Department of Geology Seminar Series Presents

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Genesis of polymetallic vein-type mineralization in the Freiberg district, Germany: Towards new exploration concepts in a historic mining district

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Science 411

Everyone is welcome to attend!

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Genesis of polymetallic vein-type mineralization in the Freiberg district, Germany: Towards new exploration concepts in a historic mining district

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Located in the Variscan metallogenetic province, the Freiberg district in Germany is marked by polymetallic and polystadial vein-style mineralization. Important mineralization stages include: Pb-Zn-Cu-Sn-quartz (I), Ag-Sb-carbonate (II), Pb-Zn-Cu-fluorite-barite (III) and Ag-Bi-Co-Ni-As-carbonate (IV) assemblages. Stages (I) to (III) have been of particular relevance for mining in a district that celebrated its 850'th anniversary in 2018 and which has given rise to some of the defining early work in the then emerging discipline of economic geology (e.g., Werner, 1791 and von Cotta, 1855).

When production in the Freiberg District ceased in 1967 it was for political reasons, with significant resource and exploration potential remaining. Efforts by junior companies in recent years to explore this potential have been stifled by the lack of modern metallogenetic concepts for the district. To start filling this gap, we carried out Rb-Sr geochronology and trace element analyses of sphalerite from different mineralization stages, in combination with microthermometric studies on fluid inclusions in ore and gangue minerals. Furthermore, we carried out thermodynamic reaction path models to better understand mineral zoning in the Freiberg district.

Rb-Sr geochronology of sphalerite reveals that the early Pb-Zn-Cu-Sn-quartz and Ag-Sb-carbonate assemblages are both of Permian age (276 ± 16 Ma), coinciding in time with extensive bimodal magmatism and post-Variscan crustal reorganization. These stages show distinct lateral zonation in relative abundance and metal content, with increasing Ag-Sb-S-carbonates in the distal parts of the district. Fluid inclusions in ore and gangue minerals of stages I and II are marked by very low salinities between 1 and 5 % eq. w(NaCl), suggesting a magmatic affiliation. In the centre of the Freiberg district boiling assemblages with trapping temperatures (T_{trap}) between 320 and 350 °C are recognized (I), while in the distal areas T_h are slightly lower (280 - 300 °C) and boiling assemblages notably absent (I). Fluid inclusions related to stage II show decreasing T_h (280 - 200 °C), indicating significant cooling.

Pb-Zn-Cu-fluorite mineralization, in contrast, formed during the Early Cretaceous (121 ± 4 Ma) as suggested by Rb-Sr geochronology of sphalerite. Fluid inclusions reveal a lower T_h (~120°C) and high salinities (17 to 24 % eq. w(NaCl + $CaCl_2$)) of the ore-forming fluids. Systematic variations of Na/Ca ratios and S-isotopes indicate fluid mixing as the major ore-forming process.

Based on these arguments it seems most likely that the Permian ore stages I and II are related to a large (30 x 20 km) magmatic-hydrothermal system - one of the largest currently known in Europe. Silver precipitation is not only restricted to boiling horizons, but occurs over very large vertical extent (at least 500 m), showing distinct mineralogical and geochemical analogies to the very fertile low- intermediate sulphidation systems of Mexico (e.g. Fresnillo) and Bolivia (e.g. Potosi). In contrast, Early Cretaceous Pb-Zn-Cu-fluorite veins are related to the opening of the northern Atlantic - similar to many fluorite-barite deposits of Europe. They formed in an extensional setting, in the basement below a sedimentary basin.

References cited:

Werner, A. G. (1791) Neue Theorie von der Entstehung der Gänge. Gerlachische Buchdruckerei. 305 pages.
von Cotta, B. (1855) Die Lehre von den Erzlagerstätten. Engelhardt Verlag, Freiberg. 326 pages.