GROUND PENETRATING RADAR (GPR) INVESTIGATIONS OF THE MISTASTIN LAKE IMPACT STRUCTURE: A CASE FOR GPR ON THE MOON.

M. Beauchamp[1], G. R. Osinski[1], T. Unrau[1], C. Marion[1], M. Mader[1], I. Antonenko[1], and T. Barfoot[2] [1]University of Western Ontario, 1151 Richmond Street, London, Ontario, Canada, N6A 5B7, [2]University of Toronto Institute for Aerospace Studies, 4925 Dufferin Street, Toronto Ontario, Canada, M3H 5T6. (mbeauch6@uwo.ca)

Introduction: Meteorite impact structures represent the dominant geological landform on the Moon [1]. This is evidenced by the immense number of impact craters on the lunar surface, from the small to the large, with the South–Pole Aitken (SPA) basin at ~2,500 km in diameter being the largest impact crater in the solar system. The recent confirmation that the Moon possesses potentially large reserves of H_2O ice in its polar regions [e.g., 2] also has major implications for the understanding of the Moon and raises exciting possibilities for long-duration human missions utilizing in situ resources. Together, these scientific attributes provided the rationale for a lunar "analogue mission" to be carried out at the Mistastin Lake impact structure in Northern Labrador, Canada, funded by the Canadian Space Agency (see [3] for overview). Mistastin is an ideal lunar analogue site, forming as it did, in a target comprising anorthosite.

In August and September of 2010, the robotic precursor phase of this lunar analogue mission was conducted at the Mistastin Lake impact structure utilizing a simulated rover consisting of several field portable scientific instruments operated by humans – the field team – directed remotely by a backroom science team located at the University of Western Ontario (London, Ontario) – the mission control team. One of the goals of this deployment was to test the functionality and the effectiveness of the field instruments in providing useful information to the mission control team. At the same time, this analogue mission had several scientific objectives; namely, impact chronology, shock metamorphism, impact ejecta, and impact resources.

Instrumentation: Ground penetrating radar (GPR) is a method of subsurface imaging utilizing high-frequency electromagnetic energy pulses which are transmitted into the ground. These pulses are partially reflected at boundaries of materials with different electrical properties to be detected by a receiver, amplified, recorded and displayed to the user. The depth of penetration of the electromagnetic pulses can vary greatly depending on the materials being investigated [4]. For this deployment we used a Sensors & Software 250 MHz Noggin-plus GPR unit equipped with a skid plate for dragging over rough terrain and optical encoded odometer for measuring distance.

Methodology: After completing an initial landing site scan (including 360º panoramic photograph and 360º LiDAR scan) the mission control team chose sites of interest to investigate further. Instructions of measurements desired were conveyed to the field team via a document with detailed photographs indicating locations for measurements. While conventional rovers would gather GPR data while travelling along a planned transect [5], due to rough terrain and vegetation as well as communication restraints the field team was given some flexibility to select the most appropriate route for the GPR transect. An approximately 180 m transect was chosen and marked with flags at 20 m intervals. Photographs of the surface were taken at each marker in both the forward and reverse directions to provide the mission control team with some context, similar to a rover-mounted camera. The GPR unit was then dragged over the marked path, collecting data at 0.05 m intervals. This data was then sent back to mission control to be analyzed and to help guide the next day's instructions to the field team.

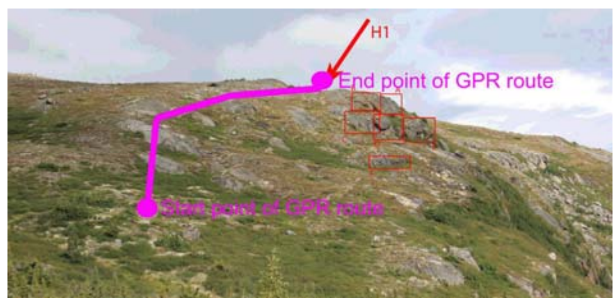

Figure 1. Approximately 180 m GPR route selected by field team following instructions from mission control team.

Figure 2. Collection of GPR data.

Results: By analyzing the data and the surface photographs the mission control team was able to distinguish the boundary between overburden and bedrock and roughly follow it over the entire length of the GPR transect. The mission control team also spotted planar features in areas where the GPR unit was above exposed bedrock (Fig. 3). These were interpreted to be either faults, fractures in the bedrock or a contact with a different lithological unit. This led them to request further GPR transects along routes parallel to the original transect, offset by 2 m to either side in order to confirm the lateral continuity of these features. Upon receipt and analysis of these transects one planar feature was confirmed to be continuous over the three transects. The mission control team then ordered geochemical analyses to be collected from the exposed bedrock on either side of the planar feature in hopes of distinguishing the nature of this planar feature. The additional transects also permitted the mission control team to further map the overburden-bedrock boundary to determine how it varies laterally.

Lunar Applications: While the electrical properties of lunar surface materials are different from those encountered at the Mistastin Lake impact structure, observations including the lack of liquid water imply that GPR would work well on the Moon [6]. Furthermore our observations demonstrate how the use of GPR could be quite valuable on the Moon to determine regolith thickness for use in construction and aid in scientific investigations by determining the depth of boundaries between different materials and by identifying and mapping features not visible at the surface.

Acknowledgments: We would like to thank everyone involved at mission control, M. Battler, A. Chanou, L. Cupelli, R. Francis, E. McCullough, L. Preston, B. Shankar, and D. Veillette as well as at the Canadian Space Agency T. Haltigin, L. Ilinca, and D. Gingras for all of their hard work and support.

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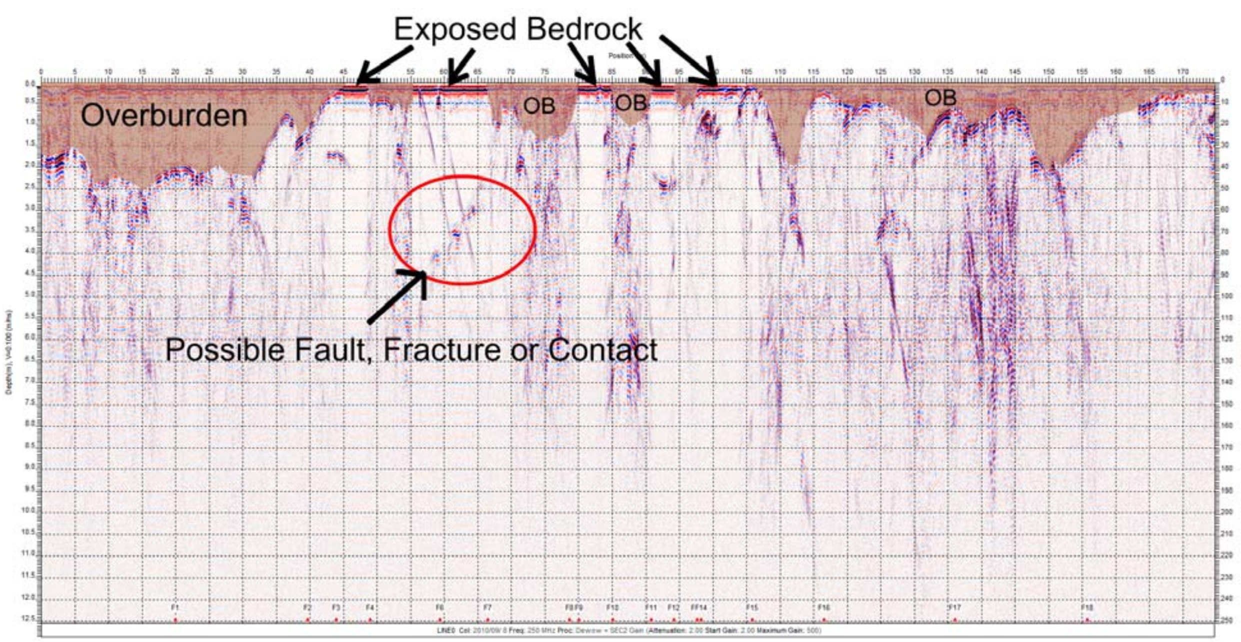

Figure 3. Example of the data product from GPR. The mission control team identified the overburden-bedrock boundary as well as a planar feature representing a possible fault, fracture or contact in the bedrock.