EXAMINING FORMATION MECHANISMS OF MARTIAN GULLIES USING MARS RECONNAISSANCE ORBITER CONTEXT IMAGERY. S. Araki[1], R. M. E. Williams[2], and A. J. Dombard[1], [1]Dept. Earth and Environmental Sciences, University of Illinois at Chicago, 845 W. Taylor St., SES MC186, Chicago, IL 60607 (saraki2@uic.edu), [2]Planetary Science Institute, 1700 E. Fort Lowell, Suite 106, Tucson, AZ 85719.

Introduction: Current temperature and pressure conditions on Mars suggest that liquid water is unstable at the surface with respect to boiling and freezing. However, gully features, generally consisting of alcoves, channels, and debris aprons and existing in a band at mid latitudes mainly in the southern hemisphere with a possible preference for pole-facing orientations [1, 2], suggest liquid agents, water perhaps being the most plausible. These observations are consistent with models by [3] that suggest liquid water is possible at some subsurface depths. Alternative proposed mechanisms suggest that gullies have been carved by release of liquid water or CO_2 reservoirs [4, 5, 6], melting of ice-rich snow pack [7], obliquity-induced melting derived from near surface ground ice [8], melting of permafrost ice by localized geothermal activity [9], or by dry or granular flows [10, 11].

Mars Orbiter Camera (MOC) and HiRISE have provided opportunities to understand gully features and formation mechanisms on Mars; however, both MOC and HiRISE typically provide partial views of the crater in which gullies tend to be found. Mars Reconnaissance Orbiter (MRO) Context (CTX) images provide wider views, and gullies studied in crater-wide contexts may show spatial patterns occurring at local scales. Our study, using CTX images, will characterize gullies by morphometry on the basis of apparent maturity and level of complexity of fluvial features, from gullies showing apparent dry flow features to highly incised, sinuous and debris flow-like features. We will determine the spatial distribution of gully classes and assess possible mechanisms of gully formation by evaluating formation hypotheses for each gully class.

Methods: We use CTX image strips (30 km with a resolution of 6 m per pixel) to classify gully features that occur within craters. This pilot study focuses on images acquired from the first six months of the primary mission (P01-P06, November 2006 through April 2007) in Mars Chart (MC) 29 (30-60º S, 180-240º W). Although additional Mars Charts from the same latitude band will eventually be added, we limit this abstract to MC 29. Ninety-three CTX images in the study region have craters with gullies.

A crater site contains one or more clusters of gullies. Representative gullies within morphologically distinct clusters were sampled. Data collected for each cluster include gully characteristics selected to test several formation hypotheses by determining whether each characteristic or group of attributes was consistent with a hypothesis. We examined key observable features that suggest apparent erosion and deposition by liquid water, including a single, dominant linear channel per alcove, the degrees of sinuousity and incision, consistent with several models [1, 4, 5, 7-9, 11]. Straight or very low sinuosity gullies or those features with a truncated or absent channel may have formed by dry or granular flow features [10]. Unchanneled, broad flows with lobate deposits, analogous to deposits of terrestrial nuee ardentes, were considered consistent with formation from liquid CO_2 [6]. Gullies forming in "pasted-on" material, identified by a mantle feature having a rounded upper boundary, supports formation by melting an ice-rich snow pack [7]. As several hypotheses have similar observational criteria, other evidence including the position of the alcove-channel transition, association with layers or whether a gully possessed a pole-facing orientation were documented. Other qualitative characteristics that may be associated with gully formation, such as correlation with other landforms near gullies (e.g., arcuate ridges, apparent mantling), were also documented. Quantitative data include lengths and widths of gully features and area measurements of debris aprons and pasted-on material.

Preliminary results: The following results are based on 37 images from P01-P03 distributed throughout MC 29, featuring data from 57 gully clusters. Crater diameters range from 3 km to 60 km.

Gully morphology. Surveyed gullies were typically channeled. The majority (84%) shows a single, dominant, linear channel per alcove, consistent with terrestrial debris flows and fluvial flow in general, and inconsistent with CO_2 flow features [6]. Alcoves are predominantly longer than wide (i.e., lengthened [1]), and channels typically have low to mildly meandering sinuousity. Relatively short, weakly defined channels, in gullies dominated by the alcove and debris apron, represented 37% of gullies. Gullies with these channel-alcove hybrids generally occurred on slopes with apparent mantling or mature gullies. Superposition of gully features suggesting multiple episodes of gully formation was observed in 64% of gullies.

Association with layers. In 40% of the gullies, horizontal strata are aligned with the position of the alcove-to-channel transition zone (Fig. 1), the proposed emitting locations for fluid seepage [4, 6]. This value is possibly an underestimate due to uncertainty with discerning the boundary between alcove and channel, generally as a result of eroded boundary features and subsequent shift of the boundary. Poor resolution of the strata due to overprinting by mantles and lighting quality also add to this effect. In 31% of cases, strata appeared to abbreviate the tops of alcoves, which suggests impeded headward erosion, and also that the strata may indicate the presence of an impermeable layer that may contribute to the formation of aquifers. No correlation was observed between upper limits of gullies or the position of the alcove-to-channel transition with the overburden topography, as suggested by [5].

Depths of alcove base. Horizontal distance, used as a proxy for depth, from crater rim to the base of gully alcoves varied from 300 m to 2045 m (mean 1060 m; n=43). Within the 40% of gullies for which the alcove bases align with a strata, the maximum alcove base depth was 1960 m (975 m, mean; n=17). These values are overestimates of actual depths by a factor of ~2, because distance was used as a depth proxy. The upper limit of alcove boundaries coincided with crater rim edges in 30% of the cases suggesting that headward erosion had lengthened alcoves to the rims.

Some preference for pole-facing slopes. Pole-facing character (on the N, NW, and NE portions on the craters) was apparent for 57% of gullies. Approximately a quarter of gullies occurred on S and SW slopes, in rough agreement with [3]. Larger, apparently more eroded alcoves tend to be found more frequently (70%) on pole-facing crater walls.

Minor association with pasted-on material. Pasted-on material occurred at five sites. Gullies were found eroding into the pasted-on material at only two sites, including on the central peak of a crater.

Discussion: The range of features thus far observed indicate that no one mechanism is responsible for formation of all gullies. Evidence for gully features analogous to terrestrial debris flow-like features supports the hypotheses for shallow [4] and deep [5] aquifer models, snowpack [7], near-surface ground ice [8], and permafrost ice melting by geothermal heating [9]. The depths of alcove bases below crater rims of order of 100 m on average and association with horizontal strata support the shallow aquifer hypothesis, while lack of correlation to overburden topography weakens the deep aquifer argument. Similarly, the lack of gullies seen eroding in or associated with pasted-on material suggests gully formation by the melting of ice-rich snow pack may not be a widely distributed process within the study region. The absence of mantling material and little evidence for gullies with low sinuosity, hybrid alcove-channels also reduce support for dry flow mechanisms. The shallow and deep liquid water and CO_2 reservoir models and near-surface ground ice hypothesis are further supported by the observed superposed debris aprons, suggesting evidence of multiple outflow events and possible infrequent, obliquity-driven formation cycles. The most likely hypotheses for more widely distributed formation mechanisms based on our observations therefore include water flow process models that differ in the source of the water, including the shallow aquifer, near-surface ground ice, and ice melting by geothermal activity models.

Future work: This is a work in process. Further data to be collected will provide a better basis for analysis. While no one formation hypothesis is readily supported or rejected as the sole operating gully formation mechanism, this study will likely yield new insights into formation mechanisms. This study will also provide a detailed, regional database of gully characteristics and possible formation mechanisms by crater site. Gully features that support different formation mechanisms can occur in the same crater, and intracrater patterns as well as regional patterns of gully types/classes should be revealed by this study.

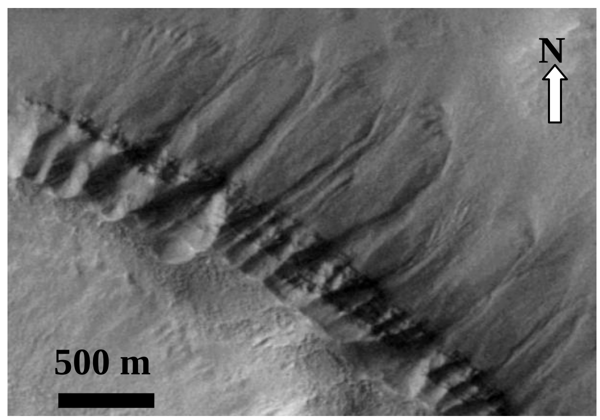

Figure 1. Horizontal strata align with the position of the alcove-to-channel transition zone in MRO CTX image P02_002002_1389_XI_41S204W_061230, 41.2º S, 204.7º W.

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