SLUSHFLOWS AS ANALOGS FOR MARTIAN GULLY FORMATION. K.A. Coleman[1], J. Dixon[1,2], K. L. Howe[3], V. F. Chevrier[1] 1W.M. Keck Laboratory for Space Simulations, Arkansas Center for Space and Planetary Science, MUSE 202, Fayetteville, Arkansas, USA < ksacolem@uark.edu>, 2Dept. of Geological Sciences, 113 Ozark hall, University of Arkansas, Fayetteville, Arkansas, USA,

Introduction: Since gullies were identified by Malin and Edgett on the surface of Mars [1] the processes of formation have remained controvertial [5-9]. In an effort to constrain the parameters of the gully forms on Mars, we developed a series of simulations of gully processes. We performed simulations using slush-ice based on suggestions that surface and subsurface ice could be partially melted by summer insolation [6] and the initial convincing arguments that gullies were created by debris flows composed of liquid water mixed with rocks and residual water ice [1].

Because evaporation rates have recently been shown to be lower on Mars than originally suggested [10, 11], we wanted to further explore our theory that slushflows are an appropriate analog to gullies on the surface of Mars. As an extension of a series of simulations attempting to identify a water-based origin for these forms, we undertook a series of flume experiments at Earth surface temperatures and pressures to explore the potential role in gully formation of water volume percentages in the slush. Our objectives were to better understand the relationships between water content in the slush and gully forms produced in the simulations that are similar to those observed on Mars (Fig 1).

Figure 1. Gully seen in ESP_013858_1405 that shows a small apron, channel, and thin apron. Image Credit: NASA/JPL/Malin Space Science Systems

Methods: Experiments were conducted in a 3 m x 0.5 m flume filled with medium grain size sand [13]. Water-ice slush, with varying ice/water percentages, was fed through a 19 mm silicone hose .3 m long to be released on the sand surface at the top of the slope. Flow volumes of slush were controlled by using a carefully measured recipe of water and crushed ice. The experiments were run over a slope angle range of 10° - 30°, corresponding to the range for gullies on Mars [4]. Simulations were run using 10 to 90 percent water by volume with crushed ice crystals. Photos of each run were taken with labels. A variety of morphometric parameters were identified and measured on each gully on which they occurred. These parameters were length, depth, and two width components on each alcove, channel and apron and a total gully length.

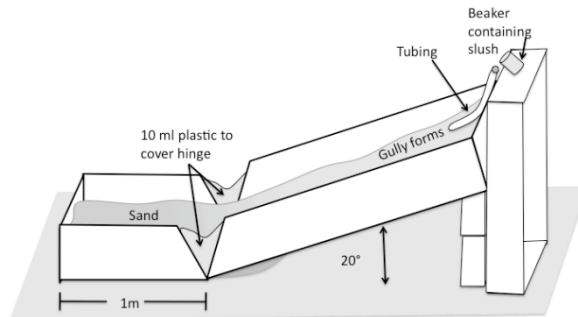

Figure 2. Experimental design of flume. |A wooden, hinged flume 3 m. x 0.5 m. was filled with level sand. The slope end was raised on blocks to 10º, 20º, or 30º. Slush was poured into 19 cm diameter tubing with one end mounted 15 cm above the sand and the other end lying on the surface of the sand to simulate the release point in a slushflow. Photographs were taken of each gully along with a variety of measurements of gully parameters.

Results: Gully forms were successfully reproduced and displayed development of the fundamental morphological components observed on Mars: alcove, channel, and apron [1]. The forms created using between 30% and 60% water in the slush (Figure 3), created forms that similar to the gully forms observed on Mars in MOC and HiRISE imagery. When water/ice slush containing only 10% water was used the process did not create gullies. The ice piled up at the mouth of the tubing and did not flow. Once it melted, the form looked nothing like a gully. Likewise simulations using 60% water and higher were not similar to gullies because they lacked a channel or apron.

Discussion: We have previously shown that gullies with morphologies resembling those of Mars can be produced by running water within our experimental flume and that it is possible to quantitatively identify controlling factors on gully morphology at earth temperatures and pressures [11, 12]. By moving to ice slush fluids and higher viscosities we are moving toward martian conditions in the simulations because average martian surface temperatures near 273K would

indicate the potential presence of ice in any water present on the surface.

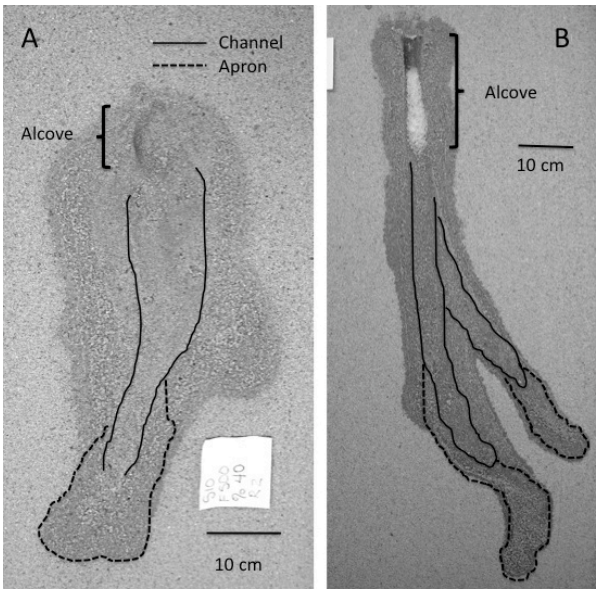

Figure 3. A) Gully created on a 10º slope with 500 ml of 40% water slush. The alcove is small and the channel narrows significantly downslope. Small levees were present on the channel and a thin apron developed from accumulated larger grains of sand. B) Gully created on a 30º slope with 750 ml of 40% water slush. An elongated alcove formed. The channel branched and aprons developed below both branches.

From the experiments reported in this study we suggest that slushflows composed of liquid water mixed with rock and residual rock ice would be an appropriate Earth analog for gully formation on Mars. One of the most important features of slushflows is the water content as the snowpack must be partially to completely saturated [14]. For this reason we performed simulations of 10% – 90% water at 10% intervals in an attempt to observe the changes in the forms produced at the different water percentages. Simulations containing between 30% and 60% water by volume created gullies similar to those observed on Mars. In these forms the slush eroded an alcove. Then the slush and entrained sediment moved downslope through a channel. Because the slush eroded sediment from the alcove, an apron formed at the end of the channel when velocities slowed.

The low water content simulations did not create gullies. They lacked enough water in the slush to facilitate flow down slope. The very high water content flows do not look like martian gullies because they lack both channel and apron. The ice crystals and sediments were so diluted by water that the flow did not attain the force required to erode more than a cursory alcove. An entrenched channel never developed and and there was not enough entrained ice crystals and sediments to create an apron.

Conclusion: Simulations performed in our flume with 30% - 60% water volume in the slush created gully forms similar to the gullies observed on Mars. Slushflows are supported as a viable Earth analog for martian gullies based on the water volumes included in the simulations that approximate martian gullies. Simulations with water volumes outside the limitations of slushflows did not create geomorphic forms similar to martian gullies.

References: [1] Malin, M.C. and Edgett, K.S. (2000) *Science, 288,* 2330-2336. [2] Heldmann, J. L.and Mellon, M.T. (2004) *Icarus, 168,* 285-304. [3] Balme M. et al. (2006) *JGR, 111,* E05001. [4] Dickson, J. L. et al (2007) *Icarus, 188,* 315-323. [5] Musselwhite, D. S. et al. (2001) *GRL, 28* 1283–1285. [6] Costard F. et al. (2002) *Science, 295,* 110-113. [7] Christensen, P.R. (2003) *Nature, 422,* 45-48. [8] Heldmann, J.L. (2005) *JGR,110,* EO5004. [9] Bart, G. D. (2007) *Icarus,187,* 417-421. [10] Sears, D. W. G. And Moore S. R. (2005) *GRL, 32*, L16202. [11] Ingersol, A. P. (1970) *Science, 168*, 972. [12] Dixon et al. (2007) *Mars Gullies: Theories and Tests.* [11] Coleman et al. (2007) *2nd International Workshop Exploring Mars and its Earth Analogues*. [12] Coleman et al. (2009) *Planetary and Space Sciences, 57,* 711-716. [13] Coleman et al., *GSA*, *submitted*. [14] Luckman. (1977) *Geog. Annul. 59,* 31-48.