STROMATOLITES - ROCKS OF LIFE

Fossilised blue-green algae are our most ancient ancestors

A strange lump of rock being used as a doorstop puzzled me. In the year 2000 I had moved with the family to a beautiful, if tumbledown, house on the banks of the Vaal River near Parys. As renovations began we started to discover all sorts of curious things about the surroundings.

Although many people have a mental picture of the Vaal as a dirty industrial ditch, in this area it is beautiful. Hundreds of thickly wooded islands form channels filled with rapids, making a filigree pattern of green foliage and whitewater as the river rushes past Parys.

Otters and fish eagles live among the islands, which is why we named our place Otters' Haunt. It is an hour's drive south of Johannesburg in the vast semicircle marking the world's oldest and largest impact crater, the Vredefort Dome.

A typical stromatolite, fossilised ancient life. This fist-sized rock is one of many that can be found in the Vaal River basin in and around the Vredefort Dome. Products of the Transvaal sea some 2600-2400 million years ago, the local stromatolites are not the oldest on Earth but they tell a startling story of life's survival against all odds.

What struck me as odd about the fist-sized doorstop was that it did not seem to come from hereabouts. It was not a the typical crystalline pink-white-and-black Parys granite but, by the whitish look of it, a limestone, and it was shaped in strange whirls almost like layers of an onion.

It could have been a lump of poured cement but when I cleaned off the outside crust with acid it looked more and more like a fossil. A geologist friend took one look at it and declared it was a stromatolite – the most ancient fossils of all.

It was an exciting discovery and it started me on a quest to learn more about the evidence of early life in and around the area. Almost certainly, the doorstop had been washed down from the plains above the crater core. But how did it get there, and what did it reveal about the Earth and our place in it?

The huge Vredefort crater was completely solidified in a matter of minutes after an earth-shattering blast. Compared with that, the story of life's evolution winds through billions of years from the tiniest beginnings until human beings made their appearance in the past few million years.

Eight years after settling here, the picture is much clearer. As a writer on popular science, I have culled knowledge from biochemists and geologists whose work is steadily converging on an explanation of life's origins – or at least its emergence on our planet from mysterious beginnings.

Claims that ancient traces of life have been discovered are always controversial but a fairly convincing picture has been drawn from the many clues in etched in stone.

Recent genomic studies show that almost all organisms, from bacteria to human beings, share the same genetic code. There is a group of universal instructions used to convert DNA or RNA sequences into proteins, the building blocks of living processes. These sequences must have begun with the earliest bacteria and archaea and have come down to us in an unbroken line.

The stromatolites of South Africa and Australia suggest that microbial life first appeared on our planet around 3.8 billion years ago and has carried on ever since. The Vredefort Dome became a Unesco World Heritage Site in 2005, and one of the designated sites of interest is a stromatolite outcropping at a point beyond the Bergland.

Not only is the crater itself the world's largest visible impact site, but here we have evidence that primitive life flourished in the area before and after the impact took place.

The stromatolites were built by colonies of blue-green algae, or cyanobacteria. We can see cyanobacteria today in the form of blooms of algae in warm water lakes and the sea. In the distant past they may have covered much of the aquatic area of the planet. They produced their food by photosynthesising sunlight, water and carbon dioxide, in the process releasing oxygen. It is the blue-green algae that we have to thank for the creation of the oxygen that make the atmosphere breathable for us. Bio-engineers are suggesting we should try to populate the Earth once again with algal blooms because they would deal with global warming, which is largely due to the build-up of carbon-dioxide in the atmosphere.
Unfortunately the technology for large-scale algal farming is quite complex and not likely to produce a global solution soon.

The word stromatolite comes from the Greek root stroma, meaning "anything spread out for sitting on or lying on" such as a carpet or mattress. The ancient communities of microorganisms constructed layers by cementing together particles of silica and other substances with a sticky mucus-like biofilm. It has been estimated that the growth rate could have been as little as .04 to 1mm per year.

Their fossils take many beautiful forms, from bubble-like domes paving the ground underfoot to multicoloured laminates of sediment looking like piles of carpeting frozen into the rockfaces. While one can easily see stromatolite patterns in rocks, they are really microfossils because their detailed structures are too small to be seen except under a microscope.

The stromatolites of the Vredefort Dome predate the impact event and probably most of them were buried or destroyed by the blast. The first question many people ask is whether a Great Extinction took place as a result of the mighty explosion on the face of our planet.

Probably not! We know that life did not go extinct despite the heat, dust storms, tsunamis and shockwaves generated by what the 2005 Unesco WHS citation described as "the world's greatest known single energy release event". Life carried on after the blast – but what makes the question intriguing is whether the course of life was altered in any way.

This is a controversial issue. Scientific authorities have differed about exactly what effect the event had on the development of life.

No less an authority than Prof Phillip Tobias, the Wits University palaeontologist, has argued that the energy released by the Vredefort event may have contributed to the transition from simple to complex cell life. The transition occurred in the period from about 2000 to 1400 million years ago. As the Vredefort crater blast is dated at 2023 million years ago, the coincidence is hard to ignore.

Others have rebutted Tobias's speculation. Professors Terence McCarthy and Bruce Rubidge, both also from Wits, say the event may have had little effect on the course of life on Earth. In their excellent book The Story of Earth and Life: a Southern African Perspective on a 4.6 billion year journey (Struik: 2005) the pair maintain that large impacts do result in mass extinctions of species. The Vredefort explosion was far larger than that which occurred 65 million years ago in Yucatan, coinciding with the final end of the dinosaurs.

But, say McCarthy and Rubidge, it is that likely that the microbes existing on Earth 2 billion years ago would have been largely immune to the impact. The microbes had shown this already by surviving numerous cosmic impacts, some probably far larger than the Vredefort event. Provided you know what you are looking for, a walk in the veld can turn up amazing specimens. I followed the riverbed of the Kromelmboog, a stream which runs into the Vaal from the east, and found several stromatolites washed down by floods. It is now illegal to remove these specimens but that's no problem, as I see it, because the law on protected areas makes it worthwhile to go exploring and find more samples.

Talk about the Vredefort Dome and you are never far from controversy. There are still lingering doubts that the crater was actually caused by an impact and may instead have arisen from a "cryptoexplosion" or "Verneshot" (an imagined blast out of the Earth like a giant cannonball). Today the majority of planetary researchers agree the crater is an astrobleme, or scar left by a large, cosmic body that came hurtling out of the sky.

Controversy surrounds stromatolites too. Some researchers say that not all ancient rocks showing layering or doming are, in fact, stromatolites: they could conceivably have formed by gradual deposition of matter in the absence of life. Telling the difference between biological and "abiotic" (non-life) stromatolites remains an area of research today.

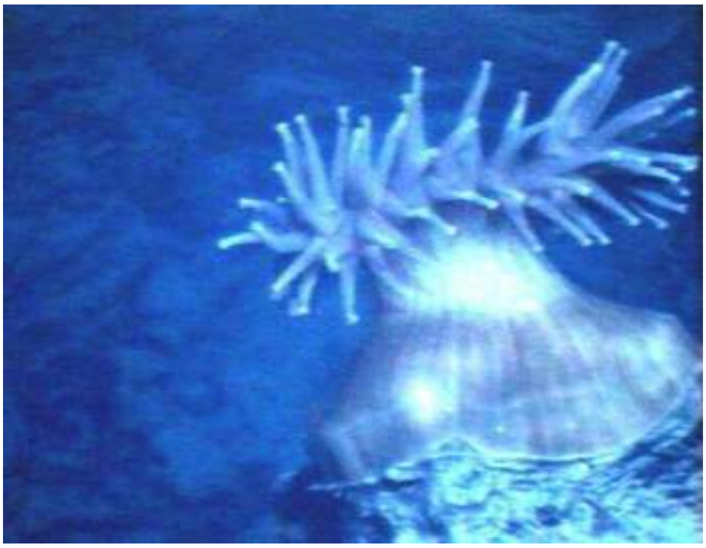
To prove the point, Nicola McLoughlin, a geologist at the University of Bergen in Norway, described an experiment in which false stromatolites were created in the laboratory. As reported in the magazine Cosmos, McLoughlin published an article In the March 2008 issue of the journal *Geobiology* describing how layered coats of enamel paint were sprayed onto a flat surface over a period of six weeks. This produced a hard, laminated piece of "rock" with patterns such as wrinkles and whirls, closely resembling the familiar biological samples of stromatolites.

McLoughlin's goal was to improve our understanding of stromatolites, not disprove that life had existed in early times. She likened stromatolites to the Rosetta stone used by Egyptologists to compare ancient languages and hence decipher hieroglyphics. A better grasp of how different stromatolites came into being will help to show the course of evolution through aeons.

Doubt and debate also surround the nature of the organisms said to have created the stromatolites. It is difficult, if not impossible, to find traces of organic material in rocks that are very old, so much of what we think we know is based on scientific detective work and inferences from the evidence. From microscopic traces know that stromatolites are mainly built of cyanobacteria under water, but also present in some structures are traces of another form of ancient life, the archaea.

Bacteria and archaea are two distinct "domains" of life which differ in major genetic and biochemical ways. Both are primitive prokaryotes or cells without nuclei; the third domain is that of the eukaryotes, of which all fungi, plants and animals consist. One would think that all three major domains of life would long ago have been recognised and studied by biologists, so it is surprising to learn that archaea were discovered and tagged as a distinct domain only within the past couple of decades.

We don't yet know much about the archaea but because they tend to be "extremophiles" - creatures capable of living in very hot, airless, and deep-water conditions - they were certainly among life's earliest representatives on Earth. Archaea flourish alongside bacteria in the thick (5cm) microbial mats that surround deep ocean vents or "mud volcanos". They are the food source of the sea anemone pictured here and of many other deep-sea creatures including fish, snails, crabs and shrimps that live only at these deep-sea vents. High salt-loving or halophilic archaea are found within stromatolites and it is possible that many of the earliest rock fossils were constructed by archaea. They enjoyed habitats where environmental conditions were far beyond the range tolerated by most organisms on Earth today.



And then there is the question of where life came from in the first place. Some leading space scientists believe that life came to Earth on comets or asteroids during the Era of Bombardment up to 3.9 billion years ago, a time when our planet was subjected to continual heavy impacts by foreign bodies.

This theory of panspermia – meaning “seeds everywhere” – regards the universe as a place where life naturally occurs, even in deep space, spreading inexorably to all regions. It does seem surprising that life could have emerged on Earth within just a few hundred million years after the formation of the planet itself. But by saying it came from space we do not dispose of the question of where that life came from.

Our solar system is about 4.6 billion years old and the Earth and Moon slighter younger, as they condensed out of spinning discs of dust to become spherical “planetisimals”. When two of these planetisimals collided they formed the Earth and Moon – the former with the heavier rocks and iron core, the latter with lighter ones that spun away to circle as a satellite of the main planet.

The first 700-800 million years of Earth’s existence are called the Hadean, a hellish era when molten seas, erupting volcanoes and bombardments of meteorites spewed out poisonous gases. Yet even in this era life may have been possible.

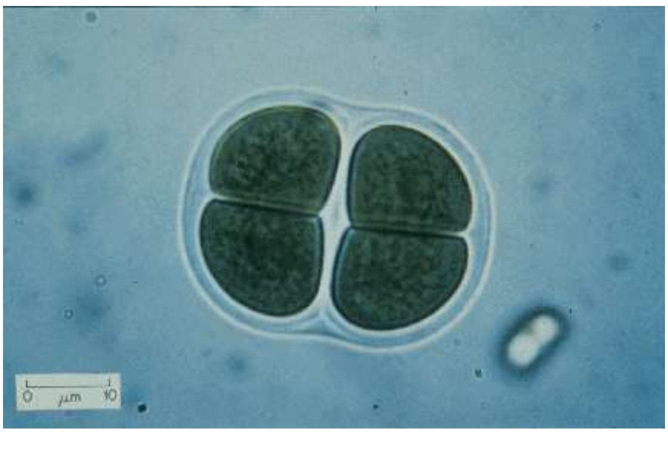
From comets, asteroids and volcanoes came the water that was to form the oceans around 4.3 billion years ago. With water came the possibility of life as we know it. Modern deep-sea researchers have discovered a great deal of biological life going at the bottom of the oceans at superheated volcanic vents, showing that an atmosphere is not necessary.

When life on Earth began around 3.8 billion years ago at the world’s surface consisted of cooling rocks and continental plates, surrounded by oceans. We would find the planet unrecognisable compared with the globe today. The atmosphere consisted of a toxic mix of methane, ammonia, and other gases including carbon dioxide.

In spite of all, living matter began to thrive. As cyanobacteria proceeded to build stromatolites, they drew in carbon-dioxide and exhaled oxygen, slowly converting the atmosphere to something like what we have today.

But the legacy they have left us is not simply oxygen. Perhaps their most significant contribution was to the evolution of advanced animal cells.

Bio-visionary author Howard Bloom offers an explanation in his book The Global Brain: The Evolution of Mass Mind from the Big Bang to the 21st Century (Wiley: 2001). Bloom says the flimsy form of cyanobacteria made it easy for them to meet and mix, “networking” their genes to strengthen each other. This is why they could evade extinction and continue to live on Earth despite catastrophic events like asteroid impacts.



Cyanobacteria flourished for some two billion years – that’s longer than any other form biological entity– before more complex creatures came along and started to eat them for their own food. Oddly enough, it was the bacteria themselves that helped to create these creatures – the protozoa or one-celled animals – which promptly became their worst enemies.

The bacteria suffered a double whammy. They had used their networking to specialise and clump together in groups that ultimately began to form the structures of more evolved cells. Having generated the Earth's oxygen, cyanobacteria had less carbon-dioxide to consume and were at a disadvantage against the oxygen-breathing protozoa. This was a disaster and the stromatolites began to die out.

In a sense, the cyanobacteria were too successful for their own good: they spawned the conditions in which oxygen-breathing animals could emerge and attack them. Few stromatolites survive today except in very salty pools like Shark Bay in Western Australia where grazers cannot live and will not go to find them.

The story is certainly not over for it would be wrong to think our species represents the peak of evolution now and forever. In fact we may just be at a way-station on life's development towards interplanetary destiny.

Or we could be doomed. The Vredefort crater blast reveals how sudden interplanetary catastrophes threaten our very existence: another asteroid could hit tomorrow, wiping us all out. But in the stromatolites we have an optimistic narrative about the emergence of complex life against all odds – a tale told in the rocks.