Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.32284

The post-depositional evolution of seafloor massive sulphides: Insights from thermodynamic modelling

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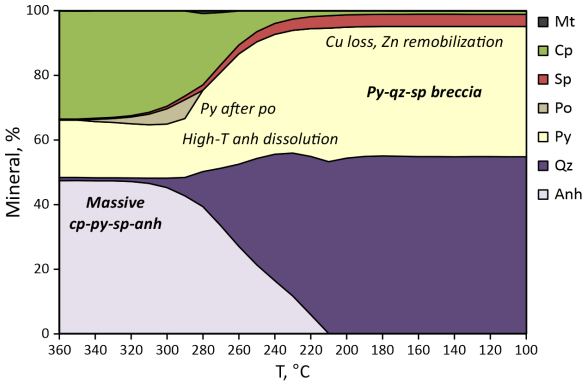
Understanding the mineralogical evolution of seafloor massive sulphide (SMS) deposits from deposition to burial and weathering is essential for evaluating the feasibility of extracting these critical metal resources. We have investigated the factors responsible for the preservation and remobilization of SMS during their reaction with hydrothermal fluids and entrained seawater using geochemical modelling. For this purpose, we used P-T-X parameters closely approximating those of the well-described TAG mound on the Mid-Atlantic Ridge.

In initial models of the interaction of a chalcopyrite-pyrite-sphalerite massive sulphide mound with oxidized seawater, the sulphide minerals were converted rapidly to secondary iron oxides, quartz, and gypsum. As this assemblage is not present at TAG, we propose that prior to reaction with the mound, the infiltrating seawater first reacted with the footwall basalt adjacent to the mound making it less oxidizing.

Reaction of the sulphides with a mixture of this evolved, more reduced seawater and a hydrothermal fluid successfully reproduced the observed range of sulphide lithologies in a regime of progressive cooling. In general, the massive sulphides in the upper regions of the sulphide mound were deposited from higher-temperature, more reduced fluids with a higher hydrothermal fluid component, whereas Cu-poor pyrite-quartz assemblages precipitated from cooler, more oxidized fluids. The figure below shows the result of simple cooling from 360°C to 100°C with a 1:1 water:rock ratio and a 4:1 hydrothermal fluid:evolved seawater ratio.



Our models show that chalcopyrite is precipitated from high-temperature, reduced fluids and dissolves at higher fO_2. A minor proportion of the copper is reprecipitated as secondary Cu minerals, but most of the Cu is removed from the system after dissolution. In contrast, Zn is dissolved in lower-temperature fluids and deposited at lower temperatures, i.e., in cooler parts of the mound. This explains the frequent observation of higher concentrations of Zn as sphalerite on the flanks of SMS deposits. Stabilization of the sphalerite, however, also requires a reducing environment. These results suggest that the greatest preservation of SMS during burial and diagenesis occurs in the absence of oxidizing seawater, i.e., in sulphide mounds protected by an impermeable silicious cap or basaltic flow.