SINUOSITY AND EJECTA EXTENT OF MARTIAN IMPACT CRATERS IN THE NORTHERN HEMISPHERE. B. C. Sheehan, Dept. Physics and Astronomy, Colgate University, Hamilton, NY, 13346-1338 bsheehan@colgate.edu; and N. G. Barlow, Dept. Physics and Astronomy, Northern Arizona University, Flagstaff, AZ 86011-6010 Nadine.Barlow@nau.edu.

Introduction: Fresh impact craters on Mars are often surrounded by layered ejecta blanket morphologies. These morphologies are not found on analogous bodies like Mercury or the Moon. Ejecta blankets are made of surface rock materials that are emplaced by ballistic and fluidization processes upon impact [1]. Ejecta morphologies allow classification of impact craters into single-layer ejecta (SLE), double-layer ejecta (DLE; Fig. 1), and multiple-layer ejecta (MLE) craters. Volatiles are believed to fluidize the ejecta blankets upon impact; H_2O is likely the primary volatile involved in the fluidization process [2]. The dominant fluidization mechanism is thought to either be subsurface water-ice vaporization upon impact, or atmosphere-ejecta curtain interactions [3, 4]. Quantifying the lobateness, a measure of ejecta blanket sinuosity, and the ejecta mobility, a measure of relative fluidization of the ejecta blanket, can provide insight into the dominant fluidization mechanism [5, 6].

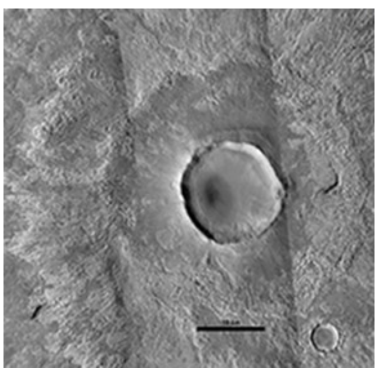

Figure 1: CTX mosaic of a DLE crater. Crater is 15.1 km in diameter and located at 40.95°N 98.28°E. Scale bar is 10 km.

Possible variations in lobateness and ejecta mobility with respect to elevation, latitude, crater size, and local albedo can reveal information about relative volatile concentrations, and may provide insights into the fluidization mechanism of the crater ejecta blankets. Similarly, lack of variations in lobateness and ejecta mobility can constrain fluidization mechanism theories by limiting likely volatile concentration locations. Prior studies suggest little variation in any quantities across all ejecta blanket morphologies, indicating relatively constant subsurface volatile abundances throughout the northern hemisphere, but these earlier studies used images from the Viking Orbiters, which generally had poorer resolution than modern imagery [7]. We therefore have instituted a new study using higher resolution data to investigate any trends in lobateness and ejecta mobility, which might reveal variations in subsurface volatile distribution.

Methodology: This study utilized image data of 5,759 impact craters in the northern hemisphere of Mars with diameter ≥5 km and which displayed a SLE, DLE, or MLE morphology. We mosaicked Mars Reconnaissance Orbiter Context Camera (CTX; 6 m/pixel resolution) images of each crater using the JMARS application. From the mosaicked images, we measured the area (A) and outer perimeter (P) of each ejecta deposit. We then calculated the lobateness (Γ) using [8]

$$\Gamma = \frac{P}{(4\pi A)^{1/2}}$$

Γ=1 indicates a circular ejecta platform while larger values indicate increasing sinuosity. We calculated the ejecta mobility (EM) ratio from

$$EM = \frac{R_e}{R_c}$$

where R_c is the crater radius and R_e is the average radius of the ejecta deposit calculated from

$$R_e = \sqrt{\frac{A}{\pi}} - R_c$$

A database was created in Excel and used to compare Γ and EM as a function of diameter. Crater data were imported into ArcGIS, where we investigated potential variations in lobateness and ejecta mobility as a function of latitude, elevation, and albedo.

Data and Results: We searched for variations in both Γ and EM for SLE, DLE, and MLE crater morphologies with respect to latitude, crater diameter, elevation, and local albedo. Examples of the aggregate data are shown in Fig. 2.

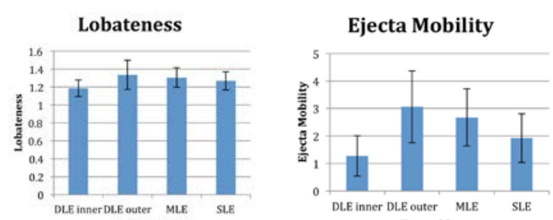

Figure 2: Aggregate data, broken into groups according to crater morphology. Uncertainties are 1σ deviations from calculated averages.

No statistically significant trends can be seen at the 1σ level for variations in either Γ or EM with respect to crater diameter or latitude.

To determine if Γ and EM might vary with respect to local albedo or elevation, craters were plotted on ArcGIS maps of the northern hemisphere of Mars. Figure 3 shows an example map for MLE craters as a function of elevation. From this analysis, we found no significant trends in Γ or EM as a function of elevation or surface albedo.

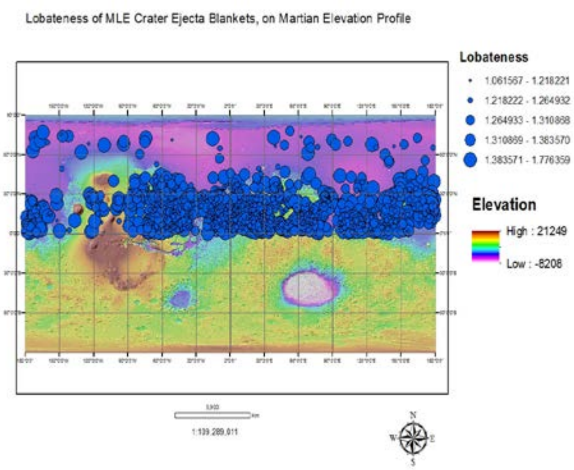

Figure 3: Lobateness of MLE crater ejecta blankets, superposed on an ArcGIS Martian elevation profile. No variation pattern is discernable.

Discussion: The improved image resolution in this study resulted in slight differences in the actual Γ and EM values compared to the original Viking study. However our results support the Viking-based studies showing no statistically significant variations in either Γ or EM at the 1σ level, for any of the independent variables tested. The data support the finding that a slight trend toward smaller Γ with smaller crater diameter resulted from resolution issues and not from a physical process [7]. These results are consistent with a larger comparison study, which finds that although improved resolution results in updates to morphology classification and quantitative values, the overall trends seen in large-scale Viking data analysis do not substantially change [8].

The lack of statistically significant trends in either Γ or EM supports the conclusion [7] that separation of craters by morphology allows for better direct comparison of ejecta blankets, and prevents unknown physical mechanisms of ejecta blanket formation from skewing the data.

The lack of statistically significant trends for either parameter against latitude indicates that volatiles causing the fluidization at the time of impact are derived from a reservoir that is homogenous throughout the northern hemisphere [9]. Using the empirical depth-diameter formula for impact craters [10], we find that the smallest craters in this study excavate to a depth of approximately 500 m. Gamma Ray Neutron Spectrometer measurements from the Mars Odyssey mission found significant variation in subsurface volatile content within the top 5 m of the crust [11]. Our analysis suggests that the dominant volatile concentration for fluidization of layered ejecta blankets comes from a deeper reservoir. The lack of variation in either lobateness or ejecta mobility with respect to local albedo further supports this idea, as local albedo depends on the physical and chemical properties of the thinnest top layer of regolith.

The lack of significant variation in either Γ or EM with elevation suggests that atmospheric volatiles play little role in the fluidization mechanism of the ejecta blankets. This is consistent with results of a comparison study of layered ejecta craters on Mars and Ganymede which found self-similarity in ejecta characteristics, implicating the role of target volatiles in both since Ganymede has no substantial atmosphere [12].

Conclusions: This study finds that separating craters by morphology prior to statistical comparison can reveal meaningful information about both ejecta blanket formation and relative subsurface volatile concentrations. We conclude that there is a reservoir of volatiles, likely dominated by H_2O ice, which is homogenous across much of the northern hemisphere of Mars at depths of at least 500 m. This reservoir is stable across the northern hemisphere and throughout geologic timescales, and is deep enough to be largely unaffected by the changing Martian obliquity cycle [13, 14]. Our results support the model that layered ejecta blankets on Mars are most likely fluidized by interaction with a deep subsurface water-rich layer , although atmospheric contributions can still play a small role.

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