MARS METHANE ANALOGUE MISSION (M3): GEOLOGICAL MAPPING WITH AN ELECTROMAGNETIC INDUCTION SOUNDER

M. Ralchenko1, M. Perrot2, C. Samson1, A. Tremlay2, S. Holladay3, and E. Cloutis4

1Dept. Of Earth Sciences, Carleton University, 1125 Colonel By Drive, Ottawa, ON, Canada K1S 5B6; maxim_ralchenko@carleton.ca, 2Dépt. des sciences de la Terre et l’atmosphère, Université du Québec à Montréal, C.P. 8888, succursale Centre-ville, Montréal, QC, Canada H3C 3P8, 3Geosensors Inc., 66 Mann Avenue, Toronto, ON, Canada M4S 2Y3, 4Dept. of Geography, 515 Portage Avenue, University of Winnipeg, Winnipeg, MB, Canada R3B 2E9.

Introduction

In June 2012, the Mars Methane Analogue Mission (M3) tested a prototype microrover with the goal of detecting, analyzing, and determining the source of methane emissions in a geological setting closely related to that of Mars [1-3]. The deployment was carried out at the abandoned Norbestos chrysotile asbestos mine, 10 km northeast of the town of Asbestos, Quebec, Canada. This location was used because methane is produced by weathering—biogenic or abiogenic—of serpentine; similar processes have been suggested to take place on Mars [2]. The June 2012 deployment simulated an integrated microrover exploration mission from both a scientific and operational perspective. The Electromagnetic Induction Sounder (EMIS) was used alongside the rover to assist in mapping the local geology by acquiring electrical conductivity and magnetic susceptibility data.

Geology

The Asbestos, Norbestos, and Thetford Mines ophiolites constitute the hanging wall of the major regional St. Joseph Fault [4]. At the Norbestos mine, this normal fault separates the hanging wall ultramafic unit from black slate in the footwall. It is only visible in a steep wall on the north side of the pit, where the only slate outcrops were found. A zone of heavily faulted rock was observed east of the lake (see Figure 2); faulting is also evidenced by abundant slickensides. Joints and cracks were observed throughout the ultramafic unit, which could act as methane conduits.

Electromagnetic Induction Sounder (EMIS)

The EMIS used at the Norbestos mine was the Dualem-2 made by Geosensors Inc. of Toronto, Canada, shown in Figures 3 and 4. It is a two-metre long rigid tube containing a transmitter oriented parallel to the ground (axis in z-direction), and two orthogonal receivers oriented parallel (x-direction; depth of exploration ≈ 3.0 m) and perpendicular (y-direction; depth of exploration ≈1.2m) to the ground [5]. The output consists of four measurements: out-of-phase electrical conductivity and in-phase, equivalent to apparent magnetic susceptibility, for each receiver. Temperature, time, and location data were also recorded.

It was anticipated that major geological discontinuities and related joints and fractures would also correspond to significant geophysical anomalies.

Survey

During surveying, the EMIS was mounted horizontally on a nonconductive sled, 25 cm off the ground. The survey traversed the entire mine site, mostly by following either mine or access roads (see Figure 4). Excavated areas were not accessible; care was further taken to note the ruins of the mill, which greatly affected raw readings because of scrap metal.

Analysis and results

Using ESRRI’s ArcMap, a base map was created from satellite imagery and the EMIS data was added to the map as vector points. Kernel interpolation with a barrier was used produce a buffered raster grid along the path defined by the discrete points from the EMIS. Geological data was added over the geophysical data to help visualize correlating features. The resultant maps for deep (> 3m) conductivity and susceptibility are shown in Figure 1. The geophysical data can be readily correlated with the geological data in several areas. Zones of extensive deformation, caused by shearing and faulting associated with the St. Joseph fault, show up as anomalies. In particular, there is an area of elevated conductivity in the centre of the map, bounded by two segments of the offset St. Joseph fault. The major fault zone to the east is characterized by both positive and negative anomalies. The area of elevated conductivity along the road in the northermost part of the map is possibly related to splay faults associated with the main fault, but there is no outcrop control to verify this observation.

The rover exploration zone was too small for the EMIS to detect large variations in physical properties. In retrospect, EMIS data could have been used in a reconnaissance mode to help select a geologically and geophysically more interesting area for the microrover tests.

Conclusions

During the deployment at the Norbestos mine, the EMIS proved to be a sturdy instrument capable of surveying efficiently on a variety of terrains, from roads to sheared bedrock. Its results can complement other investigations and assist in mapping geological features by either interpolating and plotting data on a map (Figure 1), or graphing them directly as single profiles [1]. The EMIS is sensitive to structural variations on a Martian analogue terrain, which should be useful when searching for the origins of methane seeps. Provided that any interference is stable and can be compensated for, the EMIS could be mounted on a rover to survey large areas to help to identify zones of specific interest.

References


Figure 1: Maps of the Norbestos mine with EMIS data from a depth of ≈3 m with geological data overlain: electrical conductivity (left); magnetic susceptibility (right).

Figure 2: The Norbestos mine, facing North. Tailings piles are seen in far background, and an area of heavily faulted rocks is on the right below the piles.

Figure 3: The EMIS with the Kapvik microrover

Figure 4: The EMIS in action

Figure 4: The EMIS in action