PROTOBASINS ARE NOT PART OF THE NORMAL SEQUENCE, TARGET IS IMPORTANT, AND OTHER MUSINGS ON THE CENTRAL-PEAK TO PEAK-RING TRANSITION BASED ON MERCURY'S IMPACT CRATERS.

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Introduction: I have been examining impact craters on Mercury in the size range 100 < D < 140 km. This size range covers roughly a factor of three in impact kinetic energy and, based on previous surveys [1,2,3], the craters have a mix of interior features and are within the diameter range for the transition from central-peak to peak-ring morphology. By looking at this population of craters, I hope to evaluate the extent to which varying impactor and target properties can alter the final appearance of an impact crater. Craters of similar size form from impacts of similar kinetic energy, so the cause of two craters having a similar size but different morphologies must either be a difference in the impactor (e.g., impact velocity, angle) or a difference in the target (e.g., layering, porosity, cohesiveness). A correlation of crater appearance with location would point to the importance of near-surface crustal properties, while disparate craters on similar-appearing targets may indicate that an impactor property is responsible for the difference. Mercury should be a good place to look for velocity-caused morphology differences [4], as it has the largest spread of impactor velocities in the solar system. For example, the ratio of impact melt volume to crater volume should weakly depend on impact velocity [5]. As I discuss below, my initial analysis led me to take a more detailed look at protobasins (craters with both an interior peak and ring) on Mercury, the Moon, and Venus.

Mercurian craters 100 < D < 140 km: A recent survey [3] showed ~300 craters in this size range, with 118 of those having some sort of preserved central structure. Mercury has had a complicated history of cratering, volcanism, and tectonic deformation. Many craters formed on an irregular surface such as the rim of a larger basin. Other craters have significant amounts of volcanic filling, and for many of them it appears that superposed impacts and/or tectonic deformation prior to filling altered the appearance of the central structure. Consequently, for only 45 of these 118 craters did I feel that the central structure could be confidently characterized and had not been obviously distorted by impact into a laterally heterogeneous target. The categories are as follows, in order of inferred complexity from central-peak to peak-ring crater: single central peak (*cp*, N = 12); tightly clustered multiple peaks (*mp*, N = 16); dispersed multiple peaks (*dmp*, N = 5); protobasin (*pb*, N = 5); ringed peak cluster (*rpc*, N = 3); and peak ring (*pr*, N = 4). The geographic distribution of these features (Figure 1) does not show an obvious pattern of target type versus crater type, but the *pb*, *rpc*, and *pr* craters seem to be predominately in the northern hemisphere. Five of the craters in this size range are superposed on the "smooth plains" [6], and of these there are one *cp*, two *pb*, and two *mp* craters, a noticeable if not statistically significant skewing towards ringed structures with terrain type.

As an additional test of the importance of target type, I examined the craters based on their proximity to each other, and this effort was more illuminating. There are 53 craters in [1] in this size range with a pre-

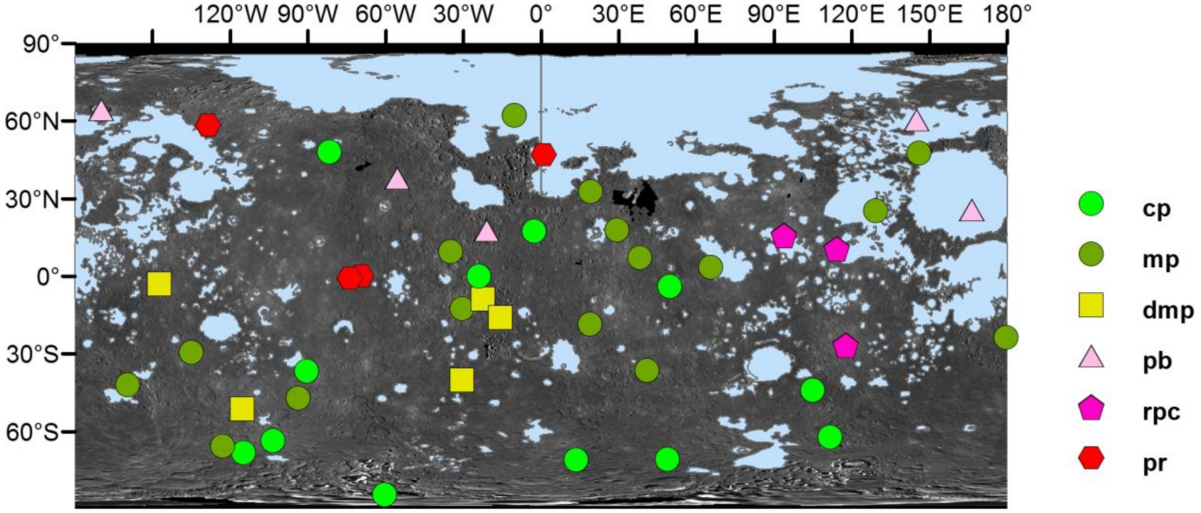

Figure 1. Locations of well-preserved Mercurian craters with 100 < D < 140 km, classified by interior structure. Light blue areas are those mapped as smooth plains in [6].

served central structure that have crater centers separated by < 360 km. However, for many of these pairs/clusters one or more of the craters is not adequately preserved to enable me to confidently compare the central structures of the nearby craters; i.e., subsequent post-impact events have buried or distorted important parts of the crater interior. I identified 5 crater pairs and 5 clusters of three or more craters for which I felt that the craters are well enough preserved to evaluate whether the central structures are similar in nature (note: in practice, for this abstract I increased the crater-crater distance until I had ten usable pairs/clusters, which occurred at 360 km). For eight of the ten cases the central structures in each pair/cluster were unambiguously similar in nature. Of these eight, there were six clusters of *cp/mp* craters, one pair of *pr* craters (Figure 2), and a pair of *pb* craters. For the two remaining clusters (three craters in each), one crater was slightly different in appearance from the other two, and in one of those cases the odd crater clearly formed on different terrain. We found no craters of similar size with unambiguously different central structures in close proximity to one another.

Protobasins: While examining craters in this size range, I observed that very few of the craters that are characterized in [1] as protobasins are prototypical. In many cases only a small arc of the ring is preserved, often the ring is very irregular, and the ring is rarely centered in the crater interior. In many of the craters the central peak is neither centered in the crater or centered within the putative ring. Often the "peak" and "ring" are in close enough proximity that one could interpret the feature as simply a ring with a bump on it or as a central peak complex with a few outlying knobs. Based on these observations, I decided to examine all of the 70 features classified as protobasins by [1] (spanning 50 < D < 195 km), and I examined proposed protobasins on the Moon and Venus. Of the 70 Mercurian protobasins, only four had a peak with a separate, surrounding ring, where both peak and ring were crater-centered and the ring encompassed more than 180° of arc. On the moon, three craters are characterized as protobasins in [7]. Of these, Antoniadi is at the base of South-Pole Aitken basin, both Antoniadi and Compton are located where the crust is unusually thin [8], and the third (Hausen) is not, in my opinion, a protobasin. On Venus, there are no clear examples of a central peak surrounded by a separable peak ring. My interpretation is that protobasins result from target heterogeneity (e.g., layering) and that a central peak and peak ring would not occur in a sequence of craters of increasing size on a planet with a homogenous subsurface. Many of Mercury's proto-basins may also reflect post-impact cratering reshaping a crater's interior, followed by partial volcanic flooding.

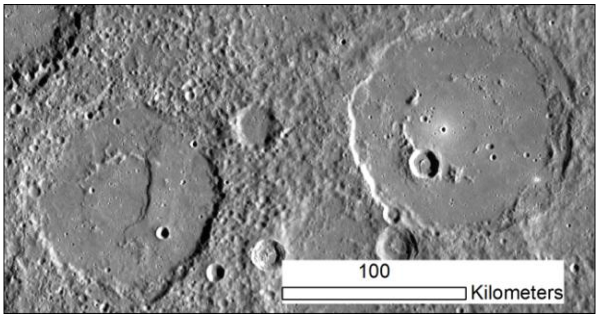

Figure 1. Mercurian peak-ring craters Boethius (D = 105 km) and Polygnotus (D = 121 km); centers are 188 km apart.

Discussion and Future Work: This initial examination of Mercurian craters is supportive of the hypothesis that target properties like cohesiveness and layering are variable enough on Mercury to affect the nature of a crater's central structure; a corollary hypothesis would be that near-surface properties also cause variation in the peak-ring onset diameter across Mercury. On the other hand, I saw no "smoking gun" of different-morphology, well-preserved craters in close proximity that would support a major role for impactor properties such as velocity altering central-structure appearance, although current observations are inadequate to negate this hypothesis. The prevalence of protobasins on Mercury is a reflection of a heterogeneous crust and a complicated interleaved history of volcanism, tectonics and cratering. There is an abundance of unusual central structures, probably with multiple origins, that can broadly be considered to share the trait of an inner peak and part of an inner ring. Stereo-derived topography, which provides critical information on the relative elevations of features within the crater, will be useful for understanding some of the complexities of Mercurian craters.

References: [1] Baker D. M. H. and Head J. W. (2013) *PSS*, *86*, 91-116. [2] Baker D. M. H. et al. (2011) *PSS*, *59*, 1932-1948. [3] Pike R. J. (1988) *Mercury*, 165-273. [4] Schultz P. H. (1988) *Mercury*, 274-335. [5] Cintala M. J. and Grieve R. A. F. (1998) *MAPS*, *33*, 889-912. [6] Denevi B. W. et al. (2013) *JGRP*, *118*, doi:10.1002/jgre.20075. [7] J. E. and Sharpton V. L. (2002) *MAPS*, *37*, 479-486. [2] Chappelow J. E. (2008) *LPSC 38*, #1441. [3] Barnouin O. S. (2012) *Icarus*, *219*, 414-427. [4] Schenk P. M. (1989) *JGR*, *94*, 3813-3832. [5] Schenk P. M. (2002) *Nature*, *417*, 419-421. [6] Johnson T. V. and Lunine J. I. (2005) *Nature*, *435*, 69-71. [7] Baker D. M. H. et al. (2011) *Icarus*, *214*, 377-393. [8] Wieczorek M. A. et al. (2013) *Science*, *337*, 671-675.