Once Upon a Puquio: Biomineralization in the Salar de Llamara, Atacama Desert, Chile

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Background Information

This study examined a modern day gypsum depositional system in the Salar de Llamara, a desiccated saline lake in the northern part of Chile's Atacama Desert. The Salar contains a number of small lagoons, called Puquios, within which we can interpret abiotic vs. biologically-mediated mineralization. Morphologically diverse mineral deposits similar to stromatolites are found within the Puquios system and microbial mats are abundant throughout. The presence of these microbial communities and biologically influenced mineral formations within the Puquios has made the Chilean government very keen to preserve the biodiversity of the Salar de Llamara.

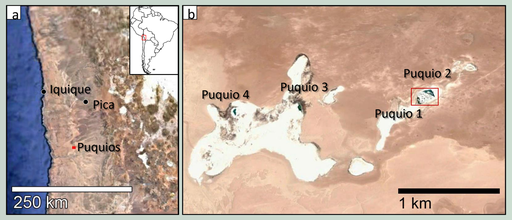
The goal of this study was to identify and understand the biomarkers of any such biologically-mediated mineralization process if they were present. To accomplish this, samples were collected from microbial mats in the Puquios, and treated to preserve the biological material in context with the minerals around it. Analyses performed on sampled material included Scanning Electron Microscopy (SEM), and X-Ray Diffraction (XRD).

Interdisciplinary studies of existing microbe-mineral interactions in extreme environments have important implications for other areas of research. For instance, understanding how these interactions work and if these biosignatures can be left behind in the rock record contributes to both our understanding of the development of life on this planet and to our continuing searches for evidence of extraterrestrial life.

Key Questions

- What minerals do we see forming in the Puquios?
- What factors impact the formation of minerals in the Puquios depositional system?

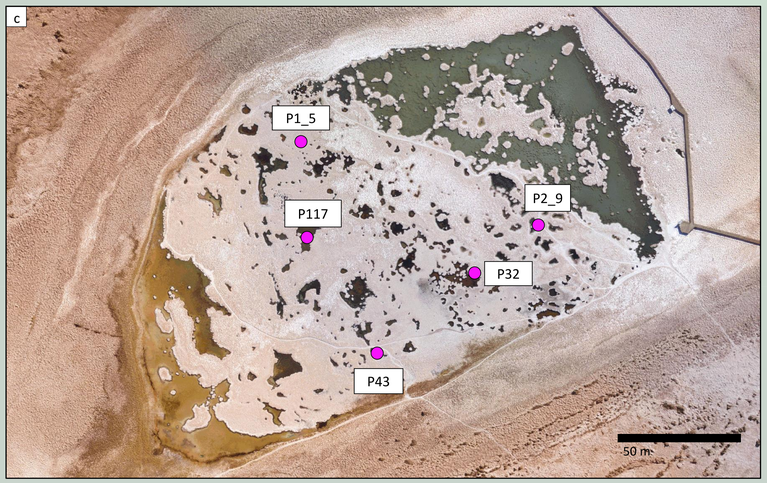
Location of the Puquios



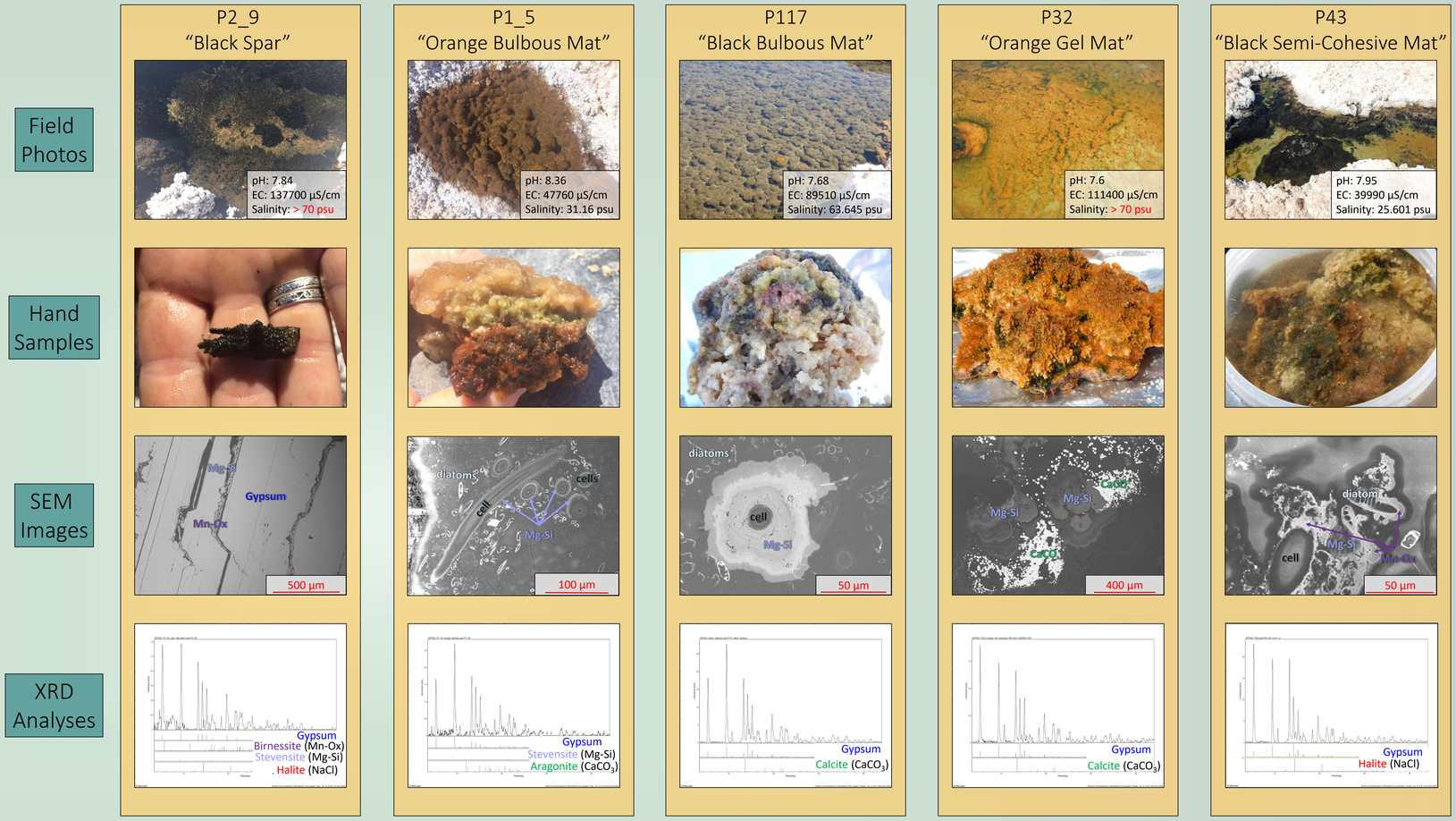
(a) regional context and location of the Puquios within northern Chile.

(b) enlarged view of the red square in (a) showing the location of the Puquios within the Salar de Llamara

(c) red box highlighting Puquio 1 and Puquio 2 in (b). labeled dots indicate locations of collected samples.



Results



Methods to this Madness

(d) increasing ETOH concentrations

(e) Cooking in a vacuum oven

(f) Grinding samples with a mortar & pestle for XRD

Sample Collection
Microbial mat samples were collected from the Puquios in November 2017, September 2018, and March 2019 and preserved in either formalin or glutaraldehyde.

Scanning Electron Microscope (SEM) analysis
Samples were treated with increasing concentrations of ethanol followed by propylene oxide to preserve microbial material in context with minerals. Samples were then impregnated with epoxy in a controlled vacuum environment (e). Finished samples were cut and polished for imaging. SEM imaging was done using a ThermoFisher Scientific Apreo Field Emission SEM (FESEM) fitted with a compound electrostatic and immersion final lens, low vacuum capability and Energy Dispersive X-Ray Spectrometer (EDS) with 60 mm Silicon Drift Detector (SDD) in the the Scanning Electron Microscopy Laboratory, NMNH.

X-Ray Diffraction (XRD) analysis
Grains subsampled from preserved material were dried and ground to a fine powder (f). XRD was performed using a Rigaku D/MAX Rapid micro diffractometer with an imaging plate detector to identify mineral phases from powdered material. Samples were exposed to an X-ray beam. XRD patterns were identified through comparison to previously published, and theoretical mineral d-spacings using the Jade 9 software application.

Conclusions

- Numerous types of minerals exhibiting varying morphologies are found in close proximity to one another within Puquio 1 and 2.
- Environmental parameters impact microbial community composition and subsequent mineral deposition.
- The presence of Magnesium Silicate, Calcium Carbonate, and Manganese-Oxide are indicative of biological influence in this system.

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