Diagenetic controls on the formation of the Anarraaq sediment-hosted Zn-Pb deposit, Red Dog district, Alaska, USA

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The Anarraaq deposit is located approximately 10 km northwest of the Red Dog mine, one of the world's largest producers of zinc. At Anarraaq, ore stage mineralization overprints siliceous, organic-rich mudstone which contains abundant pre-ore pyrite and barite layers and nodules. Based on textural observations and S and O isotopic data, we interpret the early pyrite and barite to have formed in shallow marine sediment in response to a localized flux of methane- and barium-bearing diagenetic fluid. Barite is almost ubiquitously replaced by quartz, sulfide, and lesser calcite and pyrobitumen. Textural evidence indicates that ore-stage sulfides crystalized in open space after near-complete barite dissolution. In the uppermost part of the deposit, sulfides preferentially replace barite over the surrounding intensely silicified mudstone.

The spatial coincidence between local accumulations of diagenetic barite ± pyrite and overprinting zinc mineralization at Anarraaq is also characteristic of the Red Dog Mine Area deposits. We propose that a localized flux of methane produced diagenetic conditions which resulted in the host rock being an effective trap for hydrothermal metals. Bacterial sulfate reduction (BSR) coupled to sulfate-driven anaerobic oxidation of methane (SD-AOM) can proceed at rates orders of magnitude higher than BSR alone. Furthermore, diagenetic barite formed just above the upward-migrating methane front would eventually dissolve in the advancing methane-rich pore waters. The resulting open space would significantly increase the porosity-permeability of the host mudstone. Although diagenetic carbonate is a common product of SD-AOM, there is no direct evidence for its presence in the Anarraaq sulfide deposit; this may be because it was completely replaced during ore-stage mineralization. Diagenesis of amorphous silica phases and/or remobilization of quartz may have created additional porosity at depth in the deposit and formed a siliceous cap that served to trap hydrothermal fluids within the diagenetic sediment.