BIOSIGNATURE POTENTIAL AND POSSIBLE ENVIRONMENTAL INDICATORS OF SULFATE-RICH ROCKS FROM HOGWALLOW FLATS AND YORI PASS, JEZERO CRATER DELTA FRONT, MARS.

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Introduction: As part of the Mars 2020 mission, the Perseverance rover has examined and sampled rocks from the Hogwallow Flats Member at Hawksbill Gap and the Yori Pass outcrop at Cape Nukshak, two strata on the Jezero crater delta front [1, 2, 3]. At Hogwallow Flats, two cores named Hazeltop and Bearwallow were collected. A nearby abrasion patch named Berry Hollow was analyzed in situ. At Yori Pass, a core, Kukaklek, was drilled through abrasion patch Uganik Island (Fig. 1). In situ observations suggest similar lithologies for these rocks. This abstract aims to summarize the potential for biosignatures in these samples.

Fig. 1: Images of rocks of Yori Pass (top) and Hogwallow Flats (bottom). Abrasion patches Uganik Island and Berry Hollow on left. Cores Kukaklek, Hazeltop, and Bearwallow in center and right.

Lithological Descriptions: In situ observations of abrasion patches Berry Hollow at Hogwallow Flats and Uganik Island at Yori Pass suggest that these are sulfate-rich sandstones with multiple diagenetic features. In Berry Hollow, most grains are silt to fine sand-sized. Grains are well-sorted, moderately rounded, and exhibit moderate-high sphericity. High-resolution images of the abrasion patch appear to show intergranular cements, including possible overgrowth cements. White veins cross-cut the rock.

In Uganik Island abrasion patch, most grains range from very fine sand size to medium sand size, but there are also granule-pebble-sized, rounded intraclasts composed of tan sandstone. Grains are moderately sorted, angular-rounded, and have moderate-high sphericity. Grains have a variety of colors, including black/dark gray and tan/brown. A cream-colored intergranular cement is seen between grains. Veins and vugs are lined with cream-colored, fine cement crystals, followed by pale gray/translucent blocky cement crystals that fill vein and vug interiors.

Compositional Data: In situ analyses of Berry Hollow and Uganik Island abrasion patches show that their compositions are similar [4, 5]. Both include both sulfates and siliciclastics as detrital grains.

Berry Hollow abrasion patch contains phyllosilicates, Fe-Mg-sulfates (likely hydrated), anhydrous Ca-sulfates, hematite, carbonates, and possibly chloride salts. Veins are filled with Ca-sulfates, including anhydrite.

Uganik Island abrasion patch contains phyllosilicates, anhydrous Ca-sulfates, Fe-Mg-sulfates, and ferric sulfate. Localized hematite is found and may be present in concretions. Chloride salts may be present. Veins and vugs consist of Ca-sulfate minerals, including anhydrite (Fig. 2) [4-6].

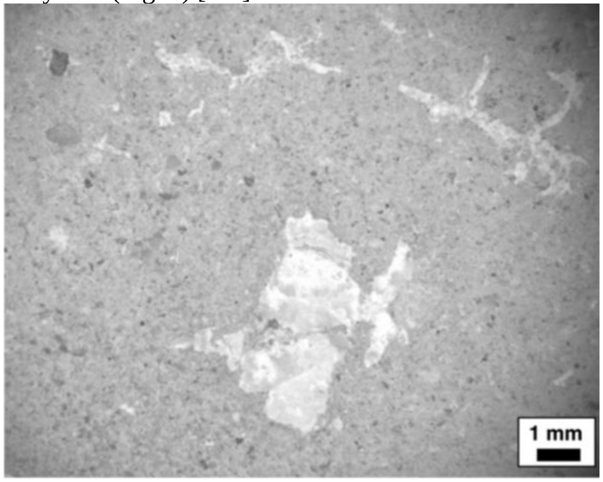

Fig. 2: Close-up image (SHERLOC Autofocus and Context Imager) of Uganik Island abrasion patch, showing white and clear crystals in veins and vugs in the clastic host rock.

The rocks of Hogwallow Flats and Yori Pass exhibit fluorescence associated with sulfate minerals. This is a potential indication that these rocks contain some form of organic material.

Habitability and Biosignature Preservation Potential: The sulfate grains which contribute to the sandstone lithologies suggest chemical precipitation of sulfate crystals elsewhere (likely upstream, but also possibly from elsewhere within the crater) in a saline lake water (or, less likely, a saline groundwater). These lake sulfate crystals had the potential to entrap any available microorganisms and/or organic compounds in their crystal interiors as solid inclusions and/or within fluid inclusions, as those host crystals precipitated [7 - 10]. Later, these lake sulfate crystals were eroded, transported, and deposited [11], possibly as a delta deposit, with siliciclastic grains, at Hogwallow Flats and Yori Pass. Although moved from their source area, and decreased in size and rounded in shape during transport, the sulfate grain interiors may retain the water chemistry and organic material of that source area. The phyllosilicates may also bear organic materials. Diagenetic minerals, including sulfate, chloride, and hematite cements, have the potential to have preserved various types of biosignatures that may reflect the organic materials of saline groundwaters. In particular, the intergranular cements and the vein and vug cements resulted from precipitation from saline acid groundwaters that flowed through the rocks after deposition. Although we do not know that exact timing of or burial depth at which intergranular and vein and vug cements formed, it is possible that they formed early in the shallow subsurface. Due to the multiple types of clastic minerals and diagenetic features in the rocks at Hogwallow Flats and Yori Pass, the samples collected there may provide the strongest likelihood of success in finding biosignatures upon sample return.

Sulfate-Hosted Fluid Inclusions as Environmental Indicators: The Ca- and Mg-sulfate minerals likely host fluid inclusions. Primary fluid inclusions in bottom-growth or cumulate crystals are remnants of past surface waters. In cements, primary fluid inclusions are remnants of past groundwaters. Even after bottom-growth or cumulate crystals have been eroded, transported, and deposited as silt or sand, they retain primary fluid inclusions in their interiors [12].

Primary fluid inclusions in both chemical sediments and cements have yielded high-resolution measurements of environmental conditions [13]. Parent water temperatures, compositions, pH, air and other gas temperatures and compositions, and parent water pressures have been documented from fluid inclusions in modern and ancient sedimentary minerals on Earth. Chemical sediments, such as sulfate and chloride minerals, typically have abundant primary fluid inclusions that are large enough to perform such analyses of environmental parameters.

The close association between primary fluid inclusions and organic material in terrestrial sulfate minerals suggests the promise that the sulfates at Hogwallow Flats and Yori Pass may offer the chance to evaluate for both organic materials and the environmental conditions in which they existed. In modern and some ancient terrestrial saline minerals, cells of extremophile prokaryotes, fungi, and algae, along with organic compounds such as glycerol and beta-carotene, have been documented within primary fluid inclusions (Fig. 3) [12 - 16]. As such, these primary fluid inclusions act as miniature habitats that can exist within crystals [14]. The liquids and any gas in the same individual fluid inclusions that host these microecosystems can be analyzed for environmental conditions.

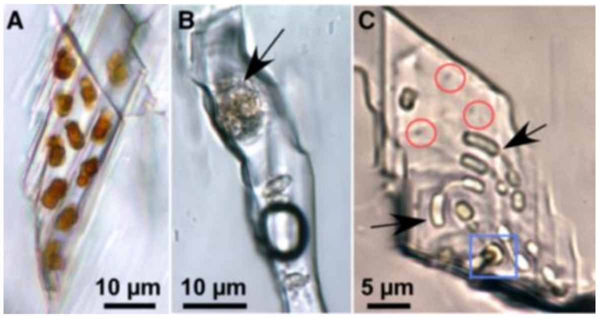

Fig. 3: Microorganisms in primary fluid inclusions in gypsum from Chile [2]. A. Algae and beta-carotene. B. Suspect *Dunaliella* algal cell (arrow). C. Archaea and/or bacteria (cocci in red circles, bacilli at arrows), and alga (blue box).

Conclusions: Returned samples of Hazeltop or Bearwallow, and Kukaklek show potential for yielding biological and environmental data about Mars' past and meeting the needs of the MSR community [17]. Sulfate minerals in both depositional and diagenetic phases may not only allow for a detailed, high-resolution history of waters on Mars, they may also prove to be the rocks sampled, to date, with the highest likelihood for the preservation of organic material.

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References: [1] Williams et al. *this conf.* [2] Stack et al. *this conf.* [3] Hurowitz et al. *this conf.* [4] Roppel et al. *this conf.* [5] Phua et al. *this conf.* [6] Núñez et al. *this conf.* [7] Martinez-Frias et al. (2006) *Rev Env Sci and Biotech*, 5, 219-231. [8] Benison & Karmanocky (2014) *Geology*, 42, 615–618. [9] Dela Pierre et al. (2015) *Geology*, 43, 855–858. [10] Benison (2019) *Frontiers Env Sci*, 7,108. [11] Benison (2017) *Geology*, 45, 423-426. [12] Karmanocky & Benison (2016) *Geofluids*, 16, 490-506. [13] Goldstein (2001) *Science*, 294, 1009-1011. [14] Lowenstein et al. (2011) *GSA Today*, 21, 4–9. [15] Conner & Benison (2013) *Astrobio.*, 9, 850-860. [16] Schreder-Gomes et al. (2022) *Geology*, 50, 918-922. [17] Herd et al. *this conf.*