RESULTS OF A SURVEY OF MARTIAN LOW ASPECT RATIO LAYERED EJECTA (LARLE) CRATERS.

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Introduction: We have identified an unusual type of layered ejecta crater on Mars, characterized by an extensive, thin (a few meters to a few tens of meters) outer layer which terminates in a flame-like sinuous morphology [1,2] (Fig. 1). We have surveyed the planet for the distribution and morphologies of these unusual craters. We find that they display either a single layer ejecta (SLE) or double layer ejecta (DLE) morphology and include outward of these layers an extensive, thin outermost layer. The ratio of the thickness to length of the outer deposit (i.e., aspect ratio (AR)) is very low (AR ~ 10^{-5}) and therefore, following nomenclature used by volcanologists for low AR ignimbrite (LARI) deposits, we have called these craters "Low Aspect Ratio Layered Ejecta" (LARLE) craters [3].

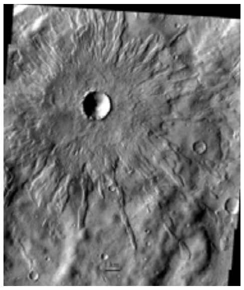

Figure 1: This 1.8-km-diameter crater (43.20°S 202.47°E) displays the typical morphology of LARLE craters. The outer deposit extends 12.1 crater radii from the rim. (THEMIS V26066007)

Survey of LARLE Craters: We used THEMIS visible (VIS) and daytime infrared (IR) images to survey the Martian surface in the ±75° latitude zone for LARLE craters ≥1-km-diameter. While most LARLE craters are >1-km-diameter, smaller ones can be found but are relatively rare and most appear to be transitioning into pedestal craters. Craters are classified as LARLE craters if they meet the following conditions:

- The inner layers display a SLE or DLE morphology.
- The outer (i.e., LARLE) layer terminates in a sinuous "flame-like" edge
- The LARLE layer has a maximum ejecta mobility value greater than 6.0,
- The ejecta deposit cannot be classified as a normal layered, pedestal, or radial morphology.

Our survey identified 141 LARLE craters in the study region. LARLE craters are more than twice as common in the northern hemisphere than in the south, with 96 northern hemisphere examples versus 45 in the south.

LARLE Distribution. LARLE craters are strongly concentrated at the higher latitudes (Figs. 2-3): 91% of all LARLE craters are found poleward of ±35° latitude. No LARLE craters were found in the 5° to 30° north and south latitude zones Mars. The frequency of LARLE craters increases dramatically between 55°N and 75°N (Fig. 3).

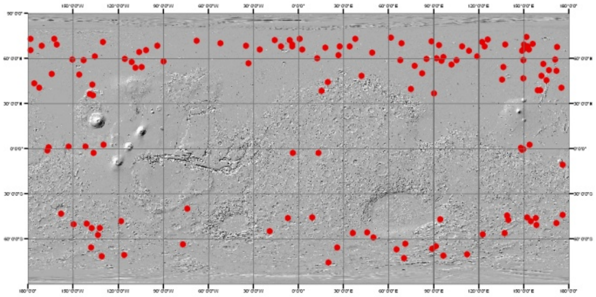

Figure 2: Distribution of LARLE craters across Mars.

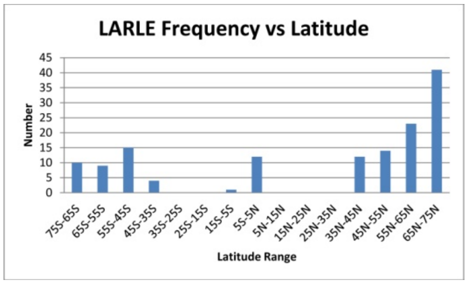

Figure 3: Plot of the frequency of LARLE craters as a function of 10° latitude zone.

LARLE craters are strongly correlated with regions of volatile-rich fine-grained deposits. Of the 13 equatorial examples, eight (62%) are found within Medusae Fossae Formation deposits. Using the Viking-based geologic maps of Mars [4-6], we find that 36 of the 141 LARLE craters formed on Amazonian units, 73 in Hesperian terrains, 29 in Nochian units, and 3 in other materials (i.e., on crater ejecta blankets, etc.). Using the more recent northern plains geologic map [7], 70 out of 91 (77%) LARLE craters in the region covered by this map formed within the Amazonian-aged Vastitas Borealis units, with 56 of those 70 (80%) on the interior unit of the Vasitats Borealis formation (ABvi). The prevalence of LARLE craters at high latitudes (but not in many lower-latitude fine-grained deposits) suggests that the presence of volatiles also is important for the formation of this morphology.

LARLE Crater Diameters. LARLE craters range in diameter from ≤1.0 km to 19.9 km. LARLE morphology is more common among smaller craters: 82% of all LARLE craters are <5-km-diameter. LARLE craters larger than 6 km are all found at latitudes poleward of ±40° (Fig. 4). The frequency of these smaller craters is greater than that expected from the impact flux at Mars and may indicate a preference for smaller craters to form as LARLE craters.

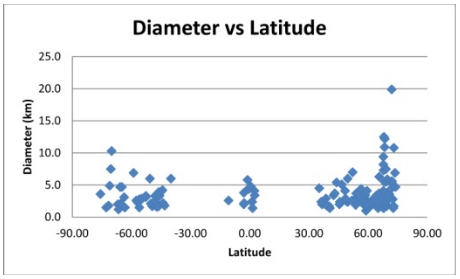

Figure 4: Diameter of LARLE craters as a function of latitude. Larger craters occur at higher latitudes.

The outer layer's radial extent (measured from the crater rim to the outermost edge of the deposit; R_d) generally displays a linear relationship to crater radius (R_c) (Fig. 5), except for one outlier. The outer layer of the largest LARLE crater in this survey has a much lower radial extent relative to its size than the other LARLE craters. Removing this one outlier, we find that the best-fit linear relationship between R_d and R_c is of the form

$$R_d = 0.169 + 10.516R_c$$

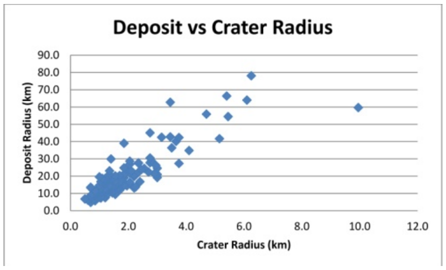

Figure 5: Maximum radial extent of outer layer (R_e) versus the crater radius (R_c). The trend is approximately linear.

LARLE Ejecta Mobility Ratios and Lobateness. Ejecta mobility (EM) ratio normalizes the radial extent of the ejecta deposit (R_e) to the crater radius (R_c):

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

Average EM of SLE craters is 1.53. Average EM is 1.49 for the inner layer of DLE and 3.24 for the outer layer, and 2.17 for the outermost layer of MLE [8]. Maximum EM of the 114 LARLE deposits in this study ranges from 6.0 to 21.4, with a median of 10.2. Highest EM values are seen for LARLE craters at higher latitudes (Fig. 6). No correlation between R_c and Maximum EM is seen. We are currently obtaining information about average EM and lobateness ("sinuosity") of the outer deposit.

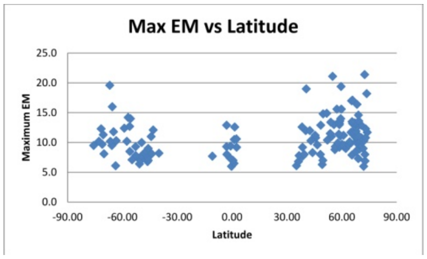

Figure 6: Distribution of maximum EM ratios for LARLE craters as a function of latitude. The highest EM ratio values are seen for craters at higher latitudes.

Discussion and Conclusions: Low aspect ratio layered ejecta (LARLE) craters are an unusual morphology seen primarily around craters at high latitudes. We propose that for LARLE craters to form, they must excavate into fine-grained volatile-rich deposits. This scenario explains the observations that LARLE craters are more prevalent at higher latitudes where such deposits dominate and the diameter-latitude relationship shown in Figure 4. The unusual R_d vs R_c results for our largest LARLE crater could be explained by either the effects of erosion or that the crater excavated substantially through the fine-grained deposit into the underlying material, thus ejecting a relatively smaller proportion of fine grain materials.

Results of our completed survey between ±75° latitude are consistent with our proposal that these features form from a base-surge-like density-driven gravity current of suspended fine-grained material [3]. The results also support our hypothesis that LARLE craters are younger, less-eroded versions of pedestal craters [9]. Future work includes completing the average EM and lobateness measurements and further investigation of these craters using imagery from CTX and HiRISE and thermal inertia data from THEMIS.

References: [1] Barlow N.G. and J.M. Boyce (2008) *LPSC XXXIX*, Abstract #1164. [2] Boyce J.M. et al. (2008) *LPSC XXXIX*, Abstract #1406. [3] Boyce J.M. et al. (2012) *LPS XLIII*, Abstract #1081. [4] Scott D. H. and K. L. Tanaka (1986), *Geologic Map of the Western Equatorial Region of Mars*, 1:15,000,000 scale, USGS Map I-1802-A. [5] Greeley R. and J. E. Guest (1987) *Geologic Map of the Eastern Equatorial Region of Mars,* 1:15,000,000 scale, USGS Map I-1802-B. [6] *Geologic Map of the Polar Regions of Mars*, 1:15,000,000 scale, USGS Map I-1802-C. [7] Tanaka K.L. et al. (2005) *Geologic Map of the Northern Plains of Mars*, 1:15,000,000 scale, USGS SIM 2888. [8] Barlow N.G. (2005) *GSA SP 384*, 433-442. [9] Barlow, N.G. and J.M. Boyce, *LPS XLIII*, Abstract #1253.