GULLIES AND AVALANCHE SCARS ON MARTIAN DARK DUNES. D. Reiss[1], R. Jaumann[1,2], A. Kereszturi[3,4], A. Sik[3,4] and G. Neukum[2], [1]Institute of Planetary Research, German Aerospace Center (DLR), Rutherfordstr. 2, D-12489 Berlin, Germany, [2]Dept. of Earth Sciences, Inst. of Geosciences, Remote Sensing of the Earth and Planets, Freie Universitaet Berlin, Germany, [3]Institute for Advanced Study, Collegium Budapest, 2 Szentháromság, H-1014 Budapest, Hungary, [4]Department of Physical Geography, Eötvös University, Pázmány 1/c, H-1117 Budapest, Hungary, (dennis.reiss@dlr.de).

Introduction: Gullies on Mars occur on slopes of impact craters, pits, valleys and hills [1]. However, in some cases gullies are cut into dark dune slopes [2, 3]. Other mass movement features on dark dune slopes are avalanche scars [4] which occur on most dune fields beside the gully features. We classified the mass movement features based on their morphology and analyzed them with respect to their distribution, slope angle, orientation and seasonal climatic conditions to constrain the possible formation process causing their different morphologies.

Data and Methods: The analysis is based on a global search of gully features on dark dunes in Mars Orbiter Camera - Narrow Angle (MOC-NA) images. The search encompassed ~55000 images from the aerobraking to the relay mission phase (subphases AB–R02). The analysis of avalanche scars on dunes where gully features were identified have been included. For slope measurements we used single Mars Orbiter Laser Altimeter (MOLA) tracks. Seasonal surface temperatures and pressures were derived from Thermal Emission Spectrometer (TES) data using volumes 1100-1399. All data sets were integrated into a Geographic Information System (GIS) using the IAU 2000 reference ellipsoid using High Resolution Stereo Camera (HRSC) imagery as a base.

Morphologic classification: Based on their morphology we classified the mass movements on dunes into different types. Examples and schematic sketches are shown in Figure 1. It is noteworthy that the schematic sketches are generalized. The morphology of the classified types can slightly vary within the study locations as well as among each other.

Type I. These gully-like features originate in small alcoves at the dune rims, which coalesce into small channel-like tracks showing a dendritic pattern on the steeper upper part of the slope. The small channels merge into sinuous main channels, which have a constant width from the source region to their terminus and show lateral embankments (levees) mainly in the lower part. The main channels occasionally coalesce. The most obvious morphological difference to gullies elsewhere on Mars is the lack of aprons at the termini. Possible reasons might be the incorporation of the eroded material into the levees and/or the homogenous sand material.

Type II: This previously unknown gully morphology on dark dunes is similar to the gullies elsewhere on Mars [1]. Characteristics of this type are V-shaped alcoves, sinuous main channels and depositional aprons. Within the alcove small dendritic channels merge into a single small channel, which is cut into the main channel and occasionally runs out onto the apron.

Type III: These features start in lengthy alcoves which merge directly into straight, deep and short main channels. The depositional aprons are large in areal extent, probably because of the large erosional volume from the alcove and the channel. Evidence of recent activity of this type has been found [5].

Type IV: These features start at the dune rims, occasionally in small alcoves. Straight linear tracks or channels, which are slightly cut into the dune material, run out on the dune slopes, reaching the base of the dune slope rarely.

Results: In total, 11 locations with gullies on dark dunes have been found. All gully locations on dunes occur in the southern hemisphere on Mars. Their latitudinal distribution is – with one exception at 65°S – limited between 46°S and 55°S (Figure 2). Measured parameters are listed in Table 1.

Region	lat [°]	lon [°E]	Type	O	S [°]	min/max. T [K]	max. P [mbar]
Galle	-51.65	328.8	I	S	ND	140/296	8.54
Green	-52.65	352	I	SSE	7.6	142/297	6.35
Kaiser	-46.9	19.5	I	S	8	136/307	5.76
			III	W	8.2		
Proctor	-47.5	30.35	I	SSW	ND	138/306	5.92
			III	W, E	ND		
			IV	W, E	12.8		
Rabe	-44.65	34.5	I	SSW	9.9	148/306	6.77
			II	E	ND		
			III	W	9.5		
			IV	W, N	ND		
Russell	-54.5	12.75	I	SSW	7.9	139/303	6.17
			IV	W	12.9		
UN1	-49.5	34.7	II	S, E	10.7	140/301	6.1
			III	W	ND		
UN2	-47.25	33.9	II	S	10.9	146/303	6.61
UN3	-45.7	36.7	II	S	11.9	145/302	6.57
UN4	-49.6	293.7	I	S	8.1	143/305	6.17
UN5	-64.45	158.5	II	S	12.4	140/293	5.88

Table 1. Derived parameters for the dune mass movement features (O = Orientation; S = Slope angle; T = Temperature; P = Pressure).

Orientations. The orientation of Type I is strongly limited to S-facing slopes (SSW to SSE). Type II occurs in most cases only on S-facing slopes, with the exception of two features in Rabe and UN1 on E-facing slopes. Type III preferentially occurs on W-facing slopes. Only in Proctor some features occur additionally on E-facing slopes. Type IV also occur mainly on W-facing slopes, but in some regions additionally on E- and N-facing slopes.

Slope angles. Measured slope angles of the locations where different types occur show that Type I and III occur on slopes with a lower angle of 7.5°-10°, whereas Type II and IV occur on slopes with an angle of 10°-13°. However, the rare MOLA shots enable these measurements only in a few places. Therefore these results should be taken cautious.

Climatic observations. The triple point of water (273 K and 6.1 mbar) can be exceeded in most study regions around L_S 270°. Minimum temperatures in all regions are at or below the CO_2-frost point around L_S 90°. The deposition of

CO_2-frost on the dark dunes is observable in MOC-imagery aquired during the southern hemisphere winter.

Conclusions: Dendritic patterns of small channels, and sinuous and coalescing main channels indicate the involvement of a fluid transport in the formation of Type I and II. The lack of these morphologic characteristics of Type III and IV indicate that they have been formed by dry mass movements. The differences in the preferred orientation of the mass movement features indicate that climatic-related processes of volatile (H_2O/CO_2) deposition and subsequent melting (H_2O) with debris flows/surface runoff or sublimation (H_2O or CO_2) with destabilizing the slope might cause the mass movements.

Further work will include investigation of high latitude dune fields [6] where no linear mass movements features have been formed to constrain which parameters could support or limit the gully and avalanche scar formation on dark dunes.

References: [1] Malin M. C. and Edgett K. S. (2000) *Science*, *288*, 2330–2335. [2] Reiss D. and Jaumann R. (2003) *GRL, 30,* 1321. [3] Mangold N. et al. (2003) *JGR.*, *108*, 5027. [4] Malin M. C. and Edgett K. S. (2001) JGR, *106*, 23429–23570. [5] http://www.msss.com/mars_images/moc/2005/09/20/dunegullies/ [6] Kereszturi, A. et al. (2007), this issue.

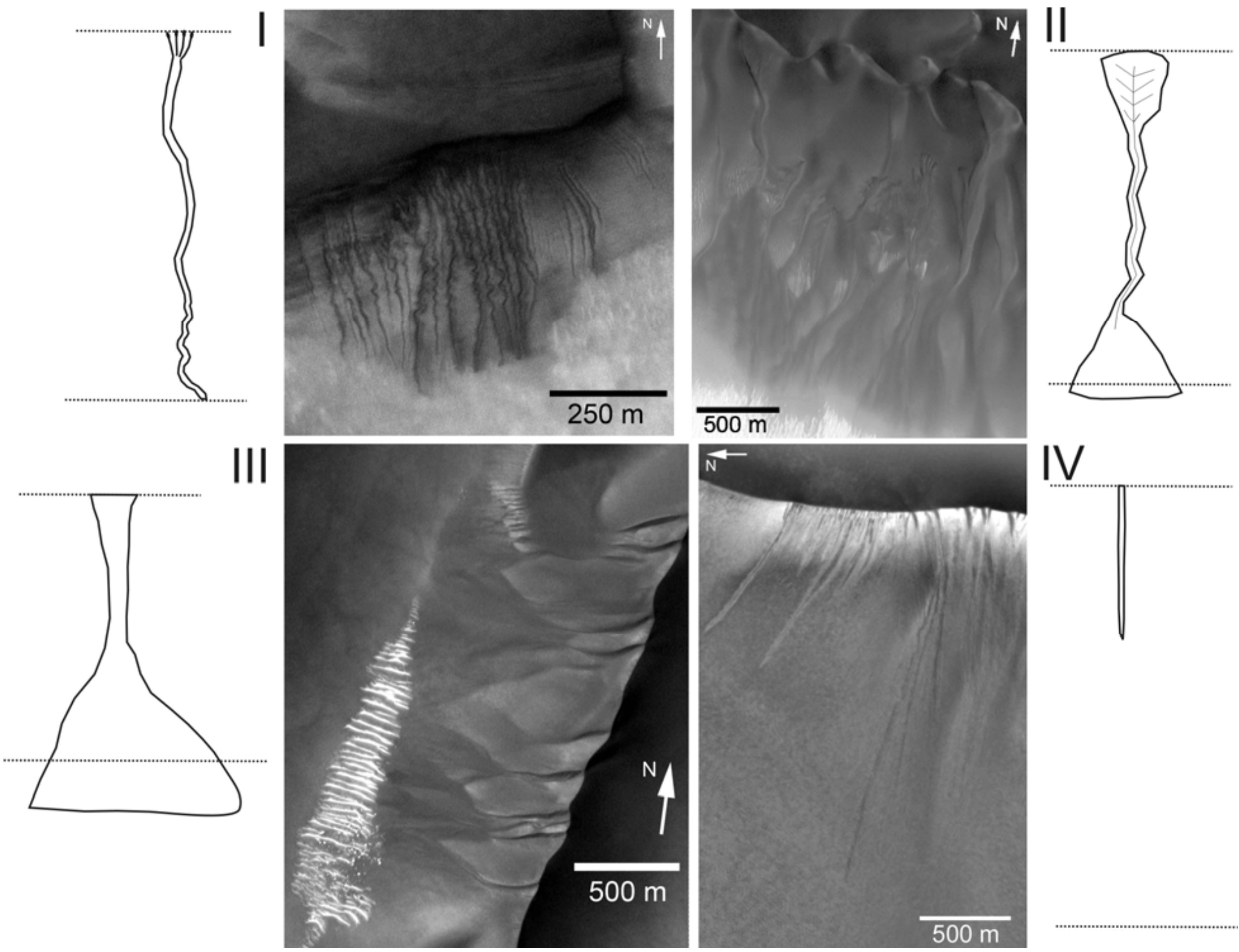

Figure 1. Examples of classified mass movements with schematic sketches. (I) Type I (MOC R1103835, Galle), (II) Type II (MOC E1103091, UN3 Noachis), (III) Type III (MOC M0704545, Kaiser) and (IV) Type IV (MOC E0201493, Russell). Dashed line of sketches indicate the dune crest line and the dune slope base.

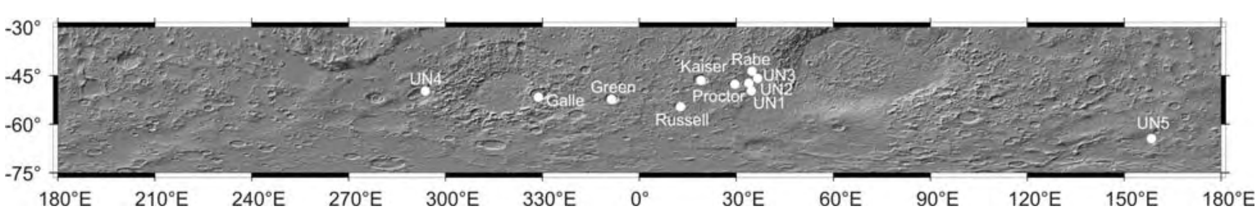

Figure 2. Location of study regions.