ASSESSING THE RELATIONSHIP BETWEEN ABSOLUTE AGE AND SURFACE ROUGHNESS WITH LROC. S. J. Lawrence[1,2], J. D. Stopar[1], L. R. Ostrach[3], B. L. Jolliff[4], and M. S. Robinson[1] [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ, USA [2]sjlawren@asu.edu [3]NASA Goddard Space Flight Center, Greenbelt, MD, USA [4]Department of Earth and Planetary Sciences, Washington University in St. Louis, St. Louis, MO, USA

Introduction: The Lunar Reconnaissance Orbiter (LRO) continues to return groundbreaking data for both planetary science and future exploration. A key goal of the second LRO extended science mission (ESM2) is to investigate volcanic processes at different temporal and physical scales including the identification and characterization of ancient (>3.9 Ga) volcanic units, with an emphasis on the ancient basalts in Mare Australe and the South Pole-Aitken basin.

Mare Australe is a loosely circular collection of mare basalts (38.9°S, 93°E) where extensive volcanism has occurred [1–6]. Previously, we reported results using LRO data to understand the extent of volcanic landforms in the Australe region [4] and basalt composition as function of new absolute model ages (AMAs) determined using recent LRO data [6]. Here, we investigate AMA-dependent variation of surface roughness at the scale of the Narrow Angle Camera (NAC) as a new analytical tool.

Background: Lunar Reconnaissance Orbiter Camera (LROC) Narrow Angle Camera (NAC) geometric stereo observations used to produce Digital Terrain Models (DTMs) are uniquely useful for a variety of purposes, including investigations of molten rock rheology [7], impact crater morphology [8], lunar volcanic landform morphometry [9] and preparation for future exploration [10]. Here, we use NAC DTMs to assess the roughness properties of the lunar surface.

As outlined by previous investigators [11–14] systematic differences in roughness exist between lunar terrains at a variety of scales. Lawrence et al. [9] also discussed NAC-scale roughness characteristics of mare volcanic landforms. In the context of the mare, which are flood basalts originally emplaced as level equipotential surfaces, it is reasonable to assume that the surface roughness of older surfaces will increase over time [15] due to impacts and tectonism. Here, we investigate roughness as a function of AMA to investigate whether using high-resolution topography to make preliminary estimates of relative ages is feasible.

Methods: LROC Wide Angle Camera (WAC) is a push-frame camera capturing seven color bands (321, 360, 415, 604, 643, and 689 nm) with a 57-km swath width in color mode and a 105-km swath width in monochrome mode from a 50-km altitude [16]. WAC data products employed include WAC global morphology basemap [17] and the GLD100 global digital elevation model [18]. Individual NAC frames were used to understand the morphology and geologic context of DTMs. All LRO data were map-projected and calibrated using the USGS Integrated Software for Imagers and Spectrometers (ISIS) [19].

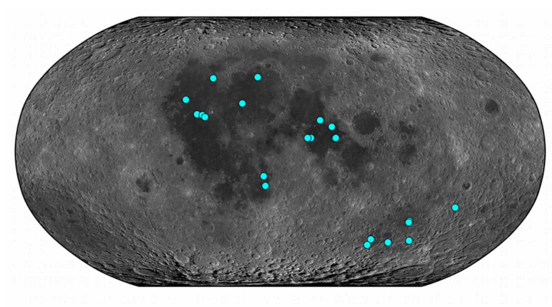

Figure 1: Locations of DTMs used in this study (cyan). WAC global morphology basemap in Robinson projection.

NAC Stereo Processing: NAC DTMs require a set of NAC stereo image pairs. The resulting topographic models have pixel scales of 2–5 m, depending on spacecraft altitude, and 1-2 m vertical precision. Absolute control is obtained by registering stereo models to LOLA cross-over altimetry tracks [14].

Absolute Model Ages: We conducted crater measurements to determine crater size frequency distributions (CFSDs) for mare units in the Australe region and derived absolute model ages AMAs [6]. All craters > 700m in diameter identified in the LROC WAC global morphology base map were included in the measurements; obvious secondaries were excluded. CraterTools [20] was used for digitization in ArcGIS and the output reduced using CraterStats2 [21]. The Neukum et al. [22] production and chronology functions were used to fit the CSFDs and derive AMAs. AMAs for regions outside of Mare Australe are from the work of Hiesinger et al. [23].

DTM Selection: 21 DTMs were used as part of this study (**Figure 1**), each selected to be on units with known AMA values, established through new CSFD determinations (in Mare Australe) or by [23]. DTM locations are shown in **Figure 1**. Eight of the DTMs are within the Australe region. 20 of the DTMs are mare basalt units; one is a smooth plains unit in Australe.

Terrain Ruggedness Index: Surface roughness was assessed using the Terrain Ruggedness Index (TRI) [24]. TRI is the average absolute value of the difference between a central pixel and its eight immediately adjacent neighbors. In each NAC DTM, homogenous study regions free of obvious sources of modification

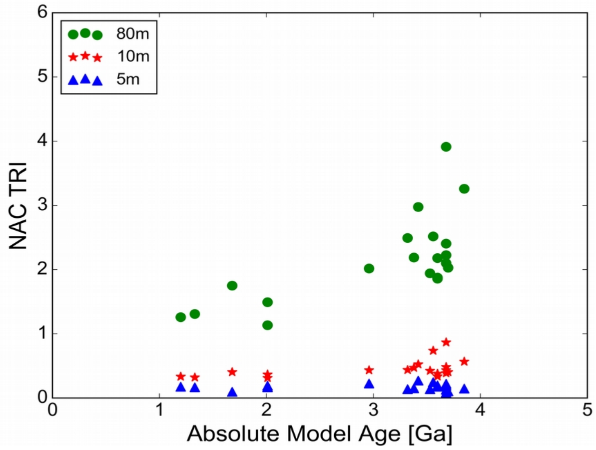

Figure 2: AMA vs. TRI for studied units at 5, 10, and 80 m pixel scales.

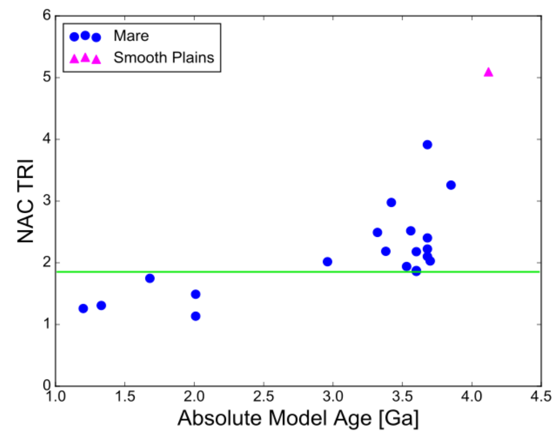

Figure 3: Absolute model age vs. TRI for mare and smooth plains units, 80 m pixel scale.

(including secondary crater chains, positive-relief volcanic landforms such as basaltic low shields, and tectonic features) with areas ≥50 km^2 and regional slopes <5º were selected for TRI analysis.

Results: TRI analyses performed at 5, 10, 20, 40, and 80 m pixel scales (summarized in **Figure 2**) displayed consistent patterns of TRI increase as a function of AMA. However, the 80m NAC TRI analyses provide the most useful contrast, with the most variability between units with different AMAs, for this specific use case.

In this parameter space (**Figure 3**), units with lower AMAs have lower TRI values (meaning: they are less rough) than regions with higher AMAs. There are two loose groupings, separated by the green line in **Figure 3**. One group consists of units with AMAs <2.5 Ga and TRI values <1.8. Units with AMAs >3 Ga have TRI values >1.9. The smooth plains unit included in this analysis has a higher TRI value than the mare units.

Discussion: That older units are rougher is not surprising; this result is consistent with investigations of surface roughness at other scales [11,12]. The dominant controller of surface roughness on a level mare plains surface should be the crater population. For Eratosthenian units, the crater equilibrium diameter is anticipated to be <100m [25], so this analysis is expected to be sensitive to the equilibrium crater population.

The bimodal distribution of TRI values is likely influenced by a sampling effect produced by the age distribution of the DTMs analyzed in this study, as well as the known variability within established crater age-date units [26, 27]. Nevertheless, the older basalt units have higher TRI values.

Implications: Eratosthenian/Imbrian basalts in this parameter space consistently have TRI values >2, so this preliminary assessment indicates that NAC TRI analysis could represent a promising method to distinguish ancient mare basalts, and possibly facilitate discrimination of cryptomare. In conjunction with controlled multispectral data sets, NAC TRI analyses could improve unit selection for crater size measurements, ultimately improving CSFD determinations.

Finally, since Copernican and Eratosthenian mare surfaces have uniformly low TRI values, this analysis also implies that future exploration missions to young basalt regions will have a generally benign landing environment.

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