Relating Martian Gullies to Material Properties of Mars Regolith Simulant, JSC Mars-1. D. M. Lorenz[1,2] and A. Elshafie[1], J.C. Dixon[1,3], [1]Arkansas Center for Space and Planetary Sciences, University of Arkansas, Fayetteville, AR 72701, [2]Barrett Honors College, Arizona State University, Tempe, AZ 85281 [dlorenz@asu.edu], [3]Department of Geosciences, University of Arkansas, Fayetteville, AR 72701

Introduction: From the arrival of Mars Global Surveyor (MGS) to the planet in 1997 until its radio silence in 2007, the Mars Orbiter Camera (MOC) relayed to Earth more than 240,000 images of the Martian surface (Fig.1). However, it was not until the analysis of Malin and Edgett in 2000 that the potential of gully investigation based on such images was fully realized. They laid out the big questions concerning the possible environmental sources and processes that contribute to Martian slope failure and induce the formation and development of gullies [1]. Since these possibilities were suggested, much more research has been initiated that aims to expose any details, including the launch of more advanced Martian orbiters, such as the Mars Reconnaissance Orbiter (MRO) that continues to relay images back to Earth. With these massive stock piles of gully images, it is our objective to find ways to extract from them more information than the presently obtainable basic slope geometry to reveal more about the geomorphology.

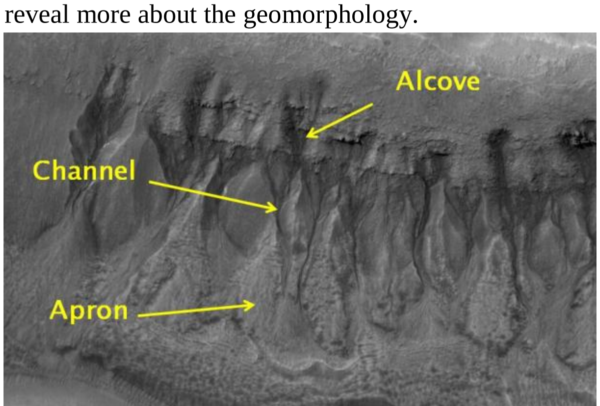

Figure 1: Example of Martian gullies with well-defined components shown with labels; image captured by MOC

In the research of Perko and Nelson, the idea is presented to combine slope stability analysis with another method of determining shear strength by means of orbiter images so as to reduce an infinite set of cohesion and angle of internal friction values—two factors that determine slope stability—to a single pair of values [2]. After his experiments involving shear tests on Mars soil simulants show a direct relationship between relative density and angle of internal friction, trial and error in using Slope/W software reveals that cohesion is a negligible factor in Mars slope stability analysis [3]. For these reasons, we focus our analysis on the two factors of internal friction angle and bulk density, a measure of the soil compaction level. We hope to draw a connection between these mechanical properties of Mars regolith simulant JSC Mars-1 and the shapes of simulated gullies to relate to available orbiter images.

Methods: Simulations were performed in a flume apparatus designed specifically for the purpose of analyzing gully formation processes. The original flume component measures approximately 0.5x2.0m^2 but was shortened in length to 0.5x0.65m^2 to facilitate greater efficiency. Water flows from an over-head bucket, through a flow meter and exits out of tubing buried beneath the regolith surface at the point of slope failure (Fig.2).

Figure 2: Experimental set up with labels

For each trial, we fill the flume with a known mass of regolith and compact it to a certain bulk density calculated through taking three height measurements of the regolith surface from the base of the flume with a vernier caliper and dividing mass of regolith by its volume. Once the surface is as leveled as possible, we raise the end of the flume to a specific height to approximate a slope angle of 10°.

We turn the flow meter to an approximate output of 6 or 7 gallons per hour and watch each gully form until a depositional apron develops. After switching off the water flow, we record photographs and measurements of length and average width for the alcove, channel, & apron as well as total length. To promote consistency, we recorded the time of each initial run so as to repeat each subsequent trial in the same amount of time for that individual density. We repeated this procedure at 3 different bulk densities for JSC Mars-1: 863.15, 973.85, and 979.41 kg m^{-3}.

Results and Discussion: Nine gully forms were successfully produced using the JSC Mars-1 simulant—three at each specified bulk density—each with a measurable alcove, channel, and apron (Fig.3).

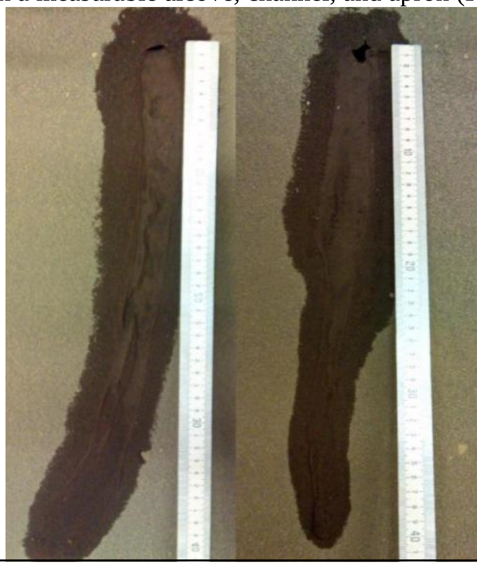

Figure 3: Two consecutive runs (no. 9 & 10) in JSC Mars-1

We did notice a possible correlation between bulk density and length, though it was not as clear as in the preliminary tests using sand. The regolith simulant displayed much more erratic behavior compared to that of sand despite the use of identical methods. However, because the sand tests were merely a way to practice the procedure and standardize our methods, we did not show repetition for each density and therefore cannot draw any conclusions concerning those data.

Nonetheless, a pattern was noticed in which JSC Mars-1 regolith compacted to a higher bulk density yielded longer gully forms than at lower compaction levels (Fig.4). What is perhaps more surprising is that, although a possible relationship between bulk density and length was noticed in both the preliminary sand tests and the official JSC Mars-1 tests, the sand tests appear to suggest a negative correlation (higher density yields shorter gullies, Fig.5) whereas the regolith data, as just stated, suggests a positive correlation. Given that these two materials have very different properties, this result confirms the need for further investigation using other soils or regolith simulants.

Both soils did agree in suggesting that the gully component dominating each respective relationship with bulk density was the channel. Channel length showed more consistency with the suspected trend in comparison to the other components, as confirmed by the repeated JSC Mars-1 data. This result can be expected as the channel tends to account for the majority of the total length in most gullies.

Another visible trend appeared only after deciding to choose the same time that it took for the first gullies to fully form for each subsequent trial per density. The purpose of this was to increase consistency but it immediately became clear that lower densities allow gullies to form faster in the regolith (Fig.4). This also agrees with logic since there wouldn't be as much loose soil to obstruct movement.

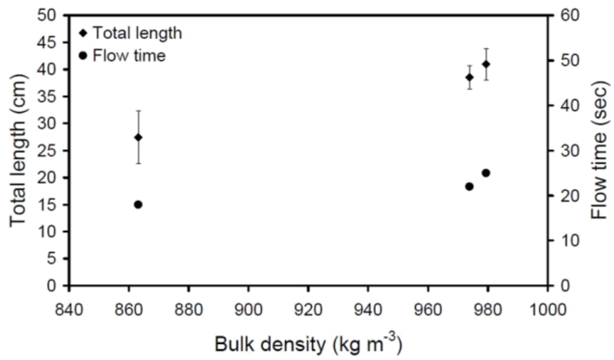

Figure 4: Results of JSC Mars-1 flume experiments

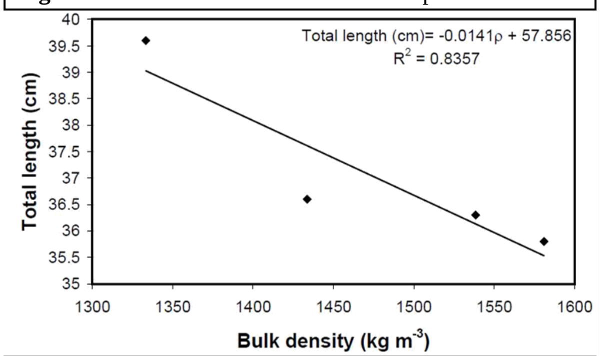

Figure 5: Results of sand experiments

Conclusion: Not many definite conclusions can be drawn to a certain and universal degree of accuracy due to the minimal amount of data available. However, it is clear that some sort of relationship does exist between the shape of slope formations and the properties of the soil upon which they form. Most likely, channel length will be the leading candidate for representation as a function of density. In order to know this relationship better, more experiments must be performed using a greater variety of bulk densities, soil analogue materials, slope angles, etc. and repeating data points many times over.

References: [1]Malin, M.C. and Edgett, K. S. (2000) "Evidence for recent ground water seepage and surface runoff on Mars" *Science*, v. 288, no. 5475, p. 2330-2335. [2]Perko, H.A. and Nelson, J.D. (2002) "Mars Global Surveyor Soil Mechanics Data Analysis" *Proceedings of Space 2002*, ASCE, p.190-198 [3]Perko, H.A., Nelson, J.D., and Green, J.R. (2006) "Mars Soil Mechanical Properties and Suitability of Mars Soil Simulants", *Journal of Aerospace Engineering*, v. 19, no. 3, p. 169-176