HOLLOWS AS EVIDENCE FOR THE NATURE AND SOURCE OF MERCURY'S LOW-REFLECTANCE SUBSTRATES.

R. J. Thomas[1,2], B. M. Hynek[2], David A. Rothery[1], Susan J. Conway[3] and Mahesh Anand[1,4], [1] Dept. of Physical Sciences, The Open University, Milton Keynes, MK7 6AA, UK, [2] LASP, University of Colorado, Boulder, CO 80309, USA, [3] LPG, Université de Nantes, BP 92208, 44322 Nantes, France [4] Dept. of Earth Sciences, The Natural History Museum, London, SW7 5BD, UK.

Introduction: The nature and source of Mercury's two low-reflectance substrates is emerging as a key issue for understanding the planet's process of differentiation and bulk composition. The significance of the lowest-reflectance substrate, low-reflectance material (LRM), a diffuse-margined unit mostly confined to heavily-cratered regions, is implied by its dominance in the ejecta blankets and beneath the volcanic infills of impact basins [1]. This, together with numerical modeling, suggests that it forms a major component of the lower crust or upper mantle [1,2], and occurs within smaller craters only due to subsequent redistribution of this originally deeply-sourced material [3]. However, the mode of genesis and detailed composition of LRM is as-yet unknown. The more distinct-margined, relatively uncratered low-reflectance blue plains (LBP) have a reflectivity intermediate between that of LRM and Mercury's average [2]. Their plains morphology indicates that they are flow deposits, and yet their spectral character differs substantially from the other major plains unit on Mercury, the more spectrally red-sloped High-Reflectance Plains (HRP). If volcanic, they suggest considerable variation in lava composition over time and/or space, while, if impact-related, they provide evidence for the depth and character of subsurface materials.

Paradoxically, the key to understanding these large-scale regional units may lie with one of the smallest landforms on Mercury, the kilometer-scale flat-floored depressions known as 'hollows'. This is because hollows preferentially occur in LRM, and appear to form by the loss of a relatively volatile substance within it under the hostile conditions at Mercury's surface [4,5]. By investigating the compositional changes of parent material as hollows form, we can discriminate between the volatile and non-volatile components of LRM as an aid to understanding its ultimate mode of formation. Moreover, by assessing the relative concentration of hollows in LRM and LBP as a proxy for volatile content, and combining this with geological analysis of the relationship between the two substrates, we can constrain hypotheses for the nature and source of LBP.

Methods: In order to investigate compositional changes during hollow-formation, we have analyzed the spectral character of flat hollow floors as seen in high-resolution multispectral images obtained by the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft. This is a departure from earlier work [4], which considers only the spectral character of the bright deposits surrounding hollows (referred to here as BCFDs, bright crater floor deposits, for historical reasons). BCFDs occur in a halo around hollows and on upstanding knobs on their floors, suggesting that they form during hollow-formation (Fig. 1). Conversely, flat hollow floors appear to be stable regions around which the hollow continues to form by scarp retreat. This suggests that the composition of BCFDs corresponds to an intermediate stage during hollow-formation, whereas the composition of material on hollow floors is indicative of its end result.

Figure 1. High resolution MDIS NAC image EN0221282722M (25 m/pixel) indicates the spatial relationship between BCFDs (white arrows) and flat hollow floor deposits (black arrows). Solar illumination from the left.

We selected ten sites where MESSENGER Mercury Dual Imaging System Narrow Angle Camera (NAC) images show parts of the hollow floor to be flat (lacking knobs of material) and for which Wide-Angle Camera (WAC) multispectral images are available with a pixel size smaller than that of the flat hollow floor area. Because space weathering renders Mercury surface spectra relatively featureless, these data could not be used to investigate mineralogy. Instead, we compared the broad spectral characteristics of overall reflectivity and spectral slope for the flat hollow floors, BCFDs and parent material. Specifically, we investigated reflectance at 750 nm (R750) and the ratio of reflectance at 430 nm to that at 750 nm (VISr, 'blueness'), comparable to metrics used in previous work on hollows using lower spatial resolution Mercury Atmospheric and Surface Composition Spectrometer data [6].

To investigate LBP, we determined the global correlation of hollows with this substrate and with LRM on the basis of all MESSENGER image data released up to September 2015 (an extension of our previously-released global catalogue of hollows [5]). We also assessed the spatial and stratigraphic relationship between LRM and LBP at the Rembrandt basin to constrain their modes of emplacement.

Results: Comparison of reflectivity and spectral slope at the ten sites indicates that flat hollow floors are the most 'blue' of the units sampled (VISr — 430 nm/750 nm — is relatively high) (e.g. Fig. 2). Both BCFDs and hollow floors are 'bluer' than the surrounding substrate, including where this is LRM. At most sites, R750 of hollow floors is intermediate between that of BCFDs and unhollowed surfaces.

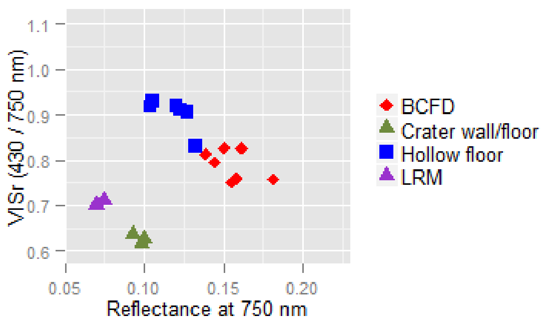

Figure 2. Comparison of the spectral character of hollow floors and associated units at Eminescu crater

In the region around Rembrandt, our mapping indicates that LBP are Rembrandt impact melt [7], while the LRM is unmelted material exhumed and exposed in the impact. Around Rembrandt, hollows form solely in LRM, and globally, 96% of the hollowed area is on regional or localized LRM, whereas 8% is on LBP.

Discussion: Our results show that flat, apparently inactive hollow floors have a lower spectral slope at visible wavelengths than the bright material present during the process of hollow-formation. Both units have higher reflectance and a lower spectral slope at visible wavelengths than surrounding units, which are presumably formed of material similar to that partially removed in hollow-formation. Spectral character in these broad terms is primarily controlled by maturity, composition and texture (e.g. grain size). One possible explanation for the relatively bright and blue-sloped deposits around and within hollows is that they are simply immature examples of their parent material, because space weathering darkens and/or reddens Mercury's surface [8]. Maturity may account for the relative reflectivity of (younger) BCFDs and (older) flat hollow floors; however, it is not consistent with the trend in spectral slope from redder to bluer between them. Additionally, the flatness of hollow floors is not consistent with ongoing complete exposure of fresh parent material, but is more suggestive of the accumulation of a lag, which halts further hollow formation at a certain depth (as described by [4]). Rather, the evidence is better explained by composition: removal of part of the volatile component of the parent material results in 'bluer' material, and its complete removal (at hollow floors) results in yet 'bluer' material. This is consistent with the removal of a more spectrally red-sloped volatile component, which is in turn consistent with work suggesting that the compounds lost in hollow formation may be sulfides [9]. Furthermore, as the reflectivity of hollow floors can approach that of the parent material, including LRM, despite relative immaturity, the evidence seen here is consistent with the low-reflectance component of LRM being non-volatile, which is intriguing in light of the twin hypotheses that graphite makes up Mercury's primary crust [10] and that LRM is exhumed from the lower crust [1].

The observed rarity of hollows in LBP and our geological interpretation of LBP at Rembrandt as impact melt suggest that melt generated during an impact that exhumes LRM contains a lesser volatile component than does exhumed LRM. Moreover, because the spectral character of hollow floors does not indicate a rise in reflectivity through volatile loss, the higher reflectance of LBP over LRM indicates a difference in composition over and above their volatile component. Modelling suggests that only crustal material was excavated in the impact, while melting extended into the mantle [1], and thus that relatively volatile-rich LRM (exhumed in the impact) comprises a significant component of the crust here, lying above less-volatile-rich, higher-reflectance mantle material, which was mixed with LRM material to form impact melt LBP.

References: [1] Ernst, C.M. et al. (2015) *Icarus, 250*, 413-429. [2] Murchie, S.L. et al. (2015) *Icarus, 254*, 287-305. [3] Rivera-Valentin, E.G. (2014) *EPSL, 391*, 234-242. [4] Blewett, D.T. et al. (2011) *Science, 333*, 1856-9. [5] Thomas, R.J. et al. (2014) *Icarus, 229*, 221-235. [6] Izenberg, N.R. et al. (2015) LPSC 46, Abstract #1344. [7] Hynek, B.M., et al., *this meeting*. [8] Lucey, P.G. & Riner, M. A. (2011) *Icarus, 212*, 451-462. [9] Helbert, J. et al. (2013) *EPSL, 369*, 233-238. [10] Vander Kaaden, K.E. (2015) *JGR: Planets, 120*, 195-209.