A Review of Martian CO2 Sublimation Processes and their Field and Laboratory Analogs. L.E. McKeown[1] and S. Diniega[2] and G. Portyankina3 and K.-M. Aye3 [1]Natural History Museum (l.mckeown@nhm.ac.uk) [2] Jet Propulsion Laboratory, Pasadena, CA, USA, LASP, 3University of Boulder, Colorado, USA

Introduction: The Martian surface is host to a diverse array of surface features that are widely attributed to the sublimation of volatiles – either in the present day or recent geological past. Atmospheric conditions even in the coldest environments on Earth are orders of magnitude different to those on contemporary Mars. Additionally, many sublimation-driven features on Mars are unlike anything seen on Earth. Therefore, understanding how sublimation drives the evolution of the Martian surface has until recently, relied heavily on remote-sensing and modelling efforts.

A new advent of laboratory experiments have offered an empirical perspective on the formation of Mars polar features, by simulating all but acceleration due to gravity on Mars. However, scaling issues introduce limitations that necessitate a multi-faceted approach. We review the laboratory and field analog work conducted to date in relation to Martian sublimation features, planned future experiments and we invite discussion on how else our understanding of the evolution of the Martian surface might benefit from laboratory and field analog approaches used to date. In addition, we review potentially sublimation-driven features on other planetary bodies and invite discussion on whether we can use analogs on Mars or Earth as natural laboratories.

Field Work: We review Terrestrial field campaigns conducted to explore analog processes of a putatively sublimation-driven nature. For example; a series of field campaigns in Utah and Arizona conducted to investigate the Sliding CO_2 Block Hypothesis in relation to linear dune gullies [1] were necessary to investigate whether sliding sublimating CO_2 blocks could erode channel morphologies and deposit lateral levées. We also discuss analog-based research using Terrestrial gullies (e.g. [2-5]) which provide a resource to investigate wet-based mass-wasting processes and highlight the need for Mars condition laboratory experiments to explore slope-destabilising sublimation feature formation under Martian conditions, of which only few campaigns have begun to investigate [e.g. 6, 7].

Laboratory Experiments: Laboratory experiments under Martian atmospheric pressure and polar temperature ranges have been integral to understanding the conditions under which active sublimation features on Mars form. For example, experiments investigating the nature of condensed ice morphologies are key to understanding the environments under which active dendritic troughs form in the present day on Mars [8]. Experiments simulating cryoventing under Mars conditions have provided a proof-of-concept of Kieffer's Hypothesis for araneiform formation [9]. Experiments under Earth conditions have even allowed us to provide a rough estimate of how much linear dune gully pits should widen with a given volume block of CO_2 [10]. Moreover, laboratory experiments under Mars conditions have revealed new exotic processes such as those instigated by metastable liquid water, which now must be considered in the context of Martian mass-wasting features [11, 6].

Conclusion: This abstract provides a non-exhaustive summary of recent empirical studies of extant processes on Mars and the advances made by this work in our understanding of the contemporary modification of the Martian surface. We present proposed next-step experiments on insolation-driven CO_2 sublimation in the context of araneiform development and we welcome and invite feedback on potential constraints – particularly from modellers. We collate key insights provided by laboratory and field studies of Martian sublimation processes, as well as related analog work on non-sublimation processes, with a view to inviting discussion among the community on how we can improve upon and utilize these methodologies going forward.

References:

[1] Diniega, S., Hansen, C.J., McElwaine, J.N., Hugenholtz, C.H., Dundas, C.M., McEwen, A.S., Bourke, M.C. A new dry hypothesis for the formation of martian linear gullies, Icarus, 225. 526-537, 2013

[2] Hartmann, W. K., Thorsteinsson, T, Sigurdson, F. Martian hillside gullies and icelandic analogs, Icarus, 162, 2, 2003

[3] Conway, Susan & Haas, T. & Harrison, Tanya & Carling, Paul & Carrivick, Jonathan. Martian gullies and their Earth analogues: Introduction. Geological Society, London, Special Publications, 2018

[4] Conway S., de Haas T. & Harrison T.N. Martian gullies: a comprehensive review of observations, mechanisms and the insights from Earth analogues. In: Martian Gullies and their Earth Analogues. Geological Society, London, Special Publications, 467, 2018

[5] Conway S.J., Butcher F.E.G., de Haas T., Deijns A.J., Grindrod P.M. & Davis J.M. 2018a. Glacial and

gully erosion on Mars: a terrestrial perspective. Geomorphology, 318, 26–57

[6] Raack, Jan; Conway, Susan J.; Herny, Clémence; Balme, Matthew R.; Carpy, Sabrina and Patel, Manish R. Water induced sediment levitation enhances downslope transport on Mars. *Nature Communications*, 8, 1151, 2017

[7] Sylvest, M. E., Conway, S. J., Patel, M. R., Dixon, J. C., and Barnes, A. (2016), Mass wasting triggered by seasonal CO_2 sublimation under Martian atmospheric conditions: Laboratory experiments, *Geophys. Res. Lett.*, 43, 12,363– 12,370

[8] Portyankina, G.; Merrison, J.; Iversen, J.J.; Yoldi Martínez de Mandojana, Zuriñe; Hansen, C.J.; Aye, K.-M.; Pommerol, Antoine; Thomas, Nicolas (2019). *Laboratory investigations of the physical state of CO 2 ice in a simulated Martian environment.* Icarus, 322, pp. 210-220. Elsevier 10.1016/j.icarus.2018.04.021

[9] L.E. Mc Keown, M.C. Bourke, J.N. McElwaine, M.E. Sylvest, and M.R. Patel. The
Formation of Araneiforms by Carbon Dioxide Venting and Vigorous Sublimation Dynamics Under Martian Conditions. *Under Review*

[10] L. E. Mc Keown, M. C. Bourke, and J. N. McElwaine. Experiments on Sublimating
Carbon Dioxide Ice and Implications for Contemporary Surface Processes on Mars.
Scientific Reports, 7:14181, 2017.

[11] M. Mass_e, S. J. Conway, J. Gargani, M. R. Patel, K. Pasquon, A. McEwen, S. Carpy,
V. Chevrier, M. R. Balme, L. Ojha, M. Vincendon, F. Poulet, F. Costard, and
G. Jouannic. Transport processes induced by metastable boiling water under martian
surface conditions. Nature Geoscience, 9, 2016.