LILLIPUT'S

S CASTLES

STROMATOLITES OF HAMELIN POOL

Robert V. Burne

On November 5, 1699, three months after Dampier visited Dirk Hartog Island and named it 'Shark's Bay', another vessel, the *Antelope*, is said to have been wrecked off the WA coast. The sole survivor staggered ashore, on what evidence suggests was Dorre Island. There he encountered an amazing world, one twelfth the scale of normal existence. He is known to us all as Gulliver, and his story was written by Jonathan Swift. Little did Swift know that, very close to his fictional Lilliput, there's a coastal ecosystem dominated by microscopic organisms – which form the stromatolites of Hamelin Pool. . .

The micro-organisms that live on the margins of Hamelin Pool are invisible to human eyes. These organisms are able to form cohesive carpets extending for tens of square kilometres over intertidal and shallow subtidal environments. These 'microbial mats' are actually communities of diverse inhabitants with population densities of over 3 000 million individuals per square metre!

They concentrate and recycle nutrients gleaned from the external environment, regulate their internal environment and dispose of their waste products. Even more amazing is the fact that some of these communities are able, as a by-product of these processes, to construct protective towers up to 1.5 metres high. These constructions, upon which the microbes dwell, are up to ten million times larger than the organisms that build them.

When these real-life Lilliputian castles were discovered in 1956, they were the first growing examples ever recorded of structures, found fossilised in very old rocks, that had puzzled geologists for more than a century. They had been named 'stromatolites' (literally 'layered rocks') because they had a finely laminated internal structure. The discovery of modern examples had far-reaching significance. They have helped us understand the significance of micro-organisms in the environment, unravel the long history of life on Earth and establish a view of planetary ecology in which the survival of life is dependent on interaction more than competition.

Previous page: An underwater view of the Hamelin Pool stromatolites.
Photo - Jiri Lochman

Left: Stromatolites growing at Hamelin Pool in a zone that is permanently under water.
Photo - Bob Burne

Right: Stromatolites similar to those at Hamelin Pool have recently been discovered in the Bahamas.
Photo - Bob Burne

WHAT ARE STROMATOLITES?

The same microbes that form stromatolites are dispersed through many shallow marine environments. However, bottom-dwelling communities dominated by microbes only become established in places where larger organisms are unable to survive. Microbes live in a world where surface forces are far more significant than gravity because they have high surface area and negligible weight. Many microbial cells have sticky surface coatings which trap sediment grains like fly-paper, and, in some microbes, cells are able to join together to form filaments that can intertwine and trap sediment. As a result, microbial communities can construct cohesive mats, composed of both sediment and organic material, that provide protection from erosion and allow a stable microbial community to develop and thrive.

Far left: A jellyfish swims among the stromatolites at Hamelin Pool, just as its ancestor, one of the first animals, did millions of years ago.
Photo - Bob Burne

Left: A stromatolite cross-section showing the laminated structure. This specimen was attached to a nodule of flint.
Photo - Bob Burne

Where the mats are growing under water rich in dissolved calcium and carbonate ions, some microbes help these ions form crystals of calcium carbonate. The mats thus become cemented, and, as successive cemented layers build up, a stromatolite is formed. Marine plants and animals may also contribute to the structure, but the stromatolite results principally from interaction between the microbial community and the physical and chemical environment. They can be compared to a self-organising system such as a coral reef. However, as stromatolites are not built by skeletons they grow very slowly - about five centimetres in 100 years (coral reefs grow ten times faster).

A metre-high stromatolite would be about 2 000 years old!

MICROBES AND THE HISTORY OF LIFE

The first living thing on Earth was probably a microbe composed of a single cell with no internal organisation. Similar microbes, known as bacteria or prokaryotes, built the first stromatolites. The oldest ones known were discovered near the mining centre of North Pole in the Pilbara and are about 3 500 million years old. Between the first appearance of life and the evolution of the first animals (about 650 million years ago), stromatolites and the microbial mats that formed them were the only macroscopic evidence of life of Earth.

Over this period microbes evolved most of the survival techniques that living things use today, and the stromatolites they constructed dominated the clear, shallow seas and formed extensive reef tracts rivalling those of modern coral reefs. One type of photosynthetic prokaryote that was abundant about 2 500 million years ago had a dramatic effect on the Earth's atmosphere and the course of evolution. These were called cyanobacteria, and they could release free oxygen. About 2 000 million years ago, this caused dissolved iron from the ancient seas to form the rich iron ore deposits of the Hamersley Range. At this time oxygen formed only one per cent of the atmosphere. When there was no more iron to precipitate, the free oxygen leaked into the atmosphere, until it formed 21 per cent of atmospheric gases.

Somewhere between 2 000 and 1 700 million years ago, two symbiotic prokaryotic microbes merged to form one organism, resulting in a single cell with internal organisation (known as a eukaryotic cell). This represented the most important step in the history of evolution. The more complex cell established the essential building block for the later evolution of higher life forms. Eukaryotic microbes joined the stromatolite-forming microbial communities and are present, alongside prokaryotes, in the microbial mats that form the modern stromatolites of Hamelin Pool.

Six hundred and fifty million years ago, rising levels of oxygen in the atmosphere and the oceans allowed the first oxygen-breathing animals to evolve. Although the biosphere has since been dominated by plant and animal species, microbes have remained a vitally

This modern-day microbe variety (*Entophysalis*) is similar to microbes which flourished two billion years ago.
Photo - John Bauld

EVOLUTION OF HAMELIN POOL AND ITS STROMATOLITES

10 000 YEARS AGO

The sea level was much lower than today and the entire area of Hamelin Pool was dry land.

7 000 YEARS AGO

A barrier at the site of the Fauré Sill protected Hamelin Pool from the rising sea level. A lake with seasonally fluctuating salinity formed in the deeper part of the Hamelin Pool basin, indicating that the climate was wetter than today.

6 000 YEARS AGO

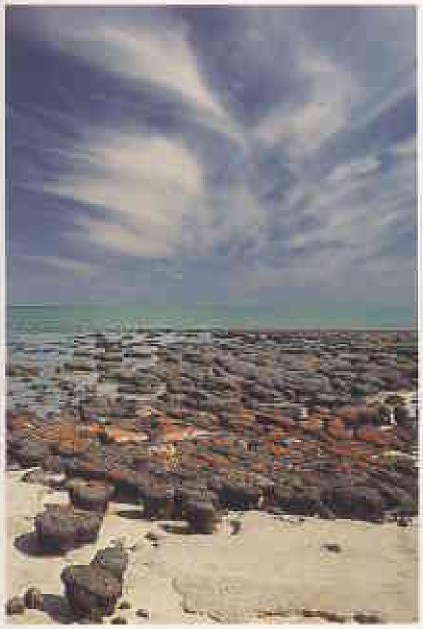
Hamelin Pool was flooded with sea water of normal salinity. Seagrass grew around the margins of the pool and on the Fauré Sill.

4 000 YEARS AGO

Sea level was two metres higher than at present. Sediment from the seagrass banks raised the Fauré Sill to near sea level, restricting water flow from the sea and increasing salinity. Seagrasses no longer grew in Hamelin Pool and other organisms were restricted. Large populations of the bivalve *Fragum erugatum* flourished.

PRESENT DAY

The Fauré Sill eroded as sea level fell. Hamelin Pool's water became twice as saline as sea water. Stromatolites first colonised shallow waters less than four metres deep around 2 000-3 000 years ago. Some are now stranded in the intertidal zone.



important part of these ecosystems. However, stromatolites and related structures have declined, as it became more efficient for microbes to exist, either in microhabitats in ecosystems dominated by faster growing organisms, such as corals, or even within the organisms themselves. In the digestive systems of ruminant animals such as cattle, sheep, goats, camels and elephants, the descendants of the earliest microbes can still find the environmental conditions that once typified the Earth's surface.

WHY HAVE STROMATOLITES FORMED AT HAMELIN POOL?

Stromatolites are now able to develop only in environments where biotic diversity is limited for one reason or another, allowing the slow-growing structures to gain a foothold. These conditions are satisfied in Shark Bay around the shallow margins of Hamelin Pool, to a depth of about four metres.

The unique history of this area has created a perfect environment for stromatolites. At the end of the last Ice Age, some 10 000 years ago, the sea level was much lower than it is today and the entire area of Hamelin Pool was dry land. By 7 000 years ago the sea had flooded much of Shark Bay, but was prevented from entering Hamelin Pool by a barrier at the site of the Fauré Sill. A lake with seasonally fluctuating salinity formed in the deeper part of the Hamelin Pool Basin, indicating that the climate of the area was wetter than it is today.

By 6 000 years ago Hamelin Pool was flooded with sea water, and seagrass grew around the Pool's margins and on the Fauré Sill. When sedimentation from the seagrass banks raised the level of the Fauré Sill to near sea level, the flow of water into Hamelin Pool was further restricted. As a result, salinity increased to a point where seagrasses no longer grew in Hamelin Pool and other living organisms were restricted. The lack of competitors allowed large populations of the bivalve *Fragum erugatum* to flourish, and their shells accumulated as extensive beach ridges. About this time, the relative sea level in Hamelin Pool began to fall and the salinity of Hamelin Pool increased to almost twice that of normal sea water.

Microbes were also able to flourish in mat-forming communities, as their major competitors and predators could not survive in the hypersaline conditions. Calcium and carbonate enabled the stromatolites to calcify, and the low rate of sedimentation was not enough to swamp the slow-growing structures. As a result, the stromatolites began growing about 2 000 to 3 000 years ago. They are now part of a flourishing ecosystem that provides shelter for small organisms, a substrate for marine plants, and a source of food for fish and crustaceans.

CLUBS, COLUMNS AND LOAFS

Although they have been studied for the past 35 years, the relationship between the distribution of microbial mats and the occurrence of stromatolites is still controversial. All the stromatolites in Hamelin Pool were once thought to have originated in the intertidal zone, where many are found today. However, a wide variety of club-shaped, columnar and reef-like forms were discovered in subtidal environments down to about four metres. This led to the conclusion that similar club-shaped stromatolites could be formed both intertidally and subtidally by different forms of microbial mat.

However, recent research suggests that many of the club-shaped, columnar and loaf-shaped stromatolites presently located in the intertidal zone originated beneath the sea. Here, they would have had the chance to grow up to the water surface. It seems likely that their distinctive shapes are a result of moulding by waves and currents and the action of sand being washed around them. They were probably exposed by falling relative sea levels over the past 2 000 years. Once they were stranded in the intertidal zone, these stromatolites were either colonised by intertidal microbial mats or eroded.

Above left: Stromatolites were stranded in the intertidal zone as the sea level fell over the past 2 000 years.
Photo - Bob Burne

The Shark Bay stromatolites are the most accessible in the world.
Photo - Jiri Lochman

Although microbial mats can grow over any stable, moist surface, the stromatolites around Hamelin Pool cannot grow above mean sea level, or deeper than four metres below it. They grow only 0.5 mm per year, while sea-level has fallen 0.5 mm a year over the period of growth. This explains why stromatolites grow to a maximum height of about 1.5 metres in the shallow sub-tidal zone, but decrease in overall height upward through the intertidal zone and downward towards the maximum depth of colonisation.

Will stromatolites continue to inhabit Hamelin Pool long into the future? What changes would cause them to die out? Their future is linked to the fate of the Fauré Sill. As long as the current pattern of seawater exchange across the sill is maintained, stromatolites will continue much as they are today. If the inflow of water is further restricted, the waters of Hamelin Pool will become even more salty and stromatolites will colonise deeper waters. If the inflow of sea water is totally cut off, then Hamelin Pool will eventually dry out. If, on the other hand, the Fauré Sill was breached, with full exchange with normal sea water, then seagrass and perhaps corals would displace the stromatolites.

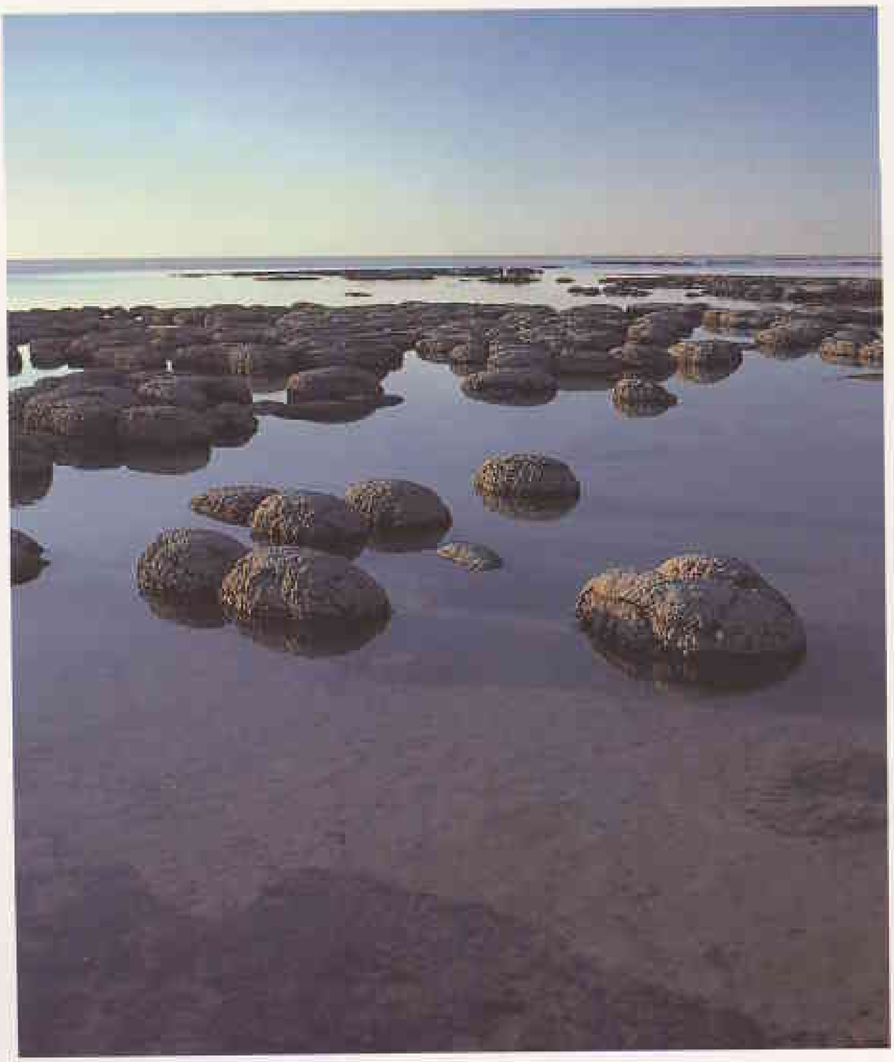
THE EARTH'S OLDEST LIFESTYLE

While the stromatolites are the result of an ecological strategy that dates back almost to the origin of life, most of the organisms forming the communities in Hamelin Pool are not themselves primitive, but are modern organisms well-adapted to and successful in their ecological niches. Some microbes are, however, similar to very ancient forms. For example, the cyanobacterium which dominates one widespread type of intertidal mat in Hamelin Pool is thought to have descended from a similar form that flourished 1 900 million years ago. Thus, it represents one of the longest continuous biological lineages known.

Since they were discovered in Hamelin Pool, only two other marine subtidal stromatolite-dominated ecosystems have been discovered - both in the Bahamas. The stromatolites there are very similar to those of Hamelin Pool, but are larger and grow in deeper water of more normal salinity.

Non-marine stromatolites and related structures (thrombolites) are found in several lakes throughout the world. They are also fairly rare, and many are threatened by human activities that lead to increased nutrient loadings in lake water or artificial drainage of lake basins. Thrombolites are also formed by microbes but have an unlaminated structure composed of small clots of carbonate cement. Some of the best examples of non-marine stromatolites and thrombolites occur in Western Australia at Pink Lake (Lake Spencer) near Esperance, Lakes Preston and Clifton in the Yalgorup National Park, Lake Richmond at Rockingham, and Lake Thetis near Cervantes.

However, the Hamelin Pool stromatolites remain the most abundant and diverse examples of growing marine stromatolites in the world today. They date back only for the past 2 000 years or so, and are therefore one of Australia's newest ecosystems. Nevertheless, they provide a unique look at what life was like at the dawn of evolution. ◘



The stromatolites of Hamelin Pool have only been growing for the past 2 000 years, but represent the Earth's oldest lifestyle.
Photo - Bob Burne

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LANDSCOPE

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When European scientists first set foot on our shores they found a bewildering array of animals and plants. Péron the Explorer *takes an intimate look at the French scientist whose name lives in Western Australia's newest national park.* *See page 20.*

This tour of the Gascoyne's desert coast guides you through Shark Bay and WA's newest national park. *See page 10.*

Close to where the fictional Gulliver is believed to have been shipwrecked lives one of the world's oldest organisms. Lilliput's Castles, *on page 34, describes the creatures and the ecosystem they have built.*

Seagrass covers 3 700 square kilometres of the ocean floor around Shark Bay. Grasses of the Sea, *on page 42, takes us on a journey through these underwater meadows.*

At first glance, Shark Bay is dry, arid and inhospitable. But if you look more closely you discover its Hidden Treasures. *See page 16.*

F E A T U R E S

R E G U L A R S

C O V E R

Green turtles (Chelonia mydas), *the commonest turtles found along our coast, begin to congregate in the waters of Shark Bay from the end of July. The Bay is the southernmost nesting area for these long-lived animals. During summer, female green turtles lay their eggs on the white sandy beaches of Bernier, Dorre and Dirk Hartog Islands, and occasionally at the northern tip of Peron Peninsula. Illustration by Philippa Nikulinsky.*

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