Arsenic as a Chemical Biosignature in Microbialites: Does Accretion Mechanism Matter?

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Project Objective

- Identify the mechanisms of arsenic incorporation in microbialites formed by a range of accretion modes within Hamelin Pool, Western Australia.

Project Rationale

Microbialites have dominated > 80% of the fossil record of Earth history, colonizing a variety of depositional environments. Throughout Earth history, the abundance of microbialites and the dominant mode of accretion have changed over time. Some modern microbial communities construct weekly lithified sheet mats where the production of organic matter exceeds mineralization. In relatively rare instances, modern microbial mats form fully lithified structures with topographic relief. Some modern structures are formed by mats that trap and bind sediments from their environment, while others accrete through microbial precipitation of micrite. In contrast, Precambrian discrete microbial buildups accreted mainly through direct precipitation of microbial micrite. Variations in microbialite deposits (discrete microbial buildups versus sheet mats) were recently hypothesized to reflect differences in the dynamic balance between environmental and microbial forces (Reid et al., 2024). This equilibrium determines the proportion of different microbial products, including organic matter, micrite, and trapped and bound grains. The Microbialite Balancing Act (MBA), a new conceptual model presented by Reid et al. (2024), aims to define the dynamic configurations of forces and products that ultimately determine the accretion mode of microbialites.

Driven by interactions between environmental and microbial forces, chemical elements are transferred between the MBA products. These products, especially the carbonate fraction, can act as geological archives for chemical elements and the biogeochemical reactions in which they participate. Arsenic is incorporated in accretionary products associated with various MBA configurations, producing microbialites ranging from sheet mats to discrete microbial buildups. For example,

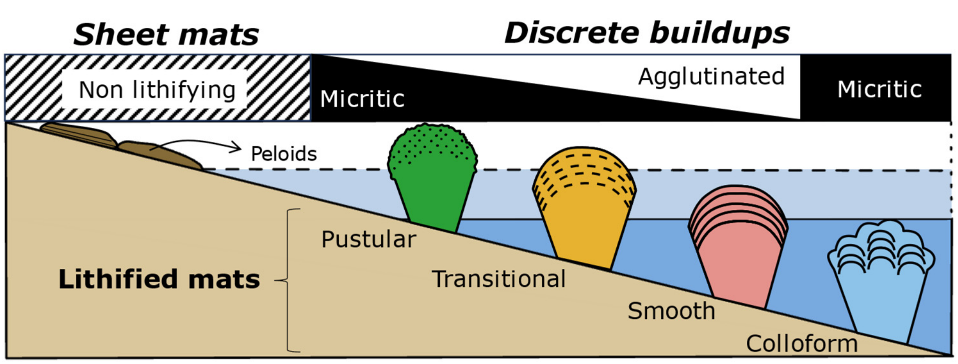

Figure 1: Growth model for microbialites in Hamelin Pool. After Vitek et al. (2022)

arsenic was noted as an element of biogeochemical interest in the 2.7 By micritic microbialites of Tumbiana (Sforna et al., 2014), the modern sheet mats in lake La Brava (Visscher et al., 2020), and the agglutinated microbialites of Hamelin Pool (Pollier et al., 2022). Therefore, arsenic may provide insight into the co-evolution of life and the environment in all microbialite accretion modes present in Earth's history. However, it is not clear how different configurations of the MBA, and thus different modes of microbialite accretion, influence the partitioning of arsenic within microbialite reservoirs, including organic matter and carbonate minerals.

APPROACH

Here we aim to quantitatively define the incorporation of arsenic into microbialites formed by variable accretion mechanisms in Hamelin Pool. Using a mass-balance approach, we will quantify [As] in seawater, sediments, and three distinct types of microbialites: 1) discrete microbial buildups (DMB) built by direct precipitation of microbial micrite; 2) DMB built by the trapping and binding of sediments; and 3) unlithified sheet mats that produce micritic grains. Sequential leaching experiments will isolate each microbialite reservoir for elemental analysis on an Agilent 8900 ICP-QQQ. To separate contributions from precipitated microbial micrite versus trapped and bound grains in concentrating arsenic in the bulk carbonate fraction, we will employ a mixing model.

SIGNIFICANCE

More than half of the world's conventional petroleum reserves are found in carbonate rocks, which include microbial carbonates. Variations in accretion mechanisms introduce heterogeneity in the petrographic characteristics of microbialite reservoirs, and the extent to which this heterogeneity impacts the geochemical record of the deposit remains unclear. The results of this study will address this knowledge gap by quantifying the impact of accretion mechanisms on the incorporation of arsenic into agglutinated, micritic, and non-lithifying microbialites from Hamelin Pool. Thus, our study will clarify interpretations of chemical biosignatures in microbial reservoirs deposited by accretion mechanisms that alternate through space and time.

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