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Svalbard (Norway) as a terrestrial analogue for Martian landforms: Results on alluvial fans

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Abstract

Small alluvial fan-like landforms have been observed on Mars in association with recent gullies. Such fans are relatively small (km-scale) when compared to large alluvial fans on Mars [1], which can reach dimensions of tens of kilometers. The small fans are part of an erosion-transport-sedimentation system (alcove-channel-apron, after [2]). Morphologically very similar systems can be studied on Svalbard (Norway), which is a cold and dry polar desert and, therefore, a potentially useful terrestrial analogue for Mars` climate and climate-related landforms. Here we give an update 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 [3]. We also present very preliminary results from the field campaign in summer 2009.

Field sites and data

Svalbard is located in the Arctic Ocean, about midway between Norway and the North Pole. Field work in 2008 was located near the capital of Longyearbyen at the mountain massifs of Adventtoppen and Hiorthfjellet (Mesozoic layered sandstones and shales) on the northern side of Adventfjorden. Field work in 2009 is planned on the Brøgger peninsula and in inner Adventdalen. All field sites are covered with airborne HRSC-AX stereo and colour images (20 cm/pixel) and derived Digital Elevation Models (DEM; grid size of 50 cm). Fans on Mars are investigated on the basis of HiRISE images (25-30 cm/pixel) and HRSC DEM (grid size 50-100m).

Results of fans in Svalbard

Basically all alluvial fans in the study area are characterized by straight and/or sinuous channels, many of which display well-developed lateral levees. Plugs are visible in many channels, and flow lobes (debris tongues) are frequent. Boulder-sized (>1 m) rocks are present, but rare. Topographic profiles along 55 fans were measured in HRSC-AX DEM. The length of fans 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 $f_{(x)} = y_0 + Ax^{pow}$. Overall gradients vary between 0.11 and 0.43, with a peak at 0.18-0.2. The concavity of the fan profiles (after [4]) shows a continous range between ~0 and 0.53, with most fans having low concavities (<0.2). Based on the combination of these observations, we conclude that fan activity at the studied field sites is dominated by debris flows. Our field observations and the climatic environment of Svalbard, with the majority of precipitation occurring as snow, leads us to propose the following model for debris flow origin: Snow melt in spring releases liquid water from the snow pack on top of unconsolidated debris or talus slopes on the base of mountains. Under "normal" conditions, this liquid water infiltrates the permeable ground until it reaches the permafrost table, where further infiltration is stopped and the water flows downhill (under a debris mantled slope, but on top of the permafrost table). Extreme weather events like occasional heavy rain can enhance the melt water production, and the pore space of the debris slopes becomes water-saturated.

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This tends to reduce the shear strength of the material, and a slope failure can result (e.g., triggered by rock fall), producing a debris flow. We did not observe evidence that the release of groundwater (in aquifers) contributes to gully and fan formation.

Comparison to Mars

Many characteristics of Martian gullies and fans are very similar to gullies and fans in Svalbard. These include the overall morphology and dimensions, slopes in alcoves, channels, and fans, and the spatial association with periglacial landforms such as polygons and patterned ground. We also observe (debris flow) plugs and unambiguous evidence for rockfall. Based on the striking analogy, we consider it possible that gullies and fans on Mars are formed by similar processes as on Svalbard, i.e. by the rapid melting of a snowpack and the resulting failure of a water-saturated debris slope. It remains to be analysed which climatic conditions on Mars are required to enable such events (e.g., precipitation of significant ice in mid-latitudes as a result of obliquity changes or variations in Mars` orbital parameters such as eccentricity [e.g., 5,6]).

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