POSSIBLE FREEZE-AND-THAW LANDFORMS ON HIGH LATITUDE SLOPES ON MARS: INSIGHTS FROM TERRESTRIAL ANALOGS IN SPITSBERGEN, SVALBARD. A. Johnsson[1], D. Reiss[2], E. Hauber[3], L. Johansson[1], M. Zanetti[4], H. Hiesinger[2], M.R. Ulrich[5], M. Olvmo[1], E. Carlsson[6], R. Jaumann[3], F. Trauthan[3], F. Preusker[3], and H.A.B. Johansson[7]. [1]Dept. of Earth Sciences, University of Gothenburg, Box 460, Göteborg, Sweden (andreasj@gvc.gu.se), [2]Institut für Planetologie, Westfälische Wilhelms-Universität, 48149 Münster, Germany, [3]Institut für Planetenforschung, German Aerospace Center, 12489 Berlin, Germany, [4]Dept. of Earth and Planetary Sciences, Washington University in St. Louis, USA, [5]Alfred Wegener Institute, 14473 Potsdam, Germany, [6]Swedish Institute of Space Physics, SE-98128 Kiruna, Sweden, [7]Stockholm University, SE-10691 Stockholm, Sweden.

Introduction: Solifluction lobes are common slope features in polar regions on Earth where freeze and thaw processes occur [1]. Mars is currently a cold and barren planet with its water resources locked up in ice caps, glaciers and ice-enriched permafrost. However, features resembling solifluction lobes have been observed on high-latitude slopes on Mars and in most, but not all, cases in close proximity to gullies [2, 3]. Lobes are found on steep inner crater walls and in planform they show striking resemblence to terrestrial solifluction lobes. These observations may point to a late phase in Mars history with transient melt water in local environments. In our study we have examined solifluction lobes on slopes in Svalbard (Fig. 1) in order to compare to the Martian lobate landforms. Specific questions we address are: how widely distributed are these lobate landforms on Mars and how do they relate to known ground-ice related landforms?

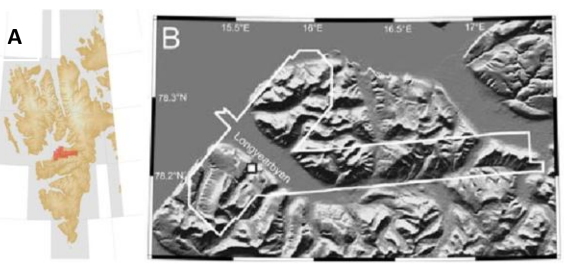

Figure 1. (a) The archipelago of Svalbard and location of study area (red). (b) Shaded relief of Hjorthamn and Adventdalen with HRSX-AX coverage outlined in white.

Data and method: The analysis on Svalbard is based on high resolution imagery with the High Resolution Stereo Camera - AX (HRSC-AX) (Fig 2) [4], which is an airborne counterpart to the HRSC aboard the Mars Express orbiter. For comparison we use satellite imagery obtained by the High Resolution Imaging Science Experiment (HiRISE) which has a similar resolution of 25 cm/pxl. By doing so we avoid the problem of comparing landforms of different scales [5]. Image analysis is complemented by field work for ground truth. This method has proven to be useful in previous investigations [6 - 8].

Svalbard: The arctic archipelago of lies well within the continuous permafrost zone and in the landscape a range of landforms with ground ice and active-layer affinity are seen. In Svalbard solifluction is the dominant form of slow mass wasting [9]. It depends on thaw of the active layer and snowmelt in summer which results in saturation and movement of the upper surface layer.

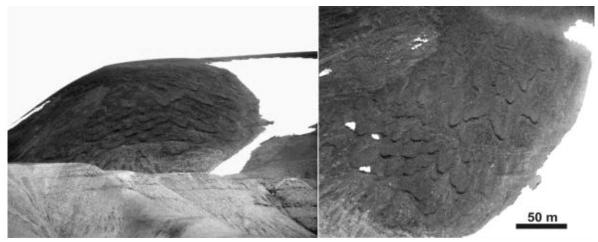

Figure 2. (Left image) Field view of solifluction lobes in Louisdalen, Svalbard. (Right image) Same site as seen by the HRSC-AX.

The present climate of Svalbard is arctic, with a mean annual air temperature ranging between about –6°C at sea level and –15°C in the high mountains. Near the study site in Adventdalen lays the capital Longyearbyen, the coldest (February) and warmest (July) months have mean temperatures of –15.2°C and 6.2°C, respectively. The mean annual air temperature is –5.8°C (average 1975-2000), but can be as low as -15° in mountain areas. Precipitation is low and reaches only ~180 mm in central Spitsbergen [10]. The central part of Spitsbergen can therefore be considered to be a polar (semi-) desert, which is defined as an area with annual precipitation less than 250 millimeters and a mean temperature during the warmest month of less than 10°C [11].

Observations: For our study we have catalogued the presence of lobate forms in all available HiRISE images between 50° N and 80° N. For comparison to Svalbard we have chosen two impact craters which display particularly well-defined lobate forms. Examples of solifluction lobes found on Svalbard and on Mars are shown in Figure 3 and 4. The overall morphology of lobate landforms on Mars and Svalbard appear very similar. The martian lobate features occur as two distinct types classed as non-sorted (Fig. 3) and sorted lobes (Fig. 4), depending on the presence of clasts along the lobe front.

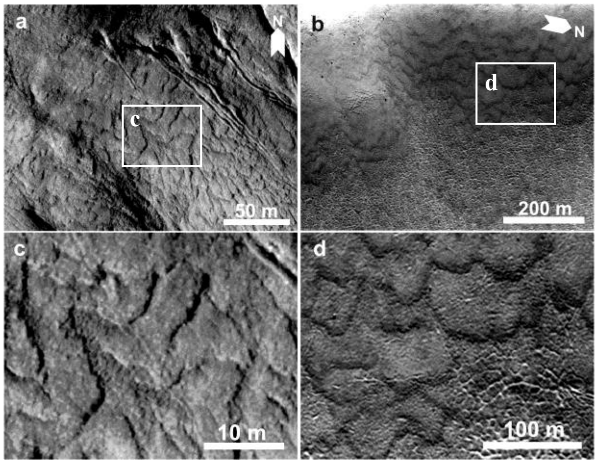

Figure 3. (a) HRSC-AX of non-sorted solifluction lobes in Svalbard. Note the close proximity to gullies. (b) Non-sorted lobes with overlapping lobe fronts on Mars. (c) Detailed view showing non-sorted lobes. (d) Close up of non-sorted lobes on Mars.

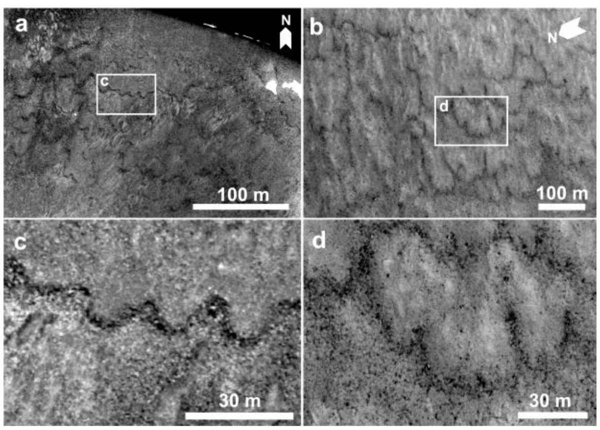

Figure 4. a) HRSC-AX overview of sorted lobes on upper portion of Advent Valley, Svalbard. (b) HiRISE image of sorted lobes on interior crater wall, Mars. (c) Detailed view of clasts forming arcuate bands along valley wall in Adventdalen. (d) Close up of sorted lobes on Mars with clasts decimeters in size.

Non-sorted lobes preferentially develop on slopes of homogenous sediments. Starting at the crater rim they form bulging arcuate lobes with overlapping lobe fronts. As well as the surrounding surface the lobe treads show a high degree of fracturing. Fracturing could be due to either thermal contraction of ice-enriched permafrost or desiccation. Sorted lobes occur on slopes with a high abundance clasts. However, where lobes have modified the slopes clasts are concentrated to lobe fronts leaving the treads relatively clast free. Both sorted and non-sorted lobes are in close proximity to gullies and patterend ground, such as polygonal and stripe-like patterns.

Discussion: The occurrence of lobate landforms on Mars raise the question if they are a result of thawing of an ice-enriched permafrost and/or snowmelt. The presence of a moist active layer requires the surface layers ice content to be recharged as ice is continuously lost by the progressive desiccation of the ground. However, seasonal thaw may have existed in local environments such as the interior of craters or on hillslopes. In recent models crater floors or poleward facing slopes have been identified as specific locations for water ice stability and deposition of ice. [12] proposed a model which state that liquid water in the ground could be stable for enough time before being sublimated. In this case the winter CO_2 frost may protect ground ice from sublimation before thawing [13]. Gallagher (2010) argue that the presence of perchlorates could act as an suppressor of the freezing point of water. In this scenario the lobes could be much younger than 5 Ma [14]. A plausible mechanism for recharge is top-down melting of snow packs [15], which could be a viable mechanism to supply moisture for freeze and thaw cycles. In this case the lobes are possibly linked to the formation of gullies since both landforms are favored by similar conditions. The presence of lobes on Mars may be an indicator of a freeze/thaw process which in turn has implications for our understanding of near surface water dynamics and local climate. However, further work is needed to constrain the processes and timing of formation.

Acknowledgements: This project was supported by the Swedish National Space Board and the Swedish Polar Research Secretariat. Thanks to the Norwegian Polar Institute for great logistics and service.

References: [1] Washburn A. L. (1956) *Geol. Soc. Am. Bull, 67,* 823–865. [2] Mangold N. (2005) *Icarus, 176*, 336-359. [3] Gallagher C. et al. (2010) *Icarus, doi:10.1016/j.icarus.2010.09.010*. [4] Neukum G. et al. (2001) *Photogrammetric Week '01, p. 117-131.* [5] Slaymaker O. (2009*) Geography Compass 3/1, 329-349.* [6] Reiss D. et al. (in review) Geol. Soc. Am.-special papers. [7] Hauber E. et al. (accepted) Geol. Soc. Am.-special papers [8] Hauber E. et al. (accepted) Geol. Soc. Lon. [9] Åkerman H.J. (1984) *Geografiska Annaler, v. 66A, p. 267-284.* [10] Hanssen-Bauer and Førland (1998) *Climate Res., v. 10, p. 143–153.* [11] Walker, A.S. (1997) *USGS Online Book. http://pubs.usgs. gov/gip/deserts/.* [12] Hecht M. H. (2002) *Icarus,156, 373-386.* [13] Costard et al., (2002) *Science, 295, 110-113.*[14] Kreslavsky M. et al. (2008) *EPSL, 56, 289-302.* [15] Christensen P. R. (2003) *Nature, 422, 45-48.*