CRITERIA FOR DISTINGUISHING BETWEEN THE TWO TYPES OF DOUBLE LAYER EJECTA (DLE) CRATERS ON MARS. N. G. Barlow[1] and J. M. Boyce[2], [1]Dept. Physics and Astronomy, Northern Arizona University, Flagstaff, AZ 86011-6010 Nadine.Barlow@nau.edu. [2]Hawaii Institute of Geophysics and Planetology, University of Hawai'I, Honolulu, HI 96822 jboyce@higp.hawaii.edu.

Introduction: Double layer ejecta (DLE) craters are defined as craters with two complete ejecta layers [1]. However, high resolution imagery of Martian craters shows that there are two distinctly different morphologic types of DLE craters [2]. The first type, labeled here as Type 1 DLE craters, displays a thicker inner layer terminating in a broad rampart and a thinner outer layer terminating in a sharper, narrower rampart (Fig. 1). A topographical moat occurs just beyond the crater rim and a strongly lineated texture of grooves and ridges extends radially outward across the inner layer [3].

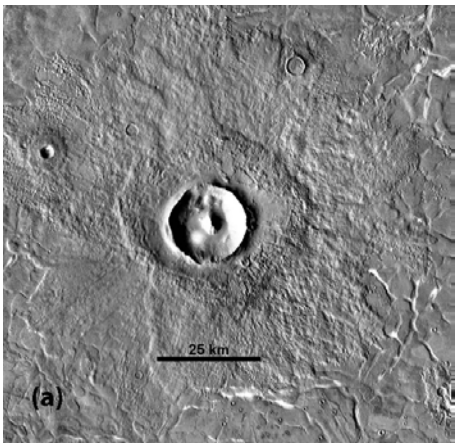

Figure 1: Example of a DLE crater displaying morphologic characteristics of a Type 1 DLE crater. Crater is 19.5 km in diameter and centered at 38.53°N 99.22°E. (THEMIS daytime IR global mosaic).

The second type ("Type 2 DLE craters") appear morphologically similar to single layer ejecta (SLE) and multiple layer ejecta (MLE) craters but with two layers. Detailed studies are beginning to reveal that the two types of DLE craters display distinct morphologic and morphometric characteristics, indicating that they form by different mechanisms [4, 5]. Therefore studies of DLE craters must be careful to distinguish among the two types in order to not mix their characteristics.

Criteria to Distinguish Type 1 and Type 2 DLE Craters: We have discovered that morphologic appearance alone is insufficient to distinguish between Type 1 and Type 2 craters. We therefore propose the following criteria to be used to distinguish a Type 2 DLE crater from a Type 1: Morphologic appearance, moat, inner layer characteristics, outer layer characteristics, and lineated texture. Both image and topographic data are needed to clearly distinguish between the two types.

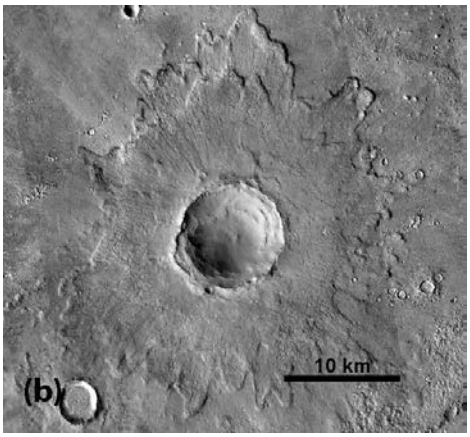

Figure 2: This DLE crater displays the morphologic characteristics of a Type 2 DLE crater. Crater is 9.1 km in diameter and centered at 41.47°N 4.89°E.

Morphologic Appearance: All DLE craters display two ejecta layers, by definition. However, familiarity with the range of DLE craters across Mars revealed that there are two distinct morphologic types, largely seen in the characteristics of the inner layer. The Type 1 DLE craters have a thicker, less extensive, and more circular inner layer whereas the inner layer of Type 2 DLE craters is thinner, has a larger ejecta extent, and is more sinuous. However, image analysis of the morphologic appearance alone is insufficient to determine if the crater is a Type 2 DLE. First, some inner ejecta layers display characteristics of both the Type 1 and Type 2 inner layers: for example, a thick inner layer that is highly sinuous. [4] labeled these as "transitional DLE craters", but addition of other criteria is expected to help better distinguish the Type 1 and 2 DLE craters from each other.

Moat: Topographic profiles across a larger number of DLE craters revealed that Type 1 DLE craters are characterized by having a well-defined moat present just beyond the crater rim [3]. A recent study of SLE, MLE, and Type 2 DLE craters reveals that a similar moat is not present for these morphologies [5]. Therefore the presence of a near-rim moat is a distinguishing characteristic of a Type 1 DLE craters.

Characteristics of Inner Layer: The inner ejecta layer displays distinctive differences among the Type 1 versus Type 2 DLE craters. Topographic profiles often

reveal it to be considerably thicker than the outer layer of Type 1 DLE craters, but occasionally Type 2 craters also display a thicker inner layer. The inner layer of Type 1 DLE craters often maintains a relatively constant elevation between the moat and the terminal rampart whereas that of Type 2 DLE craters often thins with increasing distance from the rim out to the rampart. The distal rampart of Type 1 DLE craters is wider than the rampart associated with SLE and MLE craters [6]. The rampart of Type 2 DLE craters is similar in width to those seen with SLE and MLE craters [5].

Characteristics of Outer Layer: The outer layer of Type 1 DLE craters is considerably thinner than the inner layer. The outer layer of Type 2 DLE craters is thinner than the inner layer, but there is considerable variation in terms of its thickness relative to the inner layer. Many times the two layers are almost comparable in thickness while in other situations the inner layer is noticely thicker. In both cases, the outer layer terminates in a narrow rampart, with the rampart of the Type 2 outer layer being similar in width to those seen for SLE and MLE craters. The outer layer rampart for Type 1 DLE craters is narrower than the width of the inner layer rampart, but it is still wider than those seen for SLE, MLE, or Type 2 DLE ramparts [5].

Lineated Texture: A radial pattern of grooves and ridges extending outward from the crater rim is commonly seen on the freshest crater ejecta blankets [7]. A lack of radial texture appears to simply be the result of rapid removal of these features by degradation processes rather than a primary characteristic of fresh craters. Grooves are seen crossing all ejecta layers of SLE, MLE, and Type 2 DLE craters, but typically only cross the inner layer of Type 2 DLE craters. Radial grooves on the layers of each type are generally straight, but those on the outer layer of DLE Type 1 craters commonly are curvilinear. Average groove width when normalized to crater diameter decreases as crater diameter increases. The rate at which this normalized groove width declines depends on ejecta morphology, declining less rapidly for the Type 1 DLE craters than for other ejecta types [5]. The width of the grooves also widen considerably outward from a distance of about 0.5 crater radii from the rim for Type 1 DLE craters. For all other ejecta types, the width of the grooves remains almost constant with distance.

Conclusions: Two distinctly different types of DLE craters are observed on Mars. Morphologic appearance alone is insufficient to distinguish between these two types. We therefore are developing a list of criteria by which to classify a DLE crater as Type 1 or Type 2. To date we have identified morphologic and morphometric characteristics associated with the two ejecta layers which can help us distinguish between the two DLE types. We are investigating other potential parameters, such as ejecta mobility ratio and lobateness, to determine if they also can be utilized.

The characteristics observed thus far for the two types of DLE craters suggest different emplacement processes. The Type 1 DLE craters have long been recognized as being formed by a different process than SLE and MLE craters and the results of this investigation support that idea. We find that the characteristics of Type 2 DLE craters, however, are similar enough to those of SLE and MLE craters that they all likely formed by a similar process.

References: [1] Barlow N. G. et al. (2000) *JGR, 105*, 26733-26738. [2] Barlow N. G. (2015) *46th LPSC*, Abstract #2216. [3] Boyce J. M. and Mouginis-Mark P. J. (2006) *JGR, 111*, E1005. [4] Barlow N. G. (2015) in *Large Meteorite Impacts and Planetary Evolution V*, GSA Special Paper 518, in press. [5] Boyce J. M. et al. (2015) *6th Planetary Crater Consortium*, this meeting. [6] Boyce J. M. et al. (2010) *MAPS, 46*, 638-661. [7] Boyce J. M. et al. (2015) *46th LPSC*, Abstract #1043.