The scientific significance of potential samples from the Jezero crater rim

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Introduction: The Mars 2020 Perseverance rover has been exploring Jezero crater, Mars to characterize the geology, assess the potential for rocks to represent ancient habitable environments and/or preserve biosignatures, and collect a suite of scientifically compelling samples for return to Earth (Farley et al., 2020). Thus far, Perseverance has collected samples that represent the diversity of igneous materials encountered on the crater floor and a suite of aqueously deposited sedimentary rocks from the fan and margin units (Simon et al., 2023; Bosak et al., 2024). When the rover ascends the crater rim it will encounter rock types that are not included in the current sample cache. These include rocks from the Noachian whose mineralogical, geochemical, and geochronological records would greatly expand our understanding of early Mars. Some of the exposures are understood to come from subsurface aquifers that may represent the most ancient potentially habitable subsurface environments on Mars (Ehlmann et al., 2024). Samples of these rocks will add unique scientific value to the sample cache and to the Mars sample return program by addressing outstanding questions in Mars science including potential habitability and how the climate and the interior of the planet evolved through time.

Geologic units and materials accessible in the crater rim: The crater-forming impact and subsequent erosion exposed a wide variety of key rock units within the rim. These geologic units are not accessible on the crater floor or fan and include: (1) ~4 Ga Noachian basement (NB) deposited prior to the Jezero crater forming impact; (2) ~3.8 Ga olivine/carbonate unit; and (3) a mafic capping unit. In nearby Nili Planum, the Noachian basement itself is composed of 8 distinct subunits and features (Scheller and Ehlmann, 2020). Three are exposed in the rim and in addition to containing a record of ancient crustal evolution are of particular interest for astrobiology: stratified Fe/Mg-smectite bearing materials, fractured materials that are blue-toned in HiRISE which typically have a distinctive low-Ca pyroxene CRISM signatures, and megabreccia blocks that consist of a variety of lithologies. There are also ridges in terrains with Fe/Mg phyllosilicates that may be hydrothermal features.

The astrobiological significance of crater rim rocks: The stratified Fe/Mg smectites, megabreccia, and blue-toned materials all possess CRISM signatures consistent with Fe/Mg-smectite. Clay phases are produced by water/rock reactions, so sampling these rocks could provide unique insight into the earliest climate (including quantifying how much surface water was lost to alteration of the crust) and/or ancient potentially habitable subsurface environments on Mars. Al-rich materials/kaolinite are present within some megabreccia blocks and are phases representative of extensive water/rock reaction and weathering on Earth (e.g., Gaudin et al., 2011). Sampling rocks that exhibit different extents and/or types of alteration would help to constrain our understanding of the timing and spatial distribution of subsurface water and potential subsurface habitats (e.g., Azúa-Bustos et al., 2020).

In the olivine/carbonate unit, the co-association of these mineral phases is indicative of water/rock reactions. On Earth, when olivine-rich rocks (e.g., peridotites) react with water they support subsurface microbial communities (e.g., Templeton et al., 2021). Sampling these rocks, which are younger than the NB, will provide insight into the presence of subsurface water and potential habitability at a time later in Mars' history. Samples of these regionally extensive units will also provide important insights into the origin and regional correlation with similar units across Nili Planum and within Jezero crater.

Finally, it may also be possible to identify and sample materials formed from hydrothermal activity derived from the impact energy (Fairén et al., 2010) or during the emplacement of the later, likely volcanic units (e.g. mafic capping unit), which may record water/rock reaction processes and possibly biosignatures (e.g. Djokic et al., 2017; Cockell et al., 2020)

The scientific value of sampling crater rim rocks: Investigation and sampling of the rock units and materials described above will fundamentally augment the existing Mars 2020 sample cache. With the addition of these samples from known locations and with a well-constrained geological context, the cache would represent a greater diversity of (1) rock types, (2) types, extent, and age of aqueous alteration, and (3) potential ancient habitats. This will broaden the scope of the foundational planetary science questions the cache can address, furthering the goals of the Mars Sample Return Campaign.

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