ICE-DRIVEN DEGRADATION STYLES IN THE MARTIAN MID-LATITUDES: CONSTRAINTS FROM LOBATE DEBRIS APRONS, LINEATED VALLEY FILL, AND SMALL FLOW LOBES. David A. Crown[1], Frank C. Chuang[1], Daniel C. Berman[1], and Hideaki Miyamoto[1,2], [1]Planetary Science Institute, 1700 E. Ft. Lowell Rd., Suite 106, Tucson, AZ 85719, [2]Department of Geosystem Engineering, University of Tokyo, Tokyo, Japan, crown@psi.edu.

Introduction. The Martian mid-latitudes are regions of high scientific interest given recent descriptions of mantling deposits and glacial features believed to be relicts of recent ice ages on Mars [1-4]. Geomorphic indicators of ground ice have long been proposed to be concentrated in mid-latitude zones based on analyses of such features as lobate debris aprons, lineated valley fill, and concentric crater fill in Viking Orbiter (VO) images of Martian fretted terrain and the southern highlands [5-10]. Recent climate modeling also shows specific mid-latitude volatile accumulation zones that directly correspond to concentrations of these features [11-12]. The current investigation examines the geomorphic characteristics of lobate debris aprons, lineated valley fill, and small flow lobes found on crater rims and massifs in order to characterize emplacement styles for ice-rich flows on Mars. As part of this work, we examine topographic controls on planform shape and surface lineation patterns.

Debris Aprons/Lineated Valley Fill. Studies based on VO images suggested that lobate debris aprons and lineated valley fill formed by flow of rock and ice mixtures, with latitudinal control attributed to seasonal frost deposition [6-10, 13]. Lineated valley fill covers canyon floors in the fretted terrain and within the circum-Hellas canyon systems. Debris aprons are found in similar locations, with prominent concentrations along the dichotomy boundary and in highland terrains of eastern Hellas [7-8, 14]. Debris aprons extend from massifs, mesas, canyon walls, and crater rims. Aprons frequently form complexes, in which multiple debris masses or lobes have coalesced to form a composite feature, with variable preservation of individual debris lobes. Detailed studies of the Deuteronilus Mensae [15-17], Tempe/Mareotis [18], and eastern Hellas [19-21] regions have incorporated new high-resolution imaging datasets (MOC, THEMIS, and MEX) and MOLA topography. Apron planform shapes, surface lineation patterns, and topographic profiles suggest viscous flow/deformation of apron masses, and surface textures indicate a complex history of surface mantling and subsequent degradation by aeolian processes and melting and/or sublimation of contained ice. The large range of potential terrestrial analogues (rock glaciers, debris-covered glaciers, and wet or icy debris flows) demonstrates significant uncertainties as to their ice contents and flow emplacement styles, as well as for the resulting climatic implications.

Our work to-date has analyzed 3 large populations of debris aprons: 89 aprons/apron complexes in eastern Hellas (30-50°S, 90-115°E), 65 in Tempe/Mareotis (45-55°N, 275-295°E), and 191 in Deuteronilus Mensae (30-50°N, 15-40°E) [17-21]. Morphometric characterization includes apron length, area, thickness, volume, surface slope, and relief, as well as distribution with respect to latitude, longitude, elevation, and geologic setting. Statistics have been compiled for each population. For all 345 aprons, mean values ± standard deviations are as follows: length = 7.8±7.0 km, area = 769±2161 km^2, volume = 370±1313 km^3, and relief = 0.79±0.60 km. Thicknesses at apron fronts are typically 100-300 meters and typical surface slopes are 2-6°; although typical apron lengths are ~5-20 km, apron materials can extend many tens of km from their source areas.

Mean values of the morphometric parameters are similar for the 3 apron populations. Given different geologic settings and apron source areas, this statistical characterization supports their designation as a specific class of feature that forms in Martian mid-latitude regions by one or more similar processes. The large ranges in apron lengths and volumes for each of the populations may require different emplacement processes/flow behavior for features of different size. On a graph of length vs. volume (Figure 1), Martian debris aprons are distinct from Martian landslides and terrestrial mass movements (landslides and debris flows), with greatest similarity to Martian landslides. For a given volume, debris aprons have shorter lengths, indicating that they are less mobile than Martian landslides and terrestrial features. Coalescence of multiple lobes into apron complexes may partially explain this result. Martian debris aprons are most dissimilar from terrestrial debris flows (which contain water), suggesting fluidization by liquid water is not a good explanation for their emplacement [see 22].

In order to explore triggering mechanisms/supply conditions, emplacement rates, and rheologic properties for debris aprons and lineated valley fill, we are integrating geomorphic analyses of surface features with three-dimensional characterizations of

flow shapes to provide constraints for future numerical modeling efforts. Our initial efforts are focused on examining topographic controls on flow emplacement, including changes in underlying slope, degree of lateral confinement, and response to topographic obstacles.

Some debris lobes are observed to widen as they extend from their source areas. This widening may be a function of flow over shallower slopes as the debris masses extend onto relatively flat-lying plains; in some cases, the upper zones of debris lobes are laterally confined in valleys on the rugged slopes of their source areas and flow emplacement becomes unconfined in their distal zones on the adjacent plains. Widening is indicated by lobe margins and/or surface lineation patterns. Sets of straight or slightly curved lineaments parallel to the apparent flow direction are observed in the medial zones of debris lobes. At some front margins, curvilinear lineaments oriented perpendicular to the apparent flow direction are evident. Debris lobes extending from canyon walls or tributary side canyons both superpose existing canyon floor materials and, in other cases, merge with lineated debris on canyon floors.

Some debris aprons exhibit sets of ridges parallel to their front margins. We attribute these to deformation of the apron mass in a frontal zone due to loss of mobility of the materials at the front relative to the rest of the apron mass, a relative increase in mobility of the upper part of the apron mass potentially due to increased supply from the source region, and/or to a change in underlying topography. In some cases, the apron front and ridges are deflected by small craters (≤ 1 km diameter).

Small Flow Lobes. The high spatial resolution of MOC and THEMIS images has allowed identification of a variety of small potentially ice-rich flow lobes. These are typically found extending down the interior walls of craters with diameters between ~30 and 100 km or into mid-latitude canyons. They have been interpreted previously to be remnants of glacial flow lobes or debris flows [23-25]. These features are smaller in width, length, and thickness than typical debris aprons and lineated valley fill and extend over the relatively steeper slopes (~10-20°) of crater interior rims. The differences in size and emplacement environment allow responses to small-scale topographic obstacles to be assessed. These small flow lobes provide an important comparison to larger ice-rich flow features, with respect to evaluating ice content and flow emplacement styles based on sensitivity to local topography.

Our initial work has focused on identifying and characterizing flow lobes in 2 mid-latitude zones as part of a survey of crater degradation: a) part of Arabia Terra along the dichotomy boundary (30-50°N, 0-40°E) and b) a zone of highlands east of Hellas basin (30-60°S, 110-150°E) [26]. For the eastern Hellas study region, all craters > 5 km in diameter are being examined for the presence of flow lobes on their walls. Thus far, 16 craters with lobes have been identified. Numerous lobes are typically observed within a given crater, and individual lobes are frequently deflected around or channeled by relatively small topographic obstacles (with heights of as little as 20 m) on interior crater wall slopes.

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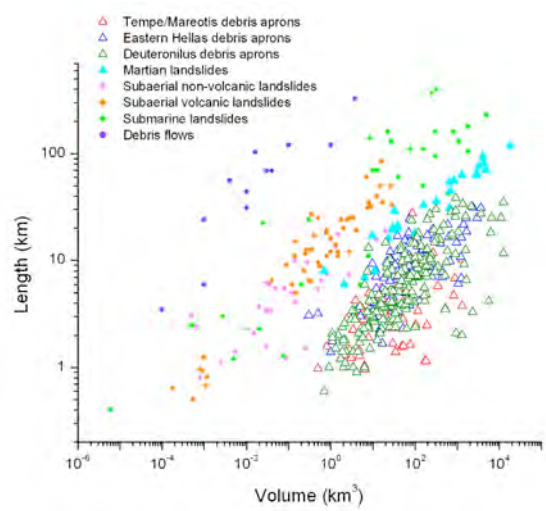

Figure 1. Plot of length vs volume for 345 Martian debris aprons, 29 Martian landslides and a suite of terrestrial mass-wasting features (32 subaerial non-volcanic landslides, 50 subaerial volcanic landslides, 44 submarine landslides, and 12 debris flows). Debris apron data from this study and other data from compilation by Legros [27].