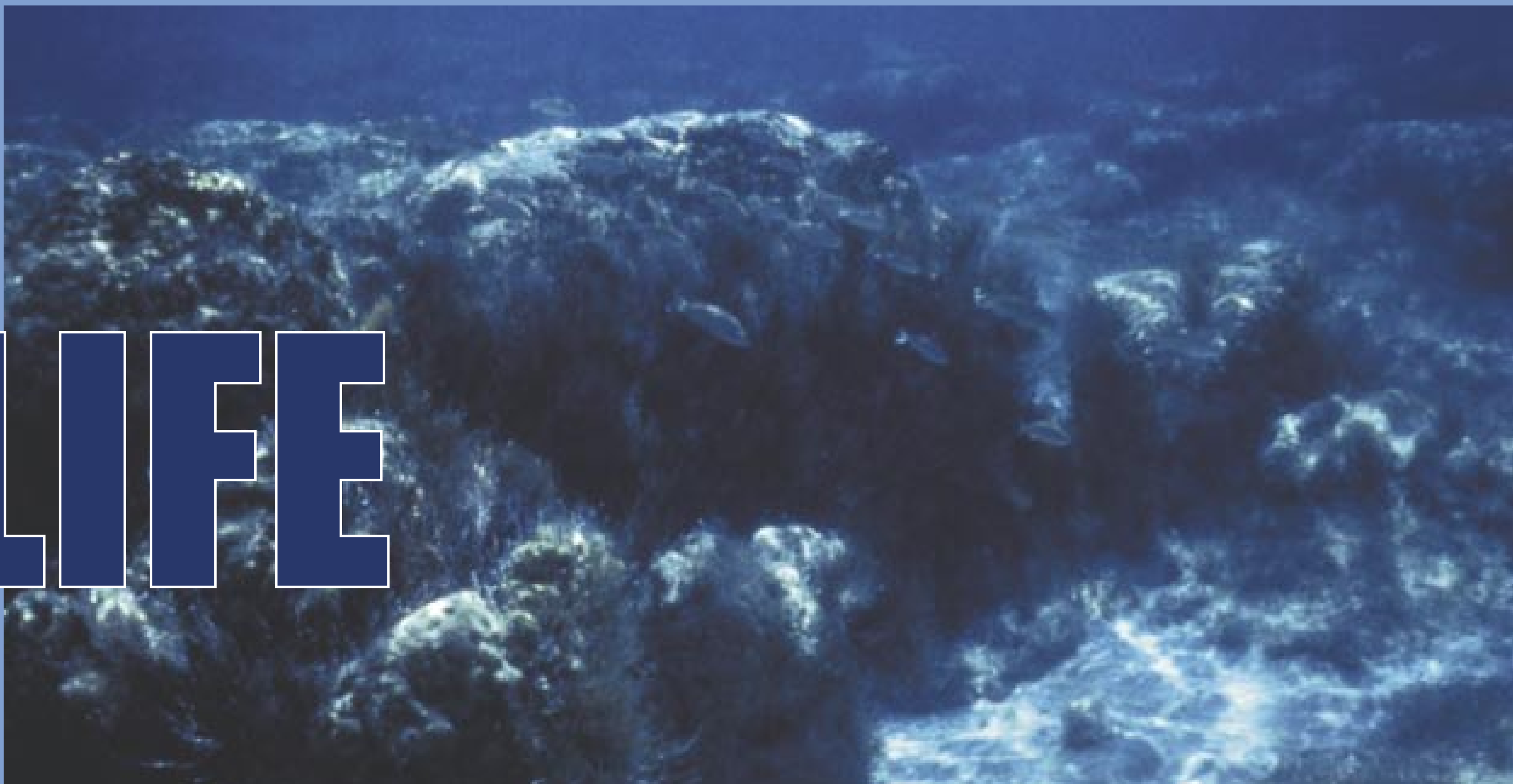
PROOF OF

An important piece of the origin-of-life-on-Earth puzzle has been discovered in a collaboration between researchers in mathematics and the earth sciences.

Stable equation ... Dr Robert Burne, PhB student Ms Tracy Slatyer and Professor Murray Batchelor, who is holding a fossilised stromatolite.

LIFE



Living stromatolites underwater at Hamelin Pool, Western Australia. Today, growing stromatolites exist in very few places around the world.

The point at which life evolved in the steaming, gassy, oxygen-less environment of early Earth is hotly debated in scientific and philosophical circles.

However, new research at ANU is showing that the earliest evidence of life represents a stable solution to a mathematical equation that models interactions between biological growth and the harsh environment of the young Earth. At the centre of this breakthrough are ancient structures found in the Australian desert – stromatolites.

Tower-like in appearance, they resemble inorganic structures similar to stalagmites, but may in fact represent relics left by the activities of fossil life forms, rising up from the ocean floor towards the sun.

Murray Batchelor, a Professor in the Mathematical Sciences Institute and the Research School of Physical Sciences and Engineering, and Dr Robert Burne, a Visiting Fellow in the Faculty of Science's Department of Earth and Marine Sciences, have applied the mathematical tools of theoretical physics to show how slimy mats of microbes could have formed the unique conical shapes of certain stromatolites on the seabed over 3,450 million years ago.

"The evidence we've come up with suggests that stromatolites were the only large-scale evidence of life for over one-third of Earth's existence, which is really very exciting," Dr Burne says.

In the journal *Physica A: Statistical Mechanics and its Applications*, the researchers have provided a mathematical model for the biological development of coniform stromatolites, directly challenging recent research casting doubt on their biotic origins.

"There have been very few previous attempts to model biological stromatolite growth mathematically," says Professor Batchelor, an Australian Research Council Professorial Fellow. "This initial breakthrough is really just the tip of an iceberg – the potential is extraordinary.

"We successfully simulated the simplest stromatolite structure, a coniform, using a mathematical model. We are now engaged in modelling more complex branching stromatolite forms."

The earliest stromatolites have been dated to the Archaean period, around 3,500 million years ago. Earth is 4,500 million years old and *Homo sapiens* are thought to have evolved a relatively short time ago, in the last two million years (or less than 0.06 per cent of the period that stromatolites have existed).

Stromatolites represent a system of life that spans almost the whole history of life on Earth. They promise to provide crucial insights into atmospheric changes that occurred between the first increase of oxygen in the atmosphere 2,200 million years ago to levels which permitted the evolution of oxygen-breathing animals 650 million years ago.

"One of our challenges is to look at the structures of different stromatolites and model what environmental influences those structures represent, and how that can be related to other changes we know took place in the Earth's system, to see if we can improve scientific understanding of the environmental evolution of the Earth," Dr Burne says.

"Ultimately what we want to do is propose a way of describing stromatolites that characterise their environmental significance. But it's a big task, so we're starting off with very simple ones."

The word stromatolite literally means "layered rocks". Fundamental to the growth of stromatolites are benthic microbial communities (BMC), mats composed of vast numbers of microbes that form cohesive carpets extending over huge areas of the ocean floor.

"You know they say we [humans] came from green slime, well the green slime was a happily symbiotic community, a 'phototrophic biofilm' – like a living surface," Dr Burne says.

Picture a living film of light-craving microbes, gradually growing towards the light, slowly but surely lifting sections of the BMC layer to an apex.

Stromatolites left high and dry at Hamelin Pool, WA.

According to Dr Burne, stromatolites formed when the chemical interactions of parts of the BMC began attracting a mineral — calcium carbonate — and the carbonate and microbe reacted to form crystals, which cemented the pyramid-like mat.

Successive layers of biofilm then began to form on top of each layer, creating a higher point each time. Ancient stromatolites grew excruciatingly slowly, perhaps about one centimetre every 100 years.

It is this 'upward growth' which is at the crux of the stromatolite debate.

Some argue that stromatolites were formed by sedimentation; a build up of minerals and particles, in a similar way that stalagmites form in caves.

Dr Burne argues coveted modern examples of stromatolites, such as those at Hamelin Pool, near Shark Bay in Western Australia, have provided strong evidence that sedimentation alone is insufficient to explain these structures.

"The conjecture principally centres around the rate of growth. These modern stromatolites in Shark Bay grow about one millimetre every 10 years.

"The nearest living thing in modern times to stromatolites is coral — it grows at the rate of about one centimetre every 10 years — 10 times faster.

"Coral cannot grow at this rate in high sedimentation areas, because it is suffocated by minerals and particles, and we suggest that this is similarly the case with stromatolites.

"There must be an additional process, we believe a biological process, for this vertical growth to happen."

Professor Batchelor applied an interface evolution equation, well known in maths and physics circles as the KPZ equation, to the stromatolite problem. He included two crucial factors in the model to demonstrate biological stromatolite growth: upward growth and mineral accretion of the microbial carpet.

"It accurately reproduced the growth of these pyramid-like shapes in the right conditions," Professor Batchelor says.

Professor Batchelor and Dr Burne, in collaboration with Professor Bruce Henry, an applied mathematician at the University of New South Wales, consultant geologist Mr Jim Jackson and ANU PhB student Ms Tracy Slatyer, used examples of stromatolites from the isolated outback of the Northern Territory, close to Heartbreak Hotel, as a basis for the simulation of biotic growth of coniform stromatolites in their model.

"In the next stage of our research we plan to investigate the Pilbara area in Western Australia to study the very oldest stromatolites known. These are possibly the earliest remaining examples of life on Earth and could yield some amazing information," Dr Burne says.

"The search for the source of life on Earth has been a bit side-tracked by the hype regarding whether life exists or existed on Mars.

"Fascination really continues to focus on Earth, where we know life exists, and especially on these stromatolites. Not only do they provide evidence of how life was so long ago, they also yield information that will assist us in coming to terms with contemporary challenges of global change."

MORE:

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Looking down on to a 1,670-million-year-old stromatolite. The rings, indicating layers, can be clearly seen. The arrow points to a 35-millimetre camera lens cap, for scale.


The layers of a large conical stromatolite are apparent in this 1,700-million-year-old example. The arrow points to a 20 cent coin.