EROSIONAL AND DEPOSITIONAL SLOPES OF NEW MARTIAN GULLY DEPOSITS. C. M. Dundas[1], S. J. Conway[2], and K. Pasquon[2]. [1]U.S. Geological Survey, Astrogeology Science Center, 2255 N. Gemini Dr., Flagstaff, AZ 86001, USA (cdundas@usgs.gov). [2]LPG, Nantes Université UMR-CNRS 6112, 2 Rue de la Houssiniére, 44322 Nantes, France.

Introduction: Martian gullies are landforms with erosional channels that have transported material from upslope alcoves to depositional aprons, similar to terrestrial alluvial fans [1]. Widespread activity has been observed in Martian gullies [2-8]. This activity primarily occurs in association with CO_2 frost and appears to be driven by the frost [e.g., 5-8]. A critical question for gully studies is whether such frost processes are the sole explanation for gullies [e.g., 7] or whether liquid water was involved in the past [e.g., 9]. Equifinality, formation of similar landforms by different processes, makes it challenging to address this question.

Martian gullies have morphologies similar to alluvial fans, suggesting that they formed via fluidized flows rather than volatile-free mass wasting. Apex slopes for deposition within channels indicate fluidized flows, as they are lower than the typical angle of repose for dry granular material [10-11]. Modeling of one of the first discovered new flows suggested that it was consistent with a dry granular flow [12], but further work on three additional flows has indicated fluidization at a level consistent with either wet debris flows or flows fluidized by CO_2 frost [13].

One key tool for addressing the problem of equifinality is to watch processes in action. This study seeks to understand the fluidization behavior and erosional and depositional slopes of current gully flows in comparison with the properties of the complete landforms, to determine whether the morphology of the full gully landforms is consistent with formation by flows like those occurring at present.

Methods: Using an expanded catalog of new Martian gully flows [14], we identified flows in locations with high-resolution Digital Terrain Models (DTMs) derived from High Resolution Imaging Science Experiment (HiRISE) images. We traced profiles along new flows (Fig. 1) and identified locations of erosion and deposition. We also identified the along-profile location of the channel mouth and traced the profiles to the end of the gully apron beyond the flow path if the flow did not reach the apron terminus. The abstract presents analysis of the first subset of this data.

We then calculated along-profile slopes. Slopes were calculated over a 20-meter along-profile baseline, and further smoothed by taking a running median of five slope points. These measures are necessary to reduce the effects of small-scale noise and artifacts in the DTMs. To avoid outliers, we consider the maximum depositional slope to be the 90th-percentile value, and the minimum erosional slope to the 10th-percentile value, of the sets of depositional and eroded locations. We also examined the vertical drop/horizontal runout ratio (D/R) of both individual flows and full gullies.

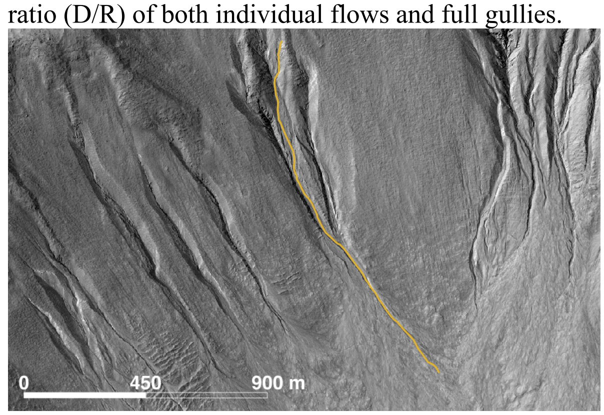

Figure 1: Gully with profile along recent flow in yellow.

Results and Discussion: The drop/runout ratio of gully flows is one of the most basic measures of fluidization. The D/R ratios for individual flows range from ~0.15–0.6. The high end of the range corresponds to a slope of ~31°, comparable to the dynamic angle of repose for many granular materials, while the low end requires significant fluidization. Flow D/R ratio correlates with that for the gully as a whole (Fig. 2) and also with minimum erosional and maximum depositional slopes; since the latter are local properties, this demonstrates that the whole-gully correlation is not solely inherited from the pre-existing topography but also correlates with properties of the dynamic flow.

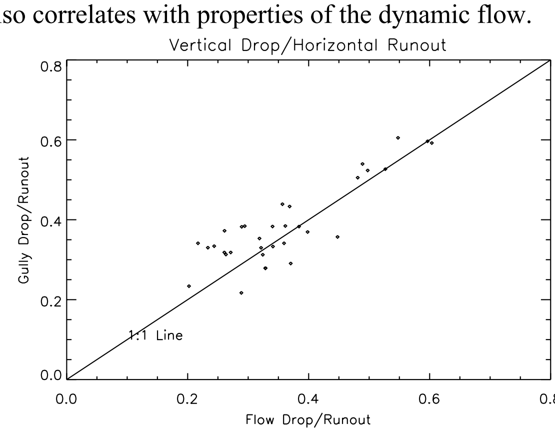

Figure 2: Vertical drop/horizontal runout ratio for individual gully flows versus the overall D/R for the host gully. 1:1 correlation line plotted for reference.

The minimum eroded slopes in individual flows are strongly correlated with the slopes at the pre-existing channel mouth (Fig. 3), with a simple 1:1 line providing a good fit. This demonstrates that the channels of gully systems are fully consistent with formation via current-type flows. Moderate scatter in the relationship is expected because individual flows in a gully may have variable degrees of fluidization and erode or infill at the existing channel mouth.

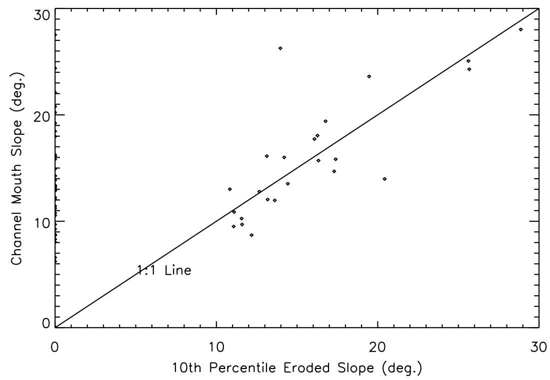

Figure 3: Minimum (10th percentile) eroded slope of individual new gully flows versus the slope at the preexisting channel mouth. 1:1 correlation line plotted for reference.

The minimum (10^{th} percentile) depositional slope of a flow provides an estimate of the farthest reach of an apron that would be constructed by identical flows. We observe that present-day flows usually have minimum depositional slopes at or above the terminal slopes of the aprons of their host gullies (Fig. 4). This is again consistent with construction of the full gully apron by current-type flows, with the farthest reach of individual aprons defined by the most-fluidized flows that have occurred in the system.

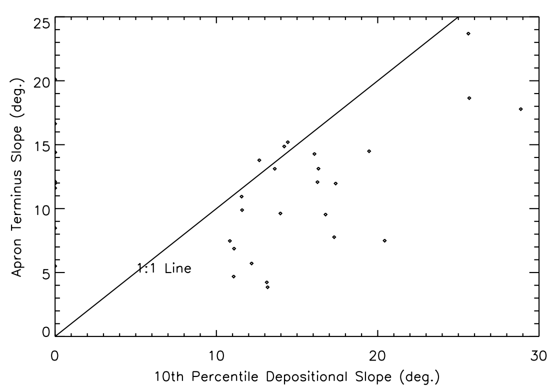

Figure 4: Minimum (10th percentile) deposit slopes of individual new gully flows versus the slope at the gully apron terminus. 1:1 correlation line plotted for reference.

Previous analyses of gully deposition have assumed that there is a well-defined slope angle at which a flow transitions from erosion to deposition, corresponding to the dynamic angle of repose. We regularly observe alternation between erosion and deposition in a given flow, and overlapping ranges of slope angles where erosion and deposition occur. This could indicate variable fluidization within a flow, remobilization of marginally stable recent deposits, or interactions between the flow and preexisting topography leading to localized deposition on steeper-than-expected slopes. Similar alternations occur in terrestrial debris flows [14-15], emphasizing the similar dynamics of CO_2-fluidized flows on Mars and wet debris flows on Earth.

Conclusions: The fluidization properties of flows ongoing in the present era are consistent with formation of gully systems entirely by such flows. Although snowmelt in a past climate is not ruled out by such observations, they are consistent with formation of gullies by CO_2 frost processes like those occurring today. The latter is thus the simplest explanation for gully formation. This permits paleoclimate histories that do not require widespread, abundant melting within the last few million years.

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