GEOMORPHIC ANALYSIS OF THE FORMATION PROCESSES OF MARTIAN GULLIES. S. J. Conway[1], M. R. Balme[1] J. B. Murray[1] M. C. Towner[2], C. Okubo[3], and P. M. Grindrod[4] [1]Planetary Surfaces Research Team, Dept. of Earth & Environmental Sciences, Open University, Walton Hall, Milton Keynes, United Kingdom, MK7 6AA s.j.conway.00@cantab.net [2]Impacts and Astromaterials Research Centre, Department of Earth Science and Engineering, Imperial College London, United Kingdom SW7 2AZ. [3]Astrogeology Science Center, U.S. Geological Survey 2255 N. Gemini Dr. Flagstaff, AZ 86001, USA. [4]Department of Earth Sciences, University College London, United Kingdom, WC1E 6BT.

Introduction: We present quantitive geomorphic analyses of high resolution digital elevation models (DEMs) of four gully systems on Mars. We first tested our methods in different gully systems on Earth, to verify that we can use slope-area analysis to discriminate between dry mass wasting, debris flow (involving water) and pure water flow. We then applied the analyses to Mars, where our results indicate that debris flow is the dominant gully-forming process.

Approach: We used airborne laser altimeter (LiDAR) data sourced from the USA's NSF NCALM and UK's NERC ARSF to generate DEMs for Earth. For Mars we used publically released HiRISE image pairs to generate DEMs following the method of Kirk et al. [1]. For each pixel in the DEMs we derived: the local slope (S), the upslope drainage area (A) and the wetness index ($ln(A/S)$), using a "Dinf" algorithm [2]. Figure 1 shows the process domains in a slope-area plot for Earth and the typical slope-area trend for a mature fluvial system. In general the slope-area plot gives information about the long profile of analyzed slopes – a positive trend indicates convex slopes, a horizontal trend indicates linear slopes and a negative trend indicates concave slopes. In slope-area plots it is hard to discriminate between dry mass wasting and debris flow. Hence, we also used process domains in Cumulative Area Distribution (CAD) plots [3] and examined the spatial patterns of wetness index [4]. The methods are described in detail in [5].

Results: We successfully verified the use of process domains defined by slope-area plots, CAD plots and wetness index maps for small gullies and slopes on Earth. Figure 2 shows the wetness index plots for three distinct processes on Earth and closely matching counterparts from Mars. We were able to successfully determine the active processes for gullies and other slopes on Mars. The detailed results are presented in [5]. Figure 3 shows an example slope-area plot for gullies in Gasa crater on Mars.

Conclusions: We ascertained that the dominant process for forming gullies on Mars is debris flow. The slopes containing gullies, and also slopes not containing gullies, show additional signals from creep, solifluction and occasionally dry mass wasting. Analysis of the location of gully heads in slope-area plots also indicates a distributed source for forming the gullies, consistent with a surface melting model [6] and inconsistent with an aquifer-based model [7]. These observations combined indicate the recent activity of small amounts of liquid water on the surface of Mars within the geologically recent past.

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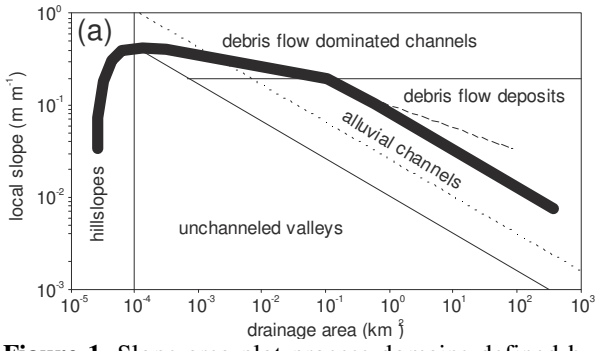

Figure 1. Slope-area plot process domains defined by Montgomery and Foufoula-Georgiou [8] and Brardinoni and Hassan [9]. The dotted line indicates the adjustment of the fluvial regime for martian gravity.

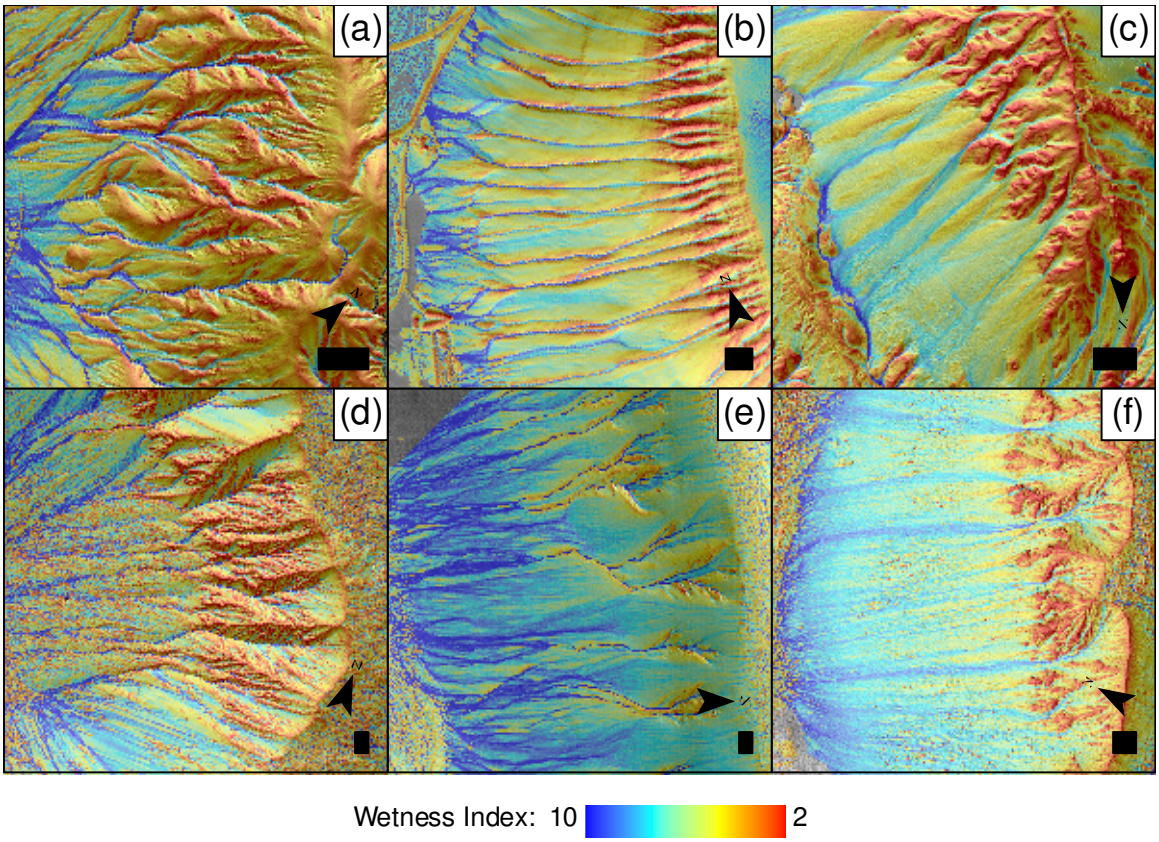

Figure 2. Wetness index maps for: (a) ephemeral water flow gullies in Death Valley, California, (b) debris flows in NW Iceland, (c) talus slopes in the St Elias Range, Alaska, (d) west-facing gullies in Gasa Crater in Terra Cimmeria, (e) south-facing gullies within a crater inside Kaiser Crater in Noachis, and (f) a non-gullied slope within a crater in Terra Sirenum. All black scale bars represent 100m.

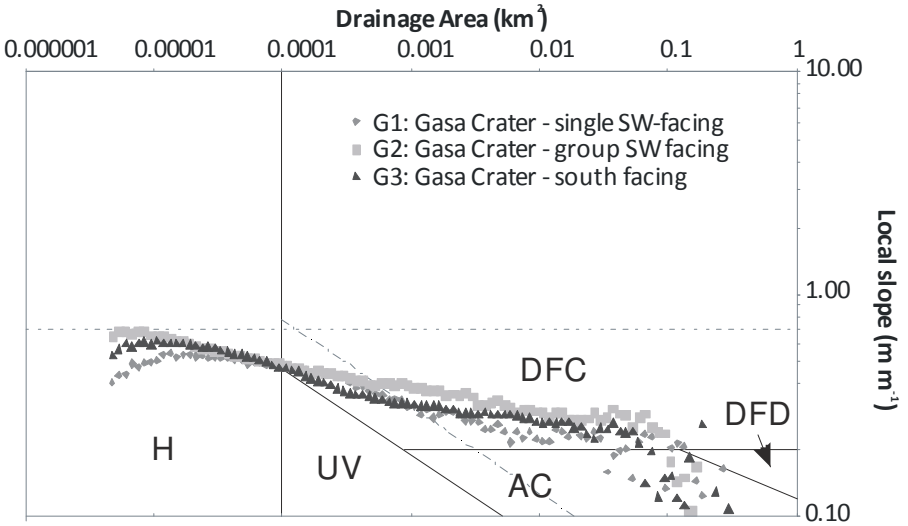

Figure 3. Slope-area plot of gullies in Gasa Crater, Mars, with domains defined by Montgomery and Foufoula-Georgiou [8] and Brardinoni and Hassan [9] marked in black lines and abbreviated as in Figure 1. The dotted horizontal line indicates the approximate location of the lower slope limit for dry mass wasting.