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Spatiotemporal zonation of the Freiberg Ag-Pb-Zn-(Cu) epithermal system

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The Freiberg district, located in the eastern part of the Erzgebirge, Germany, hosts one of the largest series of epithermal polymetallic vein deposits in Europe. The present study aims to decipher mineralogical and geochemical zoning on the vein- and district-scale and to constrain the underlying ore-forming processes. Detailed petrographic investigations, geochemical analyses and fluid inclusion studies are carried out on several vertical vein profiles within the Freiberg district in order to develop a district-scale metallogenic model. Five different mineral associations related to Permian magmatic-hydrothermal activity have been recognized within the Freiberg epithermal vein system exhibiting a distinct district-scale and vein-scale zonation. The central part of the Freiberg district is dominated by sphalerite-pyrite-quartz and galena-quartz±carbonate associations with a mean silver grade of 769 g/t (n=65). Similar base metal-rich assemblages also predominate the deepest vein intersections (>300 m below ground level) in the peripheral sectors of the Freiberg District. Vein infill at intermediate depth and peripheral positions in the district is, in contrast, dominated by a sphalerite-Ag-sulfides-carbonate association. This association is marked by an abundance of carbonate gangue and significantly higher silver grades (mean = 4800 g/t; n=25). Veins in the shallowest and most peripheral parts (depth <150 m b.g.l.) of the Freiberg district are dominated by a Ag-sulfide-quartz association with a mean Ag concentration of 4900 g/t (n= 56). Silver is mainly hosted by sulfosalts and fahlore but significant concentrations may also be associated to Ag-sulfide inclusions in galena. Even shallower, the veins comprise a stibnite-quartz association with distinctly low Ag contents (410 g/t Ag, n=4). Fluid inclusions related to the various associations yield consistent salinities in the range of 0.1 to 6.0 % eq. w(NaCl). The homogenization temperature, however, progressively decreases from about 320°C for quartz associated with proximal sphalerite-pyrite-quartz mineralization, down to ~170°C for quartz related to distal Ag-sulfide-quartz association. The general formation of the Freiberg epithermal veins is related to the continuous evolution of a magmatic-hydrothermal system in time and space. Silver deposition is most likely triggered by boiling and associated cooling and volatile-loss, which results in a distinct carbonate horizon (typically at ~500 m depth b.g.l. for peripheral parts) with significantly elevated Ag grades (sphalerite-Ag-sulfides-carbonate association).