National Aeronautics and Space Administration

FY24 Strategic University Research Partnership (SURP)

Life Detection in Serpentinizing Systems Relevant to Current and Future Astrobiology Missions

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Objectives: The primary objective of this effort is to characterize the chemical composition of soluble organic matter present in environments where interactions between water and rocks can provide the chemical conditions for life to arise and persist. A secondary objective is to determine the most effective operations to successfully perform chemically-based life-detection analysis on a future spaceflight mission to an Ocean World.
Our work focuses on analysis of samples from actively "**serpentinizing systems**", where ongoing water/rock reactions in olivine rich rocks fuel polyextremophilic microbial life sustained by the production of hydrogen and small molecular weight organic compounds. These processes are widely accepted to form the most likely basis for life expected on Europa, Enceladus and in parts of Mars shallow subsurface.

Background: One challenge of life detection strategies is to identify distributions of molecules produced by biology, versus molecules produced abiotically. One ubiquitous process that occurs on rocky bodies with liquid water is serpentinization. Serpentinization can lead to the production of chemical energy sources, such as hydrogen and small organic compounds, that are essential for chemosynthetic life. Serpentinizing systems along Earth's mid-ocean ridges and in terrestrial environments can support an active chemosynthetic biosphere, intensifying the interest in missions to serpentinizing systems in our Solar system. However, the distributions of biomolecules in these systems are not yet well characterized. Similarly, there are states in these environments with low biological activity where the chemistry is dominated by abiotic processes. We analyzed subsurface fluid samples from highly serpentinized fluids the Samail Ophiolite in Oman (see Figure 1).

Figure 1. Preparing to insert water sampling devices into the subsurface of a serpentinite rock system in Oman, to collect fluids representing extreme chemical and biological conditions.

Approach and Results:

- We use capillary electrophoresis (CE) coupled with laser induced fluorescence detection for amino acid analysis (distribution and chirality).
- Capillary electrophoresis (CE) is the simplest technique for performing liquid-based separations on a mission.
- CE has low power, low mass, high sensitivity, and high efficiency.
- CE uses low volumes of sample and reagents, and it can be coupled to multiple detectors.

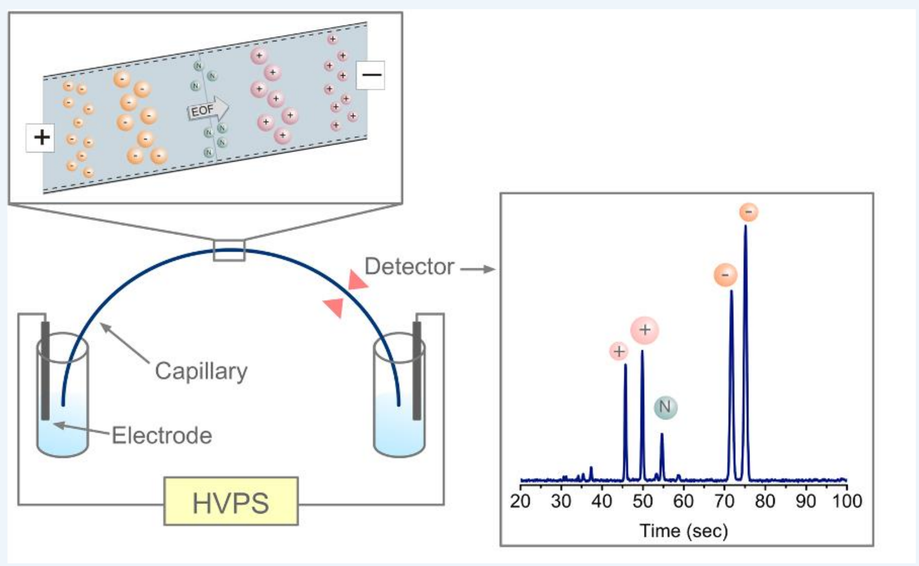

Figure 2. Diagram of a CE system indicating how ions of varying sizes and charges are separated.

- Prof. Templeton and graduate student Tristan Caro collected fluid samples from 3 depths in three boreholes that were drilled 300-400 meters into actively serpentinizing rocks in the Samail Ophiolite in Oman.
- Detailed information on the cellular abundance, fluid chemistry and rates of microbial activity in these samples has been obtained by Tristan Caro at CU Boulder (Figure 3). The microbial communities have also been characterized (Figure 4), prior to analyzing these samples at JPL using capillary electrophoresis & laser induced fluorescence to quantify amino acid abundance and distributions

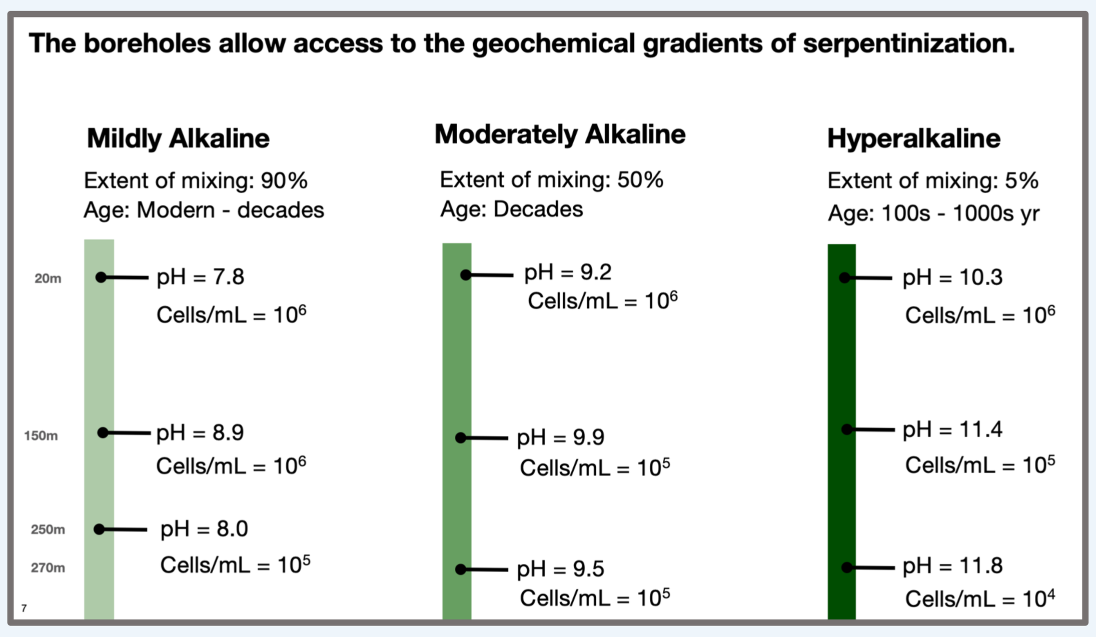

Figure 3. Examples of the gradients of pH and biological activity present in boreholes of the serpentinites in Oman.

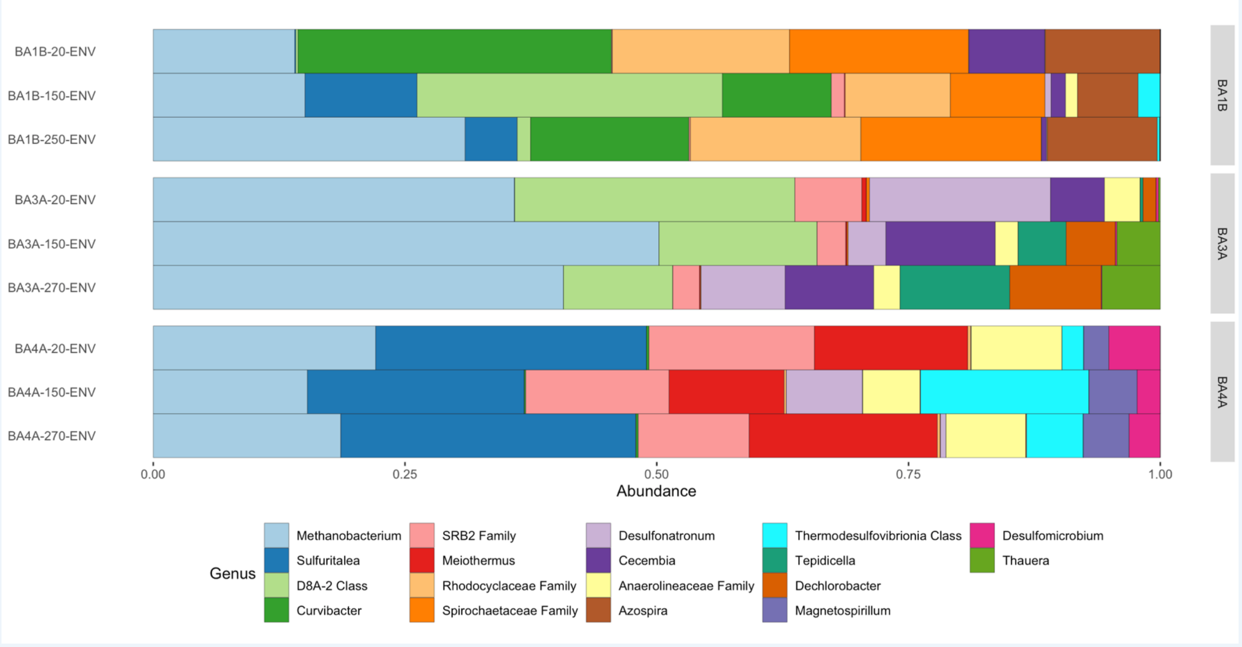

Figure 4. Microbial communities present at the boreholes of the serpentinites in Oman.

Significance/Benefits to JPL and NASA: JPL has invested significantly in the development of instrumentation for in situ chemical analysis that could be key on future missions to Ocean Worlds, specifically missions focused on habitability and life detection. This collaboration will allow us to tease apart chemical information obtained with such instrumentation in order to understand biotic versus abiotic signatures. The results from this project will then inform the implementation of this technology during future missions to allow the identification of biosignatures. Outcomes from this work would be very timely and contribute to understanding extreme environments on Earth as well as future interpretations of data from Mars sample return as well as mission concepts for the exploration of Enceladus, such as Orbilander.

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