**WHAT PART OF GULLIES ARE "SPECIAL," IMPLICATIONS FOR MSL LANDING SITES.**

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Here, we examine properties of gullies—a 'special' region for planetary protection—relevant to landing site selection and exploration of these features, which may be inadvertently encountered by the Mars Science Laboratory (MSL). This analysis takes into account gullies' scientific importance, planetary protection considerations, MSL goals and instruments, and trafficability.

**Importance of gullies:** Martian gullies were first identified by Malin and Edgett [1]. Their morphologies suggest formation by liquid or debris flow [1,2]. The agent of formation for the gullies has been debated ever since their discovery; liquid $H_2O$ [1,2], $CO_2$ [3], and dry flows [4] have all been invoked. Past work has shown that $CO_2$ is an unlikely candidate due to the temperature-pressure regime on the surface [2,5]. Additionally, experimental work on dry flows has not been able to replicate gully morphologies such as levied walls and sinuous channels [6]. Liquid $H_2O$ may be stable for short periods of time on the surface today, but may have been able to persist longer in the surface environment of the past [7].

Recently, new gullies have been observed to form within the last two martian years [8], which suggests that liquid water may still be an active agent on the martian surface. In addition, new crater count studies confirm the gullies' youth [8]. This has implications for both the geologic history and future of Mars, as well as for the possible existence of a martian biosphere. Gullies are unique in that they are the only places on the martian surface that show evidence for liquid flow today.

**Planetary protection considerations:** A 'special region' is one in which either terrestrial microbes may propagate or martian microbes may exist [9]. Liquid water is presumed to play a role in both scenarios, and thus any regions with water must be dealt with carefully to ensure protection. Previous work [9] has indicated that gullies should be classified as 'uncertain' regions, which may or may not be 'special' depending on how recently they have been active. However, even a recently active gully may be safely examined by MSL using the remote sensing capabilities of the ChemCam instrument. Gullies likely represent transient releases of water, and thus are unlikely to be habitable for any length of time. These releases occur at the top of the gully channel, where there is often an alcove created by undercutting [1]. Some gullies also appear to emanate from resistant rock layers, which may act as aquacludes [1,10]. Additional work has also suggested that gullies may be the result of surfical snow melt [11]. In each of these scenarios, the source of the gully material is at the top of the channel. By extension, this is the only part of a gully where water persists over time.

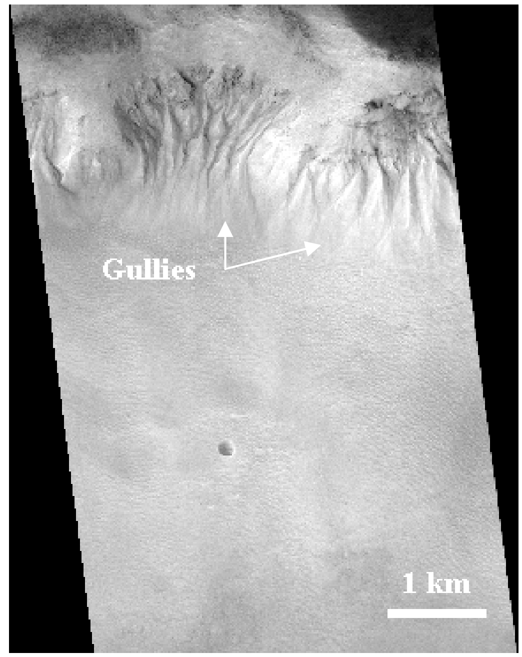


**Fig.1: Section of MOC image E1002693 in Acidalia centered at 22.88ºW, 49.87ºN. Note the flat plains adjacent to the gullied slopes. NASA/JPL/MSSS.**

Thus, as long as this top portion of the gully is avoided, there is little danger of contamination. Even if a gully were to become active at the time of its examination by MSL, the transient nature of the flow makes the likelihood of contamination extremely remote.

**MSL goals and instruments:** The primary objective of MSL is to determine past and present habitability on Mars in a variety of environments [12]. Habitability for life as it is currently understood has a number of requirements, the most important of which is liquid water. Given new evidence for recent flow in some gullies [8], gullies are an obvious place to begin studying habitability.

MSL will also have some remote sensing capabilities. The ChemCam consists of two instruments: a Laser Induced Breakdown Spectroscopy (LIBS) instrument and a Remote Micro Imager (RMI). LIBS will be able to obtain spectra on targets up to ~13 m from the rover, while the RMI provides high resolution images of the target within an 80 μRad field of view [13]. These capabilities will allow MSL to examine gullies—both channel and source region—from a distance, from the top or bottom of a slope. This further decreases the likelihood of interaction between the gully source and MSL. ChemCam can gather information about the composition of the slope material, determine if there are major compositional differences inside and outside of the gully, and examine small scale structures such as grain sorting, cross bedding, evaporite minerals, or distinctive erosional features that may indicate the presence of water.

**Finding and defining active gullies:** Remote sensing data from satellites can validate that a potential landing site does not contain obvious special regions. There is a possibility that some special regions may not be recognized from these data, and that MSL may encounter one. However, ChemCam's remote sensing capabilities allows for these regions to be studied at a safe distance. Thus, even if some gullies can be defined as special, they may still be safely examined by MSL.

It is difficult to determine what characteristics may indicate that a gully is more or less active than another. All of these features appear relatively youthful, and so it is also difficult to differentiate between younger and older ones. The more sharply defined the gully channel is, the more likely it is to be young and active. Additionally, deeper channels may also indicate youth, since dust is likely to infill an older channel. The persistence of levied walls may also be a sign of recent activity, although one author's observations of Death Valley gullies suggest that the viscosity of the fluid will play a large role in this. A higher viscosity fluid (a.k.a. liquid carrying more debris) will leave very solid levies that may erode more slowly than levies deposited by a lower viscosity fluid. Some gully-bearing regions also show evidence for several episodes of gully formation, with more defined gullies superimposing less defined ones. It may be that these regions are actively forming, and are thus more likely to become active in the near future. A careful study of these features using remotely sensed data may allow for the selection of gullies that are less likely to become active while being examined by MSL.

**Trafficability:** Landing site safety and the ability of the rover to move relatively unimpeded must both be taken into account when determining suitable landing sites for MSL. An ideal site for trafficability would be one in which the region was fairly smooth, with few large slopes or obstacles such as large boulders.

Gullies tend to form on crater walls in the midlatitudes (±30°-55°) of both hemispheres [2,14,15]. These craters tend to be relatively small, and are thus not generally suitable as landing sites in and of themselves; however, several large craters with gullies have been identified as potential sites [16]. Additionally, MSL will be able to drive to the edge of its 10 km landing ellipse [12], thus avoiding a landing in difficult terrain but still allowing study of sloped regions. Gullies have been identified on mesa wall slopes in Acidalia, a relatively smooth region in the northern hemisphere. MSL could safely land in this region and then drive to mesas containing gullies. An example of such a site is seen in Figure 1. Here gullies appear on the side of a mesa, which itself is located in a relatively smooth area. Measurements of the channel slopes return slope values of ~4°, which is very low and could be accessible by MSL depending on the consistency of the slope material. Gullied slopes in both hemispheres have average slopes ~17° [2, 15]. While many are too large to be accessible by a rover, they are all relatively shallow, and many are well within the range of MSL.

**Expected results:** If the gullies are formed by water, ice may persist in both the channel and debris apron. Even if there is only a small amount of ice in the pore space of the slope material, it should be detectable by ChemCam, which has the ability to examine the composition of the near subsurface. There may also be evidence of salts, sulfate minerals, and even phyllosilicates in the lower parts of the gully, indicating the presence of water. In addition, if the upper source region of the gully is close enough, it may also be examined from afar to further test for the presence of water via a strong H signature. Negative results would also be important, since they would conclusively show that gullies are not formed by water. Regardless, gullies are an excellent place to test a wide array of hypotheses about the martian surface and near surface environments.

**Conclusion:** Gullies offer an excellent location to study habitability on Mars. While efforts will be made to ensure no gullies in landing sites, the occurrence of a gully in landing site is not a planetary protection problem due to the fact that they are only active intermittently, and are thus not habitable in and of themselves. The gully source material is likely more persistent, and is only accessible at the gully top. If care is taken to avoid contact with the source, it is unlikely that there will be any contamination of the source from MSL. Additionally, the ChemCam instruments' remote sensing abilities allow for the examination of the gully and its source from afar, further lessening the chances of contamination. While many gullies form in small, hard to reach craters, many are observed on mesas located in relatively flat regions. These regions offer a safe landing site while placing the rover near easily reached gullies. The shallow slope angles measured here suggest that MSL could drive directly to a gully after determining that it was not a special region.

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