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The Distribution of Young Plains on Mercury

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1. Introduction

Large portions of Mercury's surface are covered by contiguous plains having densities of impact craters consistent with ages younger than the cessation of the period of late heavy bombardment [1–3]. The youngest subsets of these include smooth plains and intermediate plains [e.g., 4], the latter of which have slightly higher crater densities and often slightly more gradational boundaries. A third category, the intercrater plains, is still more heavily cratered and has a large abundance of superposed secondary craters <10 km in diameter. Many of these units have been interpreted to be volcanic in origin [e.g., 1,5], although formation through impact melting or fluidization of basin ejecta remain possible interpretations in some regions [6]. Earlier analyses from images acquired during flybys by the Mariner 10 and MESSENGER spacecraft yielded estimates of total smooth plains area ranging from 15 to 40% of the planet [2,7,8]. Here, we use images from the Mercury Dual Imaging System (MDIS) acquired from orbit to produce a global map of the distribution of smooth and intermediate plains, with implications for the temporal and spatial distribution of volcanism on Mercury.

2. Data and Methods

As the basis for our mapping, we analyze images acquired mainly as part of MESSENGER's monochrome base map campaign at an average pixel scale of 220 m (resampled to 250 m/pixel). These images cover more than 99% of the planet with an average incidence angle of 69° and an average emission angle of 11°. Thus far we have excluded isolated units smaller than ~200 km across. As closely as possible, the original extents of units were mapped; we have not excluded superposed impact craters.

Here we map the smooth and intermediate plains units using the definitions common to the Mariner 10 quadrangle maps [e.g., 4]. Thus far we have identified plains that fit the smooth and intermediate criteria, but we have not subdivided them into the two categories. There appears to exist a continuum of ages among plains, so to aid in our classification of units we are determining the crater size-frequency distributions as well as morphologic characteristics.

3. Preliminary Results

We estimate that our mapping effort is ~90% complete; final boundaries may change, and small units will likely be added. At this point, the mapped smooth and intermediate plains cover 30% of the planet (Fig. 1). It is also clear that the distribution of plains units is not uniform. We find that the majority of plains are within three contiguous formations: the smooth plains interior to Caloris basin, those surrounding the Caloris basin [9], and the northern plains [10]. These three areas account for 76% of all mapped plains, so a large difference in plains concentrations is found between hemispheres (Fig. 1).

4. Discussion

In previous mapping of smooth plains [8], the asymmetry in plains distribution was not as apparent. This difference is due to two main factors. First, the broad region centered on 0° E was imaged by MESSENGER (and was not viewed by Mariner 10) only at low incidence (near noon) and high emission angles (oblique angles), and was thus not mapped. Second, orbital data show that previous work included some regions that are somewhat more heavily cratered and may be more appropriately classified as intercrater plains. We also find that within the maps derived from Mariner 10 images there is a large amount of overlap among terrains classified as smooth, intermediate, and intercrater plains. Thus as part of our future work, will use the crater size-frequency distributions of key units together with morphology to more clearly understand the temporal distribution and classification of plains. Crater size-frequency distribution already determined for the northern, Caloris-interior, and circum-Caloris plains [3, 9, 10] show that a majority of the mapped plains formed within a short span of time.

A key question is the cause of the global asymmetry in young, widespread plains units. The lunar smooth plains (maria) dichotomy is thought to be the result of hemispherical differences in mantle temperature in part the result of differences in radioactive element abundances, resulting in generally cooler temperatures in the farside mantle and less production of basaltic partial melt [e.g., 11]. Regional variations in the thickness of the low-density, anorthositic upper crust are also likely to play a role in determining where eruptions occur, as a thinner crust increases the likelihood that basaltic magma can ascend to the surface [12]. On Mercury, it is likely that some portion of the older plains units not mapped here are volcanic in origin [13], so the crustal asymmetry may be in age rather than formational process. Elemental compositions consistent with a range of compositions from more basaltic to komatiitic-basalt [14,15] suggest that, unlike the Moon, magmas on Mercury may generally be lower in density than crustal rocks. We note that more komatiitic compositions appear to be linked with older terrains that have relatively lower reflectance [14,15], suggesting that over time a cooling mantle inhibited the high degrees of melting required for komatiitic magma compositions. However, the circum-Caloris plains, with spectral properties similar to terrains shown to be more komatiitic in composition, may prove an exception to this trend. Spatial variations in radioactive elements [16], if reflected in similar variations at depth, could have promoted increased melting and volcanism in some regions later in Mercury's history, though a simple correlation between young plains and radioactive element concentrations is not observed. The striking association of volcanic plains with the Caloris basin (Fig. 1) suggests that this large impact is also likely to have played a role in the asymmetric distribution of young plains. The impact may have caused changes in the regional mantle dynamics [e.g., 17] or structural changes that facilitated eruptions onto the surface. However, no single basin is clearly associated with the extensive northern plains [10, 18]. Completion of mapping of young plains, extension of the results to older plains, and quantification of variations in relative age will enable continued exploration of the compositional, topographic, and temporal variations in plains distribution on Mercury.

References

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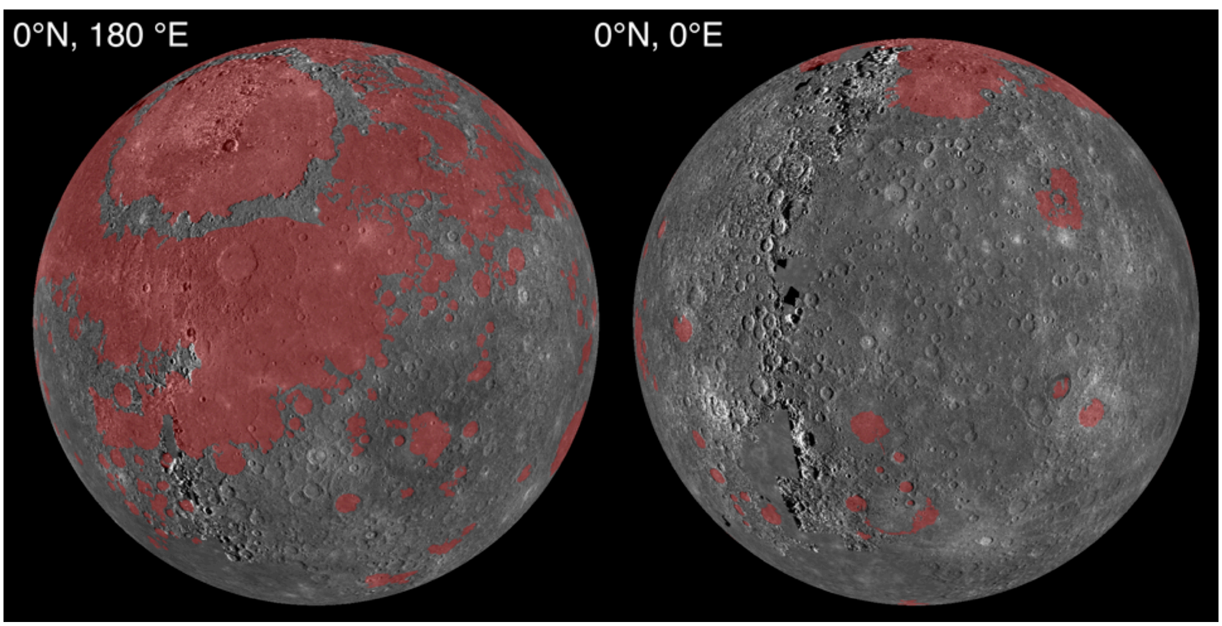

Fig. 1. Preliminary maps of the distribution of young plains (smooth and intermediate) on Mercury. The Caloris basin is at upper left. Latitudes and longitudes are for the centers of the orthographic projections.