PIT-FLOOR CRATERS ON MERCURY: CHARACTERISTICS AND MODES OF FORMATION

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Introduction: Assessment of volcanic landforms on Mercury's surface is important for understanding the planet's thermal history as well as Mercury's place within the known geologic histories of the other terrestrial planets [1, 2]. From images obtained by the MESSENGER spacecraft during its first and second flyby of Mercury, we have identified numerous *pit craters* on the floors of impact craters. Pit craters are rimless depressions that are interpreted to have formed by endogenic processes. Impact craters hosting pit craters we term *pit-floor craters*; those identified to date vary in size from 52 to 182 km in diameter.

Pit craters range in size from 2 km to almost 40 km in diameter, but there is no evident correlation between pit-floor crater diameter and size of pit crater. In fact the largest three impact craters contain small pit craters rather than large pit craters. While no lava flows are observed to cut the rim of these pit-floor craters, in all cases they are located near smooth plains deposits.

Discussion: We interpret pit-floor craters as products of shallow igneous activity on Mercury [3, 4], an inference that supports other recent evidence for volcanic activity on the planet [5, 6]. Among the arguments in favor of this interpretation are: (1) no observable ejecta surrounding the pit craters are observed; (2) pit craters lack rims; (3) the pit craters are irregularly shaped.

To date all pit craters on Mercury have been found only on the floors of impact craters and within basins, which suggests that pit craters are related to the impact process in some way. The absence of a correlation between pit-floor crater diameter and size of pit crater suggests that endogenic processes control the pit crater formation size and that the impact fracturing facilitates the rising of magma and volatiles.

Small-sized pit craters like those found in Lermontov (Fig. 1), Murasaki and Praxiteles form as irregular pits with shallow floors, often occur in clusters, and are often mantled by or proximal to high-reflectance (compared with the surroundings) pyroclastic material [4, 5]. These materials are bright because of the low abundance of ferrous iron and titanium in the silicate glass [4]. The lack of a mafic mineral absorption near 1 μm is also indicative of low ferrous iron content in silicates [7-9]. In comparison with the large-sized pit craters, small-sized pit craters are more irregularly shaped, and can have sharp or smooth rims and shallow floors.

The juxtaposition of pyroclastic material and pit craters suggests that their formation is the result of explosive venting of volatiles from degassing magma too deep to propagate to the near surface. A similar mechanism of formation was suggested for Rima Hyginus on the Moon [10]. Calculations of the volatile abundance reveal that magmas on Mercury would require more than twice the amount of carbon monoxide to emplace pyroclastic deposits a given distance than on the Moon [6]. Such outgassing from Mercury's interior favors planet formation models that allow for retention of volatiles at some stage of the planet formation process [11].

Large-sized pit craters are defined as pit craters with a maximum horizontal dimension from 20 to almost 40 km. Pit craters on other planetary objects are smaller, typically < 2 km in diameter. Pit craters in this size range on the other planets are actually calderas. Mercury's large pit craters exhibit steeper sides and are more arcuate than the small-sized pit craters. The long axis of the pit crater often concentric to the structure of the host impact crater (Fig 2). Also, they occur as isolated pits unlike the smaller pit craters that tend to form in clusters. Another difference between the two size classes of pit craters is the lack of pyroclastic material associated with the large pit craters. Only one of seven lare-sized pit craters (e.g., Glinka) is observed to have associated high-reflectance material that could be pyroclastic in origin [3].

The different morphology of large-sized pit craters suggests a different mode of formation from the small pit craters. We propose that these large pit craters arose over shallow subsurface magma bodies that formed collapse pits or calderas in association with near-surface magma reservoirs. In this scenario of pit formation, the mechanism of formation is the result of piston-like collapse over a broad magma body or evacuated chamber. Stoping of roof material by magma below pit-floor craters creates a large cavity, into which the highly fractured crater floor above collapses after magma is withdrawn.

Conclusion: Pit craters on Mercury can be classified into two categories on the basis of morphology and size. We suggest that the difference in pit morphology relates to the mode of formation: small irregular-sized pit craters are the result of explosive venting of volatiles from degassing magma too deep to propagate to the near surface, and the larger-sized, steep-sided pit craters are formed by piston-like collapse over a broad magma body or evacuated chamber similar to the formation calderas on the Earth.

The outgassing of volatiles by magmas to produce pyroclastic deposits, as evidenced primarily by the small sized pit craters, favors planet formation models that allow for retention of volatiles at some stage of Mercury's formation.

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Acknowledgements. This work is supported by the NASA MESSENGER Participating Scientist Program under grant NNX07AR75G to JJG-D.

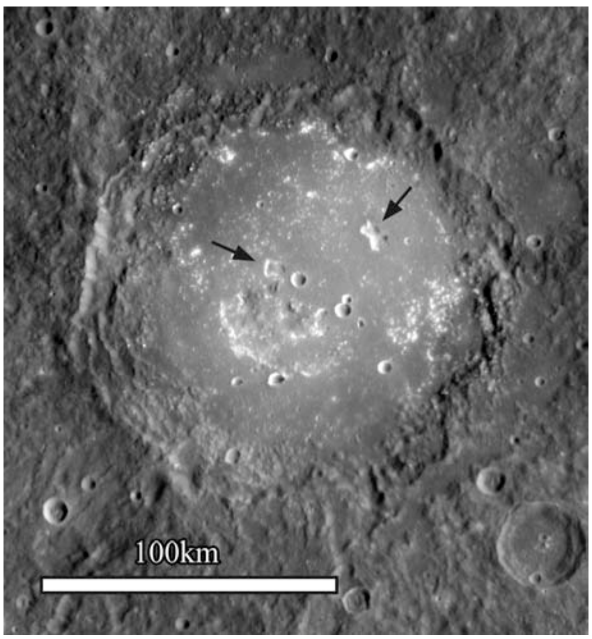

Fig 1. Small, irregularly shaped pit craters (black arrows) can be observed on the floor of Lermontov crater (15.3°N 48.1°E; 152 km in diameter). The image was acquired with the MESSENGER Narrow Angle Camera with an original spatial resolution of ~250 m/pixel.

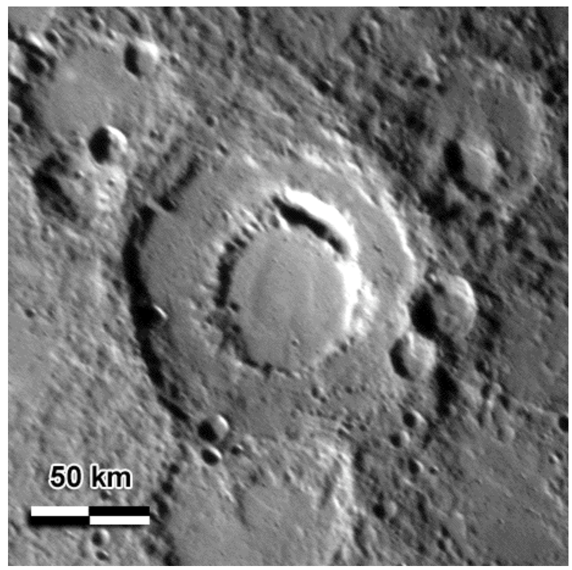

Fig 2. A large-sized pit crater in the crater Scarlatti (40.5°N, 259°E; 120 km in diameter) conforms to the arcuate shape of the central peak ring of the host crater, suggesting that the crater's structure influenced the location and shape of the pit crater. Observed within the central peak ring are subtle wrinkle ridges that may outline a smaller inner circular depression or caldera. The image was acquired with the MESSENGER Narrow Angle Camera with an original spatial resolution of 510 m/pixel resolution.