**LEARNING FROM TRADITIONAL FIELD GEOLOGY AND 2016 CANMARS ROVER-BASED REMOTE SCIENCE OPERATIONS APPROACHES TO SAMPLE SELECTION** V. J. Hipkin[1], D.W. Beaty[2], C. Caudill[3], T. Haltigin[1], G. Osinski[3], M. Battler[3], R. Francis[2], R. Hansen[4], E.M. Hausrath[5], C. Maggiori[6], R. McCoubrey[7], J. Parrish[2], M. Picard[1], E. Pilles[3], S. J. Ralston[5], K. Williford[1] and the CanMars science team. [1]Canadian Space Agency, 6767 Route de l'Aeroport, St Hubert, QC, J3Y8Y9, Canada (Victoria.Hipkin@Canada.ca), [2]Jet Propulsion Laboratory, Pasadena, CA, USA (dwbeaty@jpl.nasa.gov), [3]Centre for Planetary Science and Exploration, University of Western Ontario, London, ON, N6A 5B7, Canada, [3]Natural History Museum, London, UK, [4]Universitiy of Nevada, Las Vegas, NV 89154,USA, [6] McGill University, Montreal, QC, Canada, [7] MDA, Brampton, ON, Canada

**Introduction:** High fidelity rover-based mission operations conducted at sites on Earth that are scientific analogues of target planetary environments provide an excellent opportunity to experiment with new approaches for planetary science operations. This is especially needed as missions increase in scope and complexity, such as NASA's Mars 2020 mission which augments in situ science: *Characterize the processes that formed and modified the geologic record within a field exploration area on Mars selected for evidence of an astrobiologically relevant ancient environment and geologic diversity*, with sample return activities, *Assemble a returnable cache of samples for possible future return to Earth*, and two other Objectives, all to be achieved within one Mars year of primary science operations [1].

An overview of the 2016 Canadian Mars Sample Return Analogue Deployment and site is described in sister papers [2,3]. This paper reports the results of one of the analogue deployment test objectives:

- *To test the accuracy of selecting samples remotely using the partial context available to mission scientists using rover-based field operations, compared to the full context available to a traditional human field party.*

The purpose of this test is to derive a fundamental understanding of ways that traditional field geology and rover-based science operations differ, ultimately to make planetary surface operations more effective. In the near term, such work will help inform the design of mission operations for the selection of Mars samples, and looking further into the future, it will help gain insight towards how best to conduct planetary science operations involving astronauts aided by rovers.

**Test Design:** Key to the success of the test was the generation of a simplified test scenario that could illuminate how different perceptions of context using traditional field geology methods and CanMars rover-based operations would impact the scientific interpretations of the two teams, and provide lessons-learned relevant to future mission operations design in the limited 36-sol duration of the analogue mission.

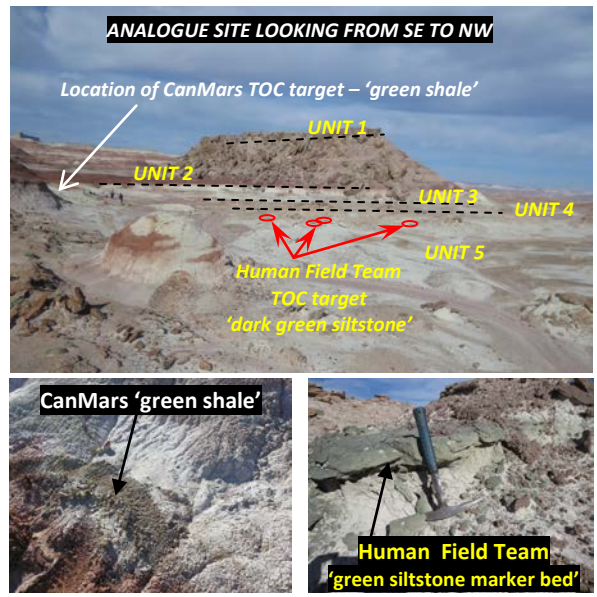


**Figure 1: Top:** Image of the analogue site working area for 2016, approximately 5km NW of Hanksville, Utah, USA, showing location of TOC targets of 2016 CanMars cache rover team (white annotation) and Human Field Team (yellow annotation). The site is relatively small, approximately 200m x 200 m, and can be easily walked in one day. **Bottom Left:** CanMars 'green shale' TOC target as seen through ZoomCam with wheel scuff for scale. **Bottom Right:** Human field team dark 'green siltstone marker bed' TOC target with rock hammer for scale.

The basic task given to both CanMars and Human Field teams was to: (1) Observe and interpret the geology of the site focussing on a subset of the Mars 2020 objectives to simplify science considerations: *Advance understanding of the habitability potential of an ancient sub-aqueous environment; Advance understanding of the history of water at the site.* (2) Document the process by which #1 above was carried out, and most importantly, the decision-making process. (3) Select for 'Return to Earth' and quantitative analysis the sample hypothesized to contain the most Total Organic Carbon (TOC). The purpose of #3 as a specific chal-

lenge objective was to focus team resources on science interpretation rather than acquisition of a certain number of samples. Multiple sample targets could be selected and investigated during each teams' investigation of the site, to be prioritised at the end of the mission.

For the purpose of *this* test, an exhaustive field validation was not planned, as a 'right answer' was not needed as much as well-documented decision-making. Instead, the Human Field Team were limited in time to one day, deemed fair simply in terms of mobility, and a decision was made not to supplement field skills with field instrumentation, aside from traditional tools of hand lens, rock hammer and acid bottles, in order to draw out strengths and weaknesses of both approaches.

**Implementation and results – CanMars Team:** The 2016 CanMars rover-based remote science operations are described in detail in [3-5] and resulting geological interpretation of the site documented in [6]. The highest priority TOC sample as determined by the CanMars Team is shown in **Figure 1 (Bottom Left)** and was identified as a green shale within the lacustrine sequence, having clay mineralogy (from VisIR measurements) and gypsum (from Raman). The lithology and depositional environment was determined by geologic context, guided by a depostional model developed by the CanMars team during mission operations[6], colour (likely indicating microbially-mediated reduced conditions), geochemistry, and mineralogy. Rover wheels were used to disturb the surface to provide the deepest possible exposure for sampling, as the lacustrine sequence was covered by a thick erosional surface. As a potentially important TOC target, ultimately discarded after rover measurement results were received, 'potato rocks' were also investigated, hypothesised to contain carbonate.

**Implementation - Field Team:** The Human Field Team validation activity and resulting interpretation of the site is described in [7]. The highest priority TOC target is shown in **Figure 1 (Bottom Right),** identified as as a dark green siltstone, and prioritized due to the inference that its dark green colour was due to reduced iron, the result of highly reducing environment that may have preserved organic carbon. This was identified within a geological sequence of 5 units shown in Figure 1 as a result of a quick field survey by the team.

**Results:** Detailed comparison of the stratigraphic units identified and the decision-making steps that led to each teams' results have begun. Of immediate note is that the two teams failed to identify each other's TOC priority targets, providing an excellent dataset to investigate how the different capabilities of each team affected the geological interpretation of the site. The-CanMars team visited the field post-mission, and felt they would have also prioritised the Field Team's dark green siltstone units, had they seen them. The Human Field Team did not see the small potato-like features that the CanMars team investigated.

**Initial findings:** Unsurprisingly, the Field Validation team was able to overcome some inherent issues faced by a rover-based team, namely limitations on visibility, maneuverability, and accessibility (e.g., in terms of rover traversability, reach of contact and remote science instruments, and lack of fresh surfaces). What was a surprise was documentation of the actual speed and ease that a traditional fieldwork perspective brought and how the ability to rapidly shift between scales, 'poke your head around the corner' and remove weathered surfaces to quickly access fresh surfaces affected Field Team decision-making. First identification of their ultimate target unit took place in the *first 10 minutes* of observing the field site from the start position. Mobility considerations often deeply constrained the rover's next moves.

The biggest strengths for the rover-based team including having a large science team with diverse expertise. Science members were able to work together to provide an in-depth synthesis of the regional geology and develop a depositional model for the site. In contrast, the small Field Team came upon features that no-one had seen before and could not interpret, such as 1m scale airplane-wing-shaped features embedded in the stratigraphy. Certainly, the four spectrometers onboard the rover were essential, and allowed the rover team to constrain mineralogy and geochemistry in a way that a traditional field team cannot. The individual spectrometry and imagery science teams processed data in tandom, making for a rich, collaborative environment to best interpret the geology to meet the mission goals.

The goal of further analysis of this rich data set is to better understand key decision points in rover operations, and whether these could have been influenced by different strategies based on lessons learned from this exercise. Similarly, the dataset will be reviewed with the goal of providing recommendations for the use of robotic assets by future planetary astronauts.

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**References:** [1] Mustard J. et al. (2013) Report of the Mars 2020 SDT [2] Hipkin et al. (2017a) LPS XLVIII,*This meeting* [3] Osinski G. R. et al (2017) LPS XLVIII,*This meeting*. [4] Caudill C.M. and Pilles E. A. (2017) LPS XLVIII,*This meeting* [5] Hawkeswell J.E. and King D. A. (2017) LPS XLVIII,*This meeting* [6] Caudill C.M. et al. (2017) LPS XLVIII,*This meeting* [7] Beaty D.W et al. (2017) LPS XLVIII, *This meeting*