BIOSIGNATURE PRESERVATION POTENTIAL OF SULFATE-RICH ROCKS FROM HOGWALLOW FLATS, JEZERO CRATER, MARS. A.P. Broz[1,2*], B. Horgan[1], H. Kalucha[3], J.R. Johnson[4], C. Royer[1], E. Dehouck[5], L. Mandon[3], E.L. Cardarelli[6,7], B. Garczynski[8], J.H. Haber[9], E. Ives[6], N. Mangold[10], T.Bosak[11], J.I Simon[12], P. Gasda[13], K. Stack-Morgan[6], E. Clave[14], B.S. Kathir[8], M. Zawaski[15], R. Barnes[16], S. Siljeström[17], N. Randazzo[18], J.M. Madariaga[19], K. Benison[20], K. Farley[3,6], L. Kah[21], W. Rapin[22], L. Kivrak[23], A.J. Williams[23], E. Hausrath[24], J. I. Núñez[4], F. Gómez[25], A. Steele[26], T. Fouchet[27], J.F. Bell[28], R.C. Wiens[1] and the Mastcam-Z and SuperCam teams.

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Introduction:

The Mars 2020 *Perseverance* Rover discovered fine grained sedimentary rocks in the Hogwallow Flats member of the Shenandoah Formation at the ~3.6- to 3.8-billion-year-old Jezero crater, Mars. Mudstones and sandstones at the 3-meter-thick Hogwallow Flats (HWF) outcrop, and a laterally equivalent outcrop known as "Yori Pass", show extensive evidence of diagenesis (alteration after deposition). Enhanced preservation of organic matter and other biosignatures can occur in early diagenetic environments associated with aqueous alteration in a lake, floodplain or pro-deltaic setting, as envisaged for HWF and Yori Pass [1]. Three drilled rock cores were collected from HWF-type bedrock as part of the Mars Sample Return Program. They are considered to be the samples with the highest potential to preserve organic compounds and biosignatures out of all samples collected so far by *Perseverance* (as of mission Sol 1000) [2]. This work outlines the implications of diagenesis for biosignature preservation in rock samples for possible return to Earth.

Methods

Mastcam-Z is a multispectral stereo imaging system onboard Mars 2020 *Perseverance* Rover. The instrument is a pair of zoomable multispectral cameras that allow for constraining the mineralogy of silicates, oxides, oxyhydroxides, and hydrated minerals [3]. SuperCam is comprised of a laser-induced breakdown spectrometer (LIBS), Raman spectrometer (532 nm), a time-resolved fluorescence spectrometer (TRF), and a visible and infrared (VISIR) spectrometer, as well as a microphone and remote micro-imager [4]. We use remote sensing observations from Mastcam-Z and SuperCam to compare chemical and multispectral data to the textures and morphology of altered rocks at HWF.

Results

Textures, morphology and geochemistry

Diagenetic features and textures include light-toned bedrock grading downward into red-green-gray mottled bedrock [5], elevated chemical index of alteration [6] authigenic Fe/Mg sulfates, clay minerals and Fe oxides [7], putative concretions, Ca sulfate-filled fractures, and rock coatings. Abrasion patches (Fig. 1) revealed multiple generations of sulfates including intergranular cements and detrital sulfate grains [8]. Hogwallow Flats likely represents different stages of diagenesis in Jezero crater that occurred under habitable conditions in the presence of liquid water and variable redox conditions. Mastcam-Z and SuperCam observations suggest major differences in redox state between Yori Pass and HWF. Mastcam-Z observations indicate low Fe^{3+} content of Yori Pass abrasions and drill tailings when compared to HWF (Fig. 2), indicating the Yori Pass core sample may be less oxidized (Fig. 3).

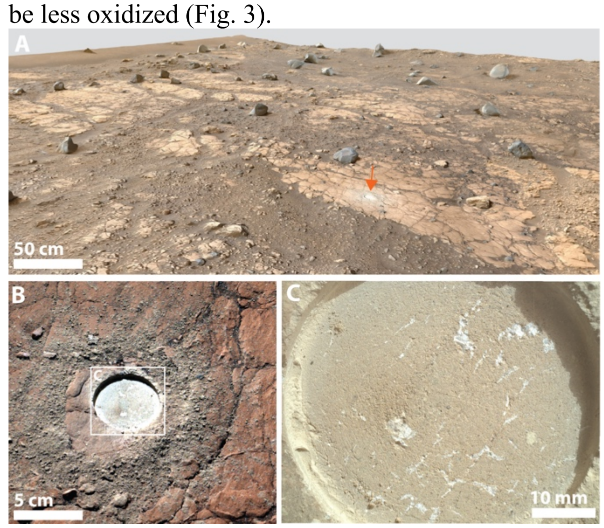

Figure 1. ***Outcrop surfaces at Yori Pass and light-toned sulfate-bearing material in bedrock revealed by abrasion patch.*** *A) 3D model of Mastcam-Z enhanced color images showing light-toned, platy and polygonal-*

fractured sandstone at Hidden Harbor outcrop, Yori Pass where orange arrow indicates position of Uganik Island abrasion patch (zcam08621, Sol 614); B) Mastcam-Z enhanced color image of Uganik Island abrasion patch showing light-toned material in abraded surface (Sol 614, zcam 03487); C) WATSON image (Sol 612, SRLC00746) showing distribution of light-toned sulfate-bearing material in patchy white areas.

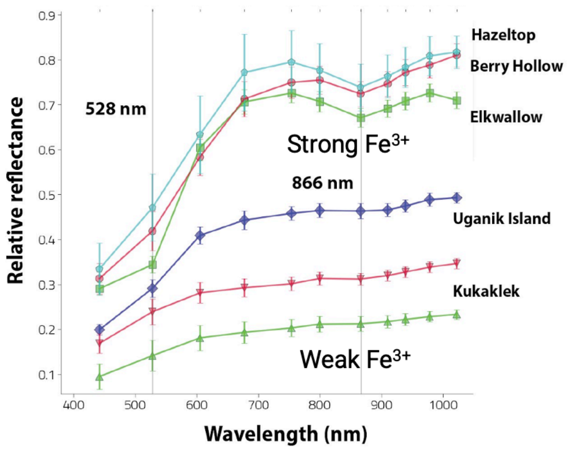

Figure 2. Mastcam-Z multispectral observations of abrasion patches and drill tailings showing variable redox state (Fe^{3+} content) at Hogwallow Flats (top 3 traces, and Yori Pass (bottom 3 traces); Co-occurring 528 nm and 866 nm bands at HWF suggest finely crystalline red hematite (WILL UPDATE LABELS)

Depositional and diagenetic setting

This sequence of light-toned, sulfate cemented bedrock overlying dark-toned, mottled and recessive bedrock repeats at least twice at HWF and possibly several additional times at Yori Pass. We interpret this interval of the Shenandoah Formation as either A) a subaerial floodplain that experienced episodes of leaching and/ or groundwater alteration and evaporation, or B) a shallow subaqueous (lacustrine or pro-deltaic) environment subject to aqueous alteration under variable redox conditions. Additionally, an eolian origin for HWF has also been proposed [5]. In any case, successive sedimentation and alteration events led to the formation of a sequence of fine-grained and horizontally-laminated strata comprising several meters of stratigraphy. Sedimentary textures and structures that could distinguish between these possibilities were not apparent due to the poorly outcropping nature of HWF strata and diagenetic obliteration of primary sedimentary structures.

Implications for biosignature preservation

We conclude that bedrock mottling likely represents early diagenesis due to water table variations leading to variable redox conditions. Furthermore, nodules/concretions, phyllosilicates, sulfate grains and cements, and mottling features may be sites of enhanced organic matter preservation. Cores may partially include mottled mudstones stratigraphically below sulfate-cemented outcrop surfaces [5]. Sulfates (authigenic and detrital grains) may contain fluid inclusions that in terrestrial examples can preserve pristine microbial cells and other biosignatures [8]. A major finding of this work is apparent differences in redox state between HWF and Yori Pass (Fig. 2), which indicate redox gradients that could have been an energy source for microbial metabolism [7]. Thus, the rock cores collected (Fig. 3) could preserve morphological, textural, chemical and/or isotopic biosignatures if life was ever present in ancient Jezero environments. These samples provide an ongoing incentive for Mars Sample Return.

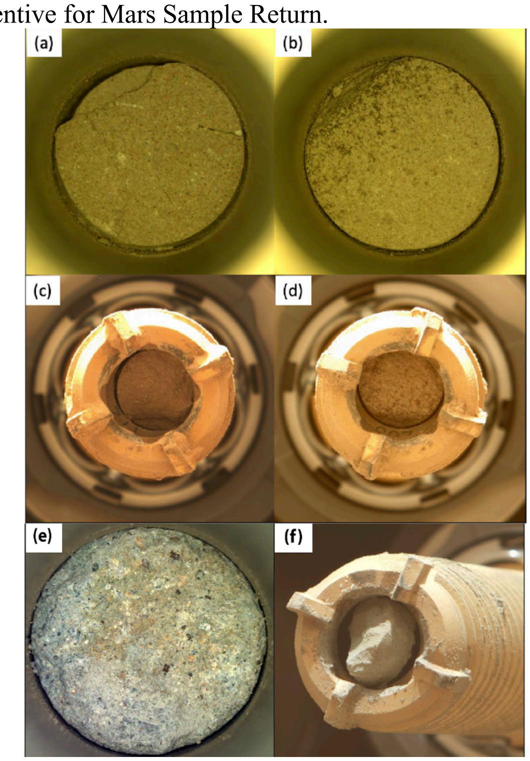

Figure 3. Rock cores collected by Perseverance rover from Hogwallow Flats (A-D) and Yori Pass (E-F). *A) Cachecam image of Hazeltop core (Hogwallow Flats, Core #12); B) Cachecam image of Bearwallow core (Hogwallow Flats, Core #13); C-D), Mastcam-Z images of Hazeltop (C) and Bearwallow (D) cores in coring bit; E-F) Cachecam and Mastcam-Z images of Kukaklek core (Yori Pass, Core #14). Sample tube diameter is ~1 cm.*

References:

[1] Stack, K. M. et al. (2023). *LPSC 53* [2] Bosak, Shuster et al., 2023, *JGR: Planets (In review)* [3] Bell, J.F. et al. (2021) *Space Sci. Rev. 217* [4] Wiens, R.C et. al. (2021). *Space Sci. Rev. 217*. [5] Benison, K. et al. (2022)

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