SITE SELECTION FOR MARS METHANE ANALOGUE MISSION: GEOLOGICAL, ASTROBIOLOGICAL, AND ROBOTIC CRITERIA. A. Boivin[1], C. Samson[1], H. Vrionis[2], A. Qadi[3], C. Scott[2], J. Stromberg[4], E. Cloutis[4], G. Berard[4], P. Mann[4], [1]Department of Earth Sciences, Carleton University, Ottawa, ON, Canada K1S 5B6; aboivin@connect.carleton.ca, [2]Department of Natural Resources, McGill University, Ste. Anne de Bellevue, QC, Canada, H9X 3V9, [3]Department of Mechanical & Aerospace Engineering, Carleton University, Ottawa, ON, Canada K1S 5B6, [4]Department of Geography, 515 Portage Avenue, University of Winnipeg, Winnipeg, MB, Canada R3B 2E9.

Introduction: The Mars Methane Analogue Mission, funded by the Canadian Space Agency through its Analogue Missions program, seeks to simulate as closely as possible a Mars micro-rover mission whose goal would be to detect, analyse, and determine the source of methane emissions. In order to achieve this goal, a Mars analogue site satisfying strict criteria has been selected. These criteria include:

- Mineralogical similarities to high-interest Martian targets;
- High likelihood of methane production (biogenic or abiogenic);
- Ability to safely deploy rover.

Based on these criteria, the Jeffrey Mine, an open pit asbestos mine near Asbestos, Québec, Canada, was selected. A preliminary visit to the mine was conducted in November 2010.

Geology: Located in the Appalachian hills, the Jeffrey Mine is the largest open pit asbestos mine outside of Russia. It is approximately 700 m deep and 3 km × 1 km wide. The Jeffrey Mine was opened in 1879 and has since produced about 28 million tonnes of material. The interior of the pit is accessible through a system of spiralling roads. The two main rock types are peridotite (serpentinite bearing) and slate which are separated by an approximately 25 m wide shear zone (Figure 1). The mine is cut across by a major regional fault [1]. The peridotite-shear zone-slate contacts are the expression of this fault in the mine.

A possible source of the recently detected methane in the Martian atmosphere [2-3] is the weathering of serpentines. This process, which can be both biogenic and abiogenic, occurs on Earth [4-5]. The presence of serpentinite in the form of chrysotile (asbestos) makes the Jeffrey Mine a likely location for this process to occur and an excellent mission analogue site. Furthermore, magnesium carbonate (another weathering product resulting from methane production) is present at the site. Magnesium carbonates have been detected on Mars in close proximity to serpentinite [6-7] and in areas of enhanced methane production on Mars [8].

Methane production occurs when serpentine, which often contains ferrous iron, releases hydrogen from the oxidation of ferrous iron to ferric iron due to weathering [4]. The released hydrogen can then react with dissolved CO_2 to produce methane [4] through the following reaction [5]:

$$CO_{2(aq)} + 4H_{2(aq)} = CH_{4(aq)} + 2H_2O$$

A potential site within the mine is located at the base of Figure 1 where a spiralling road meets the peridotite-shear zone-slate contacts where serpentinisation is prominent and weathering of the serpentinites is thought to occur. This site is most suitable due to the presence of the appropriate mineralogy as well as joints and fractures in the rock wall which would provide a path for subsurface methane seepage. Near the shear zone, the peridotite is chrysotile-bearing and schisted as well as heavily fractured and jointed. The rocks within the shear zone are very soft and are characterised by an overall talc-like texture. The slate wall is jointed and faulted. We hope to have at least one 500 m traverse planned along the rock wall for the first micro-rover field deployment in summer 2011.

Along with the rover-mounted instrument suite we will deploy handheld geochemical and geophysical equipment in order to demonstrate their capability for gas, contact, and fracture detection for possible future inclusion in a rover instrument suite. The geophysical instruments we plan to test are an Electromagnetic Induction Sounder (EMIS) and a high-density 3D laser camera.

Briefly, the EMIS is a geophysical instrument which emits a time-varying "primary" electromagnetic field from a transmitter. Eddy currents are then induced in subsurface conductors according to Faraday's Law which generate a "secondary" EM field. This field, along with the primary field can then be sensed by a receiver [9-10]. Clays are strong conductors (resistivity ranging from 1-100 Ωm) while slates are much more resistive (resistivity ranging from 6×10^2 Ωm – 4×10^7 Ωm) [11]. Based on this resistivity contrast, we expect the EMIS to be able to characterise the different rock types and their contacts. The 3D laser camera will be used to take pictures of the rock face and extract information about fracture orientation.

Astrobiology: Mars exploration missions have indicated the presence of methane with seasonal variations in concentration [e.g., 8]. This methane may be of abiotic and/or biotic origin and an ability to make this distinction would greatly contribute to efforts to determine if life on Mars currently or ever existed. Efforts in this mission will be made to identify biologically driven transformation patterns in serpentinite and magnesium carbonate minerals related to methane cycling in hopes of identifying target signatures that could provide evidence for biological activities on Mars. This work will involve geochemical as well molecular analyses. Molecular and culturing efforts will be used to determine the types of micro-organisms that exist associated with serpentitinite minerals and that may potentially be contributing to the methane production being observed on Mars.

During the preliminary visit to the Jeffrey Mine in November 2010 gas samples were collected to attempt to confirm the presence of methane at the site (Figure 2). Gas samples were collected inside or in proximity to joints and fractures. This was done based on the notion that methane production is stronger in the subsurface and that gas seepage and low redox conditions (necessary for growth of methane producing bacteria) could occur at joints and fractures. Preliminary results indicate the presence of above background methane concentrations and efforts to establish absolute measures and distinguish biotic vs. abiotic isotopic patterns are currently underway.

Robotics: The micro-rover can rove safely at a maximum incline of 30º and can overcome obstacles up to 15 cm in height. Its maximum autonomous roving speed is 80 m/h. The rover would ideally need to achieve close contact to the rock wall in order to sample gas, possibly through the use of a sensor or sampling device attached at the end of a robotic arm.

The rover is designed using a rocker-bogie modular drive system with six wheels 15 cm in height. The drive system uses a skid steering method for wheel manuver control. Figure 3 shows the design of the rocker-bogie drive system and the wheel suspension system.

Future Work: Two rover field deployments are planned. The first one, in summer 2011, is designed to test the rover technology and various instruments. The second deployment in summer 2012 will be a fully integrated experiment with the goal of simulating a Mars micro-rover mission from both a science and operational standpoint.

References: [1] Turcotte P.L. et al. (1989) *Géog. Phy. et Quat., 43,* 131-146 [2] Mumma M.J. et al. (2009) *Science, 323,* 1041-1045. [3] Formisano V. et al. (2004) *Science, 306,* 1758-1761. [4] Klein F. and Bach W. (2009) *J. Petrol., 50,* 37-59. [5] McCollom T.M. and Seewald J.S. (2001) *Geochim. Cosmochim. Acta, 65,* 3769-3778. [6] Ehlmann B.L. et al. (2008) *Science, 322,* 1828-1832. [7] Ehlmann B.L. et al. (2009) *LPS XXXX,* abstract #1787. [8] Mumma M.J. et al. (2009) *Science, 323,* 1041-1045. [9] Samson C. et al. (2006) *CASI ASTRO 2006,* Paper 17. [10] Grant F.S. and West G.F. (1965) Interpretation Theory in Applied Geophysics**.** [11] Telford W.M. et al. (1990) Applied Geophysics, 2nd ed.

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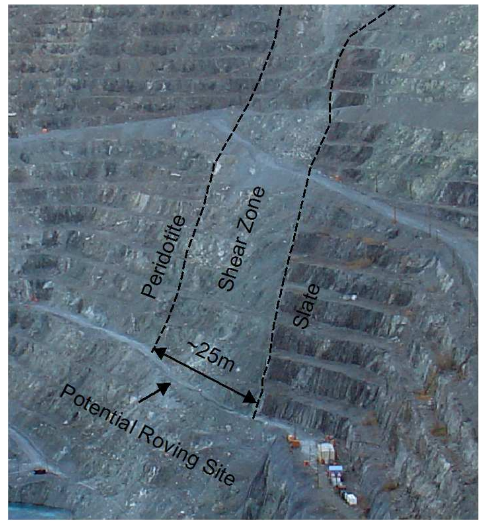

Figure 1. Photo of inside the open pit mine showing the peridotite-shear zone-slate contacts.

Figure 2. Preliminary gas sample collection at the potential roving site.

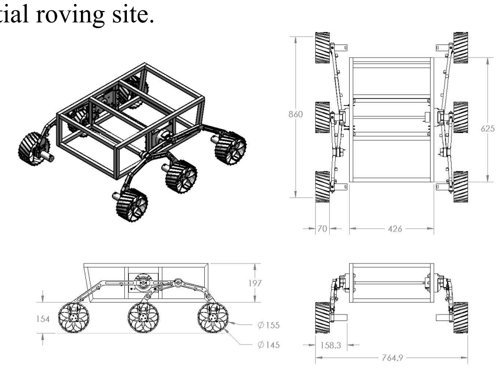

Figure 3. Micro-rover design of the rocker-bogie drive system and the wheel suspension system.