THE EFFECTS OF IMPACT ANGLE ON THE SHAPE OF LUNAR CRATERS. Nancy K. Forsberg[1], Robert R. Herrick[2] and Benjamin Bussey[3], [1] Geology Dept., 114 Hofstra University, Hempstead, NY 11550, nforsb1@hofstra.edu, [2] Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058, herrick@lpis57.jsc.nasa.gov, [3] ESTEC/ESA, Keplerlaan 1, 2200 AG Noordwijk, The Netherlands, bussey@so.estec.esa.nl.

Introduction

Laboratory experiments [1] have demonstrated that different impact angles cause distinct changes in the morphology and topography of craters. While many studies [e.g., 2] have confirmed that crater morphologies produced in the laboratory by oblique impacts are mimicked by lunar craters, very little work has been done comparing the three-dimensional shapes of fresh planetary impact craters to those experimental results. We have analyzed the three-dimensional shapes of selected lunar impact craters using high-resolution topography generated from stereo photogrammetry and here we compare the forms of lunar craters to those experimentally-generated craters.

Procedure

Information used for this study was extracted from stereo photogrammetric data collected by the Apollo 15 - 17 missions, which cover approximately 10% of the lunar surface. The Apollo imagery has a resolution of a few tens of meters. The data from the Apollo missions have already been processed to produce Lunar Topographic Orthophotomaps (LTOs), contour maps at approximately 100-m horizontal resolution and 100-m contour intervals. From the available data sixteen fresh craters were chosen to be examined. To minimize the effects of degradation and post-excavation collapse, the craters selected were fresh and of moderate size, with diameters ranging from 10 - 35 km. Asymmetric craters were chosen that exhibit a variety of ejecta distribution patterns and crater rim circularity. Symmetric craters of corresponding sizes were chosen for comparison. For the craters chosen, digital elevation models (DEMs) were created from the LTOs. Profiles were then taken in the downrange and crossrange directions.

Profiles from several of the craters can be found on the following figure. The left column shows profiles of presumed high-angle impacts at various sizes while the right column shows oblique impact sat similar sizes. Downrange profiles are shown as solid lines while crossrange profiles are dashed.

Analysis

Profiles of the DEMs were analyzed and the crater morphologies and topographies compared to the experimental data in [1]. In general, we find that lunar craters whose morphology is similar to experimental craters produced by oblique impact also have topographic shapes similar to the experimental craters [Fig. 5, 1].

Messier and Messier A have a morphology similar to experimental oblique ricochet impacts at less than 5°. Messier's topography is elongated and saddle-shaped in a manner similar to an experimental impact at 1°. Messier also has a butterfly ejecta pattern, with forbidden zones uprange and downrange. Messier A, the presumed ricochet, is steepened uprange and elongated downrange in a manner similar to a 5° impact. Messier A has whisker-like ejecta rays pointing west.

Those craters whose morphology suggests an impact between 15° and 45° consistently have a depressed rim in the uprange direction. The difference in rim heights in the uprange and downrange directions for these impacts seems to be a constant fraction (~2.5 %) of crater diameter. For example, Proclus (28.5-km diameter) has an ejecta blanket containing a forbidden zone that is similar to those produced by laboratory impacts of 10-15°, and its downrange rim height is 1 km and the uprange rim height is 200 m. We use the term "depressed rim" in the uprange direction because rim heights in the crossrange direction are similar to those in the downrange direction. Two craters (Torricelli A and Pytheas) show a slight widening in the crossrange direction similar to that exhibited by the experimental impacts at 15°.

Those craters with symmetric ejecta blankets and circular planforms suggestive of high-angle impact have nearly axisymmetric topographic shapes. For example, Sulpicius Gallus (11.8-km diameter) has nearly identical downrange and crossrange profiles.

No consistent depth-diameter difference between oblique and near-vertical impacts was observed across all crater diameters, but we do not have enough data to rule out this possibility for a limited diameter range.

Future Work

For the size range of craters studied, we have looked at most of the oblique impacts available on the LTO sheets. Future work will expand the analysis to smaller and larger crater diameters. The Clementine mission collected stereo data over a larger, mostly non-overlapping portion of the planet [3]. This data is at a substantially lower resolution than the Apollo data and more difficult to work with, but it should be useful for particular tasks such as determining whether any systematic differences in depth-diameter ratios exist. As a test we generated DEMs for the crater Angstrom (9.75-km diameter) from both the Clementine and Apollo data, and the DEM from the Clementine data was able to accurately reproduce the gross features (such as the total depth and rim height) of the LTO topography.

References

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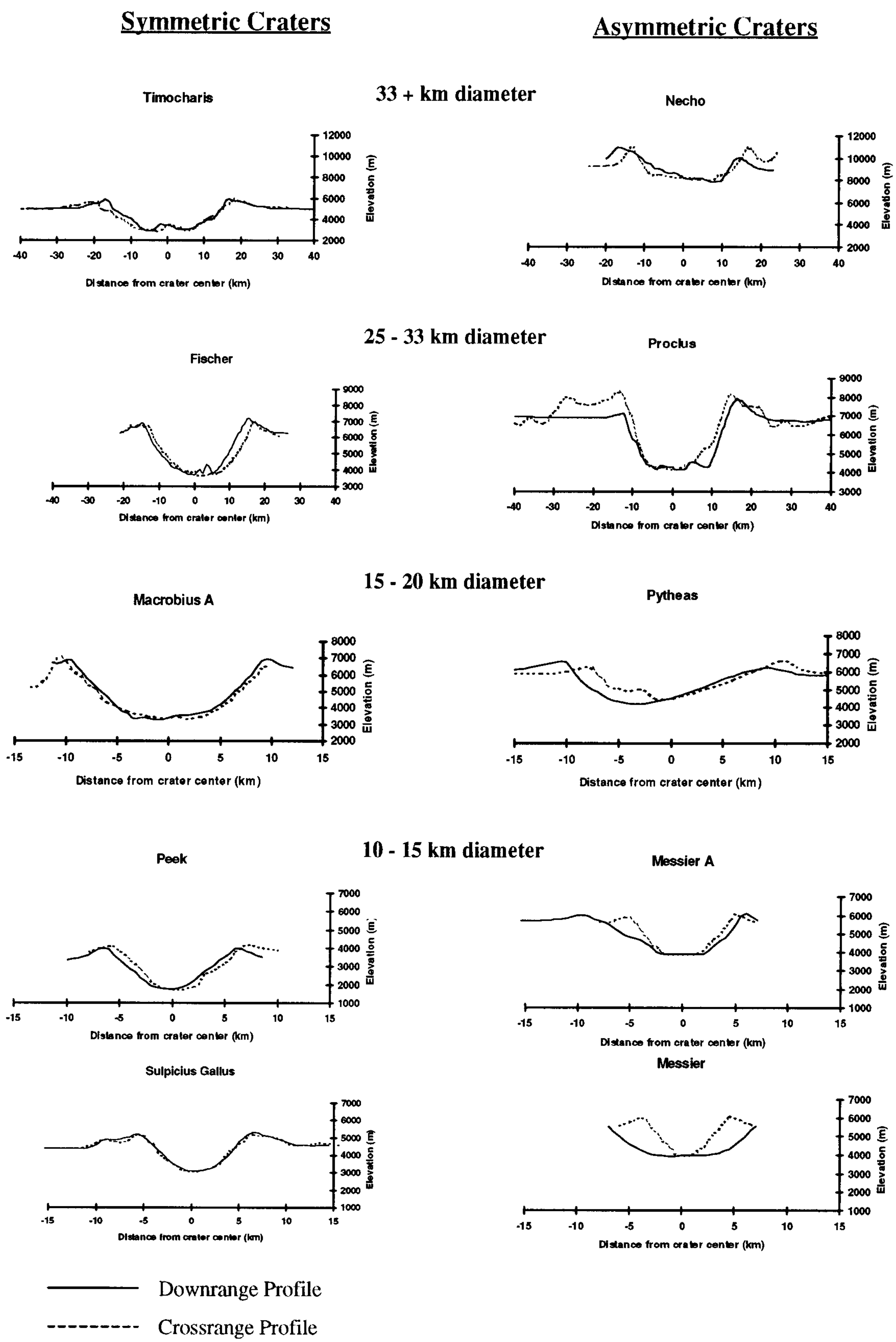
Symmetric Craters
Asymmetric Craters
33 + km diameter
Timocharis
Necho
25 - 33 km diameter
Fischer
Proclus
15 - 20 km diameter
Macrobius A
Pytheas
10 - 15 km diameter
Peek
Messier A
Sulpicius Gallus
Messier
Distance from crater center (km)
Elevation (m)
Downrange Profile
Crossrange Profile