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STROMATOLITES - A LIFE FORM THAT HAS WITNESSED THE ENTIRE EVOLUTION OF OUR PLANET

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ABSTRACT

Life on Earth was born at least 3.7 billion years ago, but since then the number of living things has grown exponentially. Surprisingly, some of the earliest life forms on our planet still exist and not just in fossilized form - stromatolites - a life form that has witnessed the entire evolution of our planet can still be discovered in certain areas of the globe. Stromatolites are living fossils, the oldest life forms on Earth. Their existence spans an incredible period - stromatolites have existed for 75% of the period since the formation of the Solar System. They are defined simply as rock structures built by colonies of microscopic organisms that do photosynthesis. These organisms are known as cyanobacteria. As the soil settled in shallow water, bacteria began to grow on it, joining the sedimentary particles and building additional layers until mounds formed. These constructions of microorganisms in the earth are perhaps the essential element in the emergence of more complex life on earth - through their respiration, they produced and developed oxygen on Earth until it came to form 20% of the Earth's atmosphere. Using the Sun as an energy reservoir, stromatolites have transformed the planet into a place capable of supporting all life forms, simple or complex.

Keywords: Stromatolites; Bacteria; Cyanobacteria; Water; Microorganisms; Respiration; Energy; Life; Solar system; Biotechnology; Bioengineering.

1. INTRODUCTION

Life on Earth was born at least 3.7 billion years ago, but since then the number of living things has grown exponentially. Surprisingly, some of the earliest life forms on our planet still exist and not just in fossilized form - stromatolites - a life form that has witnessed

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As the soil settled in shallow water, bacteria began to grow on it, joining the sedimentary particles and building additional layers until mounds formed. These constructions of microorganisms in the earth are perhaps the essential element in the emergence of more complex life on earth - through their respiration, they produced and developed oxygen on Earth until it came to form 20% of the Earth's atmosphere. Using the Sun as an energy reservoir, stromatolites have transformed the planet into a place capable of supporting all life forms, simple or complex. Today, live stromatolites can only be found in a few lagoons and saltwater bays. Western Australia is one of the places known for the significant number and variety of stromatolites, whether live or fossilized (Biddanda et al., 2015; Duda et al., 2016; Grotzinger et al., 1996; Lepot et al., 2008; Monty, 1981; Allwood et al., 2009; Mcmenamin, 1982).

The oldest stromatolite fossils date back 3.5 billion years and are located 1,000 kilometers north of the Pilbara region of Western Australia. Stromatolites are basically a window into time - they are life forms that tell us what our planet looked like near its beginnings, before the formation of continents, before there were plants, other animals, or humans, and even before there were dinosaurs (Biddanda et al., 2015; Duda et al., 2016; Grotzinger et al., 1996; Lepot et al., 2008; Monty, 1981; Allwood et al., 2009; Mcmenamin, 1982; Aversa et al., 2018 a-b, 2017 a-b, 2016 a-n; Aljohani & Desai, 2018; Alexander & Wang, 2018; Apicella et al., 2018 a-c; Marquetti & Desai, 2018; Armah, 2018; Wilk et al., 2017; Babaev et al., 2010; Buzea et al., 2015; Petrescu et al., 2015; Abdul-Razzak et al., 2012; Ajith et al., 2009; Atasayar et al., 2009; Ahmed et al., 2011; Covic et al., 2007; Willis, 1953-1954, 1957; Ha, 2010; El-Gendy, 2009; Enstrom, 2014; Hansen, 2014; RATH, 1990, 2003; Yilmaz, 2006; Ravnskov, 2009; Kunutsor, 2016; Hickey, 2007; Choudhury & Greene, 2018; Choudhury, 2018).

2. METHODS AND MATERIALS

A What are stromatolites, the creatures that have witnessed the last 3.7 billion years on Earth (Figure 1-4)?

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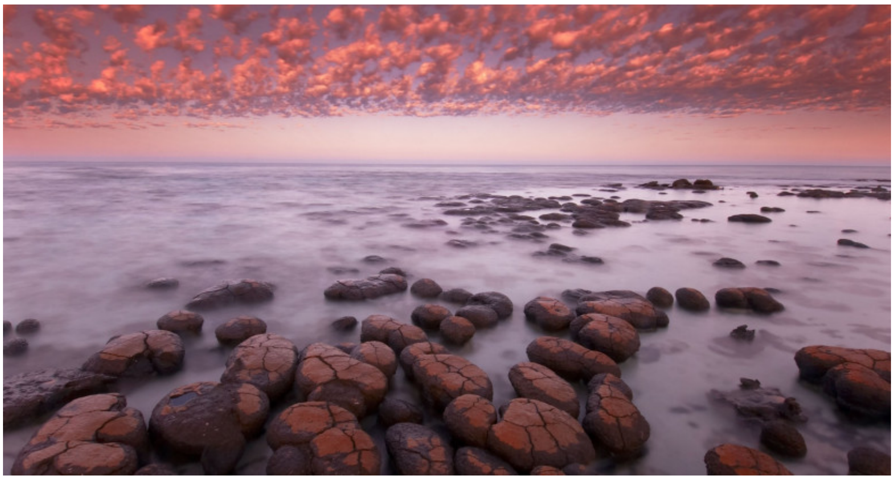

Figure 1: The stromatolites, the creatures that have witnessed the last 3.7 billion years on Earth
Source: https://en.wikipedia.org/wiki/Stromatolite

Figure 2: Visible structure of one cm of stromatolites. Fossilized stromatolite in Strelley Pool chert, about 3.4 billion years old, from Pilbara Craton, Western Australia.
Source: https://en.wikipedia.org/wiki/Stromatolite

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Stromatolites are basically a window into time - they are life forms that tell us what our planet looked like near its beginnings, before the formation of continents, before there were plants, other animals, or humans, and even before there were dinosaurs.

Figure 4: Modern stromatolites in Shark Bay, Western Australia
Source: https://en.wikipedia.org/wiki/Stromatolite

These constructions of microorganisms in the earth are perhaps the essential element in the emergence of more complex life on earth - through their respiration, they produced and developed oxygen on Earth until it came to form 20% of the Earth's atmosphere.

Using the Sun as an energy reservoir, stromatolites have transformed the planet into a place capable of supporting all life forms, simple or complex.

Today, live stromatolites can only be found in a few lagoons and saltwater bays.

Western Australia is one of the places known for the significant number and variety of stromatolites, whether live or fossilized.

Figure 5: Fossilized stromatolites, about 425 million years old, in the Soeginina Beds (Paadal Formation, Ludlow, Silurian) near Kübassaare, Estonia.
Source: https://en.wikipedia.org/wiki/Stromatolite

Stromatolites are stratified biochemical accumulation structures formed in shallow water by the trapping, binding, and cementing sedimentary grains into biofilms (especially microbial mats), especially cyanobacteria. They have a variety of shapes and structures or morphologies, including conical, stratiform, branched, and columnar types. Stromatolites are widely found in pre-Cambrian fossil records but are rare today. Very few ancient stromatolites contain fossilized microbes.

While the characteristics of some stromatolites suggest a biological activity, others possess characteristics that are more consistent with abiotic (non-biological) precipitation. Finding reliable ways to distinguish between biologically formed and abiotic stromatolites is an active area of research in geology.

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Figure 6: Paleoproterozoic oncoids from the Franceville Basin, Gabon, Central Africa.
Source: https://en.wikipedia.org/wiki/Stromatolite

Oncoids are unfixed stromatolites ranging in size from a few millimeters to a few centimeters.

Most stromatolites have a spongiostromate texture, no recognized microstructures, or cellular remains. A minority is porostromatic, with a recognized microstructure; they are largely unknown in the Precambrian but persist in the Paleozoic and Mesozoic. Since the Eocene, porostromatic stromatolites are known only from freshwater (Figs. 5-6).

Time photography of modern microbial formation of mats in the laboratory provides some revealing clues to the behavior of cyanobacteria in stromatolites. Biddanda et al. (2015) found that cyanobacteria exposed to localized light beams moved to light or expressed phototaxy and increased their photosynthetic efficiency, which is necessary for survival. In a new experiment, the scientists designed a school logo on a Petri dish containing the organisms, which gathered under the illuminated region, forming the logo in bacteria.

The authors speculate that such motility allows cyanobacteria to look for light sources that support the colony. In both light and dark conditions, cyanobacteria form groups that then spread outward, with individual members remaining connected to the colony by long lines. This can be a protective mechanism that provides evolutionary benefits to the colony in harsh environments where mechanical forces act to break microbial mats. Thus, these sometimes elaborate structures, built by microscopic organisms that function somewhat in unison, are a means of providing shelter and protection against a harsh environment.

Lichen stromatolites are a proposed mechanism for the formation of the types of stratified rock structures that form above water, where the rock meets the air, through the

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repeated colonization of the rock by endolithic lichens (Biddanda et al., 2015; Duda et al., 2016; Grotzinger et al., 1996; Lepot et al., 2008; Monty, 1981; Allwood et al., 2009; Mcmenamin, 1982).

Figure 7: Fossilized stromatolites in the Hoyt Limestone (Cambrian) exposed at Lester Park, near Saratoga Springs, New York.
Source: https://en.wikipedia.org/wiki/Stromatolite

Figure 8: Precambrian fossilized stromatolites in the Siyeh Formation, Glacier National Park.
Source: https://en.wikipedia.org/wiki/Stromatolite

Some archaic rock formations have a macroscopic resemblance to modern microbial structures, which leads to the deduction that these structures are evidence of ancient life, namely stromatolites.

However, others believe that these patterns are due to the deposition of natural materials or another abiogenic mechanism. Scientists have argued a biological origin of stromatolites due to the presence of groups of organic globules in the thin layers of stromatolites, aragonite nanocrystals (both characteristics of current stromatolites), and the persistence of a biological signal deduced by changing environmental circumstances.

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Figure 9: Fossilized stromatolites (Pika Formation, Middle Cambrian) near Helen Lake, Banff National Park, Canada.
Source: https://en.wikipedia.org/wiki/Stromatolite

Stromatolites are a major constituent of fossil records of the first life forms on earth. They reached their peak about 1.25 billion years ago and have since fallen in abundance and diversity so that at the beginning of the Cambrian they fell to 20% of their peak (Figure 7-13).

Figure 10: Stromatolites at Lake Thetis, Western Australia.
Source: https://en.wikipedia.org/wiki/Stromatolite

The most common explanation is that stromatolite builders were victims of walking creatures (the Cambrian substrate revolution); this theory implies that sufficiently complex organisms were common over 1 billion years ago. Another hypothesis is that protozoa such as foraminifera were responsible for the decline. Proterozoic stromatolite microfossils

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(preserved by permineralization in silica) include cyanobacteria and possibly some forms of eukaryotic chlorophytes (ie green algae). A very common type of stromatolite in geological records is Collenia.

Figure 11: Stromatolites at Highborne Cay, in the Exumas, The Bahamas.
Source: https://en.wikipedia.org/wiki/Stromatolite

Figure 12: Microbialite towers at Pavilion Lake, British Columbia.
Source: https://en.wikipedia.org/wiki/Stromatolite

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Figure 13: 'Crayback' stromatolite – Nettle Cave, Jenolan Caves, NSW, Australia.
Source: https://en.wikipedia.org/wiki/Stromatolite

The link between pasture and stromatolite abundance is well documented in younger Ordovician evolutionary radiation; the abundance of stromatolites increased even after the disappearance of the end of the Ordovician order and the end of the Permian, which decimated marine animals, returning to previous levels as marine animals recovered. Fluctuations in the metazoan population and diversity could not have been the only factor in reducing stromatolite abundance. Factors such as environmental chemistry could have been responsible for the changes.

While prokaryotic cyanobacteria reproduce asexually by cell division, they have been essential in preparing the environment for the evolutionary development of more complex eukaryotic organisms. Cyanobacteria (as well as extremophilic Gammaproteobacterial) are thought to be largely responsible for increasing the amount of oxygen in the Earth's primordial atmosphere through their continuous photosynthesis (see The High Oxygenation Event).

Cyanobacteria use water, carbon dioxide, and sunlight to create their food. Often a layer of mucus forms over the cyanobacterial cell mats. In modern microbial mats, debris from the surrounding habitat can become trapped in mucus, which can be cemented together by calcium carbonate to increase thin limestone laminations. These laminations can accumulate over time, resulting in the banded pattern common to stromatolites. The "domestic" morphology of biological stromatolites is the result of the vertical growth necessary for the continuous infiltration of the sun into organisms for photosynthesis.

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Stratified spherical growth structures called oncolites are similar to stromatolites and are also known from fossil records. Thrombolites are poorly laminated or non-laminated coagulated structures made from cyanobacteria, common in fossil records and modern sediments. There is evidence that thrombolites form in preference to stromatolites when foraminifera are part of the biological community (Bernhard et al., 2013; Sheehan & Harris, 2004; Riding, 2006; Peters et al., 2017; Feldmann & Mckenzie, 1998; Chen et al., 2010; Gischler et al., 2008; Braithwaite & Zedef, 1996; Ferris et al., 1997; Brady et al., 2010; Cox et al., 1989).

The Zebra River Canyon area of the Kubis platform in the deeply dissected Zaris Mountains in southwestern Namibia provides an extremely well exposed example of thrombolite-stromatolite-metazoan reefs that developed in the Proterozoic period, with stromatolites being better developed in deep locations. higher current velocity and higher sediment flow.

Modern stromatolites are mostly found in hypersaline lakes and marine lagoons where extreme conditions due to high saline levels prevent animals from grazing. One such location where excellent modern specimens can be seen is the Hamelin Pool Marine Nature Reserve, Shark Bay in Western Australia. Another location is the Pampa del Tamarugal National Reserve in Chile. A third is Lagoa Salgada ("Salt Lake"), in the state of Rio Grande do Norte, Brazil, where modern stromatolites can be seen both as bioherms (domal type) and as beds. Inland stromatolites can also be found in the salt waters of the Cuatro Ciénegas Basin, a unique ecosystem in the Mexican desert, and Lake Alchichica, a Maar lake in the eastern basin of Mexico. The only open marine environment in which modern stromatolites are known to thrive is the Exuma Cays of the Bahamas (Figure 11).

In 2010, the fifth type of chlorophyll, namely chlorophyll f, was discovered by Dr. Min Chen from stromatolites in the Gulf of Sharks (Figure 14), Bacalar Lagoon in the southern Yucatan Peninsula of Mexico, in the state of Quintana Roo, has a formation extended by living giant microbes (i.e. stromatolites or thrombolites). The microbial bed is over 10 km (6.2 mi) long, with a vertical growth of a few meters in some areas. These can be the largest living microbial dimensions of freshwater or any organism on Earth (Bernhard et al., 2013; Sheehan & Harris, 2004; Riding, 2006; Peters et al., 2017; Feldmann & Mckenzie, 1998; Chen et al., 2010; Gischler et al., 2008; Braithwaite & Zedef, 1996; Ferris et al., 1997; Brady et al., 2010; Cox et al., 1989).

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Figure 14: The stromatolites in the Gulf of Sharks, Bacalar Lagoon in the southern Yucatan Peninsula of Mexico, in the state of Quintana Roo.
Source: https://thumbs.dreamstime.com/z/stromatolites-bacalar-lagoon-mexico-estromatolitos-stromatolites-bacalar-lagoon-mexico-quintana-roo-102600694.jpg

Lake Crater Alchichica in Puebla Mexico has two distinct morphological generations of stromatolites: aragonite-rich column-like structures that form near the shore, dating from 1100 ybp, and thrombolytic structures that dominate the lake from top to bottom, consisting primarily of hydromagnesite. , huntite, calcite, and dates from 2800 ybp.

A little further south, a 1.5 km stretch of stromatolite that forms reefs (mainly of the genus Scytonema) appears in the Chetumal Gulf of Belize, just south of the mouth of the Rio Hondo and the Mexican border. Freshwater stromatolites are found in Lake Salda in southern Turkey. The waters are rich in magnesium, and the stromatolitic structures are made of hydromagnesite.

Two cases of freshwater stromatolites are also found in Canada, at Lake Pavilion and Lake Kelly in British Columbia. Lake Pavilion has the largest freshwater stromatolites known, and NASA is currently conducting research in xenobiology there. NASA, the Canadian Space Agency, and many universities around the world are collaborating on a project to study microbial life in lakes. Called the "Pavilion Lake Research Project" (PLRP), its purpose is to study which conditions on the bottom of lakes are most likely to harbor life and to develop a better hypothesis about how environmental factors affect life. microbial.

The ultimate goal of the project is to better understand the conditions that could harbor life on other planets. There is an online citizen science project called "MAPPER", in which anyone can help sort thousands of photos with the bottom of the lake and label microbial algae and other features of the lake bed (Bernhard et al., 2013; Sheehan & Harris,

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2004; Riding, 2006; Peters et al., 2017; Feldmann & Mckenzie, 1998; Chen et al., 2010; Gischler et al., 2008; Braithwaite & Zedef, 1996; Ferris et al., 1997; Brady et al., 2010; Cox et al., 1989).

Stromatolites are layered sedimentary formations that are created by photosynthetic cyanobacteria. These microorganisms produce adhesive compounds that cement sand and other rocky materials to form mineral “microbial mats”. In turn, these mats build up layer by layer, growing gradually over time. A stromatolite may grow to a meter or more. Although they are rare today, fossilized stromatolites provide records of ancient life on Earth.

The microbialites were discovered in an open pond at an abandoned asbestos mine near Clinton Creek, Yukon, Canada. These microbialites are extremely young and probably began to form shortly after the mine closed in 1978. The combination of a low sedimentation rate, a high rate of calcification, and a low rate of microbial growth appears to result in the formation of these microbialites. Microbialites from a historic mine site demonstrate that an anthropogenic built environment can promote the formation of microbial carbonate.

This has implications for the creation of artificial environments for the construction of modern microbialities, including stromatolites. A very rare type of stromatolite that does not live in the lake lives in Nettle Cave in Jenolan Caves, NSW, Australia. Cyanobacteria live on the surface of limestone and are supported by calcium-rich dripping water, which allows them to grow to the two open ends of the cave, which provide light.

Stromatolites composed of calcite have been found both in the Blue Lake in the latent volcano, Mount Gambier and in at least eight cenote lakes, including the Little Blue Lake in the lower southeast of South Australia (Figure 13) (Bernhard et al., 2013; Sheehan & Harris, 2004; Riding, 2006; Peters et al., 2017; Feldmann & Mckenzie, 1998; Chen et al., 2010; Gischler et al., 2008; Braithwaite & Zedef, 1996; Ferris et al., 1997; Brady et al., 2010; Cox et al., 1989).

3. RESULTS AND DISCUSSION

Bacalar is the municipal residence and the largest city in the municipality of Bacalar (until 2011 part of the municipality of Othón P. Blanco) in the Mexican state of Quintana Roo, about 40 kilometers north of Chetumal, at 18 ° 40 '37 "N, 88 ° 23 '43 "W. At the 2010 census, the city had a population of 11,084 people. At that time, it was still a part of Othón P. Blanco and was the second-largest city (locality), after Chetumal.

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The name probably derives from the Mayan languages: b’ak halal, which means “surrounded by reeds”, the name of the city attested by the Spanish arrival in the 16th century.

Bacalar is also the name of the lagoon, Laguna Bacalar in the eastern part of the city.

Bacalar was a city of Mayan civilization in the pre-Columbian period. It was the first city in the region that the Spanish Conquistadores managed to take and own in 1543. In 1545 Gaspar Pacheco established here the Spanish city called Salamanca de Bacalar with the help of Juan de la Cámara. The region in the southern half of present-day Quintana Roo was ruled by Bacalar, who was accountable to the captain-general of the Yucatán in Mérida.

After the city was captured by pirates in the 17th century, the Fortress of San Felipe Bacalar was completed in 1729 and can be visited today.

In 1848 Bacalar had a population of about 5,000 people. In 1848, during the caste war in the Yucatan, the rebel Chan Santa Cruz Maya conquered the city. It was not resumed by Mexicans until 1902. Bacalar was named "Pueblo Mágico" in 2006.

With a total length of over 10 km, the Holocene microbialites in Laguna Bacalar, Mexico, belong to the largest occurrences of freshwater microbialites. Microbialites include domes, curbs, and oncolites. Domal forms can grow to diameters and heights of 3 m. Microbialites are composed of low-magnesium calcite, which is largely precipitated due to the metabolic activity of Homeothrix and Leptolyngbya cyanobacteria and associated diatoms. Photosynthesis removes carbon dioxide and triggers the precipitation of carbonate.

Also, an increased concentration of carbonate in the lagoon waters, derived from the dissolution of Cenozoic limestone in a karstic system, supports carbonate precipitation. It is also observed catching and tying detrital grains, but they are not as common as precipitation. Bacalar microbialites are mostly thrombolytic, however, stromatolite sections also occur. Most Bacalar microbialites probably formed in the late Holocene (about 1 kyr BP to date). According to the ^{14}C dating, the microbialites accumulated 9 to 8 cal kyr BP; however, these ages may be too old due to the strong effect of hard water. This effect is seen in the ^{14}C era of live bivalve shells and gastropod mollusks in the Bacalar Lagoon, which is 8 to 7 horsepower KP BP.

The associated modern microbial fauna is characterized by low diversity and high abundance of bivalve mollusks Dreissena sp. and the gastropod Pomacea sp. Abundant

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grazing gastropods probably prevent the modern formation of microbialites. A comparison of Bacalar microbialites with other modern microbialite occurrences around the world shows only a few models: size, shape, microbial taxa, mineralogy, accumulation type, and settings, including water properties of microbialite occurrences, show high variability. A trend can be observed in grazing metazoans, which are rare to absent in marine and brackish examples, but apparently present in all freshwater occurrences of microbialites. Also, freshwater examples are usually characterized by high concentrations of carbonate and/or calcium ions in the surrounding waters.

Microbialites are the oldest life forms on our planet that played an important role in the early history of life on Earth, their growth depending on the physicochemical conditions of the water in which they exist, which is why a correlation of conditions is possible in the environment with the sedimentary record produced by microbialites in a very long time.

Figure 15: Stromatolites in the Gulf of Sharks, Bacalar Lagoon in the southern Yucatan Peninsula of Mexico, in the state of Quintana Roo.
Source:
https://lh3.googleusercontent.com/proxy/yODTpSeXiL7_sv2H44yFxRfCuzGSNe7mcjqj_t5Swlr0zGnI64gOaZI4wCw0o-pvk_929JqEiokMVlacNOdTqRpMeMaHl0AfiNiFjg

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Figure 16: Stromatolites in the Gulf of Sharks, Bacalar Lagoon in the southern Yucatan Peninsula of Mexico, in the state of Quintana Roo.
Source: https://thumbs.dreamstime.com/z/stromatolites-bacalar-lagoon-mexico-estromatolitos-stromatolites-bacalar-lagoon-mexico-quintana-roo-102600514.jpg

Bacalar Lagoon is one of the largest occurrences of freshwater microbialite (stromatolites) in the world, with variable morphologies in different parts of the lagoon due to the dynamics and composition of the lagoon. Bacalar Lagoon is facing anthropogenic activities derived from tourism and agriculture, constantly taking place changes in the composition of the water column derived from these activities and natural changes in the system (Figs. 14-16).

Stromatolites are organic sedimentary carbonate deposits formed by the interaction between benthic microbial communities and detrital sediments; their growth is influenced by local climate change and other environmental factors, such as system dynamics, changes in depth, the direction of light, substrate, etc. (Castro et al., 2014; Dupraz et al., 2011). The structures preserve the physicochemical conditions of the water in which they deposit, for this reason, the stromatolites consider a great proxy to make a hydrological reconstruction (Woo et al., 2004; Riding, 1999, 2000; Kendall & Mc Donell, 1998).

Paleohydrological reconstructions allow us to know the dynamic variation and composition of different water systems over time. Due to the difficulty of having a direct record of previous hydrological conditions, it is necessary to use indirect proxies, in the sedimentary record there are both biological (fossil) and non-biological (isotopic signals) proxies (Wefer et al., 1999; Lowe & Walker, 1997).

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Stable isotopic analyzes of stromatolite sedimentary records reveal information about water temperature and geochemical composition (Andrews, 2006), such as carbonate content and trace elements (Stumm, 1992).

Stromatolites grow under specific conditions of light, pH, depth, temperature, nutrient content, waves, and currents, etc., so that it is possible to link environmental conditions with lithological parameters in a paleohydrological record (Beraldi, 2014; Dupraz et al., 2011).

The carbonate structures of the Bacalar Lagoon are unique because they are one of the largest occurrences of freshwater microbialites in the world (Centeno et al., 2012; Gischler et al., 2008, 2011) and because they retain previous information about climatic and environmental conditions. and life during the sedimentation process.

As well as other karst systems such as Laguna CuatroCienegas, Gulf of Sharks, Lake Pavilion, Lake Van, etc. (Gischler al., 2008), Bacalar lagoon has carbonaceous structures (stromatolites), with an extension of 10 km along the western side. The presence of these structures is related to the concentration of carbonates and the dynamics of the lagoons. The western part of the lagoon is directly connected to sinkholes and aquifers, this interaction results in a high concentration of carbonate compared to the entire lagoon. Also, the interaction and dynamics between the lagoon and the aquifer are some of the physical processes that can lead to the growth of stromatolites. In the narrowest part of the lagoon, called “Los Rapidos”, the flow is highest, inducing a mixture of water, nutrient, and carbonate concentrations increase, and stromatolites also tend to increase (Castro et al., 2014; Babel et al., 2011; Gischler et al., 2011).

Bacalar Lagoon ecosystems need protection, governance, and policies in climate change adaptation/resilience programs. Defining policies based on scientific research, using ancient structures such as stromatolites as a proxy, explaining the past, and helping us face current challenges and visualize future transformations, is a fundamental order to make decisions and make decisions. measures to manage Mexican coastal lagoons in the Caribbean.

Through this investigation, the changes in the composition and dynamics of the lagoon could be seen, and the results can allow the realization of some projections (climatic, recharging, and anthropogenic). A paleohydrological reconstruction can be done with the analysis sedimentary record of these structures, to know how the Bacalar lagoon has changed over time, in terms of chemical composition, changes in temperature and precipitation (climate change), and due to the contribution of groundwater and other factors.

The lagoon is an oligotrophic system, with a maximum depth of 15 m and the presence of seasonality is low, the temperature in winter is ~ 28 ° C, while in summer it is ~ 29 ° C. A constant and pleasant temperature, warmer than cold, makes the area a small climatic paradise.

The lagoon is a freshwater system (conductivity of 0-2.3 mS/cm), a pH between 7.6 and 8.3 (Beltrán, 2010).

The climate of the study site is subtropically humid modulated by two meteorological processes, the first consisting of cold fronts, locally called "Nortes", present in winter and in the dry period from March to May. The second meteorological process is tropical storms with precipitation (900 mm/year) and hurricanes. The rainy season is between June and September (1250-1500 mm / year) (Conagua, 2015).

BacalarLagoonis located in the hydrological region no. 33 (RH33), on a karst platform, with five sinkholes in the western part of the lagoon with a depth of ~ 90 m, three (Cocalitos, Esmeralda, and Negro) are in the lagoon with the connecting surface, Cenote Azul has only an underground connection.

The Xul-Ha pit is connected to the lagoon through a canal (Gischler et al., 2011; Pérez, 2011; Beltrán, 2010; Perry et al., 2009).

The eastern part of the lagoon is connected to the Chetumal Gulf of Rio Hondo and the lagoons of Chile Verde and Guerrero. The variation of the groundwater layer of the lagoon was estimated at ~ 30 cm (Gischler et al., 2011).

Due to the lagoon landscape nature, the main economic income of the population comes from tourism. However, the growth of tourism and associated aquatic activities in the lagoon (some of which are not properly regulated) has a negative impact on the ecosystem, especially in stromatolites.

Bacalar Lagoon does not have regulation as a protected area, and the development plan has been evaluated. The main activities of the area are agriculture (sugar cane, rice, and corn), animal husbandry (pigs and cattle), and beekeeping.

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The stromatolite cores were collected in the western part of the lagoon with a pushing core 5 cm in diameter and a length of 11-40 cm. In addition, the core of the lake sediments was collected with plastic liners with a diameter of 5 cm and a length of 11-43 cm. Each core was stored in a cooler at 4 ° C and transported to the laboratory of the Water Science Unit (Velázquez, 2017).

The cores (lacustrine sediment and stromatolites) were divided every 5 cm for stable isotopes of ^{18}O and ^{13}C and trace element analyzes. The samples were dried at 50 °C and ground with an agate mortar.

For isotope analysis, a secondary sample was selected and the organic matter was removed, adding 50% H_2O_2, for 48 hours, the remaining sediment was rinsed with Milli-Q water and dried at 50 °C.

To establish the chronology of the lake sequence, the nuclei were dated by 14C accelerator mass spectrometry (AMS) at the Laboratory of Marine Sciences of the University of California Santa Cruz. To identify the entry of terrigenous from the lagoon, changes in magnetic sensitivity were registered at the Institute of Geophysics of UNAM (Velázquez, 2017).

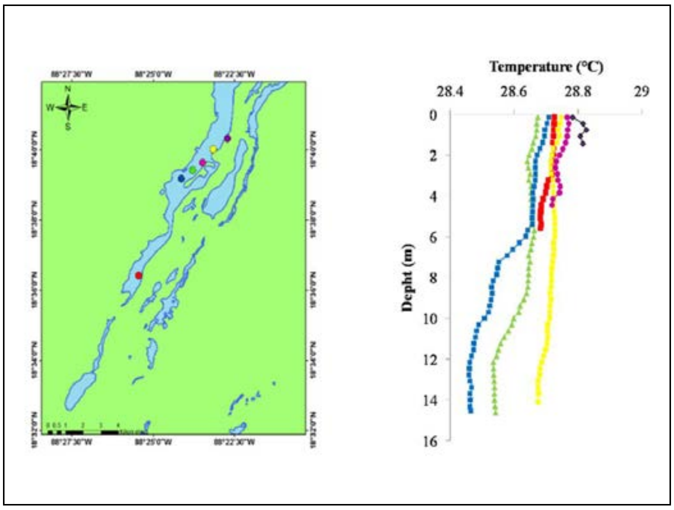

Figure 17: Temperature profile along the lagoon (left, point sites of profiles; right, profiles with the respective color of sites in the left picture).
Source: Velázquez, (2017).

The temperature profiles along the lagoon were not variable indicating that the lagoon is very homogeneous, due to the depth is very low (15 m) and permit the water mix (Figure 17). Only in the sinkholes temperature profiles were observed a thermocline around 23 m (Figure 18), (Velázquez, 2017).

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The values of alkalinity in the west part of the lagoon were greater (more than the average of the sea 140mg/l) than the samples taken in the east part. These values show that there is an inflow of water enriches of carbonates. The nitrate concentrations and TDS were very homogeneous in all the sites, while the nitrites and phosphates were lower to the limits of detection of the chromatographer (<1 ppb). The values of chlorides and sulfates are greater in the east part, while the western is lower, due to the proximity to the sea (Velázquez, 2017).

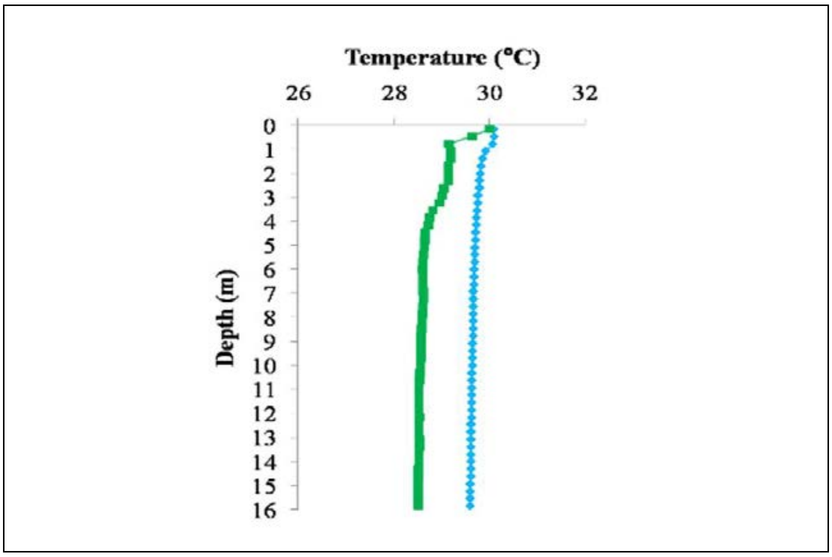

Figure 18: Temperature profiles of cenotes (green: Cocalitos; blue: Cenote Azul).
Source: Velázquez, (2017).

3.1. Lacustrine Sediment core description

RAP: the total length of 11cm, the surface was green with a little brown, and the grain size was variable sands, the surface part has more big size and contains some green rocks. The last cm has very fine coffee color sediment, and the presence of matter organic. CCoc: 36 cm length, the first 3 cm are grey darker than the rest of the core. The presence of red plant remains is observed in the entire core. BAC1: 27 cm length, grey color core, except the first 5cm (brown).

Throughout the core, plant remains are observed, maybe part of the mangrove. BAC2: 43 cm length, the first 5 cm is green, the middle core is brown, and the last 8 cm are grey with fine grains as silts. BAC3: 19cmlength, very fine sediments, the last 12cm are finer than the rest of the core. In general, the core is brown, with a grey color at the lower part. The surface sediment is green maybe to the presence of cyanobacteria (Velázquez, 2017).

3.2. Stromatolites core description

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Rap: The total length is 10 cm, the size grain is variable but the last 4cm are finer. The core is between green and brown and there are present some green rocks. In the base of the core, organic matter is observed. CCoc; The total length is 20 cm, the upper part is green and the rest is brown, there are present a lot of bivalve fragments, the sediment is sandy but in the last part the sandy is thicker. In this core, it was observed the presence of mollusks that could indicate the presence of some contaminants. BAC3: The total length is 40cm, the first 5 cm are green and the rest of the core is brown and the base is grey.

The sediment is sandy, however as the depth increases the grain size too. In some parts of the core, it is observed some mollusks (Velázquez, 2017).

The stromatolites of the Bacalar lagoon show that the morphology of these structures depends on the dynamic and composition of the lagoon. The zone of Los Rapidos (Rap) and BAC 3 has the highest stromatolites due to the flow of the water is greater than the rest of the lagoon and this promoted the water mix and thus the increment of the nutrients. In addition, in the western part of the lagoon, the carbonate concentrations are greater than in the eastern part, suggesting a groundwater inflow. This lagoon could have some changes in its composition due to human activities, this because in the place it is observed that some of the stromatolites are affected by boats, trash, wastewater, etc., for that reason it is necessary to implement some security politics to prevent the damage of the stromatolites (Velázquez, 2017).

Stromatolites are stratified microbialites, while thrombolites have rather coagulated and unclassified textures. The relatively high abundance of Precambrian microbialites compared to the younger deposits was interpreted as a consequence of an increased grazing pressure from the evolving metazoan in Earth's history (Garrett, 1970). Subsequently, this view was modified due to the discovery of more and more Precambrian and Phanerozoic microbialites appearances. These events have proven to be quite diverse in terms of shape, texture, and organic content (Pratt, 1982; Riding, 2000).

Not only did microbes evolve and algae came into play, environmental conditions, such as the carbonate content of ocean water, also changed throughout the Phanerozoic. Carbonate saturation is of great importance for the formation of microbialites because non-enzymatic precipitation of calcium carbonate in biofilms is only partially organically controlled (Riding & Liang, 2005). Modern microbialites, which can be used as analogs for their fossil counterparts, occur in a wide variety of environments.

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There are examples of hypersaline, such as the classical location of Shark Bay in Western Australia (Reid et al., 2003), stromatolites of the Bahamas submarine, which form in areas with extensive sediment redeposition (Dill et al., 1986; Reid et al., 2000), “kopara” in shallow Pacific atoll lagoons, microbialites in protected reef cavities (Reitner, 1993; Camoin et al., 1999), in willow environments (Rasmussen et al., 1993) and in alkaline lakes (Kempe et al., 1991). Microbialites also occur in freshwater lakes and lagoons, for example, in Western Australia (Moore, 1987; Moore & Burne, 1994), Western Mexico (Winsborough et al., 1994; Garcia-Pichel et al., 2004), and Canada (Laval et al., 2000). In some of these locations, metazoan pastures are rare; however, there are also examples in which pastors are present. The freshwater lagoon and lake waters containing microbialites are usually characterized by a high carbonate content.

To understand the formation of fossil microbialites, it is crucial to study modern examples. However, not all fossil examples have modern counterparts, and so do not all modern occurrences they have equivalents in the fossil records (Golubic, 1991). Therefore, it is important to increase knowledge about the emergence of modern microbialites and fossils.

This paper describes the newly discovered Bacalar location, which is one of the largest occurrences of freshwater microbialites in the world. On the one hand, the advantages over the system are the oxygenation of water and air, and on the other hand the sweetening of saltwater and restoring its quality especially based on calcium and other minerals permanently donated by Stromatolites to the system in which they live and fall. It is realistically assumed that these stromatolites, being the oldest life forms on our planet, were the first living systems to produce oxygen on our planet, long before plants. On the other hand, where they had symbiosis with water, they managed to permanently restore the quality of that water, refreshing it with various minerals, sweetening it, and turning it into fresh and potable water.

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Sample	Na^{2+}	K^{+}	Mg^{2+}	Ca^{2+}	HCO_3^-	Cl^-	SO_4^{2-}
BAC 1	55·75	4·75	78·88	325·00	183·00	41·70	1072·00
BAC 2	56·25	4·25	72·13	322·50	165·00	44·50	1100·00
BAC 3	59·88	4·50	75·75	326·25	140·00	43·50	1060·00
BAC 4	55·13	4·25	72·88	322·50	177·00	70·40	1160·00
BAC 5	51·00	4·00	69·50	325·00	201·00	66·60	1137·00
BAC 6	49·13	3·63	71·75	322·50	183·00	65·80	1113·00
BAC 7	49·25	3·50	76·13	325·00	214·00	70·60	1139·00
BAC 8	48·63	3·75	72·38	313·75	207·00	48·40	1019·00
BAC 9	49·88	4·13	70·38	308·75	232·00	34·50	1031·00
BAC 10	48·75	3·50	73·75	313·75	238·00	50·90	1038·00
BAC 11	67·88	4·88	82·38	325·00	165·00	78·00	1211·00
BAC 12	72·00	5·00	81·50	320·00	146·00	79·00	1106·00
BAC 13	70·13	5·13	84·00	316·25	189·00	81·70	1147·00
BAC 14	75·63	5·88	84·88	313·75	116·00	102·00	1154·00
BAC 15	80·00	6·00	86·75	315·00	110·00	110·00	1194·00
BAC 16	77·50	5·50	85·38	312·50	104·00	102·00	1165·00
BAC 17	67·75	5·13	83·88	312·50	104·00	185·00	1154·00
BAC 18	108·38	7·63	88·88	310·00	104·00	43·60	1030·00
BAC 19	43·13	3·88	71·25	333·75	226·00	39·10	1023·00
BAC 20	43·88	3·88	72·50	328·75	220·00	46·50	1185·00
Mean	61·49	4·66	77·74	319·63	171·20	70·19	1111·90
CHE 21	4174·00	138·50	498·50	295·00	171·00	5730·00	1346·00
CHE 22	2535·00	85·50	344·50	351·25	153·00	3060·00	1544·00
Mean	3354·50	112·00	421·50	323·13	162·00	4395·00	1445·00
Ocean water	10 760	385	1295	415	140	19 350	2700

Figure 19: The most complete results of water and freshwater analyzes (Bacalar, Mexico)
Source: Gischler et al., (2008).

The most complete results of water and freshwater analyzes (microbialites, Bacalar, Mexico) were performed by Gischler and his collaborators, being fully presented in the paper (Gischler et al., 2008) and we will briefly present them here within the table of Figure 19.

Why we consider Stromatolites to be extremely important. Besides being extremely old terrestrial life formations, probably the oldest, they have the ability to donate oxygen to the environment, creating oxygenated air as we know it today. Some studies suggest a very old concentration of oxygen in the air much higher than today, about 25-30%, along with nitrogen.

Due to the reduction of the living area and manifestation of stromatolite formations on our planet, as well as the fact that few of them are still active or fully active today, the oxygen in our planet's atmosphere has decreased and with it its concentration reaching only 22%, because given that our technological age has rapidly produced ultra-polluting technologies and most forests have been and still are massacred, and the planet's ecosystems have had the same fate, the percentage of atmospheric oxygen has dropped to about 20% today, in some more polluted places on the planet this percentage can even be reduced to 18%.

It is not the aim of this paper to demonstrate the importance of oxygen for life, and the fact that it has a lower concentration in air and water, but also in the soil, its power to give life is greatly diminished. To this deficit is added the greenhouse effect due mainly to high oxygen consumption by burning classical fuels, fossil fuels, and the elimination of carbon products extremely toxic to air, water, and our entire planet, as well as the fact that a good period of while the main shield for the protection of our planet's atmosphere, the ozone shield, was also attacked, dimmed, drilled (we don't want to explain now how, being important the fact that it has long since begun its restoration, in 2018 the big holes much diminished).

Given that not enough trees are planted annually, and forests are burned or cut down without control and/or restrictions, and other man-made devices that generate a lot of oxygen and ozone on the planet have not yet been installed, the few ecosystems made up of stromatolites still active, they are of major importance for the further creation of clean oxygen for the atmosphere but also the water of our planet.

Imagine that we want to become galactic conquerors in the future, because this is perhaps the most important task of creative humanity, still undetected, although it is already prepared in the last 70 years by several developed countries. We will certainly need to produce massive clean oxygen on the planets we will form in the future, and moving such stromatolite formations to those new places will perhaps be a future possibility and a great chance for humanity. Of course, today there is a chance that we will produce oxygen by other means, but this rare and old possibility should still be taken into account.

In any case, these rare but important formations must, at least from now on, be protected by law, so that they can develop quietly in the future as well. The modern man who ceases today, we hope to attack the planet he lives on, will also take into account the protection of these extremely vital formations for man, for plants and animals, and will protect them in the future, through measures and norms that will be imposed.

Another important idea that must be pointed out in the current work is that these wonderful natural formations on earth contain and work with the vital element phosphorus, phosphorus being the energetic element of life. Of the four general energy elements but especially of life (O, H, N, P) phosphorus is the element that makes the difference between dead and living matter. With its appearance, it is considered that life appeared on earth. Although it generally occurs in small quantities, phosphorus is the basic vital element, and especially the primary element of life, as we know it today on our planet (Aversa et al., 2016 h, 2016 m).

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An obscure compound, known as pyrophosphite, could have been a source of energy that allowed the formation of the first life on Earth.

The author suggests that pyrophosphate was relevant in the transition from basic chemistry to complex biology when life began on earth (Aversa et al., 2016 h).

They have even provided further evidence of the importance of this molecule and intend to further investigate its role in abiogenesis - this is how life on Earth came from inanimate matter billions of years ago. In reality, there are several contradictory theories about abiogenesis, each trying to bring something new about how life appeared on Earth.

What is essential in these studies, in the end, is energy. Living matter constantly needs energy to exist and function. The main energy source of living matter is produced in molecules known as ATP (adenosine triphosphate).

An ATP molecule can change any heat of the sun into a form of energy that can be used by plants, humans, and animals. An ATP molecule contains these four vital elements: oxygen, hydrogen, nitrogen, and phosphorus (thirteen oxygen atoms, eight hydrogen atoms, five nitrogen atoms, and three phosphorus atoms).

Basically, it is important how the atoms of the four elements are connected in an ATP molecule (Figure 20). ATP is constantly used and regenerated in cells through a process known as respiration, a process driven by natural catalysts called enzymes.

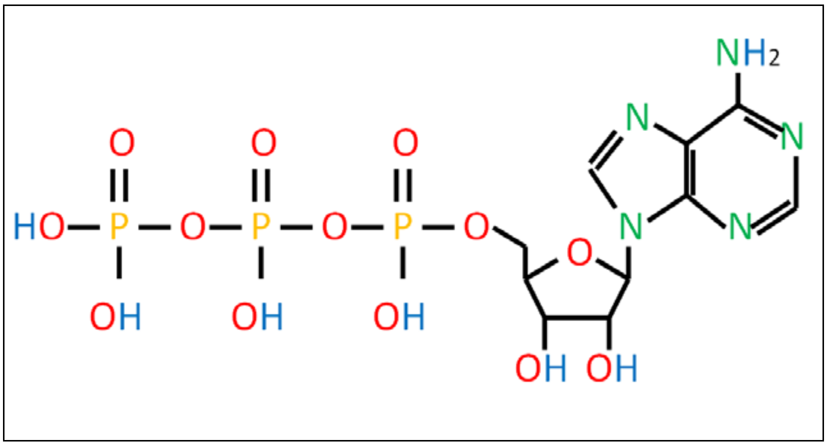

Figure 20: How the atoms of the four elements are connected on one ATP molecule
Source: Aversa et al., (2016 h, 2016 m).

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3.3. ATP carries chemical energy inside cells to carry out metabolic processes.

It is one of the final cellular respiration and fermentation and is used by enzymes and structural proteins in many cellular processes, such as motility, biosynthetic reactions, and cell division.

An ATP molecule contains three phosphate groups, which are produced by a wide variety of enzymes, including the synthesis of ATP to adenosine diphosphate (ADP), adenosine monophosphate (AMP), and various donors of a phosphate group.

Metabolic processes that use ATP as an associate in energy supply then turn it into precursors. In this way, ATP is continuously recycled in the body. The human body contains, for example, an amount of about 250g of ATP (the equivalent of a single AA battery). ATP is used as a substrate in signal transduction pathways by kinases that phosphorylate proteins and lipids. It is also used by adenylate cyclase which uses ATP to deliver cyclic AMP to the second travel molecule. The magnitude relationship between ATP and AMP is used as how a cell can feel the proportion of energy that exists and manages the metabolic pathways that produce and consume ATP. Except for its role in signal and energy metabolism, ATP is further incorporated into nucleic acids by polymerases in the transcription method. Moreover, ATP is that the neurochemical is considered to signal the sense of taste. One important reaction (biochemical reaction) is the hydrolysis of ATP into AMP in cells: ATP → AMP + PPi.

By this biochemical reaction (ATP hydrolysis) one ATP molecule becomes one AMP molecule and results in addition one pyrophosphate (PPi), which is an anion P2O74− noted with PPi. The pyrophosphate (diphosphate or dipolyphosphate) anion having structure "P2O74−" is an acid anhydride of phosphate (Figure 21).

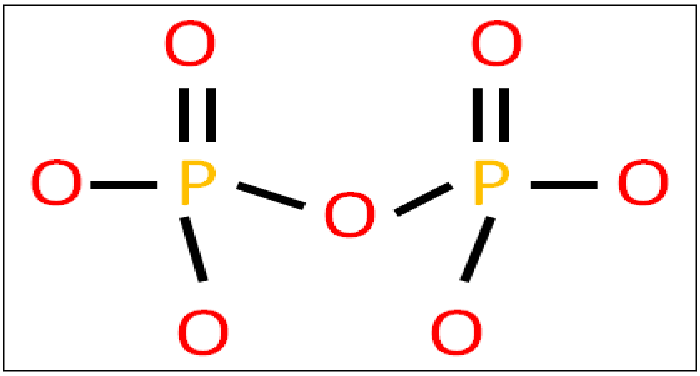

Figure 21: A pyrophosphate anion having structure "P2O74−"
Source: Aversa et al., (2016 h, 2016 m).

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The pyrophosphate is unstable in aqueous solution and hydrolyzes into inorganic phosphate (Hydrogen phosphate, see Figure 22) HPO_4^{2-} (notted with Pi) by reaction: $PP_i + H_2O \rightarrow 2\ P_i$

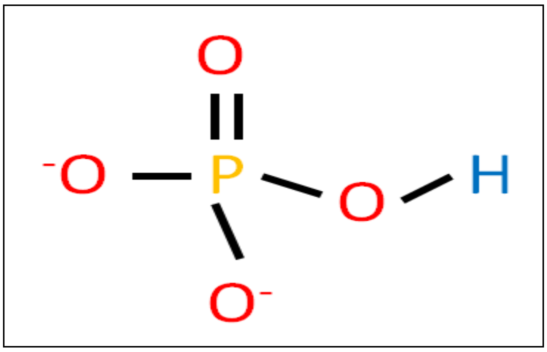

Figure 22: Hydrogen phosphate, HPO42− (notted with Pi)
Source: Aversa et al., (2016 h, 2016 m).

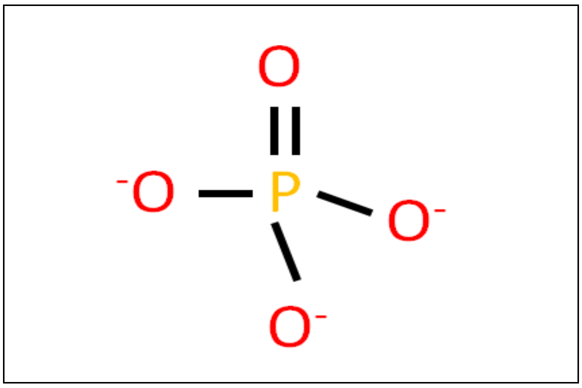

Figure 23: One phosphate ion
Source: Aversa et al., (2016 h, 2016 m).

One phosphate ion (Figure 23) is a polyatomic ion having the formula PO_4^{3-} and a mass molar of 94.97 g/mol. It is builded from one central atom of phosphorus which is surrounded by four atoms of oxygen (in a tetrahedral arrangement). A phosphate ion carries a charge negative-three and is the conjugate base of the hydrogen phosphate ion, HPO_4^{2-}, who is the base conjugate of H_2PO^{4-}, the dihydrogen phosphate ion, which in turn is the conjugate base of H_3PO_4, phosphoric acid.

4. CONCLUSIONS

Life on Earth was born at least 3.7 billion years ago, but since then the number of living things has grown exponentially. Surprisingly, some of the earliest life forms on our planet exist and not just in fossilized form - stromatolites - a life form that has witnessed the entire evolution of our planet can still be discovered in certain areas of the globe. Stromatolites are living fossils, the oldest life forms on Earth. Their existence spans an incredible period - stromatolites have existed for 75% of the period since the formation of the solar system. These are defined simply as rock structures built by colonies of microscopic organisms that do photosynthesis.

These organisms are known as cyanobacteria. As the soil settled in the shallow waters, bacteria began to grow on it, joining the sedimentary particles and building additional layers until the mounds formed. These constructions of microorganisms in the earth are probably the essential element in the emergence of more complex life on earth - through their respiration, they produced and developed oxygen on Earth until it reached 20% of the Earth's atmosphere. Using the Sun as an energy reservoir, stromatolites have transformed the planet into a place capable of supporting all life forms, simple or complex.

A major process of microbial formation in the Bacalar Lagoon was and remains the precipitation of calcium carbonate in the cyanobacterial filaments of Homeothrix and Leptolyngbya. Withdrawal of CO2 during the photosynthesis of these oxygen phototrophs and increase in pH probably triggers carbonate precipitation. Evidence of carbonate precipitation is found in the SEM of live and calcified microbial mats microbialitis. Similarly, the photosynthesis of diatoms probably contributed to the precipitation of calcium carbonate.

It is also possible that some precipitates appeared inside the microbialites in process of degradation of organic matter. A crucial factor in the carbonate precipitation in the Bacalar Lagoon is clearly, and probably always has been, the high carbonate content in the waters of the southwest lagoon, which, in turn, is a consequence of karstic aquifer circulation through the cenotes. Far from the cenotes, the carbonate content of the lagoon waters is significantly lower and microbialites are absent.

Agitation and water washing are important, as seen in the dense formation of microbialites in the "Rapids", where high currents of water are observed. In addition to precipitation, there is evidence of sediment trapping in both live microbial mats and calcified microbialites, as seen in SEM. The great abundance of herbivorous pomace gastropods in the Bacalar Lagoon and around the appearance of microbialites supports the claim that grazing takes place and is currently an important factor for the erosion of microbialites. However, this factor is clearly outweighed by the accumulation and cementation of microbialites in the waters of carbonate-rich lagoons.

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It is not at all clear whether the existence versus the absence of pastures has always been or not great importance for the formation of microbialites in Laguna Bacalar. The high abundance of grazing gastropods of the genus Pomacea in the modern lagoon and the rare appearance of gastropods in the basic material suggests that grazing has recently become important among Bacalar microbialites.

A question posed at the end of the paper in the conclusions is "will scientists be able to produce energy and oxygen in the future according to the microbial model of these microorganisms?".

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