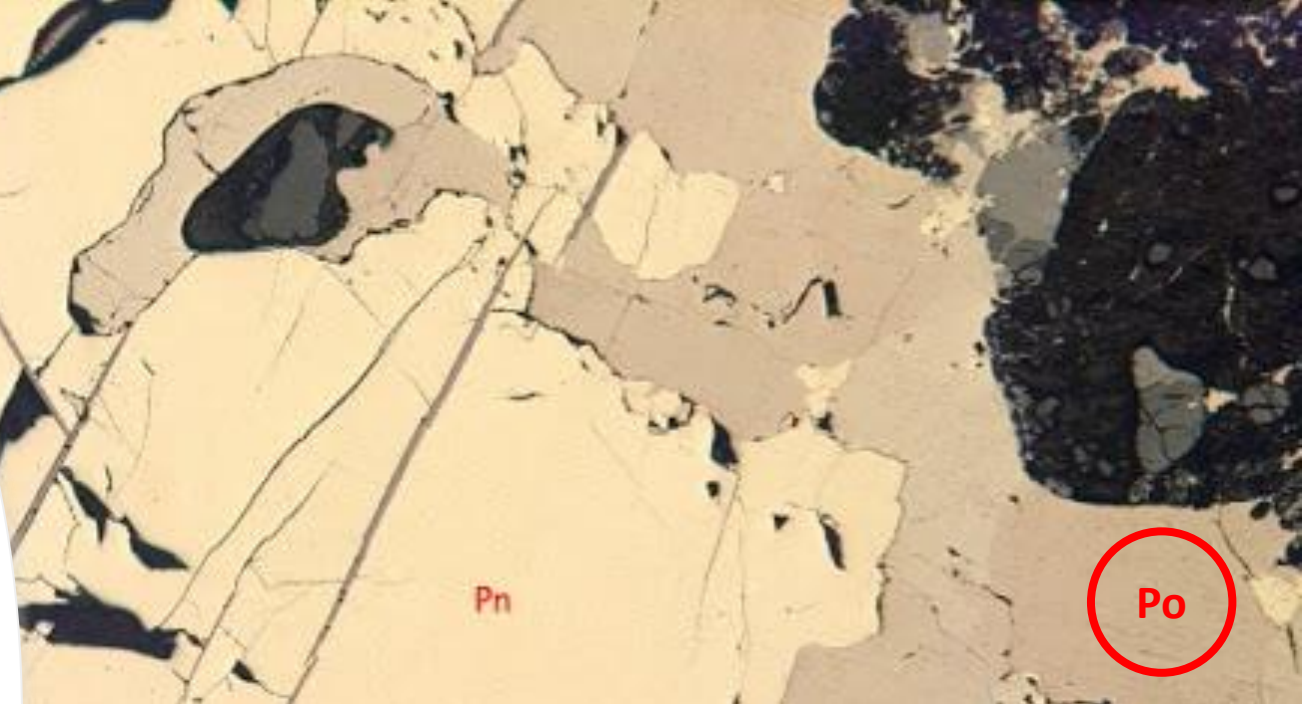
Pn: Pentlandita

Ccp: Calcopirita

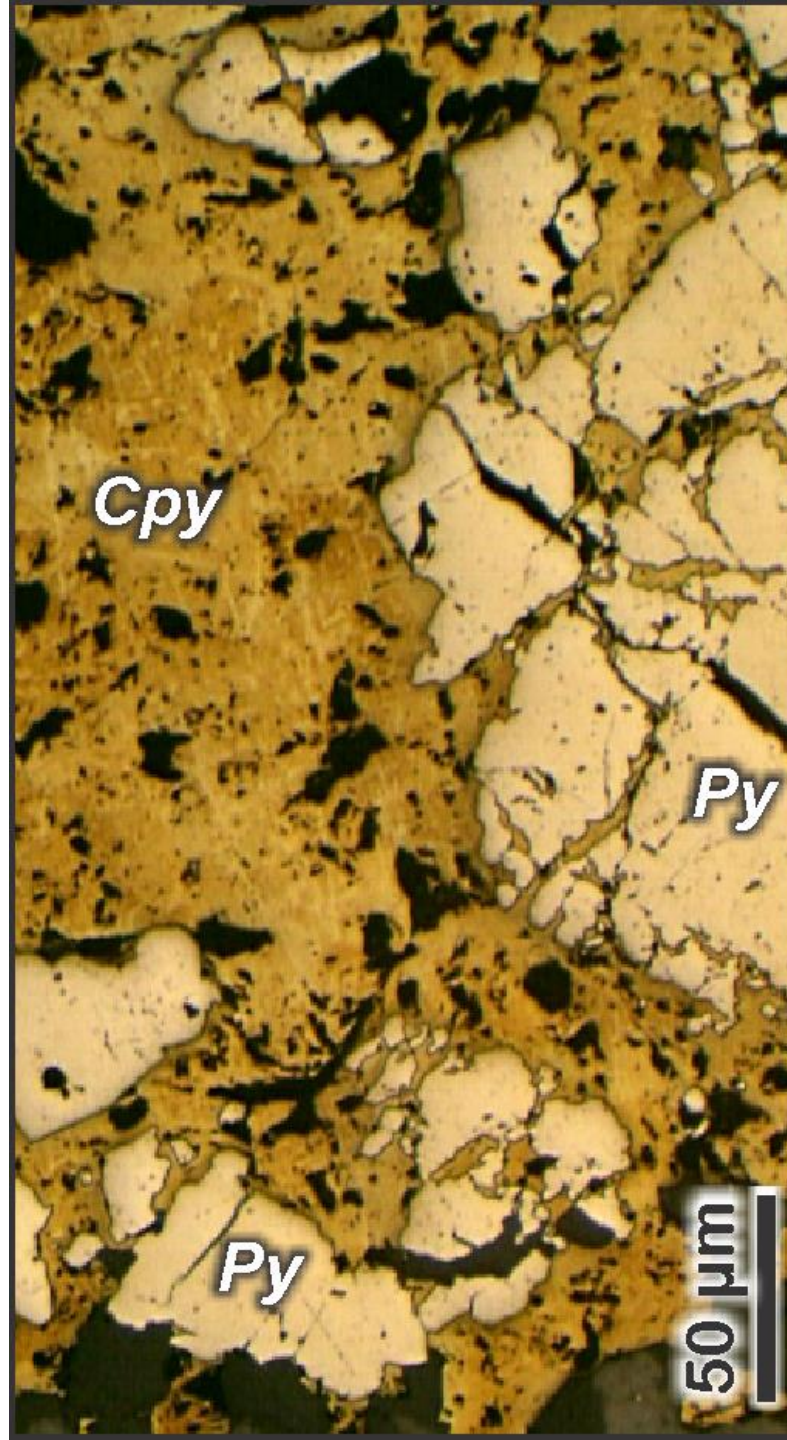
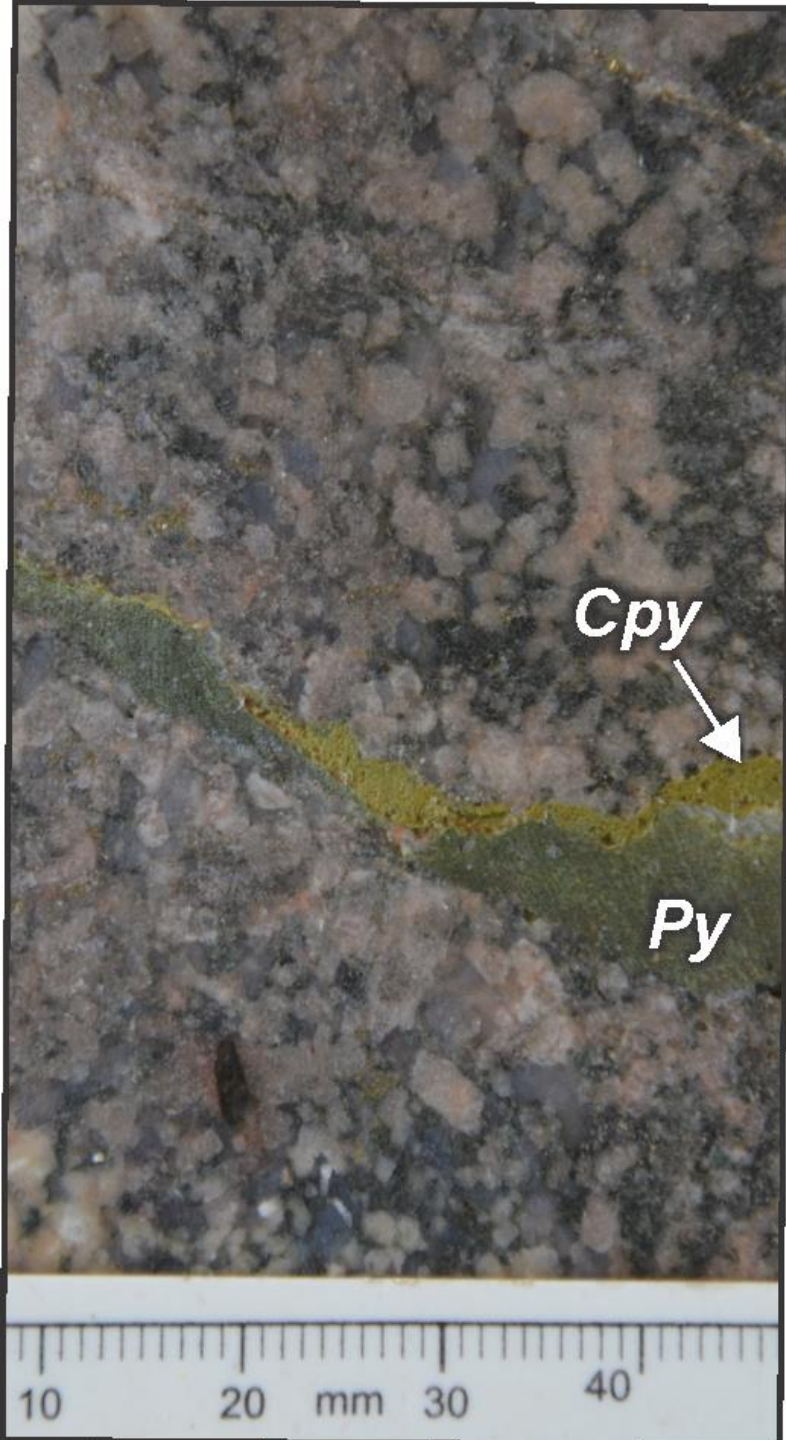
$Fe_{(1-x)}S$

$(Fe, Ni)_9S_8$

$CuFeS_2$







Uma pequena parcela dos minerais de minério são forte e distintamente coloridos. Maioria exibe fraca coloração e podem parecer "esbranquiçados" a "vários tons de cinza" aos olhos dos iniciantes.

VÍDEO  
Contraste de cor (Pirrotita e calcopirita)

[https://www.youtube.com/watch?v=xEZjwy3UpSI&list=PL5k\\_2NCH5I4BCBmeFGuLDPC7MmLX96Wir](https://www.youtube.com/watch?v=xEZjwy3UpSI&list=PL5k_2NCH5I4BCBmeFGuLDPC7MmLX96Wir)

# PROPRIEDADES ÓPTICAS AOS POLARIZADORES DESCRUZADOS

**REFLECTÂNCIA (BRILHO) = (R%)**

Representa a relação entre a intensidade de luz refletida pelo mineral e a intensidade de luz total incidente multiplicada por 100.

*“Quantidade de luz que é refletida de volta ao observador pela superfície do mineral”.*

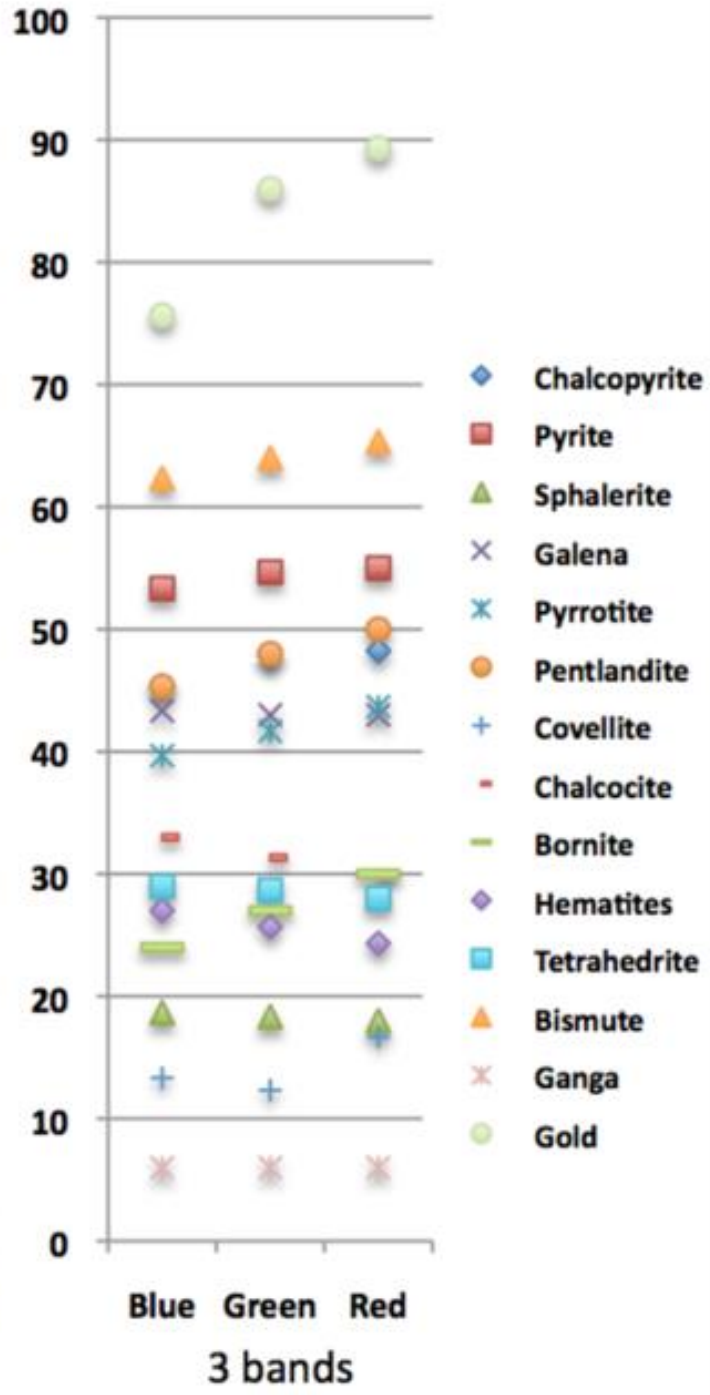
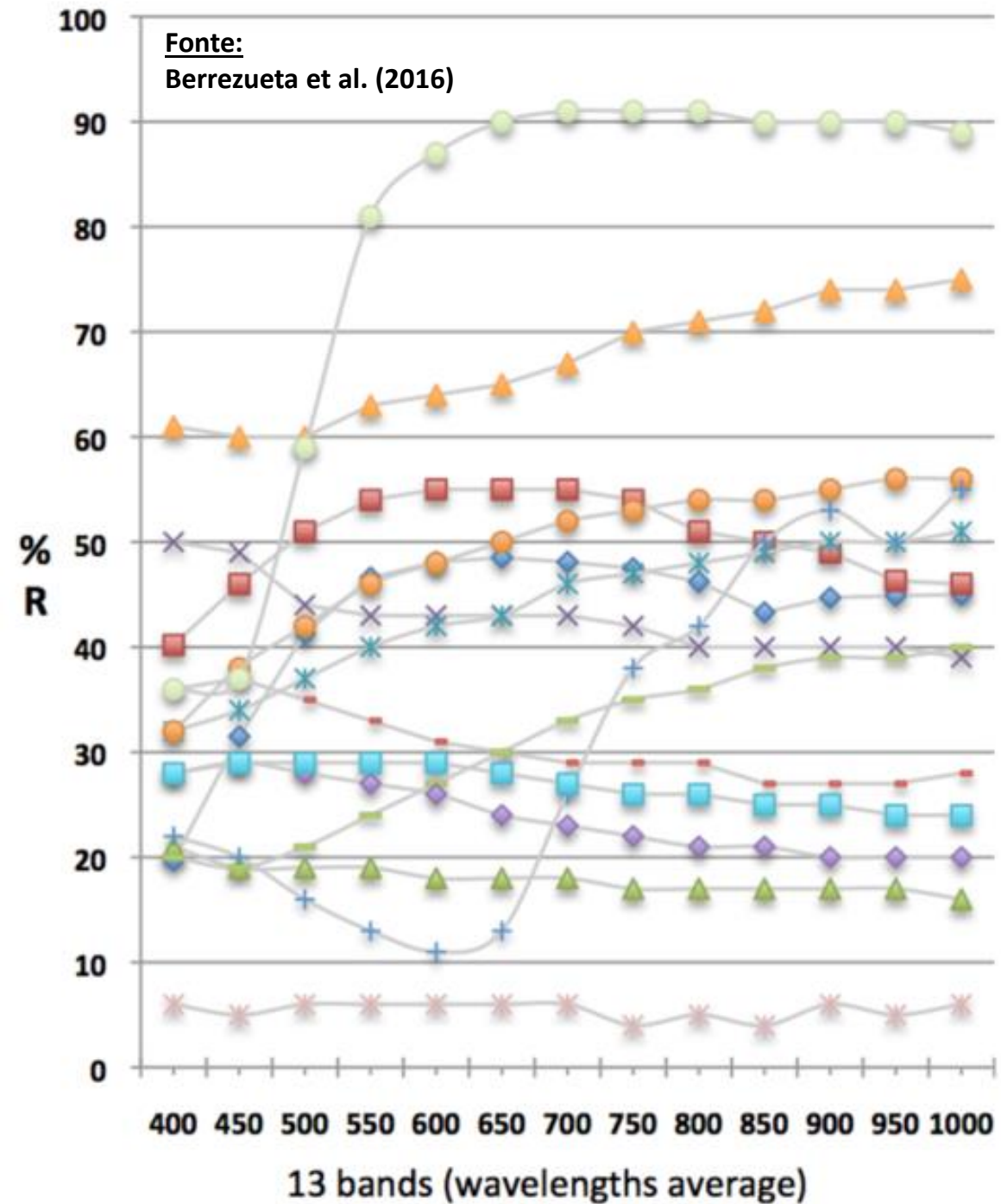
$$\text{Refectância (R\%)} = \frac{\text{Intensidade da luz refletida}}{\text{Intensidade da luz incidente}} * 100$$

PROPRIEDADE QUE PODE SER  
INFLUENCIADA POR:

- ✓ Orientação cristalográfica da superfície polida;
- ✓ Ângulo de incidência da luz na superfície do mineral;
- ✓ Comprimento de onda da luz;
- ✓ Grau/qualidade do polimento da lâmina;
- ✓ Outros minerais ao redor.



Fonte:  
Berrezueta et al. (2016)

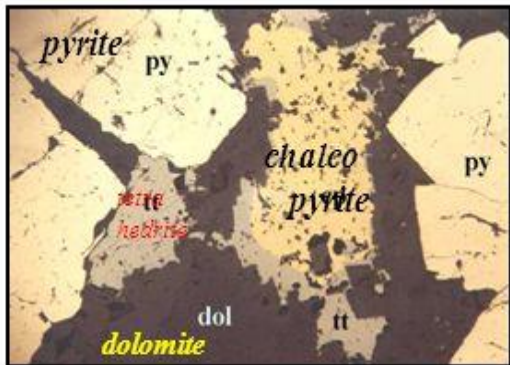
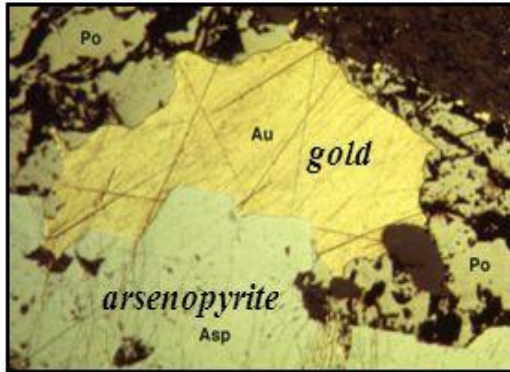


**REFLECTÂNCIA  
(BRILHO) = (R%)**  
Representa a relação  
entre a intensidade  
de luz refletida pelo  
mineral e a  
intensidade de luz  
total incidente  
multiplicada por 100.

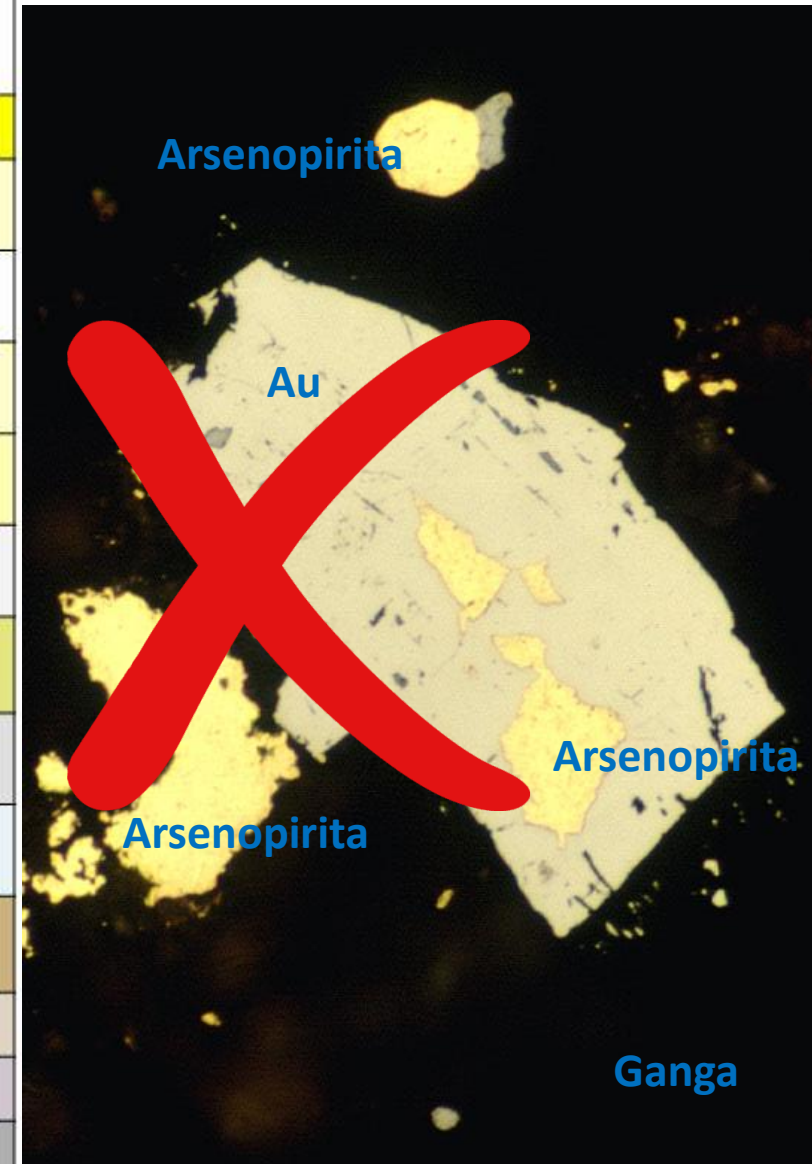


**SOME COMMON OPAQUE MINERALS:** LISTED IN ORDER OF DECREASING REFLECTANCE

**A correspondência abaixo é verdadeira?**



Mineral	Formula	Reflect.	Colour	Anisotropy	Hardness
Gold	Au	74	bright yellow	isotropic	2.5-3.0
Pyrite	FeS <sub>2</sub>	54	pale yellow	isotropic	6.0-6.5
Arsenopyrite	FeAsS	52	white	strong	5.5-6.0
Pentlandite	(Fe,Ni) <sub>9</sub> S <sub>8</sub>	1	Light yellow	isotropic	3.5-4.0
Chalcopyrite	CuFeS <sub>2</sub>	44	yellow	weak	3.5-4.0
Galena	PbS	43	grey-white	isotropic	2.5
Pyrrhotite	Fe <sub>1-x</sub> S	34-40	pinkish brown to yellow	strong	4.0
Chalcocite	Cu <sub>2</sub> S	32	light grey	weak	2.5-3.0
Hematite	Fe <sub>2</sub> O <sub>3</sub>	28	bluish grey	strong	5.0-6.0
Bornite	Cu <sub>5</sub> FeS <sub>4</sub>	22	purplish brown	isotropic	3.0
Magnetite	Fe <sub>3</sub> O <sub>4</sub>	21	brownish grey	isotropic	5.5
Ilmenite	FeTiO <sub>3</sub>	17-20	pinkish grey	strong	5.0-6.0
Sphalerite	ZnS	17	grey	isotropic	3.5-4.0
Chromite	FeCr <sub>2</sub> O <sub>4</sub>	14	dark grey	isotropic	5.5



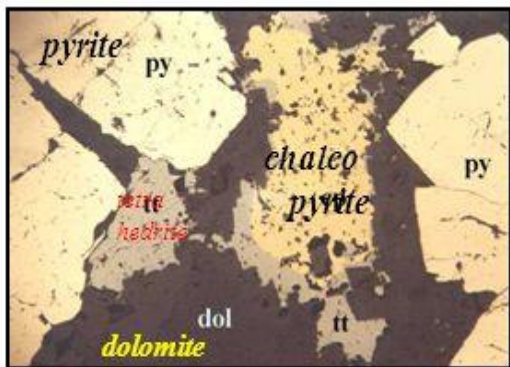
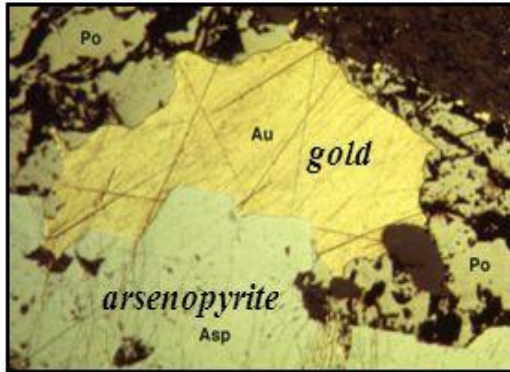
**FONTE:**

<https://slideplayer.com/slide/1707324/>

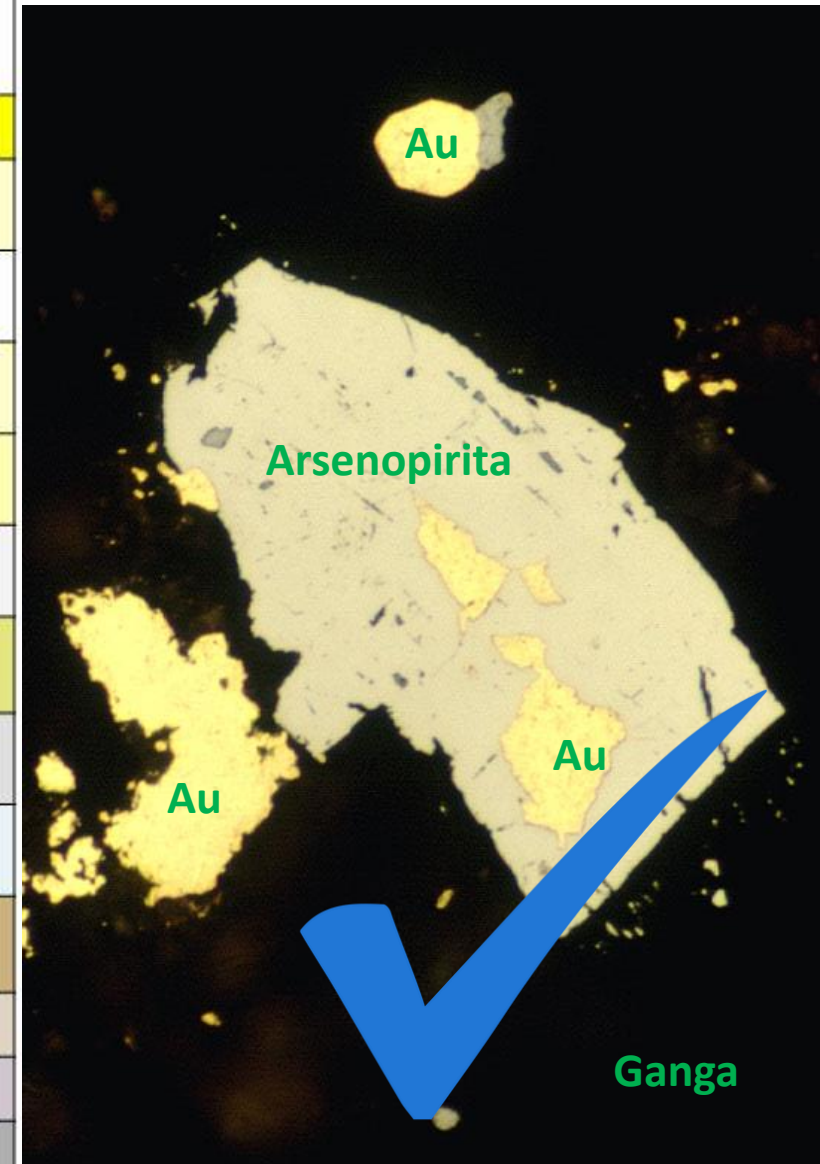


**SOME COMMON OPAQUE MINERALS:** LISTED IN ORDER OF DECREASING REFLECTANCE

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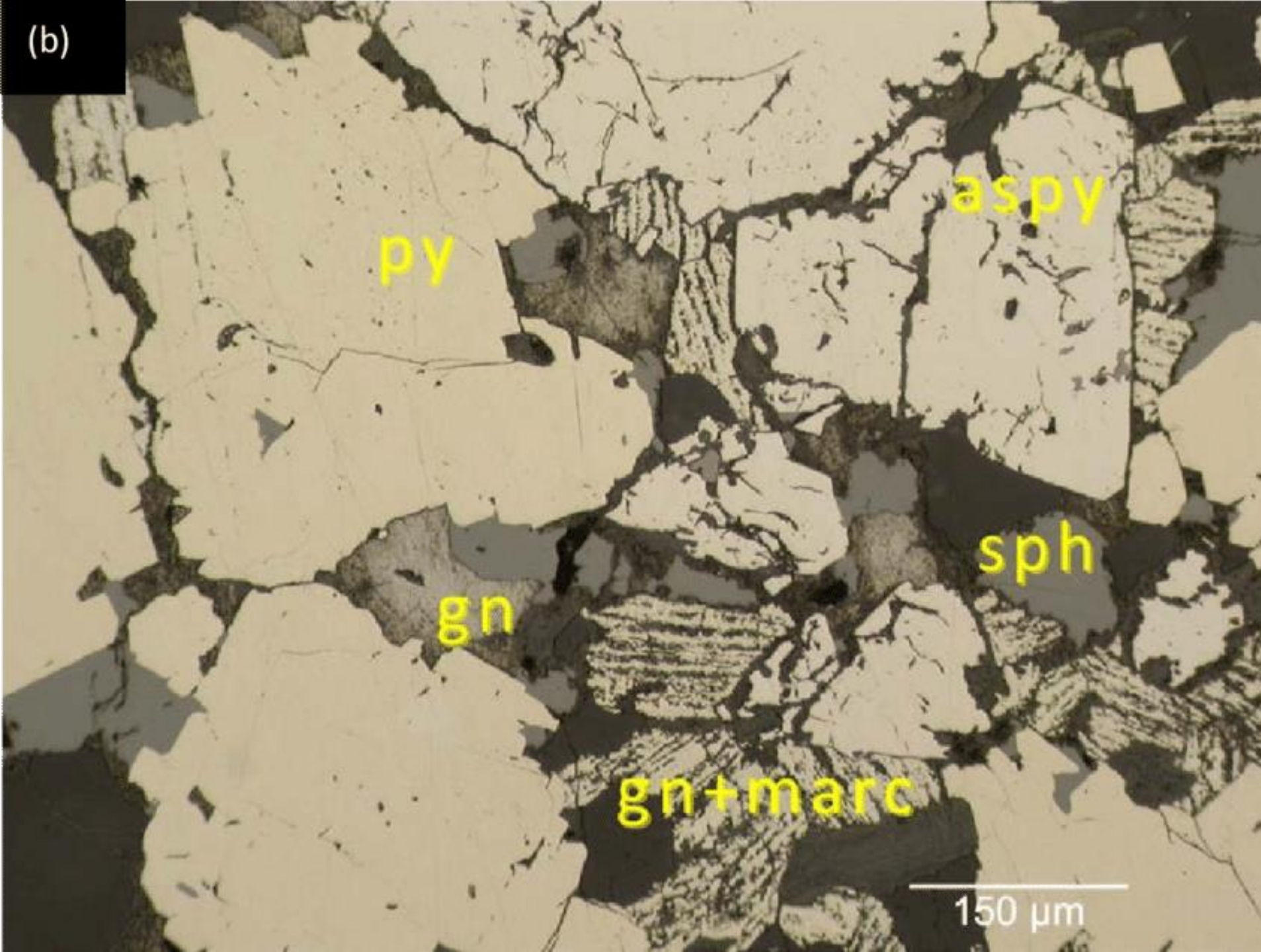
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**FONTE:**  
<https://slideplayer.com/slide/1707324/>



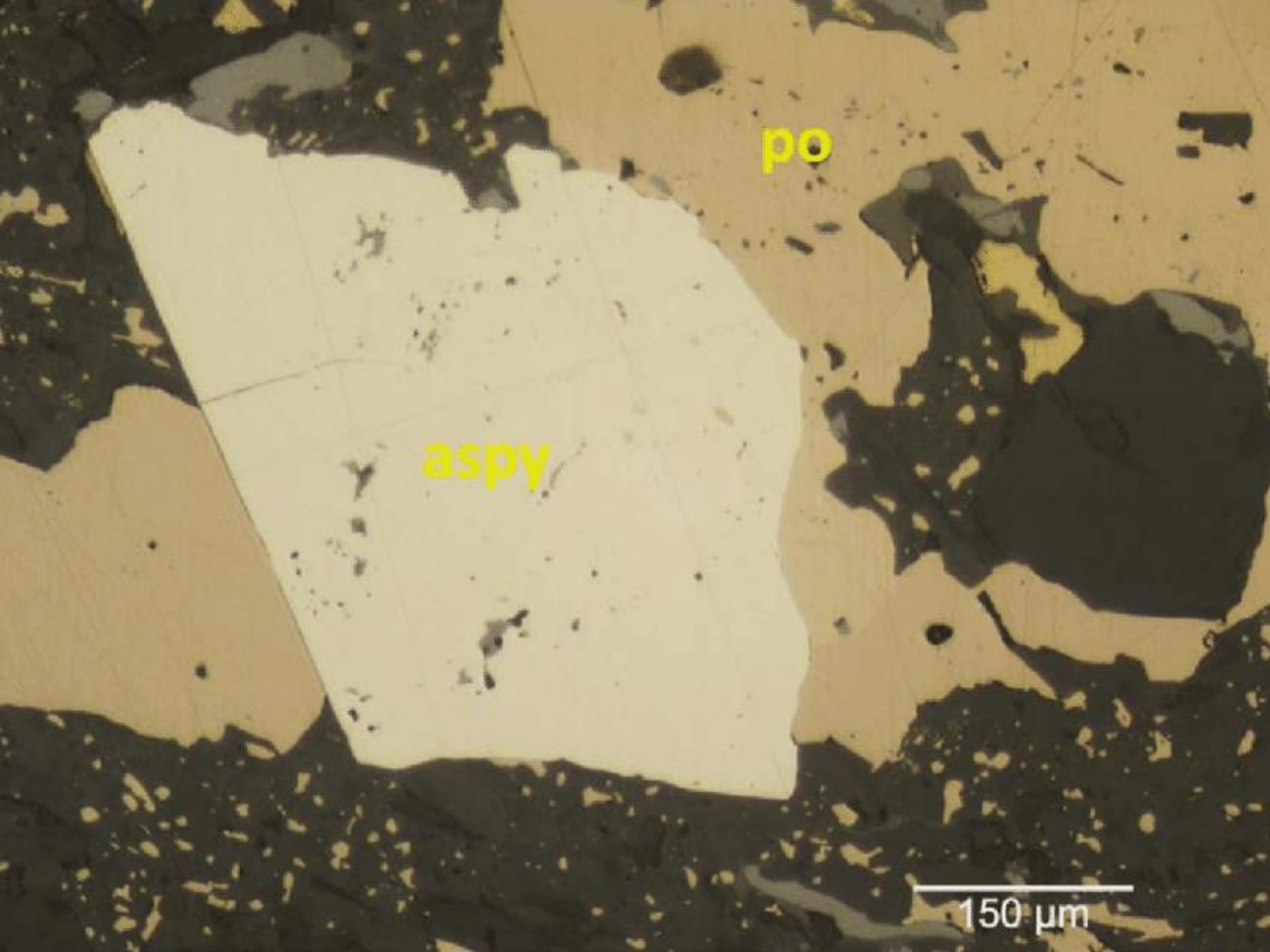
(b)



**REFLECTÂNCIA  
(BRILHO) = (R%)**

**Pirita (Py) >  
Arsenopirita (Aspy) >  
galena (Gn) >  
esfalerita (Sph)**



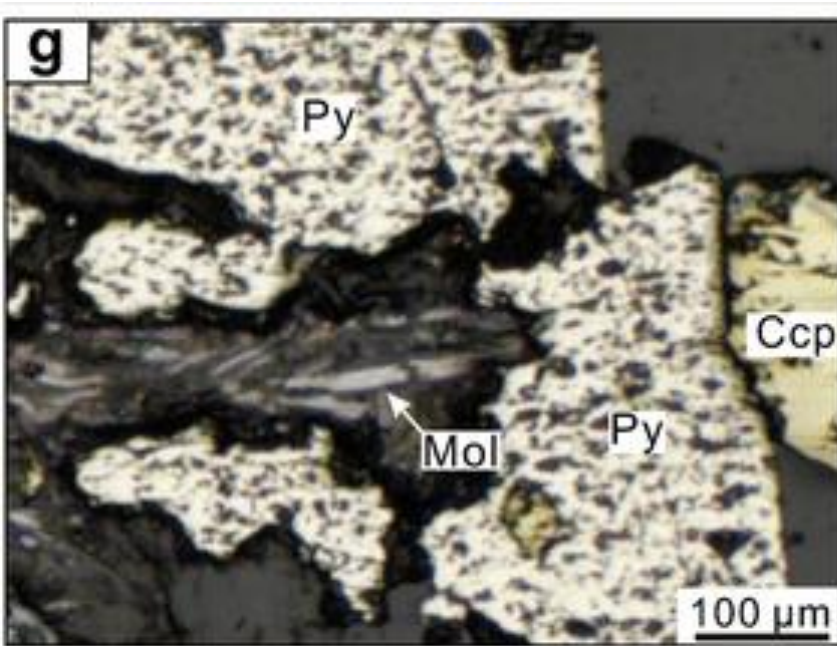


**REFLECTÂNCIA  
(BRILHO) = (R%)**

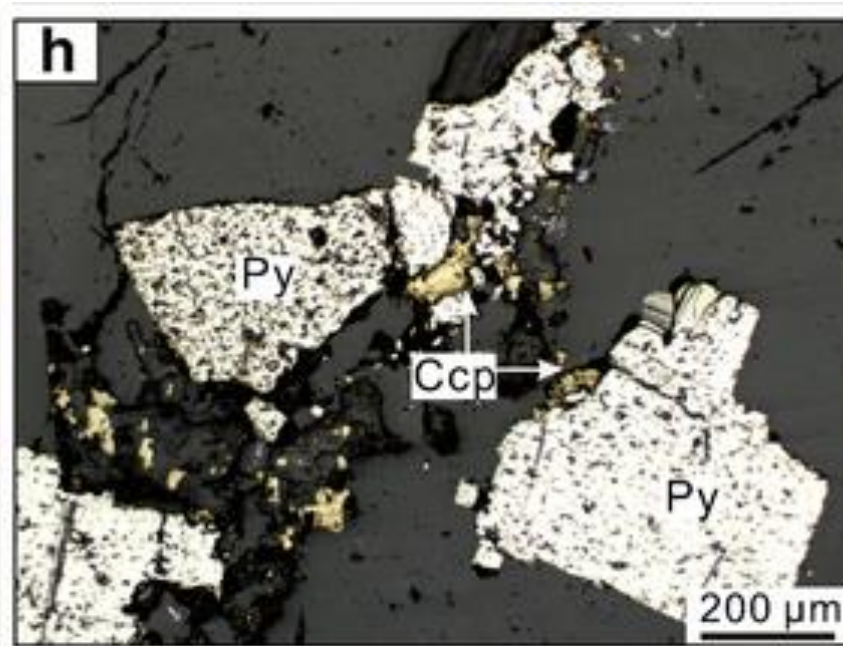
**Arsenopirita (Aspy) >  
Pirrotita (Po)**



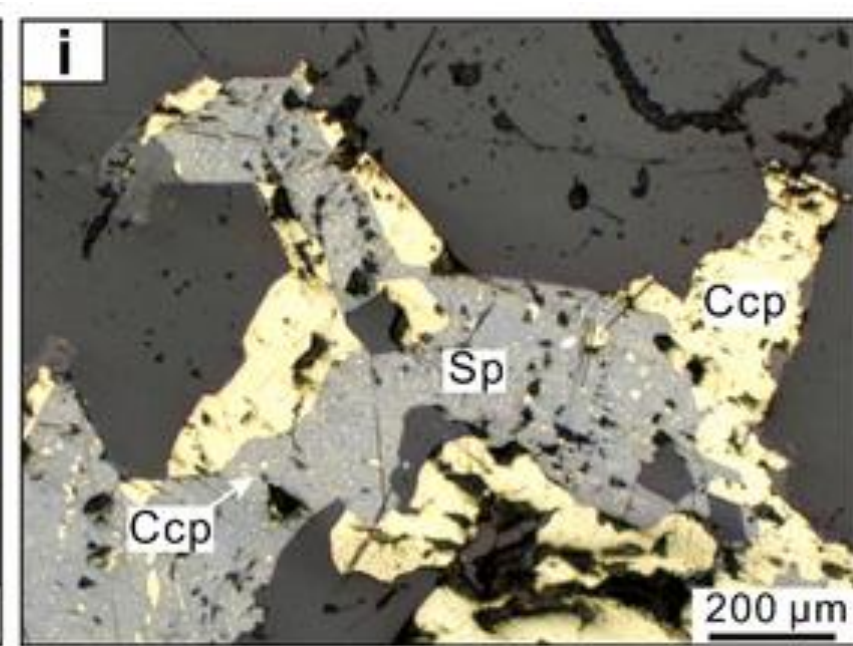
## REFLECTÂNCIA (BRILHO) = (R%)



Pirita (Py) > Calcopirita (Ccp) > Molibdenita (Mol)



Pirita (Py) > Calcopirita (Ccp) > Ganga

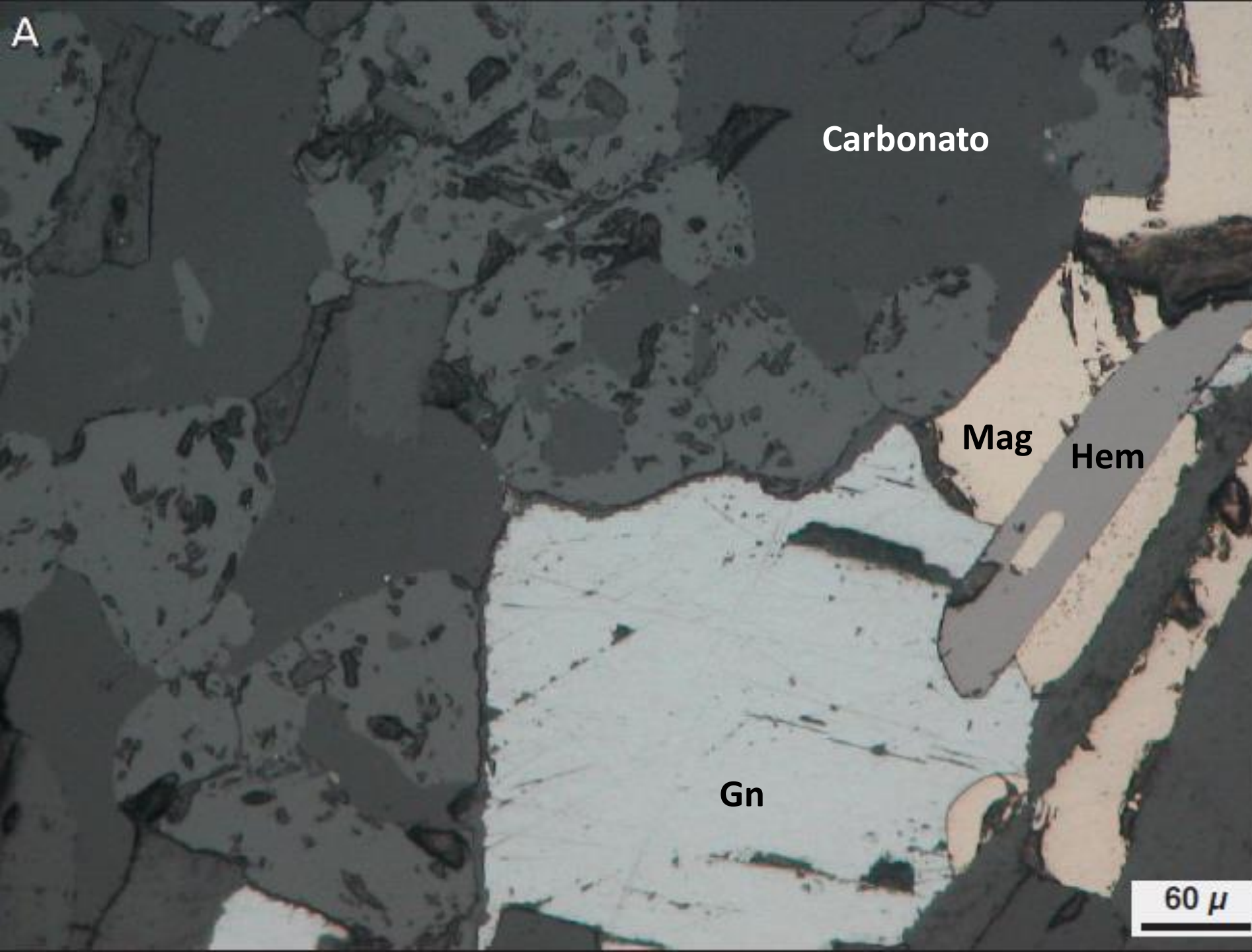


Calcopirita (Ccp) > Esfalerita (Sp) > Ganga

**APROVEITAR PARA NOTAR AS VARIAÇÕES DE COR:**

Pirita	(amarelo pálido)
Calcopirita	(amarelo mais escuro)
Esfalerita	(cinza claro)
Ganga	(cinza escuro)





Carbonato

Mag

Hem

Gn

60 μ

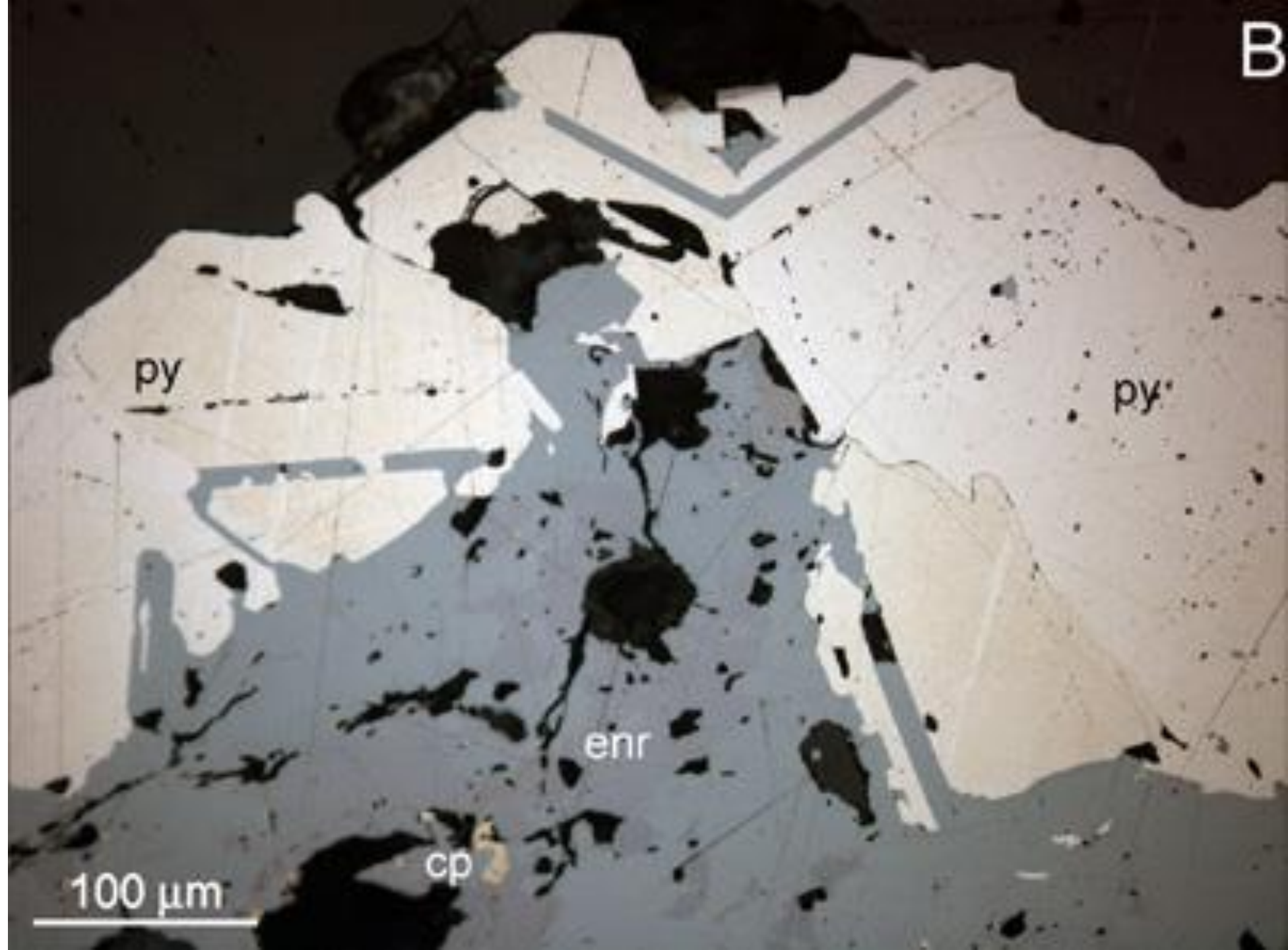
**REFLECTÂNCIA  
(BRILHO) = (R%)**

**Galena (Gn) >  
Magnetita (Mag) >  
Hematita (Hem) >  
ganga carbonática**



**REFLECTÂNCIA  
(BRILHO) = (R%)**

**Pirita (Py) >  
Calcopirita (Cp) >  
Enargita (Enr)**



# PROPRIEDADES ÓPTICAS AOS POLARIZADORES DESCRUZADOS

Cinábrio (HgS)



60  $\mu$

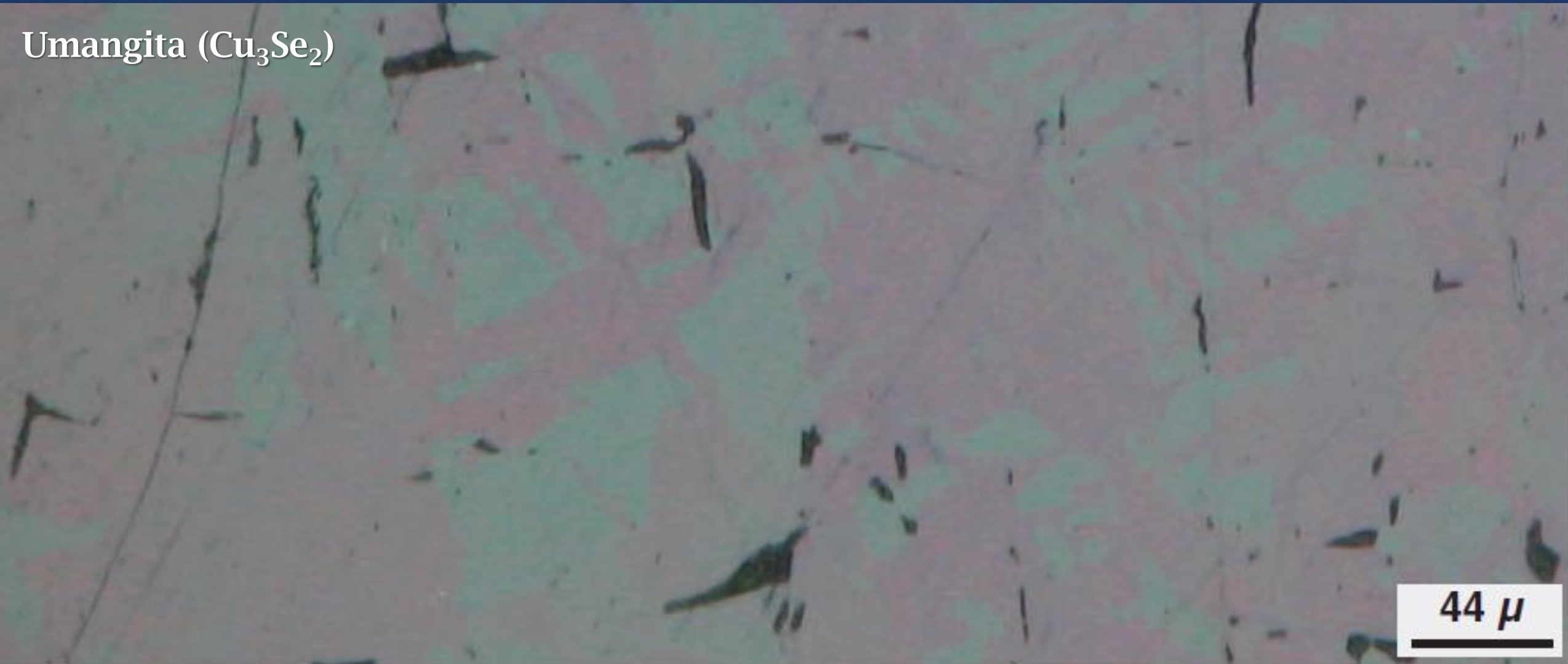
## BIRREFLECTÂNCIA / PLEOCROÍSMO

Variações de refletância e cor ao girar a platina (*propriedade analisada de modo qualitativo*). Variação da refletância dependente da seção observada do mineral.



# PROPRIEDADES ÓPTICAS AOS POLARIZADORES DESCRUZADOS

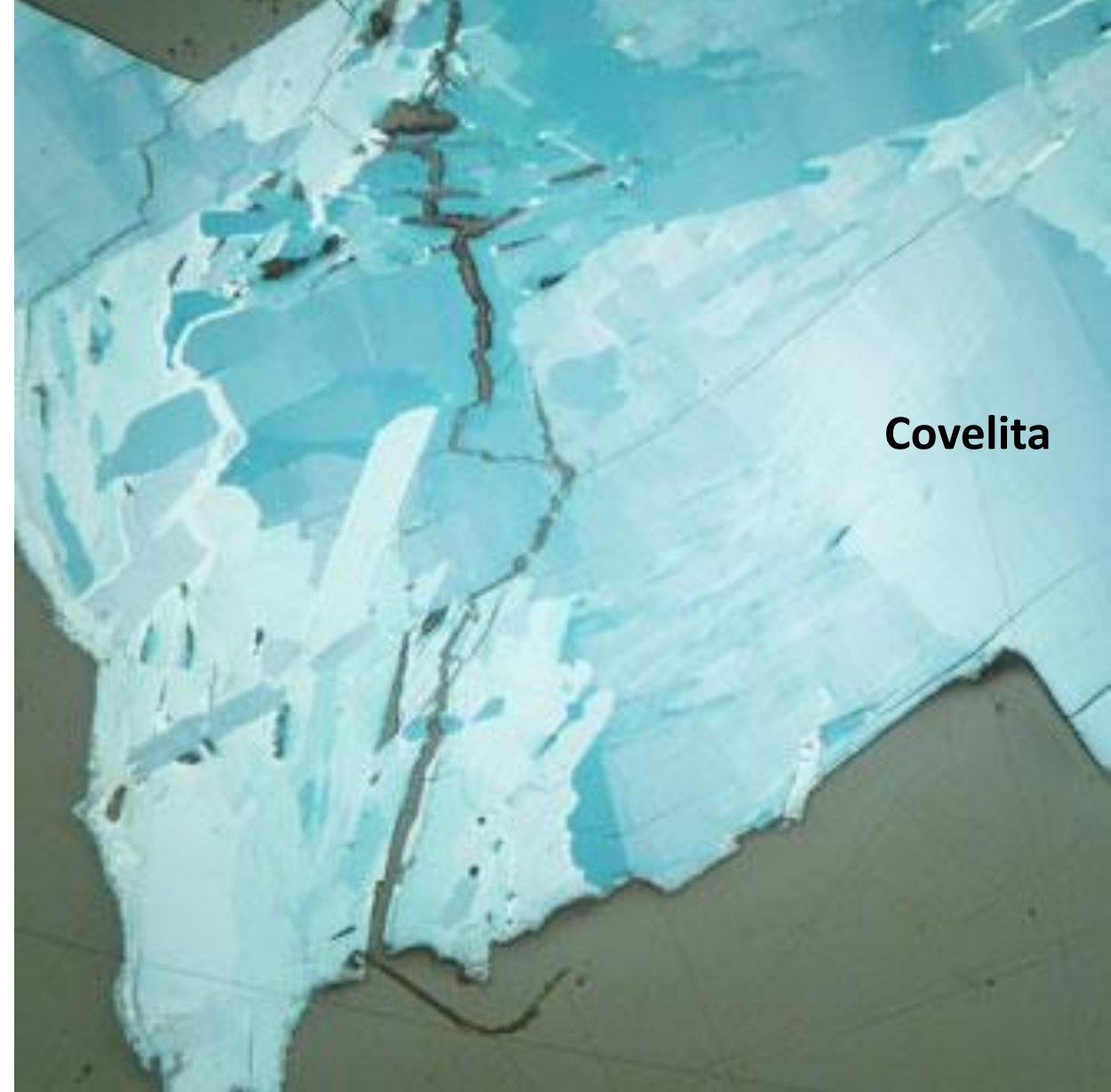
Umangita ( $\text{Cu}_3\text{Se}_2$ )



44  $\mu$

## BIRREFLECTÂNCIA / PLEOCROÍSMO

Variação de cor e/ou tonalidades que alguns minerais podem apresentar ao girar a platina.

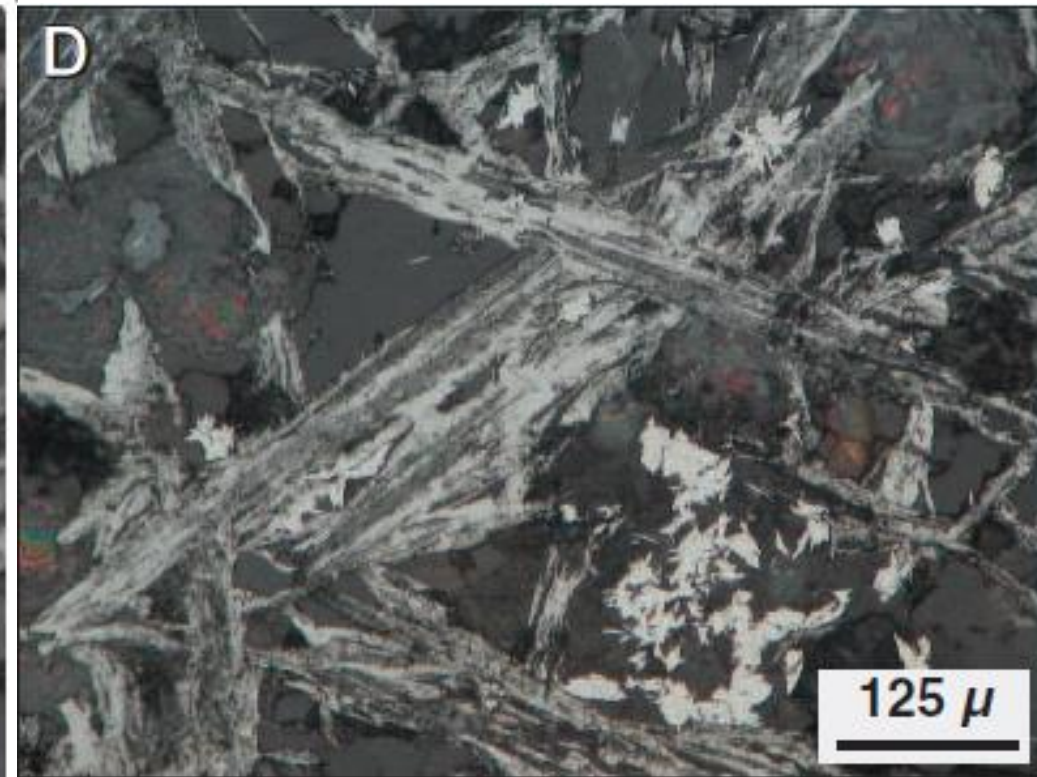
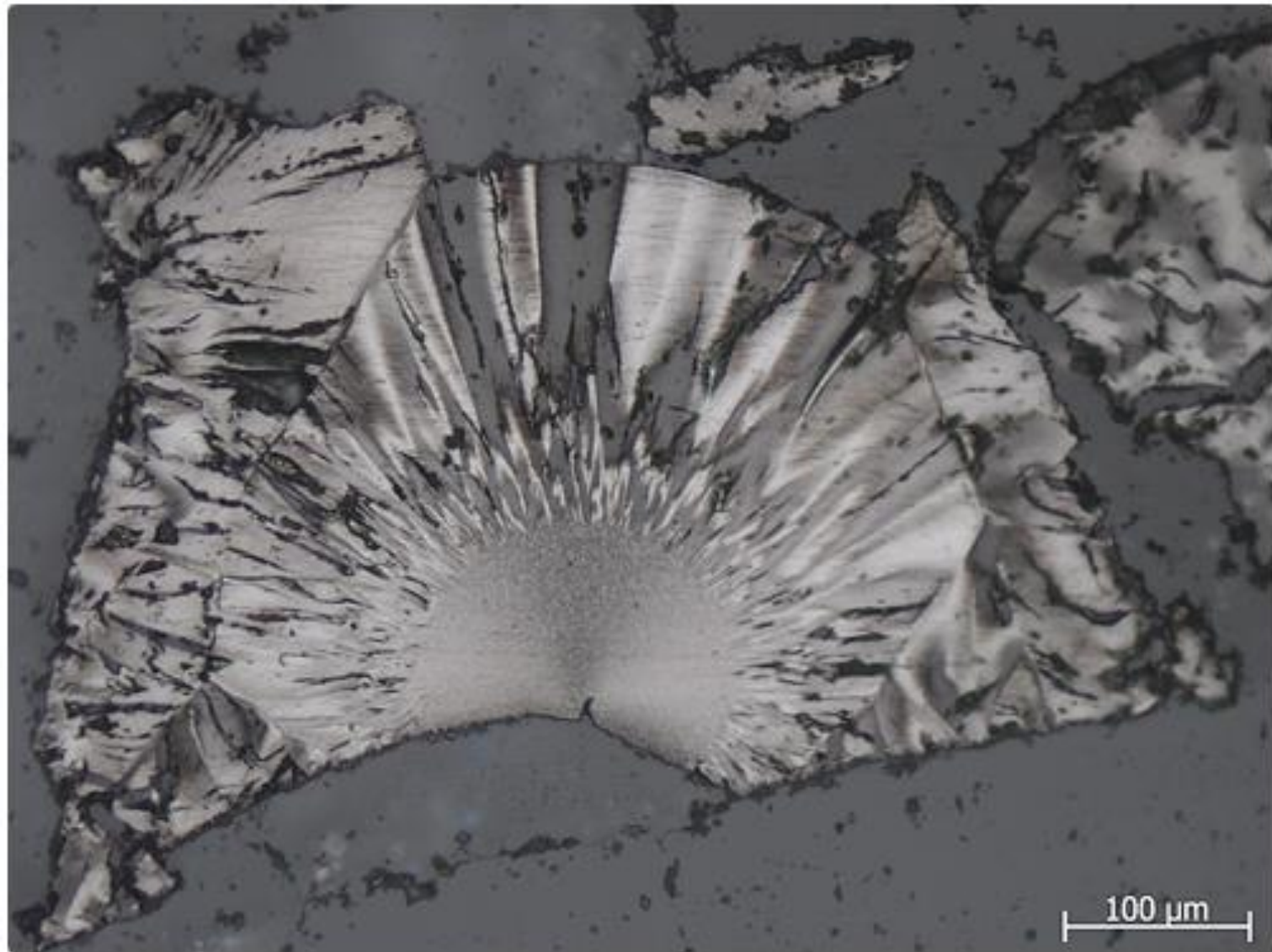


**Cristais de molibdenita (direita) e covelita (acima) com diferentes tonalidades de cor (pleocroísmo)**



## BIRREFLECTÂNCIA / PLEOCROÍSMO

Necessidade de especificar as variações de cor ao girar a platina (*independente de sua intensidade*):  
*creme a róseo, azul claro a forte, etc.*



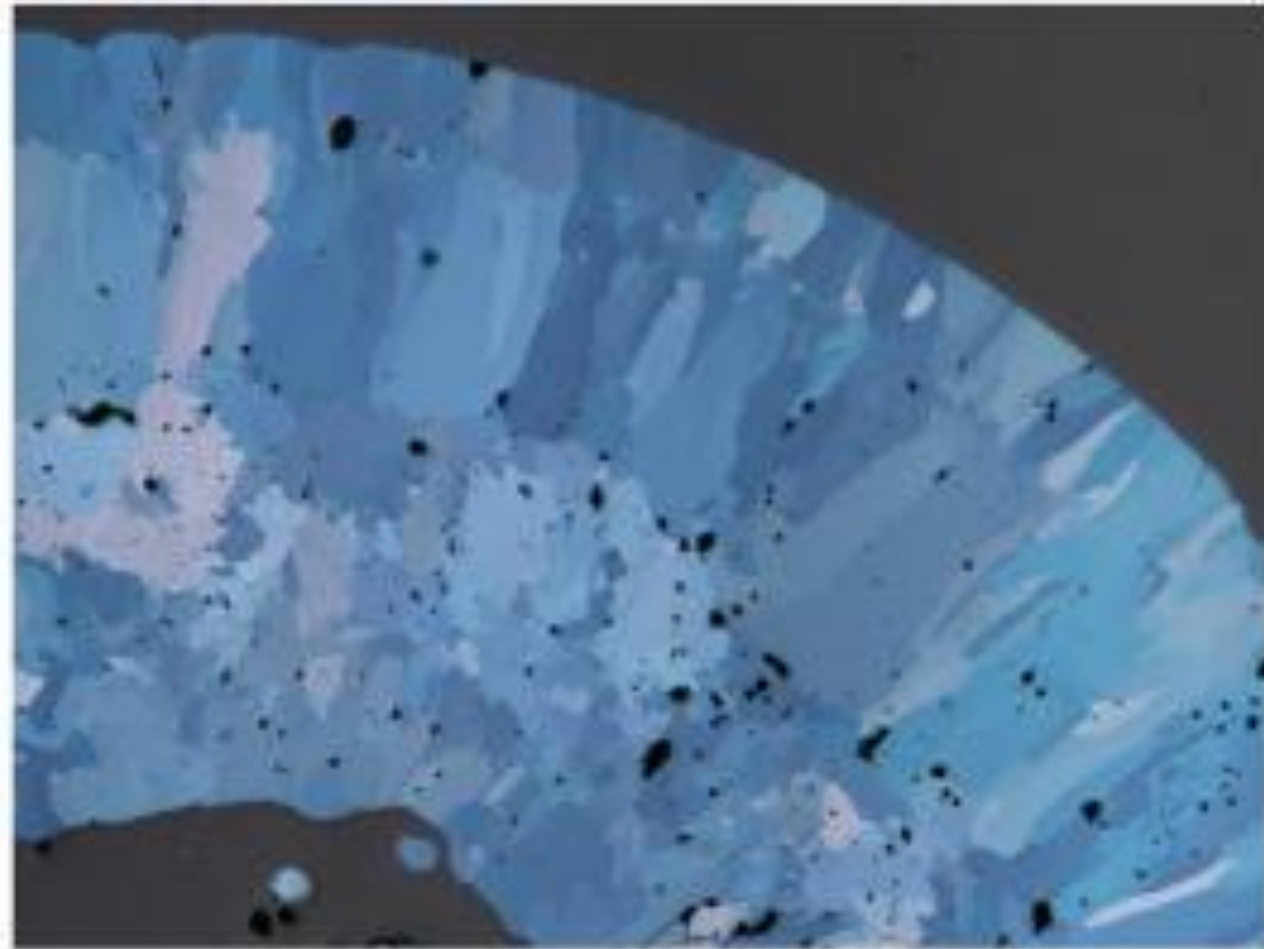
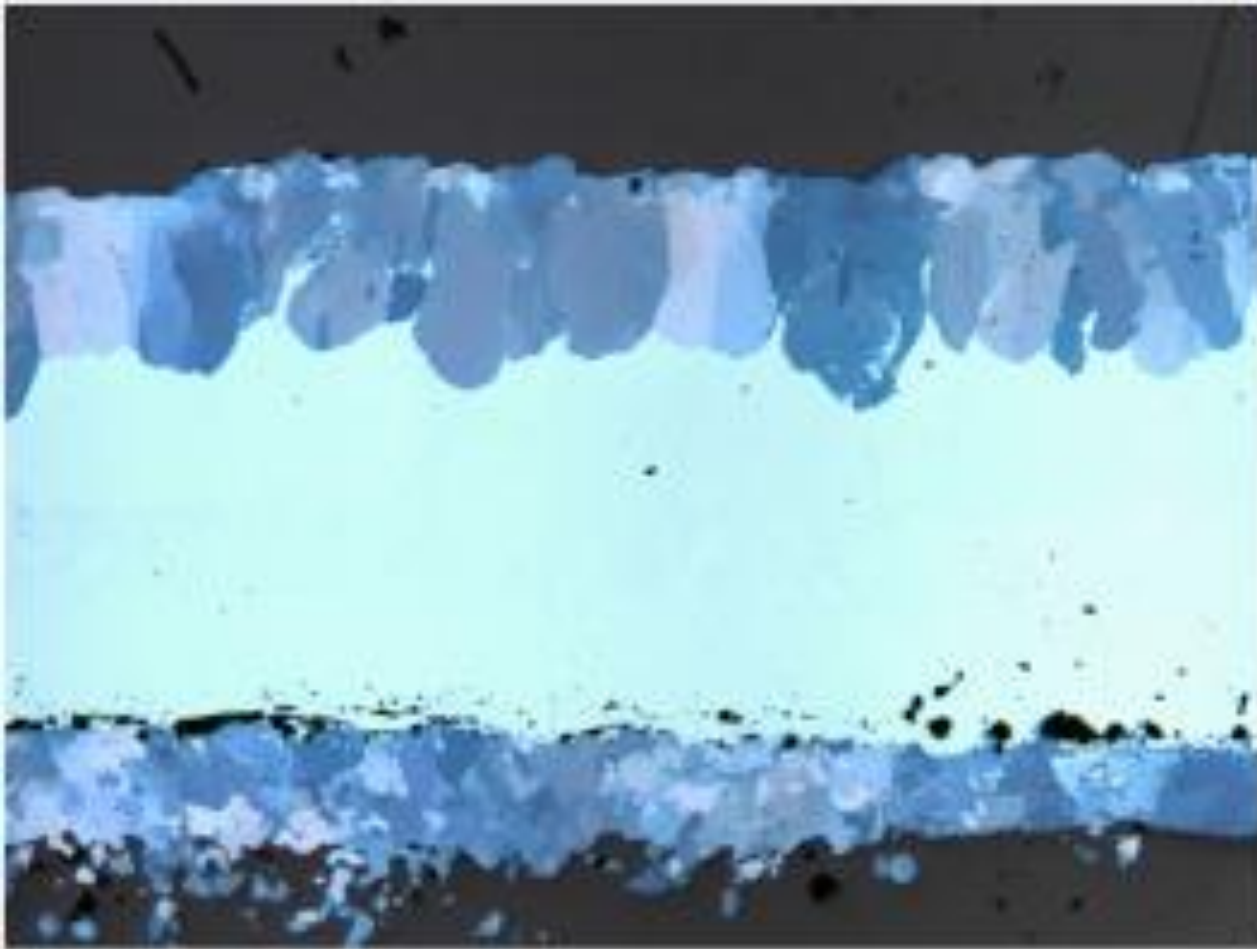
**Cristais de grafita com variação em suas tonalidades de cor (pleocroísmo/birreflectância).**

**FONTE:**

<https://www.bgs.ac.uk/sciencefacilities/laboratories/mpb/petrography.html>

## BIRREFLECTÂNCIA / PLEOCROÍSMO

Necessidade de especificar as variações de cor ao girar a platina (*independente de sua intensidade*):  
*creme a róseo, azul claro a forte, etc.*



**Diminutos cristais de covelita com variação em suas tonalidades de azul ao girar a planita (pleocroísmo/birreflectância).**



## BIRREFLECTÂNCIA / PLEOCROÍSMO

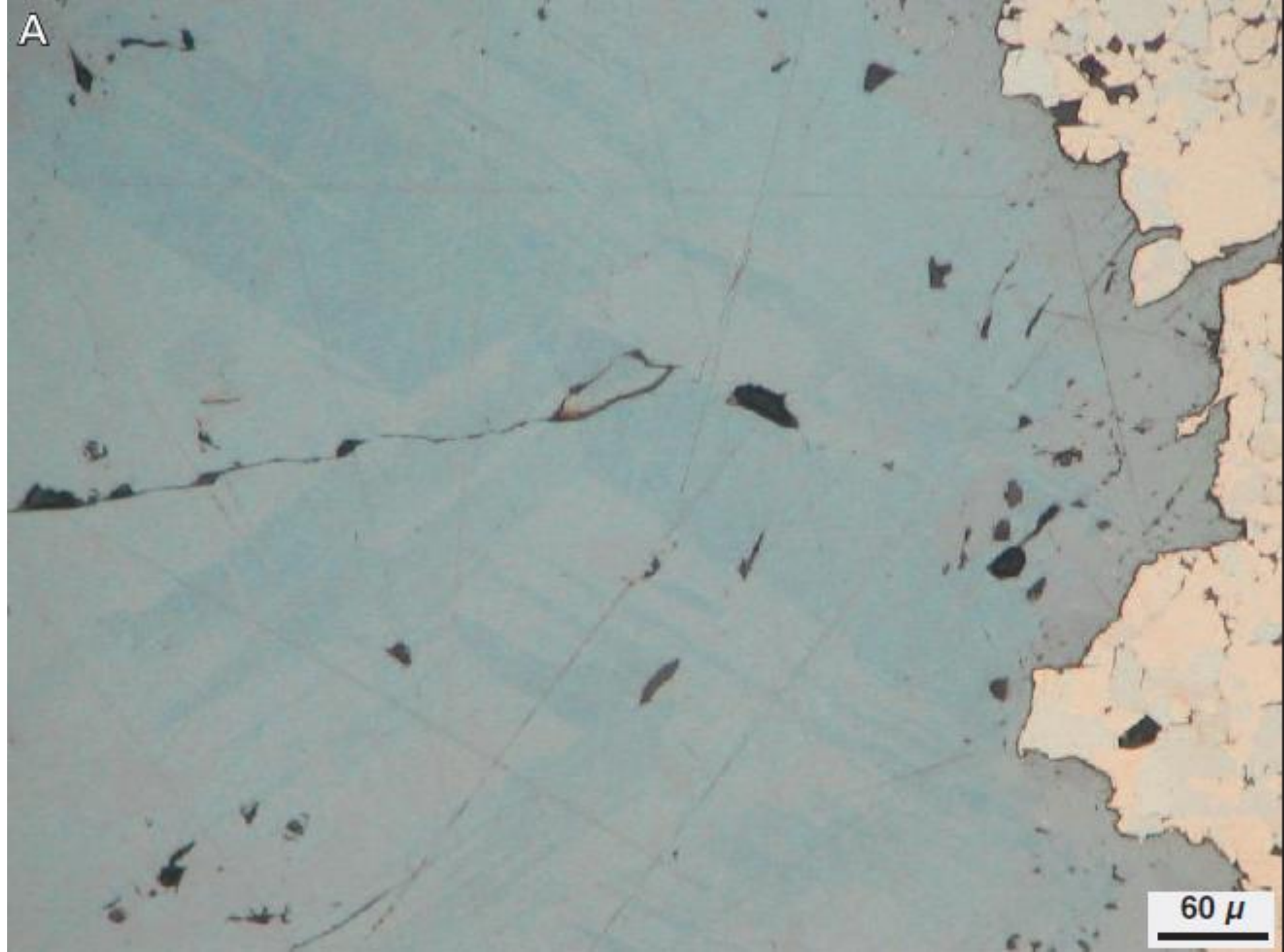
Lamellar twinning of  
metacinnabar (grey to  
bluish grey pleochroism),  
pyrite (cream);

Concepción Mine,  
Teloloapan, Guerrero,  
Mexico [j]  
Nic. //

### VÍDEO

Pleocroísmo /  
Birreflectância da grafita

[https://www.youtube.com/  
watch?v=dTRRxnzGbh4&list=  
PL5k\\_2NCH5I4AO8F5yi2VK1z  
3cQgrk\\_jHL](https://www.youtube.com/watch?v=dTRRxnzGbh4&list=PL5k_2NCH5I4AO8F5yi2VK1z3cQgrk_jHL)

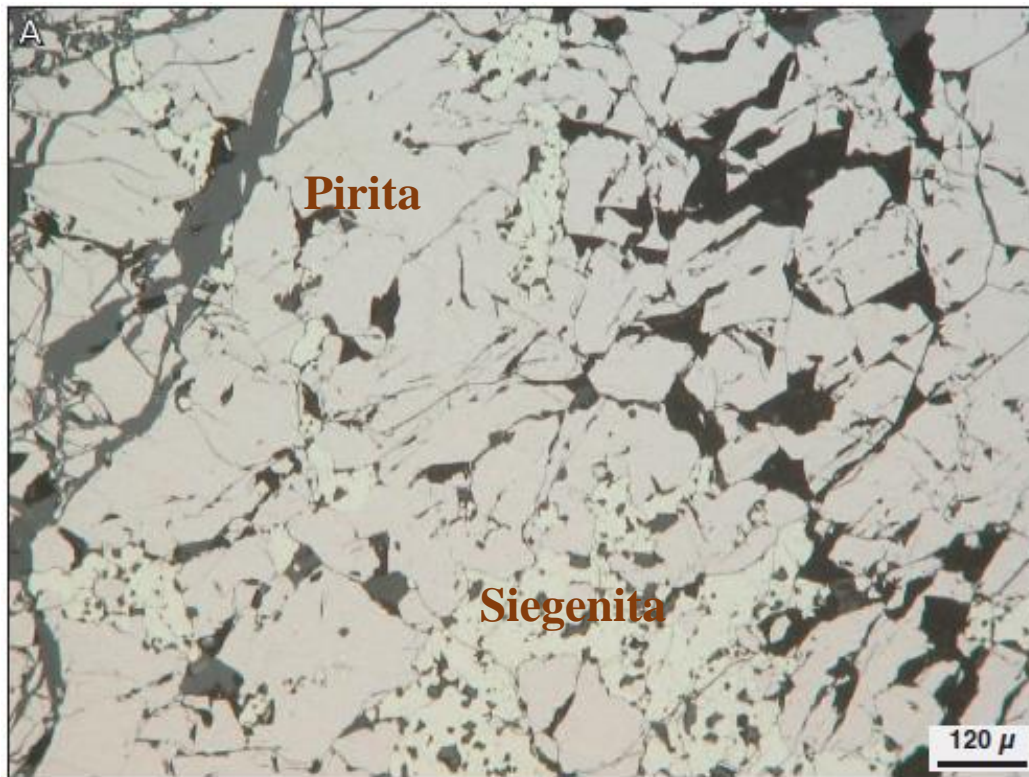


# PROPRIEDADES ÓPTICAS AOS POLARIZADORES CRUZADOS

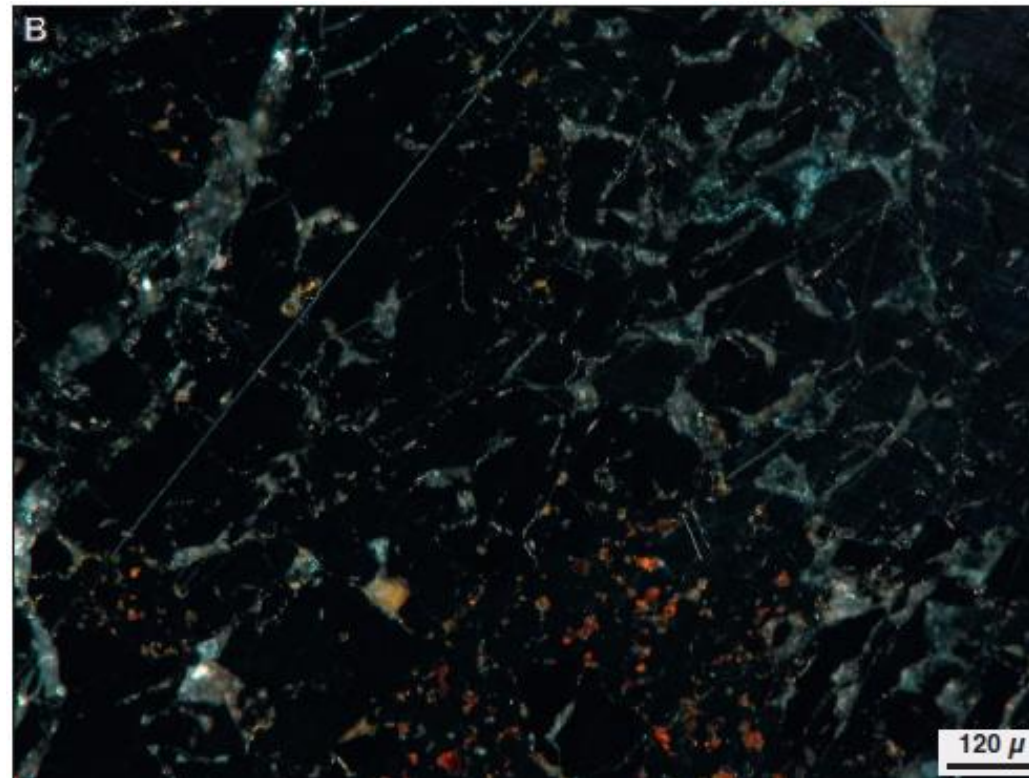
## ISOTROPIA

Minerais que apresentam extinção com os polarizadores cruzados.

*Minerais do sistema cúbico (pirita, magnetita, esfalerita, galena), ou então, seções basais de minerais do sistema hexagonal ou tetragonal.*



▲ Massive siegenite (very light grey with pink tint), irregular patches of pyrite (light cream); Shinkolobwe, Katanga, Congo [d]; Nic. //



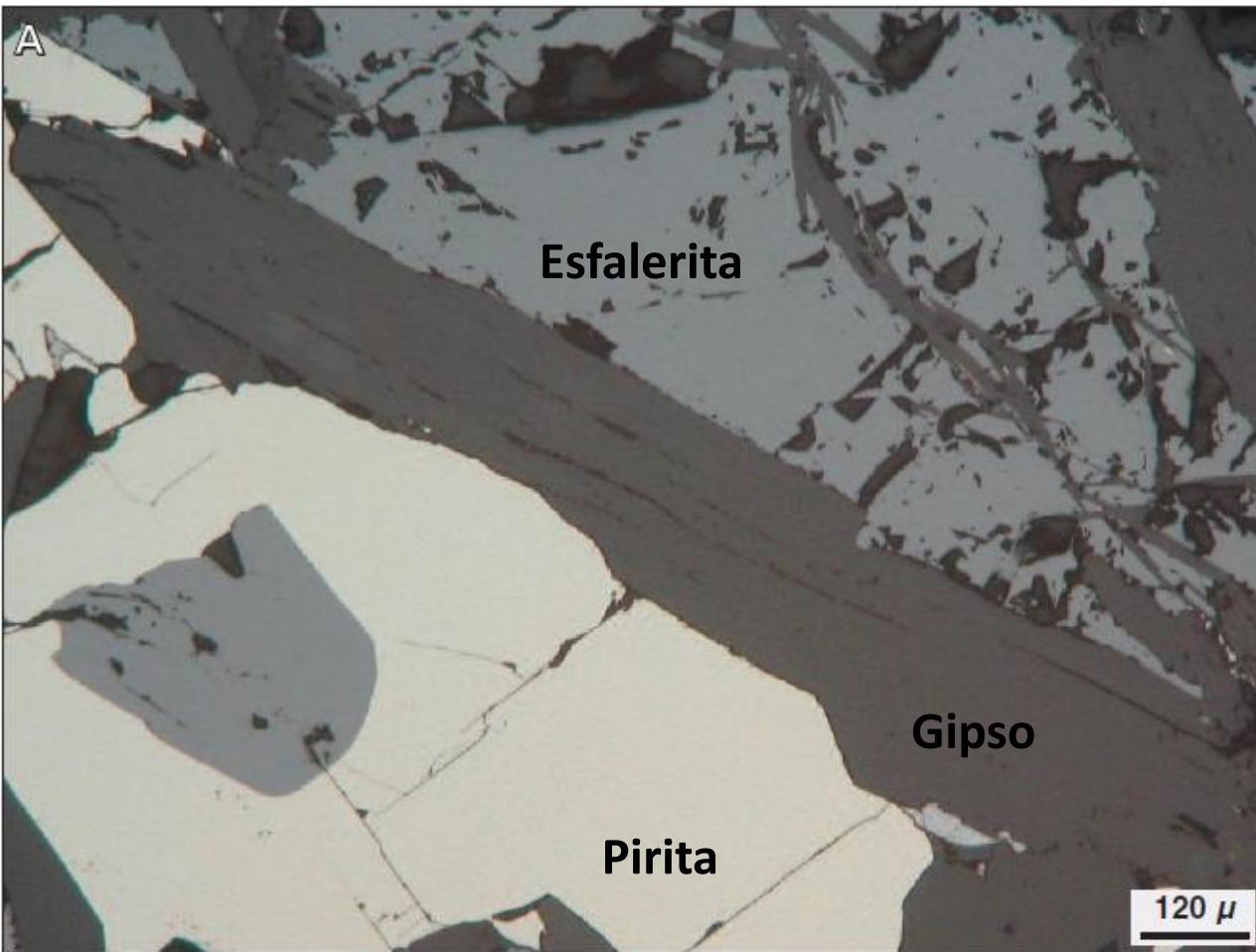
◀ Siegenite (isotropic), pyrite (isotropic); Shinkolobwe, Katanga, Congo [d]; Nic. +

Siegenite  
(Ni,Co)<sub>3</sub>S<sub>4</sub>

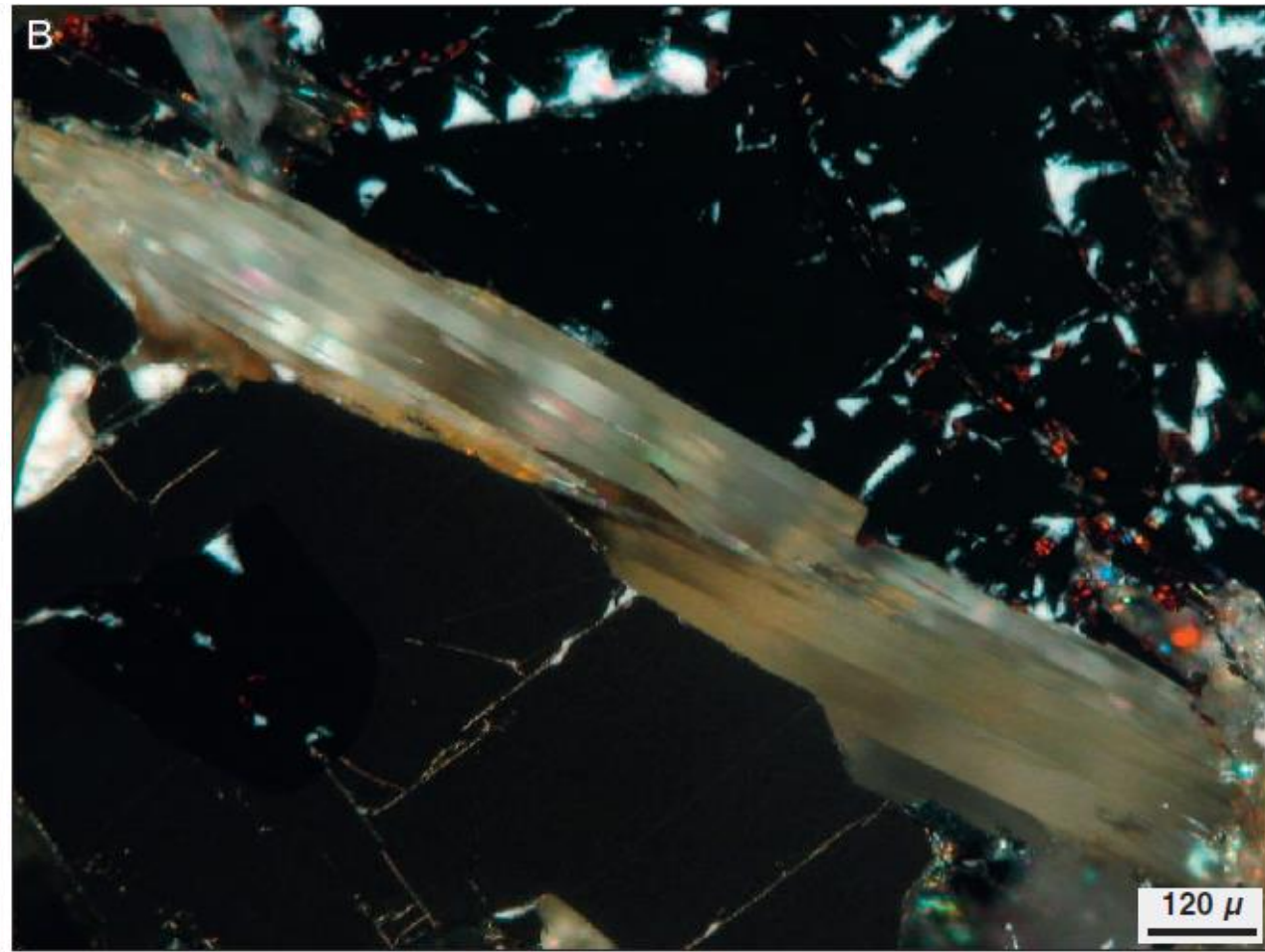


## ISOTROPIA

Minerais que apresentam extinção com os polarizadores cruzados.



**Euhedral gypsum (dark grey, cleavage parallel to long axis), sphalerite (medium grey), pyrite (cream); Meggen Mine, Lennestadt, Germany [a]; Nic. //**

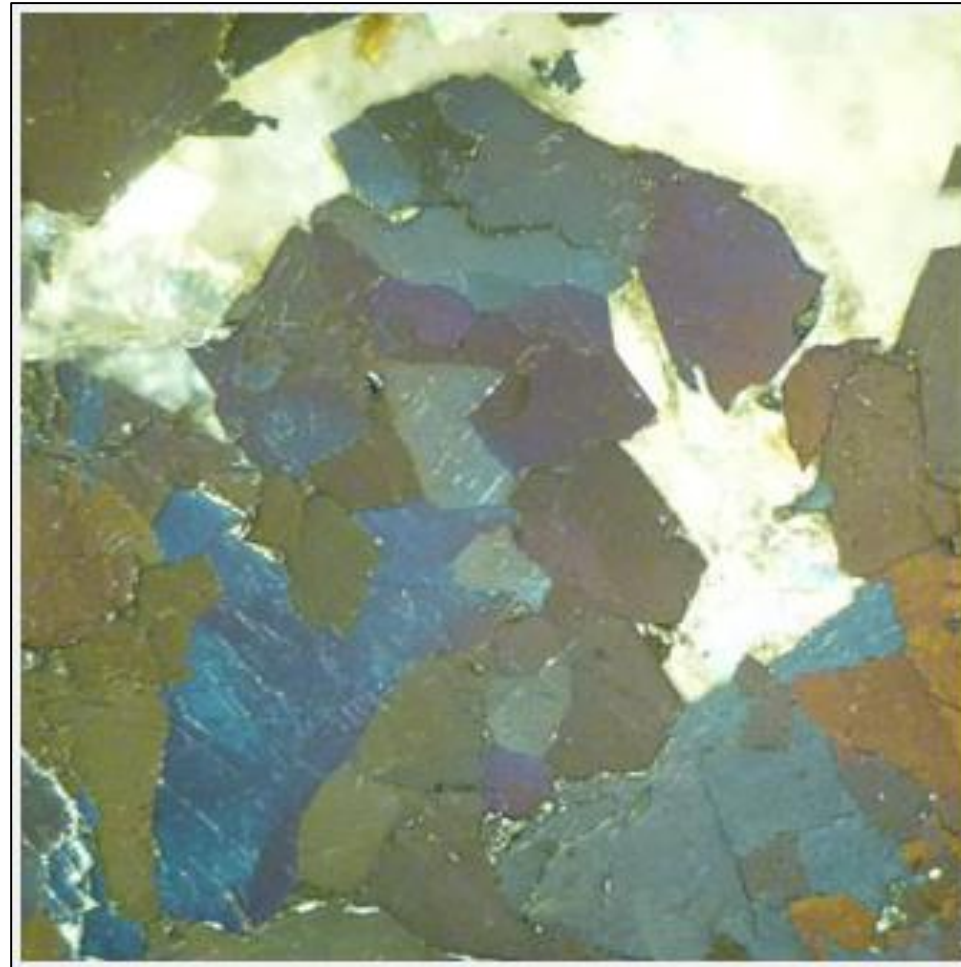
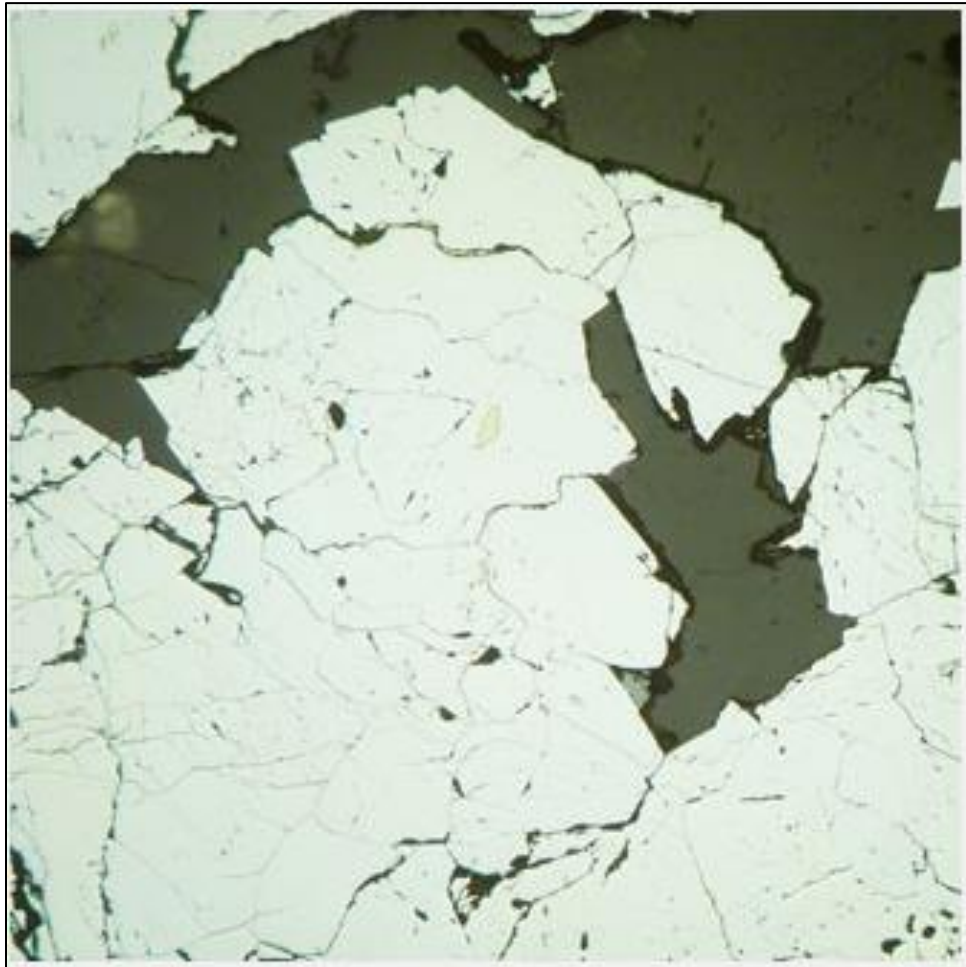


**Gypsum (milky internal reflections, pronounced cleavage), sphalerite (isotropic, few red brown internal reflections), pyrite (isotropic, slightly lighter than sphalerite); Meggen Mine, Lennestadt, Germany [a]; Nic. +**

# PROPRIEDADES ÓPTICAS AOS POLARIZADORES CRUZADOS

## ANISOTROPIA

Minerais que não apresentam extinção e apresentam variação de cor de anisotropia ao girar a platina.



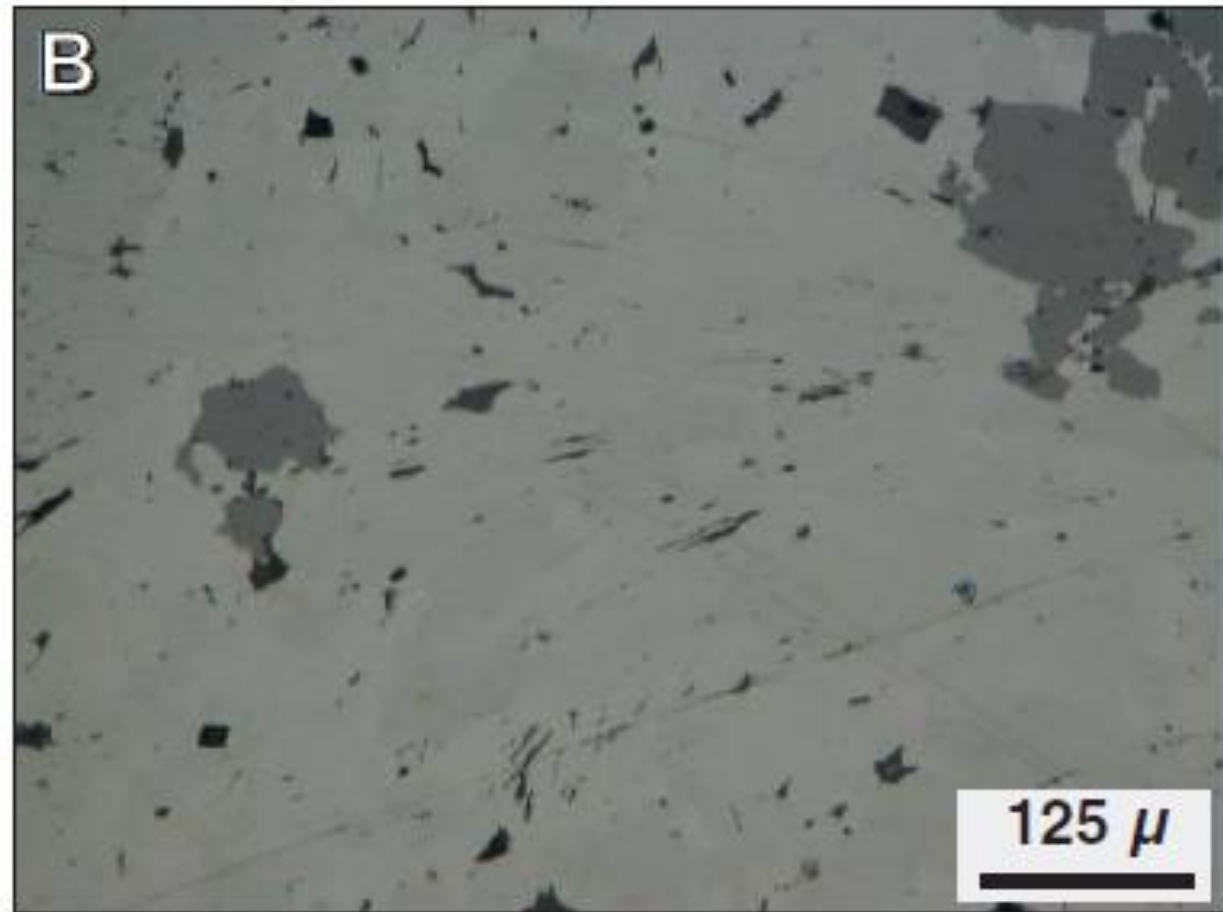
*Anisotropia pode ser fraca (calcopirita, calcosita), moderada (hematita) ou forte (arsenopirita, covellita, pirrotita).*

◀ Arsenopirita com moderada aos polarizadores paralelos (esquerda) e aos polarizadores cruzados (direta), com sua clássica forte anisotropia.

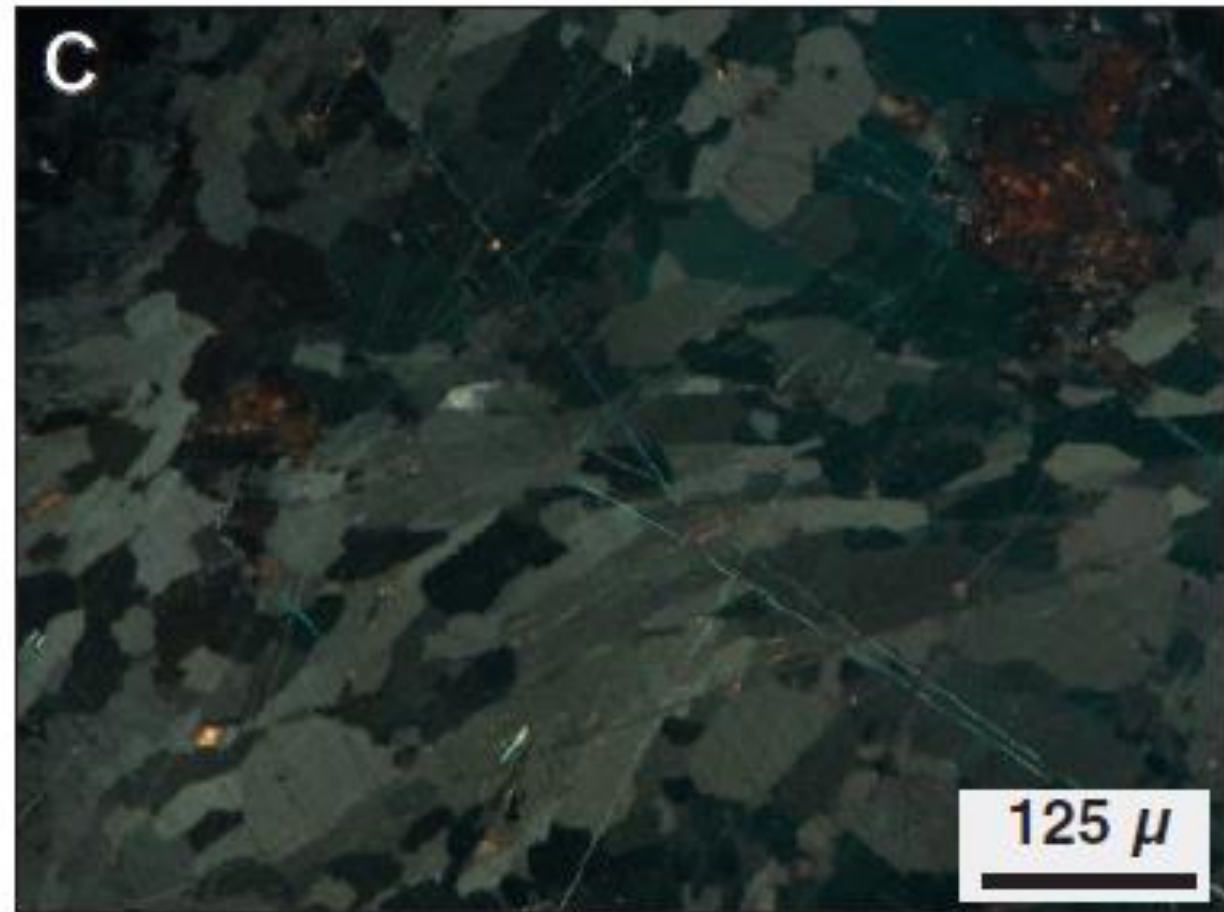


## ANISOTROPIA

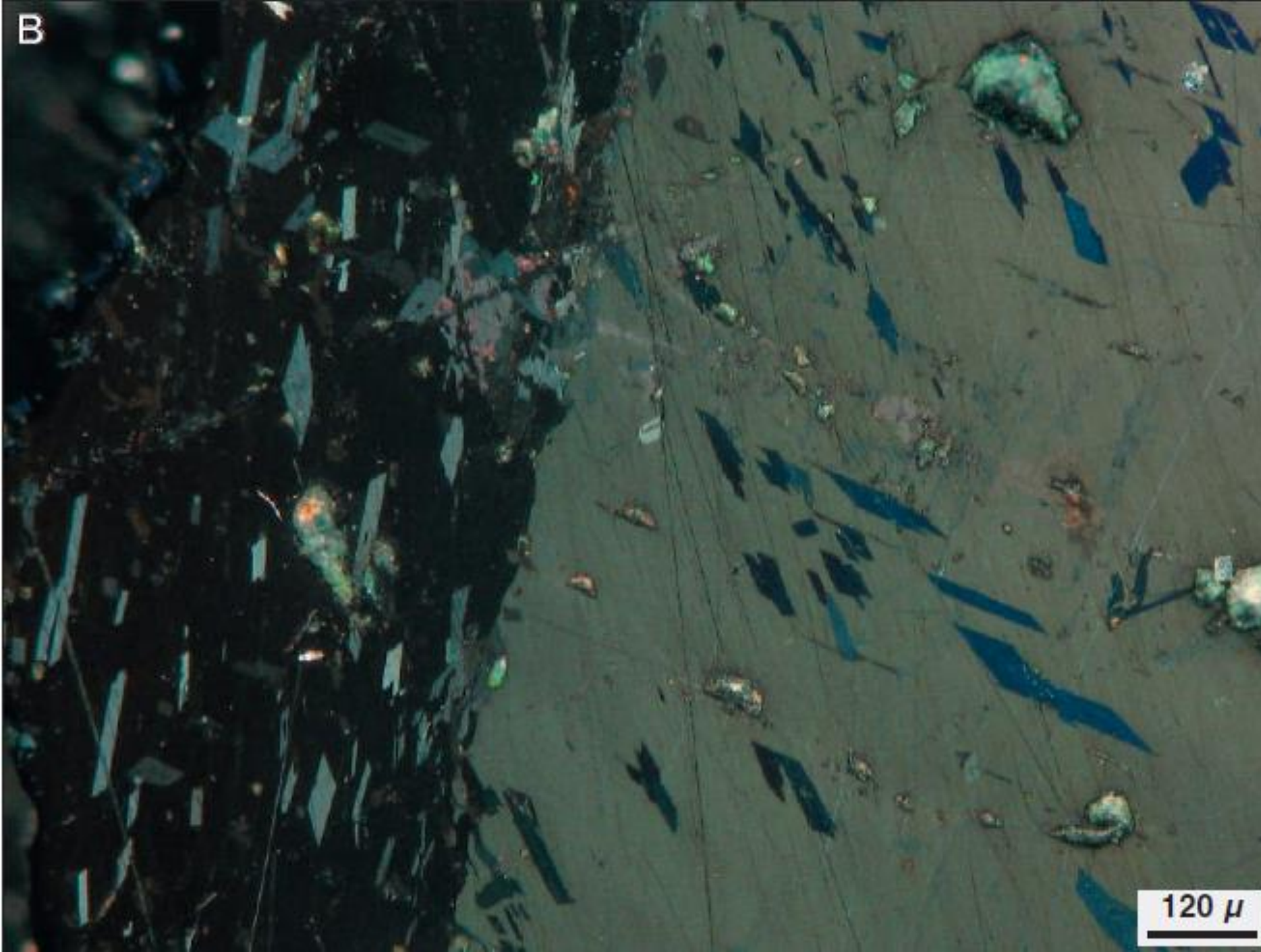
... exemplo da Boulangerita ( $\text{Pb}_5\text{Sb}_4\text{S}_{11}$ ):



Massive boulangerite aggregate (medium greys, see variation of bireflectance), sphalerite (medium grey); Bawdwin, Burma [d]; Nic. //



Boulangerite (various grey shades, anisotropy), sphalerite (brown internal reflections); Bawdwin, Burma [d]; Nic. +



## ANISOTROPIA

Ramdohrite (light and dark brownish grey anisotropy), jamesonite (blue to bluish grey anisotropy), miargyrite (bluish grey anisotropy, specs of red internal reflections).

Tatasí, Sud Chichas Province, Potosí Department, Bolivia [j]; Nic. +

*Ramdohrite*  
 $Pb_6Sb_{11}Ag_3S_{24}$

*Jamesonit*  
 $Pb_4FeSb_6S_{14}$

*Miargyrite*  
 $AgSbS_2$

VÍDEO

Anisotropia

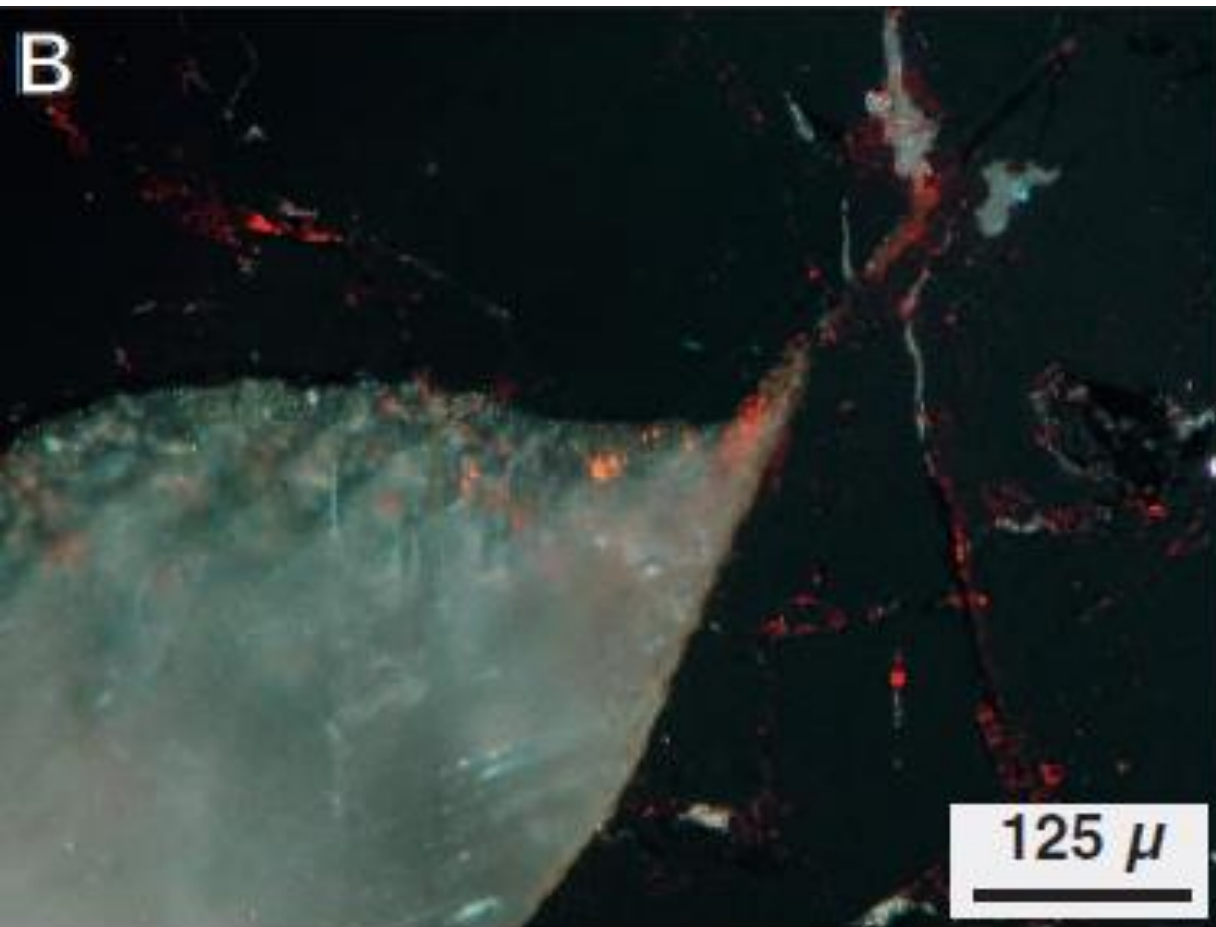
[https://www.youtube.com/watch?v=7XNfISTh37I&list=PL5k\\_2NCH5I4BCBmeFGuLDPC7MmLX96Wir&index=2](https://www.youtube.com/watch?v=7XNfISTh37I&list=PL5k_2NCH5I4BCBmeFGuLDPC7MmLX96Wir&index=2)



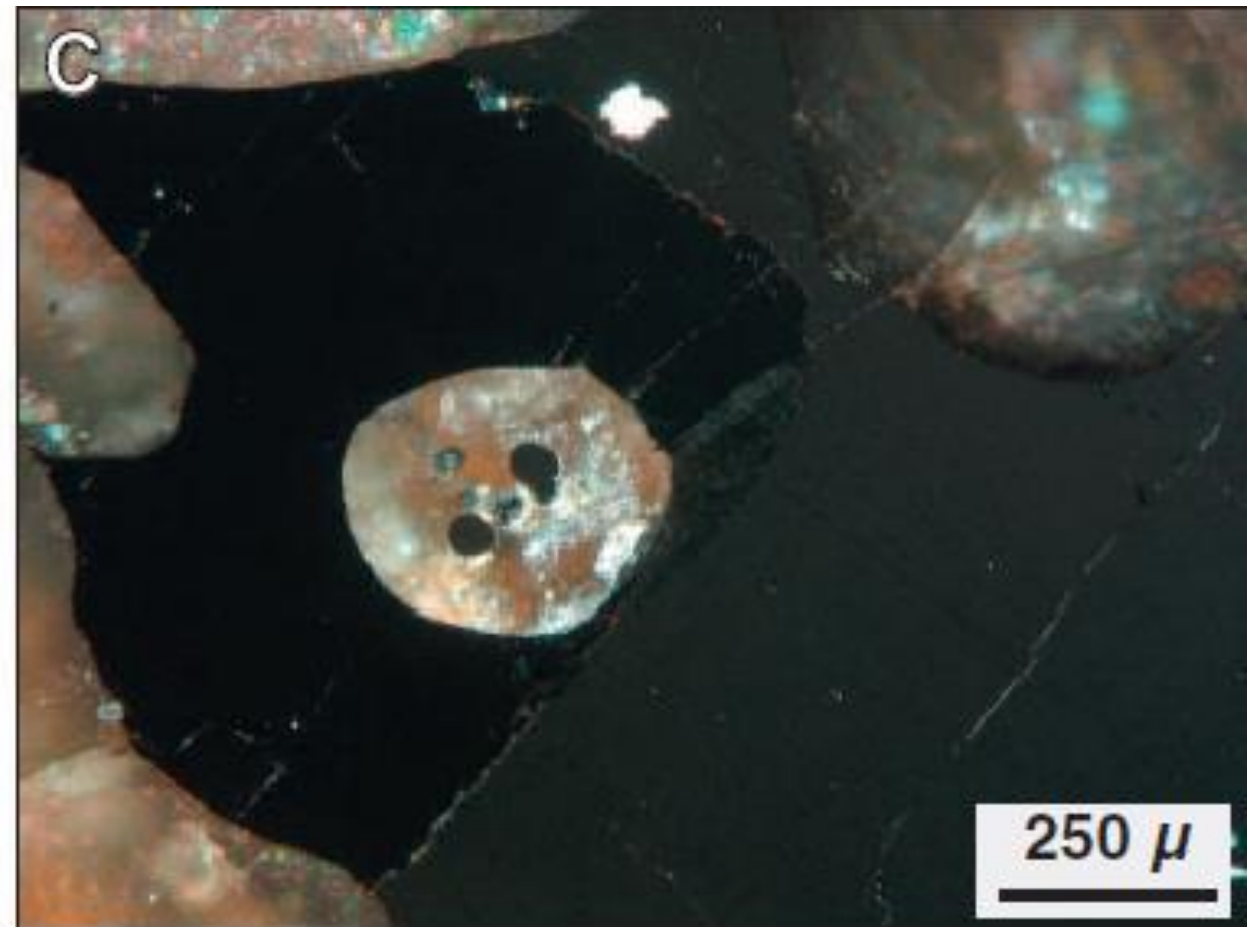
# PROPRIEDADES ÓPTICAS AOS POLARIZADORES CRUZADOS

## REFLEXÕES INTERNAS

Comuns em minerais translúcidos ou transparentes e observáveis em bordas e próximo a fraturas.

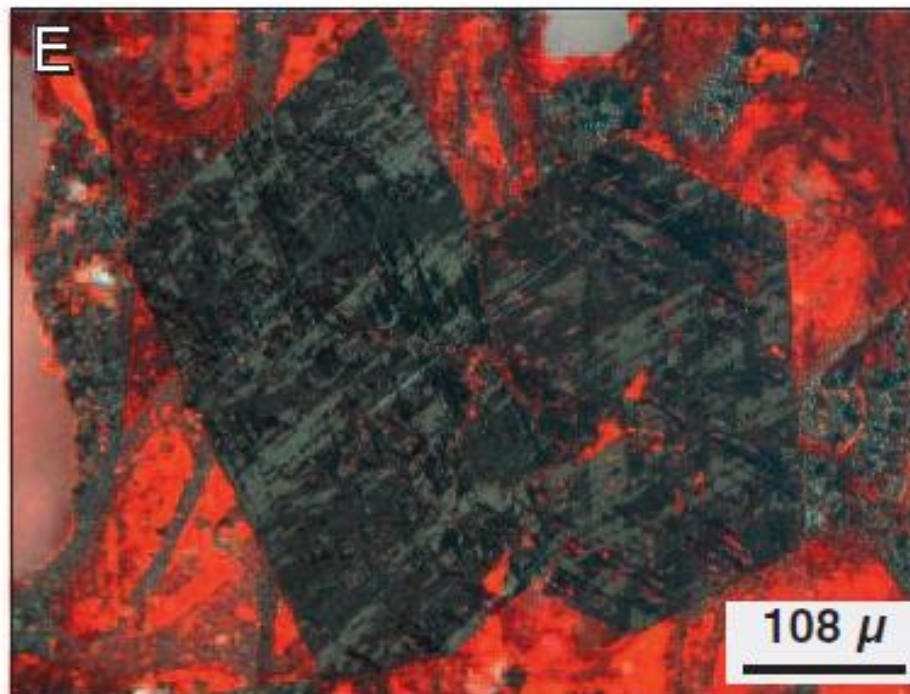
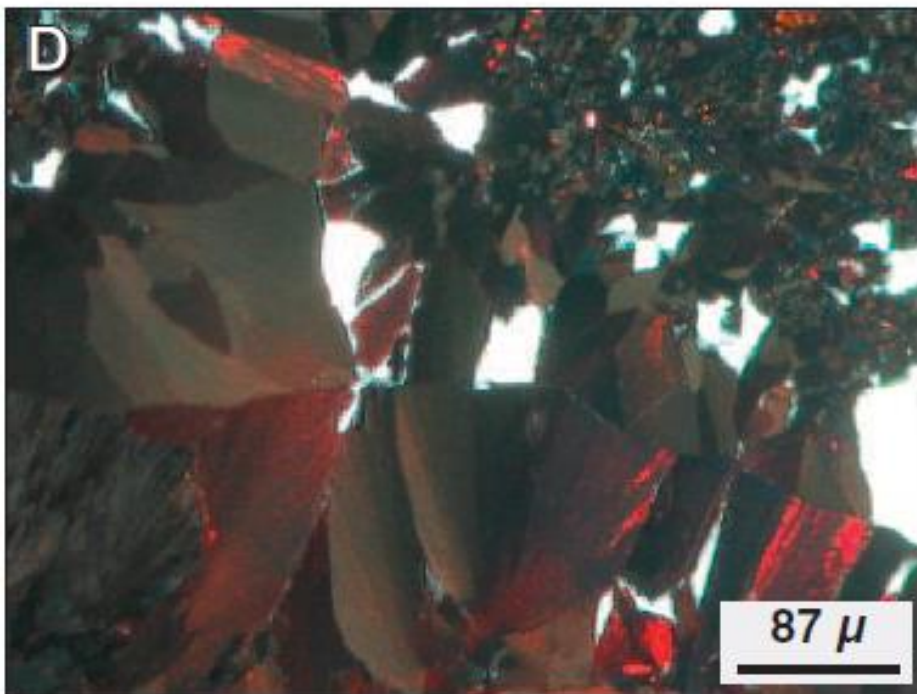
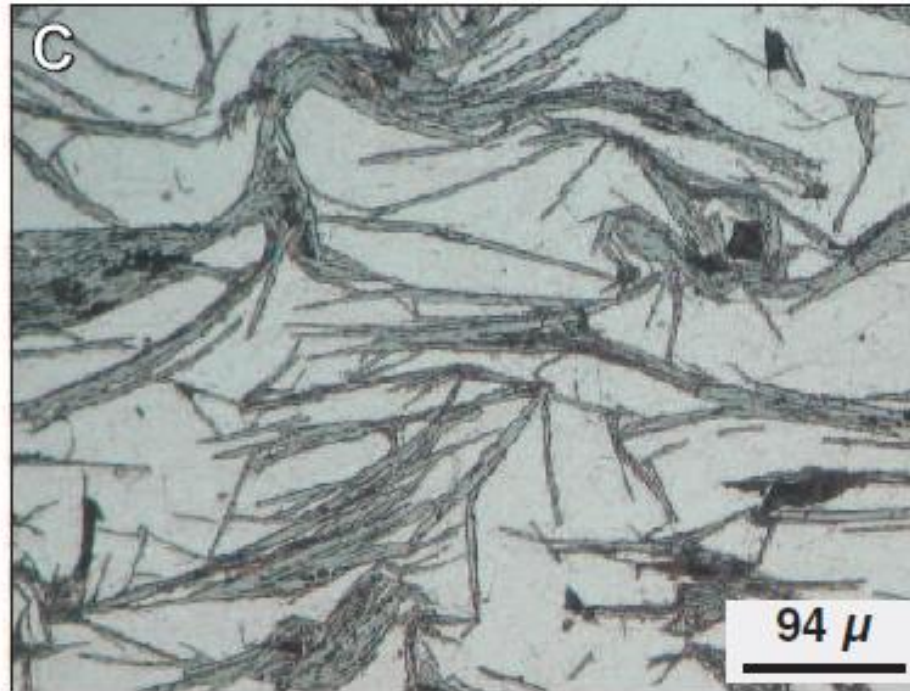
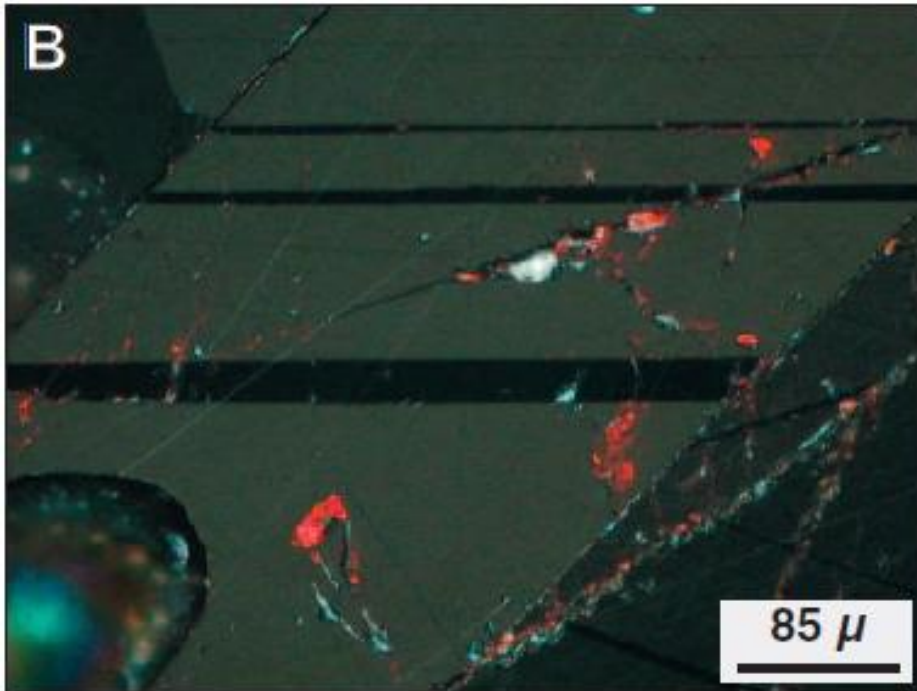


Franklinita (ZnFe<sup>3+</sup><sub>2</sub>O<sub>4</sub>) (isotrópica com reflexões internas vermelho-escuro)



Silicato (reflexões internas brilhantes).





## REFLEXÕES INTERNAS DA HEMATITA ( $\text{Fe}_2\text{O}_3$ )

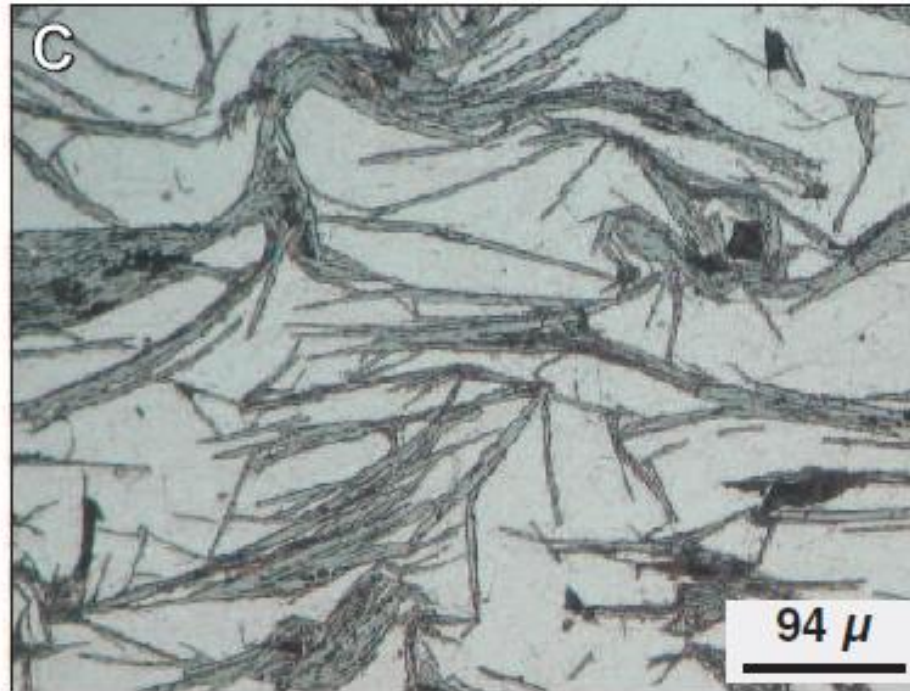
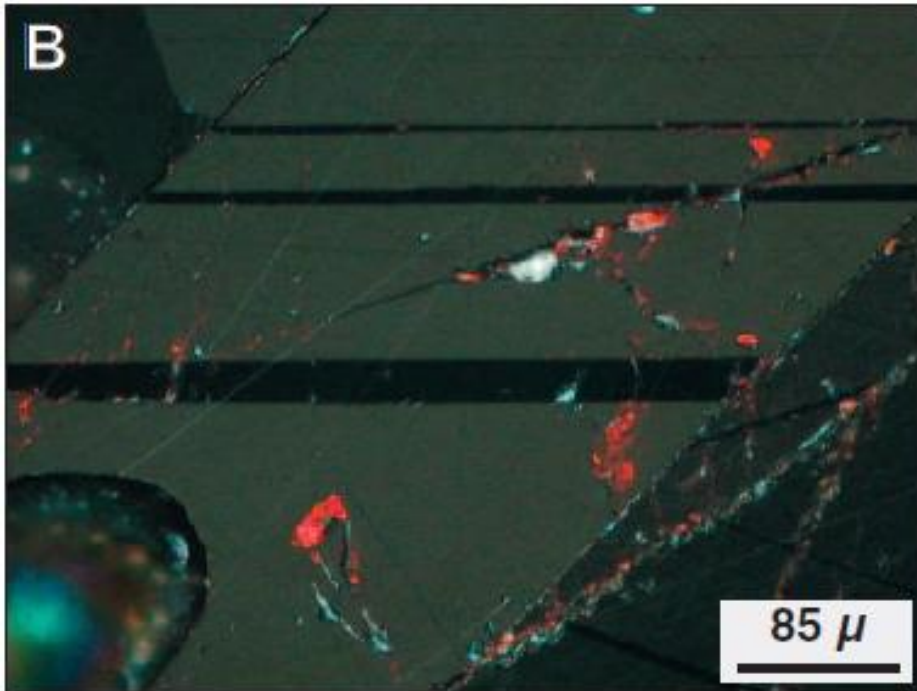
(B) Hematite (red internal reflections and anisotropy); Gamsberg, South Africa [c]; Nic. +

(C) Deformed hematite platelets (medium grey) in tiemannite (light grey); Eskaborner Berg, Tilkerode, Germany [g]; Nic. //

(D) Colloform hematite (bright red internal reflections, brownish grey anisotropy), goethite (bluish grey anisotropy, brown internal reflections); Hornhausen, Nassau, Germany [a]; Nic. +

(E) Euhedral hematite (lamellar light and dark brownish grey anisotropy, red internal reflections in matrix); Pretoria Iron Mines, South Africa [a]; Nic. +

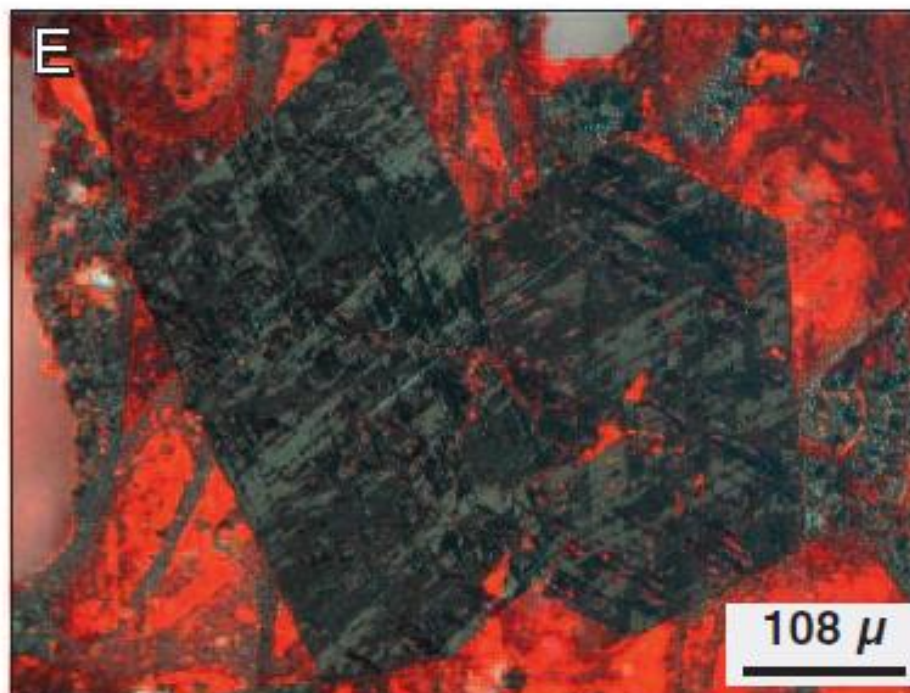
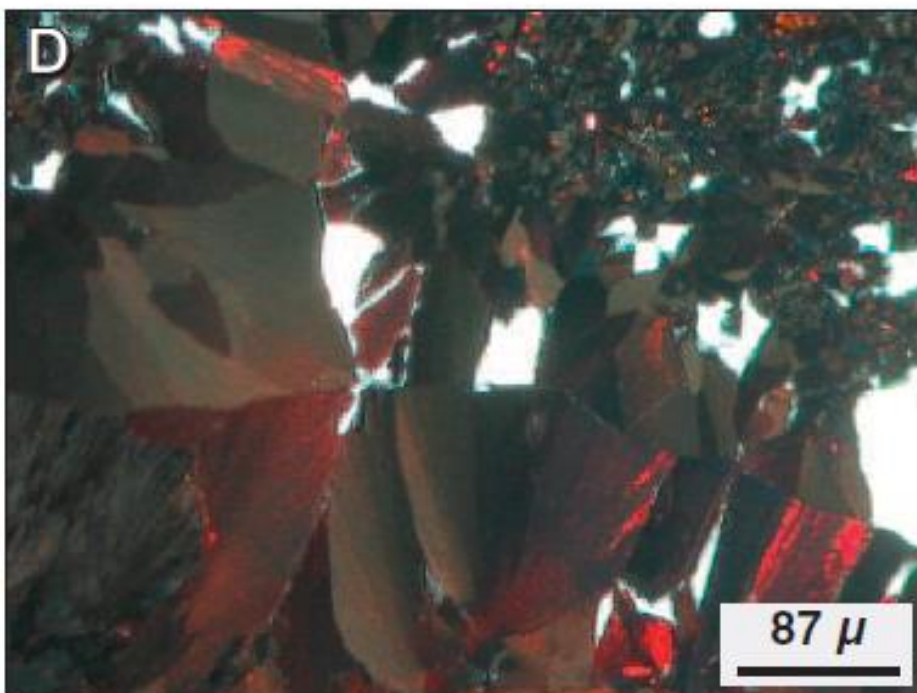




## REFLEXÕES INTERNAS DA HEMATITA ( $\text{Fe}_2\text{O}_3$ )

VÍDEO

Reflexões Internas da  
Hausmannita  
( $\text{Mn}^{2+}\text{Mn}^{3+}\text{OO}$ )



[https://www.youtube.com/  
watch?v=ZWppzm8mesk](https://www.youtube.com/watch?v=ZWppzm8mesk)

