**GULLY INCISION DEPTHS IN MANTLE AND BEDROCK IN UTOPIA PLANITIA: IMPLICATIONS FOR GULLY FORMATION ON MARS.** A. Noblet[1], G. R. Osinski[1], S. J. Conway[2], [1]Dept. of Earth Sciences, Univ. of Western Ontario, London, Canada (anoblet@uwo.ca), [2]Laboratoire de Planétologie et Géosciences, CNRS UMR 6112, Université de Nantes, France.

**Introduction:** Gullies on Mars are geologically young landforms that resemble terrestrial gullies [1]. Martian gullies are often carved within a mantling unit in the mid- to high-latitudes of Mars [2]. This mantle is a relief-muting unit [3] that is proposed to be composed of a mixture of dust and water ice that recurrently deposited during Mars' periodic high-obliquity excursions [4]. The formation mechanism of gullies is key to understand Mars' recent climate: previous works, focused on gullies carved into the mantling unit, have suggested meltwater sourced from the volatile-rich surface as one plausible gully-forming scenario (e.g. [5,6]). Other works, focused on the mantle, have studied gullies to infer the thickness of the mantle deposits [7] and provide constraints on Mars' near surface water ice volume. To test the effect of the substrate nature and slope-orientation on gully formation, we inspect individual gully alcoves in Utopia Planitia in the northern plains of Mars, record their orientation, the nature of the substrate, and calculate their incision depths.

**Approach**: We consider gullied hillslopes in Utopia Planitia, a region with abundant occurrences of ice-rich mantling material [8]. We used HiRISE images at 25-50cm/pixel [9] in a sinusoidal projection as a basemap. We inspected every gullied hillslope that we previously mapped in a previous abstract [10] using [11]'s gullied landforms global dataset (Figure 2). We focused our study on individual gully alcoves displaying a V-shaped incision profile with straight walls (Figure 1). We recorded the substrate nature, either mantle deposits or bedrock, and we measured the width of the alcove wall at its widest part, We calculated the associated incision depth, assuming a 20° cross-profile slope as observed by [12]. Finally, we record the upslope to downslope orientation value of each studied alcove.

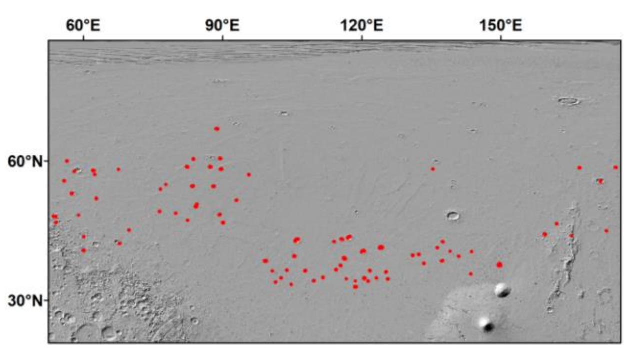


*Figure 2: Map of gullied hillslopes in Utopia Planitia mapped by [13].*

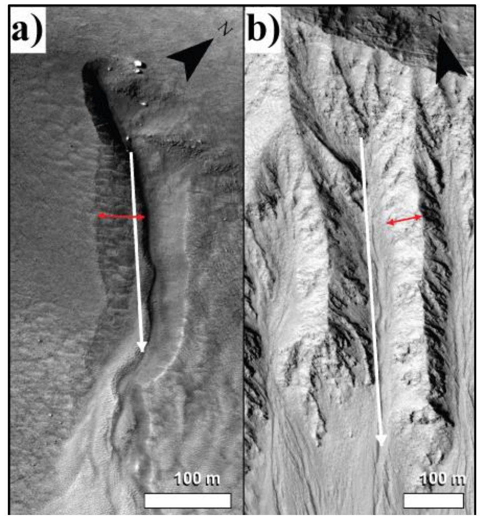


*Figure 1: Mapping method for recording the orientation of gully alcoves in white, and the alcove wall length in red. a) Mantle alcove, ESP_017181_2405. b) Bedrock alcove, ESP_017720_2200.*

**Results:** We have mapped and calculated incision depths for 542 gully alcoves, of which 306 carved in mantle substrate and 236 in bedrock. The orientation distribution of alcoves is bi-modal (Figure 3), depending on the substrate: mantle carved alcoves are pole-facing while bedrock carved alcoves are almost exclusively equator-facing. This trend reflects a global-scale trend of the mantling unit being preferentially observed on pole facing slopes [13,14].

We observe that alcove wall widths in adjacent gullies in the same type of substrate can vary by a factor of 10, which explains the important scatter of our individual data points (Figure 4). Incision depths derived for a 20° alcove wall slope are comparable in bedrock and mantle alcoves (respectively 2-46 m and 2-59 m), though they are deeper overall in mantle alcoves (median=15.6 m) than in bedrock (median=13 m). This result was expected, as the mantle deposits provides a more erodible substrate than bedrock, which results in more dramatic topographic expressions of gullies [15]. However, we note that on the contrary between ~43°N and 52°N bedrock alcoves are on average deeper than mantle alcoves. This latitudinal band of shallow mantle alcoves also overlaps with a region between 37° and 47°N where only 8 occurrences of mantle alcoves are observed.

For gully alcoves emplaced in mantle material, incision depths values do not show clear positive correlation with increasing latitude as opposed to what

[12] noted. Instead, we observe maximum depths (up to 59m) centered around 37°N and 52°N, and shallower depths (up to 20m) between 37°N and 47°N, as well as poleward of 55°N.

**Discussion**: We have shown that alcove incision depth in mantle material in Utopia Planitia does not increase with increasing latitude, contrary to the global trend of increasing mantle thickness with increasing latitude noted by [12], and have observed a region with few and shallow mantle alcoves between 37° and 52°N. We interpret this as indicative of local variations in the mantling material's physical properties on hillslopes in this latitudinal band, with shallower and less widespread mantle between 37°N and 52°N. This interpretation is in line with the identification of a stratified ice-rich sedimentary unit between ~38°N to 47°N in Utopia Planitia by [16]. This mid-latitude unit is older (~11Ma age), more degraded, and is interpreted to have different geological characteristics from the Latitude Dependent Mantle (~1.5Ma age).

We have shown that gullied slopes in Utopia Planitia follow a global trend in terms of substrate and orientation, with mantle carved alcoves occurring preferentially on pole-facing slopes. In addition, we observed that gully alcoves are found in almost equal parts in the mantling unit and in the bedrock. Our results neither prove or disprove the top-down melting scenario proposed by [6], where gully formation initiates via the melting of the mantling unit and ultimately results in the exposure of the underlying bedrock. Indeed, during mapping we observed degraded mantle remnants on the lower portion of equator-facing slopes, which could suggest that the mantling unit was removed in the upper portion of these slopes. However, we also observed 'pristine' equator-facing gullied slopes with no evidence of past mantling, as well as fresh-looking channels within bedrock carved alcoves. We suggest that another process is required to explain these morphologies in the absence of a volatile-rich mantling unit, for example the melting of recent snowpack or $CO_2$-ice driven mechanisms [17].

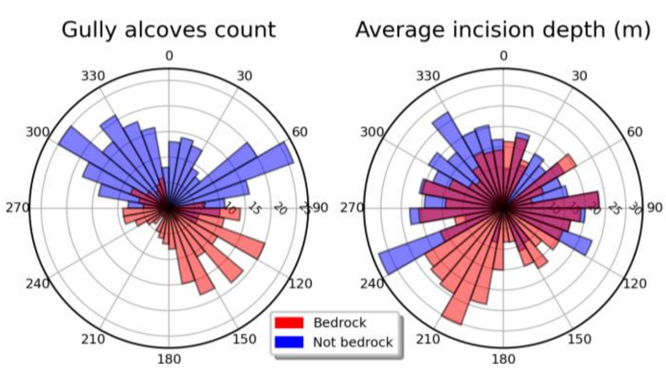


*Figure 3: a) Gully alcoves count as a function of alcove direction. b) Average incision depth for a 20° wall slope as a function of alcove direction.*

**Conclusion and further work:** We suggest that gully alcoves' average depths reflect the ice-rich mantle physical properties variations at the regional scale of Utopia Planitia, but large variability at the local scale suggest local controls and potentially local processes for gully development.

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**References:** [1] M.C. Malin and K.S. Edgett (2000) *Science*, *288*, 2330–2335.[2] J.L. Dickson et al. (2013) *Lunar Planet Sci Conf*, *44*, #1012.[3] M.A. Kreslavsky and J.W. Head (2000) *J. Geophys. Res. Planets*, *105*, 26695–26711.[4] J.W. Head et al. (2003) *Nature*, *426*, 797–802.[5] P.R. Christensen (2003) *Nature*, *422*, 45–48.[6] J.S. Levy et al. (2009) *Icarus*, *201*, 113–126.[7] S.J. Conway and M.R. Balme (2014) *Geophys. Res. Lett.*, *41*, 5402–5409.[8] R.J. Soare et al. (2005) *Icarus*, *174*, 373–382.[9] A.S. McEwen et al. (2007) *J. Geophys. Res.*, *112*, E05S02.[10] A. Noblet and S.J. Conway (2022) *Lunar Planet Sci Conf*, *52*, #1928.[11] T.N. Harrison et al. (2015) *Icarus*, *252*, 236–254.[12] S.J. Conway et al. (2018) *Geomorphology*, *318*, 26–57.[13] S.J. Conway and N. Mangold (2013) *Icarus*, *225*, 413–423.[14] M.A. Kreslavsky and J.W. Head (2003) *Geophys. Res. Lett.*, *30*.[15] J.L. Dickson et al. (2015) *Icarus*, *252*, 83–94.[16] A. Séjourné et al. (2019) *J. Geophys. Res. Planets*, *124*, 483–503.[17] C.M. Dundas et al. (2019) *Geol. Soc. Lond. Spec. Publ.*, *467*, 67–94.

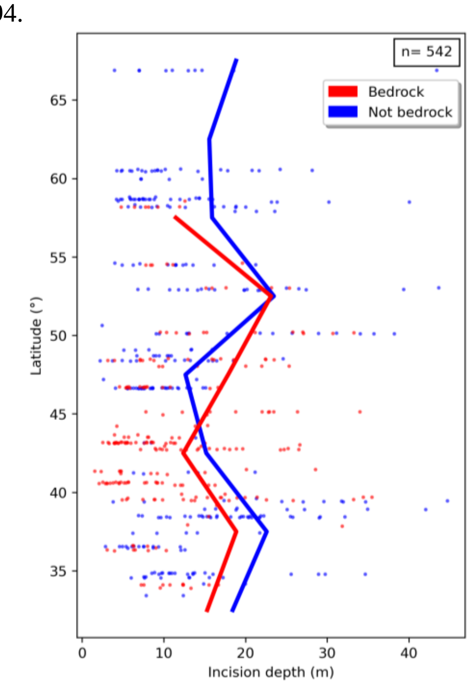


*Figure 4: Incision depth for bedrock alcoves non-bedrock as a function of latitude. Individual data points correspond to depths calculated for an alcove wall slope of 20°. The thick lines correspond to the average incision depth in 5° latitude bins for a 20° wall slope value.*