QUASI-MULTIPLE LAYER EJECTA CRATERS: AN UNUSUAL MARTIAN EJECTA MORPHOLOGY.
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Introduction: Quasi-multiple layer ejecta (QMLE) craters are an unusual ejecta morphology surrounding some fresh Martian impact craters at primaryly high latitudes. QMLE craters are characterized by a single layer or double layer ejecta morphology superposed on an extensive outer thin layer which terminates in a sinuous "flame-like" edge. We first reported on the existence of these unusual craters in 2008 with the identification of five craters at high northern latitudes [1]. We are currently conducting a global survey of the distributions of QMLE craters and have identified 42 examples within the southern hemisphere alone. The distributions and characteristics of these craters are similar to pedestal craters, suggesting a similar formation mechanism.

QMLE Crater Characteristics: The 5.5-km-diameter crater shown in Figure 1 illustrates the characteristics of QMLE craters. The initial five craters identified in 2008 all displayed a typical double layer ejecta (DLE) morphology superposed on a third, more extensive layer which often becomes discontinuous at the distal edges. According to the nomenclature suggested by the Mars Crater Consortium [2], any crater with three or more continuous or partial ejecta layers is classified as a multiple layer ejecta (MLE) crater. However, QMLE craters are morphologically different from the standard MLE craters. This is the reason we call these quasi-multiple layer craters. However, our survey of craters in the southern hemisphere suggests that some QMLE structures may have a single layer ejecta (SLE) superposed on the outer layer. Higher resolution analysis may reveal that these actually are double layer deposits. If not, we may need to consider a new name for the QMLE craters.

The outer layer of the QMLE morphology appears thinner than the inner SLE or DLE deposits. It is characterized by flame-like distal margins, with some deposits extending beyond the continuous layer. The extent of an ejecta deposit is quantified by the ejecta mobility ratio (EM) [3]:

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

where R_e = maximum ejecta extent, measured from the crater rim, and R_c = crater radius. Typical EM values for SLE, DLE (outer layer), and MLE (outer layer) craters are 1.53, 3.24, and 2.17, respectively. In comparison, the maximum EM for QMLE craters range between 6.10 and 20.44. Thus, the outer layer of the QMLE craters is much more extensive than that of normal layered ejecta blankets, suggesting enhanced flow during emplacement.

The initial five QMLE craters were found between 68.2°N and 72.9°N, suggesting that these craters might only be found in high latitudes where fine-grained icy deposits occur. We have recently begun a systematic survey of the entire planet using THEMIS daytime IR and VIS images to determine if this initial conclusion is valid. Our survey focused on craters larger than about 1 km in diameter displaying ejecta deposits with EM greater than 6.0. The outer ejecta layer had to show the highly sinuous nature of the QMLE deposits with a more traditional SLE or DLE ejecta morphology superposed on the outer layer. Pedestal craters and craters with thermally distinct rays were not included in this list.

We have completed the survey of the southern hemisphere, where we have identified 42 QMLE craters. Out of these 42 craters, 40 (95%) are found at latitudes poleward of 40°S (Figure 2). The two craters found at lower latitudes are a 2.6-km-diameter crater southeast of Apollinaris Mons and a 3.8-km-diameter crater in a sand deposit within Schiaparelli Crater. Thus our earlier conclusion that QMLE craters preferentially form at high latitudes is supported by the southern hemisphere data.

The initial five QMLE craters discovered in the northern hemisphere ranged in diameter from 5.5 to 12.6 km in diameter. The southern hemisphere QMLE craters range in diameter from 0.7 km to 10.3 km. Thirty-seven of the 42 craters (88%) are smaller than 5-km-diameter.

QMLE and Pedestal Craters: Pedestal craters display many of the same characteristics as QMLE craters, including a SLE or DLE morphology superposed on a more extensive outer layer [4]. EM values vary considerably for pedestal craters, ranging from 1.2 to 13.2 [1]. Pedestal craters are typically smaller than 2.0-km-diameter, are primarily found at latitudes poleward of ±35° latitude, and both the crater and surrounding layers are elevated above the surrounding terrain [4]. Pedestal craters are proposed to form by impact into ice-rich fine-grained materials deposited at mid- to high-latitudes during periods of high obliquity. As the planet moves to lower obliquity, ice in these

deposits sublimates, lowering the surrounding terrain and leaving the pedestal crater and surrounding deposit elevated above the surroundings.

The similarity of location, EM, and morphology between pedestal and QMLE craters suggests that they may share a common origin. We propose that the outermost extensive layer of QMLE and pedestal craters form by a similar mechanism, requiring impact into the ice-rich fine-grained materials primarily found at the higher latitudes. There are reports in the literature of terrestrial ignimbrite flows traveling over the ocean with very long run-out distances and low aspect ratios [5]. We propose that impact into fine-grained ice-rich materials follows similar physics to what has been observed with the ignimbrite flows and could be the mechanism by which the extensive outer flow of QMLE and pedestal craters is formed [6].

References: [1] Barlow, N. G. and Boyce, J. M. (2008) *LPS XXXIX*, abstract #1164. [2] Barlow, N. G. et al. (2000) *JGR*, *105*, 26733-26738. [3] Mouginis-Mark, P. (1979) *JGR*, *84*, 8011-8022. [4] Kadish S. J. et al. (2009) *JGR*, *114*, E10001, doi: 10.1029/2008JE003318. [5] Freundt A. (2003) *Bull. Volcanol.*, *65*, 144-164. [6] Boyce J. M. and Barlow N. G. (2011), this meeting.

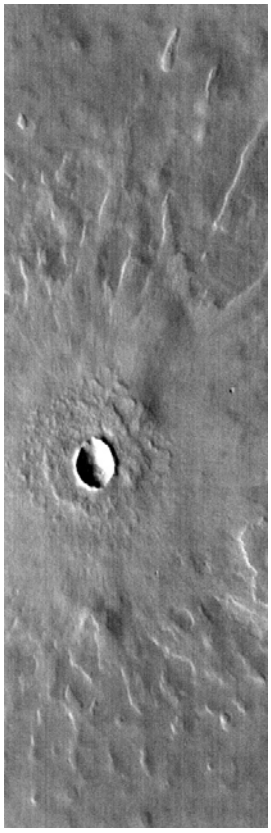

Figure 1: Example of a quasi-MLE crater. This 5.5-km-diameter crater is located at 68.27°N 266.36°E. The outer ejecta layer extends up to 17.4 crater radii from the rim. (THEMIS image I04073002)

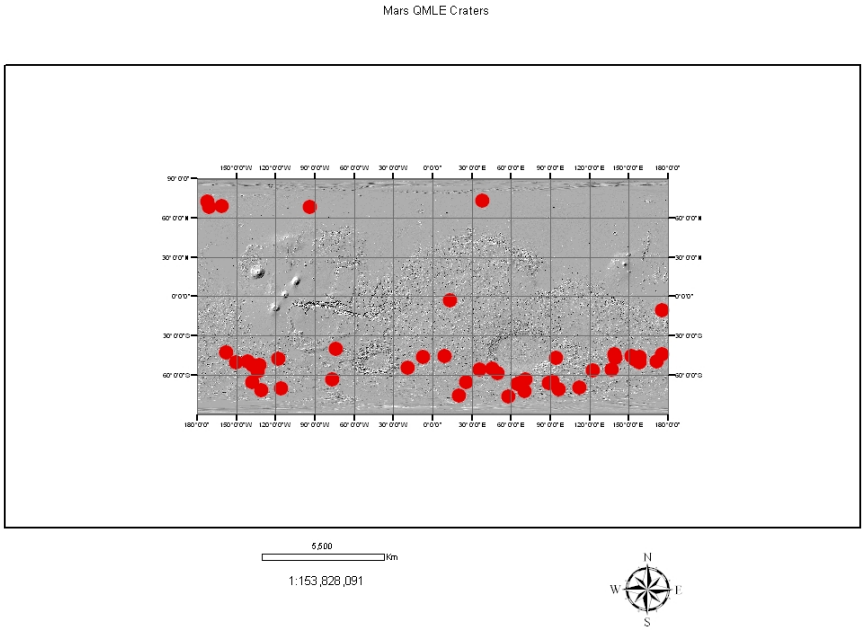

Figure 2: Distribution of QMLE craters. Southern hemisphere survey is complete; northern hemisphere survey is only beginning.