SAMPLING MARS: NOTIONAL CACHES FROM MARS 2020 STRATEGIC PLANNING.

C.D.K. Herd[1], T. Bosak[2], K.M. Stack[3], V.Z. Sun[3], K.C. Benison[4], B.A. Cohen[5], A.D. Czaja[6], V. Debaille[7], E.M. Hausrath[8], K. Hickman-Lewis[9], L.E. Mayhew[10], F. Moynier[11], M.A. Sephton[12], D.L. Shuster[13], S. Siljeström[14], J.I. Simon[15], B.P. Weiss[2], D.T. Flannery[16], Y.S. Goreva[3], S. Gupta[12], L.C. Kah[17], M.E. Minitti[18], S.M. McLennan[19], J.M. Madariaga[20], A.J. Brown[21], K.H. Williford[3], and K.A. Farley[3]. [1]Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Canada, herd@ualberta.ca, [2]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA, [3]JPL/Caltech. [4]West Virginia University, Department of Geology and Geography, Morgantown, WV, [5]NASA GFSC. [6]Department of Geology, University of Cincinnati, Cincinnati, OH, [7]Laboratoire G-Time, Université libre de Bruxelles, Belgium, [8]UNLV, Las Vegas, NV, [9]Department of Earth Sciences, Natural History Museum, London, UK, [10]Dept. Geological Sciences, CU Boulder, [11]Université de Paris, IPGP, France, [12]Imperial College London, London, UK, [13]Dept. Earth and Planetary Science, UC Berkeley, [14]RISE Research Institutes of Sweden, [15]ARES, NASA Johnson Space Center, [16]School of Earth and Atmospheric Sciences, Queensland University of Technology, QLD, Australia, [17]Dept. of Earth and Planetary Sciences, University of Tennessee, Knoxville, TN, [18]Framework, Silver Spring, MD, [19]Dept. Geosciences, Stony Brook University, NY, [20]Dept. Analytical Chemistry, UPV/EHU, Bilbao, Spain, [21]Plancius Research, Severna Park, MD.

Introduction: A central objective of the NASA Mars 2020 Perseverance rover mission is to collect and document a suite of scientifically compelling samples for possible return to Earth by a subsequent mission [1].

Strategic planning by the Mars 2020 Science Team has thus far identified a set of notional sample caches. These arose from integrating the testable hypotheses that could be addressed by Mars 2020 within the framework of the geology of Jezero crater and its surroundings [2], identifying specific locations of high scientific interest by analysis of remotely sensed data, and traversability considerations [1]. Here we describe the general characteristics of the identified notional caches and compare them to the types of samples previously prioritized by the wider Mars science community [3]. While strategic planning will guide and streamline the decision-making processes once the rover lands at Jezero crater, the actual samples collected will depend on the landing location, the traverse taken, and decisions made by the Mars 2020 Science Team.

Background: Strategic planning was carried out to determine the contents of two notional caches, with the understanding that only one would be selected, based on the scientific potential of the samples, for retrieval by a Mars Sample Return (MSR) mission [1]. One cache would include samples collected during the prime mission, focused on Jezero crater. During planning, the prime mission was assumed to last for one Mars year, during which the rover – starting from the crater floor or delta – traverses Jezero crater, crossing the delta and the crater margin, and finally reaching the crater rim. In order to mitigate the risk of inaccessibility of samples stored in the rover if a hardware failure occurs after this time, we plan to collect duplicate samples of most lithologies of interest. The prime mission would conclude by depositing a cache of samples near the crater rim, at a location accessible to future MSR missions. Duplicates of some or all of these samples would then be carried during the extended mission, which is anticipated to last another two Mars years. The extended mission would include locations further along the crater rim and outside Jezero crater, and would conclude by depositing a second sample cache – one that would contain samples collected during the extended mission as well as the duplicate samples retained from the prime mission.

Results: Three scenarios were considered, based on three possible landing site locations within the landing ellipse: landing on the delta, landing on the crater floor just off the delta, and landing to the east of the delta, near outcrops mapped as delta remnants [2]. Although the three scenarios necessitated different notional traverses and were planned independently, they shared common science priorities and the three notional caches overlap significantly. Here we describe the general types of samples that might be included in the prime and extended mission caches for these traverse scenarios.

The prime mission notional cache. All scenarios planned to sample: fine- and coarse-grained delta facies, the former with a high potential to preserve organic matter, the latter to better understand the geology of the watershed from analyses of detrital mineral grains; carbonate-bearing deposits found near the margin of Jezero crater with the potential to preserve biosignatures; crater floor units, of possible igneous origin; a sample of the crater rim; and at least one sample of regolith. These samples would enable the following major scientific questions to be addressed:

1. Did life or prebiotic chemistry ever exist on Mars, and if so, when? What habitable niches were present in Jezero crater? Are morphological, chemical or mineralogical biosignatures and biotic or abiotic organic materials preserved?
2. What was the timing of fluviolacustrine activity and any associated biosignatures in Jezero crater?

3. Are there units within Jezero crater suitable for calibrating Mars' absolute crater chronology?
4. What was the history of martian aqueous environments during the late Noachian–Hesperian, and what insights do these provide into the evolution of Mars' climate?
5. What is the origin and alteration history of the regional Noachian crust? What compositional, geochemical, and temporal information is recorded in mineral grains or clasts?

The extended mission notional cache. The region of southern Nili Planum, directly outside the western rim of Jezero crater, is geologically distinct from Jezero crater, and contains diverse rock types as old as the Early or even Pre-Noachian [e.g., 4]. All scenarios for the extended mission resulted in notional samples of regolith and samples/sample suites of: layered and other basement rocks that occur within the rim of Jezero and more distally in the Nili Planum, megabreccias, which may represent blocks of Noachian (or pre-Noachian) crust excavated by the Isidis and/or Jezero impact events; fractures that cross-cut basement rocks, which may have been produced by hydrothermal activity; olivine- and carbonate-bearing rocks that are regionally significant and may be related to units within Jezero crater; and a mafic cap rock that represents the stratigraphically uppermost unit within Nili Planum, and which may or may not be related to mafic units within Jezero. The collection of these samples would enable questions 4 and 5 above to be addressed, as well as the following:

6. What characteristics defined the early planetary evolution and habitability of Mars, in terms of differentiation, igneous processes, geomagnetism and global tectonics?
7. Do carbonates, veins, and phyllosilicate-rich deposits of Nili Planum record some former habitable environments? How did the (pre-) Noachian climate evolve, and how is that reflected in the diversity of aqueous and sedimentary processes recorded in the rocks?
8. How long did the Martian dynamo persist, and did its decline drive atmospheric loss?
9. Are there bedrock units and/or impact ejecta outside Jezero crater that are suitable for calibrating the absolute crater chronology for Mars?
10. What were the effects of the Isidis impact on a local and regional scale?

Comparison with community priorities: The samples that we anticipate will be collected by Perseverance are aligned with community priorities for Mars exploration, as outlined most recently in the International Mars Sample Return (MSR) Objectives and Sample Team (iMOST) report [3]. The anticipated samples for the prime mission cache – focused on the fluviolacustrine Jezero system, its deltaic mudstones and carbonate-bearing deposits, and potentially igneous units in the crater floor – readily address iMOST objectives that involve the characterization of a variety of geologic environments (sedimentary, subaerial, igneous) and the assessment and interpretation of potential biological activity on Mars (iMOST Objectives 1 and 2). These samples could help constrain the chronology of Mars' planetary evolution (iMOST Objective 3), and its inventory of volatiles (iMOST Objective 4). A sample of regolith would help to understand and quantify environmental hazards relevant to future human exploration (iMOST Objective 6).

Notably, the addition of samples from outside Jezero crater (within Nili Planum) has great potential for enabling the characterization of hydrothermal and low-temperature alteration enviroments and the search for very ancient biosignatures (iMOST Objective 1 and 2). Samples of the regional olivine-carbonate unit from multiple locations inside and outside Jezero crater; megabreccias, which could constrain the timing of the formation of Isidis basin; and the mafic cap in Nili Planum, could all contribute to quantifying the chronology of Mars (iMOST Objective 3). Perhaps most significantly, samples of the more ancient rocks of Nili Planum, including e.g., megabreccia blocks and impact-generated rocks from the Isidis impact, are required to adequately address the planetary-scale evolution of Mars, including the history of ancient igneous, sedimentary and impact processes, and hypotheses about the co-evolution of the magnetic field, atmosphere and climate [4] (iMOST Objective 5).

Concluding Remarks: The diverse geology of Jezero crater and the current (pre-landing) state of knowledge of the site indicate that the samples anticipated within the prime mission notional cache would readily address the majority of the iMOST objectives. Samples anticipated for an extended mission notional cache would significantly enhance the value of the cache, enabling most of the community-articulated priorities to be addressed. All samples will be collected amid a thorough ground-based campaign with the full suite of *in situ* instruments providing crucial geological context. Thus, our caching will implement the Decadal Survey's mandate to collect carefully chosen samples from a well-characterized site for eventual detailed geological and astrobiological study on Earth [5].

References: [1] Farley K.A. et al. (2021) *This Meeting*. [2] Stack K.M. et al. (2020) *Space Sci. Rev. 216,* 127 [3] Beaty et al. (2019) *Meteoritics & Planet. Sci. 54 ,* S3-S152. [4] Simon J.I. et al. (2021) *This Meeting*. [5] Squyres et al. (2011) Vision and Voyages.