2015 CANMARS MSR ANALOGUE MISSION: THE UTILIZATION OF THE THREE-DIMENSIONAL EXPLORATION MULTISPECTRAL MICROSCOPIC IMAGER (TEMMI) FOR *IN SITU* ANALYSIS.

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Introduction: The 2015 CanMars Mars Sample Return analogue mission [1] was conducted at a Mars analogue field site in an unknown location in Utah, using the Canadian Space Agency (CSA) Mars Exploration Science Rover (MESR) built by MacDonald, Dettwiler and Associates Ltd (MDA). This high fidelity analogue mission was carried out in partnership with the Centre for Planetary Science and Exploration (CPSX) at the University of Western Ontario, as part of the NSERC CREATE program "Technologies and Techniques for Earth and Space Exploration". The focus of the mission was to assess the capabilities of the instrumentation on MESR to collect scientific data and to train participants in mission operations, while adhering to the priorities and objectives for future Mars missions outlined by MEPAG [2]. The Three-Dimensional Exploration Multispectral Microscopic Imager (TEMMI) was an integrated instrument on board MESR [3, 4], and was used to image two sites: Sif and Fimbulvetr [5] at the microscopic scale (field of view: 5.7 x 2.1 mm). These images are utilized to determine grain size and shape, sorting, and overall mineralogy of the targets. The high-resolution images acquired allow for the development of stronger hypotheses regarding the depositional environment of the analogue site. This abstract addresses the results and interpretations from the use of TEMMI, as well as discussing the effectiveness of this instrument in the analogue setting.

Setting: Two sites were analyzed during the mission, Sif on Sol 2 and Fimbulvetr on Sol 11 [5]. Sif (figure 1) was identified as an optimal location for collection of the first core sample due to its sedimentary appearance. Contact analysis was performed here to develop an initial geological context of the region, as this unit is believed to represent a lower layer of the stratigraphic succession.

Figure 1. Targeting image from Sol 2 uplink of Sif, showing the intended location for TEMMI analysis.

Fimbulvetr (figure 2) was chosen for analysis on Sol 11, based on its location [4] and accessibility for the instrument. It is believed to represent some of the latest fluvial deposits within the mission site [5], as it appears in MastCam imagery [7] to be a thin "crust" of loosely compacted sediments located within a very recent fluvial channel.

Figure 2. Targeting image from Sol 11 uplink of Fimbulvetr, showing the intended location for TEMMI analysis.

Results: The image received in the Sol 2 downlink (figure 3) shows clasts of predominantly (97%) quartz ranging in size from 0.1-0.4 mm, with the remaining 3% of visible clasts determined to be feldspar and averaging ~0.05 mm in size. The overall sample was observed to be extremely clast-dominant, with a lithological classification of sandstone [8]. The grains were poorly sorted, sub-rounded (0.4 roundness index), and had a medium (0.7) sphericity. It is hypothesized that the depositional environment represented by this sample is a transitional, near-shore low-energy environment; with this hypothesis corroborated by XRF and Raman analyses from the same and nearby sites [6].

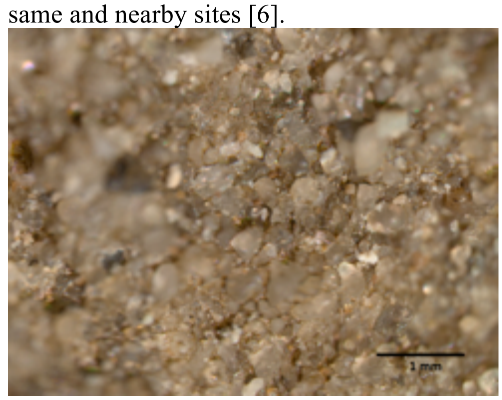

Figure 3. TEMMI image of Sif sample.

The Fimbulvetr target (figure 4) was determined to have an overall lithology of unconsolidated sandy siltstone, based on its composition of 40% medium- to coarse-grained sand clasts (average 0.54 mm), 5% fine-grained sand clasts (average 0.08 mm), and 55% silty matrix [9]. All visible clasts were quartz, although the matrix had a yellow-orange tinge suggesting possible iron oxide components. The sorting was moderate and grains were rounded to well-rounded (0.8 roundness index), with a medium sphericity (0.7).

Figure 4. TEMMI image of Fimbulvetr sample.

The two TEMMI results were applied to a grain size-lithology ternary diagram [9] (figure 5).

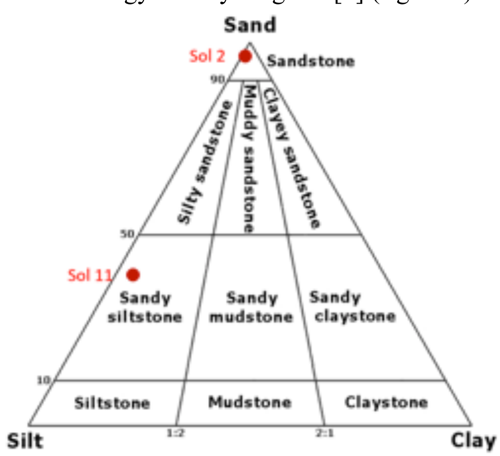

Figure 5. Clast-lithology ternary diagram [9], showing the classifications of the TEMMI samples from Sol 2 and Sol 11.

Discussion: Analysis from the two TEMMI samples suggests a low-energy fluvial to shallow basin environment, based on grain size, shape, and sorting. This corroborates the overall environmental interpretation of Yggdrasil [5].

The use of TEMMI in this mission was limited due to the mechanical restrictions of instrument deployment. To deploy the arm on which TEMMI is mounted takes 1.5 hours of mission time, and large amounts amount of energy. In several cases, TEMMI images had to be cut from the daily plan in order to travel some distance or conduct multiple analyses with other instruments. Additionally, TEMMI can only be deployed on a surface of less than 45^{o} slope, again limiting its usefulness compared to the standoff instruments, XRF and Raman [6]. On Sol 9, a TEMMI analysis of sample Modgud [4] was attempted and failed due to these limitations. Finally, some of the capabilities of TEMMI—including its multi-spectral and multi-focal image acquisition [3]—were unavailable for use during this mission. This meant that TEMMI was limited to acting as a high-resolution hand lens for the duration of the mission. While the use of other, more flexible instruments were preferred in many instances due to mission constraints, the value of TEMMI in providing context for interpretation of the chemical data collected cannot be understated.

Conclusions and recommendations: The images collected and analysed from TEMMI at Sif and Fimbulvetr provide valuable insights as to the lithology of these samples and the potential depositional environments they represent. Sif analysis reveals a lithology of quartz arenite, and Fimbulvetr is classified as an unconsolidated sandy siltstone. These both are consistent with the overall geological interpretation for the mission site [5].

In future missions, it is recommended that some of the mechanical limitations of TEMMI, particularly the restrictions on the surfaces on which it can be used and the high energy and time cost of deployment, be reduced. Additionally, all the multi-spectral and multi-focal capabilities should be available during any deployment, in order to increase the relative benefits of use compared to other instrumentation. These changes would allow for TEMMI to be used many more times in the space of a single mission, and therefore provide important and significant primary contributions to geological interpretation and analysis.

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References: [1] Osinski, G.R. et al. (2016). *LPSC XLVII.* [2] MEPAG Goals Committee (2010). *Mars Exploration Program analysis Group (MEPAG).* [3] Coulter, A.B. et al. (2012). *LPSC XLIII, #1081.* [4]. Coulter, A.B. et al. (2013). *LPSC XLIV, #2398.* [5] Christoffersen, P. et al. (2016). *LPSC XLVII.* [6] Caudill, C.M. et al. (2016). *LPSC XLVII.* [7] Harrison, T. et al. (2016). *LPSX XLVII.* [8] Folk, R. L. (1954). *The Journal of Geology,* 344-359.