GEOCHEMSITRY OF ACIDIC SALINE LAKES IN WESTERN AUSTRALIA.

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Introduction: Oceans Across Space and Time (OAST) is an Ocean Worlds mission to Earth, designed to address gaps in our understanding of habitability in extreme terrestrial environments while leveraging unique analogs to guide spacecraft missions. OAST aims to investigate the central question "How do ocean worlds and their biospheres co-evolve to produce detectable signals of a past or present living world?"

In August 2022, we conducted fieldwork across the Western Australia Transient Lakes (WATL). We selected the WATL because they represent both remnant and relict ocean and lake environments that experience cyclic wetting and drying, and derive in part from hypersaline groundwater reacting with ancient rocks over geologic time. Our August 2022 fieldwork in Western Australia included a suite of instruments and analytical techniques used by the astrobiology and planetary science community in order to characterize the physical and chemical challenges and metabolic opportunities in each environment that together determine habitability.

Field Analog - Western Australia Transient Lakes (WATL): Since only records of past liquid environments can be studied on Mars, analog environments on Earth such as the WATL present an opportunity to investigate what early lacustrine Martian environments could have been like and understand how once active lake systems leave a record of their presence behind. The WATL are located in the Archean Yilgarn Craton of Western Australia, which is host to hundreds of saline lakes [1-3]. The Yilgarn Craton is unlike any other area on Earth due to its exceptional geological stability, and the fact that this region has undergone an extensive shift in palaeomagnetic latitude during the last 500 million years, resulting in climatic extremes ranging from humid to arid, which led to varied and intense weathering of bedrock and valley fill [4]. Thus, these lake environments have been going through wet/dry cycles for millions of years and they continue to go through these cycles to the present day [4]. As a result of these cyclic patterns, salinization occurred in the Yilgarn Craton from as long ago as 2.8 Ma, concentrating in valley floors as dry and wet cycles prevailed throughout its history. Furthermore, ongoing weathering throughout this time influenced the regolith, water chemistry, and the accumulation of massive volumes of salt in the Yilgarn Craton [4]. These conditions make the lakes an analog for multiple habitable environments predicted to have existed and evolved during the Noachian and Hesperian Eras on Mars, and could help us understand how similar environments on Mars transitioned from wet to dry.

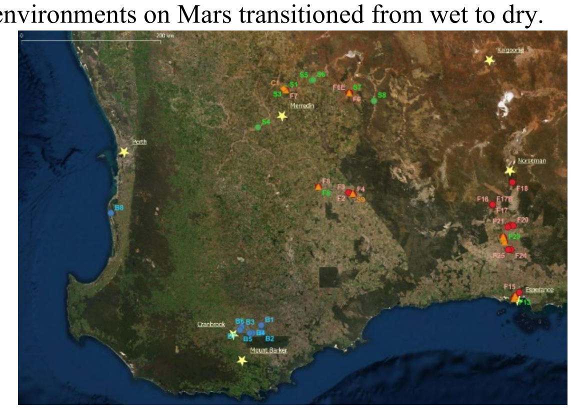

Figure 1: QGIS map of our field sites throughout the Yilgarn Craton in Western Australia.

Objective: During our fieldwork in August 2022, we visited 40 lakes across the Yilgarn Craton in Western Australia, shown in Figure 1. We moved in two teams to enable us to conduct both surveys of general environmental conditions as well as long-term incubations, and repeat visits of some environments to try and capture how these lakes change over time, diurnal shifts in precipitation in or along the shoreline of the lake environment or dilution from rain. 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.

In addition to sampling environments in areas where some astrobiological study has occurred, towards the end of the trip a small sampling effort targeted new lakes in the Southwestern part of the Yilgarn Craton. Figure 1 shows the lake sites sampled on this trip. The red dots are lake sites sampled for water properties and remote sensing, green dots are the lake sites sampled for environmental and biological studies, the blue dots represent prior under sampled lake sites in the Southwest and Lake Thetis (a site with known microbialites), and orange dots were sampled multiple times.

Overview of Results: Some of the interdisciplinary results from this campaign are described in abstracts presented at this conference: Oxygen Concentration and composition of Mars Analog Saline Environments in Western Australia [5], Biosignature Detection in Gypsum Across Varying Environments of Precipitation [6], and Mapping Mineralogy and Wet/Dry Cycles in Acidic Saline Lakes in Western Australia [7].

Geochemical Results: Overall, the lakes we sampled spanned a wide range of geochemical conditions that were measured *in situ*, including pH (2.68 < pH < 9.17), salinity (15-360 ppt), and temperature (10.32-20.9°C) [5]. Figure 2 shows the variation in salinity and pH. Additionally, the major ion geochemistry shows that the acidic lakes are particularly chemically complex, rich in Na-Mg-(Ca)-SO4-Cl, and have unusually high and highly variable concentrations of Al, K, Si, Fe, Br, F, HCO3 and some other metals. From these results, we would expect $MgSO_4$ and Na_2SO_4 minerals to precipitate under dehydration [8]. In particular, we would expect gypsum and halite to be the dominate form of precipitants from these environments [1,7]. However, to fully understand how these environments have changed through time and can be compared to Martian environments, we need to fully understand the connections between the water chemistry, precipitants, and weathered rock through time [7].

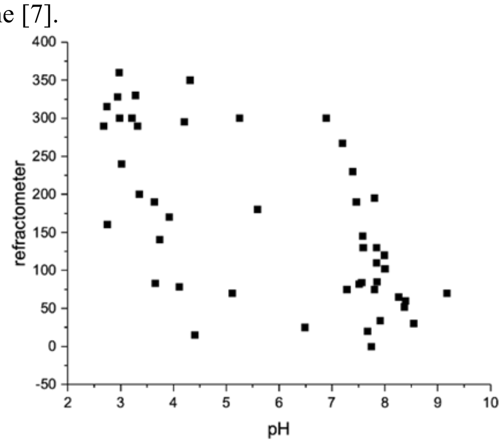

Figure 2: pH and salinity range of our field sites.

Implications: 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. Our fieldwork bridges 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 [7]. *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 [5,7]. Laboratory observations coupled with the *in situ* data can identify where potential biomarkers are more likely to be found and with what mineral assemblages [6,7]. Leveraging these results will provide a method to relate environmental and geochemical conditions 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 [9,10], 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.

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