ORIGIN AND NATURE OF A DEBRIS-TONGUE IN HELLAS MONTES, MARS

S. van Gasselt[1] (vgasselt@zedat.fu-berlin.de), E. Hauber[2], G. Neukum[1], and the HRSC Co-Investigator Team, [1]Freie Universitaet Berlin, Berlin, Germany, [2]Institute of Planetary Research, German Aerospace Center (DLR), Berlin, Germany.

Summary: We here report on results of an investigation of a tongue-shaped landform located in the Hellas Montes area and summarize morphologically derived evidence that this landform (a) originates at a formerly unknown volcanic edifice located in the north, (b) is probably older than previously assumed, (c) has been resurfaced by subsequent mass-wasting processes taking place ontop of the flow, and (c) shows a substantial degradation morphology. The hypotheses contrast to other explanations provided by earlier workers [1-3]. We agree that this landform is connected to landslide mechanisms, as suggested by [2].

Background: Terrestrial debris avalanches are instantaneous and rapidly moving chaotic mass movements of debris and water in varying concentrations allowing transitional morphologies ranging from debris flows to mudflows and other slurries [4]. They are frequently observed at volcanic edifices where their sudden formation is triggered by volcanic eruptions and flank instabilities (e.g., Mount St. Helens, Mt. Shasta [5,6]).

In 2003, Baratoux and co-workers published a paper [2] about a 50 km long and 7 km wide tongue-shaped wet debris avalanche located east of the Hellas Planitia impact basin that has been a matter of controversal discussion and was previously interpreted as a possible rock glacier analogue [2-3] (Fig. 1). Based upon the concavity of the longitudinal profile, length estimates as well as width to height ratios, Baratoux et al. [2] came to the conclusion that this landform is best described as a wet debris avalanche when compared with terrestrial data from debris flows and other debris/water mixtures. A possible connection to volcanic processes, as common in the circum-Hellas area, was established in that context as well and a small knob-like feature (rm3 in Fig. 2) was proposed as possible origin.

Observations: For this analysis, which has taken place in the context of characterization of slope morphologies in the Hellas Montes [7], all available image data (Viking, THEMIS-VIS/IR, HRSC, MOC-NA) and topographic data from MOLA have been combined and mapped. The analyses showed that the textural inventory of the surfaces of both, debris tongue and adjacent debris apron lobes (Fig. 2), are different in terms of lineations, alignments of ridges and furrows (i.e., compression pattern) and distribution of degradational pits. The elongated shape clearly indicates a formation mechanism that is different from an earlier proposed ice/debris mixture in terms of volatile contents and grain-size distribution, resulting in flow of material with a reduced yield strength. Nevertheless, as clearly pointed out by [4], various types of debris/water mixtures and other slurries are difficult to distinguish morphologically and flows can have different properties at different locations. Natural limitations in genetic classifications based upon morphometry only are well known [8,9]. The main uncertainties are (a) that the source region of the debris tongue could not be well defined earlier and (b) that height-to-width ratios have been compared with terrestrial data covering not only debris avalanches but covering the complete set of of debris/water transport systems ranging from glacial outbursts over debris flows to mudflows and an assignment seems arbitrary.

Although there are morphologic similarites to terrestrial debris avalanches and similar transport systems, such as the general elongated shape, parallel lineations on the flow surface indicating at least partly laminar flow [10], and a slightly raised terminus characteristc of a debris dam as pointed out by [2], there are several arguments against that kind of origin: Marginal side flows and debris-tongue proturbations as often observed at terrestrial avalanches of volcanic origin are completely missing. Instead the flow margins and terminus are well defined and have a convex shape similar to debris apron margins (terminal convexity). Typical avalanche characteristics such as conically shaped surface hummocks caused by wave propagation and large blocks, as e.g., observed at Mt. Shasta, are missing. In contrast to what is often observed at terrestrial debris avalanches, surface lineations show no terminal divergence but form a pattern more characteristic of glacier-like flow.

The debris-tongue surface is characterized by numerous isolated depressions indicating post-emplacement degradation. This view is also supported by observations at the flow margins which clearly show that the surface consists of a rough-textured layer now subject to degradation. Loosened fragments and coherent blocks of the surface layer slit down the margins and accumulated at the marginal base. Flowage and debris transport patterns ontop of the main debris-tongue surface resemble resurfacing after emplacement of the main debris unit.

Based upon crater counts performed by [2] the debris-tongue unit is considered to be younger than adjacent debris aprons and is therefore not directly connected to the formation and advance of debris apron material. Although own crater-size frequency distribution measurements showed similar results it is clear that there is only little chance of distinguishing circular depressions from impact craters without ejecta at the limit of image resolution, especially if circular depressions are part of the morphologic inventory of the degradation process of the debris tongue and aprons. In contrast, it seems very likely that the debris tongue is either contemporary or older than the debris apron as the contact between both units show a zone of intense compression. Further analyses of adjacent areas lead to the conclusion that the debris tongue originates in a chaotic assembly of landslide material at the western margin of an unnamed structure previously mapped as impact crater but more probably forming a collapsed caldera (Fig. 3). Arguments for a caldera construct are based upon the sharply defined appearance of the rim, tilted blocks at the interior walls and traces of gullied slide flows and other processes on the depression floor which are not known from impact crater structure. A full discussion is provided in [11].

Conclusion: .The process involved in the development of that debris-tongue landform is more akin to a slow style of deformation and creep of debris material instead of a sudden emplacement style. Nevertheless, the general shape of the landform implies a volatile content which is significantly higher than that of debris apron material that is considered to be formed by deformation of debris and ice. Except for the shape, the discussed landform currently shows only few similarities with debris avalanches found on Earth.

Earlier determined length values for the debris tongue have to be shifted to larger values as the source area is obviously not related to the remnant massif as proposed by [2]. However, true values are difficult to assess as the source area is partly covered by debris apron material and partly reworked into landslide material.

Compressional ridges on adjacent debris aprons at the debris-tongue contact indicate apron advance after emplacement of the debris tongue yielding an older relative age for the debris tongue than estimated earlier. Furthermore, surficial processes suggest resurfacing after emplacement by ongoing debris transport. Debris tongue and debris apron materials are currently subject to degradation.

We suggest that the main supply of debris and volatiles is derived from a collapsed caldera rim found in the north (Fig. 3). Earlier volcanic activity could have contributed to the release of volatiles. Subsequent rim destabilization triggered re-mobilization of volatiles and debris [11].

Further studies have to show whether debris apron material is composed of mass wasting processes such as landslides or solifluction connected with the degradation of remnant massifs or whether it was connected to active volcanic phases.

References: [1] Crown et al. (1992), Icarus, 100, 1-25; [2] Baratoux et al. (2002), Geophys. Res. Lett. 29(7), 1156; [3] Degenhardt et al. (2003), J. Geophys. Res., 108, E4, 8036; [4] Iverson (1997), Rev. Geopys., 35(3), 245-296; [5] Brantley & Glicken, (1986), Earthq. & Volc., 18(6,), 195-206; [6] Glicken (1996), USGS Open-File Report 96-677; [7] van Gasselt et al. (2005), Lun. Planet Sci. Conf., #2090; [8] Selby (1982), Hillslope Materials and Processes, Oxford, 264p; [9] Blong (1973), Eng. Geol., 7, 99-114; [10] Francis & Oppenheimer (2003), Volcanoes; Oxford, 534p.; [11] van Gasselt et al., JGR, submitted.

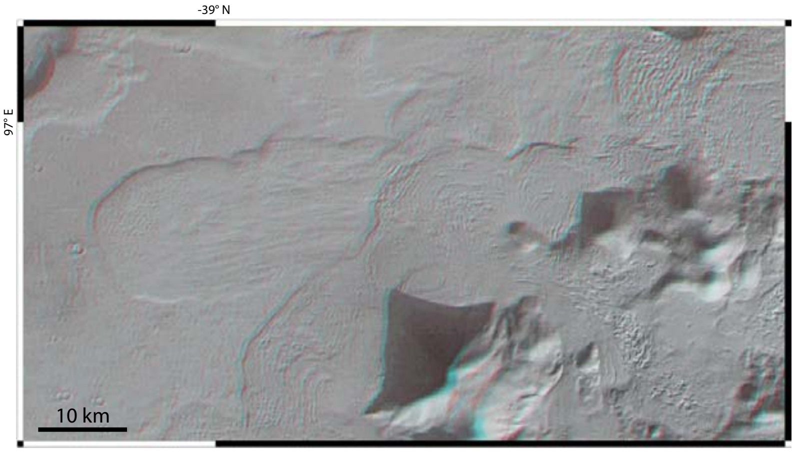

Fig. 1: Stereo anaglyph of debris tongue from nadir and stereo #1 of HRSC orbit 506. North is right.

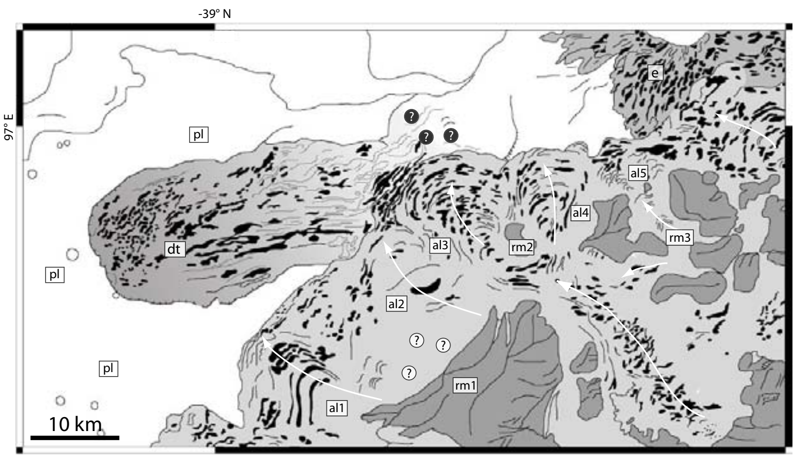

Fig. 2: Sketch map of the debris tongue [dt] in eastern Hellas. Arrows indicate debris transport across individual debris apron lobes [al1-5]. [rm] are remnant massifs. Labels [pl] indicates plains material, [e] indicates ejecta blanket material. North is right.

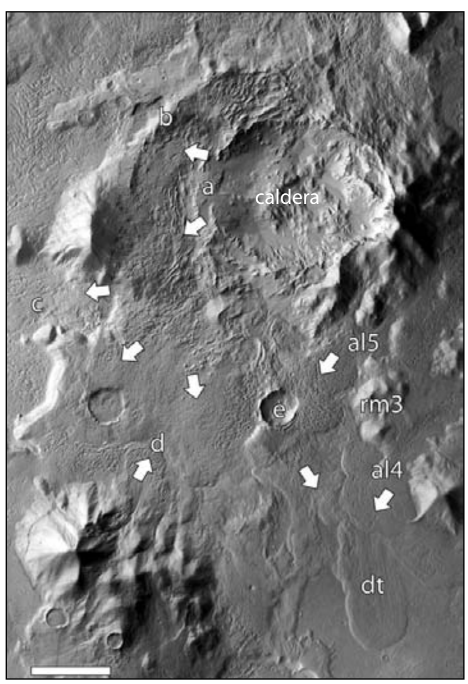

Fig. 3: THEMIS-IR daytime mosaic of study area. Arrows indicate debris transport from collapsed caldera flank (a) and debris aprons (al4, al5), (b) older remnant massifs blocked landslides and guided transport of debris towards the south, (c) debris transport into outflow channels, (d) coalescing zone of apron debris (south) and landslide material (north), (e) impact crater whose ejecta coalesces with landslide material. Apron lobes al4-5 and remnant massif rm3 as in Fig. 2. No connection between remnant massif rm3 and debris tongue can be established. Debris tongue lies underneath apron lobes al4 and al5 indicating an older age. North is top, scale bar is 20 km.