THE NATURE OF THE TRANSITION FROM LOBATE DEBRIS APRONS TO LINEATED VALLEY FILL: MAMERS VALLES, NORTHERN ARABIA TERRA-DEUTERONILUS MENSAE REGION ON MARS.


Introduction: Lineated valley fill (LVF) and lobate debris aprons (LDA) form in association with fretted terrain and fretted channels in the northern part of Arabia Terra [1-3]. Geological mapping in the region [4] shows that LVF and LDAs represent Amazonian-aged modification of the fretted topography, which itself formed prior to middle Hesperian. Analysis of MOLA data [5] revealed similar units in Mammers Valles on a Hesperian fretted valley, suggesting that down-valley flow of lineated terrain was minor; assessment of MOC and MOLA together revealed a three-component slope-texture typical of many LDAs: 1) steep 20-30° upper bedrock slope, 2) intermediate 3-5° slope with smooth texture or lineations normal to the slope, 3) main LDA slope 1-3°, extending up to 20 km, with a distal margin sloping up to 6° [5]; LDAs were interpreted [5] as debris flows lubricated by ground ice in the material undergoing mass wasting.

Among the many uncertainties associated with an understanding of the LDA and LVF are: 1) the direction of flow in LDA and LVF (either normal to the valley [2], or parallel, down-valley [6]); 2) the extent and continuity of flow in LVF [5]; 3) relationships between the LDA and the LVF; and 4) the mode of origin of the LDA and LVF (e.g., groundwater-fed, ice-assisted rock creep, ice-rich landslides, rock glaciers, debris-covered glaciers) [2-7]. Recent analyses of LVF in adjacent regions [8-9] have shown evidence for local sources of LVF in alcoves in valley walls, down-valley flow, merging of flowlines into broad trunk valleys, extensive along-valley flow, and termination in lobate deposits, all features that are similar to valley glacial landforms on Earth. In this study we analyzed LDAs, LVF, and their relationships along >900 km of the length of Mammers Valles from the crater Cerulli north to the area just south of Deuteronilus Colles (Fig. 1), and also assessed its distribution in along-valley and intersecting craters (Fig. 1). We subdivided LDAs into lineal (occurring along valley walls and crater interiors) and circumferential (aprons generally surrounding isolated massifs).

General characteristics and distribution of LDA and LVF: Mammers Valles can be subdivided into its lower reaches, where it averages <10 km in width, and its upper reaches where it is 20-30 km in width (Fig. 1). Most of the valley walls of the upper reaches are characterized by linear LDAs; high-resolution images show that LDAs are composed of dozens of parallel lobes that originate in alcoves in valley walls and extend onto the valley floor, creating a marginal ridge, and abutting similar parallel lobes emerging from the opposite wall (Fig. 2). LDAs can also emerge from theater-like remnant crater rims (Fig. 2) and from tributary valleys intersecting the main valley wall (Fig. 3); in these latter cases, the tributaries are commonly characterized by LVF that merges with the LDA, producing a larger than average lobe and/or unusual pitted surface texture (Fig. 3). Asymmetry in LDA development is commonly observed with S-facing LDAs more extensive. In narrower areas of the valley floor, lobes from opposite sides meet and their distal ridges form parallel linear ridges (Fig. 2); in wider areas, LDAs do not meet (Fig. 3) and unusual surface textures and features suggestive of ice-related periglacial processes are observed (Fig. 3, 4), including lobes showing lens-shaped deformation as the LDA lobes (arrows in Fig. 4). Where some LDAs meet in the central part of the valley, they are distorted along valley (Fig. 5) in a common flow direction, become complexly folded (N part of Fig. 5) and begin to merge into LVF. In some cases (Fig. 6) the LDAs derived from wall alcoves rapidly deform, lose their individual identity and merge into LVF. In the much narrower southern part of Mammers Valles (Fig. 1), LVF forms in the narrow tributaries from coalescing alcove-fed flow and emerges into the main channel (Fig. 7), where it joins other tributary-fed LVF and linear channel-wall LDAs, together compressing and deforming to produce ever-narrower folds until it becomes LVF. The unusual nature of superposed impact craters (Fig. 2, 4) suggests that the substrate contained significant ice [10] and that deformation has been minimal since its emplacement [5]. Along-valley slope reversals [5] are caused by local divides, where flow is away from broad accumulations in different directions (Fig. 1). Where narrow, along-valley integrated LVF flow opens into a significantly larger part of the valley (such as a large depression; Fig. 1) the distinctive along-valley flow terminates in a broad piedmont-like lobe (Fig. 8), further contributing to along-valley variations in topography [5].

Direction of flow in LDA: LDA flow direction is normal to valley walls where valleys are wide and LDAs from opposite walls are separated (Fig. 3) or simply abut (Fig. 2).

Relationships between the LDA and LVF: Where LDAs meet and begin to merge, LDA flow direction is distorted down-gradient (Fig. 5); continued merging causes LDAs to compress (Fig. 6, 7), lose their individual identity (Fig. 6), and merge into and become true LVF (Fig. 6-8).

Direction of flow in LVF: As noted by [5], topographic gradients are variable along-valley; these topographic slope reversals commonly reflect observed variations in LDA/LVF flow directions derived from detailed mapping of folds and deformed surface textures (Fig. 1). Along-valley slope reversals tend to occur at flow divides, and distinctive slope changes occur where LVF empties into wider depressions (Fig. 8).

Mode of origin of the LDA and LVF: The relationships outlined here suggest that linear LDAs and LVF are intimately related in morphology and modes of origin. Among the hypotheses outlined above for the origin of LDAs and LVF, e.g., groundwater-fed mobilization, ice-assisted rock creep, ice-rich landslides, rock glaciers, debris-covered glaciers [2-7], we interpret the evidence documented here to support a major role for debris-covered glaciers. Formation of LDAs by accumulation of snow and ice in alcoves (Fig. 2), and in tributaries (Figs. 3, 7) along the flanks of valley walls led to the formation and outward flow of glacial ice (Fig. 2); debris falling from the talus slopes above became concentrated and deformed to create the lineated glacial debris cover (Fig. 2, 3). As LDAs grew and coalesced, they merged between massifs (Fig. 6) and in valley centers (Fig. 5), and began to flow down-gradient (Fig. 5-7), forming LVF, ultimately creating large valley glaciers with divides (Figs. 1, 6, 7), local piedmont-type glaciers (Fig. 8), and very large glacial landforms [7,8] (Fig. 1).

Fig. 1. Topographic map of northern Mamers Valles; contour interval 100 m.

Fig. 2. LDA in northwest valley wall; THEMIS V04406006.

Fig. 3. LVF from tributaries feeding LDAs; THEMIS V05542017.

Fig. 4. Floor texture between LDAs; not arcuate depressions (arrows); THEMIS V05542017.

Fig. 5. LDAs meeting and distorted down-gradient; THEMIS V10572015.

Fig. 6. LDAs merging and distorting to become LVF; THEMIS V13929003.

Fig. 7. Narrow portion of Mamers with tributary LVF merging with valley wall LDA and forming folds and LVF; THEMIS V02521012.

Fig. 8. Narrow LVF flowing into depression forming piedmont-like lobe; THEMIS V14004008.