MARTIAN SURFACE PROPERTIES: INFERENCES FROM RESOLVED DIFFERENCES IN CRATER GEOMETRIES. G. J. Valiant and S. T. Stewart, Harvard University (Department of Earth and Planetary Sciences, 20 Oxford St., Cambridge, MA 02138, valiant@fas.harvard.edu, sstewart@eps.harvard.edu).

Introduction. Impact craters are a natural probe of planetary sub-surfaces, both from the excavated material and from crater geometries, which are sensitive to material properties of the target. One of the most intriguing aspects of Martian craters is the morphology of the ejecta blankets. All fresh [1] and many older [2-5] Martian craters larger than a few km are surrounded by ejecta blankets which appear fluidized, with morphologies believed to form by entrainment of liquid water [2, 4, 6-9]. In addition to the ejecta morphology, quantitative information about the subsurface composition may be derived from geometrical measurements, e.g., rim uplift height and ejecta blanket volumes.

In order to use craters to derive subsurface composition or test rampart morphology formation hypotheses, accurate measurements with quantified error estimates are required. We have developed and tested a toolkit for measurements of crater geometry using the MOLA altimetry data. Here, we present the results from geometry measurements on fresh craters in Lunae Planum and Utopia Planitia.

Crater Measurements Toolkit. The features of the toolkit include:

(1) *Digital Elevation Maps (DEMs)*: Interactive generation of DEMs from MOLA PEDR altimetry profiles (tracks) at arbitrary spatial resolution for the region of interest. Data are gridded using the Delaunay triangulation (TRIGRID function in the IDL software package). Individual outlier altimetry tracks may be removed interactively, with recalculation of the DEM.

(2) *Crater rim*: Refinement of the user-estimated crater center by convolving a ring with the topography gradient; Calculation of crater radius, rim uplift height and their variances by interpolating the rim location along individual tracks that pass within a specified fraction (e.g., 0.8) of the estimated crater radius.

(3) *Background surface*: Definition of a background, pre-existing surface from user-specified tie points and the Delaunay triangulation across the crater cavity and ejecta blanket; Fitting of an exponential uplift profile, derived from cratering simulations, from the background to the crater rim.

(4) *Volumes*: Calculation of the crater cavity, ejecta blanket, and combined uplifted background and ejecta volumes; Restriction of calculations to pie-shaped wedges to avoid gaps in the altimetry data coverage and background topographic features (e.g., ridges, nearby craters, etc.) and/or calculations on user-specified regions drawn around the ejecta blanket (e.g., the inner vs. outer ejecta layer).

(5) *Visualization*: Generation of 2-D shaded relief views and 3-D shaded surfaces of the DEM, background surface, and ejecta blankets; Viewing of track coverage, along-track profiles or arbitrary profiles through the DEM; Comparison of the generated DEM to the MOLA DEMs distributed through the Planetary Data System; Viewing of the Viking Orbiter Digital Image Maps for the region of interest.

(6) *Logs*: Record of interactive measurements which may be run again (e.g., to compare different fitting algorithms) and a crater measurement output file.

Resolution and Measurement Tests. We tested our toolkit for systematic errors and resolution sensitivity using simulated craters on different background surfaces, sampled at three different synthetic altimetry track densities (representative of the MOLA coverage at the equator, mid-, and high-latitudes) to generate synthetic DEMs using the same interpolation scheme as used on the MOLA data. We considered an ideal flat background and three backgrounds generated by tiling patches from Mars with few large craters, centered at (i) 33°N, 200°E (Arcadia Pl.), (ii) 7°N, 290°E (Lunae Pl.), and (iii) 32°N, 98°E (Utopia Pl.).

The simulated crater set, composed of 15 craters each in 8 size bins between 2 and 50 km diameter (D), included randomly generated ejecta blanket profiles (within a realistic parameter range), with both single and double-layered rampart ejecta blankets. Identical measurements were performed on each background and at each track density at a DEM resolution of 0.3 km/pix for $D \geq 6$ km and 0.15 km/pix for $D \leq 4$ km.

Overall, the MOLA data resolves craters with $D \geq 6$ km at all latitudes (Figs. 1C, 2B). Measurement accuracy begins to degrade when the number of points around the rim falls below about 10, although reasonable measurements are possible with as few as 4 rim points on $D = 4$ km craters. Large-scale topographic features that cannot be interpolated in the background surface provide the greatest source of error on volume measurements of craters with $D > 20$ km.

Resolved Differences between Utopia Planitia and Lunae Planum. We present the results from a survey of crater geometries in Utopia Planitia (U.P.) (area limited to [30-60°N, 105-124°E]) and Lunae Planum (L.P.) [6-20°N, 286-302°E]. We measured all fresh craters with $D > 4$ km that contained 4 or more track points on the rim using a 0.2 km/pix DEM for L.P. and 0.45 km/pix DEM for U.P. Fresh craters were identified by their depth to diameter ratio and ejecta blanket preservation (Fig. 3). The pie-wedge tool was used to omit gaps in track coverage and the ridges in L.P. In these cases, calculated volumes are corrected for the missing section assuming cylindrical symmetry. Our final set contained 55 craters ($3.9 < D < 32.5$ km) in L.P. and 23 craters ($4.2 < D < 45.6$ km) in U.P.

We find large, resolved differences between the two crater sets in rim uplift height (Fig. 1A), ejecta volume (Fig. 2A), depth to diameter ratio (Fig. 3), and crater cavity volume. For a given diameter, the craters in Utopia are deeper, have higher rims, and larger ejecta blankets. The observed variations are generally 2 to 5 times greater than the standard deviation (σ) in measurement errors derived from the simulated crater tests. Although ejecta volumes around the smallest craters in Lunae Planum are comparable to the absolute errors in the simulated craters, the simulations confirm that there is little systematic offset on any of the background terrains. Fig. 2A shows excellent correlation between craters within each region of study.

Discussion. The detected variations in crater geometry between Lunae Planum and Utopia Planitia are probably related to differences in the composition or structural properties of the two terrains. The larger rim uplift and cavity volumes observed in Utopia indicates a weaker terrain compared to Lunae Planum. This is consistent with the difference in geology between the northern plain, possibly containing sediment layers, and the ridged plateau.

Through detailed comparisons between the observed crater geometries and cratering simulations, we seek to constrain and map compositional variations between regions on Mars. Here, we demonstrate that significant differences may be resolved between craters on different terrains using MOLA data.

We note that both of the studied regions contain fresh, rampart-type ejecta blankets. Crater geometry measurements will be able to test formation theories for fluidized ejecta blankets. The liquid water entrainment mechanism for formation of rampart ejecta forms will be tested by comparing observed craters with a database of crater shape and ejecta blanket geometrical properties from impact cratering simulations.

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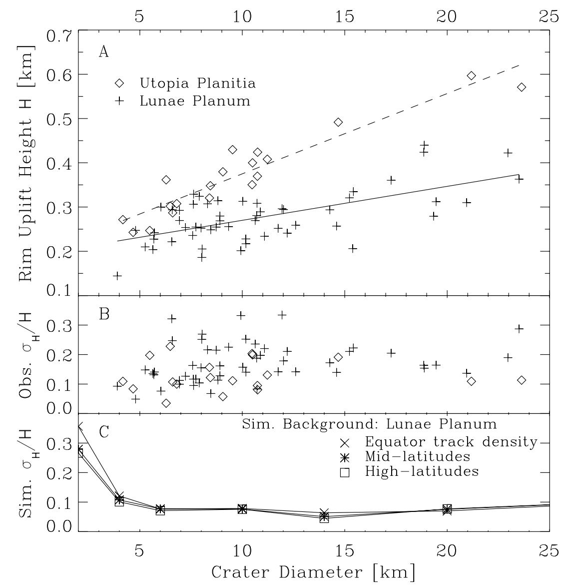

Fig. 1. A. Crater rim uplift height in Utopia and Lunae Planum with linear fits. **B.** Fractional scatter in rim height measurements. **C.** Fractional measurement error on simulated craters.

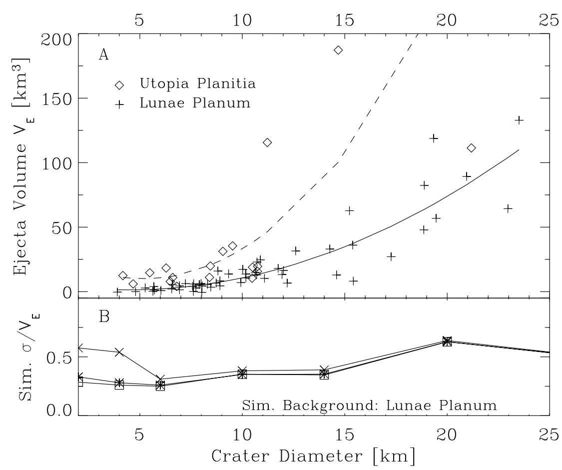

Fig. 2. A. Crater ejecta volume differences between Utopia and Lunae Planum with quadratic fits. **B.** Fractional measurement error on simulated craters.

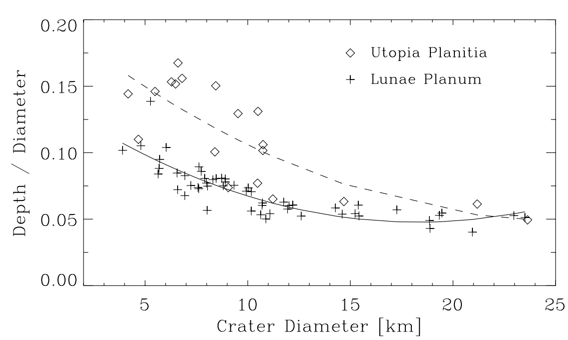

Fig. 3. Depth to diameter ratios and quadratic fits for craters surveyed in Utopia and Lunae Planum.