# MICROBIAL LIFE SIGNATURES IN ONE OF THE DRIEST AREAS ON EARTH - THE ATACAMA DESERT

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## Introduction

The Atacama Desert represents one of the oldest and most arid mid-latitude deserts on Earth. The hyperaridity is explained by its position in a double rain shadow between the Chilean Coast Range and the Andes and by the cold Humboldt Current (HC) along the coastline, preventing the formation of rain clouds above the Pacific Ocean. Therefore, the Atacama core regions can lack precipitation for decades. However, due to the cold ocean water marine fog can transport moisture into the coastal near areas of the Atacama and occasionally heavy rainfall can occur in some regions often associated to climate phenomenon El Nino weakening the HC. Due to its hyperaridity the Atacama Desert is an extreme challenging habitat not only for plants and higher animals but even for microbial life (Navarro-Gonzalez et al., 2013). Recently, we were able to show that Atacama sediments can be at least a transitory life habitat for an active microbial community after a heavy rain event in 2015 using a broad set of analytical methods (Schulze-Makuch et al., 2018). In addition to this work, we present a detailed analysis of the life marker lipid signatures of the microbial communities (1) in soil samples along a moisture gradient from the Chilean coast (coastal fog affected) into the core of the Atacama Desert and (2) within specific microhabitats. For the transect surface (0-5 cm) and near subsurface (20-30 cm) soil samples at four locations named coastal soil (CS), alluvial fan (AL), red sands (RS) and Yungay (YU) have been investigated. The microhabitats comprised a hypolith consisting of quartz that were colonized by cyanobacteria on its underside, gypsum nodules consisting mainly of gypsum with some lithic components (mostly quartz) and salt rocks from the Yungay Salar consisting primarily of halite (> 95 %) with traces of quartz and gypsum.

## West-East transect into the Atacama Desert

A series of phospholipid fatty acid (PLFA) life markers have been detected in the investigated soils from the different sites. The cell numbers calculated from PLFAs significantly decrease along the transect towards the hyperarid desert. The highest abundance has been detected at the coastal CS site (5.4 x $10^6$ cells $gSed^{-1}$), where increased moisture transported by coastal fog established a significant microbial community. In contrast, further inland the cell numbers significantly decrease down to 3.8 x $10^4$ cells $gSed^{-1}$ at the YU site reflecting the extreme arid conditions of the Atacama. Concomitantly, the number of different PLFAs decreases from about 70 at the CS site to 11 at the YU site, which might resemble a decreasing microbial diversity from the coast into the desert. The YU site is the only location were the cell numbers are higher in the 20-30 cm sample than in the surface sample. A reason for this might be that at this extreme dry location the microbial communities retreat into deeper soils to protect themselves from high surface insolation. Intact polar lipids (IPLs) were best detected in the surface sample from the CS site. The IPL inventory point to a dominance of bacteria. In addition to normal phosphatidylglycerol (PG)- and phosphatidylinositol (PI)-diacylglycerols (DAG), the life marker signature is characterized by acyletherglycerols (AEG) and dietherglycerols (DEG) with the same head groups but variable chain length. The presence of ether side chains appears to be an adaptation of the microorganisms to the extreme conditions in the Atacama region. Additionally, sulfoquinovosylacyletherglycerols (SQAEG) abundantly occur indicating the presence of photosynthetic bacteria (e.g. cyanobacteria). Surprisingly, typical archaeol or tetraether based IPLs for archaea have not been identified in the Atacama soils, although the degradation product archaeol is present.

**Microhabitats in the Atacama Desert**

All microhabitat samples contain abundant microbial life markers (IPLs and PLFAs). The bacterial cell biomass ranges from 6.2 x $10^6$ for the hypoliths to 1.3 x $10^6$ for the gypsum nodules and 8.5 x $10^5$ cells $gSed^{-1}$ for the salt rocks. Thus, cell biomass is in the same range as in the CS sample influenced by coastal fog and almost two orders of magnitude higher than in the YU site sample from the Atacama core area. While hypoliths and gypsum nodules show a high diversity of different PLFA, the salt rocks show only a restricted set indicating a much lower bacterial diversity. The reason for this is that the salt rocks are the only samples dominated by archaeal IPLs such as archaeol phosphatic acid (Ar-PA), phosphatidylglycerol archaeol (Ar-PG) and archaeol phosphatidyl glycerophosphate methyl ester (Ar-PGP-Me). In smaller amounts also the respective lipids with one extended isoprenoid side chain (sesterterpanyl ($C_{25}$) instead of phytanyl ($C_{20}$)) are present. All these biomarkers are typical for archaea living in halophilic environments (Genderjahn et al., 2018). In contrast, the hypolith and the gypsum nodules are bacterial dominated and are more similar to the lipid inventory in the surface soil sample at the CS site. They contain PG-, PI- and phosphatidyl choline (PC-) DAGs as well as their corresponding AEGs. All three microhabitats exhibit sulfoquinovosyldiacylglycerol (SQDAG), while SQAEG only occurs in the hypoliths and gypsum nodules. Both biomarkers indicate again the presence of photosynthetic bacteria.

**Conclusions**

The lipid biomarkers clearly show the presence of microbial life in Atacama soil samples after a rain event in 2015. The lipid inventory point to a bacterial dominated microbial community including photosynthetic bacteria (e.g. cyanobacteria). Significantly higher abundance of life markers were detected at the coastal near site suggesting an established fog associated microbial community at this location presumably independent from the rain event. Specific hotspots of life in the Atacama Desert are formed in microhabitats like hypoliths, gypsum nodules and salt rocks as indicated by the abundant presence of life markers including those for photosynthetic bacteria. These results confirm observations of Davila and Schulze-Makuch (2016) reporting specialized survival strategies in the Atacama Desert where microorganisms live on the underside of often translucent minerals using the deliquescence property of the rocks to get access to water. Surprisingly, archaeal signatures have rarely been found and only the salt rock forms a habitat for an abundant halophilic archaeal life.

**References**

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