GEOMORPHOLOGY OF THE TEMPE TERRA LOBATE DEBRIS APRONS. S. van Gasselt[1], E. Hauber[2], A.-P. Rossi[3], A. Dumke[1], G. Neukum[3], [1]Freie Universitaet Berlin, Insitute of Geological Sciences, Planetary Sciences and Remote Sensing, Malteserstr. 74-100, D-12249 Berlin, [2]German Aerospace Center, Institute for Planetary Research, Rutherfordstr. 2, D-12489 Berlin, [3]International Space Science Institute (ISSI), Hallerstr. 6, 3012 Bern, Switzerland. (stephan.vangasselt@fu-berlin.de).

Introduction and Background: The fretted terrain at the Martian dichotomy boundary hosts an abundance of landforms related to the creep of mountain debris and ice which have become known as so–called lobate debris aprons and units of lineated valley fills and concentric crater fills [1-6]. Although such features are related to different morphologic settings, there is a general consensus that these features are in principle genetically connected to the process of ice-assisted creep. Such creep–related landforms are generally considered to be indicators for the existence of past and present ice in the near subsurface of Mars [1-2, 5, 7]. The analogy between terrestrial rock glaciers and Martian lobate debris aprons and similar landforms [e.g., 3-4] is mainly based upon the geomorphological context [3-5, 8], the cross–sectional profile and characteristic features indicating extensional and compressional stresses. While explanations of rock–glacier origin require periglacial environmental conditions allowing rock–glacier deformation and movement by creep, aspects are recently (re-)discussed with respect to debris–covered glacial or debris–covered ice–cored systems with all consequences of precipitation and glacial flow in early Martian history [9-10]. We here investigate lobate debris aprons in the Tempe Terra/Mareotis Fossae region of Mars on the basis of high resolution imagery and topographic data and focus on the emplacement and degradational history and on a mantling deposit which indicates the past and/or present existence of near surface ice.

Data and Methodology: For this survey we analyzed high–resolution panchromatic orthoimage data with a pixel resolution of better than 15 meters and derived products from the Mars Express (MEx) High Resolution Stereo Camera, (HRSC, [11-12]) and image data obtained by the Mars Reconnaissance Orbiter (MRO) Context Imager instrument (CTX, [13]). For comparison with previous work we additionally processed and included all available image data from the Mars Global Surveyor (MGS) Mars Orbiter Narrow–Angle Camera (MOC–NA, [14-15]) covering the Tempe Terra/Mareotis Fossae area. For topographic information we made use of a high–resolution digital terrain model mosaic with a pixel scale of 100 m that was derived from bundle–block adjusted HRSC data.

Geomorphologic Settings: The Tempe Terra/Mareotis Fossae region is located between 270-295°E and 40-55°N and is characterized by flat and smooth northern lowland terrain and the southern cratered highland terrain; both units are seperated by a steep escarpment which marks the global dichotmoy boundary. Within the Tempe Terra/Mareotis Fossae embayment, several simple and complex–shaped isolated remnant and massifs occur that are delineated by lobate–shaped debris aprons extending up to several hundred meters from the remnant massifs. At several locations, these aprons coalesce and form a complex and irregularily–shaped apron constructs. East and west of the Tempe Terra embayment, remnant massifs become relatively flat and aprons gradually disappear.

Model on Landscape Evolution: According to our observations (e.g., figures 1-2) we propose a multi-stage model for landscape evolution in the Tempe Terra region, which needs further verification in other areas of the dichotomy boundary. We have currently no observational basis for assumptions on the formation of remnant massifs in the near–escarpment region of the highland–lowland boundary which means that all we can say about the emplacement and distribution of remnant massifs is that they are either autochthonous, i.e., erosional remnants of highland material [1-2, 4, 6, 16-18] or uplifted crustal material as suggested for the southern hemispheric circum–Hellas and Argyre Planitiae remnants [19]. Alternatively, an allochthonous origin is conceivable though less likely, i.e., emplacement by impact processes, similar to alternative explanations for the southern hemispheric remnant–apron features [e.g., 19-20]. However, remnants have undergone erosional processes, be it by fluvial erosion, or be it by gravitational processes, such as landsliding and mass wasting as well as deflation and denudation. The rugged and partly conical shape and the generally smooth appearance of exposed remnant material, and observations of surficial lineations and ghost impact craters furthermore support the theory of early remnant erosion and deflation. We cannot rule out that with an appropriate amount of volatiles under early environmental conditions formation of typical periglacial phenomena, such as frost creep, gelifluction and early rock–glacier formation took place but as we cannot directly observe such features we base our assumptions on terrestrial analogs, i.e., dominant processes and landforms in cold–climate landscapes and on the assumption that episodic obliquity changes for Mars controlled the distribution of ice in early Martian history in the same way as it does today.

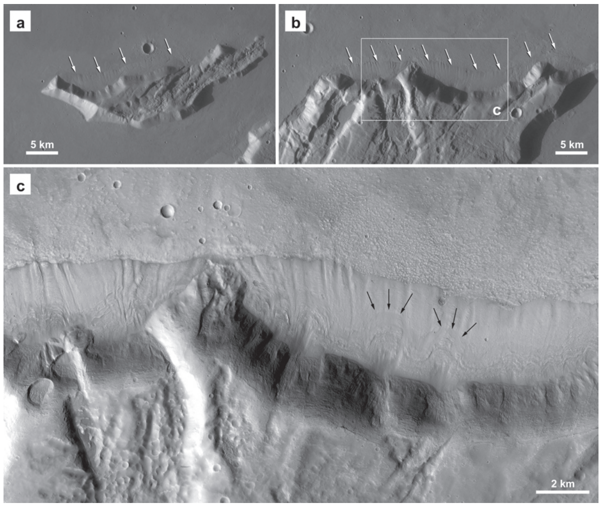

Figure 1. Lobate debris aprons at isolated remnants of highland material in western Tempe Terra. [a] Massif at 35.36°N with lobate debris aprons (white arrows) on the northern side, but not on the southern side. The difference might be due to reduced (year–integrated) insolation on the sun-protected northern side (north is up, illumination is from the west/left). [b] Remnant highland massif with marginal lobate debris apron (white arrows). The LDA appears striated, with stripe orientation parallel to inferred flow direction (north is up, illumination is from the west/left). [c] Detailed view of LDA shown in [b]. A convoluted or undulating pattern (in plan view) characterizes the texture of the upper (southern) parts of the LDA. The position of the lobes (e.g., black arrows) are controlled by indentations of the southern scarp. These indentations or niches might be caused by faults, as they seem to be connected to lineations on the plateau surface of the massif. The striations in the LDA are interpreted to be induced by differential flow or creep velocities of the LDA and associated shear stresses. The additional loading from material downwasted along the indentations might have triggered the differential velocities, with higher creep rates at the positions of increased loading (north is up, illumination from southwest/lower left).

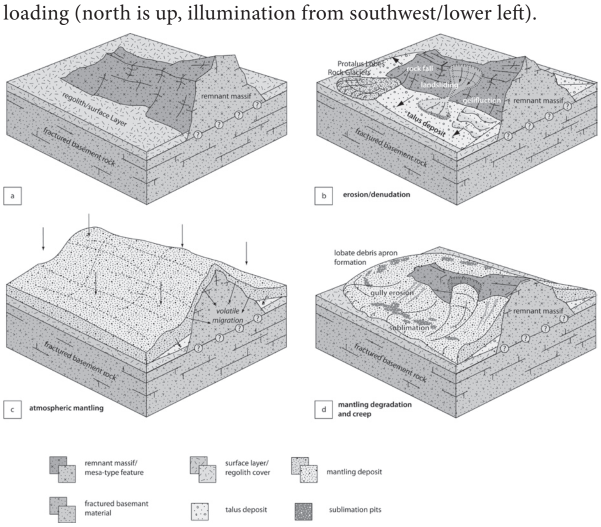

Figure 2. Reconstruction of landscape evolution in Tempe Terra/ Mareotis Fossae. [a] erosional remnant of highland material as initial landform; [b] degradation processes act on remnant surface leading to a smoother relief and a variety of landforms associated with cold–climate landscape degradation; [c] homogeneous deposition of an atmospheric/eolian mantling deposit in geologically recent times; [d] degradation by sublimation and gravitational mass movement and gully erosion.

Our observations in Tempe Terra and research in different regions by other workers have shown that a wide–spread mantling deposit covers vast areas of the northern and southern mid-latitudes [21-24]. Remnants were covered by this eolian/atmospheric deposit and buried underlying topography and traces of earlier evidence of landscape evolution. As sublimation pits beyond the extent of debris aprons show, that mantle covered the Tempe Terra/Mareotis Fossae region homogeneously; as a consequence, estimates on the true relief of remnants is at best speculation as a significant volume is hidden. As a result of the degradation state of individual remnants, the mantling deposit either covered the remnant completely and/or it was remobilized gravitationally by downslope movement and revealed the underlying topography. Apron material moving downslope forms ridges or beads as well as furrows or crevasses as function of compressional and tensional stresses, respectively. The process of mantling re–deposition and gravitational mass movement has advanced until geologically recent times, and even epsiodical events might be conceivable as indicated by our observations. Differential stresses and graviational mass movement, perhaps even by reactivation of underlying periglacial landforms, have ultimately lead to formation of landforms indicative of characteristic cold–climate phenomena, such as rock glaciers, typically known from periglacial environments. Subsequent sublimation, perhaps also initiated at cracks and crevasses, contributed to apron degradation and revealed underlying surfaces [24-25]. This process is thought to have been active until at least 50-100 Myr ago as crater–size frequency distributions indicate. The activity might go on in recent times but the process of apron degradation might be prolonged and slowly paced so that impact–crater deformation is barely visible.

Acknowledgements: Parts of this work is being supported by the Helmholtz-Alliance *Planetary Evolution and Life.*
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