

ESTIMATING THE VOLUME OF NON-POLAR ICE ON MARS: GEOMETRIC CONSTRAINTS ON THE VOLUME OF MIDLATITUDE DEBRIS COVERED GLACIERS. J. S. Levy¹, C. I. Fassett², C. Schwartz², J. L. Watters¹ and J. W. Head³ ¹University of Texas Institute for Geophysics, Austin, TX 78758, joe.levy@utexas.edu ²Mount Holyoke College, South Hadley, MA 01075 ³Brown University, Providence, RI 02906.

Introduction: Initial geomorphic analyses of mid-latitude landforms that appeared to be related to viscous flow (notably lobate debris aprons, LDA; lineated valley fill, LVF; and concentric crater fill, CCF) interpreted these features as indicators of ground ice emplaced by vapor diffusion in a different climate epoch, and the mobilization and flow of ice-cemented debris [1-4,9]. Following early insights [5], more recent studies [11-16] have noted the similarities to debris-covered glaciers and interpreted these features as deposits due to the accumulation and glacial flow of ice that formed during climate excursions and became covered with debris during and toward the end of their emplacement [11-16]. In both end-member cases, these landforms contain ice that has been removed from the shallow climate system [17] and sequestered beneath debris cover (glacial) or within pores in a debris deposit (viscous debris flow). How much ice has been removed from the global hydrological cycle by this sequestration? Although the distribution of these landforms has been mapped locally [1-4,9,11-16] no study has fully assessed the volume/mass of ice represented by these landforms for these two end-member scenarios [10], or its proportion of the modern water inventory on Mars.

Methodology: Here we present a new approach to estimating the volume of glacial deposits on Mars. LDA, CCF, and LVF were mapped over martian mid-latitude (30-50° north and south latitude) bands using CTX image mosaics supplemented by THEMIS-VIS daytime image mosaics at ~1:250k scale. For each landform type, geomorphic parameters were extracted to estimate the volume of the feature using gridded MOLA topography. For LDA, volume was calculated as the total volume within the LDA shapefile above the lowest point around the LDA perimeter. This is a reasonable approach to estimating LDA volume, given the flat to shallowly-angled basal slopes measured beneath LDA by SHARAD [15, 16]. For LVF, volume was calculated by first segmenting continuous LVF landforms into rectangular subsections. Valley wall slopes on either side of the LVF subsection were then extracted from gridded MOLA data (likely under-estimating the steepness of the valley wall slope, which leads to an underestimation of volume). These slopes were then projected beneath each LVF subsection to produce a triangular prism of inferred LVF volume. Finally, for CCF, several morphometric properties were extracted

from catalogues of northern hemisphere crater morphologies [20] including: crater diameter, d and measured crater depth, D_m . CCF fill radius, r_f is measured from CTX images of the crater, measured along two orthogonal profiles that span the spatial limit of “brain terrain” surface texture or concentric surface lineations. Using these quantities measured from MOLA and CTX data, relationships between fresh-crater depths and diameters on Mars, coupled with elementary calculus (solids of rotation), permit us to make quantitative estimates of CCF fill volume (see EPSC for details).

Dealing with Uncertainty. This measurement approach makes a minimum set of assumptions regarding the geometry of glacial landforms on Mars. SHARAD imaging of LDA suggests that basal slopes are low beneath LDA and are regionally homogenous [15, 16]. LVF are difficult to image with SHARAD [16], but where bottom reflectors have been detected, LVF appear to fill generally U-shaped, flat-bottomed valleys. Accordingly, LVF volume estimates have also been calculated by assuming a trapezoidal valley cross section that is half the depth of the valley calculated by projecting valley walls beneath lineated valley fill. Finally, for all landforms, minimum and maximum ice masses can be estimated by multiplying by 30% and 90% ice volume fractions (rock glacier and debris-covered glacier, respectively) and by assuming negligible ice densification from compaction.

Results and Preliminary Implications: CCF ice volume calculations for the northern hemisphere (completed at the time of submission) range from $1.3 \times 10^4 \text{ km}^3$ to $3.8 \times 10^4 \text{ km}^3$ (assuming rock-glacier ice mixing ratios and debris-covered glacier ice mixing ratios, respectively). LDA ice volume measurements from the northern hemisphere span $4.4 \times 10^4 \text{ km}^3$ to $1.3 \times 10^5 \text{ km}^3$, assuming the same mixing ratios as above. LVF measurement is ongoing at the time of writing but will be completed by LPSC. For comparison, observed polar cap water ice volume is $3\text{-}5 \times 10^6 \text{ km}^3$ [18-19], and estimates of latitude-dependent mantle (LDM) ice volume is $\sim 4 \times 10^5 \text{ km}^3$ [13]. It is clear from these initial results that martian glacial landforms represent a significant, but previously unquantified component of the global water inventory.

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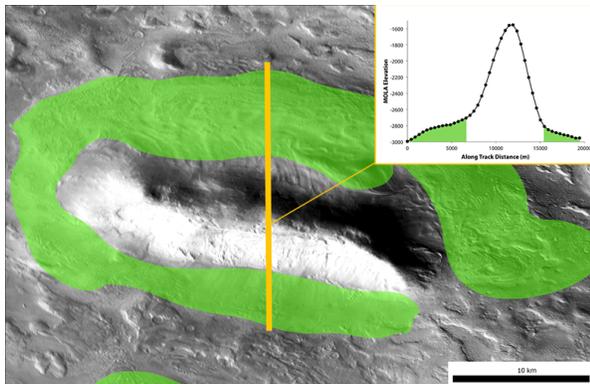


Fig. 1. (Above) Schematic illustration showing LDA volume measurements. LDA are mapped on CTX data mosaics, and then the minimum elevation of the LDA is extracted from MOLA. The LDA elevation above that minimum is then extracted and integrated over the LDA surface.

Fig. 2. (Right) Schematic illustration of LVF volume estimation. Base image adapted from SHARAD diagram in [15]. c) shows example LVF segments over MOLA shaded relief. Green and yellow rectangles are areas where valley wall slopes are measured. Slopes are then projected beneath the LVF. Blue line in a) indicates half-depth estimation from projected valley walls. Note significant vertical exaggeration in a), and that most LVF are too narrow to image with SHARAD.

