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ICELANDIC DEBRIS FLOWS AND THEIR RELATIONSHIP TO MARTIAN GULLIES. S. J. Conway¹, M. R. Balme¹, J. B. Murray¹, M. C. Towner² and J. R. Kim³, ¹Planetary Surfaces Research Team, Dept. of Earth and Environmental Sciences, Open University, Walton Hall, Milton Keynes, United Kingdom, MK7 6AA, ²Planetary Surfaces Research Team, PSSRI, Open University, Walton Hall, Milton Keynes, United Kingdom, MK7 6AA, ³MSSL, UCL, Holmbury St. Mary, Dorking, Surrey, United Kingdom, RH5 6NT. s.j.conway@open.ac.uk

Introduction: Martian gullies and Icelandic debris flow gullies show remarkable similarities in terms of morphology (e.g. both display the alcove – channel – debris apron structure) and in terms of scale (**fig 1**). The aim of this project is to assess whether there is a link between their formation processes through the use of detailed morphological analysis.

A debris flow, by definition, requires fluid [1]: *“Debris flows occur when masses of poorly sorted sediment, agitated and saturated with water, surge down slopes in response to gravitational attraction. Both solid and fluid forces vitally influence the motion”*. In Iceland the debris flows are initiated by oversteepening and over-saturation of the regolith mantle, with the source of the water being from snowmelt or storm events [2]. The Icelandic flows occur on regolith mantled slopes of 25-30° on the sides of fjords that are cut into basaltic bedrock: a good analogue for Martian gullies [3].

The gullies above the town of Ísafjörður in the Westfjords region of Iceland provide a unique opportunity to study recent debris flows because the debris flow frequency is unusually high (the minimum return time between large flows is 4 years [2]). On other slopes in Iceland debris flows are much less frequent and/or smaller because they are supply limited, so the regolith on the slopes must reach a certain thickness and steepness before it can slide. By studying very fresh debris flows the influence of post-depositional reworking is minimized.

Approach: A detailed GPS survey was performed of five debris flows located above the town of Ísafjörður and one located in an adjacent valley. An air survey comprising of air photography (at better than 25cm/pixel) and LiDAR (at 1.0-1.5m posting) was commissioned and the data is pending. These data and additional field observations can be compared to datasets from Mars, such as imaging data from HiRise and MOC NA and digital elevation models derived from HiRise stereo-photogrammetry. From a database of MOC NA images [3] the alcove, channel and debris apron have been mapped. The same has been done for with available air photography in Iceland (Westfjords, Eastfjords and north of Akureyri).

Results: Debris flows above Ísafjörður have a typical distinctive morphology, with large (up to 5m high) convex levées and a channel that is irregular in cross

section. They are from 200 to 1000 metres long and several metres to tens of metres wide. The deposits of the smallest flow (200m long) have a calculated volume of 143m³ and those of a medium flow (700m long) of 11600 m³ (**fig.2**). Sixty-two gullies from across Iceland were mapped, independent of dominant process. The channels have lengths between 209m and 1426m and a sinuosity between 1.0 and 1.2. The alcoves have an area of between 628m² and 0.4x10⁶m² (mean 44184m²).

From preliminary analysis of 71 gullies in three areas (North of Argyre Planitia, Noachis Terra and Terra Sirenum) gully channels on Mars have lengths between 123m and 3256m and they have a sinuosity between 1.0 and 1.1. The alcoves have an area of between 231m² and 2.6x10⁶m² (mean 0.5x10⁶m²). During observations it has been noted that some of the channels and debris aprons display levées.

Discussion: Initial results suggest that debris flow could be an important factor in the formation of Martian gullies. Gullies in Iceland and on Mars have similarity of scale, in terms of length and alcove size (although the maximum alcove size on Mars is larger). There is also similarity in terms of form, as the sinuosity is very similar. Ongoing work including producing elevation models from HiRise will enable more detailed morphological analysis to assess specific debris flow traits. Erosion and deposition maps like **fig.2** can be made from these elevation models.

The Icelandic debris flow in **fig.2** shows that the slope is an important controlling factor on deposition and erosion patterns. The main erosional part of the channel ceases at 32° and the mixed area of erosion and major deposition ceases at 23°. There is little deposition at lower slope angles as the debris flow has exhausted its material (this is a relatively small flow for Ísafjörður). The flow continues on slopes as low as 8°. The flow does not necessarily follow the line of greatest slope, the breakout on the right of the diagram is following the most optimal path, but the levées have blocked further flow.

Conclusion: The assessment of the 3D shape of the Martian channels, including long sections and cross sections, will be able to tell us the contribution of debris flow to these channels. This analysis is pending photostereogrammetry. By using the same techniques used for terrestrial debris flows the erosion and deposi-

tion patterns can be assessed in a manner similar to that demonstrated in **fig.2**. Due to the abundant regolith on Mars any debris flow would be limited by the frequency and intensity of events that supply water, like those in Ísafjörður. The physics of debris flows are not well understood, but the morphology is unique [1,5]. Debris flow does not occur if there is too much or too little water, so the assessment of debris flow morphol-

ogy on Mars will provide a strong constraint on the water content of flows in Martian gullies.

References: [1] Iverson R. M. (1997) *Rev. Geophys.*, 35, 3, 245-296. [2] Decaulne, A. et. al. (2005) *Geogr. Ann. A*, 87A, 4, 487-500. [3] Balme, M. R. et. al. (2006) *J. Geophys. Res.*, 111, E05001. [4] Costard, F. et. al. (2002) *Science*, 295, 110-113. [5] Costa, J. E. (1984) Chapt.9, in *Devel. and App. of Geomorphology*, 268-317.

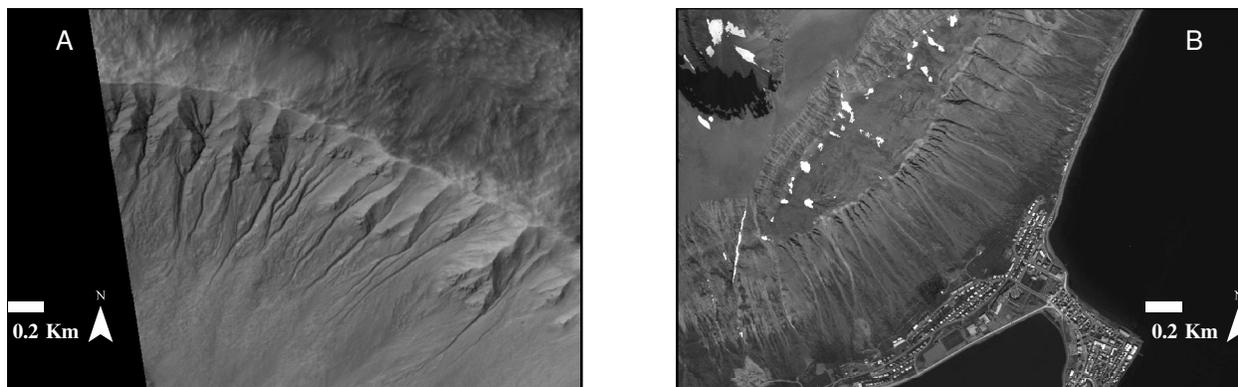


Figure 1: Scale and orientation the same for both; (A) MOC-NA number E1401935 and (B) Air Photograph of Gullies above Ísafjörður N1394, ©LMÍ 1994

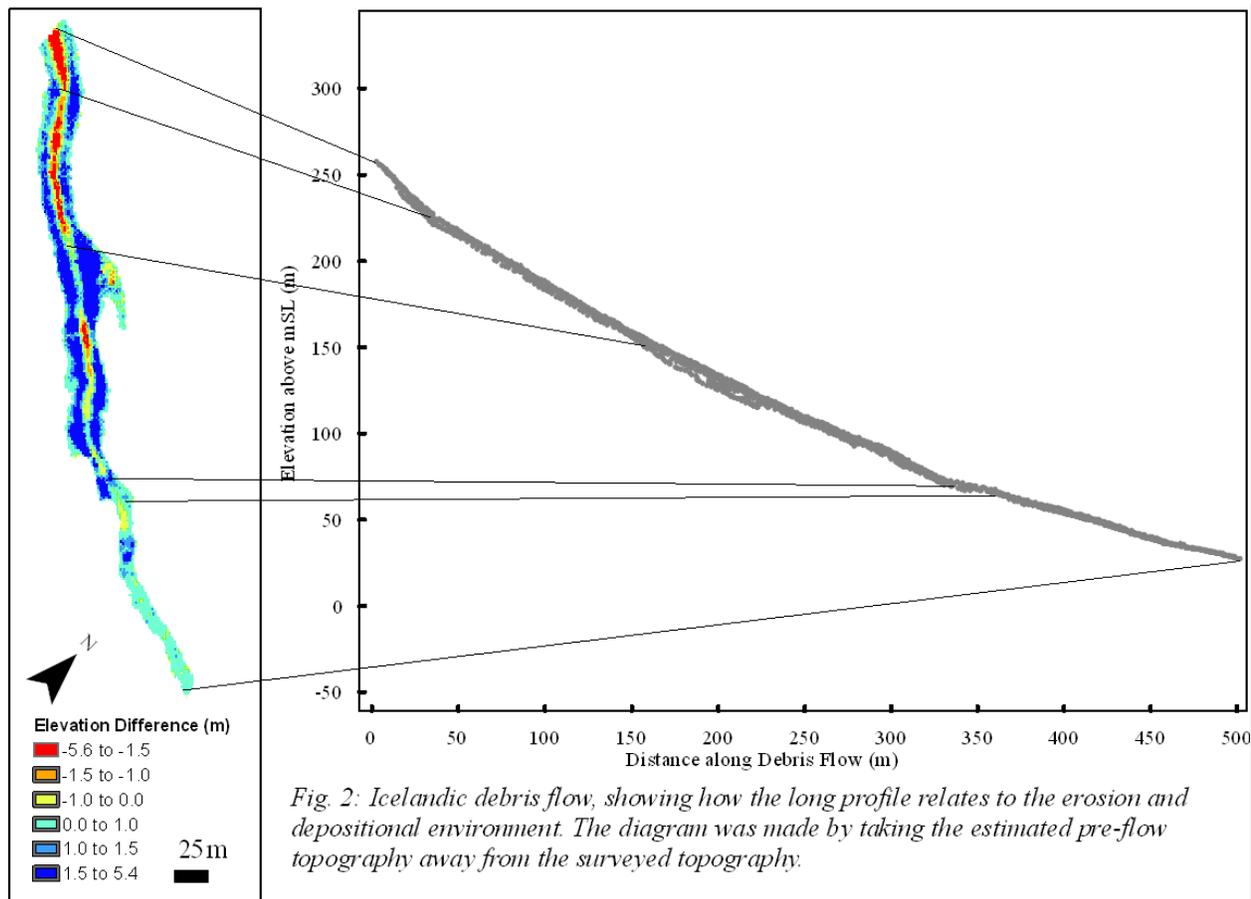


Fig. 2: Icelandic debris flow, showing how the long profile relates to the erosion and depositional environment. The diagram was made by taking the estimated pre-flow topography away from the surveyed topography.