LASER-INDUCED LUMINESCENCE IN JEZERO CRATER, MARS, AS SEEN BY THE SUPERCAM INSTRUMENT ON THE PERSEVERANCE ROVER.

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Introduction: The SuperCam instrument is part of the Mars rover Perseverance and has been analyzing Jezero crater since landing in February 2021. SuperCam is a remote sensing instrument on the rover mast that conducts chemical analyses using Laser-Induced Breakdown Spectroscopy (LIBS) and Time-Resolved Luminescence Spectroscopy (TRLS), mineralogical analyzes using Raman and VISIR spectroscopy, acoustics analyses using a microphone, and textural analyses using a remote micro-imager (RMI) [1-2]. Here, we present preliminary results from the TRLS analyses.

Background: The SuperCam TRLS technique uses a collimated 532 nm laser to activate luminescence centers in minerals at meter-scale distances from the rover. Both luminescence from minerals and organic materials should be detectable by SuperCam. Mineral luminescence due to trace element impurities and other defects has been more readily detected than organic fluorescence, which has not clearly been detected thus far. Lab work conducted prior to launch demonstrated that rare earth elements (REE^{3+}) are readily detected at ppm levels in minerals such as apatite and zircon, and transition metals are detected in a variety of minerals such as silicates (e.g., Cr^{3+} and Fe^{3+}) and carbonates (Mn^{2+}).

TRLS Concept of Operations (ConOps): Due to constraints of operating remotely on another planet, limitations on power and time, and instrument operational constraints, some experimentation was required to determine the best ConOps strategy for TRLS. The primary considerations are sunlight interference, gate width, time delay, number of laser pulses and whether they are summed on the detector or read out individually, and number of locations to analyze on a target versus the number of spectra to collect per point. The current strategy for initial interrogation of unknown targets is, after sunset to minimize sunlight, to collect 20 spectra per point with each spectrum comprised of 10 co-additions on the detector with a single exposure starting during the laser pulse (allowing both Raman and TRLS to be collected simultaneously) with a gate width of 0.5 ms. When possible, target selection focused on phosphates and zircons identified by instruments with higher spatial resolution (PIXL or SHERLOC) to search for REE.

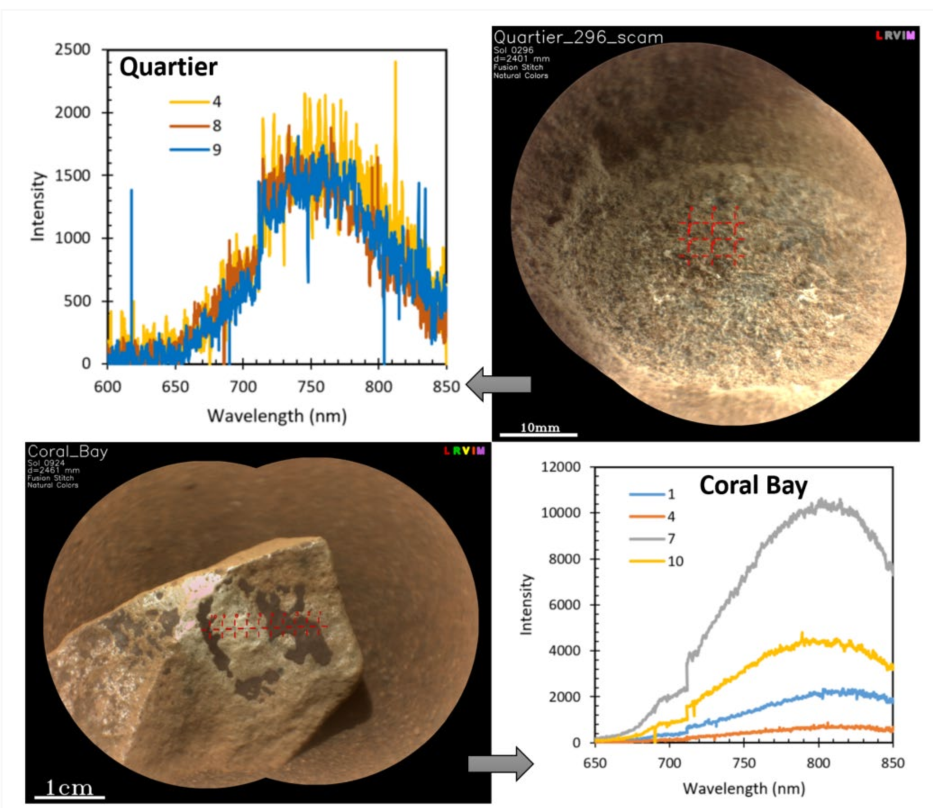

Fig. 1: Luminescence spectra from Quartier (top) and Coral Bay (bottom).

Observations in Jezero: Twelve dedicated luminescence activities and three Raman activities with luminescence have been conducted through sol 1000 (Table 1). Prior to sol 300, several luminescence activities revealed weak to medium strength broad features centered at ~750-760 nm. Figure 1 (top row) is an example of this type of luminescence found in the Quartier abrasion patch (sol 296, target name: Quartier_296_scam) in the Séítah formation, an olivine-rich cumulate rock [3]. All points in this target showed a weak to medium strength broad feature in this region, with locations 4, 8, and 9 having the strongest signal. After this sol 296 observation on Quartier, the longer gate width post-sunset luminescence activities showed no clear signatures (Table 1). However, two Raman activities collected on small, light-toned float rocks with discontinuous dark coatings (targets Chignik and Coral Bay) exhibited strong luminescence centered at around 800-830 nm (Figure 1, bottom row). The signal was significantly more intense than previous observations even with the much shorter gate width (100 ns vs. 0.5 ms).

Discussion and Future Work: Determining the cause of observed luminescence signals in unknown targets can be quite challenging [3], particularly given the constraints of operating on another planet. The targets themselves provide an additional challenge as multiple minerals are likely present within the analytical field of view (~mm), which could result in signals from multiple minerals being present or simply a reduction in signal due to the luminescing mineral forming a relatively small fraction of the footprint. Co-located analyses by SuperCam or other instruments can provide additional clues as to what minerals and elements are present but these are not directly co-located with the same sized footprint and so there is always some uncertainty in interpretation.

Given these caveats, the weak broad features centered around 750-760 nm are posited to be due to Fe^{3+} in feldspar minerals, as is commonly observed in terrestrial feldspars [3], but other possibilities exist as well. The strong, broad features centered around 800-830 nm on light-toned rocks are more difficult to identify and work is in progress to determine the most plausible sources. LIBS and VISIR data on these materials indicate they are enriched in Al, Cr, Ti, and Ni and may be predominately composed of kaolinite and/or halloysite but several other phases are likely present as well [4-6]. If additional similar rocks are found along the traverse, we will attempt to conduct a lifetime analysis, which may help identify the luminescence center.

References: [1] Wiens et al. (2021) Space Science Reviews, 217(1):4. [2] Maurice et al. Space Science Reviews, 217(3):47. [3] Beyssac et al. (2023) J. Geophys. Res., 128(7). [4] Gaft et al. (2005) Luminescence Spectroscopy of Minerals and Materials [5] Forni et al (2024), this meeting, [6] Royer et al. (2024), this meeting, [7] Bedford et al., (this meeting). [8] Clave et al. (2023) 54th LPSC, #1898.

Sol	Target name	Target Type	Features Observed	Time of Day (LST)	Gate Width (ms)	Gate Delay (ns)	No. of Steps	Step Size (ms)	No. Co-adds	No. Spectra
61	Dzilh_scam_2 *dził*	Natural rock	Reflected sunlight	13:59	0.01, 0.1, 0.25, 0.5, 1	750	1	NA	1	50
89	Hastah_tsaadah_scam_89 *hastą́ʼáadah*	Natural rock	Weak, broad, center ~750-760 nm	18:29	0.5	640	2	0.5	1	50
95	Ashdla *ashdlaʼ*	Natural rock	V. weak, broad, center ~750-760 nm	18:22	0.2	640	4	0.2	1	50
163	Guillaumes_163_trls	Abrasion	Weak, broad, center ~750-760 nm	18:42	0.5	640	4	0.5	1	50
191	Bellegarde_191b_scam	Drill tailings	V. weak, broad, center ~750-760 nm	18:13	0.5	640	4	0.5	1	50
209	Garde_209b_scam	Abrasion	Noisy	17:41	0.5	640	4	0.5	1	50
270	Dourbes_270	Abrasion	None	17:51	0.5	640	4	0.5	1	50
296	Quartier_296_scam	Abrasion	Broad, center ~750-760 nm	17:43	0.5	740	1	NA	10	10
473	Elkwallow_Gap_473_TRLS	Abrasion	Noisy	17:08	0.5	640	1	NA	10	10
513	Berry_Hollow_513a_scam	Abrasion	Weak, broad, multi-center? [8]	13:21	0.0001	650	4	0.00003	1	50
513	Berry_Hollow_513b_scam	Abrasion	None	17:34	0.5	760	1	NA	10	10
578	Novarupta_trls	Abrasion	None	18:38	0.75	740	1	NA	10	20
681	Chignik	Light-toned rock	Strong, broad, center ~830 nm	11:53	0.0001	640	1	NA	10	40
881	Gabletop_Mountain_881b_scam	Abrasion	Noisy	18:14	0.5	640	1	NA	10	20
924	Coral_Bay	Light-toned rock	Strong, broad, center ~800-830 nm	12:01	0.0001	640	1	NA	10	40

Table 1: List of luminescence observations through sol 1000.