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Origin and Significance of Plains on Mercury

Brett W. Denevi (1), Mark S. Robinson (2), Scott L. Murchie (1), David T. Blewett (1), Nancy L. Chabot (1), Carolyn M. Ernst (1), Sean C. Solomon (3), and James W. Head (4).
(1) Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA. (2) School of Earth and Space Exploration, Arizona State University, Tempe, AZ, USA. (3) Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC, USA. (4) Department of Geological Sciences, Brown University, Providence, RI, USA.

Abstract

Monochrome and color images from MESSENGER's orbital phase are used to examine the global distribution of plains on Mercury. We compare the properties of plains and their modes of formation.

1. Introduction

Mercury has experienced widespread resurfacing: plains cover much of the surface and no terrain is as heavily cratered as that of the lunar highlands [1-6]. Plains formation appears to have occurred throughout much of Mercury's history. Intercrater plains formation extended through the period of heavy bombardment [7], and smooth plains formation may have continued into the second half of solar system history [3, 8]. Geologic maps also document the presence of plains transitional between these two types [e.g., 9], suggesting a continuity of types over time. Here we examine the global distribution and characteristics of plains on Mercury and their role in crustal formation and resurfacing. What is the global distribution of plains (intercrater to smooth)? Are the types of plains distinct, or is there a gradation between end-members? Do plains units all share the same range of spectral properties, indicating similar compositional characteristics?

2. Orbital imaging campaigns

The six combined flybys of Mercury by the Mariner 10 and MESSENGER spacecraft provided images of ~98% of the planet's surface, though often at extreme illumination and viewing geometries. Images from MESSENGER's orbital operations provide our first global look at Mercury under conditions optimized for viewing both surface morphology (relatively high incidence angles, 225 m/pixel) and color (lower incidence angles, 1.2 km/pixel, photometrically corrected [10] 8-band mosaics).

3. Distribution of plains

A preliminary map of mercurian plains covering ~55% of the planet was produced from Mariner 10 and MESSENGER flyby data [5]. From the orbital monochrome and color base maps, we examine previously unmapped terrain and areas where flyby data did not allow for an unambiguous interpretation.

The largest expanse of terrain for which only low-incidence-angle data were available prior to orbit is centered at ~0°E longitude. Multispectral images indicated several regions with higher average reflectance and steeper than average spectral slope, consistent with the color of high-reflectance plains (HRP), like those within the Caloris basin. However, surface morphology was not discernable. Orbital images confirm that these regions are indeed plains deposits, as are the majority of examples of HRP-like color for which morphology has thus far been assessed. However, no new examples of young, large-scale plains, apart from Borealis Planitia, are observed in the monochrome orbital images. Whereas plains units are globally distributed, the largest expanses are Caloris Planitia, the circum-Caloris plains, and Borealis Planitia. These three units alone cover ~15% of Mercury's surface. Other units are often either smaller (many are contained within small basins) or are more heavily cratered so that determining their original extent is difficult.

4. Variation among plains

Color variations among smooth plains are well documented [5, 11], with subtle changes in slope and ranges in reflectance from 20% above to 15% below that for average terrain [5, 11]. Observations from the global color base map are consistent with flyby results. On the basis of flyby data, these color and albedo variations were interpreted to reflect varying abundances of a spectrally neutral opaque component, such as an iron- or titanium-bearing oxide mineral [5, 11-13]. MESSENGER's X-Ray Spectrometer and Gamma-Ray and Neutron Spectrometer will aid in interpreting these color units in terms of lithologic units. Preliminary results indicating low abundances of iron and titanium [14] suggest that the search for the cause of color variations, especially in regions of low-reflectance material, must continue.

Determining the variation of plains formation through time is also challenging. A major complication in determining the age and extent of many plains units is the density of secondary craters. Secondary craters dominate the crater population at much larger diameters than on the Moon or Mars [3]. In contrast to the Moon, where the boundaries of most lunar maria are relatively easy to detect, secondary craters obliterate large portions of plains and mask unit boundaries (Fig. 1). We find many regions that grade from smooth to transitional plains (Fig. 1), or transitional to intercrater plains. The distinction between these units appears to be largely the enhanced population of secondaries in some locations, which destroy any original morphologic boundary, and render a once-sharp color boundary into a weak gradational variation.

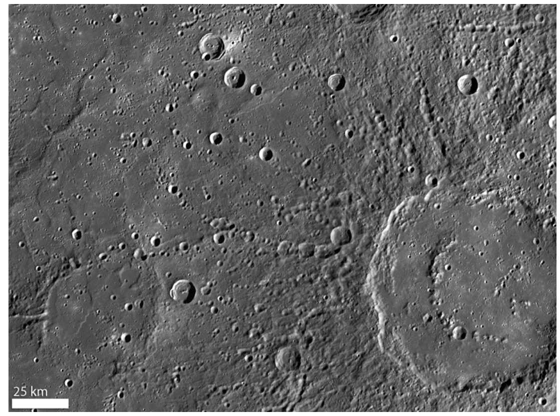

Fig. 1. Example of smooth plains unit obscured by primary and secondary craters (45° N, 215°E).

5. Origin of plains

Strong evidence for a volcanic origin of many plains units [e.g., 1, 2, 4] indicates that volcanism played an important role in shaping Mercury's crust [5]. However, many plains units lack clear evidence for source regions, flooding or embayment relationships, or color boundaries, suggesting that alternate mechanisms of formation are possible (e.g., impact-produced melt or fluidized basin ejecta). Impact melt production is predicted to be 14 times higher on Mercury than on the Moon [15]. Initial observations suggest that impact melt is abundant on Mercury (Fig. 2); a quantitative comparison of lunar and mercurian impact melt now underway will help understand what fraction of plains may have formed as impact melt.

References

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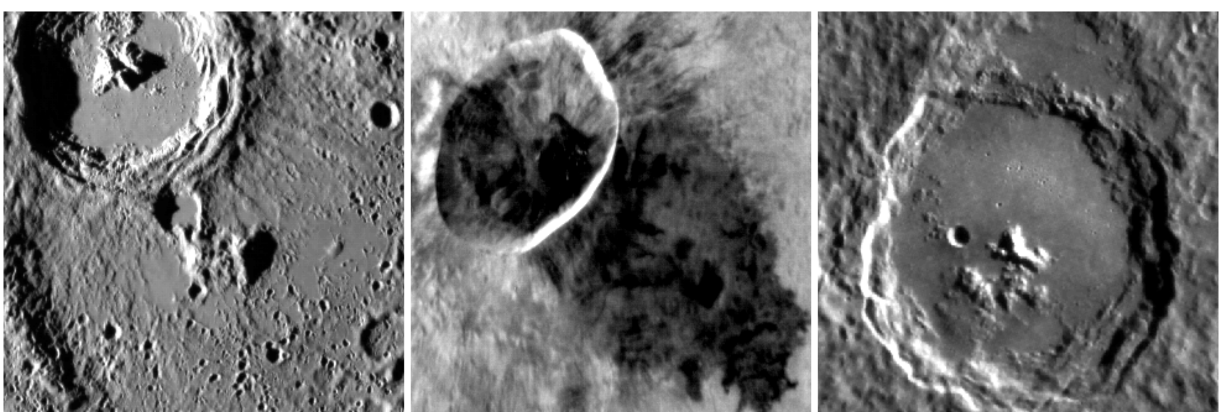

Fig. 2. Impact melt on Mercury. Left: Kuiper (62 km diameter), with ponds of melt to its south. Center: An unnamed crater at 9.0°S, 264.6°E (13 km diameter) with a 20 km flow of impact melt. Right: The extensive melt pond within and to the north of Sibelius (94 km diameter).