DETECTION OF GULLIES ON CENTRAL PEAKS AND CRATER RIMS ON MARS: IMPLICATIONS FOR THE ORIGIN OF GULLIES. J. L. Dickson and J. W. Head, Dept. of Geol. Sci., Brown Univ., Providence, RI 02912 USA, james_head@brown.edu.

Introduction and Background: Since the detection in MOC images of geologically recent gullies on Mars [1], several hypotheses have been proposed for their origin. These can be subdivided into models of groundwater seepage [1-3] and melting/runoff of isolated snowpacks [4]. While these models have attempted to account for the concentration of gullies in the mid-latitudes, few studies have examined their immediate geological context. *Christensen* [4] noted that MOC data have revealed gullies on isolated surfaces that would be unlikely locations for groundwater seepage. In this work, we present the results of our survey of geological environments of gullies revealed in MOC images. Our survey consisted of all 5,167 MOC narrow-angle images acquired between 30°S and 45°S through imaging phase R09 (September, 2003). We show examples of gullies found on central peaks and on crater rims, where there appears to be insufficient volume for a contained aquifer, a critical component of all seepage models. These examples also illustrate families of gullies with alcoves that emanate from different elevations, not distinct layers. This leads us to favor a surface melting/runoff origin for these examples.

Central Peak Gullies: Our survey has revealed several examples of gullies that are found on the walls of central peaks within craters in the southern mid-latitudes, in addition to gullies found on isolated mesas. An example is provided in Figure 1a (subframe of MOC E15/00539), which shows the alcoves and channels of several gullies incised into the central peak of Lohse Crater, at 17.21°W, 43.72°S. Alcoves range in greatest width from ~100 m to ~700 m, and channels extend for several hundred meters to the east, off of the MOC frame. While these gullies exhibit a west-east trend, gullies found in the same image to the north show both north-south and south-north trends. The alcoves are found at variable elevations along the slope of the central peak, and no evidence for layering has been observed. Both the alcoves and channels exhibit lower albedos than the terrain into which they are incised. The gullies appear fresh and no superposed impact craters are observed.

Gullies on Crater Rims: Most gullies associated with impact craters are located on interior walls [1,2,5]. However, we have observed multiple examples in MOC data of gullies that have formed on the outside of craters with raised rims. Figure 2b (subframe of MOC E11/03663) shows the southern rim of a ~5km diameter crater on the floor of the larger Newton Crater, at 157.62°W, 39.77°S. These are found within a region of high gully concentration (Figure 2a). These gullies show a poleward orientation, consistent with the well-formed gullies on the inside of the crater's northern rim. The dimensions of these gullies are smaller than those to the north, with channels that extend only a few hundred meters, and depositional fans that are ~100m long and ~100m wide at their terminus. Alcoves are not resolved at MOC resolution, given the small size of these gullies. It is unclear whether they emanate from a continuous layer on the outside of the crater rim or from a consistent elevation. Consistent with previous studies of gully landforms, these gullies appear to be the youngest features within their proximity, showing depositional aprons that are superposed on the terrain immediately surrounding the crater.

Well-formed gullies on the outside of craters have also been observed along the northeast rim of Hale Crater, a location well studied due to its high-concentration of gullies. Figure 3a (subframe of MOC image R07/02277) shows a traverse of the northeast rim of Hale Crater, at 35.60°W, 35.43°S. Gullies are observed on both the inside and outside of the rim crest. Alcoves for all gullies are close to the crest of the rim (within tens of meters), but the rim has remained intact. Well-defined fans are observed for the gullies within Hale Crater, but channels extend off of the MOC frame for the gullies on the outside of the rim. All gullies observed appear youthful and are stratigraphically the youngest features in the region of study.

General Observations and Discussion: Our survey of the geologic setting of MOC images that exhibit gully landforms in the middle/high latitudes of Mars permits us to outline patterns with regard to morphology, distribution, and immediate geological context. We found 15 clear examples of gullies on central peaks, mesas, and raised crater rims, primarily along the northern margin of Argyre Basin and in Newton Crater (158°W, 40°S). Our findings of these features confirm the assertion of *Christensen* [4] that specific families of gullies on Mars occur in locations unlikely to produce groundwater seepage.

Models that invoke groundwater seepage for the formation of martian gullies [1-3] all depend upon either sufficient subsurface volume behind the gully for a confined aquifer that undergoes fluctuation in pressure [1,2] or sufficient geothermal activity that would transport volatiles from greater depth to the surface [3], which would then be released through seeps. Our observations of the geological context of gullies suggest that these conditions are not met across the surface of Mars. Well-defined gully alcoves in regions of small subsurface volume have been found (Figures 1 and 2), and no relationship between gully distribution and centers of geothermal activity has been observed.

In their updated survey of gullies on Mars, *Edgett et al.* [5] restated their observation that gully alcoves emanate from specific layers exposed on given slopes. While this is common, we have documented examples of gully alcoves that do not exhibit this relationship (e.g. Figure 1a and Figure 2a), and we suggest that this will be an effective preliminary test to differentiate gullies formed by groundwater seepage and those formed by runoff of melted snow.

Edgett et al. [5] also noted that there does not appear to be a global preference for poleward-facing slopes, as was initially thought [1]. They did observe that gullies in specific areas face the same direction, and our findings are generally consistent with this observation. No craters have been observed in our survey that exhibit gullies facing each other. We have, however, found occurrences of gullies on the inside and outside of the same crater rim, as in Figure 3.

Most proposed models call on late Amazonian climate change as a factor in gully formation. Recent work has attempted to model the orbital cycles of Mars over the last 10 Myr. [6], and to tie those cycles to the geological record observed on the surface [7,8]. We feel that the features documented in this study are best explained by surface accumulation of snow, followed by melting and runoff, as proposed by *Christensen* [4], which would be consistent with significant climate change in the late Amazonian (e.g., 8).

References: 1) M. Malin and K. Edgett, Science, 288, 2330, 2000; 2) M. Mellon and R. Phillips, JGR, 106, 23,165, 2001; 3) E. Gaidos, Icarus, 153, 218, 2001; 4) P. Christensen, Nature, 422, 45, 2003; 5) K. Edgett et al., LPSC 34, #1038, 2003; 6) Laskar et al., Icarus, 170 (2), 343, 2004; 7) Mustard et al, Nature, 412, 411, 2001; 8) Head et al., Nature, 426, 797, 2003.

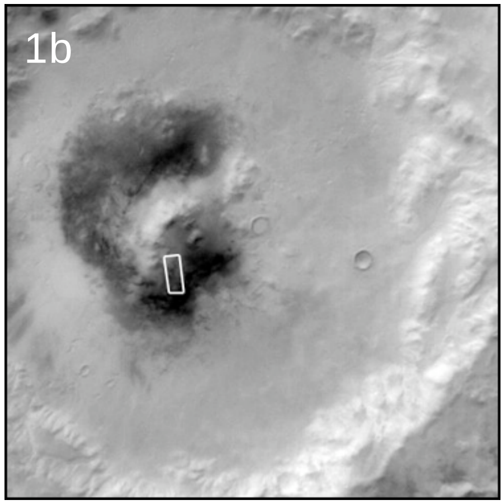

Figure 1. (a) Subframe of MOC E15/00539, showing gullies incised into the central peak of Lohse crater. (b) MOC E15/00540, context for 1a.

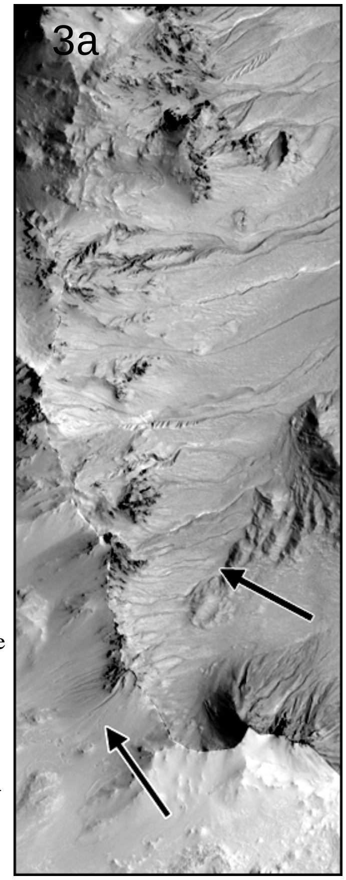

Figure 3. (a) Subframe of MOC R07/02277, showing gullies on opposite sides of the rim crest of Hale Crater. Opposite sides of the crater wall were contrast stretched separately. (b) Sketch map for 3a.

Figure 2. (a) MOC E11/03663. Box is context for 2b. (b) Subframe of MOC E11/03663, showing gullies on the outside of the crater rim crest. (c) Sketch map for 2b.