CHARACTERIZING THE STRATIGRAPHY OF THE NILI PLANUM REGION OUTSIDE JEZERO CRATER: IMPLICATIONS FOR MARS 2020 STRATEGIC PLANNING.

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Introduction: The Mars 2020 team has developed plans for exploration and sample collection of the Nili Planum region outside Jezero crater (Fig. 1) for the possibility of an extended mission. This extended mission would follow and complement the exploration of Jezero, as it expands investigations of the regional stratigraphy [1-2] to new settings and would likely extend the accessible geology ~1-2 billion years compared to the primary mission. This area has representative units of Nili Fossae and the Nili Planum regions [3-6], including the canonical Noachian Basement, Olivine-carbonate Unit, Mafic Cap Unit, and putative younger fluvial-lacustrine deposits and presumably spans Pre-Noachian/Early Noachian to Hesperian time [1-4]. This stratigraphy likely records prior surface and subsurface aqueous environments, volcanic processes, and impact processes. It is also characterized by the ancient record of Mars contained in the Noachian Basement Group [4] enabling exploration of early planetary differentiation and magmatic and dynamo evolution, the history of martian global tectonics, changes in climate, potentially habitable environments, and possibly even astrobiological signatures through this time period (>4.0-2.5 Ga).

This geologically diverse area has been mapped at CTX scale [5] and HiRISE scale for only the Noachian Basement [4] in order to guide the extended mission plans. In this study, we characterized the Nili Planum stratigraphy and units near Jezero at HiRISE scale and outline Mars 2020 high priority science and returned sampling goals for part of a possible extended mission. We describe results from initial strategic planning of potential rover paths and science campaigns in Nili Planum by the Mars 2020 science team that are addressable by Perseverance operations in the region.

High priority Nili Planum science objectives: The *in situ* and returned sample science (RSS) in the Nili Planum include: (1) exploring habitable environments and potential biosignatures outside of the Jezero lake environment, (2) quantifying radioisotopic age(s) to provide absolute time constraints for the region, including well-defined crater-retaining surface(s) and/or the Isidis basin impact event, (3) evaluating the nature of ancient aqueous environments (subsurface and surface) that make up the Jezero watershed to study climate transitions (e.g., to a colder and drier climate) through time, (4) investigating planetary accretion and evolution using igneous lithologies to probe the planet's interior, (5) seeking records of ancient climate to test atmospheric evolution models (e.g., atmospheric loss), (6) characterizing and sampling a diversity of ancient crustal/basement lithologies that can track planetary differentiation and dynamo activity, and (7) studying the geology of a basin-forming impact (Isidis).

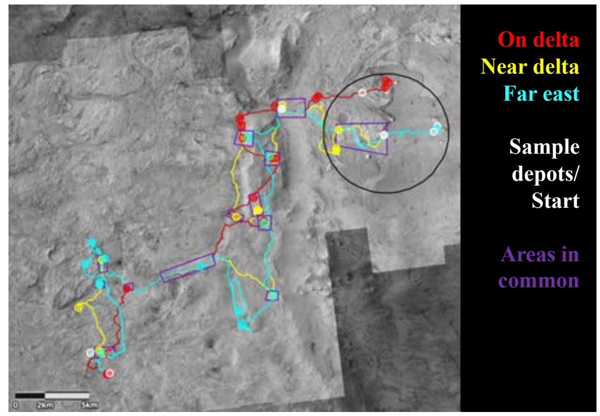

Figure 1: Region and suggested extended mission rover paths outside Jezero crater. Color coding indicate 3 paths that afford high priority science and sampling objectives in Nili Planum. After exiting Jezero, all paths traverse the crater rim and end in the Midway area.

Science targeted along evaluated rover paths: We studied the Nili Planum region using HiRISE, HiRISE color, and HiRISE DEMs [6]. Detailed rover path planning indicates that an extended mission could reach critical outcrop targets (Fig. 2) needed to address extended mission science priorities. The considered paths encounter units interpreted to span Early Amazonian to possibly pre-Noachian periods, overlapping all major events in martian history. The ≤50 km traverses and science investigations would notionally take 3-4 Earth years to complete.

Geologic units in Nili Planum that are further from the Jezero crater rim are expected to be less perturbed by the Jezero impact event. The physical and thermal effects of the impact could potentially disturb primary (or ancient secondary) rock textures and mineralogical features, reset the formation ages of older Nili Planum units, e.g., 3.8 Ga Olivine-carb. [7] and basement units, and could perturb the paleomagnetic record obtained at the time of their formation.

The extensive outcrops of Noachian basement geology will provide critical data for martian history where the meteorite record is completely absent (between ~4.0 Ga and ~2.3 Ga [9-11]). Likewise, some megabreccia lithologies may predate those observed in the surface geology [4].

Exploring past habitable environments and potential biosignatures beyond the Jezero lake environment is important because Jezero crater and the Nili Planum likely represent different hydrologic regimes over different time intervals. Water availability and climatic conditions in the Early Noachian are considered to be more conducive to habitability [12]. Subsequently, Mars' climate and habitability changed drastically [12] suggesting that Early Noachian environments are particularly important for astrobiology and habitability exploration. Lastly, if Mars had life these ancient units could possibly have a record of its prebiotic chemistry.

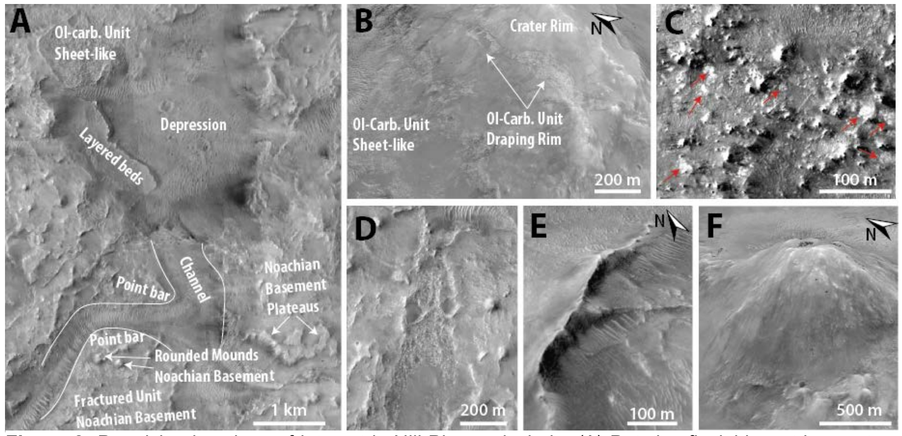

Figure 2: Promising locations of interest in Nili Planum include: (A) Putative fluvial-lacustrine system carving out bedrock with various expressions of Noachian basement (smooth plains, plateaus, fractured units, and mounds). (B) Distinct expressions of Olivine-carbonate in a sheet and draping the Jezero crater rim. (C) Megabreccia blocks outside Jezero (red arrows). (D) Channel-like Olivine-carbonate unit. (E) Inferred mineralized-fracture ridges. (F) Cone-shaped km-sized mounds of unknown lithology.

In the Nili Planum, there are numerous opportunities to study widespread crater-retaining surfaces, including the Olivine-carb. and the high-Ca-pyroxene-bearing mesa-forming Mafic Cap Units [2,3,6,13]. These surfaces may serve as marker horizons that could be datable using radioisotope geochronology of returned samples. The composition of these lithologies will also enable probing the martian interior and its potential heterogeneity in comparison to martian meteorites [10]. If the Olivine-carb. unit with an estimated surface crater-age of 3.82 Ga [7] contains secondary phases such as carbonate and phyllosilicates, it would be an astrobiologically compelling unit as well [14].

The Noachian Basement and Olivine-carb. units also record numerous aqueous environments that may provide insight into changing climate, habitability, and water availability and chemistry. Remote sensing data include evidence for extensive episodes of Fe/Mg-smectite and kaolinite formation that may be attributed to separate aqueous environments [4,8] as well as the formation of carbonate, serpentine, and clay formation in the Olivine-carb. Unit [1,14]. Mars 2020 science team discussed the following hypotheses for the formation of these: deposition in extensive standing bodies of water; hydrothermal alteration of impactites or volcanic units; groundwater alteration; and/or chemical weathering or pedogenic environments [e.g. 1-8]. In addition to the older units, the extended plan encompasses waypoints and possible samples for more recent, fluvial channel deposits and possible local lake deposits. The textures of a variety of expected primary and secondary minerals (e.g., clays, carbonates, silica, sulfates, and chlorides) will determine whether preservation of microorganisms and organic compounds was likely [15].

Acquiring rock samples that span the time from pre-Noachian to the Early Amazonian should enable future returned sample analyses of the ancient martian dynamo field and determine when it declined [17]. This will critically test the hypothesis that the loss of the dynamo drove atmospheric loss and climate change on Mars. Future measurements of oriented bedrock samples could also test the hypothesis that ancient Mars experienced plate tectonics and true polar wander [17].

Mars exploration provides a window into the history of a neighboring, potentially habitable planet. An extended mission in the Nili Planum region is essential to this goal because it would enable geological, chemical, and potentially biological observations and sample return science for the most ancient potentially habitable environments known in the Solar System.

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