

Oxygen and carbon stable isotope study of carbonates from a sediment-hosted copper ore deposit in the Lubin area (Poland)

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Sediment-hosted stratiform copper (SSC) ore deposits of economic significance are known from various sites around the world. The largest European ore system of this type, the *Kupferschiefer* deposit, is located in the *Zechstein* Basin in eastern Germany and southwest Poland. Economic deposits are restricted to a region straddling the southern margin of the former *Zechstein* Sea and northern margin of the Variscan Orogenic Belt. Present exploitation in Poland is concentrated within several deep mines of the Lubin-Sieroszowice mining district in the Fore-Sudetic Block. On average, these deposits contain 2% Cu (350 Mt metal in total), 0.2 % Pb, 0.1 % Zn, and 60 ppm Ag as well as other metals (Ni, Mo, Co, V, As, Au, Pt+Pd).

Copper mineralization occurs at the contact between Lower Permian (*Rotliegendes*) terrestrial redbeds (sandstones) and volcanics, and Upper Permian (*Zechstein*) marine siliciclastics, shales, carbonates, and evaporites. The mineralization is associated with a redox boundary, along the *Rote Fäule* (RF) – a red, hematitic footwall alteration. Mineralization of Au, Pt+Pd is associated with the RF zone, while Cu-Pb-Zn mineralization is concentrated within the reduced zone. Cu-, Pb-, and Zn-bearing minerals are distributed in zones of several kilometres extent and transgress the host-rock lithology.

The processes of metal enrichment is broadly related to dissolution of copper from source rocks and re-precipitation along a redox boundary between underlying sandstones and a reduced horizon, concentrated on a thin layer of organic-rich shale. Our stable oxygen and carbon isotope analysis of carbonates from the *Kupferschiefer* deposit provides insight into the processes of low-temperature hydrothermal alterations that led to this extreme metal enrichment.

Samples of carbonates (calcite and dolomite) have been collected from the three deep copper mines in Poland (Lubin, Rudna and Polkowice-Sieroszowice) and represent a variety of rock types (dolomites, calcite cements in sandstones and shales, and late calcite veins and vugs) from both oxidized and reduced zones. In total over 80 samples have been analyzed.

$\delta^{13}\text{C}_{\text{VPDB}}$ values vary from -10.10 to +5.52‰ and $\delta^{18}\text{O}_{\text{VPDB}}$ from -13.29 to +3.00‰. Dolomite is characterized by minor variability and isotopically heavier $\delta^{13}\text{C}_{\text{VPDB}}$ (+0.92 — +5.52‰) and $\delta^{18}\text{O}_{\text{VPDB}}$ (-1.57 — +3.00‰) values, regardless the redox zone. In contrast, calcite (from sandstone cements and late-stage veins and nodules) is enriched in lighter isotopes of $\delta^{13}\text{C}_{\text{VPDB}}$ (-10.10 — +2.54‰) and $\delta^{18}\text{O}_{\text{VPDB}}$ (-13.29 — +0.65‰), and the values are more diverse. This suggests the system has not been subjected to pervasive, long lasting hydrothermal alteration, as the dolomites preserve their primary, marine isotopic signature. The meteoric water isotopic composition of calcite cements and late calcite veins agrees with data published by other authors, and is associated with metal-bearing fluids. Further study of fluid-rock interactions based on stable isotope analysis combined with fluid inclusion investigations can bring an important implications for better understanding of the processes of the *Kupferschiefer* ore formation.