

Textural complexity in sulfide and telluride minerals resulting from mineral replacement reactions

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Over the past decade, many mineral replacement reactions have been recognized to occur via the coupled dissolution re-precipitation (CDR) mechanism, *i.e.* they proceed via dissolution of the parent phase into a fluid, coupled with the precipitation of the product(s). The product is porous, enabling the reaction to run to completion. Recent research has dramatically improved our understanding of the mechanisms and kinetics of CDR reactions, with applications to understanding mineral formation processes in nature, but also in materials synthesis. We review existing studies relevant to mineral processing and ore petrology, with a particular emphasis on the diversity of textures resulting from CDR reactions, and the role of CRD reactions in controlling the scavenging of minor ore components.

Pentlandite ((Fe,Ni)₉S₈) and violarite ((NiFe)₂S₄) are the main Ni ores in massive sulfide deposits; the nature of these phases is important for flotation and smelting. Violarite pseudomorphs after pentlandite are common in the cementation zone; however, solid-state transformation of pentlandite to violarite is sluggish and results in multi-phase assemblages. In contrast, using CRD reactions, pentlandite can be quickly transformed to violarite under mild hydrothermal conditions. The replacement is pseudomorphic and preserves the crystallographic orientation of the parent pentlandite (epitaxial nucleation); the scale of the replacement depends upon the relative rates of the dissolution and precipitation steps, with nm-scale preservation when the precipitation rate is much faster than the dissolution rate.

Refractory Au-Ag-tellurides are replaced by gold in ~24h via CRD under hydrothermal conditions (200 °C), providing an alternative to roasting. The gold textures are similar to those observed in natural 'mustard gold'. Depending on the nature of the Au-Ag-telluride, the replacement can lead to remarkably complex textures that belie the simple reaction conditions. These textures evolve because of the interaction between CRD and solid-state driven reactions.

Experimental studies of the sulphidation of hematite in the presence of Cu(I) provide insights into the formation of chalcopyrite and bornite. In uranium-bearing experiments, uranium scavenging was coupled with the mineral replacement reactions. This process could be important for explaining U distribution in IOCG deposits.

Experimental sulphidation of magnetite and pyrrhotite reveal that reaction textures and the nature of the reaction products are controlled primarily by non-equilibrium processes (e.g., kinetics of dissolution and reprecipitation). In systems containing Bi(III) and Au(I) in solution together with pyrrhotite, pyrrhotite did not scavenge Au at temperatures lower than the Au(s)-Bi(s) eutectic, but a Au-rich metallic Bi melt precipitated at higher temperatures. The Bi-melt precipitation was coupled with the topotactic replacement of pyrrhotite by magnetite.

These new experimental results reveal a wealth of complexity in fluid-mediated mineral replacement textures, which are governed by a complex interplay between processes such as mineral dissolution, nucleation and growth of new phases, evolving reaction-generated porosity and/or fracturing, or competition with solid-state diffusion.

Occurrence of tellurides in the Stavelot Massif, Belgium

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The Stavelot Massif, Belgium, is a large massif of Cambro-Ordovician metasediments (ca. 100 x 40 km), surrounded by discordant Lower Devonian conglomerates. Tellurides were reported in two localities: (i) in sulphide-bearing quartz veins cross-cutting chloritoid-bearing schists of Ordovician age in the Salm syncline, and (ii) in quartz veins cross-cutting a granodiorite mineralised in molybdenite, chalcopyrite, marcasite and pyrrhotite, outcropping at Herzogenhügel, close to the Helle valley.

Copper sulphides, occurring in the quartz veins from the Salm syncline, show petrographic textures which were investigated in detail by Hatert [1, 2, 3]. Primary assemblages mainly contain bornite, chalcopyrite, and chalcocite, whereas secondary sulphides are djurleite, digenite, anilite, spionkopite, yarrowite, and covellite. Tellurides occur as minute inclusions in bornite and chalcocite, frequently showing myrmekitic textures indicating a syncrystallization of tellurides and primary sulphides. Identified tellurides are native tellurium, altaite, melonite, and tellurobismuthite. Inclusions of galena, cobaltite, and wittichenite were also observed in bornite.

In the quartz veins from the Helle valley, tellurides occur in close association with galena, marcasite, chalcopyrite, molybdenite, and pyrrhotite. These minerals form tiny black metallic grains reaching 2-3 mm in diameter, included in the quartz veins. Under the ore microscope, beautiful myrmekitic textures were observed. Identified tellurides are joséite-B, aleksite, benjaminite, hessite, as well as an unidentified telluride.

All tellurides were examined under the ore microscope, to observe their petrographic textures. They were analysed with an electron-microprobe, to determine their chemical compositions. These compositions fit very well with the ideal formulae of these tellurides, except for the unidentified telluride from the Helle valley, which shows a composition between those of pilsenite and tsumoite. This mineral certainly corresponds to a new species.

In the Helle valley, tellurides are of magmatic origin, and crystallized during the formation of the quartz veins cross-cutting the schists hosting the granodiorite intrusion. In the Salm valley, tellurides formed during the crystallization of primary sulphides, shortly after the peak of Variscan metamorphism that reached 360-420°C / 2 kbar in this area. The occurrence of tellurium-bearing minerals in the Salm valley is due to the presence of cotecule and pseudocotecule in these rocks, for which a hydrothermal origin is now clearly established [4].

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