CanMars 2016 MSR ANALOGUE MISSION SCIENCE OVERVIEW. C. M. Caudill[1], G. R. Osinski[1,2], L.L. Tornabene[1], T. Haltigin[3], V. Hipkin[3], M. Battler[1], S. Duff[1], J. O'Callaghan[1], and the 2016 CanMars Team. [1]Centre for Planetary Science & Exploration/Dept. Earth Sciences, University of Western Ontario, Canada. [2]Department of Physics and Astronomy, University of Western Ontario, Canada. [3]Canadian Space Agency, St-Hubert, Quebec.

Introduction: The CanMars Mars Sample Return (MSR) analogue mission [1, 2] was successfully completed following the 2016 mission cycle as a multi-year, multi-national effort. Overall successes include: geologic characterization of an "unknown" Mars analogue field site in Utah, USA; testing of CSA rover hardware and software; vetting of operational, procedural, and sample acquisition workflows of a MSR mission; and detailed documentation of operations and logistics necessary to carry out high-fidelity analogue missions. The CanMars Science Team was responsible for daily planning and synthesizing rover-derived data for geologic interpretations. The work also evaluated the efficacy and limitations of the instrument suite in identifying priority samples in the cache phase of a MSR mission (prior to sample retrieval). This was accomplished using a suite of stand-in and integrated instruments on board the CSA Mars Exploration Science Rover (MESR) built by MacDonald, Dettwiler and Associates Ltd. (MDA). The analogue mission was carried out in partnership between the Canadian Space Agency and the Centre for Planetary Science and Exploration (CPSX) at the University of Western Ontario, as part of the NSERC CREATE project "Technologies and Techniques for Earth and Space Exploration" (create.uwo.ca).

The highest priority science goals of the 2016 analogue mission cycle were to assess paleoenvironmental habitability potential and preservation of ancient biosignatures from organic-rich carbon. This follows the 2015 mission cycle, which focused on geologic characterization [3]. Among the 2016 instrument suite, a SHERLOC stand-in Raman spectrometer was used, capable of detecting potential biomarkers in situ. However, consistent testing and evaluation of the depositional model was important at each new site to understand the habitability potential. To this end, a number of spectrometers (X-ray fluorescence (XRF) [4], laser-induced breakdown (LIBS) [5], Raman [6], and visible-infrared (VIS-IR) [7]) and micro-imagers (MESR-mounted three-dimensional exploration multispectral microscopic imager (TEMMI) [8], as well as digital camera stand-ins for the Mars2020 wide angle topographic sensor for operations and engineering (WATSON) and remote micro-imager (RMI) [9]) allowed us to derive mineralogy and lithology with emplacement energies and redox states. The general geologic interpretation of the field site based on pre-mission imagery and the 2015 mission cycle [3] was that of a catchment basin for various fluvial regimes, where fluctuating water tables produced streams and lakes.

Mission Science Overview: A gradation of near-shore sediments can be expected to have a shallowing sequence of carbonates overlain by clays, then siltstones, and lastly sandstones. The bottommost unit exposed in the landing area is a white layer, likely comprised of lacustrine deposits and/or with volcanic ash. This interpretation was based on the shrink-swell erosional characteristics. This unit was analyzed via imagery only and not targeted with instrument suites.

Deposition of the white lacustrine and/or volcanic ash layer was followed by a braided channel environment, expressed by lenticular sandstone outcrops primarily observed near the center of the basin. The sandstone has abundant soft-sediment deformation features and overlies a highly erosional pebble-rich siltstone. The lenticular sandstone units are typically <1 m in thickness and meters to tens of meters in length. The siltstone-sandstone unit may also represent a near-shore marine facies. This interpretation would mean that the bottommost stratigraphic series could represent an inland sea, followed by a regression, prior to emplacement of the lacustrine unit(s). Within the sandstone unit, one small outcrop of potential organic-rich 'black' coarse-grained sandstone was identified. These deposit types can appear with siliceous sandstones in coastal plains environments. Such a deposit would have a potential for biopreservation, though not as good a candidate as the marginal lacustrine facies (shale units). This outcrop was targeted for Raman analysis. If a Raman signature for kerogen was demonstrated, it would be ranked highest sampling priority, but such a signal was not detected.

Next in sequence, white shales with green shales are present, overlain by red shales. All three shale sequences have the same shrink-swell erosional characteristic and smectite clay mineralogy (observed by VIS-IR [7]), which likely indicate a volcanic component. All three layers also appear to have cm-scale evaporitic lenses that represents a variable water table. This sequence represents a deepening of lake deposits to deposit clays; we interpret the paleolakes were shallow based on the absence of abundant observed carbonate packages. Mixed montmorillonite-illite mineralogy suggests fluid-controlled diagenesis and prolonged water-sediment interactions in the basin. The red units have alternating bands of purple coloration, which may indicate small-scale reducing conditions.

Diagenesis is strongly influenced by the chemistry of the depositional water as well as through microbially-mediated processes that are constrained in part by the sediment influx rate of the lacustrine deposits. Shales can retain water in sediment pore space for a long time after deposition, enhancing the preservation potential of perhaps significant amounts of organic matter from the time of deposition. Lithology and depositional environment of the shales was determined by geologic context, color, and mineralogy. Potential kaolinite, muscovite, and nontronite were observed, and montmorillonite-illite were observed with high confidence via VIS-IR [7], and supported by geochemistry [4, 5, 10]. In the green shales, Raman [6] identified gypsum with strong peaks and high certainty. The potential nontronite may indicate the weathering of volcanics with microorganisms involved in reduction of iron as soils undergo anoxia (producing the reduced form of the clay).

Above the shale beds, sandstones are present. Trough cross stratification and soft sediment deformation features were observed in situ and from various rocks falls derived from this unit. These sandstones represent a transition to a fluvially-dominated regime. Present resolution and access to those beds prevents us from determining if a siltstone unit is present between the shales and sandstones, and if a non-marine shore line or near shore facies is present at the top of the second lacustrine sequence. At the top of this sandstone, a clast-rich sandstone is present, with cm-scale or larger clasts. This higher energy paleochannel acts as the main capping unit in the region, protecting the underlying shales from erosion. A highly erosional regime followed, forming current-day inverted channel topography.

Sample Priorities: The ultimate utility of a MSR analogue mission, aside from testing workflows and procedures prior to undertaking extraterrestrial missions, is that the chosen sampling targets can be field-verified for return of best organic-rich carbon. The science team ranked the marginal lacustrine facies highest for organic carbon and biosignature preservation. Ranking is difficult, as the preservation is highly dependent on the weathering state and general preservation of the lithologies. The following sections describe the two highest priority return samples chosen based on rover-derived observations and analysis, with 1 being highest priority.

Sample 1. Green Shale: Dysoxic to anoxic conditions result from exhaustion of free oxygen by oxidation of organic matter in the isolated deep zone of a lake. The darker green coloration likely indicates a microbially-mediated reducing depositional environment, and therefore representative of the best paleohabitability. Gypsum was also observed in this unit, which may represent microbial oxidation of sulfide to sulfate.

Sample 2. Red-Purple Shale: Purple-red clays may indicate higher total organic carbon (TOC) and/or oxidized conditions in a low energy environment with possibility to preserve organic matter. Preservation pathways are known in oxide and oxyhydroxide minerals. Purple bands may represent cm-scale windows of very well preserved organic carbon.

Conclusions: Field validation studies from the Utah analogue site are ongoing to confirm success in rover acquisition of the best samples for preservation of ancient biosignatures [11]. However, a number of in-simulation lessons learned in regard to mission workflow, procedure, and management may directly influence future Mars rover operations. For example, strategic planning days [12] were used in the CanMars mission to give the team a break from tactical planning to focus on the huge volume of data return and develop and strengthen depositional models. During these strategic days, pre-planned sequences were uplinked to the rover. We found that these days were essential for the team to refine depositional models that would determine lithologies for sample targeting. One week of the mission was focused on rover autonomy [13, 14] and associated science and planning workflows. Through use of novel autonomy techniques and software with multi-sol planning, we developed a workflow that maximized the science return and sampling opportunities. We propose that a combination of strategic planning days with multi-sol rover autonomy represents the best use of human and rover resources.

Acknowledgements: We thank the CSA and CanMars team for the dedication and long hours spent which made this mission a reality. Our international guests (from NASA, UKSA, and DLR) aided us in making this a very closely simulated analogue mission, and helped us make most of this opportunity for future MSR efforts. This work was funded by the Natural Sciences and Engineering Research Council of Canada's CREATE program and the Canadian Space Agency.

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