THE GOLDEN DEPOSIT IN THE CANADIAN ARCTIC AS AN ANALOGUE FOR JAROSITE DEPOSITION AT MERIDIANI PLANUM AND MAWRTH VALLIS, MARS. M. M. Battler[1], G. R. Osinski[1], D. S. S. Lim[2], A. F. Davila[2], F. A. Michel[3], M. A. Craig[1], M. R. M. Izawa[1], L. Leoni[4], G. F. Slater[4], A. G. Fairén[2], and S. W. Starratt[5], [1]Dept. of Earth Sciences, University of Western Ontario, 1151 Richmond St., London, ON, Canada, N6A 5B7, mbattle@uwo.ca, [2]SETI Institute and NASA Ames Research Center, MS 245-3, Moffett Field, CA, USA, 94035, [3]Institute of Environmental Science, 2240 Herzberg Bldg., Carleton University, 1125 Colonel By Dr., Ottawa, ON, Canada, K1S 5B6, [4]School of Geography and Earth Sciences, McMaster University, 1280 Main St. West, Hamilton, ON, Canada, L8S 4K1, [5]USGS, 345 Middlefield Road, Menlo Park, CA 94025, USA.

Introduction: Surficial deposits of the OH-bearing iron sulfate mineral jarosite have been observed in several places on Mars, such as Meridiani Planum [1, 2] and Mawrth Vallis [3]. Jarosite is thermodynamically stable under a majority of temperature and pressure conditions on present-day Mars and, as such, jarosite may contain chemical or textural indicators of Mars' history, perhaps including evidence of biological activity [4]. Martian jarosite deposition mechanisms are not known, but by comparing Martian sites to analogous sites on the Earth we may be able to deduce conditions of formation, and thus paleoenvironments on Mars during the time of deposition.

Analogue site description: Located in a semi-arid cold desert 100 km east of Norman Wells, NWT, Canada, the Golden Deposit (GD, [5]) is visible from the air as a brilliant golden-yellow patch of un-vegetated soil, approximately 140 m × 50 m (Fig. 1). The GD is underlain by permafrost and consists of yellow ochre, which is precipitating from seeps of acidic (pH ~2), iron-bearing groundwater. Jarosite formation is thought to be due to pyrite oxidation at depth [5]. On the surface the GD appears as a patchwork of raised polygons, with acidic waters flowing from seeps in troughs between polygonal islands. Jarositic mud extends beneath vegetation up to 70 m out from the deposit and is mixed with mineral fragments presumably weathered from bedrock and glacial till. Microbial filaments and diatoms were observed in a few channels, indicating that GD water chemistry can support life.

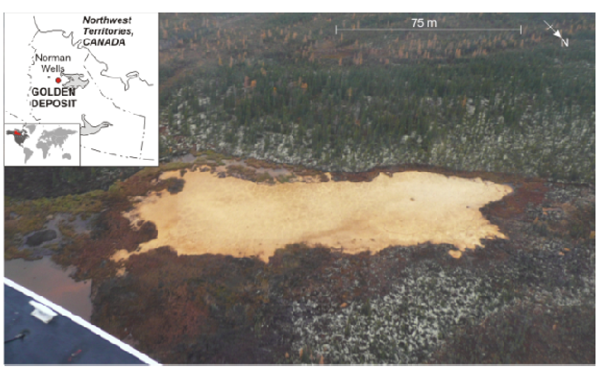

Figure 1. Aerial photograph of the GD, Sept. 2009. Inset maps show location of NWT, Canada, and approximate location of the GD.

Analytical techniques: Sediment samples and water chemistry data were collected in September 2009. Detailed mineral determination was performed on 43 samples for this study via X-ray diffraction (XRD; Co K-alpha radiation (λ = 1.7902 Å), Rigaku Rotaflex, 45kV, 160 mA, 2º-82º 2θ) at the University of Western Ontario. Oxide and trace element abundances for 6 representative samples were determined by Acme Analytical Laboratories (Vancouver) Ltd. via inductively coupled plasma (ICP) emission spectrometry. Spectra of 48 samples powdered to <53 µm were collected with an Analytical Spectral Devices Inc. FieldSpec Pro HR spectrometer at the University of Winnipeg Planetary Spectroscopy Facility [6]. 0.35-2.5 µm spectra were acquired at i30º, e0º relative to Spectralon® with an ~5 mm field-of-view, using a 50 watt quartz-tungsten-halogen light source; 500 spectra were averaged to increase the signal-to-noise ratio.

Results:

Mineralogy and spectroscopy. Mineralogy of most samples, as determined by XRD and confirmed with ICP emission spectrometry, is predominantly natrojarosite and jarosite. Most samples contain varying amounts of hydronium jarosite, goethite, quartz, and clays, with hematite in some areas. UV-Vis-NIR spectral analysis indicates that the GD is jarosite and natrojarosite, which spectrally dominate and mask the spectral signatures of other minerals present in minor quantities. To produce a spectrum analogous to one that could be acquired by an orbital instrument flying over a similar jarositic deposit on the surface of Mars, we produced a representative spectrum via linear mixing of the spectra of 21 of the surficial samples collected (Fig. 2). Spectra created in this way can be used as ground truth for the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM), particularly when sulfate minerals are dominated by jarosite. The GD linear mixture spectrum can be directly compared to smoothed CRISM spectral data published by Farrand et al. [3] from an ovoid patch in the Mawrth Vallis region of Mars (Fig. 3), interpreted to be dominated by the presence of jarosite or natrojarosite. Both show jarosite absorption features at 2265 and 2460 nm, and other minerals are masked.

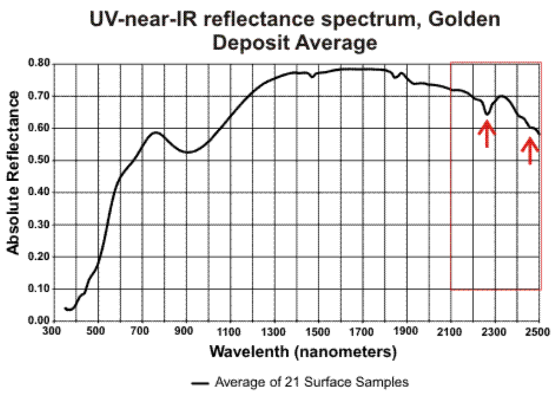

Figure 2. UV-Vis-NIR reflectance spectrum of the GD, to simulate perspective of an orbital instrument. Average obtained via linear mixture of the spectra of 21 surficial samples. Red arrows indicate absorption features centered at 2265 and 2460 nm, corresponding to features in the Mawrth Vallis spectra.

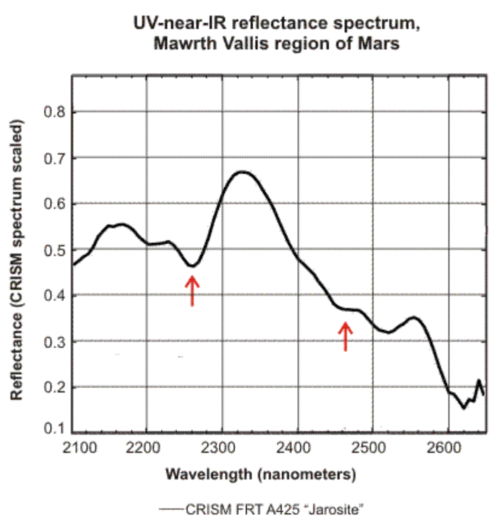

Figure 3. Smoothed CRISM spectrum from the ovoid jarosite deposit in Mawrth Vallis (modified from [3]).

Water chemistry. Water pH varies significantly over short distances depending on proximity to acid seeps, from 2.3 directly above seeps, to 5.7 several meters downstream from seeps within the deposit, and up to 6.5 in ponds proximal to the deposit. Temperatures vary independently from pH and range from 2.8 ºC to 10.2 ºC. In general, temperatures are highest within seeps and at the edge of the deposit. Temperatures decrease slightly inside the deposit (down to ~6.0 ºC), and decrease significantly with radial distance outward from the deposit to a minimum of 2.8 ºC.

Discussion: Although the GD appears to be spectrally homogeneous, careful observations reveal mineral and geochemical heterogeneity at sub-meter and sub-centimeter scale. Therefore, spectra with the relative spatial resolution of orbital imagery are only useful for identifying the major mineralogy and drawing course-scale conclusions, especially when obtained from jarosite-dominated locations. This has implications for the limitations of spectral analysis as a remote sensing technique, and the importance of ground-truthing to gain a detailed understanding of a jarositic site of this nature.

The sharp increases in pH noted with short distances from seep sites are likely due to dilution by active layer water, and consumption of hydronium by hydronium jarosite and jarosite precipitation. Maximum temperatures are measured in ponds around the edge of the deposit, presumably because of increased thermal inertia due to water depth and heating by sunlight. Temperatures are also higher at seep sites and in shallow streams, likely reflecting day time heating, or water may be slightly heated in the subsurface, despite the permafrost environment.

Implications for Mars: The GD is similar to Meridiani Planum and Mawrth Vallis in terms of chemistry, mineralogy, and potential depositional environment (permafrost and arid conditions), and to Mawrth Vallis also in terms of size, albedo, surface texture, and geomorphology. Thus, the GD offers a new possible analogue for the formation of these Martian deposits. Despite low pH and cool temperatures, the GD is hospitable to microbial life; thus sites on Mars may also have supported life, and may contain evidence of past life. Although surface mineralogy is analogous, the bedrock beneath the GD is not similar to the presumed sulfate-sandstones or volcanic rocks beneath Meridiani Planum. However, the Fe-Mg smectite layer underlying the Mawrth Vallis site [3] may be comparable to the pyritiferous shale beneath the GD; small pyrite crystals may be present, but not detectable from CRISM data. GD may be of special interest as Mawrth Vallis is being considered as a landing site for NASA's Mars Science Laboratory mission. The GD also demonstrates that Martian deposits may show considerably more chemical and mineral variability than indicated by the current remote sensing data set.

References: [1] Squyres, S.W. and 18 colleagues (2004) *Science*, *306*, 1709-1714. [2] Klingelhofer, G. and 18 colleagues (2004) *Science, 306,* 1740-1745. [3] Farrand, W.H., Glotch, T.D., Rice Jr., J.W., Hurowitz, J.A., and Swayze, G.A. (2009) *Icarus, 204*, 478-488. [4] Natrovsky, A., Forray, F.L., and Drouet, C. (2005) *Icarus, 176*, 250-253. [5] Michel, F.A and van Everdingen, R.O. (1987) *Canadian Mineralogist, 25*, 221-226. [6] Cloutis, E., Craig, M., Kaletzke, L., McCormack, K, and Stewart, L. (2006) *LPSC XXXVII*, Abstract #2121.

Acknowledgements: Nicola Barry is thanked for assistance in the lab. This study was supported by funding from the Canadian Space Agency and NSERC.