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Cold-climate landforms on Mars and Earth-analogues in Svalbard

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Abstract

Periglacial landforms on Earth reflect cold-climate conditions and are intimately related to processes due to the presence of ground ice and perennially frozen ground, permafrost. The overall objective of this thesis is to investigate the potential of Svalbard as an analogue to Mars cold-climate landforms, and explore past and present processes and surface conditions on Mars by inference from morphological counterparts in Svalbard. Svalbard has unique advantages that make it a very useful study area. Svalbard is easily accessible and offers a periglacial landscape where many different landforms can be encountered in close spatial proximity. These landforms include thermal contraction cracks, slope stripes, rock glaciers, gullies, debris flows, solifluction lobes, protalus ramparts, and pingos, all of which are close morphological analogues to landforms on Mars.

An approach of integrated landscape analysis, inferred from landform assemblages in Svalbard, is aimed to explore modeling landscape evolution on Mars. Key datasets include visual remote sensing data of similar resolution (20–25 cm/pxl) from Svalbard (High Resolution Stereo Camera–Airborne Extended [HRSC-AX]) and Mars (High Resolution Imaging Science Experiment [HiRISE]). Additional data are digital elevation models over both Svalbard and Mars and remote sensing data from Mars, such as Thermal Emission Imaging System (THEMIS) and Context Camera (CTX) images. Field work was done in combination with remote sensing to acquire ground-truth data.

In Svalbard, fluvial and debris-flow processes are evident in the formation of gullies, but the morphological characteristics clearly show that the transport and sedimentation of eroded material are predominated by debris flows. Most investigated gullies on Mars lack clear evidence for debris-flow processes. The Martian gully fan morphology is more consistent with the deposition of small overlapping fans by multiple fluvial flow events. Clear evidence for debris flows on Mars was only found in two new locations, in addition to a few previously published examples. Detailed studies on debris-flow deposits in a young mid-latitude crater on Mars suggest the action of liquid water after Mars' last ice age (0.4–2.1 Ma ago). It may represent the most recent morphological indication of water induced mass wasting on Mars.

An investigation of small-scale lobes on Mars northern high-latitudes and their morphological counterparts in Svalbard (solifluction lobes) further suggests widespread thawing and the presence of transient liquid water in the recent past on Mars. Finally, different qualitative scenarios of landscape evolution on Mars to better understand the action of periglacial processes on Mars in the recent past are proposed.

The results show that field work is a suitable approach in analogue studies and facilitates acquisition of first-hand experience with permafrost environments. Based on the morphological ambiguity of certain landforms, it is concluded that Martian cold-climate landforms should not be investigated in isolation, but as part of a landscape system in a geological and spatial context. Analogous landforms in Svalbard occur in strikingly similar proximity as on Mars, which makes them useful to infer the spatial and chronological evolution of Martian cold-climate surface processes. The analysis of the morphological inventory of analogous landforms and landform systems in Svalbard and on Mars give substantial information to constrain the processes operating on the surface of Mars

Keywords: Mars, Svalbard, Spitsbergen, periglacial, ice, permafrost, Earth-analogues, terrestrial analogues, geomorphology, landforms, solifluction, debris flow, gully, craters, cold-climate