Following the Water on Mars: A Molecular Study for Understanding Near Surface Brines on Mars and Icy Worlds

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According to my initial proposal, I planned two visits to JPL to perform low-temperature vibrational spectroscopy experiments (NIR and Raman) for a week in October 2020 and then a week more in February 2021 to conduct low-temperature X-Ray Diffraction (XRD) experiments for iron-rich smectite and sulfate-Cl salt mixtures. Because of the extreme COVID restrictions in the USA, we had to revise this travel plan.

I traveled to JPL for a week in December 2021 and performed several low-temperature VNIR, Raman, and XRD measurements with hydrated Ca-sulfate-Cl salt mixtures. My NPP advisor, Janice also accompanied me on my first day at JPL to meet with our collaborators and set up the first set of experiments together. Gypsum ($CaSO_4.2H_2O$) can lose its structural water and convert to the bassanite ($CaSO_4.0.5\ H_2O$) and anhydrite ($CaSO_4$) forms through (i) heating above 150 °C and (ii) for gypsum mixed with Cl-salts at around 80 °C. I previously performed several thermal dehydration experiments with gypsum and low temperature FTIR experiments for my NPP project. There I discovered that the structural water of gypsum was released ~150 °C and my experiments also revealed that fast freezing of gypsum plus 1% $CaCl_2$ from 25 °C down to -90°C and then gradually heating the sample up to 25 °C again (freezing/heating cycle) presented the possible signatures of gypsum-bassanite-anhydrite mixtures. Previous papers questioned the analysis of gypsum and its derivatives at Gale Crater. They noted that warm conditions (~6° to 30°C) inside the CheMin sample chamber led to the dehydration of gypsum in the samples, forming bassanite in a period of sols during the XRD measurements. They also suggested that gypsum may have dehydrated over martian sols, forming the anhydrite-bassanite-gypsum mixture. According to in situ and orbital analyses, Cl-salts are distributed all over the planet Mars. Moving forward, regions rich in Cl and S salts on Mars could reveal potential near-surface frozen or liquid brines at low temperatures, whereas gypsum releases structural water and converts to its dehydrated phases. This may be an important clue for the possibility of subsurface life on Mars or Icy Worlds through ongoing Mars missions and the upcoming Europa Clipper mission.

To reveal these phase changes in gypsum-Cl salt mixtures, I first conducted cryogenic-VNIR experiments with guidance from Dr. Robert Hodyss. In Figure 1, we worked on replacing the low-temperature sample chamber in the spectrometer. We quickly froze the gypsum-water and gypsum-Cl salt mixtures from 25 to -90 °C and then heated them gradually back up to 25 °C and recorded multiple spectrum at specific temperatures.

After the completion of the VNIR experiments, Dr. Tuan Vu taught me how to prepare the samples and initiate the low-temperature XRD measurements shown in Figure 2. In these experiments, we heated the gypsum-Cl salt mixtures up to 120 °C and noted additional phase changes. Expanding on this, we decided to conduct low-temperature Raman experiments using the same experimental protocol for VNIR and XRD measurements. These Raman measurements helped us to confirm the varied phase changes of gypsum-Cl salt mixtures with the aforementioned techniques. I am preparing an abstract now combining all of our experimental data from JPL that will be submitted to the Lunar and Planetary Science (LPSC) 2022 Conference. Furthermore, I am writing up a manuscript to describe all of our experimental results related to Mars and plan to submit this to a scientific journal in the coming months.

Because of the COVID restrictions and my NPP termination date, I could not travel to St. Louis to collaborate with Dr. Pablo Sobron and perform the last task of this project in person. We are planning to set up online meetings to discuss our experimental data from JPL and implement those results into the planetary systems.

I really appreciate the NASA Astrobiology Early Career Collaboration Award for giving me this chance to start up the new collaborations for this project and future ones. I learnt how to use new spectrometer techniques, including low temperature VNIR and XRD, and developed my skills. These new results gave an exciting and complimentary insight for my gypsum-Cl salt mixture project. This project will help us to understand the aqueous history of Mars, its potential water resources, and complement the spectral data set collected from ongoing Mars missions by NASA and the upcoming Europa Clipper mission.

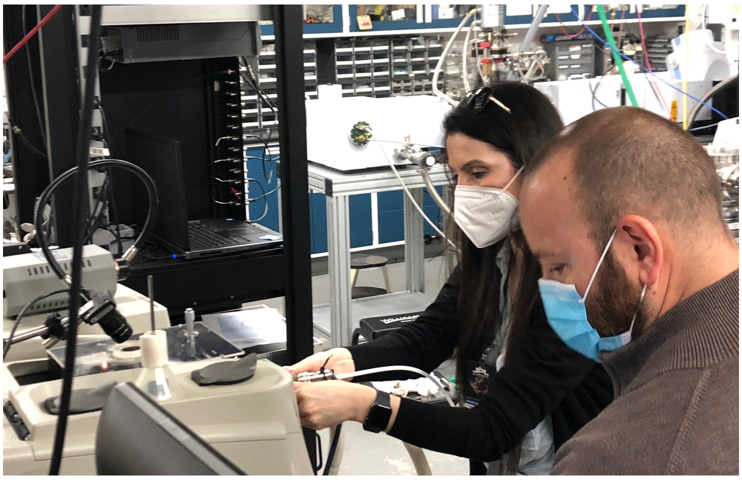

Figure 1. Robert and I working with low-temperature VNIR spectrometer to replace the low-temperature and pressure sample chamber into the spectrometer. (Credit: J. Bishop)

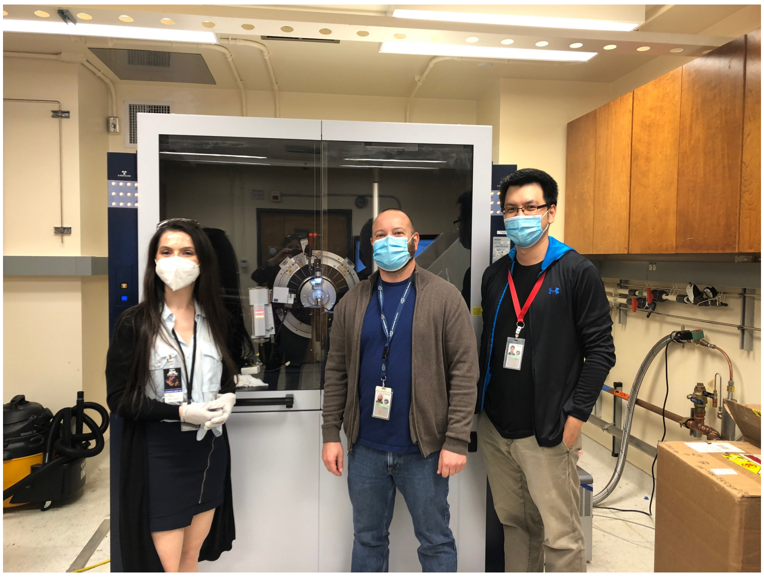

Figure 2. This photo was taken during the instructions for the low-temperature XRD experiments. Left to Right: Merve, Robert and Tuan. (Credit: J. Bishop)