ORIGIN OF PLAINS ON MERCURY: INSIGHTS FROM MESSENGER'S FIRST MERCURY FLYBY.

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Introduction: During the first encounter with Mercury by the MESSENGER (MErcury Surface, Space ENvironment, GEochemistry, and Ranging) spacecraft, a number of instruments will provide information that will assist in analysis of the smooth and intercrater plains of Mercury, whose origin is controversial [1]. Volcanic deposits provide one of the most important clues to mantle composition, the location of interior thermal anomalies, and the general thermal evolution of the planet. Volcanism commonly forms extensive smooth plains, but little is known with certainty concerning the history of volcanism on Mercury [1]. In contrast to the Moon, with distinctive composition-related albedo variations between highlands and volcanic maria, Mercury albedo is relatively uniform. Prior to Apollo 16, a widespread lunar upland smooth plains unit (Cayley Formation) was mapped, lying stratigraphically between younger low-albedo maria and the highlands. A goal of Apollo 16 was to understand this distinctive non-mare phase of volcanism [2]. Instead, the Cayley Formation consisted of impact breccias, suggesting that it was a combination of local and basin-related impact ejecta. On the basis of Apollo 16 results, lunar light plains were subsequently considered by most workers to have been emplaced by impact processes [3] rather than extrusive volcanism. Subsequent documentation of cryptomaria [4], as well as the moderate-albedo apparently volcanic Apennine Bench Formation [5], suggested that some lunar light plains might be volcanic.

Mariner 10: Arriving at Mercury shortly after Apollo 16, Mariner 10 revealed two smooth and widespread Cayley-plains-like units (Fig. 1a): smooth plains and intercrater plains. These widespread plains deposits were proposed to be volcanic in origin [6-7]; others, influenced by Apollo 16 results, argued that they represented basin ejecta [3, 8]. The relatively low resolution of Mariner 10 images was insufficient to resolve lunar-like volcanic features [e.g., 7, 9]. Lobate fronts exposed at the edge of smooth plains (Fig. 2, 3) suggested volcanic flow margins, but similar features are seen on the margins of lunar basin ejecta lobes [9, 10]. Crater counts of Caloris basin ejecta and smooth plains deposits, however, indicated that the plains were emplaced after the Caloris basin [11], and they were thus interpreted to be volcanic, not contemporaneous ejecta emplacement. On the other hand, lunar Cayley plains often showed younger ages than adjacent basin ejecta deposits. Reprocessed Mariner 10 color data [12] provided additional evidence for the possible volcanic origin of the smooth plains. Head and Wilson [13] assessed a range of scenarios for volcanism on Mercury and found that a thick low-density crust could inhibit and potentially preclude dikes from forming effusive eruptions, particularly if aided by global compression [7].

What is the nature of upper mantle volcanic source regions and how can this be used to understand the origin of plains on Mercury? FeO abundance of mantle source regions generally corresponds to that of erupted magma. Lunar mare deposits have a significant contrast in FeO content relative to ancient anorthositic crust. Candidate volcanic deposits on Mercury do not differ from the telescopic hemispheric average spectrum, suggesting that the source is not enriched in FeO relative to the crust, or that the crust is not depleted in FeO relative to the mantle [14]. If the plains deposits had a significant difference in FeO relative to uplands, they would appear as mappable units in spectral parameter maps. Global crustal abundance of FeO is estimated as <6 wt% [15]. Candidate volcanic compositions include high-Mg, low-Fe magma (e.g., Earth komatiites, FeO abundances <5 wt%) and low-Fe mafic lunar lavas [5]. The MESSENGER mission will provide very important information on the possible volcanic origin of surface plains deposits, but will also permit assessment of mantle characteristics and mineralogy from surface mineralogy and chemistry.

MESSENGER First Mercury Flyby: This encounter will provide significant data to help address these questions. The Mercury Dual Imaging System (MDIS) [16] will provide multispectral image data both for part of the region imaged by Mariner 10 (Fig. 1b) and for a large portion of Mercury not seen by Mariner 10 (Fig. 1c), including the interior plains of the Caloris basin and the circum-Caloris region characterized by smooth plains (compare Fig. 1a, 1c). These data will permit the detailed spectral characterization of units from the known part of Mercury, already shown to have some Mariner 10 spectral characteristics suggestive of volcanism [12, 14]. Armed with a new characterization of known geological units, these findings can then be extrapolated to the previously unseen portion (Fig. 1c) to assess the character, distribution, and stratigraphic relationships of plains seen there. Further characterization will be undertaken in conjunction with the Mercury Atmospheric and Surface Composition Spectrometer (MASCS) Visible and Infrared Spectrograph (VIRS) [17], so that high-spectral-resolution data can be combined with high-spatial-resolution image data. These data will not only allow the interpretation of mineralogy from fresh craters for characterization of the plains and intercrater plains, but also permit the assessment of the thickness of plains units from the depths of craters with distinctive mineralogies [18]. Data from the Mercury Laser Altimeter (MLA) [19] will be used to characterize the plains surface, compare it to those of plains of volcanic origin on other planets [20], and assess potential emplacement, loading, and deformation scenarios. Analysis of these data will be combined with data on any gravity and magnetic field anomalies detected during the flyby. This synergism in addressing the important problem of the magmatic evolution of Mercury is typical of how multiple instrument results (geology, mineralogy, geochemistry, geophysics) will be brought together during future MESSENGER flybys as well as the orbital phase of the mission [21].

References: [1] J. W. Head et al. (2007) *SSR*, 131, 41. [2] N. J. Trask and J. F. McCauley (1972) *EPSL*, 14, 201. [3] V. R. Oberbeck (1975) *RGSP*, 13, 337. [4] J. W. Head and L. Wilson (1992) *GCA*, 55, 2155. [5] P. D. Spudis and B. R. Hawke (1986) *LPI-TR 86-03*, 105. [6] B. C. Murray et al. (1975) *JGR*, 80, 2508. [7] R. G. Strom et al. (1975) *JGR*, 80, 2478. [8] D. E. Wilhelms (1976) *Icarus*, 28, 551. [9] S. M. Milkovich et al. (2002) MPS, 37, 1209. [10] J. W. Head et al. (2000) *Env. Effects on Vol. Erupt*., Plenum, NY, 143. [11] P. D. Spudis and J. E. Guest (1988) *Mercury*, U. Ariz. Press, 118. [12] M. S. Robinson and P. G. Lucey (1997) *Science*, 275, 297. [13] J. W. Head and L. Wilson (2001) *Workshop on Mercury*, LPI, 44. [14] M. S. Robinson and G. J. Taylor (2001) *MPS,* 36, 841. [15] D. T. Blewett et al. (1997) *Icarus*, 129, 217. [16] S. E. Hawkins, III, et al. (2007) *SSR*, 131, 247. [17] W. E. McClintock and M. R. Lankton (2007) *SSR*, 131, 481. [18] J. W. Head (1981) *Moon Planets*, 26, 61. [20] J. F. Cavanaugh et al. (2007) *SSR*, 131, 451. [20] M. Kreslavsky and J. W. Head (2008) *LPS*, XXXIX, this volume. [21] S. C. Solomon et al. (2007) *SSR*, 131, 3.

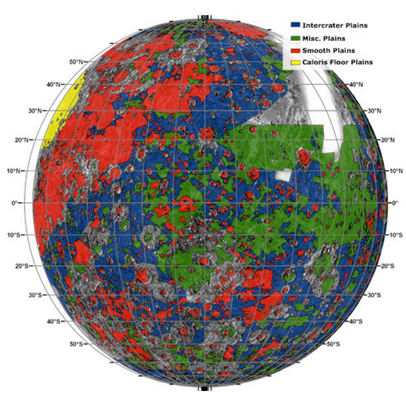

Fig. 1a. Distribution of plains mapped from Mariner 10 images.

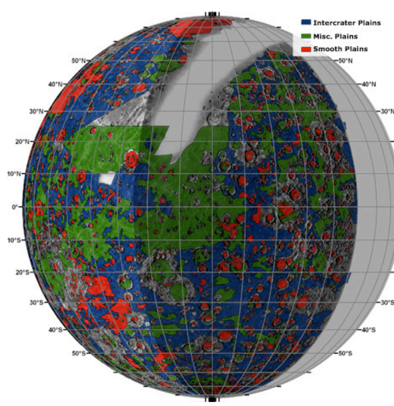

Fig. 1b. Incoming viewing geometry for MESSENGER's first Mercury flyby.

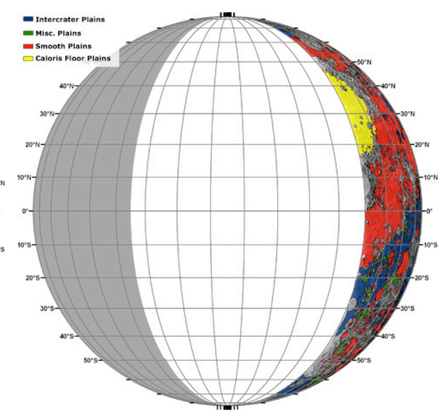

Fig. 1c. Outgoing viewing geometry for MESSENGER's first Mercury flyby.

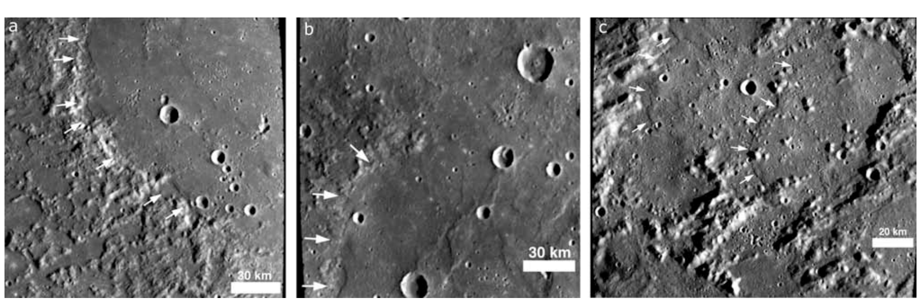

Fig. 2. Smooth plains on Mercury; arrows outline edges of smooth lobes: (a) embaying the margin of Van Eyck;(b) within the Odin Formation; (c) within the Nervo Formation [1].

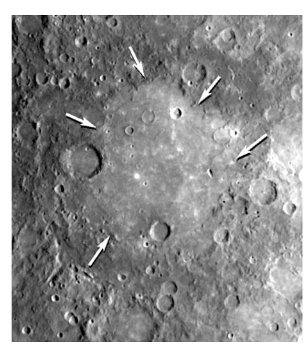

Fig. 3. Plains on floor of Tolstoj basin appearing to embay older features (arrows).