MICROBIAL SURVIVAL IN HYPER-ARID ENVIRONMENTS: EXRTRACTING WATER FROM ATMOSPHERIC HUMIDITY.

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Introduction: The Atacama Desert (Chile) is the closest terrestrial analogue to the extreme arid conditions on the surface of Mars [1]. Photosynthetic bacteria are virtually absent in soils [2], and even hypolithic cyanobacteria, commonly found in hyperarid stony deserts, are rare [3]. This is due to the extremely low availability of liquid water, which almost exclusively arrives in the form of fog and dew [1,3]. Yet, the discovery of endolithic microorganisms inside halite crusts in the driest part of the Atacama Desert [4] shows that even in such extreme conditions ecological niches exist where life can grow in relative abundance and diversity. Halite crusts are commonly found in evaporictic deposits called *Salares*, and have characteristic irregular shapes, which are the result of wind erosion and partial-dissolution and re-precipitation, during rare and transient wet events (Figure 1).

Figure 1. *Top* Halite crusts. Scale is approx 10 cm. *Bottom*. Cyanobacterias inhabiting the pore space between halite crystals.

The crusts are composed nearly exclusively of halite (96-99%) with minor amounts of gypsum (1–3%) and traces (~1%) of sylvine and quartz [3]. Colonies of Chroococcidiopsis-like endolithic cyanobacteria can be found 3-7 mm beneath the crust surface, distributed within pores and cracks (Figure 1) [4].

Halite crusts are likely one of the most challenging environments for life on Earth. Any liquid water within the pore space of the halite will be saturated with NaCl (~32% w/v), resulting in a water activity $a_w \leq 0.75$. The endolithic communities have to face large temperature oscillations, occasionally more than 50°C in a day cycle, and long periods (several years) without rain [1]. However, the abundance of microorganisms within the halite crusts, and their paucity in the surrounding soil, suggest that halite crusts possess particular physical and/or chemical properties that enable the occurrence and preservation of microbial ecosystems in such extreme conditions.

By means of time-series measurements of the relative humidity (RH), water vapor density (W_d), temperature (T), and photosynthetic active radiation (PAR), we show that the survivability of endolithic microorganisms in the crusts is due to the hygroscopic properties of halite, which enables the use of water extracted directly from atmospheric water vapor.

Methods: We studied the micro-weather conditions simultaneously inside and around the halite crusts by means of a HOBO® microweather-station equipped with two RH/T sensors, and one PAR sensor. We adapted the HOBO® micro-station to measure the RH and T simultaneously outside and within a natural halite crust, colonized with endolithic microorganisms. The station was emplaced on June 16, 2006. The data presented in this study corresponds to one year of continuous measurements.

Results and discussion: The main source of moisture and humidity in Yungay is sea breeze from the Pacific Ocean [1], which frequently results in dew formation and occasionally fog. These transient wet events do not produce measurable moisture and quickly dissipate after sunrise when temperatures rise, providing soil microorganisms with <75±15 h yr^{-1} of liquid water during conditions suitable for photosynthetic activity [3].

On the other hand, halite deliquescence facilitates water condensation at relatively low humidity levels (RH >75%)[5,6]. We recorded up to four intense episodes of water condensation within the crusts, which provided relatively constant moist conditions for periods of several days, while the air humidity followed a normal daily trend that inhibited the occurrence of liquid water outside the crusts [5] (Figure 2).

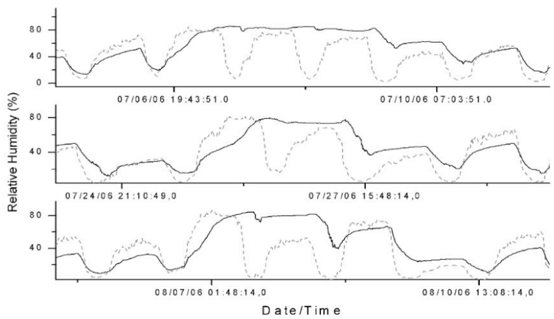

Figure 2. Three episodes of moist conditions inside the halite crust. Due to mineral deliquescence, water vapor condensates within the pore space of the halite at RH_h >75% (black solid line). At the same time the air relative humidity follows the typical daily variation (light dashed line). From [5]

The resulting NaCl saturated solutions, can be used by the endolithic microorganisms for primary productivity and growth. These prolonged moist episodes were rare, and mainly occurred in the wintertime. We also measured more frequent (~60 yr^{-1}), but shorter (1-8 hours) deliquescence episodes [5]. These short-duration events typically took place at sunrise and resulted in the simultaneous occurrence of liquid water and sunlight, thereby enabling photosynthetic activity within the crusts (Figure 3). If deliquescence occurs every time that the relative humidity inside the crusts > 75%, we have estimated a total of 290 hr yr^{-1} of water condensation within the halite crusts (Figure 4). Assuming that the minimum requirements for the onset of photosynthetic activity are the presence of liquid water and light, this resulted in longer and more stable conditions for potential photosynthetic activity inside the halite crust than in the soil or under stones (213.8 hr yr^{-1} vs. <75±15 h yr^{-1}, respectively). Of all the liquid water that reaches the soil in the Yungay area, only 20% is available for photosynthetic activity because it occurs simultaneously with light [3]. On the other hand, ~70% of the water that condenses within the halite crusts occurs simultaneously to photosynthetic available radiation, and can be used by the organisms for their metabolic activity [5]. Halite deliquescence is therefore an efficient mechanism to trap air moisture and enable photosynthetic activity in extreme, hyper-arid environments. Hence, halite crusts may be the last available niche for primary productivity in extreme, hyper-arid conditions [5].

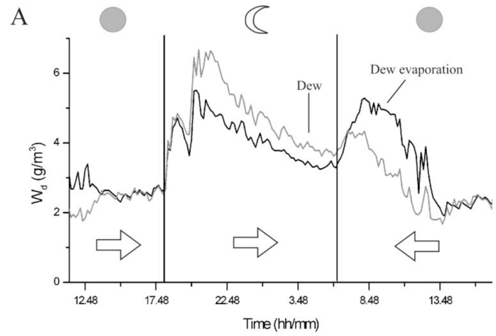

Figure 3. Daily variation of the water vapor density inside (black line) and outside (light line) the halite crusts. Thick arrows indicate the dominant wind direction. From [5]

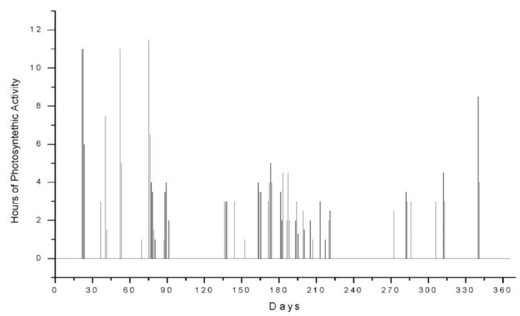

Figure 4. Episodes of photosynthetic activity for halite endoliths during one year. Each line represents a period of time when RH_h > 75% and PAR > 0 simultaneously. From [5]

Conclusions: The results presented here show that if deposits of halite exist on Mars, they may represent one of the last environments where life could have withstood the increasing arid conditions [7]. Considering the Atacama as an analog, these microhabitats could be localized, easily identifiable and relatively abundant. Halite crusts on Mars may still host traces of endolithic microorganisms and may therefore represent important targets for future life-search missions on the planet.

References: [1] McKay et al. (2003). [2] Navarro-Gonzalez et al. (2003). [3] Warren-Rhodes et al. (2006). [4] Wierzchos et al. (2006). [5] Davila et al. (2008) JGR-Biogeosciences. In Press. [6] Cohen et al., 1987 *J. Phys. Chem. 91*, 4563–4574. [7] Rothschild, 1990 *Icarus* 88, 246–260