
3) Relationships between LDA and LVF: Where massifs face outward to plains (Fig. 2), debris aprons spread out as lobes from alcoves and deform in relation to their neighbors; where they meet obstacles, they compress and flow around the obstacles (Fig. 3), in some cases where the obstacle is parallel to the crater wall, they converge and flow through a low point in the obstacle to create a piedmont-like lobe (Fig. 6) and local LVF. Where massifs are close together, LDAs converge in the middle of the valley, turn and flow laterally, often forming divides (Fig. 5). In some cases (Fig. 4), LVF flows from two different valleys, converges, incorporating a LDA from the southern valley wall, and forms a huge broad fold more than 25 km in length that becomes part of the linear LDA in the southern part of the valley wall (Fig. 1). Thus, at least in these numerous cases, LDA becomes LVF and vice versa.

4) Relationship of LDA/LVF to adjacent walls and origin of the lubricating agent: Numerous local alcoves appear to be the source of the concentric outward ridges that are the hallmarks of the LDA deposits (Figs. 2, 3, 5, 6); these are very similar to the debris-covered glacier source alcoves seen in the two regions interpreted to represent integrated valley glacial landsystems [7-8]. Detailed topography often shows evidence for depressions at the head of the ridges and the base of the massifs, suggesting that ice and snow once accumulated there to form debris-covered glaciers.

5) Mode of origin of the LDA and LVF: These relationships suggest that the LDA and LVF are intimately related in morphology and modes of origin. Formation of LDAs by accumulation of snow and ice in alcoves along the flanks of massifs and valley walls, led to the formation and outward flow of glacial ice; debris falling from the talus slopes above became concentrated and deformed to create the lineated glacial debris cover. As LDAs grew and coalesced, they merged between massifs (Figs. 5, 6) and in valley centers, and began to flow down-gradient, forming LVF, creating local piedmont type glaciers (Fig. 6) or larger valley glaciers with divides (Fig. 5), and very large glacial landsystems (Fig. 1, 4) [7, 8].

6) Implications for the geological history of Mars: This interpretation implies that significant snow and ice accumulated for a sufficient period of time in the Amazonian [4] to produce the LDAs and lead to their coalescence to produce extensive LVF valley glacial landsystems. A plausible explanation for these relationships is that water ice was mobilized from polar reservoirs during periods of obliquity higher than present [9-12] and was deposited preferentially in the 30-50° N latitude band, an interpretation supported by the widespread nature of similar deposits at these latitudes [13].

Fig. 1. Topographic contour map of study region: 100 m contour interval. Arrows show mapped directions of flow.

Fig. 2. Massif with circumferential LDA. Themis V13879005 with Viking inset for comparison.

Fig. 3. Linear LDA along crater wall. Note alcoves, lobes, obstacle divergence. Themis V10834007.

Fig. 4. Large fold where LVF converges and becomes LDA. Themis V11433004.

Fig. 5. Massif LDAs meet and flow laterally from a divide, forming LVF. Themis V14216012.

Fig. 6. Linear LDA blocked by parallel ridges, merges to form LVF and piedmont lobe in gap. Themis V12057009.