IMPACTS OF TAPHONOMIC EVOLUTION ON CHEMICAL BIOSIGNATURES IN MICROBIALITES

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PROJECT OBJECTIVES

- Determine which elements are transferred from microbial organic matter into carbonate minerals during early taphonomy.
- Develop a workflow to constrain the preservation mechanism of chemical biosignatures within microbialite systems.

PROJECT RATIONALE

Microbialites dominate the fossil record for over 80% of Earth history and represent significant components of carbonate reservoirs around the world. Various microbial metabolisms contribute to microbialite lithification, each of which can be based on biogeochemical cycling of elements capable of supporting life. These metabolisms can leave evidence of their existence in the geochemistry of accreted microbialites. Under certain conditions, these geochemical biosignatures can be preserved in the geological record and serve as archives of the dynamic interplay between microbes, minerals, and their environment (Sforna et al., 2014). However, because significant changes in the geochemical composition of microbialites occur during early taphonomic modification and later diagenetic alteration (Sforna et al., 2017), establishing the mechanisms driving the geochemistry of ancient microbialites can be challenging.

Key insights from our previous work indicated that Arsenic (As), involved in the microbialite-building communities of the Hamelin Pool, Australia, is initially incorporated into microbial organic matter before being transferred to the carbonate fraction of the microbialites during early taphonomic evolution (Pollier et al., 2022). Our new data suggest that additional elements, such as S, Mg, and Sr, experience a similar taphonomic transfer as As, while others exhibit the opposite behavior (Fig. 1). Taphonomic transfer likely impacts preservation of elemental concentration, and thus their interpretation as chemical biosignatures. A key implication is that some biosignatures will be enhanced by taphonomy, while others may result from non-biological geochemical

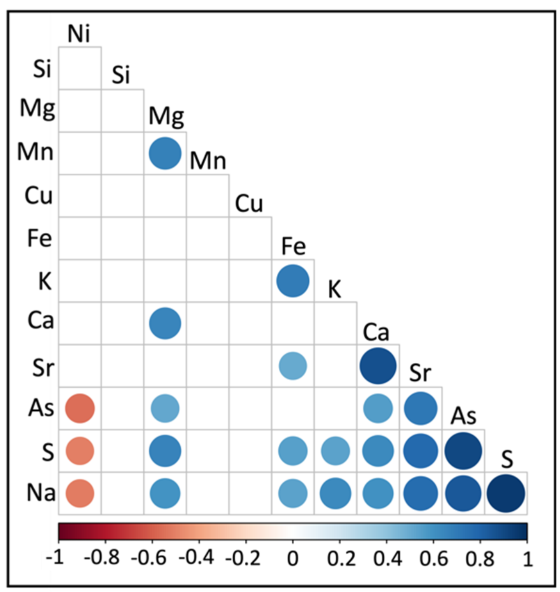

Figure 1: Correlogram showing significant correlation coefficients (R) of bulk elemental composition of Hamelin Pool microbialites. Circle size indicates correlation strength.

artifacts incorporated after accretion of initial architecture. Further, some biosignatures may also be lost during early taphonomy. Consequently, improved characterization of the origin, timing, and rate of taphonomic transfer between organic matter and carbonate mineral fractions, as well as the ultimate fate of a biosignature, is needed to better understand the geological record.

APPROACH

Hamelin Pool, Western Australia is an ideal living laboratory to address the challenge of defining the impacts of taphonomic alteration on chemical biosignatures. Taphonomic modification of microbialites has already been characterized petrographically (Vitek et al., in review) and subdivided into two successive stages: (1) precipitation of micrite along laminations and around clots; and (2) precipitation of aragonitic marine cement infill. Thus, Hamelin Pool microbialite fabrics provide a stepwise window into microbialite accretion and evolution. We will conduct a sequential leaching experiment to chemically isolate the organic matter and carbonate fractions within each stage of the taphonomic evolution. Their elemental composition will be measured using an Agilent 8900 ICP-QQQ. Statistical analyses, such as correlograms and principal component analyses will be presented. Distribution coefficients will be calculated for each element presented.

SIGNIFICANCE

Characterization of the taphonomic exchange of elements during the evolution of microbialites will provide new insight into the processes influencing the preservation of chemical biosignatures. Results from Hamelin Pool microbialites are anticipated to differentiate between 1) true chemical biosignatures, 2) chemical biosignatures that were potentially lost during taphonomic transfer, and 3) geochemical artifacts unrelated to microbial activity that were derived from the environment and incorporated during early taphonomy. This step is required to disentangle the impacts of early taphonomy from the effects of further diagenetic alteration on microbialite geochemistry. The results of this study will provide critical insights for the interpretation of biogenicity in the geological record of early Earth, including carbonate reservoirs such as the pre-salt deposits of Brazil (Wright & Barnett, 2017).

REFERENCES

Pollier C.G.L., Koschik C., Vitek B., Reid R. P., Suosaari E. P., Wu Z., Oehlert A. M. Incorporation mechanisms of arsenic in microbialites: a case study form Hamelin Pool (Western Australia). CSL Annual review 2022.

Sforna, M.C., Daye, M., Philippot, P., Somogyi, A., Zuilen, M.A. van, Medjoubi, K., Gérard, E., Jamme, F., Dupraz, C., Braissant, O., Glunk, C. and Visscher, P.T., 2017. Patterns of metal distribution in hypersaline microbialites during early diagenesis: Implications for the fossil record. Geobiology.

Sforna, M.C., Philippot, P., Somogyi, A., Van Zuilen, M.A., Medjoubi, K., Schoepp-Cothenet, B., Nitschke, W. and Visscher, P.T., 2014. Evidence for arsenic metabolism and cycling by microorganisms 2.7 billion years ago. Nature Geoscience, 7(11), 811–815.

Vitek, B.E., Suosaari, E.P., Oehlert, A.M., Dupraz, C., Pollier, C.G.L. and Reid, R.P. (In review). Bidirectional Fabric Evolution in Hamelin Pool Microbialites, Shark Bay, Western Australia. The Depositional Record.

Wright, V.P. and Barnett, A., 2017. Critically Evaluating the Current Depositional Models for the Pre-Salt Barra Velha Formation, Offshore Brazil. Search and Discovery AAPG Datapages, 51439.