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Bedrock layering revealed by hollows on Mercury

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Abstract

We performed a thorough analysis of MESSENGER MDIS-NAC images with a resolution higher than 10 m/pixel located on top of central peaks and peak rings of Mercury. Sporadically, these frames capture hollows on top of the peaks revealing a not-previously detected layered structure at their floors. Here we investigate their origin and possible significance.

1. Introduction

The Mercury Dual Imaging System (MDIS), on-board the NASA MESSENGER (Mercury Surface, Space, ENvironment, GEochemistry, and Ranging) spacecraft, provided over 250,000 images, ~26,000 of which were gathered at a resolution better than 10 m/pixel by the Narrow Angle Camera (NAC). NAC images with such resolution are found at high-northern latitudes, where MESSENGER elliptical orbit reached its minimum altitude of 200 km, constantly decreasing during its final crashing phase. Such high-resolution images are key to uncover the morphology, texture and structure of the Hermean surface, however, Mercury is extensively covered with regolith that does not permit to look directly at the pristine bedrock. The areas where such exposed bedrock is most likely detected are usually located on steep scarps, such as crater walls, or crater central peaks and peak rings, where mass wasting processes cause regolith removal. In particular, crater central peaks often reveal the sub-surface lithology that was uplifted, tilted and strained by the impact process [1]. Moreover, on Mercury, regolith removal might occur also via hollows formation which are supposed to form because of a process of sublimation or volatile loss [2,3]. In order to find the bedrock exposures, we checked all NAC images with a resolution better than 10 m/pixel that captured locations of interest, such as those described above, with particular attention to those craters that also encompass hollows. Nonetheless, chances of finding such evidence are very low because of the scarce coverage of such high-resolution images that need to capture both peaks and hollows.

2. Exploring the data

We investigated more than 26,000 MDIS/NAC frames with a resolution better than 10 m/pixel (hereafter called HR-NAC), and manually selected all those footprints located on top, or nearby, steep scarps such as crater central uplifts, crater walls, fault scarps and hollows on a GIS environment. This work was repeated twice by different people -to avoid missing any useful frame- by dividing the selected footprints into categories (i.e., central peaks, fault scarps, etc.). Secondly, we batch-processed the selected frames with the USGS ISIS3 software to visually check the images on the GIS starting from the central peak category.

3. Layering revealed

We found more than 900 HR-NAC footprints located on the categories of interest. More than 300 of these are related to crater central peaks and peak rings. After importing the latter frames into the GIS, we verified that only few tens of these show a texture that could be seemingly be related to bedrock exposure. However, three peak-related HR-NAC frames surprisingly revealed evidence of putative layered and uplifted mega-blocks outcropping on the floor of some hundreds-meters wide hollows (e.g., Figure 1). Although it is quite common to observe tilted layered blocks in correspondence of crater uplifts on Earth and Mars [e.g., 1,4], it was never observed on Mercury before. In fact, observing such features implies the existence of layered bedrock before the crater formed. No evidence of layering was provided for Mercury so far, however, it is possible that the surface's widespread lava flows have undergone a layering process, whether a) flow interruptions occurred causing a bedding discontinuity, or b) the high temperature difference at the surface of Mercury caused a cyclic cooling of the lava flow surface. By measuring the putative layers drawn in Figure 1 (right) we estimate an almost

constant layer width of 10-16 m. We aim at repeating the measurements also on other similar features found elsewhere on Mercury.

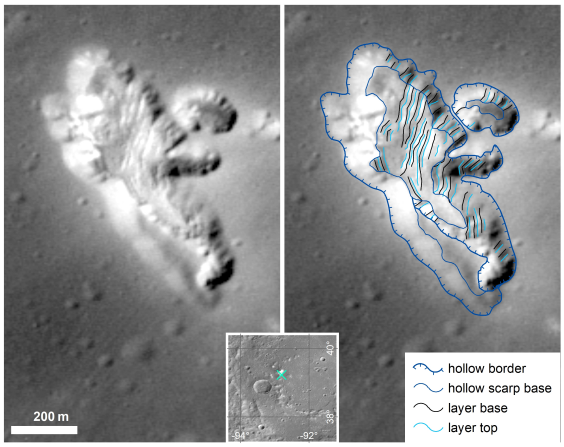

Figure 1: Hollow located on Al-Hamadhani western peak ring (inset) as shown by the 4 m/pixel MDIS/NAC frame EN1066825461M (left). We used a polyline layer to mark the main morphological features, including the putative tilted layers (right).

4. Summary and future work

We found evidence of putative layered Hermean bedrock outcropping on the floor of some hollows located in correspondence with crater central peaks and peak rings. This was possible thanks to an accurate analysis of hundreds of MDIS/NAC images with a resolution better than 10 m/pixel. The occurrence of such features revealed to be less than 1% of the coverage provided by HR-NAC frames. This depends on several conditions that must occur together: 1) the HR-NAC frame must be on top of a crater uplift; 2) the crater uplift must have hollows causing regolith removal; 3) the bedrock of the analyzed area had to be layered prior to the impact. Since Mercury has no sedimentary rocks on its surface, the origin of such layering must be investigated and could be linked to lava flow evolution. Another cause of the observed lineaments could be due to rock parallel and systematic fracturing. With this work we aim at understanding the origin and evolution of such discontinuities. To this end, we are checking other HR-NAC frames occurring also on other locations such as crater walls, fault scarps and other hollows occurring away from crater uplifts. Finally, we will compare our results with what is usually observed on Earth or Mars.

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