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Reconstructing the recent climate of Mars: What can we learn from periglacial terrestrial analogues?

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Many very young landforms on Mars resemble terrestrial glacial and periglacial surface features in permafrost regions and show a latitude-dependent geographic distribution. They include surface mantling, viscous flow features, polygonally fractured ground, patterned ground, fractured mounds, and gullies. Collectively, these landforms are hypothesized to represent the geomorphological surface record of Martian ice ages that were triggered by astronomical forcing and associated climate changes.

We use the permafrost landscape of Spitsbergen (Svalbard, Norway) as an analogue to the assemblage of cold-climate landforms that is typically found in mid-latitudes on Mars. Although relatively warm and wet as compared to other cold-climate analogues on Earth, Spitsbergen is a particularly instructive morphological analogue to Mars as it offers many surface features in a close spatial context that are strikingly similar to those on Mars. Based on this comparison, which uses remote sensing and field data from Svalbard, we identify similarities as well as differences, both of which are important in the use of analogues as a means to establish testable hypotheses. We then propose possible scenarios which may help to understand the evolution of Martian landforms into their present state. Of particular interest with respect to the habitability of Martian permafrost is whether liquid water was involved or not.

Most phenomena on Mars, but not Svalbard, can plausibly be explained by “dry” permafrost scenarios without the need to invoke freeze/thaw. Examples of such processes are the slow creep of ice-debris mixtures in permafrost, such as debris-covered glaciers, ice-cored moraines, rock glaciers or protalus ramparts. Dry scenarios can also be consistent with a significant role of snow or firn. The reduced gravity on the Martian surface implies that significantly thicker snowpacks are required to transform firn into glacier ice, hence thick perennial snowpacks and related nivation phenomena are expected to be geomorphically more important than on Earth. In combination with wind-transported dust, this will also lead to a relatively greater importance of niveo-aeolian processes.

Other landforms could be explained with and without the availability of liquid water. Examples are thermal contraction polygons, which could form as ice-wedge polygons indicating thaw and liquid water, or, alternatively, as sublimation polygons. Former glaciers could have either been warm-based or cold-based, and therefore do not provide constraints on the history of liquid water. Some landforms such as gullies, however, seem to definitely require at least transient liquid water sometimes in the last $\sim$10 Ma. We conclude that liquid water is unlikely to have a significant effect in the last few million years, but could have been more important before $\sim$5 Ma, when specific conditions (the obliquity of the rotational axis, the orbital eccentricity, and the season of perihelion) combined to generate a more favourable climate than today.