EVAPORATION EFFECTS ON THE FORMATION OF MARTIAN GULLIES. K. L. Bryson[1] and D. W. G. Sears[1,2], [1]Arkansas Center for Space and Planetary Science, University of Arkansas, Fayetteville, AR 72701, [2]Chemistry and Biochemistry, University of Arkansas <katie@weirdguy.net>.

Introduction: Gully features were first observed in the images taken by MOC in impact craters, south polar pits and large martian valleys [1], tending to mid-latitudes [2]. HiRISE imagery supports the conclusion that the gullies were formed by fluvial erosion [3], but the source and composition of this fluid is unclear. The superposition of the gully aprons over aeolian features, e.g. dunes, suggests gullies to be relatively young. These features are usually interpreted in terms of groundwater surface runoff and infiltration, so their length is governed by loss of water due to infiltration into the regolith [1]. However, another factor possibly controlling gully length is the evaporation of the fluid carving the gullies, in which case we might observe a relationship between gully length and the structure of the adjacent dunes [4]. The number of dune crests per unit length (dune frequency) is a function of wind speed; all else being equal, and wind speed is a factor in determining evaporation rate of fluids on the surface of Mars.

The linear increase of the evaporation rate of water for wind speeds ranging up to 12 m s^{-1} at -15ºC has been experimentally determined [5]. The dependence of evaporation on wind speed is not strong, and temperature plays a more important role in determining evaporation rates. However, at lower temperatures the data shows [5] that the dependence of evaporation rate on wind speed is more significant.

This study explores the possible relationship between the gully length and wind speed as reflected in dune frequencies. We predict that if evaporation is a limiting factor in gully formation that a given location on Mars, and all else being equal, there should be a negative correlation between gully length and dune frequency. In addition, the slope of the correlation will be temperature dependent, the correlation will be steeper for gullies forming at low temperatures. The formation of gullies at temperatures much below zero Celsius requires that the gullies were formed from strong brine solutions. Brine solutions such as NaCl and $CaCl_2$ have eutectic points near 30ºC [6] while ferric sulfates have eutectic points as low as -98 to -68º C [7].

Methods: Images containing gullies and dunes from mid martian latitudes and varying longitudes were examined. Processed HiRISE images that have been radiometrically calibrated, stitched, and geometrically projected were used. After ensuring that the gullies and dunes were fresh and that the image contained at least five gullies suitable for these measurements, twelve HiRISE images with the geographical distributions shown in Figure 1 were selected and gully parameters and dune frequencies were measured. Since dunes are more prevalent in the southern hemisphere in craters [8], all but one of the images is located inside a crater and only three of the images are from the northern hemisphere. The alcove, channel, apron, and total gully lengths were measured for each gully, while the frequency of linear and transverse dunes at the base of each gully were measured.

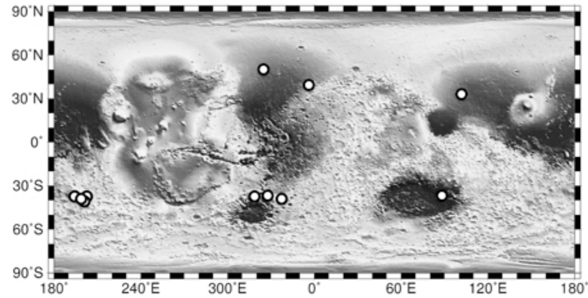

Figure 1. *The distribution of images examined in this study overlain on a grayscale MOLA map (Courtesy GSFC/NASA). The images are distributed over a variety of landscapes, but are dominate in the southern hemisphere as most dunes on Mars are prevalent in southern hemisphere craters.*

Results: Figure 2 presents an example of a HiRISE image measured and the resulting graph of total and component lengths versus dune frequency. To identify the images in which an inverse correlation is present, a statistical test of significance was per formed (Table 1). Relationships between component length and dune frequency were observed in two of the images where no inverse correlation to total gully length was observed. The lack of an inverse correlation between total gully length and dune frequency in these images may be due to degradation of the gullies or differences in local stratigraphy.

Discussion: The four images in which neither total gully length, or the lengths of any of the components of the gullies, display a relationship with dune frequency, suggests that either the wind velocities were too low to influence evaporation, or that temperatures were too high to cause significant dependence of the evaporation rate on wind velocity. In one of these images (PSP_003662_1410) the dune frequencies are over a very small range, which could result in the lack of a noticeable effect of wind on evaporation rate.

The slopes of the inverse correlations can give relative temperatures during the formation of the gullies (Table 1). Those with similar trend line slopes that

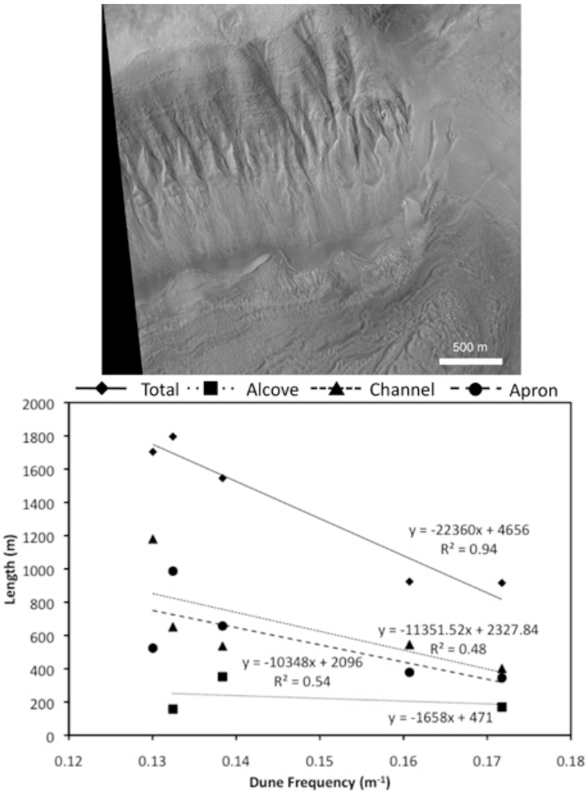

Figure 2. *A HiRISE image (PSP_004176_1405) measured with graph of gully components and total gully length versus dune frequency. For the gullies and adjacent dunes shown in this image the shorter the dune frequency the longer the total, channel, and apron lengths.*

are gentler likely formed at similar and warmer temperatures then those with steeper slopes.

Though the graph of measurements taken in image PSP_002114_2300 do not show an inverse correlation

Table 1. *Slope and statistical data for total gully length and dune frequencies. N is number of gullies. Statistical significance is the 85 (p<0.15) or 95% confidence level (p < 0.05).*

	N	R^2	p-value	Slope
No correlation				
PSP_001908_1405	5	0.00	0.93684	-38
PSP_002330_1385	10	0.03	0.64471	-844
PSP_003662_1410	5	0.14	0.52831	14906
PSP_006794_2200	5	0.01	0.88793	829
No correlation in Total length, but with components				
PSP_002114_2300	6	0.05	0.67162	-5185
PSP_006922_2120	6	0.03	0.75698	-577
Inverse correlation				
PSP_004176_1405	5	0.94	0.00591	-22360
PSP_005648_1405	5	0.55	0.1506	-22427
PSP_006791_1415	7	0.69	0.02015	-15221
PSP_006866_1375	6	0.42	0.16099	-4225
PSP_006888_1410	5	0.92	0.00984	-8508
PSP_006922_2120	9	0.76	0.00225	-6621

between total gully length and dune frequency, it does show a correlation to apron and channel length. The slopes for these components in comparison to those components found in the other images are much stronger, indicating that the gullies were formed at the lowest temperatures. This is consistent with the extreme latitude of this site, 49.5 N.

Composition of Fluid: Variations in the trend slope of length versus dune frequency indicate that the ambient temperatures during gully formation differ at various sites. Since much of the martian surface is < 273 K and temperature variations are required, the fluids that formed these gullies were not pure water. Salt-rich solutions or brines can remain liquid down to -50ºC. Brines composed of NaCl and $CaCl_2$ have been suggested on Mars [6], but the chloride bearing minerals have been localized in Noachian deposits in the southern hemisphere [9]. Large evaporitic deposits of magnesium and calcium sulfates have been detected in numerous locations [10], but Mg and Ca-sulfates have high eutectic points, around 270 K [11]. Ferric sulfates can have eutectics as low as 175 to 205 K [7]. Abundant jarosite ($KFe_3(SO_4)_2(OH)_6$) has been found in Meridiani Planum [12] and some soils in Gusev Crater contain up to 30% pure ferric sulfates [13]. These fluids have evaporation rates under martian conditions that are strongly dependent on temperature [6,7].

Conclusions: Activity within gullies has been shown to be on mission time scales [14], but gully formation has not been observed during these time scales. Since our results indicate a relationship with wind, then evaporation rate is the controlling factor of the time scale. As NaCl at its eutectic (252 K) evaporates a factor of 30 times slower then pure liquid water (0.03 mm h^{-1}) [6], then a 10 m deep flow would take ~40 years to evaporate. This means that gullies could be forming on tens to hundreds of years time scales.

References: [1] Malin, M. C. and Edgett, K. S. (2000) *Science,* doi:10.1126/science.288.5475.2330. [2] Heldmann, J.L. and Mellon, M.T. (2004) *Icarus* 169, 285. [3] McEwen, A.S. et al. (2007) *Science,* doi:10.1126/science/1143987. [4] Sears, D. et al. (2005) LPSC XXXVI, Abstract #1496 [5] Chittenden, J.D. et al. (2008) *Icarus*, 196, 477. [6] Sears, D.W.G. and Chittenden, J.D. (2005) *GRL*, 32(L23203), doi: 10.1029/2005GL024154. [7] Chevrier, V. and Altheide, T. (2008) *GRL*, doi:10.1029/2008GL035489. [8] Hayward**,** R. K. et al. (2007) *JGR*, 112, doi:10.1029/2007JE002943. [9] Osterloo, M. M. et al. (2008) *Science*, *319*, 1651. [10] Gendrin, A., N. et al. (2005) *Science*, 307, 1587. [11] Kargel, J. S. (1991) *Icarus*, 94, 368. [12] Klingelhöfer, G., R. V. et al. (2004) *Science*, 306, 1740. [13] Johnson, J. R. et al. (2007) *GRL* 34(L13202), doi: 10.1029/2007GL029894. [14] Malin, M.C. et al. (2006) *Science* 314, 1573.