KEY PERSEVERANCE SAMPLING LOCATIONS FOR THE ANCIENT MARTIAN CRUST AND IMPLICATIONS FOR MARS SCIENCE.

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Introduction: Since Feb 2021, the Perseverance rover has collected samples in the Jezero crater [1]. The plan baselined at the 2018 landing site selection, subsequently further developed by the Mars-2020 team, and presented to the Decadal Survey included the exploration and sampling of the Jezero crater rim and the Nili Planum area, a rock record that is important to preserving the science return of the endeavor [2].

Specifically, the science team identified the following prioritized science objectives [2] aligned with community objectives [3] that are not covered by the current sample cache: 1) Investigate the habitable environments with potential biosignatures from a more ancient time interval and from a diverse set of geological environments (incl. exposed subsurface) than the Jezero crater sedimentary deposits (Fig. 2). (2) Determine radioisotopic ages for well-defined crater-retaining surfaces and/or the Isidis basin impact event. (3) Characterize ancient aqueous environments to study climate, environmental transitions, and habitability on ancient Mars. (4) Investigate planetary accretion, crustal evolution, and dynamo activity through analysis and sampling of igneous lithologies. (5) Study the geology of basin-forming impacts. In addition, for the Jezero rim and any Jezero ejecta: (6) Analyze Jezero impactites for potentially habitable hydrothermal environments and radioisotopic dating of the Jezero crater formation.

From 2018 to now, we used a combination of High Resolution Imaging Experiment (HiRISE) and Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) data to further characterize Jezero rim and Nili Planum, culminating in our prioritized sample location recommendations: (1) *Monument Valley* and (2) *Northwest Jezero rim* (Fig. 1)

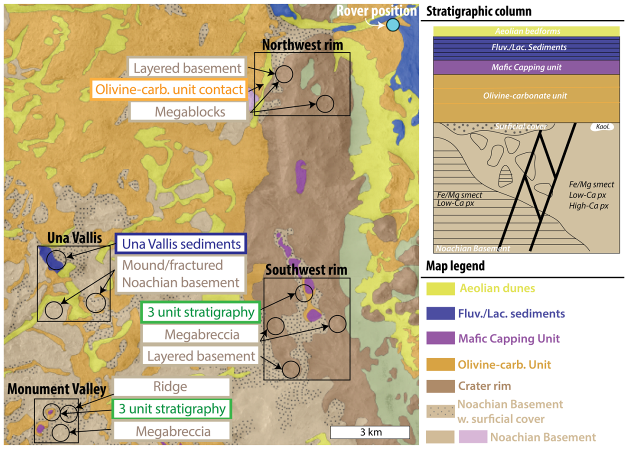

Fig. 1: Overview map of four key areas in geological map from [2]. Locations and features from Fig. 3 are highlighted. Stratigraphic column after [3-5] shows the age relationship between units.

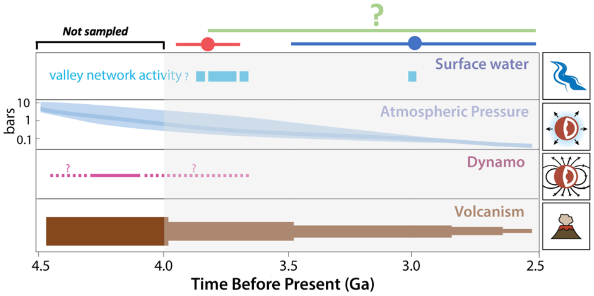

Fig. 2: Schematic of major events in early Mars history. Circles with error bars and shaded grey areas represent estimated ages of samples from Séítah (red), Máaz (blue), and the Jezero sedimentary fan (green) already obtained by the Perseverance rover. Unshaded rectangle represents the estimated ages for Noachian Basement materials.

Geologial setting: Nili Planum constitutes the region within a 10 km radius of the western Jezero crater rim and consists of ancient (> 4 – 3.8 Ga) crustal units cut by younger fluvial channels, including the Jezero inlet channel. Orbital mapping [4] showed that Nili Planum contains representative units of the ≥ 4 Ga Noachian Basement Group [5], the 3.82 Ga Olivine-Carbonate Unit [6], and the overlying Mafic Cap Unit [5] (Fig. 1). These can be observed across 100,000 km^2 throughout the ring massifs of the Isidis impact basin, often referred to as *Nili Fossae* [7]. This 3-unit stratigraphy contains unique records of the formation and evolution of early Mars and rocky planets in general (Fig. 2). The most important scientific considerations for the Nili Planum crustal stratigraphy are (1) its ancient age (> 4-3.8 Ga) (2) two units with well-characterized crater chronology for radioisotopic dating [5-6], (3) widespread Fe/Mg-smectite clay, kaolinite clay, and carbonate orbital signatures throughout the Noachian Basement Group and Olivine-carbonate unit that archive and likely affected Mars' climate [5-9], and (4) orbital signatures of different igneous materials in all units representing ancient crustal evolution following accretion: low-Ca pyroxene (LCP), olivine, and high-Ca pyroxene (HCP) [5-7].

Comparison of sampling locations in Nili Planum, the Jezero rim, and inside the Jezero crater: Identifying key sampling locations is dependent on balancing three separate factors: (1) suitability for addressing science objectives, (2) the value of uplifted and impact-deformed crustal materials versus undeformed, intact, and complete crustal stratigraphy, and (3) distance for the rover to drive. We identify four key locations for exploration: the *Northwest Jezero rim* [further discussed in 10], *Southwest Jezero rim, Monument Valley,* and *Una Vallis* (Figs. 1 and 3). If the traverse length is not limited, a sampling transect across the *Monument Valley* mesa would be our highest priority because they offer the most complete, continuously exposed geological cross section of the Nili Planum stratigraphic column. This sequence can also be found in the *South Jezero rim*, but there the Noachian Basement has been uplifted and partially deformed by the Jezero impact (Fig. 1).

The Perseverance rover has already sampled units of olivine-carbonate cumulate rock and basaltic lava flows [1] exposed in the Jezero crater floor. These units are of uncertain origins, but could be age equivalent to the Olivine-Carbonate Unit and Mafic Cap Unit, respectively. Further sampling of these units would be of high priority to contextualize the previously sampled Jezero crater floor. However, the Noachian Basement Group is the most unique, high science value sample because nothing equivalent has already been sampled.

The Noachian Basement Group is a diverse assemblage of at least 8 different units and features [5]. The "layered basement" is a particularly important sampling target for objectives 1-5 and can be observed uplifted and deformed in the *Northwest Jezero rim* (Fig. 3). Similar layered sections elsewhere, which contain Fe/Mg-smectite and low calcium pyroxene (LCP), pre-date the Isidis impact and typically outcrop in Isidis grabens down to several km depths. The layered basement can also commonly be observed as forming 10 m to km-scale megabreccia blocks thought to have formed by the Isidis impact [5] (Fig. 3).

Megabreccia deposits [5] can also uniquely meet science objectives 1-5 given that they pre-date the Isidis impact (~ 4 Ga) (Fig. 3). Megabreccia would be first encountered by the rover in *Northwest Jezero rim* (Fig. 3), while larger and better defined outcrops are present in *Southwest Jezero rim* (Fig. 3). However, the proximity of the deposits to the Jezero rim means they may have been formed by the Jezero impact and therefore be younger than most Nili Planum megabreccia. A large megabreccia outcrop in *Monument Valley* at one crater diameter from the center of Jezero crater is more likely to predate Jezero formation. Other parts of the Noachian basement include parts of the Jezero rim that have Fe/Mg-smectite clay signatures in CRISM data but are deformed and difficult to relate back to regional exposure types. Ridges in *Monument Valley* have been attributed to subsurface aqueous materials [5,7] important for science objectives 1 and 3. *Una Vallis* (Fig. 3) offers another exposure of Noachian Basement Group morphologically unlike that observed in the Jezero rim and *Monument Valley* locations. Here, the basement is exposed in characteristic mounds, plateau, and fractured geomorphology [5]. *Una Vallis* also offers the opportunity to study ancient fluvial deposits related to the Jezero inlet channel system.

In summary, our recommened sampling locations for addressing science objectives 1-5 in order of importance are: (1) Undeformed 3-unit stratigraphy (Noachian Basement to overlying olivine-carbonate unit to overlying Mafic Cap unit), Isidis megabreccia, layered basement, and ridges in *Monument Valley*. (2) uplifted layered basement and megabreccia in *North Jezero rim*. If time and drive distance allow, the rover could explore alternative, spectacular Noachian basement locations in the *South Jezero rim* and *Una Vallis*.

References: [1] Farley K. A. et al. (2022) Science, 377, eabo2196. [2] Simon J. et al. (2021) LPSC LII #2548. [3] Beaty, D. W. et al. (2018) MAPS, 54, S3-S152. [4] Sun V. & Stack K. M. (2020) USGS Map #3464. [5] Scheller E. & Ehlmann B. L. (2020) JGR, 125, e2019JE006190. [6] Mandon L. et al. (2020) Icarus, 336, 113436. [7] Bramble, M. et al. (2017) Icarus, 293, 66-93. [8] Ehlmann B. L. et al. (2011) Nature, 479, 53-60. [9] Scheller E. et al. (2021) Science, 372, 56-62. [10] Mayhew L. et al. (2024), this LPSC.

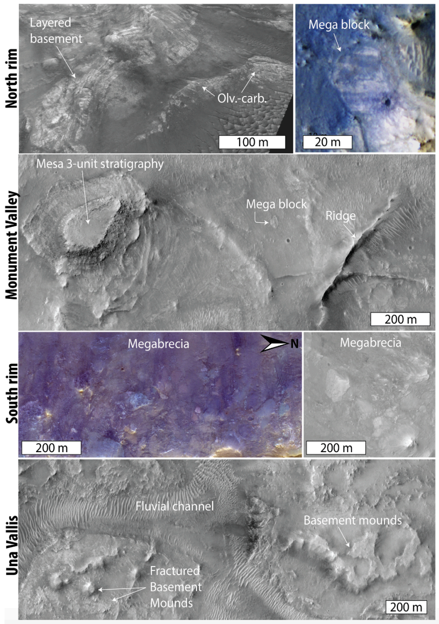

Fig. 3: HiRISE images showing our prioritized sampling locations outside Jezero crater. Context map showing their relative locations is shown in Fig. 1.