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Microbial colonization of Ca-sulfate crusts in the hyperarid core of the Atacama Desert: implications for the search for life on Mars

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ABSTRACT

The scarcity of liquid water in the hyperarid core of the Atacama Desert makes this region one of the most challenging environments for life on Earth. The low numbers of microbial cells in the soils suggest that within the Atacama Desert lies the dry limit for life on our planet. Here, we show that the Ca-sulfate crusts of this hyperarid core are the habitats of lithobiontic micro-organisms. This microporous, translucent substrate is colonized by epilithic lichens, as well as endolithic free-living algae, fungal hyphae, cyanobacteria and non photosynthetic bacteria. We also report a novel type of endolithic community, ''hypoendoliths'', colonizing the undermost layer of the crusts. The colonization of gypsum crusts within the hyperarid core appears to be controlled by the moisture regime. Our data shows that the threshold for colonization is crossed within the dry core, with abundant colonization in gypsum crusts at one study site, while crusts at a drier site are virtually devoid of life. We show that the cumulative time in 1 year of relative humidity (RH) above 60% is the best parameter to explain the difference in colonization between both sites. This is supported by controlled humidity experiments, where we show that colonies of endolithic cyanobacteria in the Ca-sulfate crust undergo imbibition process at RH >60%. Assuming that life once arose on Mars, it is conceivable that Martian micro-organisms sought refuge in similar isolated evaporite microenvironments during their last struggle for life as their planet turned arid.

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INTRODUCTION

The Atacama Desert of Chile spans 1000 km from 30°S to 20°S along the Pacific coast of South America. The driest parts of the Atacama Desert occur from approximately 22°S to 26°S in the Central Depression, a broad valley flanked by the Coastal Cordillera to the west, and the Western Andes Cordillera and Andes to the east (Fig. 1). Precipitation in this hyperarid region averages <1 m year^{-1} (McKay *et al.*, 2003). Geological and soil mineralogical evidence suggests that hyperarid conditions have persisted for the past 3–4 million years (Hartley & Chong, 2002; Hartley *et al.*, 2005) making it one of the oldest deserts on Earth. This extreme dryness gives rise to Mars-like soils (Navarro-González *et al.*, 2003), which along with the lack of liquid water makes the Atacama Desert one of the best terrestrial analogs of the surface of Mars (McKay *et al.*, 2003). Therefore, the study of terrestrial life in such an extremely dry environment provides new insights regarding the environmental limits of life on Earth, and also a first approximation to assessing the potential for life on Mars.

Microbial life in the hyperarid core is indeed extremely scarce, and some colonization strategies observed in deserts around the world are distinctly absent, such as hypolithic communities (Warren-Rhodes *et al.*, 2006). Primary producers are practically absent in the soils, although there do seem

