HALITE CRUSTS AS TARGETS FOR THE SEARCH FOR LIFE ON MARS.

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Introduction: The Atacama Desert (Chile) ranks as the driest desert on Earth, with long-term mean annual rainfall as low as a few millimeters in its driest zone [1]. Photosynthetic bacteria are virtually absent in the soil, which is also depleted in organic molecules due partially to non-biological oxidation processes [2]. Liquid water availability is extremely low, and almost exclusively arrives in the form of fog and dew [1,3], making the Atacama Desert the dry limit of photosynthetic activity and of primary production on Earth [3]. Due to these extreme conditions, life in the Atacama Desert has evolved survival strategies that are not found in other environments where liquid water is more abundant.

During its transition from a relatively wet to a hyper-arid planet, Mars necessarily had to cross a range of climate conditions similar to those found today in the Atacama Desert, particularly with respect to precipitation levels and aridity. Therefore, by studying the survival strategies and adaptations of microorganisms in the Atacama Desert, we can infer the fate of putative martian microorganisms as the surface of the planet turned into a hyper-arid desert, and pinpoint specific microhabitats with a strong astrobiological potential, which can be targeted by robotic missions on the surface.

Halite endoliths in the hyper-arid core of the Atacama Desert: Relatively abundant communities of endolithic microorganisms can be found within halite (NaCl) crusts in the driest part of the Atacama Desert [4] (Figure 1). These halite crusts have a large spatial distribution and characteristic irregular shapes, which are the result of wind erosion and partial dissolution and re-precipitation of evaporitic deposits, during rare and transient events of higher values of relative humidity. The crusts are composed nearly exclusively of halite (96-99%) with minor amounts of gypsum (1–3%) and traces (~1%) of sylvine and quartz [4]. Colonies of endolithic, *Chroococcidiopsis*-like photosynthetic cyanobacteria can be found 3-7 mm beneath the crust surface, distributed within pores between halite crystals [4].

The interior of halite crusts provides microorganisms with mineral nutrients and more favorable moisture regimes than if exposed directly to the atmosphere, as well as protection against harmful radiation. The abundance of photosynthetic microorganisms within the halite crusts, and their paucity in the surrounding soil, is due to the hygroscopic properties of halite [5]. NaCl readily absorbs water vapor at the so-called deliquescence relative humidity (DRH~ 75% at T= 25°C). When DRH is reached, water vapor condensates into aqueous solutions on the crystal surface and/or within the pore space between crystals [5]. Through this mechanism, halite endoliths have access to liquid water 20-30 times more often than soil bacteria. Halite crusts may therefore represent the last available niche for photosynthetic activity in extreme hyper-arid environments [5].

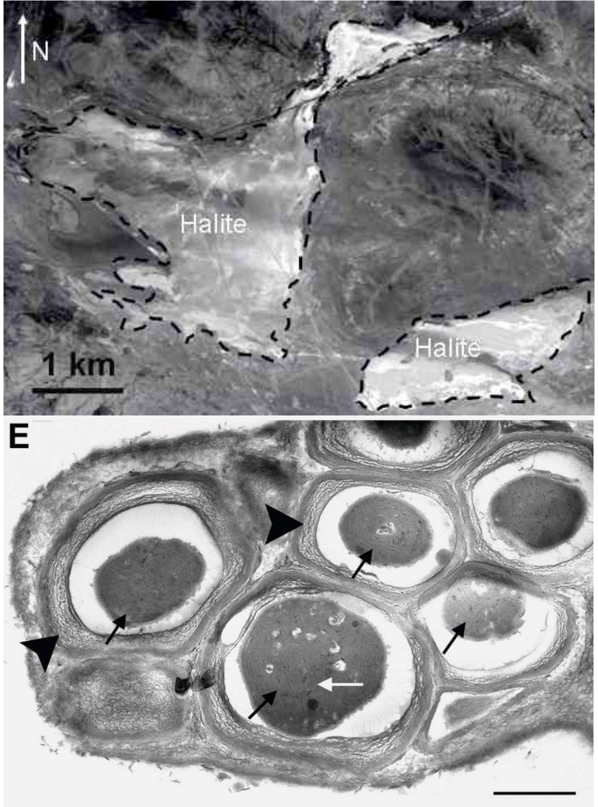

Figure 1. *Top*. Deposist of halite crusts (bright and doted-lined area) in the hyper-arid core of the Atacama Desert (Yungay). Scale = 1 km. *Bottom*. Transmission Electron Microscopy of Endolithic cyanobacteria extracted from the crusts. Scale bar 1mm. From [4]

Evaporitic deposits on Mars: Recently, Osterloo et al. (2007) [ref. 6] identified and mapped widespread deposits with a chloride salt component, in regions of the southern highlands of Mars (Figure 2). These chloride-bearing materials are possibly cemented or indurated. Individually, most chloride-bearing deposits are small in area (<~25 km^2), and commonly occur in topographic lows relative to the surrounding terrain. The geomorphology of the deposits is consistent with formation in an evaporitic environment [6]. These deposits bear strong similarities to evaporitic deposits in the Atacama Desert.

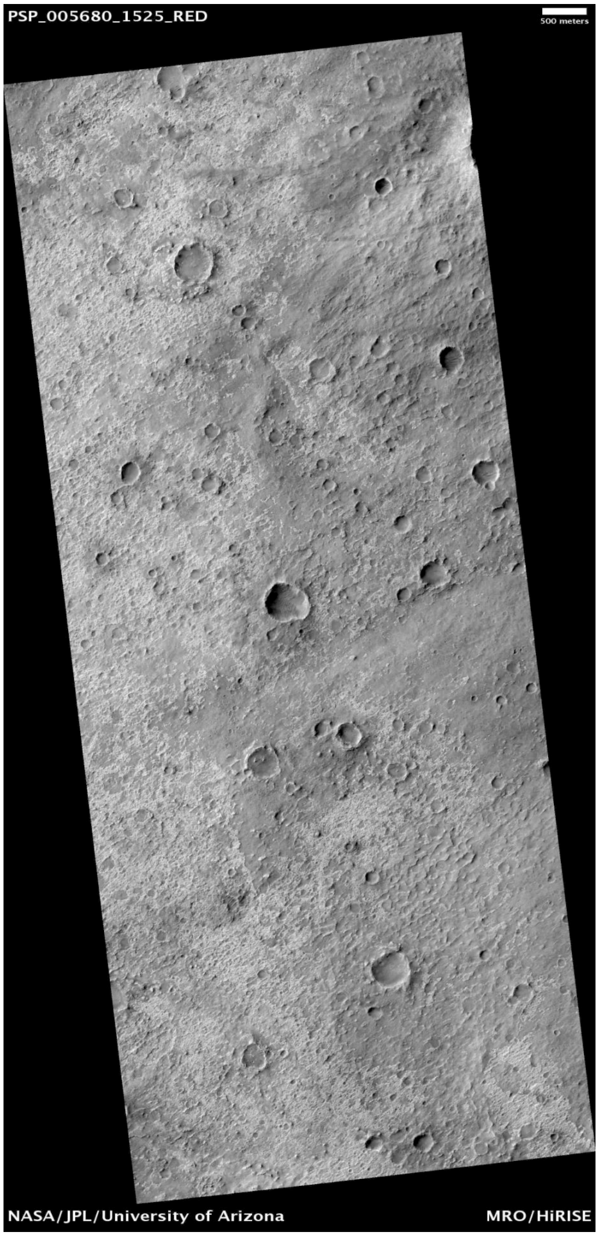

Figure 2. Chloride-bearing materials (white) on Mars identified by [6]. Photo credit: NASA/JPL/University of Arizona. Scale = 500m

Relevance for Astrobiology: In order to survive in extreme arid conditions, microorganisms can evolve physiological ecological adaptations. Physiological adaptations include the capacity to transform into resistant or vegetative forms; the formation of thick cell walls to prevent waterloss; the elaboration of a conspicuous extracellular glycan and others extracellular polymeric substances, synthesis of abundant UV-absorbing pigments, or maintenance of protein stability and structural integrity. Physiological adaptations depend on the biomolecular structure of life (the type of genetic code, the biomolecules forming the membranes…) and therefore cannot be directly extrapolated to hypothetical life forms in a different planet, which may be based on alternative biomolecular architectures.

Ecological adaptations, on the other hand, include the especial organization of individuals into complex population structures that enhance the survivability of the individuals (i.e. biofilm organization), or the colonization of niches that provide transient episodes of habitability conditions. These kinds of adaptations are more relevant to Astrobiology, as they are largely determined by the physico-chemical characteristics of the colonized niche. Under similar climate conditions, microorganisms on Mars could have colonized niches that have proven favorable for the survivability of microorganisms on Earth, such as halite crusts.

Conclusions: If life ever existed on Mars, during the transition from a relatively wet to a hyper-arid planet, photosynthetic microorganisms dwelling on the surface likely had to adapt to the decrease in water availability. Taking the example of microorganisms in the Atacama Desert, these adaptations would have likely been physiological and ecological. The later could have involved the colonization of the interior of rocks that could provide enhanced moisture conditions, protection against harmful radiation, and at the same time enable photosynthesis. Like in the Atacama Desert, the chloride-bearing materials recently identified on Mars may represent one of the last niches available on the surface for photosynthetic microorganisms [7], and must be therefore considered a site with a strong astrobiological potential in future life detection mission on the planet.

References: [1] McKay et al. (2003) *Astrobiology, 3,* 393–406. [2] Navarro-Gonzalez et al (2003) *Science, 7,* 1018-1021. [3] Warren-Rhodes et al. (2006) *Microb. Ecol.* 52 (3), 389-398 [4] Wierzchos et al. (2006) *Astrobiology* 6, 415-422. [5] Davila et al. (2008) *JGR-Biogeosciences*. In Press. [6] Osterloo et al. (2007) AGU Fall-meeting. Abstract #P13D-1563. [7] Rothschild, 1990 *Icarus* 88, 246–260.