Potential Biomarkers in Planetary Analog Brine Environments
Project Report

Western Australia Transient Lake (WATL) Fieldwork 2022

Due to the COVID-19 pandemic, Australia had restricted travel to and from the country for 2 years and as a result our fieldwork campaign to Western Australia was delayed. However, the travel restrictions were lifted on March 3rd, 2022, and we were able to complete our fieldwork from July 26th - August 18th, 2022. This fieldwork campaign consisted of 18 people across various institutions as part of the Oceans Across Space and Time (OAST) Project. OAST is a NASA-funded astrobiology project designed to address gaps in our understanding of habitability in extreme terrestrial environments while simultaneously leveraging these unique analogs to guide upcoming Ocean World missions in our solar system. For more information on why we went to the Western Australia Transient Lakes (WATL), please see the introduction/motivation of the "Lewis and Clark Astrobiology Grant Project Report Supplemental Material."

During this fieldwork we visited 40 lakes across the Yilgarn Craton in Western Australia, for exact locations of each lake site see "2022_WATL_Sites.xlsx" in the supplemental material documents. With 18 people total, we split into two smaller groups both working separately and at times jointly on larger lake systems. The reason why we divided the teams into two smaller groups was to try and capture how these lakes change over time because if it rains, then that will change the geochemical characteristics of the lakes and what may be precipitating in or along the shoreline of the lakes. For the purposes of this project report, I'll only be describing my group and only focusing on the research that I accomplished in the field.

The team I was on was designed to scout out lakes of interest from our down selected list of lakes and then relay back to the other team, which lakes they should or shouldn't go to depending on the geochemical characteristics of the lake environment. Additionally, my team had analyses that were quicker overall and allowed us to sample more lakes, while the other team's science analyses took a longer time. For this reason, my team was called the Fast team, while the other team was called the Slow team. Additionally, towards the end of the trip most of the team went back to Perth to go back home, however, a couple people stayed longer to sample more lakes (the Bonus team) in the Southwestern part of the Yilgarn Craton in Western Australia.

Figure 1 in the supplemental material document shows the lake sites that the whole team sampled on this trip. The red dots are lake sites that the Fast team sampled, the green dots are the lake sites that the Slow team sampled, the blue dots are the lake sites that the Bonus team sampled, and the orange dot is where the whole team sampled together. Figure 2 in the supplemental material shows the lake sites from Figure 1 that were sampled twice to try and capture how the lake environments changed over time. Lastly, the red, orange, and blue dots on the map in Figure 1 were locations that I specifically sampled at. Our fieldwork schedule/timeline is as follows:

- <u>July 26th - August 2nd</u>: We were in Perth preparing for our fieldwork by working with our collaborators at Curtin University.
- <u>August 3rd</u>: We traveled to our first place of residence in Merredin, WA.
- <u>August 4th</u>: We had our whole team fieldwork day in the Lake Brown and Lake Campion area.
- <u>August 5th</u>: The Fast team set out to sample 4 lake sites near Hyden, WA.
- <u>August 6th</u>: The Fast team sampled 3 lake sites East of Lake Brown.
- <u>August 7th</u>: The Fast team drove to Esperance, WA and along the way sampled Lake Gounter near Hyden, WA.

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- August 8th: The Fast team sampled 4 lake sites north of Esperance in the Salmon Gums area.
- August 9th: The Fast team sampled 3 lake sites in Esperance, WA.
- August 10th: The Fast team traveled to Norseman our 3rd place of residence.
- August 11-13th: The Fast team sampled 9 lake sites between Norseman and Esperance. On the 13th we drove back to Esperance and met with the whole group.
- August 14th: Our full group split up again with most people going back to Perth to fly home, while a small group (Bonus team) went to Cranbrook, WA.
- August 15th-17th: The Bonus team sampled 7 lake sites near Cranbrook, WA and sampled Lake Clifton on the way back to Perth before heading home.

*Note: I'm mostly focusing on the group I was with, so here the total is 34 sites. However, with everyone's lake sites the total sites that were sampled is 40.

Research

My work is modeled as a mock mission—scaling from the orbital to lander and finally to laboratory study—to the WATL. The preliminary research I have done is using Earth-orbiting spacecraft data to identify environments that have high biosignature preservation potential in the WATL, such as lake shoreline deposits with evaporitic minerals. Hence, the orbital part of the mock mission, which was used to down select lake sites to sample for this fieldwork. We then completed the lander part of the mission, by completing our fieldwork in the WATL. This consisted of ground truthing the remote sensing data and by measuring environmental parameters (i.e., pH, salinity, temperature, water activity, etc.) to see how these conditions may influence organic/biomarker preservation or alteration. Lastly, the laboratory part of the mission will be future research and is designed to mimic what a rover or sample return mission may encounter with sample acquisition, discriminating between potential biosignatures and features produced by nonbiological processes. This future work aims to resolve and characterize microscale morphological fabrics and their potential for larger scales of life detection.

The WATL environments may be a great place to preserve potential biomarkers because of the precipitation of salts in and around the shoreline of the lakes (specifically gypsum and halite). Thus, my objective was to collect primarily gypsum and halite samples (also sediment and any other mineral assemblages present) from the lake and surrounding shoreline and analyze the samples *in situ* with a portable spectrometer, LIBS, XRF, and Raman instruments. See Figures 3-6 of the supplemental material document for what these instruments looked like being used in the field. Multiple samples were taken to capture the variation within each lake environment and the samples were recorded at each site through triplicate sample collection with each instrument. To mimic planetary missions to Mars we also adapted a similar approach to how we collected data. For example, similar to rover missions to Mars we completed our sample collection in the following order: portable spectrometer, XRF, Raman, LIBS. Thus, we made sure to do the nondestructive sample techniques first (i.e., VNIR spectrometer, XRF, and Raman) and then completed sample collection with the more destructive sample techniques (i.e., LIBS) second. The samples will be analyzed in the lab after fieldwork with the same instruments and with lab-based instruments to compare how different the spectra look *in situ* vs in the lab, and how they compare to the remote sensing data. These analyses will help give a more precise measurement of gypsum and halite, and identify other salts that biomarkers may be associated with. This will be specifically important for sites F9, F17, and F19-F21 because of the various features that we saw along the surface and shoreline of the lakes. Figures 10-17 show various ways salt precipitated out of these lake environments and what other mineralogical features could be associated with these salts, such as diagenetic veins and weathered rock. Thus, it is important we connect these *in situ* features to the remote sensing to inform where the best places are in these environments for potential biomarkers to be preserved, and then compare these environments to Mars.

Overall, from all the lakes that were sampled, I gathered 109 samples and over 300 spectra from the instruments. In addition, the lakes we sampled spanned a wide range of geochemical conditions that were measured *in situ* (Figure 7), including pH ($2.68 < pH < 9.17$), salinity (15-360 ppt), and temperature (10.32-20.9°C). From the 40 lakes that were sampled, we were able to resample 8 lakes on different days to capture the change these lakes went through over time. For example, Figures 8-9 show how different site F9 looked from August 8th to August 13th. From these two dates, the geochemical conditions changed enough for salt to start precipitating along the shoreline on August 13th, while we didn't see any salt crusts along the shoreline on August 8th. The salt precipitation along the shoreline and the thick salt bed, located several centimeters underwater, at site F9 is shown in Figures 10-12. Studying the geochemistry and environmental parameters in these lakes will provide insight to the starting bulk composition of the water column, which is needed to fully understand what salts could precipitate out of the lakes when they go through evaporative stages. This will give context to where biomarkers are more likely to be found and connect the features to the environment they are found in. Changing groundwater conditions, flux, and wet/dry cycles within the WATL will change the pH, temperature, and salinity which will directly affect other environmental parameters (e.g., water activity, chaotropicity, nutrients, etc.). Understanding the influence of varying ionic concentration and composition across multiple WATL field sites on these processes will allow me to connect between the orbital observations, environmental data, and preservation and extrapolate lessons learned to the history of environments on Mars and how these may have altered or preserved biomarkers.

Significance

Studying the evolution of the WATL will provide new perspectives on how similar environments on Mars transitioned from wet to dry. The wet/dry cycles in the WATL provide a snapshot in time of what could have occurred on Mars and a window into how environmental change affects habitability and the preservation of geological records. Thus, this work will seek to uncover how the WATL evolve in order to systematically search for, contextualize and understand the provenance of putative biomarkers in the WATL environment. The scaled approach described here will bridge the gap between orbital, *in situ*, and laboratory observations by using connections between each scale to further understand habitability and preservation in these ancient lake environments that are prevalent on Mars. By utilizing orbital data to identify aqueous minerals in these environments, areas that may have a high biosignature preservation potential can be pinpointed and investigated for further examination. *In situ* observations can be used to confirm orbital investigations, determine the habitability of the environment, and understand how environmental parameters may alter or preserve biomarkers. Laboratory observations coupled with the in-situ data can identify where potential biomarkers are more likely to be found and with what mineral assemblages, and can determine whether such features are true biomarkers or not. Leveraging these results will provide a method to relate environmental and geochemical conditions

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to putative biomarker preservation to similar environments on Mars. For example, if certain chemistries promote biomarker preservation and certain minerals are good preservers, then that will inform where to look for future missions on Mars. To date, the only potential biosignatures that have been detected on Mars is methane in the atmosphere and complex organics in mudstones (Eigenbrode et al., 2018; Ten Kate, 2018), and there has yet to be a positive indication that life was once present. Thus, with this approach future missions can identify areas that have a higher preservation potential in lacustrine environments and are more likely to result in a positive life detection result.