MARS 2020 CACHE CURATION PROTOCOL: DEVELOPING A MARS REGOLITH ANALOGUE

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Introduction: The Mars 2020 rover mission will collect and cache samples from the martian surface for possible retrieval and subsequent return to Earth. If the samples are returned, that mission would present an opportunity to analyze returned Mars samples with geologic context on Mars. In addition, they may provide definitive information about the presence of organic compounds that could shed light on the existence of past or present life on Mars. Mars sample return (MSR) presents unique challenges for the processing and curation of samples [1]. Post-mission analyses will depend on the development of a set of reliable sample handling and analysis procedures that covers the full range of materials that may or may not contain evidence of past or present martian life.

MSR Curation Protocol- Initial scanning by XCT: As part of planning for the initial characterization and subsequent distribution to the scientific community, samples would be analyzed while still sealed in their containers with non-destructive, non-invasive techniques. Hanna et al. (2017) [2] suggest that X-ray Computed Tomography (XCT) may minimally alter samples for most subsequent techniques including organic analyses. In fact, several studies show no alteration of organics [in meteorites] following exposure to synchrotron radiation [3], but work is needed to quantify the effects of laboratory XCT radiation on the types of organics that may be present in returned martian samples at energies that will allow in situ examination through the Mars 2020 cache tube. Our overall plan is to apply laboratory XCT radiation for a range of energies and fluences to a selection of organic compounds added to Mars analogue regolith material using compositions that reflect a Mars surface material composition. Organics have been selected based on recommendations by the 2014 Organic Contamination Panel [4], but analogue regolith material will be needed to provide the most realistic representation of Mars surface materials. This will enable a better understanding of which classes of compounds are most susceptible to alteration by XCT and the subsequent breakdown products that may be produced during XCT analyses.

MSR Curation Protocol- Developing a Mars Analogue: The value of analogue materials in pre- and post mission investigations is well established. The Allende meteorite, which fell just prior to the return of the Apollo 11 lunar rocks, set the stage for the use of extraterrestrial analogues by allowing laboratories preparing for Apollo samples, to test-run procedures and instruments using the meteorite. Today, standard laboratory practice includes analogue materials and sites to characterize mission instruments, refine field campaign procedures, and to conduct experiments to reproduce the processes found in meteorites and the results from landed missions [5]. Less common are analogue materials maintained by repositories for curation research, or to establish MSR sample handling procedures and protocols, but that is changing [6]. With future science goals focused on finding extraterrestrial life, it is necessary to select a reliable analogue material for martian surface materials in order to support the diverse set of curation objectives [7] needed to ensure the preservation and robust scientific analysis of returned martian samples. Since the Mars 2020 mission has not selected a landing site to date, an average martian surface composition must be selected, and future work might include refinement of the analogue composition once a landing/sampling site is chosen.

Evaulation of a Mars analogue- Mars surface composition compared to MMS and JSC Mars-1: Mars surface composition is well documented from 40 years of both orbital and landed missions [8]. Most of Mars' surface is covered by a veneer of regolith that is sourced from a mix of martian and extraterrestrial infall materials [9]. Regolith will likely be a significant component of any returned samples collected at or near the surface. Choosing an analogue for use in a variety of curation activities should likely take this into account. Possible anlogues to consider include well-characterized terrestrial samples and actual Mars material from meteorites. Mars meteorites, which now number over 100 distinct samples, are not fully representative of Mars' surface, and too little mass exists to provide for both laboratory and curation research.

The two best known and well-characterized terrestrial analogues are basalts; Mojave Mars simulant (MMS) and JSC Mars-1. MMS is a basalt from the Tropico Group of the western Mojave Desert, chosen for its physical appearance, broadly applicable chemistry and inert hygroscopic characteristics. It was used in the development of the 2007/8 Phoenix and Mars Science Laboratory (MSL) missions to study sampling-tool interactions in icy soils [10]. JSC Mars-1 is the sub-millimeter fraction of weathered volcanic ash from Pu'u Nene cinder cone on the Island of Hawaii. Weathered ash from Pu'u Nene is cited as a close spectral analogue

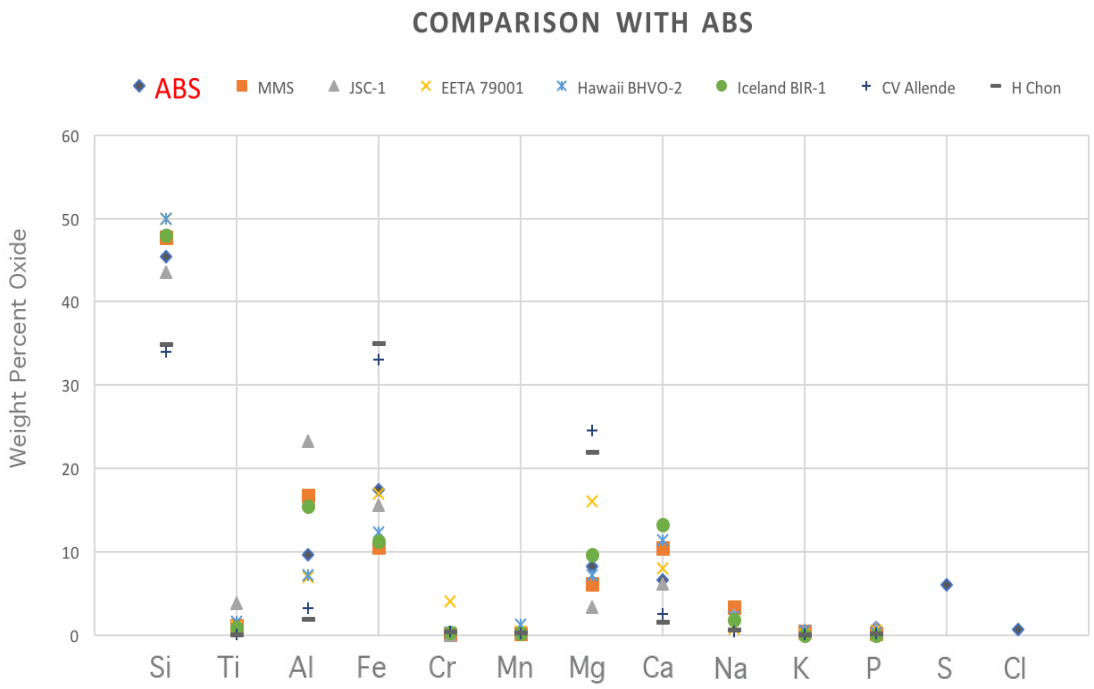

Figure 1. Mars Average Basalt soil (ABS) compared with MMS and JSC Mars-1 terrestrial analogues, USGS basaltic standards and calculated averages of the bulk composition of the shergottite EETA79001 Lithology A, Allende CV carbonaceous chondrite and H chondrites. Note the significantly lower Si, Al and Ca values in contrast to higher Fe, and Mg of the chondrites.

to the bright regions of Mars [11]. It has been used for a variety of studies, from examining the physical properties of regolith for human exploration, to experiments on organics alteration on Mars [12]. In addition to the two terrestrial analogues, an Average Basalt Soil (ABS) reference is available for comparison, which is based on landed mission data [13,14]. When compared with ABS, MMS and JSC Mars-1 are only a moderate compositional approximation. ABS, originally calculated by Taylor and McClennan (2009) using Viking through MER-A and MER-B data, is recently updated by O'Connell-Cooper (2017) [14] utilizing data that only includes Alpha-Proton X-ray spectrometer data (APXS) from MER-A, MER-B, and MSL. When compared against MSL's ChemMin data [14], the ABS shows that Mars regolith is likely a global unit with a primarily basaltic composition. Comparing ABS against the average compositions of MMS and JSC Mars-1 along with shergottite EETA79001 Lithology A yields significant differences in Si, Fe, Al, and Mg oxides (Figure 1). As meteoritic infall is a known process impacting Mars surface [15], Allende, and average H and L chondrites were also reviewed. None of the materials alone are satisfactory analogues based on elemental comparison with ABS. With thoughts towards finding or designing a Mars regolith simulant, we looked to standard materials available from the USGS reference materials program, which included tholeiitic basalt from Iceland (BIR-1) and basalt from Hawaii (BHVO-2) that might be complimentary JSC Mars-1. Results show (Fig. 1) a range of variation from ABS, with the significant differences of low iron in the terrestrial rocks, and too little silica from meteorite infall materials.

Our next steps will be to look at mixing combinations of analogue materials similar to previous efforts [16], or potentially developing simulants composed of pure minerals that will provide tunable mixtures in sustainable amounts. This would allow complete control over testing mission-specific analytical parameters and sample handling techniques for future missions.

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