A MORPHOMETRIC COMPARISON OF MARTIAN DOUBLE LAYERED EJECTA CRATERS AND IMPLICATIONS FOR THE EFFECT OF TARGET LITHOLOGY.

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Introduction: Layered ejecta is the dominant type of ejecta morphology surrounding craters ≥ 5 km in diameter on Mars [1]. These include single- (SLE), double- (DLE), and mulit- (MLE) layered ejecta morphologies [2] and are considered to have been emplaced via ground hugging flow [3]. Volatile content within (or on) the target [3] and/or atmosphere [4] is generally recognized as the dominant variable enhancing mobility during emplacement, though it has also been suggested that the presence of unconsolidated surface materials may aid in mobility as well [5]. Previous studies have shown that ejecta mobility (the distance ejecta travels from the crater rim) increases with increasing latitude [6, 7, 8] and appears to reflect volatile content on Mars [9]. Other studies show that lobateness (sinuosity of ejecta blankets) is greater at lower latitudes and less at higher latitudes [10]. Are these morphometric observations a result of volatile content or target lithology, or both? Here, we aim to determine whether bulk target lithology has any affect on morphometric properties between DLEs situated on sedimentary targets to those on volcanic targets.

Methods: We have reevaluated the DLEs in Robbins Crater Database [11] to compile our own database of 1345 DLEs. Here we define a DLE as any crater that clearly displays two layers of ejecta. Of these, 205 craters were selected for morphometric analysis, including ejecta mobility (EM) and lobateness (Γ): 127 on volcanic terrains and 78 on non-volcanic terrains in the northern lowlands. Crater sizes range from ~3 to 20 km in diameter. DLEs situated on volcanic terrains were split into 5 groups based on their major geographic locailty (i.e., Northern and Southern Tharsis, Elysium, Syrtis Major, and Hesperia Planum) and range from ~5 to 50° latitude [8]. Bulk lithologies are considered to be dominantly basalts emplaced by lava flows [12]. Northern lowland DLEs were split into 3 groups (Acidalia/Chryse, Arcadia, and Utopia Planitiae) ranging from ~25 to 70° latitude. The target lithology in these regions is interpreted to be thick deposits of sediment (≤ ~1 km) derived from outflow channels [12]. Java Mission-planning and Analysis for Remote Sensing (JMARS) software [13] was used for measurements and analysis, including CTX and THEMIS VIS imagery. We binned our data every 10° latitude for both volcanic and non-volcanic DLEs (Table 1), average EM and lobateness within each bin, and plot them against the average latitude (Figs. 1 and 2).

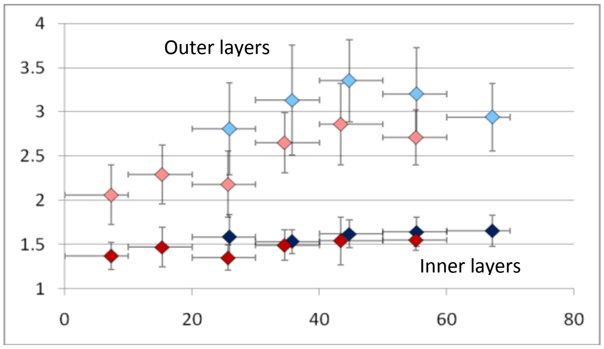

Fig. 1 – Avg. EM (y-axis) plotted against avg. latitude (x-axis) in 10° increments. Blue = non-volcanic; red = volcanic. Outer layers are light colors, inner darker.

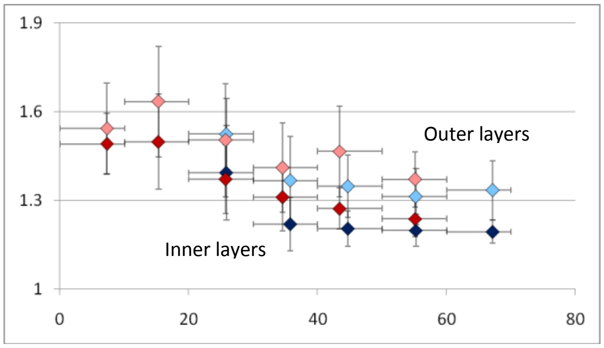

Fig. 2 – Avg. Γ (y-axis) plotted against avg. latitude (x-axis) in 10° increments. Light colors are outer layers, darker colors are inner layers. Blue = non-volcanic; red = volcanic.

Bin	Volcanic	Non-volcanic
0 – 10°	16	0
10 – 20°	27	0
20 – 30°	26	5
30 – 40°	41	20
40 – 50°	11	32
50 – 60°	6	13
60 – 70°	0	7

Table 1 – Number of DLEs within each bin.

Results: Collectively, ejecta mobility appears to generally increase with increasing latitude (Fig. 1). This is most apparent for the outer layers but is also observed for inner layers. Averaging ejecta mobility and latitude within each bin, we see that non-volcanic DLEs have slightly larger EM values than volcanic DLEs (Fig. 1). There is clear separation between the outer layer EM of the two groups while virtually no distinction can be made between the EM of the inner layers. It is also interesting to note that the average outer layer EM peaks around 45° for both groups and then generally decreases.

Figure 2 displays lobateness values for DLEs. Overall, volcanic and non-volcanic DLEs at various latitudes appear to be very similar, but some slight separation is observed. Lobateness for both groups generally decrease with increasing latitude. Outer layer lobateness is slightly greater than inner layers for both groups.

Discussion: Our results on ejecta mobility seem to reflect general subsurface volatile concentrations on Mars in that both increase with increasing latitude [9]. Figure 1 shows the average EM of outer layers of both groups gradually rise, peak, and begin to fall all with increasing latitude. The peak between both groups occurs ~45° and correlates well with the existence of mid-latitude glaciation thought to occur throughout much of the Amazonian [14, 15]. This abundance of ice may also explain the peak seen in our graphs. Because the average EM of both groups increase with latitude, volatile content is suggested to be the main variable controlling this property and is consistant with previous observations [6, 7, 8].

On average, DLEs on non-volcanic terrians have slightly higher EM values than those on volcanic terrains (Fig. 1). We suggest that a major factor responsible for this observation is the strength contrast between largely basaltic and sedimentary targets, and their ability to host volatile-rich materials. It has been suggested that the outer ejecta layer is emplaced via ballistic sedimentation [16] where primary, airborne ejecta reimpacts the surrounding surface thereby incorporating target material (secondary ejecta) into the ejecta blanket [5, 17, 18]. This incorporation of local material allows ejecta to move as a ground-hugging flow. Secondary ejecta will be much easier to incorporate into the ejecta blanket if the target is loose, unconsolidated sediment rather than volcanic rock, thus allowing for greater runout distances (i.e., EM) [5, 18]. An additional volatile variable would reduce friction between particles and enhance mobility further. This difference in target lithology between non-volcanic and volcanic DLEs and the abundance of volatiles at higher latitudes [9, 14, 15] may explain our observed EM values. Because there is virtually no distinction of inner layer EM values between volcanic and non-volcanic DLEs may suggest that the inner layer is emplaced after the outer layer. An already emplaced outer layer may provide a similar surface (e.g., ejecta blanket) on which the inner layer can travel upon regardless of target type (e.g., volcanic or non-volcanic). For example, outer layers would be affected by the pre-impact target much more than the inner layer which may only be affected by the already emplaced ejecta blanket (i.e., outer layer).

The parameters affecting EM for non-volcanic DLEs may also be affecting their observed lower lobateness values. Figure 2 shows that the average lobateness of both layers for non-volcanic DLEs is nearly identical with the exception of DLEs around ~30° which appear to be higher. With the abundance of surficial sediment and volatiles at higher latitudes, friction between the ejecta blanket and the target can be expected to be low and may result in ejecta to runout at equal distances from the crater rim. In comparison, volcanic DLEs lobateness seems to be higher at lower latitudes and lower at higher latitudes. More friction between ejecta and the target as well as within the ejecta blanket itself should be expected at lower latitudes where there are less volatiles [9, 14, 15] and a contrast in lithology (i.e., volcanic rock). Drag on the surface may cause ejecta to split into more “lobes” equating to a higher lobateness. As DLEs move poleward volatile content should increase [9, 14, 15] thereby reducing friction and a decrease in lobateness. This seems to be consistent with our results.

Conclusions: We suggest volatile content in the subsurface is the main variable controlling EM variations with latitude. In addition, target lithology seems to be the main variable controlling lobateness while the addition of volatiles will be an aiding variable. In summary, we suggest that impact into a sediment, volatile-rich target can enhance mobility and allow ejecta to runout further at approximately equal distances while ejecta derived from impact into volcanic rock will experience more drag on the surface resulting in lower EM and higher lobateness.

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