A SIMULATED ROVER EXPLORATION OF A MARS ANALOGUE SITE: GYPSUMVILLE/LAKE ST. MARTIN, MANITOBA, CANADA
E. Cloutis[1], J. Stromberg[1], D. Applin[1], S. Connell[1], K. Kubanek[1], J. Kuik[1], A. Lechowicz[2], A. Parkinson[1], M. Ramirez[1], N. Turenne[1], J. Cieszecki[3], M. Germinario[4], R. Kum[3], R. Parson[4], R. Walker[4], E. Wiens[4], J. Wiens[4], and S. Mertzman[5]. [1]Dept. Of Geography, University of Winnipeg, 515 Portage Ave., Winnipeg, MB, Canada R3B 2E9; e.cloutis@uwinnipeg.ca; [2]Dept. Of Earth, Atmospheric and Planetary Sciences, Purdue University, West Lafayette, IN, USA; [3] Garden City Collegiate, Winnipeg, MB, Canada; [4] Shaftesbury High School, Winnipeg, MB, Canada; [5] Dept. of Earth & Environment, Franklin and Marshall College, Lancaster, PA.

Introduction: A major driver of Mars exploration is the search for past or present life [e.g.,1]. An important contributor to this effort is exploiting terrestrial analogue sites that have some geological and/or astrobiological relevance to Mars. These sites can be used for various purposes, such as:

- Developing expertise in rover operations and assessing operational procedures (e.g., [2, 3];
- Assessing performance and utility of scientific instruments on past, present, or future Mars rovers;
- Testing instruments in environments with Mars-relevant geological/astrobiological characteristics.

We undertook a rover-like investigation at the Gypsumville, MB, Canada Mars analogue site [4, 5] in the summer of 2018. Our goals were to:

- Assess target selection and sample triage (relevant to Mars sample return), based on a combination of imagery taken at different scales and with inputs from various Mars rover-relevant analytical instruments;
- Assess the scientific importance of targets selected by an off-site science team via a post-deployment site visit by the team, and more detailed and comprehensive analysis of samples in the laboratory;
- Determine how future deployments could be improved to better inform Mars rover operations and instrument selection.

Site description: The Gypsumville site is located ~200 km north of Winnipeg, MB, Canada. The main feature of interest is the ~20 km diameter impact structure (Lake St. Martin – LSM) [4, 5], which includes a central uplift of shocked granitic materials, granitic and carbonate impact melts, post-impact deposits of evaporites (largely gypsum), and extensive slumping, reworking and cementation of impact-affected materials by surface or ground water, forming poorly sorted and partially lithified sediments (termed "red beds").

Two areas of exposed red beds within an aggregate pit were selected as "landing sites" (LS1 and 2) – both with minimal vegetation and some topographic expression. LS1 had ~ 3 m high exposures of red beds, including faces where layering is observed, to older, more scree-covered slopes. LS2 was characterized by spoil piles of red bed blocks. The aggregate pit is located approximately equidistant between the crater rim and central peak, contains reworked materials from both rim and peak, and has been partially cemented by gypsum-rich groundwater or from an adjacent sea [5].

Field campaign: A 3-day field campaign was undertaken involving an off-site science team and an on-site team (for instrument deployment). The field campaign involved various activities to simulate a rover-based exploration of an impact structure in the context of a "fast motion" deployment where some rover activities are undertaken in a compressed time frame.

Offsite team. The offsite team consisted of individuals who had not previously visited the site and included grades 10-12 students with essentially no geological experience, and first to fourth year university students who had taken between one and six physical geography/geology courses.

The off-site team was tasked with initially identifying regions of interest (ROIs) within each LS on the basis of panoramic color imagery, and then targets of interest (TOIs) within each ROI which were imaged at higher resolution and characterized in the field by reflectance and Raman spectroscopy. These data were all used to rank the TOIs for science value/sample return. The team was provided with only basic information to guide their deliberations. This included a very basic explanation of cratering dynamics, such as production of impact melt, shock effects, the nature of suevite, and post-impact reworking mechanisms, and the effects of hydrothermal alteration, and a brief introduction to possible crater-associated biosignatures. They were also provided with a basic structural (but not geological) map of the site showing the location of the LSs.

Image dimensions and scales, respectively, were: (1) LSs: 10s of meters; few cm; ROIs: few meters, sub-cm; TOIs: few decimeters, sub-mm.

A few rules were imposed on the science team:

- a maximum of 20 high priority targets (i.e., deemed important enough for sample return);
- a "no going back rule: i.e., if a TOI in a subsequent ROI was found to be more scientifically valuable than a previously identified high priority TOI sample in a previous ROI, the first sample's priority could not be downgraded. This was done to reflect the "reality" of sample acquisition;
  - the "ROI rule": detailed data for the TOIs within a single ROI could be compared with each other for

prioritization prior to moving to another ROI. This was implemented to reflect the ability of a rover to linger within an ROI.

Post-deployment sample analysis (not available during the field campaign) included characterization by XRD, XRF, and wet chemistry to assess, post-deployment, success in identifying TOIs of high science value.

Onsite team. The onsite team was tasked with data acquisition as directed by the offsite team. Onsite team members who had no prior knowledge of the geology of the site were also tasked, while onsite, with independently identifying TOIs at the two LSs.

Results (1): Some factors that impacted the planned science activities are worth mentioning.

1. We had planned to use a drone to acquire overhead imagery to help guide traverse planning and ROI and TOI identification. However conditions at the site were too windy for its deployment.
2. A field-portable XRD was planned to be used for sample triage, but it was realized that such data (as acquired by the CheMin instrument on Curiosity) is generally not used for TOI identification [5].
3. Communication to/from the site was intermittent or slow. As a result, we were not always able to quantitatively analyze reflectance and Raman spectra. Spectral analysis ended up relying largely on "screen shots" of spectra captured by cell phones.

Results (2): The science team realized early on that the site was geologically diverse: containing clasts of widely differing appearance. They therefore decided that some portion of their time and sample allocation should be devoted to understanding and sampling the "baseline" geology of the site.

Some trends emerged during the first two days of activities. These include:

- Some ROIs and TOIs were quickly identified by all offsite team members as high priority. In general, 1-3 ROIs were identified by all team members, with the rest usually supported by <50% of the off-site team.
- As the ROIs and TOIs were prioritized, it emerged that lower-priority ROIs generally had less TOIs. This was because the tonal and textural diversity of the site could be effectively captured by the first few highest priority ROIs and their associated TOIs.
- The number of TOIs that were identified as high or medium priority for sampling was generally less for the lower priority ROIs, and also more TOIs were discarded from these lower-priority ROIs after detailed analysis. This was mostly due to the fact that later TOIs could be compared to earlier TOI results, and TOIs with similar spectral characteristics to earlier TOIs were generally discarded (i.e., assigned low priority for sampling) unless they showed distinct textural differences with similar spectral characteristics compared to earlier TOIs.
- The majority of the Raman spectra showed only one weak or no Raman peaks and strong fluorescence. As a result, TOI prioritization heavily relied on the reflectance data.
- The reflectance spectra proved to be more useful for mineral identification, with multiple phases being identifiable, but of varying specificity.

One of activities associated with this deployment was to identify TOIs for sampling, assigning them as high, medium, or low priority. This was done via a downselect process using: (1) the panoramic color imagery; (2) the ROI color imagery; (3) the TOI color imagery; and finally (4) the Raman and reflectance spectra of the TOIs that survived the first three steps.

Lessons learned: This study helps inform future field campaigns as well as providing insights into data analysis for future planetary rover operations.

- Slow downlink-uplink between the field and off-site teams impeded quantitative spectral analysis.
- Related to this, we were unable to confidently search for, or identify small differences in absorption band positions, which could be indicative of important mineralogical variations.
- Even if communication issues were not present, the analysis would have benefited from the availability of spectral libraries and easy-to-apply and rapid spectral analysis tools.
- The use of imagery at the three different scales (LS, ROIs, TOIs) resulted in changes in sample prioritization with potential TOIs being both upgraded and downgraded.
- Target selection and geological interpretation was hampered by the lack of scale bars in the imagery. Stereo imagery or other techniques (such as lidar) could help to mitigate this issue.

Summary and conclusions: Field-based rover-relevant deployments provide invaluable operational experience, help to identify potential pitfalls and issues, and inform best practices for future deployments.

References: [1] *NASA Astrobiology Strategy* (2015) NASA. [2] Foing, B.H. et al. (2011) *IJA, 10*, 141-160. [3] Qadi, A., et al. (2015) *Adv. Space Res., 55*, 2414-2426. [4] McCabe, H.R., and Bannatyyne, B.B. (1970) *Geol. Surv. Manitoba, 3*, 70-79. [5] Leybourne. M.I., et al. (2007) *G3*, 8, 1-22.

Acknowledgements: Thanks to the CSA, CFI, MRIF, NSERC, and UWinnipeg for supporting this study, as well as the various parents and teachers who provided key logistical support.