Université de Liège
Faculté des Sciences
Département de Géologie
Laboratoire de Minéralogie

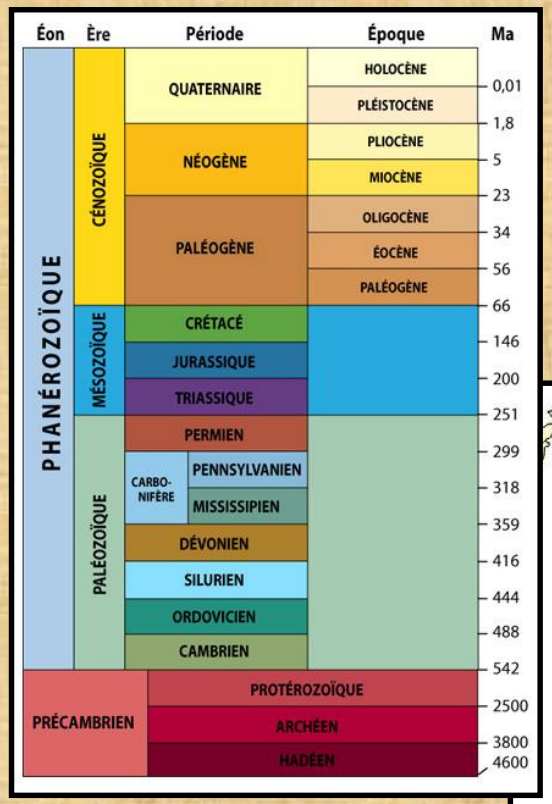
Copper sulfides and tellurides from the Stavelot Massif, Belgium

Prof. Frédéric Hatert

Tavagnasco, August 2017

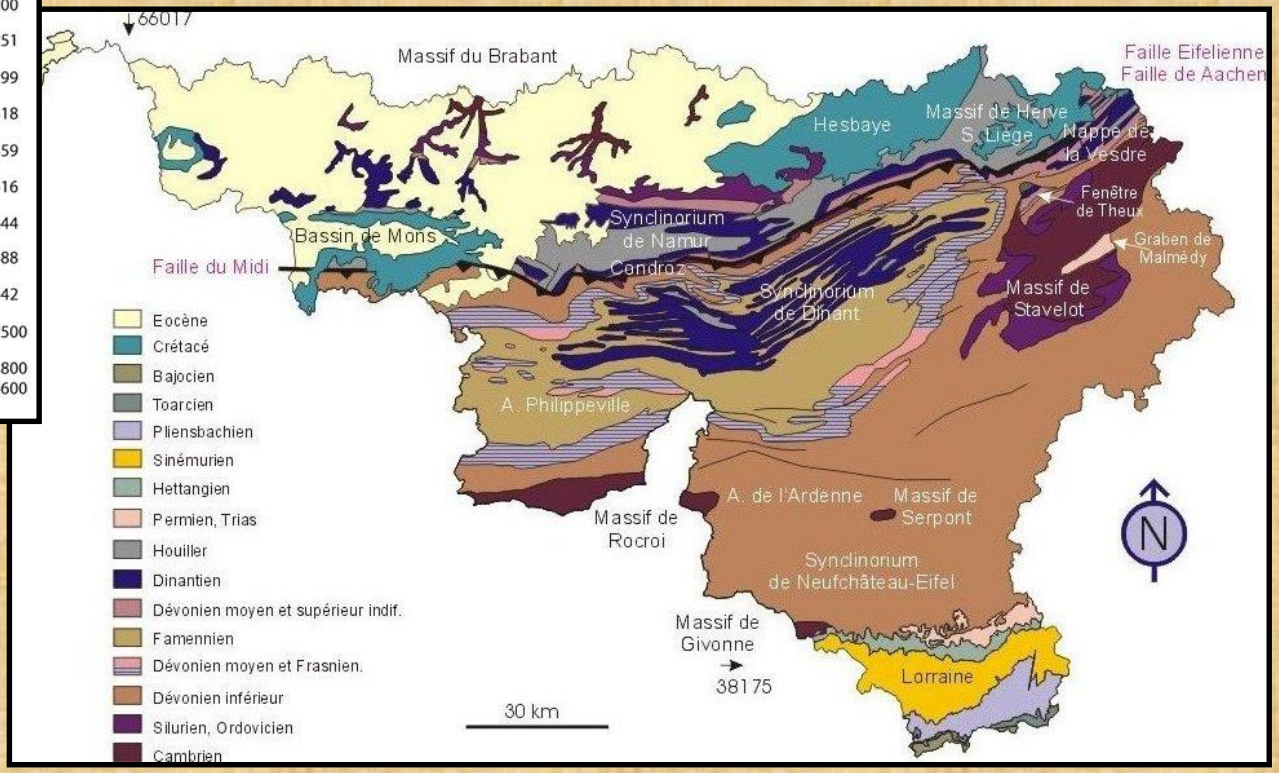
Geology of Belgium

Université de Liège



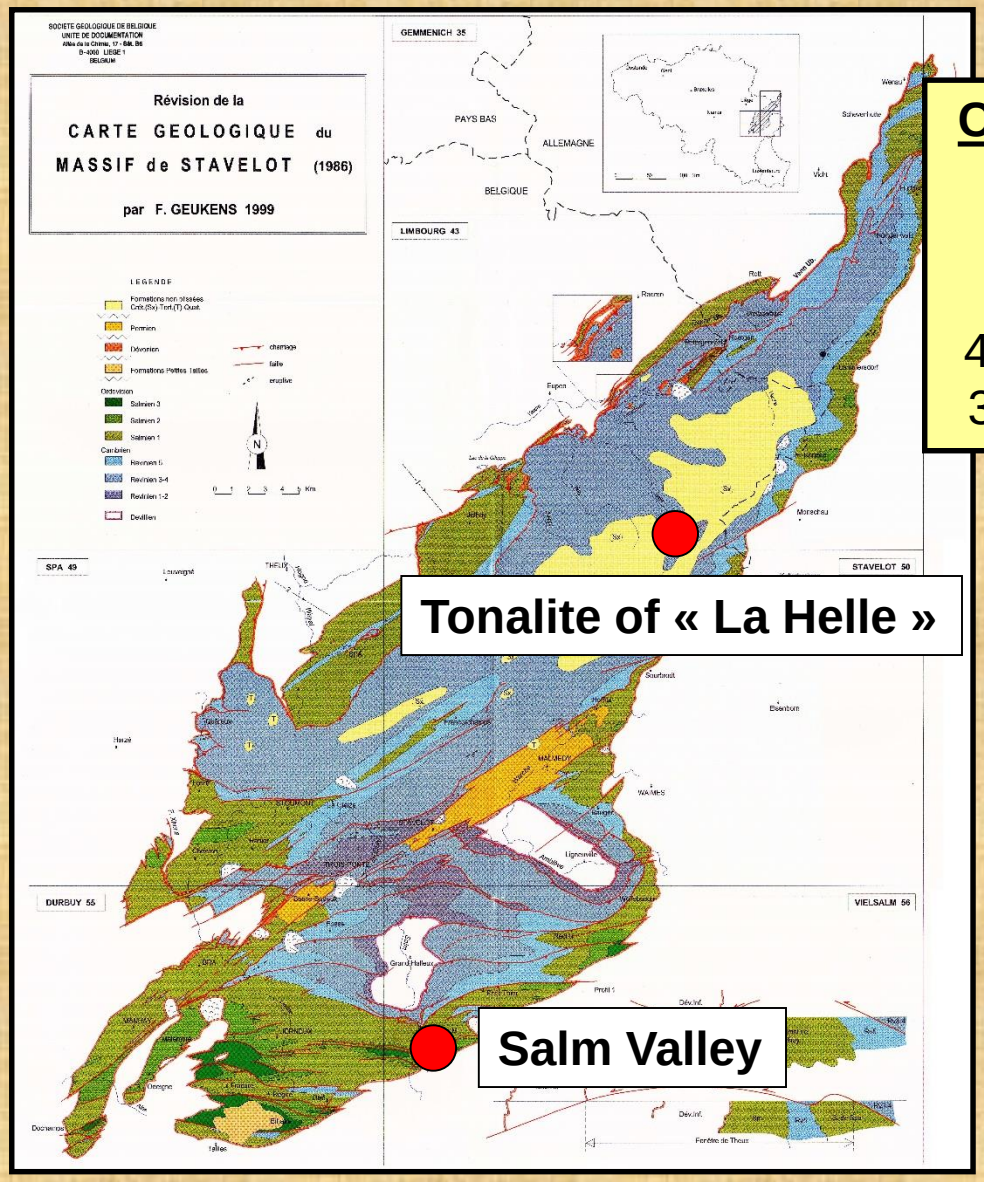
Cambro-Ordoviciens Massifs:

Stavelot, Rocroi, Serpont, Givonne



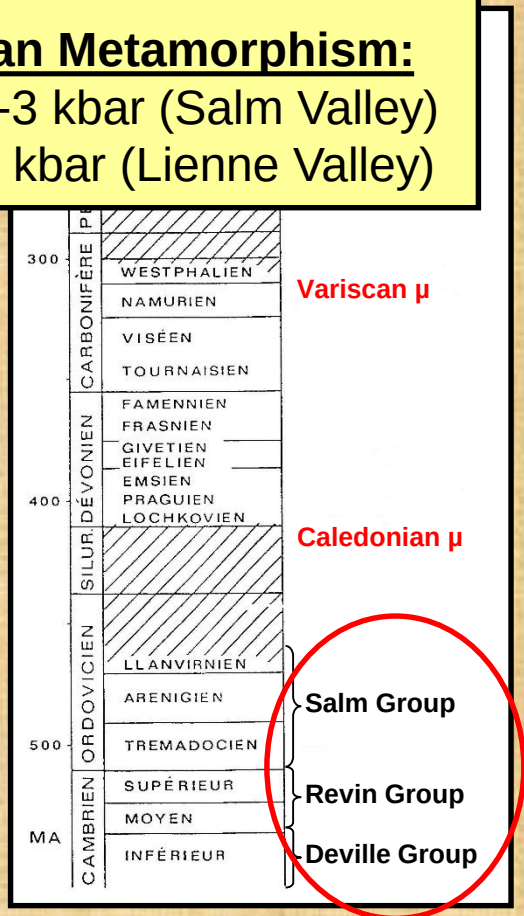
The Stavelot Massif

Université de Liège

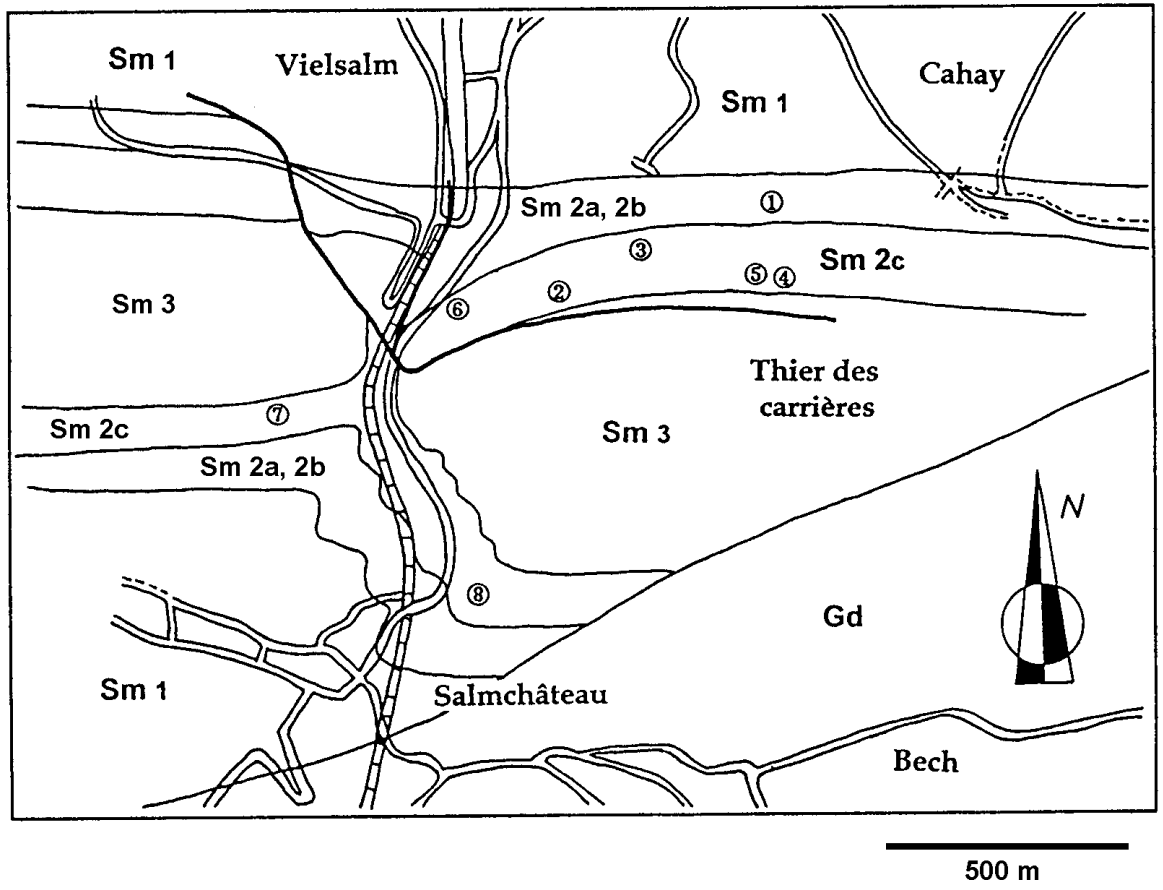


Caledonian Metamorphism:
300°C (Salm Valley)

Variscan Metamorphism:
420°C/2-3 kbar (Salm Valley)
380°C/2 kbar (Lienne Valley)



The Salm syncline



Salm Group

Sm3 = Bihain Fmt.
Sm2 = Ottré Fmt.
Sm1 = Jalhay Fmt.

Disseminations:
1, 2, 7

Pseudocoticules:
3, 7

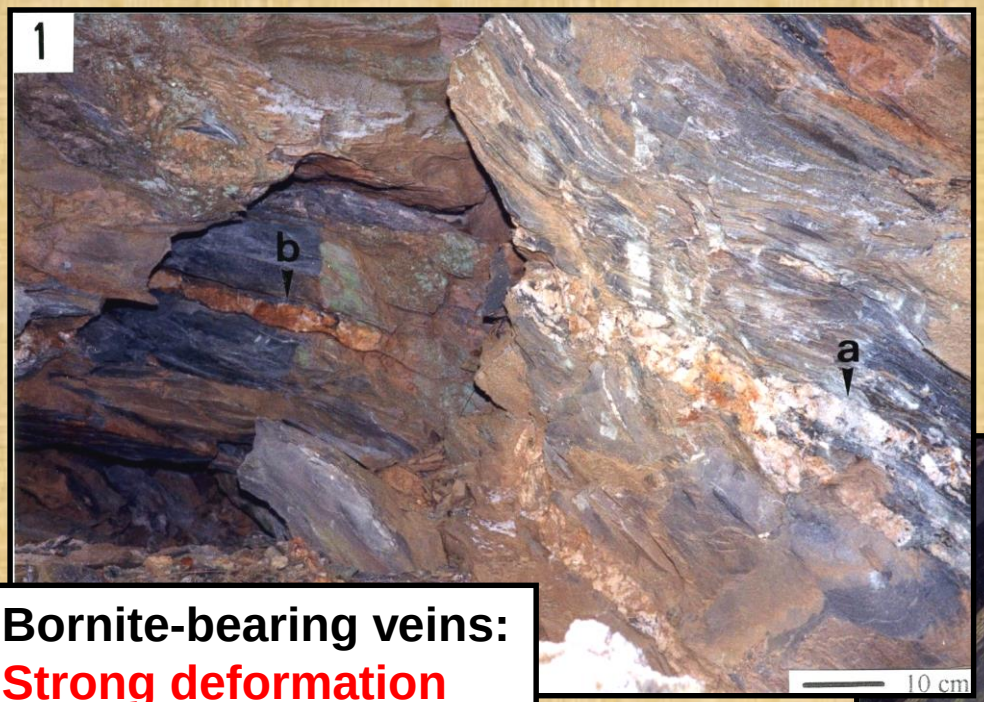
Linear quartz veins:
2, 3, 6

Deformed quartz vein:
4, 5, 6, 8

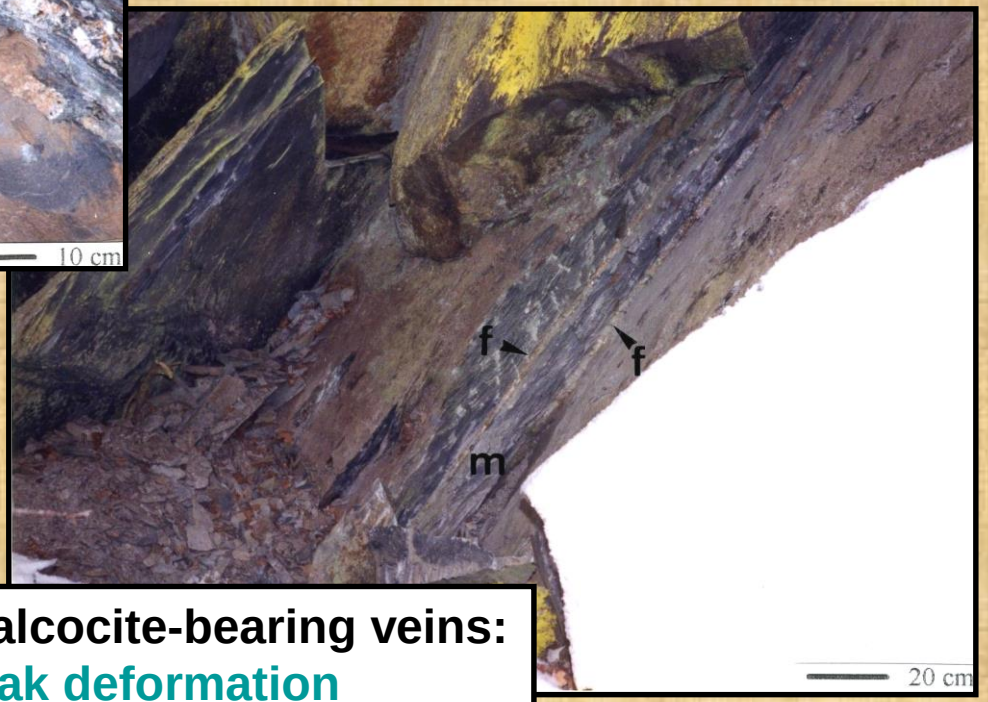
Copper sulfides mineralizations localized in the Colanhan Mbr. (Sm2c) schists

Sulfide-bearing quartz veins

Université de Liège



Bornite-bearing veins:
Strong deformation



Chalcocite-bearing veins:
Weak deformation

Correlation between deformation and mineralogy

Mineralogy of the quartz veins

Université de Liège

Cu-Fe-sulfides: Bornite, chalcopyrite, idaite.

Cu-sulfides: Covellite, yarrowite, spionkopite, digenite, anilite, djurleite, chalcocite.

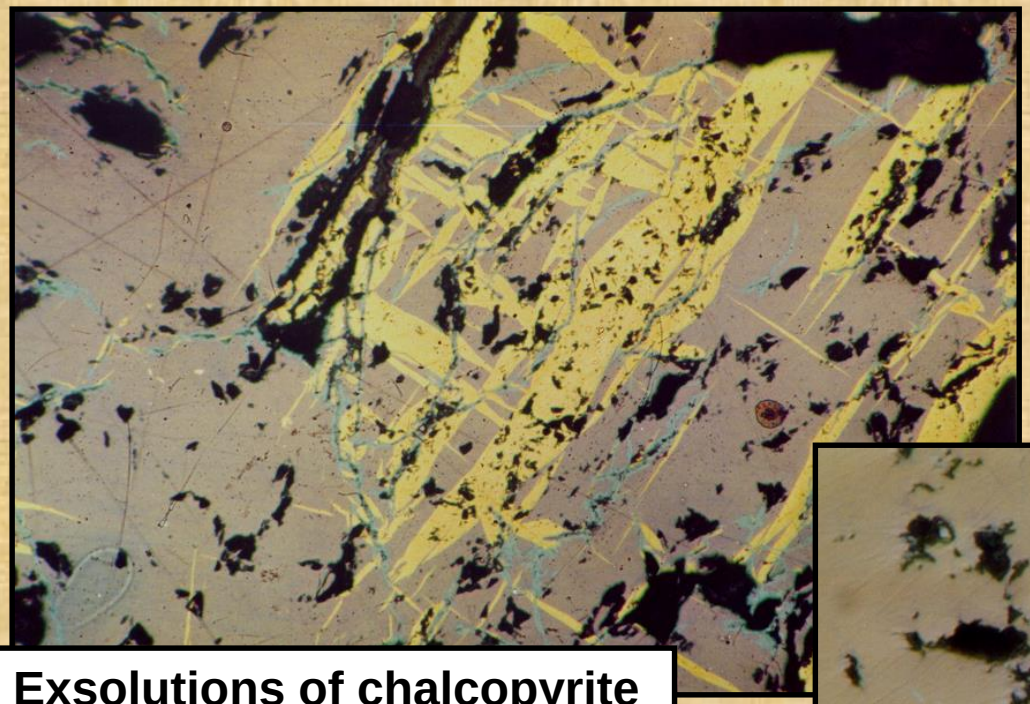
Inclusions: Altaite, arsenopyrite, cobaltite, galena, melonite, pyrite, sphalerite, tellurobismuthite, tellurium, wittichenite.

Secondary minerals: Azurite, brochantite, chalcomenite, chalcophyllite, connellite, cuprite, delafossite, goethite, langite, libethenite, malachite, mimetite, paratellurite, pharmacosiderite, pseudomalachite, teineite, torbernite, wulfenite.

Many exotic minerals, greatly appreciated by mineral collectors!

Primary copper sulfides

Université de Liège



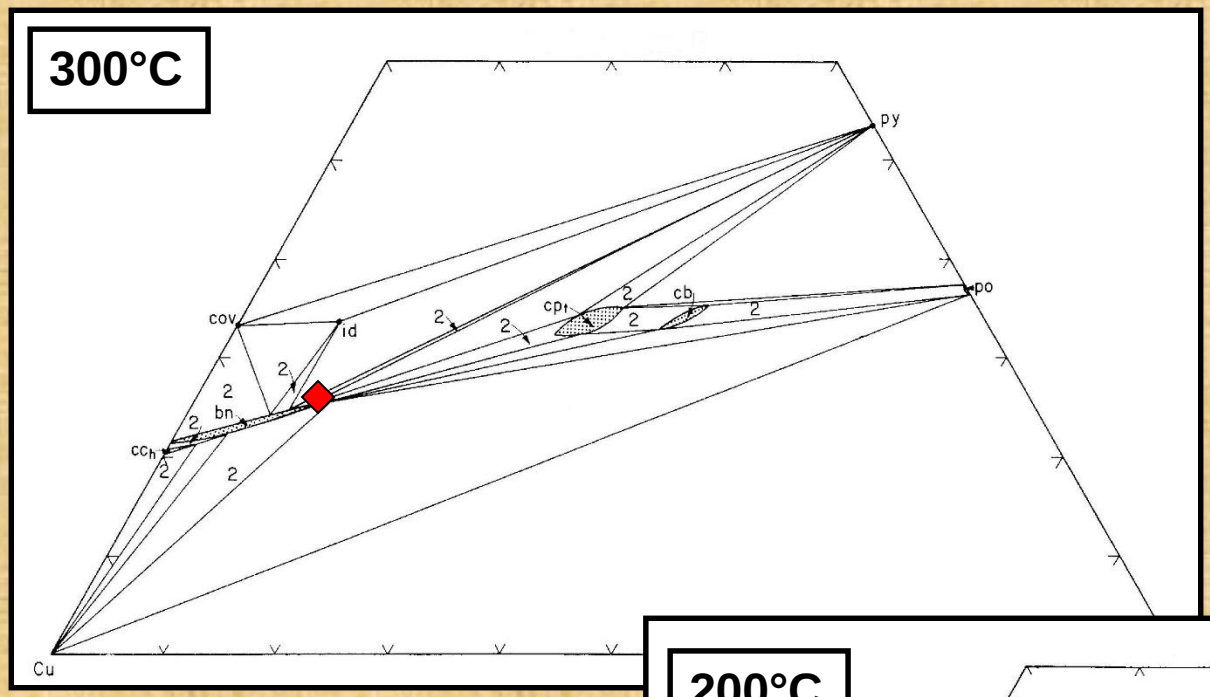
Exsolutions of chalcopyrite in bornite

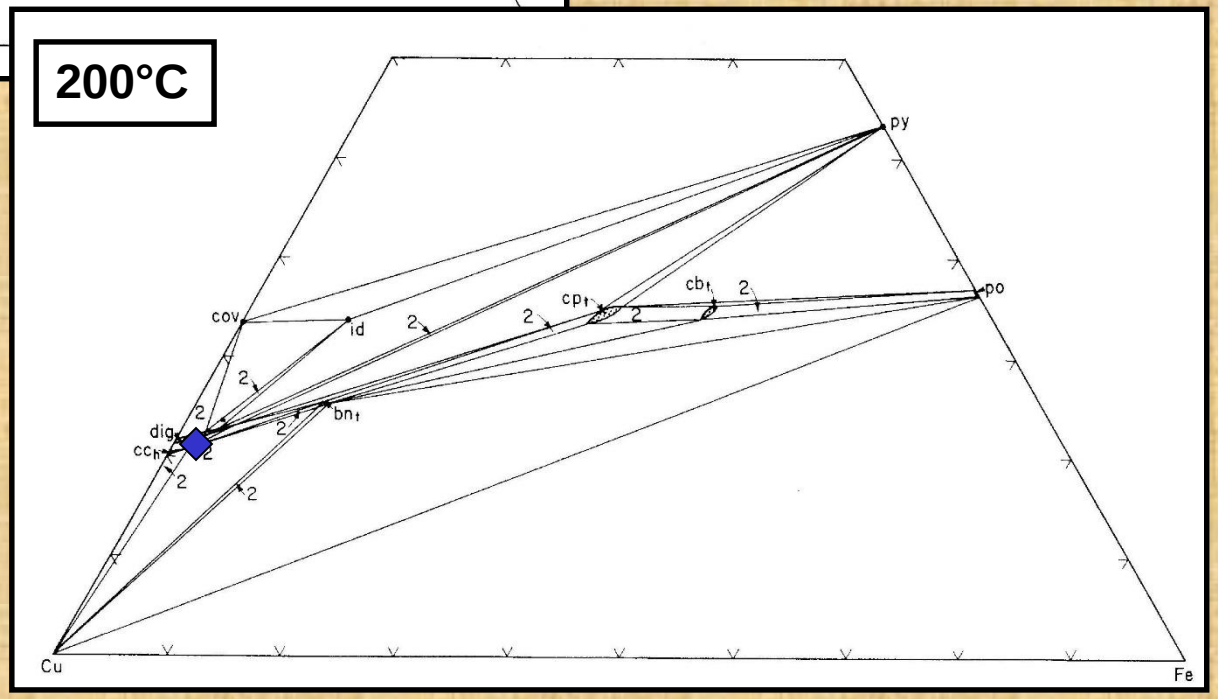
- **Bornite**, $Cu_{4.95}Fe_{0.99}S_{4.00}$
- **Chalcopyrite**, $Cu_{1.00}Fe_{0.98}S_{2.00}$
- **Chalcocite**, $Cu_{2.00}S_{1.00}$

Myrmekitic intergrowth of chalcocite and bornite

Université de Liège

Crystallisation temperatures of primary sulfides





◆ : Bornite + chalcopyrite (15%)
◆ : Chalcocite + bornite (80%)

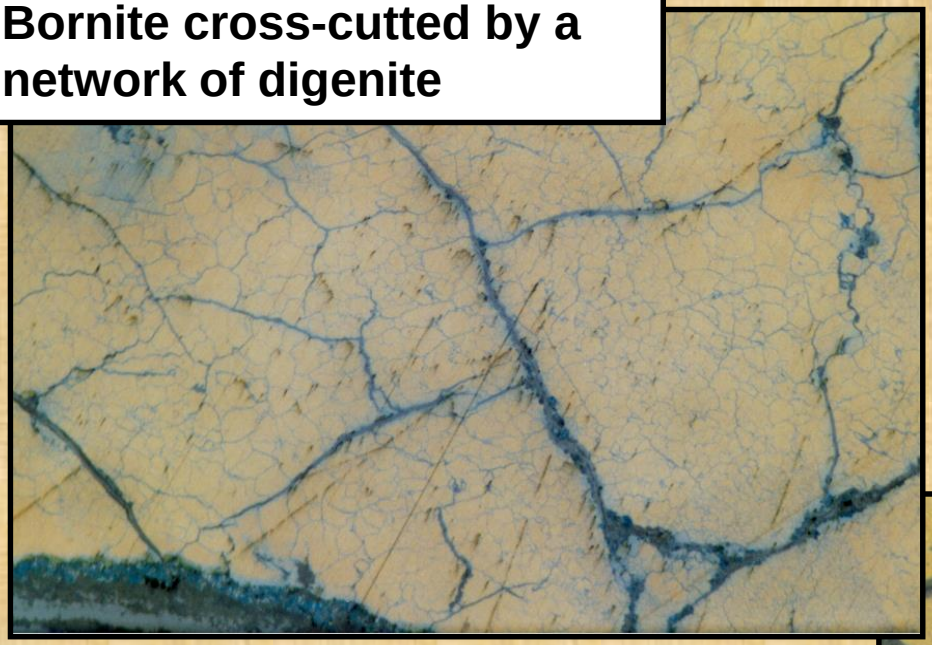
- Below 300-350°C: exsolution of chalcopyrite lamellae in bornite
- Below 200°C: myrmekitic intergrowths of chalcocite and bornite

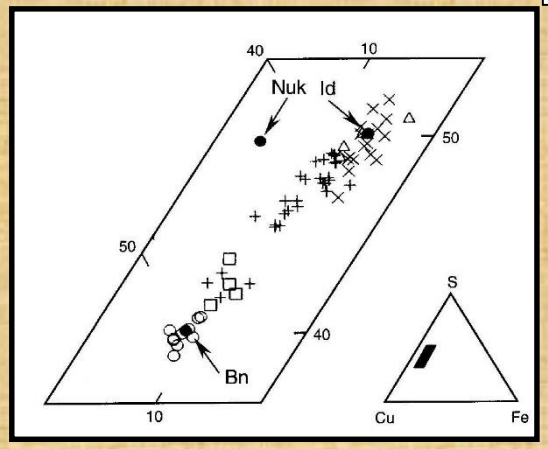
Yund & Kullerud (1966)

Sequence I: Oxidation of bornite

Université de Liège

Bornite cross-cutted by a network of digenite





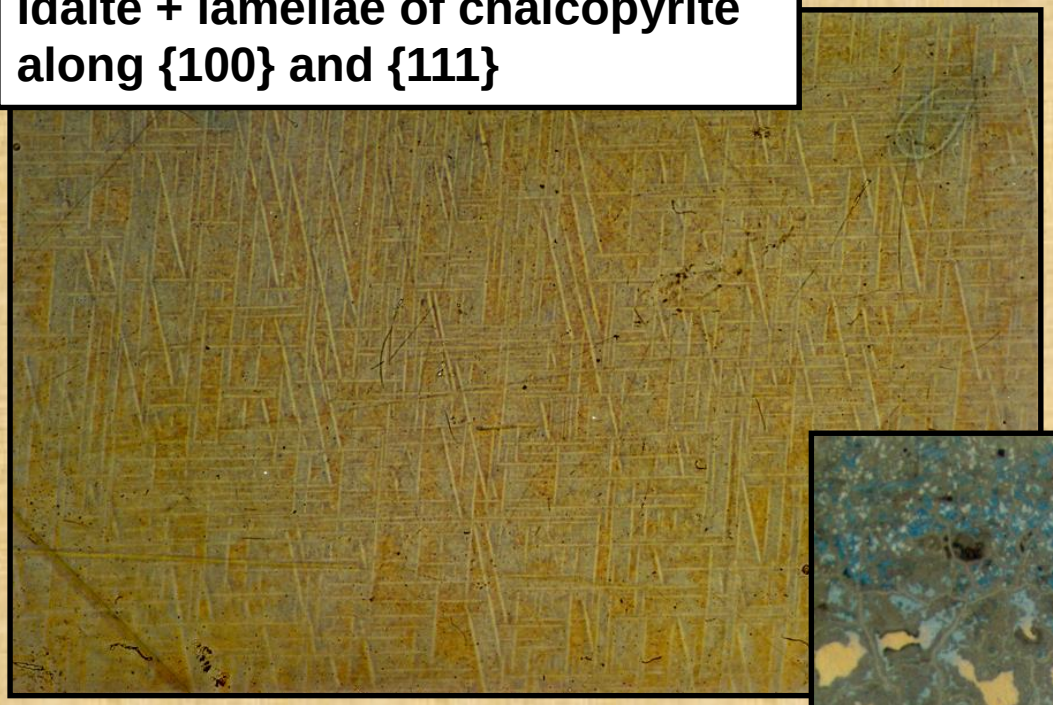
- **Digenite**, $Cu_{8.95}S_{5.00}$ (Cu/S = 1.79)
- **Idaite**, $Cu_{3.25}Fe_{0.97}S_{4.00}$
- **Covellite**, $Cu_{1.02}S_{1.00}$

Bornite, idaite, covellite and oxidation minerals

Sequence I: Oxidation of bornite

Université de Liège

Idaite + lamellae of chalcopyrite along {100} and {111}



Bornite, idaite, covellite and oxidation minerals

Bornite

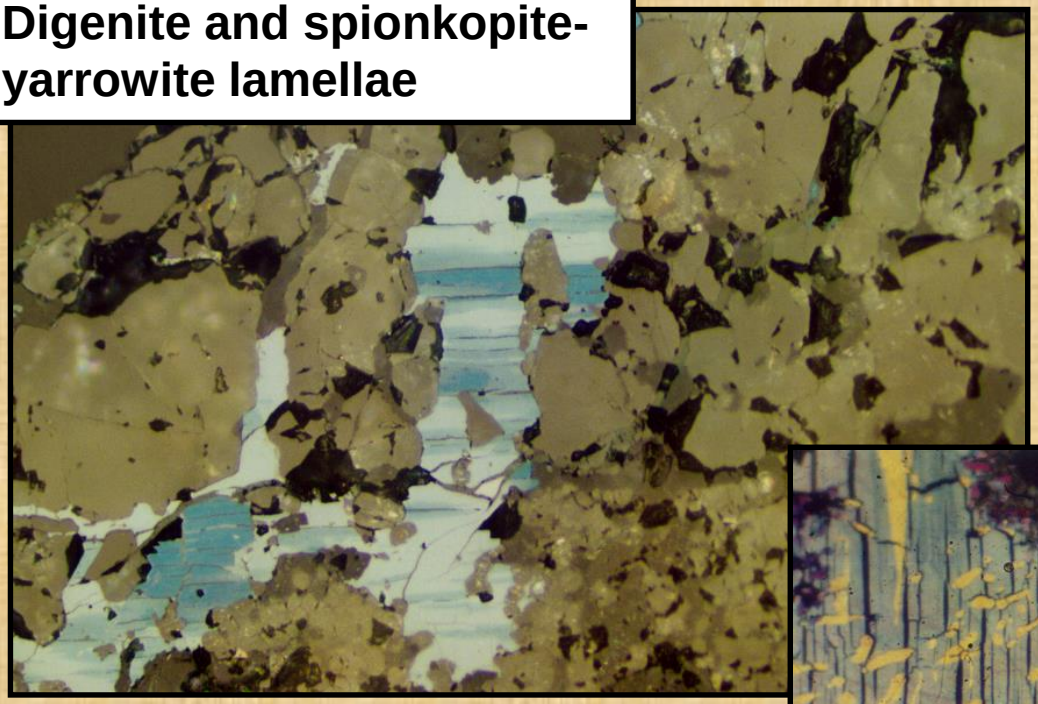
Digenite | **Idaite + chalcopyrite**

Covellite + Ox. minerals

Sequence II: Oxidation of chalcocite

Université de Liège

Digenite and spionkopite-yarrowite lamellae



- Chalcocite, $Cu_{2.00}S_{1.00}$ (Cu/S = 2.00)
- Djurleite, $Cu_{30.61}S_{16.00}$ (Cu/S = 1.91)
- Digenite, $Cu_{8.95}S_{5.00}$ (Cu/S = 1.79)
- Anilite, $Cu_{6.97}S_{4.00}$ (Cu/S = 1.74)
- Spionkopite, $Cu_{39.64}S_{28.00}$ (Cu/S = 1.42)
- Yarrowite, $Cu_{8.96}S_{8.00}$ (Cu/S = 1.12)
- Covellite, $Cu_{1.02}S_{1.00}$ (Cu/S = 1.02)

Chalcocite-djurleite

↓

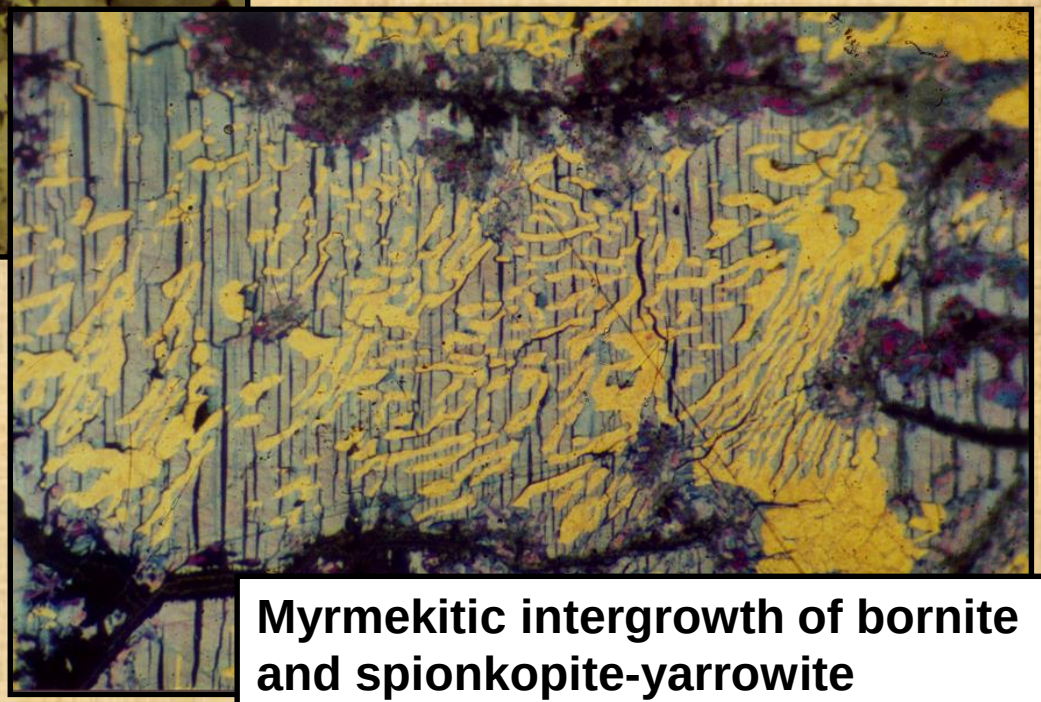
Digenite-anilite

↓

Yarrowite-spionkopite

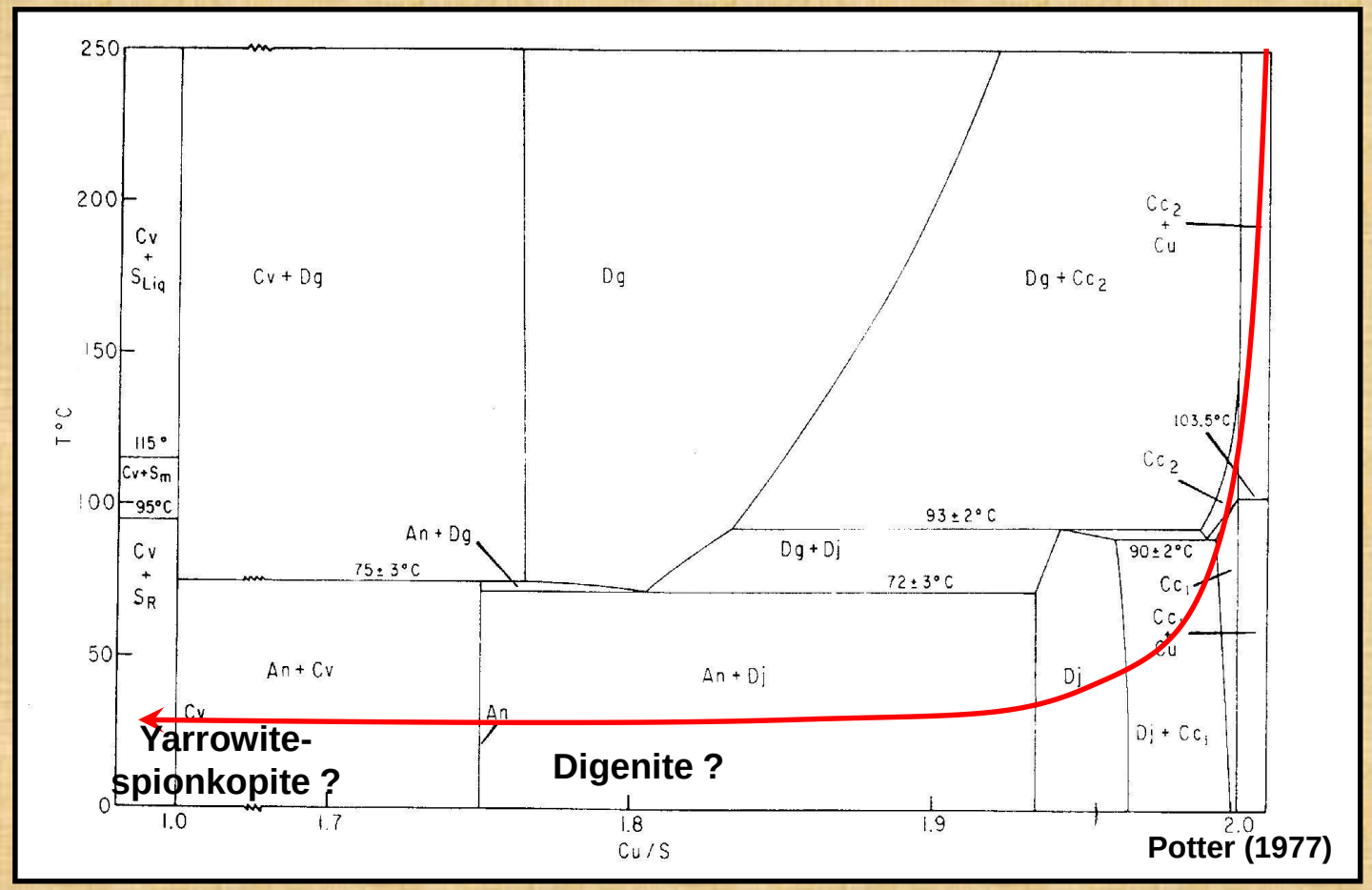
↓

Covellite + ox. minerals



Myrmekitic intergrowth of bornite and spionkopite-yarrowite

Genesis of secondary copper sulfides



Chalcocite-*H*

↓

Chalcocite-*M*
(103.5 °C)

↓

Djurleite
(93°C)

↓

Low digenite
or
Anilite + djurleite
(72°C)

↓

Spionkopite +
yarrowite

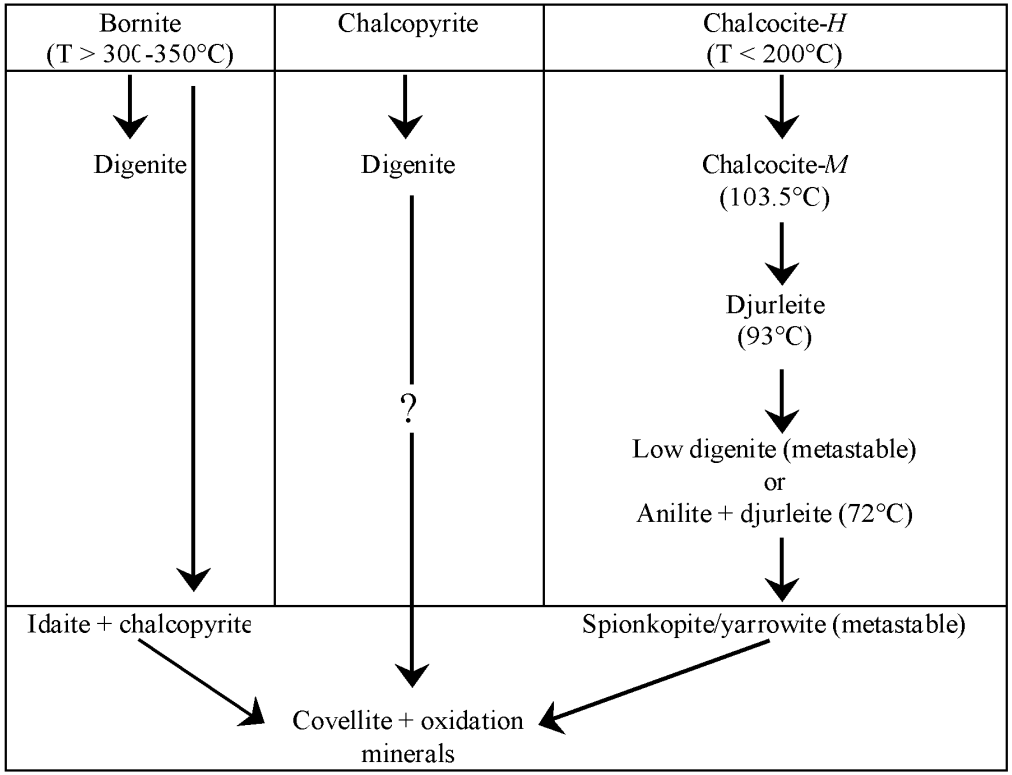
↓

Covellite +
ox. minerals

Digenite metastable ➡ **submicroscopic intergrowths of anilite and djurleite?**

Yarrowite and spionkopite metastables ➡ **difficulty of nucleating covellite (Potter, 1977)**

Université de Liège



Transformation sequences

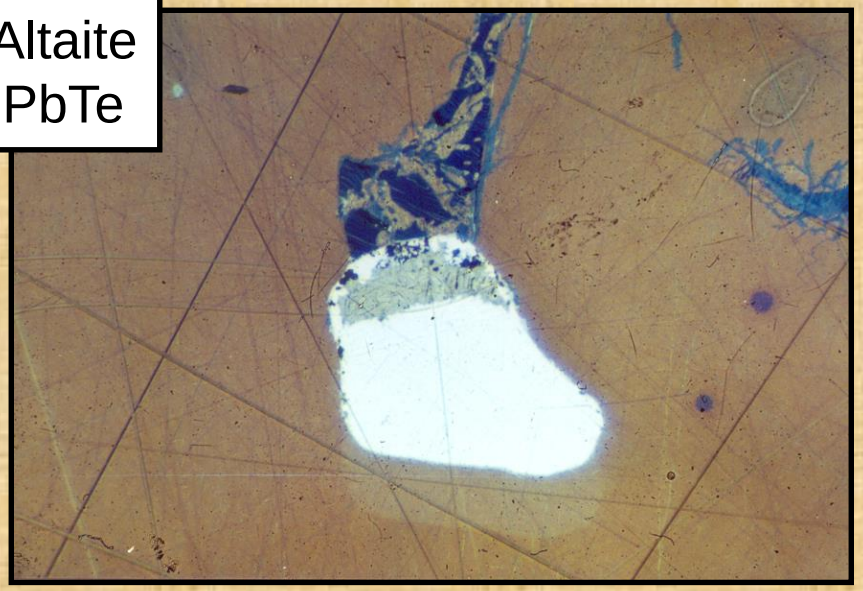
- **Weakly deformed chalcocite-bearing quartz veins** **T < 200°C**
- **Strongly deformed bornite-bearing quartz veins** **T > 300-350°C**

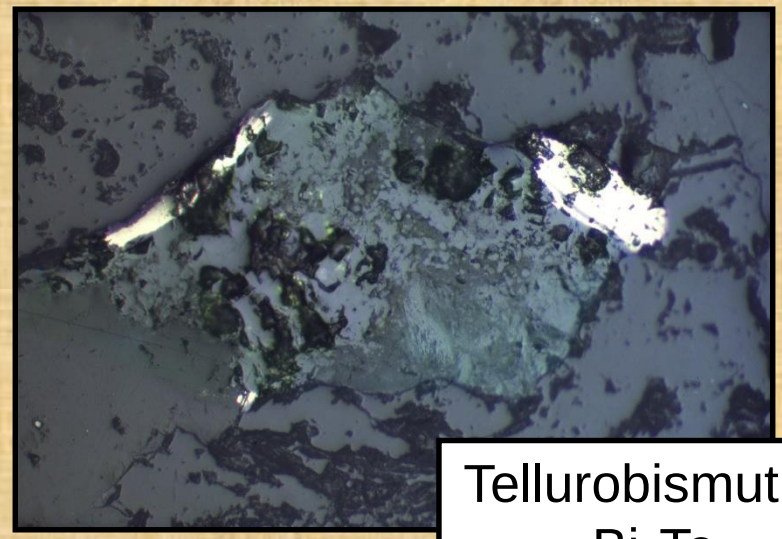
Bornite-bearing veins closer to the peak of metamorphism and deformation

Tellurides from Vielsalm

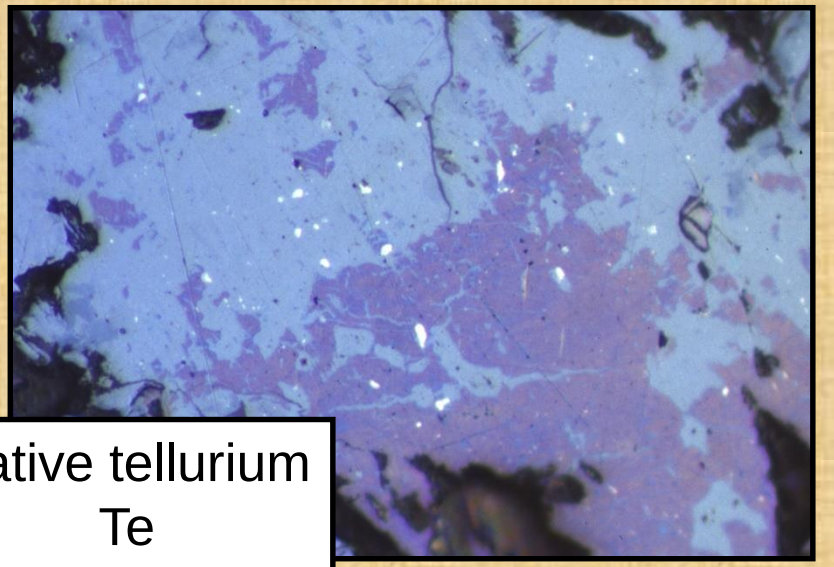
Université de Liège

Altaite
PbTe





Tellurobismuthite
Bi_2Te_3

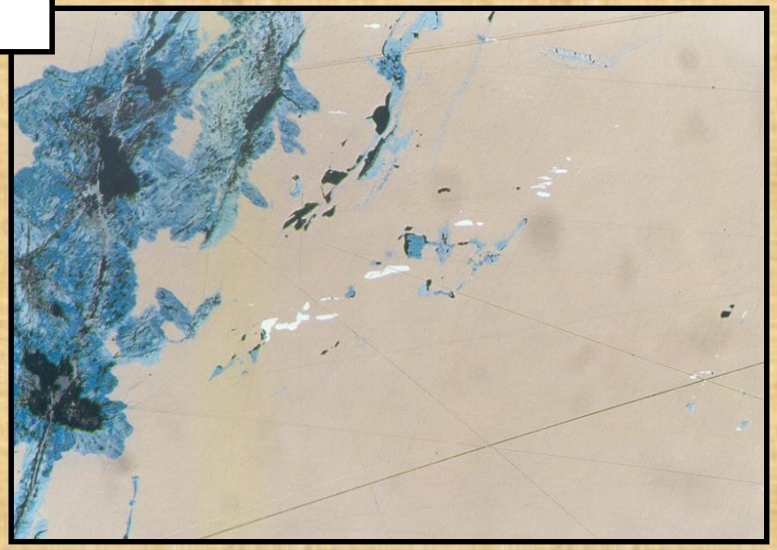


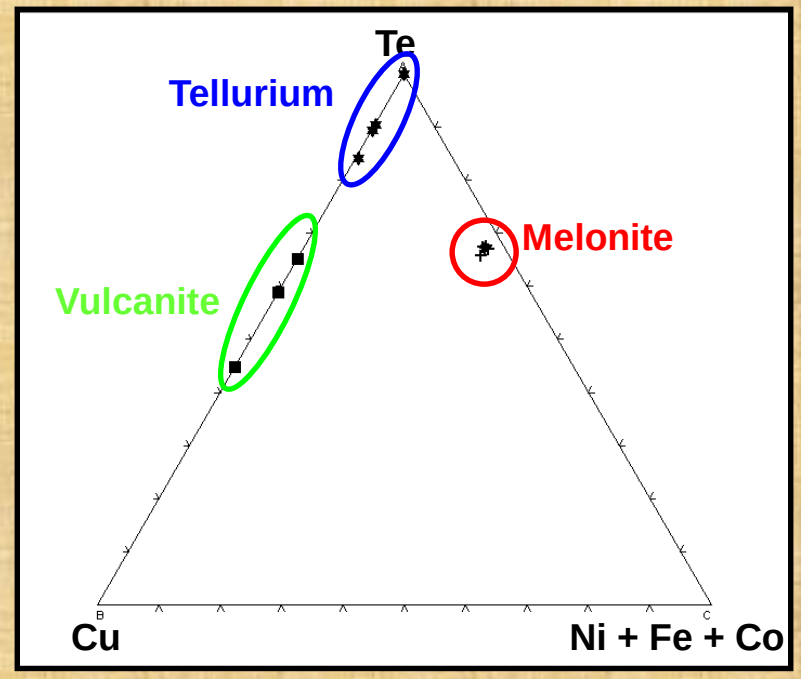
Native tellurium
Te

Altaite: $(Pb_{0.97}Cu_{0.03})Te_{0.99}$
Tellurobismuthite: $Bi_{2.00}(Te_{2.96}Se_{0.02})$
Native tellurium: $Te_{0.89}Cu_{0.10}$

Tellurides from Vielsalm

Galena
PbS





Galena: $(Pb_{0.98}Fe_{0.02})S_{1.00}$
Cobaltite: $(Co_{0.84}Fe_{0.06}Ni_{0.05})As_{1.04}S_{1.01}$
Wittichenite: $Cu_{3.04}Bi_{1.09}S_{2.87}$
Melonite: $(Ni_{0.78}Cu_{0.13}Bi_{0.10})Te_{1.89}$
Vulcanite: $Cu_{0.92}(Te_{0.77}S_{0.28})$

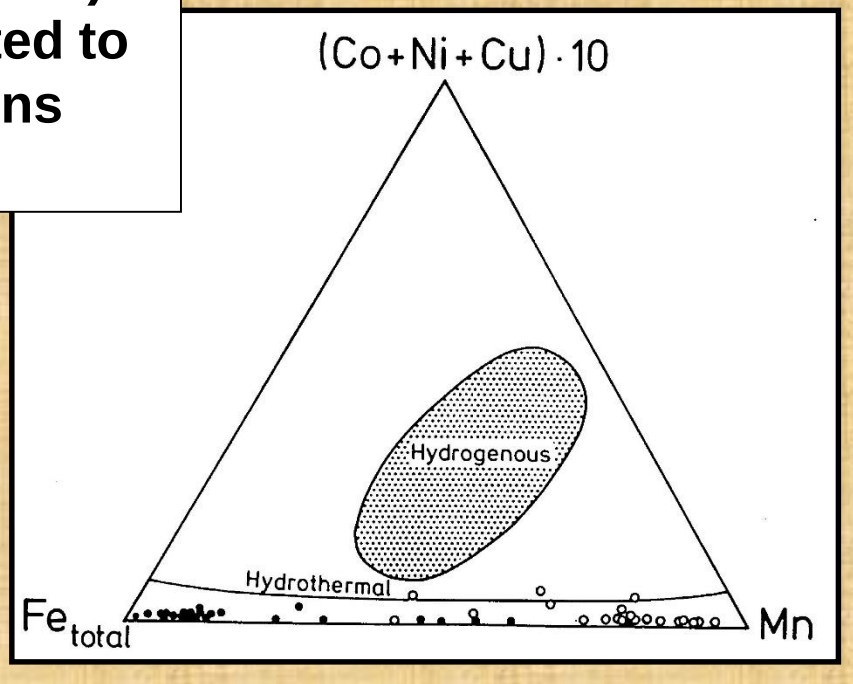
Tellurides from Vielsalm

Origin of tellurides

Université de Liège

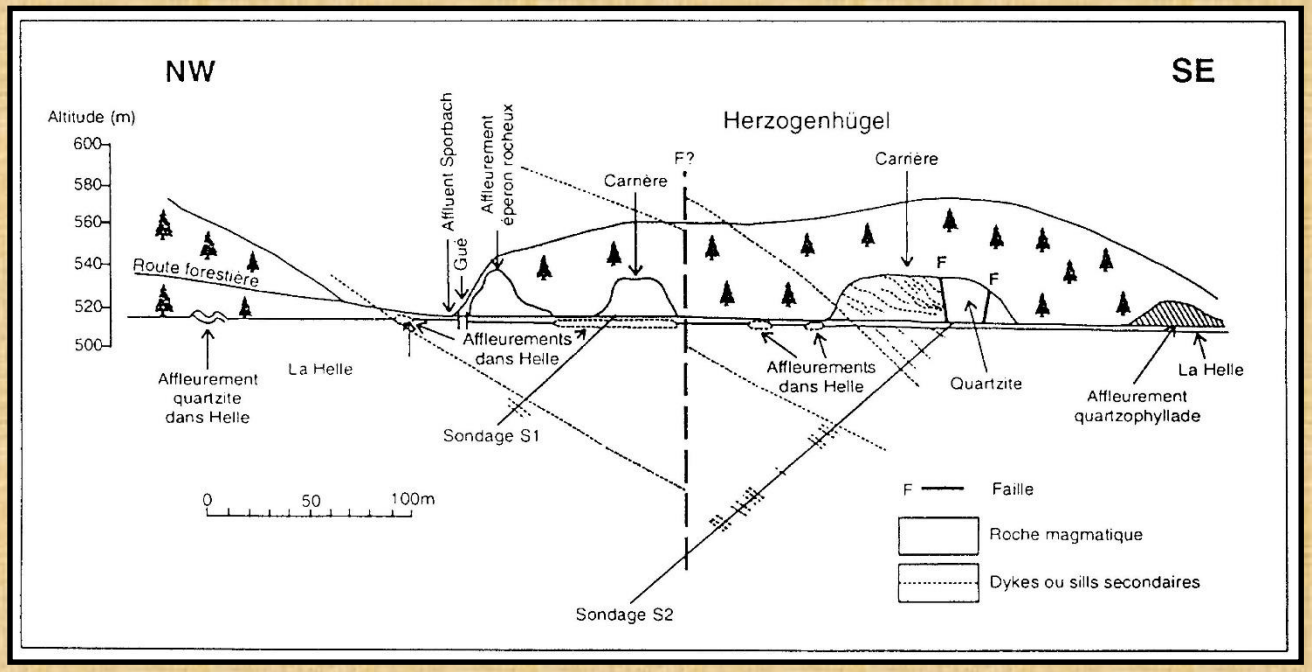
- **Tellurides located in copper-bearing quartz veins.**
- **Quartz veins crosscut schists of Ordovician age.**
- **Crystallisation during Variscan metamorphism, at temperatures lower than 420°C.**

- **Origin of tellurium: remobilization from pseudocoticules (spessartine quartzites).**
- **Coticules and pseudocoticules related to magmatism; hydrothermal exhalations (Krosse & Schreyer, 1986).**



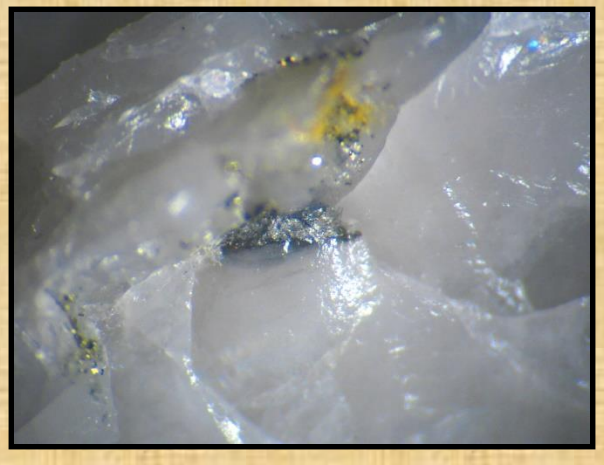
The tonalite of « La Helle »

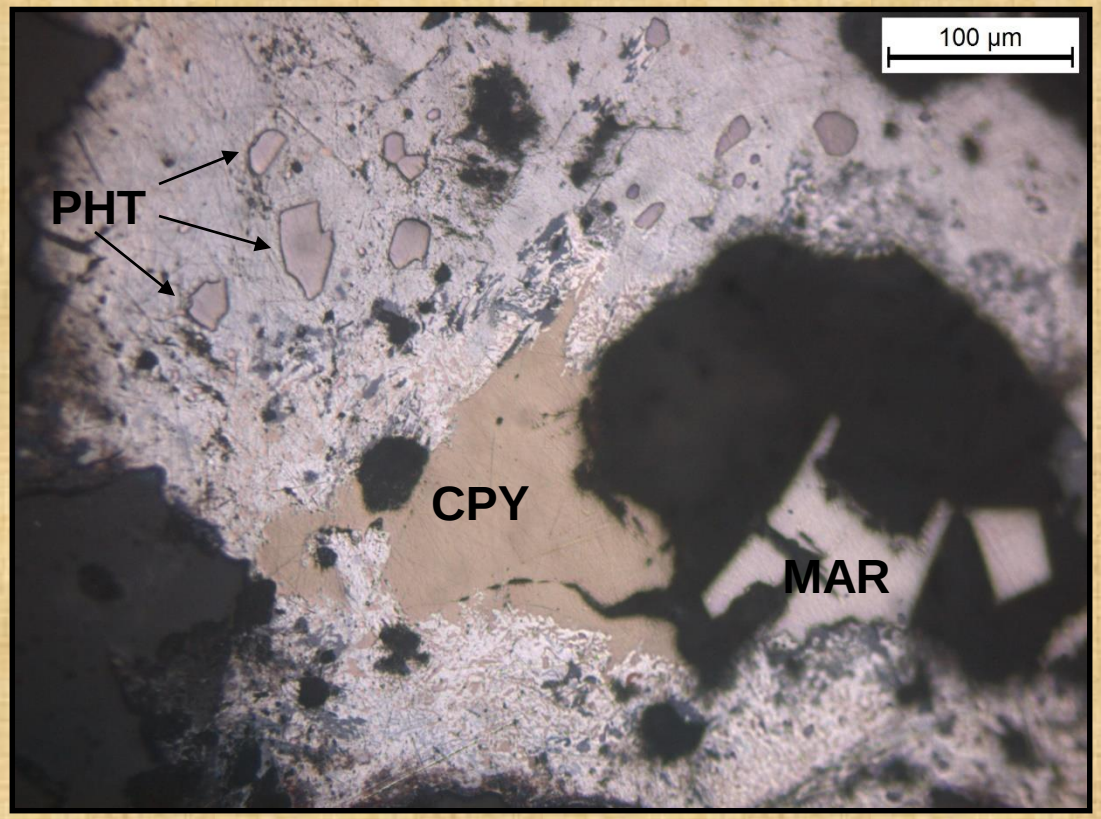
- **Granodiorite intrusion of ca. 100 m diameter.**
- **Located close to the river of « La Helle ».**
- **Intruded in quartzites of the Revin Group (Upper Cambiran).**
- **Porphyry-copper-type mineralization.**
- **Inclusions of pyrrhotite, chalcopyrite, and molybdenite.**



- **Tellurides occur in quartz veins crosscutting the host rocks.**

Tellurides from La Helle

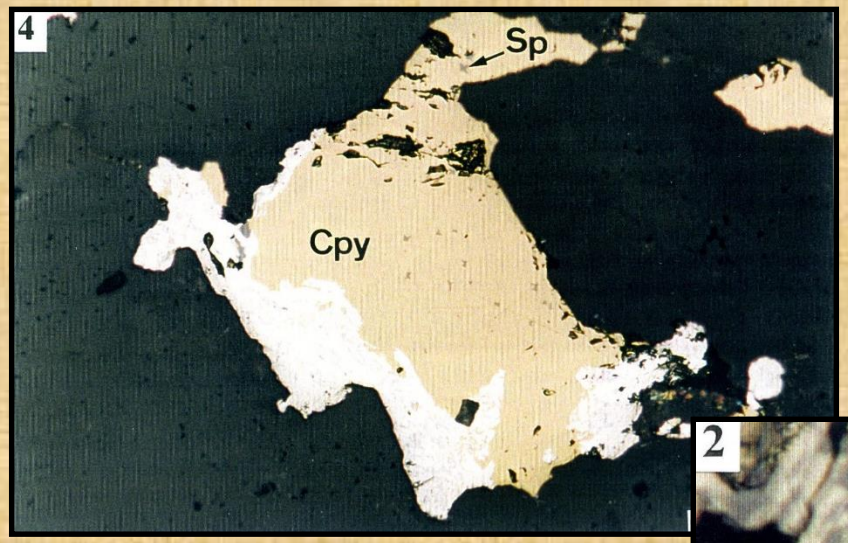




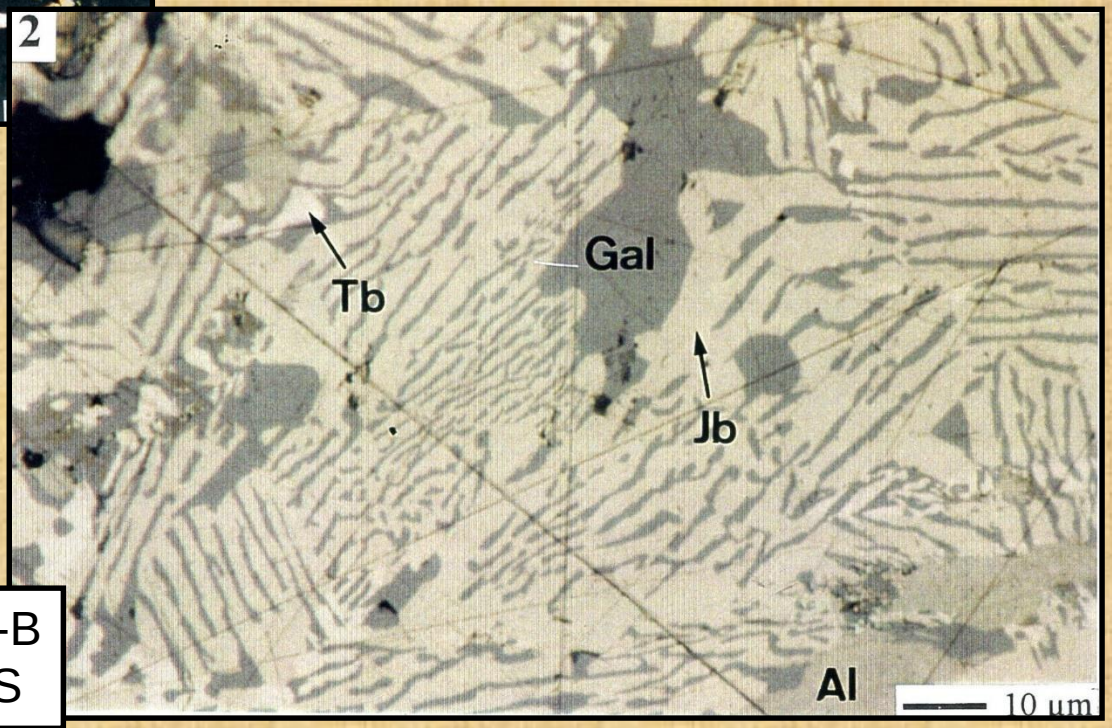
Chalcopyrite: $Cu_{1.00}Fe_{0.99}S_{2.01}$
Marcasite: $Fe_{1.00}S_{2.00}$
Pyrrhotite: $Fe_{0.86}S_{1.00}$

Tellurides from La Helle

Université de Liège



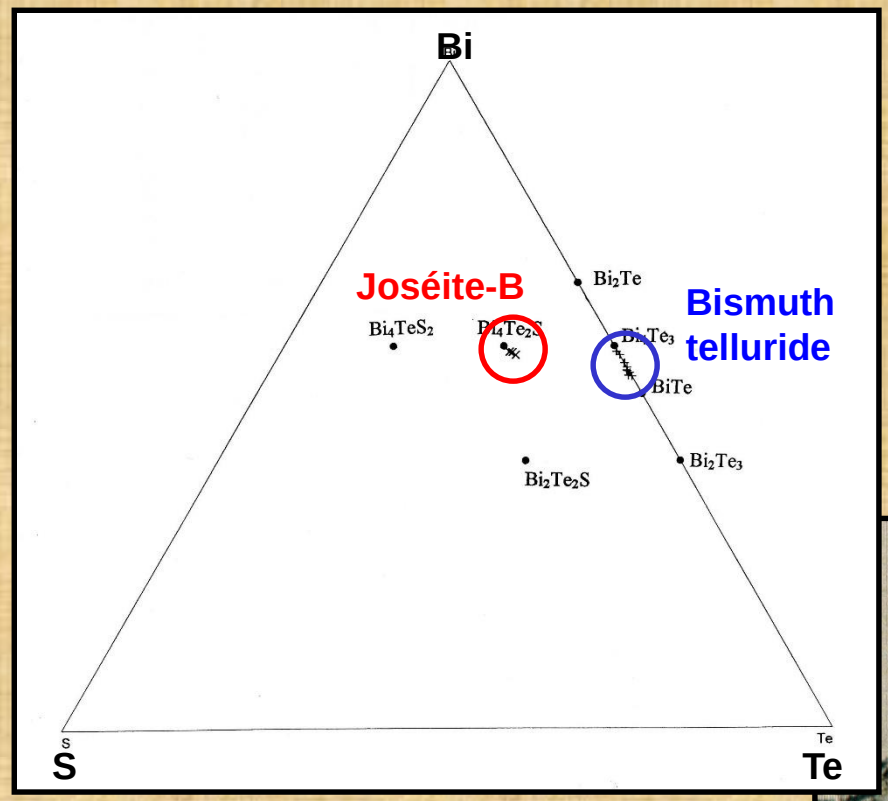
Sphalerite: $(Zn_{0.88}Fe_{0.11})S_{1.01}$
Galena: $(Pb_{0.96}Bi_{0.02}Ag_{0.02})S_{1.00}$



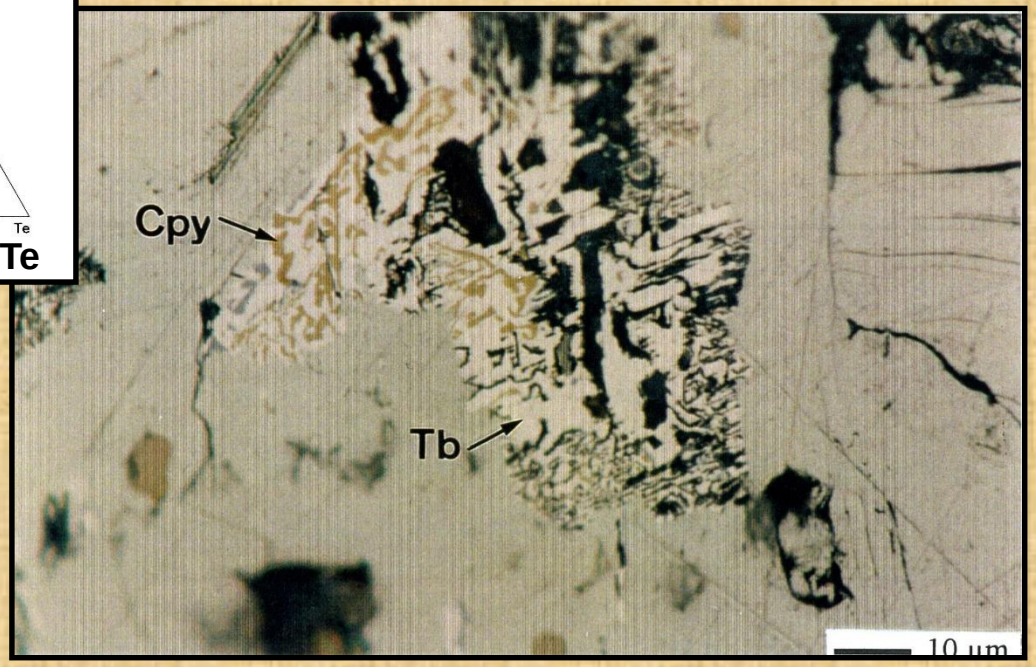
Joséite-B:
$(Bi_{3.83}Pb_{0.09})Te_{2.08}(S_{0.93}Se_{0.06})$

Joséite-B
Bi_4Te_2S

Tellurides from La Helle



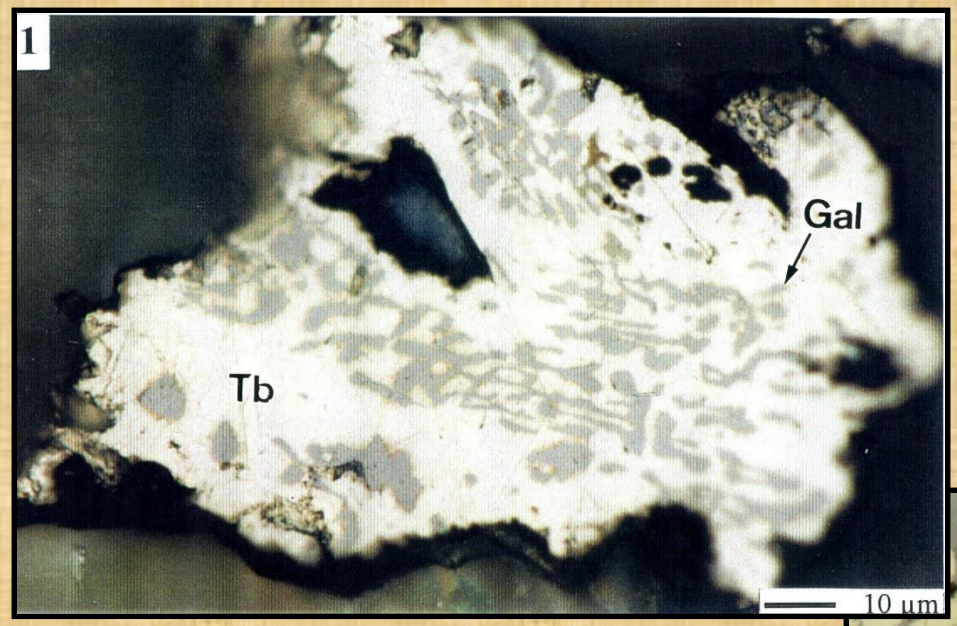
- **Bismuth telluride, white compared to joséite-B.**
- **Chemical composition between tsumoite (BiTe) and pilsenite (Bi_4Te_3)**



New mineral species?

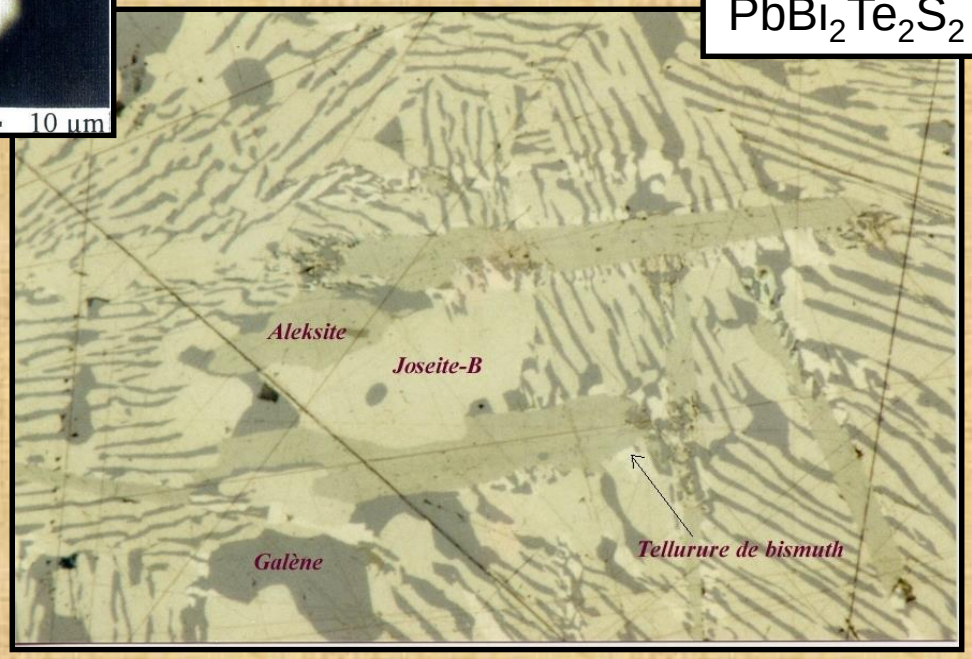
Tellurides from La Helle

Université de Liège



Benjaminite: $(Ag_{1.80}Pb_{1.20})(Bi_{5.56}Pb_{0.82}Cu_{0.58})(S_{11.39}Te_{0.33})$

Aleksite $PbBi_2Te_2S_2$



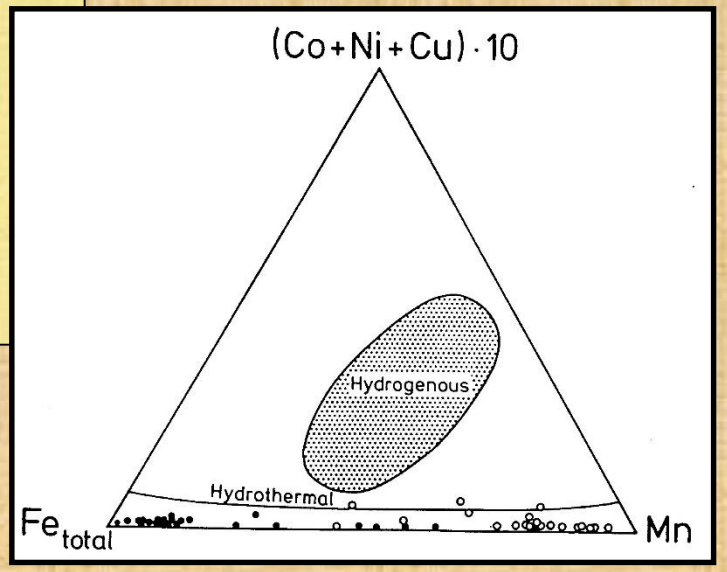
Aleksite: $(Pb_{0.76}Bi_{0.28})Bi_{2.00}Te_{1.99}S_{1.90}$
Hessite: $Ag_{1.99}Te_{1.01}$

Genetical considerations

Université de Liège

Tellurides from Vielsalm

- Tellurides located in copper-bearing quartz veins.
- Quartz veins crosscut schists of Ordovician age.
- Crystallisation during Variscan metamorphism, at temperatures lower than 420°C.
- Origin of tellurium: pseudocoticules (spessartine quartzites).
- Coticules and pseudocoticules related to magmatism; hydrothermal exhalations (Krosse & Schreyer, 1986).



Tonalite of « La Helle »

- Tellurides located in quartz veins from the granodiorite.
- Intrusion took place during Silurian period.
- Magmatic origin of tellurium.

Conclusions

- Petrographic and electron-microprobe investigations of copper sulfides from Vielsalm have shown the occurrence of tellurides inclusions, idaite, anilite and spionkopite-yarrowite.
- Two transformation sequences have been established, starting from bornite and chalcocite, to explain the observed petrographic textures
- The bornite-bearing quartz veins are more deformed and of higher temperature than the chalcocite-bearing quartz veins
- Tellurides occur in two localities of the Stavelot Massif, Belgium
- In Vielsalm, these minerals are associated with copper sulfides, in quartz veins crosscutting Ordovician schists. These veins are of metamorphic origin (max. 420°C), but tellurium was remobilized from pseudocoticules, which were produced by