LINEAR LOBATE DEBRIS APRONS, PIEDMONT-LIKE LOBES, AND CRATER FILL IN THE ACHERON FOSSAE GRABEN REGION, MARS: EVIDENCE FOR DEBRIS-COVERED GLACIER FORMATION AND FLOW.

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Introduction: Lineated valley fill (LVF) and lobate debris aprons (LDA) are widespread in fretted terrain in the northern part of Arabia Terra [1-3], but occur elsewhere in this latitude band in the northern hemisphere, such as at Acheron Fossae, a series of arcuate parallel graben on a rise north of Olympus Mons (217-237° E; 34-40° N) where the graben floors are characterized by viscous flow-like features [4] resembling LDAs and LVF. Questions associated with the analysis of LDAs and LVF are: 1) the range of environments in which LDAs form; 2) the relation of LDA to underlying topography; 3) the nature and direction of flow in LDAs; 4) relationships between the LDA and the LVF; and 5) 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) [2-9]. Recent analyses of LVF in the Deuteronilus Mensae region [10-11] 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 landsystems on Earth.

In this study we analyzed the floors and walls of the graben composing Acheron Fossae [4], examining the viscous flow-like features there and assessing their morphology, topography, relation to underling topography, slope and orientation. We also compared the graben floor structures to lobate deposits found on the pole-facing slopes of impact craters superposed on the Acheron Fossae region (Fig. 1). We previously [12] subdivided LDAs into *linear* (occurring along valley walls and crater interiors) and *circumferential* (aprons generally surrounding isolated massifs), a distinction we found useful here.

Description of Viscous Flow Features in Acheron Fossae: The Acheron region lies on the NW flank of the Tharsis rise and forms a broad north-facing topographic arch at least 700 km long, and rising 2-3 km above the surrounding plains; its eastern edge forms a broad dome-like high about 150 km in diameter. Acheron Fossae dissect this basic background topography, forming at least two sets of graben [4] in which viscous flow features of various types and stages of development occur. The Acheron terrain is mapped as Noachian in age, and the graben are embayed by plains materials of Hesperian and Amazonian age [13]. Thus, the graben themselves, although showing characteristics suggesting at least two generations of formation [4], have apparently not been active in the Amazonian. Thus, these features could serve as a template of known geometry to assess the role of modification by LDA and LVF. Three types of viscous flow features are seen in the Acheron region and differ somewhat from the classic LDA and LVF in Deuteronilus [3]; we focus on he eastern half of Acheron (Fig. 1) to illustrate these: **1) <u>Linear LDAs</u>:** Distinctive lobate features are observed on the graben floor (Fig. 2). The ridged texture of these features is generally parallel to the graben walls and is somewhat sinuous but does not commonly form the discrete fold-like lobes typical of many LDAs [3,6,7,14]. The reason for this appears to be the distinctly straight linear walls of the graben, which do not form the alcoves that are common on sinuous valleys and their tributaries in the Deuteronilus region [14, 15]; in these areas alcoves serve as distinctive accumulations zones for snow, ice and rockfall, and thus are the emergent point of the lobes forming the individual folds within the broader LDAs. Do the linear LDAs show significant lateral movement? Figs. 2-4 show a 7-8 km diameter impact crater on the floor and rim of an ~8 km wide graben; here, in the perspective view (Fig. 4), it is clear that the linear LDA forming on the north-facing graben wall is extending across the floor, over the rim, and down into the impact crater over a distance of ~6-7 km. There is also evidence that linear lobate debris aprons are forming on the south-facing slopes, although they tend to be less prominent. The nature of the linear LDAs developed on the floors of Acheron Fossae are much more similar to these developed in graben locally along the dichotomy boundary in the Deuteronilus-Protonilus region (e.g., Coloe Fossae [16]) than along the boundary scarp or in channels and crater walls there [10-12,14-16]. **2) Lineated valley fill and piedmont-like deposits**: In environments in Acheron where slopes increase, such as in the dome-like structure at the eastern end, structures and morphologies differ. Here, linear debris aprons are developed in the graben, but rapidly turn and flow downslope to create lineated valley fill and, where the graben open to the surrounding plains, large piedmont-like lobes (Figs. 1, 5). In this perspective view, the large piedmont-like lobate debris apron emerges from the graben, flows around an obstacle, and spreads out into a large fan about 30 km wide. A similar fan is formed just to the north, from flow emerging from the wide graben there (Fig. 1). Thus, in these cases, linear LDAs produce LVF which in turn forms large lobes as the LVF flows down slope and out onto the surrounding plains. **3) Post-Acheron Impact Craters:** In this environment, numerous post-Acheron impact craters show evidence of the same type of lobate fill (Fig. 6-7) as seen in the crater on the floor and wall of the graben (Fig. 2,4). The northern parts of these craters show interior wall and floor textures (central uplifts, wall terraces, floor roughness) typical of relatively fresh impact craters. The southern walls and floor, however, are almost completely obscured by a darker smoother material forming lobate deposits extending from the inner wall down on to the crater floor. In detail, the deposits are characterized by the same lobate ridged texture seen elsewhere in LDAs; the lobes also follow local topography on the crater floor (Fig 6,7). Dating of these occurrences will help to determine the age of the deposits and their potential duration of activity.

Range of environments in which LDAs occur: These occurrences broaden the longitude range in which northern mid-latitude LDAs and LVF are observed extending the range sufficiently to suggest that the deposits may be common globally at other similar longitudes [14], and thus may be related to broad climate latitudinal change rather than specific conditions related to the dichotomy boundary scarp. These occurrences also broaden the geological setting to include linear graben (see also [16]) and emphasize the importance of occurrence inside superposed impact craters, and north-facing slopes.

Relation of LDA to underlying topography: We are currently comparing the topography of relatively unmodified graben to those whose floors are completely covered by fill in order to estimate the fill thickness. The presence of positive topography on the graben flank (Fig. 3; at A' end), together with several outward facing lobes (Fig. 2, bottom) suggest that some of the flank topography may be related to filling of the graben and emplacement of debris on the flank, a process seen in Arabia Terra [17]. Clearly, the linear aspect of the graben walls and the flatness of the substrate form linear LDAs that do not tend to flow laterally (Fig. 2) unless the slope increases considerably (Figs. 1, 5).

Mode of origin of the LDA and LVF: The topographic characteristics of the linear LDAs, the LFV and the piedmont-like lobes, their slopes and relation to underlying topography, all suggest that ice-assisted viscous flow (with ice contents in excess of 40-50% [e.g., [9]) was the major process operating to form these features; we interpret the majority of the features to be related to the formation and evolution of debris-covered glaciers.

References: [1] R. Sharp, *JGR*, 78, 4073, 1973; [2] S. Squyres, *Icarus*, 34, 600, 1978; [3] S. Squyres, *JGR*, 84, 8087, 1979; [4] P.

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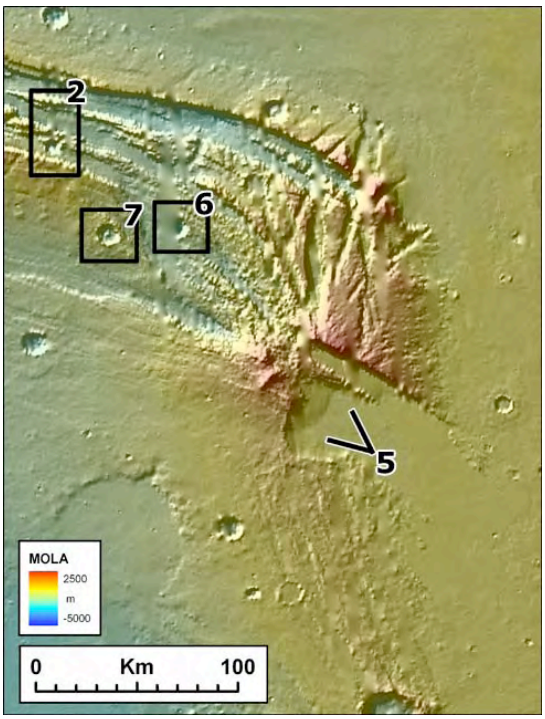

Fig. 1. MOLA gradient map of eastern Acheron Fossae.

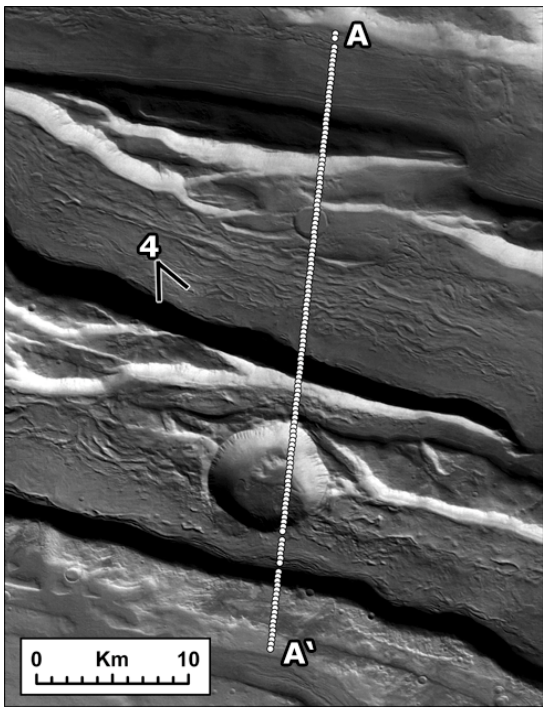

Fig. 2. Graben, linear and LDAs. HRSC 0037.

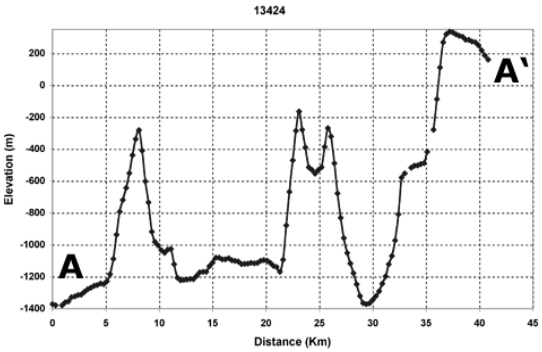

Fig. 3. MOLA altimetric profile (orbit 13424) across Fig. 2.

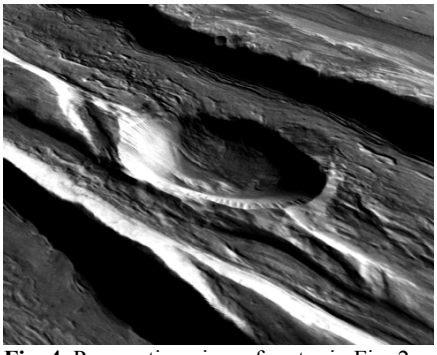

Fig. 4. Perspective view of crater in Fig. 2; arrow in Fig. 2 shows viewing perspective. HRSC 0037 draped on MOLA. VE=2x.

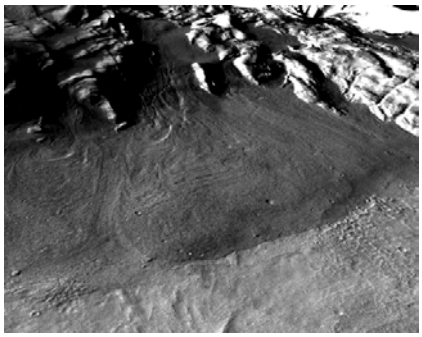

Fig. 5. Perspective view of piedmont-like LDA emerging from graben. THEMIS V09791029 and V01852010 draped on MOLA. VE=2x.

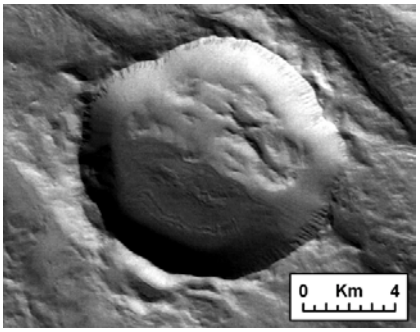

Fig. 6. Impact crater with wall and floor LDA; HRSC 0037.

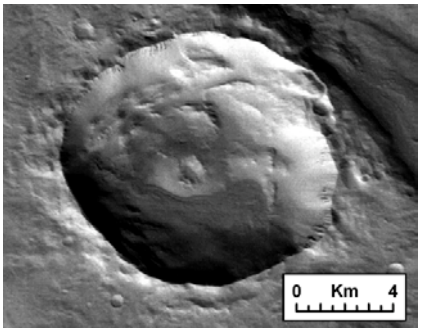

Fig. 7. Impact crater with wall and floor LDA; HRSC 0037.