WHAT COULD BE LEARNED ABOUT THE GEOCHRONOLOGY OF MARS FROM SAMPLES COLLECTED BY M-2020.

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Introduction: Based on meteoritic evidence, Mars accreted as early as 2 Ma after the formation of the first solids in the solar system [1] from material with an O-Ti-Cr-Ni isotopic provenance distinct from the Earth-Moon system [2]. It likely formed a magma ocean within ~100 Ma after solar system formation [3], from which the martian core last equilibrated with its mantle at pressures of ~14 GPa [4]. The formation of most of the mass of the Martian crust is constrained to have occurred by 4.35 Ga [5,6]. Remanent magnetization in martian meteorite ALH 84001 demonstrates a dynamo had initiated on Mars at or before 4.1 Ga [7]. Sample return is necessary because meteorites lack geologic context and their orientation with respect to the paleomagnetic field is not known [8].

The M-2020 mission is designed to collect and cache drill cores obtained by an instrumented rover. These cores could subsequently be returned to Earth for analysis in terrestrial laboratories, from sites either near the Isidis basin or Gusev crater. The key objectives, summarized elsewhere [9], include potential for major astrobiological insight and recovery of histories of climate and dynamo activity. Geochronological investigations will provide temporal context for each of these objectives. This is an interim report from the M-2020 Objectives team regarding progress towards identifying key materials and techniques needed to optimize the recovery of temporal constraints on Martian history.

Geochronology Subobjectives:

1. *Calibrate the Martian cratering chronology* by radioisotope dating a surface with well defined cratering statistics, and calibration of the bombardment history by radioisotope dating of impact melts and breccias. Martian crater chronology models are calibrated against the lunar cratering record [10]. However, the earliest (4.2-3.9 Ga) lunar bombardment history still is debated [11], application of which to Mars potentially introduces uncertainties of hundreds of millions of years [12], addressable with sample return.

2. *Determine the thermal/magnetic history of Mars* to interpret mantle convection and dynamo history (including the timing of magnetic field cessation), with implications for atmospheric escape. Oriented samples of *in situ* igneous or sedimentary rocks would be required, ideally from stratigraphic sections.

3. *Determine the evolution of the Martian hydrosphere*, including the transition to habitability, using combined $\delta^{18}O$ and U-Pb dating of zircon or other U-rich accessory phases, and the timing of water/rock interaction processes (e.g., hydrothermal alteration).

4. *Determine the timing attributes of a martian sedimentary system*, including the various aspects of source-to-sink analysis with detrital zircon chronology.

5. *Improve our understanding of the timing* (e.g., Hf-W, Sm-Nd) *and processes* (nucleosynthetic anomalies and stable isotope fractionation of lithophile and siderophile elements) involved in the accretion and early differentiation of Mars, particularly from Noachian sediments.

6. *Determine the history of surface exposure*, including the timing and rates of crustal uplift/erosion and burial on Mars by U-Th-He and cosmogenic nuclide (^{3}He, ^{21}Ne, ^{10}Be, ^{26}Al) dating of surface rocks.

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