Early diagenetic phosphate and tungsten-metabolizing coccoid microbes interpreted from an Eocene lacustrine oil shale

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Oil shale in the Uinta Basin of eastern Utah, USA, is present in 8 organic-rich units of the Eocene Green River Formation (upsection from R1 to R8). Previous analyses of oil shale from R8 have identified intervals of early diagenetic carbonate fluorapatite (CFA) with zoned enrichments of rare-earth elements and actinides.

Organic geochemical analyses of R8 oil shale indicate deposition in a stratified lake with tiers of planktonic algae, nitrate- and sulfate-reducing bacteria (SRB) and deep water or substrate methanogens. Scanning Electron Microscopy of oil shale from both outcrop and core also may have identified fossilized examples of some of these microbes, in the form of microcrystalline CFA arranged as globular structures in clusters of up to 80. Biogenicity is suggested by features such as (i) organic stringers draping the clusters (geological context), (ii) similar morphology and limited size range of individual globules to that of coccoid bacteria or archaea (biological morphology), and (iii) intergrown pairs indicating binary fission (biogenic process).

Electron-dispersive spectrometry and microprobe analyses have also indicated the presence of tungsten (W) in some clusters, specifically those located in or adjacent to organic-rich laminae and stringers (the organic-rich material does not record W). This could also indicate biogenic process. Such stringers are likely to be the most anoxic, high sulfide, low-molybdenum (Mo) availability horizons in the shallow substrate. Under such conditions, several types of microbe, including SRBs, are able to metabolize with W- rather than Mo-enzymes.

Shallow substrate decay of the organic stringers, potentially also of lysed coccoid microbes, would have released phosphate and may have brought porewaters to supersaturation, inducing bio-mineralization. Microbial cell walls also may have provided the nucleation surfaces that initiated CFA precipitation. While it remains uncertain as to whether the W is incorporated into the apatite lattice, adsorbed on the CFA, or still associated with remnant organic matter in the globules, the research concludes that microbes may have influenced local geochemical conditions, which promoted the natural sequestration of phosphorus and toxic metals from a lake environment.