THE VOLCANIC ORIGIN OF A REGION OF INTERCRATER PLAINS ON MERCURY. Brett W. Denevi[1], Carolyn M. Ernst[1], Jennifer L. Whitten[2], James W. Head[2], Scott L. Murchie[1], Thomas R. Watters[3], Paul K. Byrne[4], David T. Blewett[1], Sean C. Solomon[5], and Caleb I. Fassett[6], [1]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA, [2]Department of Geological Sciences, Brown University, Providence, RI 02912, USA, [3]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, DC 20560, USA, [4]Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015, USA, [5]Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY 10964, USA, [6]Department of Astronomy, Mount Holyoke College, South Hadley, MA 01075, USA.

Introduction: Understanding the origin of the intercrater plains on Mercury is key to deciphering the planet's geologic history, including the timing and extent of volcanism, the interior thermal history, and the origin and evolution of the crust [e.g., 1,2]. Intercrater plains are the nearly level plains that occur within and between clusters of larger craters and have a high density of small craters, many of which are thought to be secondary in origin [1]. Intercrater plains are more heavily cratered than Mercury's smooth plains, but less so than the lunar highlands, suggesting they are younger than the oldest terrain on the Moon and are the product of widespread resurfacing that removed a population of craters <40 km in diameter [3]. The mechanism of this resurfacing is controversial and may have involved fluidized ejecta from ancient basin-forming impact events [4,5] or effusive volcanic eruptions [6–8]; little unambiguous evidence in favor of either origin was found in Mariner 10 data. Here we present evidence from MESSENGER data for the volcanic origin of a large region of intercrater plains that buried an ancient impact basin nearly as large as Caloris.

Results: We examine a broad region centered at ~18°N, 20°E (Fig. 1). This terrain was not observed by Mariner 10 and was seen only at high emission angles during MESSENGER's second and third Mercury flybys. A series of ridges and troughs ~5–40 km in width extend up to 350 km in length (Fig. 2a). These features closely resemble the lineations known as basin sculpture found radial to large basins such as Caloris (Van Eyck Formation) [9,10] or the lunar Imbrium basin [e.g., 11]. The lineations are truncated to the north by the northern smooth plains [12] and to the east by the Rachmaninoff basin [13]. These features appear to be the most prominent remnants of a large impact basin, noted by Preusker et al. [14] and listed as a "probable" basin by Fassett et al. [15]. Using these features to define a rim, we find that the basin is ~1500 km in diameter, nearly the same size as the Caloris basin (1550 km) and twice as large as the Rembrandt basin (716 km). Other primary features associated with the rim have been buried by plains or eroded by subsequent impacts, including an unnamed basin ~730 km in diameter [15] that overlaps what would be the southern rim. However, along the southwestern portion of the suggested rim, a series of thrust faults extends over 800 km (Fig. 2b); these structures may have been localized by a buried rim. The northeastern and southwestern portions of the rim correspond to moderately elevated topography compared with the center of the basin (up to 4 km difference), and the center of the basin corresponds to locally thinned crust (20 km vs. up to 80 km outside the basin rim [16], Fig. 1).

Within the center of the basin is a region of smooth plains ~400 km across [17]. These smooth plains embay intercrater plains, which cover the remainder of the basin floor and portions of the rim and exterior (Fig. 3). The surface of the intercrater plains region is intermediate in reflectance, but tens of craters (Fig. 1) within the basin excavate high-reflectance material with a steep spectral slope. This material is consistent in color with the high-reflectance red plains (HRP), which are observed across much of the surface [18,19] and are interpreted to be volcanic in origin [12,17–22]. Crater excavation depths suggest that this buried color unit lies beneath a surficial layer approximately 500 m thick, and that the excavated HRP unit may extend to depths >4 km. Craters that excavate both HRP and low-

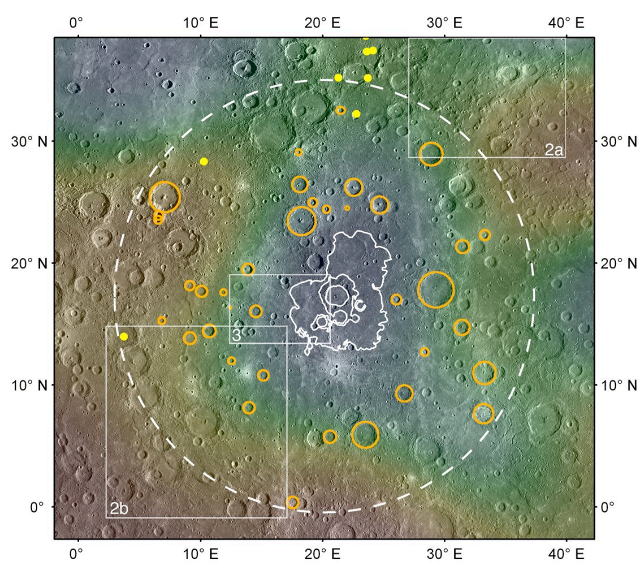

Fig. 1. Location of basin (dashed line) is shown with a model of (color-coded) crustal thickness [16]. White outline indicates interior smooth plains, yellow dots show locations of vents, and orange circles show craters that have excavated HRP-like material. Locations of Fig. 2 and 3 are outlined.

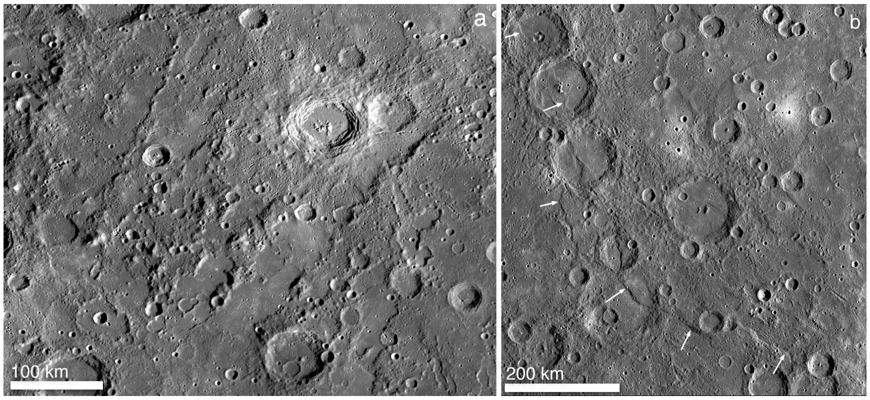

Fig. 2. (a) Basin sculpture radial to the northeastern rim. (b) Tectonic deformation follows the expected location of, and was likely localized by, the southwestern basin rim.

reflectance material (LRM) are observed near the buried basin rim, and some large craters within the basin excavate LRM. Eight irregular depressions interpreted to be volcanic vents [17,23,24] are also found close to the rim (Fig. 1), consistent with locations of vents observed near the rim of the Caloris basin and along the margins of volcanic smooth plains deposits [12,17]. Intercrater plains are by definition older than smooth plains, and the crater-size frequency distribution of these intercrater plains suggests that they formed during the late heavy bombardment, with an estimated age of ~4.0 Gy [17]. Age dating the basin itself is difficult due to the limited remaining exposure of the rim and ejecta.

Discussion: In interpreting the origin of intercrater plains on Mercury from Mariner 10 observations, the common lack of clear stratigraphic relationships [8] and the absence of compositional information made discriminating between an impact and volcanic origin difficult. In the region described here, we find both a clear stratigraphic relationship of intercrater plains burying portions of the interior, rim, and exterior of a ~1500-km-diameter impact basin, and color relationships suggesting that the unit is compositionally distinct. The evidence for the presence of this basin includes preserved portions of the rim and basin sculpture, localized tectonic features, vents associated with the rim, thinned crust, and interior smooth plains. We interpret the intercrater plains to be similar in color and composition to HRP, but buried beneath ~500 m of local and distant ejecta that has resulted in a surficial cover of regolith of intermediate color and composition. This situation is analogous to lunar cryptomaria, basaltic deposits buried by highland ejecta. The intercrater plains overlie LRM that may represent the original basin floor.

Data from MESSENGER's X-Ray Spectrometer suggest that the northern volcanic HRP have a low-iron basalt-like composition [25], and visible and near-infrared color properties suggest that the majority of the smooth plains share this composition [17]. There are many broad regions of older terrain where material with the color characteristics of HRP is exposed by impact craters [21]. If the low-iron basalt-like composition of HRP can be interpreted more broadly as the product of partial melting of the mantle, then volcanism may have been more common during the late-heavy bombardment than previously recognized. Although some portion of smooth and intercrater plains are surely of impact origin, these color relationships help discriminate those of volcanic origin. The degradation state of basins, and the fact that fewer large (>500 km) basins are observed on Mercury than on the Moon, is also consistent with more extensive modification by volcanism on Mercury [15]. Mercury's abundant smooth plains already attest to the importance of volcanism in forming the planet's crust; the identification of volcanic intercrater plains suggests that it may have been a dominant process.

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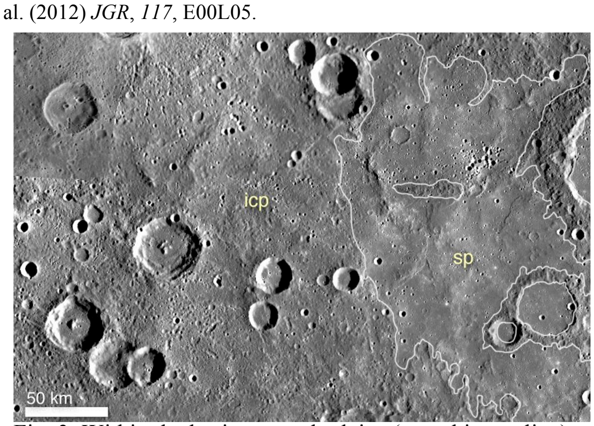

Fig. 3. Within the basin, smooth plains (sp; white outline) embay intercrater plains (icp).