LIGHT-TONED VEINS AND MATERIAL IN JEZERO CRATER, MARS, AS SEEN IN-SITU VIA NASA'S PERSEVERANCE ROVER (MARS 2020 MISSION): STRATIGRAPHIC DISTRIBUTION AND COMPOSITIONAL RESULTS FROM THE SUPERCAM INSTRUMENT.

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Introduction: Within Jezero crater, the Perseverance rover currently explores the lowermost-exposed scarp of the delta (Fig. 1) **[1,2]**. Here we: (1) present the distribution of light-toned veins currently observed via the rover along its route in Jezero crater; (2) introduce compositional results of veins as analyzed via Perseverance's SuperCam instrument, and place them into the context of results from the other instruments.

Methods: To track the presence (and absence) of light-toned veins in Jezero terrains, we systematically review the images acquired with the rover at different scales via the NavCam, MastCam-Z, SuperCam's Remote Micro-Imager (RMI) **[3,4]** and the WATSON cameras.

Composition: light-toned veins and material have now been analyzed via several rover instruments: Mastcam-Z multi-spectrometer, PIXL micro-XRF, SHERLOC Raman, SuperCam multiple techniques including Raman **[5-7]**. Here we focus on results from SuperCam's Laser-Induced Breakdown Spectrometer (LIBS).

Results: Light-toned veins were not observed during the exploration of the crater floor (i.e. until sol ~440 of the mission) that is composed of aqueously altered igneous rocks **[8-9]**. Light-toned veins have currently been observed in the 2 regions of the delta scarp visited with Perseverance: Hawksbill Gap (HG) and Cape Nukshak (CN) (Fig. 1). Veins are mostly seen in the HG's Hogwallow Flats member and in the CN's Yori Pass member (interpreted as representing former subaqueous environments **[1]**). Several fine veinlets (e.g. Fig. 2D) are also observed in the Kibler Knob rocks that have an olivine-rich composition similar to Séítah crater floor rocks **[8]**. Observing light-toned material is made challenging by: (1) the light conditions; (2) the dust that covers most terrains; (3) the small width of some veins. Many veinlets have been observed thanks to SuperCam/LIBS analyses, as the first laser shots remove the dust. Altogether, this suggests that additional veins than the ones observed could be present in the terrains explored.

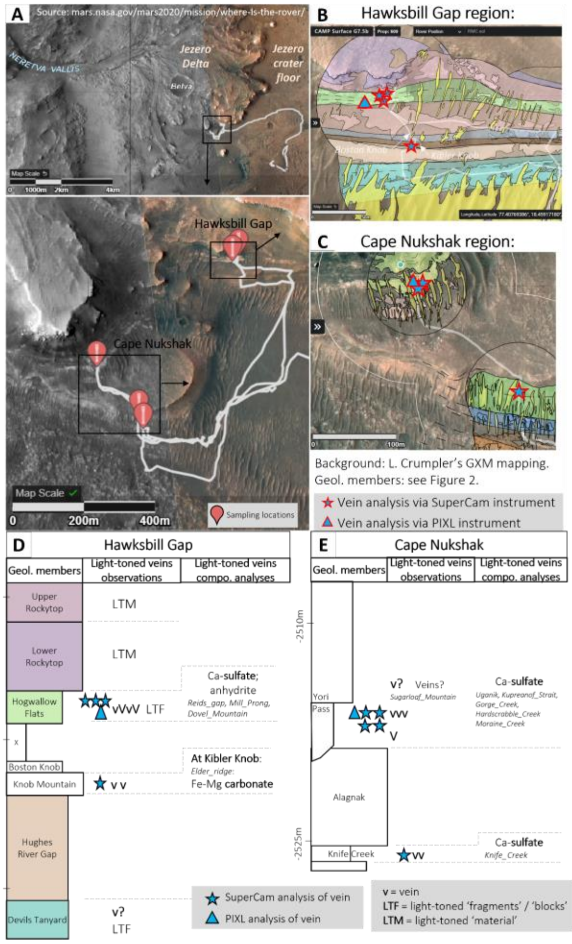


Fig. 1: **A.** Perseverance rover's route in Jezero crater up to sol 640. **B.-E.** Light-toned veins observations and compositional analysis via the SuperCam instrument.

Morphologically and texturally: light-toned material is typically observed cutting through the rocks: often in the form of veinlets millimetric in width up to centimetric in width (Figs. 2,3). At CN, heavily fractured light-toned material is observed in areas up to ~10cm wide (Fig. 2C) and up to ~m long.

Composition: based on SuperCam data, most veins analyzed are interpreted as calcium sulfate. The LIBS analyses show an enrichment (compared to the surrounding host rocks) in calcium and a depletion in other typical major oxides (Si, Ti, Al, Fe, Mg, Na, K; Fig. 3), as well as sulfur detection. Co-located SuperCam VISIR analyses are also consistent with a sulfate signature. SuperCam Raman analyses provide further constraints on the hydration of the Ca-sulfate veins analyzed, clearly identifying anhydrite **[5]**. The veinlet analyzed at Kibler Knob (Fig. 2D) shows a unique composition, interpreted as Fe-Mg carbonate, based on SuperCam VISIR and LIBS analyses.

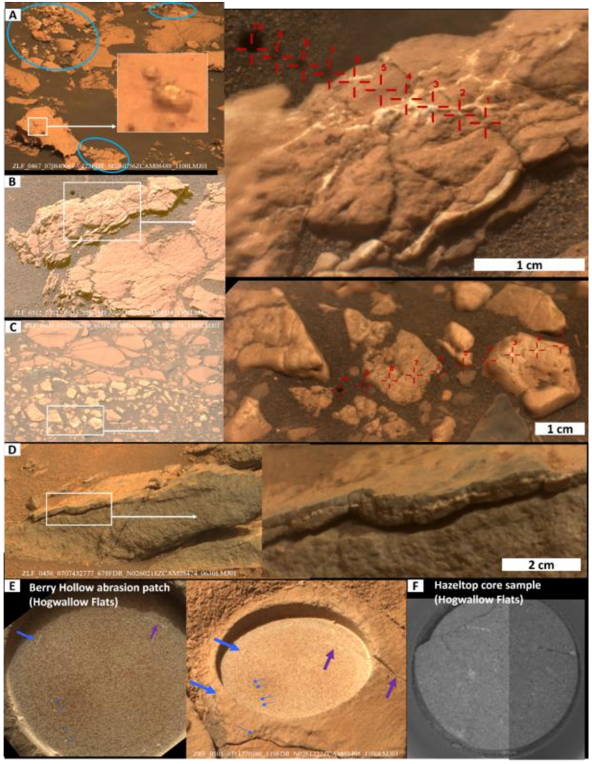
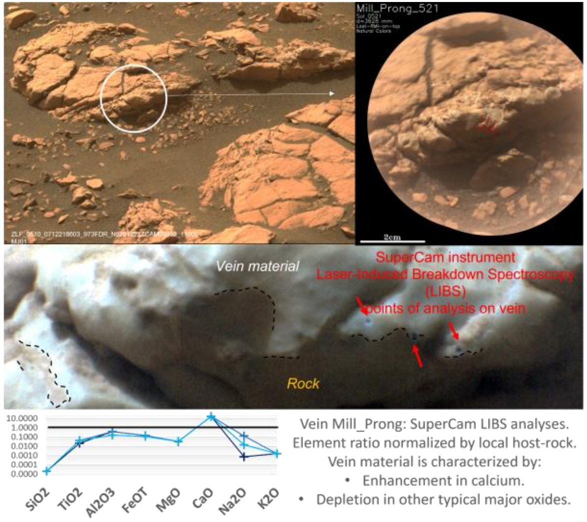


Fig. 2: Examples of light-toned veins and material. As seen via Mastcam-Z & RMI images in sedimentary rocks (**A-C**) and at Kibler Knob (**D**). **E**: In an abraded patch (WATSON & Mastcam-Z images). **F**: Sampling tube CacheCam image. Mcam-Z images IDs: ZLF_0467_0708400697_223FDR_N0260756ZCAM08489_1100LMJ01, ZLF_0512_0712395533_206RAD_N0261222ZCAM08536_1100LMJ01, ZRF_0609_0721008289_863FDR_N0301096ZCAM03476_1100LMJ01, ZLF_0456_0707432777_678FDR_N0260218ZCAM08474_0630LMJ01, ZRF_0505_0711770186_519FDR_N0261222ZCAM03405_1100LMJ01.

Interpretation & discussion: Ca-sulfate veins cut through at least ~2m of sedimentary rocks at HG and ~10m at CN, suggesting an emplacement via regional event(s). Light-toned material fills several concretions at Hogwallow Flats (Fig. 2A) and cut through the bedding of delta rocks, and thus represents at least 1 late episode of fluid circulation, post concretions formation and post sediment lithification. At Kibler Knob, the nature and origin of the Fe-Mg bearing carbonate veins (Fig. 2D) and of the rocks they cut is less clear but indicate a very distinct fluid composition than at Hogwallow Flats and Yori Pass. *Comparison with previous Mars rover missions:* after Ca-sulfate veins encountered with previous rover missions at Endeavour crater **[10]** and at Gale crater **[11,12]**, the presence of similar features in a different context at Jezero crater suggests that such features may provide a greater understanding of aqueous processes across space and time on Mars. The anhydrous nature of the Jezero veins notably differs from the bassanite composition of most Gale crater veins that have been interpreted as emplaced via hydraulic fracturing, and gypsum dehydration **[11-14]**.



Vein Mill_Prong: SuperCam LIBS analyses.
Element ratio normalized by local host-rock.
Vein material is characterized by:
- Enhancement in calcium.
- Depletion in other typical major oxides.

Fig. 3: Composition of a light-toned vein as analyzed with the SuperCam instrument's LIBS technique. Mcam-Z image ID: ZLF_0510_0712218603_973RAD_N0261222ZCAM08533_1100LMJ01.

Perspectives include continuing tracking the presence (and absence) and composition of these veins in the most recent portions of the Jezero delta. These veins are not visible from orbit, and thus their study in-situ is a unique opportunity to understand the late episode(s) of fluid circulation from which they originated, as well as their astrobiological potential **[15]**. Further analyses will also be possible on Jezero cached samples (e.g. Fig. 2F) to be brought back to Earth.

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