THE PERIPHERAL PEAK RING: A COMPLEX IMPACT CRATER MORPHOLOGIC FEATURE PROBABLY RELATED TO CRATER RIM COLLAPSE.
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Introduction: Most impact craters are known only from remote observations so that in general, topographic features of roughly circular and concentric character constitute their morphologic expression. In complex craters [e.g., 1], commonly recognized morphologic features are crater rim, zone of terracing, central peaks and/or peak rings. At particularly large craters an additional morphology of the multi-ring basin [2] is distinguished by having additional topographically asymmetric scarps vs. the symmetric profiles of peak rings. The slump widths between the multi-ring basin scarps are also relatively broad and continuous compared to those found in typical terrace zones. We distinguish an additional morphologic feature, a second type of peak ring that occurs near the edge of a crater typically superposed on the lower part of the terraced zone – the Peripheral Peak Ring.

Peak Rings and Peripheral Peak Rings: Using Viking and Mars Orbital Camera images, 680 Martian impact craters having internal complex impact morphological features as defined by [3] and diameters between 10 km and 290 km were classified into the following categories: Central Pit, Central Peak, Collapsed Central Peak, Peak Ring, Degraded, and the newly defined Peripheral Peak Ring. Although the transition between Central Peak and Collapsed Central Peak morphology is gradational, a distinction is made based on the presence of single vs. multiple summits.

A general size and morphology progression is observed from Central Peak to Collapsed Central Peak to Peak Ring morphologies. This morphologic progression is similar to that obtained by Alexopolous and McKinnon [4] for Venusian complex craters, but on Mars the range of transition diameters is greater. For Peak Rings, the ratio of final crater diameter to Peak Ring diameter decreases from ~7 to ~2 as diameter increases, reaching an apparent limit in the largest craters.

In a fraction of Martian complex craters primarily between 10 - 90 km diameter (although also developed in craters up to 140 km diameter), a Peripheral Peak Ring is observed (Figs. 1 & 2); a topographically symmetric ring with morphologies often similar to those of Peak Rings, but always occurring proportionately farther out near craters' rims. These rings occur at a near constant rim to ring ratio of ~1.3 (Fig.3). Examples of this additional ring occur in craters having other complex crater morphologies, including conventional Peak Rings, resulting in craters with two concentric Peak Rings. The term Peripheral Peak Ring (PPR) denotes the proximity of these rings to the crater rim and their symmetric profile in a radial direction after correcting for the slope of the terraced zone. MOLA topographic data were used to study PPR's in 13 craters establishing that the rings generally lie near the bottom of the terraced zone. The crater rim/PPR ratio is ~1.3, outside the range values for conventional Peak Rings. Its uniform value is thought to reflect near linear complex crater depths [5] after crater collapse is complete.

Peripheral Peak Ring Morphology: PPR's can be one (or rarely multiple sections) of apparent monolithic blocks, or the PPR can have a rubbly appearance similar to that of Peak Rings. Some craters show the PPR as having multiple levels. Examples occur in which the PPR has azimuthal sections that are monolithic, sections that are rubbly, and sections that have no PPR at all. As in the example shown in Fig. 1, monolithic examples sometimes have shapes that "fit" back into the crater rim. Also, PPR's sometimes show the same polygonal faceting as developed in crater rims (e.g., Fig. 1). These indicate that at least the monolithic examples are derived from the crater rim.

Peripheral Peak Ring Formation: The monolithic examples are strong evidence that blocks from the crater rim separated and slid downwards across the terraced zone until stopping near the crater floor. The rubbly examples are thought to represent cases where the failing rock isn't strong enough to maintain internal cohesion once sliding begins. This collapse is not part of the traditional crater modification process but represents rim wall collapse of material that slides (monoliths) or flows (rubble) across the top of the slumped blocks comprising the terraced zone. The near-constant ring ratio results from the near linear relationship between crater depth and the resulting proportional widths for the terraced zone. Also, because PPR's have a near-constant ring ratio, and can occur in craters having conventional Peak Rings, the source of the PPR can't be overcollapse of the central uplift.

Why do PPR's form only in some craters, and are relatively common on Mars compared to other planetary surfaces? It appears that PPR formation is largely restricted to areas where basalt is present at the surface (e.g., Sinai Planum). This implies that the country rock must have a minimum competency for PPR's to form; an underlying weak layer, such as impact ejecta/regolith or sediments, may also be required to allow initial failure of the rim. Whether a specific crater develops a rubbly or monolithic PPR presumably depends on the local rim rock strength.

The restricted geographic distribution of complex craters containing PPR's and their ubiquity in some regions (e.g., Coprates) further suggests that local crustal character, such as layering, varies across the Martian surface and influences final crater morphology.

Implications: In some cases the presence of PPR's may have led to classifying complex craters as multi-ringed basins, but complex craters may have two symmetric rings interior to their rim (i.e. the crater has only one single asymmetric scarp). Preliminary investigation reveals PPR craters on Venus and Mercury. As multi-ringed basin morphology is inferred to require a varying strength regime near a planetary surface [1] mis-identification of the morphology can lead to invalid models of internal strength. If their formation requires the presence of a strong layer overlying a weak layer, then presence of a PPR is another cratering probe (if admittedly crude) into near-surface geology.

Acknowledgements: We are grateful to Jim Frawley at JPL for providing MOLA data, and to W.M. Hartmann for discussion.

References:: [1] Melosh, H.J., 1989, Impact Cratering, Oxford Monographs on Geology and Geophysics no. 11, 245 pp.; [2] Hartmann, W.K. and Kuiper, G., (1962) Comm. Lunar and Planetary Lab 1:51-66; [3] Rodinonova J.F et al (2000) *Morphological catalogue of the craters of Mars*, http://selena.sai.msu.ru/home/Mars_Cat/Mars_Cat.htm. [4] Alexopoulos J.S, and McKinnon W.B. (1994) GSA Special Paper 293, 29-50; [5] Garvin et al. (2003) Craters on Mars: Global Geometric Properties from Gridded MOLA Topography. Sixth International Conference on Mars, Abstract 3277.

Figure 1. Viking image of Martian Peripheral Peak Ring Crater, SAI #1078. Crater diameter is 58 km. Example of a PPR occurring in a crater having a conventional Peak Ring as well.

Figure 2. MOLA Topographic data for Martian SAI Crater #2668, showing both a PPR with both monolithic and rubbly components. Crater diameter is 40 km. X and Y axes are longitude (east) and latitude (south), respectively. Vertical scale is in meters.

Figure 3. Graph of "ring ratio" for Peripheral Peak Ring craters. Ring ratio decreases slightly with crater rim diameter presumably reflecting a slightly disproportionate effect in crater collapse such as the decreasing proportion of the terrace width versus that of the crater floor.