MODELING BRIGHT GULLY DEPOSITS' FORMATION IN HALE CRATER. K. J. Kolb[1], O. Aharonson[2], J. D. Pelletier[1], A. S. McEwen[1], and the HiRISE Science Team, [1]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721; kkolb@LPL.arizona.edu, [2]Division of Geological and Planetary Sciences, California Institute of Technology, MC 150-21, Pasadena, CA 91125.

Introduction: Hale Crater, a Late Hesperian/Early Amazonian [1] 120 km x 150 km impact crater, hosts a large number of giant gullies (or ravines) with a variety of orientations. Gully distributions and orientations have strong implications for distinguishing among gully formation theories, which frequently depend on insolation or a local aquifer. Several of the gullies exhibit bright deposits that are unmodified at the 0.26 - 0.31 cm/pixel scale of images acquired by the High Resolution Imaging Science Experiment (HiRISE) aboard the Mars Reconnaissance Orbiter (MRO). Two recently formed bright gully deposits (BGDs) imaged by the Mars Orbiter Camera (MOC) at other locations were initially interpreted as evidence for water on the surface in recent years [2]. One of these BGDs was modeled by Pelletier et al. [3] who found that, although water could not be ruled out in the formation of the studied BGD, the dynamics of dry flows were sufficient to account for the observed morphology. Whether the bright gully deposits' formation requires liquid water is an important question because they have the potential to mark sites of recent liquid water on the martian surface.

HiRISE has imaged several other unmodified BGDs, most of which occur in fresh craters on steep slopes averaging 26-35° [4]. The average slopes along the east rim of Hale Crater are ~19-20°, and four BGDs are located there as seen in HiRISE images (Fig. 1). Average slope values do not account for the concavity of crater walls seen in visible imagery, so high-resolution topography is needed. Due to the lower average slopes, we suggest that the Hale BGDs are some of the best candidates for extremely recent deposits that required fluidization, such as saturation by liquid water [5]. Here, we have derived a Digital Elevation Model (DEM) in order to model BGDs and determine their best-fit flow parameters.

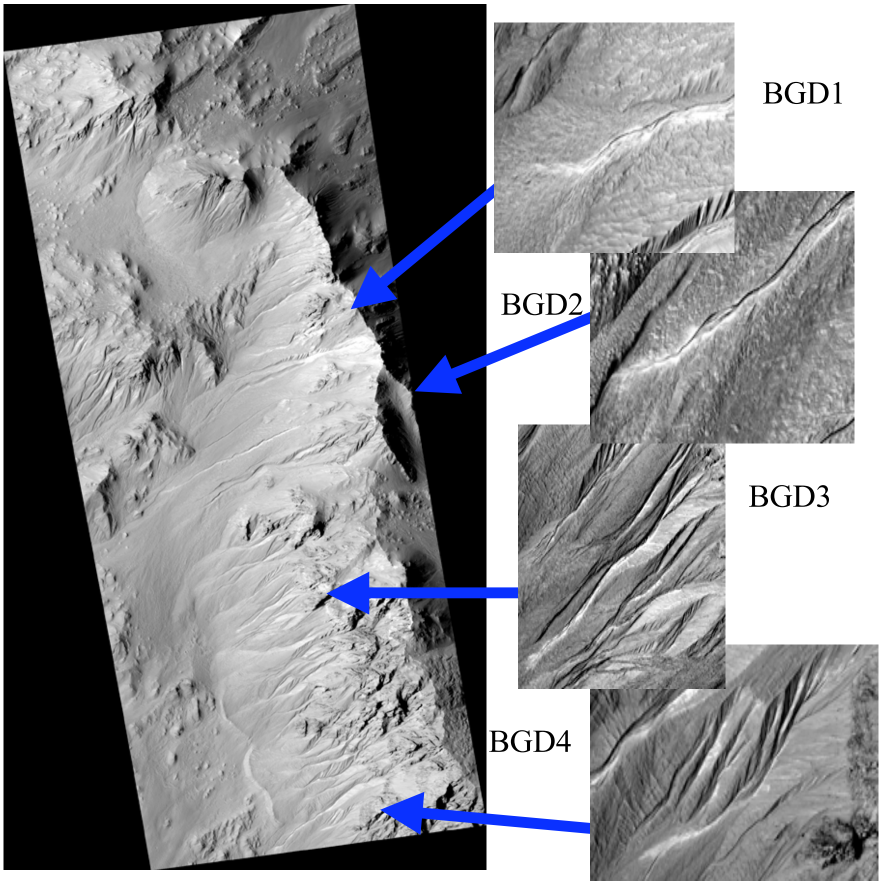
Observations: The BGDs seen in the HiRISE images include four clear features (Fig. 1) and three fainter ones, all of which exhibit a redder signature than the bluer surrounding gully deposits in RGB composite images (Fig. 2). BGDs elsewhere on Mars imaged in color HiRISE images have similar colors-reddish, but not as red as the dust mantles covering much of the planet. All of the BGDs seen in the HiRISE stereo pair are present in MOC image R0702277, the earliest (2003) high-resolution image of this region. No visible changes in shape have been detected, as would be expected if the deposits were composed of water frost [6]. We support the hypothesis that the deposits are bright because they contain light-toned or fine-grained material that was transported by the flow. Bright material is obvious upslope of the BGDs and appears to be pervasive throughout the crater.

Gullies in Hale Crater emanate from isolated mounds and terraces, the central peak, and the rim and exhibit many fluvial characteristics. Their channels often meander and have terraces indicative of past flow levels, while some contain streamlined islands. We interpret the BGDs as recent activity within gullies rather than marking the initial gully formation. Although there are no previous images without the BGDs here, there is good evidence that the host channels existed before they formed (e.g. BGD 4, Fig. 2). Also, the deposits have volumes orders of magnitude less than that removed to form the gully alcoves and channels.

All of the Hale BGDs reside in gullies that exhibit well-developed fluvial characteristics. This is atypical of other BGDs, which typically are located in gullies with narrow and shallow channels [7]. The Hale BGDs stand out in false color images (Fig. 2), but their host gullies are not obviously unique in grayscale images. It can be noted that, overall, gullies in Hale show little modification.

Methods: We produced a high-resolution DEM (1 m/post) of a portion of Hale Crater using the commercial stereo software package SOCET SET (® BAE Systems) [8] and the HiRISE stereo pair PSP_002932_1445 and PSP_003209_1445 processed using ISIS3 from the USGS [9]. High-resolution topography is essential for modeling flows in gullies because their scale (typically 10s to 100s of meters wide) is much smaller than available topography from the Mars Orbiter Laser Altimeter (MOLA), which has spot diameters of ~168 m and along-track spacing of ~300 m [10].

We extracted 1D flow paths through the gullies with bright deposits by following the direction of steepest descent using RiverTools [11] to examine the potential source regions' slope profiles. We selected a pixel corresponding to the furthest extent upslope that we could trace a particular channel and examined the flow path produced. The extracted 1D slope profiles include steep slopes consistent with a dry mass wasting initiation of downslope movement



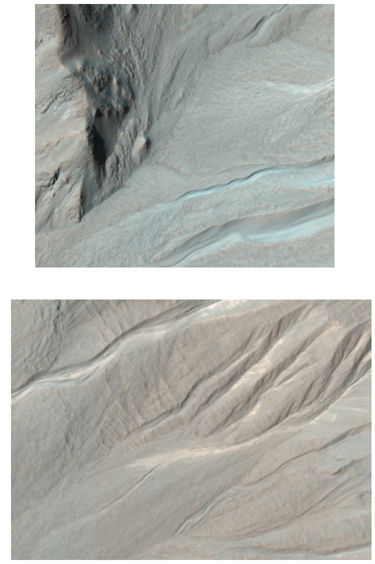


Figure 2. RGB false color image PSP_003209_1445. Not map projected. Rotated so that north is roughly up. Top (~1050 m across) shows redder color of BGD1 compared to an ordinary (blue) debris apron. Bottom (~800 m across) shows BGD4 forming midslope.

Figure 1. HiRISE PSP_003209_1445, ~5 km across. North is up with illumination from the upper left. Blue arrows mark the alcoves of the gullies with bright deposits.

for the bright gully deposits in Hale. It should be noted that analysis of the Hale DEM is particularly complicated because the gullies are well developed and contain multiple channels within individual ravines.

Future Work: We plan to follow the modeling methods of Pelletier et al. [3], which are briefly described here, to model BGDs 1, 2, and 3 seen in Fig. 1 (BGD4 is cut off on the edge of the DEM). We will model the flows with FLO-2D [12], a 2D finite-difference code that solves the dynamic wave momentum equation and models open channel flow quantifying fluid drag with a Manning roughness or a Bingham rheology.

We will use 1D kinematic modeling to determine the viscosity and yield stress of a dry granular flow, for a given average particle size, flow thickness, flow density, and particle density, that would occur where each of the BGDs is found along the slopes. These parameters are input into FLO-2D to mimic a dry granular flow. Output of the models includes flow paths, depths, and velocities. We will compare the flow paths and resulting deposit morphologies to the actual BGDs and determine if the best-fit flow parameters are consistent with dry granular or fluid flow. While distinguishing between wet and dry debris flows is difficult due to the similarities in flow parameters found in terrestrial settings [3], but we distinguishing between a debris flow and a fluid carrying sediment is possible.

References: [1] Cabrol N.A. et al. (2001) *Icarus*, 154, 98-112. [2] Malin M.C. et al. (2006) *Science*, 314, 1573-1577. [3] Pelletier et al. (2007) submitted to *Geology*. [4] McEwen A.S. et al. (2007) *Science*, 317, 1706-1709. [5] Kolb K.J. et al. (2008), *Workshop on Martian Gullies*, Abstract 8028. [6] Williams K.E. et al. (2007) *GRL*, 34, doi:10.1029/2007GL029507. [7] Kolb K.J. et al. (2007) *Seventh International Conference on Mars*, Abstract 1353. [8] Kirk, R.L. et al. (2007) *Seventh International Conference on Mars*, Abstract 3381. [9] http://isis.astrogeology.usgs.gov/ [10] Neumann G. A. et al. (2001) *JGR*, 106, E10, 23,753-23,768. [11] Rivix, LLC. (2005), RiverTools 3.0. [12] FLO Engineering, Inc. (2006), FLO-2D User Manual, Version 2006.1. Nutrioso, Arizona.