MARTIAN LOW-ASPECT-RATIO LAYERED EJECTA (LARLE) CRATERS: CONSTRAINTS ON FORMATION MODELS FROM ANALYSIS OF LARLE DISTRIBUTION AND CHARACTERISTICS. N. G. Barlow[1] and J. M. Boyce[2], [1]Dept. Physics and Astronomy, Northern Arizona University, NAU Box 6010, Flagstaff, AZ 86011-6010; Nadine.Barlow@nau.edu, [2]Hawaii Institute of Geophysics and Planetology, University of Hawaii, Honolulu, HI 98622; jboyce@higp.hawaii.edu.

Introduction: We have previously reported on the existence of an unusual exterior morphology associated with Martian impact craters primarily located at latitudes poleward of ~±35-40° [1-4]. The craters display a typical single layer ejecta (SLE) or double layer ejecta (DLE) morphology adjacent to the crater rim but are surrounded by a much more extensive and sinuous deposit beyond the normal ejecta blanket (Fig. 1). These outer deposits extend up to 21 crater radii from the crater rim but have thicknesses less than ~10 m, resulting in very low aspect ratios (AR = thickness/length). Following the volcanology nomenclature for low-aspect-ratio ignimbrites (LARI), we call these Martian features low-aspect-ratio layered ejecta (LARLE) deposits.

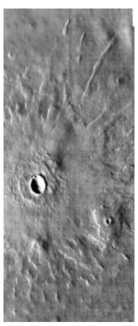

Figure 1: 5.5-km-diameter crater located at 68.27°N 266.36°E, displaying a double layer ejecta blanket and the outer sinuous and discontinuous LARLE layer. The LARLE deposit extends up to 16 crater radii beyond the crater rim.

We have completed a survey using THEMIS daytime IR (100 m/pixel resolution) and VIS (18 m/pixel) images to identify all LARLE craters ≥1-km-diameter in the ±75° latitude zone. The database includes the central coordinates of the crater, crater diameter, references of up to five THEMIS images containing the feature, the geologic unit on which the crater occurs, perimeter and area of the LARLE deposit, average deposit radius from crater rim, maximum and average ejecta mobility ratios, and lobateness of the deposit. LARLE craters are defined as those meeting the following criteria:

- The inner normal ejecta blanket displays 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.

Distribution: Our survey has identified 140 LARLE craters in the ±75° latitude zone. LARLE craters are distributed in three regions: 38 (27%) are located between 40°S and 75°S, 13 (9%) are found in the 3°N to 11°S zone, and 89 (64%) are located between 35°N and 75°N. (Fig. 2). Most of the equatorial LARLE craters are within the Medusae Fossae Formation deposits while the northern hemisphere LARLE craters primarily occur on the Vastitas Borealis interior unit (ABv_i) of [5]. The geologic units on which the LARLE craters occur range in age from Noachian through Amazonian, although all the craters appear to be of Amazonian age. A consistency among all LARLE craters is that they are located in geologic units characterized by fine-grained deposits proposed to be ice-rich.

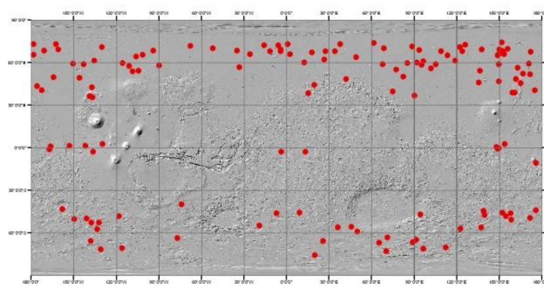

Figure 2: Distribution of LARLE craters. Background image is MOLA-derived shaded relief.

Morphometric Characteristics: LARLE craters range in diameter from 1.0 km (the lower diameter cutoff of this study) to 12.2 km, with a median diameter of 2.8 km. Most (83%) LARLE craters are smaller than 5 km in diameter. The largest LARLE craters are found at higher latitudes (Fig. 3).

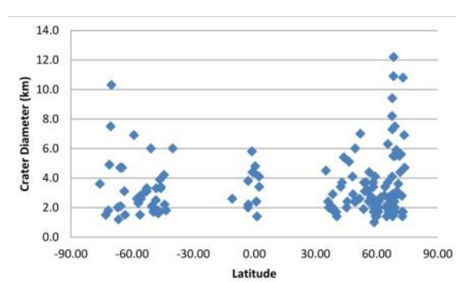

Figure 3: Crater diameter versus latitude for LARLE craters. The largest LARLE craters are found at high polar latitudes.

There is a general linear trend between the crater radius (R_c) and the average radius of the LARLE deposit (R_d) (Fig. 4).

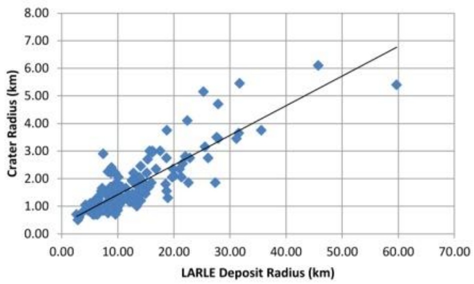

Figure 4: The average radius of the LARLE deposit generally follows a linear trend with crater radius.

The data can be fit by a linear regression of the form

$$R_c = 0.3485 + 0.1074R_d$$

The average radius of the LARLE deposit is greatest at the higher polar latitudes, but there is no unique relationship between deposit radius and latitude.

The extent of the LARLE deposit is quantified through the ejecta mobility (EM) ratio [6]:

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

We have computed both the average EM and EM of the maximum extent of the deposit ("Max EM") of the LARLE deposit. There is generally a linear trend between average and Max EM, although some scatter is seen. Average EM ranges between 2.56 and 14.81 with a median of 7.44. Max EM ranges between 6.0 and 21.4 with a median of 10.2. The highest EM values (both average and maximum) are associated with craters at higher latitudes, although there is a large range in EM values within a particular latitude zone (Fig. 5). No trend between EM and crater diameter is observed.

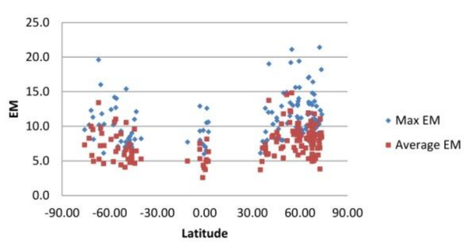

Figure 5: Distribution of average and maximum EM values as a function of latitude.

The sinuosity of the LARLE deposit is quantified by the lobateness (Γ), which compares the outer perimeter (P) to the area of the deposit (A) [7]:

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

A deposit with a circular edge has Γ =1 while more sinuous termini have Γ >1. The lobateness of the LARLE deposits ranges from 1.45 to 4.35 with a median of 2.05, which is higher than the median Γ associated with SLE, DLE, or multiple layer ejecta (MLE) morphologies [4]. LARLE deposits display no trends between Γ and latitude, crater diameter, or EM.

Discussion and Implications for LARLE Formation: Our survey of the distribution and characteristics of craters displaying a LARLE deposit reveal a number of properties which can help constrain the formation mechanism of this unusual morphology. LARLE craters are found within deposits of ice-rich fine-grained materials. Craters displaying the LARLE morphology tend to be small—standard depth-diameter relationships indicate that these craters are excavating to depths of a few hundred meters, which is well within the thickness estimates of the fine-grained deposits. This suggests that the craters are excavating entirely within the fine-grained ice-rich mantling deposits—this likely explains why the LARLE morphology is not seen around larger craters or around most craters within the equatorial region of the planet where such deposits are thin or non-existent.

The LARLE deposit occurs in addition to a normal SLE or DLE morphology. The LARLE deposit has much greater extent (EM) and sinuosity (Γ) than those of normal SLE, DLE, or MLE deposits [3, 4], indicating a different emplacement mechanism. The low aspect ratio and large EM and Γ values of these deposits are comparable to those associated with base surge deposits created during large chemical and nuclear explosions and high-viscocity volcanic events on Earth. A test to predict the EM of two LARLE craters using the fluid dyanamics equations for base surge deposits gives remarkable consistency with observed values [8]. We therefore propose that impact excavation into ice-rich fine-grained deposits produces a base surge of primary ejecta which creates the LARLE deposits observed around this unique group of Martian impact craters [9].

References: [1] Barlow N. G. and Boyce J. M. (2008) *LPSC XXXIX*, Abstract #1164. [2] Boyce J. M. et al. (2008) *LPSC XXXIX*, Abstract #1406. [3] Barlow N. G. and Boyce J. M. (2012) *LPSC XLIII*, Abstract #1253. [4] Barlow N. G. and Boyce J. M. (2012) *3rd Planet. Crater Consortium Mtg*, Abstract #1204. [5] Tanaka K.L. et al. (2005) *USGS Sci. Invest. Map 2888*, 1:15,000,000 scale. [6] Barlow N. G. (2005) *GSA SP 384*, 433-442. [7] Barlow N. G. (1994) *GRL, 99*, 10927-10935. [8] 3] Boyce, J., et al., (2012) *LPSC XLIII*, Abstract #1017. [9] Boyce J. M. et al. (2013) *LPSC XLIV*, Abstract #1004.