POLAR- AND MIDDLE-LATITUDE MARTIAN GULLIES: A VIEW FROM MGS MOC AFTER 2 MARS YEARS IN THE MAPPING ORBIT. K. S. Edgett, M. C. Malin, R. M. E. Williams, and S. D. Davis, Malin Space Science Systems, Inc., P.O. Box 910148, San Diego, California 92191-0148, USA.

Introduction: In 2000, Malin and Edgett [1] published initial results regarding the discovery, geomorphology, and possible origin of polar- and middle-latitude gullies on Mars (e.g., Fig. 1). Except for gullies in Nirgal Vallis, and a single example at 24°N near the mouth of Kasei Vallis, all of the gullies documented through December 2002 occur poleward of 30° latitude in both hemispheres. The Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) began its third Mars year of observations in the nearly-circular, nearly-polar mapping orbit on 12 December 2002. More than 128,000 MOC images have been acquired; of these, > 54,000 are narrow angle (NA) images of resolution 1.5 to 12 m/pixel. Of the NA images, ~1300 exhibit polar- and middle-latitude gullies. This sample, 8.7 times the number of images examined by Malin and Edgett [1], provides an opportunity to re-evaluate the geomorphic, statistical, and geographic relationships described in the original paper.

Methods: In 1999, most initial gully locations were identified as a result of efforts to obtain long MOC NA traverses across impact craters for crater morphology studies. After several hundred examples were identified, targeting efforts in 2000 and 2001 shifted to a focus on trying to find more gullies: we tested the hypothesis that these occur in regional clusters by targeting as many crater and trough walls as possible across the martian surface at middle and high latitudes. We evaluated the observation that most gullies occur poleward of 30° latitude by imaging crater and trough walls at lower latitudes. In 2001 and 2002, we examined the hypothesis that gullies are so geologically young that they are active today by re-imaging gullies to look for changes; we also re-imaged gullies from off-nadir orientations for stereo, and we re-imaged them at higher resolution to look for additional details. All MOC NA images of gullies acquired through mission subphase E20 (September 2002) were map-projected and the azimuth of each gully, relative to north, was determined. Notes on each gully were also recorded; for example, we identified the setting (e.g., crater, trough, massif), the relationship of the channel to exposed layer outcrops, the superposition of eolian bedforms by gully aprons, and the superposition of impact craters on gully landforms, among other things. As of December 2002, azimuths and notes for ~10,000 individual gullies in ~1100 images in both martian hemispheres and at all longitudes have been obtained (we plan to do the rest by March 2003).

Observations: The paragraphs that follow summarize our key observations through December 2002:

1. No Preference for Poleward-Facing Slopes. Contrary to our earlier report [1], gullies show no particular preference for poleward-facing slopes (Fig. 2). However, gullies in specific locales may all face in a specific direction: for example, all of the gullies in Nirgal Vallis are on the south-facing wall of the valley. In the northern hemisphere, more gullies face south than north.

2. Occurrence in Regional Clusters. This observation was stated in the original paper [1], and is amplified by > 2 Mars years' worth of data. Gullies occur in regional clusters. Gaps, in which no gullies occur between clusters, are observed. More gullies occur in the southern hemisphere than the north.

3. Association with Layers. This observation was also stated in the original paper [1]. We reiterate it here after examining ~1300 images. Any model for the origin of gullies must explain the relationship with layers. Gully channels typically head at a specific layer exposed on a given slope (e.g., Fig. 1). Within a given regional cluster, gullies may all head at the same layer where it is exposed in different crater and trough walls.

4. Youth of Gullies. As described by Malin and Edgett [1], most gully landforms are the youngest geomorphic features where they occur—their aprons may superpose eolian bedforms, their channels cut otherwise uncratered slopes, some have albedos distinct from their surroundings (indicating a lack of dust coatings). Although our conclusion remains that gullies are generally geomorphically young, they are not uniformly young: a few examples of cratered gully channels and aprons have been found. In some cases, the craters may all be secondaries from a single impact (e.g., MOC image E02-02002). In other cases, the gully landforms are not cratered but they are not the youngest features; for example, some gully aprons have been cut by cracks that are concentric or semi-concentric with the crater or trough floor in which they occur (e.g., MOC image E10-04140); some gully aprons and channels have been superposed by dune sand (but, in some cases, a younger channel has been cut through the dune sand). In cases where gullies have been re-imaged to look for change, no new gullies or other geomorphic changes have been observed.

5. Geomorphic Clues to Fluid Properties. Banked, sinuous, and anastomosing channels, channel piracy, and tributary and distributary systems all attest to the nature of the fluid involved in gully genesis and maintenance. The channels are free of debris, suggesting that they have experienced an event or events of sufficient energy to flush material through them in relatively recent geologic time.

6. Different Gullies, Lumping vs. Splitting. Not all gullies have the same attributes. They may not have all formed the same way. In the Malin and Edgett [1] work, we lumped where today we might split. In particular, gullies that occur on dune slip faces—which are rare features found only in Russell, Kaiser, and a few other southern Noachis intracrater dune fields—have formed in indurated material and appear to be a variant of otherwise typical dune slip face avalanches. Dune gullies have no apron, no alcove, and tend to be leveed. The overall impression is that these may be slip face avalanche deposits that lost volume, perhaps by removal of a volatile, after emplacement by mass-movement. No new dune gullies have been observed despite extensive re-imaging efforts.

Discussion: Our initial determination that gullies typically occur on poleward-facing slopes was wrong, but the 8-fold increase in observed gullies has strongly confirmed their apparent relationships to layers and regional clusters. Models for the origin of gullies and the nature of the fluids involved in gully formation and transport of clasts through these conduits must take into account the geologic and geomorphic observations evident in MOC (and, more recently, THEMIS VIS) images. Models that invoke snowmelt, for example, must explain the relationship to layering, and why two craters of similar size can occur within a few kilometers of each other, yet one has gullies and the other does not (Figure 3 shows this holds true even for large craters such as Hale (which has gullies) and neighboring Bond (which does not)). Models invoking gas-supported flow rather than liquid must explain banked, sinuous, anastomosing channels, channel piracy, distributary channels, and other geomorphic aspects of gullies. In our view, only models that involve flow of a liquid through subsurface layers that emerges at the surface in a given crater or trough—and at the same layer in a neighboring crater or trough—can explain the relationship to layering. Regional clusters suggest that the layers through which the fluids may have moved have limited lateral extent. The most likely fluid is liquid water; regional clusters may represent geologically recent martian aquifers.

Reference: [1] Malin M. C. and Edgett K. S. (2000) *Science, 288,* 2330–2335.

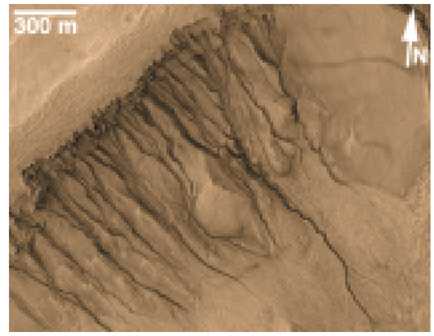

Figure 1: Gullies typically originate at a specific layer exposed on a given slope. Sinuous and banked channels, pirated channels, and distributary channels are all indicators that the responsible fluid was a liquid. Subframe of MOC image E11-04033, 39.0°S, 166.1°W.

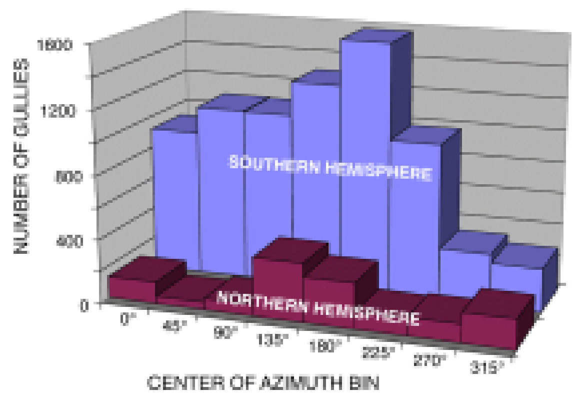

Figure 2: Hemispheric azimuthal orientation, clockwise from north, of ~10,000 gullies from MOC subphases AB1–E20 (Sept. 1997–Sept. 2002). No specific relation to poleward-facing slopes is seen.

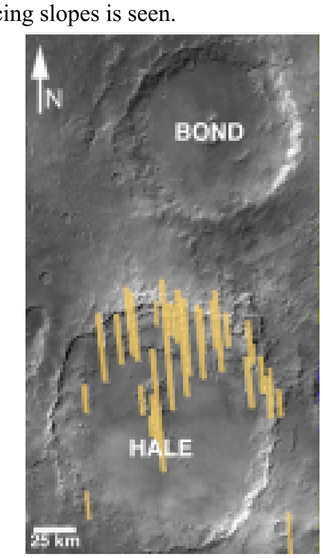

Figure 3: Orange bars indicate locations of MOC NA images with gullies. None occur in Bond (33°S, 36°W), but many are found in Hale (36°S, 36.5°W). If gullies resulted from a climate influence, such as snowmelt, both craters would be expected to have gullies.