Speciation of uranium products formed during *in situ* biostimulation of the Old Rifle, CO aquifer

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Uranium bioremediation strategies focus on the addition of a reduced carbon source to stimulate the growth of indigenous microbial communities in subsurface sediments. This growth leads to conditions that promote the reduction of soluble U(VI) species in groundwater to relatively insoluble and immobile U(IV) species. Field studies to date focus on U(IV) products formed in deep sulfate reducing conditions, which have been identified as uraninite (UO_{2+x}), monomeric or mononuclear U(IV) species that lack crystal structure and are associated with biomass or iron-bearing minerals, and phosphate coordination polymers to which U(IV) is bound. However a systematic molecular-to-pore scale characterization of changes in U(IV) product speciation and stability as bioremediation proceeds is not extant.

In this study, we deployed sediment reactors into a groundwater well at the Old Rifle, CO aquifer during biostimulation with acetate. Sediments were harvested as the aquifer progressed through metal- and sulfate-reducing regimes, and were characterized by spectroscopic, microscopic, wet chemical, and microbiological techniques. U(IV) product local structure and reactivity exhibits little apparent change despite large changes in redox state, accumulated uranium in the sediments, and microbial community structure. This result suggests that similar U(VI) reduction mechanisms may be operating throughout the biostimulation campaign.

The link between the origin of organic matter and GEMS in extraterrestrial materials

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There appears to be a genetic relationship between chondrite matrices, interplanetary dust particles (IDPs) and cometary material. All are dominated by fine-grained, crystalline silicates (predominantly olivine and pyroxene) with similar ranges of properties, along with amorphous silicates or GEMS (glass with embedded metal and sulfide) and organic matter. They also contain circumstellar grains (stardust), many of which are GEMS-like.

There have been longstanding debates about whether GEMS and the organic matter are interstellar or solar in origin, although these are rarely linked. Interstellar silicates are almost entirely amorphous. Therefore, the crystalline material must be products of high temperatures in the nebula. In primitive materials, crystalline silicates into which Na, Al, Ca, etc. could have gone are rare, and they are presumably in GEMS that formed along with the crystalline material. Organic matter is abundant in the ISM, but would have been destroyed during formation of the crystalline silicates. If all GEMS are also high-T nebular products, then almost no ISM dust can have survived and the organic matter in chondrites, IDPs and comets must also be solar in origin. Hence, it is of paramount importance to determine whether or not most GEMS are solar or interstellar [1].

The fraction of ISM silicate grains that are circumstellar is estimated to be ~0.3% [2]. Therefore, the stardust in chondrites/comets should have been accompanied >100 times as many ISM grains. 1-6% of GEMS are stardust [3], which suggests that the remaining GEMS must be interstellar. Yet the crystalline silicates require that a significant fraction of GEMS are solar. We will use meteoritic and IDP data to try to resolve the conflicting estimates of the abundances of solar and interstellar GEMS. This will provide important constraints on the production and processing of dust in the ISM, and on the origin of organic matter in primitive extraterrestrial materials.

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DOI:10.1180/minmag.2013.077.5.1