ANALYSIS OF LAYERING AT MARS NEAR-SURFACE USING ATTENUATION OF CHLORINE GAMMA RAYS. J. M. Keller[1], W. V. Boynton[1], R. M. S. Williams[1], S. Karunatillake[2], and the GRS Science Team, [1]Lunar and Planetary Laboratory, University of Arizona, 1629 E. University Blvd., Tucson, AZ 85721, [2]Cornell University, Ithaca, NY 14853 (jkeller@lpl.arizona.edu).

Introduction: Data collected by the Mars Gamma Ray Spectrometer (GRS) orbiting aboard the 2001 Mars Odyssey spacecraft indicates that the global distribution of chlorine on Mars is heterogeneous [1]. The GRS 50% footprint has a diameter of ~440 km for low energy Cl lines and ~540 km for high energy Cl lines, however smoothing with a 10-degree radius filter is required to improve signal to noise for the Cl signal [2]. Even with this smoothing, Cl concentration vary across the globe by a factor of ~3-4 , with highest Cl concentration centered over the Medusae Fossae Formation materials to the west of Tharsis Montes and low Cl values in the southern highlands and around Utopia Planitia. *Keller et al.* [1] describe this global distribution in further detail along with possible geologic mechanisms that may be responsible including Cl-rich fine deposits, dilution by Cl-poor rocks, volcanic acid-fog reactions [3, 4], alteration in hydrothermal systems [5], and aqueous leaching, transport, and deposition. *Newsom et al.* [6] also discusses the distribution of Cl based upon an investigation of regions with evidence of either extensive bedrock or proposed meter-thick mantling by airborne materials.

While GRS detects gamma rays from the upper few tens of cm of the martian surface, lower energy gamma rays are more attenuated by the surface and atmosphere than higher energy gamma rays. Here, we use this difference in attenuation to search for evidence in the GRS data for significant regional layering of Cl within the upper few tens of cm of the surface. Evidence of layering would provide insight into the 3-dimensional distribution of Cl and the distribution of materials at the martian near-surface.

Chorine Layering Models: A high energy and low energy Cl gamma ray peak, 6111 and 1951 keV respectively, were used to look for evidence of attenuation that might indicated layering. Using a gamma ray and neutron transport code and models using various non-layered compositions, we determined that the thickness of the martian atmosphere has an effect on the flux of high and low energy Cl gamma ray lines generated at the surface. This is due to atmospheric effects on the the neutron energy distribution found at the surface. We found that the ratio of 6111/1951 gamma rays at the surface is a smooth function of atmospheric thickness and reasonably independent of surface composition. An atmospheric correction was determined by fitting a 3rd order polynomial to non-layered model results. This factor has been applied to all 6111/1951 results presented below.

Next, we determine the flux of 6111 and 1951 keV Cl gamma rays predicted at the surface of Mars from various two-layer models summarized in Table 1. For soils, we adjusted the Cl content of mean Pathfinder soil. The rock composition was representative of a medium iron basalt. For each model listed, we assigned top-layer depths of 0, 5, 10, 20, and 40 cm. Additionally, for Model A and B involving only soils, we adjusted the water composition to values of 1, 3, 5, and 7.5 wt% equivalent water. For Model C and D involving soil and rock, we used a soil water composition of 3 wt%.

Table 1.

Model	Top Layer	Bottom Layer
A	High Cl soil	Low Cl soil
B	Low Cl soil	High Cl soil
C	High Cl soil	Low Cl rock
D	Low Cl rock	High Cl soil

Figure 1.

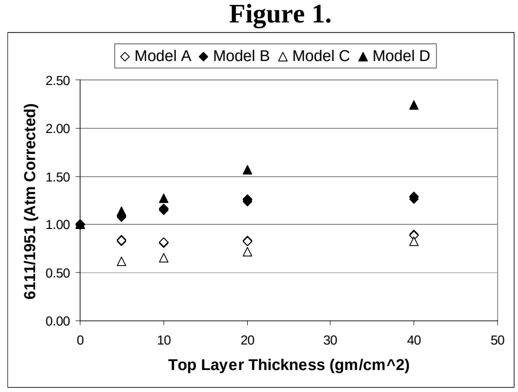

Figure 1 shows the ratio of the 6111 and 1951 keV gamma ray fluxes at the martian surface as a function of top layer thickness obtained from each of these four models. For all four, the 6111/1951 ratio is equal to 1 if there is no layering (top layer thickness = 0). The 6111/1951 ratio increases for layering scenarios in which the high Cl soil component is below the low Cl material (soil=closed diamond, rock=closed triangle). This is due to attenuation by the upper layer of the low energy 1951 gamma rays produced in the bottom layer. Meanwhile, when the high Cl soil component is above the low Cl component (soil=open diamond, rock=open triangle), the ratio reaches a minimum value when the top layer thickness is 5 g/cm^2 and reapproaches a value of 1 as the top layer becomes thicker than the GRS detection depth. The plot also shows that if significant variations in regional layering of Cl-rich and poor material occurs on Mars within the upper few tens of cm of the surface, we would expect to observe the 6111/1951 ratio vary by a factor of roughly 2 to 4.

Before analyzing actual GRS data for evidence of layering, it is important to note that the models described above represent end-member layering cases involving pure bedrock and homogeneous soils with no rock. For a complete analysis regarding the distribution of Cl with depth, it is important to consider the work of *Squyres and Evans* [7] who demonstrated that material mixing geometry has an effect on gamma ray flux due to shielding of neutrons in rocks larger than the neutron mean free path. *Kim et al.* [8] have begun modelling the effects of rocks embedded in soils.

GRS Chlorine Data: We have analyzed GRS spectra summed over 15x15, 10x10, and 5x5 degree grids. The 5x5 data was smoothed with a 10-degree radius mean boxcar to improve statistics [2]. Additionally, we summed over eight regions characterized as potentially being dusty or rocky based on previous remote sensing data. For each dataset, we determined Cl concentration values using both the 6111 and 1951 keV peaks and calculated the ratio of these two lines. Finally, we applied the atmospheric correction described above. Figure 3 shows plots of the ratios and corresponding sigmas for region, smoothed 5x5, and unsmoothed 10x10 data, with area- and sigma-weighted global average values of 1.0, 0.96, and 0.83 respectively. The deviation from unity for the gridded data is likely due to the effects of sigma-weighted averaging.

How many if any of the plotted data points in Figure 3 are significantly higher or lower than the global average value for the 6111/1959 ratio? We looked for outliers using an area- and sigma-weighted statistical test which accounts for both the root-mean-square variation in the dataset and the sigma values of each datapoint. We applied a two-tailed student t probability test using n-2 degrees of freedom to identify grid points with a probability of less than 32% (1σ) and 5% (2σ) likelihood of being drawn randomly from a normal parent population. For the unsmoothed data and region data, none of the points passed either test. For smoothed 5x5 data, <10% of the datapoints passed the 1σ outlier test and these do not cluster into regions significantly larger than the GRS footprint. No smoothed 5x5 datapoints passed the 2σ outlier test.

While these results do not prove that layering of materials with varying Cl concentrations does not exist on Mars, we are unable to conclusively identify large scale layering within the spatial and current statistical resolution of the GRS dataset. Further modelling efforts (e.g. [8]) and additional gamma ray data are required to allow GRS identification of regional Cl layering within the upper few tens of cm of the surface if it is indeed present.

References:

[1] Keller, J. M. et al. (2006) *JGR, submitted*. [2] Boynton, W. V. et al. (2006) *JGR, submitted*. [3] Banin et al. (1997) *JGR, 102, 13341-13356*. [4] Tosca et al. (2004) *JGR, 109, E05003*. [5] Newsom et al (1999) *JGR, 104, 8717-8728*. [6] Newsom et al. (2006) *JGR, submitted*. [7] Squyres and Evans (1992) *JGR, 87, 14,701-14,715*. [8] Kim et al. (2006) *LPS XXXVII*.

Figure 3.