THE SCIENTIFIC VALUE OF COLLECTING SAMPLES FROM THE JEZERO CRATER RIM.

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Introduction: The Mars 2020 mission has been conducting ground-based investigation of the geology, habitability, and biosignature preservation potential and collecting samples for return to Earth in Jezero crater, Mars for nearly 3 years [1]. Analysis of these samples will address outstanding questions in Mars science including potential habitability and how and why the climate the interior of the planet evolved through time. As of December 2023, samples of 4 igneous rocks of the Jezero crater floor and 9 sedimentary rocks of the Jezero fan and inner margin, remain on the rover. 15 tubes remain to be filled to enhance the diversity of the cache and broaden the scope of the science questions that can be addressed with returned sample studies.

The next step in the mission is to explore the Jezero crater rim. It will be imperative to investigate and sample the diversity of crater rim rocks because they represent materials from Mars' most ancient crust [2-3] older than those sampled in Jezero crater, a diversity of geologic processes, and potential ancient habitable environments that have not yet been investigated or sampled. Ongoing mapping efforts are using orbiter data and long-distance images from Perseverance to identify and interpret the geologic context of the crater rim [4]. Building on this effort and the broader geologic context for the crater rim put forward by previous studies, we identify diverse targets for in situ investigation and potential sampling by Mars 2020.

Unique geologic units accessible in the crater rim: The geologic context and stratigraphy of the crater rim is inherently complicated due to processes resulting from the crater forming impact. Yet key rock units not accessible on the crater floor are exposed within the crater rim (e.g. Fig. 1): (1) uplifted diverse ~4 Ga Noachian basement (NB) units deposited prior to the Isidis impact basin (3.9-4.1 Ga [2-3,5]) and the Jezero complex crater forming impact; (2) ~3.82 Ga olivine/carbonate-bearing unit [6]; and (3) ~3.8 Ga mafic capping unit. The latter two units post-date, and therefore were likely unaffected by, the Jezero impact [7,8]. The opportunity to sample impact melt and related hydrothermal features may also arise.

The science value of crater rim rocks: *Noachian basement units.* Interrogation of the Noachian basement exposed along the crater rim will be the first opportunity to investigate the oldest and deepest rocks on Mars [2,3,5]. The NB consists of 8 visually distinct subunits and features [5]. Certain outcrops in the crater rim have been noted to have a similar geomorphological expression and spectral signature as three of these regional subunits (Fig. 1).

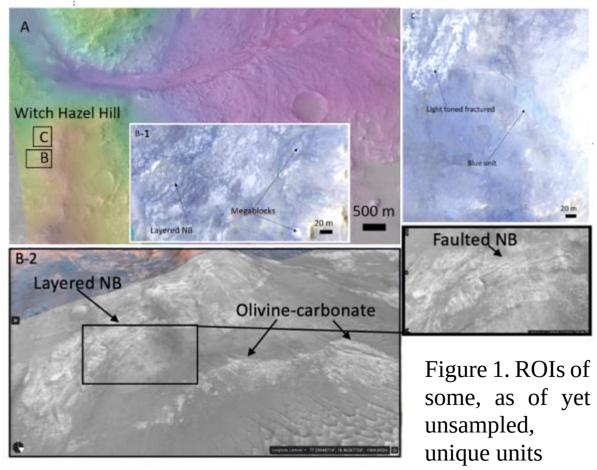

Figure 1. ROIs of some, as of yet unsampled, unique units within the Witch Hazel Hill area of the northern crater rim.

(1) *The stratified unit* is comprised of decameter-thick layers with a CRISM signature consistent with Fe/Mg smectite. Smectite clays result from water/rock interaction and have high biosignature preservation potential. Abundant clays are present in the oldest rocks on Mars, suggestive of more intense alteration than that experienced by younger units in the region. Thus sampling these rocks will offer the opportunity to learn about the earliest climate, weathering and alteration processes, and ancient habitable environments. (2) *The blue-fractured unit* possesses a distinct blue color in HiRISE data and a unique low-Ca pyroxene (LCP) signature with little to no Fe/Mg-smectite in CRISM data indicative of limited alteration and the dominant presence of reduced iron (Fe^{2+}) interpreted as igneous materials predating or formed during the Isidis impact [3]. A sample of this unit would retain chemical signatures from early crustal evolution following accretion and could provide a unique measurement of the timing of the Isidis impact and critical constraints on the martian geologic timescale. (3) *The megabreccia* are composed of blocks up to 100s m in size with a wide variety of albedos, textures, and lithologies and likely include some of the oldest rocks on Mars [5]. Sampling the megabreccia will enable investigation of ancient basement rocks revealing insights into the earliest planetary evolution processes including crust formation, the strength and timing of the dynamo and whether its

evolution drove the loss of early atmosphere [9]. In many cases, the megabreccia contain Fe/Mg-smectite-bearing, often stratified materials linked to the same questions of biosignatures, climate, and habitability as the stratified unit [5]. A kaolinite-bearing block has been identified in the rim and could represent the result of extensive weathering and alteration, such as observed in widespread Noachian weathering profiles [10,11], and provide further insight into earliest climate evolution and habitable environments.

Olivine-carbonate and mafic capping units. These regional units may reveal connections to the broader geology of Nili Planum, Nili Fossae, and Syrtis Major and to similar units on the crater floor. Understanding these relationships is necessary to determine the emplacement mechanisms and timing of these units. Due to their regional distribution, these units are important to sample for geochronology to calibrate ages derived from crater counting. The presence of carbonate in association with olivine is suggestive of water/rock interaction and may provide information about the loss of early Martian surface water to weathering interactions with the crust [12]. On Earth actively reacting olivine-rich rocks provide both nutrients and habitats for subsurface biospheres [e.g. 13].

Opportunistic features. Impact processes are likely to have resulted in the production of impact melt and perhaps hydrothermal systems [14]. Samples of such materials can be analyzed to determine the age of the Jezero impact further constraining the chronology of Mars. Minerals preserved in hydrothermal systems on Earth record water/rock reaction processes and may harbor biosignatures.

Notional sample cache of crater rim rocks: Of the 15 tubes remaining on the Perseverance rover, up to 2 tubes may be filled during the remaining Margin campaign [15]. This leaves as many as 15 or as few as 13 tubes to be filled with samples from outside Jezero crater. If rover exploration is limited to the crater rim, we propose that a *minimum* notional cache from the crater rim (Fig. 2) should include: (a) 1 sample of the stratified NB unit. If there is compositional or depositional/emplacement diversity within the sequence, we propose collecting sample(s) to capture the diversity; (b) 1 sample of blue fractured NB unit; (c) 3-4 samples of megabreccia representing lithological diversity including an Al/kaolinite-rich block; (d) at least 1 and, if there is diversity in the composition and/or geologic context, up to 2, samples of the regional olivine/carbonate unit; (e) 1 sample of the mafic capping unit. The notional cache also contains samples of opportunity that are of high scientific value but are difficult to identify using only orbiter data and will require ground-based rover data to identify. These could include: (f) at least 1 sample of a hydrothermal feature; (g) 1 sample of NB that preserves chemical reaction fronts (e.g. pyroxene in contact with secondary phases) which may represent sites of ancient water/rock reaction [16] (such a scenario may be represented by one of the above samples and may not need to be collected independently); (h) 1 sample of an impact melt and (i) additional examples of NB megabreccia focusing on diversity of primary crustal lithology and degree and style of surficial weathering and subsurface alteration should be collected. Acquisition of samples along the crater rim is an important opportunity to significantly expand the diversity of the already existing cache. This will enhance the overall scientific value of Mars sample return, and justify NASA's investment in this effort, by enabling investigation of Decadal-level scientific questions outlined by the Mars community [17,18].

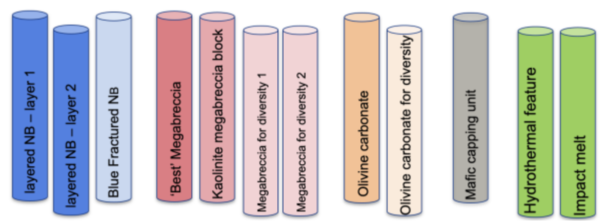

Figure 2. Illustration of sample tubes representing one version of a potential cache of samples that could be collected from the crater rim. Down dropped tubes represent samples that could be collected if the opportunity arose given the time available, the result of in-situ observations, the planned strategic route, and the composition of the collected cache.

The Jezero crater rim samples expand the scientific value of the current sample cache by accessing: (1) a diversity of ancient ≥4 Ga Martian crust materials that preserve records of ancient climate, habitability, magnetic dynamo, and igneous processes, (2) ancient uplifted potentially habitable subsurface environments for biosignature investigations, and (3) materials from crater dated surfaces to constrain Mars' surface ages.

References: [1] Farley et al. (2020) *SSR* 216. [2] Simon et al. (2021) LPSC LII #2548. [3] Scheller et al. (2024) this LPSC. [4] Deahn et al. (2024) this LPSC. [5] Scheller and Ehlmann (2020) *JGR Planets* 125. [6] Mandon et al. (2020) *JGR: Planets*. [7] Hundal et al. (2022) *GRL*, 49. [8] Sun and Stack (2020) *USGS Map #3464*. [9] Mittelholz et al. (2018) *ESS*, 5. [10] Ehlmann et al. (2011) Nature, 479. [11] Carter et al. (2015) Icarus, 248. [12] Wernicke and Jakosky (2021). *JGR Planets*. 126. [13] Templeton et al. (2021) *JGR Biogeosciences* 126. [14] Osinski et al. (2013) Icarus, 224. [15] Siljeström et al. (2024) this LPSC. [16] Hausrath et al. (2024) this LPSC. [17] Beatty et al. (2018) iMOST. [18] Search for Life in the Universe (2019) https://nap.nationalacademies.org/catalog/25252/an-astrobiology-strategy-for-the-search-for-life-in-the-universe