LARGE PIT CRATERS ON MERCURY: GLOBAL DISTRIBUTION AND OCCURRENCE. Jeffrey J. Gillis-Davis1, Matthew M. Markley1, Timothy A. Goudge2, James W. Head2, Zhiyong Xiao3,4 Klaus Gwinner5. 1Hawaii’i Institute of Geophysics and Planetology, University of Hawai’i – Manoa, 1680 East-West Road, Honolulu, HI 96822, USA 2Dept. of Geological Sciences, Box 1846, Brown University, Providence, RI 02912, USA 3Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85719, USA. 4China University of Geosciences (Wuhan), Wuhan, Hubei, P. R. China, 430074. 5DLR Institute of Planetary Research, Berlin, Germany. (contact: gillis@higp.hawaii.edu).

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 acquired following insertion of MESSENGER into orbit around Mercury, we have identified numerous large pit craters within and outside the floors of impact craters. Pit craters are rimless depressions, ranging in size from 2 km to almost 40 km, and are interpreted to have formed by endogenic processes [3,4,5], an inference that supports abundant other evidence for volcanic activity on the planet [6,7,8].

Here we discuss the global distribution and occurrence of large (>20 km across) pit craters on Mercury in order to retest and revise as needed our earlier hypotheses [5] that such features (a) formed by piston-like collapse over a broad magma body or evacuated chamber, (b) tend not to be associated with pyroclastic volcanism, and (c) occur only in impact craters.

Background: Pit craters have been classified into two categories on the basis of morphology and size. Small pit craters, <20 km across, are identified as explosive pyroclastic volcanic centers, whereas pit craters larger than 20 km across appear to be products of collapse [9]. The juxtaposition of bright, spectrally red pyroclastic material and small pit craters suggests that their formation is the result of explosive venting of volatiles from magmatic degassing [4,5]. In contrast, large pit craters lack bright, spectrally red surrounding material (an exception is Glinka crater), exhibit steeper sides, and are more arcuate in map view than small pit craters. Also, they occur as isolated pits, unlike the smaller pit craters that tend to form in clusters. Large pit craters have been interpreted to form by piston-like collapse over a broad magma body or evacuated chamber similar to the formation of calderas on Earth [5]. Where stopping of roof material by magma below pit craters creates a large cavity, the highly fractured crater floor above collapses after magma is withdrawn.

Evidence cited [5] in favor of a shallow, non-effusive igneous origin for large pits was: (1) no observed ejecta surrounds them; (2) they lack rims; (3) they are irregularly and often arcuately shaped; (4) they are not associated with bright or spectrally red pyroclastic material; (5) no lava flows are observed to cut their rims, and (6) they are spatially associated with smooth plains.

Seven large pit craters were found in the Mercury Dual Imaging System (MDIS) images from the first Mercury flyby [5]. All of these pits were located on the floors of impact craters. Compared with small-sized pit craters, they were larger and more arcuate. Their maximum horizontal dimension ranges from 20 to almost 40 km, which is comparable to sizes of large calderas on Earth [10], Venus [11], and Mars [12]. Furthermore, the long axes of the pit crater are often aligned with the structure of the host impact crater. Impact craters that contain pit craters were termed pit-floor craters [5]; those originally identified varied in diameter from 55 to 120 km in diameter.

The apparent connection between impact crater and pit crater led to the hypothesis that pit craters are related to the impact process in some way [5]. However, no correlation exists between pit-floor crater diameter and size of pit crater [5] – the largest three impact craters originally identified contain the smallest pit craters rather than largest pit craters. In addition, pit craters do not occur in the center of the host impact crater, as often observed for Mars [13]. These observation suggested that endogenic processes control pit crater formation size, whereas impact fracturing facilitated the locus of magma ascent and controlled pit crater shape.

Datasets: The distribution and geologic setting of large pit craters have been further investigated using orbital images from MDIS high-resolution narrow-angle camera (NAC) and wide-angle camera (WAC) [10]. Spectral properties of the large pit craters have been examined using MDIS 8-band color images [14] photometrically corrected using a standard phase function [15].

General Results From New Orbital Observations: The orbital MDIS data reveal many new large pit craters. We have identified 39 (eight of these unconfirmed) new pit craters contained within impact craters and nine pit craters (four of these unconfirmed) outside of an impact crater (Fig. 1). These figures bring the total number of large pit craters to 55.

In addition, new spectral and geomorphological information has been derived from the near-global, high-resolution WAC and NAC data. In our previous study [5] only the pit crater on the floor of Glinka exhibited evidence of pyroclastic material surrounding it. From orbital observations, however, of those original seven
large pit craters, five exhibit steep, spectrally red continuum, which is indicative of pyroclastic material [4]. And, taken collectively, pyroclastic material is found in association with most large pit craters. Moreover, for some of the pit craters for which high-resolution (better than 200 m/px) NAC data exist, we have noticed that the relief appears draped (high-frequency topography muted) by what appears to be pyroclastic material (Fig. 2).

Some of the large pit craters classified by this study as not hosted by an impact crater were identified as pyroclastic vents by other workers (e.g., pit near Raditladi [16], and pit near Caloris [7]). In addition, some previously identified pyroclastic deposits (e.g., Praxiteles [4]) are included here as large pit craters. In both cases, we elected to include these pit craters under our classification of large pit craters because the characteristic that excluded them from pit-floor craters was their spatial relation with bright, spectrally red pyroclastic material. In addition, we decided to change the classification pit-floor crater to a sub-classification. In place, we are proposing the term large pit floor craters >20 km across, interpreted to be of endogenic origin. This change is necessary because these interpreted volcanic craters, although occurring mostly within impact craters, can also occur within smooth and intercrater plains.

**Conclusions:** Of our original three hypotheses [5], two – namely that (1) large pit craters tend not to be associated with pyroclastic volcanism and (2) they occur only in impact craters – are now falsified. However, on the basis of terrestrial and extraterrestrial analogs, their large size still suggests that they form by piston-like collapse over a broad magma body or evacuated chamber. Like a resurgent caldera, such features are now seen often to be associated with pyroclastic volcanism.

**References:**


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![Fig. 1. (left) MDIS monochrome image of a large pit crater not contained in a host impact crater. (right) WAC color image showing bands 1000, 750, 430 nm in the red, green, and blue channels, respectively. The crater probably does not appear spectrally red like most pyroclastic deposits because ejecta from a near by fresh crater (just out of the upper left field of view) is superposed on it.](image1)

![Fig. 2. Scarlatti crater showing large pit crater with spectrally red material draping local topography, suggesting pyroclastic volcanism is associated with pit-floor craters. Arrow points to sinuous feature that could be a volcanic rille.](image2)