MERCURY PIT-FLOOR CRATERS: PERSPECTIVES ON THEIR ORIGIN FROM LUNAR FLOOR-FRACTURED CRATERS. Lauren M. Jozwiak[1] and James W. Head[1]. [1]Department of Geological Sciences Brown University, Providence, RI 02912 USA (lauren_jozwiak@brown.edu).

Introduction: High-resolution images obtained during the first MESSENGER flyby of Mercury revealed the presence of irregularly-shaped pit craters, rimless steep-sided depressions (Fig. 1) that are inferred to have formed by non-impact processes [1]. These features range in maximum horizontal dimension from 20 to almost 40 km, and often occur on the floors of impact craters (varying in size from 55 to 120 km in diameter), leading to the designation of these craters as pit-floor craters. On the basis of several lines of evidence, the pit craters were interpreted to be of volcanic origin: lack of evident rims typical of impact craters; no observable ejecta; irregularly shaped compared to most impact craters, with the long axis of the pit crater often concentric to the rim of the host impact crater. No signs of associated extrusive flows were reported [1]. Pit craters were thus concluded to represent evidence for igneous modification of the surface. On the basis of these characteristics and associations, pit craters on Mercury were interpreted to have formed through collapse into an underlying drained magma chamber (a collapse caldera) (Fig. 2), thus representing evidence for near-surface magmatic activity on Mercury. These features were seen to extend the range of evidence for magmatism beyond such surface expressions as smooth plains [2] and pyroclastic deposits [3,4]. We use additional observations reported for Mercury and planetary analogs to assess this hypothesis.

Ascent and Eruption of Magma: The Moon: The frequency and manifestations of magmatic intrusions in the crust of a terrestrial planetary body provide important insights into the dynamics of magma ascent and eruption, for the influence of crustal composition, and the role of shallow crustal structure in emplacement mechanics. For example, conditions of ascent and eruption of magma on the Moon [5,6] favor the propagation of magma through dikes to the surface to often produce high-volume, high flux eruptions. Evidence exists, however for a range of features associated with shallow intrusion, as dikes propagate to the near surface and stall. Among the most prominent examples of such features are floor-fractured craters (FFC) [7], interpreted to represent magmatic dike intrusions into low-density crater floor breccias, and lateral spreading into a sill-like or laccolith-like body, lifting the floor of the floor in a piston-like manner in the process. This process tends to shallow and fracture the crater floor. Such a shallow intrusion process would seem to be an excellent candidate to produce the pit-floor craters recently documented on Mercury [1]. In order to assess the collapse-caldera hypothesis for their origin, we first review the nature of the FFC population on the Moon, assess similar examples on Mercury, and finally, assess the origin of the pit craters as collapse calderas.

Recently [8] we categorized and mapped the distribution of the lunar floor-fractured crater population, and this work also supports the formation of floor-fractured craters by shallow magmatic intrusion. The floor profiles, generated with LOLA topography, show 1) flat fractured floors for the largest craters, and those closest to the mare and 2) smaller craters, and ones farther from the mare have more convex floors and concentric fracture patterns. The first type appears to be a manifestation of an underlying intrusion with greater driving pressures, and/or intrusion thickness combined with a thinner overlying crust, allowing for piston-like floor uplift. The second type of craters appears to be manifestations of smaller intrusions and lower driving pressures, also governed by the thicker highland crust. Since FFCs seem to be an excellent indication of shallow intrusions on the Moon, what types of similar features are seen on Mercury?

Floor Fractured Craters on Mercury: MESSENGER's first Mercury flyby revealed a single example of a lunar-like floor-fractured crater (Fig. 2); although for MESSENGER, as with Mariner 10, the illumination geometry was less than favorable for the detection of floor-fractured craters over much of the rest of the area imaged. Noted by Head et.al. [2], a 35-km-diameter floor-fractured crater (Fig.2B), is located near the margins of extensive deposits of smooth and intercrater plains that have been interpreted to be of volcanic origin by Robinson et al. [9] and Head et al.[10]. In contrast to fresh impact craters [11], the interior of this crater (Fig. 2B, C) appears highly modified, with the south–southeastern wall slumped inward, wall terraces indistinct and obscured, and the floor of the crater generally appearing shallower than for the fresh example.

The most distinctive parts of the crater interior are two dome-like located on the eastern and western parts of the crater floor. These dome-like features are unlike central peaks in their morphology and position, additionally the crater is too small for the domes to represent peak rings [11]. Although it appears to lack floor fractures, and its apparent moat ridge does not have a greater elevation than its rim, this floor-fractured crater appears to be most similar to lunar Class IVB [7,8], as exemplified by the lunar crater

Gaudibert (33-km diameter). In addition to morphologic similarities, Gaudibert and this Mercury crater, also occur in close proximity to volcanic plains, supporting the interpretation that floor fractured craters are formed by shallow magmatic intrusions whose laccolith-like structure causes bending and uplift in the overlying crater floor [7,8].

Assessment of Pit Floor Craters: With this interpretation of floor fractured crater formation, the Moon emerges with evidence for at least a few hundred instances of shallow magmatic intrusion where the intrusions lie under crater floors. The question then arises, does Mercury, another heavily cratered terrestrial body, also display evidence for shallow magmatic intrusion? Despite a large crater population, and previous assessment on their likely presence [12], to date only one possible floor fractured crater on Mercury has been reported in MESSENGER data [2].

We have studied the feasibility of this model of magmatic intrusion through dike emplacement as a result of mantle magma overpressurization, and found that it seems unlikely to be the underlying mechanism of the crater pits is sub-surface magmatic intrusion. We used order of magnitude approximations for compositional parameters [13], the intrusion dimensions modeled from the crater pit dimensions, and values comparable to other silicate bodies for the material constants; to obtain workable guidelines for the initial investigation of this mechanism [14]. Using this model, the theoretical magma over-pressure associated with these crater pits is typically below that needed to allow for easy dike propagation through the crust. This result is consistent with the recent work of Wilson and Head [15], postulating that the mantle and crust structure of Mercury do not favor small scale magmatic events, but does favor fewer large scale massive flooding events from large fractures. This result is supported by the lack of features associated with shallow magmatic intrusion, most notably floor fractured craters, and also small shields and other similar features.

This model does not preclude shallow magmatic intrusion on Mercury, although it does suggest that dike propagation may arise in more select circumstances such as in the interiors of impact craters. For example, special instances when a crater forms over a mantle area with sufficient melt accumulation, whereby the crater formation causes extensional stresses in the crust, decreasing the overburden pressure and allowing the dike to propagate. In this scenario, crater pits could represent pyroclastic events with either explosive or passive degassing of the intruded magma, with the overlying floor subsequently subsiding and forming the observed pits. Head et.al. [16] described a similar scenario on the Moon in Orientale, wherein a single explosive pyroclasitc event produced an elongated pit, 7.5 km wide by 16 km long. As there is already observed evidence for pyroclastic events on Mercury [3], the provenance of crater floor pits as subsidence features following a dike emplacement event, volatile exsolution and buildup, but lacking an explosion should be investigated. This diffusive loss of volatiles could cause collapse rather than an eruption.

References: [1] J. Gillis-Davis et.al. (2009). *EPSL. 285*. 243-250. [2] J. W. Head et al. (2008) EPSL [3] L. Kerber et al. (2009) *EPSL, 285*, 263-271. [4] L. Kerber et al. (2009) *Icarus, 206*. 669-684. [5] L. Wilson and J. W. Head (1981) *JGR, 86*.2971-3001. [6] J.W. Head and L. Wilson (1992) *Geochim.et. Cosmochim. Acta., 56*. 2155-2175. [7] P. Schultz (1976) *The Moon.15*. 241-273. [8] L. Jozwiak et al. (2012) *LPSC XLIII,* Abstract # 1512. [9] M. S. Robinson et.al. (2008) *Science, 321*. 66-69. [10] J. W. Head et al. (2009) *EPSL, 285.* 227-242. [11] R.J. Pike et.al. (1988) *Mercury, U. of Arizona Press*. 165-273. [12] P. Schultz (1988) *Mercury, U. of Arizona Press.* 274-335. [13] L. Wilson and J.W. Head (2008) *GRL, 35*. L23205. [14] A.M. Johnson and D.P. Pollard (1973). *Tectonophysics 18*, 261-309. [15] L. Wilson and J.W. Head (2012) *LPSC XLIII,* Abstract # 1316. [16] J.W. Head, L. Wilson, and C.M. Weitz (2001) *JGR, 107*. E1.

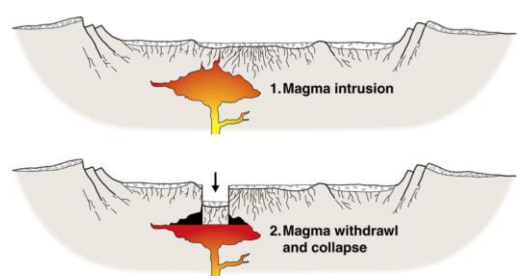

Fig 1: Schematic illustration of pit crater formation on the floor of an impact crater. (1) Magma intrudes into a reservoir in the shallow crust along the base of a low-density brecciated zone beneath the crater floor. (2) Subsequent magma withdrawal causes foundering and collapse of the reservoir roof in the absence of structural support. From Gillis-Davis 2009 [1]

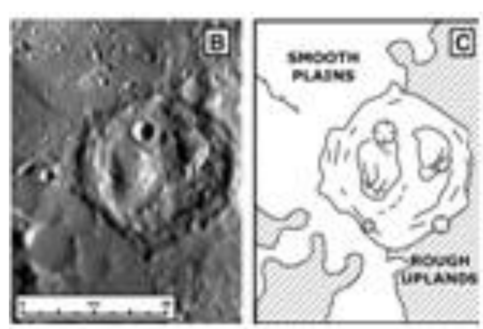

Fig 2: (B) Floor-fractured ~ 35-km-diameter crater on Mercury (7.5°N, 104.3°E) (see Head et al. [2]). MDIS NAC image EN0108826977M. (C) Sketch map of major features in (B) showing domes and fractures and proximity to smooth plains. From Head et.al. 2009 [10].