DISTRIBUTION AND CHARACTERISTICS OF MARTIAN LOW ASPECT RATIO LAYERED EJECTA (LARLE) CRATERS.

N. G. Barlow[1] and J. M. Boyce[2], [1]Dept. Physics & Astronomy, Northern Arizona University, Flagstaff, AZ 86011-6010 (Nadine.Barlow@nau.edu), [2]Hawaii Inst. Geophysics & Planetology, University of Hawaii, Honolulu, HI 96822 (jboyce@higp.hawaii.edu).

Introduction: An unusual type of layered ejecta crater has been identified on Mars, characterized by a normal ejecta morphology superposed on an extensive outer layer which terminates in a flame-like sinuous morphology [1,2] (Fig. 1). We previously called these craters Quasi-Multiple Layer Ejecta (QMLE) craters because the initial examples all displayed a double-layer ejecta (DLE) morphology superposed on the outer layer. Nomenclature guidelines [3] recommend that any ejecta deposit with three or more partial or complete layers should be called a multiple-layer ejecta (MLE) crater, but the QMLE craters are morphologically distinct from normal MLE craters which led to their designation as "quasi MLE" craters.

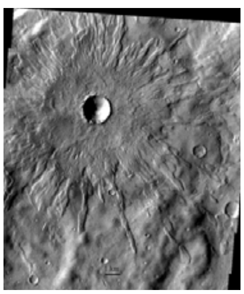

Figure 1: This 1.8-km-diameter crater (43.20°S 202.47°E) displays the typical morphology of LARLE craters. The outer deposit extends 12.1 crater radii from the rim. (THEMIS V26066007)

We are conducting a global survey of the distribution and characteristics of these unusual craters and have discovered that many examples display a single layer ejecta (SLE) morphology superposed on the outer layer. The ratio of the thickness to length of the deposit (i.e., aspect ratio (AR)) is very low (AR ~ 10^{-5}) and therefore, following the nomenclature used by volcanologists for low AR ignimbrite (LARI) deposits, we have replaced the QMLE designation with "Low Aspect Ratio Layered Ejecta" (LARLE) for these craters [4].

Survey of LARLE Craters: We are utilizing THEMIS visible (VIS) and daytime infrared (IR) images to survey the entire surface of Mars for LARLE craters ≥1-km-diameter. Craters are classified as LARLE craters if they (1) display a SLE or DLE morphology superposed on an extensive outer layer, (2) the outer layer terminates in a sinuous "flame-like" edge, (3) the outer layer has a maximum ejecta mobility value greater than 6.0, and (4) the ejecta deposit cannot be classified as a normal layered, pedestal, or radial morphology [3]. To date, we have identified 114 LARLE craters in the 70.67°N to 75.75°S latitude range, although the database is complete only within ±65°. LARLE craters are slightly more common in the northern hemisphere, with 69 examples found there compared to 45 in the south.

LARLE Distribution. LARLE craters are strongly concentrated at the higher latitudes (Fig. 2): 89% of all LARLE craters are found poleward of ±35° latitude. Of the 13 equatorial examples, eight (62%) are found within Medusae Fossae Formation deposits. In the northern hemisphere, 70% of the LARLE craters occur within the Borealis Province units [5]. The distribution of LARLE craters indicates they preferentially form in geologic units consisting of fine-grained deposits. 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 ejecta morphology.

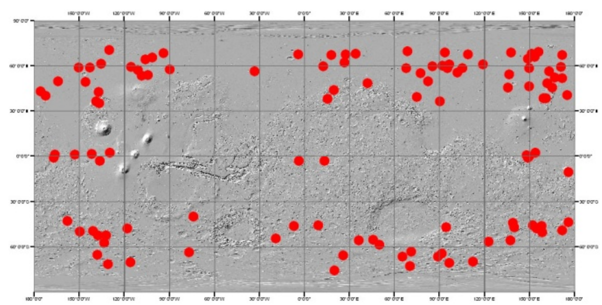

Figure 2: Distribution of LARLE craters across Mars.

LARLE Diameters. Craters displaying LARLE morphology range in diameter from the study's minimum diameter of 1.0 km to 12.5 km. LARLE morphology is more common among smaller craters: 79% of all LARLE craters are <4-km-diameter. LARLE craters larger than 6 km tend to be found at higher latitudes (Fig. 3).

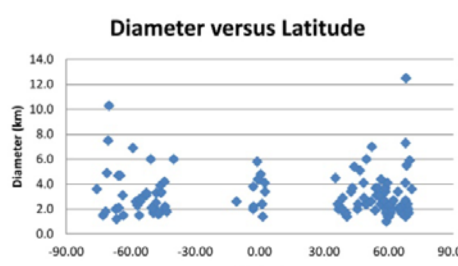

Figure 3: Diameter of LARLE craters as a function of latitude. Larger craters occur at higher latitudes.

The outer layer's radial extent (measured from the crater rim to the outermost edge of the deposit) generally displays a linear relationship to crater radius (Fig. 4).

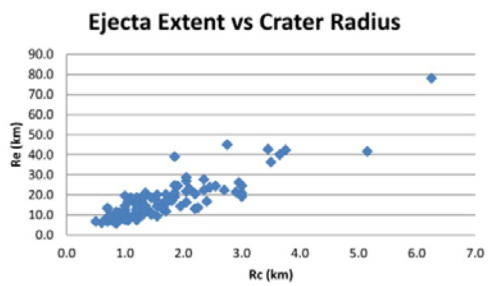

Figure 4: Maximum radial extent of outer layer (R_e) versus the crater radius (R_c). The trend is approximately linear.

LARLE Ejecta Mobility Ratios. Ejecta mobility (EM) ratio normalizes the radial extent of the 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 [6]. Maximum EM of the 114 LARLE craters in this study ranges from 6.0 to 21.1, with a median of 10.2. Highest EM values are seen for LARLE craters at higher latitudes (Fig. 5). No correlation between R_c and EM is seen.

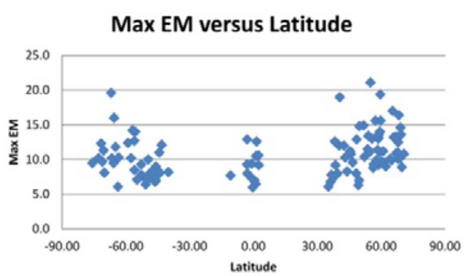

Figure 5: Distribution of maximum EM ratios for LARLE craters as a function of latitude. The highest EM ratio values are seen for craters at higher latitudes.

LARLE and Pedestal Craters: Pedestal (Pd) craters, which are small craters surrounded by an elevated pedestal, are similar in many respects to LARLE craters. Both LARLE and Pd craters display SLE or DLE morphologies superposed on a more extensive outer layer. Most Pd craters are ≤5-km-diameter although some range up to 8 km, which overlaps the diameter range of the LARLE craters. The highest concentrations of Pd craters are found poleward of ±35° latitude, with equatorial Pd craters mainly located in the Medusae Fossae Formation [7]. This is similar to the LARLE crater distribution found in this study. Mean EM of Pd craters is lower than that of LARLE craters (3.09 to 5.62 for Pd), but some Pd EM extend to values of ~8.00 [7]. Pd craters are proposed to form when sublimation removes ice from the surrounding terrain, leaving the crater and its surrounding layered deposits elevated. We propose that similarities between the distributions and characteristics of Pd and LARLE craters result from a similar origin for these two morphologies. Both form from impacts into ice-rich fine-grained deposits. The outer extensive layer is produced by collapse of an ejecta column into a radially spreading, suspension-driven, dilute gravity current [4]. This deposit can undergo cementation by melting of near-surface ice. Craters formed by this process initially display characteristics of LARLE craters. Those which have been modified by sublimation of ice in the surrounding terrain transition into Pd craters, where cementation of the outer layer allows these features to remain elevated. Examples of Pd craters with marginal sublimation pits [8] demonstrate the mechanism by which degradation of the outer layer proceeds. The current survey reveals a few examples of LARLE craters which appear to be transitioning into Pd (Fig. 6). This model explains the similar geographic distribution and diameter range of Pd and LARLE craters as well as the smaller EM of the more modified Pd craters. Our model also provides an explanation for the emplacement and cementation of the outer layer for both LARLE and Pd craters [4].

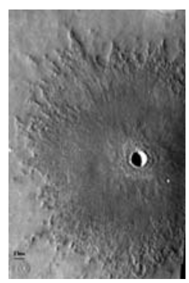

Figure 6. This 1.4-km-diameter LARLE crater (40.52°N 175.69°E; EM = 19.0) shows indications along its outer edge that it is transitioning into a Pd crater. (THEMIS V09718014)

Conclusions: Low aspect ratio layered ejecta (LARLE) craters are an unusual morphology seen primarily around craters forming in ice-rich fine-grained materials. Our global survey does not yet include latitudes poleward of ±65°, but preliminary results are consistent with our proposal that these features form from a suspension-driven dilute gravity current and are genetically related to pedestal craters. Future work includes completion of the survey 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] Barlow N.G. et al. (2000) *JGR 105*, 26733-26738. [4] Boyce J.M. et al. (2012) *LPS XLIII*, Abstract #1081. [5] Tanaka K. L. et al. (2005) *USGS Sci. Inv. Map 2888*, 1:15,000,000 scale. [6] Barlow N.G. (2005) *GSA SP 384*, 433-442. [7] Kadish S.J. et al. (2009) *JGR 114*, E10001. [8] Kadish S.J. et al. (2008) *GRL 35*, L16104.