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Arsenic enrichments in active microbial mats of the Dead Sea shores as analog of potential Archean trace metal biosignatures

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The vast majority of prokaryotic organisms produce Exopolymeric Substances (EPS) constituting biofilms. Biofilms are ubiquitous, harbor element (including metals) binding properties and can be the matrix for orgamineralizations. These properties place fossilized-EPS among the most ancient traces of microbial life on Earth. They form sedimentary structures diagnostic of biological activity in some of the oldest sedimentary rocks of the Archean. However, the metabolisms hosted by such ecosystems remain poorly understood albeit available molecular, isotopic or fossilized signatures. New proxies that could help characterizing microbial ecosystems and better understand the coevolution of the geosphere and the biosphere are therefore needed.

We here describe trace metal signatures of a modern, arsenic-rich microbial mat fueled by oxygenic and anoxygenic photosynthesis as an early ecosystem analog, to better understand how microbial mats and their chemo-sedimentary signatures can be preserved in the Archean geological record. We coupled in-situ imaging of the mat from a modern Dead Sea spring system with Raman spectroscopy, X-ray mapping, metagenomics data and chemical analyses. Arsenic enrichments in the anoxygenic photosynthetic layer of the mat reached a 10'000-fold level as measured by µPIXE, and was associated to Mg-Si-rich EPS. The latter ultimately mineralized into aragonite with a co-enrichment of Sr, Mn and Mo. At the mat scale, the mineralized zone (rich in Fe, Sr and Ca from authigenic calcium carbonates and detrital clay) is located above the As-enrichment layer, in association with Mn. Metagenomics data support the potential for arsenic oxidation and reduction throughout the system and synchrotron-based speciation analyses shall confirm the links between elemental enrichments and microbial metabolic pathways. The collective dataset describes a chemically dynamic microbial mat where microbial activity, EPS chemical affinity and environmental processes lead to specific organic and mineralized chemical signatures, which could be linked to metabolic activity.

Comparing this study to a well-recognized and characterized arsenic-rich microbial system of the Archean, such as the stromatolitic units of the Tumbiana Lake (2.72 Ga, Pilbara, Western Australia) provides chemical insights into the transformation of microbial mats to their fossilized counterparts at the microscale, to further validate the promises of metal biosignatures for reconstructing Archean ecosystems.