ANALYZING THE EVOLUTION OF SURFACE ROUGHNESS OF LUNAR MARE. E.R. Jawin[1], W.S. Kiefer[2], B. Bussey[3], J.T. Cahill[3], M.D. Dyar[1], C.I. Fassett[1], P.D. Spudis[2], [1]Astronomy Department, Mount Holyoke College, 50 College Street, South Hadley, MA 01075 (jawin22e@mtholyoke.edu), [2]Lunar and Planetary Institute, Houston, TX, [3]Applied Physics Laboratory, Laurel, MD.

Introduction: About 17% of the lunar surface is covered by mare basalts [1], mainly concentrated on the lunar nearside. The main period of mare volcanism occurred during the late Imbrian Period, ~3.3-3.8 Ga [2], although volcanism continued to a lesser extent until ~1.2 Ga [3]. These dates were assigned by Hiesinger et al. using crater size-frequency distribution measurements applied to pre-defined mare units (Figure 1) [2, 3, 4]. These mare units were defined to be spectrally homogeneous according to Clementine multispectral data and represent a single eruptive phase [4].

After eruption, the constant bombardment by meteorites and radiation on the lunar surface leads to the buildup of regolith over time [5]. The regolith is understood to be between 2 and ~10 m thick on the mare [6], with a heterogeneity of particle sizes ranging from meter-sized rocks to submicron particles (most regolith material is under 1 mm in size) [5].

Regolith thickness increases with age as a surface is exposed to the space environment. The rate of regolith accumulation is thought to be ~2 m/Ga [5]. We sought to determine the relationship between surface roughness and age of lunar mare, in relation to regolith development. To do this, we compared surface roughness measurements using circular polarization ratio (CPR) values at both S- and P-band wavelengths (12.6 and 70 cm wavelengths, respectively), and various surface characteristics from Lunar Orbiter Laser Altimeter (LOLA) measurements. The comparison of these data sets allows us to evaluate roughness on a range of length scales.

Methods: Based on the mare age calculations of Hiesinger et al. [2, 3, 4], ~6 units were chosen in each of three age categories: Young (~1.2-1.7 Ga), Middle (2.4-2.6 Ga), and Old (3.7-3.9 Ga) (Figure 1). Each unit was analyzed using a 6 x 6 km analysis box.

A full description of the methods used in this project to determine roughness is provided in a companion abstract [7] and only a brief summary will be given here.

LOLA Data. LOLA's five spot configuration [8] allows for multiple measurements of the lunar surface to be grouped together and analyzed cohesively.

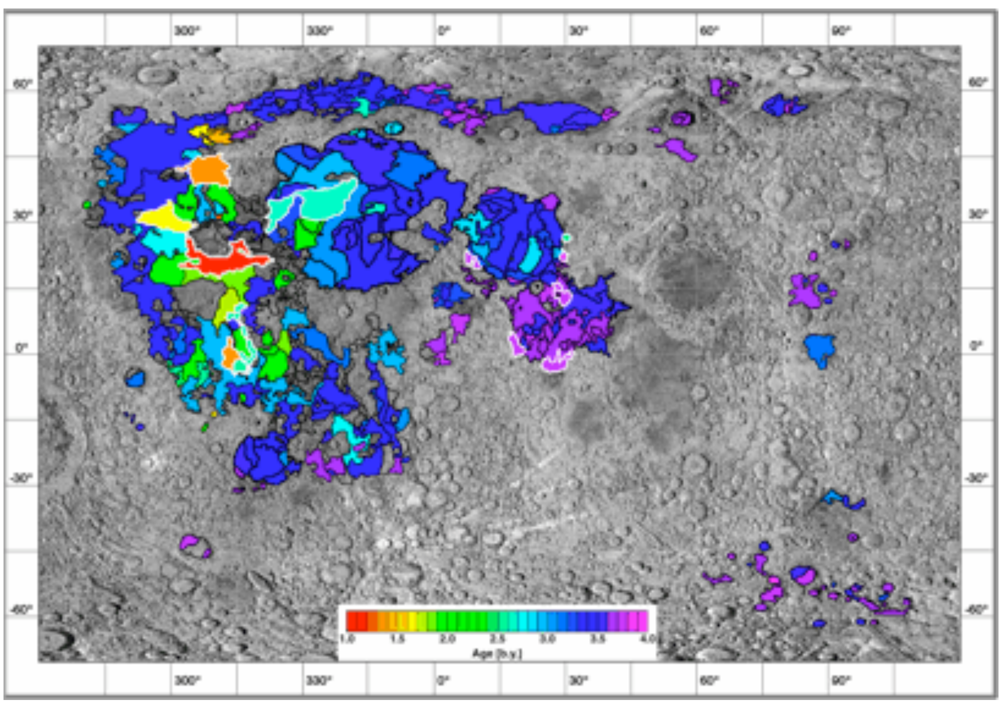

Figure 1. Map of mare units, from [4]. Units studied in this project are outlined in white.

MATLAB was used to group three successive LOLA shots together and generate a least squares best-fit plane. The RMS misfit of each point from this plane was then calculated, which represents the roughness of the lunar surface on a scale of ~25-50 m [9]. Mean slope values were also measured for the data by calculating the angle between the least squares plane and a horizontal plane.

The MATLAB script also calculated the average pulse width for each group of three shots. Pulse width, measure by LOLA, represents the time interval of each returned laser pulse [9]. Small-scale topographic variations cause the returned beam to be broadened in time; this delay is a function of surface roughness on the scale of the 5 m laser footprint [9].

Radar Data. Two radar wavelengths, S- and P-band, were used in this study. S-band data was gathered using the Mini-RF on LRO [10], while P-band data was collected from Arecibo and Green Bank Observatories [11]. Using ISIS and ArcMap, we gathered circular polarization ratios (CPR) for mare of varying ages. CPR data represents the ratio of the orientation of backscattered radar – the intensity of the same sense over opposite sense of that transmitted (SC/OC) [10]. The mean and standard deviation CPR values for each mare unit analyzed were compared with the RMS topographic variation and average pulse width values.

Results: Topography data for RMS topographic roughness, mean slope, and pulse width were gathered using LOLA data for the suite of lava flows, as well as P-band CPR data; S-band CPR data collection is ongoing. Plots of topographic roughness and mean slope versus age are shown in Figures 2 and 3, respectively. As age increases, roughness on the scale of 25-50 meters appears to remain relatively constant (Figure 2); this suggests any cratering and regolith generation that accumulates over time does not greatly alter the surface roughness on relatively long length scales.

Mean slope of the surface appears to increase with age (Figure 3); there is a marked increase in mean slope between young-middle aged mare, and older mare. This is likely due to the saturation of older mare flows by ~100 m diameter craters, which are less ubiquitous on young or middle aged mare.

P-band CPR, when plotted against topographic roughness (Figure 4), appears to increase linearly, suggesting that flows which are rougher on shorter (decimeter-meter) length scales in P-band CPR will also be rougher on longer (25-50 m) scales as well.

The analysis of additional mare units, as well as the addition of S-band CPR data, will provide robust data about the evolution of surface roughness with age.

References:

[1] Head, J.W. (1976) *Rev. Geophys*., 14, 265-300. [2] Hiesinger, H. et al., (2000) *JGR*, 105, E12, 29,239-29,275. [3] Hiesinger, H. et al., (2003) *JGR*, 108, E7. [4] Hiesinger, H. et al., (2010) *JGR*, 115, E03003. [5] Langevin, Y. & Arnold, J.R. (1977) *Ann. Rev. Earth Planet. Sci*, 5, 449-489. [6] Chapman, C.R. et al., (2007) *Icarus*, 189, 233-245. [7] Jawin, E.R. et al. (2012), *LPSC 43, this meeting*, 1343. [8] Rosenburg, M.A. et al., (2011) *JGR, 116,* E02001. [9] Smith, D.E. et al, (2010) *GRL, 37*, L18204. [10] Raney, R.K. et al, (2011) *Proc. IEEE*, 99, 5. [11] Campbell, et al. (2007), IEEE Trans. Geosci. Remote Sens. 45, 4032-4042.

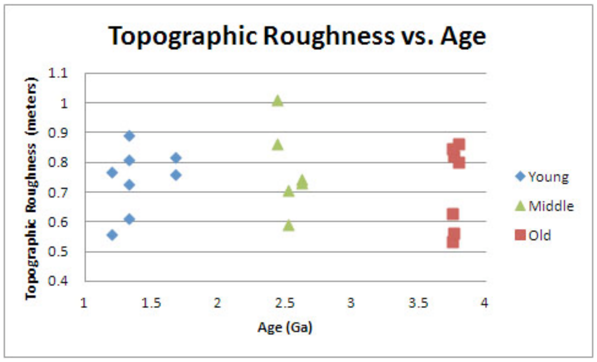

Figure 2. RMS topographic roughness vs. age for the suite of mare units

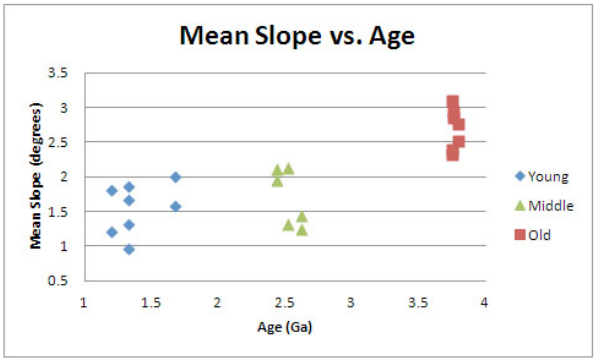

Figure 3. Mean slope vs. age for the suite of mare units

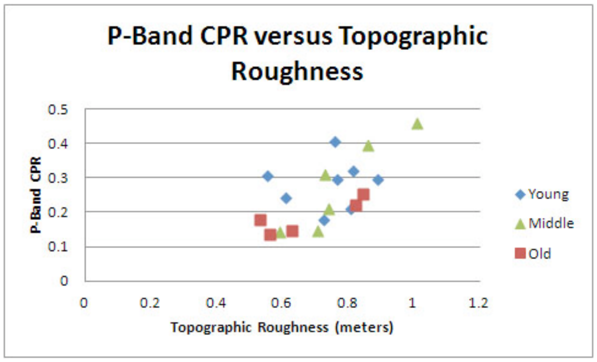

Figure 4. P-band circular polarization ratio vs. RMS topographic roughness for the suite of mare units