

Field characterization of debris-covered glacial environments in Wyoming and their implications for the search for life on Mars

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In collaboration with Dr. Stefano Nerozzi (*University of Arizona*) and Dr. Alicia Rutledge (*Northern Arizona University*)

In May 2026, I was chosen to receive the NASA Astrobiology Early-Career Collaboration Award to support an 10-day field research trip in Wyoming with my advisor Dr. Stefano Nerozzi, and a subsequent 7-day sample processing trip at Northern Arizona University in collaboration with Dr. Alicia Rutledge.

Sulfur Creek and Galena Creek Glaciers

The first portion of this research involved traveling to Shoshone National Park in Wyoming in order to conduct water, sediment, and rock sampling. We collected samples at sources of ice/snow melt on each glacier under the guidance of Dr. Stefano Nerozzi and Dr. Alicia Rutledge. The water samples inform on the potential for habitability and preservation of biological material within the debris-covered ice as well as the nutrient exchange between the water and rocks. We took water and sediment samples from 10 sites across both glaciers.



These samples were filtered and pre-processed on-site and will be analyzed for chemical species and biotic presence. Within NAU-provided water sampling kits, separate tubes were filled for future lab analysis of water isotopes ($\delta^{18}\text{O}$, D/H), Anions (Cl, SO_4 , Br, F, NO_3 , PO_4), dissolved inorganic Carbon (DIC), dissolved organic Carbon (DOC), and cations and trace elements. The measurements that were collected on site were temperature, pH, and dissolved Silica concentration. These are documented as closely to the time of water sample collection as possible to stay accurate to the sampling site conditions. Figure 1 shows the dissolved SiO_2 reading from one of the sampling sites. This value fits within the standard range for glacial meltwater due to its lower total dissolved solids.

I will later perform DNA extraction on the used water sampling filters for further microbial investigation. The trapped material in the filter may provide further evidence for biosignature preservation within the debris-covered ice and the characteristics of any microbes present.

Figure 1. Hanna low-range Silica Colorimeter



Figure 2. (Left) Sulfur Creek Glacier about halfway to cirque, (Right) Group picture taken towards the cirque of Sulfur Creek Glacier (Dr. Alicia Rutledge, Dr. Ben McKeeby, Dr. Stefano Nerozzi, Maddy Christensen, Tyler Foote).

Throughout the duration of the fieldwork, we continued to make geomorphological observations on the types of plagioclase and pyroxene rocks that were heavily abundant in the area and how the flow of the glaciers has changed over time. By looking at various Lichen species on the rocks, it was easier to identify regions of high movement and disturbance. At the cirque of Sulfur Creek Glacier, we also took time to observe how the thermal inertia of large rocks can differentially melt the surrounding snow to create glacier tables. We finished our geomorphological work on Sulfur Creek Glacier by taking Ground-Penetrating Radar measurements across a 30-meter transect towards the bottom of the glacier. GPR measurements can assist in quantifying the depth of the debris above the glacial ice and detect potential rocky layers hidden beneath.

Towards the base and surrounding area of the glaciers, we also took tree cores as part of a continuing dendrochronology study started in 2025. These cores provide additional microclimate context to the dynamic history of these glaciers over time and establish a deeper record than the United States Department of Agriculture SNOwpack TELemetry Network (SNOTEL) weather station near Galena Creek can provide. The tree cores will be processed with the assistance of UA collaborator Dr. Agata Buchwal at the UA Tree Ring Laboratory.



Figure 3. (Left) Dr. Nerozzi demonstrating proper tree-coring technique in the meadow surrounding Sulfur Creek Glacier; (Right) Tyler Foote extracting a tree core sample with the assistance of Maddy Christensen.

Sample Processing and Analysis

The first phase of sample processing was conducted at Northern Arizona University (NAU) in Flagstaff, AZ with Dr. Alicia Rutledge and her graduate student, Candice DeAnda. I organized all of the sediment and rock samples, separated by grain/particle size, and analyzed them using two methods of spectroscopy. This is to not only determine sediment composition, but it is also an opportunity to look for alterations on rock exteriors that may not be present in the interiors. I cut the largest rocks from applicable sediment samples in half to achieve this additional alteration analysis.

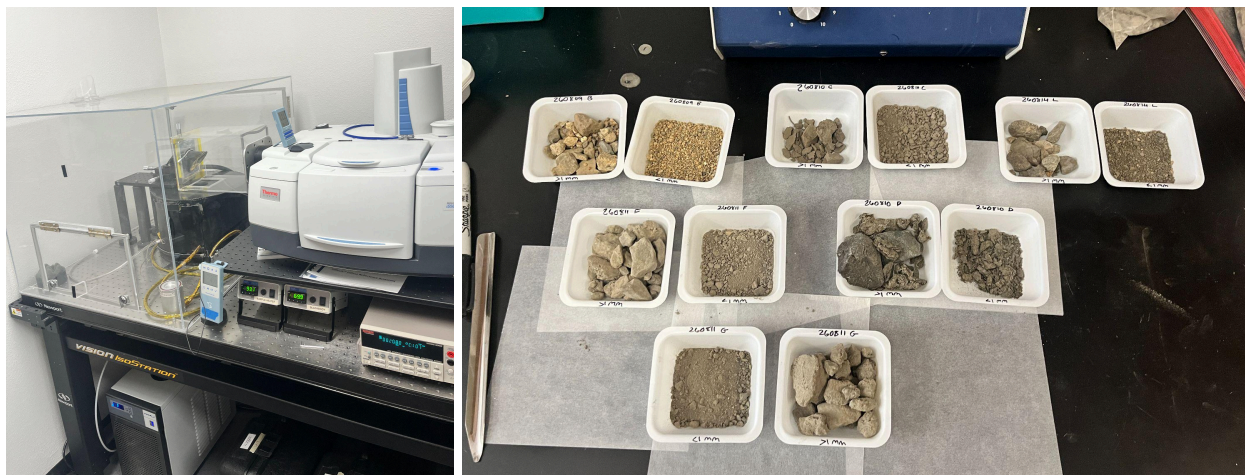


Figure 4. (Left) Fourier Transform Infrared (FTIR) Spectrometer; (Right) WY Sediment samples separated by collection location and general grain size prior to further sieving and data collection.

I gathered sample data first from the ASD visible/near-infrared (VNIR) spectrometer which is similar to the CRISM instrument for Mars and measures reflectance spectra from 400-2500 nm. This method helps identify small quantities of alteration minerals within a sample and where water has interacted with the sample. I then processed the samples through the Fourier Transform Thermal Infrared (FTIR) Spectrometer which measures emitted light in the infrared region, similar to the THEMIS and TES instruments for Mars. This method provides a deeper understanding of the bulk mineralogy of a sample and how it originally formed. The data that FTIR produces is comparable to global Mars datasets.

Throughout my time at NAU, I gained in-depth training and experience in multiple spectroscopy methods and created a database of sample spectra from both instruments that will now be analysed and interpreted to determine specific sample compositions. This contributes to a more thorough characterization of these glacial environments, their potential for preserving biological material in debris-covered glaciers, and how they can inform our understanding of analogous landscapes on Mars.