EPSC Abstracts
Vol. 6, EPSC-DPS2011-354-2, 2011
EPSC-DPS Joint Meeting 2011

They're alive! Present-day evolution of Martian dunes

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Abstract

The sharp brinks and margins, smooth and steep lee slopes, and lack of superimposed landforms (such as small impact craters) on many Martian sand dunes suggests that these features are geologically young.

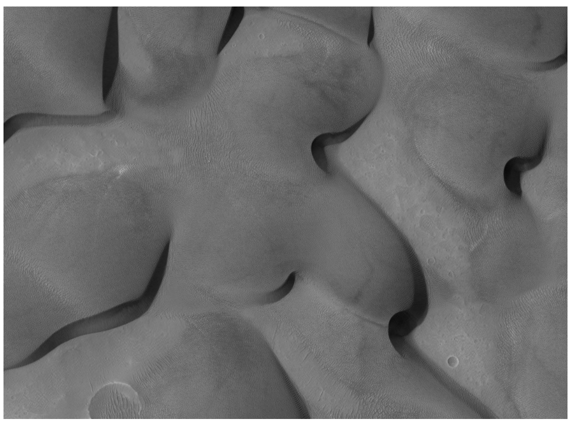

Figure 1: Martian dunes that appear 'active', with clean brinks and smooth/steep lee slopes (HiRISE image PSP_010413_1920; 20°N,79°E; image width is about 500m).

Within the last decade, and often primarily through the detailed inspection of high-resolution (HiRISE) images, we have finally found clear evidence that many dunes of Mars are active -- through both aeolian and seasonal (frost) processes. However, it is yet unclear if active dune formation does occur or if we are observing surficial modification of dunes which formed under different climate conditions.

1. Introduction

Numerous Mars missions have established that Mars has an active atmosphere and plentiful sediment supply. Aeolian bedforms (e.g., ripples and dunes) are found at all scales and often with mature, regular patterns [2], implying that aeolian processes have been active over a range of timescales. Ripples have been observed to migrate on the Martian surface, both in in-situ [9] and orbital [8] observations. However, despite many monitoring studies, it has been difficult to determine if the many dunes on Mars are also active or are relict and cohesive features from a past environment. Here, we present an overview of studies from the past decade that conclusively show that many dunes are active, at least within a surficial layer. Additionally, we'll outline ongoing studies that aim to establish whether or not dunes are currently forming or migrating.

2. Erosional processes

Several small (~1000m^2) dunes have been observed to deflate and disappear over ~5yr periods [1,3], indicating that rapid aeolian transport of sand does indeed occur on Mars. However, neighboring dunes often showed little signs of changes, implying an uneven distribution of saltation activity, perhaps due to differences in cohesion within dunes of different sizes.

Small grainflow avalanches are commonly observed along the brinks of dunes. Southern mid-latitude [4] and northern polar [7] dunes also contain larger gullies which have been observed to be actively forming over the last two winters through a seasonal frost-driven process. Up to hundreds of cubic meters of material erode per event, creating classic alcove-apron or alcove-channel-apron features, generally on the lee slopes of the dunes.

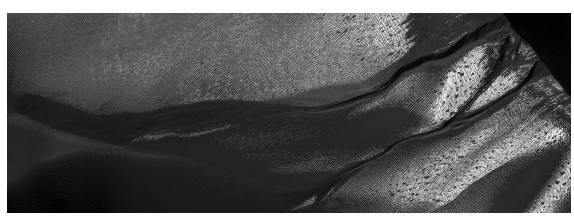

Figure 2: Active dune gullies within Matara crater dune field (HiRISE image ESP_019636_1300; 50°S, 35°E; image width is about 500m).

The observed combination of these (apparently common) erosional processes with the pristine nature of many dune slopes and brinks strongly suggests that the rate of aeolian (dune-forming) processes must be at least sufficient to restructure those dunes [7], and that in some cases the rate is sufficient to destabilize the dune.

3. Aeolian processes

Grainflow streaks formed and faded on yearly timescales on a dune within Rabe crater [5], implying that sand does migrate from the stoss to the lee slope. This has been supported by observations of ripple migration over dunes [8] and movement of dune margins [3,7].

4. Evidence of induration

Some dunes, especially in the southern polar regions [6], have rounded brinks and low slopes. These dunes are likely completely frozen and are not currently active through aeolian processes. Further studies are needed to see if these are the relict frozen cores of dunes, or the natural evolution of a dune which is affected now only through subsurface and surface frost processes.

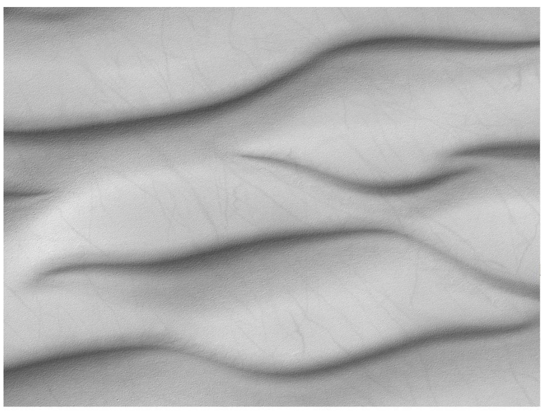

Figure 3: These dunes are likely frozen, causing them to have evolved through polar processes into low slopes and rounded forms (HiRISE image PSP_006716_1220; 60°S, 340°E; image width is about 800m).

5. Implications and future studies

Currently, several monitoring studies are ongoing to track ripple and potential dune migration rates, as well as rates of gully formation and other erosional processes. Determination of such rates, especially in locales where these processes are in competition (i.e., erosional processes create brink and slope defects, which are filled in through aeolian processes), will greatly aid efforts to understand exactly which processes are dominant in determining the Martian dune shapes and sizes. This will aid dune evolution modeling efforts and enable better interpretation of current dune forms with regards to past and present climate conditions.

At this time, the most pressing question concerning dune evolution is about whether dune migration occurs, or if only a surficial layer of sand is being redistributed (with the dune interiors 'frozen', perhaps due to subsurface ice). Answering this question will provide important information about the dune fields' ages, the subsurface ice/thermal environment, and past atmospheric conditions.

Acknowledgements

SD was supported by an appointment to the NASA Postdoctoral Program at the Jet Propulsion Laboratory, California Institute of Techology, administered by Oak Ridge Associated Universities through a contract with NASA.

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