Research Statement

Dr. Jeff R. Havig

Summary: My primary research focus is to improve our understanding of rock-water-microbe interactions, and how those interactions 1) drive chemical reactions on the Earth's surface, 2) can be used to interpret the effects of anthropogenic inputs, and 3) can be used to interpret the rock record, especially the Paleoproterozoic and Archean. My work fills a critical need for understanding geochemical cycling and sequestration of elements on the Earth's surface. I use a wide array geochemical tools to characterize geochemical environments and trace the influence of life on geochemical reactions across a range of settings. My objective is to build a world-class environmental geochemistry lab that functions independently as a leader using geochemistry to understand changes in the environment, to develop biosignatures to look for past life on Earth and Mars, and to interpret the ancient rock record on Earth to help us understand current and future changes.

Figure 1. Preferential weathering of tan dolomite exposing grey chert in stromatolites found in the 2.0 Ga Nash Formation, WY.

Environmental geochemistry is in a golden age of exciting innovations in analytical capabilities and changing paradigms. New techniques, ever decreasing detection limits, and a renaissance in genomics approaches coupled to new geochemical proxies have created a critical need for geochemists that can bridge aqueous geochemistry, microbiology, and geology through field-based approaches. Characterizing geochemical environments in this context allows testing and exploring the limits of systems as they relate to element solubility, cycling, sequestration, and potential for remobilization. I employ wholistic sampling and analysis techniques coupled to integrative and collaborative approaches resulting in rigorous field contextualization with cutting-edge geochemical analyses. My work will help answer questions such as: How are anthropogenic effects influencing the ability of lakes to sequester carbon from the atmosphere? Where did life first arise on Earth? Is there evidence for past life on Mars?

Approach

Most of my sampling and analytical expertise is in aqueous environments. Techniques I use include analysis for major elements (e.g., electron microprobe, ion chromatography, ICP-OES, SEM-EDX), trace elements (e.g., ICP-MS, SIMS), carbon and nitrogen isotopes (e.g., Gas Bench and EA-IR-MS, BIO-SIMS) as well as *in situ*/real-time (e.g., pH, conductivity, temperature, dissolved oxygen, field spectrophotometry). **It is of utmost importance to my research program to train students and postdocs in sampling and using analytical techniques available. I am excited to bring new capabilities to the department, and to explore opportunities to bring new instrumentation and/or update existing instrumentation that would benefit my lab as well as others in the department.**

Examples of current projects that I would like to focus on in the next five years:

Novel biosignatures preserved by silica precipitating hot springs. We are using modern hot springs in Yellowstone National Park (YNP) to interpret ancient hot spring deposits including the 3.5 Ga Dresser Fm. of Western Australia and putative evidence for past life on Mars. We have learned there may be a characteristic trace element enrichment by life (Havig et al., in revision). Funding targets for this work include NASA Exobiology and NASA Habitable Worlds programs.

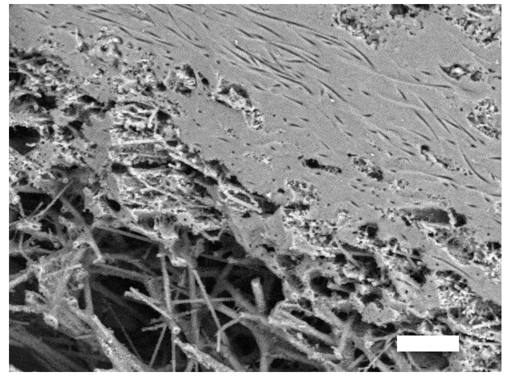

Figure 2. SEM image of silica precipitates around bacterial filaments from an alkaline hot spring in Yellowstone showing a transition from individual bacterial filaments coated with silica (bottom) to massive infill of microbial filamentous biofilm (top). Scale bar is 20 µm.

Hypolithic microbial communities as analogs for the first terrestrial oxygenic phototrophs. We are examining hypoliths (microbial communities living under siliceous sinter) in YNP as analogs for microbial communities living on continental surfaces prior to 2.5 Ga. Characterization showed they provide unique environments protecting microbial communities from UV radiation and desiccation (Havig and Hamilton, 2019). Funding target for this work includes the NSF Geobiology/Low Temperature Geochemistry program.

Carbon uptake/sequestration and redox chemistry of stratified systems. To better constrain the effects of trace element cycling in a redox-stratified system, I spearheaded a project studying permanently redox-stratified Fayetteville Green Lake, NY. This work resulted in a better understanding of trace element cycling (Havig et al., 2015; Herndon et al., 2018) and impacts of carbon cycling on the carbon isotope signal (Havig et al., 2018) as it relates to the Proterozoic ocean as well as modern lakes. Funding targets for this work include the NSF Geobiology/Low Temp. Geochem. program and the ACS Petroleum Research New Directions Fund.

Anthropogenic inputs and snow algae-subglacial dynamics. Atmospheric CO_2 may act as a stimulant for primary productivity in snow algae (Hamilton and Havig, 2017; 2018), contributing to accelerated surface melt and loss of glacial mass, and the produced biomass may serve as a primary driver of supra and sub-glacial microbial communities, effecting subglacial weathering (Havig et al., 2019). Funding sources for this work include NASA Exobiology and NSF Geobiology/Low Temp. Geochem.

Geologic mysteries of the Medicine Bow Mountains. Some of the most positive carbon stable isotope values as well as the end of the largest and most protracted positive isotope excursion are recorded in the 2.0 Ga Nash Fm. Putative hot spring deposits have been reported in the 2.7 Ga Colberg Metavolcanics, which would be only the second such system described in the Archean. To characterize the geochemistry and determine reliable age dates for the units, funding would be sought from NSF Sedimentary Geology and Paleobiology and Geobiology/Low Temp. Geochem. programs