IDEAL MICROHABITATS ON MARS: THE ASTROBIOLOGICAL POTENTIAL OF POLAR DUNES.

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Introduction: We briefly summarize the work and results obtained by the Mars Astrobiology Group at Collegium Budapest Institute for Advanced Study during the last 10 years on the Dark Dune Spot–Mars Surface Organism (DDS-MSO) hypothesis. The spots have been discovered by [1]. Proposed explanation for their changes was given by [2]. During our research we fused remote observations (MEX, MGS, MRO) of Mars, collected and analyzed samples of cryptobiotic crust (CBC) from hot and cold deserts on Earth, estimated environmental parameters and used results from Mars chamber tests [3] as well as analysis of microbial communities in the ice of Antarctic desert carried out by other researchers [4,5]. We also used our results and methods to gain insight into the estimation of the astrobiological potential not only for dunes but other surface features on Mars as well.

The model: The surface and shallow subsurface of Martian polar dark dunes as microhabitats were first suggested by our group in 2001 [6], the first detailed description was presented in [7], the latest version in [8], and finally, terrestrial cryptobiotic crust dominated by cyanobacteria was suggested as a possible partial analog of Martian microbiological communities [9,10].

We identified DDS-phenomena in the southern [6] and northern polar regions [10]. Based on the morphology [11,12], temperature-dependent behaviour [13], seepage-like features emanating from DDSs [6] were interpreted as interfacial water-driven rheologic process, where water can percolate downwards in the southern [12] and northern [14] polar regions of Mars. In the model we have developed, the following stages are repeated in every year:

1. early springtime sunshine causes sublimation and jets of CO_2 [15] or geyser-like eruptions [16];
2. sunshine penetrates through the holes, reaches waterice layers, and light-absorbing dark basaltic dune grains [11];
3. thin interfacial waterice layer forms on dune grains on a daily basis [6,7], subice greenhouse effect contributes to the process;
4. hypothetical MSOs start to metabolize, where wetting/drying takes place on a daily cycle [6,7];
5. thickening interfacial water layer causes seasonal seepage-like features in the southern [17] or northern polar regions [18], and the produced surface features differ from those formed by geyser-like activity, but resemble seepages in the Antarctic Dry Valleys [19];
6. at the end of spring the surface gets dry and the MSOs go into dormant state [11];
7. annual recurrence of DDS and seepage roughly at the same location [20].

Basic elements of the model:

H_2O source: the surface and shallow subsurface layer of dunes gain waterice from the atmosphere (by condensation all day in winter, and only in nighttime during spring and summer), and from the internal ice mass of the dunes. Thermal wave penetrating into dunes could mobilize H_2O molecules toward the surface. The porous volumes inside the dunes may contain some waterice as cement [21], and inside the north polar sand sea waterice was observed by neutron spectrometry [22].

Temperature: based on observations during the movement of liquid-like seepages the temperature is above 160-180 K, but inside the Dark Dune Spots because of low albedo it must be higher than the average. The minimum temperature for metabolism is around 253 K [23], but some publications suggest it may be even lower, around 233 K [24]. This value is not necessary all the day, but it is sufficient for a short period around noon.

Heat insulation: to gain and maintain "high" temperature of dune grains, heat insulation is necessary. One possibility is a water vapor layer formed by the volume decrease of ice during melting [17]) between the dune grains and the bottom of the ice cover.

Liquid water: based on thermodynamical computations and observations on the Earth, at waterice/mineral surfaces a few-molecule-thin liquid-like interfacial water layer forms [25,26]. Thickened liquid layer may give rise to the seepage-like process.

Available water: H_2O on Mars (1-100 precipitable micrometer) condensed on dunes is probably enough for microbial processes. Water activity (a_w) is around 1 at nighttime, but it is very low at daytime because waterice sublimates fast at elevated temperature. Waterice cover keeps enough water tension for microorganisms.

H_2O trapping: trapping of ice is critical at elevated temperature. The following factors may reduce the sublimation rate: presence of brines [27], vapor diffusion through porous layer (mm-thick layer of clay-sized grains may reduce waterice loss below 1 mm/hour at 273 K under Martian conditions [28]), strong adsorption by hygroscopic materials like clays

[29] and zeolites (with 90 kJ bond energy waterice loss at 253 K is 0.01 micrometer/hour). It is unknown whether a hypothetical organism could use such strongly bonded H_2O [30]. Hygroscopic materials were also observed on Earth inside cryptobiotic crust [31].

Radiation shielding: waterice could give enough radiation shielding with meter thickness [32], which is larger than available at the seasonal cap. H_2O snow gives better protection with cm thickness. One mm rocky layer may give enough shielding [33] while let enough light income for photosynthesis. Shadow effects also reduce the cumulative radiation flux [34].

Chemical environment on Mars: toxic for known terrestrial living organisms today, where the oxidants destroy organic material. The dark color of the dunes suggests less red material there and so less oxidants. The real concentration and composition of oxidants is unknown, thus it is difficult to quantify this parameter.

Nutrients and transport processes: based on examples from the Earth, nutrients and waste products can be transported in waterice: inside water filled ice veins [35], adsorbed water film, and by diffusion [36]. Transport may happen in connection with H_2O migration and daily wetting-drying as well as sublimation-condensation.

Survival strategies: based on our observations of terrestrial extremophiles, important and Mars-relevant survival strategies are summarized in *Table 1.*

Stresses/ survival strategies	Mars analog for low temperature	Mars analog for dryness	Mars analog for UV radiation
UV pigmentation			*Tolypothrix, Nostoc* (Tunisian Sahara, west of Matmata)
rock coverage	*Gloeocapsa atrata, G. punctata* , (Devon Island, Arctic Canada) *Miocrocoleus chthonoplastes, Chroococcidiopsis* (Antarctica)	hypolithic colonies (wind shaded voids)	*Symplocastrum, Microcoleus* (Western Australia, Barlee Lake area), fibre optics strategy
mucilageneous sheath		*Microcoleus chthonoplastes* (Tunesian Sahara)	
dew trapping "antennas"		*Microcoleus chthonoplastes* (Tunesian Sahara)	
seasonal shifting into different layers		*Microcoleus paludosus* (Tunisian Sahara, El Hamma-Kabili) road)	*Microcoleus paludosus* (Tunisian Sahara, El Hamma-Kabili road)

Table 1. ***Observed survival strategies and examples***

Conclusion: dark dunes may hold less oxidants, trap waterice on their top and inside as well. At 1-2 mm depth radiation shielding and light for photosynthesis is good enough for metabolism. Conditions are favourable for water uptake at nighttime, and for metabolism at daytime. Beyond the above-mentioned possibilities, a hypothetical microorganism might take up water and metabolize during separate periods with aquaporine-like structures [37]. Another possibility is that during the gradually changing daily conditions, short wet and warm periods overlap each other. A weathered crust-like layer on the top of dunes may produce as favourable micro-environments as desert varnish on the Earth [38,39].

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