COMPOSITIONAL CONSTRAINTS ON LUNAR SILICIC VOLCANIC REGIONS USING LROC NAC PHOTOMETRY.

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Introduction: Remote sensing data indicate localities on the Moon where felsic rocks occur as a result of nonmare volcanic or intrusive activity. The Lunar Prospector Gamma Ray Spectrometer (LP-GRS) detected high thorium (Th) contents, which, coupled with low FeO (<5 wt%), implicates an alkali-suite rock type [1]. Lunar Reconnaissance Orbiter (LRO) Narrow Angle Camera (NAC) images reveal cones and domes at these locations that have unique morphologic and reflectance characteristics suggesting a volcanic origin and a mineralogical composition that differs from mare basalt deposits [1-5]. LRO Diviner spectral data show direct evidence for silicic compositions at these sites [6-8].

Photometric analysis provides further evidence that these features result from silicic volcanism. Lunar samples contain small bits of granite or felsite (fine-grained, alkali-feldspar- and silica-rich material). These materials are light in color and have intrinsically high reflectance [9,10]. Photometric studies of areas disturbed by rocket exhaust (blast zones) at the Apollo landing sites [11] allowed us to optimize a photometric function that can be used to fit reflectance data for silicic volcanic regions such as the Compton-Belkovich Volcanic Complex (CBVC), Hansteen Alpha (HA), parts of Aristarchus ejecta, and the Gruithuisen domes. Photometric modeling is used to test variable parameters to determine which could best account for the reflectance characteristics observed over a range of illumination conditions, as well as to estimate the best-fit values for parameters that are related to physical and mineralogical properties of the soil [12].

Methods: We chose several regions of interest (ROIs) at the CBVC and HA (Fig. 1), and one ROI each at the Gruithuisen Gamma (GG) dome and Aristarchus ejecta (AE) site, and used NAC images with a variety of illumination conditions to obtain reflectance data. We then applied a Hapke photometric function to fit the reflectance (I/F) data, normalized to the Lommel-Seeliger function (IoF/LS) to reduce viewing geometry effects [13,14]. To compare between sites, we normalize reflectance to a 45° phase angle.

Fitting the reflectance data allows us to extract a single scattering albedo (*w*) for each site. The single scattering albedo depends on properties such as composition and grain size; it increases with increasing feldspar content and decreases with increasing FeO-bearing minerals [11,15]. We use *w* values to infer mineralogy at the highly reflective silicic volcanic regions. To approximate mineralogy at the Apollo sites, we did a normative mineralogical analysis on soil samples taken from Apollo and Luna landing sites. We then compared the plagioclase and mafic mineral (ilmenite, pyroxene, olivine) content to the corresponding *w* values obtained for each site, and used these values to assess correlation trends with *w* and to assess possible mineralogical compositions of the silicic regions.

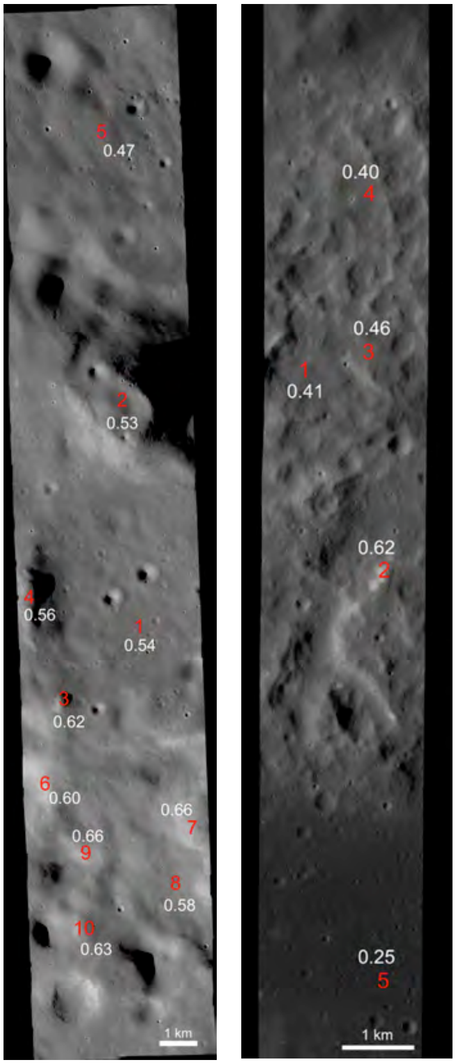

Fig. 1: Regions of interest (red values) and single scattering albedos (white values) at the CBVC (left; NAC image M103852760R) and Hansteen Alpha (right; NAC image M181494651L).

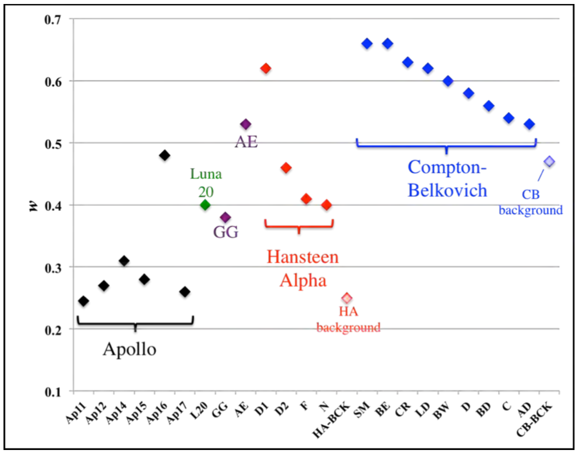

Fig. 2: Single scattering albedo (*w*) for the Apollo blast zones and regions of interest at Hansteen Alpha, Compton-Belkovich, Gruithuisen Gamma, and Aristarchus ejecta.

Results: *Reflectance Measurements:* We fit NAC reflectance data at CBVC, HA, AE, and GG with the Hapke photometric function and normalize to a 45° phase angle. These results show that the CBVC has the highest normalized reflectance and highest *w* of all the sites chosen for comparison. The normalized reflectance ranges from 0.23 to 0.34 at the CBVC for a 45° phase angle, from 0.19 to 0.30 at HA, and averages 0.13 for the Gruithuisen Gamma dome. Apollo 16 has the highest reflectance values for the landing site soils, with a normalized reflectance of 0.18.

Mineralogical Comparisons: Apollo soil mineralogy data correlate with *w* values such that more reflective soils have higher *w* and plagioclase contents, and lower mafic contents. Using data [16] for soils from Apollo blast zones [11], we find correlations between normative mineralogy and *w*. Single scattering albedos range from 0.24 to 0.48 for the Apollo and Luna sites, with Apollo 16 and Luna 20 having the highest values. The normative plagioclase content for the Apollo blast zones ranges from 34 wt% at Apollo 17 to 78 wt% for Apollo 16. The average ilmenite content ranges from 1.0 wt% for Apollo 16 to 16 wt% for Apollo 17. Increase in feldspar content for the samples is consistent with an increase in *w*.

The silicic volcanic regions all have high *w* values, as is expected because, on average, they have higher reflectance values than the Apollo sites. The Gruithuisen Gamma dome has a *w* of 0.38, Aristarchus ejecta has a *w* of 0.53, Hansteen Alpha has *w* values ranging 0.4–0.62, and the CBVC has the highest values, ranging between 0.53–0.66 (Fig. 2).

Discussion: Remote sensing provides strong evidence for the presence of felsic rocks at the Compton-Belkovich Volcanic Complex, Hansteen Alpha, the Gruithuisen Domes, and in parts of Aristarchus ejecta. These regions are more reflective than surrounding regions, indicating that they are compositionally different. Sample data and photometric modeling show that soils with the highest plagioclase and lowest mafic contents have the highest reflectance and single scattering albedos. There is a correlation between *w* and alumina content, but there is also a strong anticorrelation between *w* and the mafic content of soils (Fig. 3) (equally strong for $FeO+MgO+TiO_2$ and pyroxene+olivine+ilmenite). Using the relationship for *w* and mafic content of Apollo and Luna samples, we find that extrapolating to higher *w* values for the silicic regions is consistent with very low $FeO+MgO+TiO_2$ contents, and is consistent with interpretations of felsic rock types.

Conclusion: LROC NAC images can be used to extract reflectance properties of areas of silicic volcanic regions on the Moon. Photometric models developed for Apollo, Luna, and Surveyor landing site studies allow us to study the relationship between photometric properties of soils and their mineralogical composition. We find that the silicic volcanic regions have high single scattering albedos that are consistent with different proportions of highly reflective minerals including alkali feldspars and quartz, and low concentrations of mafic minerals. Of the sites studied, the CBVC has the highest retrieved *w* values.

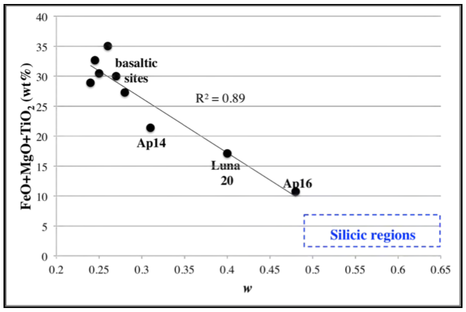

Fig. 3: Relationship between *w* and mafic content for Apollo and Luna samples. Silicic volcanic regions extrapolate to the dashed region using this trend.

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