EPSC Abstracts
Vol. 8, EPSC2013-438-1, 2013
European Planetary Science Congress 2013

The mechanisms of hollow-formation and of exposure of hollow-forming material at the surface of Mercury

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1. Introduction

The hollows of Mercury are fresh-looking irregular sub-km scale, flat-floored, steep-walled rimless depressions (Fig. 1). Relatively high-reflectance, relatively 'blue' material occurs around them and on their floors. Hollows often occur in clusters, most commonly on the floors, peak structures and walls of impact craters. The morphology of hollows suggests that they form by the loss of a volatile substance from the surface [1] and that their formation was relatively recent. Investigation of the source of this volatile material and the mechanisms of its loss is important for understanding Mercury's volatile budget and the rate and style of geomorphological activity [3].

2. Surveys conducted

To identify hollows and study their distribution, we conducted a thorough survey of all NAC monochrome and WAC multiband images in four pole-to-pole 20° wide strips taken before September 2012 by the MDIS (Mercury Dual Imaging System) camera onboard the MESSENGER spacecraft. The four strips were centred at -55° E, 0° E, 90° E and 170°E. These locations were chosen to investigate the effect of insolation and of the Caloris basin on hollow abundance. The strip centred on 0° E crosses the 'hot pole', which is one of two equatorial points that host the subsolar point at perihelion and so receive the maximum insolation of any location. The strip centred on 90° E crosses a complementary 'cold pole' where local noon occurs only at aphelion. The strip centred at 170°E crosses the Caloris basin, which is the largest basin on Mercury and has a thick volcanic infill [2], attributes which may have unique effects on the occurrence and localisation of hollows.

We identified and measured hollow clusters and noted associations with slope aspect, pyroclastic volcanism and substrate spectral character.

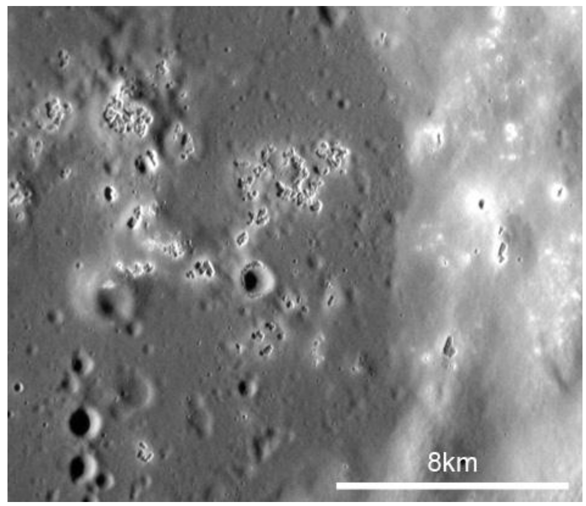

Figure 1: Hollows on the floor and terraced wall of an unnamed impact crater at 46.4°N, 318.7°E.

3. Results and Interpretations

We observed 104 hollow clusters, with significant longitudinal variation in areal extent. In 20% of cases, hollows form on slopes with a preferred aspect, most commonly on the sun-facing slope (Fig. 2). There is therefore a weak correlation of hollowing with insolation, which is consistent with their formation by sublimation and/or photon-stimulated desorption.

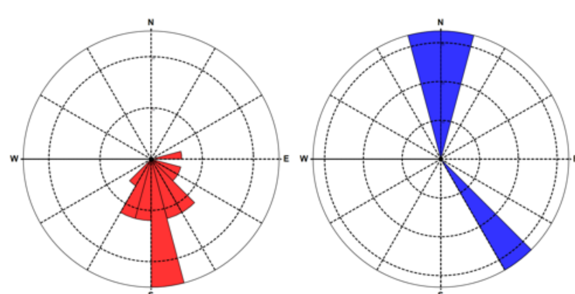

Figure 2: Preferred aspects in the northern (n=18) and southern (n=3) hemispheres.

Where net insolation is lowest, in the ‘cold pole’-crossing strip, hollow-formation is more strongly associated with pyroclastic volcanism than elsewhere. If formation of hollows and volcanic activity was contemporaneous, endogenic heat flow may have promoted either migration of volatiles to the surface or hollow-formation by sublimation at these locations.

Hollows form in either regional or local low reflectance deposits in 86% of cases, implying that this is the volatile-bearing deposit. In contrast, they rarely form on high reflectance plains (HRP) of probable volcanic origin: this difference is particularly clear where an impact crater straddles the boundary between the two substrates and hollows form only in the low reflectance material (Fig. 3).

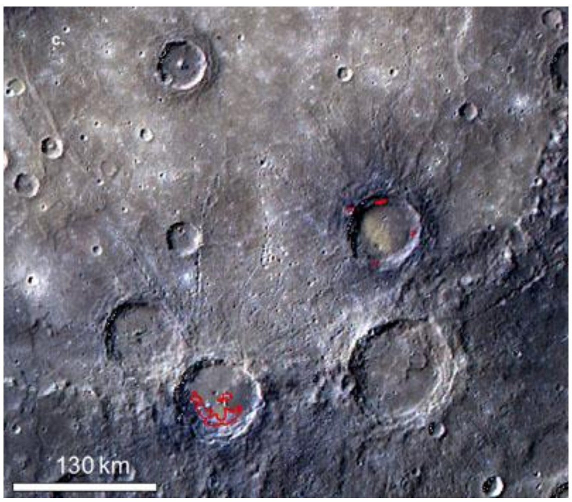

Figure 3: Hollows (outlined in red) form in low reflectance deposits in impact craters at the rim of Rembrandt basin, not on its HRP fill.

86% of hollow clusters studied occur in impact craters or their ejecta, suggesting that craters localize the release of this material to the surface. Hollows often form on crater walls, central complexes and fills, consistent with existing theories [1] that hollow-forming volatiles are exhumed during crater formation. However, they also occur where crater infills abut or overlie these structures (Fig 4.), suggesting that hollow-forming volatiles also migrate up through crater fills.

Hollow clusters are additionally found in the hanging walls of thrust faults over and younger craters puncturing old, degraded craters. This suggests that these processes have re-exposed near-surface hollow-forming volatiles which were emplaced earlier in the history of the crater.

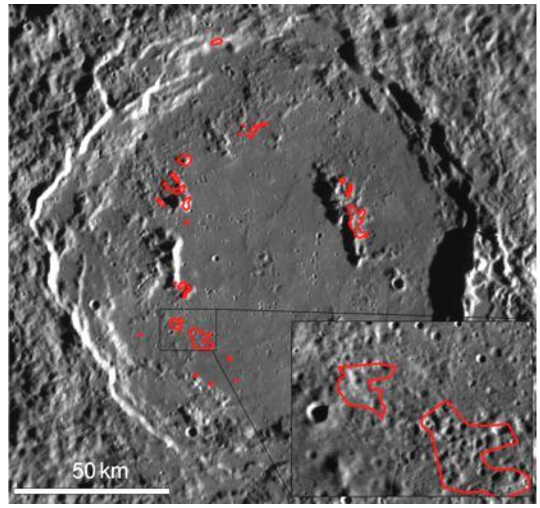

Figure 4: Hollows (outlined in red) in the crater infill overlying the peak ring of Sousa (0° E, 46.7° N)

6. Summary and Conclusions

Hollow-formation shows some correlation with insolation. This favours sublimation and/or photon-stimulated desorption as hollow-forming mechanisms. However, this correlation is not strong, suggesting that the threshold for hollow-formation is easily-reached on Mercury.

The presence of hollow-forming volatiles at the surface and their ability to reach it is likely to be the strongest control on hollow-formation. Their surface emplacement may occur by a range of mechanisms: exhumation from depth during impact crater formation, migration through volcanic crater infills and re-exposure by fault-bend folding and impacts.

References

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