MINERALOGICAL AND SEDIMENTOLOGICAL CONTROLS ON BIOSIGNATURE INCORPORATION IN ORGANOSEDIMENTARY DEPOSITS OF THE SALAR DE ATACAMA (CHILE)

Clément G. L. Pollier, Christophe Dupraz[2], Caroline L. Tran, Jazmin Garza, Erica P. Suosaari[1], Brooke E. Vitek, R. Pamela Reid, Amanda M. Oehlert

1) Department of Mineral Sciences, National Museum of Natural History, Smithsonian Institution, Washington, DC 20002, United States of America

2) Department of Geological Science, Stockholm University, Stockholm, 114 18, Sweden

PROJECT OBJECTIVES

- Characterize the mineralogical and sedimentological compositions of diverse organosedimentary deposits in the Salar de Atacama.
- Assess how variations in facies characteristics of organosedimentary deposits influence trace element enrichments and stable isotope fractionation patterns.
- Develop a conceptual model using facies-specific elemental partition coefficients and isotope fractionation factors to improve the interpretation of biosignatures over geological time.

PROJECT RATIONALE

Microbes have influenced and/or induced the formation of sediments since at least 3.5 Ga, forming a long-standing sedimentological archive. Organosedimentary deposits are composed of carbonate, evaporite, and silicate minerals, as well as organic matter (Reid et al., 2024). Each of these compositional fractions in organosediments can be an archive for trace elements (e.g., As, Zn, Cu, Fe, Mn) and stable carbon and sulfur isotope ratios, the incorporation of which may be affected by microbial processes (i.e., Sforna et al., 2014). However, interpreting enrichment

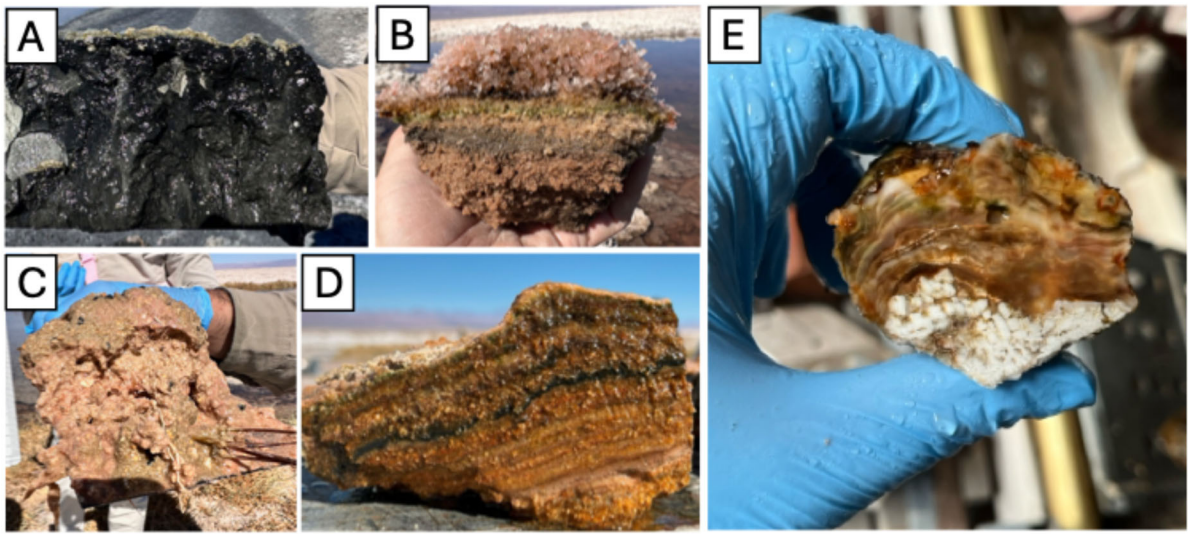

Figure 1: Organosediments observed in the Soncor and Aguas de Quelana marginal lake systems, locally known as lagoons, in the Salar de Atacama. (A) Mud, (B) Evaporite, (C) Granular sediment, (D) Unlithified microbial mat, and (E) Lithified microbial mat.

patterns or stable isotope ratios as chemical biosignatures is complicated by uncertainty about how changes in the proportion, spatial distribution, and mineralogy of the fractions comprising organosedimentary deposits influence the incorporation of trace element patterns and stable isotope ratios.

APPROACH

We investigated modern sedimentary deposits in the saline lakes, locally referred to as lagoons, along the eastern margin of the Salar de Atacama (Chile), where mud, granular sediment, evaporite, and microbialite deposits coexist (Fig. 1). We collected 101 samples from these diverse facies, and integrated bulk geochemical, mineralogical, and microscale imaging analyses to characterize their composition. Sequential leaching experiments quantified the proportions of the organic, evaporite, carbonate, and siliciclastic fractions, while FIB-SEM nanotomography revealed their spatial distributions, and X-ray diffraction confirmed mineralogical composition. Compositional characteristics of each organosedimentary deposit was related to trace element enrichment patterns and stable carbon and sulfur isotope ratios. Finally, we contextualized these results with complementary analyses of lake water chemistry, establishing elemental partition coefficients and fractionation factors for each organosedimentary deposit.

SIGNIFICANCE

Sedimentological characteristics, mineralogy, and the chemical conditions under which each organosedimentary deposit form exert an influence on their elemental enrichment patterns and stable carbon and sulfur isotope ratios. Consequently, mud, granular sediments, evaporites, and microbialites of varying degrees of lithification each capture unique information about the environmental conditions and microbe–mineral interactions. We propose a conceptual model that can be applied more broadly to compare geochemical datasets across multiple facies of organosedimentary deposits, offering multi-faceted evidence for identification of chemical biosignatures. Because organosedimentary deposits often exhibit vertical and lateral facies transitions, this model facilitates a more continuous reconstruction of biosignatures within a given stratigraphic sequence compared to interpretations based on individual facies in isolation. The expanded perspective proposed here is anticipated to enhance understanding of the dynamic biogeochemical processes that drove the formation of heterogeneous organosediments in the geological record. Additionally, advancing our knowledge of sediment formation in the Salar de Atacama will be useful in refining conceptual models of ancient microbial carbonate deposits in analogous continental evaporitic systems (*i.e.,* Virgone et al., 2013).

REFERENCES

Reid, R. P., Suosaari, E. P., Oehlert, A. M., Pollier, C. G. L., & Dupraz, C. (2024). Microbialite Accretion and Growth: Lessons from Shark Bay and the Bahamas. Annual Review of Marine Science, 16(1).

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

Virgone, A., Broucke, O., Held, A.-E., Lopez, B., Seard, C., Camoin, G., Swennen, R., Foubert, A., Rouchy, J.-M., Pabian-Goyheneche, C., & Guo, L. (2013). Continental Carbonates Reservoirs: The Importance of Analogues to Understand Presalt Discoveries.