Veiki-moraine-like Landforms in the Nereidum Montes Region on Mars: Insights from Analogues in Northern Sweden. A. Johnsson[1], D. Reiss[2], E. Hauber[3], M.D. Johnson[1], M. Olvmo[1], H. Hiesinger[2]. [1]Department of Earth Sciences, University of Gothenburg, Gothenburg, Sweden (andreasj@gvc.gu.se). [2]Institut für Planetologie, Westfälische Wilhelms-Universität, Münster, Germany. [3]Institut für Planetenforschung, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Berlin, Germany

Introduction: Mars is a cold hyper-arid planet where liquid water is extremely rare [1]. Most water is instead found in a number of frozen reservoirs such as the polar caps, 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 CO_2 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 glacier. These martian ring-shaped 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]. As it sharply ends to the east it may represent the maximum extent of this former ice sheet (Fig. 1A). The Veiki moraine is characterized by ridged plateaus that are more or less circular and surrounded by a rim ridge (Fig. 1B). The newly acquired national LiDAR data over Sweden enable us studying these landforms in unprecedented detail. They also enable 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) How does the ring-shaped landforms relate to other, well-preserved, possible glacial landforms within the mountain complex? (3) Do the ring-shaped landforms indicate the maximum extent of former ice sheets on Mars? (4) Was any meltwater involved and are the preserved landforms ice-cored?

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/m^2, 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.

Observations: The martian rings-shaped landforms 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 and covers an area of approximately 80 km^2 (Fig. 2A). Individual landforms form irregular open and enclosed ridges (Fig. 2B) and tend to be more elongated towards the lobe margin. By shadow measurements ridges are approx. 10-15 m in height. Ridges show a high concentration of clasts and boulders (Fig. 2C). The outer lobe border 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. In some areas Veiki moraines also show elongation parallel to the lobe margin (Fig. 1C).

Discussion: The rings-shaped landforms are located in close spatial proximity to other landforms of possibly glacial origin such as pronival rampart-like glaciers and remnant cirque glaciers. The topography around the rings-shaped landforms shows features that may be interpreted 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. The floor of the valley, adjacent to the ring-shaped landforms shows a number of exhumed impact craters which probably represent the pre-glacial surface. The very few fresh looking impact craters point to a relatively young surface age post glacial recession.

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. We have also found 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.

References: [1] McEwen et al. 2011, (5) 333. [2] Milliken et al., 2003. JGR-Planets (E6) 108. [3] Holt et al.,2008. Science (21) 322. [4] Arfstrom et al., 2005. Icarus (2) 174. [5] Scanlon et al., 2015. PSS. [6] Head et al. 2006. Met & Plan Science (10) 41. [7] Lagerbäck, 1988. Boreas 17.

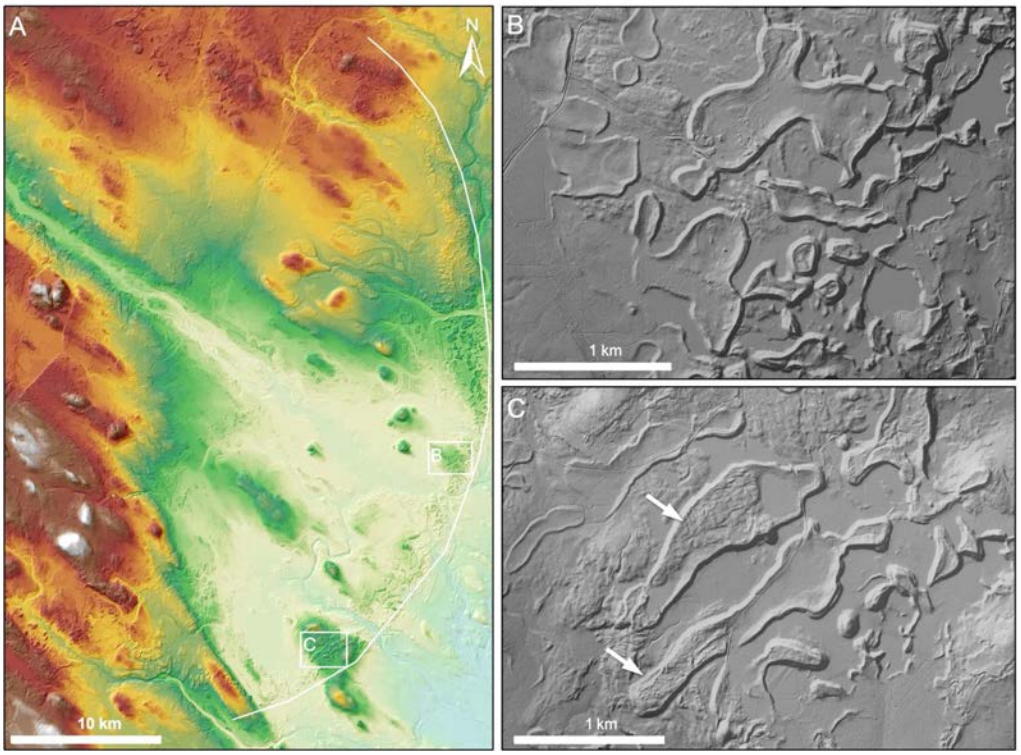

Figure 1. (A) LiDAR raster image of aVeiki moraine arc close to Lainio, Sweden (white line). Vertical relief approximately 500 m. (B) Veiki moraine is characterized by the rimmed ridge plateaus. (C) Veiki moraine tend to elongate parallel to the arc front (white arrows). Illumination from northwest.

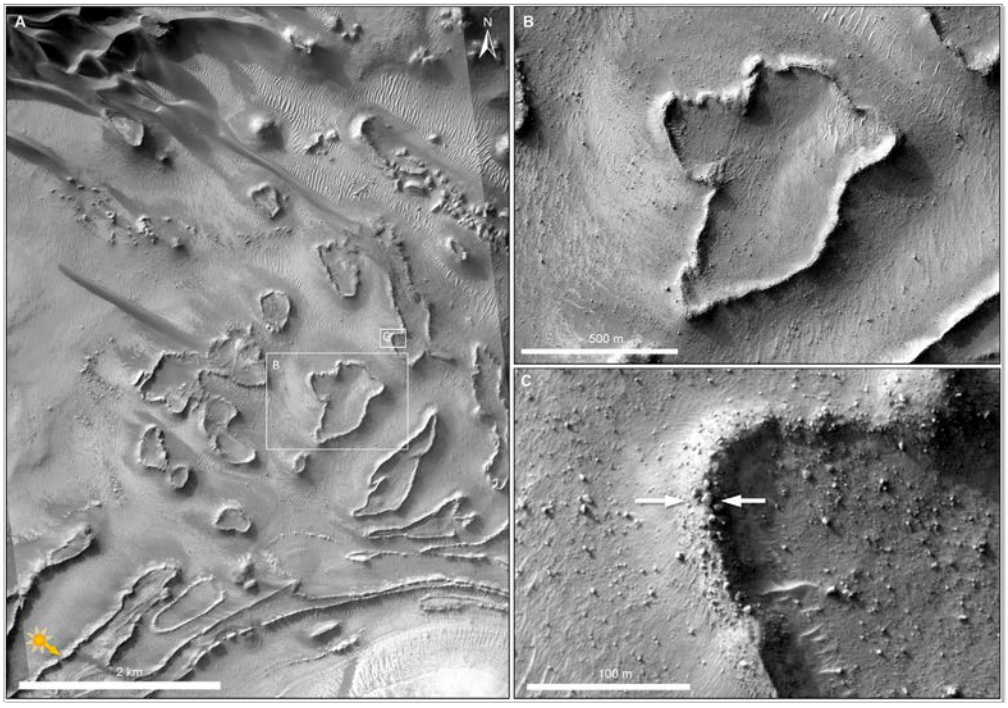

Figure 2. A) HiRISE image of multiple irregular ring-shaped landforms on Mars. B) Ridges form enclosed depressions. Shadow measurements indicate rim heights ranging from 10 to 15 m similar to Veiki moraines. C) Rim contain a high concentrations of large clasts (white arrows).