Arsenic metabolism and cycling in early Earth oceans

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In extreme environment such as hypersaline lakes lacking oxygen, arsenic (As) offers an alternative to oxygen or sulfate for microorganisms to survive. Phylogenetic studies indicate that microbial As metabolism is ancient and may have emerged prior the Archaea/Bacteria split more than 3.4 billion years (Ga) ago. Although the antiquity of the As(III) oxidation as a bioenergetic mechanism has been suggested a decade ago, no support for As-based life has been found in Archean rocks until now.

Here, we present the results of the study of the distribution, inter-element correlation and speciation of arsenic in 2.7 billion years old stromatolites from the Tumbiana formation (Pilbara, Australia) at different scales, from the cm- to the nm-scale using a combination of Synchrotron Radiation X-ray Microfluorecence (SR-μXRF), Synchrotron Radiation X-ray Absorption Near-Edge Structure (SR-μXANES) and Raman spectroscopy.

Although, the distribution of As is governed by the remobilization and concentration as nugget-type features caused by diagenesis and metamorphism, we identified microbial carbonaceous remains composed almost exclusively of As. We associated this distribution pattern to the occurrence of a complete As cycle at this site, with As(III) oxidation and As(V) reduction by microbes living in permanently anoxic conditions. These results also suggest that a complete As cycling could have been present in marine environments several hundred millions years before the Earth's oxygenation.