Project Summary / Abstract

Numerous lines of evidence suggest that during the early Noachian Period, the surface of Mars had liquid water and may have been habitable. However, evidence also indicates that there was a major climate shift at the end of the Noachian, likely accompanied by episodic cycling of wet-to-dry and freeze-thaw conditions. If there was life on early Mars, or just robust organic carbon cycling without life, it suggests that Noachian Mars could have been habitable for heterotrophic life. How would habitability have changed through the late Noachian to early Hesperian climate transition (NHCT), as Mars froze and dried, becoming the cold desert it is today? Specific targets for habitability studies of Noachian Mars include dried up lake beds (e.g., the bottom of Jezero Crater) and long dry hydrothermal systems (e.g., Eridania basin). Abundant hydrated clay minerals and putative hydrothermal deposits are targeted by habitability researchers partially because they provide the best conditions for preservation of organic compounds. Recent rover data have shown that organic compounds are present at these target locations; present and future missions will likely reveal even more organics on present-day Mars, preserved in Noachian terrain. A better understanding of the potential for heterotrophic habitability and the relationship between organics and clay minerals is needed.

With this proposal, we aim to 1) provide context for these new and future organic chemistry data, 2) improve our understanding of potential heterotrophic metabolisms on early Mars via Gibbs energy yield calculations, 3) understand how habitability changed on early Mars through the NHCT, and 4) improve our understanding of mineral-organics relationships in these settings. The proposed research will furthermore inform on the potential for heterotrophic metabolisms in lake and hydrothermal system analogue settings in Iceland. To do this, we will evaluate wet-to-dry/freeze-thaw cycling conditions of 1) sediments from several lake environments in Iceland, including the dried up lake bed of Hagavatn, and Lake Kleifarvatn, which has ongoing hydrothermal activity, 2) hydrothermal vent precipitates composed of saponite from the Strytan Hydrothermal Field, northern Iceland, which have been shown to trap organic compounds, and 3) existing experimental hydrothermal precipitates, including saponite and nontronite clays amended with organic compounds during growth. Once samples have been collected, they will be carefully homogenized and then comprehensively characterized for organic inventory. Sample analysis will begin with baseline evaluation of total organic carbon (TOC) concentrations, along with XRD, micro-Raman, micro-FTIR, nano-IR, and SEM analyses to help identify mineral-organic associations. This will be followed by a dichloromethane (DCM) extraction and analysis to identify and quantify organics extracted from the samples. To assist with organics identification and mineral-organics relationships, we will also use engineering test units (ETUs) for 1) the Sample Analysis at Mars (SAM), and 2) the Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals (SHERLOC).

To test the fate of organics during wet-to-dry/freeze-thaw cycles, samples will be placed in a Mars Environmental Cycling Simulation Chamber (MECS), which will mimic the characteristics of early Mars atmosphere, temperatures, and pressures through the NHCT. MECS experiments will last for +2 and +6 months; after each of these time steps samples will again be evaluated for OC compound type and concentration using the same instrument suite outlined above. At the heart of this proposal is the assumption that predictions of Gibbs energy can be used as a proxy for understanding the habitability of an environment. We will conduct energy yield calculations for heterotrophic metabolisms using data from each time point, allowing us to quantitatively evaluate the changes in habitability across the NHCT.