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Geochemical Controls on the Distribution of Deep-seated Zn-Pb Mineralization Hosted by Zechstein Carbonate (Ca2) Gas Reservoirs in the North German Basin, Germany

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Abstract

Deep-seated hydrothermal Zn-Pb mineralization in the North German Basin (NGB) is restricted to peripheral parts of the central and western Lower Saxony Basin (LSB), where it was drilled at depths of about 2.7-3.6 km. The mineralized intervals are hosted by Zechstein carbonate (Ca2), which is one of the highest quality gas reservoir rocks in the NGB. Natural gases stored in these reservoirs contain anomalously high concentrations of hydrogen sulfide, which is indispensable for sulfide precipitation. Although it is explicit that the H_2S was sourced from Zechstein evaporites, the generation mechanisms are yet not fully understood. Our fluid inclusion and isotope study indicates that low temperature (~125-160°C) methane-dominated thermochemical sulfate reduction (TSR) was the most likely process that produced considerable amounts of H_2S in Ca2 reservoirs in the Pompeckj Block (PB).

Origin and metal contents of metalliferous fluids, which mixed with available H_2S in the LSB, are not known. Moreover, the metal budget of fluids is not well constrained in many European sediment-hosted ore systems. To address this knowledge gap we investigated halogen and metal contents in fluid inclusions hosted in fracture-filling minerals from Zechstein and Carboniferous strata. Our data shows that metalliferous fluids originated in majority from evaporation of seawater and to a lesser extent from salt dissolution. Fluid inclusions from Upper Carboniferous fracture-filling quartz show the highest Zn and Pb contents in the fluids which migrated during the basin inversion stage. In the LSB the contents of metals reach up to thousands of ppm's and are comparable with concentrations in fluid inclusions from fracture-filling minerals in Carboniferous strata and Rotliegend brines in the North-Eastern German Basin (NEGB). The investigated fluids are much more enriched in metals relative to compositions of modern basinal brines suggesting efficient metal enrichment processes at depth. Beside base metals such as Zn and Pb the ore-forming fluids are also enriched in trace elements such as B, Mn, Rb, Sr, Cs, Ba, Tl and Li. Elevated concentrations of certain critical metals can also be observed, namely Ge at levels of up to thousands of ppm's and in lesser amounts Pd, Sb and Bi.

In conclusion, the enrichment of metalliferous fluids at depth (absent in the PB) as well as CH_4-dominated TSR reactions producing hydrogen sulfide (absent in the NEGB) in Zechstein carbonate exerted major geochemical controls on deposition and distribution of Zn-Pb sulfide mineralization in the NGB.