INVESTIGATING TRANSITIONAL SUBSURFACE HABITABLE ZONES IN MARTIAN PALEOLAKE ANALOG ENVIRONMENTS

Kennda L. Lynch
Lunar & Planetary Institute, USRA
3600 Bay Area Blvd, Houston, TX 77058
klynch@lpi.usra.edu

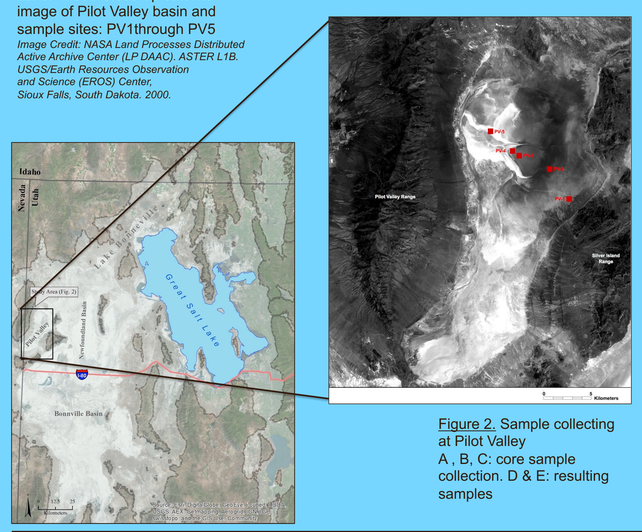
INTRODUCTION

While the Curiosity rover continues to provide growing evidence of the salty paleolake origins of Gale Crater, the Perseverance rover is now preparing to explore Jezero Crater in February of 202 and begin seeking signs of ancient life within the paleolake deposits. Further, in 2022 the ExoMars Rover will begin its journey to explore the potential paleolake basin of Oxia Planum. All these missions seek to understand the habitable environments within martian paleolakes, and their capability for preserving biosignatures of past life. To accomplish their respective goals, all accessible habitable zones with preservation potential will need to be considered, and this should include transitional subsurface habitable zones within the sedimentary deposits.

FIELD SITE

Pilot Valley (figure 1) is a closed topographic basin that lies west of the Bonneville Salt Flats and the Silver Island mountain range. The upper 6 meters of the basin constitutes a brine aquifer that is ground water recharged by run-off from the Silver Island Mountain Range. It is the most pristine of the three major sub-basins of the Great Salt Lake Desert, hence it serves as an excellent paleolake basin model.

Figure 1. Map of the Great Salt Lake Desert and adjacent Great Salt Lake. Inset: Close-up satellite image of Pilot Valley basin and sample sites: PV1through PV5
Image Credit: NASA Land Processes Distributed Active Archive Center (LP DAAC). ASTER L1B. USGS/Earth Resources Observation and Science (EROS) Center, Sioux Falls, South Dakota. 2000.



Pilot Valley Characteristics
Avg. sediment/brine pH: 6
Avg. sediment/brine temp: 20° C
Brine Chemistry:
Major Anions
$[Cl^-]$: 19340 mg/L
$[SO_4^{2-}]$: 3019 mg/L
$[NO^{3-}]$: 54 mg/L
Note: Perchlorate and chlorate have both been detected and quantified in Pilot Valley → Please see ***Lynch et al. Astrobiology, 2019*** *for more details.*
Major Cations
$[Na^+]$: 85398 mg/L
$[K^+]$: 14074 mg/L
$[Mg^{2+}]$: 2400 mg/L
$[Ca2+]$: 2400 mg/L

Figure 2. Sample collecting at Pilot Valley
A , B, C: core sample collection. D & E: resulting samples

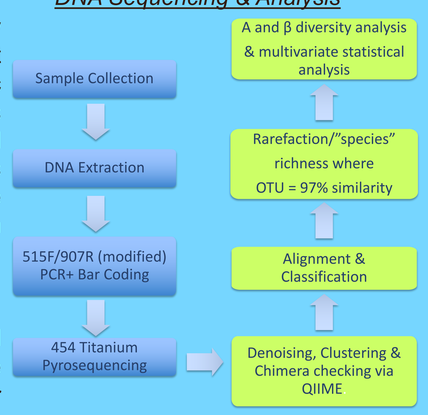
METHODS

Field Work
Sediment and aquifer fluid samples from Pilot Valley were collected along a defined horizontal transect (figure 1 inset) from the basin rim to the topographic center of the basin. Sediment core samples (figures 2A & 2B), down to a depth of 2 m, were collected from field sites identified in figure 1. Sample cores were obtained using an AMS Extendible Core Sampler and recovery tripod, which retrieves 5 cm diameter cores up to 60 cm long at a time.

Geochemical Analysis
Cation/anion compositions and TIC/TOC, and average hydration were determined for all core samples (Tables S1-S3). Average Free water content of the sediments was determined by weight. Cation and anion compositions of brine aquifer fluids were determined at each sample site as well (Table S4)

Mineralogical Analysis
QEMSCAN - The clay (≤3 micron) fraction was extracted from the sediment cores and analyzed using QEMSCAN at the Colorado School of Mines.
X-Ray Diffraction - Measurements were made using a Scintag XDS 2000 theta/theta goniometer with 2.2 kW sealed copper X-ray source.

DNA Sequencing & Analysis



Acknowledgements. This research is supported by the NASA Harriet Jenkins Pre-Doctoral Fellowship Program, the Edna Bailey Sussman Internship Program, the Colorado School of Mines Bechtel K-5 Initiative, The University of Montana and the NASA Astrobiology Institute.

MOTIVATION

In our long-term study of Pilot Valley , we investigate the microbial ecology of a terrestrial groundwater-fed paleolake basin along mineralogical and geochemical gradients. Our overarching goals are to: 1) Characterize microbial diversity in this understudied environment. 2) Assess the correlation between microbial diversity and mineralogical and geochemical variation. 3) Assess the influence of this relationship on biosignature preservation in order to better model groundwater-supported paleolake systems on Mars.

RESULTS TO DATE

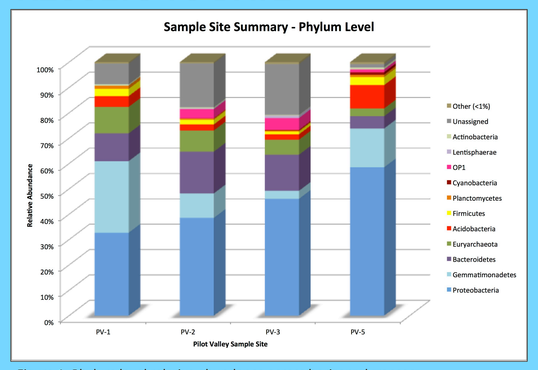


Figure 1. Phylum level relative abundance across horizontal transect.

Beta diversity analysis of depth-averaged community structure along the horizontal transect (Figure 1) indicates that, despite significant alpha diversity, there is no significant difference in the overall populations between the sample sites, suggesting minimal phylogenetic variability along the horizontal evaporative gradient, though there is variation in taxa abundance along the transect.

In the vertical transect, the dominant members of the community shift abruptly into discrete layers (Figure 2a). PCoA and PERMANOVA analysis of the Bray-Curtis (R2=0.46, PADONIS=0.001), Morisita-Horn (R2= 0.52, PADONIS=0.001), unweighted Unifrac (R2= 0.25, PADONIS=0.001) and weighted Unifrac (R2= 0.61, PADONIS=0.001) metrics show that the subsamples cluster into three distinct groups (Figure 2b). Within these three groups, the dominant taxa are evident down to the genus level.

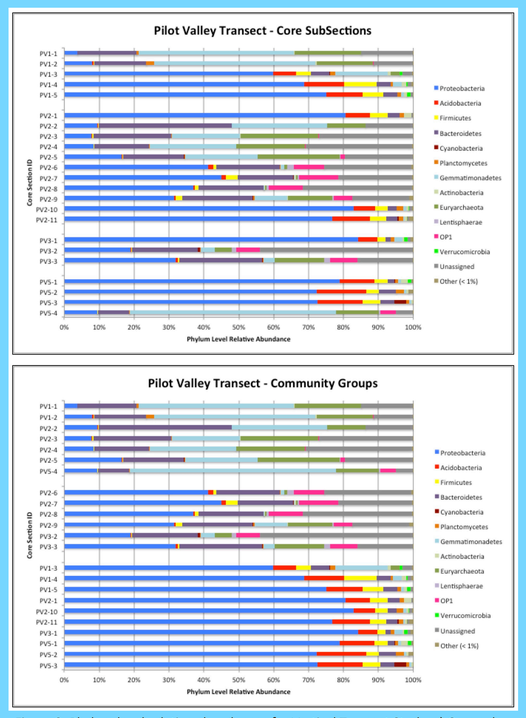
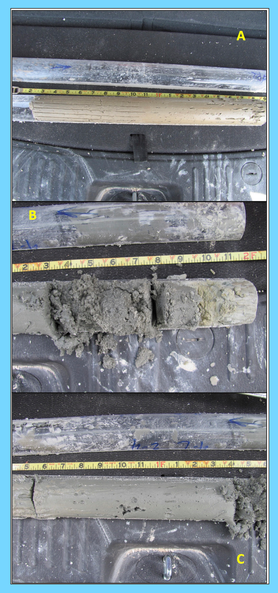


Figure 2. Phylum level relative abundances for Vertical Transect Study. a) Core sub-sections b) Community groups.

CCA plots (Figure 3 and 4) of vertical transect constrained by the 8 most correlated quantitative environmental variables and one qualitative variable (grain size) confirms that communities organize into the same three distinct groups.



Twenty-two environmental variables were measured at Pilot Valley. Only the physical characteristic of grain size, seems to be an influential factor on community assembly (Figure 5, Table 1).

Table 1. Cluster Groups

Group 1	
PV1-1, PV1-2, PV2-2, PV2-3, PV2-4, PV2-5, PV5-4	Grain Type - Fine Clay Clearly seen fine compacted clay sized particles. (Figure S6a)
Group 2	
PV2-6, PV2-7, PV2-8, PV2-9, PV3-2, PV3-3	Grain Type - Coarse Clear large euhedral salt crystals. (Figure S6c)
Group 3	
PV1-3, PV1-4, PV1-5, PV2-1, PV2-10, PV2-11, PV3-1, PV5-1, PV5-2, PV5-3	Grain Type - Fine Silt Silt/sand-sized particles with some small evaporite crystals in the mix. (Figure S6b)

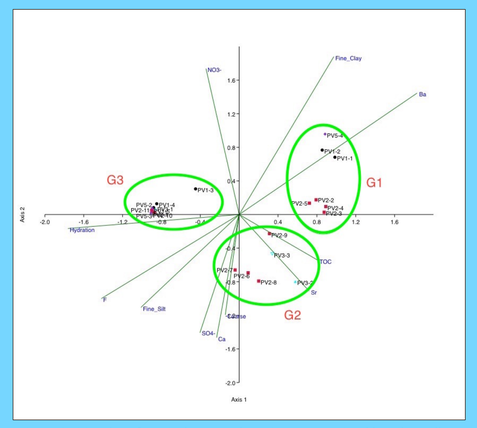


Figure 3. CCA plot of vertical cores subsections constrained by Pilot Valley environmental factors - scale factor 1. Groups identified as G1-Group1, G2-Group 2, G3-Group 3. Group 3 Members: PV1-3, PV1-4, PV1-5, PV2-1, PV2-10, PV2-11, PV3-1, PV5-1, PV5-2, PV5-3.

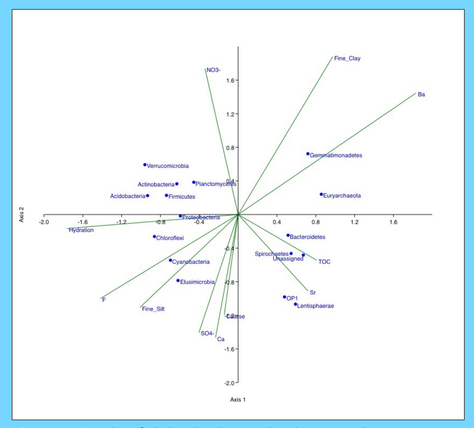


Figure 4. CCA plot of phylum-level group distributions with respect to environmental constraints.

CONCLUDING REMARKS

- Grain size effects on community structure observed in this study could impact what actually gets preserved in which sedimentary layers.
- It is likely that preservation would be higher in the clay-sized sedimentary layers than in the secondary mineral layers as continual groundwater flow could potentially cause re-dissolution of minerals and destruction of preserved biomarkers in those layers.