

GEOMORPHIC SIGNATURE OF LOBATE FLOW FEATURE IN THE CRATERS OF NEWTON BASIN, MARS: IMPLICATIONS FOR MODERATE DEBRIS-COVERED GLACIATION. Rishitosh K. Sinha and S.Vijayan, PLANEX, Physical Research Laboratory, Navrangpura, Ahmedabad-380009, India, rishitosh@prl.res.in.

Introduction: Analysis of glacial landforms on Mars has revealed obvious consistency in the extent and timing of ice-related processes to the scale of resulting landforms [1,2]. For example, large-scale (several kilometers) lobate debris apron (LDA) and lineated valley fill (LVF) stand out as landforms emplaced during major period of glaciation (~100 Ma-1 Ga; obliquity: $>45^\circ$) [1], whereas, small-scale (within few 100's of meters) gully and polygonal crack features are an outcome of localized, relatively minor period of glaciation of the recent past (within past ~10 Ma; obliquity: $\sim 30^\circ$ - 35°) [3,4]. Further inferring episodic reduction in the accumulation and flow of ice due to influence on the late Amazonian climate linked to the Mars' spin/axis-orbital parameters.

Scientific Rationale: Geomorphic evidence indicates that, as the regional glaciation transitioned from major-moderate-minor periods, glacial landforms of varying scales were emplaced in stratigraphy, such that the gully and polygonal features superpose the lobate debris-covered glaciers in the downstream, indicating temporal relationships [5-7]. A change in the climate cycle that has influenced the nature and extent of ice accumulation and flow has thus been interpreted [7].

This Study: We focus our geomorphic observation to Newton basin (40.50°S , 201.97°E ; ~300 km) to primarily demonstrate that the craters formed in the basin interior have preserved intriguing evidence for episodic glaciation in the region. Further, our analysis signifies that (1) crater diameter has been a key factor in controlling the flow extent of debris-covered glacier; (2) the lobate flow features (LFF) in the interior of basin crater's are of moderate debris-covered glacial origin; (3) LFFs originate only from the pole-facing slope of the craters; and (4) the pattern of ice accumulation and flow in this region (i.e. the pole-facing preference) has not varied, at least for the past ~100 Ma.

Study Region: The center of basin's interior is ~3.5 km deep from top of the rim and the floor is extensively modified by numerous craters preserved over it. These craters in the interior of the basin have been previously reported for preserving gullies and arcuate ridges over their pole-facing slopes and patterned deposits over the floor [7,8]. We reinterpret the patterned floor deposits as LFF [9], and constrain their extent and timing of formation to substantiate that they are an outcome of moderate debris-covered glaciation.

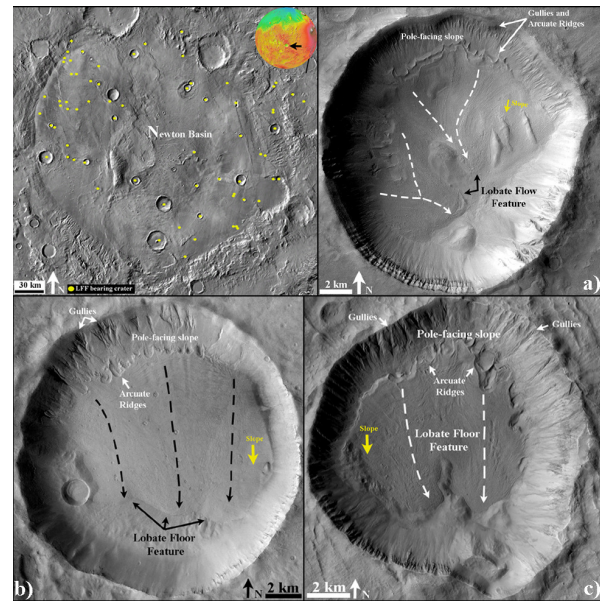


Figure 1. Regional survey of Newton basin for identification of LFF bearing craters in the region. The 'yellow circle' represents detection of a host crater in the interior of which we found LFF. Some examples of LFFs identified in the region is shown as Figures 1a, 1b, and 1c. Note the typical pole-facing orientation preference and integrated flow pattern displayed by each of the LFFs. The LFFs are different from CCF and VFF glacial features in the sense that their flow patterns, extents, scales, and periods of formation show considerable difference. Gullies and arcuate ridges formed in recent time-scales (past 10 Ma), with similar pole-facing orientation preferences, superpose LFF.

Observations: *Survey of LFF-bearing craters:* The presence of LFF-bearing craters in the basin's interior was noted in ~35 MRO CTX images [10], within which, 68 craters were found to contain evidence for tongue-like LFFs at the vicinity of their pole-facing walls (Figure 1). The diameter of these LFF bearing craters range from ~0.5 to ~21 km, with 4 km being the average crater diameter. It was noticed that the smaller and larger diameter craters both display LFF in their interior. The LFF flow extent varies from ~0.16 to ~8 km. The flow pattern of LFF typically follows down-slope characteristics, with flow undergoing bending/shortening/extending while between/over/around topographic obstacles.

LFF surface texture: LFF deposits display presence of brain-terrain texture on their surface that typically show groups of linear to arcuate shaped open and closed cells [11]. Presence of polygonal crack features that appears crisp and rigid [4], and show strong topographic contrasts, dominates LFFs surface from top to bottom.

LFF geomorphic units: LFF is found to be typically composed of multiple lateral and arcuate set of flow ridges visible at the foot of pole-facing wall, mid-way over LFFs' surface, and at the front-end of the LFF deposits [12]. Dominant occurrence of ring-mold crater (RMC) on LFF surface was noted from the pole-facing wall base to the LFF extent over the host crater floor [13]. It was observed that several pole-facing wall gullies and arcuate ridges formed at the crater wall base superpose LFF.

Results and Interpretations: (1) The overall scale and extent of LFF lies within few 100's of meters to few kilometers, which classifies them at an intermediate position between concentric crater fill (CCF) and viscous flow feature (VFF) [2,14]. (2) The smaller and larger flow extents of LFF were found to show a positive correlation with the diameter; further emphasizing that crater diameter has been a key factor in controlling the flow extent (Figure 2). (3) From our survey of LFF orientation preferences within Newton basin, we found that pole-facing wall slope preferences are dominant. (4) The geomorphic units found associated with LFF indicate possible presence of ice preserved beneath the surface. (5) The typical downslope flow characteristics of LFF in conjunction with the observed geomorphic units suggest that LFF resulted from possible debris-covered glaciation. (6) From our count of craters over two of the LFFs (Fig. 1b & 1c), we have estimated the best-fit age of LFFs spanning from ~100-10 Ma (Figure 3). Although, a rigorous timescale for LFF formation is still not entirely clear keeping in mind the limitations of the crater count method over glacial terrains.

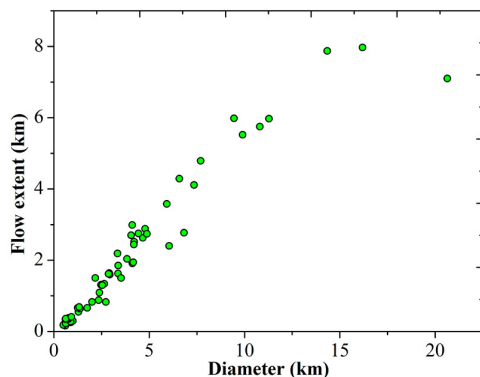


Figure 2. Plot comparing the distribution of LFF bearing host craters having varying diameter with the LFF flow extent.

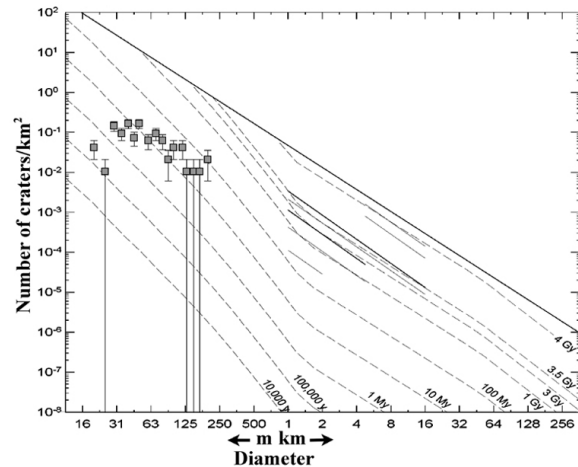


Figure 3. Crater count plot for the best-fit age (~100-10 Ma) of the two (Fig. 1b & 1c) LFF bearing craters using [15].

Conclusions: (1) The emergence of LFF between CCF and VFF indirectly suggest that LFF might belong to a moderate glacial phase, where ice/snow accumulated in relatively greater extents to that which facilitated formation of VFF, but lesser than to which resulted in CCF formation. (2) The dominant pole-facing preference for LFF makes the point suggested in previous studies stronger, i.e. there have been hardly any change in the orientation preferences during the course of formation of glacial/periglacial features having different scale and extent in the mid-latitudes during episodic glaciation. (3) The glacial period during which LFF was emplaced could be interpreted as an obvious episodic shift in the Late Amazonian glacial history that led to formation of these moderate scale glacial features within Newton basin.

References: [1] Baker D.M.H. et al. (2010) *Icarus*, 207, 186-209. [2] Levy J.S. et al. (2010) *Icarus*, 209, 390-404. [3] Morgan G.A. et al. (2010) *Icarus*, 208, 658-666. [4] Levy J.S. et al. (2009) *JGR*, 114, E01007. [5] Sinha R.K. and Murty S.V.S. (2013) *JGR*, 118, 1609-1631. [6] Sinha R.K. and Murty S.V.S. (2015) *Icarus*, 245, 122-144. [7] Head J.W. et al. (2008) *PNAS*, 105, 13258-13263. [8] Berman D.C. et al. (2005) *Icarus*, 178, 465-486. [9] Sinha R.K. and Vijayan S. (2016) *Icarus*, in revision. [10] Malin M.C. et al. (2007) *JGR*, 112, E05S04. [11] Levy J.S. et al. (2009) *Icarus*, 202, 462-476. [12] Arfstrom J. and Hartmann W.K. (2005) *Icarus*, 174, 321-335. [13] Kress A.M. and Head J.W. (2008) *GRL*, 35 (23), L23206-8. [14] Milliken R.E. et al. (2003) *JGR*, 108, E05057. [15] Hartmann W.K. (2005) *Icarus*, 174, 294-320.