INFORMATION ON SUBSURFACE STRATIGRAPHY DERIVED FROM MARTIAN SINGLE AND DOUBLE LAYERED EJECTA CRATERS.

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Introduction: Martian craters with fluidized ejecta – including single-layered, double-layered and multiple-layered craters – have been studied extensively, with their formation often suggested to be linked to varying concentrations of subsurface volatiles [1,2]. A recent catalogue on martian impact craters [3,4] classifies crater ejecta along with their location, diameters and ejecta extents, potentially providing new information on the links between these morphologies and the subsurface. We regionally examine SLE and DLE craters within the catalogue to see if they can provide information on subsurface layering, in particular, whether their formation and ejecta behaviour is consistent with subsurface volatiles, small grain size and poor grain cohesion, or a combination of both.

Methods: This study used craters identified as SLE and DLE within the catalogue. The regional variations in three parameters – onset diameter, ejecta mobility (EM; the ratio of ejecta radius to crater radius), and the Pearson's correlation coefficient between EM and radius – were examined. To map these parameters the craters were binned into 5 x 5° bins (encompassing an area of ~9 × 10^5 km^2 at the equator), and only cells within sufficient numbers of craters were used. To estimate the potential fraction of misclassified craters, a subset of 630 craters in Utopia Planitia were examined and their morphology classified independently of the catalogue.

Results: Onset diameter (i.e., the smallest diameter at which a particular morphology is observed), can be used to estimate the minimum depth to a particular target material. Both SLEs and DLEs show a latitudinal trend with onset diameter decreasing away from the equator, consistent with previous works (e.g., [5-7]). SLEs show strong longitudinal trends at low latitudes. Many of the highest onset diameters correspond to regions with broad lava plains (Hesperia Planum, Elysium Planitia, Syrtis Major Planum, Tyrrhena Terra, Xanthe Terra), suggesting a possible relationship between the desiccation of surface volatiles and/or the high viscosity and/or strength of the target materials preventing the formation of small craters.

Ejecta mobility provides a measure of the viscosity of the surface hugging ejecta flow, and is determined by grain size and cohesion, volatile content, and melt content [8]. Both SLE and DLE morphologies display more mobile ejecta in the northern lowlands, with the outer layer of DLE ejecta generally showing the highest mobility, consistent with previous studies [7,9]. Clear correlations of ejecta mobility with morphology were observed, as well as longitudinal variation in EM for SLE craters. The least mobile ejecta on the planet for both SLE and DLE craters was around the volcanic regions of Tharsis, Hesperia and Elysium.

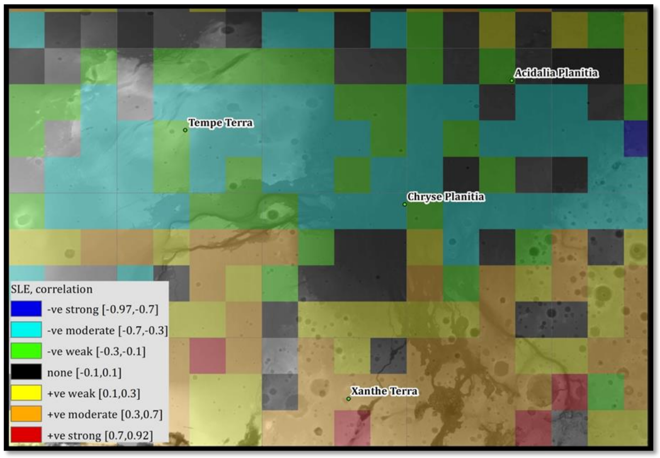

Figure 1: The correlation between ejecta mobility and diameter for SLE craters in Chryse Planitia. The correlation changes from a moderate positive value in Arabia Terra, to a moderate negative value in the lowlands. Approximately 1980 SLE's are within the extent of the figure.

The Pearson's correlation coefficient between EM and crater radius provides a measure of how strongly crater size and ejecta extent vary together. The radius of the continuous ejecta blanket scales with crater radius for craters within the gravity regime [10,11]. Early studies of layered ejecta craters found a positive correlation, possibly consistent with larger craters excavating deeper into a putative subsurface cryosphere [12]. We observe deviations away from a strong positive correlation, which we attribute to the additional influence of target composition on the magnitude of surface flow (Figure 1). SLE craters generally show a moderate positive correlation at low latitudes, changing to a moderate negative correlation above ~25 °N and a weak negative correlation in some regions above ~40 °S. This suggests that the effect of the target on promoting ejecta mobility decreases with increasing latitude. Negative correlations may be due to the stratification of target composition with depth, with larger craters incorporating a smaller fraction of volatiles, melt and/or mobile particulates within their total ejecta. Regional variation is also observed.

We have developed a subsurface layering model that is consistent with the spatial patterns observed. In this model, the behaviour of SLE and DLE craters is explained by the viscosity and/or strength of the layers within the target. Whether this is dominated by its volatile content or by grain size will likely vary regionally on Mars, and will be dependent on topographic, climactic, erosional and other factors. The majority of SLE and DLE craters were observed to fall within 6 regions A–F (4 for SLE's and 2 for DLE's; Figure 2). In each of these regions, the craters show similar values in all three parameters (Table 1). No simple latitudinal trend is observed as significant variation is seen globally and regionally, indicating a complex relationship with the subsurface properties. The observed spatial patterns are not dominated solely by the stability of ice under obliquity near the present value [13] nor ice deposition at recent moderate obliquity (25–35°) within the last 10 Ma [14,15]. Details of the six units will be discussed.

Conclusions: The observed variation in onset diameter, ejecta mobility, and correlation between ejecta mobility and radius for single- and double-layered ejecta craters is presented. SLE and DLE craters were found to show a complex relationship with the subsurface characteristics. Significant longitudinal and regional variation was found that has not observed in previous works. The SLE behaviour at latitudes > ±30°, and the DLE behaviour at all latitudes, was interpreted to be likely due to the low viscosity fluidized behaviour of a volatile-rich substrate given the geologic history of the regions examined. In some locations it was found plausible that the observed behaviour was influenced by fine-grained materials without requiring significant volatile content. A plausible regional model of subsurface layering consistent with these results will be presented; however, other explanations could also be derived. Future work will be focused on testing the predictions of this model, in particular, the thickness of subsurface volatile rich and/or fine-grained and low cohesion layers.

Table 1: Regional patterns in SLE and DLE craters

Ejecta mobility	Onset diameter	EM-Diameter correlation	
		Positive	Negative
Low EM	Small	A	D
	Large	B	C
High EM	Small	E	F
	Large		

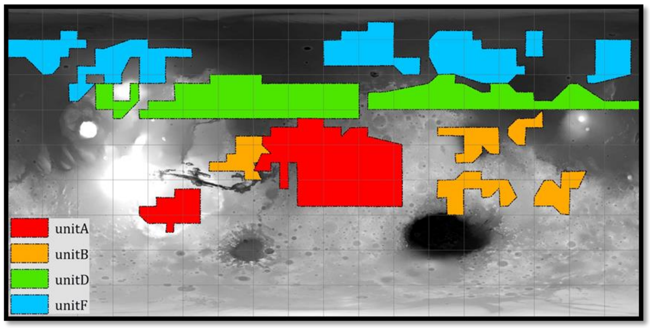

Figure 2: Regional patterns observed in the behavior of SLE craters. Within each of these regions, SLE craters show similar values of onset diameter, ejecta mobility, and correlation between crater radius and ejecta radius (Table 1). The attributes of SLE craters in these regions may be providing information on the distribution of volatiles and grain size in the subsurface.

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