**THE TOPOGRAPHIC SHAPE AND SURFACE ROUGHNESS OF A FEW LUNAR CRATERS**, O. Barnouin[1], D. Smith[2], M. Zuber[3], M. Robinson[4], G. Neumann[2], E. Mazarico[2], B. Denevi[4], T. Duxbury[5], E. Turtle[1], and the LOLA and LROC instrument teams, [1]JHU/APL, Laurel MD 20723 (olivier.barnouin@jhuapl.edu); [2]NASA GSFC, 8800 Greenbelt Road, Greenbelt, MD 20771; [3]Dept. of Earth, Atmospheric, and Planetary Sciences, MIT, Cambridge, MA 02139; [4]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287.[5]Dept. of Physics and Astronomy, George Mason University, Fairfax, VA 22030.

**Introduction**: Topographic data measured from the Lunar Orbiter Laser Altimetry (LOLA) and the Lunar Reconnaissance Orbiter Camera (LROC) are used to assess the relationship between observed surface features and their topographic expressions. As part of an effort to carefully combine LOLA altimetric datasets with the high-resolution images from LROC 's Narrow Angle Camera (NAC), we investigate the topography of a few lunar craters. The ultimate goal is to correlate surface properties characterized with LROC with roughness characteristics obtained from LOLA. This will provide a quantitative means by which to assess the properties of polar regions that are permanently shadowed and provide new data on crater shapes (diameter and depth) that can be compared to Pike [1]. The excellent vertical resolution of LOLA (<10cm), should provide significant improvements to existing measurements of ejecta thickness and rim heights, previously only possible using shadow measurements or stereo imaging techniques.

**Background**: The spatial resolution of both the LOLA (5 m spots separated by 25 m) and LROC NAC instruments (0.5-2m per pixel) are finally permitting the study of the surface geomorphology of the Moon at scales only possible previously on Mars [e.g., 2], and some asteroids [e.g., 3, 4]. The objective of this current study is to improve our understanding of the topography of craters on the Moon, which with many other ongoing studies by LRO team members, should enhance our knowledge of the original reference frame that has been used as the basis for understanding cratering on planets and asteroids. As our understanding of this lunar reference frame improves, new insights into the formation and evolution of craters on other planets and asteroids are expected.

**Approach**: All of the LROC NAC images that were obtained by the LRO spacecraft at <100km altitude were acquired simultaneously with LOLA altimetry. The boresight of the LOLA instrument was designed to acquire topography in the region where the left and right frames of LROC images overlap. A careful assessment of a few images with LOLA altimetry shows that this is indeed the case (Fig 1). Along-orbit track errors between the images and the location of the LOLA footprints are within 20-30 NAC pixels (i.e., <20-30m). The exact across-track location of these footprints possesses a greater error, but will be improved upon as the LRO mission proceeds. The data are of very good quality and allow assessment of the shape of and the nature of the topography within craters.

**Results:** As an example, Figs. 2-4 provide details on the geomorphology of different regions within the crater Moore F located at 37.4 N and 185.0E. This crater is a very fresh complex crater located within the lunar highland, possessing pristine crater walls, ejecta and impact melts. The crater formed in a fairly complex region of the lunar farside, where multiple craters have clearly battered the target surface. This may explain the asymmetric and complex terracing observed on the southeastern wall of the crater, which might have been the result of zones of weakness generated by previous impacts. The ejecta pattern is fairly symmetric and thus does not indicate an oblique origin to the asymmetric collapse of the crater during its modification stages of formation.

The LROC image show evidence for impressive debris flows cascading off the steepest portions of the crater walls (Fig 2.). LOLA indicates that these walls are very steep, sometimes in excess of 38º especially right near the crater rim-crest. This exceeds the slope of loose cohesionless regoliths whose maximum angle of repose is ~35º [5]. It is therefore likely that the observed flows are granular in nature, leaving behind exposed bedrock or very well packed soils.

The NAC images of Moore F crater also reveal a complex floor of fresh impact melts, broad terraces and slumps that are derived from its walls, and a central peak interspersed with a complicated brecciated surface. Both LROC images and LOLA indicate that the slumps, terraces and brecciated terrains are rough, but the melts are flat and smooth.

The last terrain investigated is the continuous ejecta facies. We expected these areas to be fairly rough, as they should have been emplaced as an ejecta sheet of boulders and fines with velocities in excess of ~100 m/s according well-known scaling rules [6]. However, these ejecta are at least as smooth as the impact melts within the crater. To quantify the roughness of the various terrains investigated, Fig. 4 compares the standard deviation of heights as function of various baselines (see [7] for how to compute). The results show that the roughest areas are located at the crater walls and in the very distal ejecta within the small crater located to north the Moore F. The smoothest areas include the continuous ejecta and the crater interior with its melts.

**References:** [1] Pike, R. J., 1974. *GRL* 1, 291–294; [2] McEwen et al. 2007., JGR 112, 10.1029; [3] Veverka J. et al. (2001) *Science, 292*, 484-488; [4] Fujiwara et al., 2006, *Science*, 312:1330–1334; [5] Das, B.M. 2000, *Fund. of Geotech. Eng*, 593pp.; [6] Holsapple, K.A., *Ann. Rev. of Earth and Planet. Sci.*:21, 333 (1993); [7] Barnouin-Jha, O. et al., 2008. *Icarus*, 198, 108-124. [8] Riris, H., et al. 2007, *Proc. SPIE* 6555, pp. 65550I.

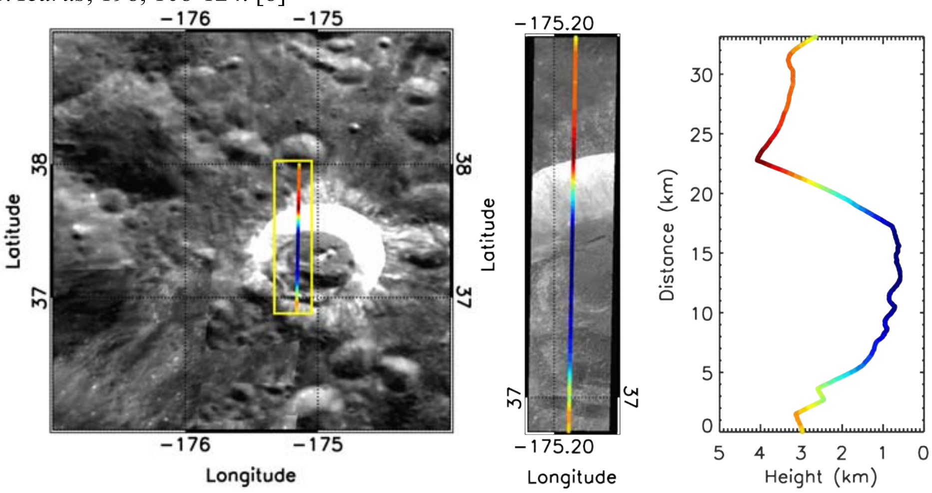


**Figure 1.** Clementine image (left) of crater Moore F where the yellow outline indicates location of a LROC mosaic composed of the left and right frames of image M110383422 (middle). The location of LOLA profile is overlain where colors represent heights as shown in the graph (right).

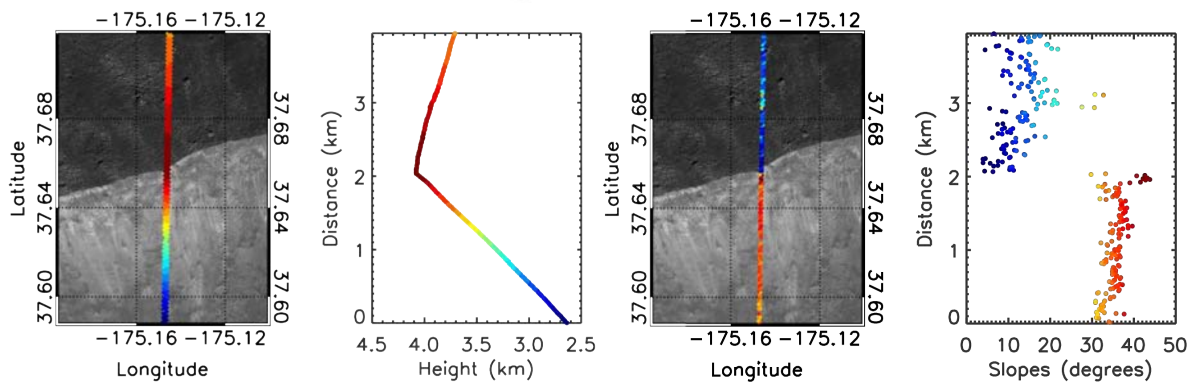


**Figure 2.** Enhanced view of the wall of crater Moore F. Left two figures show the elevation, while the right two show slopes measured by LOLA. The location of the individual shots are shown by the colored spots on the NAC mosaic. The slopes shown were computed from the four triangles that the five spots from each LOLA shot define [8].

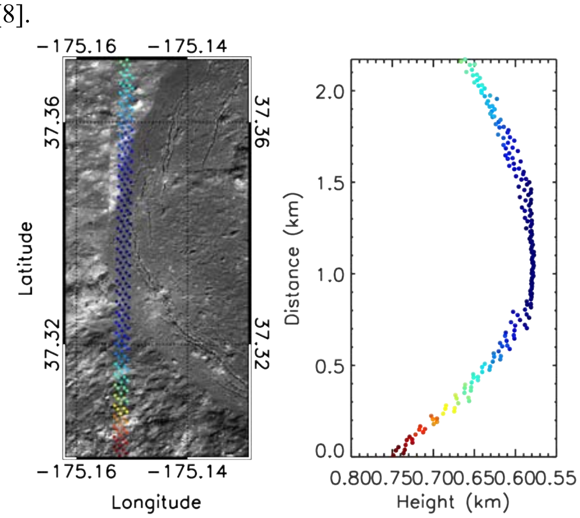


**Figure 3.** Elevation measured by LOLA of the central region of crater Moore F. The track traverses impact melt, and terraces and slumps derived from the crater wall.

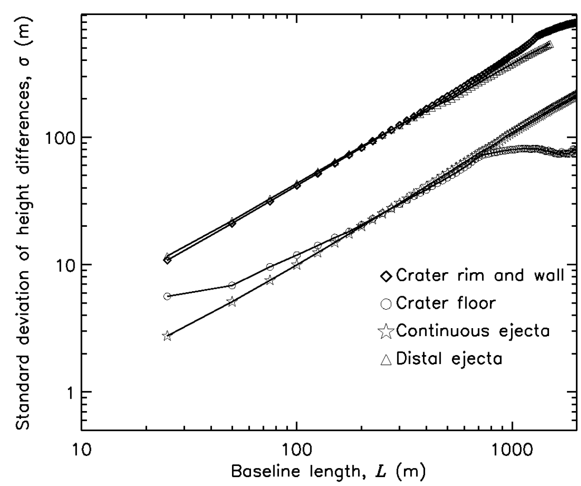


**Figure 4.** Sum of the standard deviation of heights along the LOLA tracks for several regions of the Moore F crater, providing a quantitative measure of surface roughness at various horizontal baselines along the surface.