EVIDENCE FOR SNOW AND ICE ACCUMULATION AIDING DEBRIS FLOW AND GLACIAL FLOW AT MID- TO LOW-LATITUDES ON MARS.

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Summary: Mars Express HRSC (High-Resolution Stereo Camera) image data of eastern Hellas reveal details of debris aprons at the base of massifs characterized by numerous concentrically ridged lobate and pitted features suggesting extremely ice-rich glacier-like viscous flow and sublimation. This, together with new evidence for recent ice-rich debris-covered glaciers at the base of the Olympus Mons scarp suggests geologically recent and recurring glacial activity in low- and mid-latitude regions of Mars.

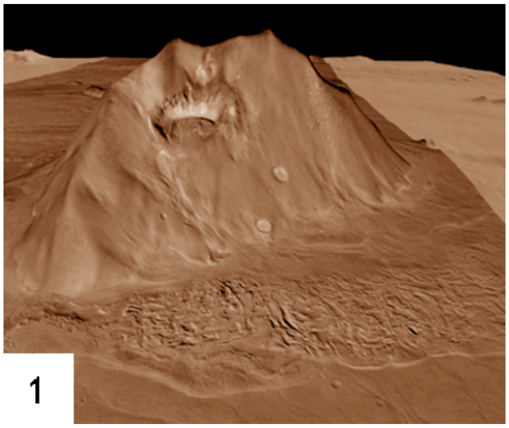
Introduction: Debris aprons are geomorphic features seen in mid-latitudes of Mars that are interpreted to be viscous flow features of material containing some portion of lubricating ice derived from adjacent highlands [1]. Recent studies have not been able to distinguish conclusively among multiple models of apron formation [2] (e.g., ice-assisted rock creep, ice-rich landslides, rock glaciers, and debris-covered glaciers) because of the inability to determine the proportion of ice in the rock debris.

Description and Interpretation: New HRSC data of a massif-marginal lobe in the eastern Hellas region shows that the proportion of ice in this deposit was substantial enough to signify glacial and debris-covered glacial activity. An 18 km wide lobe extends about 8 km from the base of a 3.75 km high massif (Fig. 1). The lobe is up to about 250 m thick, has a convex upward topographic profile, and is separated from the base of the massif by an irregular 50-100 m deep depression. Within the lobe itself (Fig. 2), a distal 4 km zone is characterized throughout by a fretted and honeycomb-like texture of irregular pits and ridges. Depressions typically 20-40 m deep make up 30-40% of this zone and occur between linear moraine-like ridges forming broad convex-outward lobes. These patterns of sinuous ridges and irregular depressions are typical of Earth glacial deposits that remain following debris-containing glacial ice advance, stagnation, and ablation. Debris input to glaciers occurs most commonly at ice margins and is thus concentrated along the base of cirques and in medial debris septa that ultimately become medial moraines. Proximal debris addition from rockfalls and increasing debris concentration from below by ice sublimation results in supraglacial debris mantles in the distal direction with great spatial variability in thickness and grain size. As ablation proceeds, debris accumulations represented by englacial septa emerge and form longitudinal or transverse debris ridges separated by areas of cleaner or bare ice. Continued ablation results in the downwasting of the cleaner ice to produce pits, dirt cones and topographic inversion between the ridges, and ultimately the emerging or redistributed debris becomes thick enough to retard further sublimation. The morphological similarities of features observed to glacial deposits (Figs. 1,2) are thus suggestive of processes of snow and ice accumulation, viscous flow of debris-containing ice, and subsequent sublimation of significant volumes of ice leaving behind numerous large sublimation pits tens of meters deep and intervening morainal ridges.

Further evidence for viscous flow of very ice-rich material is seen in HRSC data of an hourglass-shaped deposit occurring in two craters at the base of a 3.5-4 km high massif located on the eastern rim of the Hellas Basin (Fig. 3-4). Two adjacent circular depressions about 9 and 16 km in diameter extend outward from the base of the massif into the surrounding lowlands. In the proximal crater, the floor is a regionally flat surface that lies nearly at the rim, about 500 m above the surrounding plain. The floor tilts away from the massif at less than a few degrees slope. The surface texture on the floor of the crater shows unequivocal evidence for streamlines and lobes typical of ice flow and ice-lobe interaction. Four discrete zones are progressively compressed, join together at the low point in the crater rim, and flow through a narrow breach less than 2 km wide, dropping several hundred meters in elevation and spreading out onto the lower crater floor, creating a set of lobate ridges and depressions further indicative of viscous flow. This configuration is very similar to Earth glacial environments, such as the 60 km wide Malaspina glacier.

HRSC data reveal the presence of several 25 km-long debris-covered glacier-like features along the Olympus Mons basal scarp that are clearly superposed on top of the larger, and thus older, debris-covered piedmont glaciers (Fig. 5). The sources of the lobes are cuspate alcoves in the basal scarp, topographic depressions that are natural traps for wind-blown snow in terrestrial rock glacier environments (e.g., Fig. 6; Mullins Valley, Antarctica). Evidence supporting a debris-covered glacier interpretation includes: 1) origin in alcoves, 2) elongated subparallel concentric ridges, 3) distinctive terminal moraines, and 4) their strong morphological similarities to terrestrial rock glaciers of known glacial origin (compare Fig. 5-6).

References: [1] S. Squyres (1978) *Icarus*, 34, 600. [2] T. Pierce and D. Crown (2003) *Icarus*, 163, 46.



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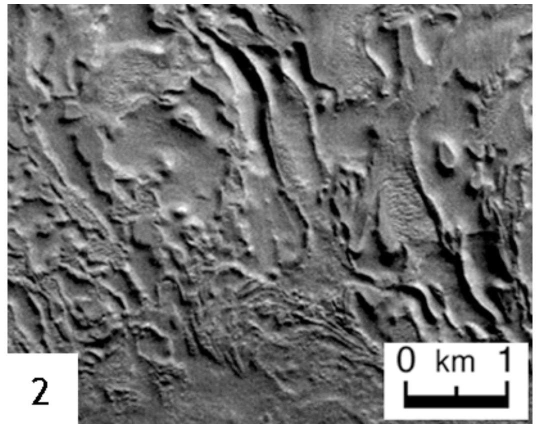

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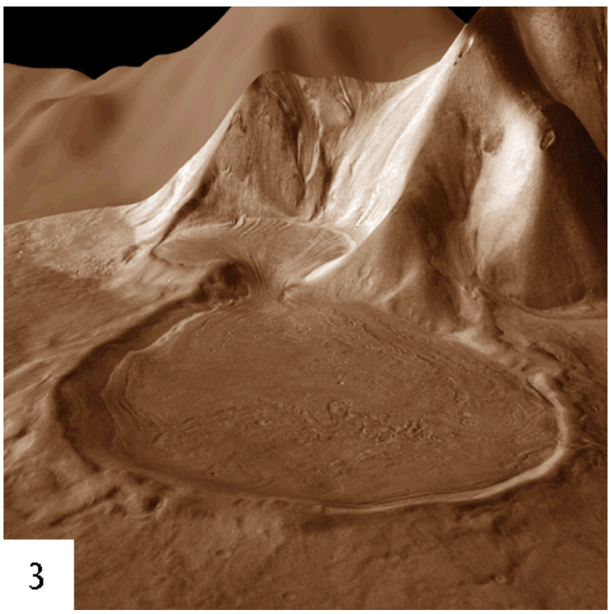

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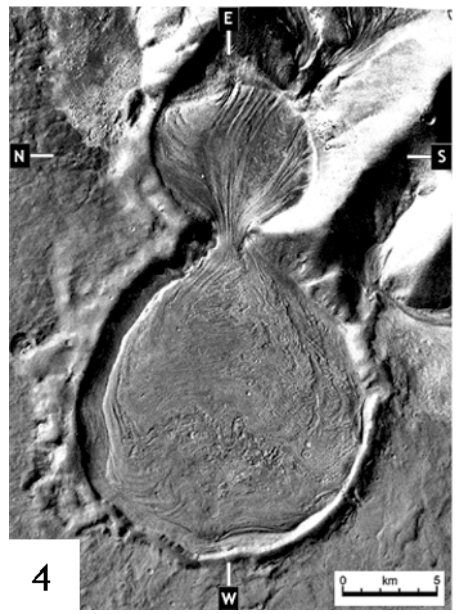

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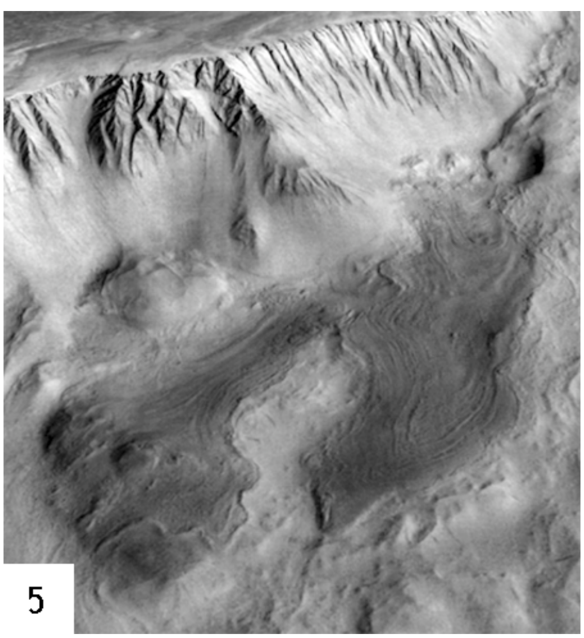

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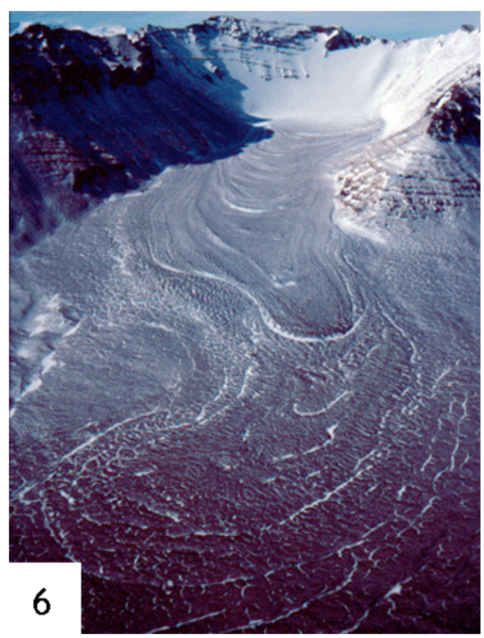

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