REGIONAL-SCALE LROC NAC PHOTOMETRIC ANALYSIS OF THE TAURUS-LITTROW VALLEY: A COORDINATED INVESTIGATION AND CALIBRATION USING SOIL COMPOSITIONAL DATA.

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Introduction: From December 11th-14th, 1972, Apollo 17 astronauts Eugene Cernan and Harrison Schmitt explored the complex geology of the Taurus-Littrow Valley on the Moon, and provided extensive documentation, including collecting 741 rock and soil samples (110 kgs) and taking >2000 photographs of the lunar surface [e.g., 1; references therein]. Over the last four decades, integration of Apollo 17 field observations with orbital data has provided new insights into the complex geologic history of the Moon. Specifically, the coupling of Apollo 17 sample data with photometric analyses of Lunar Reconnaissance Orbiter Camera (LROC) Narrow Angle Camera (NAC) images can provide compositional and physical information about the lunar surface at exceptional spatial resolutions (~0.5 mpp) [2,3]. For this study, we investigate the effects of composition, mineralogy, glass content, grain size, and surface roughness on the photometric properties of the lunar surface by conducting a coordinated analysis of Apollo 17 sample data and employing the first ***regional-scale*** Hapke photometric parameter map at NAC resolutions. Our goal is to provide new insights in to the geology of the Taurus-Littrow Valley, and attempt to develop a robust compositional and mineralogical calibration for investigating other lunar science sites using NAC photometry.

$$\frac{IoF}{LS} = \frac{w}{4}[p(g) + H(\mu_0, w)H(\mu, w) - 1][1 + B_{CO}B_C(g, h_c)]S(i, e, \theta) \quad (1)$$

$$LS = \frac{\mu_0}{(\mu_0 + \mu)} \quad (2)$$

$$H(x, w) = \frac{(1 + 2x)}{\left(1 + 2x\sqrt{(1 - w)}\right)} \quad (3)$$

$$p(g) = \frac{(1 - b^2)}{2}\left(\frac{(1 + c)}{(1 - 2b\cos g + b^2)^{\frac{3}{2}}} + \frac{(1 - c)}{(1 + 2b\cos g + b^2)^{\frac{3}{2}}}\right) \quad (4)$$

Methods: For our initial investigation, we selected twenty-five LROC NAC images, that cover the Taurus-Littrow Valley at high spatial resolutions (~0.5 mpp), and over a range of illumination conditions. The USGS's Integrated Software for Imagers and Spectrometers (ISIS3) was used to photometrically correct and map project the NAC images [2,3; references therein].

The photometric parameter of most interest to this study is the single scattering albedo (*w*) owing to its observed correlation with surface properties (i.e., composition) [e.g., 3]. Nonlinear optimization was used to generate *w*-maps for the Taurus-Littrow Valley. Specifically, we used the interior-point algorithm to minimize a modified and reduced form of the Hapke model (Equations 1-4) [4] to determine an optimum value for the single scattering albedo (for a complete description of the variables and methods see [2-4]). The i, e, g, and I/F values used were calculated for each pixel by producing backplanes using a NAC DTM.

The computationally intensive nature of this problem and the linear scaling of the algorithm computation time with increasing size of the input data required the use of

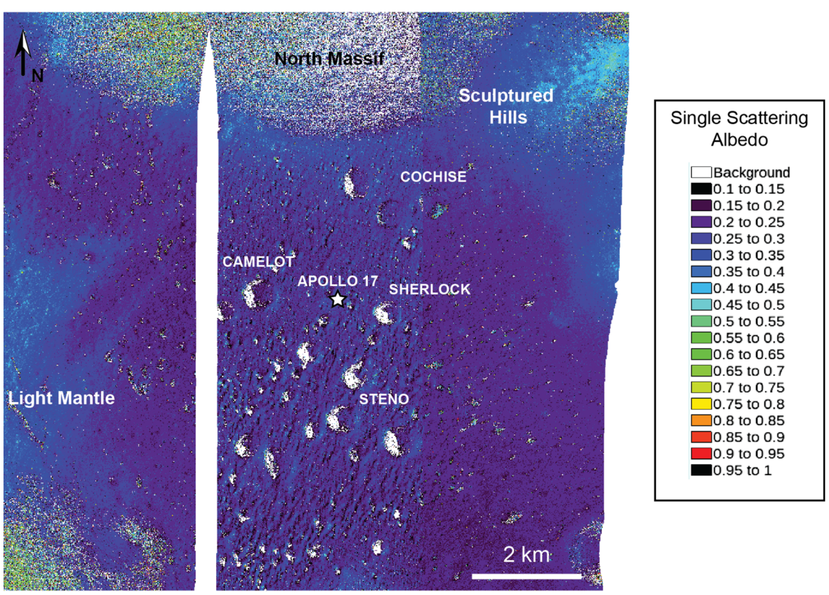

Figure 1. Regional w-map of the Taurus-Littrow Valley, generated using a modified workflow described in [3] (See text).

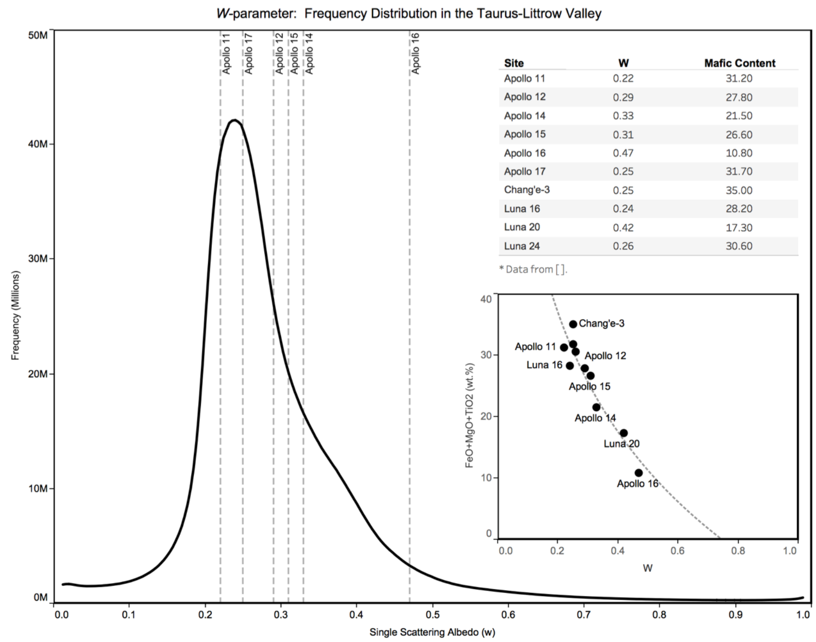

Figure 2. Frequency of modelled values for single scattering albedo (w) within the Taurus-Littrow Valley. Compositional and photometric characteristics of the Apollo landing sites and other significant science sites shown for comparison (external data from [3]). Mafic content defined as FeO+ MgO+TiO_2 (wt.%).

high performance and parallel computing. Specifically, we used the High Performance Computing Laboratory in the Dept. of Earth and Planetary Science at Washington University in St. Louis, which houses a 576 core Linux cluster. To reduce computational time, we employed the algorithm using distributed computing, combined with the parallel computing capabilities of MATLAB. From our initial processing routines, we were able to reduce the computation time for a single NAC image from several weeks to >10 hours, making regional photometric analysis at NAC resolutions feasible. Additionally, resampling the NAC images from 0.5 meters to 1 or 2 m can further reduce the computation time significantly.

For our initial investigation, we further simplified and reduced the number of free parameters within the model. Specifically, we fixed values for the angular width (b) and magnitude (c) of the forward and backward scattering lobe, the amplitude of the coherent backscatter opposition effect (CBOE; B_{CO}), the CBOE angular width parameter (h_c), and the mean slope angle (θ) based on values obtained by previous studies [3,5]. Our goal is to gradually re-introduce free parameters back into the model in future iterations to increase the accuracy of the model output. Additionally, the initial guess for the single scattering albedo ($w_o = 0.5$) can affect the resulting best-fit value, where the algorithm approaches a local minimum in numerical space, but not necessarily a global minimum. Therefore, we evaluate the affect of 'w_o' on the modelled 'w'.

Results and Discussion: The regional w-parameter map for Taurus-Littrow Valley (with a resolution of 2 mpp, as determined by the resolution of the NAC DTM used for image processing) is shown in Fig. 1, and is comprised of >***1.7 billion*** data points. A frequency plot for *'w'* is shown in Fig. 2, along with modelled values from [3] at Apollo landing sites. For reference, the w-value at each landing site is overlain on the frequency plot.

Inspection of Fig. 2 allows delineation of geologically significant units and boundaries within Taurus-Littrow valley. For example, the basaltic valley floor, with a prominent peak in w-values at 0.23 owing to its mafic contents (using FeO+ MgO+TiO_2 as a measure), has noticeably lower w-values than the surrounding more feldspathic highland massifs. The Sculptured Hills has intermediate w-values (~0.40-0.45), similar to Luna 20 (Fig. 2), which are distinctive within the valley. Less obvious, but still apparent, is the difference in the modelled single scattering albedo for northern and southern units of the light mantle deposit (Fig. 1). As compositional differences are not expected [1], the observed differences are likely the result of other regolith properties (i.e., maturity, grain size, glass content, etc.) as suggested by [1].

Continuing Efforts: For select soil sample sites and geologic units of interest, we create regions of interest to determine modelled w-values and generate statistics. These values are then compared to results from analytical studies of Apollo soils and analog samples [6,7], as well as compositional and mineralogical data [8-11], to investigate the validity of our methodology and correlation between regolith properties and single scattering albedo.

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