

EXPLORING THE MORPHOLOGY OF SIMPLE CRATERS THAT HOST POLAR DEPOSITS ON MERCURY: IMPLICATIONS FOR THE SOURCE AND STABILITY OF WATER ICE. Carolyn M. Ernst¹, Nancy L. Chabot¹, Hannah C. M. Susorney², Olivier S. Barnouin¹, John K. Harmon³, and David A. Paige⁴. ¹Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA (Carolyn.Ernst@jhuapl.edu); ²Johns Hopkins University, Baltimore, MD 21218, USA; ³National Astronomy and Ionosphere Center, Arecibo Observatory, Arecibo, PR 00612, USA; ⁴Department of Earth and Space Sciences, University of California, Los Angeles, CA 90095, USA.

Introduction: Over 20 years ago, Earth-based radar images of Mercury's polar regions revealed bright features, which led to the hypothesis that water ice is present at the poles [e.g., 1]. Comparison with Mariner 10 images confirmed that these deposits are located within high-latitude impact craters [2, 3], and thermal models indicated that such features should contain permanently shadowed areas [4]. Orbital images from MESSENGER's Mercury Dual Imaging System (MDIS) indicate that all radar-bright deposits within craters > 10 km in diameter collocate with regions of permanent or persistent shadow [5, 6]. Observations by the MESSENGER Neutron Spectrometer [7] and Mercury Laser Altimeter (MLA) [8] and thermal models incorporating MLA topography [9] provide independent lines of evidence in support of the hypothesis that Mercury's polar deposits consist primarily of water ice. Recent images of permanently shadowed craters in Mercury's north polar region have revealed regions of anomalously dark and bright albedo [10, 11] consistent with those observed by MLA [8].

Pre-MESSENGER thermal models suggested that long-lived water ice would not be stable in idealized bowl-shaped craters (with a ratio of depth d to diameter D of 0.2) < 10 km in diameter located more than 2° of latitude from the poles, even if covered by regolith [12]. Yet MESSENGER results show that radar-bright deposits collocate with numerous small craters located substantially farther than 2° from the poles [5, 6]. The presence of polar deposits within these small craters could indicate that the water ice on Mercury was relatively recently emplaced; however, if these host craters are shallower than assumed for earlier calculations, the interior thermal environment could be more favorable to the retention of water ice on geologic timescales, as thermal models show more sunlight is scattered into crater interiors by steeper walls. Determining the morphology of small polar craters that host radar-bright deposits offers the potential for new insight into the source, nature, emplacement timeframe, and migration of the radar-bright material at Mercury's polar regions.

Methods: Our goals are to determine which small craters host radar-bright deposits and to measure the morphology of the small crater population, particularly those that host radar-bright deposits. We began with a study area in Mercury's north polar region between 75° and 85°N and -30° and 120°E (Fig. 1). With data from

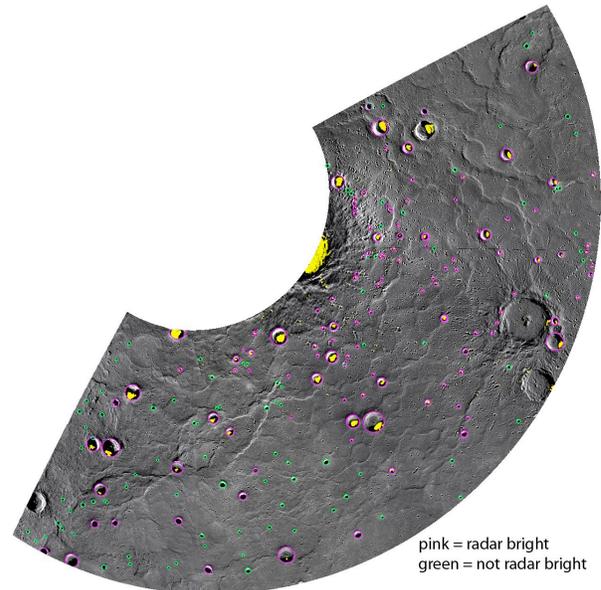


Figure 1. Study area in Mercury's north polar region (75° to 85°N, -30° to 120°E), shown in polar stereographic projection. An MDIS base map is overlain by areas of high radar backscatter (shown in yellow) [1].

MDIS and MLA, we characterized the shapes of all craters with diameters between 5 and 30 km in this region and ascertained whether they host radar-bright material. The 5 km lower limit is to ensure adequate comparison with the Earth-based radar data, which has a pixel scale of ~1.5 km. The 30 km upper limit is to capture the transition from simple to complex crater morphology, which occurs around 10 km diameter on Mercury [13, 14].

Observations: We analyzed 145 craters in the study area, 99 of which have diameters between 5 and 10 km. Of these smaller craters, 56% appear to host radar-bright material. The distribution of these host craters is systematic. Figure 2 illustrates the percentage of craters that host radar-bright deposits versus longitude for multiple latitude bins. Closer to the north pole, a larger percentage of small craters host radar-bright material. Also, a larger percentage of small craters host radar-bright material closer to Mercury's cold pole longitude (90°E). These trends have been previously observed for larger craters (≥ 10 km in diameter) in Mercury's north and south polar regions [5, 6]. The higher percentage at higher latitudes and near ~60°E

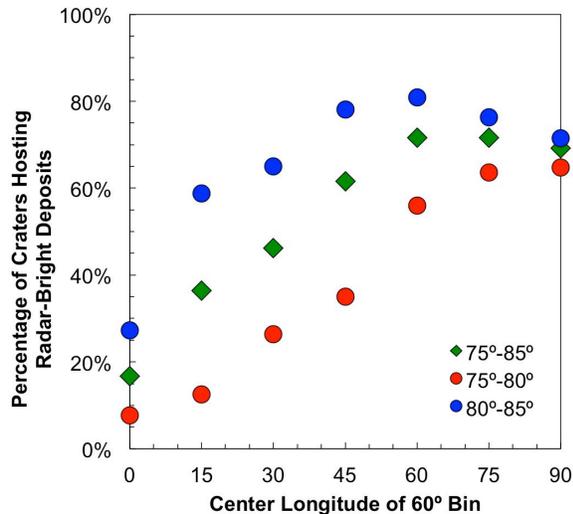


Figure 2. Percentage of craters hosting radar-bright deposits versus longitude for 60° latitude bins. In general, more craters host radar-bright deposits in areas closer to the cold pole longitude (90°E) and at higher latitudes. The high percentages around 60°E may be influenced by Prokofiev secondary craters.

may be influenced by the large number of secondary craters surrounding Prokofiev crater (~86°N, 63°E).

We used MDIS and MLA data to measure crater diameters and MLA data to measure depths for all craters in the study area between 5 and 30 km in diameter. These measurements are illustrated in Figure 3 for the overall population, those near the hot pole longitude, and those near the cold pole longitude. Results suggest that these craters are shallower (average d/D of 0.12) than assumed for earlier thermal models (0.2) [12], and that there is no substantial difference between the

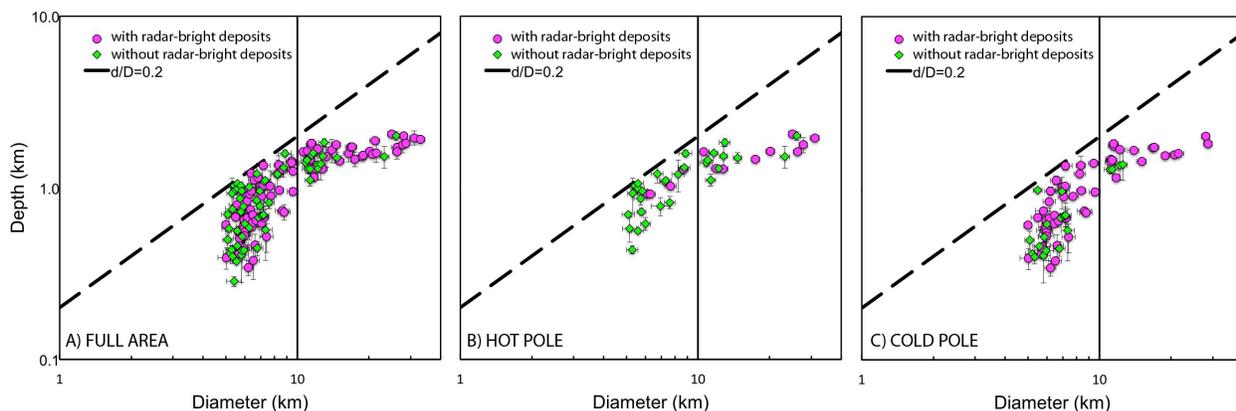


Figure 3. Depth versus diameter for craters that appear to host (pink) and not to host (green) radar-bright material in the Harmon et al. dataset [1]. (a) Craters in the entire study area; (b) craters surrounding the hot pole longitude (-30° to 30°E); (c) craters surrounding the cold pole longitude (60° to 120°E). The dashed line represents the 0.2 d/D ratio used in thermal models [12]. The vertical lines represent the transition diameter between simple and complex craters on Mercury [13,14]. Fewer craters host radar-bright deposits near the hot pole than the cold pole longitude. There is no significant difference in d/D for the craters that host radar-bright deposits in these areas.

shapes of craters that do and do not host radar-bright deposits. There is likely an interplay among proximity to the hot/cold pole longitudes, proximity to the north pole, and morphology (d/D) that governs whether or not a crater can host radar-bright material.

Implications: The difference between the average d/D found for these small craters and the “ideal” 0.2 ratio used in previous thermal models is sufficiently large to warrant updated thermal models. Results of these newer models have implications for the age of the ice near Mercury’s poles. If new thermal models find that a smaller d/D ratio does not markedly change the thermal models, the ice deposits must be geologically young (less than 1 Gy in age). If a smaller d/D ratio does change the results of the thermal models, ice may be stable in these small craters for more than 1 Gy.

References: [1] Harmon, J.K. et al. (2011) *Icarus*, 211, 37–50. [2] Harmon, J.K. et al. (1994) *Nature*, 369, 213–215. [3] Harmon, J.K. et al. (2001) *Icarus*, 149, 1–15. [4] Paige, D.A. et al. (1992) *Science*, 258, 643–646. [5] Chabot, N.L. et al. (2012) *GRL*, 39, L09204, doi: 10.1029/2012GL051526. [6] Chabot, N.L. et al. (2013) *JGR Planets*, 118, 26–36. [7] Lawrence, D.J. et al. (2013) *Science*, 339, 292–296. [8] Neumann, G.A. et al. (2013) *Science*, 339, 296–300. [9] Paige, D.A. et al. (2013) *Science*, 339, 300–303. [10] Chabot, N.L. et al. (2013) *LPS*, 44, abstract 1693. [11] Ernst, C.M. et al. (2013) *AGU Fall Meeting*, abstract P11A-04. [12] Vasavada, A.R. et al. (1999) *Icarus*, 141, 179–193. [13] Pike, R.J. (1988) in *Mercury*, Univ. Arizona Press, pp. 165–273. [14] Barnouin, O.S. et al. (2012) *Icarus*, 219, 414–427.