**HYPSOMETRIC ANALYSIS OF GLACIAL FEATURES: A SURVERY OF LOBATE DEBRIS APRON POPULATIONS IN EASTERN HELLAS BASIN AND DEUTERONILUS MENSAE, MARS.**

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**Introduction:** Geologic features on Mars show evidence of modification by water and ice [1-5]. Past obliquity variations may have promoted the exchange of volatiles between the polar ice reservoirs and the midlatitudes, allowing the accumulation of glaciers and formation of periglacial terrain [6-8].

Probable glacial features, such as lobate debris aprons (LDAs) and intra-valley fill have been observed on the eastern rim of Hellas Basin and in Deuteronilus Mansae, ranging from latitudes of 30°N to 60°N and 30°S to 60°S (Figure 1) [8-9,10-12]. LDAs originate at the base of steep massifs and are characterized by lobes of gently sloping, convex-upward surfaces with steep outer margins. The flow-like morphology of these features, including radial and concentric lineations, suggest these features were formed by glacier-like viscous flow processes [13-14]. The shallow radar (SHARAD) instrument aboard the Mars Reconnaissance Orbiter (MRO) returned results for these features consistent with massive ice deposits, supporting the hypothesis that these are debris-covered glaciers [15], thought to have formed from atmospheric precipitation of water ice during the late Amazonian [8, 16].

These fairly young probable glaciers are important because they represent significant amounts of present-day, near-surface ice, with implications for martian climate and geologic history, the regional and global water distribution, and astrobiology.

**Hypsometric Analysis:** Terrestrial glaciology uses the hypsometric curve, or the empirical cumulative distribution function of elevations, as a method of constraining parameters such as the equilibrium line altitude (ELA) and mass balance of a glacier. ELA is the position, or elevation, at which accumulation is balanced by ablation. Mass balance, the difference between accumulation and ablation, is crucial to the survival of a glacier over time. Both these parameters can serve as key indicators of climate change, as they are closely related to temperature and precipitation.

We apply terrestrial glaciology inventory methods to the lobate debris aprons on the eastern rim of Hellas Basin and in the northern region of Deuteronilus Mensae, Mars to complete a detailed areal inventory of the buried ice deposits and to evaluate the hypsometric curve of each feature. We then examine the relationship between LDA hypsometry, latitude and elevation in order to understand the effect of past climatic variations on present-day, nonpolar ice distribution. Finally, we compare the hypsometric curves and distribution of different curve types of the Deuteronilus Mensae population of LDAs to the eastern Hellas population. The Thermal Emission Imaging System (THEMIS) Day IR 100m Global Mosaic was used in conjunction with Mars Reconnaisance Orbiter Contect Camera (CTX) images to determine areal extent, and Mars Orbiter Laser Altimeter (MOLA) data were used to ascertain elevations [17]. The JMARS software was used to processs and assess these datasets [18].

*Initial Results.* In eastern Hellas, LDA hypsometric curve shapes exhibit a strong dependence on elevation (Figure 4a). At elevations above 500m MOLA, LDAs exhibit hypsometric curves with a single peak, classfied in this study as Type I curves. At MOLA elevations between -2000m and 500m, LDA hypsometry exhibits curves with two peaks where the downslope peak is larger than the upslope peak (Figure 3.) These curves, classified as Type II, are similar to classic terrestrial alpine glaciers in that they can indicate a steady-state glacier with accumulation and ablation zones, and could potentially be used to determine the (most likely defunct) equilibrium line altitude of a lobate debris apron. Finally, LDAs below -2000m MOLA elevation generally exhibit double-peaked curves in which the upslope peak is greater in magnitude than the downslope peak. These hypsometric curves have been classified as Type III. This change in hypsometry with elevation signals a probable past shift in temperature and precipitation dependent on elevation.

Initial results from Deuteronilus Mensae indicate that most LDAs exhibit Types I or Type II hypsometric curve, weakly dependence on latitude (Figure 4b). This change in hypsometry with latitude could signal a different process occurring with changing climate in the region.

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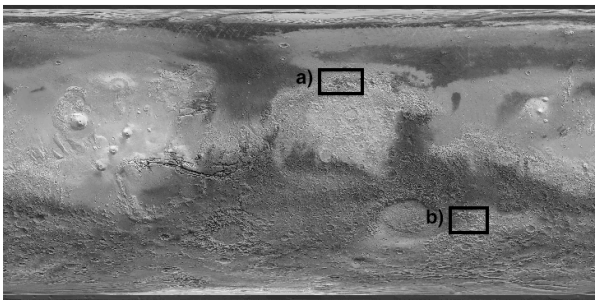


**Figure 1:** Location of major lobate debris apron (LDA) complexes at **a)** Deuteronilus Mesae (centered at 45°N, 22°E), and **b)** the eastern rim of Hellas Basin (centered at 45°S, 105°E). Background is the Thermal Emission Spectrometer Albedo global map in JMARS [18].

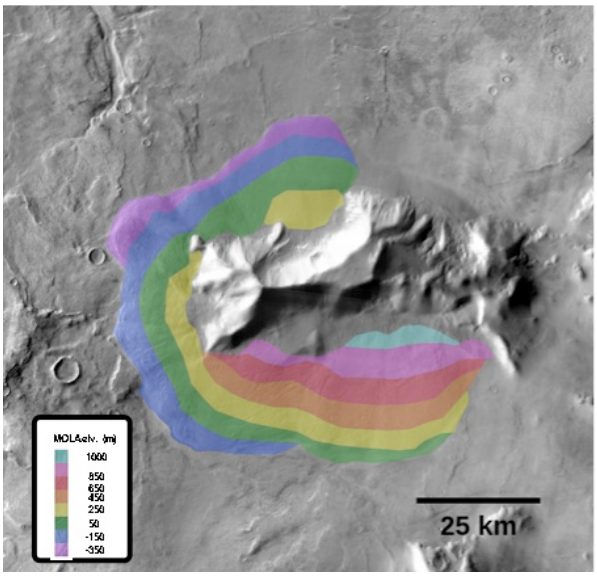


**Figure 2:** Example of hypsometric analysis of Type II lobate debris apron (LDA) surrounding a massif on the eastern rim of Hellas Basin, identified in Figure 1b. Base imagery is THEMIS daytime infrared imagery in JMARS [18]. The base of the apron is at MOLA elevation -350m and it is centered at 45°S, 102°E. Average elevation bins are identified by color. (Figure from Rutledge and Christensen 2010 [19].)

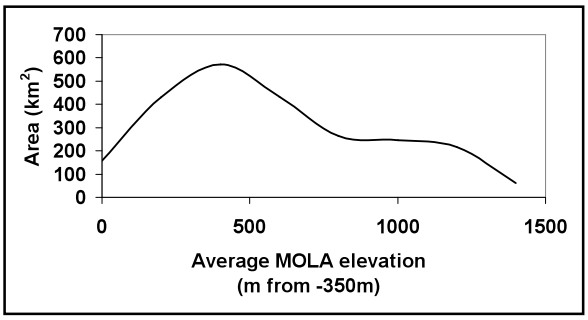


**Figure 3:** Hypsometry of the lobate debris apron identified in Figure 2, exhibiting a Type II hypsometric curve, where the curve has two peaks, the first one higher than the second. This possibly indicates paleo-accumulation and ablation zones during a period of active glaciation. LDAs exhibiting Type II hypsometric curves are commonly found in the mid-elevations of eastern Hellas, from -2000m to 500m MOLA elevation. (Figure from Rutledge and Christensen 2010 [19].)

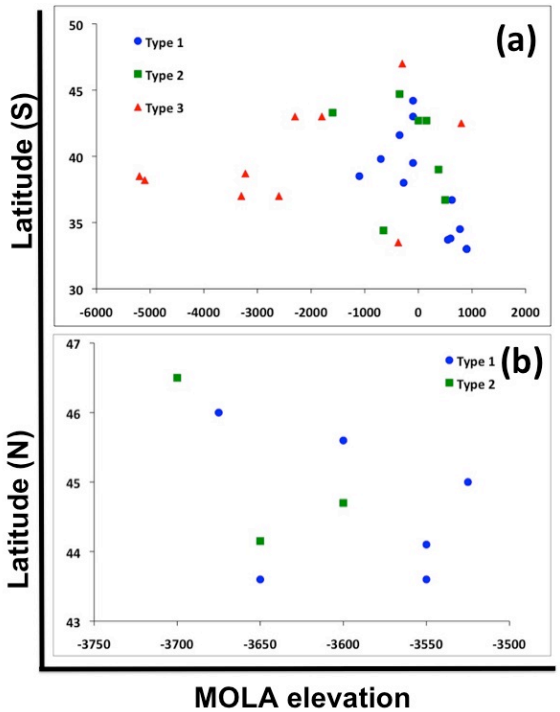


**Figure 4**: (a) Distribution of hypsometric curve types in eastern Hellas Basin. There is a clear dependence of curve type on elevation. The lower latitudes of this population contain only Type III LDAs. (b) Distribution of hypsometric curve types in Deuteronilus Mensae. Curve types exhibit only a weak correlation with elevataion.