

The Swamp Fluid, Biogenic Mineralization Model for Tabular Sandstone-Hosted Uranium, Sahara Mine, Emery County, Utah, USA

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This study integrates geological, geochemical, mineralogical, and microbiological data from the Sahara uranium deposit (Salt Wash Member, Morrison Formation, Emery County, Utah) to propose a new genetic framework for tabular, sandstone-hosted uranium deposits: the Swamp Fluid, Biogenic Mineralization Model. The model links structural trapping along fluvial systems, creating swamps; humic fluid mobilization of uranium from volcanic ash, subsequently descending into the buried channel aquifers; density-stratified aquifer chemistry along a two-fluid interface, mid-aquifer; and microbially-mediated mineralization at the mid-aquifer interface.

Bentonitic swamps formed where transverse faults disrupted fluvial channels, promoting accumulation of volcanic ash and organic-rich sediments. Humic acids generated in these environments leached uranium and associated metals, which were expelled during burial into adjacent channel sandstones and focused into structural lows, particularly where channels intersected collapse-structure faults associated with deep Paradox Basin evaporite dissolution. Airborne GeoTEM data delineate this buried hydrologic framework and identify favorable structural targets.

Mineralization initiated when sulfate-rich brines entered the reducing, humic-rich aquifers upon compaction of sulfate-containing units below, establishing a density-stratified two-fluid system. At the interface, sulfate-reducing bacteria (SRB) and methanogenic archaea mediated sulfate reduction and humic acid degradation, releasing sulfide, Fe^{2+} , and U^{4+} . Iron monosulfide seed crystallites, formed within microbial cells, nucleated pyrite and greigite via semi-inorganic nucleation, where organically generated constituents combined inorganically. Methanogenesis of humic acid released reduced uranium that combined with silica to form coffinite.

Sustained mineralization reflects a feedback cycle in which calcite cementation above the two-fluid interface during mineralization displaced humic fluids downward into the interface, maintaining metal supply. Vertical stratification of uranium- and vanadium-rich humates produced compositional zoning expressed by various secondary uranium and vanadium minerals formed during subsequent oxidation.