MORAINE-LIKE LANDFORM ASSEMBLAGES IN THE NILOSYRTIS MENSAE REGION, MARS. A. Johnsson[1], J. Raack[2], E. Hauber[3]. [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: Numerous studies have reported on landforms on Mars that share striking similarities to glaciers on Earth, where water-ice is believed to still be present under insulating debris cover [1]. These martian landforms include viscous flow features (VFF) [1], glacier-like flows (GLF) [2] and lobate debris aprons (LDA) [3]. The notion of preserved water ice was confirmed by SHARAD measurements [4]. In terms of possible glacial depositional landforms most studies have focused on small-scale moraine-like ridges that are associated to gully systems in interior crater environments [e.g., 5], large-scale landforms at the equatorial volcanic province [e.g., 6], landforms suggesting basal glacial meltwater processes [7,8] and possible drop-moraines from past CO_2 glaciers [9].

In this study we investigated an area that border areas of known VFF's and GLF's along the dichotomy, in the Nilosyrtis Mensae region. The motivation was to search for landforms that may provide new insight into glacial and climatic conditions in Mars' recent history.

Here we report on preliminary results of possible glacial depositional landforms associated with three valley systems in the Nilosyrtis Mensae region (Fig. 1). Observed landforms include a series of small-scale ridges associated with three valley entries. These ridges are hypothesized to be recessional moraines, which may provide insight into past climate and glacial dynamics such as maximum extent and cycles of glacial retreat. Moreover, the assembly of small-scale ridges on Mars show similarities to drop moraines located in the Dry Valleys, Antarctica (Fig. 2) that may provide useful terrestrial analogues.

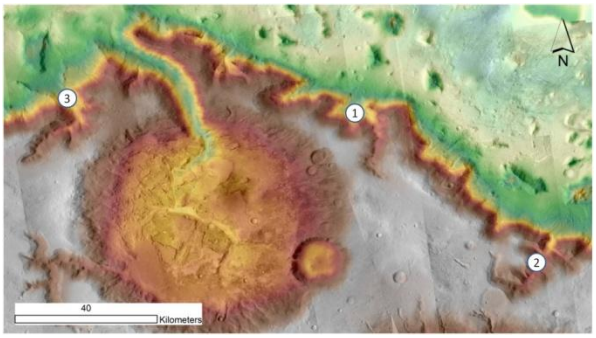

Figure 1. Location of the cliff face and studied valley systems in Nilosyrtis Mensae.

Figure 2. Stocking glacier, Antarctica. White arrows point to a sequence of drop moraines separated by ~100 m [10]. Credit: CNES/Airbus.

Data and methods: For our study we used Context Camera Images CTX (6 m/pxl) and MOLA topography. The study will greatly benefit from future HiRISE images (0.25 m/pxl) but to date such coverage is not available in the region of interest. For Earth comparison we used publicly available Google Earth images.

Observations and results: The study region is dominated by fretted terrain, mesas, cliffs and flat floored valleys. The studied north-facing cliff range is ~250 km long and are a few hundred to a more than a thousand meters in height. The cliff is characterized by deeply incised valley systems. Here we report observations from two valleys of the three studied valleys.

Valley system 1 (VS1): consists of three connecting tributary valleys with a total catchment of ~220 km^2. The largest valley are associated with two small cirques that contains possible VFF remnants. In the upper section of the valley a small tongue of VFF residue is still present. The other two connecting valleys are alcove shaped depressions similar to terrestrial cirque glaciers. The outlet valley contains deposits that terminate in a lobate feature similar to a terrestrial terminal moraine. The latter are followed by a succession of small-scale ridges separated by a few hundred meters (Fig. 3). These ridges show a striking resemblance to moraines associated with present-day glaciers in the Dry Valleys of Antarctica. Located in between the ridges are aligned small-scale hills or large boulders.

Valley system 2 (VS2): consists of a main valley and three alcove-shaped tributary valleys with a total catchment of ~250 km^2. Like VS1 this system has remnant VFF on the valley floors and VS2 display similar features and ridges that extend outwards from

the valley entry (Fig. 4). The main valley also display features that resemble terrestrial truncated spurs at the entrance However, the in-valley spurs seem much less modified

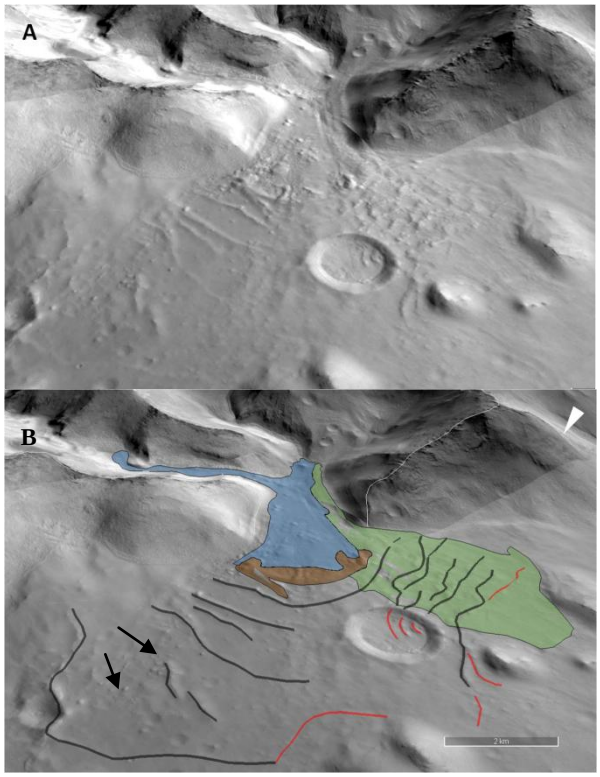

Figure 3. A) Perspective view of VS1 from Google Earth CTX mosaic and MOLA. B) Same area overlaid by preliminary mapping: the lobate moraine-like landform (brown), remnant knobby terrain (blue), lateral knobby terrain (green), small-scale ridges (black lines), possible ridges (red) and aligned hills/boulders (black arrow). Scale bar is 2 km.

Discussion and preliminary conclusions: Here we report on landforms that may provide insights into Late Amazonian deglaciation in the Nilosyrtis region. Although the true nature of the small-scale ridges are difficult to decipher from CTX imagery alone, the physical context in which they occur may suggest a glacial depositional system. The main glaciers would have been fed by a number of tributary valleys and cirque glaciers. The larger lobate moraine-like remnants at valley entrances may represent the last stage before glacier-like flow ceased and the ice disappeared. The succession of small-scale ridges at the valley system entrances are interpreted as possible recessional moraines. The spacing between ridges of the three valley systems are within the range of 400-800 m and may show a cycle of retreat and standstills of these past glaciers.

If the interpretation of these ridges are correct, then they may be used as proxies for past glacial extents and ice-volumes. The succession of ridges may potentially contain a climate signal of glacial retreat and periods of glacial standstills.

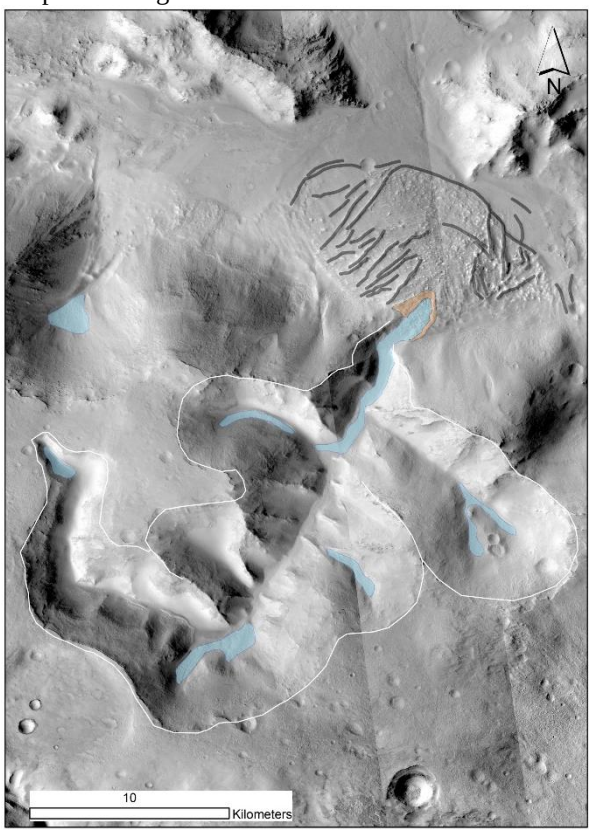

Figure 4. Overview map of VS2 (white outline) with CTX mosaic as base image. Preliminary mapping showing VFF and knobby texture (blue). Possible moraine assemblages (black lines). Large moraine-like feature (brown).

Based on the currently available data it is difficult to determine whether these past glaciers were warm or cold based. The observed aligned small-scale hills/boulders may suggest at least localized basal sliding. However more work is needed for a more complete reconstruction and understanding of climate and possible glacial history in this area. The study area currently lack coverage by HiRISE (25 cm/pxl) that may give better clues about the geomorphology than at present. Future work will include HiWish HiRISE images for selected sites, Cassis images and DTM's.

References: [1] Milliken et al., 2003. JGR-Planets (E6) 108. [2] Hubbard et al., 2014. Cryosphere 8. [3] Hauber et al. 2008. JGR-Planets. [4] Holt et al.,2008. Science (21) 322. [5] Arfstrom et al., 2005. Icarus (2) 174. [4] Gallagher and Balme, EPSL (1) 431. [6] Scanlon et al., 2015. PSS. [7] Butcher et al., 2017. JGR-Planets. [8] Gallagher et al., 2015. EPSL 431. [9] Head et al. 2006. Met & Plan Science (10) 41. [10] Swanger et al. 2017. Scientific Reports 7.