The Laisvall and Vassbo sandstone-hosted Pb-Zn deposits along the eastern front of the Scandinavian Caledonides: An example of phosphorous-rich sulphide-mineralized Cambro-Ordovician sour gas reservoirs

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The Laisvall and Vassbo sandstone-hosted Pb-Zn deposits along the eastern front of the Scandinavian Caledonides: An example of phosphorous-rich sulphide-mineralized Cambro-Ordovician sour gas reservoirs.

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Stratabound, non-stratiform, epigenetic galena-sphalerite mineralization in Ediacaran–Cambrian sandstone, including the previously mined deposits at Laisvall and Vassbo, occurs along the eastern front of the Caledonian orogen in Sweden and Norway [1, 2, 3, 4]. The sandstone is part of a transgressive siliciclastic sedimentary sequence that at Laisvall and Vassbo rests unconformably on top of Proterozoic crystalline basement beneath the Caledonian thrust nappes. In the present study, a detailed paragenetic sequence has been established including several mineral phases, locally abundant, that had not been described earlier. The pre-ore stage minerals at Laisvall are typical diagenetic cements. Quartz and K-feldspar overgrowths rimming pre-existing detrital quartz and K-feldspar grains, respectively, were recognized in optical and SEM-cathodoluminescence studies. The K-feldspar overgrowths are barium-rich [5]. These authigenic overgrowths post-date the deposition of clay cements around detrital grains but pre-date anatase, xenotime with micron-scale galena inclusions, pyrite, and locally up to 5% fluoroapatite. Pre-sphalerite cementation was completed by precipitation of calcite, and in places fluorate and/or barite. Sphalerite precipitated together with fluoroapatite and sericite followed by galenat Ba-micaž Ba-K-feldspar sericite. Both sphalerite and galena partly replaced earlier pyrite. At Vassbo, barite post-dates sphalerite and galena, while fluoroapatite nucleated with sphalerite around fecal pellet-like structures made of biogenic apatite. Intimate intergrowth of solid organic matter with sphalerite and barite noticed at mesoscopic scale at the Laisvall deposit was described in detail under SEM.

Most samples yield positive sulphur isotope ratios for galena and sphalerite at both deposits (δ34Ssulphide +20 to +35 ‰) indicating thermogenic sulphate reduction (TSR), with oxidation of organic compounds by HSO4⁻ [6] of Cambro-Ordovician marine origin (δ34Sseawater +27 to +33 ‰, [7]). The sulphur isotope signature of sulphide may be explained by Rayleigh fractionation in a sulphur-starved system. The paucity of ore-stage calcite is suggestive of conditions favouring CO₂ production by TSR that inhibit carbonate cementation in siliciclastic reservoirs [8]. In addition to (i) TSR-produced H₂S (δ34Ssulphide +28 to +35 ‰) as main sulphur source, the present study identified two more potential sources of reduced sulphur that could explain the total range of δ34S values (δ34Ssulphide +12 to +35 ‰) at both deposits: (ii) Reduced sulphur brought up along feeder faults [4] from sulphides in the basement in low pH metal-bearing fluids (represented by δ34Spalherite= +2.5 ‰); and (iii) H₂S with sulphur isotope ratios most probably derived from pyrite in overlying black shale brought down along faults to the sandstone (represented by δ34Spyrite -13 to +15‰). Local quartz dissolution and staurolite formation prior to sphalerite precipitation is spatially associated with Zn-Pb sulphides. Two complementary processes may explain this local secondary porosity: (i) Dissolved organic acids (probably produced by the oxidation of organic compounds during TSR), as well as K⁺ and Ba²⁺ (cations known for their frequency of solvent exchange, K_w) lower the activation energy for quartz dissolution [9, 10, 11]; and (ii) quartz dissolution due to gas pressure increase in a hydrodynamically closed reservoir [8].

References: