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Active Processes on Mars: Dry Ice and Dunes

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Abstract

Icy volatiles on Mars are responsible for geomorphic changes on dunes, taking place in today's climate. Both north and south polar regions show sediment transport in the spring, associated with sublimation of seasonal ice. Using HiRISE, the High Resolution Imaging Science Experiment, on the Mars Reconnaissance Orbiter (MRO), we explore possible mechanisms.

1. Introduction

Spring sublimation of Mars' seasonal CO_2 polar cap is responsible for erosion of the surface and formation of araneiform terrain (spidery channels) in the south polar region known as the cryptic region [4, 7, 8]. The process requires that seasonal CO_2 ice is at times translucent, allowing sunlight to penetrate and warm the ground below. The ice layer then sublimates from the bottom, trapping gas, which flows to the nearest opening, eroding and entraining loose material from the surface [5, 9].

On polar dunes in the southern and northern hemisphere there are a variety of seasonal phenomena active in the spring, imaged in detail by MRO/HiRISE [2]. Sediment transport on dunes in the southern hemisphere has been observed and the timing is constrained to southern spring [1], and similarly in the north, constrained to northern spring [3]. Sublimation of CO_2 is implicated by the seasonal timing, but what is the actual mechanism? Is it similar to that forming araneiform terrain? Various suggestions have been put forth: fluidization of loose material, liquid salt brines [6], pressurized gas escaping from under a slab of seasonal ice, and/or sliding blocks of ice. Possibly all of these mechanisms are operative in different places at different times. We have new HiRISE images that show new channels carved by sliding blocks of ice. Sub-ice gas flow and dry mass-wasting are implicated in other locations.

2. HiRISE observations

HiRISE images now span 3 martian southern spring and 2 northern spring seasons. Temporal series of images of the same sites show changes from year-to-year and within a season.

The dunes at 70S/178E are trapped in a crater, typical of many southern hemisphere dune fields. Alcoves and long channels are easily identifiable. HiRISE images were acquired in the second and third southern spring to look for morphological changes. As shown in Figure 1 and 2 changes were discovered.

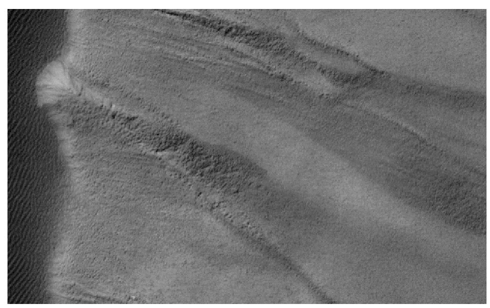

Figure 1: ESP_014185_1095, lat/lon = -70/18.18E.

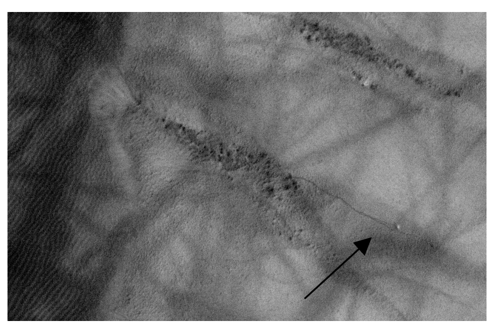

Figure 2: ESP_021899_1095. A new channel with a block of ice at the end is observed.

3. Sliding blocks of ice

Figure 1 shows a small area of one of the dunes, imaged in the second southern spring monitored by HiRISE. Figure 2 shows the same area, with a new channel, about a year later. (Most albedo marks are dust devil tracks.) Inspection of all the terrain covered in both of the images shows 4 new channels with blocks of ice at the ends. In addition numerous blocks of ice are observed at the distal ends of existing troughs.

Analysis of the entire set of images shows that the blocks slid down sometime between $L_s = 205$ and $L_s = 250$. Our proposed mechanism is that chunks of ice near the crest of the dune come loose at the end of spring, and slide down thinly frosted or already-defrosted slopes. Gas sublimating from the bottom of the ice block may lubricate the slide if bare slopes have begun to warm up. The channel carved is initially very shallow, however over a number of martian years may deepen, and serve to guide more blocks downhill.

This mechanism may explain the enigmatic zigzag channels on Kaiser crater dunes, shown in Figure 3: if the ice block hits a small obstacle, changing its direction, it will go off the directly downhill direction until it runs out of energy, then slide down in the other direction, like a pendulum. It is also possible that the sliding block bulldozes sand up until it blocks its direct path, forcing it to change direction.

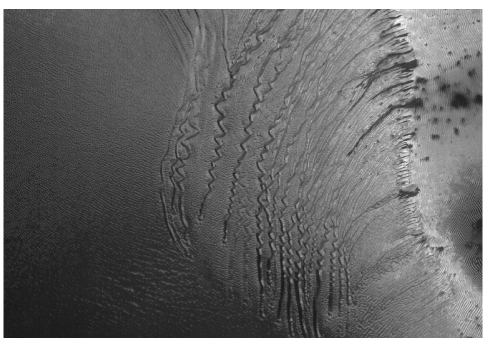

Figure 3: PSP_010749_1325, lat/lon = -47.25/19.49E.

4. Other mechanisms

Tiny channels leading up the stoss side of dunes in the northern hemisphere and others connecting to the base of dunes show the efficacy of gas flow to move loose material and carve channels on dunes in the northern hemisphere [3, 9]. This mechanism is similar to the formation of araneiform terrain. On the dunes the gas flow leads to slipface grainfall.

Clouds of dust from material cascading down the dune slip face have also been observed [3], consistent with dry mass-wasting triggered by an overburden of material at the dune brink or by cohesion at the brink being weakened by CO_2 sublimation.

5. Summary and Conclusions

HiRISE images are giving us insight into the process of sediment transport on martian dunes. The role of CO_2 was implicated simply by the timing, but the actual mechanisms are now being illuminated by data.

Acknowledgements

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