STUDYING CRATERING AND PIT FORMATION PROCESSES WITH GALILEO AND MRO DEMS

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Introduction: Measurement of final crater dimensions from spacecraft imagery and the construction of scaling trends are important for studying the cratering process on planetary scales. Topographic data adds an important third dimension to these data, allowing depths, slopes and volumes of features to be studied. We are utilizing topographic profiles to develop constraints for the various formation mechanisms suggested for central pit craters, an unusual crater type seen most commonly on ice-rich bodies [e.g. 1, 2, 3].

We extracted multiple cross-sectional topographic profiles of central peak and central pit craters on the icy Galilean moon of Ganymede from digital elevation models (DEMs) created from Galileo Solid State Imager (SSI) images (e.g. Fig. 1). See [4] for methods. Here we present examples of how measurements made from these profiles are being used to investigate transitions in crater morphology and note the implications of our observational work for one pit formation mechanism - drainage of a central pool of impact melt water into sub-surface fractures [e.g. 1, 5]. We will present full results of Ganymede observations and of our ongoing investigation of Martian central pit craters using DEMs from HiRISE [6] at LPSC.

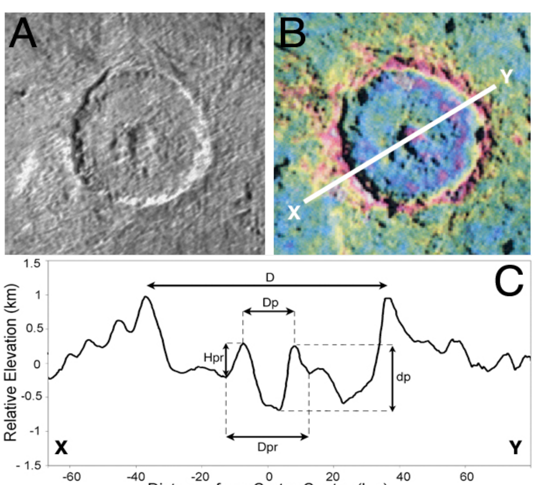

Fig. 1: A) 77km central pit crater on Ganymede. B) DEM of A. Relative elevation values are color-coded. Profile line in 'C' is marked. C) Topographic profile with pit and pit rim measurements noted.

Ganymede Observations: A) Transition from peaks to pits: Small pit craters on Ganymede tend to have raised rims around the central pits; larger floor pit craters have irregular broken rims [7]. The topographic data acquired has allowed measurement of their dimensions. The size-morphometry progressions of central peaks and peak-rings have added support to the hypothesis that peak-rings develop from central peak collapse [8]. Similarly, any common trends in the central peak and pit-rim size could support a link between the two morphologies.

Pit-rim 'diameters' (D_{pr}) were measured as shown in Fig. 1C, and compared to central peak diameters (D_{cp}) in Fig 2A. Central peak diameters increase as crater size increases ($D_{cp} = 1.67\exp(0.05D)$). The increase in pit-rim diameters with increasing craters diameter (D) in craters smaller than D~53km can be described using the same equation as for central peak diameters. Central pit craters larger than D~53 km have relatively broad pit-rim diameters (Fig 2A). The volume of peaks and pit-rims increases with increasing crater size; their trends can be described with a single equation (Fig. 2B).

B) Transition from conical to flat-floored pits: Acquisition of central pit profiles has allowed assessment of variations in pit slope and depth and enabled more accurate volume estimates than could be achieved with diameter and shadow-derived depth measurements alone. In craters larger than D~70km pit depth remains ~0.8km whilst pit diameter continues to increase (Fig 2C), producing a change in the morphology of pit shapes, from conical to flat floored (as noted by [7]).

Discussion and Implications: The similar diameters of central peaks and pit-rims in craters D<53km (Fig. 2A) suggests a genetic relation between central peaks and central pit rims. *The rims of central pits may represent large central peaks that have continued to form in the same way as classical central peaks,* but also incorporate a pit at the peak centre. This seems very much the case on Mars where the continuum from peak to summit-pit morphology is more obvious due to the greater frequency of summit-pit craters relative to Ganymede [9].

In craters larger than D~53km central pit-rims are broader than expected for a central peak in a crater of the same size (Fig. 2A). This suggests that *an additional process is occurring above D~53km to widen the central features*. The change in feature width trend does not correspond with the peak-to-pit transition, but at a slightly larger crater diameter showing that if this is related to pit formation then it does not overprint the central uplift at small pit sizes.

The volumes of central peaks and pit-rims increase as crater size increases, following the same trend (Fig 2B). If central feature broadening above D~53km is a consequence of pit formation that causes localized expansion, such as the refreezing of melt-water in fractures, then it must broaden central features without noticeable surface expression of a volume increase. Alternatively, central feature broadening at D~53km could could reflect *the basal collapse of a large central uplift.* This would cause a broader peak/pit-rim base without affecting central feature volume. Hydrocode simulations have successfully recreated basal collapse of central peaks [5]. Modeling is ongoing to investigate whether pit formation can occur as a natural part of this process or whether an additional mechanism predominates.

The apparent cap on pit depth in craters above D ~ 70km could be due to the pooling of progressively larger volumes of impact melt water on the pit floor. This has implications for the melt drainage model of pit formation as it implies that the melt produced in smaller craters is able to drain away, but that there is not enough fracture space to accommodate all melt in the larger craters, or that fractures freeze shut prior to full drainage. The extent to which impact melt water can drain into sub-surface fractures before they freeze shut is the subject of an investigation by [10]. More likely however, is the influence of domes. Central domes are thought to form via the upwelling of warm ice at the crater center [7]. As the cap on pit depth occurs at a similar crater diameter to that at which domes begin to be noted it suggests that *dome upwelling alters crater morphology by raising the pit floors before the domes can be seen in surface images.*

Additional insights from HiRISE DEMs: HiRISE imagery provides the capability to analyze small-scale morphology of central pit craters on Mars, revealing a number of features unseen in Ganymede examples due to the different data resolution. We are studying the orientations of bedrock layers exposed in pit-rims of Martian craters with the use of HiRISE DEMs [See 11]. This may help shed light on whether the trend in pit-rim diameters with crater size changes at D~53km due to peak collapse or as a consequence of pit formation.

Acknowledgements & References: This work was funded by Imperial College and grant #NNX08BA96G from NASA's Outer Planets Research Program. [1] Croft (1983). JGR, 88, 17-89. [2] Wood et al. (1978). LPS IX 9th pp. 3691-3709. [3] Passey & Shoemaker (1982), In Satellites of Jupiter, Ed.:Morrison, UofA Press, pp. 379-434. [4] Bray et al. (2008). MAPS 43(12):1979-1992. [5] Bray (2009) PhD thesis, Imperial College, London, UK. [6] McEwen et al. (2007), JGR 112. [7] Schenk (1993). JGR 98:7475-7498. [8] Alexopoulos & McKinnon (1992), Icarus 100:347-363. [9] Barlow & Alzate (2008) Large Meteor Impacts IV, Abs 3071. [10] Elder et al., (2010) LPSC Abs 2519. [11] Caudill et al. (2011), LPSC 42 Abs.

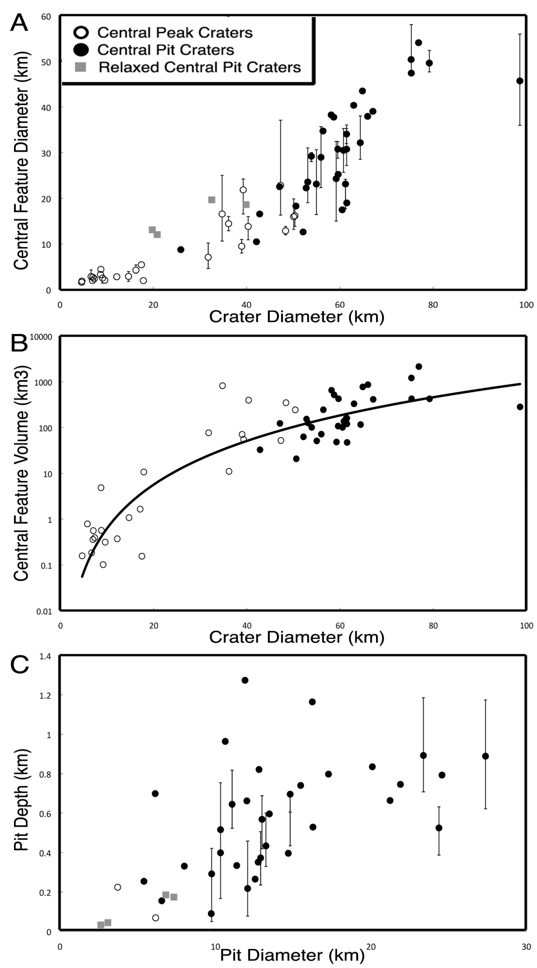

Fig. 2:A) Central feature diameter with crater diameter. Key applies to all plots. B) Central feature volume with crater diameter. C) Pit depth with pit diameter. The two 'peak' measurements denote pit dimensions in summit-pit craters.