

**MODIFICATION OF GRABEN ALONG THE DICHOTOMY BOUNDARY IN EASTERN ARABIA TERRA (COLOE FOSSAE; 53-59°E, 37-41°N): NATURE AND EVOLUTION OF LOBATE DEBRIS APRONS AND THEIR RELATIONSHIPS TO LINEATED VALLEY FILL AND GLACIAL SYSTEMS.** James Dickson<sup>1</sup>, James W. Head<sup>1</sup> and David R. Marchant<sup>2</sup>, <sup>1</sup>Dept. Geol. Sci., Brown Univ., Providence, RI 02912, <sup>2</sup>Dept. Earth Sci., Boston Univ., Boston, MA 02215. (james\_dickson@brown.edu).

**Introduction:** The dichotomy boundary represents a fundamental transition between the northern lowlands and southern uplands. The most well-defined portion of the boundary occurs as a complex set of scarps and reentrants where the boundary extends into northern mid-latitudes (~25-47°N), between 0° and 80°E. A considerable portion of the boundary (northern part of Arabia Terra) is comprised of well-developed fretted terrain and fretted channels [1] and is the site of lineated valley fill (LVF) and lobate debris aprons (LDA) [2-3]. A framework for the interpretation of modification processes operating on and near the dichotomy boundary is provided by a detailed geological history and chronology of this region [4]; the fretted channels and valleys formed prior to middle Hesperian and the associated LVF and LDAs represent Amazonian-aged modification of the fretted topography. The LDA and LVF are characterized by very low slopes and thus have historically been interpreted to be related to viscous gravity flow of debris lubricated by groundwater or ice, with ice thought to have been supplied by vapor diffusion and condensation in slope talus. Major outstanding questions include: 1) the detailed structure and texture of the LDA; 2) the origin of structures in the LDA and LVF; 3) the direction of flow in LDA and LVF [2,5]; 4) the relationships between the LDA and the LVF; 5) whether LDAs represent single or multiple events; 6) the origin of the lubricating agent; and 7) the mode of origin of the LDA and LVF (e.g., ice-assisted rock creep, ice-rich landslides, rock glaciers, debris-covered glaciers) [2-8]. Recently, regional analyses of LVF [9-10] 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 analysis, we studied an unusual region (36-42°N 53.5-58°E) characterized by a series of narrow linear graben (Coloe Fossae), extending for about 200 km NW-SE along and just south of the dichotomy boundary (Fig. 1). We compared the LDAs and LVF found here with areas characterized by mesas and broad sinuous valleys of the fretted terrain [11-13] and to Acheron Fossae [14] an area of LDA/LVF development outside northern Arabia Terra. We found it useful to subdivide LDAs into *linear* (occurring along valley walls and crater interiors) and *circumferential* (aprons generally surrounding isolated massifs) [12].

**Detailed structure of LDAs in the Coloe Fossae Region:** The scarp defining the main dichotomy boundary, and the mesas that extend to the north, are both characterized by classic examples of LDAs, and the new spacecraft data permit the detailed characterization of their internal structures and textures. Along the scarp itself, LDAs, seen at Viking resolution to be broad aprons, are revealed to be characterized by multiple individual lobes (Fig. 2, top; Fig. 3, bottom) extending 5-7 km from scarp alcoves into the surrounding plains; characteristics include proximal radial ridges, distal concentric ridges, and irregular pits and depressions (Figs. 2, 3). In some cases (Fig. 3, bottom) there is clear evidence of a younger, smaller set of lobes extending 3-4 km out on top of the broader 10-12 km lobes. Along the N-S portion of the scarp (Fig. 1.6) LDAs extend from the scarp about 16 km out into the adjacent lowlands; here there is evidence for extensive pits and irregular depressions, often following the radial and concentric ridged texture. Similar relationships are seen along the mesas that

characterize Protonilus Mensae, the region in front of the scarp; LDAs are formed of multiple individual lobes distinctly related to alcoves (Fig. 4) with radial, concentric and pitted textures, with small-scale pitting particularly abundant on the distal margins. More than one generation of lobe formation is also suggested by the stratigraphic relationships with a smaller (4-6 km) more distinctive set of lobes extending out over the larger more extensive (16-18 km) lobes (Fig. 4). At some mesas (Fig. 5), LDAs form and extend for considerable distances, extending around obstacles and joining LDAs that are forming from the mesa itself. Portions of the proximal parts of these two peripheral lobes (Fig. 5, bottom) are similar to LVF textures; in addition, LDAs extending downslope from the eastern part of the mesa are being deformed into folds and incorporated into the along valley flow of the broad lobe (Fig. 5 lower right). Within the graben of Coloe Fossae, the surface texture is much more linear and wavy (Fig. 8) than that typical of the more lobate LDAs surrounding mesas. Similar relationships are seen in Acheron Fossae [14], where viscous-flow floor texture in flat, straight-walled graben form classic linear LDAs, due to the fact that local alcoves are minimized in the straight graben wall. This linear LDA texture forms from LDAs converging from the walls and meeting in the center; as at Acheron [14], where slopes steepen, the linear LDAs can flow down-valley, often forming distal lobes. The waviness in the lineated valley fill (Fig. 8) can often be related to small irregularities in the graben walls. Central structures in the lineated LDAs include broad folds, some of which appear to be breached, forming axial depressions (Fig. 8, arrows; compare to Fig. 5).

**Relationship of LDAs to LVF:** In cases where scarps and mesas are in close proximity, LDAs forming on opposite slopes rapidly merge and form LVF (Fig. 2, bottom). LDAs formed in a topographically constrained area such as a sloping impact crater interior (Fig. 6, bottom) show evidence of compression against the distal rim of the crater, diversion to the N, and flow out into the surrounding region to form an LVF-like texture. The linear LDAs on the floor of Coloe Fossae (Fig. 8) are testimony to the fact that LVF can originate from valley walls and form LVF-like textures.

**Mode of origin of LDAs and LVF:** Evidence of melting associated with LDAs and LVFs in the Arabia Terra region is extremely rare, but in one location in this region (Fig. 7), several small channels are seen draining from the front of LDAs; the unusually abundant pitting in the LDA here and the frontal pits at the location of the small channels suggests that a significant component of ice was involved in the formation of these deposits [e.g., 6-8]. These observations outlined here 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 mesas and scarp walls (Figs. 2-4, 6, together with debris from surrounding scarps, led to the outward flow of debris-covered glaciers. As LDAs grew and coalesced, they merged between massifs (Figs. 2, 5) and in valley centers (Fig. 8), and began to flow down-gradient, often forming LVF, and creating integrated glacial landsystems (Fig. 1).

**References:** [1] R. Sharp, *JGR*, 78, 4073, 1973; [2] S. Squyres, *Icarus*, 34, 600, 1978; [3] S. Squyres, *JGR*, 84, 8087, 1979; [4] G. McGill, *JGR*, 105, 6945, 2000; [5] B. Lucchitta, *JGR*, 89, B409, 1984; [6] T. Pierce and D. Crown, *Icarus*, 163, 46, 2003; [7] N. Mangold,

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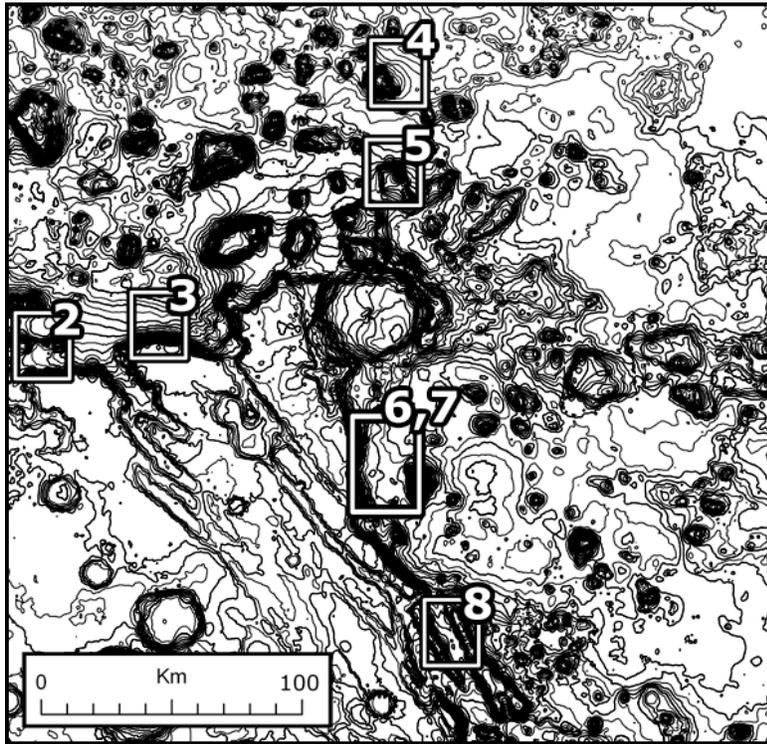


Fig. 1. Topographic map of the Coloe Fossae region; contour interval 100m.

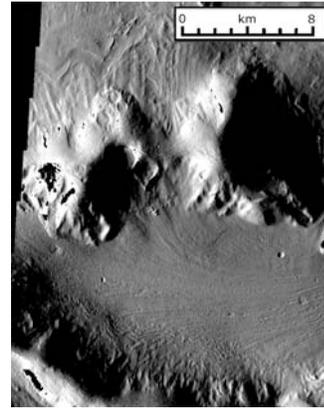


Fig. 2. LDAs and LVF; THEMIS V05341013.

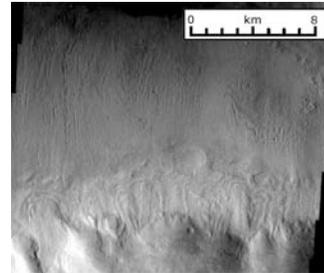


Fig. 3. LDAs; THEMIS V03044003.

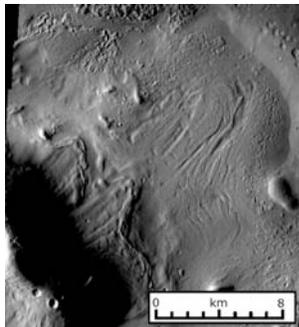


Fig. 4. LDAs; THEMIS V13204004.

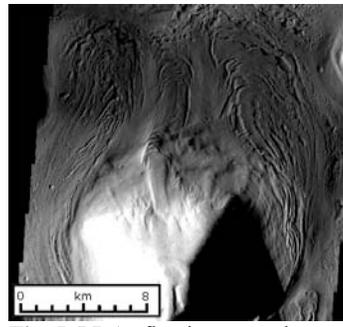


Fig. 5. LDAs flowing around mesa; THEMIS V13204004.



Fig. 6. LDAs; THEMIS V11669003.

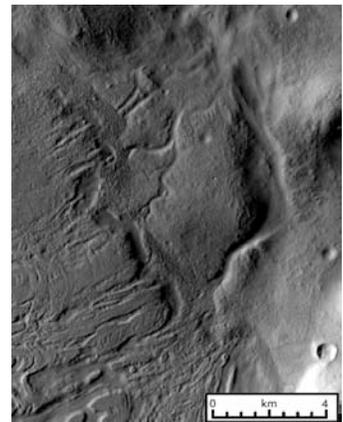


Fig. 7. Small channels; NE part of Fig. 6.

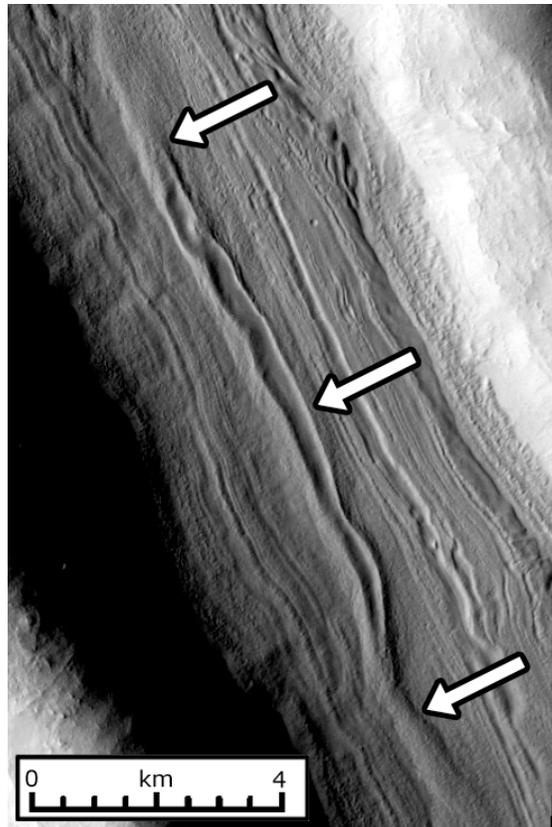


Fig. 8. Linear LDAs forming LVF; note breached fold; THEMIS V04492006.