**THE MARS SAMPLE RETURN ANALOGUE COLLECTION.** M. T. Thorpe[1], M. A. Velbel[2], E. Hauber[3], K. T. Tait[4], F. Thiessen[5], E. Sefton-Nash[5], and the MSR Campaign Science Group (MCSG). [1]UMD, NASA GSFC, CRESST, michael.t.thorpe@nasa.gov, [2]Michigan State University, [3]DLR- Institut für Planetenforschung, [4]Royal Ontario Museum and University of Toronto, [5]ESA.

**Introduction:** The Mars 2020 Perseverance rover touched down in Jezero crater on February 18th, 2021, and sealed the first sample for a potential Mars Sample Return (MSR) later that summer. As of sol 1088, 23 rock cores have been collected across a diverse set of lithologies that span rock types from sedimentary to igneous. As the cache on Perseverance continues to grow, the overall portfolio of MSR expands, creating long lasting implications for a wide sector of the scientific community as well as supporting detailed analyses for generations to come. To best prepare for these precious samples to potentially return to Earth one day, NASA and ESA are jointly planning to create a MSR Analogue Collection that will be available to the community in the near future.

In 2023, the "Rock Sample Team", appointed by the MSR Joint Science Office (JSO), recommended a suite of field sites for analogue samples that were primarily selected for engineering and technology development purposes [1]. In other words, these samples were nominated as candidates to test the physical behavior of the MSR rock cores during the tube opening and other procedures. The work by the Rock Sample Team has culminated in the collection of five analogue samples for the MSR Analogue Collection [Fig. 1]. To critically evaluate and/or supplement these engineering and technology targeted analogues, the Mars Sample Return Campaign Science Group (MCSG) set out to identify scientific analogues for addressing compositional changes that may occur after collecting the MSR samples.

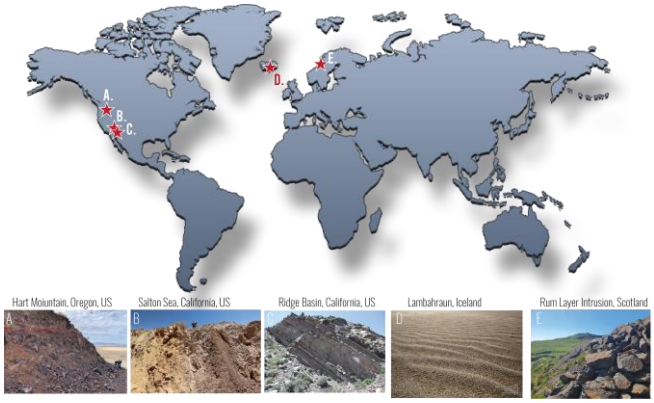


***Figure 1**. The field sites from which samples were collected in 2023 combining to form the current MSR Analogue Collection.*

**Methods:** The MCSG designated a sub-team, the Analogue Team, to explore the collection and approached the scientific analogues by (i) first evaluating if the current collection could also serve as viable compositional analogues for scientific measurements and if not, (ii) proposing new field sites to collect scientific analogues. To best evaluate the compositional fit for MSR samples, the MCSG team developed an *analogue quality match criteria rubric*. Using this rubric the team first highlighted key features and attributes in the MSR cache and then performed a detailed exercise of running each current and proposed analogue through this rubric to address the representivity of the MSR Analogue Collection. An example of this rubric is presented in Table 1, where the MCSG focused on the sedimentary samples collected during the fan and upper fan campaigns.

| Feature | Attribute | Target |
|---|---|---|
| **Mineral** | Detrital primary rock-forming minerals – identity and proportions | Mars-similar sedimentary rocks |
| | Authigenic minerals – identity and proportions | |
| **Chemical-Mineral** | Chemical element abundances and isotopes of (SSAP-relevant or time- and/or sterilization-sensitive) host minerals or other solid host-phases of elements of interest (CHNOPS elements, Fe and other FRTE, and Ce) | Clay minerals and other phyllosilicates |
| | | Sulfates ± hydrous |
| | | Carbonates ± hydrous |
| | | Cl-minerals ± hydrous |
| **Physical** | Classification | Texture |
| | Grain (particle) size distribution | |
| | ± s.d. | |

***Table 1**. An example of the analogue quality match criteria rubric developed by the MCSG for the sedimentary rocks collected during the fan and upper fan campaigns. Acronyms used: SSAP (Sample Safety Assessment Protocol), CHNOPS (Carbon, Hydrogen, Nitrogen, Oxygen, Phosphorus, and Sulfur), and FRTE (First row transition elements).*

**Results:** The MSR sedimentary samples from the fan and upper fan campaigns were determined by the MCSG Analogue Team to represent the highest priority to re-examine. The rationale for prioritizing these

sedimentary samples was largely because the samples currently in the MSR Analogue Collection were quickly identified as analogues that imitate the physical properties of the fan and upper fan sedimentary samples on Mars but do not have the same composition as the Fan samples [2].

Sedimentary rocks in the fan deposits range in grain size from mudstones all the way to boulder conglomerates [3-4]. The Mars 2020 samples collected range in lithologies from mudstone to pebble conglomerates [Table 2]. Compositionally, the fan samples are broadly characterized by having a mafic to ultramafic provenance, with detrital grains primarily composed of primary olivine, altered olivine, and basaltic lithic fragments with plagioclase and pyroxene phases likely [5-6]. The sedimentary rocks also likely contain phases compositionally similar to Cr- and Ti-spinels. Secondary alteration products include phases that are stoichiometrically similar to phyllosilicates of the smectite (saponite, hectorite) and serpentine (lizardite, greenalite, hisingerite) groups [5-6]. The cement materials in these sedimentary rocks appear to be compositionally similar to Fe-Mg carbonate with perhaps minor amounts of compositionally similar Fe-Mg sulfates [5-6]. Some of the sedimentary fan and upper fan samples also contain areas that are enriched in silica, suggesting silica cement is also likely present [5-6].

When placing these key compositional findings from the Perseverance rover into the *analogue quality match criteria rubric* and evaluating the two sedimentary rock samples in the current MSR Analogue collection (Figure 1), the MCSG team detailed four major findings; (i) The mafic components in the fan and upper fan samples from MSR (i.e., unaltered detrital olivine and pyroxene, with plagioclase, basaltic lithic fragments) are missing from the current analogue collection, (ii) a compositionally close relation (an unspecified smectite) of a major alteration product in Jezero fan and upper fan sedimentary rocks (Fe-Mg clay minerals including smectite) is likely to occur in at least one of two units sampled for sedimentary-rock analogs in hand [7], (iii) other major alteration products are missing from the current analogue collection (e.g., nontronite, saponite, hydrous sulfates, hydrous carbonates, and hydrated silica), and (iv) the current collection does not currently include samples that benchmark organic analyses.

| Clastic sedimentary rock type | Mars 2020 samples |
|---|---|
| Mafic coarse mudstone | Bearwallow / Hazeltop, Mageik/ Shuyak |
| Texturally immature mafic sandstone/wacke | Skyland/ Swift Run, Kukaklek, Melyn |
| Mafic granule-pebble sandstone/wacke | Otis Peak, Pilot Mountain |

**Discussion and Recommendations:** It is important to note that there is no perfect analogue for Mars on Earth, a non-unique finding from this work but something important to highlight. Moreover, this extract sentiment has been detailed for years and previously reported [8]. However, we can approach the analogue collection by tackling individual criteria outlined in the analog rubric to better build a comprehensive suite of analogues for investigating the sensitivity of these components to post-receiving alteration. Thus, the MCSG recommends:

*i. Confirming any alteration products, specifically smectite, present in the current sedimentary analogues.*

*ii. Identifying new sedimentary rocks with a primary mineralogical assemblage that more closely resembles the sedimentary rocks from the fan and upper fan campaigns.*

*iii. Identify new sedimentary analogue candidate with alteration products that more closely resembles the sedimentary rocks from the fan and upper fan campaigns.*

**Future Work:** The MCSG plans to address these recommendations for the fan and upper fan sedimentary rocks in summer 2024 with field campaigns set to supplement the current MSR Analogue collection. Moreover, the MCSG will also turn their attention to re-examine both the igneous and regolith samples in the MSR Analogue collection, running through a similar exercise and developing a sample specific analogue quality match criteria rubric. Finally, the MCSG will continuously work to build the MSR Analogue collection as the Perseverance rover continues to diversify its cache, focusing our next efforts on the margin unit samples most recently collected.

**Acknowledgments:** Rock Team, MDT team, Joel Hurowitz, Luca Barale, Andreas Beinlich.

**References:** [1] Fiona LPSC 2024, [2] Siebach AGU 2023, [3] Gupta LPSC 2024, [4] Mangold LPSC 2024, [5] Siebach LPSC 2024, [6] Tice LPSC 2024, [7] Link 1982, [8] Hipkin 2013,