FIELD TESTS AND GROUND TRUTHING OF A SURFACE-BASED NEUTRON DETECTOR IN THE ATACAMA DESERT, CHILE.

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Introduction: Many photogeologic studies and very recent results from orbital geochemical mapping experiments are consistent with the presence of shallow subsurface ice deposits on Mars. The next step in studying these deposits will be to visit them on the surface, probably with mobile robotic explorers. In order for such rover missions to be successful, they must carry instruments capable of identifying and mapping the deposits detected from above.

One approach to detecting subsurface hydrogen is to use a neutron detector capable of discriminating between epithermal and thermal energy neutrons. On planetary bodies with thin or nonexistant atmospheres, fast neutrons produced in the shallow subsurface by galactic cosmic ray interactions are moderated through collisions with nuclei in the regolith. The leakage spectrum of neutrons from a hydrogen-rich regolith will have a higher thermal to epithermal neutron flux ratio than an H-poor regolith.

The task we wish to address is the optimization of a neutron detector for a Mars rover platform. A prototype instrument has been developed and preliminary control tests have been conducted in order to characterize the response of the detector. This prototype instrument was used in conjuction with the Zoe rover for a blind science field test as part of the Life in the Atacama (LitA) Project [1]. In this test, a science team with no prior knowledge of a remote field site commanded the rover in a Mars mission simulation. Using the suite of instruments on the rover, including the neutron detector developed in this project, the science team attempted to characterize the geology of the remote site, including the presence or absence of subsurface hydrogen (e.g., in water). This test provided an opportunity to learn how neutron data taken at the martian surface can be used in conjunction with other types of data in a mission-like scenario to provide a more complete understanding of the planet's surface and shallow subsurface.

The preliminary results from this test are presented here. Data returned from the neutron detector, as well as correlations between neutron detector data, satellite imagery, and data from instruments on-board the Zoe rover are examined. In addition, results from models using Monte Carlo Neutral Particle eXtended code (MCNPX) are used to interpret detector counts returned from the field. Future, non-blind interpretations are also discussed. These tests will allow for ground-truthing of neutron detector data based upon soil moisture content analysis and more precise spectral correlations from orbital satellite imagery.

Instrument Design: The prototype detector consists of a dual ^{3}He proportional counter tube design. In order to operate the detector, signal processing electronics, spectrum analysis software, and a power supply are also required. On Earth, the atmosphere shields the surface from cosmic rays which would produce fast neutrons in the surface of Mars. Therefore, for testing our instrument on Earth, our design also includes a small neutron source to simulate cosmic ray production of fast neutrons. This source will be in the form of an encapsulated 0.5 microgram pellet of ^{252}Cf, which emits about 10^4 fast neutrons per second via spontaneous fission.

Methodology: Given a generic soil composition containing variable amounts of hydrogen, MCNPX was used to generate simulated detector counts. The resulting look-up table allows detector counts from the field to be compared to modeled detector counts from MCNPX. Expected count ratios (thermal over epithermal neutron counts) for various degrees of hydration are shown in Figure 1.

Figure 1: MCNPX generated model of count ratio versus percent hydrogen abundance within a generic soil composition.

Neutron detector integrations took place in 200-m intervals, resulting in seventeen data points along a total traverse of approximately 3,400 meters. Although the absolute position was unknown to the remote science team, the traverse was primarily due south, with neutron measurements taken within the rover's tracks. The traverse began and ended at two areas of scientific interest, called "locales", and therefore, a significant amount of data is available for those points, locales

880 and 890 respectively. Observations at locale 880 include a panoramic image, visibile to near infrared spectra (VNIR), thermal infrared spectra (TIR), and flouresence imager (FI) observations. These instruments are used in conjunction in order to characterize the abundance of clay minerals, biologic activity and bound-hydrogen. Along the traverse, data are limited to navigational camera images taken approximately every meter and ASTER orbital imagery. Therefore, analysis of data taken during the traverse utilized vegetation, rock abundance, and ASTER-derived chlorophyll spectral features to determine if correlations exist with the amount of bound-hydrogen in the near-surface. At locale 890, navigational images were also acquired, as well as a small FI suite.

Results: Figure 2 shows the resulting count ratios for each point along the traverse, converted to percent hydrogen abundance through the MCNPX model.

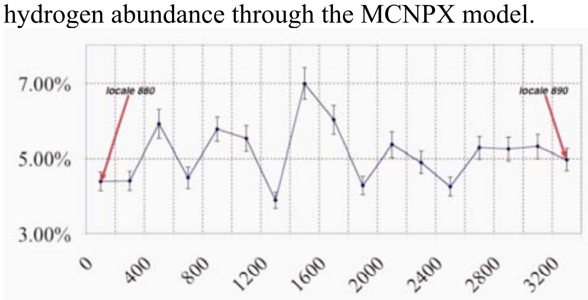

Figure 2: Percent hydrogen versus traverse distance with associated error bars for each measurement.

Figure 3 shows the traverse on a sub-frame of the orbital ASTER image for the region, demonstrating that the maximum count ratio corresponds well with the relatively large-scale drainage channel seen approximately 1,600 meters into the traverse.

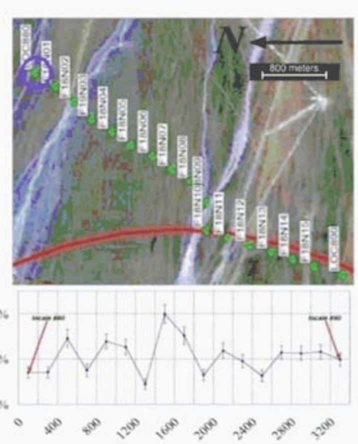

Figure 3: ASTER image showing traverse and hydrogen abundance values for each location. Two large drainage channels are observed and correlate with increases in count ratio near 500 and 1,600 meters. Increased vegetation levels also correlate with higher count ratios.

Vegetation was observed throughout the traverse and correlated well with the increases in count ratio seen at 600 and 1,200 meters. TIR spectra at locale 880 clearly show evidence of bulk silicate mineralogy, consisting of amorphous or fine-grained quartz, feldspars, and clays. VNIR soil spectra show water and clay absorption bands present. Evidence for both water and clay minerals suggets bound-hydrogen is relatively abundant within the near-surface soil. Data from the FI instrument indicates biologic activity is present at this location as well. In addition, locale 880 corresponds to a hydrogen abundance of 4.4%.

Hydrogen abundances greater than 4.4% consistently showed increased levels of vegetation, until approximately 2,600 meters into the traverse. At this location, vegetation levels dropped, soil and rock abundances returned to levels similar to those seen at locale 880. An FI measurement made at 3,400 meters returned no positive biologic signals. Although no vegetation was seen in navigational images, count ratios reached a constant level of approximately 1% higher than those observed at locale 880.

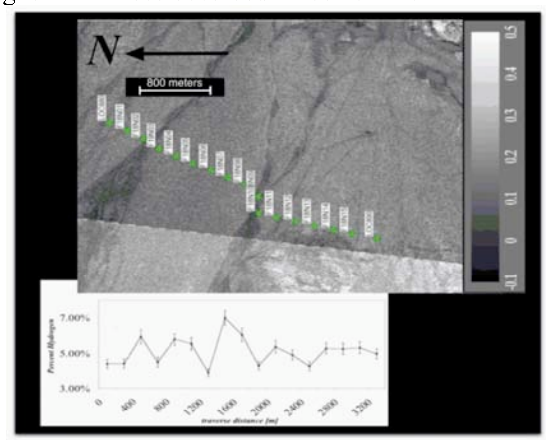

Figure 4: ASTER-derived chlorophyll spectral feature versus count ratio for the traverse. Hydrogen abundance remains near 5 % for the last four points along the traverse, which correspond to areas of increased chlorophyll abundance in the image.

When count ratios for those points are compared to an ASTER-derived image designed to enhance chlorophyll spectral features, a correlation is observed. Further analysis is necessary, however, to determine the effect of additional variables. Brighter pixels indicate a stronger "red edge", while black pixels indicate bright, non-vegetated surfaces.

Conclusions and Future Work: Good correlations were seen between neutron detector count ratios and areas along the traverse with increased abundances of bound-hydrogen, including drainage channels and vegetation. Future work will determine the moisture content from soil samples taken at each location of the traverse. Additional field tests conducted in the Atacama desert will determine the detector response to known geologic hydrogen deposits.

References: [1] Wettergreen, *et al.* (2004) LPSC XXXVI, Abstract #2316.