GEOMORPHOLOGY OF DEBRIS APRONS IN THE EASTERN HELLAS REGION OF MARS.

David A. Crown[1], Sarah B.Z. McElfresh[2], Timothy L. Pierce[3], and Scott C. Mest[2], [1]Planetary Science Institute, 620 N. 6th Ave., Tucson, AZ 85705, [2]Dept. of Geology and Planetary Science, University of Pittsburgh, Pittsburgh, PA 15260, [3]Dept. of Geological Sciences, University of Texas at Austin, Austin, TX 78712.

Introduction: The highlands of Promethei Terra east of the Hellas Basin are distinguished by a concentration of lobate debris aprons found in association with highland massifs, impact craters, and canyon walls [1-8]. Recent MGS analyses of their surface morphology and topographic characteristics suggest that the eastern Hellas aprons are ice-rich flow features with complicated emplacement histories and surface degradation by loss of contained ice [9-12]. Current work combines analyses of MOC, THEMIS, and MOLA data to further characterize the morphology, morphometry, and distribution of debris aprons, in order to provide constraints for models of apron formation and to assess styles of highland degradation.

Background: Lobate debris aprons belong to a group of Martian mid-latitude features that are considered geomorphic indicators of ground ice [6, 13-19]. Understanding their formation and age may have significant implications for evaluating volatile inventories and climatic conditions on Mars. MGS analyses related to the current investigation have focused on debris aprons and lineated valley fill in the fretted terrain of the northern hemisphere [20-23]. These studies provide evidence for ice-facilitated flow of aprons on the basis of their topography and suggest that progressive thermokarstic degradation accounts for much of the observed small-scale surface texture.

Previous Results: Recent geomorphic studies of 54 debris aprons in eastern Hellas using MGS datasets provide new evidence that this apron population consists of ice-rich flow features derived from local highland slopes [9-12]. A suite of small-scale surface textures and geomorphic features records a history of viscous flow, as well as surface degradation by aeolian processes and melting and/or loss to the atmosphere of contained ice. Typical eastern Hellas apron complexes consist of a combination of small to large mass movements/flows, enriched in ice initially or as debris accumulated; subsequent post-emplacement flow of the resulting debris masses largely produced the observed planform morphology and patterns of surface textures. Differences in apron topography reflect variations in ice content/internal distribution, flow mechanisms and emplacement history, age, and/or preservation state. Ongoing 1:1M-scale geologic mapping studies [3-5] have identified a series of additional, smaller aprons in Promethei Terra north of Reull Vallis, expanding the population to 90 features. GIS analyses are being used to quantify morphometric properties of the debris aprons and examine their distribution [11].

Apron Surface Morphology: Analysis of MOC narrow-angle images from the MGS extended mission allows evaluation and refinement of the morphologic classification [9-12] developed from images released earlier. The surface textures and geomorphic features previously identified are observed in extended mission images and exhibit similar patterns and relationships. Additional evidence for viscous flow is provided by well-defined lineations and flow ridge patterns [24], which delineate small discrete lobes or differential flow within large apron masses. New images of apron fronts show zones of transverse ridges, presumably resulting from compression during late stages of flow; in several places, apron fronts appear to be slightly deflected around small (~1 km diameter) impact craters, consistent with post-emplacement flow and suggesting slow movement at the flow front.

The interpretation of the sharp-ridge texture [9-12] as an erosional texture formed upon removal of knobby and ridge-and-valley textures is clearly supported by newly released images. The polygonal, linear, and curvilinear forms of the sharp-ridge texture reflect the internal structure of the apron mass and show patterns aligned with the apparent local flow direction. New observations of topogaphic lows, or moats, between aprons and their source massifs reveal erosional textures that support earlier hypotheses that moats are either 1) sites of enhanced apron degradation adjacent to massifs or 2) represent cases where the apron mass has moved away from the massif. Both scenarios imply a decrease in supply following moat formation, potentially identifying apron complexes that are older or more evolved members of the population. Additional evidence for loss of ice is observed within the apron complex at 46.5°S, 248.7°W, where several narrow, poorly-defined drainage features extend from an apron front through adjacent plains.

Impact craters superposed on apron surfaces are also being investigated to document apron stability and estimate stratigraphic ages. Aprons exhibit small, fresh craters and craters that appear to be filled. Fresh craters are rare and noticeably less abundant than filled craters on most apron surfaces, which have very low overall crater densities. Filled craters could result from mantling of apron surfaces [12, 25], be produced from aeolian redistribution of material across apron surfaces, or represent apron surface materials protected from erosion in crater interiors. In addition, ring-shaped hills are also observed on several apron surfaces; these could form by melting of ground ice [26-27] or could be impact craters on surfaces buried by thin aprons. Some craters appear to have non-circular shapes, suggesting deformation in the downslope direction.

Analyses of MGS extended mission images have also resulted in the identification of a particular grouping of previously recognized textures and features in several of the westernmost aprons of the population [e.g., 37.1°S, 265.9°W; 38.8°S, 263°W; 43.2°S, 263.1°W]. In these cases, apron surfaces show rugged, hummocky topography with high-standing mesas or hills with raised rims and slightly depressed central zones separated by adjacent sloped or flat-floored cavities in the apron surface. In some cases, the pattern is irregular but equant, and in others the pattern is elongated in the direction of flow or can have a shortened appearance near apron fronts. The low-lying regions between mesas and hills are typically smooth; knobby texture can be observed within some of the central depressions. The rugged topography is observed along with prominent longitudinal lineations and ridges as well as patches of smooth material that superpose knobby and ridge-and-valley textures [10, 12]. In some places, the fabric of flow lineations and knobby texture are apparent beneath the smooth material, and in others a labyrinth of small cracks and pits is exposed, representing an early stage of thermokarstic degradation [12, 22]. The attributes of this grouping of features and textures suggest more varied as well as more pristine surfaces, implying that these aprons are younger, less degraded, or experienced less post-emplacement flow relative to the rest of the population.

Apron Morphometry: GIS analyses of the 90 mapped debris apron complexes in eastern Hellas and corresponding MOLA datasets have been used to provide quantitative characterizations of the apron population [11]. Apron complexes extend 1.3 to 52.2 km from their sources. Planimetric areas of individual complexes range from 6 to 4035 km^2 (mean = 538 km^2), volumes from 0.5 to 3769 km^3 (mean = 310 km^3), and apron front thickness ranges from 14 to 1450 m (mean = 341 m).

The change in height (H, measured from source region to lowest elevation of deposit) divided by length (L) is a parameter (apparent coefficient of friction) that has been used to characterize the mobility of different types of geologic flows [e.g., 28-29]. H for the debris aprons can be determined in two ways depending on the inferred emplacement style: 1) maximum relief within an apron complex (40 m to 4.1 km, mean = 1.2 km) would represent flow as in a rock glacier or debris-covered glacier, or 2) the elevation difference between the peak of the associated massif and the plains adjacent to the apron front (240 m to 5.1 km, mean = 2.1 km) would represent the maximum H corresponding to potential landslides. H/L values for these cases are similar (range ~0.01 to ~1.4, mean = ~0.2). These mean values correspond to those of large terrestrial pyroclastic flows [28] and volcanic dry avalanches [29]; the range of values includes a wider spectrum of terrestrial flow types, including small pyroclastic flows and nonvolcanic dry avalanches. A recent study of an elongate apron in eastern Hellas suggested that it contained liquid water based on its morphometry and comparison to terrestrial debris flows [30]. The current analysis shows that, although this deposit has an atypical morphology for the eastern Hellas features, its morphometry is not unique. The range of H/L values for the eastern Hellas aprons suggests significant variation in mobility, although comparison to terrestrial data does not uniquely determine emplacement style or conditions.

Debris Apron Formation: Continued analyses of Viking, MGS, and Odyssey datasets for the eastern Hellas debris apron population are being used to assess geomorphic characteristics in terms of potential models of apron emplacement, as well as to understand apron degradation. Although, on the basis of previous characterizations, the eastern Hellas aprons appear to be a population of similar features, the observed geomorphic characteristics do not preclude multiple types of formation mechanisms. Future work will attempt to evaluate rock glacier, ice-rich landslide, and debris-covered glacier models for Martian debris aprons [12, 21-22] and to discriminate differences due to emplacement processes, ice content/distribution, and age/state of preservation. The potential models/terrestrial analogues for Martian debris aprons are different in terms of the source of ice (atmospheric precipitation vs ground ice), amount of ice (interstitial, lenses, or thick core), and timing of mixing ice with debris (prior to apron formation or following “dry” mass-wasting) and thus have significantly different environmental implications.

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