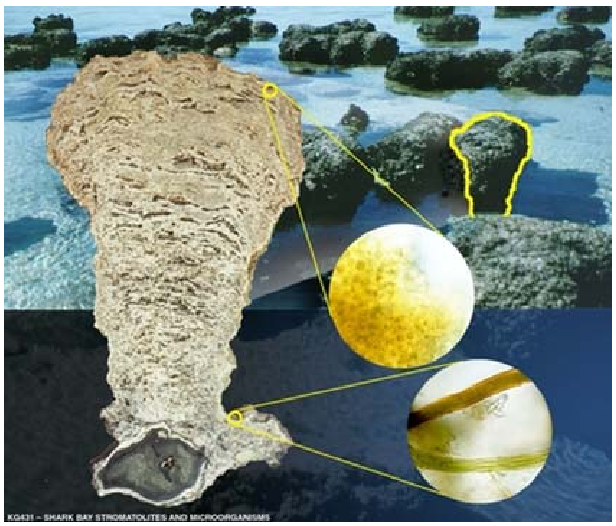
ANDYSEZ No. 54

STROMATOLITES

– actually microbialites

– Andy Spate

Having recently heard lots about limestones containing stromatolites at Cango Caves, South Africa, and having a long-term interest in stromatolites in Australia from those living in the freshwater around Mount Gambier and in the various brackish lakes and estuaries north and south of Perth to those very long dead in northern Australia I felt that it is time to satisfy the urgings of your freshly-bleeding editor and produce an ANDYSEZ on the subject.



Internal structure of an estuarine stromatolite from Shark Bay, Western Australia. Note the insets showing different microbes. From the World Heritage Discovery Centre at Shark Bay.

Firstly I would like to quote from Ken McNamara's excellent stromatolite book:

> *Examining the fossil record is rather like looking through a number of windows to glimpse fragments of life far back in the shadowy past. When fossils are missing from the strata as they often are, or if they are poorly preserved, our view back into the past is obscured … Occasionally, with exceptionally well-preserved fossils, the fine details of extinct organisms can be seen and our view is clearer. By piecing together these widely spaced images we can try and produce a story of the history of life that in many ways resembles a movie made from a few disjointed frames. The paleontologists' job is to fit these few images together to tell the story of the comings and goings of bacteria, fungi, plants and animals over the last 3,500 million years (= 3.5 billion years).*
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> *Most of the obvious evolutionary events in this movie have been packed into the last 600 million years, for it is since that time that most of the major groups of animals and plants on Earth have evolved. To put this into perspective, if we imagine that the movie runs for one hour (that is, 3,600 seconds), then one second of the movie will represent about one million years of real time. This means that the great explosion of marine life in the Cambrian period took place with only ten minutes of the one-hour movie to run. [Celebrities], such as dinosaurs, came and went in a couple of minutes, disappearing with just one minute … left. But what a minute! In this final sixty seconds [the Mulu Limestone was deposited] flowering plants developed, primates evolved and most of the other groups of living mammals appeared. Only in the last half second did humans make their debut.*
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> *If we look very closely at this movie we can see lurking in the background of every frame single-celled organisms; these have remained virtually unchanged during the comings and goings of all the animals and plants that have ever lived. Not only have they persisted for the first two-thirds of the movie with no other life forms for company, and they are still living in a few places in the world at the end of the movie!* (McNamara, 2009, pp. 5-7).

Stromatolites from Limmen West National Park, Northern Territory. Ballirini Dolomite > 1.2 billion years old. Note that the tops of the stromatolites are toward the viewer; i.e. the boulder is on its side.

'Mega' stromatolite from near Gregory National Park, Northern Territory. Supplejack Member of the Skull Creek Formation 1.6 billion years old.

Layering in a stromatolite fragment from the Supplejack Member near Gregory National Park.

Shark Bay stromatolites.

Microbial communities form complex ecosystems with a wide variety of microorganisms lacking the nuclei and other organs within their single cells. They include bacteria, microalgae and other small organisms. The dominant members of the ecosystem include the single-celled photosynthetically active cyanobacteria (the so-called blue-green algae). These began to occur about 2,700 million years ago (three quarters of the age of our solar system!). To quote McNamara again:

> *It has been proposed that photosynthetic [single-cell organisms], probably cyanobacteria, were responsible for increasing the level of oxygen in the atmosphere, from much less than 1 percent to the present-day level of 21 percent. Their existence is also preserved … not only by their fossilized remains but more commonly by the complex structures they created: domes or columns of sediments called stromatolites (also known as microbialites) for some of these cyanobacteria have the amazing ability to make rocks.* (p. 8, emphasis mine)

To be pedantic (which I never am!) stromatolites are layered microbialites whilst those lacking internal layers are termed thrombolites. Marine microbialites such as those in Hamelin Pool in the Shark Bay World Heritage property in Western Australia are have layered structures and are thus 'true' stromatolites whilst those in brackish coastal lakes such as Lake Clifton (south of Perth) and Lake Thetis (north – in Nambung National Park) are thrombolites. These have a 'clotted' (lumpy) internal structure. What McNamara does not cover in his otherwise excellent book are the many forms of freshwater microbialites in the freshwater cenotes around Mount Gambier. Nor does he cover the subaerial stromatolites of New South Wales (and other) caves. More about these later.

Lacustrine thrombolites from Lake Thetis, Cervantes, Western Australia.

So how do these organisms make limestone or dolomite? McNamara says:

> *Stromatolites are constructed by the activity of microbial communities that trap and bind sediment, and are also able to precipitate carbonate minerals. … a complex sequence of changing bacterial communities colonise and then build stromatolites. Vital to their growth is a dynamic balance between the rate of sedimentation and the periodic hardening of the colonies of cyanobacteria that live on the surface of the stromatolite.*
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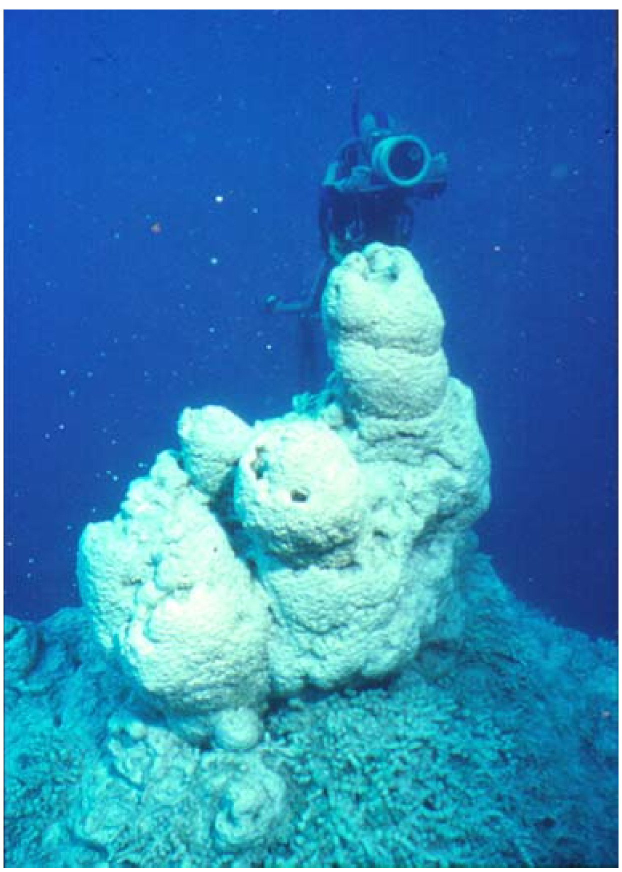
> *Firstly, a pioneer microbial community is established. This is dominated by filamentous cyanobacteria that arrange themselves vertically, then wrap around grains of sand, trapping them in a mucous-like film. This is then replaced by another microbial community containing quite different microbes … These new bacteria are basically organic sludge degraders, similar to the type that decomposes compost heaps. These bacteria form a continuous mucilaginous sheet on*

top of the first layer of sediment. Next, a third group of bacteria come to the party. These are sulfate-reducing bacteria that, by feeding on the mucous-like film left by the first community, promote the growth of aragonite crystals (a form of calcium carbonate) and the formation of a thin crust.

The fourth, and final, bacterial community to colonise the surface is dominated by spherical coccoid cyanobacteria. These are active microbes that bore into the previously crystallised aragonite crust, leaving behind tiny tunnels that become filled with new crystal growth – a sort of bacterial reinforced concrete. Rather than destroy the fabric of the mats, these cyanobacteria contribute to the construction of the stromatolite. This sequence of colonisation by different types of bacterial communities is repeated thousands and thousands of times, resulting in the slow growth of the stromatolite of hundreds, or even thousands, of years.

… Stromatolites [thrombolites] that form in lakes, though, appear to grow quite differently. Unlike marine stromatolites, those form in lakes do not trap layers of sediment. Their internal structure is a 'clotted' jumble of non-layered aragonite. … In the thrombolites, heavy calcification of the sticky cyanobacterial sheaths is very important, something that doesn't happen in layered, marine stromatolites that trap more sediment from the water. (pp. 15-19, emphasis mine)



Freshwater microbialite in Blue Lake, Mount Gambier (image courtesy of Mia Thurgate).

Fossil microbialites, and similar communities, are widespread in our limestones and dolomites particularly the ancient rocks widespread in northern Australia. Some date back as much as 3.43 billion years! Living microbialites are found in many places along the Western Australian coast and overseas in places such as the Bahamas. As mentioned above, both Mia Thurgate (1996) and Julia James and others (Cox et al 1989) have described growing stromatolites in settings quite different to the ones that McNamara describes. The so-called 'craybacks' of Jenolan, Wombeyan and elsewhere in New South Wales are considered by Cox et al to be stromatolites. Their abstract states:

> *Stalagmites, which appear to be deposited by cyanobacterial action, have been identified in two caves in New South Wales (Australia). These have a characteristic morphology, which has given rise to local names likening them to crustaceans. We have studied these speleothems, and the cyanobacteria covering them, by microscopic and chemical techniques. Both calcite precipitation and aeolian sediment trapping are involved in their deposition, which is strongly controlled by environmental conditions. They can be regarded as stromatolites within currently accepted definitions of the term.*

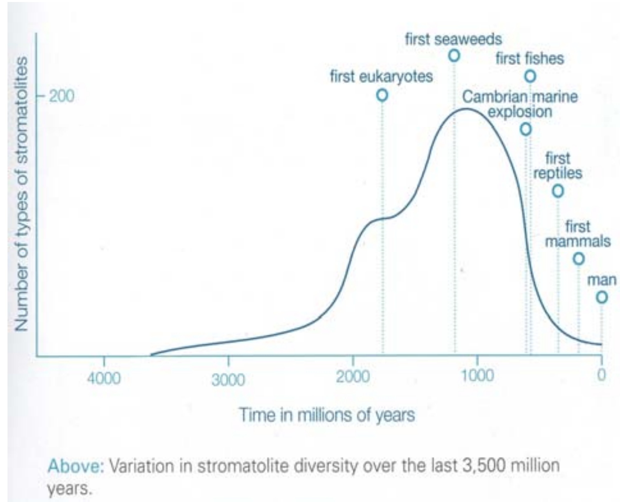
Freshwater microbialites on the wall of Gouldens Hole, Mount Gambier (image courtesy of Kirsty Dixon).

Mia's paper revealed the presence of tens of thousands of actively forming microbialites in cenotes and in Blue Lake near Mount Gambier. Based on the external morphology, 14 different types have been identified with columnar growth forms being most common. Three genera of diatoms and three genera of cyanobacteria are the most likely responsible for the development of these stromatolites – or are they thrombolites?

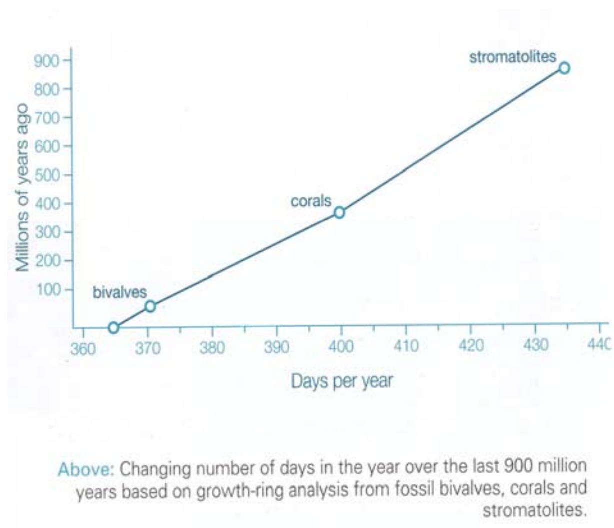
Lacustrine thrombolites from
Lake Clifton, Western Australia.

Neil Kell not admiring the
stromatolites at Lake Clifton.

As well as changing the Earth's atmosphere from one dominated by carbon dioxide to an oxygen-rich environment so that we could be here today they are also useful for giving us clues to other aspects of Earth history. Studies of 850 million year old Northern Territory showed that each year back then had about 450 days – giving a day length of around 20.1 hours. The Earth's rotation is slowed by tidal friction – the moon moving a bulge of water around the world. We are currently slowing at about two hundred thousands of a second each year. McNamara calculates that the Earth will stop rotating in 4,384,794,990 AD. Even our great young friend Patrick will not be around then!



Stromatolite diversity through time.
Note that eukaryotes are organisms with
cells having a nucleus and other organelles
(from McNamara 2009)



Changes in days per year through time
(from McNamara 2009).

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