GULLY FORMATION ON MARS: IMPLICATIONS FOR LATE PALEO MICROCLIMATES. V. C. Gulick1 and N. G. Glines1, 1 The SETI Institute / NASA Ames Research Center (MS 239-20, Moffett Field, CA 94035, (virginia.c.gulick@nasa.gov, natalie.glines@nasa.gov).

Introduction: The role liquid water played in the formation of gullies in Mars’ recent geological history continues to be actively debated nearly two decades after their discovery. Numerous global studies have mapped their distribution inspiring numerous hypotheses to explain their formation (for recent reviews see [1, 21]). However, the diversity of gully morphologies has led many to conclude that gullies likely formed by multiple processes. To better understand the relative importance of various gully formation and modification processes, we have been conducting detailed morphologic and morphometric studies of gullies in a variety of environmental settings on Mars using HiRISE and CTX images and DTM’s. Studied gully locations include: the slopes Palikir Crater [12, 13, 14], Corozal Crater [18], Moni Crater [19, 20], the central peak of Lyot crater [3, 4], along the western rim of a polar pit (Sisyphi Cavus), two gully systems in Hale Crater [2], and the central pit and western rim of Asimov Crater [15]. For comparison, we also studied gullies on the Kaiser dunes and a large gully on the Matara dunes [17].

Here, we summarize some of our findings based on study of several integrated gully sites [2]. We then further explore the gullies on the central peak of Lyot Crater [3, 4] and identify adjacent landforms that are consistent with free/thaw processes [5, 6]. Based on these observations, we propose a local atmospheric hydrologic cycle associated with a potential ice-covered paleolake.

Drainage Systems:

Using HiRISE and CTX images, we produced detailed drainage maps of gully systems (see Figure 1, for example). Close-ups of these maps (Figure 2) reveal that the gully systems on the crater slopes and on the central peaks form complex, highly integrated and ordered, tributary systems in the source regions with fingertip tributaries merging into progressively larger tributaries which eventually all merge into the main gully channel. The main gully channel is incised along the mid-sections and forms channels with levees on the aprons transitions when viewed close up at HiRISE resolution.

Several aspects of the observed morphology are consistent with water erosional processes operating within a fluvial system. Integrated drainage and debris aprons that are heavily dissected by channels with levees are both consistent with fluvial activity where flow from confined to unconfined at a sudden decrease in slope. As flow spreads out on the apron, water infiltrates and evaporates, sediment concentration increases and flow behaves more like a debris flow.

Figure 1: Detailed drainage maps of gully systems on Palikir crater (left) and on the central peak of Lyot crater (right).

Figure 2: Examples of integrated gully systems on the central peaks of Hale (left) and Lyot (right) craters as mapped using HiRISE images. See [16] for details on Hale gully system. Close up of gully area one of Lyot central peak in Figure 1.

Longitudinal Slope Analysis:

In our previous [2] and current research, we found that most gullies we’ve studied have concave profiles. Deviations in the longitudinal profiles generally correlate to areas where the gullies have incised through stratigraphic layers. We also found that gullies in our study regions formed on alcove slopes less than ~25° and on apron slopes less than ~16°. This is significantly less than the angle of repose needed to initiate (~33°) and to maintain dry flows (apex fan slopes >21°) under Mars gravity [7].

We also note several interesting correlations and associations in our study locations. When we compare the individual gully volumes with their associated debris aprons, the gully volumes are significantly larger than the apron volumes [2, 10]. We have attributed the discrepancy in volumes to the initial water, ice, and volatile
volumes contained in the system that were lost to the system during gully formation [2]. In contrast, in the two dune gullies we studied, the apron volumes are similar to or larger than their gully volumes.

To better understand the potential paleo-environments associated with gully formation on Mars, we are carrying out detailed mapping of the regions surrounding the gully systems. Here, we report on some of our results based on mapping other associated landforms in the Lyot central peak region (Figure 3).

**Figure 3: Left: Map showing locations of gullies, potential snow pack and peak area, potential paleolake levels, thermokarst channels and depressions (beaded streams) and other channel forms. Right: CTX DTM showing gullies, potential paleolake levels and other landforms.**

**Potential Thermokarst Landforms and Paleolake in the Central Peak Region of Lyot Crater:**

Based on our recent mapping of Lyot Crater’s central peak region, we have identified flat-floored, circular-to-oblong depressions, which are connected by channels [5, 6, 3]. These potential thermokarst landforms are morphologically similar to beaded streams on Earth. The terminal margins of these bead and channel systems flow southwards towards a region which is the lowest elevation in the northern hemisphere (~7000 m in elevation). The gullies which preferentially form on the western side of the central peak also mostly flow towards this region. The beaded streams and other associated landforms terminate at an elevation of ~6800 m.

We suggest that this may represent the margin of a paleolake that may have existed during a period of higher obliquity. Winds blowing over an ice-covered lake towards the peak region could evaporate/sublimate sufficient water vapor to deposit as snow at a cold trap on the western central peak slopes at ~1.7 to 2 km higher elevation. This snow could have melted seasonally. According to Fig. 14 in Gulick et al 1997 [11], if we assume a current surface temperature of 265 K on the floor of Lyot Crater, snow could accumulate at 2 km higher in elevation on the central peak over a similar area at rate of over a meter/year of equivalent water. Estimated sublimation rates from the snowfield on the central peak region of Lyot are on order of 10s of cm/year. Clearly more sophisticated regional modeling is required to examine this possibility.

Could liquid water have ever been stable enough to flow on the surface of Lyot crater? Haberle et al. [11] addressed the stability of water on Mars with respect to freezing or boiling and stated that liquid water need not be stable with respect to evaporation, but only with respect to boiling and freezing. They pointed out, that liquid water is generally not stable on Mars or Earth with respect to evaporation, as the lower limit of liquid water stability is defined by the freezing curve and is independent of ambient pressures. Furthermore, the boiling point is the temperature at which the saturation vapor pressure equals the total external pressure, regardless of the external pressure source. They estimated that the temperature and pressure range in which liquid water could exist on Mars is between the triple point of water at 273 K and 6 mbar and 283 K and ~12 mbar. Within this range, the total pressure can be supplied by CO2, and water vapor need not be present to stabilize liquid water against boiling. Haberle et al. estimated that the surface pressure on the floor of Lyot Crater does exceed 10 mbar.

We analyzed the available TES surface pressures and temperatures and THEMIS temperature data over the central peak of Lyot Crater and found that surface pressures ranged between ~9 and ~11 mbar. TES surface temperatures ranged up to ~276 K and THEMIS up to ~265 K. This enters a favorable range where liquid water is stable against boiling. In fact, we find that nearly 90% of TES pressure values exceed 10 mbar on Lyot central peak regions [3].

We are continuing to explore this potential water source. This mechanism if correct would also have important astrobiological and paleoclimatic implications for late Mars geologic history.

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**References:**