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Large Scale Resurfacing in the Early History of Mercury

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Abstract

Imaging of Mercury by Mariner 10 unveiled a planet with more extensive plains units than on the Moon, while recent MESSENGER imaging revealed that the more recent smooth plains are due to widespread volcanism [1]. Even the most heavily cratered terrains of Mercury exhibit a lower density of craters smaller than about 100 km in diameter than on the Moon, attributed to resurfacing by the formation of ancient intercrater plains. These observations indicate that Mercury underwent an active geological evolution. However, the timeline of the major phases of this evolution are unknown. In this work, we address the ages of the most heavily cratered regions on Mercury, that represent the oldest visible units, by interpreting their crater population in the framework of the most recent lunar crater chronology [2].

1. Introduction

During flybys and orbital operations by the MESSENGER spacecraft, it has been proposed that Mercury's geological activity (e.g. volcanism) may have extended into relatively recent epochs, possibly as young as about 1 Gyr ago [3, 4]. This is a changed perspective from what emerged from interpretations of Mariner 10 imaging, namely that the crustal contraction of Mercury revealed by the numerous lobate scarps inhibited volcanism long before the last mare volcanism on Moon [cf. 5]. Less studied has been the chronology of the earliest geological features that can be detected on Mercury since the early work by [6], which qualitatively associated the heavily cratered terrains and volcanically formed intercrater plains with the epoch of the Late Heavy Bombardment (LHB).
As is true for other terrestrial bodies, except for the Earth and Moon, Mercury's geological chronology in terms of absolute ages has not been determined from dating rock samples. Rather it must be inferred by observations of the impact crater record, with age then extrapolated from the better constrained lunar chronology. Quantitative assessments of the lunar impact-based chronology were derived from Apollo and Luna rock samples, which is the basis for cratering chronologies for other terrestrial planets [e.g. 7].

2. Methodology

In this paper, we measure crater size-frequency distributions (SFDs) for the most heavily cratered terrains on Mercury and interpret them in the context of the Model Production Function (MPF) chronology [8] in order to determine the absolute ages of these units. The age of the most heavily cratered terrains is an important benchmark for Mercury, as it provides an upper limit for the formation of discernible main geological units, like the widespread volcanic smooth plains in the annulus surrounding the Caloris basin and in high northerly latitudes of Mercury [e.g. 1]. In order to identify the most heavily cratered terrains on Mercury [9], we measured craters larger than 25 km on a global mosaic obtained by MESSENGER based on imaging during the first year in orbit about Mercury. The mosaic has a resolution of 500 meter per pixel and covers almost the whole surface. The highest crater areal density was found in the so-called Norther Heavily Cratered Terrains (NHCT), a large region est of Caloris basin. This region appears to be a remnant of once more extensive cratered regions in the northern hemisphere after extensive resurfacing in adjacent localities by the northern volcanic plains, circum-Caloris volcanic plains, and the more recent cratering and basin-formation east of our selected NHCT.

3. Age determination

Figure 1 shows a plot of the cumulative number of measured craters for the NHCT and the MPF weighted best fit to the data. The MPF is obtained by using an impactor SFD resembling that of the main asteroid belt, which is more suitable for fitting old units [8, 10]. The crater SFD of the lunar pre-Nectarian terrains is also shown for a comparison. As can be seen, the MPF fits the NHCT data quite well.

For interpreting the crater SFDs for Mercury in the context of the lunar chronology, the data cannot be directly compared between Mercury and the Moon because of different impact velocities, gravitational focusing, and other differences that affect crater scaling. For example, the identical population of observed near-Earth objects that strike the Moon should result in ~3-4 times as many craters on Mercury in the size range relevant for this work (20-400 km), primarily due to the higher impact velocities at Mercury [11].

As can be seen, even though the observed crater population for the NHCT is similar to that for pre-Nectarian lunar terrains (Fig. 1), we would have expected a far higher crater density on the NHCT (instead of slightly lower) if they were equally ancient. For the case in which neither terrain is assumed to be saturated, the observed NHCT crater density actually implies that these supposedly ancient terrains on Mercury are several hundred million years younger than the most ancient observed terrains on the Moon, or about 4 Gyr old.

4. Conclusions

The specific age for the NHCT derived in previous section is, of course, model-dependent.

Nevertheless, the most heavily cratered terrains on Mercury must be appreciably younger than lunar heavily cratered terrains, whatever flux model is adopted for the Moon. Therefore, formation of intercrater plains outside of the most heavily cratered terrains on Mercury must have happened subsequent to 4 Gyr ago, and the appreciable volcanism that created intermediate and smooth plains [1] happened during still later times. Since the much more abundant cratering rate on Mercury compared with the Moon should have produced a terrain thoroughly saturated with craters, the fact that most heavily cratered Mercurian terrains are probably undersaturated in craters larger than 25 km diameter suggests that a powerful crater destruction process must have occurred. A major component of the crater destruction process was the formation of the intercrater, intermediate and smooth plains on Mercury, presumably due to voluminous volcanism (see [11] for more details on the age determination and implications for the early evolution of Mercury).

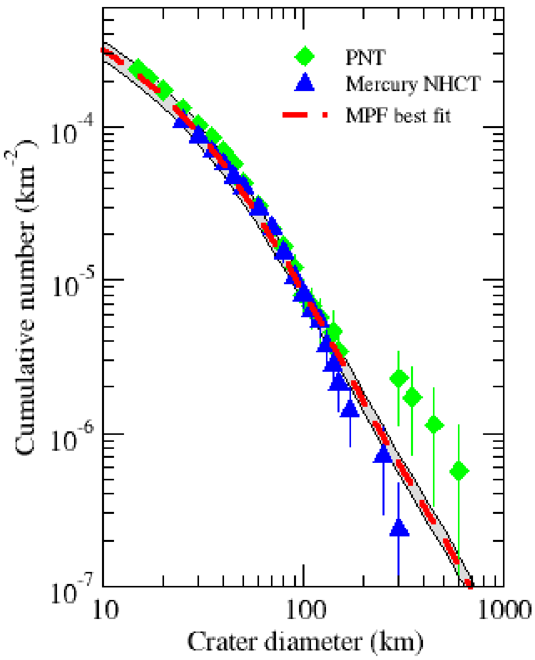

Figure 1: Crater SFDs for the NHCT and lunar pre-Nectarian terrains (PNT). The MPF best fit for the NHCT is also show. The MPF was used to derive the age of NHCT terrains, using a recent lunar chronology rescaled to Mercury (see text).

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