MORPHOLOGIC PROPERTIES OF MARTIAN GULLY SYSTEMS. C. B. Welty[1], D. A. Crown[2], M.R. Balme[2], [1]Washington State Department of Natural Resources, 1111 Washington St. SE, Olympia, WA 98502, [2]Planetary Science Institute, 1700 E. Ft. Lowell Rd., Suite 106, Tucson, AZ 85719, cbwelty@gmail.com.

Introduction: As geologically young features, Martian gullies are significant to our understanding of the potential for surface fluid flow on Mars. The objective of our research is to document the small-scale morphologies of Martian gully systems in order to explore the potential diversity of gully formation processes and to determine if small-scale gully morphology can be used to distinguish between the various mechanisms proposed on the basis of larger-scale characteristics. In our current work, we expand upon earlier studies of gullies using HiRISE images [1] to more fully explore quantitative relationships between parameters that characterize the physical properties of gully systems.

Our new results provide the means to compare specific morphometric parameters and to study the locations and settings in which gullies form. Interpretations of parameter relationships can indicate potential controls on gully formation and distribution.

Background: Research on Martian gully systems has explored trends in gully morphology and distribution. Initial surveys using HiRISE images noted gross similarities in form with significant morphologic diversity in small-scale characteristics [1-2]. Previous studies have observed trends in gully orientation [3-5, 9-10] and preferential formation at mid-latitudes [3-7, 9-10]. This project builds on earlier work and includes creation of an expanded database for detailed analyses to help understand gully formation processes.

Methods: In-depth analyses of the physical properties of 410 gully systems were conducted using Geographic Information Systems (GIS) software and an extensive database of high-resolution images of the Martian surface. Morphologic parameters included: gully dimensions, as described by Malin and Edgett [5], (alcove length and width, apron length and width, length of the incised channel, and total gully length), channel sinuosity, orientation direction, and latitude. Gullies were systematically selected and measured from a collection of HiRISE images (~1 meter/pixel) distributed across the Martian surface and Bleamaster and Crown's [8] image dataset covering Dao and Harmakhis Valles (DHV) of MOC (~1.5 to 12 meters/pixel) and THEMIS visible wavelength images (~19 meters/pixel). Gullies in this dataset were then categorized by location: DHV walls, northern and southern hemisphere craters, and a combined category of other location types (i.e., mesa walls and southern pits). Parameters were measured using GIS and then compared graphically and statistically to determine parameter relationships and trends.

Results: This in-depth examination of the morphometric properties of 410 gullies across Mars reveals trends potentially reflecting gully formation processes. Our data show that the dimensions of different components of gully systems vary considerably, but that there are typical shapes and sizes evident within the entire population and subpopulations examined (Figure 1). This suggests, for example, that gullies on the walls of DHV and those in impact craters are produced by a similar process or suite of processes.

	Alcove Length	Alcove Width	Apron Length	Apron Width	Total Gully Length	Channel Length	Sinuosity	Orientation
All Data Summary								
Mean	382.5613	167.2469	606.5056	215.3117	1339.6569	752.3724	1.054	174.334
Std.Dev	277.5256	147.273	468.2381	177.0014	874.0962	616.8439	0.0353	84.1332
Min	38.9296	8.9295	38.3157	20.5268	187.7267	47.2203	1.0031	2.5766
Max	1566.0241	1393.1208	3777.9288	1248.1736	5104.4503	4266.5172	1.2243	358.8118
DHV Walls Summary								
Mean	474.7408	227.3604	756.4822	296.4429	1016.7011	1669.6159	1.0646	155.8832
Std.Dev	347.7887	159.8512	514.1478	212.8612	830.4391	1042.8554	0.0415	63.9281
Min	49.461	12.571	86.058	42.4258	149.8886	272.828	1.0036	42.1579
Max	1566.0241	820.6598	2894.931	1031.128	4266.5172	4935.9336	1.2243	356.8377
All Craters Summary								
Mean	362.077	153.8468	546.9706	188.9513	666.4331	1232.1278	1.0499	194.8849
Std.Dev	223.2683	177.2656	469.6476	174.8051	431.351	776.9297	0.03	86.3573
Min	38.9296	8.9295	38.3157	20.5268	90.7809	290.9599	1.0047	2.5766
Max	1387.537	1776.9978	3777.9288	1560.8707	3059.7292	5104.4503	1.172	358.8118

Figure 1. Summary table of gully parameter measurements (in meters) for all data and divided into DHV and crater walls.

Statistical correlation values between the morphologic parameters were examined. Relationships between some gully dimensions were moderately to strongly related (Figures 2 & 3). The DHV population had consistently higher correlation values than other locations.

Correlation R-Values for Parameter Comparisons	All Data	DHV walls	All craters
alcove length vs alcove width	0.7620	0.8173	0.6280
alcove length vs apron length	0.7797	0.8691	0.7073
alcove length vs apron width	0.7847	0.8357	0.7034
alcove length vs sinuous channel length	0.8055	0.8407	0.7396
alcove length vs total gully length	0.8749	0.8896	0.8448
alcove width vs apron length	0.7802	0.8313	0.7535
alcove width vs apron width	0.8772	0.8839	0.9168
alcove width vs sinuous channel length	0.6862	0.7826	0.4955
alcove width vs total gully length	0.7965	0.8108	0.7642
apron length vs apron width	0.8321	0.8979	0.8278
apron length vs sinuous channel length	0.7565	0.8931	0.6185
apron length vs total gully length	0.9208	0.9529	0.9023
apron width vs sinuous channel length	0.7863	0.8677	0.6073
apron width vs total gully length	0.8488	0.8781	0.8494
sinuous channel length vs total gully length	0.8708	0.9116	0.8129
orientation vs total gully length	0.0300		
sinuosity vs total gully length	0.1502		
orientation vs sinuosity	0.0187		
sinuosity vs alcove length	0.2191		
sinuosity vs alcove width	0.1438		
sinuosity vs apron length	0.0933		
sinuosity vs apron width	0.1706		
orientation vs alcove length	0.0041		
orientation vs alcove width	0.0013		
orientation vs apron length	0.0405		
orientation vs apron width	0.0797		

Figure 2. Calculated correlation r-values for measured parameters for all data combined, DHV walls, and all crater gully data.

Strongly correlated relationships include, for example, that between apron length and total gully length (Figure 3). In the top example (a), regression lines demonstrate the positive association of increasing total gully length with increasing apron length. Weaker correlations, such as those comparing sinuosity with total gully length, reveal that no correlation exists between these parameters.

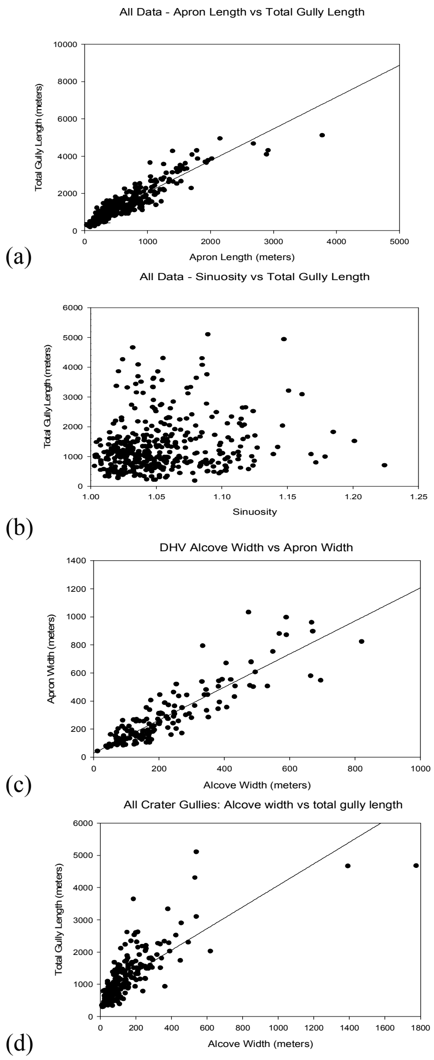

Figure 3. Sample regression graphs for parameter comparisons; examples of strong, weak and moderate correlations.

There was a significant overall trend of southwest facing orientations, with the fewest gullies facing east. Results also indicate a latitude dependency of gully formation between 30 and 70 degrees north and south (Figure 4), similar to results from previous studies of gully ditributions [3-4, 6-7, 11]. This analysis of different location types and global distributions documents a switch from gullies primarily facing poleward at locations closer to the equator to mostly equator facing gullies in higher latitudes at ~40 degrees (Figure 5). Previously observed trends in gully orientation [3-4, 10] produced similar results, although Balme et al. [3] and Dickson et al. [4] found less of an equator facing trend at high latitude.

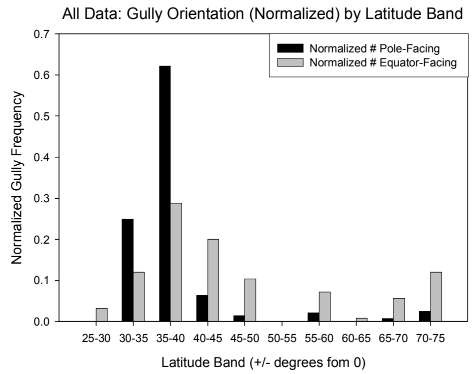

Figure 5. Normalized counts of pole-facing and equator facing gullies, indicating the switch in facing direction at ~40 degrees north and south.

Discussion: Correlations between morphometric parameters were strong in some cases, indicating similar size relationships in gully morphologies. We show that longer gullies have longer and wider alcoves, suggesting longer gullies form from a larger source volume. From the low correlation values, we can conclude that gully morphometry does not correlate with orientation, suggesting that pole-facing and equator-facing gullies are formed by the same mechanism. The narrow range of sinuosity values in this dataset indicates a consistency in gully formation conditions, such as similar slopes and fluid content. In this and previous studies, gully orientations and latitudes follow a predictable pattern. These trends suggest that gully formation mechanisms are likely consistent across the Martian surface.

Future research into gully formation processes based on this expanded datset will explore how gullies formed and what mechanisms determine their morphologies. Comparisons using these same parameters on Earth analogs and experiments can be used to determine the conditions required for Martian gully formation.

References: [1] Welty, C.B., and Crown, D.A. (2008) *LPSC XXXIX*, Abstract 2295. [2] Gulick, V.C. et al. (2007) *Eos Trans. AGU, 88(52)*, Abstract P31B-0439. [3] Balme, M.R. et al. (2006) *Journal of Geophysical Research 111*, E05001. [4] Dickson, J.L. et al. (2007) *Icarus 188 2*, 315-323. [5] Malin M.C. and Edgett K.S. (2000) *Science, 288,* 2330–2335. [6] Costard F. et al. (2002) *Science, 295,* 110-113. [7] Malin, M. C. & Edgett, K. S. (2001) *Journal of Geophysical Research 106,* 23429-23570. [8] Bleamaster III L.F. and Crown D.A. (2005) *Geophysical Research Letters, 32, L20203,* doi:10.0129/2005GL023548. [9] Milliken, R.E., et al. (2003) *Journal of Geophysical Research, 108,E6*, 5057. [10] Berman, D.C., et al. (2005) *LPSC XXXVI*, Abstract 1213. [11] Heldmann, J.L., Mellon, M.T. (2004) *Icarus 168*, 285–304.