

**INFRARED SPECTROSCOPY AND GEOCHEMISTRY OF COLD WEATHERING PRODUCTS IN A TERRESTRIAL ICY ENVIRONMENT: IMPLICATIONS FOR WEATHERING ON MARS.** A. M. Rutledge<sup>1</sup> and P. R. Christensen<sup>1</sup>, <sup>1</sup> School of Earth and Space Exploration, Arizona State University, Tempe, AZ; alie.rutledge@asu.edu.

**Introduction:** Geologic features on Mars show evidence of modification by water and water ice [1-5]. Past obliquity variations are hypothesized to have allowed the formation and stability of ground ice near the equator, possibly promoting the accumulation of glaciers [6-8]. Massive ice deposits, including probable glacial and periglacial features have also been observed in the east Hellas Basin and Deuteronilus Mensae regions, located at the midlatitudes of Mars [8-11]. These features indicate present-day, near-surface ice has been in contact with geologic materials, creating an environment in which cold weathering processes could have been occurring, and might still be at work.

Weathering processes in cold terrestrial environments are not well understood, and processes acting on subglacial and englacial sediments and rocks are not well characterized due to the remote location of many glaciers and the difficulty of collecting samples [12-13]. The types of weathering products and energy sources produced in a glacial environment will drive the overall energy budget for any microbial communities present [14]. The subglacial energy budget for microbes thus has implications in the search for life on other planets, making glacial and periglacial terrains excellent sites for future exploration. However, planetary ice deposits are difficult to study due to their sensitive nature and are thus limited to observation from orbit at present. It is therefore a key concern to better understand the types materials and alteration products that can be observed and constrained from orbital data.

*Analog study.* In this study, we characterize the types of weathering products present in a terrestrial glacial system using ground-truthed remote sensing techniques. Robertson Glacier, Alberta, Canada (115°20'W, 50°44'N) provides an excellent testbed for this technique as it is accessible, and its recent and continuing retreat allows fresh subglacial and englacial sediments to be sampled. Samples of bedrock and glacially altered rock and sediments were collected on a downstream transect of Robertson Glacier in September 2011 (Figure 1). Infrared laboratory spectra of these samples were collected using the TIR spectrometer at Arizona State University and used to determine the composition and abundance of minerals in rock and sediment samples, with a primary focus on differentiating weathering products.

*Remote sensing.* To correlate the geolocated samples to orbital remote sensing data, infrared spectra of the region was be measured at the time of sampling

with the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) satellite instrument.

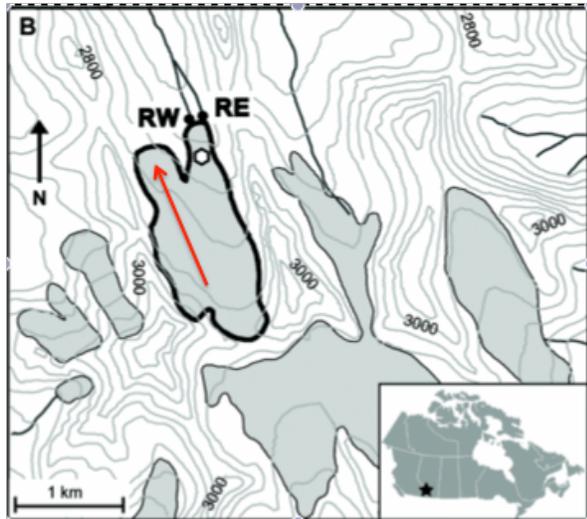
The goal of the rock and sediment sampling is to characterize the weathering products present in a glaciated silicate-carbonate system using infrared spectroscopy. The goal of the ASTER data collection campaign is to determine whether glacial weathering products can be detected from spaceborne infrared spectra, which has implications for planetary orbital studies. The overall goal of the project is to link ground-truthed sampling and characterization of geologic processes with remote sensing capabilities.

*Geochemical data.* Temperature, conductivity, pH, and ice/water samples were collected at each location. Ice and water were analyzed for major and minor elements at Arizona State University. It was observed that pH decreased in the downstream direction, and Ca<sup>+2</sup> and SO<sub>4</sub><sup>-2</sup> in solution increased downstream (Figure 2). This is initially consistent with earlier studies of similar systems [13]. Differing from earlier studies, however, the majority of the observed changes in concentrations seem to occur immediately at the supraglacial-subglacial interface, and little change is observed further downstream in the proglacial plain. Initial conclusions are that the majority of the rock weathering seems to be occurring at the ice-rock interface rather than in the outwash stream.

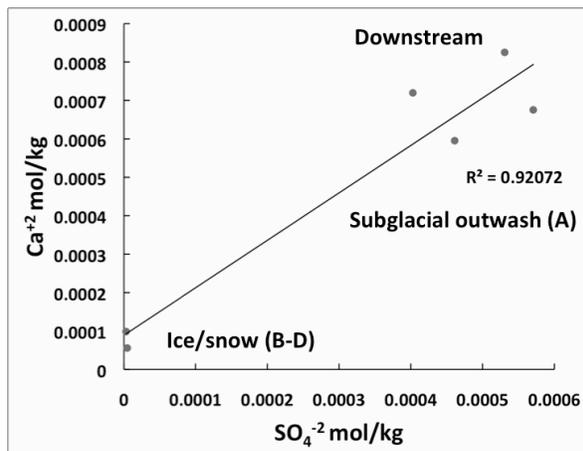
*Initial results.* Initial results from both laboratory and ASTER data indicate the presence of weathering products. Laboratory spectra of field samples are promising in that major bedrock mineral assemblages and a variety of alteration products can be identified (Figures 3 and 4). A general trend of decreasing carbonate abundances with elevation (i.e. residence time on the ice) is observed, which is consistent with the increasing Ca<sup>+2</sup> ion concentrations towards the terminus. However, more mineralogical work is required to refine the types of weathering products present in the system.

**References:** [1] Parsons, R.L. and J.W. Head (2005) *Lunar Planet. Sci.*, XXXVI, abs. 1139. [2] Baker, V.R. et al. (1992) in *Mars*, Kieffer, H.H. et al, Tucson, Ariz., 493-522. [3] Squyres, S.W. (1984) *Ann. Rev. Earth Planet. Sci.*, 12: 83-106. [4] Squyres, S.W. et al. (1992) in *Mars*, Kieffer, H.H. et al, Tucson, Ariz., 523-554. [5] Lucchitta, B.K (1981) *Icarus*, 45: 264-303. [6] Fanale, F.P. et al. (1986) *Icarus*, 67: 1-18. [7] Head, J.W. et al. (2003) *Nature*, 426: 797-802. [8] Forget, F. et al. (2006) *Science*, 311: 368-371. [9]

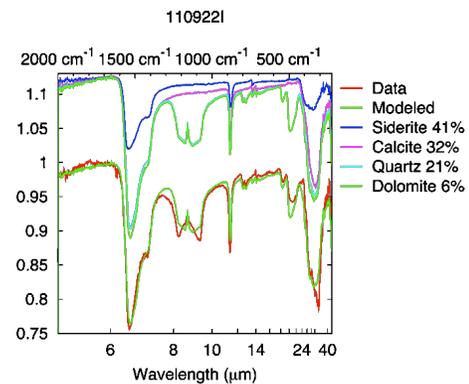
Crown, D.A. et al. (1992) *Icarus*, 100: 1-25. [10] Tanaka, K.L. and Leonard, G.J. (1995) *J. Geophys. Res.*, 100: 5407-5432. [11] Head, J.W. et al. (2003) *Nature*, 426: 797-802. [12] Dixon, J.C. and C. E. Thorn (2005) *Geomorphology*, 67: 127-145. [13] S. P. Anderson et al. (1997) *Geology*, 25(5): 399-402. [14] Boyd, E. S. et al. (2010) *Environ. Microbio. Rep.*, doi:10.1111/j.1758-2229.2010.00162.x. [15] Boyd, E. S. et al. (2011) *Appl. Environ. Microbiol.*, 77(14): 4778-4787.



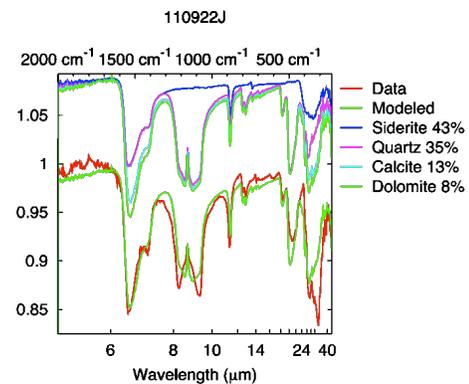
**Figure 1:** Map of sampling location. Robertson Glacier, Alberta, Canada. From Boyd et al. 2011 [15]. Red arrow indicates sampling transect.



**Figure 2:** Increasing ion concentrations from the subglacial system to the proglacial outwash system. The greatest amount of change is observed at the glacier itself; little change is seen between ion concentrations in the immediate subglacial outwash and the ion concentrations present ~2.5 miles downstream in the outwash plain.



**Figure 3:** Deconvolved TIR spectrum of upper glacier, supraglacial rock sample. This surface was in contact with the local glacier ice and meltwater. A greater proportion of carbonates to silicates is observed in this sample.



**Figure 4:** Deconvolved TIR spectrum of supraglacial, near-terminus rock sample. This surface was in contact with the local glacier ice and meltwater. A decreasing proportion of carbonates to silicates is observed in this sample.