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Conical landforms on Mercury and Mars - indicators of volatile release

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Abstract

Molards are cones of debris that result from the disaggregation of ice-cemented blocks transported by mass movements. Recently, the origin of molards has been directly linked to permafrost degradation on Earth. We have found candidate molards in crater ejecta on Mercury and Mars, which by analogy we link to volatile loss post-emplacement.

1. Introduction

Distinctive landforms resulting from the degradation of discontinuous mountain permafrost are rare. In our recent research in Iceland, we have uncovered a landform that fills this gap – so called “molards” (Figure 1). These landforms are cones of debris which result from the disaggregation of ice-cemented blocks transported by mass movements [1,2]. We reported for the first time the direct association between the ice cemented block and the resulting molard landform [3]. Permafrost conditions are a pre-requisite for forming the ice cement within the blocks, and its subsequent degradation triggers the mass movement leading to the formation of the final molards. In our paper, we show that molards are recognisable in remote sensing data. In addition, we report that the distribution and morphology of molards give insights into landslide dynamics. This new terrestrial work led us to search for such landforms on other planets where the role of volatiles in landscape evolution is under debate. Volatiles are substances that easily change phase, for this work we refer to ices (H_2O, CO_2, N_2, S, Cl) becoming gas or liquid. Our preliminary work has revealed molard-like landforms on Mercury and on Mars.

2. Mercury: Caloris Ejecta

Conical mounds are found around the Caloris Basin on Mercury. We mapped their locations and found that their distribution is consistent with them being part of the Caloris ejecta blanket. Their shape and the fact that debris from their flanks buries surrounding materials (Figure 2) suggests they continued to evolve long after the basin was formed. Because their

Figure 1: Formation of a molard in the Móafellshyrna landslide, 2012. Left frozen block and right, cone shaped molard.

flank-slopes and shapes are similar to molards on Earth we suggest a similar formation via volatile loss. In the last few years Mercury has been revealed to be much more volatile-rich than previously thought [e.g. 4], and our discovery of candidate molards in the ejecta of the Caloris Basin suggests that the crust and mantle has been enriched in volatiles since the basin formed ~3.8 billion years ago.

3. Mars: Hale Crater

We have found candidate molards in the ejecta flows of the one billion year old Hale Crater, which are similar in morphology and spatial distribution to molards found in the Mount Meager debris-avalanche deposits on Earth [5] (Figures 3 & 4). Hale impact has already been proposed to have occurred into ice-rich materials [6] and hence it is not unlikely that the ejecta may also have contained ice. The presence of molards suggests that not all the ice was melted by the impact and that the ice itself was contained within the pores of the soil, rather than massive glacial ice. In future work we aim to constrain both the initial ground ice content at the Hale impact, but also the conditions during ejecta emplacement.

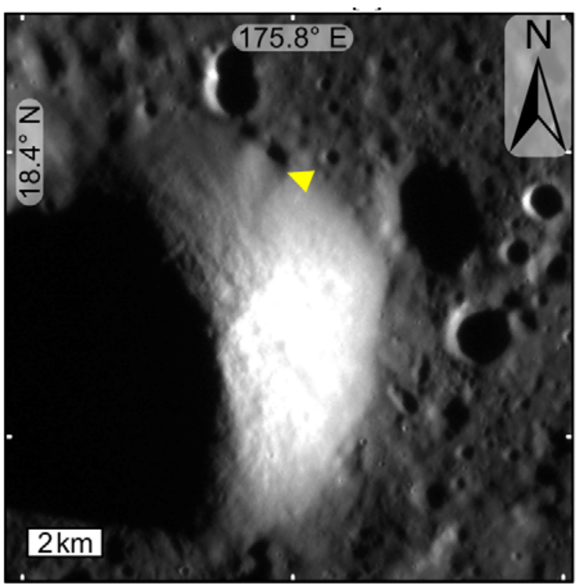

Figure 2: Conical knob on Mercury. Yellow arrow indicates crater on Caloris Planitia partially obscured by knob material. A subtle notch in the knob is visible above this crater.

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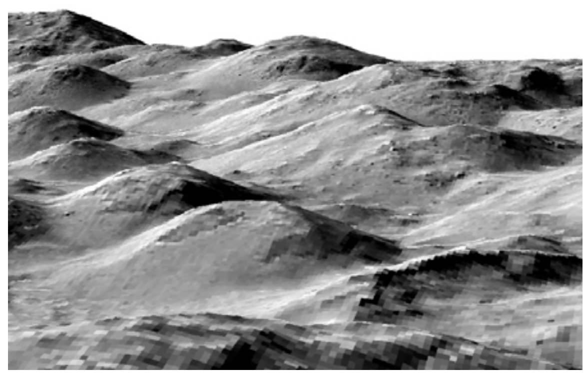

Figure 3: Oblique view of candidate molards in Hale crater ejecta. Cone basal diameter is about 150 m.

Figure 4: Comparison between candidate molards in Hale crater ejecta, left and molards in Mount Meager, right.