USING REMOTE SENSING TO IDENTIFY WET-DRY CYCLES IN PLANETARY-ANALOG BRINE ENVIRONMENTS.
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Introduction: The Western Australia Transient Lakes (WATL) are located in the Archean Yilgarn Craton of Western Australia, which is host to hundreds of saline lakes [1]. The Yilgarn craton, the source of the sulfate and iron minerals in these lakes, is approximately the same age as the Noachian and Hesperian rocks on Mars, which make this field site a uniquely suited analog for Mars [1,2]. In addition, the lakes in this region host extreme environments for life. This investigation primarily focuses on these lakes as a field analog for the Oceans Across Space and Time (OAST) project (https://oast.eas.gatech.edu/). The WATL were selected for study due to the various physicochemical and biological challenges within these environments that influence the boundary between life and non-life. OAST seeks to determine habitability in highly saline, low water activity environments on Earth to explore the observable signals of habitability, identify the strategies that life uses to deal with environmental stress, and determine biomarkers that are signals of these conditions. To determine the limits of life in these environments, measurements of environmental parameters such as pH, temperature, salinity, water activity, ionic strength, etc. will be taken to establish how they affect life in these extreme settings and how these conditions change over time.

The WATL saline lakes are excellent targets for investigations on the limits of habitability because they have a wide range of geochemical conditions, including pH ($1.7 < pH < 8.6$), salinity (10-280 ppth), and temperatures (0-50°C) [1]. More importantly, the acid lakes and groundwaters are chemically complex; rich in Na-Cl-Mg-SO_4 and have unusually high and highly variable concentrations of Al, Si, Fe, Br, and some other metals [3]. The WATL are exciting not only because they are chemically and physically diverse, but because they host complex microbial communities in these extreme settings [4]. Our study will inform site selection for field campaigns at the WATL in 2021 in order to best observe lakes with a broad range of pH, temperatures, and chemistries.

Hairy Blobs: The WATL lakes are also of interest due to their preservation of exotic putative biomarkers, including “Hairy Blobs” [5]. Hairy Blobs are masses of black radiating filaments or ‘‘hairs’’, shown in Figure 1. It remains ambiguous on what their true composition is. These Hairy Blobs are found in halite and gypsum in five lakes in Southwestern Australia, and are among the first putative microbial remains described in acidic saline lake environments [5-6]. These unusual structures have implications for preserved life in extreme settings, so it is important to determine if they are: (1) true biomarkers, and (2) relevant in the search for extraterrestrial life. These structures are peculiar because they appear biotic in origin, but whether they preserve microorganisms or pseudofossils is not yet clear. In order to select the best range of lakes to explore for preservation records, such as within halite and gypsum, we turn to reflectance spectra remote sensing.

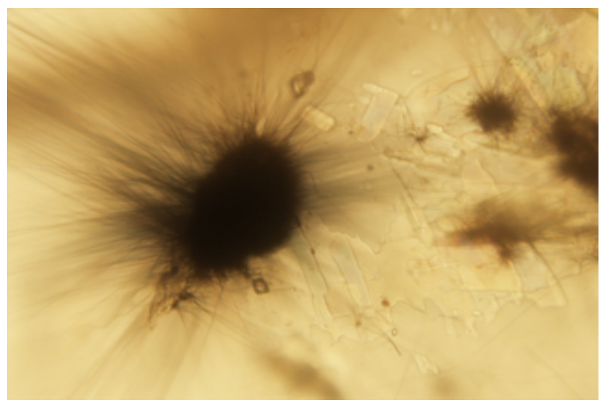

Figure 1: *Hairy Blob preserved in modern halite around fluid inclusions. (Plattner & Olcott in prep).*

Objective: To choose from the hundreds of shallow lakes, we used spectral data from the Operational Land Imager (OLI) on the Landsat 8 spacecraft to determine what wet/dry stage these lakes are in and what type of evaporative minerals they contain. Specifically, the spectral bands that we are interested in are band 5, band 6, and band 7 which correspond to 0.85-0.88 μm, 1.57-1.65 μm, 2.11-2.29 μm, respectively. The WATL change over time when they fluctuate in depth, which is due to varying wet/dry stages from the influx of groundwater and rainwater [1]. When these stages occur chemistries, pH, salinity, and other factors change, so it is critical to distinguish when these lakes go through wet/dry cycles. To determine when these lakes are in a wet/dry stage the abundance of evaporative minerals (such as halite and gypsum) needs to be identified around the lake shorelines and salt crusts of the WATL.

Since its launch in 2013, Landsat 8 has accumulated a large time series of image data over our region of interest. This multiyear database was used to establish how these lakes have changed over time, both seasonally and from year to year. By looking at the temporal evolution of these lakes, we can characterize the composition of minerals around their shorelines and determine the seasonality of gypsum and halite abundances. Through this analysis we can determine the ideal times to analyze and sample these lakes for biomarker and biological activity. Additionally, we will characterize the seasonal cycles and variability in surface hydrology for these features. Ultimately, this investigation will help determine which lakes will be of primarily interest for the OAST project in Western Australia.

Method: To do this analysis, we obtained Landsat 8 data from USGS. Using this data, a map of the gypsum distribution around the lakes was constructed by completing band ratios in QGIS. With the band math tool, two different band ratios were analyzed, (band 5/band 6) and (band 5/band 7). These bands were used because they exaggerate the spectral features of gypsum, specifically the highly reflective and absorptive portions of its spectrum. Landsat 8 has 11 bands, in which band 6 & 7 cover the deep absorption features of gypsum, while band 5 covers the high reflectance portion of the gypsum spectrum. Band 6 is centered around 0.86 µm and band 7 is centered around 1.6 µm, and both of them highlight the dark regions in the returned images. Band 5 is centered around 2.2 µm and highlights the bright areas in the images, which represent gypsum. By doing these ratios we can see the gypsum distribution clearly as they appear as brighter areas in the returned images. Two different ratios were completed to verify that the areas in the returned images were likely gypsum.

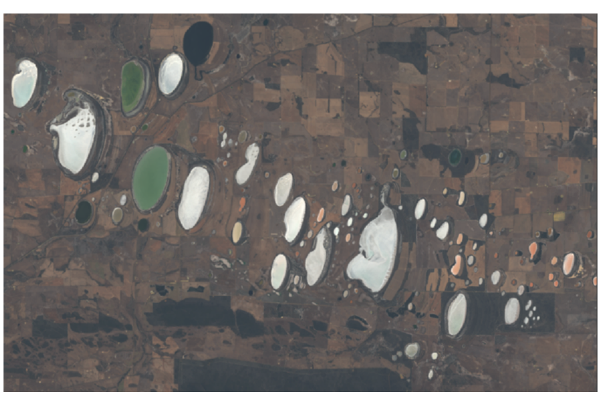

Figure 2: *This is a true color image taken on December 26th, 2016 and the Landsat reference number is LC08_L1TP_111084_20161226_20170314_01_T1.*

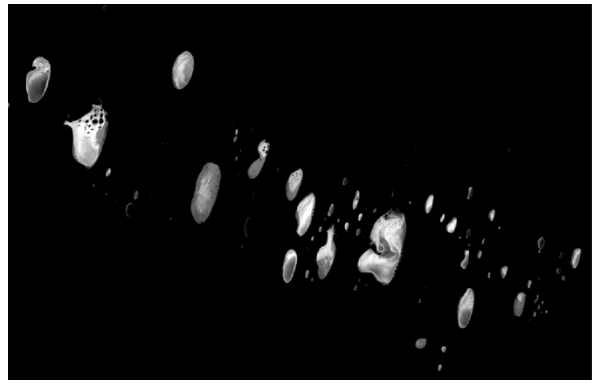

Figure 3: *This image is a band 5/band 6 ratio used to estimate the gypsum distribution. Bright values indicate areas of increased gypsum.*

Results: From the analysis, various images (e.g. Figure 2&3) were produced for different months spanning the last 3 years. For each month, a true color image was produced along with monochromatic images. From these two distinctive images we estimated the distribution and concentration of gypsum surrounding the lakes. Additionally, by comparing different months in a calendar year we characterized the seasonal variability in gypsum. From the results, there is notably more gypsum overall in the WATL during December relative to other months. Thus, we interpret these lakes to undergo a seasonal dry cycle at this time due to the increased abundance of evaporate minerals visible near their shores. This intuitively makes sense as this is local summer in Australia. Furthermore, the produced band ratio images (band 5/band 6) and (band 5/band 7) ratio image we can verify that the highlighted regions are in fact gypsum around these lakes. The images that were obtained were nearly identical, which strengthens our interpretation that these regions are rich in gypsum.

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