Origins of life 3.9 billion years ago!

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Introduction

Roughly 3.9 billion years before present (3.9 BBP), life on earth was very different, in fact it hadn't even started. The atmosphere was largely composed of harsh gases (reducing gases) such as carbon monoxide, carbon dioxide and methane. Yet in these harsh conditions, life did evolve, and importantly that life evolved into photosynthetic organisms which changed the planet. The production of oxygen by the very first photosynthetic organisms (photoautotrophs) changed the atmosphere and as little as 350 million years before present (MBP), sparked the evolutionary explosion of the Cambrian Diversification. In turn, this lead to the evolution of us, Homo sapiens. One set of organisms that first started this process were the cyanobacteria, also known as blue green algae. These are very primitive single celled organisms that can be very common in marine and freshwater habitats. Some of the earliest records of the existence of cyanobacteria come from Stromatolites, simply speaking, humps and lumps of sand grains stuck together in discrete layers by the cyanobacteria inside.

Today, almost 4 billion years later, stromatolites still exist, and the only example of marine coastal Stromatolites in the world are in the Bahamas. Here they form in harsh dynamic coastal areas where sand is suspended in the water column as a source for the cyanobacteria to build the Stromatolite slowly over time. But here lies a problem. Cyanobacteria are photosynthetic and so need light as their energy source. But in coastal areas dynamic enough to supply the sand to build the Stromatolite, the cyanobacteria get buried frequently, often for months, possibly years at a time. How can a light-dependent organism adapt to cope with this harsh regime of being buried at sea? We investigated this as part of the Miami University research programme Research Initiative on Bahamian Stromatolites, using a remote sensing method called chlorophyll fluorescence. This method uses light energy re-emitted by photosynthetic organisms to measure their activity. Using this, we measured cyanobacteria in buried Stromatolites to find out how they coped with being buried.

Findings

Coping with burial at sea

Basically the cyanobacteria simply shut down their photosynthesis when they are buried. Stromatolite samples buried artificially under a sand and sea-water mixture showed a gradual decline in photosynthesis, in sharp contrast to samples maintained in site water and kept in darkness. So it wasn't just the darkness of burial that caused this decline. The decline of photosynthetic activity of buried samples correlated with the concomitant decrease in oxygen potential. When the samples were unburied, they only switched on their photosynthesis when they were exposed to low light. When the low light was temporarily switched off, the cyanobacteria started to shut down again. An example of a stromatolite sample is shown below (Figure 1). Note the blue-green layer just below the surface which is the layer of cyanobacteria in amongst the sand grains which they have stuck together with sticky gluelike polymers they secrete.

Figure 1: A stromatolite sample, cross sectioned to show the white sand grains stuck together by sticky polymers produced by the cyanobacteria. The cyanobacteria can be seen as a clear blue green layer just below the surface. The image shows a sample about 2 cm wide.

Waking up the "dead"

The next thing to do was to investigate naturally buried stromatolites by diving down and collecting some samples. Stromatolite samples that had been buried for over a week under sand in the sea by natural processes were quickly cut out and returned to the lab on the research ship, The Walton Smith, to see if we could reactivate their photosynthesis. As they shut down when we buried them due to a lack of oxygen and light, we tried combinations of these two factors to see if we could "wake them up". We quickly re-buried the samples but had a probe in place to measure their photosynthesis activity. When they were buried, photosynthesis was quickly shut down as we'd seen before. In fact it took less than 60 minutes to completely shut down the cyanobacteria and they stayed like this for a further hour. Then we used the probe to supply a low level of light, but nothing happened, the cyanobacteria stayed switched off. However once the sample was unburied and remained in low light, photosynthesis immediately increased, showing signs of stabilising after a further 2 hours. Then we tried using samples that had been buried for a month of natural burial at sea. These samples were returned to the laboratory and re-buried with the probe and a small oxygen line in place. There was no initial photosynthetic reactivation between sampling and re-burial and the application of oxygen during burial also had no effect on the cyanobacteria, which stayed switched off. However, once we gave them oxygen and low light, even though they were still buried, they started to "wake up" their photosynthesis. By a combination of experiments with controls to compare the results we had shown that buried cyanobacteria in stromatolites could be reactivated with a combination of oxygen and low light.

Conclusions: Interplanetary travel?

- The work has shown so far that the cyanobacteria that have built stromatolites on the Earth for almost 3.9 billion years can survive being buried for long periods of time, and that during this burial, a lack of oxygen and light triggers them to switch off their photosynthesis. That's important for two reasons. Firstly it explains how they can cope with being buried and therefore why they are so important in building stromatolites in harsh dynamic coastal systems. Secondly it means that the cyanobacteria need oxygen to keep their photosynthesis systems working. That's important because we think of photosynthesis as simply producing oxygen (that's how they changed the Earth's atmosphere 3.9 BBP), but in fact they need oxygen as well.

- The other important finding of the work so far is that the cyanobacteria can be reactivated by a combination of low light and oxygen, even after long periods of burial. That's an important strategy to enable them to adapt to their harsh conditions. But it also makes scientists wonder about more farfetched possibilities. Just maybe then, cyanobacteria could survive in space where there is little light and no oxygen, possibly buried in a meteorite or comet. Then if they crash landed on a planet with oxygen, even only a small level in the planet's atmospheres, and were exposed to light, they could "wake up from the dead" and colonise the new planet. Interplanetary travel by small single celled cyanobacteria!

- Coming back down to earth, the findings do tell us the importance of cyanobacteria in building stromatolites 3.9 BBP to the present day, which in turn helps us understand the very origins of life on Earth.

References

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