A MODEL OF RECENT MARTIAN GULLY AND ALCOVE FORMATION BY SEEPAGE OF WATER.

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Introduction: This abstract presents a model that describes how Martian gullies and alcoves of recent age could form under present day atmospheric conditions. This model utilizes long-term seepage of groundwater, as opposed to sudden outbursts of large volumes of groundwater, to perform the erosion that forms the gullies and the alcoves.

Discussion: Mars Orbiter Camera (MOC) images have revealed the presence of gullies on many Martian craters and valley walls. It has been suggested that these gullies were formed by flowing water. In addition, age relations between the gullies and other surface features suggest a very recent age of formation [1]. Therefore, it is possible that water flowed at these locations under present day atmospheric conditions. However, water is not stable on the Martian surface where many of these gullies are found.

At most locations, under present day Martian atmospheric conditions, water released to the surface will either freeze or boil [2]. Because of this instability, rapid outbursts of large volumes of groundwater have been invoked to explain the erosion that forms the recent gullies. Seepage of groundwater is common on Earth, but rapid outbursts of large volumes of groundwater are relatively rare.

Another important consideration is the tendency of gullies to be located on pole facing slopes of craters and valleys. This strongly suggests a relationship between solar insolation and gully formation. This relationship, in turn, suggests that the sublimation rate of ice may play an important role in the formation of gullies.

Gullies often have heads that have been called alcoves [1]. The morphological differences between gullies and alcoves suggest different styles of formation and erosion. Another interesting characteristic of alcoves is that they are sometimes filled with a material that is morphologically distinct from crater and valley wall material. These alcoves have been classified as filled alcoves [1]. The model of gully formation presented here takes all of the above observations into consideration.

Model: In accordance with this model, water that initially seeps from crater or valley walls will boil, freeze, or infiltrate into the ground. If seepage continues, the water that freezes may build up as a relatively narrow and irregular sheet of ice, which may propagate down the slope of a crater or valley wall. Seepage of groundwater that leads to the formation of such ice sheets is a common occurrence on Earth.

As water continues to seep from the valley or crater wall, the ice sheet becomes progressively thicker. Thus, some of the water flowing under this sheet of ice may be isolated from the atmosphere and so it may not boil [3]. Also, the freezing rate of water flowing under the ice sheet may drop due to the insulating effect of the ice [4]. Any water that flows out from under the ice sheet will freeze and add to the expanding ice sheet, boil away, or infiltrate into the ground.

According to this model, it is this atmospherically isolated and thermally insulated flow of water that is responsible for most of the erosion and transport of material that forms the gullies. This model of gully formation allows for relatively low flow rates of water to perform the necessary erosion over relatively long periods of time, as opposed to other models that require rapid outbursts of large volumes of groundwater. Also, the model's reliance on ice can explain the preference of gullies for pole facing slopes, as sublimation rates are lower at these locations.

The presence of an ice sheet may have an erosional effect of its own. The freezing and thawing of water associated with the ice sheet could cause erosion of wall material beneath and around the perimeter of the ice sheet. As on Earth, when water in near surface material freezes, the expansion that occurs can pry material loose and accelerate erosion. This type of erosion may explain the formation of the alcoves that are often associated with gullies.

In this model, an alcove is a theater-shaped depression formed by the erosional effect of an expanding sheet of ice. An alcove may gradually form as wall material is eroded away from the perimeter of an ice sheet by freezing and thawing of water in near surface material. The ice sheet could then expand as water seeping around its perimeter freezes. This may continue until adjacent alcoves merge together. Eventually, seepage may decrease or cease and the ice formation may sublime away to reveal a newly formed alcove and gully.

Observations: Figure 1A is a MOC image of the wall of Dao Vallis that shows several filled alcoves. In this image, gullies appear to be originating from zones of material that possesses a smoother texture than the surrounding stratified wall material. It may be that this smooth textured material that fills the alcove is dust-covered ice. It is suggested that the features in Figure 1A represent recent or active examples of the model presented above.

Figure 1B is a MOC image of a filled alcove that has been eroded in such a way that a cross section of the filling material is visible. It is possible that exposed cross sections have thinner dust covers due to their fresh surfaces. As a result, ice at the cross sections may sublime more quickly, eroding the ice formations progressively from these areas. Eventually, if seepage decreases or ceases, the ice sheet may sublime away completely to reveal a newly formed alcove and gully (Figure 1C).

Conclusions: The model presented above describes how water may persist on the surface of Mars for relatively long periods of time under present day atmospheric conditions. Assuming long-term seepage of groundwater, the model explains how the erosion that forms the observed gullies can be performed without the need for sudden outbursts of large volumes of groundwater. The pole facing preference of gullies can be explained by the model's dependence on ice formation and sublimation rate. Additionally, the formation of alcoves may be explained by the erosional effect of freezing water around the perimeter of an expanding ice sheet. Finally, the material within filled alcoves is explained by the models requirement of ice.

References: [1] Malin, M.C. and Edgett, K.S. (2000) Science, 288, 2330-2335. [2] Lobitz, B., etal. (2001) PNAS, 98, no.5, 2132-2137. [3] Carr, M.H. (1983) Icarus, 56, 476-495. [4] Wallace, D. and Sagan, C. (1979) Icarus 39, 385-400.

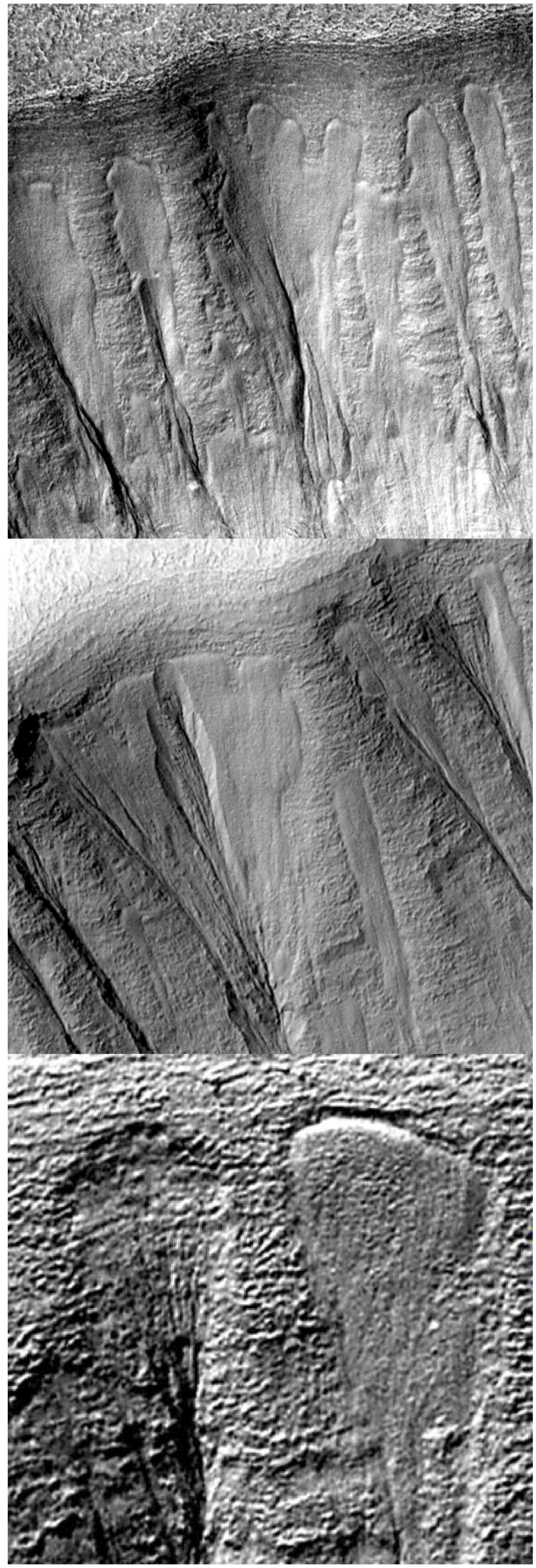

Figure 1: Three MOC images of the north slope of Dao Vallis. A slope of about 30 degrees has been derived from Mars Orbiter Laser Altimeter (MOLA) data for the upper portions of the valley wall in these areas. The lighting is from top left.

A (top): Definitive examples of filled alcoves. Several gullies appear to originate from the material filling the alcoves, which is assumed to be dust-covered ice. This suggests that water seeps from the wall underneath the filling material before surfacing near the bottom of the formation. The variety of widths of these filled alcoves may represent varying degrees of alcove erosion and ice sheet expansion. If these processes continue, individual alcoves could merge together. The complex alcove in the center of the image may represent such a formation. A portion of MOC image M11-01601.

B (middle): A filled alcove showing an eroded cross section of the filling material. The cross section appears to be eroding outward. This could be the result of a higher sublimation rate at the cross section due to a thinner dust cover. If the formation of ice from water seeping from the wall of the alcove is less than the sublimation rate of the ice, the filling material may completely disappear. A portion of MOC image M03-07529.

C (bottom): It is suggested that the alcove on the left side of the image was once filled with dust-covered ice that has sublimed away and that the alcove on the right side of the image is currently filled with dust-covered ice. Differing seepage rates or episodes may explain the disparity between these two alcoves. A portion of MOC image M03-06266.