Understanding the role of CO_2 frost sublimation on Martian gullies

G. Ito[1,2], M. Sylvest[1], J.C. Dixon[1]
[1] Arkansas Center for Space and Planetary Sciences, University of Arkansas, Fayetteville, AR
[2] University of Michigan, Ann Arbor, MI

Introduction: Gullies on Mars (Fig. 1) typically resemble those on Earth, and are composed of alcoves, channels, and talus aprons.

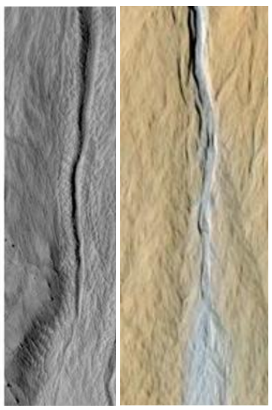

Fig. 1. HiRISE images showing morphology of a Martian gully [1].

Martian gullies are frequently thought to be created by running liquid water [2]. However, granular flow caused by sublimation of CO_2 frost [3] may also be a feasible hypothesis. This hypothesis does not require liquid water, which is difficult to exist on the surface of Mars except in special local conditions. Active gullies are found in HiRISE images [1] where temperatures and pressures are below 273 K and water's triple point of 6.1 mbar, respectively. Also, CO_2 is relatively abundant in the atmosphere of Mars; CO_2 frost regularly condenses and sublimates on the surface according to diurnal and seasonal temperature changes [4]. Additionally sublimating CO_2 gas acts as a lubricant to aid the flow of grains [5]. There is a high possibility that CO_2 sublimation is playing an important role in the initiation and the development of Martian gullies. Our goal in this study is to conduct an experiment that tries to further the understanding of Martian gullies by observing grain movements caused by sublimation of CO_2 frost.

Methods: Apparatus preparation and experiments were conducted in a 3 °C room. In a plastic container (Fig. 2. I), regolith (JSC Mars 1) was poured to about a thickness of 0.5 cm. Next, a layer of shaved dry ice was placed on top of the regolith. Then, the dry ice was covered with a thin layer of more regolith. This layering of regolith and dry ice simulates the Martian surface where CO_2 frost forms and is covered with aeolian deposits. The container was set at typical Martian gully slopes (20° to 35°). A 500 W halogen lamp was set at 25 cm above to speed sublimation. The surface movements of the regolith were recorded with a HD webcam (Fig. 2. II) for an average of 40 minutes.

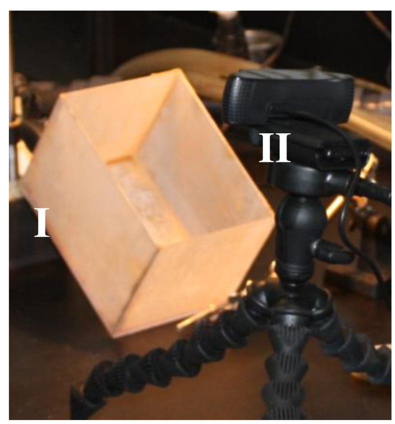

Fig. 2. Experiment set-up. I. Container. II. Webcam.

Results and Discussion: The movement is best described by a combination of granular and mass flows (Fig. 3). The mean velocity of granular flow is within a range of 0.1 cm/min. to 0.4 cm/min. Average granular flow rate increases with slope angle (Fig. 4).

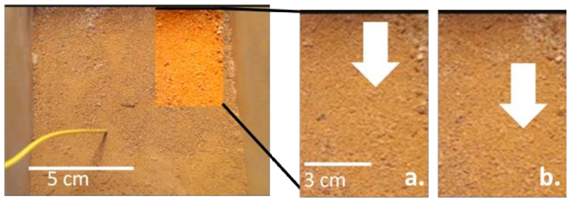

Fig. 3. Still images of regolith movement at 28° slope, 128 sec. apart. Arrows indicate positions of one sample grain.

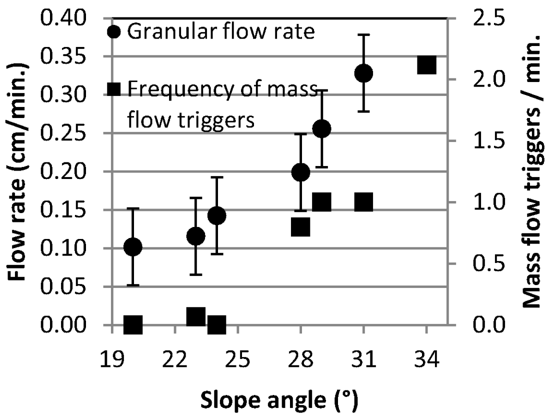

Fig. 4. Plot showing granular flow rate and frequency of mass flow triggers vs. slope angle.

CO_2 sublimation on slopes closer to the critical angle (34°) is likely to have a greater impact on gully morphology than lower angles. Additionally, grains fell down the slope rather than being uplifted by sublimating gas. Occasional collapses trigger mass flows, and the frequency of collapses generally increases with angle steepness (Fig. 4). A large collapse occurred at 34° where multiple layers slid together, and an alcove-like formation was observed (Fig.5). This was drastically different from other mass flows in which only the top regolith slid. 34° is the critical angle for this material; it is likely that the weight of a pile of regolith that formed during preparation caused a larger stress which led to this larger collapse. This may be tied to the initiation of alcoves. Furthermore, a channel may be created from the grain flow after the collapse, but the apparatus used in this experiment was insufficient in size. Another implication may be that the collapses and grain flows create gullies indirectly by moving larger rocks or breaking edges of aquifers on Martian surface.

Fig. 5. Still image of a large collapse that occurred at 34° slope.

Conclusions: Sublimating CO_2 gas from frost alone can cause granular flows in regolith. Because of the limitation of the apparatus size, no channels were formed in this experiment. We would like to use a larger container in the future to accommodate space to form alcoves, channels, and talus. Nevertheless, there were signs of gully morphology, an alcove-like formation, during the collapses. Even if CO_2 sublimation by itself does not form gullies directly, it may be an indirect cause as granular flows and collapses can initiate other mechanisms that form gullies. CO_2 frost sublimation is likely to be playing an important role in forming Martian gullies.

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