SPECTRAL AND MORPHOLOGICAL STUDIES OF MERCURY'S HOLLOWS.

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Introduction: Flyby observations of the planet Mercury by *Mariner 10* and *MESSENGER* showed that some impact craters contain unusual high-reflectance patches that have relatively flat ("blue") reflectance spectra at visible to near-infrared (vis-NIR) wavelengths [1-5]. High-resolution images returned by *MESSENGER* since the spacecraft began orbiting Mercury orbit in March 2011 reveal that the high-reflectance, blue areas consist of shallow irregular rounded depressions with flat floors and bright interiors and halos [6]. These features are termed "hollows". This contribution presents preliminary results of morphological and spectral analyses of the hollows intended to constrain the origin of these enigmatic features.

Morphological Types: Hollows have several morphological expressions, sometimes in combinations. Most are associated with impact structures.

Central peaks or peak rings. The Eminescu peak-cluster basin [7, 8] and the Raditladi double-ring basin [9-11] are examples of central peak mountains that have high reflectance and shallow spectral slopes. Hollows are found on the peaks and floor adjacent to the peaks [6]. Hollows on the floor may begin to develop around the topographically high peaks.

Extensive floor hollows or "etched terrain." Craters such as Sander, Kertesz, and Tyagaraja have areas of the crater floor that are covered with large numbers of hollows that have coalesced. Loss of material appears to have occurred to a particular depth, estimated at a few tens of meters [6, 12].

Floor circumference. Hollows are often found around the edges of a crater floor where it meets the wall. This may be another situation where hollow formation proceeds adjacent to a topographic high.

Exposed stratum. In a number of small craters, a layer of bright material is observed to crop out below the rim, suggesting that a layer of hollows-forming material has been exposed.

Crater ejecta/isolated occurrences. Hollows are found in the continuous ejecta of some craters. Isolated individuals or small groups have also been found away from obvious impact structures. The knobs on which these hollows formed, however, may be remnants of degraded crater rims or ejecta deposits.

Formation Mechanisms: Formation of the hollows likely involves loss of a volatile phase(s) that is unstable when exposed to Mercury surface conditions. Candidate processes include sublimation driven by solar heating or volatilization induced by space weathering (ion and/or micrometeoroid bombardment). Materials containing the volatile-bearing phase could have originated at depth been exposed by cratering, or they could be related to differentiation of impact melt [12].

Correlation With Global Color Unit: Mounting evidence indicates that hollows are associated with the global color unit known as the low reflectance material (LRM) [3, 4, 13]. Fig. 1 illustrates this association.

Spectral Properties: We have compared eight-color spectra extracted from Mercury Dual Imaging System (MDIS) multispectral cubes to laboratory spectra of analog minerals in order to provide clues to the composition of Mercury's surface. Fig. 2 shows spectra for Tyagaraja's floor hollows, mature LRM, and a small (fresh) plains crater (SPC) relative to mature intermediate terrain (IT) plains [3, 4, 13]. Fig. 3 presents the MDIS reflectance spectra on the same plot together with laboratory spectra from the U.S. Geological Survey and RELAB spectral libraries, including highly reduced minerals that have been considered as Mercury analogs [14, see also 15]. Mercury's spectrum lacks prominent absorption features, and the dominant spectral variations in the vis-NIR are changes in albedo and overall spectral slope. Therefore much of the spectral information can be condensed into a ratio-reflectance plot such as the one in Fig. 4.

Discussion: Mercury is quite dark. The hollows, which are among the brightest surfaces on the planet and are brighter than many fresh crater rays on Mercury [3, 6], have about the same 630-nm reflectance (~15%) as a mature *Apollo 16* soil. The albedo of LRM (~6%) is similar to that of ilmenite. If Mercury's surface is dominated by an Fe-free silicate, then a darkening agent with a flat spectrum is needed to move the mixed spectrum down and to the left in the ratio-reflectance diagram. Troilite (FeS) has about the same ratio and reflectance as the Mercury surfaces, but *MESSENGER* geochemical remote sensing results [16, 17] preclude large amounts of iron in the surface. Nanophase metallic iron [18] or troilite [19] produced by space weathering could provide the needed spectral characteristics. Note that the bright hollows cannot contain abundant elemental sulfur (S), because S is far too red in the visible relative to the hollows (Fig. 4), which are bluer than average Mercury. (Note however that different forms of sulfur can have different colors [20]). One hypothesis is that the phase responsible for general darkening is especially abundant in the LRM. If this phase, and/or one that occurs with it, is susceptible to decomposition when exposed to surface conditions, destruction of the phase and loss of the volatile leads to collapse and formation of the hollows. Destruction of the phase(s) leads to an increase in the reflectance of the residual material, accounting for the brightness of the hollows. Eventually, lateral impact mixing and normal space weathering homogenize the surface, causing older hollows to lose their high reflectance.

References: [1] D. Dzurisin (1977), *GRL 4*, 383. [2] B. Rava, B. Hapke (1987), *Icarus 71*, 397. [3] M.S. Robinson et al. (2008), *Science 321*, 66. [4] D.T. Blewett et al. (2009), *EPSL 285*, 272. [5] D.T. Blewett et al. (2010), *Icarus 209*, 239. [6] D.T Blewett et al. (2011), *Science 333,* 1856. [7] S.C. Schon et al. (2011), *P&SS 59*, 1949. [8] D.M.H. Baker et al. (2011), *P&SS, 59*, 1932. [9] R. Strom et al. (2008), *Science 321*, 79. [10] L.M. Prockter et al. (2010), *Science 329*, 668. [11] S. Marchi et al. (2011), *P&SS 59*, 1968. [12] W.M. Vaughan et al. (2012), *LPSC 43rd*, this mtg. [13] B.W. Denevi et al. (2009), *Science 324*, 613. [14] T.H. Burbine et al. (2002), *M&PS 37*, 1233. [15] J. Helbert et al. *LPSC 43rd*, this mtg. [16] E. Rhodes et al. (2011) *P&SS 59*, 1829. [17] L. Nittler et al. (2011) *Science 333*, 1847. [18] P.G. Lucey, M.A. Riner (2011), *Icarus 212*, 451. [19] T. Noguchi et al. (2011), *Science 333*, 1121. [20] D. Nash (1987), *Icarus 72*, 1.

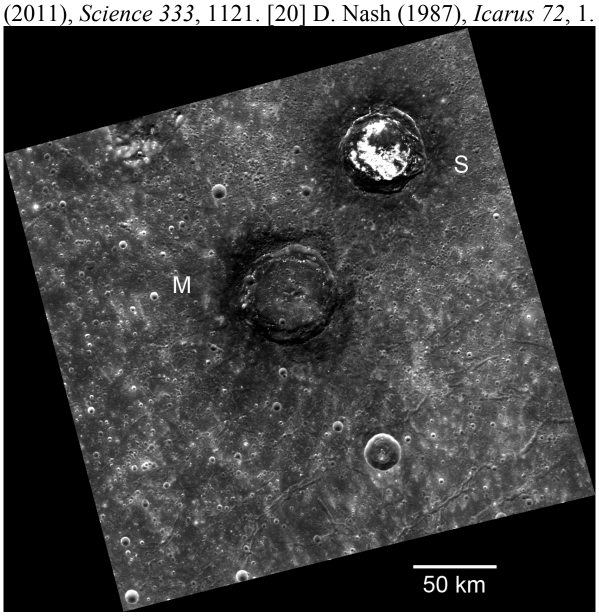

Fig. 1. Sander (S) has extensive hollows on its LRM floor and walls. Hollows are also found on Munch's (M) LRM rim and walls, and smaller hollows are present near Munch's central peaks.

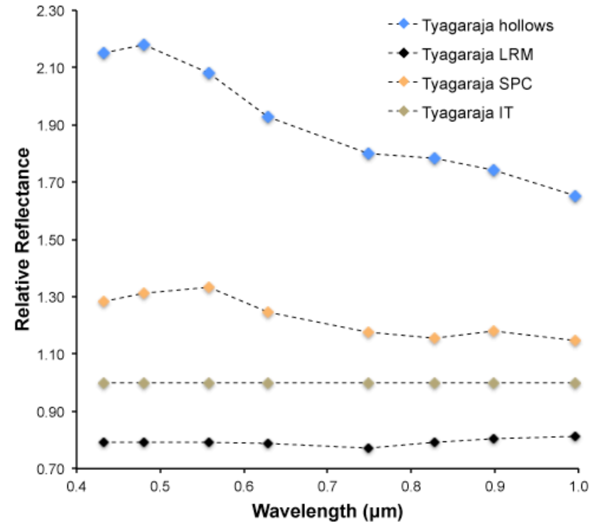

Fig. 2. MDIS spectra in and near Tyagaraja crater, relative to the spectrum of nearby mature IT plains.

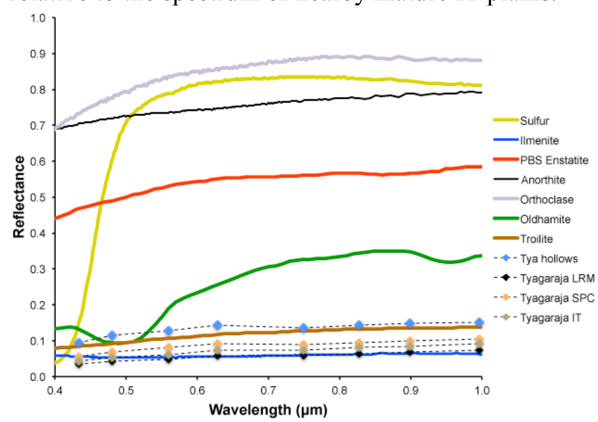

Fig. 3. MDIS spectra from Fig. 2 with lab spectra for several Mercury analog minerals. PBS enstatite is a very low-Fe pyroxene extracted from an aubrite [15].

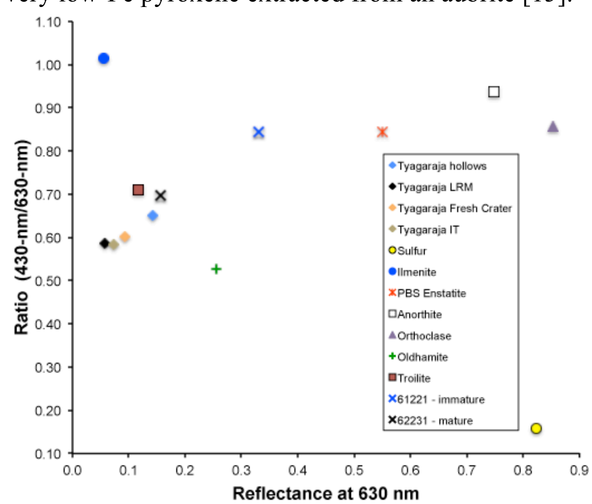

Fig. 4. Ratio-reflectance plot for spectra of Fig. 3, with fresh and mature lunar highland soils (Xs). Greater ratio value (*y*-axis) corresponds to bluer spectral slope.