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Transformation sequences of copper sulfides at Vielsalm, Stavelot Massif, Belgium

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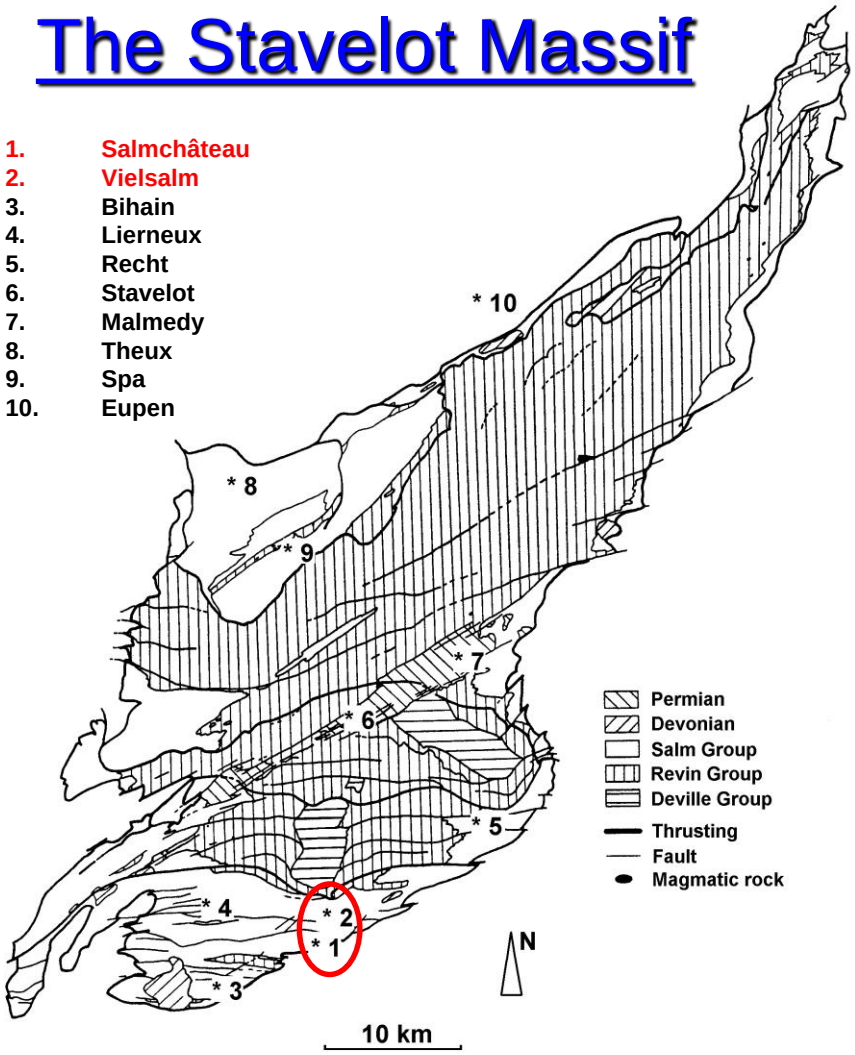
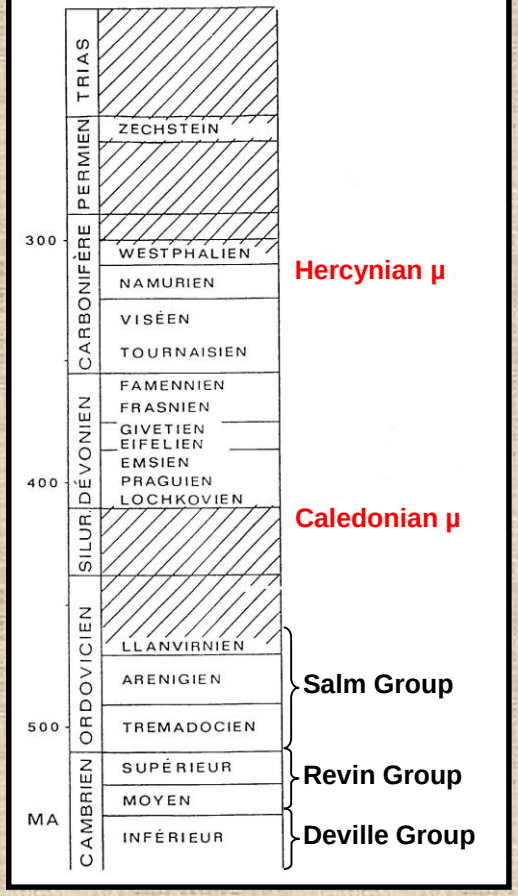
The Stavelot Massif

1. Salmchâteau
2. Vielsalm
3. Bihain
4. Lierneux
5. Recht
6. Stavelot
7. Malmedy
8. Theux
9. Spa
10. Eupen



Modified from Geukens (1986)



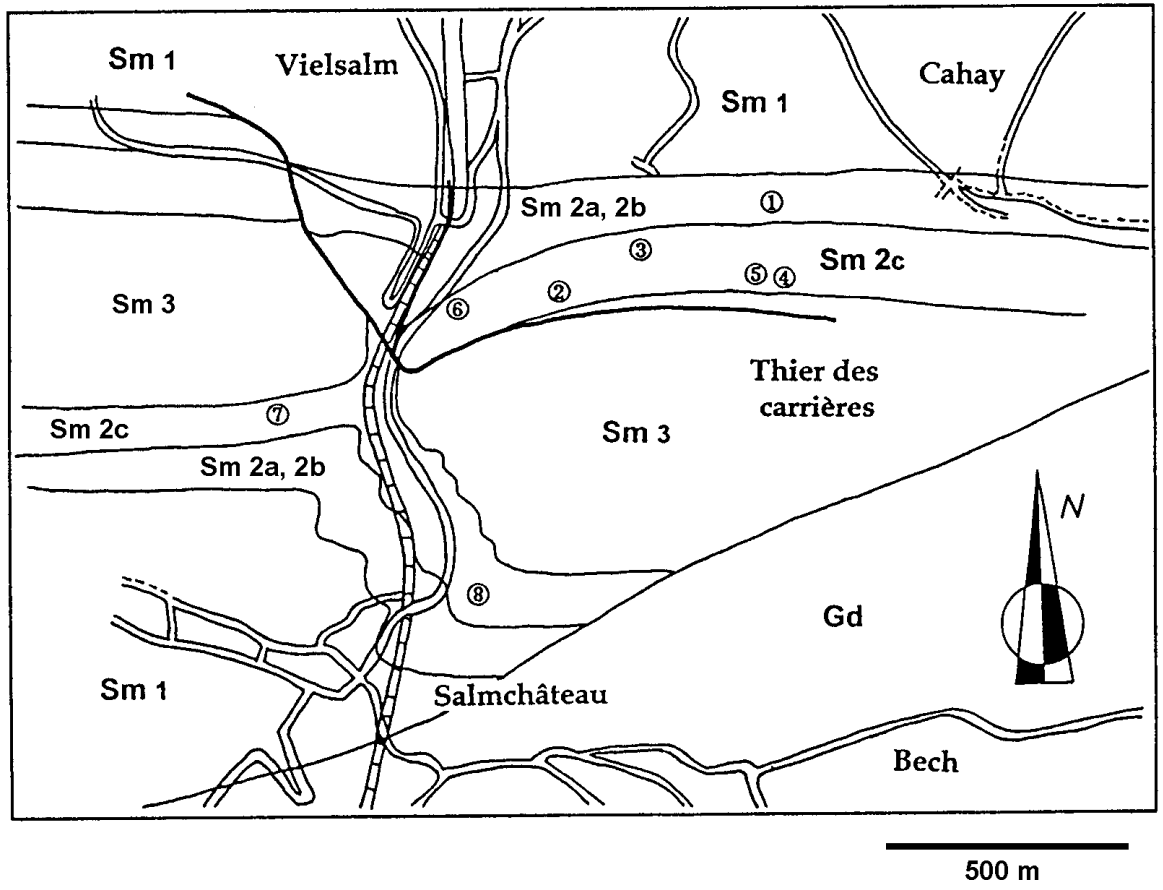
Hercynian metamorphism

360-420°C
2 kbar
Salm Valley

Salm Group

- Bihain Fmt.
- Ottré Fmt.
  - Colanhan Mbr. (Sm2c)
  - Les Plattes Mbr. (Sm2b)
  - Meuville Mbr. (Sm2a)
- Jalhay Fmt.

The Salm Valley



Salm Group

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

Disseminations:
1, 2, 7

Pseudocoticules:
3, 7

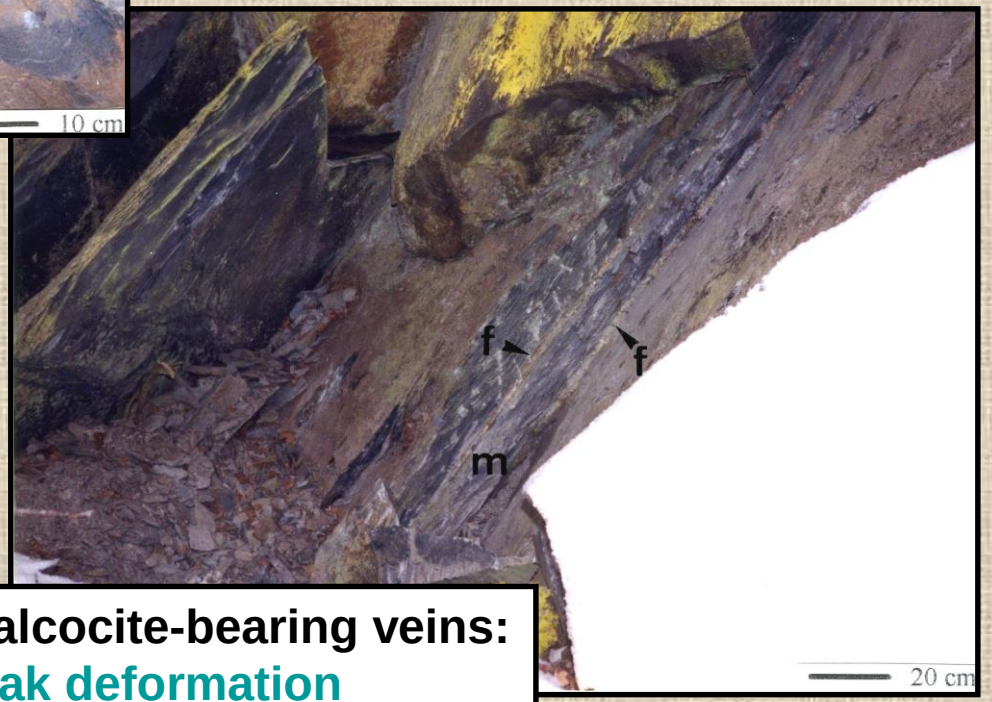
Linear quartz veins:
2, 3, 6

Deformed quartz vein:
4, 5, 6, 8

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

Quartz veins

Bornite-bearing veins:
Strong deformation



Chalcocite-bearing veins:
Weak deformation

Correlation between deformation and mineralogy

Mineralogy of the quartz veins

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

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

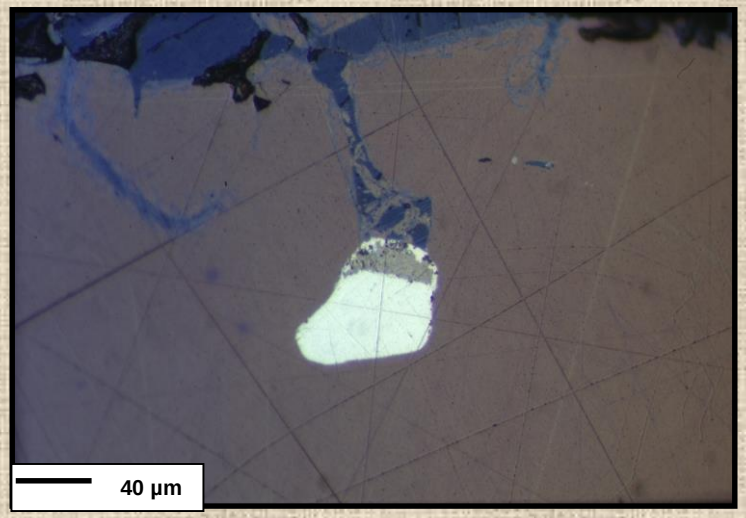
Inclusions: Altaite, arsenopyrite, cobaltite, galena, melonite, pyrite, sphalerite, tellurobismuthite, tellurium, wittichenite.

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

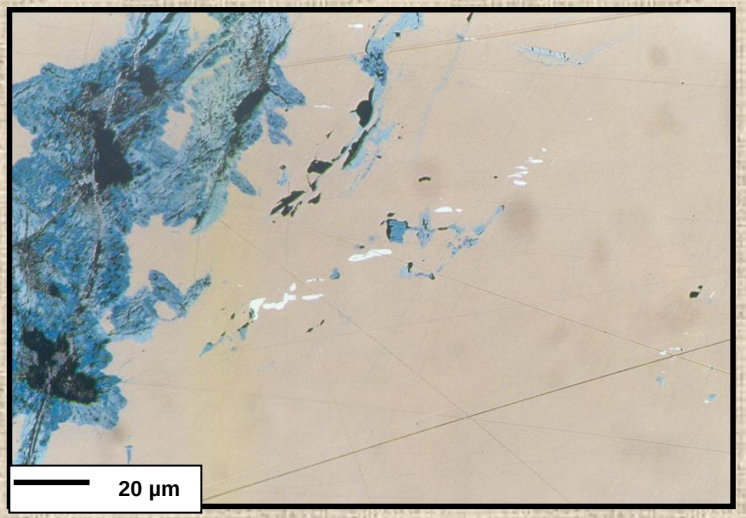
Many exotic minerals, greatly appreciated by mineral collectors!

Some inclusions

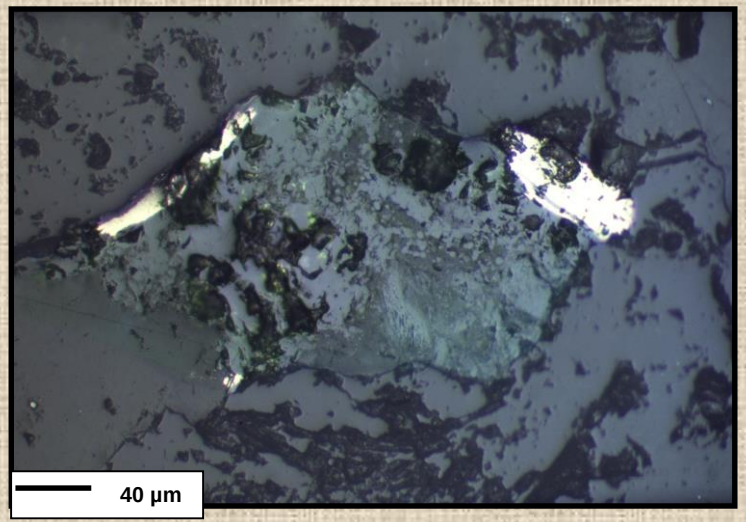
Altaite, PbTe



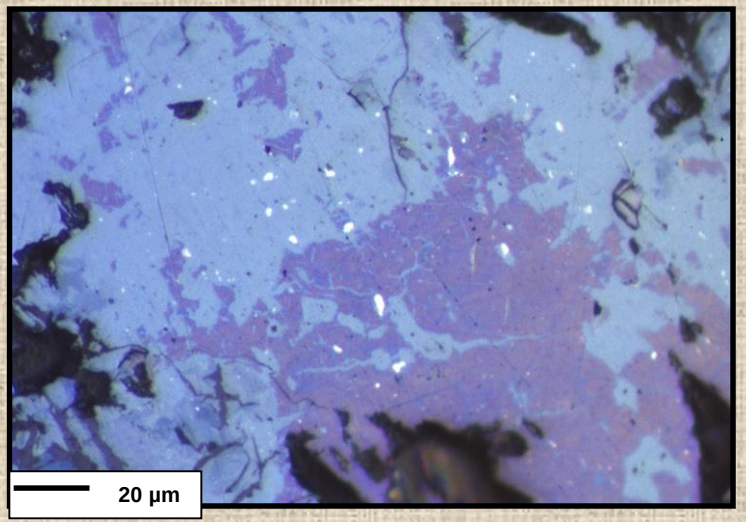
Galena, PbS



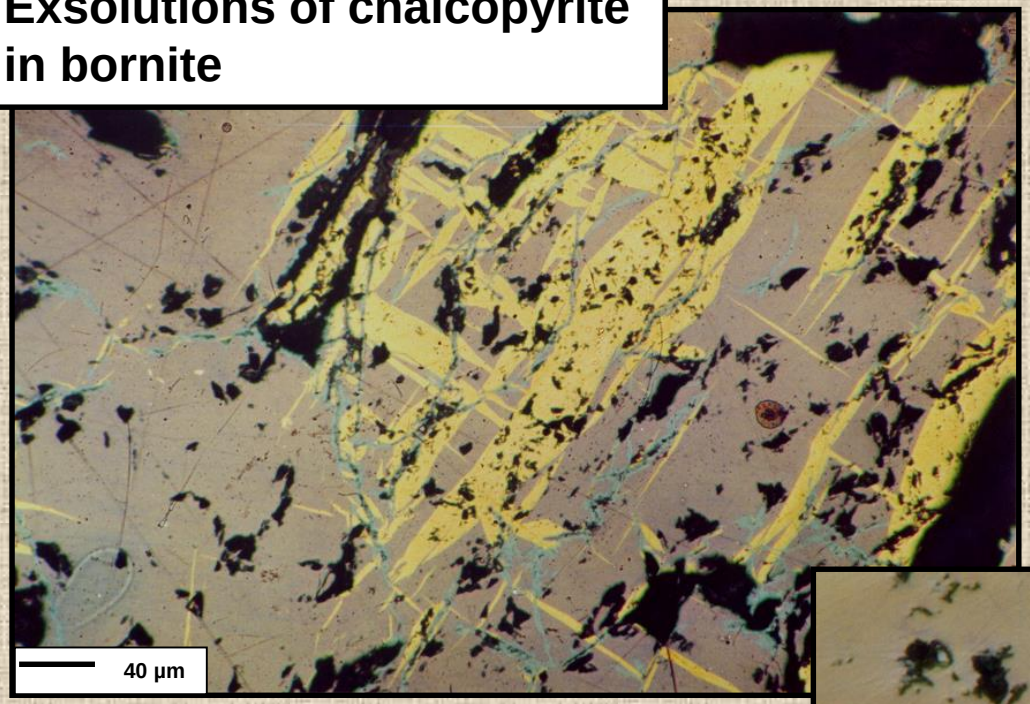
Tellurobismuthite, Bi_2Te_3



Tellurium, Te

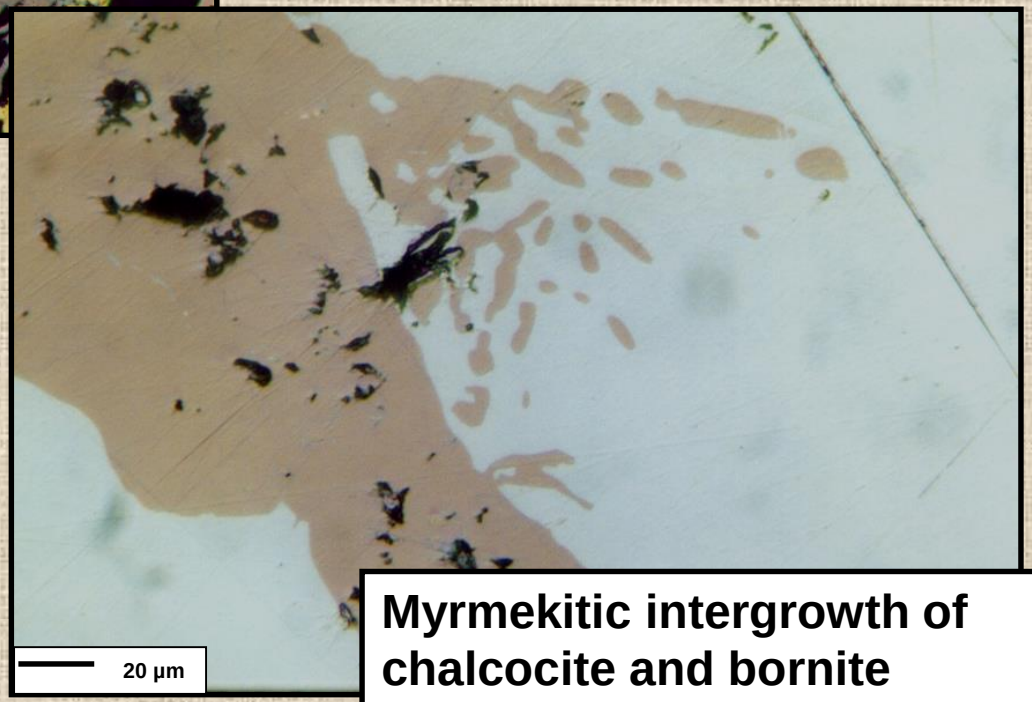


Exsolutions of chalcopyrite in bornite



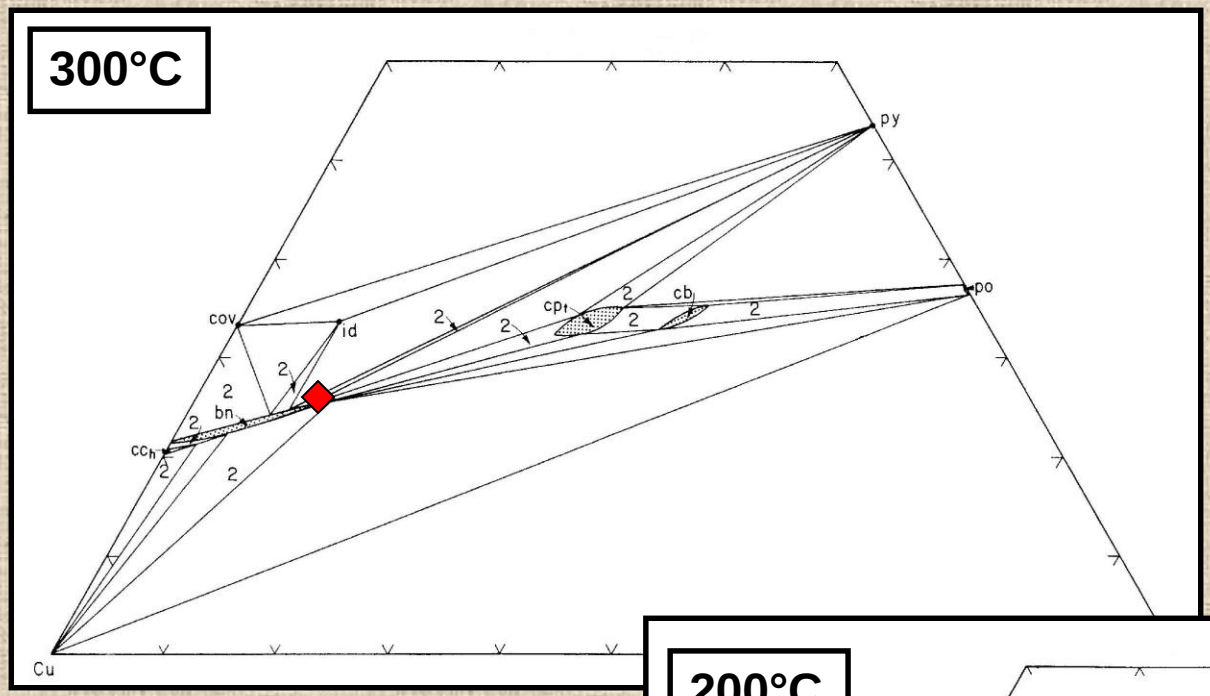
Primary copper sulfides

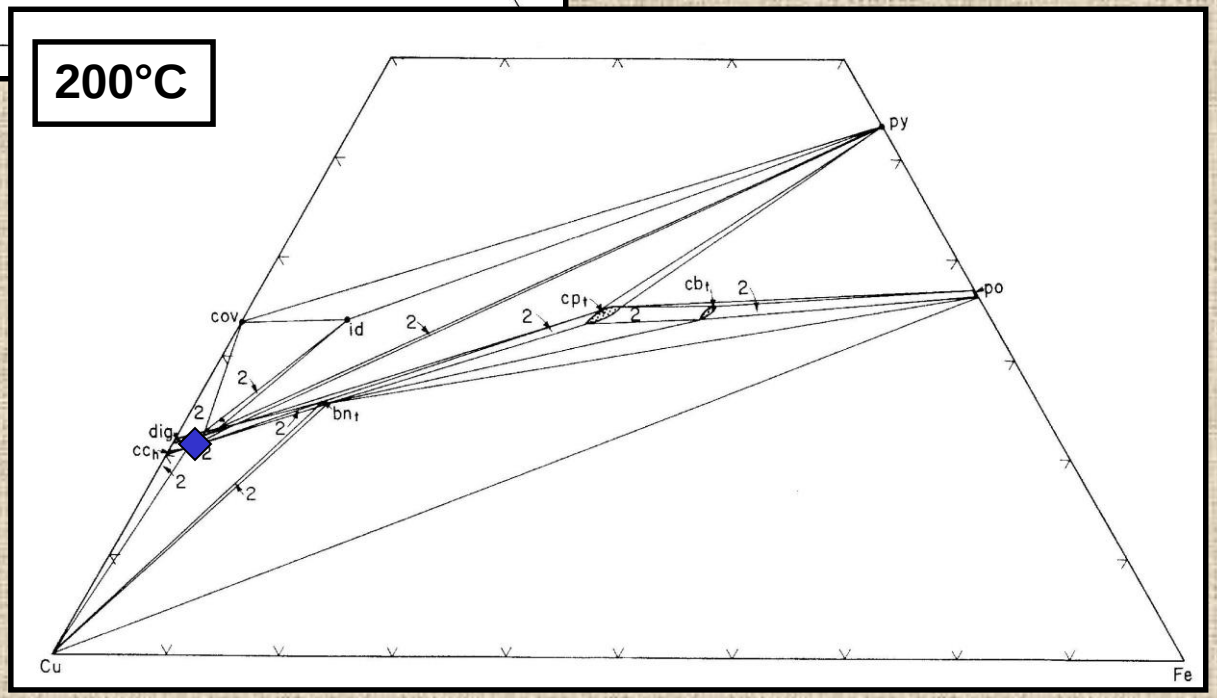
- **Bornite**, $Cu_{4.95}Fe_{0.99}S_{4.00}$
- **Chalcopyrite**, $Cu_{1.00}Fe_{0.98}S_{2.00}$
- **Chalcocite**, $Cu_{2.00}S_{1.00}$



Myrmekitic intergrowth of chalcocite and bornite

Crystallisation temperatures of primary sulfides





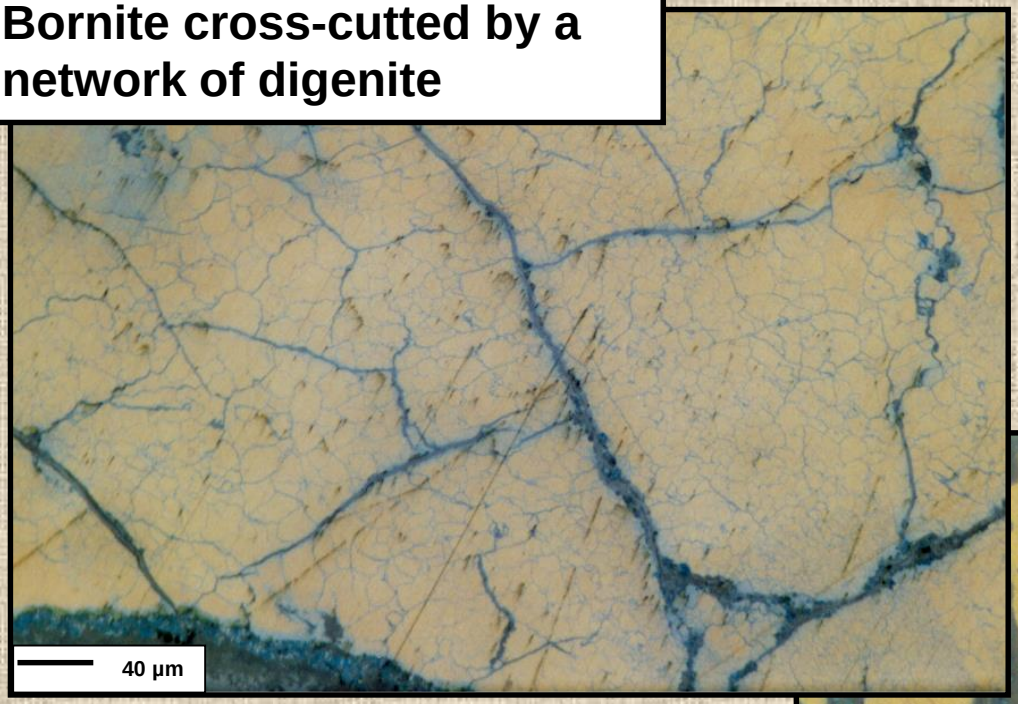
◆ : Bornite + chalcopyrite (15%)
◆ : Chalcocite + bornite (80%)

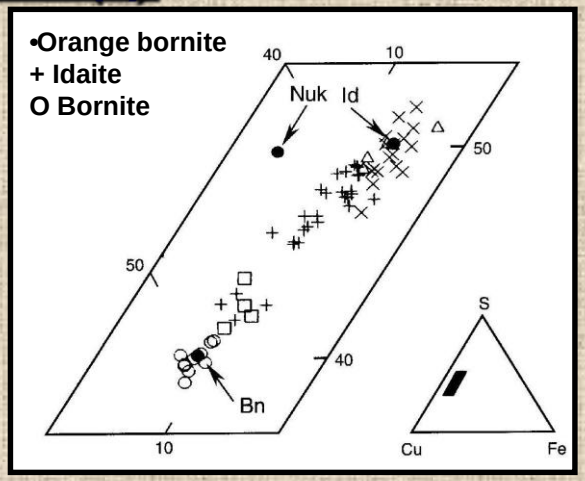
- Below 300-350°C: exsolution of chalcopyrite lamellae in bornite
- Below 200°C: myrmekitic intergrowths of chalcocite and bornite

Yund & Kullerud (1966)

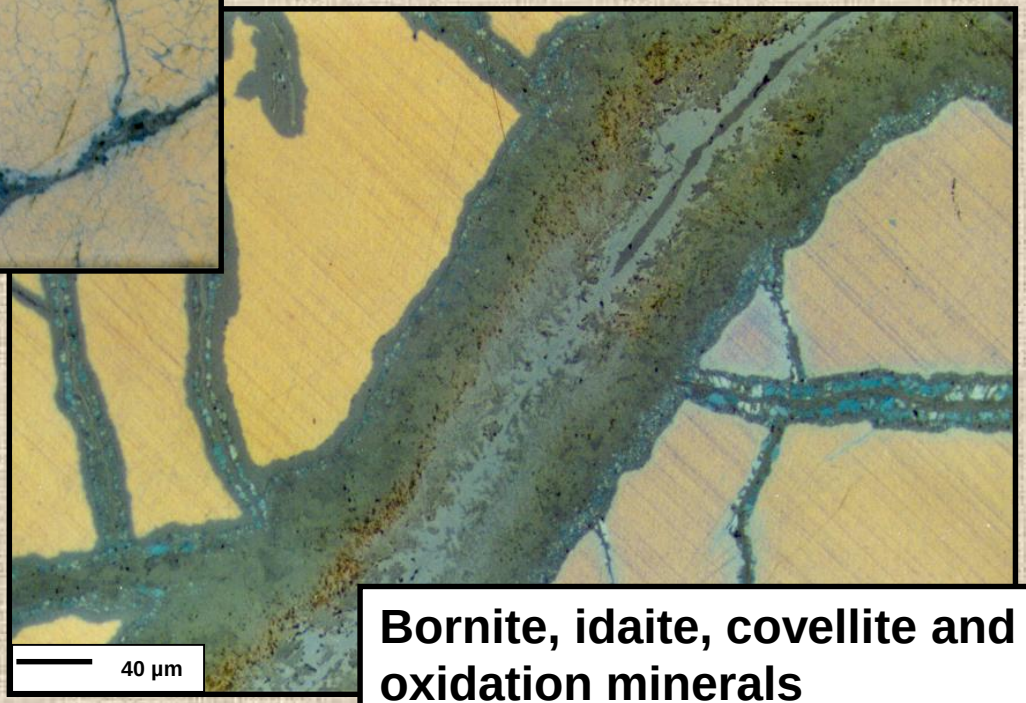
Sequence I: Oxidation of bornite (I)

Bornite cross-cutted by a network of digenite





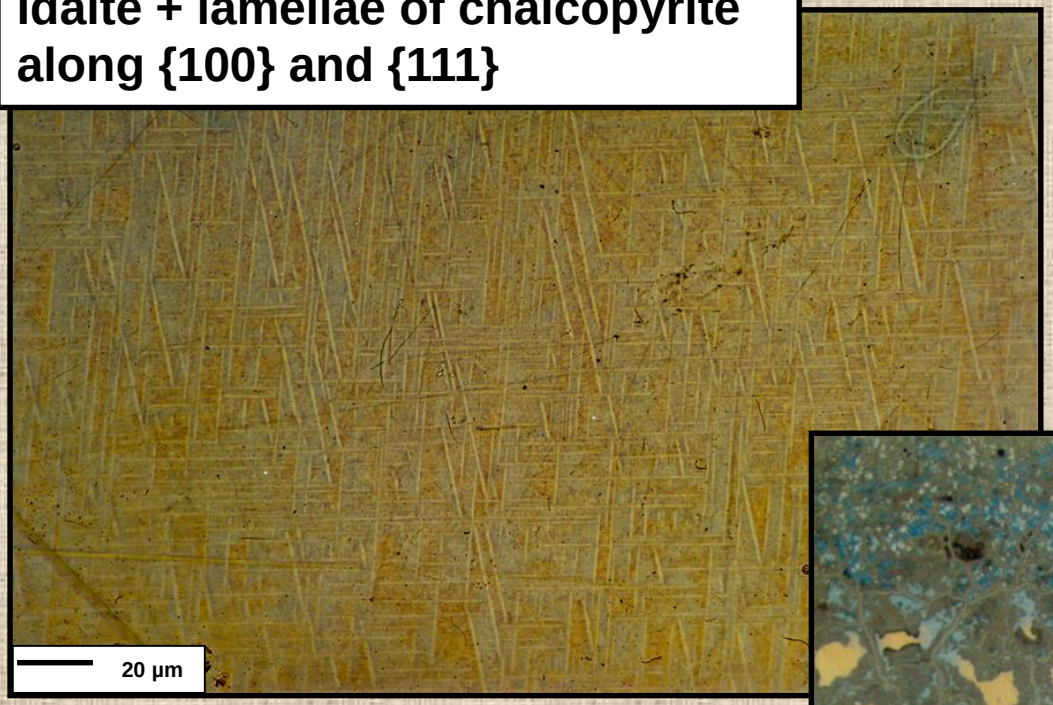
- **Digenite**, $Cu_{8.95}S_{5.00}$ (Cu/S = 1.79)
- **Idaite**, $Cu_{3.25}Fe_{0.97}S_{4.00}$
- **Covellite**, $Cu_{1.02}S_{1.00}$

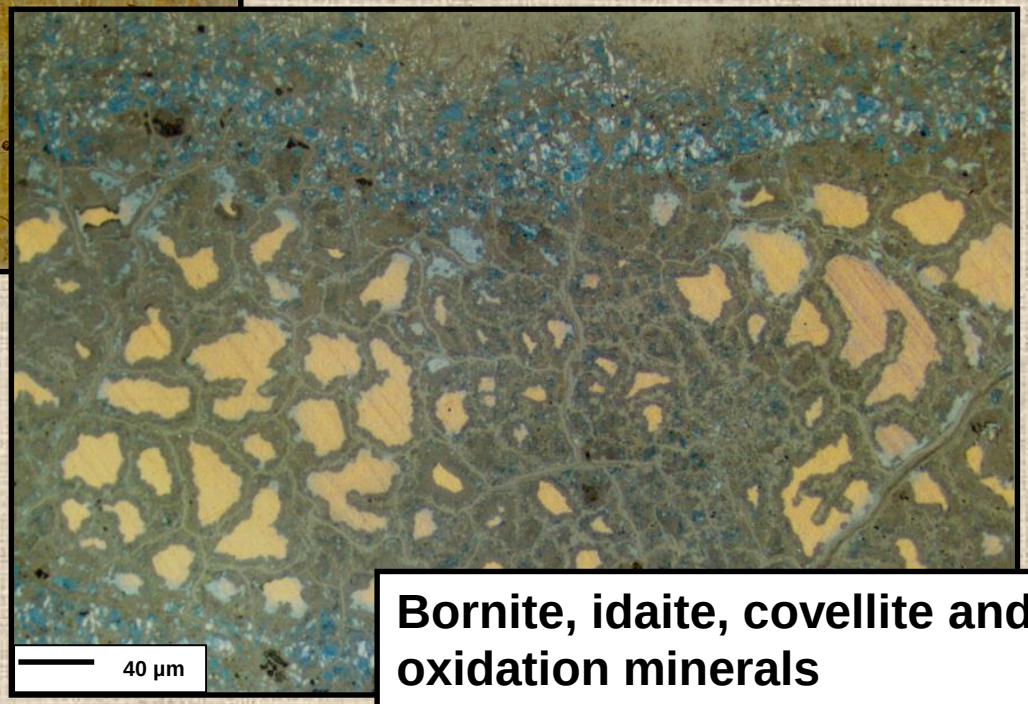


Bornite, idaite, covellite and oxidation minerals

Sequence I: Oxidation of bornite (II)

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





Bornite, idaite, covellite and oxidation minerals

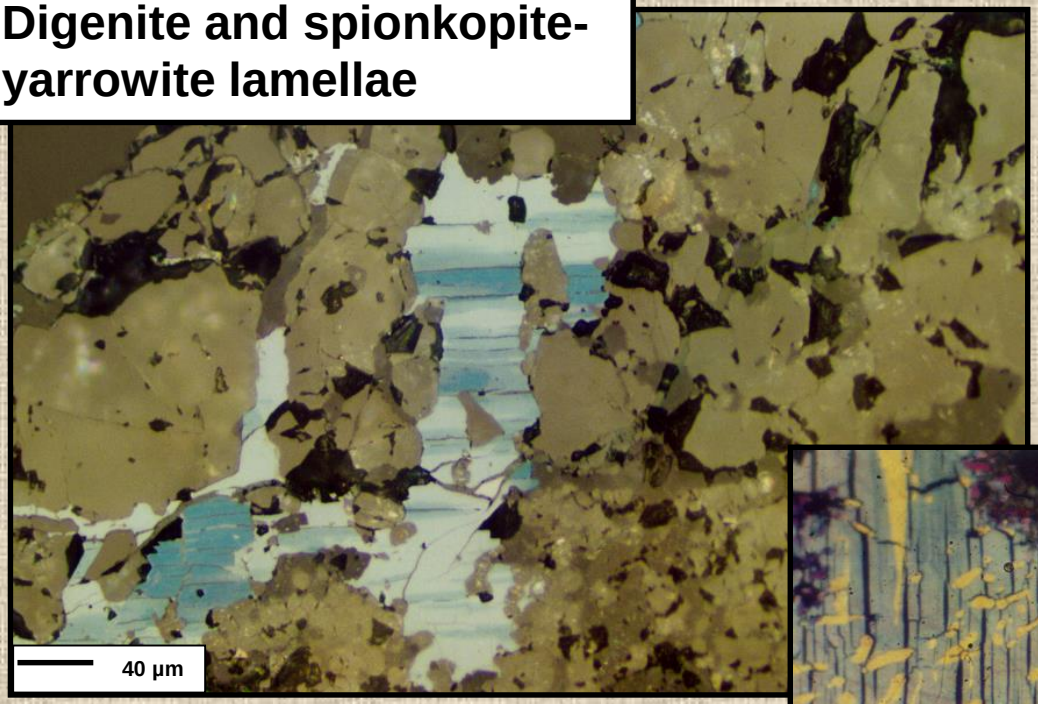
Bornite

Digenite **Idaite + chalcopyrite**

Covellite + Ox. minerals

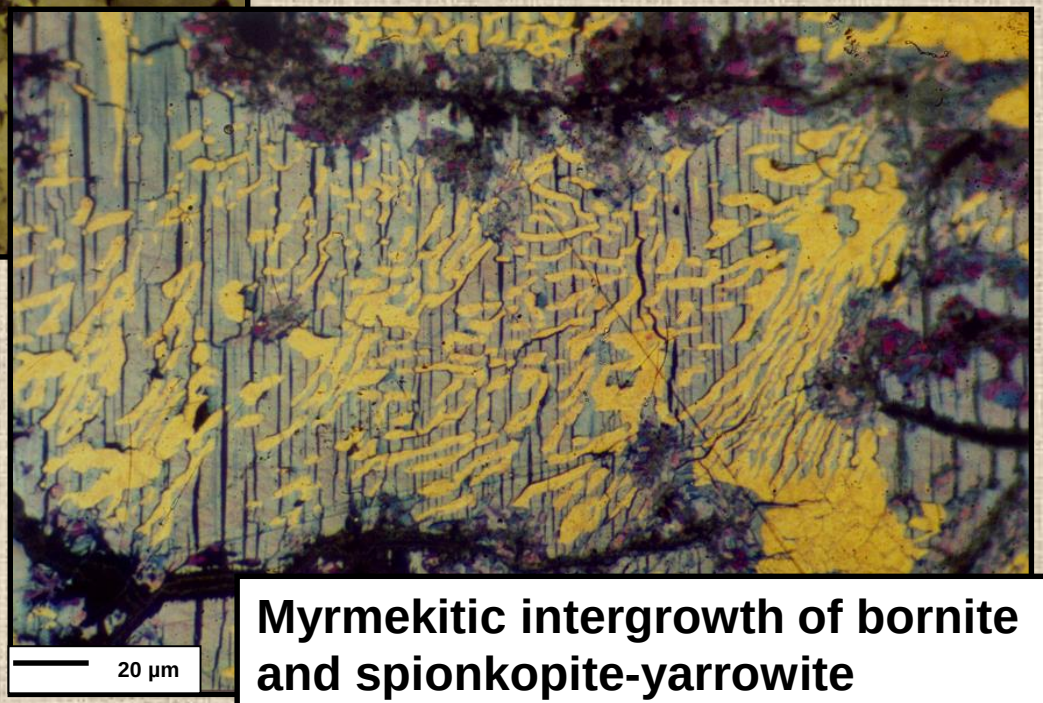
Sequence II: Oxidation of chalcocite

Digenite and spionkopite-yarrowite lamellae



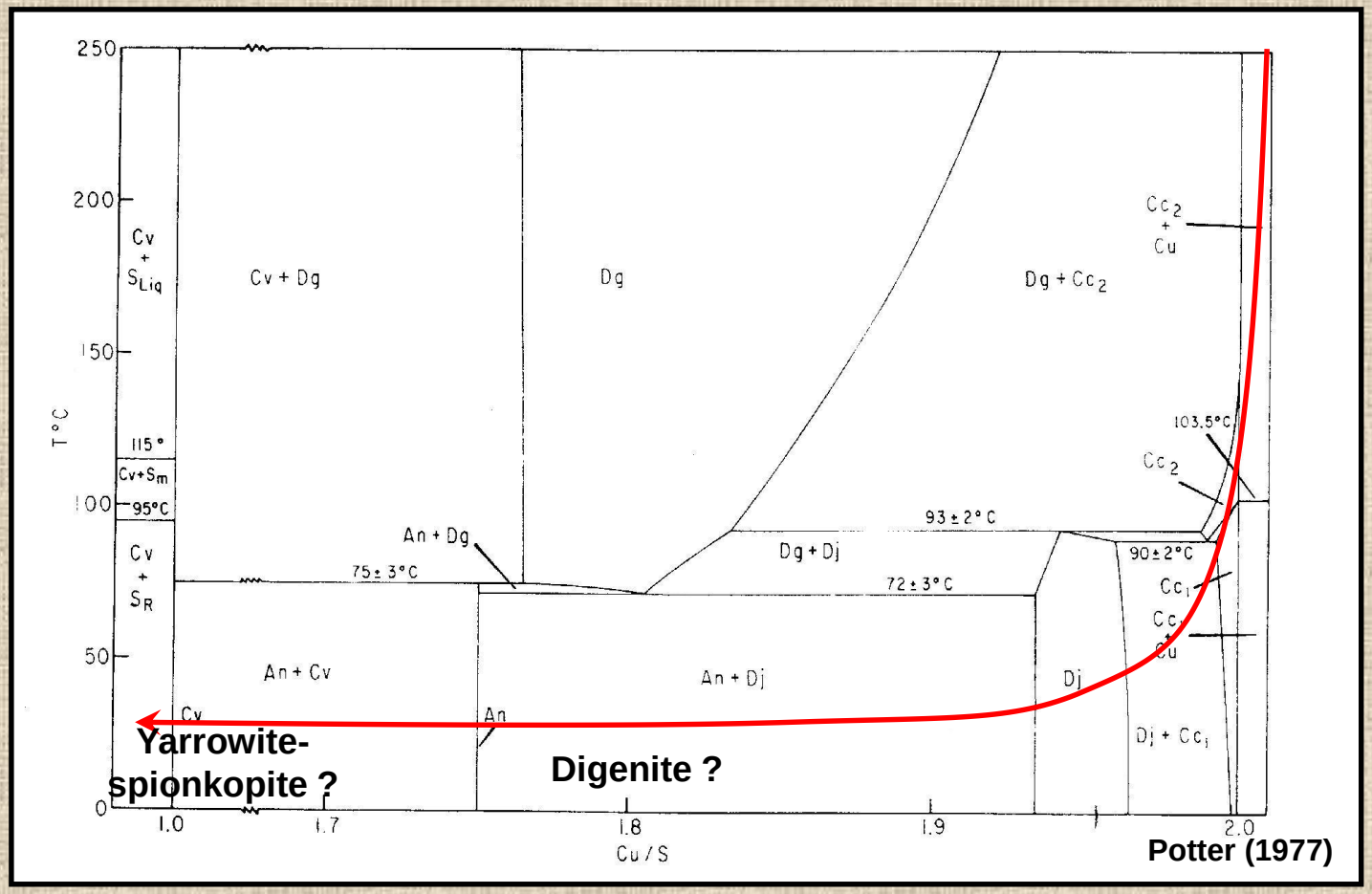
- Chalcocite, $Cu_{2.00}S_{1.00}$ (Cu/S = 2.00)
- Djurleite, $Cu_{30.61}S_{16.00}$ (Cu/S = 1.91)
- Digenite, $Cu_{8.95}S_{5.00}$ (Cu/S = 1.79)
- Anilite, $Cu_{6.97}S_{4.00}$ (Cu/S = 1.74)
- Spionkopite, $Cu_{39.64}S_{28.00}$ (Cu/S = 1.42)
- Yarrowite, $Cu_{8.96}S_{8.00}$ (Cu/S = 1.12)
- Covellite, $Cu_{1.02}S_{1.00}$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

↓

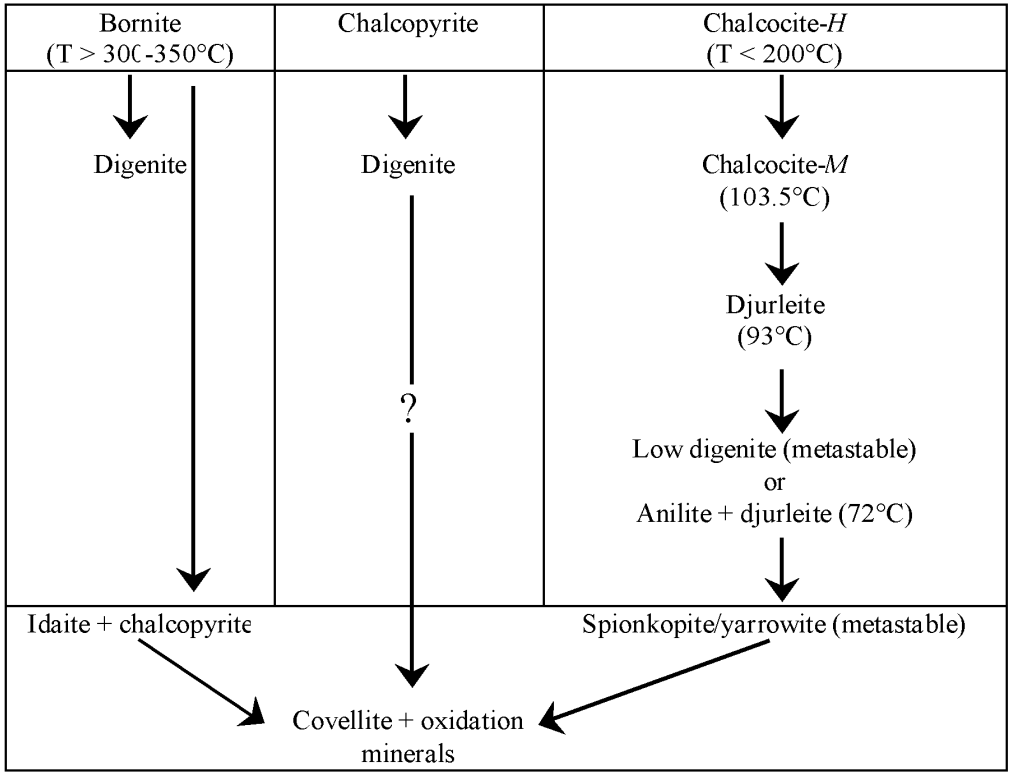
Spionkopite + yarrowite

↓

Covellite + ox. minerals

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

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



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

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