Emplacement Chronology of Double Layer Crater Ejecta on Mars

Tanya N. Harrison, Livio L. Tornabene, & Gordon R. Osinski

Centre for Planetary Science and Exploration/Dept. of Earth Sciences, Western University, London, Ontario, Canada
SETI Institute, Mountain View, California

Introduction

- Martian double layer ejecta (DLE) craters occur preferentially in the mid-latitudes in regions displaying evidence of periglacial features, hence, their formation is thought to involve volatiles in some manner [e.g., 1–5]
- DLE ejecta morphology consists of a distinct inner layer and a significantly thinner outer layer (Fig. 1)
- The timing of emplacement of these layers has been a subject of debate
  - Some authors have proposed that the outer layer is ballistically dropped, followed by the inner layer as a viscous ground-hugging flow [6, 7]
  - Others propose the inner layer is deposited first, followed by a base surge or tornadoic winds forming the outer layer [1,5]

Methods

- Inspected the contact between the inner and outer ejecta layers of three relatively youthful-looking/well-preserved (based on morphology and the presence of pitted materials [8]) on the crater floor DLE craters in order to look for contacts that had experienced minimal amounts of post-emplacement modification: Mariacour, Steinheim, and an unnamed crater at 43°07′N, 225°70′E.
- Analysis conducted using a combination of Mars Reconnaissance Orbiter Context Camera (CTX), High Resolution Imaging Science Experiment (HiRISE), and Mars Odyssey Thermal Emission Imaging Spectrometer (THEMIS) daytime IR data in Java Mission-planning and Analysis for Remote Sensing (JMARS) software [9].

Results

- Mars Orbiter Laser Altimeter (MOLA) profiles across the ejecta blankets show the inner layer sits topographically lower than the outer layer in all cases, with a sharp downward slope at the contact (Fig. 2)
- Contact morphology of all three DLE craters is highly variable, ranging from sharp and well-defined (Fig. 2–5a) to poorly defined (Fig. 4–8b) or disrupted (Fig. 4b), varying spatially around each single crater. This variation can lead to challenges in identifying win- vs. post-impact modification processes at the layer contact.
- The radial features characteristic of DLE craters [5] are linear atop the inner layer, seemingly unaffected by pre-existing topography. Conversely, the radial features are clearly deflected by pre-existing topography on the outer layer [cf., 5].
- The radial features and transition in morphology at the layer contact are consistent with terrestrial observations of base surges [10] formed in nuclear explosion craters and volcanic settings. These surges are capable of significant erosion with or without significant deposition and exhibit a change in morphology at the point where the surge velocity shifts from supercronic to subsonic [5,10].

Interpretation and Discussion

- Based on the variability of contact morphology across each of the craters and the presence of apparent base surge scoriage features, we propose the following sequence of events for the emplacement of DLE crater ejecta following the initial impact event:
  1. Ejecta sourced from the uppermost portion of the target region [11] is emplaced via ballistic sedimentation and radial flow [e.g., 12] during the excavation stage of the impact process, forming the outer layer and secondaries
  2. The inner layer, potentially sourced from deeper portions of the target region [11] is emplaced during the modification (final) stages of the impact process as a viscous ground-hugging flow
  3. As crater modification causes, material entrained in the ejecta plume above the crater begins to fall and move radially outwards from the crater as a base surge [13], scouring the radial features into the inner and outer layers of the ejecta blanket. As the surge passes over the viscous, melt-rich inner layers, portions of the layer edge are modified, destroying the well-defined contact between the two layers, resulting in the morphologies of Figs. 3–5b.

Fig. 1. Example of a DLE crater, Steinheim (CTX image mosaic). Dotted line outlines the contact between the inner and outer ejecta layers. Red line indicates the MOLA transect in Fig. 2. White boxes denote the locations of Figs. 5b & c. NGS/JPL-Caltech/MASS/US

Fig. 2. MOLA transect of the Steinheim ejecta blanket. See Fig. 1 for context.

Fig. 3. Unnamed crater (41°N, 226°E). a) CTX mosaic atop THEMIS daytime IR. White boxes denote the locations of Figs. 4–c. NMA/JPL–Caltech/MASS/US. b) Example of a disrupted contact between the inner and outer ejecta layers. From HiRISE anaglyph of images ESP_024575_2235 and ESP_024575_2235. NGS/JPL-Caltech/MA.

Fig. 4. Mariacour Crater (53°N, 28°E). a) CTX P17_00781_2375_XL_SSN003W strip THEMIS daytime IR. White boxes denote the locations of Figs. 4–c. NGS/JPL–Caltech/MASS/US. b) Example of a poorly defined contact between the inner and outer ejecta layers. HiRISE ESP_015645_2235. NGS/JPL–Caltech/MA.

Fig. 5. Steinheim Crater (54°N, 19°E), ejecta layer contact (dotted by white arrow). a) Example of a poorly defined contact between the inner and outer ejecta layers. HiRISE ESP_007235_2235. NGS/JPL–Caltech/MA.

Fig. 6. Example of a sharp, well-defined contact between the inner and outer ejecta layers. From HiRISE anaglyph of images ESP_019848_2235 and ESP_019848_2235. NGS/JPL–Caltech/MA.

Fig. 7. Example of a sharp, well-defined contact between the inner and outer ejecta layers. From HiRISE anaglyph of images ESP_008303_2235 and ESP_007736_2235. NGS/JPL–Caltech/MA.

Fig. 8. Example of a sharp, well-defined contact between the inner and outer ejecta layers. From HiRISE anaglyph of images ESP_019848_2235 and ESP_019848_2235. NGS/JPL–Caltech/MA.

References: