FORMATION OF RECENT MARTIAN GULLIES BY AVALANCHES OF CO_2 FROST. T. Ishii and S. Sasaki, Department of Earth and Planetary Science, University of Tokyo, 7-3-1 Hongo, Tokyo, 113-0033, Japan. (te-tsu@eps.s.u-tokyo.ac.jp).

Introduction: The observation of recent gullies related to a possibility of the existence of liquid water on present Mars [1] is much debated in recent years. However, liquid water cannot be stable on the surface of present Mars, because average surface temperature is far below 273K and average surface pressure is slightly below water's triple point of 6.1 mbar. There are some regions on present Mars where temporarily liquid water is stable, but the regions have little correlation with the distribution of gullies [2].

About 95% of the Martian atmosphere is composed of CO_2 and the volatile dominating present Mars may not be H_2O but CO_2 [3]. A scene of CO_2 frost which is condensed on gully landforms like terrestrial H_2O snow is displayed by the MOC image (Fig.1). Musselwhite et al. [4] suggest a possibility of the gully formation by liquid CO_2 eruptions. But this scene is probably associated with avalanches of CO_2 frost condensed on the slope because no spouts of liquid CO_2 from the inside of the slope are observed in the image.

We infer the gully formation by avalanches of CO_2 frost and demonstrate that this hypothesis can explain the distribution, orientation and morphological features of gullies.

Orientation and Distribution: Gullies are dominantly observed on poleward-facing slopes [1]. Costard et al. [5] report the orientation of 213 gully landforms classified by latitudes in the southern hemisphere. The result indicates a correlation between slope orientations and latitudes. The correlation can be interpreted as the existence of a different lower marginal latitude among slope orientations. The marginal latitude of the coldest poleward-facing slopes is equal to the limit latitude at which gullies can be observed, and east and west slopes should have higher marginal latitude than that of the coldest south slopes. Furthermore, gullies on the warmest equatorward-facing slopes dominantly prevail in polar region and the limit latitude should be the highest.

Methods and Results: We calculate maximum thickness of CO_2 frost, which condense on slopes of 30 degrees in the southern hemisphere, as a function of latitude, obliquity and slope orientation. Models of Kieffer et al. [6], Mellon and Jakosky [7] and Mellon and Phillips [8] are referenced in our calculation of surface temperature and thickness of CO_2. The result is shown in Figure 2a, 2b and 2c. These figures indicate the distinct correlation between slope orientations and the marginal latitude, and approximately accord with the distribution reported by Costard et al. [5]. In our model, the temperature of sublimation point of CO_2 is fixed at 145K. The simplification of frost point may cause some variance of CO_2 frost thickness but the distribution of CO_2 frost will not be largely changed.

Discussion: Morphologies of alcoves, channels and aprons are defined in detail by Malin and Edgett [1] and the morphological features of channels and aprons are probably major evidence of the possibility of the gully formation by fluid flow as liquid water. Figure 3 shows remains of dry granular flows on the layered slope in an impact crater. In the upper part of the wall, the remains exhibit an alcove-like feature such as wedged shape with a tapering end. But the remains display no features of channels and aprons. If gullies are formed by dry flows of eolian material deposited on slopes by Mars' wind [9], channels characterized by deep incision with steep walls cannot be formed, because the eroded bedrock will be filled by the eroding material itself. And aprons as terrestrial alluvial fans could not be formed because of the absence of a steady passage of eroding material.

If eroding material is CO_2 frost, which condenses on slopes in the middle and high latitudes by midwinter, flowed CO_2 frost as eroding material sublimes to the atmosphere by next summer and does not leave. CO_2 frost condensed in the upper part of slopes slips down in winter and sublimes to the atmosphere by the increasing solar irradiance from spring to summer. By iteration of this process, scratches by solid CO_2 flows may grow gradually deeper and change into V-shaped channels. And steady passages of eroded material can build the feature of alcoves.

Figure 1 shows the remnant of CO_2 frost extended from the distal end of alcoves to the lower part of the slope in the south polar region. Other parts on the slope have the remnant of CO_2 frost only between small furrows. The difference of residual amount of CO_2 frost among each part may be caused by the difference of thermal property of each ground material. However, little residual CO_2 in the upper part of alcoves and thick CO_2 frost raked together in the distal end of alcoves suggest the occurrence of avalanches of CO_2 frost in gully landforms. Black fragments on the thick CO_2 frost deposit probably indicate that avalanches of CO_2 frost cause erosion of the slope bedrock at the same time.

The hypothesis of gully formation by avalanches of CO_2 frost can explain the distribution, orientation and morphologic features of gullies. Furthermore, the young undegraded appearance of gullies can be explained by CO_2 frost which condenses on slopes and renews the surface of gullies in an annual cycle.

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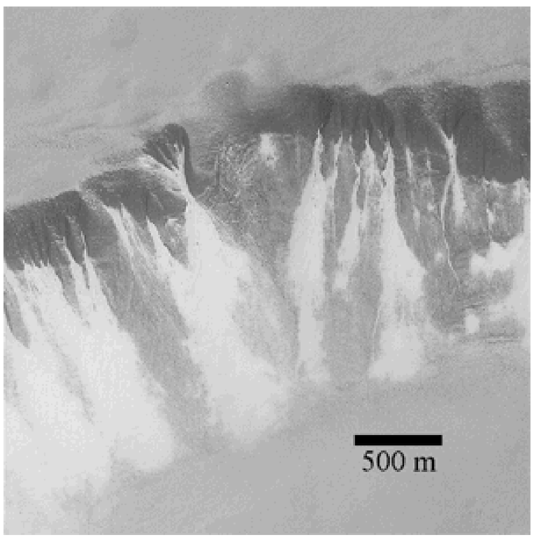

Figure 1. Remnant CO_2 frost on gully landforms. This landform is located near 70.7°S, 358.2°W. *Credit NASA/Malin Space Science System*

Figure 2. Maximum thickness of CO_2 frost **a.** on poleward-facing slope, **b.** on west-facing slope and **c.** on equatorward-facing slope in the southern hemisphere. Slope angle is 30°. The black areas in **a.** cannot be precisely calculated because of the formation of permanent CO_2 frost. The amount of condensed CO2 is calculated by the total balance between outgoing infrared radiation to the space and incoming energy flux into poleward-facing slopes, including the solar irradiance, the infrared radiation from the atmosphere, the reflected solar irradiance and the infrared radiation from adjacent flat plane and the heat flux into or out of the subsurface by conduction [6, 7, 8].

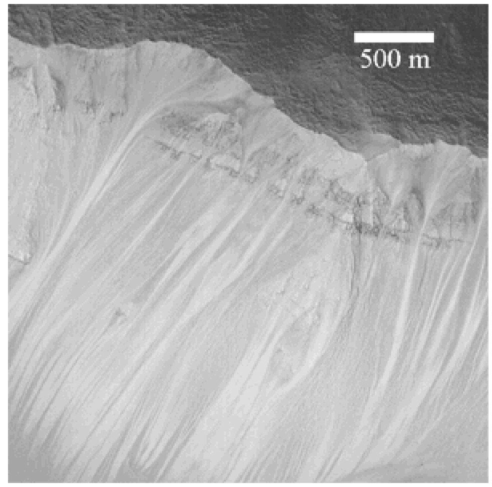

Figure 3. Dry granular flow from layered slope. Located near 30.2°N, 272.8°W. *Credit NASA/Malin Space Science System*