VOLCANIC PLAINS IN CALORIS BASIN: THICKNESS, TIMING, AND WHAT LIES BENEATH.

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Introduction: Among Mercury's largest expanses of smooth volcanic plains are those filling the Caloris basin (1550 km in diameter, centered at 31.5ºN, 162.7ºE). The fill, classified as high-reflectance red plains (HRP) [1-3], is spectrally distinct from the circum-Caloris plains and the Caloris rim structure and is likely a product of extensive partial melting of the upper mantle [2].

Preliminary estimates of the fill thickness near the center of Caloris from MESSENGER flyby images ranged from 1 to 4 km, indicating the presence of a substantial volume, rather than only a thin veneer, of volcanic material [3, 4]. Post-flooding impact craters of varying sizes in the basin interior excavated material from depth that would otherwise remain hidden. Many craters excavated low-reflectance material (LRM) [1, 2, 5], indicating the presence of a spectrally distinct unit beneath the HRP material. We use the superposed craters to estimate the thickness of the high-reflectance plains across the basin and to probe the nature of the near-surface, following the techniques detailed by Ernst et al. [4].

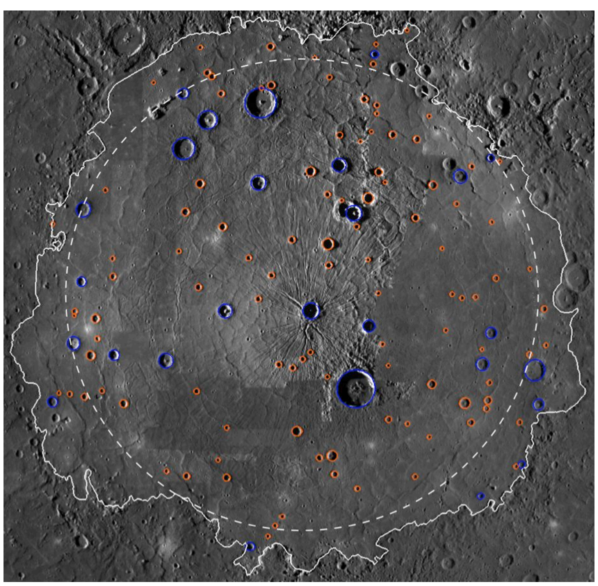

Figure 1. Color classification of 133 craters larger than 10 km in diameter within the Caloris basin. Craters outlined in blue excavated and/or uplifted spectrally distinct LRM from depth. Craters outlined in orange have not exposed LRM. The dashed circle indicates the portion of the basin within 640 km from the center.

Observations: From orbital images taken by MESSENGER's Mercury Dual Imaging System (MDIS), we identified 141 craters ≥ 10 km in diameter within the Caloris interior plains (area = 1.67×10^6 km^2), of which 133 are suitable for color classification on the basis of available MDIS data (Fig. 1). In general, larger craters exposed LRM and smaller craters did not. Within a radial distance of 640 km from the center of the basin, no craters smaller than 25 km exposed LRM. Two small craters (4 and 6 km in diameter) just inside the basin rim excavated LRM, indicating a thinning of the fill at the basin edge.

The spatial distribution and large number of color-classified craters provide the means to make regional estimates of thickness. Plotting depth of excavation versus radial distance from the center of Caloris (Fig. 2) allows for a characterization of the thickness of HRP across the basin. The layer of plains material is

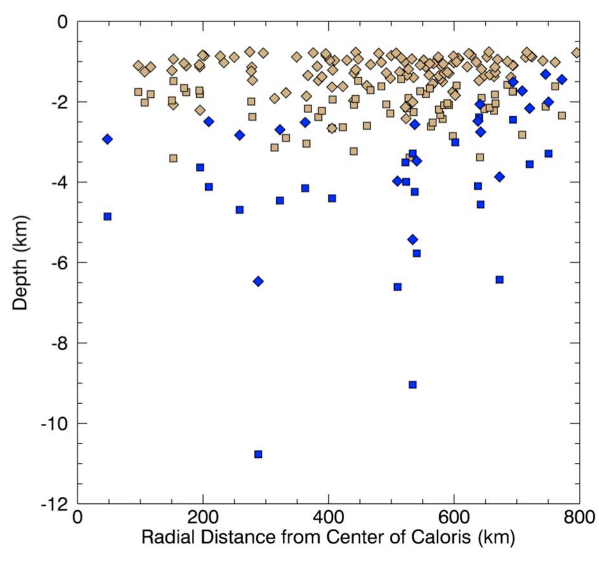

Figure 2. Depth of excavation of crater ejecta (diamonds) and central peak material (squares) versus radial distance from the center of Caloris. HRP is represented by tan symbols, and LRM is represented by blue symbols.

consistently at least ~2.5 km thick to a radial distance of 640 km. This thickness of HRP material is consistent with those inferred from fault restriction measurements [6]. Outward of 640 km distance, LRM appears at shallower depths.

We have assessed the degree to which the thickness of HRP material within Caloris departs from axisymmetry about the basin center. We split Caloris into parts on the basis of three separate geographic criteria: (1) north versus south, according to spectral units [1]; (2) east versus west; and (3) high elevation versus low elevation, defined from a map of Mercury Laser Altimeter data interpolated to 16 pixels per degree. We found no systematic differences in the thickness of HRP material with azimuth or with elevation. Therefore, there is no increase or decrease in HRP thickness relative to the long-wavelength topography of Caloris, implying that the fill must have occurred before most, if not all, of the large-scale tectonic modification of the basin and the surrounding area.

In all cases where the HRP is penetrated, LRM is present beneath it. Across the basin, within ~640 km from the center, LRM is seen at depths from as shallow as 2.5 km to as deep as ~11 km; no HRP is ever observed from depths greater than ~3.5 km. If all of these instances of LRM are sampling a single stratigraphic layer, such a layer of LRM must be at least 7.5 to 8.5 km thick beneath the current surface of the HRP.

From observations of Caloris alone, one cannot determine whether the LRM is basin floor material, plains material that predated the HRP, or the product of a magmatic intrusion [3]. However, Rembrandt basin (~715 km in diameter, centered at 32.8ºS, 87.5ºE), the second-largest well-preserved basin on Mercury, offers a clue. Rembrandt is also flooded with volcanic HRP material that is spectrally distinct from the basin's ejecta and unfilled portions of the basin interior, which exhibit LRM signatures. In Rembrandt, therefore, the original basin floor material can be inferred to be LRM. By analogy, the LRM exposed by craters in the Caloris interior most likely comes from the basin floor itself rather and than volcanic or plutonic material, although some combination of sources cannot be excluded.

Discussion: The expansive northern plains, proposed to be similar in age to the Caloris interior plains [7], are host to several hundred ghost craters [8, 9]. Large ghost craters imply that the plains thickness must exceed 1.5 km in places [7].

Image analysis has revealed no partially flooded or unambiguous buried (ghost) craters ≥ 10 km in diameter in the interior plains of Caloris, contrary to earlier inferences from lower-resolution flyby images [1, 3]. The absence of flooded and ghost craters means that HRP emplacement occurred within a geologically short interval, with the possible exception of thin veneers of later material. Moreover, one or more of the following must be true: (1) the plains are sufficiently thick to have fully buried all craters that formed between basin formation and plains infill; (2) the plains were emplaced so soon after basin formation that no large post-basin craters formed before plains infill; (3) the complex tectonic deformation of the basin interior has rendered ghost craters unrecognizable.

Crater size–frequency distributions from MESSENGER flyby data are similar for the interior and exterior plains [10], but the density of craters at a given diameter is substantially higher for the basin rim and ejecta deposits [11]. For the plains to significantly postdate the basin, there must then be a class of craters that were buried by the plains material. That there is no evidence for the presence of such buried craters, even where the volcanic fill is thinnest within the basin, therefore poses a conundrum.

One possibility is that the interior fill is not distinctly younger than the basin and, if so, the higher density of craters on the Caloris rim and ejecta deposits may be the result of non-uniform self-secondary cratering [12-15] or target material property differences between ejecta deposits and impact melt [15-18], both of which have been documented for lunar craters. Another possibility is that some of the LRM excavated by craters within Caloris represents an earlier episode of volcanic activity. Further characterization of the crater size–frequency populations across this region may help to elucidate these issues.

Conclusions: The floor of Caloris is likely to consist of LRM, and most of the basin is filled with volcanic plains at least 2.5 km thick, with thinner fill toward the edge of the basin. The major episode of plains emplacement must have occurred within a geologically short interval and must have predated most, if not all, of the regional large-scale tectonic modification.

References: [1] Murchie, S.L. et al. (2008) *Science*, *321*, 73–76. [2] Robinson, M.S. et al. (2008) *Science*, *321*, 66–69. [3] Watters, T.R. et al. (2009) *EPSL*, *285*, 309–319. [4] Ernst, C.M. et al. (2010) *Icarus*, *209*, 210–223. [5] Denevi, B.W. et al. (2009) *Science*, *324*, 613–618. [6] Klimczak, C. et al. (2012) *LPS*, *43*, 1959. [7] Head, J.W. et al. (2011) *Science*, *333*, 1853–1856. [8] Watters, T.R. et al. (2012) *Geology*, *40*, 1123–1126. [9] Klimczak, C. et al. (2012) *JGR*, *117*, E00L03. [10] Strom, R.G. et al. (2008) *Science*, *321*, 79–81. [11] Fassett, C.I. et al. (2009) *EPSL*, *285*, 297–308. [12] Shoemaker, E.M. et al. (1968) in *Surveyor 7 Mission Report. Part 2. NASA Tech. Rep.*, *32-700*, pp. 75–134. [13] Plescia, J.B. et al. (2010) *LPS*, *41*, 2038. [14] Plescia, J.B. and Robinson, M.S. (2011) *LPS*, *42*, 1839. [15] Hiesinger, H. et al. (2012) *JGR*, *117*, E00H10. [16] Schultz, P.H. et al. (1977) *Proc. Lunar Sci. Conf. 8*, 3539–3564. [17] Dundas, C.M. et al. (2010) *GRL*, *37*, L12203. [18] van der Bogert, C.H. et al. (2010) *LPS*, *41*, 2165.