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Martian Mid-Latitude Craters with Unusual Rim Deposits: Evidence for Volatiles or Topographic Control?

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Introduction: The study of Martian craters have revealed a diverse record with some unique morphologies. [1] recognized the existance of several types of impact craters on Mars an the influence of surface flow on ejecta emplacement. The formation of ramparts has also been attributed to atmospheric effects rather than to volatiles. Later, [2, 3] cautioned that some of these morphologies could form when fine-grained material is accelerated by the atmosphere and incorporated into a ground-hugging debris flow. Here, we examine the nature of unusual deposits forming massive bulges found on three curious mid-latitude craters similar in size. This study is part of an assessment of double-layered ejecta craters ≤ 20 km in diameter on the northern plains.

Analysis: For this analysis, five data sets were integrated: Viking Orbiter and Mars Orbiter Camera (MOC) images, visible- and infrared-bands from Thermal Emission Imaging System (THEMIS), and topography from Mars Orbiter Laser Altimeter (MOLA). Three lobate ejecta craters located within a 10-degree latitudinal band on the northern plains display an unusual bulge structure on their rims. All three craters are ≤ 15 km in diameter with bulges on their western side. Based on the size/frequency distribution for the young Martian plains, ≤ 10% of the craters here are in the 7-15 km size range [4]. Importantly, as described in more detail below, the general morphology of these craters is very similar.

Crater at 28.3º N, 116.7º E. Viking images for this 14.9 km diameter crater located on northwestern Elysium Planitia reveal a double-layered ejecta and a central peak. They also show an unusual, massive structure located on the crater's southwestern rim (Figure 1a). Because the ejecta follow the outline of this deposit, it seems reasonable to conclude that it formed at the same time the crater was created. Recent studies by [5] and [6] have found evidence that ejecta emplacement on double-layered ejecta crater does not occur as a single unit. Thus they conclude that the inner and outer ejecta layers are created by different mechanisms.

A Digital Elevation Model (DEM) created using the IDL-based program GRIDVIEW [7], based on MOLA gridded data (256 pixel/degree in latitude and longitude), confirmed the existence of the topographic bulge. To better constrain its morphology, we extracted a series of topographic profiles through the bulge and the center of the crater. The DEM shows clearly that the south rim of the crater stands slightly more than 100 m above the north rim (slope = 0.2º). Moreover, the crater floor seems to dip ~1º NE. The lobe measures ~8 km in the E-W direction, and ~4 km N-S, with the highest elevation corresponding to ~3,970 m below the planetary mean radius. Comparison of day and night THEMIS-IR shows no apparent features or internal structure within the bulge. However, day-IR imaging also shows a tail of material ~180 degrees from the bulge. Thus, this deposit is composed of fine-grained material that cools more rapidly at night [8].

Crater at 31.2º N, 88.7º E. Located SW of Utopia Planitia a ~7.3-km diamter crater displays a circular feature on its northwestern rim resembling that on the crater at 28.3º N. Profiles extracted from the gridded MOLA topography give an elevation difference of ~40 m between the NW and SE side of the rim. Although the ejecta on this crater is more degraded than on the 15-km crater, a rayed-ejecta texture and an antipodal tail are also observed. In contrast, the bulge's topography is not massive and does not have a moat at the intersection with the rest of the ejecta blanket. Unfortunatly, the night THEIMS-IR data is not available to compare with the day-IR data for this crater.

Crater at 38.0º N, 338.8º E. An 11.6 km unnamed crater south of Acidalia Planitia (Figure 1c) also displays an unusual accumulation of material on its southwestern rim. In the case of this crater, the deposit is not as evident as on the other two craters and small "knobs" are found on its surroundings, with the ejecta deflecting around some of them. THEMIS night- and day-IR images does not reveal any distinctive characteristics on the bulge or the ejecta blanket.

Discussion: Analysis of the bulges' extension, as measured from its edge to the crater's rim gives a ratio of ~0.6 to 0.8 R, where R is the crater's radius. Five origins for the unusual deposit are possible: (a) a pre-existing crater buried by the excavation of these 3 craters, (2) an oblique impact, (3) shallow ground-ice, (4) pre-existing topography, and (5) a combination of factors. The lack of a butterfly pattern on the ejecta blanket and the round-shaped rim on these craters argues against an oblique impact origin. Likewise, the lack of a significant structural complexity as seen by IR data argues that the bulges' formation does not depend on a compositional difference within the target material, but rather on the emplacement mechanism and its interaction with the pre-existing topography.

Coincidentally, two of the three craters have an antipodal tail to the bulge, suggesting that a jet formed during the excavation of the crater as a consequence of a collision with a pre-existing topographic relief. The circular outline of the bulge limits the possibilities for the origin of the topographic obstacle. Therefore, a pre-existing impact crater seems like the best candidate. However, we were not able to find convincing evidence suggesting that this could be the case for any of the three craters. When looking at examples of multiple craters we found that infilling or encroachement by ejecta material is common. So, the preferred topography that could control the formation of these unusual deposits are pitted cones or domes. [9] found a concentration of pitted cones and domes in Acidalia Planitia and Cydonia Mensae, with the ones south of 40.5° N latitude having a more cone-like morphology. They interpreted these structures to be either mud volcanoes or spring deposits.

The similarities of these features in size, location and geometry suggests similar formation processes for all of them. Perhaps the slight differences in topography (i.e. how massive the bulge is) result from weathering of the deposit. If so, the 15-km crater is the freshest and therefore youngest, whereas the more degraded 11.6-km crater is the oldest. A more detailed analysis need to be done in order to confirm the origin and evolution of these features. A fourth smaller crater with a possible unusual rim deposit was found. In this case, the bulge is also on the west side of a ~4 km-diameter pedestal crater on the Hecates Tholus area.

References: [1] Carr et al. (1977) *JGR*, 82, 4055-4066. [2] Schultz and Gault (1979) *JGR*, 84, 7669-7687. [3] Schultz and Gault (1984) *LPSC XV*, 732-733. [4] Strom et al. (1992) I*n* Mars, Univ. Arizona Press, 383-423. [5] Mouginis-Mars and Boyce (2005) *LPSC XXXVI*, Abstract #1111. [6] Suzuki et al. (2005) *LPSC XXXVI*, Abstract #2331. [7] Roark et al. (2004) *LPSC XXXV*, Abstract #1833. [8] Christensen et al. (2003) *Science*, *300,* 2056-2061. [9] Farrand et al. (2005) *JGR*, *110*, doi:10.1029/2004JE002297.

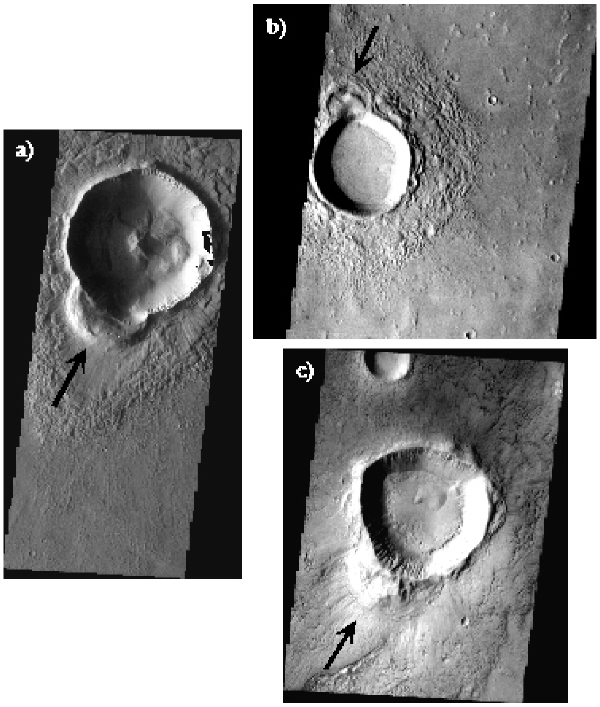

Figure 1. THEMIS-VIS images (Band 3, 100 m/pixel) for:
a) 14.9 km crater at 28.3º N, 116.7º E (V05863016);
b) 7.3 km crater at 31.2º N, 88.7º E (V09696023); and,
c) 11.6 km crater at 38.0º N, 338.8º E (V03109003).
Arrows point the unusual structures.

Table 1. Summary of craters found to have an associated, usnual rim deposit on the northern plains.

Crater			Deposit			
Latitude (°N)	Longitude (°E)	Diameter (km)	Location[§]	Distance to rim (km)	Estimated Radius (km)	Ratio
28.3	116.7	14.9	SW	4.5	4.5	0.6R[†]
31.2	88.7	7.3	NW	2.9	1.8	0.8R
38.0	338.8	11.6	SW	4.6	4.6	0.6R

[§] Location of deposit relative to the crater.

[†] R = Radius of the crater.