MODELING OF MARS SCIENCE LABORATORY CURIOSITY'S DYNAMIC ALBEDO OF NEUTRONS INSTRUMENT DATA USING ELEMENTAL GEOCHEMISTRY. C. Hardgrove[1], J. Moersch[2], I. Mitrofanov[3], M. Litvak[3], A. Behar[4], W.V. Boynton[5], L. Deflores[4], D. Drake[6], F. Fedosov[3], D. Golovin[3], I. Jun[4], K. Harshman[5], A.S. Kozyrev[3], A. Malakhov[3], R. Milliken[7], R.O. Kuzmin[3,8], M. Mischna[4], M. Mokrousov[3], S. Nikiforov[3], A.B. Sanin[3], C. Tate[2], A. Varenikov[3] and the MSL Science Team. [1]**Arizona State University, Tempe, AZ (craig.hardgrove@asu.edu);** [2]University of Tennessee, Knoxville, TN; [3]Space Research Institute, RAS, Moscow, Russia; [4]Jet Propulsion Laboratory/California Institute of Technology, Pasadena, CA; [5]University of Arizona, Tuscon, AZ; [6]Techsource, Santa Fe, NM, USA; [7]Brown University, Providence, RI; [8]Vernadsky Institute for Geochemistry and Analytical Chemistry, Moscow, Russia.

Introduction: *Dynamic Albedo of Neutrons (DAN) Instrument.* The DAN instrument on the *Curiosity* rover has been acquiring data in both passive and active mode throughout the duration of the Mars Science Laboratory (MSL) mission [1, 2]. DAN active mode data are acquired by firing the Pulsed Neutron Generator (PNG) for several minutes (usually ~5 minutes) and integrating the resulting signal in each of the DAN detector elements (DAN-DE) time bins from 0 – 100,000 microseconds. The shape and amplitude of the resulting "neutron die-away" curve will be a function of both the structure (the presence of discrete or gradational layering) and geochemistry of the subsurface to a depth of ~60cm [3].

DAN Sensitivity. Geochemically, DAN is most sensitive to the abundances of specific elements in the subsurface, in particular hydrogen and neutron absorbing elements like chlorine and iron [4]. In addition to DAN's primary sensitivity to chlorine and iron, the resulting neutron energy spectrum detected by the DAN-DE will be a function of the entire elemental composition of the subsurface to ~60cm. For a select number of locations throughout Curiosity's traverse we have acquired DAN data that are spatially co-incident (or co-incident to a geologic unit) with Alpha-Proton X-Ray Spectrometer (APXS) measurements and Sample Analysis at Mars (SAM) data [5, 6]. APXS measurements alone provide a nearly complete geochemical assay for neutron absorbing elements (Cl, Fe). Where the data have been acquired, SAM provides an external measurement of the H_2O content in the near-surface.

Geochemically-Constrained Modeling of DAN Data. In this work we assume the upper-layer composition within the sensing area of the DAN measurement (~1.5 meters) is equal to the APXS- and SAM-derived composition (See **Table 1** for locations). A suite of models are then run varying both the depth of the upper layer as well as the H and Cl composition in the lower layer. The best-fit models are determined by comparing them with the DAN data at the nearest location using a Chi-squared Pearson statistic criterion as described in Sanin et al. [7].

Methods: The standard method for interpreting planetary neturon spectrometer data is to compare measured neutron counting rates with those generated from a suite of Monte-Carlo (MCNPX) library models to determine a best-fit [8]. Here, we take a slightly modified approach to those presented by Litvak et al., Mitrofanov et al., and Sanin et al. [2, 7, 9]. In those studies each DAN measurement was compared to a previously generated suite of MCNPX models which included variable hydrogen in the upper and lower layers, as well as variable upper layer depth. Chlorine was allowed to vary uniformly in both layers but was fixed for a given set of models. Here we use a fixed composition for the upper layer from APXS and SAM, but allow the depth of the upper layer to vary, as well as the chlorine content and hydrogen content of the lower layer (**Figure 1**).

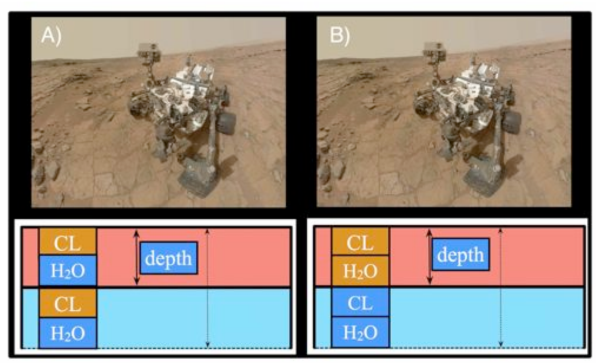

Figure 1: Two-layered conceptual parameter space for determining DAN best-fit models. Colored boxes represent model inputs; orange parameters are fixed while blue parameters vary. *a*) Independent modeling by Litvak et al., Mitrofanov et al., Sanin et al., to derive best-fit depth, H in both layers and Cl content. *b*) Geochemically-constrained modeling presented in this work can be used to derive best-fit depth, H and Cl content in the lower layer. Image credit: *NASA/JPL-Caltech/MSSS*

We are able to apply this modeling to any location where the surface can be approximated as laterally homogeneous to within ~1.5 meter, the scale of DAN's lateral sensitivity. This approximation is reasonable for the Sheepbed and Gillespie Units within Yellowknife Bay, as these consist of flagstones ~60-80cm across with ~cm of loose soil between as a thin lag overlying some portions. Where multiple APXS measurements were made within a unit, an average composition can be used for the upper layer. In addition, APXS measurements for the Sheepbed Units were acquired for both brushed and unbrushed targets, therefore, (when available) brushed target compositions can be used for the upper layer composition instead of the average composition derived from individual APXS measurements acquired within that unit.

Results: Using the average composition of Lower Sheepbed, with an upper layer Cl content of 1.40 wt.% and H_2O content (from SAM) of 1.83 wt.%, we find the best-fit model has a probability of acceptance of 78%. The model parameters consist of an upper layer depth of 23 +/- 5cm with a lower layer composition of 2.3 +/- 0.5 wt.% H_2O and 0.0 +/- 0.1 wt.% Cl.

For comparison, the best-fit two layer model presented by Litvak et al. for Lower Sheepbed has a 95% probability of acceptance with an upper layer H_2O content of 1.43 wt.%, lower layer H_2O content of 2.90 wt.%, and a depth of 20 +/- 3 cm. The chlorine content is 1.05 +/- 0.07 wt.% in both layers [10].

Although the resulting statistics are not as high from this work as those found via the independent two layer modeling in Litvak et al., we find the statistics to be sufficient to pursue a refinement of the models. A logical next step will be to model the entire Upper Sheepbed layer as the composition of "Ekwir 1 brushed". If the bulk of the upper layer surface area that DAN is sensitive to (~1.5 meters^2) consists of material similar to that of "Ekwir 1 brushed", this may be a more geologically plausible model. Modeling will also be conducted for an average Upper Sheepbed composition, "Wernecke brushed" composition, as well as Lower and Upper Gillespie averaged compositions and Rocknest.

Discussion: Initial modeling results using the average APXS-derived Lower Sheepbed composition provide a reasonable χ^2 value of 78%, however, as discussed this could be improved by modeling the upper layer using just the "Ekwir 1 brushed" composition. The best-fit model has a very low chlorine content in the lower layer (0.0 +/- 0.1 wt.%), in the lower layer below ~23cm. An initial interpretation of this is consistent with the discovery of relatively abundant clay minerals (~20%) in the Sheepbed unit mudstone [11]. Terrestrial studies of volcanically-derived sedimentary rocks indicates that clays consistently have very low chlorine content. This is presumed to be due to the leaching process that occurs during the diagenesis of the clays [12]. In addition, chlorine is a volatile element and typically concentrates in any fluids percolating through a rock-system.

The χ^2 values found from the modeling of Lower Sheepbed DAN data using an average APXS-derived Lower Sheepbed composition are not as high as those found by the independent modeling by Litvak et al. The value, however, is reasonable and suggests that when modeling DAN data it may not be sufficient to assume that the distribution of chlorine is homogeneous with depth, particularly in Yellowknife Bay where the processes that formed clays may have influenced the distribution of chlorine in the near-surface.

References: [1] Jun, I., et al., (2013) JGR, X, Y-Z. [2] Mitrofanov, I. (2013) *44th LPSC,* Abstract #1487. [3] Litvak, M., et al., (2008) Astrobiology, 8. [4] Hardgrove, C., et al., (2011) Nuc. Instr. Methods A, 659. [5] McLennan, S., et al., (2013) Science. [6] Ming D., et al., (2013) Science. [7] Sanin, A., et al., (*submitted*), JGR. [8] McKinney, G.W. et al (2006), Los Alamos LA-UR-06-6206. [9] Litvak, M., et al., (2013) AGU. [10] Litvak, M., et al., (*submitted*) JGR. [11] Vaniman, D., et al., (2013) Science. [12] Ogita et al., (1967) Geochem. Journal.

Table 1: Initial modeling results for average Lower Sheepbed composition and resulting χ^2 value. Conceptual models of other geologic subunits along the DAN traverse are shown.