A TALE OF TWO CRATERS: USING GEOLOGICAL MAPPING TO ASSESS THE ROLE OF IMPACT MELT IN THE FORMATION OF HOKUSAI CRATER, MERCURY.

Mallory J. Kinczyk[1], Olivier S. Barnouin[2], Carolyn M. Ernst[2], and Paul K. Byrne[1], [1]Planetary Research Group, Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, Raleigh, NC 27695, [2]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723.

Introduction: Understanding the factors that control crater shape and the characteristics of crater deposits can shed light on impact crater formation mechanisms. Differences in crater characteristics are manifest throughout the Solar System, from uniform continuous ballistic ejecta deposits on the inner terrestrial planets and fluidized multi-layered rampart craters across the surface of Mars [1], to shallow and relaxed craters on the icy moon, Enceladus, which lack visible ejecta deposits and secondary crater chains [2]. Each of these expressions of the impact process can be attributed to some combination of differences in the crater formation process and post-impact crater modification.

On Mercury, one of the most perplexing impact structures is Hokusai crater (**Figure 1**). The freshest of only a few so-called lobate craters on Mercury's surface, Hokusai is characterized by its fluidized ejecta deposits that terminate in a rampart morphology reminiscent of single-layered craters on Mars, and is distinct from other well preserved craters on the planet [3]. Here we use geological mapping to gain insight into the role of impact melt in the formation of the ejecta deposits of Hokusai crater. We investigate the geological context of Hokusai and a similar-sized crater, Abedin (**Figure 2**), located in Mercury's Borealis Planitia (BP), a vast expanse of lava plains in the planet's northern hemisphere. By comparing the distribution of impact melt at these two craters, we may determine if the quantity and distribution of melt was a contributing factor in the formation of Hokusai's rampart morphology.

Hokusai. Hokusai is a 94 km-diameter ringed peak-cluster basin located within BP (at 57.8ºN, 16.7ºE). The rim and continuous ejecta deposits have a ropey morphology bounded by distal ramparts that stand up to 500 meters above the surrounding terrain [3]. It is a relatively young landform, with only a few small superposed craters, and a distinctive ray system [5].

Abedin. At 115 km in diameter, Abedin is a protobasin [4] located at the edge of BP (at 61.7ºN, 349.3ºE). It has crisp features including distinct impact melt ponds, a continuous ejecta deposit, and a prominent field of secondary craters—an appearance that corresponds to a degradation state of Class 4 [6]. This classification is assigned to Abedin because the basin lacks rays. The rim of the basin tapers gradually into the continuous ejecta, with a feathery distal morphology that grades into the surrounding field of secondary craters.

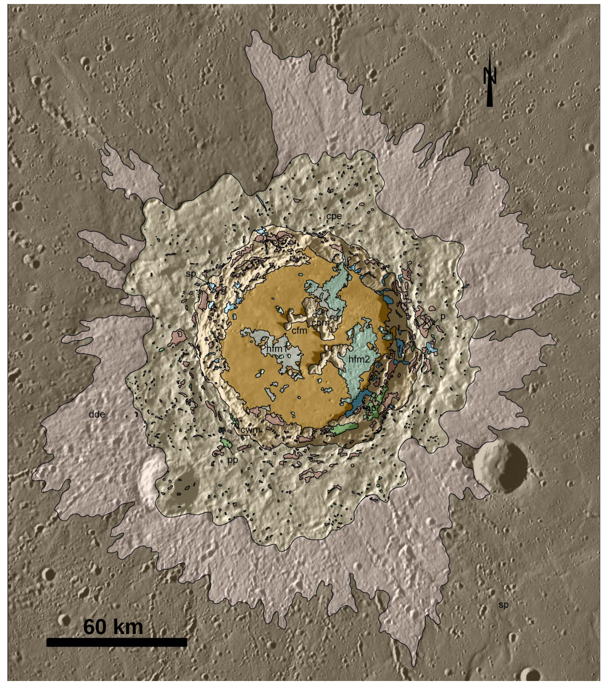

Figure 1. Geological map of Hokusai crater. Diameter: 94 km, Coordinates: 57.8ºN, 16.7ºE

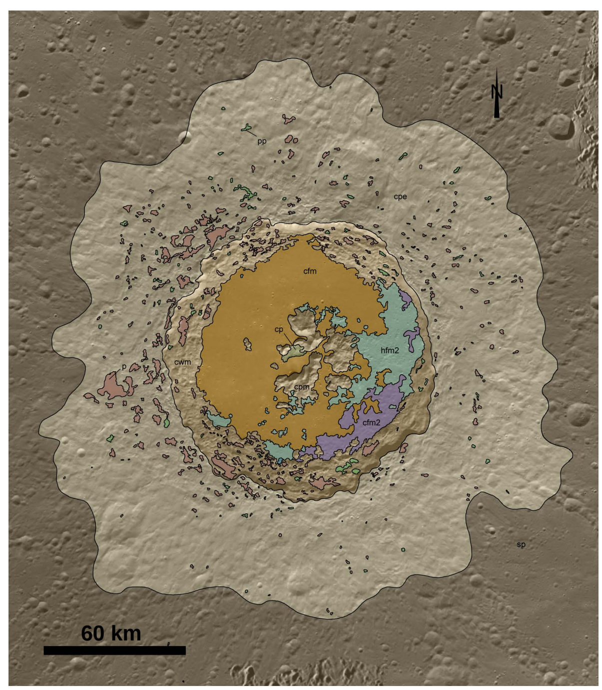

Figure 2. Geological map of Abedin crater. Diameter: 115 km, Coordinates: 61.7ºN, 349.3ºE

Mapping Methods: In order to better understand the characteristics of the ejecta deposits for each crater, we defined and mapped crater units on the basis of morphology. A monochrome image basemap (166 meters/pixel (mpp)) [7] and a collection of individual targeted high-resolution images (17–36 mpp) obtained by the MESSENGER Mercury Dual Imaging System (MDIS) instrument were used for detailed geological mapping.

Geological units were identified purely on the basis of morphology (rather than by color or composition). We interpret regions within the crater deposits that do not vary in elevation to be impact melt. Many melt ponds at Hokusai display alternating regions of high and low reflectivity ("mottling") in the monochrome basemap. However, this characteristic was not a major determining factor in the mapping process. In most cases, the boundaries of geological units were defined only by pronounced changes in surface morphology. An inferred boundary was used in regions that were covered in shadow in all available images, or where a change in morphology was gradational.

Mapped units: Units corresponding to numerous discrete crater facies, in addition to melt ponds, were differentiated during the mapping process. Here we highlight several noteworthy mapped units:

Ponds (p) are smooth deposits found in localized, low-lying regions bounded by elevated topography on three or more sides. Most melt ponds at Hokusai have a mottled appearance. Ponds are predominantly situated within the wall terrace or ejecta deposits of the craters. Many show evidence of banks or embayment of surrounding terrain and encompassed terrains.

Continuous proximal ejecta (cpe) is a massive deposit surrounding the crater depression. This unit is truncated by distal ramparts at Hokusai in the north and east and transitions to a lobate morphology at the southwestern extent of the deposit. A variety of morphologies is present including hummocky, undulating, and blocky deposits. A distinguishing feature of this unit at Hokusai is its ropey texture nearest to the crater rim.

Discontinuous distal ejecta (dde) is found at Hokusai only. It is characterized as a discontinuous hummocky deposit with sub-radial texture. The deposit is pitted in some areas which is consistent with the presence of underlying secondary craters. Kilometer-scale hummocks and underlying secondary craters are primarily present to the southwest, whereas hummocks tens to several hundred meters in diameter dominate to the north and east.

Discussion: A comparison of the mapped distribution of impact melt at both craters reveals that there is a greater amount of impact melt per unit surface area at Hokusai than at Abedin, even though Abedin has a greater overall volume of impact melt due to its larger size. It has previously been suggested that Hokusai's unique rampart morphology is indicative of a high velocity impact [8] that formed approximately three times more melt than produced by an impact of average velocity at Mercury [3]. However, recent work by coauthors suggests that the greater concentration of melt at Hokusai may be explained by the combination of a large projectile and a relatively low impact velocity [6]. The resulting large volume of melt may have been the determining factor for the formation of distal ramparts.

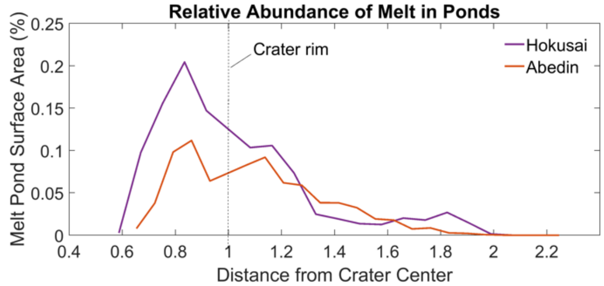

Figure 3. Distribution of impact melt as a function of distance from crater center. Melt abundances have been normalized by crater diameter. Though Abedin, because of its slightly larger size, has more melt overall, Hokusai has a higher melt to total surface area ratio.

The distribution of impact melt ponds at each crater as a function of distance from crater center is shown in **Figure 3**. Melt identified within ponds at Hokusai is concentrated primarily within the wall terraces and near-rim ejecta deposits. In contrast, Abedin exhibits a more spatially even distribution of impact melt ponds. It is possible that the clustering of identified impact melt at the rim of Hokusai results from a greater amount of impact melt being mixed in to the distal portions of the ejecta deposit, fluidizing the ejecta to form ramparts similar to those found on Mars [3]. Whereas water acts as the fluidizing agent on Mars [1,9], an unusually high abundance of impact melt at Hokusai might have acted as the fluidizing agent in this isolated scenario on Mercury. This may shed light on the mechanisms that underly rampart crater formation on other bodies as well, supporting the notion that other mechanisms may provide a fluidizing agent to form ramparts without an abundance of volatiles in the target body [10].

References: [1] Carr, M. H. et al. (1977) *JGR, 82,* 4055–4065, [2] Greeley, R. et al. (1982). *Sat. of Jup., A83-16226 04-91,* 340–378, [3] Barnouin et al. (2015) *LPS, 46,* #2672, [4] Baker, D. M. H. et al. (2011). *Planet. Space Sci., 59,* 1932–1948, [5] Ernst, C. M. et. al. (2016) *LPS, 47,* #1374, [6] Kinczyk, M. J. et al. (2016) *LPS, 47,* #1573, [7] Denevi, B. W. et. al. (2018) *Sp. Sci. Rev., 214,* 2–52, [8] Xiao, Z. et al. (2014) *Icarus, 228,* 260–275, [9] Greeley, R. et al. (1980) *Proc. Lunar Planet. Sci. Conf. 11,* 2075–2097, [10] Boyce, J. et al. (2010) *Meteor. & Planet. Sci., 45,* 638–661.