DIAGENETIC ALTERATION OF HOGWALLOW FLATS, JEZERO CRATER, MARS.

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Introduction: The Shenandoah Formation spans more than 50 meters of vertical stratigraphy at the delta front region within Jezero Crater, Mars [1]. The Hogwallow Flats (HWF) member of the Shenandoah Formation is a ~5 vertical meter stack of light-toned, platy and fractured sedimentary rocks that alternate in section with shaly, dark-toned, extensively mottled and deformed strata (Figure 1). These rocks appear to be significantly different in texture, color and morphology compared to other rocks in the Shenandoah Formation. Strata at HWF appears to be heterolithic siltstones and fine sandstones that may represent part of a subaqueous depositional system such as a distal turbidite bed [1]. These rocks also show diverse diagenetic features, suggesting that fluid flow during or after deposition has pervasively affected rocks at HWF. Similarly, strata observed at Yori Pass (YP) at a similar elevation to HWF shows comparable stratigraphy and diagenetic features, suggesting HWF may be a laterally- continuous unit with widespread distribution in the delta front. This work uses Mastcam-Z multispectral images from the *Perseverance* Mars Rover in conjunction with geochemical data from the SuperCam instrument to constrain the depositional and alteration history of HWF. A second objective of this work is to relate diagenesis to the biosignature preservation potential of rocks at HWF.

Methods

Mastcam-Z is a powerful multispectral stereo imaging system onboard Mars 2020. The instrument is composed of a pair of zoomable multispectral cameras that allow for constraining the mineralogy of silicates, oxides, oxyhydroxides, and hydrated minerals [2]. 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. [3]. In this work 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 and morphology

Color-enhanced Mastcam-Z images of finely layered dark-toned rocks at HWF show evidence of diagenesis in the form of dark-toned coatings, putative mottling features, filled fractures, and deformation (Figure 1). Light-toned platy rocks show evidence of diagenesis in the form of sulfate enrichment, gradual subsurface color changes from tan to red to gray and sulfate-filled fractures, some of which occasionally resemble desiccation features [4]. Also observed are a diverse set of nodules, concretions and rock coatings that vary in color, morphology, thickness and composition.

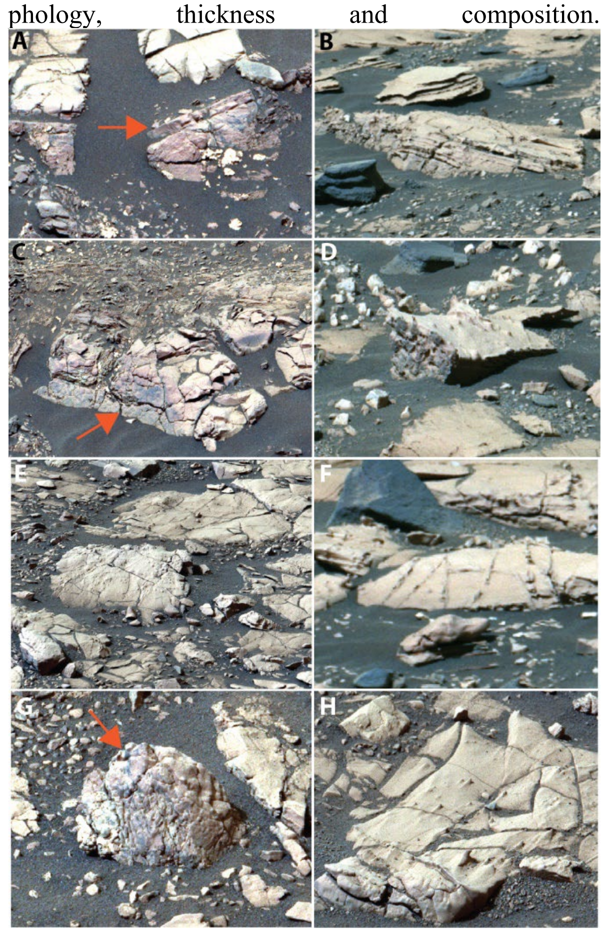

Figure 1. *Altered sedimentary rocks at Hogwallow Flats as seen by Mastcam-Z (enhanced color).* ***A-C,*** *Light-toned, platy, fractured rocks that alternate in-section with dark-toned, mottled, shaly rocks;* ***D-E,*** *nodular features in bedrock;* ***F,*** *putative vein fill with positive relief;* ***G,*** *extensively mottled, lumpy, dark-toned clast with putative dark coatings;* ***H,*** *Fractures and abundant wind-abraded nodules in the surface of light-toned bedrock. Arrows in A, C and G show color variations of strata. All images are from Mastcam-Z sol 461 zcam08482 L0 mosaic and can be viewed/downloaded at https://www.jpl.nasa.gov/images/pia25672-perseverances-mastcam-z-views-hogwallow-flats*

Multispectral and geochemical properties

Nodular features, putative concretions and bedrock observed at the Pignut_Mountain target at HWF (sol 464) appear to contain a mixture of sulfates, hematite, orthopyroxene (OPX), and other Fe^{3+} - bearing alteration phases (Figure 2). The presence of OPX is inferred from the broad near-infrared absorption features centered near 910 nm as well as reflectance peaks near 754 nm [5]. Additionally, the 866 nm band is significantly broader and more rounded than would be expected for pure hematite [5]. It is possible that the nodules are composed of variable amounts of hematite and other minerals like OPX, Fe smectite (nontronite) and/or Fe sulfates.

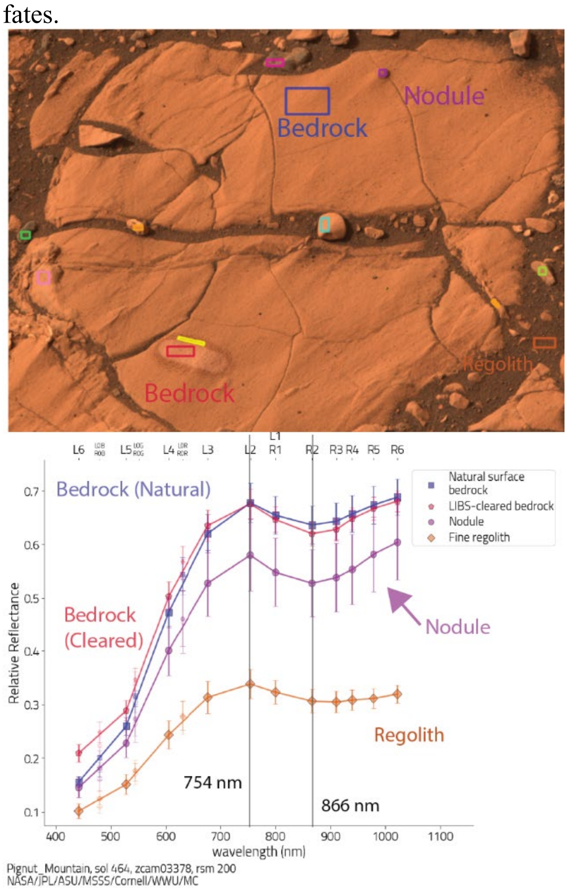

Figure 2. *Mastcam-Z context image and spectra of light-toned bedrock, nodules, pebbles and veins at the Pignut_Mountain target (Sol 464, zcam03348). Highlighted is the 866 nm band due to hematite.*

The median chemical index of alteration (CIA) from rocks at HWF and YP was generally > 50 and up to ~65 in some targets [6], indicating these rocks could have experienced significant open-system aqueous alteration [7]. Alternatively, the elevated CIA at HWF and YP could have resulted from the presence of detrital Al/Si-rich phases formed elsewhere that were transported to paleolake Jezero, and thus caution is needed when interpreting alteration history of martian rocks by using CIA alone.

Timing of diagenesis: Early versus late

Filled fractures imply late fluid flow, after lithification, but mottling is often due to early diagenesis [8]. Sulfate-enriched bedrock could represent early diagenesis, whereas the nodules and/or concretions could have formed at any time. One possible type of diagenesis that could have been responsible for the mottled colors at HWF is “burial reddening”, which on Earth can result from the dehydration of Fe oxyhydroxides (ferrihydrite, akageneite and/or goethite) and subsequent transformation into fine-grained Fe oxides (hematite) [9]. However, the relative timing of this process (early vs. late) and how this process influences biosignature preservation are not fully understood.

Implications for biosignature preservation

Early/late diagenetic sulfates (e.g., anhydrite) and Fe/Mg carbonates have the potential to preserve biosignatures, including those with a textural, chemical, and/or isotopic origin [10]. Mottling is common in terrestrial nonmarine mudstones and is usually associated with early diagenesis [8]. These areas could represent ancient redox gradients and thus may be sites of enhanced organic matter preservation. Alteration phases including Fe/Mg phyllosilicates in HWF and YP rocks could indicate sites of enhanced organic preservation, but in some cases these phases are associated with poor preservation of organic carbon, such as in clay-rich terrestrial mudstones that experienced strongly oxidizing conditions during alteration or shortly after burial [11].

Critically, there is no current evidence of more severe alteration such as metamorphism, illitization of smectite, or zeolitization at HWF. These are common alterations observed in Precambrian mafic nonmarine rocks [12], and are all generally associated with poor organic preservation. This works suggests that rocks at HWF have experienced a complex alteration history, possibly including early diagenetic open-system weathering, and that these rocks may represent sites of enhanced biosignature preservation potential.

References:

[1] Stack, K. M. et al. (2023) LPSC 53 (This vol.) [2] Bell, J.F. et al., (2021) *Space Sci. Rev. 217* [3] Wiens, R. et. al., (2021) *Space Sci. Rev. 217*. [4] Stein, N. et al., (2018) *Geology 46: 515-518.* [5] Haber, J. et al 2022 *JGR: Planets.* [6] Dehouck, E, et al. (2023) LPSC 53, This vol. [7] Mangold, N., et al (2019) *Icarus 321: 619-631.* [8] Piper, G. et al (2005) *Chem. Geology 178,* 75-97. [9] Spinola, D. et al., (2018) *Geoderma 315, 149-159.* [10] Hays, L.E. et al., (2017) *Astrobiology 17,* [11] Broz, A. (2022) *JGR: Planets* 127. [12] Liivamägi, S. et al., (2014) Geology 42: 4, 323-326.