Correlating Martian Gullies to Mechanical Properties of Mars Regolith Analogs

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Introduction

Images of gullies on the Martian surface are continually captured directly by orbiters (Fig.1), but image analysis is limited to basic slope geometry. If we can link the shapes of simulated gullies to the mechanical properties of regolith that determine slope stability, more can be understood from images alone regarding the formation of gullies. Two principle determinants of slope stability for unconsolidated material on Mars are friction angle & bulk density[1]. Given that we have a relationship representing friction angle as a function of density (Fig.7), our objective is to find another between bulk density of regolith & dimensions of gullies that form in simulated experiments and correlate to actual Mars gully images.

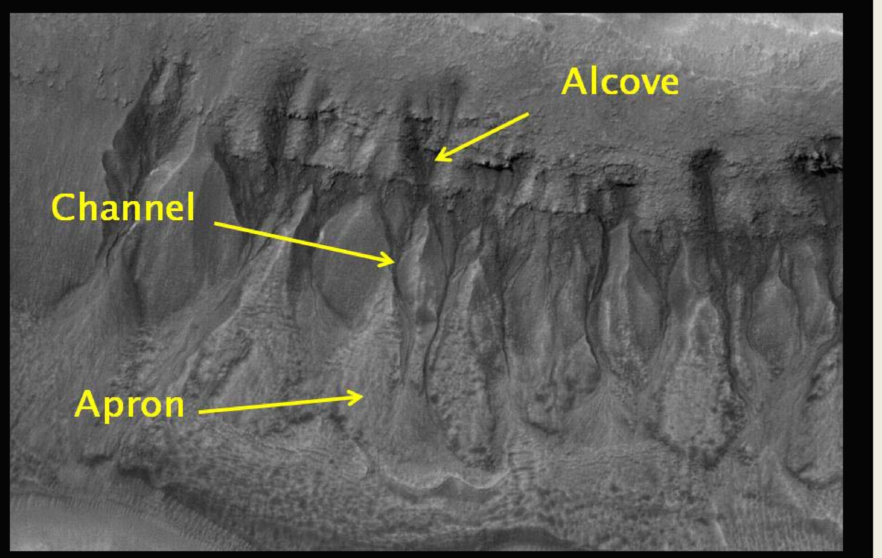
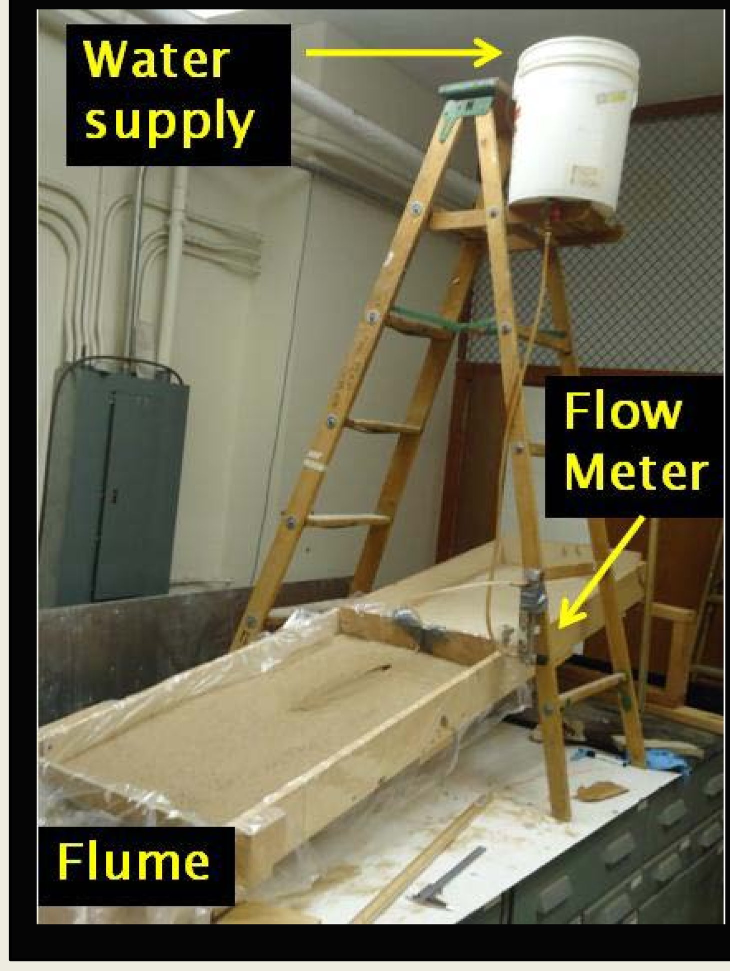


Fig. 1: 38.2°S, 190.6°W; Single impact crater in the Terra Cimmeria region; gullies shown are located on the crater's northern wall.

Methods

1. Flume experiments were run to simulate gullies at different bulk densities computed by measuring a constant surface height for a known mass of regolith.
2. Once density is fixed and regolith surface is leveled, set flume to a specific slope angle [approx. 10°].
3. Flow water at a specific rate [≈6-7 gph] until depositional apron forms. Record time of initial run per individual density and repeat the same time in subsequent trials.
4. Measure length and average width for alcove, channel, and apron as well as the total length.
5. Repeat at least three trials for each of the three densities

❖ In between runs, wet regolith dried overnight in an oven at an approximate temperature of 110°C.



❖ Preliminary sand tests were performed in the flume to practice procedure & standardize methods as JSC Mars-1 supplies were limited. Data points were not repeated as sand was not the focus of the research but are still used for comparison (Fig. 4).

Fig. 2: Flume apparatus with components labeled.

Results

Fig. 3: Comparing resultant gullies of preliminary sand tests (left) to two consecutive runs in JSC Mars-1 (right) to illustrate the difference in uniformity when working with smaller particle sizes

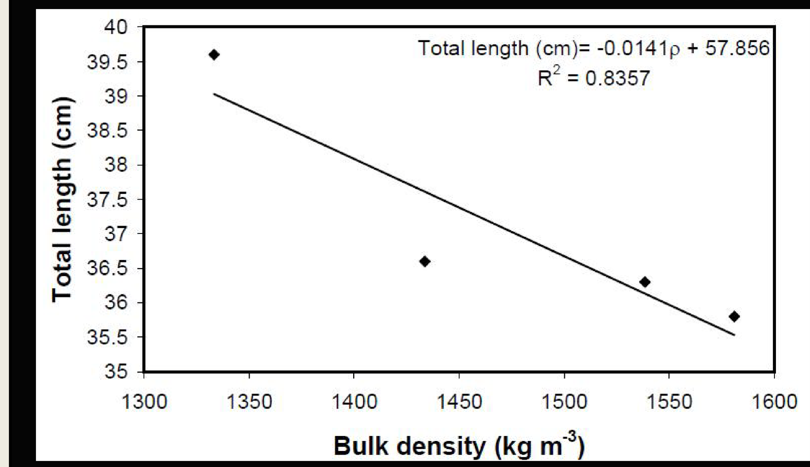


Fig. 4: Total length as a function of bulk density in sand; results inconclusive without repeatability

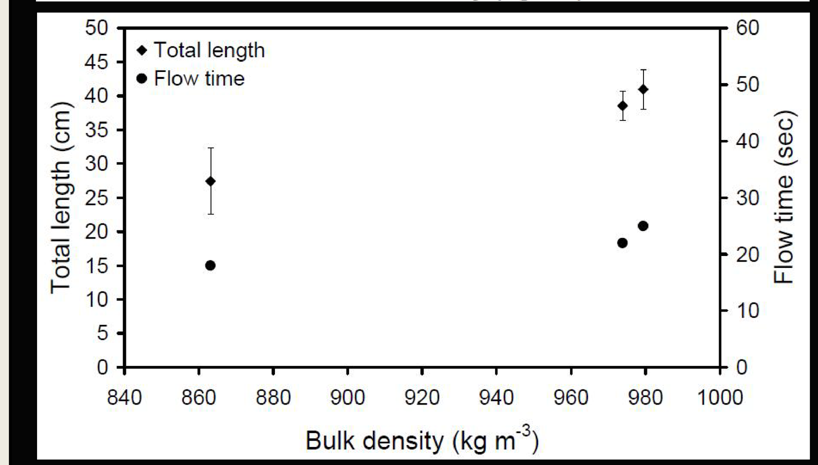


Fig. 5: Total length and flow time as functions of bulk density in JSC Mars-1

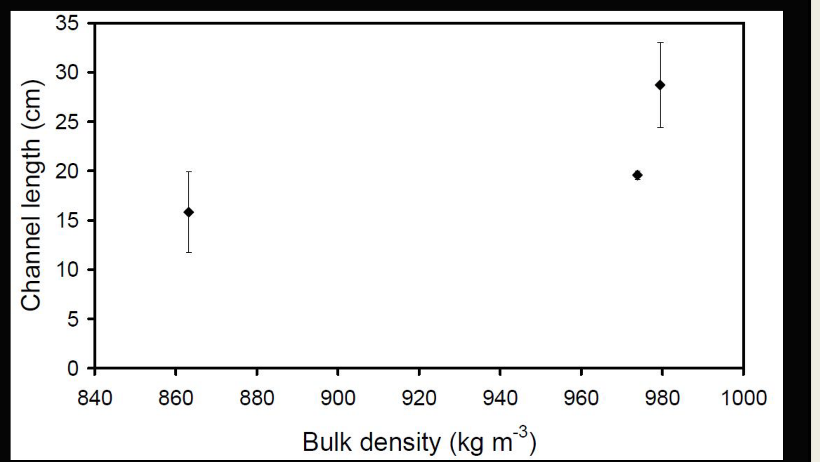


Fig. 6: Channel length as a function of bulk density in JSC Mars-1

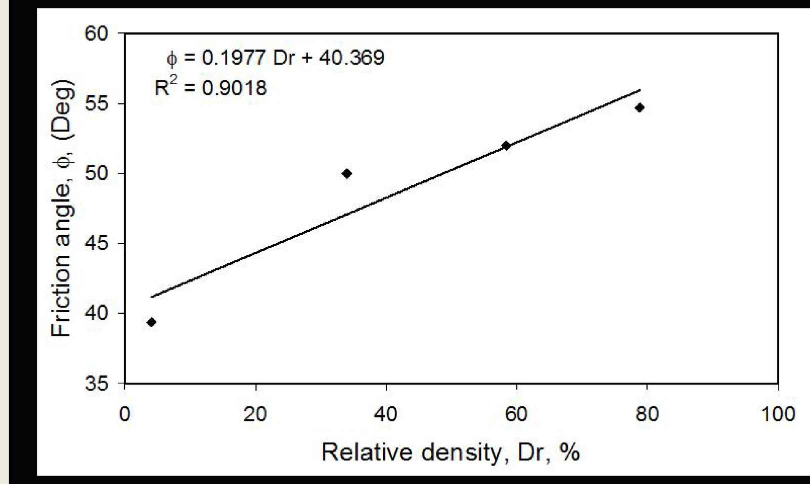


Fig. 7: Friction angle as a function of relative density in JSC Mars-1.

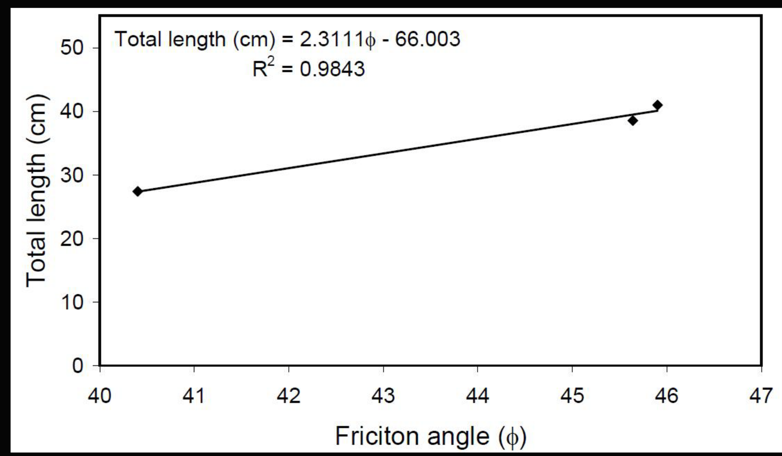


Fig. 8: Total length as a function of friction angle in JSC Mars-1, as concluded by intermediate relationship with bulk density (Fig. 7).

Discussion

- The regolith simulant displayed much more erratic behavior compared to sand despite the use of identical methods (Fig. 3). But, as sand was used only as a preliminary measure to secure methods and we did not show repetition, these data cannot be used to draw conclusions.
- Correlation between bulk density and length, though not as clear as in the preliminary tests and the two separate correlations observed exhibit slopes in opposite directions (Fig. 4,Fig. 5).
- Bulk Density seems to have the greatest impact on length of the channel, over the other components. Channel length displays the most consistency with the suspected trend, as confirmed by the repeated JSC Mars-1 data (Fig.6). This makes sense as the channel tends to account for the majority of total length in most gullies.

Conclusion

Minimal series of data limit the conclusions that can be drawn. However, it is clear that some relationships do exist:

- Bulk Density has an impact on gully length. For JSC Mars-1, total length increases as bulk density increases.
- Flow time increases as bulk density increases , therefore longer formations correspond to longer flow times (Fig. 5).
- Using relationship of friction angle as a function of bulk density (Fig. 7), total length and friction angle were found to have a positive linear correlation (Fig. 8).
- As alcove & apron lengths show much more variability, perhaps channel length will prove to be a more accurate representation as a function of density than would total length. In JSC Mars-1, channel length increases as bulk density increases.

In order to know these relationships better, we must perform more experiments using a greater variety of bulk densities, soil analog materials, slope angles, etc. and repeat data points many times over.

References & Acknowledgements

[1]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

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