# TRANSFORMATION SEQUENCES OF COPPER SULFIDES AT VIELSALM, STAVELOT MASSIF, BELGIUM

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Located in the southeastern portion of the Stavelot Massif, the Salm syncline shows, between Vielsalm and Salmchâteau, a geological section containing schists of the Salm Group, of Lower Ordovician age. This area was first affected by a very low-grade metamorphism during the Caledonian orogeny (0.8-3 kbar / 280-380°C), and then by a low-grade metamorphism during the Hercynian orogeny (2 kbar / 360-420°C), which is responsible for the crystallization of the metamorphic minerals observed in the quartz veins and in the schists.

The quartz veins crystallized at the end of the Hercynian metamorphic phase. Fluid circulations through the rock fractures, coupled with metasomatic processes, resulted in concentration of numerous chemical elements, such as Cu, Mn, Te, or Mo, within the quartz veins. This explains the diversity of minerals discovered in this area: copper sulfides, which constitute the main topic of the present study, Mn-bearing aluminosilicates, such as davreuxite and ottrelite, and manganese oxides, such as lithiophorite, cryptomelane, nsutite, and hollandite-strontiomelane. The sulfides-bearing quartz veins investigated herein cross-cut the green to violet chloritoid-bearing schists of the Colanhan Member (Middle Salm Group, Sm 2c).

The sulfides bornite, chalcopyrite, idaite, covellite, yarrowite, spionkopite, anilite, digenite, djurleite, and chalcocite have been identified by ore microscopy, and their identification is confirmed by electron microprobe analyses. The chemical composition of idaite is significantly enriched in Cu, when compared with the ideal formula $Cu_3FeS_4$, and a progressive compositional evolution from bornite to idaite has been observed. The X-ray powder diffraction pattern of idaite is indexed in the space group $I\text{-}42m$, similar to that of stannite, and gives the unit-cell parameters $a$ = 5.279(4) and $c$ = 10.47(2) Å.

The association of primary sulfides indicates that the bornite-bearing quartz veins have crystallized above 300-350°C, whereas the chalcocite-bearing quartz veins have crystallized below 200°C. Relations among sulfides indicate the occurrence of two sequences of transformation, responsible of the formation of secondary sulfides: chalcocite-$H$ → chalcocite-$M$ → djurleite → low digenite or (anilite + djurleite) → yarrowite + spionkopite → covellite + oxidation minerals, and bornite → idaite + chalcopyrite → covellite + oxidation minerals. The crystallization of chalcocite-$M$, djurleite, and low digenite or (anilite + djurleite) took place between 103.5 and 72°C. The associations idaite + chalcopyrite, yarrowite + spionkopite, and covellite + oxidation minerals, were produced under meteoric conditions.