TERRESTRIAL IRON HOT SPRINGS AS ANALOGS FOR ANCIENT MARTIAN HYDROTHERMAL SYSTEMS. M. N. Parenteau[1], J. D. Farmer[2], L. L. Jahnke[1], and S. L. Cady[3], [1]Exobiology Branch, NASA Ames Research Center, Moffett Field, CA, USA (Mary.N.Parenteau@nasa.gov), [2]School of Earth and Space Exploration, Arizona State University, Tempe, AZ, USA, [3]Department of Geology, Portland State University, Portland, OR, USA.

Introduction: The history of water on Mars is uncertain, yet ample evidence indicates that an active hydrologic cycle once existed on Mars [1, 2]. Today liquid water is unstable at the Martian surface due to the low temperature and atmospheric density. However, evidence suggests that climatic conditions on Mars may have been different during the Noachian, after the intial period of heavy bombardment. Given the evidence for widespread volcanism and higher heat flow, the subsurface could have provided a major habitat for thermophilic life and warm mineralizing surface springs could have provided optimal conditions for fossil biosignature capture and preservation [3, 4]. Indeed, hydrothermal springs might have been habitable even if the Martian climate was less favorable overall than that found on the early Earth.

We have been studying a subaerial terrestrial iron hot spring as an potential analog for hydrothermal systems on Mars. In this multidisciplinary study, we have characterized the aqueous geochemistry, mineralogy, and microbial biosignature production and preservation at Chocolate Pots hot springs in Yellowstone National Park. Microbial biosignatures can link modern microbial ecosystems to the geological record, and with high fidelity preservation, this type of fossil evidence can be used to infer the paleobiological role of microbes and paleoenvironmental conditions. We are investigating biosignature capture and retention in modern iron-mineralized microbial mats, to determine 1) the nature of fossil biosignature information that survives early degradation, (particulary oxidative processes) that prevails in the surface layers of photoautotrophic microbial mats and 2) the earliest stages of diagenesis in the iron oxide deposits that accumulate beneath mats and the impact on biosignature retention.

Methods: The aqueous geochemistry, primary and diagenetically altered minerals, microfossils, biofabrics, and lipid biomarkers were characterized across a range of spatial scales using ion chromatography; inductively coupled plasma mass spectroscopy; X-ray and electron diffraction; light, epifluorescence, scanning electron, and transmission electron microscopies; and gas chromatography-mass spectroscopy.

Results: Chocolate Pots hot springs in Yellowstone National Park is a group of actively accumulating iron deposits. The anoxic vents waters are 50 - 53ºC with a pH of 5.6 - 5.8 and aqueous Fe(II) concentration of 4.7 - 5.9 mg/L. The primary precipitate in the vents and outflow channels is 2-line ferrihydrite with minor amounts of silica. The diagenetic phases goethite, hematite, and nontronite were identified in lithified cores removed from an outflow channel [5].

The iron deposits are colonized by four types of microbial mats containing cyanobacteria and filamentous anoxygenic phototrophs [6, 7]. TEM examination of the cyanobacterial cells revealed iron-permineralized carbonaceous microfossils that retained taxonomic features that allowed their identification to the genus level (Fig. 1). Powder X-ray diffraction of bulk samples and selected area electron diffraction of individual cells indicate that 2-line and possibly 6-line ferrihydrite encrust and permineralize the cells.

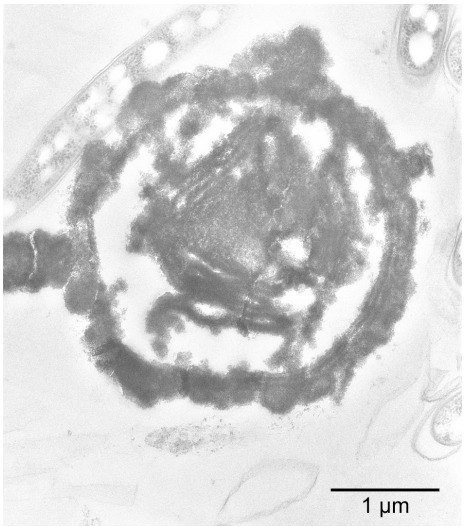

Figure 1. Iron permineralized cyanobacterial cell (*Cyanothece minervae*) from Chocolate Pots hot springs.

A robust suite of geologically significant lipid biomarkers (most notably 2-methylbacteriohopanepolyol and mono- and dimethylalkanes) were identified and linked to phototrophic source organisms (Fig. 2). These biomarkers were found to survive in the iron oxides beneath the microbial mats.

Discussion: Although permineralization by silica is considered to result in fossils with the highest cellular fidelity, results of our investigation of the early preservation of phototrophic cells at Chocolate Pots hot

springs indicate that iron permineralization can produce exceptionally well preserved microfossils.

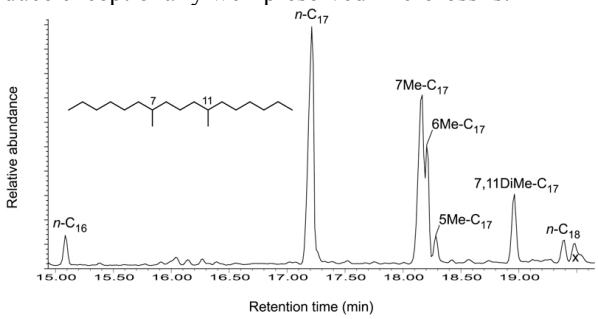

Figure 2. Gas chromatogram of hydrocarbon fraction of *Synechococcus*-Chloroflexi mat displaying mid-chain branched monomethylalkanes (7-methyl, 6-methyl, and 5-methylheptadecanes) and one dimethylalkane (7,11-dimethylheptadecane).

We recognize that the nature of biosignature preservation observed in this study occurs early in the diagenetic history of the Chocolate Pots sinter deposits; however, it is clear that at the earliest stage, fossil biosignatures have survived the initial stages of diagenesis, namely microbial degradation and mineral accretion onto biological surfaces. We are in the process of characterizing the impact of early diagenetic phase changes (recrystallization of opaline silica to more ordered phases, such as cristobalite and quartz, and ferrihydite to hematite or goethite) on the preservation of microfossils and primary biofabrics in iron oxide and silica hydrothermal deposits located near Chocolate Pots in YNP. Taphonomic studies of biosignature preservation in modern microbial ecosystems that evaluate the impacts of early diagenesis can lead to an imporoved understanding of paragenetic histories in iron and silica hydrothermal systems and the impacts on fossil preservation. The systematic documentation of microbial biosignatures (biofabrics, microfossils, and lipid biomarkers) in modern, iron-silica hydrothermal springs can lay important groundwork in the search for evidence of fossilized microbial life in ancient iron-rich hydrothermal deposits on the early Earth and Mars.

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