CREVASSE-LIKE OPENINGS AS INDICATORS OF FLOW IN MARTIAN GLACIER-LIKE FORMS. C. J. Souness[1], B. Hubbard[1], [1]Centre for Glaciology, Institute of Geography and Earth Sciences, Aberystwyth University, Ceredigion, Wales, UK, SY23 3DB (primary author email: cjs07@aber.ac.uk).

Introduction: Repeated surveys of Mars' mid-latitudes have revealed widely distributed but locally concentrated populations of glacier-like forms (GLFs) (e.g. [1]). These appear to constitute a low-order component of what have been described as integrated glacial landsystems [2].

GLFs - apparently composed predominantly of massive water ice [3-4] - exhibit geomorphologic evidence that points to a history of flow and localised deformation (Figure 1) [5-7]. Examples of such evidence include concentric ridges and down-slope orientated chevron-like patterning [6-8], moraine-like ridges (MLRs) (e.g. [9-10]), and a general lobe-shaped appearance suggestive of viscous ice and debris mobilisation [6-7]. However (given that these icy features appear to be the relics of a past 'ice age' [11-14] and that current surface temperatures in these areas are extremely low), it is highly unlikely that motion occurs at a rate sufficient to permit direct observational measurements, either in situ (by an unmanned rover) or through use of repeat satellite imagery. Flow rates have been calculated based on modelled ages (4 Ma bp – 5 Ma bp [14; 11]) and the present day morphology of VFFs, indicating very low shear stresses [5]. Some tentative estimates of dust content (< 4%) and ice grain size (> 1 mm) have also been presented based on numerical flow modelling experiments [15]. However, these findings do not explain the full range of VFF morphologies [15].

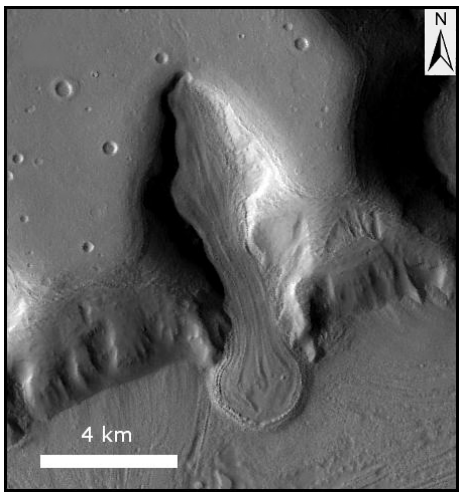

Fig. 1: A valley GLF in Protonilus Mensae. Note the apparent flow-parallel lineations, the piedmont lobe-like terminus and the moraine-like ridge that bounds the GLFs snout.

Persisting uncertainty regarding the details of GLF accumulation and flow limits our ability to infer how GLFs formed and how large a role liquid water has played in their development (e.g. [5]). This is unfortunate as a clearer idea of how and at what rate Martian GLFs flow could improve our understanding of what role (if any) liquid water has played in Mars' recent cryospheric history. It could also help to establish a better understanding of how and to what extent flowing ice has shaped the surface of contemporary Mars.

Geomorphological indicators of flow rates on terrestrial glaciers: The spatial velocity field of terrestrial valley glaciers generally varies systematically. This flow creates or modifies a broad range of surface morphologies and associated landforms. Examples of these include medial moraines, englacial folding and foliation, ogives and arcuate surface patterning and, perhaps most obviously, crevassing.

Crevasse-like openings on Martian GLFs: During a survey of GLF distribution within Mars' mid-latitudes, conducted using 8058 individual Context Camera (CTX) images [1], many instances of crevasse-like openings (CLOs) were observed on the surface of GLFs (Figure 2). These were seen in a range of contexts and also in conjunction with similarly aligned surface markings comparable in appearance to crevasse traces (such as observed on terrestrial glaciers) and, in some cases, linear, positive-relief features similar in appearance to crevasse-fill ridges (Figure 3) that are occasionally seen in de-glaciated areas on Earth.

Assuming the terrestrially-determined causal relationship between motion and morphologies also exists on Mars, observations of crevasses or crevasse-like openings (CLOs) on GLFs would yield information on (current or former) GLF flow. Based on the assumption that GLF flow is controlled by the same variables as determine glacier flow on Earth (i.e. ice thickness; slope; variable drag on the valley sides etc.), the morphology of CLOs will reflect variations in these controlling variables on GLFs.

Methods: Hertzfield et al. [16] described crevasses as "the writings in a glacier's history book." If we assume that ice flow varies in a systematic manner on Mars, similar to the manner in which it does on Earth (see above), surface expressions of flow could be used to infer internal processes and conditions such as ice thickness and strength.

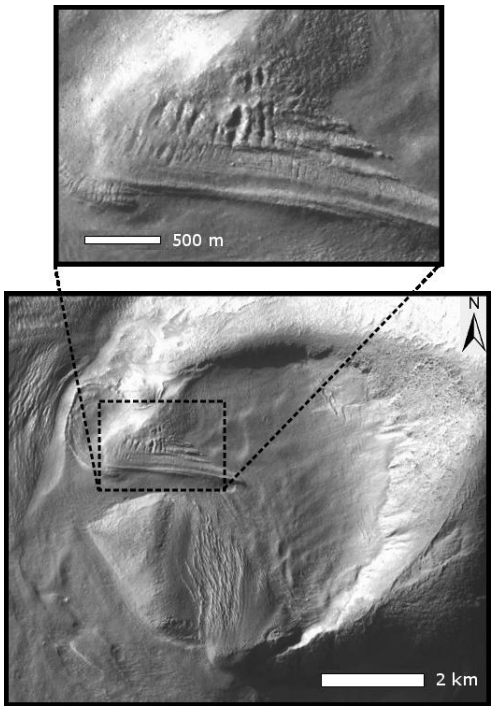

Fig. 2: A GLF flowing from a cirque-like alcove in eastern Hellas (CTX image B20_017616_1391_XI_40S257W). Where the main 'tongue' flows over the cirque lip pronounced CLOs are visible, creating the appearance of a terrestrial 'icefall'.

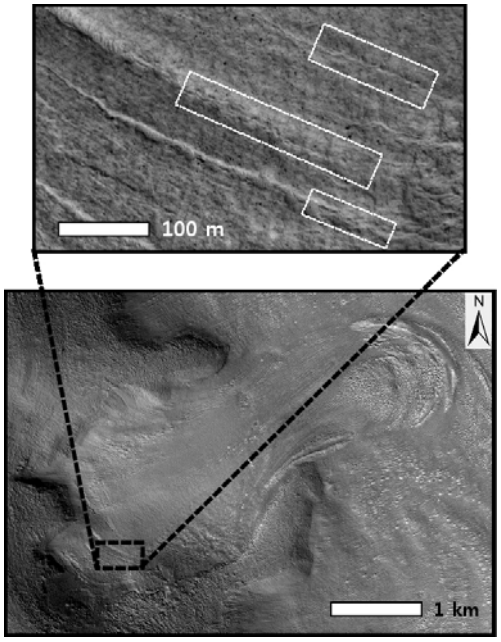

Fig. 3: A detail view (top frame) of CLOs near the headwall of a cirque GLF (bottom frame) in Deuteronilus Mensae (HiRISE image ESP_023605_2205_RED). Note that toward the S.E of the image (top frame) the CLOs change from negative relief troughs to positive relief ridges (highlighted in white boxes). Illumination is from the bottom left.

The images identified as containing one or more GLFs by Souness et al. [1] were revisited and inspected for evidence of CLOs. A new database was constructed identifying those GLFs observed to exhibit CLOs. A GIS was built showing their locations, permitting analysis of their distribution relative to the remainder of the population and to variations in geographic and topographic setting. Individual GLFs were also selected for closer analysis. These images were examined and mapped using ArcMap software, highlighting features and textures in the context of local flow direction.

Results: We present a detailed inventory of 74 CLO-bearing GLFs (37 in the northern mid-lats and 27 in the southern mid-lats), including a map of their distribution and an analysis of that distribution relative to geographical factors.

Detailed analyses of selected GLFs show highly localised incidence of CLOs (e.g. Figure 2). Assuming flow mechanics on Mars broadly similar to those documentaed on Earth, this indicates that some GLFs have locally variable flow regimes.

Conclusions: The observed evidence suggests GLFs develop CLOs (i.e. the extensional threshold of their fabric is surpassed) in the following circumstances:

1. Strain rate is affected by variable slope at the ice-bed interface, resulting in local extension and/or compression of ice;

2. Strain rate is affected by drag at a shear margin (e.g. along valley sides or where two or more ice flows converge);

3. Strain rate is affected by frictional variations at the ice-bed interface, likely caused by an external agent (possibly liquid water).

Examples will be given of all three contextual scenarios.

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