

New visions in the genesis of roll front uranium deposits

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Ore-stage pyrites in roll front uranium deposits across the world (e.g., in Kazakhstan, North China, South Australia and U.S.A) share remarkably similar evolutions of their textures, trace element and $\delta^{34}\text{S}$ signatures. Based on the study of a typical roll front deposit located in North China (i.e., Bayinwula), we demonstrate that the features of ore-stage pyrite, revealed in detail via high-resolution trace element mapping by LA-ICP-MS, reflect the internal dynamic evolution of the biogeochemical processes responsible for sulfate reduction, rather than externally-driven changes in fluid or sulfur sources through time. Upon percolation of oxidizing meteoric waters into regionally primary reduced sandstones, roll front systems (RFS) become self-sufficient with the systematic repetition of their activity cycle. Reducing-dominant conditions at the redox interface favor the formation of biogenic framboidal pyrite by bacterial iron and sulfate reduction ($\delta^{34}\text{S}$ from -30.5 to -12.5 ‰), which is also responsible for the uranium mineralization. When the redox interface becomes oxidizing-dominant, RFS enter in a translation stage characterized by the re-oxidation of reduced sulfur minerals inducing an increased supply of sulfate and metals in solution to the bacterial sulfate reduction (BSR) zone. The translation of the roll front is marked by increased rates of the BSR associated with the precipitation of variably As-Co-Ni-Mo-enriched concentric pyrite (up to 10,000's of ppm total trace element contents) with moderately $\delta^{34}\text{S}$ values (from -13.7 to -7.5‰). A final stage of pyrite cement with low trace element contents and heavier $\delta^{34}\text{S}$ signature (from -6.9 to +18.8‰) marks the end of the roll front activity cycle. It corresponds with a “run-away” stage of the BSR, which ends the cycle by filling pore spaces and depleting the nutrient supplies for the sulfate-reducing bacteria. After the transposition of the RFS geochemical-mineralogical zoning downward the reservoir, this activity cycle can start over again.

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