ANALYSIS OF POSSIBLE INTERFACIAL WATER DRIVEN SEEPAGES ON MARS

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Introduction: A large number of seasonal albedo features is visible in the polar terrains of Mars, including spider-like structures [1,2,3,4] and various dark spots [5,6,7,8,9]. Among them a special group is localized on dark dunes, called Dark Dune Spots (DDSs) [10,11]. In a previous work [12] we showed that during the first phase of the DDS development in early southern spring, fan shaped, diffuse streaks form in downwind direction, possibly by the interaction of wind and geyser-like activity from below the CO_2 ice cover [8]. In a later phase, with higher temperature and less CO_2 ice cover, water ice is exposed on the surface and confined slope streaks appear [13]. Here we analyze indications for a movement of these confined, water ice related streaks, and propose a possible model for their origin (Fig. 1.).

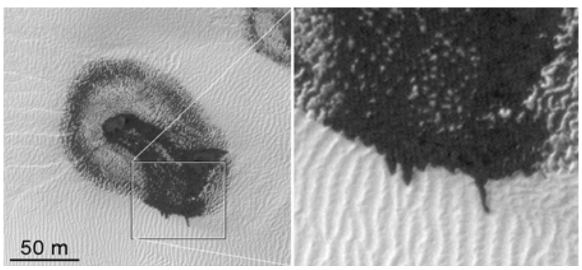

Fig. 1. DDS (left) and confined slope streak emanates from it (right) on HiRISE image PSP-3432-1115

It has been shown by thermodynamic modeling [14] that undercooled liquid interfacial water can also at martian temperatures exist in the Martian surface in case of the presence of water ice, particularly below a covering ice-layer at the upper surface. This is expected to have various consequences on chemical, mechanical or possibly even biological processes.

Methods: For the analysis we used HiRISE (MRO), HRSC (MEX), MOC (MGS) images, with topographic data from MGS MOLA PEDR dataset with processing version L [15], and temperature data from TES (MGS) measurements [16], using the “vanilla” software. Temperature data show annual trend, and were derived for daytime around 2 pm, local true solar time. Note that the surface temperature values have spatial resolution around 3 km, and they can be taken only as rough approach of the surface temperature of the whole dune complex and not different parts of it. The change of seasonal albedo structures was analyzed on the dunes inside three craters: Russel (54S 12E), Richardson (72S 180E) and an unnamed crater (68S 2E) during southern spring.

There is a great debate on the presence of liquid water on Mars today. Based on thermophysical considerations, under present water vapor content of the atmosphere, the presence of a thin layer of interfacial water is inevitable on mineral surfaces due to van der Waals pressure [14], this is followed by a freezing point depression. The lower limiting temperature of the liquid phase can reach about 190 K and less under Martian conditions if an average atmospheric water content of 10 pr µm is taken.

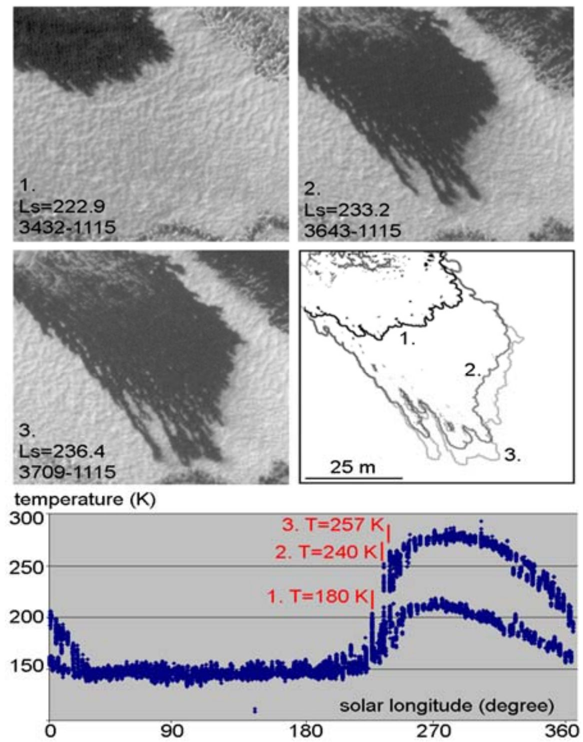

Fig. 2. Movement of one slope streak in an unnamed crater at 68S 2E, on three HiRISE images (top) with overlain flow fronts (top right), and average annual temperature curve (bottom) of the crater

Results: Based on *HiRISE images,* the internal structure of DDSs consists of a darker umbra-like central, and a lighter penumbra-like outer part (Fig. 1.). During the advancement of spring, with the increasing surface temperature, flow-like structures appear, emanating from the spots. They are composed of dark material with relatively constant albedo. The dark color is probably represents the low albedo dune grains, and may arise because the covering ice sublimates or the phase change of ice, and may be influenced even by solutes from the salt/mineral grains. The advancing flow front follows the meter sized furrow-like depressions between the small, probably wind-blown ripples. During the late phase of the dark material’s movement, the source region became lighter, showing that the dark material moved away and left behind other stuff, or the source region became covered by whitish frost again (the top left corner on phase 2 and 3 in Fig. 2.).

Based on TES data (Fig. 2.), when streaks start the movement, the annual characteristic temperature at the analyzed craters is between 180 and 220 K. During the movement, the estimated speed of the dark material is between 0,1 and 1,4 m/day. There are DDSs where the dark stuff did not move, but where movement appeared, it usually happened on meter scaled distance on a day. This suggests the presence of some critical limit, above which the movement took place, and happens at reasonable distance.

Based on *theoretical considerations*, undercooled liquid interfacial water on Mars is to be expected down to about 190 K [14]. The spring sunshine probably heats up the dark dune grains, interfacial water appears around them below an ice cover or in a mineral-ice mixture in the top layer of the ice-covered dunes, and downward movement could take place forming slope streaks (Fig. 3.). The coincidence between the theoretical limit of 190 K and the observed temperature suggests they are in causal connection.

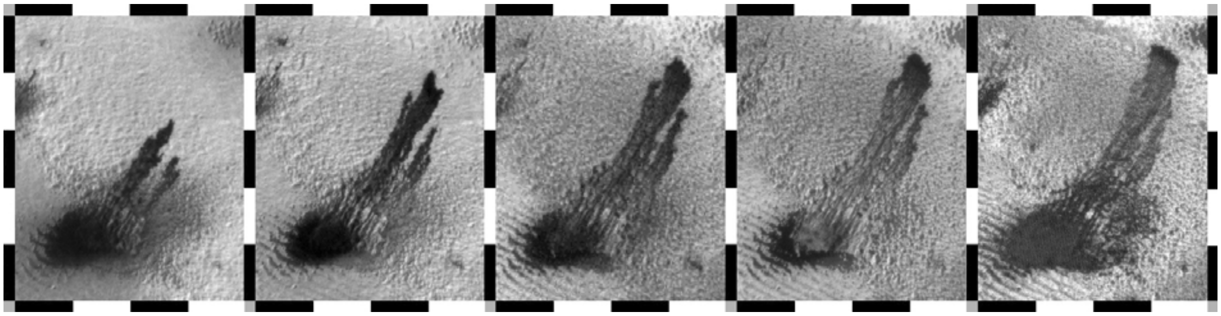

Fig. 3. 80x100 m sized subsets of a DDS-seepage in Richardson crater. HiRISE image numbers (Ls-values): a – PSP-3175 (210.6), b – PSP-003386 (220.7), c – PSP-003597 (230.9), d – PSP-003742 (238.1), e – PSP-003953 (248.5).

Modelling the movement: The movement showed average speed in the order of m/day, and the process probably takes place around noon. The downward flow of layers of liquid water at slopes can be described in first approximation by Darcy´s law of saturated flows in porous media: $Q=-\kappa_\phi A\ \Delta h/\Delta l$, where $Q[m^3s^{-1}]$ is the discharge, $A[m^2]$ is the "wetted" area, $k_f[ms^{-1}]$ is the hydraulic conductivity (of the order of the real flow velocity), $\Delta h[m]$ is the height difference of beginning and end of the flow, and $\Delta l[m]$ ($>\Delta h$) is the length of the flow track.

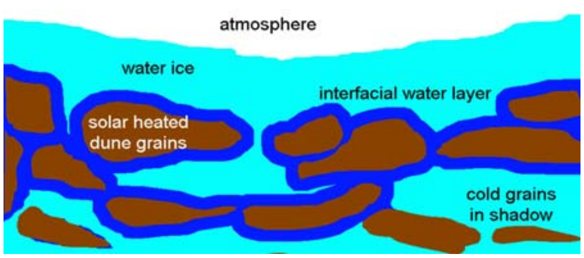

Fig. 4. Possible cross sectional structure of the dune's top based on Möhlmann´s [14] sandwich model

The m/day flow speed (or $(10^{-3}–10^{-4})$ ms^{-1}) is compatible to hydraulic conductivities of fine grained terrestrial sand in the size range of 0.2–0.063 mm. Assuming that the interfacial water remains liquid for the order of hours per day (i.e. about 10^3 s to 10^4 s per day), and taking a thickness of liquid interfacial water layer in the range of millimeters, and a width of the seepage front of metres, the surface A is of about 10^{-2} m^2; then, a water flow of the order of $Q = (10^{-5}-10^{-6})$ m^3s^{-1} is to be expected to fed the seepage flows (Fig. 4.). This corresponds to several litres per day.

Conclusion: Synthesizing observations of MRO's HiRISE camera with TES temperature data and theoretical modeling, it seems to be possible that on the water ice covered southern polar dunes during springtime, seepage phenomena takes places with the help of interfacial water at subzero temperatures. The presence of liquid-like water may have astrobiological consequence [17,18], especially if it still could be present in a later seasonal phase when the temperature is higher.

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