ANOMALOUS SHALLOWING OF LUNAR IMPACT CRATERS IN THE SOUTH POLE-AITKEN BASIN FROM LUNAR ORBITER LASER ALTIMETER (LOLA) OBSERVATIONS. Michael M. Sori[1] and Maria T. Zuber[1], [1]Dept. of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA, 02139 (mms18@mit.edu).

Introduction: Data [1] obtained from the Lunar Orbiter Laser Altimeter (LOLA) [2] aboard the Lunar Reconnaisance Orbiter [3] spacecraft are providing the most spatially dense and accurate measurements of lunar topography to date. LOLA profiles are particularly well suited for the quantitative characterization of impact structures, in order to elucidate the nature of the process of hypervelocity impact crater and basin formation and modification. This study seeks to understand if and how crater and basin morphology are affected by regional variations (surface or subsurface) across a single planet. LOLA data are used to compare the depth-to-diameter ratios of large impact craters and basins (>60 km in diameter) found in the lunar highlands to those found within the South Pole Aitken (SP-A) basin.

Depth-Diameter Relationships of Lunar Craters and Basins: Impact craters and basins are the most pervasive distributed features of lunar topography. These structures follow a size-morphology sequence. From smallest to largest, this sequence is: simple craters, complex craters, multiringed basins. In previous study, it was observed that transitions between these crater types are gradual [4]. The transition zone between complex craters and multiringed basins on the Moon occurs approximately for diameters in the range of 130 km to 280 km [5].

The depth-diameter relationship of impact features changes between each type of crater [6]. But to date there has not been a study of whether there is any relationship between depth-diameter ratio and terrain type. In particular, ratios of larger craters and basins have not yet been systematically measured with a high-quality data set of globally consistent quality. A quantitative understanding of these ratios will allow investigation into both impact processes [4] and sub-surface lunar structure [7].

LOLA Observations: Now, LOLA [2] on LRO [3] has provided the most accurate and extensive topographic data ever taken for the Moon [1]. LOLA provides both more highly-resolved data, over 5×10^9 measurements of elevation, and far better spatial coverage of the lunar surface than all previous laser altimeters. This data can be used to accurately calculate depth-diameter ratios of large craters and basins in different regions of the Moon and compare them to results previously obtained.

LOLA [2] ranges to the surface with 5 beams, 10-12 m apart, distributed in an X-pattern, at a rate of 28 Hz. In the LRO mapping orbit, the instrument places 5-m spots on the lunar surface spaced ~50 m along track. The range precision of the instrument is 10 cm and the radial accuracy from precision orbit determination is <1 m.

Procedure: In order to examine the depth-diameter ratios of large lunar impact structures, LOLA data has been used to study large craters and basins in both the SP-A basin and the lunar highlands. Figure 1 shows impact features considered in the SP-A basin.

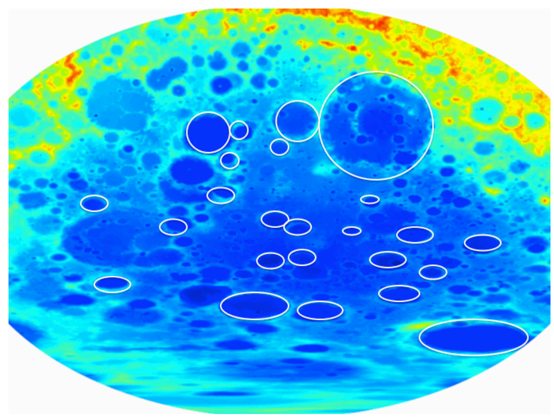

Figure 1: Topographic map [1] of the SP-A basin, with each impact structure considered in this study marked by a whie ellipse.

Due to their more complex morpohology and smaller sample size, large impact features warrant a more careful, non-automated study than small ones. For each impact feature, altitude profiles were extracted from a topographic map provided by the LOLA science team [8] using a software program [9]. Accurate depths are estimated for each crater, so that depth may be plotted as a function of diameter for the impact features.

The resulting plot of depth-diameter relationsip comparing impact features in the SP-A basin to impact features in the farside lunar highlands in shown in Figure 2. Data points corresponding to simple craters taken from another LOLA study [10].

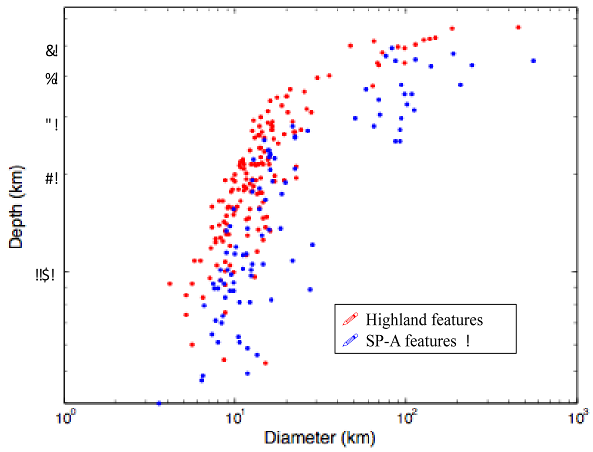

Figure 2: Depth as a function of diameter for impact structures in both the SP-A (blue) and farside highlands (red).

Discussion: Best-fit lines to the depth-diameter plot show that there is a statistically significant difference in depths between SP-A impact features and farside highland impact features; those found in the SP-A basin are anomalously shallow. We consider various mechanisms to explain this observation.

Portions of the SP-A basin are flooded with maria, a feature noticably absent in the farisde highlands. However, a map of the lunar southern hemisphere [11] identifying locations of maria by their characteristic albedo difference shows that only four of the studied impact structures contain such deposits. Removal of these four data points from the depth-diameter plot does not elimate the statistically significant regional differences in depths. Ejecta deposit fill could similarly shallow a single crater, but should not operate preferentially in the region as a whole.

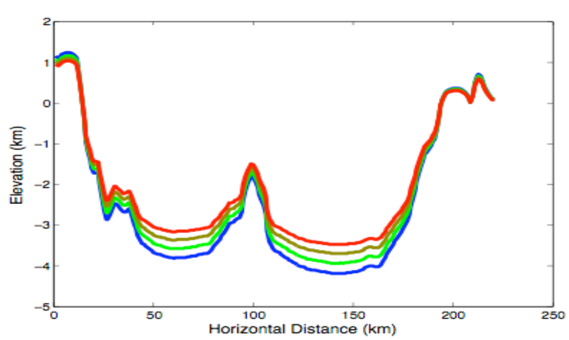

Figure 3: Viscously relaxed topographic profiles of the impact feature Mach over four equally spaced time steps. In this example, a viscosity of 8.7×10^{26} Poise is needed to shallow the basin by the appropriate amount over 3×10^{9} years.

We considered viscous relaxation of impact structures as a potential mechanism of shallowing. Viscous flow is an important feature of craters in icy satellites, but has also been proposed as a significant effect on rocky bodies over geological time scales [12]. A higher degree of relaxation in the SP-A basin could be explained with a thermal anomaly, perhaps caused by the SP-A basin-forming impact itself, that would produce lower lithospheric viscosity and thus shorter relaxation times.

We tested the plausibility of the viscous relaxation hypothesis by shallowing average topographic profiles of craters or basins over lunar history according to formulas given in [12]. An example is given in Figure 3. Though we can demonstrate how large basins might flow viscously, we cannot explain the consistent shallowing of SP-A craters over the entire diameter-space studied; both short- and long- wavelength features are shallowed by approximately the same proportion, and thus cannot be explained with viscous flow.

We also considered the possibility that the SP-A contains large deposits of cryptomaria. The presence of maria deposits, lower crater density, and low crustal thickness make the SP-A a plausible location for cryptomaria. Complex craters provide a geometry that can be tested for shallowing as a result of deposition of material. If the floor-to-peak heights of central peaks in complex craters in the SP-A are relatively shorter than the floor-to-peak heights of those in complex craters in the farside highlands, a deposition of material such as cryptomaria provides a direct explanation. Peak-to-rim heights should be similar in both regions if shallowing is the result of deposition. Analysis of central peak morphology is currently ongoing, and is expected to shortly reveal if the cryptomaria hypothesis provides a plausible explanation for the anomalous shallowing of impact structures in the SP-A basin.

References: [1] Smith D. E. et al. (2010) *GRL, 37,* doi:10.1029/2010GL043751. [2] Smith D. E. et al. (2010) *Space Sci. Rev., 150,* 209-241. [3] Chin G. et al. (2007) *Space Sci. Rev., 129,* 391-419.[4] Melosh H. J. (1989), *Impact Cratering, A Geologic Process*, Oxford University Press, New York. [5] Wilhelms D. E. (1987) *U.S. Geol. Surv. Prof. Pap. 1348.* [6] Pike R. J. (1974) *GRL, 1,* 291. [7] Williams K. K. and Zuber M. T. (1996), *LPSC*, *27,* 1441. [8] Smith D. E. et al. (2010) *LPSC, 41,* 1993. [9] Luis J. F. (2007). *Computers & Geosciences, 33,* 31-41. [10] Talpe M.J. et al. (2011) *LPSC*, *42*, 2549. [11] Head J.W. III and Wilson L. (1992) *Geochim Cosmochim. Acta*, *56,* 2155-2175. [12] Solomon S. C. et al. (1982) *JGR 87,* 3975-3992.