70-CM RADAR STUDIES OF BLOCKY CRATER EJECTA AS A GUIDE TO MEGAREGOLITH THICKNESS ACROSS THE NEARSIDE OF THE MOON. G. A. Morgan[1] B. A. Campbell[1], T. W. Thompson[2] and B. R. Hawke[3], [1]Center for Earth and Planetary Studies, Smithsonian Institution, MRC 315, PO Box 37012, Washington, DC 20013-7012, morganga@si.edu, [2]Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109, [3]HIGP, University of Hawaii, 1680 East-West Road, Honolulu, HI 96822.

Introduction: After the formation of the feldspar-rich lunar crust – hypothesized to have originated from the crystallization of an early magma ocean – the surface of the Moon was significantly reworked by basin forming impacts during the late heavy bombardment. This was followed by smaller scale, but continuous impact gardening that has occurred throughout the remainder of geologic history. The impact-generated highland "mega-regolith" accounts for a substantial proportion of the upper crust, so its thickness, origin and compositional variability are key to our understanding of lunar crustal evolution.

Radar studies of the Moon's upper crust provide insight into the three-dimensional regolith structure. The enhancement of backscatter in 70-cm (P-band) radar echoes that encounter blocky constituents (10 cm - 1 m in diameter) within crater ejecta enables us to identify impacts that have excavated large bedrock blocks from the underlying basement. Through the application of empirical lunar crater depth-diameter relationships (see Pike, [1,2]), it is then possible to estimate the depth to the bedrock in a particular region. Thus the mapping of radar-bright craters provides a proxy for mega-regolith thickness across the lunar surface.

Thompson et al (2009) [3] applied this methodology to the southern nearside highlands and found a distinct decrease in the population of bright craters south of ~48°, which they attribute to the presence of South Pole-Aitken basin ejecta. We have expanded upon this work by surveying radar bright craters across almost the entire nearside of the Moon.

Methodology: We used 70-cm wavelength radar images of the lunar nearside obtained by transmitting a circular-polarized signal from the Arecibo Observatory and receiving echoes from the Moon in both senses of circular polarization at the Green Bank Telescope (see [4]). Radar returns in the same sense of circular polarization (SC) as that transmitted are attributed to diffuse scattering by rocks >10 cm in diameter, at the surface and buried within the probing depth of the radar signal (<40 m; [5]). The radar mosaics used had a spatial resolution of 500 m/pixel, allowing radar bright craters as small as ~ 1 km to be surveyed. Every crater with radar-bright ejecta within about one crater radius was counted. All the images were mosaicked and co-registered with LOLA 64 pixels/degree gridded global datasets. Radar-bright craters were identified in the radar mosaic and were measured on hill shade maps of the LOLA dataset to maintain consistency in the measurements. The final radar-bright crater count exceeded 500 craters.

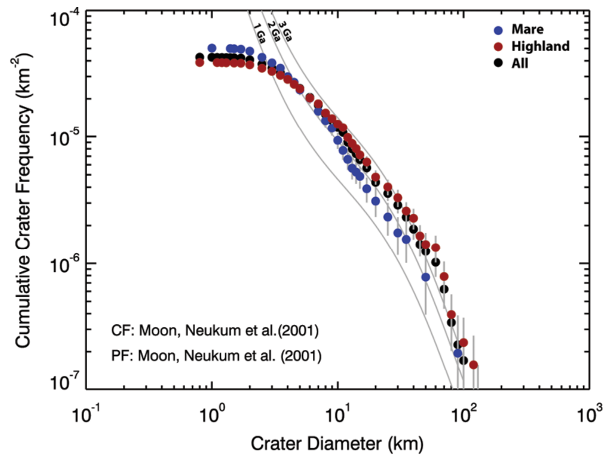

Fig. 1. Size frequency distribution of radar bright craters on the Lunar nearside.

Results: The Size-Frequency Distribution (SFD) of all the bright craters surveyed demonstrates that their maturity (from a radar perspective) is size dependent (Fig. 1). This is apparent in Fig. 1 as the SFD crosses the lunar isochrones. This is especially evident for the smallest craters (<10 km diameter) that appear to be most susceptible to a loss of radar brightness, attributed to a relatively rapid break-up of the blocky components within their ejecta blankets by subsequent smaller impacts. In contrast, craters ~40 km and larger may remain bright for > 3 Ga - older than many of the mare [6,7]. Our survey also demonstrates a distinct difference in the SFD of radar bright craters on the mare relative to the highlands. Compared to the highlands, the mare exhibit a greater number of the smallest diameter craters, which we attribute to a thinner regolith. Conversely, the highlands show greater numbers of radar-bright craters >10 km in diameter. This can be explained by the greater age of the highlands. The spatial distribution of craters on the two units is discussed below:

Mare: The highest spatial density of radar-bright craters on the nearside is located within the maria (Fig. 2), and the unit as a whole exhibits greater numbers of the smallest radar-bright craters relative to the highlands (Fig. 1). This result is expected as the mare post-dates the late heavy bombardment and thus possesses a much thinner regolith than the surrounding highlands. A large amount of crater-density variability is observed, but the spatial pattern correlates well with mare age (see [6-8]). Our map shows nice agreement with the density map of all craters > 20 km produced by [8]. The greatest concentration of radar bright craters are located in Maria Humorum and Nubium, which have been dated to about 3.5 Ga [6,7].

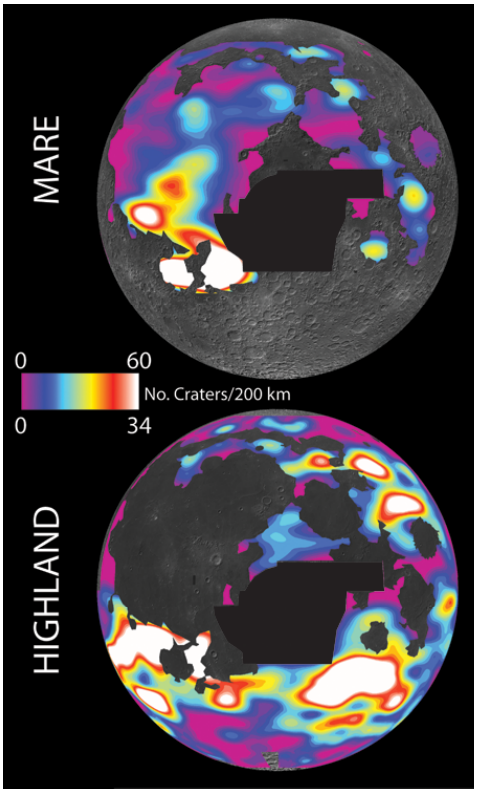

Fig 2. Density of radar-bright craters (larger than 0.5 km diameter) per 200km diameter area (Area: 1.3x10^5 km^3) for the mare and higlands

Highlands: The highlands do not show the same correlation between the density of radar-bright craters and inferred surface age (Fig. 2). One of the most heavily cratered terrains on the Moon is located on the southern nearside highlands between 30° – 90° S (see [8]). However, our radar survey, in agreement with [3], shows a significant deficit, relative to the average, in the density of radar-bright craters south of ~50° latitude. We also attribute this to South Pole – Aitken ejecta.

An additional region of relatively low-density in radar-bright craters is apparent in the highlands to the south of Mare Crisium. This region shows a strong contrast with areas north of Crisium, in which some of the highest density measurements are observed (Fig. 2). One possible explanation for this pattern is that the mega-regolith south of Mare Crisium is significantly thicker due to ejecta from the putative pre-Nectarian Fecunditatis impact basin (site of Mare Fecunditatis). Wide density variations also occur around Orientale basin in the SW highlands. We also attribute this to the influence of ejecta from the basin forming impact.

Conclusions: The emplacement of the maria after the late heavy bombardment precluded the formation of a thick mega-regolith. As a result the distribution of radar-bright craters appears to be dictated primarily by mare age. In contrast, the highlands record the late heavy bombardment, and the resulting mega-regolith is comprised of ejecta from basin forming impacts.

Studies of lunar impact populations are sensitive to the occurrence of ejecta from basins that formed late in the bombardment. This has been demonstrated by the Head et al (2010) [8] investigation of the radial distribution of craters about the center of Orientale Basin. Their work showed a decrease in cumulative crater density as a function of distance towards the center of the basin, which they attribute to the removal of pre-existing craters by Orientale ejecta. This approach however, is limited in its abilility to spatially resolve the ejecta blankets of older basins that are either saturated in craters (due to the longer exposure time within the late heavy bombardment) or burial by ejecta from later basin formation events. Studying the distributions of radar-bright craters offers a means of mapping basin ejecta thickness that is complementary to studies using multi-spectral data (see [9,10]).

The next stage in our work is to further analyze the radar-bright crater density measurements on the highlands and provide mega-regolith thickness estimates from crater depth measurements.

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