MECHANISMS AND SOURCES INVOLVED IN THE FORMATION OF HOLLOWS ON THE SURFACE OF MERCURY.

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Introduction:

High-resolution images of the surface of Mercury have revealed an unusual landform: shallow, rimless irregular hollows with steep, crisp margins, often floored and/or haloed by relatively high reflectance, relatively blue material and occurring in clusters. The source(s) and composition of the hollow-forming material and the mechanism for hollow formation are currently debated. As hollows require material loss, the hollow-forming material is thought to have a volatile component, for instance sulfides or chlorides [1]. Suggested sources include differentiated impact melt [1], komatiitic volcanic crater infill [2] or a buried volatile-rich volcanic layer within the crust which was brought to the surface by impact cratering [3]. Loss of this material and hollow formation appear to have occurred by sublimation or volatilization by space weathering [3].

This study examines all available imagery to identify hollowed areas within several pole-to-pole strips of Mercury's surface. The locations of these clusters and their presence in even very old, degraded impact craters suggest a tectonic control over the release of hollow-forming material from depth toward the surface. A weak association with aspect is observed, suggesting that higher insolation favours hollow formation. However, a smaller area of hollowing was observed at a 'hot pole' of Mercury than at a more average location, indicating that insolation is not the primary control.

Methods: Surveys were made of Mercury's surface by examining the full catalogue of black and white narrow angle images and colour wide angle images taken by the MDIS (Mercury Dual Imaging System) instrument onboard the MESSENGER spacecraft currently orbiting Mercury. The surveys covered areas from pole to pole at -65° E to -40° E (survey 1) and -5° E to 10° E (survey 2). The location of survey 2 was chosen to cross a 'hot pole', one of two longitudes on Mercury where the surface is under the Sun at perihelion and thus receives the greatest average insolation. If insolation is a primary control on hollow formation, it is probable that this region would undergo more hollowing than others. The size and shape of all hollow clusters were recorded, as were their relationships with impact craters, tectonism, local and regional terrain types and, where they formed on a slope at a preferred orientation, the aspect of that slope.

Results: 75 hollow clusters have been identified so far, with fewer observed in the 'hot pole' survey 2 than in survey 1. The vast majority occur in impact craters: in the high walls and rims of simple craters and along the terraces and on the peaks and smooth floors of complex craters. Where they form on only a part of a smooth crater floor, they cluster close to and concentric with the walls and peaks (Fig. 1). Those that do not occur in craters are often associated with bright crater ray deposits (Fig. 2).

Hollows were most frequently observed in craters with a morphology consistent with a Calorian age or younger (using the scheme developed by Barnouin et al., 2012 [4]), though in survey 1 there are occurrences in much older, very degraded craters (Fig. 3). In older

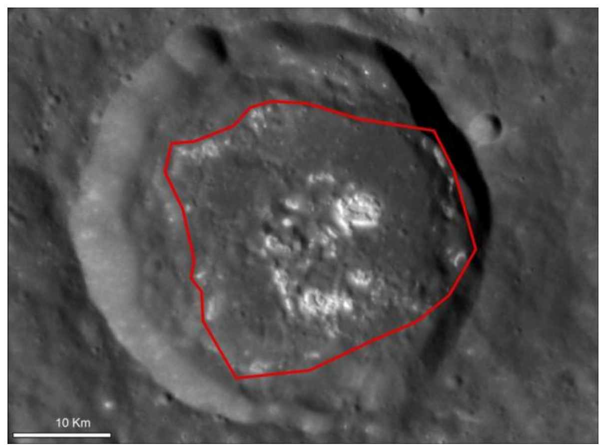

Fig. 1. Hollowing (outlined in red) is concentrated at the walls and peak of complex crater Wergeland. Location:, -56.2° E, -37.9° N

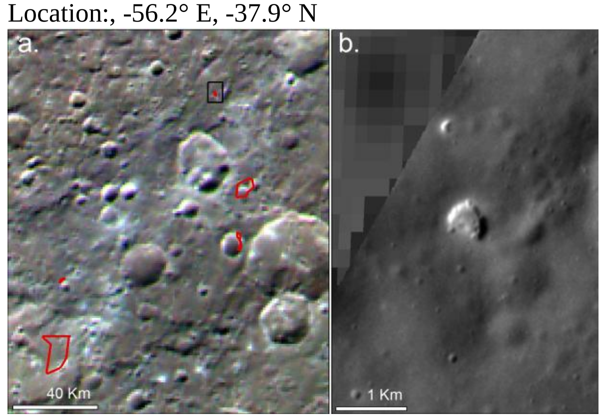

Fig. 2. Hollow formation in association with a bright crater ray. (a) Colour composite centred on -56.3° E, 45.6° N, red: hollow clusters, black box: location of b; (b) hollows in non-impact crater host material.

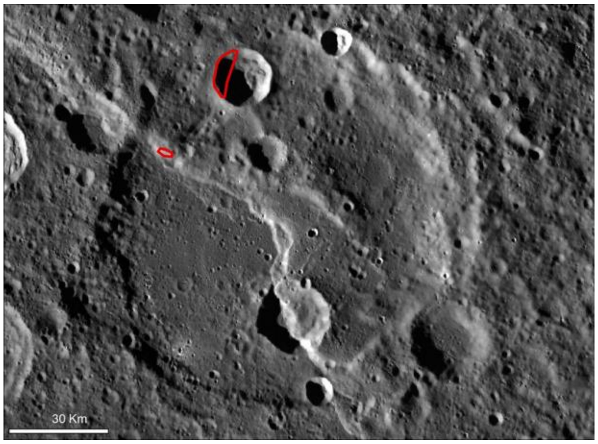

Fig. 3. Old, degraded impact crater crossed by a thrust fault. Hollows occur in areas outlined in red. Location: -52.7° E, 58.2° N

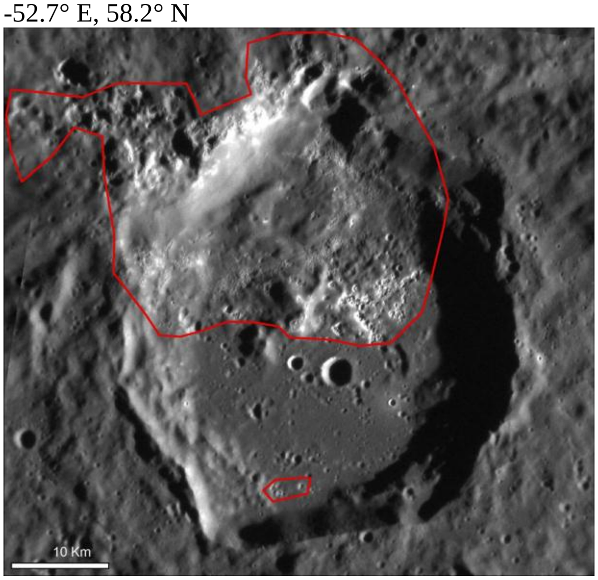

Fig. 4. Intensive hollow formation on the surfaces revealed by slumping and the material derived from them. Location: -3.6° E, 25.5° N

craters, hollows occur in smaller superposed craters, on the surface above the hanging wall of thrusts crossing the crater, or along tectonic lines of weakness such as their walls and peak rings.

Extensive hollowing was observed where a crater wall had undergone slumping, both in the slump scar and in the slumped material (Fig.4).

A preferred slope aspect for hollow formation was observed in 35% of cases. This was always towards the south in the northern hemisphere and the north in the southern hemisphere.

The overwhelming majority of hollow clusters formed in regions where the present surface can be characterized as low-reflectance material (LRM) or intermediate terrain (IT) [5]. Very few are observed on smooth plains except where this material is a local deposit within a large impact crater.

Discussion:

Sources of hollow-forming volatiles. The occurrence of hollows in curved clusters following the walls and rims of impact craters, within slumped material from their walls and in uplifted central peaks suggests there is a structural control on their formation. Hollowing is not seen at the many thrust faults on Mercury unless they cross old, degraded impact craters. This presumably implies that the path from the source region to the surface is too great to allow release of the volatile material at the low fault angles characteristic of thrust faulting but that it can be accessed by fracturing caused by impacts. This has implications for the source depth of the hollow-forming material.

The presence of hollow clusters on crater walls and rims does not support a source within differentiated komatiitic infills. Their presence in old craters does not support the theory that their source is differentiated impact melt unless the differentiated material rich in volatiles was initially emplaced at depth and only later brought to the surface where it could cause hollow formation.

Mechanisms of hollow formation. The presence of hollows on sun-facing slopes shows there is some correlation between hollow formation and insolation. This supports sublimation as a mechanism for volatile loss to form hollows. However, the 'hot poles' receive more insolation than other areas of Mercury's surface, particularly in their equatorial regions, and yet fewer hollow clusters were observed at that location than at a non-'hot' location.

This implies that other factors play a greater role in hollow formation than insolation. Smooth plains form a larger percentage of the surface area of the 'hot pole' survey area and this may account for the difference, as hollows rarely form on plains. This may be because they are not a good source of hollow-forming material and/or because they form a barrier to the release of volatiles to the surface if they are present at depth.

References: [1] Vaughan et al. (2012) *LPS XLIII*, Abstract #1187. [2] Helbert et al. (2012) *LPS XLIII*, Abstract #1381. [3] Blewett et al. (2011) *Science, 333*, 1856-9. [4] Barnouin et al. (2012) *Icarus, 219*, 414-427. [5] Denevi et al. (2009) *Science, 324,* 613-618.