PERVASIVE ICE-RELATED EROSION OF MID-LATITUDE MARTIAN CRATERS. Alan D. Howard[1], [1]Planetary Science Institute, 1700 East Fort Lowell, Suite 106, Tucson, AZ 85719-2395 (ahoward@psi.edu).

Introduction: Mid-latitude craters on Mars display distinctive degradation morphologies, ranging from muted, rounded appearance to extensive erosion of both interior and exterior crater walls. The primary focus here is the erosional modification of mid-latitude craters by ice-related processes.

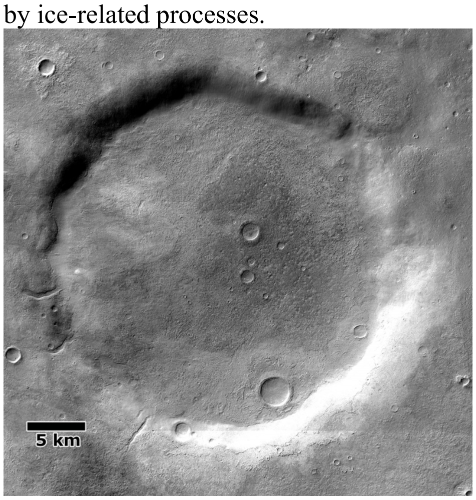

Fig. 1. CTX image of "softened" crater at -9.10°E, 45.83°S. Note the smooth texture of the intercrater plains, suggesting deep mantling.

"Softened" craters: An appreciable fraction of craters in the southern mid-latitudes embody the description of "softened" craters [*1*] which display muted topography with rounded crater rims (**Fig. 1**). The crater floor is often relatively flat, sometimes with indication of concentric crater floor (CCF) morphology, and the floor often meets the rounded rim at a sharp break in slope. Softened craters appear to be a morphology developed on the lowest relief (most degraded) craters. Softened craters, have been suggested to result from deep (~1 km) flow relaxation of subsurface ice [*1, 2*], or alternatively deep mantling (e.g. [*3*]). Mantling by itself can produce rounded crater rims, but only if mantle accumulation is slope-normal and, for typical crater morphology, only after very deep accumulation relative to the initial crater relief [*4*]. Coupling mid-latitude mantling with solifluction [*5*] or shallow glacial flow probably best describes degradation of such craters, perhaps also requiring weathering of the crater rim.

Skeletal, or "donut" craters: Both the interior and exterior walls of mid-latitude glaciers have been subject to lateral erosion and crater wall steepening (**Fig. 2**). Several studies have documented crater wall mass wasting associated with crater interior gullies and lobate debris aprons, but the interior morphology in **Fig. 2** shows maintenance of steep interior crater walls during considerable lateral erosion of all crater walls. The crater walls are free of primary crater wall morphology, such as roughness and slumps. The joint rim of the two craters is missing, in part from burial, but the sharp drop-off to the interior at the rim junction suggests erosional attack as well.

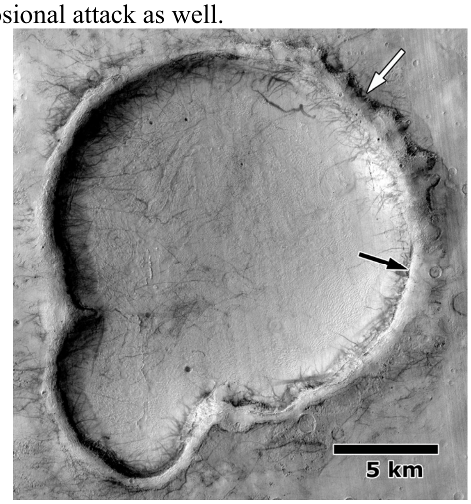

Fig. 2. CTX image of a skeletonized mid-latitude crater at -130.38°E, 47.02°S. Black arrow points to steep interior crater wall, and the white arrow show erosional steepening of exterior crater wall.

The outer wall of the crater rim also displays a steep scarp at several locations, such as along the NE rim as at the white arrows. This steep section is bordered to the outside by a smooth depressed surface. Such nearly planar depressions are common at locations where exterior crater walls are steep, suggesting a process connection.

The portion of the crater rim between the interior and exterior scarps is broadly convex, similar to the rim crest in **Fig. 1**. The inference to be made from this morphological pattern is that the inner and outer crater rim have undergone dominantly basal erosion and appreciable retreat. Skeletal crater rims are largely limited to craters less than 20 km diameter.

The crater interior rim shown in **Fig. 3** has been eroded on the inside at the contact with CCF. On the outside, several depressions filled with smooth, presumably icy accumulations have likewise undercut the ejecta. There may be a mass conservation issue unless the ejecta is primarily icy or fine-grained enough to be wind-eroded and transported when disaggregated. Similar lateral erosion has occurred to secondary crater clusters of Galle crater in the mid-latitudes, accompanied by coalescence of adjacent craters into large, smooth-floored depressions.

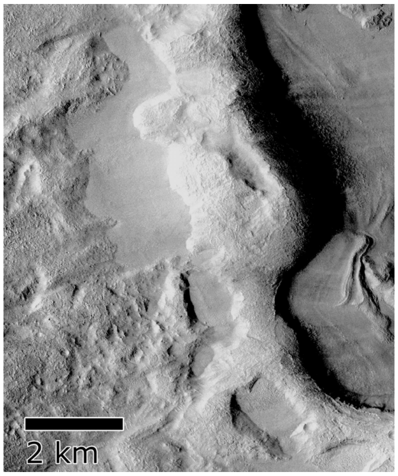

Fig. 3. CTX image of the SW rim of a 23.5 km diameter crater at 14.17°E, 38.99°S. Crater interior to right.

Glacial Erosion of Crater Interior: The interior of the crater shown in **Fig. 4** is infilled by several episodes of glacial flows. The most recent glacial advance, shown in **Fig. 5**, is bordered by steep slopes along the edges of higher terrain (**Fig. 5b**) that may be remnants of interior crater wall slumps. These steep slopes adjacent to the glacial flows are a strong indication that the steepened slopes resulted from lateral erosion by the glacial flow.

Conclusion: All of the documented steep slopes on the interior and exterior rims of the craters have been backwasted at the contact between ice deposits and the crater walls. To achieve the considerable lateral erosion, erosion must have occurred through the entire depth of the ice adjacent to the eroded slopes. The erosional mechanisms are presently unclear, particularly whether liquid meltwater or freeze-thaw disaggregation were required.

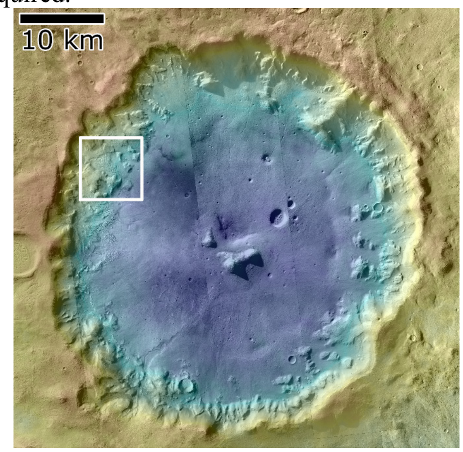

Fig. 4. CTX mosaic of Glaciated crater at 75.8°W, 43.4°S. Box shows location of Fig. 5.

References: [1]. Squyres, S. W., (1989), *Icarus* **79**, 229-88. [2]. Jankowski, D. G., Squyres, S. W., (1993), *Icarus* **106**, 365-79. [3].Clifford, S. M., Zimbelman, J. R., (1989), *LPSC 19*, Abst. 1102. [4]. Howard, A. D., (2004), *LPSC 35*, Abst. 1054. [5]. Johnsson, A. *et al.*, in *Dynamic Mars: Recent and Current Landscape Evolution of the Red Planet,*. (Elsevier, 2018), 239-69.

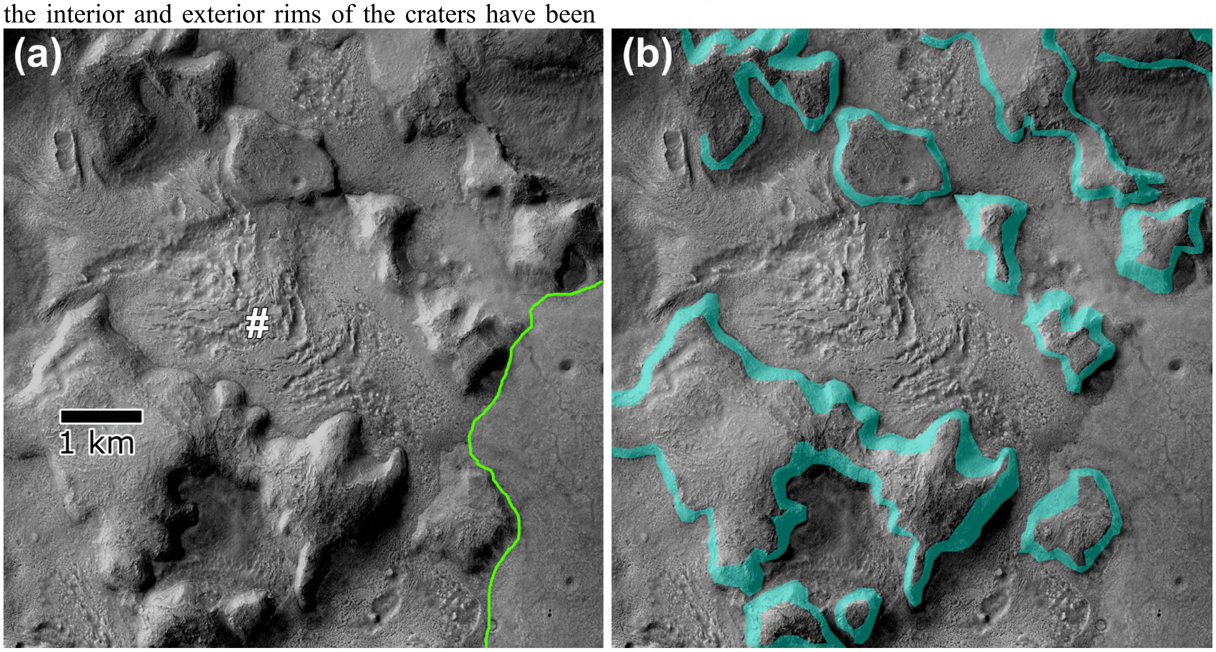

Fig. 5. Ice-eroded slopes in the interior of crater shown in Fig. 4. (a) Overview. Green line demarcates limits of a more recent glacial flow covering an earlier flow. Note deep sublimation emphasizing flowlines at "#". (b) Aqua toning of slopes oversteepened by glacial erosion.