PHOTOBIOLOGY AND BIOGENIC PRESERVATION COMPARISONS BETWEEN PLEISTOCENE EVAPORITE BEDS AND BURIED PERMIAN BRINES. Scott M. Perl[1-3] Bonnie K. Baxter[4], Aaron J. Celestian[2], Charles S. Cockell[5], Alex L.Sessions[6], Preston Tasoff[1], Sarah J. Crucilla[1], Frank A. Corsetti[7]

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Introduction: Evaporite mineralogy can precipitate on Earth and other planets following the evaporation of hypersaline lakebeds. These mineral types are a record of former aqueous histories and a more robust and diagnostic feature showing the timing and potential chemistries of the ancient lake systems. Evaporites are key features in studying fluid systems and preserved geobiological markers from those aqueous systems, both modern and ancient, and minerals halite and gypsum have been observed in sites where cellular life has lived inside the water columns of active and former closed basin lake systems. These evaporite minerals are diagnostic of aqueous activity and potential regions for biogenic entombment of organic matter sourced from microorganisms [1].

The purpose of this paper is to discuss the photobiological response from halophilic microorganisms in their preserved mineral settings from different solar flux environments.

Methodology & Field Sites: The chosen field sites are an evaporating closed-section of the Great Salt Lake, Utah, USA [2], a dried Pleistocene evaporite lakebed of Mojave Desert, CA, USA [1], and the Permian Boulby salt mine formed from the Zechstein Sea leading to the Zechstein Formation suite of evaporites [3], (Fig 1). These evaporitic settings serve as my Mars analogue sites due to the high saline waters and similar evaporite minerals to those found on Mars [4]. This site gives the proper Martian analogue settings since they have similar geochemical and fluvial settings as the ancient sites that *Opportunity* and *Curiosity* have explored [5,6]. While the benefit of having active terrestrial (modern) study sites is being able to investigate mineral precipitation reactions in real time, these modern records also provide a proper initial "stopwatch" for the monitoring of preserved biological processes and mineral modification solely due to the added presence of microbial life.

Geobiology of Preserved Extant Life: Halophilic microorganisms can survive high doses of ultraviolet (UV) light, desiccation of their environment, and osmotic challenges. These poly-extremophile microorganisms may be excellent life forms to study when considering a search for potential current or extant life in a Martian evaporite formation. Considering that the timescales of geological changes are magnitudes longer than the adaptation of halophilic and other extreme life, survivability of biological evidence in ever-changing hypersaline settings can be both physical and chemical. [1]. To live in salt-saturated brine, halophiles must balance osmotically such that their cells do not shrivel up due to water loss. This is accomplished in part by the intracellular accumulation of osmotic reflection coefficients, which balance against the salt on the outside of the cell membrane [7]. Halophiles are shown to accumulate potassium ions and organic compatible solutes [8,9], which explains their success in salty environments. These extremophiles also have modifications

Fig. 1. Sterile extracted NaCl mineralogy from Permian evaporite beds. Extracted salts and evaporitic material show versions of pigments observed in the modern but significantly lacking in opacity (as compared to Fig. 2). Fluids are still present in these salts and show distribution differences between the Permian NaCl, KCl, and polyhalite sets [3].

in their proteins that help them function at high salt [10].

Applications to Recurring Slope Lineae (RSL): Recent evidence of potentially seasonally flowing brine fluids have been observed by CRISM in the form of the Recurring Slope Lineae (RSL) [11] These dark slope streaks seem to become elongated over several Martian years on crater walls of steep angles of repose leading into the possibility of these streaks being sourced by a highly viscous brine that is extends during the warmer Martian seasons and remains at its previous length during the colder months. The survivability and somewhat stable nature of potential surface brines bodes well for subsurface fluidic flow where more recent evaporite mineralogy may be precipitated on modern Mars. In a saturated brine water molecules that interact with ions are less available to support life (as we know it) and some have theorized that life cannot tolerate the saturated acidic Martian brines [12] however there is ample evidence from several hypersaline environments where halophilic organisms that are able to maintain homeostasis and thrive just as non-extreme microorganisms can despite the lower a_w and acidic saline lakes [13, 18]

Using Modern Evaporites for Relative Microbial Preservation Timing: The modern Great Salt Lake is highly productive despite the reduced solubility of oxygen of hypersaline waters. Phototrophs power the system [14] anaerobic activities are prevalent [15], and methanogenesis has been detected [16]. The metabolism of these microbial communities, living at salt saturation, is complex, but such reactions occur more slowly than at lower salinity levels [17] These pigments underlie important strategies for overcoming the challenges of an extreme environment and also give us clues to potential biosignatures (Fig. 2, [1]) even after

Fig. 2. (Left) Modern evaporite NaCl with traces of embedded gypsum and larger microbial material (Right) Highly pigmented NaCl showing modification of the evaporite matrix due to photobiological processes . (Left) Recent preservation of organic and biological material intact due to the inactivity of younger fluids in the region post-precipitation. (Right) Originally surface evaporites from a dried lakebed retaining pigments from the initial preservation and later burial.

DNA has been lost to time. These same detection strategies can be critical for future astrobiology and planetary landed campaigns to determine not only the survivability of organics, which can be found with no relationship to biological processes, but to future life (as we don't know it) mission concepts that since the Viking missions, we have not done yet.

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