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Debris Flow as a Mechanism for Forming Martian Gullies

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The current low temperatures and pressures at the martian surface are not conducive to the stability of liquid water; hence the discovery of recently active, fluvial-like gullies [1, 2] presents an apparent paradox: how can these fluvial landforms have occurred if water is not stable at the surface? To approach this problem we have compared the morphometric properties of gullies in various settings on Earth to those of gullies on Mars. We have measured debris flows in Westfjords, Iceland [3] and gullies in La Gomera, Canary Islands [4]. The Iceland elevation data were generated from differential GPS and a LiDAR survey, and the La Gomera data from differential GPS. In addition we used elevation data from the Shuttle Radar Topography Mission (SRTM) extracted along previously mapped debris flows in the Taurids Mountains, Turkey [5] and the Colorado Front Range, USA [6]. We have compared these data to preliminary analyses of stereo HiRISE images of martian gullies in four locations using a method to extract point elevation data developed by Kreslavsky [7]. In all cases the elevation along the centre channel of the debris flow or gully was used for comparison to Mars. For Iceland and La Gomera we also extracted cross-profiles for comparison with martian gullies.

Simply comparing the longitudinal profiles of gullies on Mars and different situations on the Earth highlights the variability between debris flow sites on Earth. The martian gully profiles are most similar to debris flows in the Taurids Mountains and in the Colorado Front Range. The overall slope is shallower on Mars compared to the Iceland debris flows and the ephemeral water flow gullies in La Gomera. The runout or total length of gullies is also more variable and greater for Mars than for Iceland and La Gomera. Caution should be taken in interpreting the cross profiles for Mars as the error on the elevation is at least 1m and there is low sampling density in comparison to the other datasets. The v-shaped La Gomera cross profile and the Icelandic debris flow compare well to the Mars example in terms of wall-slope and channel shape.

The longitudinal profiles are all concave, showing the influence of water on the slope profile. Hillslope profiles influenced by creep are convex up and hillslope profiles and talus slope [8] profiles (formed by mass wasting and rockfall) are of constant gradient (once equilibrium is reached). Ephemeral gullies tend to follow the shape of the hillslope on which they form for the majority of their length [9], as shown by our data from La Gomera. Hence, as hillslope debris flows tend to produce a slightly concave profile [10, 11], as shown in our examples, this seems the best fit for the martian data. Ephemeral gullies are usually v- or square bottomed [12, 13], the La Gomera examples we studied falling into the latter category. However the martian cross-profiles fit better with the examples from Iceland, as there is a suggestion of levees present in some of the Mars examples.

Our results tentatively suggest, based on the morphology alone, that debris flow is a plausible mechanism for forming martian gullies. Future work will include analysis of whether there is a slope-area threshold for initiation of incision for martian gullies, and the analysis of along-profile slope-area relationships.

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