ARE THERE COMPOSITIONALLY DIFFERENT TYPES OF HOLLOWS ON MERCURY? Noam R. Izenberg (noam.izenberg@jhuapl.edu)[1], Rebecca J. Thomas[2], David T. Blewett[1], Larry R. Nittler[3] [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA. [2]Department of Physical Sciences, The Open University, Walton Hall, Milton Keynes MK7 6AA, UK, [3]Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015, USA.

Introduction. Hollows on Mercury are irregularly shaped, flat or hummocky floored, rimless depressions found primarily on the floors, walls, and central peaks of impact craters. Many have associated high-reflectance halos or interiors, and distinctively low visible to near-infrared spectral slope compared with surrounding materials [1, 2, 3]. Hollows lack superimposed impact craters and generally appear morphologically fresh. They occur across the planet, with individual hollows as small as 0.1 km^2 in area or less, to clusters of depressions, to large, coalesced groupings hundreds of square kilometers in area. A compiled global catalog of 445 groups of hollows [3] has since been expanded to 481 groups.

Hollows are often found in close proximity to deposits of low-reflectance material (LRM) [4], pyroclastic pits or deposits [5], or both. Spectrally, hollows that are in or near LRM are brighter, and "bluer" (i.e., lower in visible to near-infrared slope), but have high ultraviolet (UV)-visible spectral slopes similar to those of LRM. Conversely, hollows in or near pyroclastic deposits, although still brighter and bluer than those deposits, have low UV-visible spectral slopes, similar to those of nearby pyroclastic materials [6].

Hypotheses for the origin and formation of hollows include sulfide and/or chloride volatilization and sublimation and subsequent mass wasting [1-3, 7, 8]. Most hollows are too small to allow individual compositional measurements by the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft's X-Ray Spectrometer (XRS). However, XRS measurements indicate that the highest S abundances are found in regions with large amounts of LRM [9, 10] and, in contrast, a targeted measurement of Mercury's largest pyroclastic deposit found very low S [11]. In addition, Mercury's surface is so intensely space weathered and thermally cycled [8,12] that possible sulfide absorption features in the visible to near-infrared spectral reflectance of surface materials are subdued or absent. A sulfide material would have to fill more than 90% of the field of view of the Mercury Surface and Atmospheric Composition Spectrometer (MASCS) Visible and Infrared Spectrograph (VIRS) to be detectable in a spectrum [6].

Different types of hollows. Hollows can be spectrally differentiated in terms of the UV ratio ("UVr", reflectance at 310 nm divided by that at 390 nm). With this parameter we classify hollows as "high UVr" (associated with LRM), "low UVr" (associated with pyroclastics), or "intermediate" (mixed or no clear associations with LRM or pyroclastics) [6]. We can't determine from available spectral observations alone whether the spectral variability of hollows is genetic or associative, but an examination of morphology and stratigraphy may permit us to distinguish between the two possibilities.

The association of hollows with LRM is consistent with the hypothesis of a sulfur-related origin for most hollows. However, the existence of hollows with no clear association with LRM or primary association with pyroclastic deposits suggests alternative possibilities. If all hollows are genetically similar, hollows near pyroclastic deposits may be covered by or mixed with pyroclastic materials. If the range of UV ratios of hollows is not due to mixing, then a compositional difference may be likely. For example, hollows associated with pyroclastic deposits may be of a "volcanic volatile sequestration" variety [1, 2], hosted by materials compositionally different from LRM.

Hollows investigation. We compared the geological association and spectral reflectance of the 11 largest areas of hollows on Mercury. Initial results show a complex relationship among hollows, pyroclastic deposits, and LRM, illustrated here in three examples (Fig. 1). The extra-low UVr implies that hollows material, even if mixed with pyroclastic material, is different from the high-UVr materials associated with LRM. VIRS spectral parameters [6] for all areas are shown in grey in Fig. 2, with the three example areas color coded for emphasis.

Tyagaraja crater (Fig. 1A). Hollows in Tyagaraja are brighter, bluer, and lower in UV ratio than Tyagaraja's pyroclastic deposits. Exceptions are hollows closest to the LRM area inside the crater (blue circle in Fig. 1A), which have a much higher UV ratio, similar to that of LRM.

Basho crater (Fig. 1B). The walls and proximal ejecta of Basho have the low reflectance indicative of LRM, and hollows within the crater have a high UV ratio. Basho crater has no pyroclastic features.

Raditladi crater (Fig. 1C). Hollows in Raditladi have a low UV ratio but are associated with extensive LRM deposits and only an areally limited pyroclastic deposit.

Discussion. Our initial findings suggest that in many cases, the UV ratio of hollows varies according to their association with LRM and pyroclastic material. This pattern may result from a dependence of the formation process for hollows on their geological association, but it may also indicate simply that LRM or pyroclastic materials under- or overlie the hollows and dominate the spectral reflectance at the resolution of the available data.

We also observe sites where hollows' reflectance differs from that of associated materials. In some cases the UVr of hollows exceeds that of associated pyroclastic deposits.

Several explanations for these variations are possible:

1. Extra-low-UVr hollows are more recent and thus less space weathered than pyroclastic deposits and higher-UVr hollows.
2. Extra-low-UVr hollows are unaffected by mixing with LRM or pyroclastic deposits and so indicate the actual spectrum for hollows.
3. Variations in the spectral character of deposits in and around hollows result from variation in the composition or texture of this material between different sites, rather than by domination of the spectrum by other materials. For example, in the LRM, the phase susceptible to loss might be an inherent component of the rock (e.g., a sulfide). In pyroclastic deposits, volatiles associated with eruption could have directly "frozen out" on the surface and covered, reacted with, or altered the country rock and formed volatile-bearing minerals later destroyed by the surface environment, thus forming hollows.

It may be possible to distinguish between scenarios by comparing the variation in spectral character between areas more and less proximal to pyroclastic material and LRM within each site, as well as between different sites.

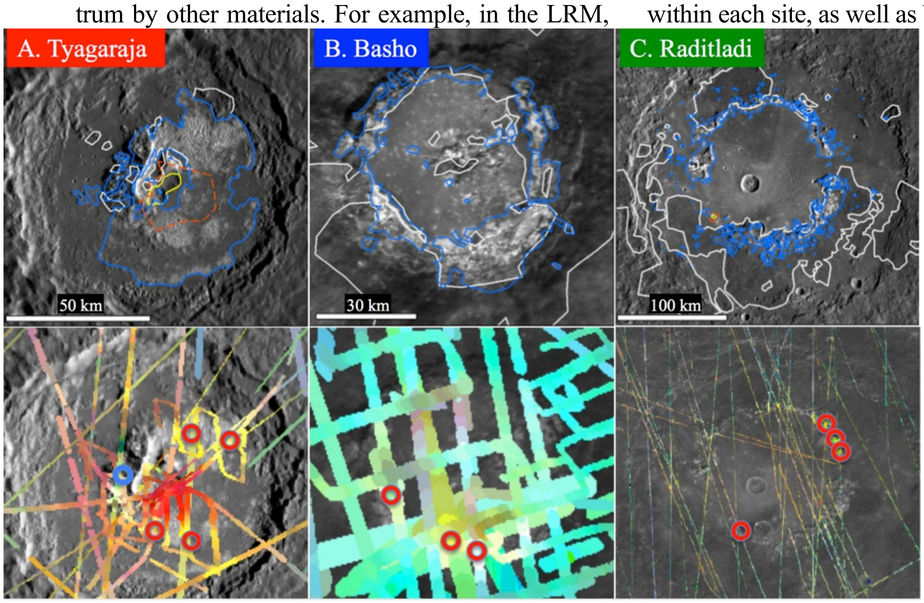

Fig. 1. Examples of the relationship between hollows, LRM, and pyroclastic deposits in Mercury craters Tyagaraja, Basho, and Raditladi. Top row shows image mosaics of the craters with pits outlined in yellow, pyroclastic deposits in orange, LRM in white, and hollows in blue. Bottom row shows the same craters overlain with VIRS groundtracks colored on the basis of spectral parameters: red = reflectance at 575 nm; green = reflectance at 415 nm / reflectance at 750 nm; blue = reflectance at 310 nm / reflectance at 390 nm. Hollows tend to show as yellow, pyroclastic material in red, and LRM as green to cyan.

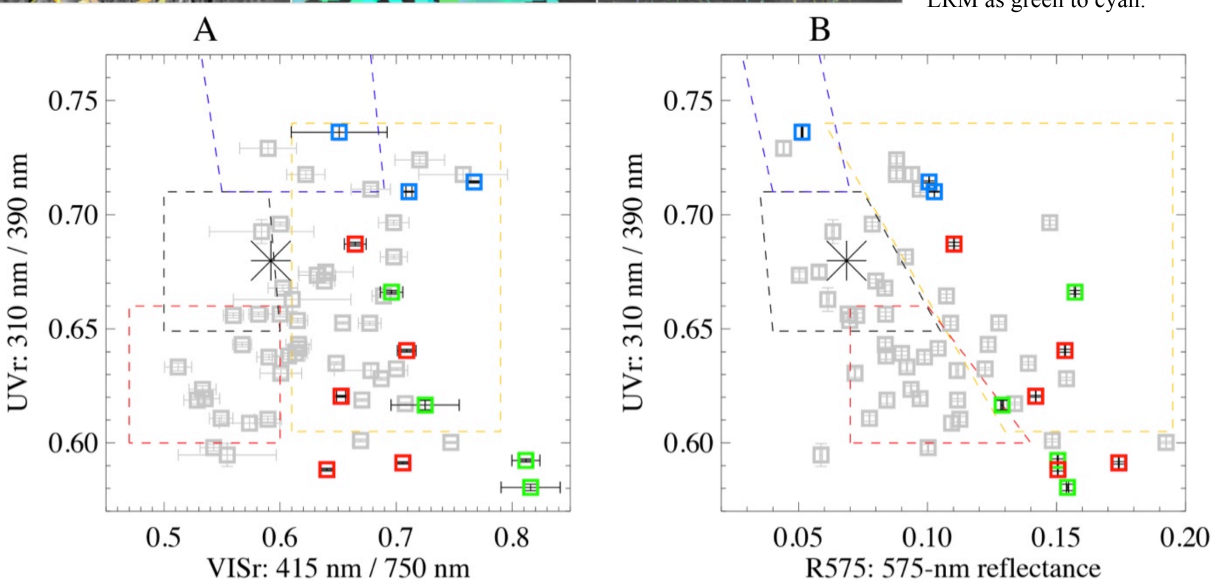

Fig. 2. VIRS spectral parameters compared for 11 hollows regions on Mercury's surface. (a) UVr versus VISr (the ratio of reflectance at 415 nm to reflectance at 750 nm). (b) UVr versus R575, the reflectance at 575 nm. Spectral unit regions [6] are enclosed by dashed lines. Tyagaraja locations are red, Raditladi green, and Basho blue.

References:
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