The unexplored geobiological heritage of Chile: key to understand the past and future.

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Abstract. An amazing diversity of extreme environments exists from Patagonia to the northern most of Chile, which host biogeological ecosystems that has been poorly explored, studied and understood. These geobiological ecosystems offer world-class sites for investigations of the possible origin of life on Earth, which will vastly increase our knowledge of life in extreme environments and their biochemical applications in biotechnology. It may ultimately offer insights into the possibilities for extraterrestrial life. The geobiological heritage must be registered and conserved in honor to its importance in the understanding of the nature of life and its biotechnological potential.

The following text contextualizes the relevance of the geobiological heritage of Chile and presents a brief description of some ecosystems.

Keywords: Microbialites, Stromatolites, Heritage, Chile.

1. Introduction

Since time immemorial, humans have wondered about their origin and how life on earth began and evolved into the plethora of organisms we know today. During the search to understand the origins and evolution of life on our planet, much evidence of ancient life has been found preserved as fossils in terrestrial rocks.

Thanks to the new opportunities offered by space technology, we can search for evidence of life elsewhere in the Solar System and perhaps even outside it on extrasolar planets. Investigations show that on Mars and the Galilean moons of Jupiter, like the volcanic Io and the icy Europa, fluids and gases are present in extreme physicochemical conditions. This raises the possibility of extraterrestrial life for which the best candidates would be the extremophile bacterial communities that we find on Earth.

The Earth was formed about 4,500 Myr ago and the first forms of life were prokaryotic. One of the earliest pieces of evidence for life is fossils of ancient bacteria called stromatolites and thrombolites that have been dated to about 3,400 Myr ago on the planet. Both are organo-sedimentary deposits found in the seas or saline lakes that are formed by bacterial communities, which trap sediments and induce the precipitation of minerals. They differ in that stromatolites contain layers of sediment formed from layers of bacteria, while thrombolites are formed by accretion of minerals with no layered structure.

The earliest surface environment of the Earth present during the Archaean era (2.5 to 3.7 billion years ago) was extreme. The seas lacked large quantities of oxygen and the atmosphere was warm, dusty, devoid of oxygen and rich in toxic volcanic gases. The stromatolites formed by photosynthetic bacteria were adapted to living on the margins of the Archaean oceans. These photosynthetic bacteria were mainly responsible for the capture of the carbon dioxide in this early atmosphere and were the major players in the release of oxygen, thereby changing the composition of the atmosphere and oceans over geologic time. With oxygen in the atmosphere the evolution of the higher forms of life we know today became possible.

The observation of the life that currently inhabits the Earth is one of the keys to understanding the forms of life found in the fossil record and such knowledge will be invaluable if we ever find extraterrestrial life. The present is the key to understanding the past and the future.

2. Geobiological heritage of Chile

In the world there are just a few places where microbialites such as stromatolites and thrombolites are widely exposed and still alive. Chile contain an amazing diversity of extreme environments with well-developed microbialites colonies, and offer a world-class site for investigations, some sites examples are (See Figure 1): Lagunas de Amuyo, “Puquios” of Salar de Llamara, Salar de Aguas Calientes, the marginal shallow lakes of Salar de Atacama (Ex. Tebenquiche and La Brava), Salar de Aguilar, Lago Sarmiento and Laguna Amarga in Torres del Paine and Laguna de los Cisnes in Tierra del Fuego.

The Laguna Amarga and Lago Sarmiento are part of the Geosite of the Geological Society of Chile, but this actual title doesn’t guarantee their preservation.
In order to contextualize the relevance of the geobiological heritage of Chile, the following text presents a brief description of some of these sites.

### 2.1. The Stromatolites Colonies of Laguna Amarga, Torres del Paine

The maximum depth of Laguna Amarga is 4.1 m and its altitude is 80 m a.s.l. (Campos et al., 1996). The average pH of the lake is 9.1, whereas the salinity and temperature average 26.1 mg/l and 11.7 °C, respectively (Campos et al., 1996). Physio-chemical conditions are reflected by a phytoplankton community dominated by Cyanophyceae Aff.Gloescaspa and Artemia (Campos et al., 1996).

The lake forms a habitat for colonies of modern microbialites, which are attached to the mud and sand of the lake bottom and covered by a few tens of centimeters of water. The stromatolites form a main colony at least 100 m long and 20 m wide, parallel to the coast, in which domal, bulbous and E-W elongated stromatolites compose a semi-coherent mat belt. Some stromatolites with dome shapes (Figure 2) pioneer the generation of colonies in other locations around the main stromatolite colony (Solari et al. 2010).

The living dome-shaped stromatolites are composed of a sequence of white and grey layers (Figure 2). The top layer is a homogeneous crust of carbonate with less than 1% sediments (Figure 2). In general, the layers are composed of a framework of filamentous cyanobacteria surrounded by an extracellular polymeric substance with carbonate precipitation (Solari et al. 2010).

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**Figure 1:** Location of some geobiological ecosystems in Chile.

**Figure 2:** The stromatolites of Laguna Amarga at different scale point of view (From Solari et al., 2010)

### 2.2 The thrombolites of Lago Sarmiento, Torres del Paine

Lago Sarmiento has a maximum depth of 312 m. It is an alkaline lake with a mean salinity of 1.9 mg/l, a pH of 8.3 to 8.7, and a mean surface water temperature varying between 6.2°C in winter and 12.2°C in summer (Campos...
et al., 1994). Massive dead carbonate microbialites are exposed along the shoreline of Lago Sarmiento and up to 8 m above it (Figure 3), as a result of a drop in the water level. Similar microbialites are actively growing under the water surface of the lake, consisting of non-laminated, clotted calcium carbonate classified as thrombolites (Airo, 2010).

Changes of the water level are evidenced by four terraces (T4, T3, T2 and T1 Figure 4). Below the T1 terrace, 8 m of dead thrombolites is exposed along a large part of the coastline. Under the water, living microbialites composed of gastropods with aragonite shells and cyanobacteria filaments enclosed by calcite are observed. The distinctive clotted structure, observed on both microscopic and macroscopic scales classifies these deposits as thrombolites. In the thrombolites, zones of different colors separated by clear contacts are observed. The contacts of the light brown, white, grey and dark brown colors of the thrombolites zones are interpreted as resulting from four different lake levels and colonies development (Solari et al., 2010).

2.3 Microbialites of Tebenquiche and La Brava lakes, Salar de Atacama

Water temperature in Tebenquiche Lake reached 21.5°C in March and 31.0°C in November, and correspondingly, 24.6 and 30.1 °C in La Brava Lake (Farias et al., 2014). Based on pH measurements (7.4–8.6 and 7.8–8.2 for Tebenquiche and La Brava, respectively), both systems can be classified as moderately alkaline. Saline and hypersaline conditions were determined (38–150 g/L brine, Farias et al., 2014).

Tebenquiche and La Brava lakes display different microbial ecosystems, composed by: organic-rich and non-lithifying microbial mats and domes shapes microbialites

Figure 4: Stromatolites colonies of Laguna Tebenquiche and Laguna La Brava at different scales (From Farias et al., 2014).

2.4 Microbialites of “Puquios” Salar de Llamara

Four shallow lakes (Called “Puquios”) and more than 200 water pounds exist in a subsided area of Salar de Llamara. The “Puquios” of Salar de Llamara are almost the unique lakes in the Central Depression of northern of Chile. They are shallow (ca. 50 cm deep), with high salinity, alkaline pH and a well-developed microbial ecosystem characterized by Demergasso et al. (2003) and Rasuk et al. (2014).

The shallow water bodies were the habit of microbialites, stromatolites, microbial mats and films. The “Puquios” are dominated by partial submerged domes shapes microbialites, formed by the gypsum precipitations (Figure 5). The water level, salinity and chemistry are maintained by the continuous recharge of groundwater. Therefore, the recharge and the chemical characteristic of the groundwater support the microbial ecosystem.
3. Conclusion

The geobiological heritage and ecosystems must be preserved to the next generations because they: offer a world-class sites for investigations of the origins of life on the planet, that will vastly increase our knowledge of life in extreme environments and their biochemical applications in biotechnology, may ultimately offer insights into the possibilities for extraterrestrial life.

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References
