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Small Craters (Secondaries) on Mercury's Northern Plains

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1. Introduction

Since the MESSENGER spacecraft entered orbit, Mercury's far northern latitudes have been imaged at unusually high resolution. Our preliminary study of the population of small craters in a western portion of the northern plains concentrates on craters 100 m to 1 km in diameter, sizes that could not be studied anywhere on Mercury from earlier MESSENGER flyby imaging.

Many narrow-angle camera (NAC) images of the northern plains characteristically show a field of larger craters with subdued morphology on which superimposed clusters or chains of rather fresh but much smaller craters are sprinkled. We have tabulated crater diameters, positions, and morphological parameters for a typical NAC image, EN0210982250M, centered near 70°N and 321°E, taken on 11 April 2011 (Fig. 1). A context frame for this image (Fig. 2) shows that the locale is fairly far from two very large, comparatively recent craters. Larger craters (~1 km) were measured over the entire NAC image (labelled A). Smaller craters (few hundred meters) were measured on two subframes, one encompassing a cluster of these tiny craters (B), the other where clusters of these tiny craters are less frequent (C). Craters were classified on a 1 = fresh to 4 = highly degraded scale, and also on whether they are within obvious crater chains or clusters.

2. Crater Statistics

An R plot of the size-frequency distributions (SFDs) of "all" craters (i.e., not distinguished by crater class or clustering) from the entire NAC image (A) and from the two subframes of Fig. 1 is shown in Fig. 3; we show context counts for craters >10 km in diameter *D* from a part (M) of a north polar mosaic of wide-angle camera images and for craters down to about 4 km diameter from a smaller part (Msw) of that mosaic, which includes our NAC image. Craters ~100 km in diameter approach the empirical saturation spatial density; they are class-4 ghost craters, presumably inundated by a thick succession of lava flows that have wholly erased such craters <40 km in diameter. A very sparse population of fresh primary craters several to tens of kilometers in diameter clearly formed after northern plains volcanism largely ceased.

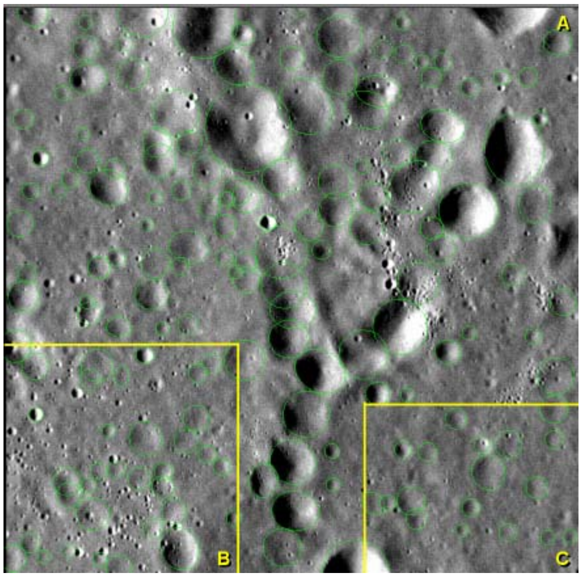

Fig. 1. NAC image "A" and subframes "B" and "C" (green circles = identified larger craters). North is to the right; the image is about 20 km wide (near 70°N and 321°E).

At diameters <10 km, Fig. 3 shows a steeply rising population of craters saturating at <2 km. These are mainly class 2 craters, commonly in chains or clusters; they are almost all secondary craters, as evidenced by their less-than-pristine morphologies, spatial non-randomness, and the steep SFD. Craters are near empirical saturation for diameters from 600 m to 2 km, but morphology degrades progressively for smaller craters. Class 1 and 2 craters peak near 2 km diameter, class 3 near 1.5 km, and class 4 near 800 m. This is classic evidence that, after these secondary craters formed, they were degraded by processes – perhaps inundation by lava flows of depth roughly 100 m – that slightly degraded the larger secondary craters, substantially degraded smaller ones, and completely erased such craters <500 m in diameter.

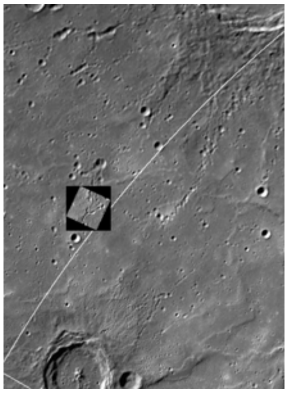

Fig. 2. Position of image in Fig. 1 on mosaic (with 70º/330ºE lat/long lines).

This subdued, undulating topography was then subsequently re-cratered by the clusters of tiny craters a few hundred meters in diameter. These craters approach empirical saturation within the densest clusters but remain sparse outside major clusters. We suggest that these are mostly far-field secondaries from one or more very distant large primary craters, which formed more recently, after the larger secondaries were already degraded and erased. Because these small clustered craters have a steep SFD, they must be secondaries. But because they are mostly pristine (class 1) in morphology, they must have been formed by high-velocity ejecta from afar (or by high-ejection-angle ejecta).

3. Interpretation and Conclusions

These craters clearly do not represent continuing equilibrium between crater production and destruction. Instead, we see prominent evidence of episodic cratering and/or degradation. Because the vast majority of all craters <10 km in diameter are secondary craters, evidence for episodicity is unsurprising; secondaries form at stochastically distributed moments when large craters form. On the other hand, the presumably volcanic processes that degraded these craters may also have been episodic. We can identify the approximate scales of depth of lava flows that have inundated these northern plains craters: (a) the ghost craters, even if originally topographically relaxed by other processes, must have been covered by a succession of lava flows many kilometers thick; (b) the secondary craters ~1 to 10 km in diameter have been degraded at the 100 m vertical scale; and (c) since the small-crater clusters formed, subsequent processes have modified the landscape hardly at all (< ~10 m depth).

We conclude that secondary craters, of various sizes, formed at different times from primary craters near and far, overwhelmingly dominate the population of small craters (*D*<10 km) on Mercury's northern plains. Any plan for identifying primary craters with the intention of dating small units on Mercury will require thoroughly unravelling the complicated history of secondary craters.

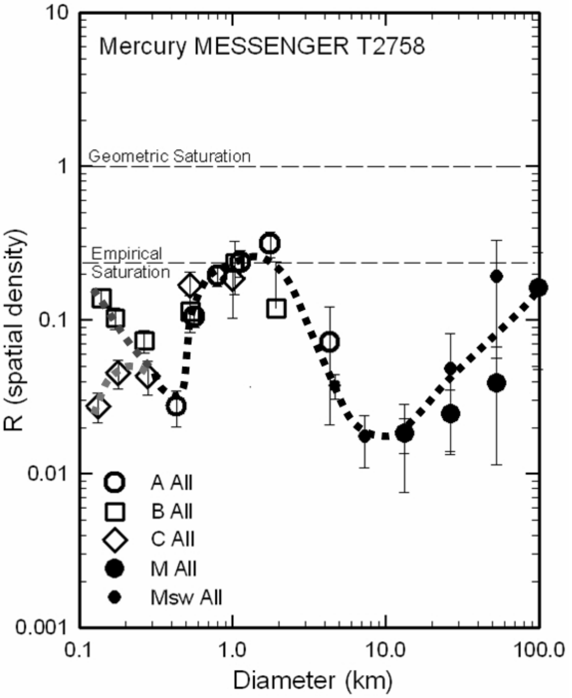

Fig. 3. R plot (target T2758) for “All” craters from NAC image “A” and subframes “B” and “C” and from parts of mosaic “M” and “Msw”. Different SFD trends are evident at the smallest diameters for clustered (B) and non-clustered (C) craters.