POTENTIAL FOR SAMPLING OF SUBGLACIAL AND ENGLACIAL ENVIRONMENTS IN MARS' MID LATITUDES, WITHOUT DEEP DRILLING. F. E. G. Butcher[1], N. S. Arnold[2], S. J. Conway[3], D. C. Berman[4], J. M. Davis[5], M. R. Balme[6]. [1]Department of Geography, University of Sheffield, UK (f.butcher@sheffield.ac.uk), [2]Scott Polar Research Institute, University of Cambridge, UK, [3]CNRS, UMR 6112, Laboratoire de Planétologie et Géodynamique, Université de Nantes, France, [4]Planetary Science Institute, Tuscon, USA, [5]Natural History Museum, London, UK, [6]School of Physical Sciences, The Open University, UK.

Introduction: Viscous flow features (VFFs) in Mars' mid latitudes are widely interpreted as debris-covered glaciers [e.g., 1]. VFFs are key candidate sites for future landed exploration because of their potential to provide *in situ* water resources [e.g., 2]. Their subglacial and englacial environments are also of significant astrobiological interest [3] because of the availability of water ice, and the relative protection these environments could provide from extreme radiation conditions at the surface. However, deep drilling into debris-covered ice to obtain samples of such environments poses significant technological challenges.

We present observations from Nereidum Montes (51.24°W, 42.53°S) which suggest that materials on or near to the surfaces of VFFs could contain a component of debris transported from their deep interiors and/or beds. Up-glacier dipping internal structures are exposed in the wall of a gully, which incises through a VFF from its headwall to its terminus (Figure 1A–B). The structures, which are near to the VFF terminus, appear to connect the VFF bed (or deep interior) to pronounced, flow-transverse structures on its surface. We performed image and 3D analysis of the structures, along with ice flow modelling experiments which demonstrate that the structures occur within a zone of ice flow compression. Similar up-glacier-dipping structures in glacier flow compression zones on Earth provide transport pathways for subglacial and englacial debris to the surface [4, 5]. Such flow compression structures could therefore provide access to en/subglacial materials at or near the surface, without the high risks and costs of deep drilling.

Methods: We analyzed the VFF-internal structures using 25 cm/pixel High Resolution Imaging Science Experiment (HiRISE) images, and a digital elevation model (DEM) generated from them. We also analyzed a 25 cm/pixel 3 band enhanced color (merged IRB) HiRISE image. We measured the dip directions of the VFF-internal structures using the qgSurf plugin for QGIS. We also input the DEM and an inferred VFF bed topography into the Ice Sheet System Model to simulate the VFF stress regime [6]. We derived the VFF bed topography by interpolating from elevation values around the VFF terminus, along the base of the gully wall (which appears to incise to the VFF bed), and the

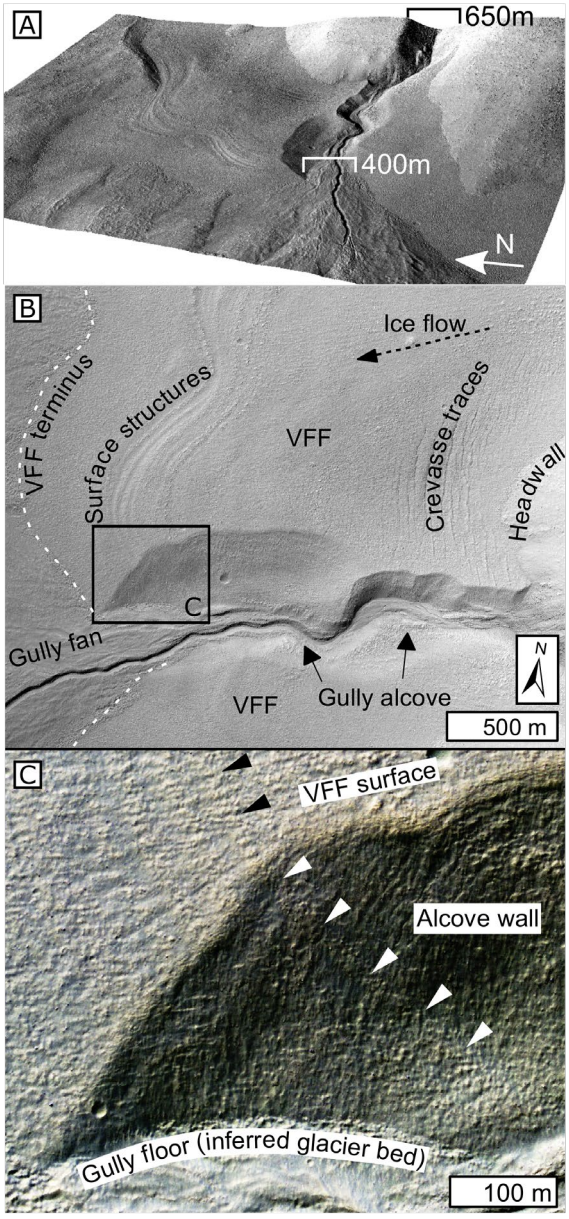

Figure 1: (A) *Oblique 3D HiRISE (ESP_015947_1370) view of the gully-incised VFF.* ***(B)*** *Top-down HiRISE (ESP_015947_1370) view of the gully incision through the VFF, showing surface flow structures and crevasse traces.* ***(C)*** *HiRISE merged IRB image ESP_051036_1370 showing the color signature of the VFF-internal structures (white arrows) and associated surface structures (black arrows). Extent in B.*

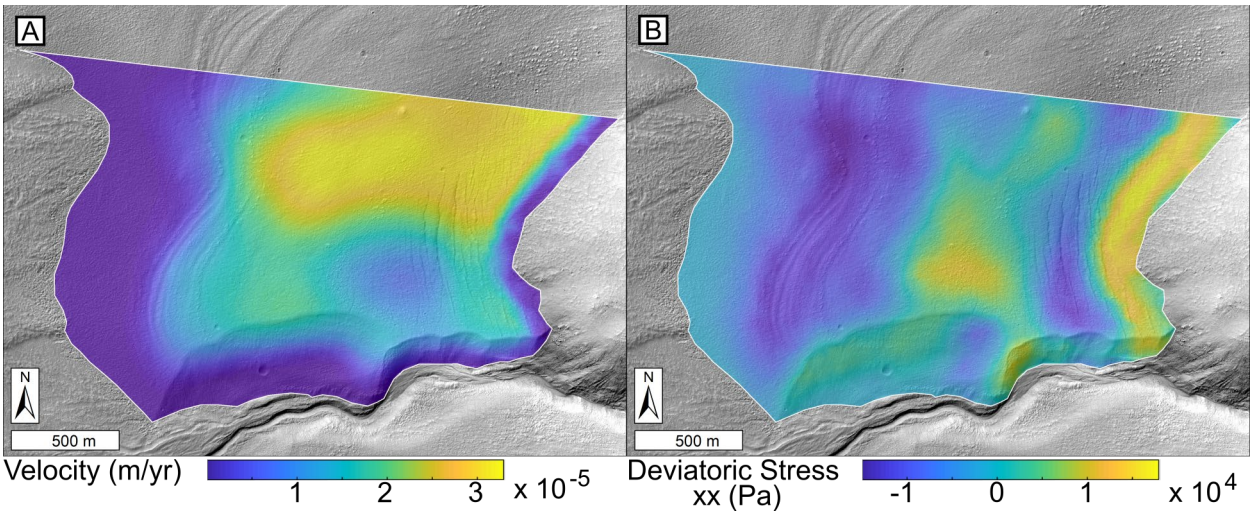

Figure 2: ***(A)*** *Reconstructed surface velocity of the VFF.* ***(B)*** *Reconstructed horizontal deviatoric stress at the surface of the VFF. Negative deviatoric stresses indicate longitudinal flow compression. Basemap HiRISE image: ESP_051036_1370.*

contact between the VFF and the headwall. We simulated ice flow assuming a frozen bed, and present-day mean annual surface temperature (~210 K).

Results: The VFF-internal structures connected to the prominent VFF-surface structures dip up-glacier (NE) at ~20° from the VFF bed. The VFF bed dips ~12° to the SW. Further up-glacier, internal layering within the VFF is approximately bed-parallel. The color signatures of the internal structures, and corresponding surface structures, are redder than the bulk VFF, which appears bluer (Figure 1C). This could suggest differences in roughness and/or lithic fraction [7].

Modeled ice flow velocities reach a maximum of ~3.5 mm per 100 Earth years (Figure 2A). The surface structures associated with the up-glacier dipping internal structures correspond closely with a band of horizontal flow compression (Figure 2B) where ice flow velocity slows towards the VFF terminus (Figure 2A). Crevasse traces near to the VFF headwall also correspond with a zone of flow compression. The lack of pronounced relief within the field of crevasse traces suggests that the original crevasses closed as they were transported into the compressional zone from the zone of extensional flow upslope.

Discussion and Conclusions: We suggest that the up-glacier dipping VFF-internal structures are analogous to shear deformation structures formed under compressional regimes within glaciers on Earth [4–5]. Under wet-based and polythermal regimes, the structures often transport significant volumes of englacial and/or subglacial debris to the surface [4]. Shear zone structures in cold-based glaciers can also transport debris from the glacier bed and/or interior, albeit in smaller volumes [5, 8]. We do not speculate on the past thermal regime of the VFF studied here, but suggest that the up-glacier dipping VFF-internal structures, and their corresponding surface structures could contain a component of englacial and/or subglacial debris which could be sampled without deep drilling. Surface structures that appear to have formed by flow compression are very common on VFFs across Mars' mid-latitudes, so such transport of subglacial and englacial debris to glacier surfaces could have been a widespread process.

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