Nanophase coffinite in organic-rich sedimentary ore deposits: implications for uranium biogeochemical cycling

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The potential for complex metal-organic interactions involving uranium in sedimentary environments has long been recognized. Organic matter can influence U distribution, stability, mineralization and redox state, and hence control the form and mobility of U in the subsurface. Less is known about the roles of microbes in such interactions. The structure and composition of colloidal and nanoparticulate U phases associated with sedimentary organic matter in low-temperature U ore deposits have remained obscure. Here we present direct evidence from synchrotron x-ray spectroscopy and transmission electron microscopy of U speciation, redox state and phase within an ancient sedimentary U ore deposit (Mulga Rock, Western Australia).

Uranium was found as diffusely distributed nanocolloidal phases within organic matter, as nanoparticulate coffinite and uraninite within ellipsoids resembling mineralized microbial cells, and as nanoparticulate aggregated rims formed around framboidal pyrite (Fig. 1). Collectively, our observations demonstrate that organic matter and microorganisms have localized reductive nanoparticulate U precipitation in ancient sedimentary U ore deposits, and that the molecular signatures of degraded organics and microbial biomass, along with co-mineralization of framboidal pyrite in organic matrices, may provide a new biogeochemical "halo" for U exploration. Furthermore, our results show that *in situ* chemical extraction operations will require a multi-faceted approach to recover U from oxide and silicate phases, as well as consider the potential for significant acid mine drainage generation via oxidation of pyrite framboids.

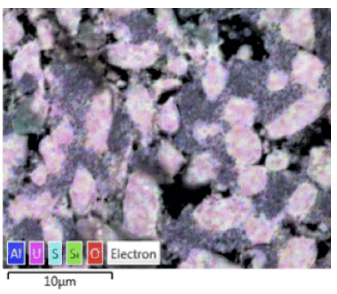

Fig. 1. SEM EDX elemental map of sedimentary uranium ore deposit, displaying nanoparticulate coffinite as microfossils (pseudomorphs?) associated with framboidal pyrite.