

How was mercury sequestered in an ancient ‘greenhouse climate’ lake?

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Toxic metals are a common occurrence in organic-rich rock, and it is widely accepted that biogenic processes played a role in metal enrichment. However, exactly when and what processes effectively sequester toxic metals from surface environments for millions of years, and the composition and distribution of organic/mineral phases hosting the metals, remains uncertain. When better understood, the processes could then be adapted to the present-day clean-up of land and water bodies polluted by industrial activity; the distributions could enable separation of the metals from the oil shale during any future extraction and processing of the petroleum in order to avoid polluting modern environments.

Previous geochemical analyses of Green River Formation (GRF) strata in the Uinta and Piceance Creek basins (Utah and Colorado) have identified high concentrations of toxic heavy metals, including mercury, in beds of oil shale. It is interpreted that these beds originated from the accumulation of organic detritus in sodic-carbonate dominated, low sulfate, high alkalinity “Lake Uinta”, during the Early Eocene Climatic Optimum.

An optical petrography, LA-ICP-MS, XRF, and SEM-EDS study of a ~4.75 mm x 70 µm filamentous structure from a GRF oil shale has identified a complex interweaving of carbonaceous material and diagenetic, blocky carbonate fluorapatite (CFA). The CFA also encloses rhombic crystals of ferroan dolomite and micron to sub-micron scale, electron-dense metal sulfides, mostly rhombohedral crystals of HgS (cinnabar). Larger ferroan dolomite crystals and various metal sulfide particles, including spicular FeS₂, are present external of the filament, but HgS is absent.

Based on additional organic geochemistry, and known morphology and behaviour of modern microbial species, the filament is interpreted as fossilized *Beggiatoa*. It would have inhabited the soupy shallow substrate beneath the alkaline Lake Uinta during a lake regression. Evaporative pumping promoted dolomite precipitation, and the waters also became more sulfidic, promoting FeS precipitation. In alkaline lake waters, HgS is soluble, but microbial metal detoxification, by oxidation of alkaline-soluble Hg and S complexes, may have caused intra-cellular precipitation of HgS. Death of the microbe would have released polyphosphates resulting in P-saturation and crystallization of CFA (or precursor), trapping the HgS before it dissolved and re-entered the porewaters.