SULFATE ALTERATION IN THE CRATER FLOOR OF JEZERO CRATER, MARS AS OBSERVED BY MARS 2020 SHERLOC AND PIXL INSTRUMENTS. S. Siljeström[1], A. D. Czaja[2], A. Corpolongo[2], E.L., Berger[3], E. Cardarelli[4], R. Barthia[5], S. Bykov[6], S. Sharma[4], A. Steele[7], P. Conrad[7], R. Roppel[6], R. Jaubeck[3], A. Y. Li[8], E. Scheller[9], J. Razzell Hollis[10], R. Morris[11], T. Fornaro[12], S. Asher[6], K. Moore[4], Y. Liu[4], N. Randazzo[13] K. Steadman[4], A. Fox[11], L. DeFlores[4], A. Yanchilina[14], W. Abbey[4], C. Lee[15], C. Rodriguez[16], M. Wu[16], K. Winchell[16], S. Imbeah[16], B. Bleefeld[16] and M. Minitti[17], [1]RISE Research Institute of Sweden, Stockholm, Sweden (sandra.siljestrom@ri.se), [2]Department of Geosciences, University of Cincinnati, Cincinnati, OH, USA (andrew.czaja@uc.edu), [3] Jacobs, NASA Johnson Space Center, Houston, TX, USA, [4]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA, [5]Photon Systems Incorporated, Covina, CA, USA, [6]University of Pittsburgh, Pittsburgh, PA, USA, [7]Carnegie Institution of Washington, Washington, DC, USA, [8]University of Washington, Seattle, WA, USA, [9]Massachusetts Institute of Technology, Cambridge, MA, USA, [10]The Natural History Museum, London, UK, [11]NASA Johnson Space Center, Houston, TX, USA, [12]INAF-Astrophysical Observatory of Arcetri, Florence, Italy, [13]University of Alberta, Edmonton, Alberta, Canada,[14]Impossible Sensing Incorporated, St. Louis, MO, USA, [15]Lunar & Planetary Institute, Universities Space Research Association, Houston, TX, USA, [16]Malin Space Science Systems, San Diego, CA, USA, [17]Framework, Silver Spring, MD, USA.

Introduction: Sulfates are ubiquitous on the surface of Mars as identified by orbiters and in situ rover-based observations. Due to their capability to bind water, sulfates are potential large reservoirs of water and therefore are important for understanding the hydrological cycle on Mars and potential for life. Orbital-based observations suggests that the sulfates found globally are primarily monohydrated Mg-sulfates, polyhydrated sulfates and gypsum [1]. In addition, in situ rover-based measurements have identified Ca-sulfates such as anhydrite, bassanite and gypsum, and Fe-sulfates such as jarosite on the surface on Mars [2, 3]. However, the exact identity of the polyhydrated sulfates identified from orbit is unknown [4].

Recently, the Perseverance rover identified a variety of alteration minerals in igneous rocks of the floor of Jezero Crater including sulfates, carbonates and perchlorates [5, 6]. The sulfate detections have an associated fluorescence signal (doublet fluorescence), possibly indicating the presence of organic matter [7].

Here we report the sulfate chemistry (cation and hydration) of four different crater floor targets (Fig. 1): *Guillaumes* and *Bellegarde* in the Máaz unit (basaltic to basaltic-andesite) and, *Dourbes* and *Quartier* in Séitah (olivine cumulate) [5, 6] as observed by paired proximity science observations: Raman and fluorescence by SHERLOC (Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals) and elemental composition by PIXL (Planetary Instrument for X-ray Lithochemistry).

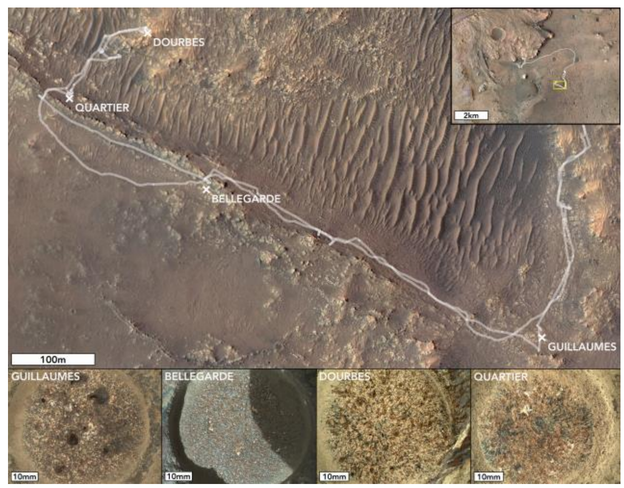

Fig. 1: Map of Jezero crater showing crater floor targets.

Results: SHERLOC and PIXL data were collected on the abraded patches 1 to 10 sols after the abrasion had taken place (Fig. 2-3).

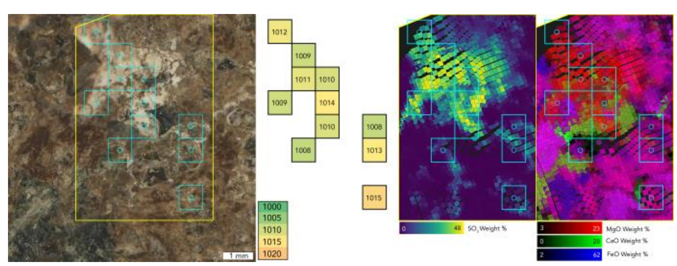

Fig. 2: Co-located SHERLOC and PIXL data of target *Quartier*.

The identified sulfates in *Quartier* appear primarily to be Mg-sulfates with varying amounts of Ca-sulfates. The closest match for the Mg-sulfates is polyhydrated sulfates such as starkeyite or pentahydrite though less hydrated Mg-sulfates also appear to be present [4]. The Ca-sulfates in *Quartier* are interpreted to be primarily less hydrated Ca-sulfates such as anhydrite or bassanite. The identified sulfates in *Dourbes* are primarily Mg-sulfates which appear less hydrated than *Quartier* ($MgSO_4$ * $3H_2O$) and possibly amorphous [4]. In both targets the detected sulfates are closely associated with other alteration minerals such as carbonates and perchlorates with the carbonates forming a rim around the sulfates. In the *Guillaumes* and *Bellegarde* targets, the sulfates appear to be primarily Ca-sulfates, most likely bassanite, and often associated with perchlorates [8]. The fluorescence signal indicating organic molecules, which is detected in *Bellegarde* and *Quartier*, shows a linear correlation with sulfate signal intensity and is preferentially concentrated to the less hydrated Ca-sulfates such as bassanite and anhydrite.

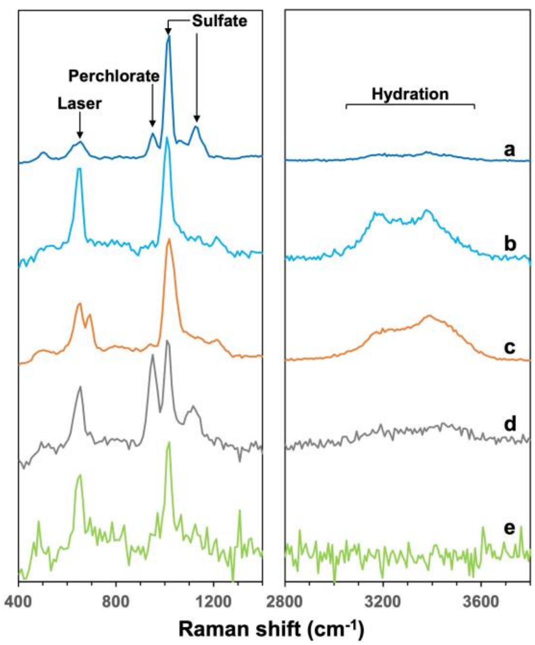

Fig. 3: Representative Raman spectra of a) *Quartier* Ca-sulfate, b) *Quartier* Mg-sulfate, c) *Dourbes* Mg-sulfate, d) *Guillaumes* Ca-sulfate, and e) *Bellegarde* Ca-sulfate

Discussion: The identification of starkeyite in the *Quartier* target is in line with predictions from experiments on the stability of sulfates under Martian surface conditions [9]. Additionally, in the *Dourbes* target the Raman peaks of Mg-sulfates are broader and at higher wave numbers than in Quartier indicating possible presence of amorphous Mg-sulfate with three water molecules, which is in line with what is predicted from laboratory experiments [4, 10]. Recent detections from CheMin on the Curiosity rover in Gale Crater indicated a large component of the Mg-sulfates is amorphous [11]. The spatial relationship between the different minerals with the sulfates in the center with a carbonate rim suggest that the carbonates were deposited first, and a neutral sulfate-rich brine later formed the sulfates [6].

The fluorescence signal correlated to the less hydrated Ca-sulfates also provides insights into the formation history of the organic matter, though full characterization of the putative organic matter present is only possible through samples from these units returned to Earth.

Conclusion: Based on data from the SHERLOC and PIXL instruments on the Perseverance rover, we identified possible pentahydrate or starkeyite, possible amorphous Mg-sulfates and Ca-sulfates such bassanite or anhydrite within the igneous rocks of Jezero crater. These results yield insights into the stability of sulfates under Martian surface conditions. In addition, the results also allow for spatially resolved relationships to be determined between the sulfates, other secondary minerals, organic molecules, and the primary igneous mineral within which they were deposited. Our results allow us to interpret the alteration history of the crater floor units of Jezero crater and the sulfur cycle of the Syrtis region and Mars more broadly.

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