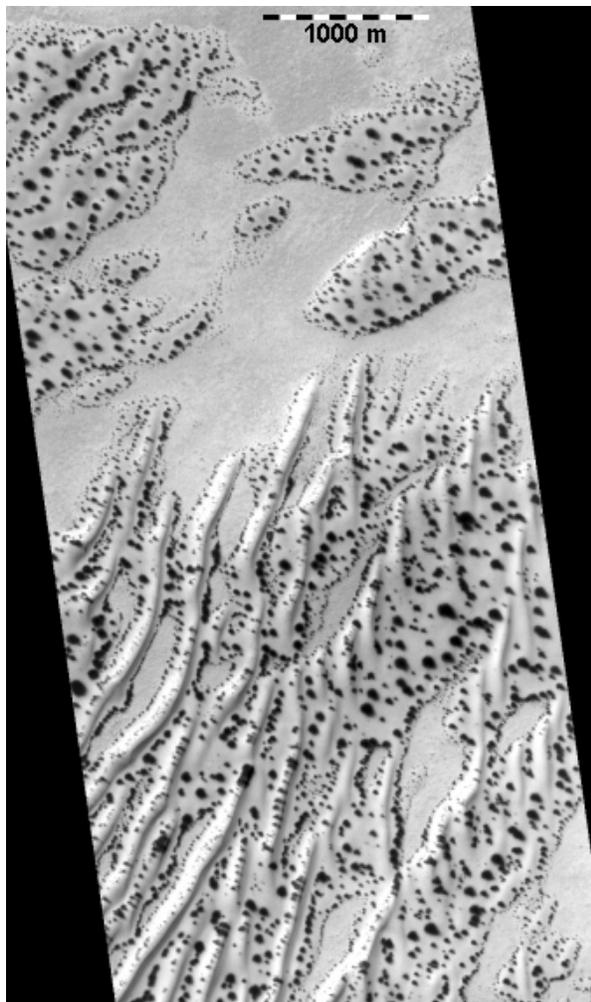


**DEFROSTING AND MELTING, NOT DEFROSTING ALONE.** *T. Gánti<sup>1</sup>, A. Horváth<sup>2,3</sup>, Sz. Bérczi<sup>4</sup>, A. Gesztesi<sup>2</sup>, E. Szathmáry<sup>1</sup>* <sup>1</sup>Collegium Budapest (Institute for Advanced Study), 2 Szentháromság, H-1014 Budapest, Hungary, <sup>2</sup>Budapest Planetarium, H-1476 Budapest Pf. 47, Hungary, <sup>3</sup>Konkoly Observatory, H-1525 Budapest Pf. 67, Hungary, <sup>4</sup>Eötvös University, Dept. G. Physics, H-1117 Budapest, Pázmány 1/a. Hungary (planet@mail.datanet.hu)

### Abstract

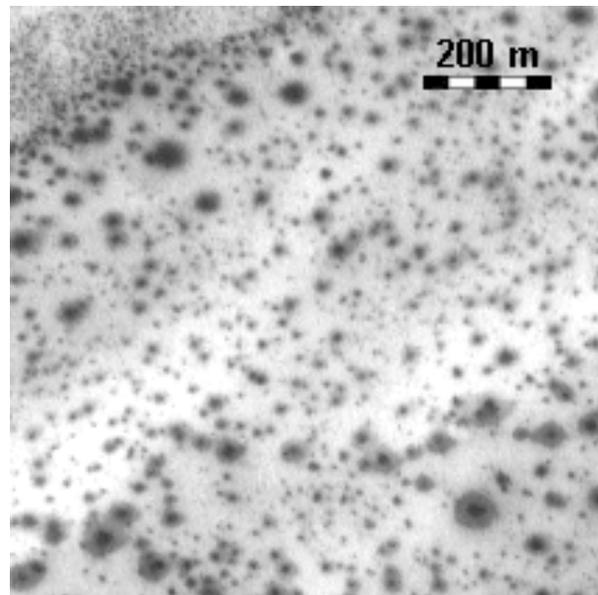
In craters of the Southern polar region ( $-50^\circ$  to  $-82^\circ$ ) of Mars *dark dunes (DD)* are apparent, which are covered by white snow/ice during the Martian winter, and on which characteristic, growing splotches, called *dark dune spots (DDSs)* appear at the end of the winter. Malin *et al.* explain the appearance and temporal development of these spots by defrosting processes. Based on the images of the *Mars Global Surveyor (MGS)*, we show here that solely sublimation processes cannot explain the shape, development and characteristic features of these spots; other processes must also be invoked. We list the supporting evidence and the associated explanations.



**Figure 1.** DDSs form only on the “sandy” surface of the dark dunes: the boundary of the latter is sometimes clearly marked by a matching boundary of the DDSs population. This indicates a causal link between spot formation and development and the material features of the dunes. Sun illuminated from upper left, north is up. (Date of MGS MOC image: E05-00762, 2001-06-08,  $L_s = 174^\circ$ ,  $\lambda \sim 155^\circ W$ ,  $\phi \sim -62^\circ$ , Number of our DDS-Catalogue = 34.)

### Introduction

In the Southern polar region of Mars, dark spots with characteristic shape and location appear in the white snow/ice covering the DDs inside impact craters by late winter/early summer. These spots grow with time until they coalesce in the summer while the white cover of snow disappears. These spots are very peculiar and exclusively form on the dunes of eolian origin, indicating that the dunes somehow critically influence their formation. Their characteristic features and development markedly differ from the same of the spots belonging to other types. Malin and Edgett [1, 2] hypothesized that the sublimation (defrosting) of the Martian ice cover is responsible for the origin and development of the spots. By investigating images of several thousand such spots we concluded that solely sublimation processes could not explain the formation of these spots. The shape, location, development and other features of the DDSs prompt us to suggest that some fluid phase must be invoked in their explanation, which under the given circumstances cannot be anything else but liquid water.



**Figure 2.** DDSs are circular on flat surfaces. Defrosting cannot be responsible for this since it is affected by various surface conditions. To the contrary, the origin and seepage of a fluid phase (water) below the ice cover is consistent with the facts. Sun illuminated from upper left, north is up. (Date of MGS MOC image: M07-01643, 1999-09-08,  $L_s = 203^\circ$ ,  $\lambda \sim 166^\circ W$ ,  $\phi \sim -65^\circ$ , Number of our DDS-Catalogue = 54.)

### Observations

Analysis of several thousand DDSs on more than 200 MGS MOC narrow-angle images supports the following list of general features:

I. DDSs are only to be found on dark dunes to the extent that sometimes the border of their occurrence exactly

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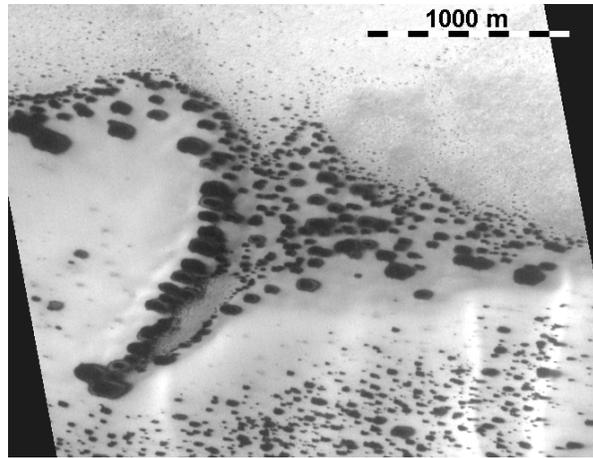
matches the boundaries of the latter. They never form outside of the matter of the dark dunes (Fig. 1).

II. On flat or nearly flat territories the spots are circular (Figs 1 and 2).

III. On mild slopes the spots are elongated downhill, thus forming large-axis elongated ellipsoid shapes in parallel orientation (Fig. 3).

IV. On steeper slopes flow-like extensions emanate from the spots pointing downhill (Fig. 4).

Other general features of DDSs are treated elsewhere [3, 4].



**Figure 3.** On mild and medium slopes the DDSs are parallel elongated downwards, indicating their development is influenced by gravity. Since sublimation is not affected by gravity in the given size range, elongation of the spots must be explained by the seepage of some matter in fluid phase. Sun illuminated from upper left, north is up. (Date of MGS MOC image: M04-01220, 1999-08-16,  $L_s = 189^\circ$ ,  $\lambda \sim 113^\circ W$ ,  $\phi \sim -71^\circ$ , Number of our DDS-Catalogue = 13.)

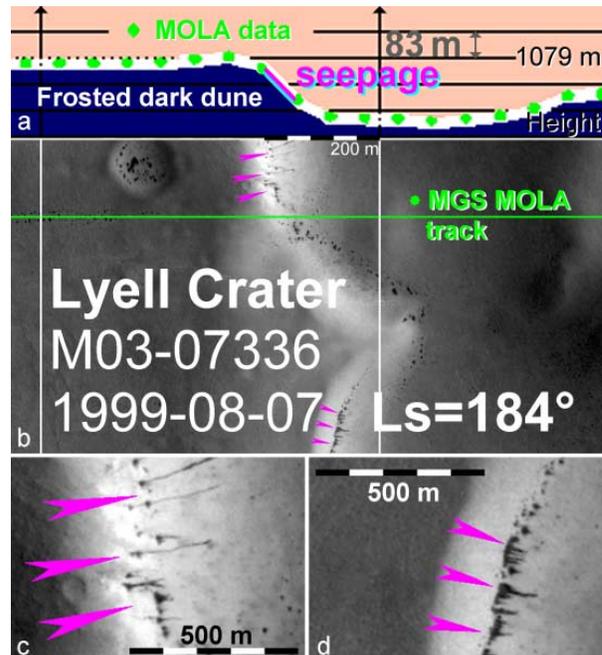
### Interpretations

1. The fact that the DDSs form only on the surface of the eolian DDs indicates that the formation of the former is somehow linked to the material of the latter. This may be attributable to either the chemical composition and/or the physical structure (porosity) of the dunes. The process of frosting may depend on the quality of the soil, because the soil grains may act as crystallization seeds for frost formation. Defrosting is, however, independent from the soil because it happens on the surface of the ice/snow cover.

2. The fact that on flat sites the spots are circular and that they grow radially indicates that spot formation is isotropic in the plain of the surface. The spot formation thus cannot be mere defrosting, because the sublimation process depends on wind, the direction and angle of insolation, etc. Such type of radial growth is, however, readily explainable in terms of capillary diffusion of some liquid in the porous regolith. In pT conditions of Mars that fluid cannot be anything else but liquid water.

3. The fact that spots on mild slopes become ellipsoids pointing downwards indicates that spot spread is affected by gravity. In the given size range sublimation processes are independent from gravity. Again the only sensible interpretation is the active role of a fluid phase, namely (as explained above) liquid water.

4. On steeper slopes regular flows are apparent. These cannot be interpreted as open creeks, however; rather, melted water slowly percolates downwards in small canals below the ice.



**Figure 4.** On steeper slopes flow-like extensions may originate from the slopes. They cannot be taken as surface flows; rather, they indicate seepage under the ice. But, of course, this implies liquid water. On MGS MOC images **b, c, d** Sun illuminated from upper right, north is in the right lower corner. (Date of MGS MOC image: M03-07336, 1999-08-07,  $L_s=184^\circ$ , Lyell Crater,  $\lambda \sim 15^\circ W$ ,  $\phi \sim -70^\circ$ , No. of our DDS-Catalogue = 16.)

### Conclusions

The listed facts and their interpretations clearly show that the formation of DDSs cannot be explained solely by the frosting-defrosting hypothesis. If we combine this with the recent finding of Horváth *et al.* that spots begin to form in the soil—frost boundary layer, we may accept that besides defrosting some liquid phase must also play a key role in spot formation. Under the given Martian conditions this can only be liquid water. We think that necessary melting of the ice is influenced by some biological factors [5, 6].

### Acknowledgments

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