Metalheads of the Early Earth: Biologically Mediated Accumulation of Transition Metals and Metalloids in 3.5 billion–year–old stromatolites

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Stromatolites of the 3.5 billion–year–old Dresser Formation (Easten Pilbara, Western Australia) are arguably the oldest convincing evidence of life on Earth. However, these putative microbial edifices have not been free of contention in discussions of their possible biogenic origins, because weathering has generally inhibited the preservation of reliable biosignatures, as well as original chemistry and mineralogy. Here, we report on exceptionally preserved, sulfidized (mainly pyrite and sphalerite) stromatolites from Dresser Formation drill cores. High-resolution elemental mapping and precise in situ analysis of the sulfide for the concentrations and spatial distributions of transition metals (Cr, Mn, Fe, Co, Ni, Cu, Zn, Mo, Ag, Au, Hg and Pb) and metalloids (As, Sb and Te) show that the majority of these sedimentary and hydrothermally sourced elements are concentrated in wrinkly layered and digitate/dendrolitic microfabrics of the stromatolites. In addition, micro-textural and mineralogical characterization reveals that these elements reside in texturally distinctive organic matter–rich porous pyrite hosting probable biofilm remains. Hence, we interpret these diagnostic enrichments of transition metals and metalloids to be the product of microbial utilization, as well as binding of these elements to the organic matter of microbial communities, either during stromatolite growth, or thereafter, during burial and degradation. However, in this scenario, post–depositional processes have accounted for the accumulation of some elements, in particular As and Mo, which are rather concentrated in pyrite showing textural evidence of secondary origins. Collectively, our data illustrate that even in some of Earth's oldest known stromatolites, characterizing the concentrations and distributions of transition metals and metalloids unveils diagnostic element enrichment patterns driven by biological activity.