MEASURING DYNAMIC ANGLE OF REPOSE IN LOW GRAVITY ENVIORNMENTS USING MARTIAN SAND DUNES.

C. Atwood-Stone[1] and A. S. McEwen[1], [1]Lunar and Planetary Lab, University of Arizona, Tucson, AZ (catwoods@lpl.arizona.edu).

Introduction: The dynamic angle of repose of non-cohesive granular material is an important parameter affecting surface features and processes. This angle is the slope at which a given avalanching granular material will stabilize and come to rest. Conventionally this angle has been assumed to be independent of gravity, however it has recently been suggested by *Kleinhans et al., 2011* [1] that, based on experiments performed during parabolic flights, this angle decreases with decreasing gravity. In order to evaluate this claim we propose to measure the dynamic angle of repose in-situ in a real low gravity environment. To this end we will be measuring the lee slopes of active sand dunes on Mars, as the slipfaces of sand dunes are known to form at or slightly below the dynamic angle of repose [2]. Specifically we will be examining three dune fields that have recently been determined to be active: Herschel Crater [3], Nili Patera [4], and Gale Crater [5]. [See Figure 1]

Methods: To measure the lee slopes of the dunes we examine the HiRISE DTMs of the three dune fields in ArcMap. We create elevation profiles through the slipfaces of a total of sixty-eight sand dunes in the different locations. The data in these profiles is then examined, and each profile is cut down such that only the relatively linear portion representing the slipface itself remains. A line of best fit is then calculated for each profile, the slope of which is considered to be the slope of the dune.

The dunes in each field should show a small range of slopes. The steepest slope that is measured in a field (excluding outliers) is taken to be the dynamic angle of repose for the sand found in that area. On Earth the dynamic angle of repose for desert sand dunes ranges between 30° and 35° [6]. This variation is due to certain properties of the local sand, primarily grain roughness and angularity. MER results indicate that Martian sand grains are similar to dune sands in terrestrial deserts. Thus if the dynamic of repose is independent of gravitational acceleration then we would expect the dynamic angles we measure in Martian dune fields to fall in this range. If however the results of *Kleinhans et al., 2011* [1] are accurate then we should observe that the angles for the Martian dune fields are 5° to 7° lower then those found on Earth.

Results: The slopes measured for the Herschel Crater dunes range (barring a few outliers) between 28° and 31°, weighted somewhat toward the top of that range, thus the dynamic angle for the Herschel Crater dune field is ~30-31°. In Nili Patera slopes are

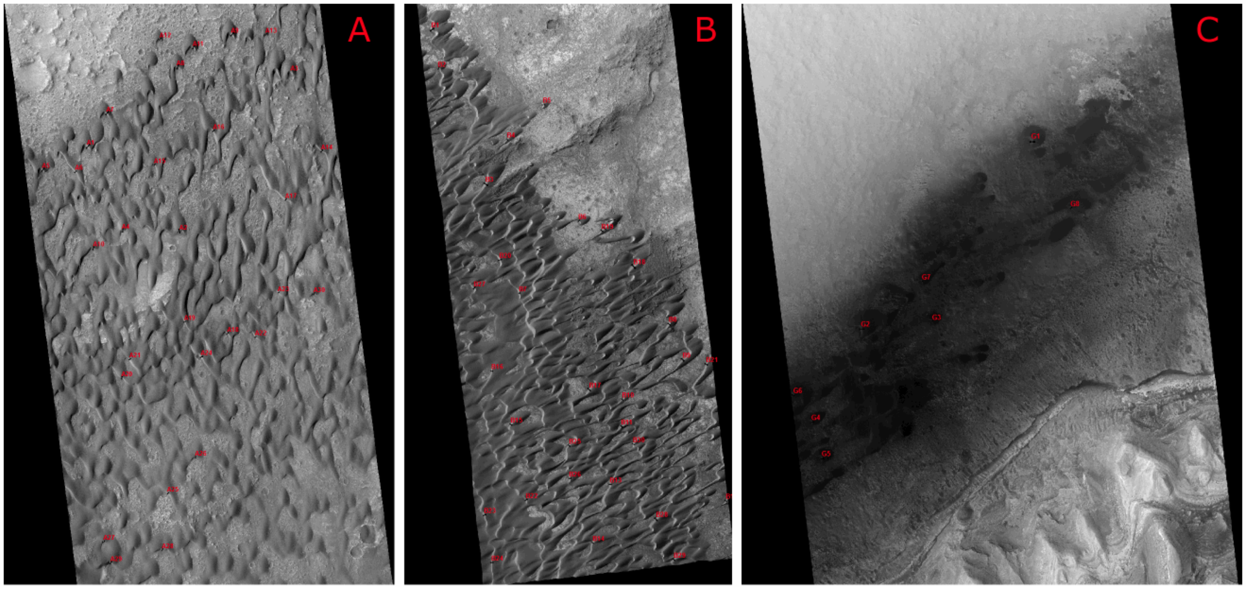

Figure 1: HiRISE orthoimages of A: The Herschel Crater dune field DTM [DTEEC_002860_1650_003572_1650_U01], B: The Nili Patera dune field DTM [DTEEC_017762_1890_018039_1890_A01], and C: The Gale Crater dunes DTM [DTEEC_012551_1750_012841_1750_U01]. The red alphanumeric codes on the orthoimages show the approximate locations of the different dunes measured for this project.

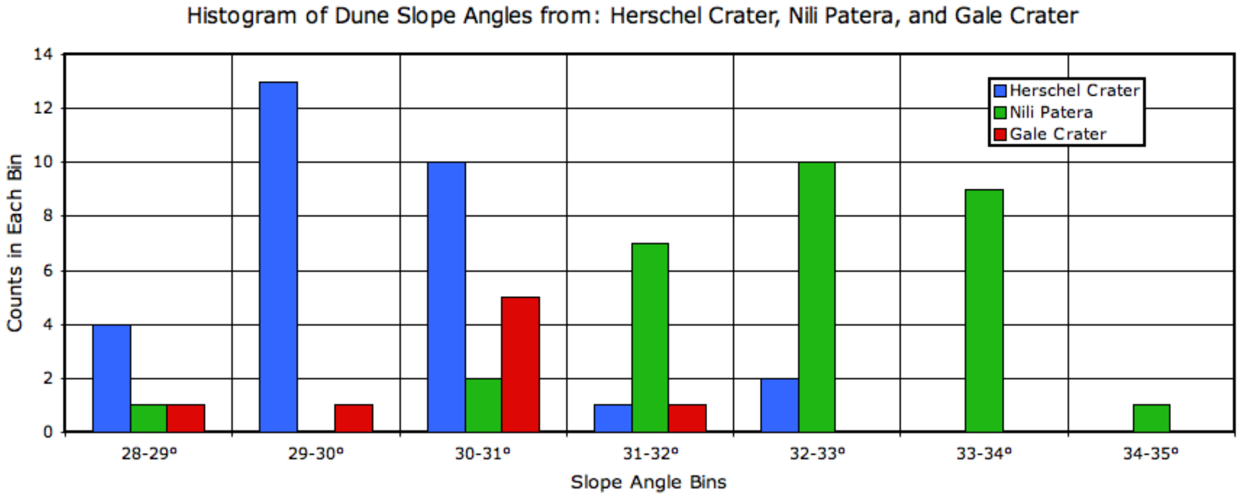

Figure 2: Histogram of measured slope angles from Herschel Crater, Gale Crater, and Nili Patera binned into one-degree increments. The steepest bin filled by each dune field (excluding obvious outliers) is taken to be the angle of repose for the sand of that region. Thus Herschel Crater and Gale Crater have dynamic angles of repose of approximately 30-31° each and Nili Patera has a dynamic angle of repose of approximately 33-34°.

measured between 31° and 34°, indicating a dynamic angle for the dune field of ~33-34°. Finally at Gale crater slopes were measured between 28° and 31°, strongly weighted toward the top of that range, which gives up a dynamic angle of repose of ~30-31°. [See Figure 2] These dynamic angles of repose fall within the 30° to 35° range observed on Earth, and furthermore show values near both the top and the bottom of that range. Therefore we are able to show, using in-situ measurements in a low gravity environment, that the dynamic angle of repose is independent of changes in gravitational acceleration.

Discussion: Another interesting result that comes from these data is that the dynamic angle at Nili Patera is ~3° lower than that found at the other two dune fields. This should indicate that the Nili Patera sands are rougher and more angular than those found at Herschel and Gale Craters, which in turn implies that the Nili Patera sands are less mature and shorter traveled. This result fits nicely with our observations of these regions as a probable nearby sand source has been identified for Nili Patera [7], whereas a similar local source is not evident for Herschel or Gale Craters. Thus we are able to learn about sediment texture using orbital imagery.

The *Kleinhans et al., 2011* [1] results have been used recently by *Horgan and Bell, 2012* [8] to suggest that Martian dune gullies are able to form at their observed low angles without the action of CO_2 frost [9, 10], but instead form by simple dry granular flow with lower dynamic and higher static angles of repose. Our results show that lower gravity will not lead to a lower dynamic angle of repose of dry material on Mars, and thus support the observation of CO_2 frost in the formation of the Martian dune gullies.

In sum, by measuring the lee slopes of active Martian sand dunes using HiRISE DTMs we are able to determine that the dynamic angle of repose of dry granular material is in fact independent of gravitational acceleration.

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