Application of Terrestrial Geomorphic Threshold Theory to the Analysis of Small Channels on Mars. E. B. Rosenshein[1], R. Greeley[1], and J. R. Arrowsmith[1], [1]Arizona State University, Department of Geological Sciences, Box 871404, Tempe, AZ 85287 (ellen@asu.edu)

Introduction: The valley networks on Mars have been a source of controversy for many years. Their origin, whether by sapping or by precipitation and runoff, remains unknown, yet has implications for the climate history of Mars. An overland flow origin implies that Mars was once much warmer, while an origin by sapping does not have this requirement. Recent terrestrial work on the geomorphic thresholds for channel initiation use the drainage area above a channel head versus the slope at the channel head to delineate surface process types. We applied this method to Martian landscape characterization. Specifically, appropriate measurements of 8 of 22 channels identified in the Syrtis Major region were executed. Analysis of these preliminary measurements indicates that this method, while promising, needs further refinement to be applied to Mars in a more meaningful way. We will continue this refinement as more data becomes available.

Approach: New work in terrestrial quantitative geomorphology may provide insight into the origin of the valley networks on Mars. Recently, Montgomery and Dietrich [1,2,3] focused on channel initiation and the conditions necessary to maintain a channel. Working in mostly humid-temperate areas, they defined a model that predicts whether a slope should become channeled by surface overland flow or remains unchanneled. This model utilizes the drainage area above the channel head versus the local slope gradient to illustrate their findings. Channels begin when sufficient shear stress exists from overland flow to carve a channel. This occurs when both the slope and the drainage area are large enough to produce enough shear stress on the ground surface [1,3,4]. By comparing drainage area versus slope, the thresholds for unchanneled flow and overland flow erosions can be found, as well as the threshold for landsliding (Fig. 1). The implicit assumption in this work is that sapping channels begin in the area of diffusion dominated flow or in the area of landsliding, but with low drainage areas. Using this hypothesis to determine whether channels on Mars lie in the area assumed to contain sapping mechanisms, or whether these channels lie in the region of runoff driven erosion is the major thrust of this work.

Sites for analysis were chosen based on the availability of MOLA (Mars Orbiter Laser Altimeter) data, focusing on the area between 11.0 and 16.0 N, 307.5 and 312.5 W. The area is thought to be about 3.8 byr [5], and many channels are found in the region. These channels are often obscured because of the great amount of cratering in the area.

The channels were then identified by examining the Viking Orbiter images of this area, as well as MOC (Mars Orbiter Camera) wide-angle images, and choosing channels that appeared to be unmodified, with clearly defined heads and drainage basins. The slope and drainage area for each channel head were determined, and then compared with the model of geomorphic thresholds from Dietrich et al. (1992) [4].

Results: A total of 22 channel heads were identified in the target area, of which 8 had sufficient MOLA data to determine the slope of the channel head. All of the channel heads measured have slope vs. drainage area measurements of higher values than those in the Dietrich et al. (1992) [4] model (Fig. 1). The thresholds were extrapolated to include these areas, and with this extrapolation, all of the points except one plot in the area of surface overland flow with erosion. The remaining point plots in the region of landsliding and surface overland flow.

Interpretation: A possible flaw introduced into this work is in the data collection. The MOLA data is still relatively sparse for this type of high resolution work. The MOC (Mars Orbiter Camera) narrow-angle images do not resolve a large enough area to help determine the extent of the drainage area above a channel head, and the MOC wide-angle images are often of too low a resolution to be useful. Errors are easily introduced into the calculations of slope and area. The slopes appear reasonable, while the areas are orders of magnitude above what seems reasonable for terrestrial approximations. The MOLA data are not easily manipulated or gridded, so determining drainage areas becomes quite difficult. This will be rectified fairly soon, with the release of more data, and computer programs to utilize this data.

It is also possible that the selection of channel heads was incorrect, and that the graphs represent processes occurring farther downstream. The degraded and discontinuous nature of the valley networks presents great difficulties in assessing where they begin. It is also plausible that tectonics and other processes affected the regions in which the valley networks occur after channel formation had ceased, thus skewing the data.

Another possibility is that both the extrapolation and the drainage areas are correct, and this is an accurate representation of processes which occurred on Mars in its past. If true, this leads to the quite important realization that at some point, water did flow on the surface of Mars, and exceeded the critical shear stress of the ground such that channels were carved.

Application of Terrestrial Geomorphic Threshold Theory to Small Channels on Mars: E. B. Rosenshein, R. Greeley, and J. R. Arrowsmith

While it is true that our data plots beyond the scope of Dietrich et al.'s 1992 [4] work, this does not indicate that our results are erroneous. The extrapolation given to the data is justifiable as a first approximation solution, because this extrapolation continues the earlier trend of the thresholds. These data would be better understood if the geomorphic thresholds were recalculated, using the variables appropriate to Mars.

Conclusion: The method put forth by Montgomery and Dietrich (1988, 1992, 1994) [1,2,3] and Dietrich et al. (1992) [4] provides a way of quantifying where channels begin in a landscape. One of the great mysteries of the planet Mars is how the valley networks formed- was it from surface overland flow or from sapping? Using Montgomery and Dietrich's (1988, 1992, 1994) [1,2,3] model is one way to evaluate this problem. The resolution of MOLA data, along with the resolution of images, are the largest problems uncovered so far. Determining variables for use in the equations for thresholds of geomorphic processes will be a problem as well.

These obstacles did not prevent us from conducting a preliminary characterization of the Martian landscape. The unexpected results serve to highlight the difficulties in applying this hypothesis to Mars. We are continuing our investigation into this problem, however, and hope to soon overcome the problems inherent to this application.

Acknowledgements: This work is supported in part by a NASA Space Grant.

References: [1] Montgomery, D.R. and Dietrich, W.E. (1988) *Nature 336*, 232-234. [2] Montgomery, D.R. and Dietrich, W.E. (1992) *Science 255*, 826-830. [3] Montgomery, D. R. and Dietrich, W.E. (1994) In: Process Models and Theoretical Geomorphology (Kirby, M.J., ed.), 221-246. [4] Dietrich, W.E. et al. (1992) *Geology 20*, 675-679. [5] Baker, V.R. et al. (1992) In: Mars (Kieffer, H.H. et al., eds.), 493-522.

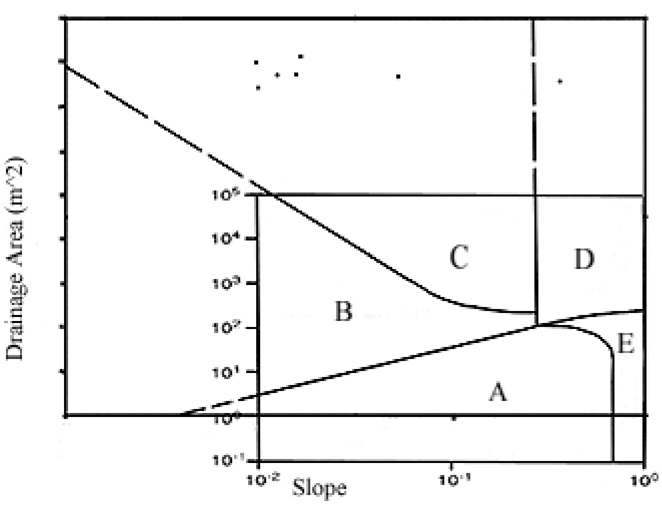

Figure 1: Drainage area vs. slope plot, adopted from [4], showing both the theoretical thresholds and our data. These thresholds depend on several key variables, including gravity, transmissivity, precipitation, the critical boundary shear stress, and the angle of internal friction. The thresholds define the following areas : A- diffusion dominated erosion, B- surface overland flow with no erosion, C- erosion caused by surface overland flow, D- surface overland flow and landsliding, E- erosion caused by landsliding alone. Sapping is assumed to occur in the areas of A and E, with low areas and high slopes. Precipitation and runoff processes dominate the area on both sides of the line separating areas B and C.