INTERNAL STRUCTURE AND COMPOSITION OF THE UPPER GALENA CREEK ROCK GLACIER, WYOMING, INFERRED FROM ELECTROMAGNETIC METHODS. J.D. Pharr[1], J.W. Holt[2], J.S. Levy[2], S. Nerozzi[2], E.I. Peterson[2], and C.M. Stuurman[2], [1]Center for Space Research, Department of Aerospace Engineering and Engineering Mechanics, University of Texas at Austin, Austin, TX, 78759, (jimpharr@utexas.edu), [2]Institue for Geophysics, Jackson School of Geosciences, University of Texas at Austin

Introduction: The use of terrestrial analogs as a means to investigate the geological and morphological properties of Mars proves to be useful in the understanding of the Martian terrain [1]. The establishment of an analog on Earth for the Lobate Debris Aprons (LDAs) seen in the fretted terrain of Mars is paramount to the understanding of Martian geological features. In order to facilitate this, examination of a lobate feature in the Absaroka Range located within the Shoshone National Forest, the Galena Creek Rock Glacier (GCRG), was utilized.

While the GCRG is a not a perfect model for the LDAs of Mars, it does exhibit ice from glacigenic origins [2] that is dependent upon environmental conditions for stability similar to LDAs of Mars [3]. The environmental conditions would result in exposed ice on the GCRG to melt while the conditions on Mars within the mid-latitudes would result in the sublimation of exposed ice. The debris layers of the GCRG and LDAs of Mars preserve the ice from the environmental factors of the area [3] by insulating the ice underneath.

Ground penetrating radar (GPR) and time-domain electromagnetic methods (TDEM) were used to better understand the internal structure and composition of the upper rock glacier, near and on the accumulation zone, and to study the feasibility of the GCRG as a terrestrial analog for the mid-latitude ice found in the fretted terrain of Mars. Figure 1 is a map of the area showing the GPR lines and the TDEM locations.

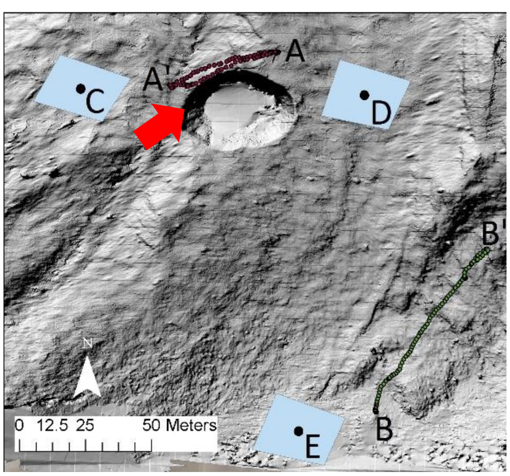

Figure 1: DEM of the upper glacier near the accumulation zone Note the thermokarst pond in the upper center (marked by a red arrow).

Methods: *GPR:* Two GPR transects were performed, one directly on the accumulation zone in the cirque and one near a thermokarst pond where ground truth could be observed. Soundings were taken in a ~32m line (between A and A′ in Figure 1) and a ~64m line (between B and B′ in Figure 1) at 50 and 100 MHz. Figure 2 shows the 50MHz radargram near the thermokarst pond after a bandpass filter and migration was applied. Measurements were also taken within the accumulation zone using the same antennas. Figure 3 shows the 100 MHz radargram in the accumulation zone, a line of ~64m, after a bandpass filter and migration was applied. Analyses of the hyperbolae within the radargrams allowed for extrapolation of subsurface electromagnetic wave velocities and associated relative dielectric constant in each area.

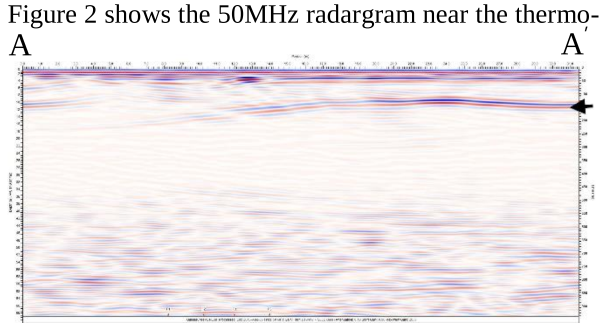

Figure 2: 50MHz GPR acquired at GCRG from A to A′ in Figure 1. Arrow indicates extensive lateral reflector between 8 and 18m in depth.

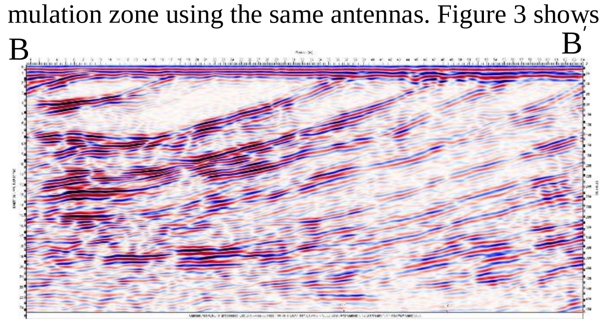

Figure 3: 100MHz GPR acquired at GCRG from B to B′ Point B.

TDEM: TDEM is a method by which the conductivity structure of the subsurface in a given area can be modeled via voltage decay through the subsurface medium. Three TDEM soundings were taken at both locations, two by the thermokarst pond (points C and D in Figure 1) and one in the accumulation zone, (point E in Figure 1) using a 20x20m square loop. Analysis of the

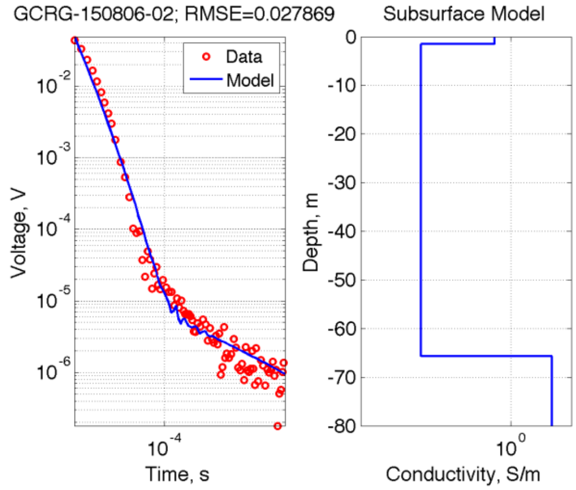

Figure 4: Processed TDEM from point D near the thermokarst pond. A best-fit-three-layer model was applied to the measured voltage decay with a fixed top layer based on ground truth. This model produced layer interface depths at 1.67m and 65m. The middle layer is highly resistive consistent with high ice content.

data and application of a three-layer model allowed for the extrapolation of apparent resistivities and a composition of the GCRG in those areas. A TDEM sounding near the thermokarst pond (point D) can be seen in Figure 4.

Observations: Analysis of the GPR data on the accumulation zone reveals laterally extensive uniform sets of reflectors indicative of significant sharp dielectric contrasts in the subsurface with similar geometry in both the 50 and 100MHz data sets continuing down to a time delay of 750 ns. These reflectors have an average surface dip angle of approximately 32.15° and range from 15-35°. Additionally, the EM wave velocity ranged from 0.1 to 0.147 m/ns at a time delay ranging from 40-100 ns. These velocities correspond to a dielectric constants ranging from 4.15 to 8.9.

Near the thermokarst pond, the data show a laterally extensive reflector at a time delay between approximately 125 and 250 ns in both frequencies. Below this, there is a lack of any major reflectors. Additionally, the EM wave velocity around the pond ranges from 0.114 to 0.148 m/ns. The associated dielectric constants for these velocities range from 4.1 to 6.9.

Analysis of the TDEM soundings of the area project a three-layer model that is approximately uniform across the accumulation zone and near the thermokarst pond. On average, these inversions showed a conductive layer down to a depth of 1.67 m and a resistive layer from 1.67 m to 65.27 m in depth.

Discussion: The dipping reflectors seen in the accumulation zone radargram can be interpreted, based on the subsurface radar velocity calculations, as alternating bands of englacial debris and slightly dirty ice, or perhaps even water saturated ice, indicative of cyclical climatic accumulation. Comparing the calculated dip angle (~32.15º) of said reflectors to the angle of the debris band seen in ground truth within the bank of the thermokarst pond (~45º) and taking into account the topographic change of the area, it is reasonable to assume similar subsurface geometry throughout the accumulation zone and thermokarst pond area. However, after accounting for the geometry of the thermokarst pond and minimum distance from the waterline to the GPR track, it is interpreted that the large reflector seen in Figure 2 at a depth between 8-18 m, assuming an average EM wave velocity of 0.132 m/ns, is a reflection from the water within the pond. Therefore, due to the strength of this reflector, no further structures are visible. Furthermore, these dipping reflectors and debris bands intersect the surface near ridges in the area.

The TDEM soundings acquired in the area fit reasonably well with a three-layer model consisting of a conductive top layer 1.67m over a highly resistive midlayer ~53-69m thick. The resistive nature of the midlayer is consistent with a high ice content. Finally, the upper glacial bulk thickness is locally constrained to ~55-70m.

Conclusion: Based upon TDEM and GPR results along with ground truth, it can be concluded that the upper GCRG is a good but not a perfect terrestrial analog for LDAs on Mars. The GCRG exhibits features such as debris-covered ice, glacial stability based upon environmental conditions and massive ice, all of which can be seen within the mid-latitudes of the Mars fretted terrain [2,3,4]. Further work and research must be conducted to better understand the intricate nature of lobate features and their viability as terrestrial analogs.

References:

[1] Leveille, T. (2010) Planetary and Space Science, 58, 631-638. [2] Potter, N. (1998) Geografiska Annaler, 80,251-265. [3]Lucchitta, N. (1984) JGR, 89, B409-B418. [4] Holt J.W. (2008) Science, 322,1235-1238.