Photometric Investigations of Lunar Anorthositic Highlands Using LROC NAC Images and Derived Data

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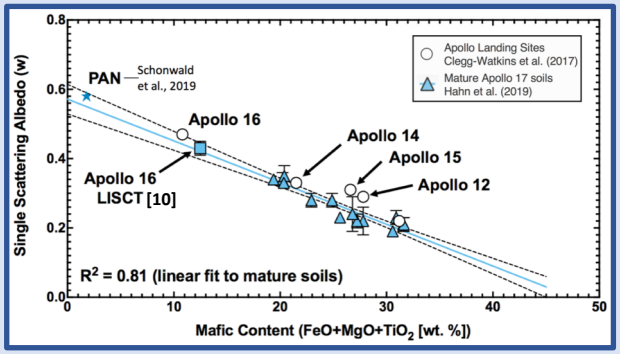

Figure 1. Soil compositions vs. NAC-derived *w*. Linear fit is to the mature Apollo 17 soils.

Methods. NAC DTMs used to determine incidence and emission angles at every pixel in NAC image resampled to DTM pixel scale. Solve the Hapke equation for single-scattering albedo (*w*) and the "b" parameter, corrected for local topographic effects [3-5,8,9].

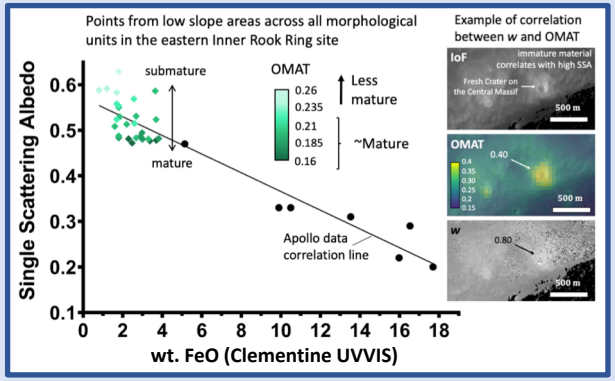

Figure 2. Soil composition (FeO) from Inner Rook Ring PAN site vs. NAC-derived *w*, showing effect of maturity.

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Ten-plus years of imaging the Moon with LROC under different illumination conditions enables photometric studies of the lunar surface with the Wide Angle Camera (WAC) [1,2] and the Narrow Angle Cameras (NAC) [3-6]. In a study of Apollo landing sites, we found a strong correlation of single scattering albedo (*w*) with composition, mainly related to the mafic mineral content vs. plagioclase [3] (Fig. 1), which can be extended to low mafic mineral contents to investigate locations of PAN or "purest anorthosite" as defined by Ohtake et al. [7]. Our aim is to better understand the distribution of crustal rock types at the NAC scale.

Correlation of *w* with OMAT shows the effect of maturity (Fig. 2). The correlation with composition is greatest with mature soils.

In areas where hyperspectral data indicate anorthosite with >95% plagioclase, *w* approaches 0.55-0.60 where FeO is very low (<1 wt%). However, from the correlation of *w* with FeO, we estimate that the plagioclase proportion in mature regolith in most areas does not exceed 95%, indicating the presence of other mafic components (pyroxene, olivine) among the primary anorthositic rocks. Although concentrations may locally exceed 98% plagioclase (*cf.* 4.6 kg FAN sample 60015 [11,12]), we infer from the photometric data that more mafic variations of anorthosite are more common. These findings have implications for the efficiency of plagioclase separation from the lunar magma ocean as well as for the mineral & chemical composition of the primary lunar crust. Separation of plagioclase cumulates upward from the solidifying magma ocean likely carried trapped melt to produce anorthosite with ~90% plagioclase.

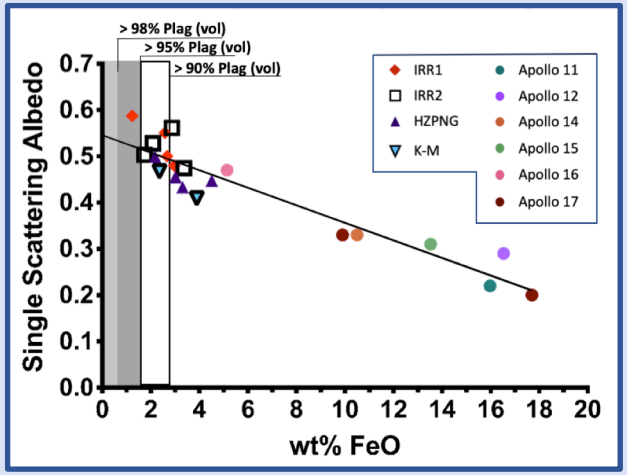

Figure 3. Soil compositions at four PAN sites vs. NAC-derived *w*. IRR1,2: Inner Rook Ring massifs; HZPNG: Hertzsprung; K-M: Korolev-M. FeO contents equivalent to PAN > 98% plagioclase, > 95% plagioclase, and >90% plagioclase indicated by shaded bars at low FeO. At PAN sites, most locations have more mafic soil than PAN.

References: [1] Hapke et al. (2012) *JGR-P* **117**, E00H15. [2] Sato et al. (2014) *JGR-P* **119,** 1775–1805. [3] Clegg et al. (2014) *Icarus* **227**, 176-194. [4] Clegg-Watkins et al. (2016) *Icarus* **273,** 84-95. [5] Clegg-Watkins et al. (2017) *Icarus* **285**, 169-184. [6] Watkins et al. (2020) this conference. [7] Ohtake et al. (2009) Nature 461, 236-241. [8] Hahn, T., et al. (2019) *Lunar Planet. Sci.* **50**, #1976. [9] Schonwald et al. (2019) *Lunar Planet. Sci.* **50**, #1239. [10] Pieters, C., et al. (2008) *Advances in Space Research* **42**, 248-258. [11] Ryder and Norman (1980) Catalog of Apollo 16 Rocks. NASA JSC Curatorial Facility, Houston. [12] Wieczorek et al. (2006) *New Views of the Moon, RiM-G* **60**. MSA, Wash., DC.