INVESTIGATIONS OF PHYLLOSILICATE AND SULFATE LAYERING IN INTRAPLAYA DEPOSITS; ANALOGS FOR MARTIAN LAYERED DEPOSITS.

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Introduction: The evolution of the martian climate is recorded in its sedimentological and stratigraphic record. Thick sequences of layered, martian sedimentary materials commonly contain phyllosilicates overlain by sulfate bearing units and are thought to record the transition between neutral pH aqueous alteration in the Noachian to an acidic evaporitic system in the late Noachian to the Hesperian [1, 2]. In some locations on Mars, however, phyllosilicates and sulfates are interbedded, occur in close proximity, or the stratigraphic relationship may be reversed [3-5] allowing the examination of their temporal and geochemical relationship. Additionally, local occurrences of phyllosilicate-bearing strata are observed in rocks deposited during the Hesperian [6], a finding seemingly at odds with the hypothesis of global acidic environments in the Late Noachian/Early Hesperian. Although this model of linear evolution is consistent with the "drying out" of Mars over time and thus provides an important framework, it is possible and indeed perhaps likely that regional differences in aqueous geochemistry were prevalent and are preserved in the martian rock record. In addition to recording an aqueous history, these ancient environments may also record evidence for past life or at the least the chemical building blocks for life. Perhaps the mineralogy present in such sediments records the biochemical reactions produced by microbial metabolism?

The understanding of aqueous geochemical reactions that may support habitability on Mars is crucial to the big picture questions in the search for life elsewhere. Analog environments on Earth provide an excellent opportunity to fully study these processes so that we may interpret par martian environments. Sediments deposited in playa basins in Western Australia (WA) are a particularly good analog for the sediments seen in Gale Crater [7] and by the Curiosity rover at Yellowknife Bay [8]. Within the analog sediments iron, magnesium and calcium sulfates, iron sulfides, and smectites are found, similar to the mineralogies found by Curiosity [9].

As part of a study of terrestrial analogs of martian habitable environments, we have derived mineral maps from airborne hyperspectral data of acid saline ephemeral lakes in WA to evaluate the co-occurrences of phyllosilicates and sulfates on Earth to better understand similar environments on Mars (Figure 1). These analogs have been recognized as important chemical

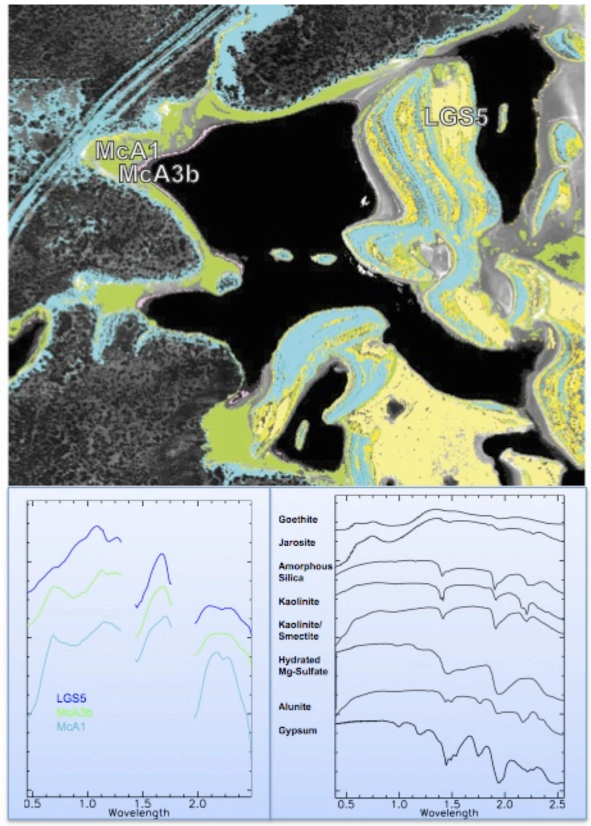

Figure 1. A. HyMAP target mineralogy at Lake Gilmore (gypsum = yellow, alunite = purple, hydrated Mg-sulfate = green, Fe/Mg clay = blue, kaolinte = teal B. HyMAP surface spectra of core sites. Surface spectra reflect clay and iron oxide mineralogy near the shore and sulfate mineralogy within the basin. C. Library spectra of possible sample mineralogies. Gypsum is identified by the 1.75 µm absorption, alunite by an absorption at 2.17 µm and hydrated sulfates are identified by absorptions near 1.4 and 1.9 µm. However, due to water in Earth's atmosphere, these bands are excluded. Phyllosilicates have a diagnostic feature near 2.2 µm; kaolinite is distinguished by a doublet in this region.

terrestrial analogs for aqueous mineral formation and geochemical variability on Mars [10-14]. The variability has been offered as an alternate formation mechanism for some of the phyllosilicates and sulfates on Mars, suggesting that at least some different mineral chemistries may be separated by chemical gradients rather than temporal boundaries [15]. These terrestrial systems produce a variety of hydrated minerals including sulfates, phyllosilicates and Fe-oxides, and support several hydrologic or depositional events over time including variations in groundwater infiltration during wet/dry cycles and acidification of ground and surface waters. Indeed, geochemical calculations suggest that similar groundwater circulation and acidification toward the surface may be responsible for the mineralogical variability on Mars [14, 16].

Continuing on this project, we have collected shallow core samples within the WA playa basins in order to integrate Mars analog surface and subsurface sampling with results from remote sensing data and better understand the formation, evolution and preservation of the sequences of layered sulfate and phyllosilicate deposits on Mars and the interpretations that can be made from remote sensing.

Methods: Seven shallow cores were collected from representative deposits in each of the surface spectral units. Cores were collected on the playa surfaces as well as within the playa islands and shorelines, with an emphasis on sampling potential transition zones between mineralogical assemblages produced in circum-neutral conditions and those produced in acidic conditions. A simple coring system was utilized to collect shallow cores up to ~45-50 cm in depth. The core tubes are pre-cut lengths of PVC pipe, and were driven vertically downward into the substrate using repeated blows from a rubber mallet and then manually extracted (Figure 2). The length of each core was photo-documented with a digital camera and spectrally logged and a spatial resolution of 1cm with an ASD VIS/NIR spectrometer. Aliquots of sediment will be prepared for X-Ray Diffraction (XRD) and petrographic analysis (grain mounts). The goal of this analysis is to determine the mineralogy present in the core samples and, coupled with our investigation into the sedimentary structures present, use this information to constrain their origin and modification processes.

Figure 2. Co-author Brad Thomson demonstrating shallow core sampling technique in Western Australia.

Results and Conclusions: Figure 3 is an image of shallow core sample LGS5 taken from layered playa islands with Lake Gilmore. This particular sample shows increased variability representing changes in sulfate chemistry and oxidation states (as can be seen by the dark red coloration with depth).

Figure 3. Sample LGS5

As alluded to in the introduction, mineralogic variation with depth and across the playa surface may be caused by biochemical reactions. The mineralogy we observe may therefore be indicative of microbial presence. To further explore this hypothesis we are preparing sample sections for microbial DNA extraction to access the metabolic characteristics and behaviors that cause geologic materials to become acidic [17]. If oxidizing microbes are identified near the surface, then it is possible that these organisms are responsible for the change in chemistry from neutral to acidic conditions seen in Martian rocks. If not the change may be due to groundwater circulation as proposed by Baldridge et al. (2009) or some other geologic process.

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