CONSTRAINING STRENGTH PROPERTIES IN MARTIAN SURFACE LAYERS BY MODELLING THE PERIPHERAL PEAK RING IMPACT CRATER MORPHOLOGY. Jason Nycz and Alan Hildebrand, Department of Geology and Geophysics, University of Calgary, 2500 University Drive NW, Calgary, Alberta, Canada. T2N 1N4. jcnycz@ucalgary.ca, ahildebr@ucalgary.ca.

Introduction: Examination of Viking, MOC, MOLA, HRSC, THEMIS, and most recently HiRISE data reveal the presence of impact craters (both simple and complex) that contain a partial or completely collapsed rim. These collapse features have been named Peripheral Peak Rings [1]. PPR occur where an apparent strong near surface layer exists. Albedo and spectral reflectance data establish this near surface layer as basalt, and it is seen in both the rims and the PPR of some impact craters. PPR's are interpreted to form when the crater rim wall, after conventional slumping to form the terraced zone overlying the slumped blocks (in the case of a complex crater), fails thereby detaching large blocks that slide downwards across the terraced zone towards the crater floor. Most recent high-resolution data can better constrain these observations allowing for slope stability modelling which can in turn be used to better understand the strength properties of the upper Martian crust.

Peripheral Peak Ring Formation: PPR are clearly blocks from the crater rim that separated and slid downwards across the terraced zone until stopping near the crater floor (fig 1). PPR can be differentiated from the outermost terrace zone based on morphology. Whereas the slump blocks that form the terraces show downward displacement consistent with normal faulting, PPR undergo displacement that is much more lateral, across the tops of the terraces (in the case of complex craters). This causes the tops of some PPR to be higher in elevation than the resulting crater rim, a phenomenon not seen in terraces. This will result in the somewhat paradoxical situation that subsurface sounding interior and adjacent to the rim would reveal uplifted strata of the structural rim uplift rather than the first down slumped block. Examples of well developed PPR have been observed in simple craters as well (fig 2), and most PPR have shapes that fit back into the depletion zone which once held them.

Why do PPR's form only in some craters, and are relatively common on Mars compared to other planetary surfaces? Geograpically, 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, is needed to facilitate failure of the rim. The final morphology of the PPR (single block, multiple blocks, or a more rubbly appearance) 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., the relatively young volcanic terrains) further suggests that local crustal character, such as layering, varies across the Martian surface and influences final crater morphology.

PPR Observations: Evidence of near surface layering is observed in most occurrences of craters having both PPR and available high resolution images of the crater rim (Figs 1, 2). In some of the younger and better preserved craters, similar layering is also seen in their respective PPR. Examination of these layers using THEMIS daytime thermal infra red spectral data shows they have similar spectra to those of Martian basalt [3]. Aside from these layers, the rest of the crater rim and surrounding terrain has spectra consistent with those of Mars' bright regions [4]. Additional work is needed to determine to what extent the spectra of these areas are influenced by dust. However, since many of these craters exist in regions with a low dust composite index [3] and mid range average thermal inertia [4], it is reasonable to conclude that at least some of these craters are in areas with low dust cover, and that the spectral differences seen between the basalt layers and underlying strata are not influenced by thick dust cover.

Strength layering in the near surface: The observed layering in the rims of craters containing PPR's will produce a strength contrast of strong (basalt) over weak (regolith/sediment). Slip line analysis has determined that for a given disruption cavity diameter, the crater state is defined by the cohesion, or yield stress of the rock [5]. The cohesion is a value given for a homogeneous hemispheric half space. Considering the layering required for the formation of the PPR, instead of a single cohesion value for the entire halfspace, a postulated strong (and dense) layer (basalt) overlies weaker strata. At the crater rim, the principal stress is the downward pressure determined by gravity, rock thickness, and density. Once enough basalt is present to allow the critical overburden stress to be reached, wall failure will presumably occur once tension fractures initiated interior to the crater rim generate a slip plane. Lack of confining pressure on the crater wall allows the PPR to detach from the crater rim and slide outward and downward.

Numerical Modelling: Sufficient constraints exist so that the required strength distribution may be modelled. Topographic profiles of Martian PPR craters were obtained from MOLA data and thicknesses of near-surface basalt layers were obtained using HiRise images. Lithology was confirmed with THEMIS spectral data. These geometries were entered into 2-D models with the material properties obtained by using the Hoek-Brown failure criterion [6] and from [7,8]. The models consisted of three layers (ejecta/regolith, basalt, sediment layers/unknown lithologies), and the safety factor for the slopes was determined using both the Morgenstern-Price and Simplified Bishop limit equilibrium methods. Although using published strength properties in the simplified model did not produce a critical slip plane (Safety Factor of 1), models with the basalt in the near subsurface had a significantly lower SF (2-4), than models with the basalt removed (SF 7-35). Models were then run varying such factors as cohesion, friction angle and disturbance factor to obtain the critical failure plane that most closely matched the topography of the observed post failure slopes of crater rims containing PPR. Results show that while it is possible to model observed PPR formation, it was not possible to model failure in any crater rims which did not have a basalt layer relatively close to the surface without using unreasonably weak strength values for the bedrock. This matches very well with the observed distribution of PPR craters on Mars. The modelling constrains the strength properties of the basalt and underlying weaker layer existing in the upper crust.

Implications: Presence of the PPR can be used as an indicator of strength contrast in the near surface of Mars. In addition, crater morphology can be integrated with other remote sensing methods to provide a probe of the Martian crust.

References: [1] Nycz and Hildebrand (2005), LPSC XXXVI Abstract #2167. [2] Melosh, H.J. (1989) Impact Cratering, Oxford Press. [3] Bandfield et al (2000), *Science* 287. [4] Ruff & Christensen (2002), *J. Geophys. Res* 107, E12. [5] Melosh, H.J.(1977) Impact and Explosion Cratering, Pergamon Press. [6] Hoek et al. (2002). *NARMS-TAC Conf* 267-273.[7] Neuffer & Schultz (2006),*J. Qtr Eng Geol & HGeol.* 39. [8] Nahm et al. (2007),LPSC XXVIII Abstract #1976.

Figure 1. HiRise image of northen rim of SAI Crater #5496. 27km diameter, lat 23N, long 208E, Amazonis Planetia. Image resolution is 35cm/pixel. Depth from crater rim to floor is approx 1500m. Crater shows multiple PPR blocks and basalt layering in the crater rim. Area in image is 7.1km wide

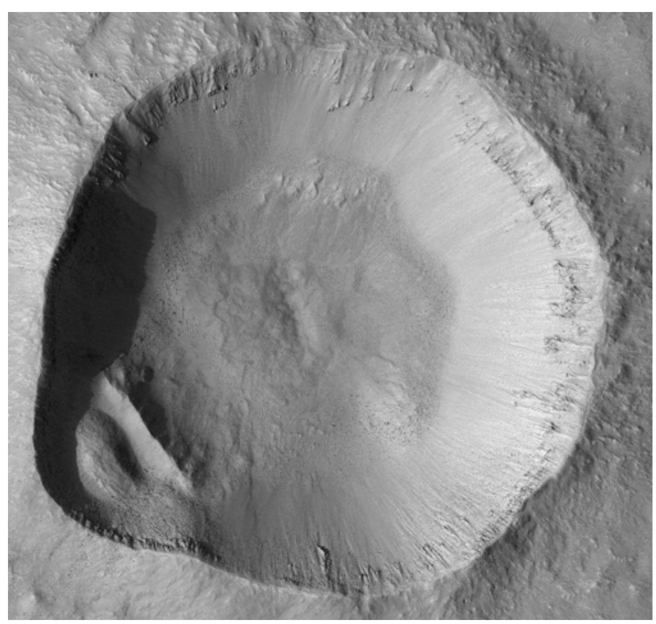

Figure 2. HiRise image of a simple 4km diameter impact crater showing a partial PPR, basalt layering in the rim, and no signs of having undergone gravitational collapse to a complex crater. lat14N, long 123.3E. Resolution is 29cm/pixel. Also of note is the basalt layering seen in the rim is nearest to the surface and appears most massive where the PPR is formed. Both Images courtesy NASA/JPL/University of Arizona.