

Veiki-moraine-like landforms on Mars: Insights from analogues in northern Sweden.

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1. Introduction: Mars is a cold hyper-arid planet where liquid water is extremely rare [1]. Most water is instead locked in a number of frozen reservoirs such as the polar caps, latitude-dependent near surface ground ice and as glacier ice. Previously, numerous studies reported on glacier landforms such as viscous flow features and lobate debris aprons where water-ice is believed to be present under insulating debris cover [2]. This notion was confirmed by SHARAD measurements [3]. However, very little is known about glacial landforms in which water is an important factor. Most studies have focused on moraine-like ridges that are associated to gully systems in crater environments [4], glacier landforms at the equatorial volcanic province [5] and drop-moraines from CO₂ glaciers [6]. Here we report on unusual irregular ring-shaped landforms within a mountain complex in Nereidum Montes, Mars. These landforms are well-preserved and may suggest recent ablation of a debris-covered, cold-based glacier. These martian ring-shaped moraine-like landforms show a striking resemblance to the Veiki moraine in northern Sweden. Veiki moraines are believed to have formed at the lobate margins of a stagnant ice-sheet during the first Weichselian glaciation [7]. The Veiki moraine is characterized by ridged plateaus that are more or less circular and surrounded by a rim ridge. The moraine complex sharply ends to the east. The newly acquired national LiDAR data over Sweden enable us studying these landforms in unprecedented detail. They also allow us exploring geomorphological similarities between Earth and Mars in large spatial contexts. This study aims to increase our understanding of glacial landforms on Mars by comparison to terrestrial analogues. Questions addressed are: (1) how morphological similar are the martian landforms to the Veiki moraine of Sweden? (2) Do the moraine-like landforms indicate the maximum extent of former ice sheets also on Mars? (3) Was any meltwater involved?

2. Data and Methods: For our study we use HiRISE (25 cm/pxl), CTX (6 m/pxl), MOLA topography and point data. CTX images have been processed using ISIS 3.0. The terrestrial analogues are covered by LiDAR. The LiDAR data have a point density between 0.5 to 1.0 points/m², with a footprint of 0.5 m and a scan angle of 20°. Accuracy of the z-axis is typically better than 0.1 m on flat surfaces. Field work is planned for 2017 and an forthcoming HiRISE DTM will allow for more detailed analysis of the martian landforms.

3. Observations: The martian moraine-like landforms (MLL's) are located at the end of a valley that are open in the eastward direction. In plan form the overall morphology has a distinct lobe shape (Fig. 1 A) and covers an area of approximately 80 km². Individual MLL's form irregular opened and enclosed ridges (Fig. 1B). By shadow measurements ridges are calculated to be 10-15 m in height. Ridges show a high concentration of boulders and clasts (Fig. 1 C). The outer lobe perimeter is mainly made up of fractured mounds. The Veiki moraines in northern Sweden show a similar irregularity of landforms forming ridged plateaus and enclosed depressions (Fig. 1D).

4. Discussion: The MLL's are located in close spatial proximity to other landforms similar in morphology to pronival rampart glaciers and cirque glaciers. The topography around the MLL's shows features that show similarities to roche moutonnées, bergschrunds (crevasses at the head of a glacier), arêtes, cols (saddle-like narrow depression formed by two head ward eroding cirques that reduce an arête) and cirques. If these interpretations are correct it shows an area with clear evidence of possibly current and former presence of glacier ice.

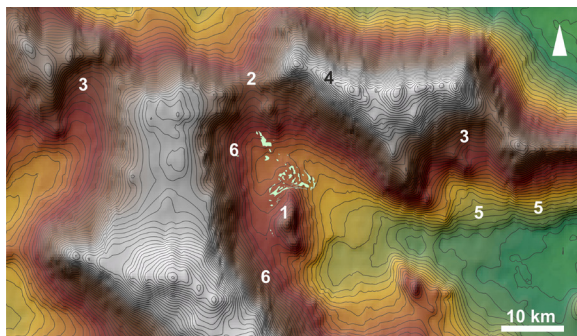


Figure 2: MOLA topographic map with 100 m contour lines and locations of possible glacial morphologies. Area located at the western part of Nereidum Montes. MLL's outlined in green dots (center). 1) Roche moutonnées. 2) Col. 3) Cirques. 4) Arête. 5) Pronival rampart. 6) Bergschrunds.

The floor of the valley, adjacent to the MLL's shows a number of exhumed impact craters which probably represent the pre-glacial surface. The very few fresh looking impact craters may point to a relatively young surface age post-glacial recession.

5. Summary: We have identified an area in the Nereidum Montes region that shows clear evidence

of glaciation, including possibly preserved glacier ice and glacial landforms. This include landforms strikingly similar to the Veiki moraines of northern Sweden. A better understanding of these features may provide important insight into martian geologic and climatic history. This project is on-going and more work is needed to gain a better understanding of the sequential evolution of glacial landforms in this area.

Acknowledgements: This project has been financially supported by the Swedish National Space Board.

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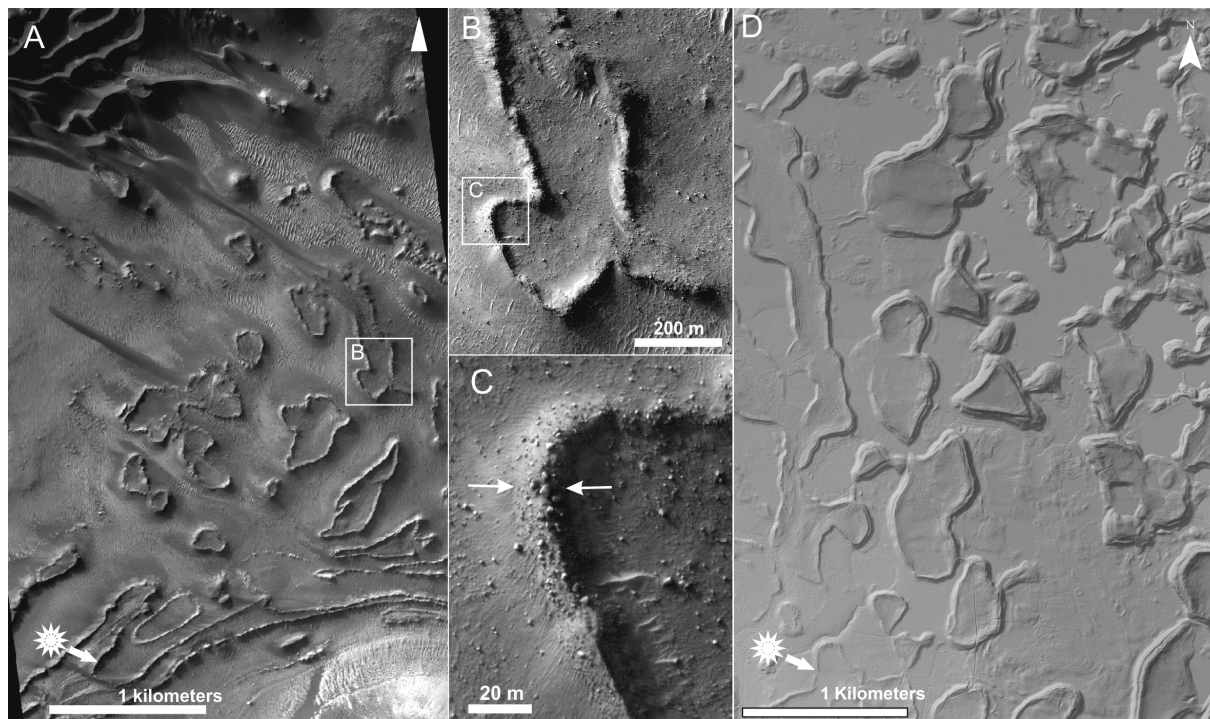


Figure 1. A) HiRISE image of multiple irregular MLL's forming a lobate pattern. B) Ridges form enclosed depressions with heights between 10-15 m. C) High clast concentrations at the ridges. D) LiDAR image of possible terrestrial analogues, called 'Veiki moraine' from northern Sweden.