PRESENT-DAY MARTIAN DUNE GULLY ACTIVITY. S. Diniega[1], S. Byrne[2], N. T. Bridges[3], C. M. Dundas[2], and A. S. McEwen[2], [1]Program in Applied Mathematics, The University of Arizona, 617 N. Santa Rita Ave., P.O. Box 210089, Tucson, AZ 85721-0089 (serina@math.arizona.edu), [2]Dept. of Planetary Sciences, The University of Arizona, [3]Applied Physics Laboratory, John Hopkins University.

Martian slope gullies (composed of an alcove, channel, and apron) have been the focus of much controversy in recent years, as scientists seek to understand how they develop and what they imply about the martian environment. Formation theories have involved a wide range of environmental conditions and processes, such as groundwater eruption [1, 2], the melting of snow or ice following climate change [3, 4], or dry granular flow [5, 6]. However, a dearth of observations or information about the environmental setting of slope gully formation has made it difficult to evaluate among competing theories.

Dune gully observations

In this study, we focus on slope gullies found on martian dunes in the southern hemisphere – a class of gullies that has been neglected in previous slope gully studies. Using MOC, CTX, and HiRISE images, we identified dune gullies throughout the southern hemisphere (Fig. 1). We found 18 gullied dune fields, seven of which had sufficient overlapping high-resolution coverage for identification of gully activity within the last five martian years, such as alcove/channel widening and/or apron extension between images (Fig. 2). Using this repeat coverage, we were able to constrain the times of definite morphologic changes as well as signatures of recent activity (albedo and textural signatures that were associated with recent apron deposition, and which faded soon after appearing and did not re-appear in subsequent years).

We found that the overlap of six periods (spanning less than a martian year) when definitive morphological changes occurred in four gullies is tightly constrained to late southern winter (∼Ls140-150). This timing is consistent with the appearance of recent apron deposits within a total of 18 gullies in seven fields, strongly implying the existence of a seasonal control on current dune gully activity.

Assessment of current theories

The dune gullies are similar in morphology to martian slope gullies [4] and their observed timing of activity is consistent with the timing of non-dune gully deposit changes [7, 8], implying a similar formation mechanism. Using our observations and knowledge about the structure and formation of sand dunes, we had a unique opportunity to evaluate different non-dune gully evolution hypotheses with narrow constraints on surficial and subsurface materials, martian environmental conditions, and

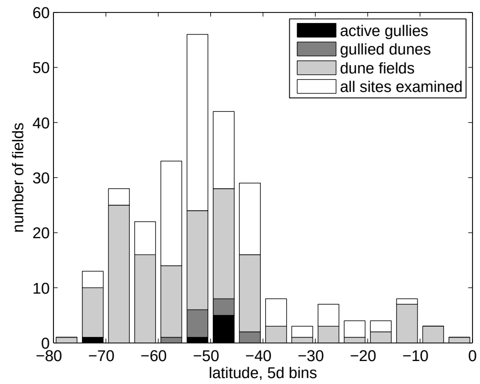

Figure 1: Histogram illustrating study coverage of inspected dune fields, dune fields containing gullies, and fields containing active gullies within southern latitude bands. As it is difficult to identify gullies in MOC/CTX images, or to definitely identify gully activity even in HiRISE images, these amounts are lower-limits.

timescale.

We found that most of the currently popular theories about gully formation are not supported by the observed timing and/or the the geological context of this study: theories involving subsurface reservoirs of liquid – such as a shallow [2] or deep water aquifer [9], erupting through the surface are not supported in the geological setting of this study, as there is no reason that a liquid should be stored within or intrude into a dune, and then be extruded from or near the crest, the highest elevation point on the dune. For ground ice (or buried snowpacks) to melt and cause gully activity [10] under present martian conditions requires heating through insolation or geothermal activity – the first mechanism is not consistent with the timing of gully formation, and the second seems implausible as there are no other signs of regional heating. It also seems unlikely that current gully activity could involve meltwater from surficial snowpacks [3, 4], as climate models generally show that mid-latitude snowpacks can only accumulate during high obliquity periods [11], and it is doubtful that a snowpack could remained insulated for the 400kyr since the last period of high obliquity, especially near the crests of dark dunes. Dry flow models [5, 6, 12] alone cannot explain the observed latitudinal and seasonal bias, although it is possible that required initiation mechanisms, such as strong winds, can account for the observed seasonal and latitudinal controls.

The theories that are the most consistent with current observations are those driven by seasonal frost accumulation. Proposed mechanisms include the seasonal loading of volatile condensates onto surfaces and the entrainment of surficial material in frost avalanches [13, 14], the initialization of material transport by the energetic release of sublimating CO_2 [15], or the reduction of the dynamic inter-particle friction, which may enable increased fluidity and mobilization [16, 17]. Images of gullies during late winter show that CO_2 frost preferentially accumulates and is retained within gully alcoves/channels [18]. Additionally, observations and thermal modeling of frost accumulation on slopes in the southern mid-latitudes [19] shows that peak CO_2 frost accumulation coincides with the observed timing of gully activity.

Conclusion

Although our observations do not rule out the role that fluvial processes may have played in past gully activity, our results strongly imply that a seasonal control, such as the accumulation of CO_2 frost, is driving current gully formation and evolution on martian dunes. Further observations and measurements of these features, along with quantitative investigations regarding proposed frost-driven gully formation processes, are needed to conclusively determine the extent to which seasonal frost is involved in the formation and evolution of martian gullies.

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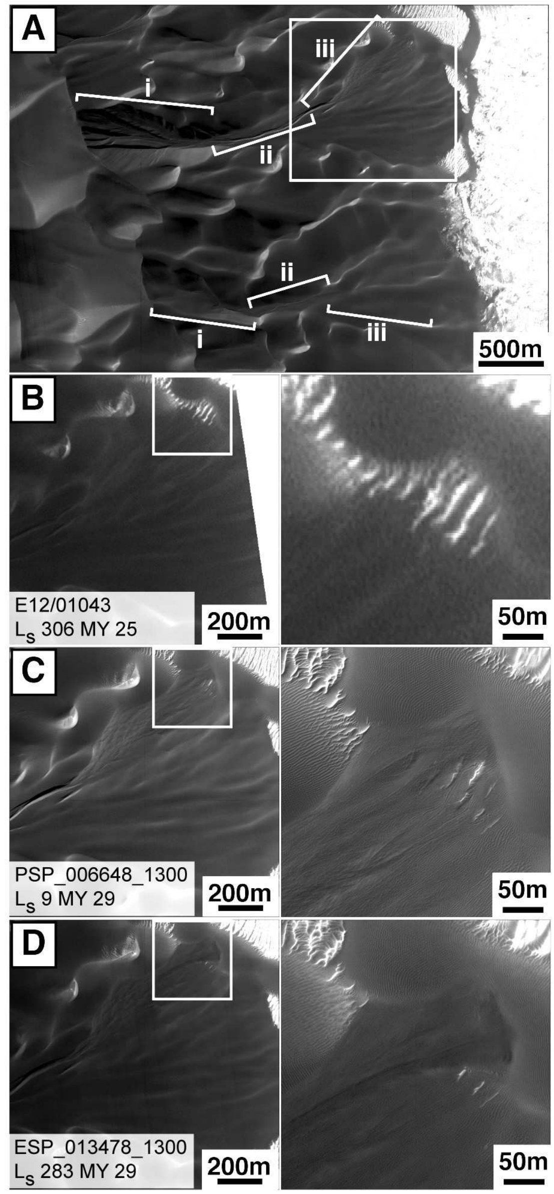

Figure 2: Portion of HiRISE image PSP_006648_1300 (A and C) containing two large classic gullies (with (i) alcove, (ii) channel, and (iii) apron) in Matara crater (49.5S, 34.9E). The bottom gully is heavily degraded, but the top gully is sharply-defined and currently active, as shown in insets: in 2002 (B), bright bedforms were visible at the foot of the debris apron. Those bedforms were increasingly covered in 2007 (C) and 2009 (D). The most recent deposit exhibits both the albedo and texture signatures of recent deposition. For full resolution images, go to http://www.msss.com/moc_gallery/ (MOC) or http://hirise.lpl.arizona.edu/ (HiRISE).