ISOLATING THE ROLE OF VOLATILES IN THE EROSION OF BEDROCK CHUTES ON MARS. J. N. Levin[1,2], J. L. Dickson[2], M.P.Lamb[2] [1]Columbia University (j.levin@columbia.edu), [2]California Institute of Technology.

Introduction: Martian gully channels [1], which typically incise indurated fine-grain material like the latitude-dependent mantle [2] and dunes [3], frequently emanate from amphitheater-shaped chutes that are eroded into bedrock at the crest of steep slopes [1], most commonly crater walls in the mid-latitudes of Mars. Though gully channels are morphologically similar to water-carved landforms on Earth, recent work has tied these features to seasonal CO_2 activity [4]. If gully channels can be incised by processes that do not involve H_2O [5], does the same hold true for bedrock chutes, which are made of considerably stronger material? This project aims to explore the role of dry rockfall in the erosion of the bedrock alcoves of Martian gullies. Bedrock chutes may also preserve a longer record of gully activity than their associated channels, which have been shown to be ephemeral features over long timescales [2].

To understand the capacity for bedrock erosion on steep slopes in a completely dry environment, we follow upon the work of Bart [6] and Kumar et al. [7], who have shown that features that are broadly visually similar to Martian gullies are observed on fresh crater slopes on the Moon [7]. The long duration success of both the Mars Reconnaissance Orbiter and the Lunar Reconnaissance Orbiter allow us to make observations and measurements using data not previously available.

We performed a global survey of bedrock chute morphology on Mars using Digital Elevation Models (DEMs) we generated using Ames Stereo Pipeline [8] from Context Camera (CTX) [9] imagery. High resolution DEMs generated from High Resolution Imaging Science Experiment (HiRISE) [10], and Lunar Reconnaissance Orbiter Narrow Angle Camera (LRO NAC) [11] imagery were used for Mars and the Moon respectively, to compare the morphology of bedrock chutes on Mars to those on the Moon in closer resolution, and validate the CTX measurements.

Lunar Survey: Target locations for Lunar erosion were identified using a slope map generated from Kaguya Terrain Camera [12] data to filter locations with slopes between 30-40°. All potential LRO NAC stereo pairs that overlap an area of sufficiently steep slope were visually inspected for erosional landforms. Chute measurements were taken in locations with sufficient DEM coverage.

Mars Survey: After conducting a global survey of 4 – 9 km diameter craters with potential CTX stereo pairs, CTX DEMs were generated and used to systematically measure bedrock chute relief on North and South facing slopes. Martian slopes were categorized based on their orientation and the presence of regolith-incised channels beneath the bedrock chutes.

Comparison of Chute Morphologies: The morphologies of Lunar erosional landforms (Fig 1a) were analyzed using qualitative observations and quantitative measurements taken from the DEMs. These were compared with measurements of bedrock chutes in a range of Martian environments that do and do not host gullies (Figs. 1-2): equatorial (Fig 1b), midlatitude pole-facing slopes without channels (Fig 1c), and midlatitude pole-facing slopes with channels (Fig 1d).

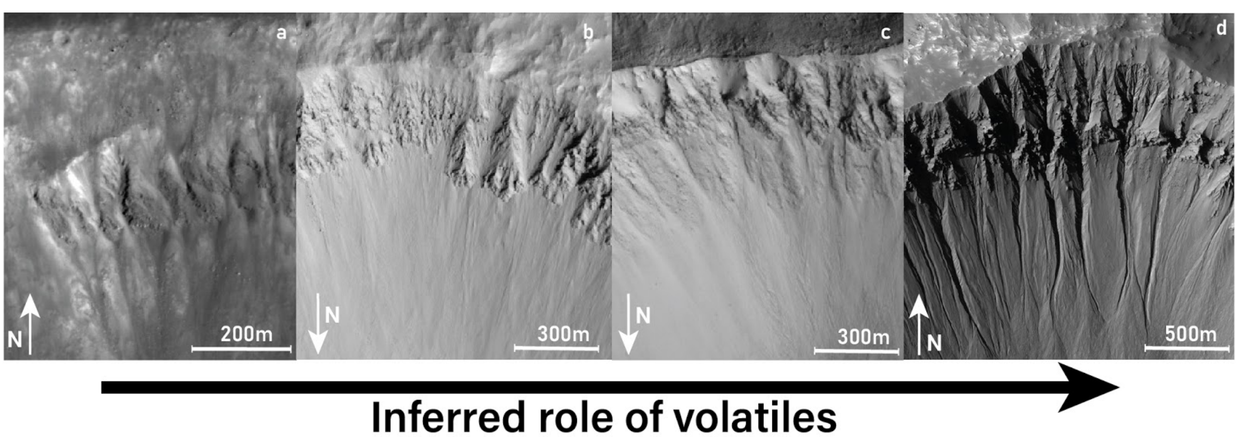

Figure 1: Examples of bedrock chutes on slopes with rising inferred role of volatiles a) Lunar, b) equatorial, c) midlatitude pole-facing without channels d) midlatitude pole-facing with channels

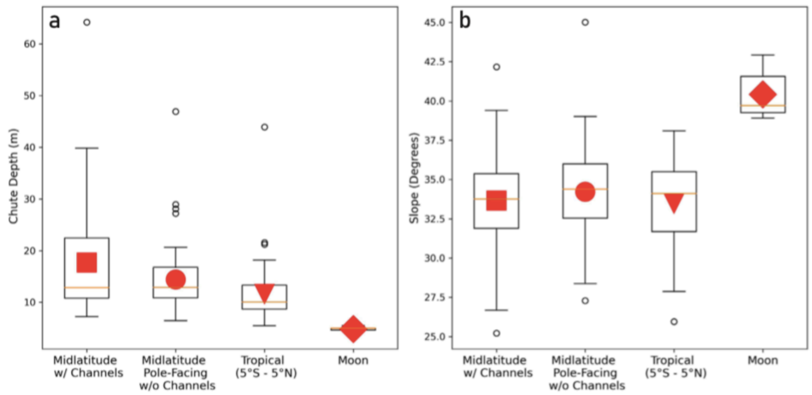

Figure 2: Bedrock chute morphology (a) chute relief, b) slope) measurements by category

Results show that lunar chutes (Fig 1a) are statistically shallower than martian chutes. Though deep chutes were observed on channel-less slopes and equatorial craters on Mars, statistically, bedrock chutes there tended to smaller than those on slopes with channels (Fig 2). As expected, lunar chutes were also found to be much steeper than martian chutes.

Globally on Mars, the deepest chutes were shown to be pole-facing chutes in the southern hemisphere (Fig 3). This observation echoes the orientation preference exhibited by gullies for cold, pole-facing slopes [1]. However, the trend of deeper chutes on the pole-facing slope as compared to the equator facing slope continues below the known region where gullies form, showing a clear orientation difference from 10° - 30° S (Fig. 3).

Implications: While our lunar survey revealed some debris chutes on the Moon that can mimic some gully channels on Mars [6-7], we have not observed the same channelization on the Moon that is comparable to a typical gullied system on Mars (Fig. 1d). Some bedrock chutes observed on Mars, particularly in the equatorial regions where gullies are not found, are morphologically similar to lunar chutes, suggesting that volatile-free processes can indeed erode bedrock on steep slopes on Mars. The spectrum of measured bedrock chute relief spanning from shallowest Lunar chutes to deepest Martian midlatitude chutes, as well as the clear orientation dependence observed in the martian southern hemisphere leads us to conclude that CO_2 and H_2O play a role in the erosion of bedrock chutes on Mars [4]. The mechanism by which bedrock alcoves are eroded on Mars requires further testing, and may involve volatile-processes from previous climate regimes not directly related to the process that carves gully channels (e.g. glaciation), that also prefer cold, pole-facing midlatitude slopes.

Our results implicate volatile activity within gully alcoves, which preserve a much longer geologic record than typically ephemeral gully channels. Thus, gully alcoves could potentially reveal H_2O and CO_2 related processes within terrains that do not host gullies on contemporary Mars.

References: [1] Malin and Edgett, 2000, *Science*, 288, 2330. [2] Dickson et al., 2015, *Icarus,* 10.1016/j.icarus.2014.12.035. [3] Diniega, S. et al., 2010, *Geology*, 38, 1047. [4] Dundas et al., 2015, *Icarus,* 251, 244-263. [5] Pilorget and Forget, 2016, *Nat. Geosci.* 9, 65-69 [6] Bart, 2007, *Icarus*, 10.1016/j.icarus.2006.11.004. [7] Kumar et al., 2013, *J. Geophys Res.,* 118. [8] Beyer et al., 2018, *Earth and Space Science,* 5. [9] Malin et al. 2007*, J. Geophys Res.* 112, [10] McEwen et al., 2007, *J. Geophys. Res.,* 112. [11] Robinson et al., 2010, *Space Science Review,* 150: 81. [12] Kato et al., 2010, *Space Science Review,* 154: 3.

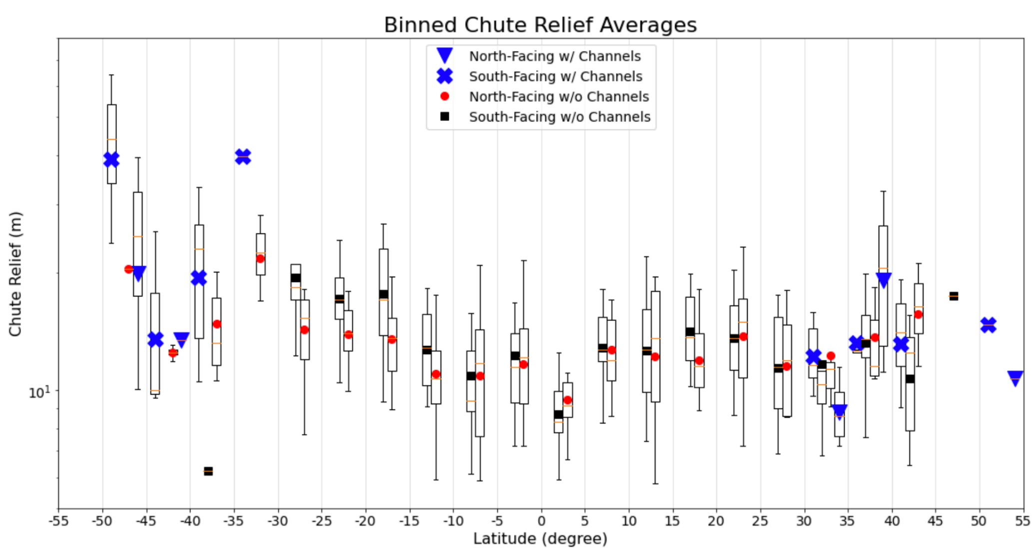

Figure 3: Average chute relief measurement of orientation dependent crater slopes with and without channels in the regolith, binned by 5°