QUASI-MLE CRATERS: AN UNUSUAL CRATER MORPHOLOGY AT HIGH MARTIAN LATITUDES.
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Introduction: A unique impact crater morphology is found at high latitudes on Mars. These craters display a double-layer ejecta (DLE) morphology similar to other DLE craters in these regions. However, the DLE morphology is superposed on a third, very extensive ejecta layer. By definition, these craters should be classified as multiple-layer ejecta (MLE) craters [1], but they do not display the characteristics of MLE craters seens elsewhere on the planet. We therefore call these high-latitude unusual craters "quasi-MLE craters". Quasi-MLE craters have similar characteristics to the much smaller pedestal (Pd) craters. We propose that quasi-MLE and Pd craters have similar origins.

Quasi-MLE Craters: The 5.5-km-diameter crater shown in Fig. 1 illustrates the characteristics of quasi-MLE craters. A double-layer ejecta (DLE) structure, similar to those of other DLE craters in the region, surrounds the crater within 2.4 crater radii of the rim. The two DLE layers are superposed on a third, much more extensive layer which typically becomes discontinuous at the distal edges. According to the ejecta nomenclature proposed by the Mars Crater Consortium [1], any crater with three or more continuous or partial ejecta layers is classified as a multiple-layer ejecta (MLE) crater. However, the crater shown in Fig. 1 is morphologically distinct from lower-latitude MLE craters. To distinguish this unusual structure from the more typical MLE morphology, we call these unique high-latitude structures "quasi-MLE craters".

We are conducting a survey to determine the distribution and ejecta characteristics of quasi-MLE craters on Mars. To date we have identified five examples of this unique crater ejecta class. These five craters are all found near 70°N latitude but at a range of latitudes within the Vastitas Borealis Formation. They range in diameter from 5.5- to 12.6-km in diameter (Table 1). We are extending our survey to the southern polar region to determine whether quasi-MLE craters are found at both poles or if they are only a north polar region phenomenon.

Table 2 compares the average ejecta mobility ratio (*EM*) and lobateness (Γ) of the quasi-MLE craters with those of typical DLE and MLE craters. Ejecta mobility ratio is a normalized measure of the ejecta extent [2, 3]:

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

where R_e = maximum ejecta extent, measured from the crater rim, and R_c = crater radius. The interior DLE structure of the quasi-MLE craters has slightly larger EM for both the inner and outer DLE layers compared to those of other DLE craters in the northern plains. The outer layer has much higher EM than either DLE or MLE craters.

Lobateness (Γ) is a measure of the sinuosity of the layered ejecta deposits [4]. It is defined in terms of ejecta area (A) and perimeter around the edge of the ejecta deposit (P):

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

Γ for the inner DLE layers of the quasi-MLE craters is higher than that of typical DLE craters. Γ for the outermost layer of quasi-MLE craters is much greater than that of typical DLE or MLE craters.

Pedestal Craters: Pedestal (Pd) craters are small (typically <2-km-diameter) craters found at high latitudes on Mars (typically in the 40°-60° latitude range in both hemispheres [5]). They are characterized by both the crater and ejecta blanket being elevated above the surrounding terrain. Pd craters typically display one or two inner layers superposed on an extensive outer layer and appear morphologically similar to the quasi-MLE craters except for their smaller size and elevated topography. *EM* for the outer layer of Pd craters in the northern hemisphere ranges between 1.2 to 13.2 with a mean of 3.27. Γ for the Pd outer layer ranges between 1.01 to 2.49 with a mean of 1.1.

Discussion and Implications: Quasi-MLE craters are a unique crater-form found at high latitudes on Mars. Their inner DLE structure is slightly larger in *EM* and Γ compared to other northern hemisphere DLE craters and they sometimes display other ejecta structures commonly seen in DLE craters (such as a moat at the base of the rim and radial grooves in the inner ejecta layer) [6]. Their outermost layer is much more extensive and sinuous than that seen for the outer layer of typical DLE or MLE craters. The high *EM* and Γ values of the outer layer suggest it was very-volatile rich when emplaced. This is consistent with the volatile-rich nature of the target material as indicated by geologic mapping [7], neutron spectrometer data [8], and ground-penetrating radar [9].

Quasi-MLE craters display morphologic similarities to the smaller Pd craters. Quasi-MLE craters display higher *EM* and *Γ* values than Pd craters and are located closer to the poles. Pd crater ejecta must be armored against erosion in order to remain elevated above the surroundings—one possible mechanism is the production of excess impact melt during impacts into volatile-rich targets, which has been proposed on theoretical grounds [10] and observed at Haughton Crater [11]. Kadish and Barlow [5] proposed that sublimation of ice in the surrounding target during obliquity variations produce the topographically-elevated Pd craters. Quasi-MLE craters may be the larger-crater version of Pd craters, with the outer extensive layer containing large quantities of impact melt produced during impact into the volatile-rich Vasitatas Borealis Formation. The higher latitude at which quasi-MLE craters are found would contain higher volatile concentrations, increasing *EM* and *Γ* of the associated ejecta deposits. A base surge mechanism lubricated by the target volatiles may explain the very large runout distances of the ejecta associated with these craters [12]. Ejecta deposits of the larger quasi-MLE craters are likely thicker than those of the smaller Pd craters which, combined with the lower sublimation rates at higher latitudes, would prevent quasi-MLE craters from being topographically elevated above the surroundings like Pd craters.

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Table 1: Characteristics of Quasi-MLE Craters

	Crater 1	Crater 2	Crater 3	Crater 4	Crater 5
Latitude	68.27N	68.44N	69.02N	72.83N	72.89N
Longitude	266.36E	189.31E	199.27E	188.44E	38.32E
Diameter (km)	5.5	12.6	8	6.3	11.5
Inner Layer					
Γ	1.16	1.10	1.15	1.14	1.26
EM	2.13	1.94	2.02	2.11	2.10
Intermediate					
Γ	1.19	1.16	1.41	1.27	1.65
EM	3.52	3.68	3.20	4.26	3.86
Outer Layer					
Γ	2.15	1.56	1.34	1.18	1.75
EM	20.44	10.29	8.47	9.22	10.50

Table 2: Comparison of Quasi-MLE, DLE, and MLE

	Γ	EM
Quasi-MLE		
Inner Layer	1.16	2.06
Intermediate	1.34	3.70
Outer Layer	1.60	11.78
DLE		
Inner Layer	1.09	1.52
Outer Layer	1.14	3.38
MLE		
Outer Layer	1.18	2.90

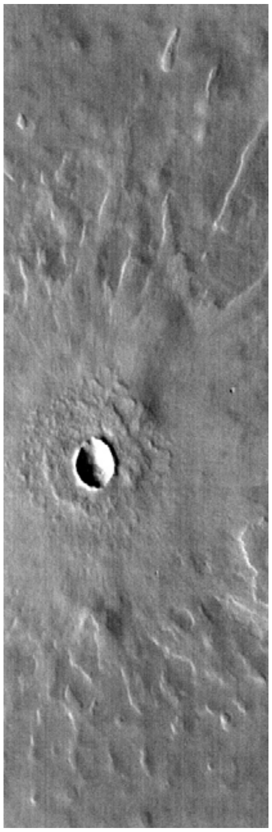

Figure 1. Example of a quasi-MLE crater. This 5.5-km-diameter crater is located at 68.27°N 266.36°E. The outer ejecta layer extends up to 17.4 crater radii from the rim. (THEMIS image I04073002)