SIZES AND DISTRIBUTIONS OF THE TWO MORPHOLOGIC TYPES OF DOUBLE LAYER EJECTA CRATERS IN THE NORTHERN HEMISPHERE OF MARS. N. G. Barlow, Dept. Physics and Astronomy, Northern Arizona University, Flagstaff, AZ 86011-6010 Nadine.Barlow@nau.edu.

Introduction: Double Layer Ejecta (DLE) craters are defined as having two complete ejecta layers surrounding the crater [1]. However, the DLE morphologies of craters at mid- to high-latitudes are different than those of craters at lower latitudes. The higher latitude (henceforth "Type 1") DLE deposits are characterized by a thick inner layer and thin outer layer. The thick inner layer typically terminates in a broad distal rampart, unlike the narrower ramparts at the edges of the outer thinner layer [2]. The sinuosity of the inner layer is much lower (i.e., more circular) than the outer layer [3]. A topographically depressed moat occurs adjacent to the crater rim and a strong radial texture composed of troughs and ridges extend from near the crater rim across the entire continuous ejecta blanket [2]. The broad rampart of the inner ejecta layer often is composed of hummocks, elongated blocks, fractured material, and other indicators of material disruption caused by decreases in flow velocity (Fig. 1).

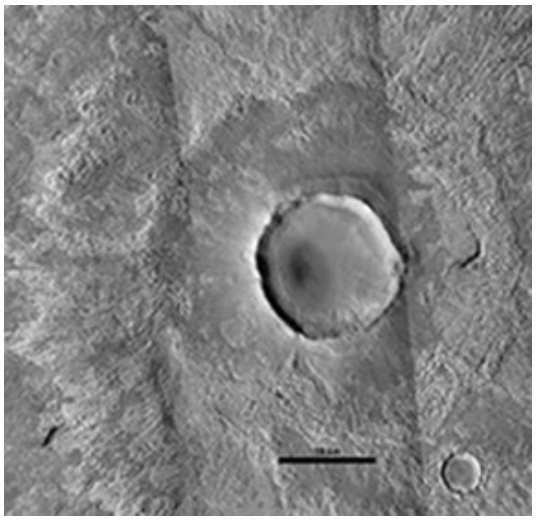

Figure 1: CTX mosaic of a "Type 1 DLE" crater. Crater is 15.1 km in diameter and located at 40.95°N 98.28°E. Scale bar is 10 km.

Type 1 DLE craters are typically found in the ~30°-50°S and 25°-60°N latitude zones [4]. DLE craters at lower latitudes are more similar in morphologic appearance to single layer ejecta (SLE) and multiple layer ejecta (MLE) craters. In this case, both ejecta layers appear thin, are terminated by narrow ramparts, and display similar lobate sinuosities. We classify these morphologies as "Type 2 DLE" craters (Fig. 2).

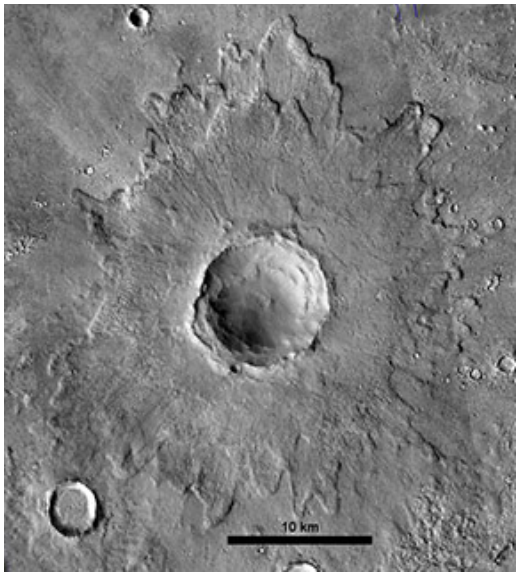

Figure 2: CTX mosaic of a "Type 2 DLE" crater. Crater is 9.1 km in diameter and centered at 41.47°N 4.89°E. Scale bar is 10 km.

The two types of double layer ejecta morphologies are proposed to form by different mechanisms. Type 2 are proposed to form in a manner similar to SLE and MLE craters, which are generally thought to form by a combination of ballistic and flow processes [2, 5-6]. Several formation models have been proposed for the Type 1 deposits, including flow versus base surge [2], debris flow [7], and impact into a glacial substrate followed by mass movement [8]. While Type 2 DLE craters are typically found at lower latitudes than Type 1 DLE craters, there are exceptions. Investigating the sizes and spatial distributions of Type 1 versus Type 2 DLE craters may provide insights into the environmental conditions under which these two morphologies form and thus help to constrain the formation mechanism of these different classes of DLE crater.

Methodology: DLE craters in the northern hemisphere of Mars are being classified as Type 1 or Type 2 based on their morphologic characteristics as revealed in Thermal Emission Imaging System (THEMIS) visible (18 m/pixel) imagery. The craters in this study are derived from those classified as DLE craters in the *Revised Catalog of Large Martian Impact Craters* [9]. This study has thus far classified 862 DLE craters in the 30°N to 75°N latitude zone. Classification into Type 1 or Type 2 depends on the presence

of the characteristic morphologic features described above for each class.

Information about each crater's location, diameter, and preservational state are included from the original *Catalog*. In addition to the classification of each crater as a Type 1 or Type 2, this study also is noting whether the radial texture of grooves and ridges is detected at the THEMIS VIS resolution. All information is collected into an Excel datasheet and transferred into ArcGIS shapefiles for analysis.

Preliminary Results: Considering the latitude zone studied thus far, it is not surprising that the majority (677 craters, or 79%) of the DLE craters are classified as Type 1. Type 2 craters comprise 13% (115 craters) of the craters studied to date. The remaining 8% (69) are classified as transitional between Types 1 and 2 since they display characteristics of both types.

Figure 3 shows the distribution of the Type 1 (red squares), Type 2 (green triangles), and transitional (blue circles) DLE craters. This map shows that there is no strong latitudinal or regional variation in the distribution of the different DLE types within the current study area.

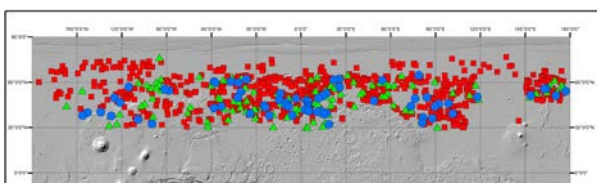

Figure 3: Distribution of Type 1 (red squares), Type 2 (green triangles), and transitional (blue circles) DLE craters. The overall distribution shows no strong latitudinal or regional concentrations of the three DLE crater types. Classification of DLE craters in the region immediately north of Elysium Mons has not been completed. Background image is MOLA shaded relief map.

Type 1 and transitional DLE craters are found in similar diameter ranges. The lower diameter cut-off for this study is 5 km. Type 1 DLE craters are found in the 5.0 to 23.0 km diameter range while the transitional DLE craters have diameters between 5.0 and 19.9 km. The Type 2 DLE craters show the largest diameter range with craters ranging from 5.0 to 115.5 km. Type 1 craters dominate at diameters <14 km. Transitional DLE craters reach their highest concentrations in the 14-20 km diameter range while Type 2 DLE craters dominate at diameters >20 km.

We divided the study area into 5° latitude zones to investigate the role of latitude on the different DLE types. Type 1 dominates at all latitudes within the study region. Type 2 DLE craters reach their highest concentrations in the 30°-45°N zone. Transitional craters have their peak concentrations in the 35°-45° region.

We also investigated DLE type as a function of both diameter and 5° latitude zone. No strong trends other than those already seen with the individual diameter and latitude analyses were revealed.

Not all DLE deposits display the radial texture of grooves and ridges that have been stated to be a major characteristic of the Type 1 DLE craters. This analysis reveals that 25% of the Type 1 DLE, 27% of the Type 2 DLE, and 57% of the transitional DLE display the radial structure at THEMIS VIS resolution. While most craters which clearly display the radial texture are preservationally among the freshest craters, there also are many very fresh craters which do not display observable grooves and ridges. Latitude and crater diameter do not strongly affect the presence or absence of the radial texture across the ejecta deposits.

Conclusions and Future Work: The preliminary results of this study show that while Type I DLE craters dominate within the 30°N-75°N region, there are a reasonable number of Type 2 and transitional DLE craters in this same region. Crater diameter seems to be the major contributor to the type of DLE crater, with craters <14 km in diameter tending to be Type 1, craters in the 14-20 km range showing transitional morphologies between the two types, and larger craters tending to show Type 2 characteristics.

Future work includes completing the analysis for the 0°-30°N latitude zone, extending the analysis to DLE craters in the southern hemisphere, and investigating the role of terrain properties on the formation of the different DLE morphologies. Higher resolution Context Camera (CTX; 6 m/pixel) will be used to determine if the classification of DLE type and the presence/absence of the radial texture undergoes changes from the THEMIS VIS analysis. The eventual goal of this project is to provide observational constraints on the possible formation models proposed for the Type 1 DLE craters.

References: [1] Barlow N. G. et al. (2000) *JGR, 105*, 26733-26738. [2] Boyce J. M. and Mouginis-Mark P. J. (2006) *JGR, 111*, E1005, doi: 10.1029/2005JE002638. [3] Barlow N. G. (1994) *JGR, 99*, 10927-10935. [4] Barlow N. G. and Perez C. B. (2003) *JGR, 108*, E8 5085, doi: 10.1029/2002JE002036. [5] Oberbeck V. R. (2009) *MAPS, 44*, 43-54. [6] Osinski G. R. et al. (2011) *EPSL, 310*, 167-181. [7] Wulf G. and Kenkmann T. (2014) *LPSC XLV*, Abstract #1792. [8] Weiss D K. and Head, J. W. (2013) *GRL, 40*, 3819-3824. [9] Barlow N. G. (2006) *LPSC XXXVII*, Abstract #1337.