MODELING THE FORMATION OF LOBATE DEBRIS APRONS ON MARS BY CREEP OF ICE-RICH PERMAFROST.

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Introduction: A wide variety of mid- to high-latitude surface features on Mars has long been attributed to viscous creep and flow phenomena associated with near-surface ground ice. On the basis of Viking Orbiter images, Squyres [1] identified two classes of creep-related landforms: (1) softened terrain, which results from in situ viscous deformation and is particularly evident in impact craters with degraded rims and flattened topographic profiles, and (2) debris aprons, which are produced by mass wasting along escarpments, e.g., lobate debris aprons, lineated valley fill, and concentric crater fill. Such features have been linked to kilometer-thick layers of permafrost (with upper boundaries less than 200 m deep) at higher latitudes [2], an interpretation that is consistent with recent GRS observations indicating a high water content in the very shallow Martian subsurface [3].

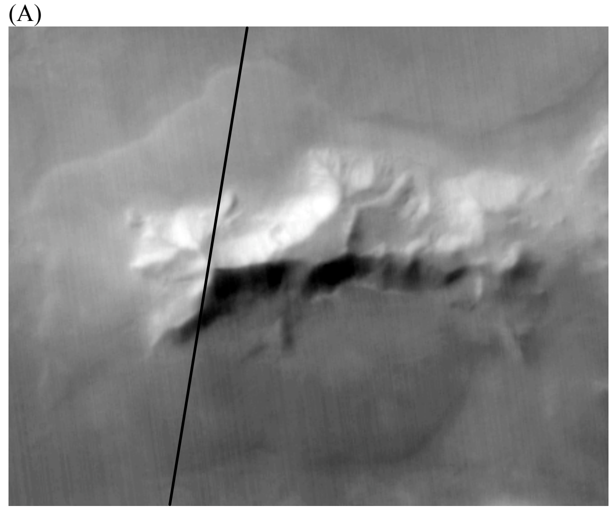
We are using MOC and MOLA data to document the structural and topographic characteristics of softened landforms and debris aprons in the Hellas and Noachis regions. By comparing the observed landforms to the results of finite-element models of viscous creep relaxation which incorporate recent laboratory measurements of ice/rock mixtures [4-6], we can constrain the conditions necessary to allow such deformation on Mars [7,8].

Observations: Debris aprons are broad, thick accumulations of material with convex-upward topographic profiles (*e.g.*, Fig. 1) that are commonly found at the bases of escarpments east of the Hellas impact basin [9]. To look for patterns between the location or nature of mountains and whether or not they exhibit debris aprons, we have characterized debris aprons in a region east of the Hellas impact basin (*cf.* Fig. 2) extending from 30° to 40° south latitude and from 240° to 280° west longitude. Using MOLA data we quantified a variety of attributes of mountains in the study region: latitude, longitude, maximum flank slope, total slope, total height, total width perpendicular to the long axis, and basal altitude.

The only attributes that showed even weak correlations to the existence of debris aprons were latitude and slope, and these were not statistically significant. Debris aprons are more abundant to the south of our study region, which seems consistent with the lower average annual temperatures and annual insolation if near-surface ice (the stability of which is strongly temperature dependent) plays a large role in debris apron formation. Similarly, a correlation between the existence of debris aprons and basal altitude was expected. However, despite a slight depletion of debris aprons in the portion of the study area within Hellas (westward of ~270°W) no correlation with altitude was observed. We are currently in the process of expanding our study area down to 50° south to further investigate the correlation with latitude.

Figure 1: Example of a debris apron around a mountain near Hellas at 45ºS, 255°W. (A) MOC image (M0204416) with the approximate location of the MOLA groundtrack. (B) MOLA topographic profile (orbit 10725).

(A)



(B)

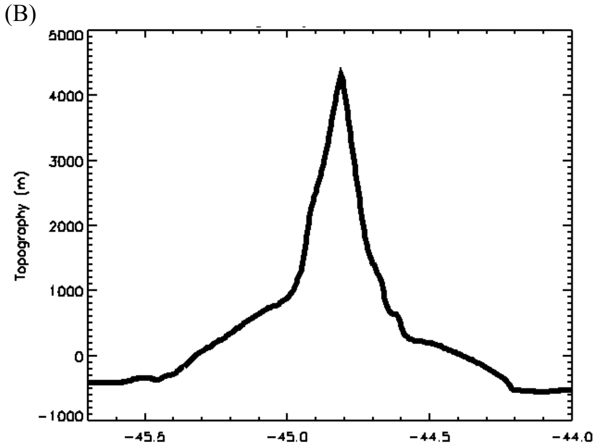
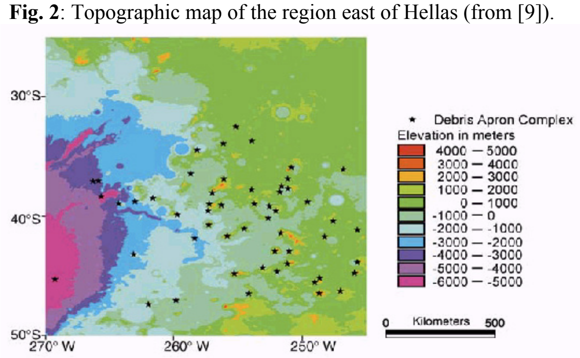
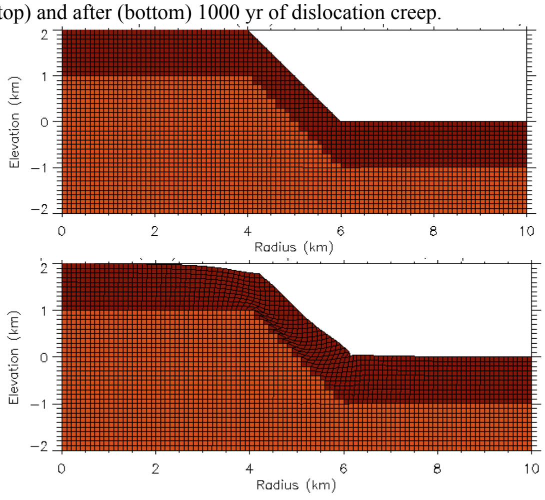


Fig. 2: Topographic map of the region east of Hellas (from [9]).



Modeling: We have applied finite-element analysis to investigate the possible formation of debris aprons by creep of an ice-rich surface layer. Our models incorporate recent laboratory measurements of the rheological parameters for dust/water ice mixtures undergoing dislocation creep and grain size dependent creep [4,5]. Both of these deformation mechanisms are relevant under present Martian conditions: T_{surf} = 200 K [10]; dT/dz = 15 K/km [11,12]. We have built models of scarps (45° slopes, *e.g.*, Fig. 3) and of talus (assumed to start at the angle of repose, ~34°, *e.g.*, Figs. 4 and 5). We are currently extending these models to lower slopes (from 25° to as shallow as ~1°) observed for Martian debris aprons [13,9].

Fig. 3: Cross section of a finite-element model of a 45° scarp with a 1 km thick layer of 30% ice by volume (dark red), before (top) and after (bottom) 1000 yr of dislocation creep.



Our simulations demonstrate that the final morphology is very dependent on the initial distribution of the ice-rich material (*cf.* Figs 4 and 5). Furthermore, even under present Martian conditions, viscous creep can occur quite rapidly; on timescales of 10^3 - 10^4 years for the amounts in these models. However, if the mobility of the ice is restricted by a surface layer that resists deformation, or the high volume fractions of ice inferred to be present within a ~1 m surface layer [3] does not continue to significant depths, the deformation timescales could be significantly longer.

Fig. 4: Cross-section of a slope of ice-rich material (uniform composition of 30% ice by volume, regardless of shading) after 7500 yr of dislocation creep. Solid diagonal line illustrates initial topography near the angle of repose, 34°.

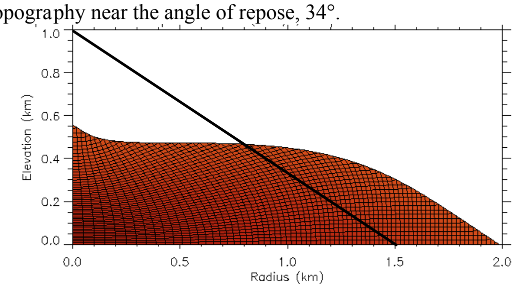
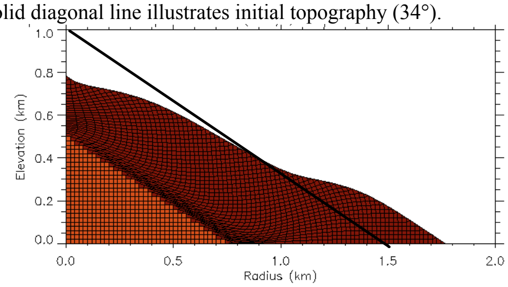


Fig. 5: Cross-section of a 500 m surface layer of ice-rich material (30% ice by volume, dark red) after 7500 yr of dislocation creep. Solid diagonal line illustrates initial topography (34°).



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