MORPHOLOGIC AND MORPHOMETRIC COMPARISION OF GULLIES ON SVALBARD AND MARS. D. Reiss[1], H. Hiesinger[1], E. Hauber[2], M. Zanetti[1], F. Preusker[2], F. Trauthan[2], G.M. Reimann[1], J. Raack[1], F., A.E. Carlsson[3], A. Johnsson[4], M. Olvmo[4], R. Jaumann[2], H.A.B. Johansson[5], L. Johansson[4] and S. McDaniel[5]. [1] Institut für Planetologie, Westfälische Wilhelms-Universität, 48149 Münster, Germany, [2]Institut für Planetenforschung, German Aerospace Center (DLR), 12489 Berlin, Germany, [3]Swedish Institute of Space Physics, Box 812, SE-981 28 Kiruna, Sweden, [4]Earth Science Centre, Göteborg University, Box 460, SE-405 30 Göteborg, Sweden, [5]Stockholm University, AlbaNova University Center, S-10691 Stockholm, Sweden, [6]Reactive Surfaces, Ltd, 300 West Avenue, Austin, Texas 78701, USA (dennis.reiss@uni-muenster.de).

Introduction: The morphology of gullies on Mars indicates that they were formed by the action of water [1]. However, it is not clear what the dominant gully forming process is. On Earth, gullies might have formed by the processes of overland flow or debris flows, or a combination of both [1]. In this work we compare the morphologic and morphometric observations and measurements (slopes, depth-width ratios and sinuosities) of Martian gullies with terrestrial analogs from Svalbard, Norway, in order to constrain the formation process (fluvial and/or debris flow).

Study area: Svalbard is located at 76°-81°N and 10°-35°E, in the continuous zone of permafrost. The present climate of Svalbard is an arctic desert [2]. With low mean annual air temperatures and very low precipitation, mostly as snow, it is potentially a good analog for comparative Martian studies. The study area is located near the capital of Longyearbyen, around the mountain massifs of Adventtoppen and Hiorthfjellet on the northern side of Adventfjorden.

Data and methods: We report on our field work in summer 2008 in Svalbard and a simultaneous flight campaign with an airborne version (HRSC-AX) of the High Resolution Stereo Camera (HRSC) onboard Mars Express [3]. Field measurements were made for gully apron channel and levee dimensions (widths, depths, heights, and local slope), made at vertical increments of 10 m, were combined to make detailed morphometric profiles. These ground measurements were compared with HRSC-AX orthoimages (20 cm/pxl spatial resolution) and corresponding Digital Elevation Models (DEMs) with a spatial resolution of 50 cm/pixel. The results of the field work and analysis of Svalbard images are compared with measurements of Martian gullies using HRSC-DEMs with a spatial resolution of ~50 – 100 m/pxl (used for slope measurements) and High Resolution Imaging Science Experiment (HiRISE) with a spatial resolution of 25 cm/pxl (used for morphology; length and depth were measured using shadows). The morphology and morphometry (slopes, depth-width ratios and sinuosities) of the gullies on Svalbard are compared to those on Mars. A study of fan parameters (e.g., gradients, concavity) on Svalbard and Mars are reported by Hauber et al. (LPSC 2009, this conference).

Morphology: Figure 1 shows an example of a gully system in Svalbard (1a) and on Mars (1b). The overall morphology and dimensions appear very similar. However, closer inspection of channels on the alluvial fans on Svalbard reveal that they are accompanied by lateral deposits (levees) (Fig. 1c) indicating that they are predominantely formed by debris flows. Furthermore, debris tongues are visible on the surface (see also Hauber et al., this conference). In general the texture of the fan surface which is not eroded by channels appears smooth at a spatial resolution of 20 cm/pxl, although the grain size consists of blocky material (mostly between ~10 to ~50 cm). On Mars, channels dissecting alluvial fans are less frequent compared to Svalbard (Fig. 1d). Although, levees on Martian channels can occur [e.g., 4], they seem to occur rarely. The search for levees in 30 HiRISE (25 cm/pxl resolution) images containing gullies revealed no definite levees (e.g., Fig. 1d). Gullies should be visible at this resolution, because they are cleary visible 20 cm/pxl HRSC-AX imagery. The overall fan surface on Mars lacks levees, and is furrowed by several small channels, similar to surface textures on Earth resembling sheetwash and rill erosion.

Morphometry: Preliminary morphometric parameter measurements for gullies on Svalbard and Mars consist of slopes, width-depth ratios and sinusoisty of gullies.

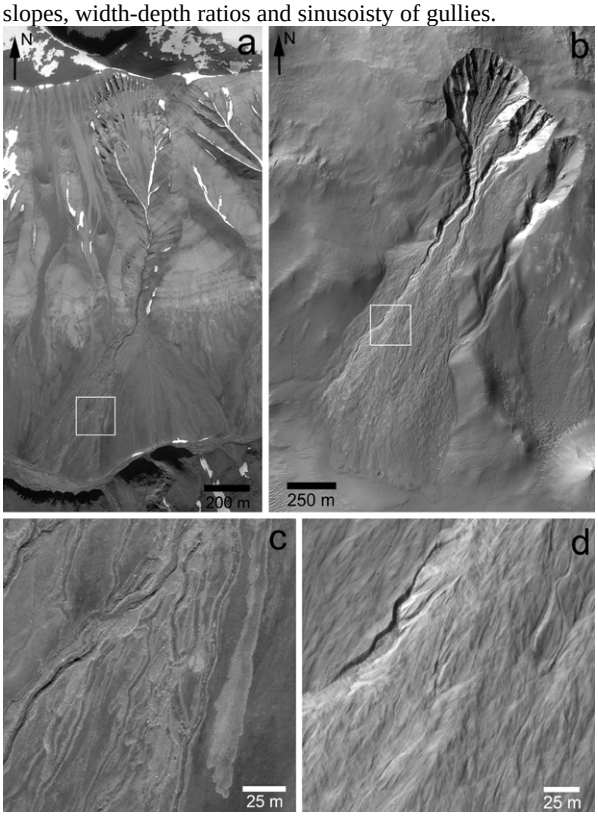

Figure 1. Examples of gullies on Svalbard (a, c; HRSC-AX, 20 cm/pxl) and on Mars (b, d, HiRISE PSP_006888_1410, 25 cm/pxl).

Slopes: Slopes for alcoves and channels were measured on surrounding terrain unaffected by erosion. Slopes were also measured along the center of the gully apron. Table 1 summarizes the median values of the measured gully alcoves, channels and aprons. The in-situ measurements are in good agreement with the measurements from the HRSC-AX DEMs (Table 1). Martian values for alcove and channel slopes are ~10° and ~7.5° lower, respectively. Our measured Martian apron slopes are ~3° higher, than those found on Svalbard, but about 3° lower than Martian values measured by using HiRISE stereo pairs [5]. This discrepancy might be caused by smoothing effects in the lower resolution HRSC-DEM measurements.

	n	S [°] alcove	S [°] channel	S [°] apron
Svalbard, HRSC-AX	14	35.4	25.4	10.8
Svalbard, in situ	9	35.0	28.8	11.8
Mars, HRSC	19	25.3	20.1	14.3

Table 1. Summary of slope measurements.

Depth-width ratio: Figure 2 shows the individual cross-section measurements from Svalbard (green, channels without levees; blue, channels with levees) and Mars (red, channels without levees). The depth-width ratios of channels on Svalbard and Mars are in good agreement, although many measured channels on Mars are much larger than the small gullies measured on Svalbard. The fits show that channel depth is about 1/4 of the width. In Svalbard, no differences between the ratios of channels without levees and channels with levees was observed. The median depth-width ratios of individual gully channel cross-section measurements from our work and Curry [6] and for terrestrial ephemeral gullies from Radoane et al. [7], are summarized in Table 2. On Mars, depth-width ratios are in the same range as our Svalbard values and other terrestrial gullies.

Sinousity: Measurements of gully sinuosity in Svalbard (n=20) range from 1.027 – 1.137 with a median value of 1.047. Similar values were dervided for Martian gullies (n=17), which range from 1.018 to 1.221 with a median value of 1.049.

Discussion: Morphological observations of the gullies on Svalbard suggest that debris flow processes play a significant role in their formation, although fluvial processes after snowmelt or rainfall contribute to their formation. On Mars, such clear evidence for debris flow processes were not be observed in high resolution imagery. Morphometric parameters for gullies on Svalbard and on Mars are similar. Differences in slopes might be due to differences in lithology or because on Mars most gullies occur at craters with specific wall slopes. All width-depth ratios are similar. However, the same range of values were measured for terrestrial gullies formed by fluvial processes [6, 7]. As noted by [8] it can not be determined from cross-sectional morphology whether

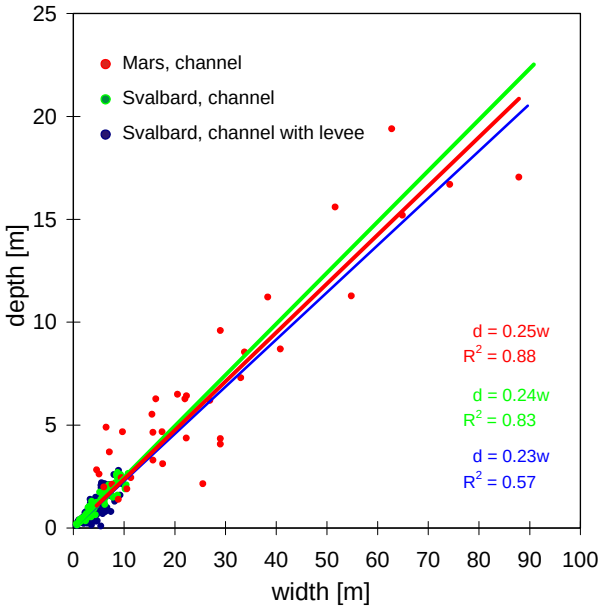

Figure 2. Depth and width measurements from individual cross-sections measurements on Svalbard (green, blue) and Mars (red). Note that the fits of the Svalbard measurements are extrapolated for better visibility.

	N	d/W median	d/W median min	d/W median max
Svalbard, in situ channel with levee	11	0.22	0.17	0.34
Svalbard, in situ channel	9	0.26	0.22	0.29
Mars, HiRISE channel	16	0.20	0.05	0.62
Earth[1], avg. gully channels	6	0.23	0.18	0.68
Earth[2], avg. ephemeral gullies	12	0.27	0.13	0.42

Table 2. Summary of median depth-witdth ratios of individual gullies. [1]data from [6], [2]data from [7].

channels were eroded by fluvial or debris flow processes, as debris flow channels are often subsequently incised by fluvial processes.

Conclusions: We conclude that morphometric parameters alone can not be used to distinguish between gullies formed by fluvial or debris flow processes. Morphologically, gullies on Mars and Svalbard appear similar, and continued detailed investigations should be done to establish methods of determining debris or fluvially dominated processes.

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