MORPHOMETRY OF ALLUVIAL FANS IN A POLAR DESERT (SVALBARD, NORWAY): IMPLICATIONS FOR INTERPRETING MARTIAN FANS. E. Hauber[1], F. Preusker[1], F. Trauthan[1], D. Reiss[2],
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Introduction: Alluvial fan-like landforms have been identified on Mars [e.g., 1-3]. Since alluvial fans are recorders of processes that are sensitive to climatic conditions [e.g., 4], the investigation of possible Martian fans can reveal information about the planet`s climate. In lieu of direct observations of active depositional processes on Martian fans, comparisons with terrestrial analogues can constrain models of Martian fan formation derived from remote sensing data. Since present-day Mars is cold and dry, alluvial fans formed in cold deserts should be considered as useful analogues. The probably closest climatic analogue to Mars on Earth are the Antarctic Dry Valleys [5], but polar deserts can also be found in the Arctic. We report on our field work in summer 2008 and a simultaneous flight campaign with an airborne version (HRSC-AX) of the High Resolution Stereo Camera (HRSC) onboard Mars Express [6]. The results are compared with measurements of Martian fans, based on HRSC DEM.

Study Area: Our study area is in Svalbard near Longyearbyen (78°13'0"N, 15°38'0"E), around mountains of Mesozoic layered sandstones and shales) on the northern side of Adventfjorden. Climate data are available from the nearby Longyearbyen airport (just a few km from the study area). The present climate is arctic [7], with low mean annual air temperatures and very low precipitation, mostly as snow (Tab. 1). Svalbard is in the zone of continuous permafrost.

Table 1. Annual mean temperature and precipitation (1912-1993).

Temperature at Longyearbyen airport [°C] [7]			
Mean	*SD*	*Min.*	*Max.*
–6.3	1.7	–12.2	–3.1
Precipitation at Longyearbyen airport [mm] [7]			
Mean	*SD*	*Min.*	*Max.*
180.7	49.8	86.4	317.0

Data and Methods: Stereo images acquired in July 2008 (at the end of the snow melting season) were processed to orthoimages with a spatial resolution of 20 cm/pixel, and corresponding Digital Elevation Models (DEM) with a grid spacing of 50 cm/pixel (Fig. 1). Simultaneous field measurements focused on channels and levees (widths, depths, heights), which were determined at vertical increments of 10 m, together with the local slope. The results of these measurements are reported elsewhere [Reiss et al., this conference]. Here we report on our preliminary analysis of fan parameters (gradients, concavity) on Svalbard, and compare them to Mars (Holden and Mojave craters).

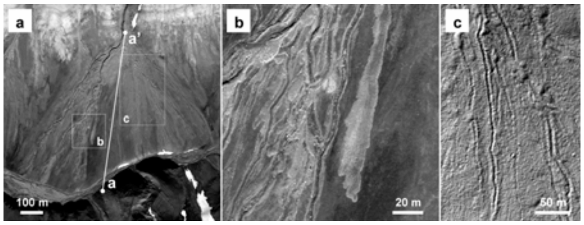

Figure 1. Examples of Svalbard fans (HRSC-AX). **(a)** Alluvial fan with active part on the left (see Fig. 3 for profile a-a'). **(b)** Leveed channels (left) and debris tongue (middle right). **(c)** Shaded HRSC-AX DEM, resolving the levees of channels.

Observations of Svalbard fans: Alluvial fans in the study area are present on slopes of all orientations. They typically coalesce into bajadas (Fig. 2a).

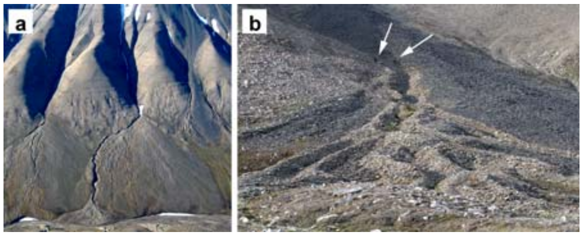

Figure 2. Field photos of alluvial fans in Svalbard. **(a)** Coalescing fans forming a bajada in Hannaskogdalen. Fans are sparsely vegetated (moss, lichens) and are characterized by many channels and debris tongues. **(b)** Channels with well-developed levees are abundant on the fans (arrows point to persons for scale).

Morphology. Basically all alluvial fans in the study area are characterized by sinuous channels (Fig. 1c), many of which display well-developed lateral levees (Fig. 2b), and debris tongues (Fig. 1b). Boulder-sized (>1 m) rocks are present, but rare. Where a vertical section of the fan can be observed (typically at the toe, where braided rivers cut the fans), it appears poorly sorted. Following the reasoning of, e.g., [8,9], we conclude that the fans in our study area are heavily affected by debris flows, but the presence of channels clearly indicates that fluvial processes were also important. The complex interplay between fluvial incision and debris flows on alluvial fans is well known also from fans in different climatic environments [e.g., 10].

Gradients and Concavity. Topographic profiles along 55 fans were measured in HRSC-AX DEM. Fan length ranges between 80 m and ~800 m, with heights between 9 and ~140 m (from apex to toe). The profiles of the Svalbard fans can be approximated very well with a power law function of the form $y_{(x)} = y_{(0)} + ax^b$ (Fig. 3). Overall gradients vary between 0.11 and 0.43, with a peak at 0.18-0.2 (Fig. 4a). Several measures have been suggested to quantify the concavity of river and fan profiles [e.g., 1, 11]. We use a simple method (explained in Fig. 3), which was suggested by Langbein [12] and is still widely used [e.g., 9, 13,14]. The Langbein-concavity of the fan profiles shows a continous range between ~0 and 0.53 (Fig. 4b).

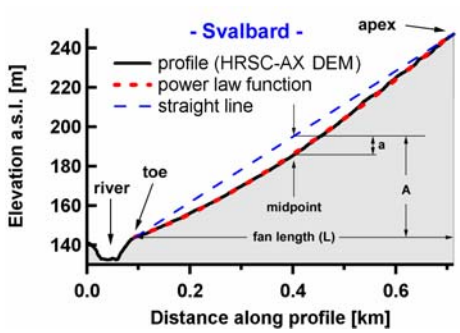

Figure 3. Profile along Svalbard fan shown in Fig. 1a. Note the close fit of a power law (red) to the real topography. Concavity (after [12]) is the ratio a/A, measured at L/2 from the toe (see Fig. 4b).

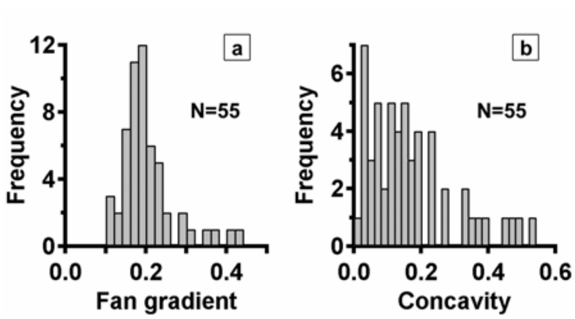

Figure 4. Histograms of fan (a) gradients and (b) concavities [12].

Preliminary observations of Martian fans: The topography of Martian fanlike features [2,3] is studied on the basis of DEM derived from HRSC stereo data [15,16], with a grid spacing of 50-100 m. An example of a profile along a Martian fan in Holden crater (Fig. 5) exhibits a Langbein-concavity of 0.194 and a gradient of 0.069. While the concavity falls in the range observed on Svalbard, the gradient is less (cf. Fig. 4). Another major difference is the fan dimension, with the fan in Holden Crater being much larger (note that the fan of Fig. 5 corresponds to only a portion of the fan H1 of [1]). We also produced a HRSC DEM of Mojave Crater on Mars, which displays a number of fans with dimensions similar to those on Svalbard [3].

Discussion: Alluvial fans form by one or a combination of the following mechanisms: avulsing channelized rivers, sheet flows, and debris flows [17]. Previous studies comparing Martian and terrestrial fans have examined the usefulness of the concavity of along-fan profiles to discriminate between fluvially-dominated fans (concave-upward profiles) and debris-flow dominated fans (~linear profiles) [1,2]. Morphological observations suggest that Svalbard fans are heavily affected by debris flows. However, their profiles show a continuum between more or less linear profiles and distinct concave-upward profiles, independent of orientation (which possibly controls snow accumulation and melting, and therefore depositional processes). We conclude that morphometric measures alone do not enable an unambiguous interpretation of processes acting on alluvial fans. Instead, complementary morphologic studies using high-resolution images seem to be required to discriminate between debris flows and fluvial activity on Mars, e.g., can we identify levees or debris tongues in HiRISE images? Their resolution is ~30 cm/px and should enable it. Even then, quantifiying the respective role of different depositional processes might be hard to achieve.

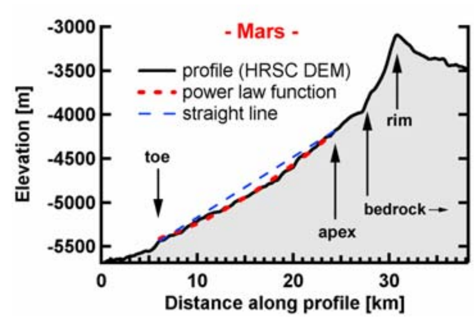

Figure 5. Profile across fan in Holden Crater, Mars, measured in HRSC DEM. Overall gradient is 0.069, concavity [12] is 0.194.

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