THE POTENTIAL ROLE OF FINE DUST ON MARTIAN LINEAR DUNE GULLY ACTIVITY.

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Introduction.
On Mars, active linear gullies (characterized by long, up to 1km, channels) have been observed [3]. These features are predominantly located in southern hemisphere, inter-crater dune fields, between latitudes 36.3°S to 54.3°S and 64.6°S to 70.4°S [1].

High resolution change detection imagery from the High-Resolution Imaging Science Experiment (HiRISE) has indicated a range of associated geomorphological characteristics. Linear gullies have linear-to-sinuous channels, bounded by lateral levées which terminate in a singular `main' pit and often, multiple smaller `detached' pits [5]. The main pit is found at the base of the linear gully, is generally similar in diameter to the channel and typically has a circular shape. Detached pits surround the main pit or distal end of the channel. These often have no associated channels and appear as small circular depressions radial to the main pit, but in some cases have small `tails' [5]. Recurrent Diffusing Flows (RDFs) were identified as digitate relatively low albedo patches lateral to the linear gully channel which sometimes have a higher albedo `white halo' [6].

While gullies characterized by alcove-channel-apron morphologies are abundant on Earth and reflect wet debris flow mass movement, linear dune gullies have no direct Terrestrial analog. As liquid water is currently not stable on the Martian surface and based on field tests involving sliding CO_2 ice blocks within dune fields in Utah, it has been hypothesized that linear gullies are formed by seasonal CO_2 sublimation activity [2].

The `sliding CO2 ice block' hypothesis proposes that carbon dioxide ice blocks, (detached from frost deposits on dune crests during the Martian spring) incise long linear channels as they move downslope, lubricated by a cushion of gas brought about by the Leidenfrost effect [9]. Once they become stationary, they continue to sublimate, and erode sediment *in situ* to form a singular terminal pit. In some cases, the CO_2 block may fragment, eject and propel smaller sublimating ice blocks that erode an array of smaller pits along the ejection trajectory. Analog laboratory experiments also indicated that subsurface gas jetting once a block burrows may result in endogenic pits either formed directly by the gas jet, or by granular cluster deposition forming `impact pits' on the surface, which were found to be more likely in the presence of dust-sized grains [5].

Mars is subject to frequent regional and even planet encircling dust events (PEDE). These storms can redistribute significant quantities of dust and are being observed to affect atmospheric and surface processes [11,4]. We propose that this includes linear gully formation on aeolian dunes.

In terms of sublimation activity, we hypothesize that dust encased in the seasonal CO_2 ice layer can absorb incoming radiation creating `vapor prisons' and 'channels' within the ice, as was proposed by Kieffer [8], leading to more brittle ice and hence greater fracture density in spring [9]. While the timing of such a 'self-cleaning' process is unconstrained, we postulate that greater redistribution of dust may affect block activity and hence disrupt the trends in annual linear gully pit formation previously observed [5].

In addition, Recurring Diffusive Flow features lateral to linear gully channels may represent ejected material from within channels, enhanced by the presence of dust [1,5]. If their activity is influenced by dust redistribution, we expect to see measurable change before and after global dust storms on Mars.

To test the role of global dust storms on the level of linear gully activity on dunes, we report on a comparative study of linear gully change before and after the 2018 PEDE.

Methods.
We conducted surveys at 5 sites on Mars. These sites were selected using the following criteria:

1. Located between 36.3°S to 54.3°S and 64.6°S to 70.4°S and linear gullies reported previously [1].
2. Hosted > 7 linear gullies with visible main and detached pits (Fig.1).
3. Had HiRISE imaging available for at least 4-5 of the Mars years between MY 28 and 36 (as well as imaging before and after the 2018 PEDE).

Qualitative study.
We examined all available HiRISE images for our sites. Our initial qualitative investigation documented the types of interannual geomorphic changes evident in the absence of prior global dust activity as in [5] (Fig. 1*)*. This included observing RDF appearance and disappearance, main pit size increase, bright deposits in channels/pits that may be blocks and detached pit formation following spring activity. From this, we identified parameters to quantitatively measure.

Quantitative study.
We analyzed summer HiRISE images taken before and after the 2018 PEDE using JMARS geospatial software to conduct a quantitative comparison of the surface change from spring sublimation activity, observed before and after the PEDE. A custom shape layer in JMARS was used to create points and polygons (Fig. 2) measuring the following activity:

1. Main pit diameter.
2. The number of detached pits per main pit.
3. Presence/growth of RDFs.

These measurements were taken across all sites in the summer images for each year with imaging available between MY28 and MY36 (including before and after the 2018 PEDE. A control database was created for each site using a 3-4 MY period, where no extensive dust storm activity occurred. The data from the quantitative and qualitative studies were also compared to previous research conducted on this topic [2, 5 ,7].

Discussion.
This work is ongoing and the quantitative assessment is still being analyzed, however we can report qualitatively that there appears to be measurable change in baseline activity following the 2018 PEDE.
We observe changes in the shape and appearance of many main pits (for example changes in roundness, development of tails etc. Further, preliminary observations indicate that detached pit formation on the local scale, is enhanced with dust redistribution, as was observed for 'impact' pits in laboratory experiments. Further geomorphological analysis as well as empirical lab observations will be needed to address whether the source of these pits owes to endogenic gas jetting, or if detached pits formed by enhanced block fracturing. Comparative studies such as this on the effects of fine dust on sublimation features will help broaden our understanding of the feedback between atmospheric processes and surface change on Mars in the present day.

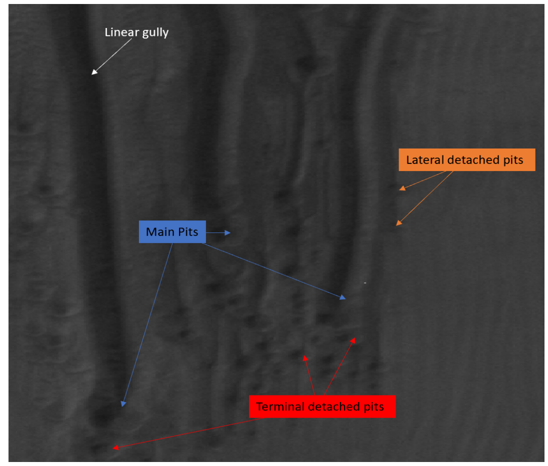

Fig.1. Three linear gullies in the Hellas Planitia dune field. The geomorphic detached pit (divided into terminal and lateral) and main pit features and indicated.

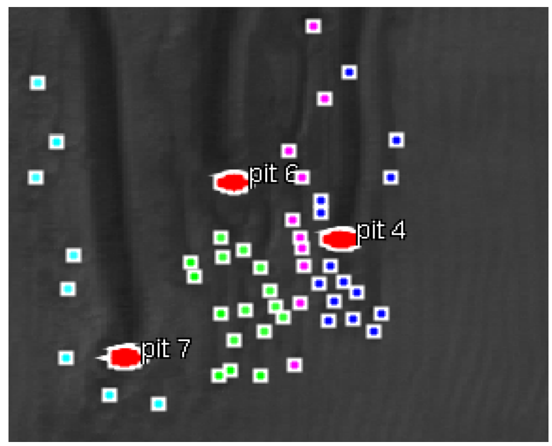

Fig. 2. Main Pits (4-7, red) of 3 gullies (Fig. 1) in the Hellas Planitia dune field. Image taken during summer of Mars year 33. Each pit has a series of color-coded detached pits.

References.
Pasquon et al., 2016, Icarus. [1] Diniega, S., Hansen, C.J., McElwaine, J.N., Hugenholtz, C.H., Dundas, C.M., McEwen, A.S., Bourke, M.C., 2013, Icarus. [2] Mangold, N., Forget, F., Peulvast, F.C.J.-P., 2002, EGS General Assembly Conference Abstracts, vol. F27. [3] McEwen, A.S. et al., 2021, Journal of Geophysical Research: Planets. [4]
Mc Keown, L.E., Bourke, M.C. and McElwaine, J.N, 2017, Scientific Reports. [5] Pasquon, K. et al., 2016, Icarus. [6] Piqueux, S. et al, 2015, Icarus. [7] Kieffer et al., 2006, Nature. [8] Mc Keown, L.E. PhD Thesis, 2018. [9] Leidenfrost, 1966, International Journal of Heat and Mass Transfer [10] Holmes et al., 2021, Earth and Planetary Science Letters [11].