Investigation of Mineralogies During the Delta Front Campaign by SHERLOC.

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Introduction: NASA's Perseverance rover has been exploring and measuring the Jezero crater environment for nearly two years. The SHERLOC (Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals) instrument can raster scan rock surface and generate high resolution Raman and luminescence maps to search for signs of life on Mars [1]. To date, the SHERLOC instrument has detected a variety of mineralogies and potential organic materials in the crater floor associated with past aqueous environments [2,3]. Although SHERLOC is designed to resonantly enhance deep UV chromophores, non-UV-absorbing, high-scattering molecules such as sulfates can be easily detected. Sulfates have been observed widely on Mars by both remote sensing and other rovers and are an important marker for past hydrological cycles [4,5]. Here we report on sulfate detections during the Delta Front campaign.

Methods: SHERLOC excites a target with ~14 uJ deep UV 248.6 nm pulses with a diameter of ~120 um and an annulus of ~10 um. The light is collected and scattered by the spectrometer with a resolution of ~0.27 nm. False color maps are generated based on the scan type: 15 ppp for 1296 pt survey scans (5x5 mm), 500 ppp for 100 pt HDR (7x7 mm) scans, and 500-900 ppp for 100 pt detail (1x1 mm) scans. Terrestrial samples measured with SHERLOC analogue instruments provides a reference database to be used against spectra measured on Mars.

Results: Of the ten targets measured during the Delta Front campaign, four show signatures of sulfate: Pignut Mountain (Sol 463), Berry Hollow (Sols 505, 513), Novarupta (Sols 570, 573) and Uganik Island (Sols 614, 617, 618, 620). Two targets measured show weak signatures of carbonate: Thornton Gap (Sol 489) and Novarupta (Sols 570, 573). Pignut Mountain is a fine-grained sedimentary natural surface in Hogwallow Flats that was dust cleared by the SuperCam LIBS laser; Berry Hollow is an abraded fine-grained sedimentary rock at Wildcat Ridge; Uganik Island is an abraded fine-grained sedimentary rock at Yori Pass; Thornton Gap is an abraded medium-grained sedimentary rock at Skinner Ridge; Novarupta is an abraded fine-grained sedimentary rock at Enchanted Lake.

Pignut Mountain has a single point with Raman bands at 1020 and 1130 cm^{-1}, consistent with anhydrite. No OH-stretching bands were observed.

On Sol 505, many points in Berry Hollow contained Raman bands at 1020 and 1140 cm^{-1}, consistent with anhydrite. A few points did show very weak OH stretching bands at ~3500 cm^{-1}, but they did not match the expected intensities for a more hydrated calcium sulfate such as gypsum or bassanite. On Sol 513, detail scans targeted a thin white vein that contained high intensity Raman bands at 1014, 1125, and 1154 cm^{-1}, again consistent with anhydrite. Like on the first sol, a few points contained weak OH stretching bands at ~3500 cm^{-1}, but they did not match the expected intensities for a more hydrated calcium sulfate. Some variation of the peak positions of the sulfate bands was observed.

Uganik Island was scanned by SHERLOC 14 times over the course of six sols, the most of any target thus far in Jezero crater. Like Pignut Mountain and Berry Hollow, many points contained high intensity Raman bands at 1014, 1125, and 1154 cm^{-1}, consistent with anhydrite.

Thornton Gap has an extensive number of points with a single Raman band at ~1090 cm^{-1}, consistent with ν_1 of carbonate. However, no other bands were observed to constrain the identification.

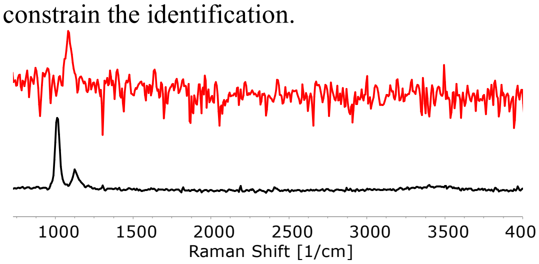

Figure 1: Characteristic Raman spectrum of carbonate from Thornton Gap (red, Sol 489) and anhydrite from Berry Hollow (black, Sol 513).

Novarupta has several points with a single Raman band at ~1090 cm^{-1}, consistent with ν_1 of carbonate. However, no other carbonate bands were observed to constrain the identification. Additionally, a couple points contained Raman bands at 1020 and 1140 cm^{-1}

consistent with anhydrite but were not collocated with the carbonate.

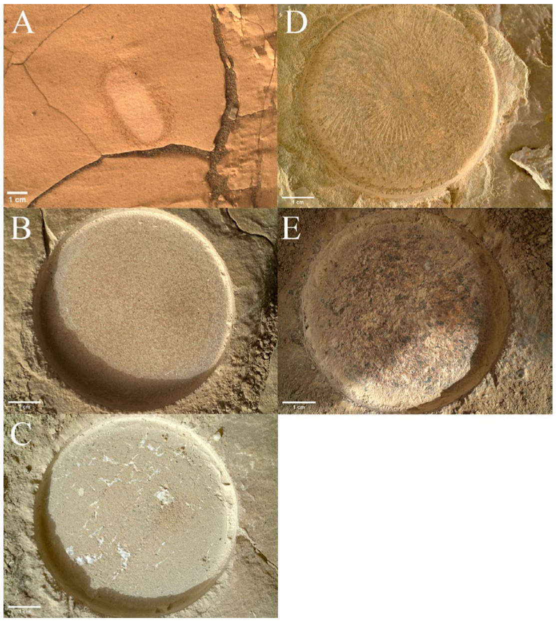

Figure 2: WATSON standoff images of (A) Pignut Mountain, Sol 463; (B) Berry Hollow, Sol 504; (C) Uganik Island, Sol 612; (D) Novarupta, Sol 568; (E) Thornton Gap, Sol 483. Scale bar in bottom left =1 cm.

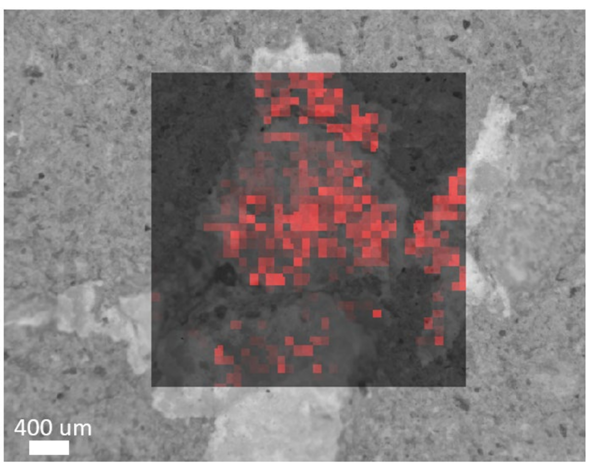

Figure 3: Raman map of ~1020 cm^{-1} sulfate band in the 1296 pt survey scan overlayed on an ACI image of Uganik Island from Sol 618.

Discussion: All targets were fine-grained, with targeted analysis on large white grains on Berry Hollow and Uganik Island. It is likely that the anhydrite detections not associated with a larger vein could be from some dust produced during the abrasion process or a single crystal of a sulfate surrounded by the sandy matrix. Since sulfates are highly scattering, it is not surprising that a small grain can be observed easily.

Low intensity OH stretching bands observed in Berry Hollow and Uganik Island are probably coming from a different plane of the sulfate crystal. Since anhydrite is nearly transparent to deep UV, the deep UV laser can penetrate deeper into the surface and excite a large volume of material. Material a few hundred microns below the surface could retain some water even though the surface is exposed to the dry Martian ambient conditions. Additionally, a low concentration of another mineral such as magnesium sulfate cannot be ruled out.

On Uganik Island, the largest sulfate grain was targeted. The teflon calibration target scatters deep UV Raman light and its highest intensity Raman band has a similar cross section to that of sulfate. This can be used to estimate the thickness of the sulfate grain in the map or to estimate its purity as neither PTFE nor sulfate absorb UV light. The large sulfate grain also appears to have a discontinuity at the edge where it meets the matrix that has significantly lower intensity. This could be because there is a sharp decrease in thickness near the edges, but most likely is caused by highly absorbing impurities mixing with the sulfate at the boundary. This can also be observed in a few of the areas with darker toned material. Unfortunately, these molecules are not enhanced by the deep UV laser as no Raman bands of interest could be observed.

On both Novarupta and Thornton Gap, carbonates were observed to be widely distributed in the lighter-toned material. Additionally, the intensities are all roughly similar indicating that the excitation volume is similar although there are differences in grain size.

Conclusions: The number of sulfate detections within targets is like that as seen in the Crater Floor Campaign; however, the Delta Front campaign mainly consists of minimally hydrated calcium sulfates in comparison to the widely observed magnesium sulfates during the Crater Floor campaign [6]. This observation suggests that as water levels receded from Jezero crater, the more soluble sulfates were concentrated in the crater floor whereas the less soluble sulfates precipitated out first.

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References:

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