Structural Controls on Epithermal Ag-Pb-Zn Vein Systems in the Eastern Erzgebirge, Germany

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The Freiberg District in Saxony, SE Germany, is home to one of Europe's most historically significant Ag-Pb-Zn vein systems, yet its structural controls and tectonic setting have long remained poorly described. In the present study an integrated structural geology approach was applied to characterize the tectonic controls on this epithermal system and the distribution of ore within it. The analysis reveals that NW-SE trending second and third-order dextral fault systems parallel to the Elbe Shear Zone, a major fault zone located to the East of the Freiberg District, likely bound the main mineralized areas. NE-SW trending dilation (normal) faults linking these dextral systems created persistent dilational zones during transtension related to late- to post-orogenic stages of the Paleozoic Variscan Orogeny. These structural corridors localized fluid flow and possibly felsic magmatism, serving as key fluid pathways and trap sites. Paleostress data support regional transtension and localized extension consistent with syn-mineral fault dilation and vertical fluid migration.

Moreover, structural reconstructions suggest that repeated fault reactivation during Permian to Mesozoic, mostly extensional events, contributed to local remobilization and preservation along significant lithospheric structures (faults and shear zones). Importantly, our structural reconstructions highlight the influence of fault linkage, rheological contrasts, and post-Variscan reactivation on mineral system evolution, providing insights for targeting still-covered extensions of the Freiberg system. These results also show how reinterpreting classical districts through a modern structural geology and mineral systems lens can unravel the tectonic architecture behind ore-forming processes and open new exploration frontiers in Europe and beyond.