Stromatolites

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Note: In PDF format most of the images in this web paper can be enlarged for greater detail.

Bahamian Stromatolites

by Chet Raymo

"EXUMA, Bahamas—I felt a bit like a field cryptozoologist recently as I snorkeled in the shallow waters of a tidal channel near Lee Stocking Island in the Exuma Cays of the Bahamas. Below were dozens of massive ovoid humps (shown above), many three feet or more high, like giant dinosaur eggs partly buried in the seafloor sand. These strange objects were clearly of biological origin, but unlike anything I had seen before. In water made milky by tide-stirred sand, they beckoned as if from some prehistoric dream. These are the famous Bahamian giant stromatolites, and their story is as curious as any wide-eyed tale of the Loch Ness monster."

"Stromatolites are stony structures built up by living organisms, in this case by algae and cyanobacteria (photosynthesizing bacteria). The microbes live in gooey mats on the top surface of the structures. The mats trap fine sediments carried across them by tidal currents. As the mats are made opaque by sediments, the microbes move upwards seeking sunlight. Layer after layer of sediments are cemented into growing columns or domes.

Large stromatolites were common in the seas of the early Earth, but they are rare today. They are found only at a few sites in the Bahamas and at Shark Bay in western Australia.

For more than 3 billion years after the formation of the Earth, all life on the planet was microscopic, ancestral to the algae and cyanobacteria of the Bahamian stromatolites. These soft-bodied microorganisms left a scant fossil record—except for the gritty, enduring stromatolites. Fossil stromatolites have been found in sedimentary rocks of all continents, ranging back 3.5 billion years. They have been an important focus of paleoecologists studying the early evolution of life. Other scientists use fossil stromatolites to reconstruct ancient physical environments. For these studies, observations of modern "living" stromatolites are of crucial importance for a proper interpretation of the ancient fossils.

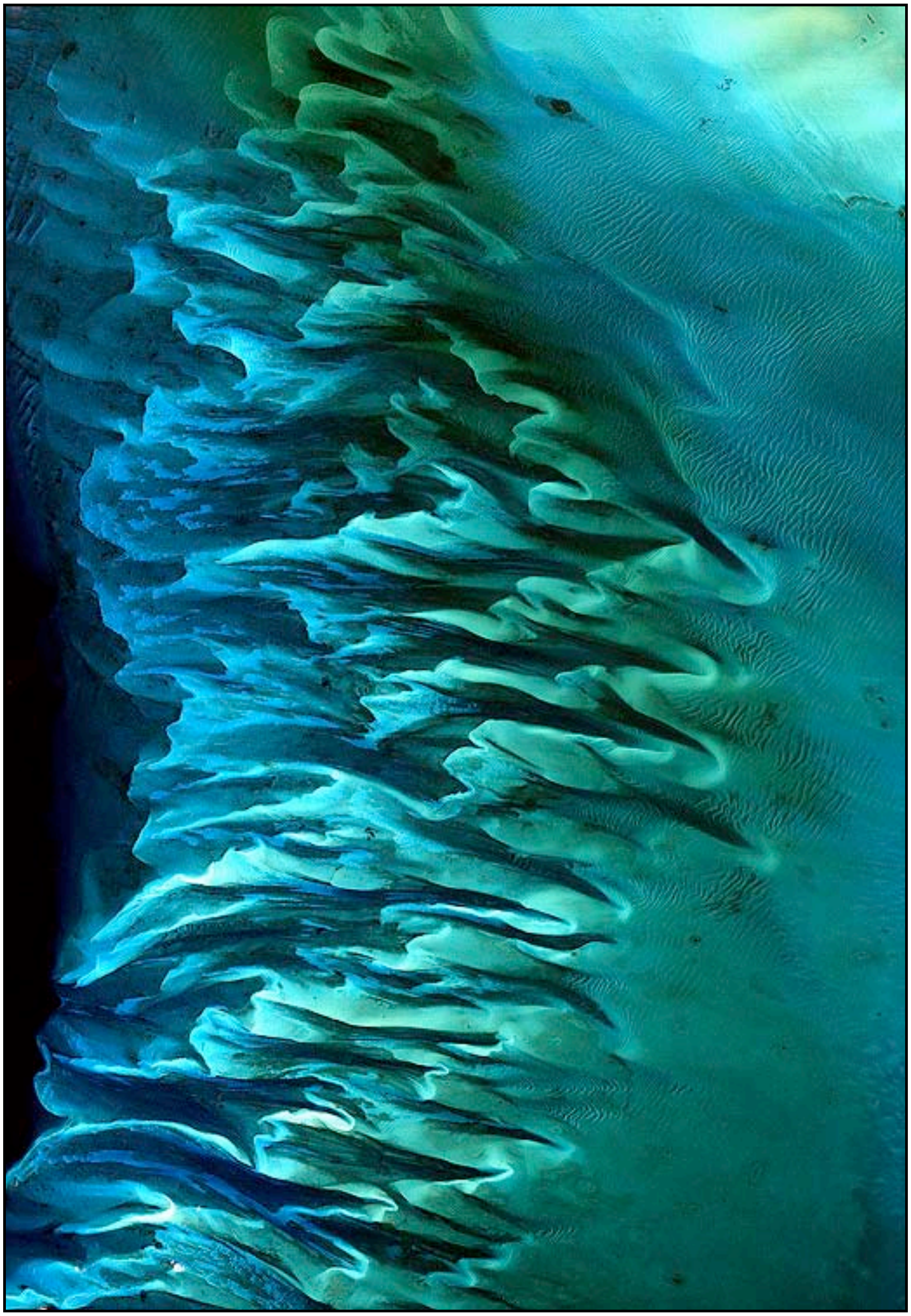
If stromatolites were once so common, why are they rare today? The answer seems to be that stromatolite-building colonies of microbes had no efficient predators when all life on Earth was microbial. Today, many larger, multicelled animals—fish, gastropods, worms—graze on the microbes. Only in high-stress environments, such as the super-salty waters of Shark Bay and the tide-scoured channels near Lee Stocking Island, can microbial colonies survive long enough to build significant structures. Migrating sand waves on the floor of the Lee Stocking channel also seem to play a role in controlling the growth of the stromatolites and protecting the colonies from grazers. In fact, it was difficult for us snorkelers to "graze" our eyes on the stromatolites. Quickly, the tidal current carried us away from what we wanted to see. Acaba picked us up with the boat and took us back "upstream" for another drift across the stromatolite assemblies.

Not all geologists accept that all fossil stromatolites are of organic origin; dissenters point to other non-living geological processes that could lead to layered structures in sedimentary rock. This may be true, but seeing the Bahamian stromatolites swept by sand on the shallow floor of the Lee Stocking channel makes it clear that what microbes are doing today they could likely have done billions of years ago, in conditions and environments that were ideal for fossilization. These strange, dark humps on the floor of a Bahamian tidal channel are a kind of Lock Ness monster, cryptosurvivors from an ancient age, hidden from view until their discovery in the early 1980s, and now offering scientists a glimpse into an ancient world that has been mostly erased from the face of the planet." —Raymo, 1998

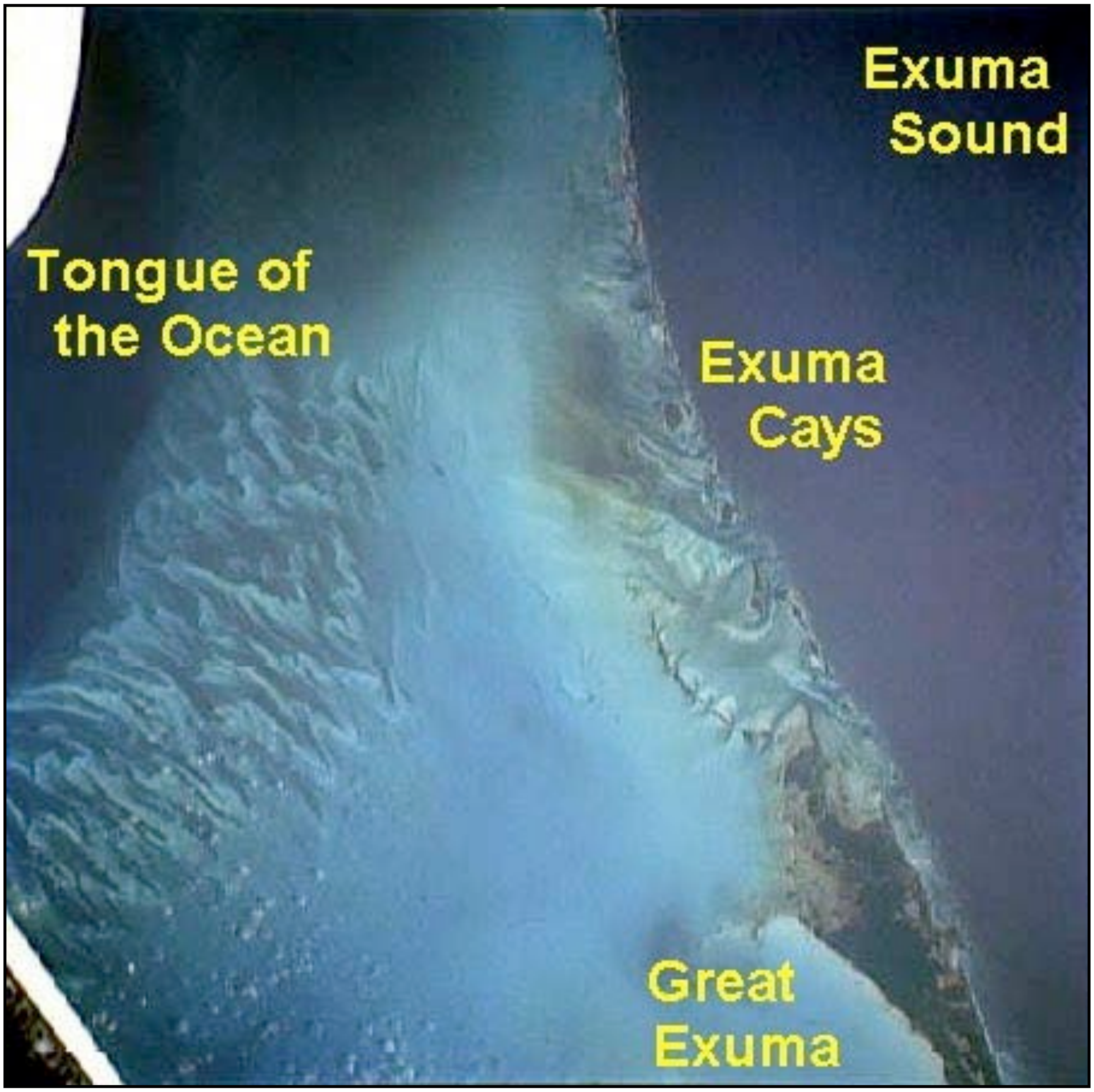
In this true-color image taken from space the turquoise, deep green, and sapphire blue waters surrounding the Bahama Islands stand out against the deeper blue of the Atlantic Ocean. Because the 700 islands and islets sit on underwater plateaus called "banks", the waters of the Bahamas are very shallow, ranging from barely covering the ocean floor to 82 feet (25 m) in depth.

The Great Bahama Bank is clearly visible in the center of the image above curling around the central islands. The largest island, Andros is just left of center in the image. Nassau is to the right of Andros, and Eleuthera to the right of Nassau. Cat Island is southeast of Eleuthera with Long Island south of Cat Island. And Great Exuma Island is just west of Long Island (see map below). In the upper part of the image, the islands of Great Abaco (left) and Grand Bahama (right) sit on the Little Bahama Bank (May 18, 2001, MODIS/Terra image courtesy of NASA).

East and south of Andros Island (left-edge center above) and west of Great Exuma Island (right-edge below center) the Great Bahama Bank drops sharply into deep water called the "Tough of the Ocean" because of its distinctive shape. Here strong tidal currents have sculpted the sand at this edge of the bank into fantastic folds that can be seen from space.

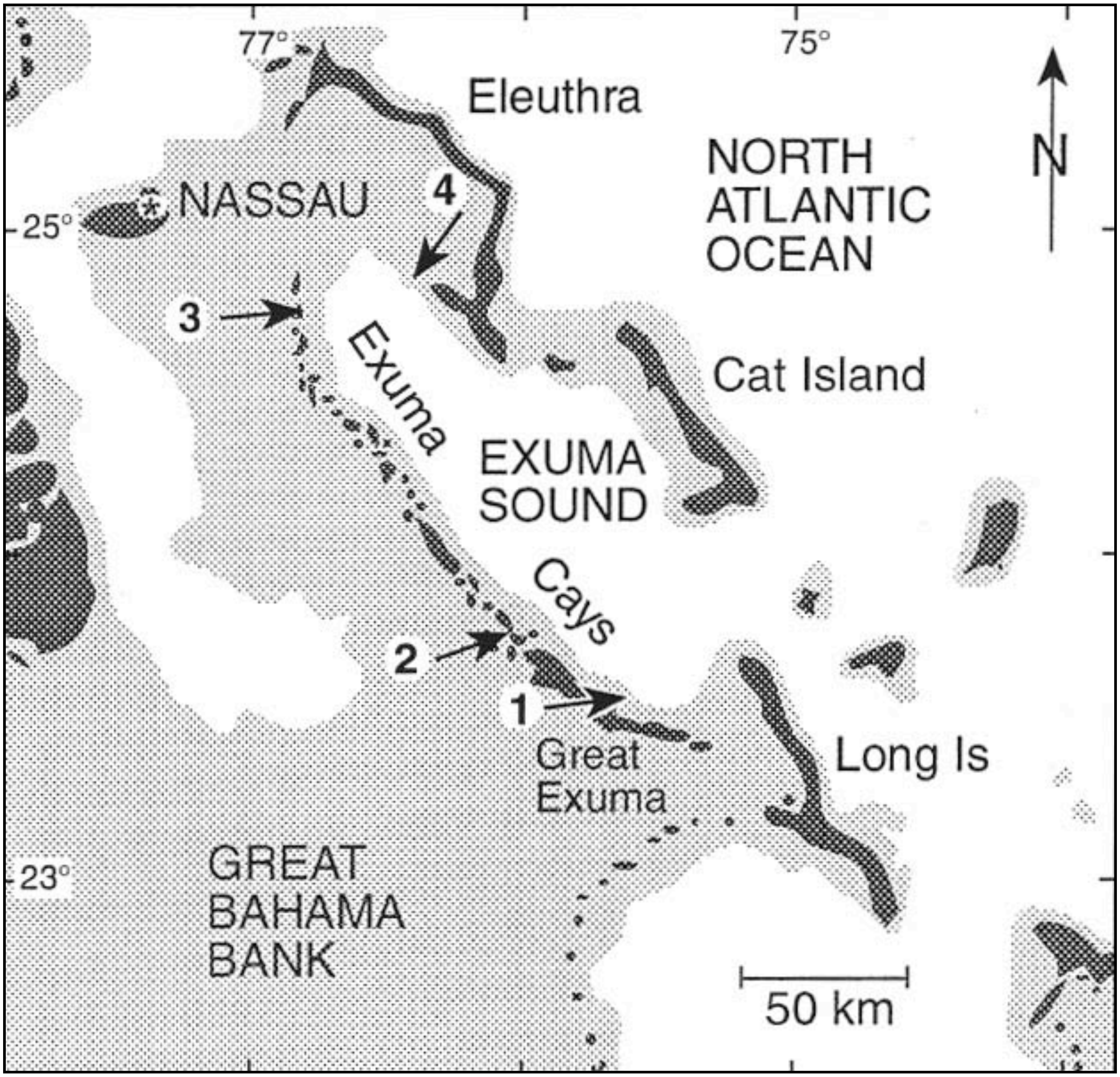


This extraordinary image from space captures the meeting place of deep waters and the shallow waters of the Grand Bahama Bank. This platform reef drops off quickly into the Tongue of the Ocean, which is a branch of the Great Bahama submarine canyon. The Exuma Cays, where stromatolites are found, are ~16 miles (25 km) east of these current sculpted sand bars. In the upper right of this image note the ripples of sand waves (ETM+/Landsat 7 image).



The vertical rock walls of the Great Bahama submarine canyon rise 14,060 feet (4285 m) from their greatest depth to the shallow waters of the surrounding bank, which is why the water is so dark in color compared to the reef. The shallowest parts of the reef here are no more than 3 to 7 feet (1-2 m) deep. As a result, this narrow neck of the Grand Bahama Bank is like a mountaintop being swept by tremendous winds blowing from one deep valley to the next. Here they are tidal currents sweeping west across an underwater mountaintop from Exuma Sound to the depths of the Tongue of the Ocean. This explains why the currents in the channels between the Exuma Cays are so powerful.

Web Reference
http://earthobservatory.nasa.gov/IOTD/view.php?id=2780



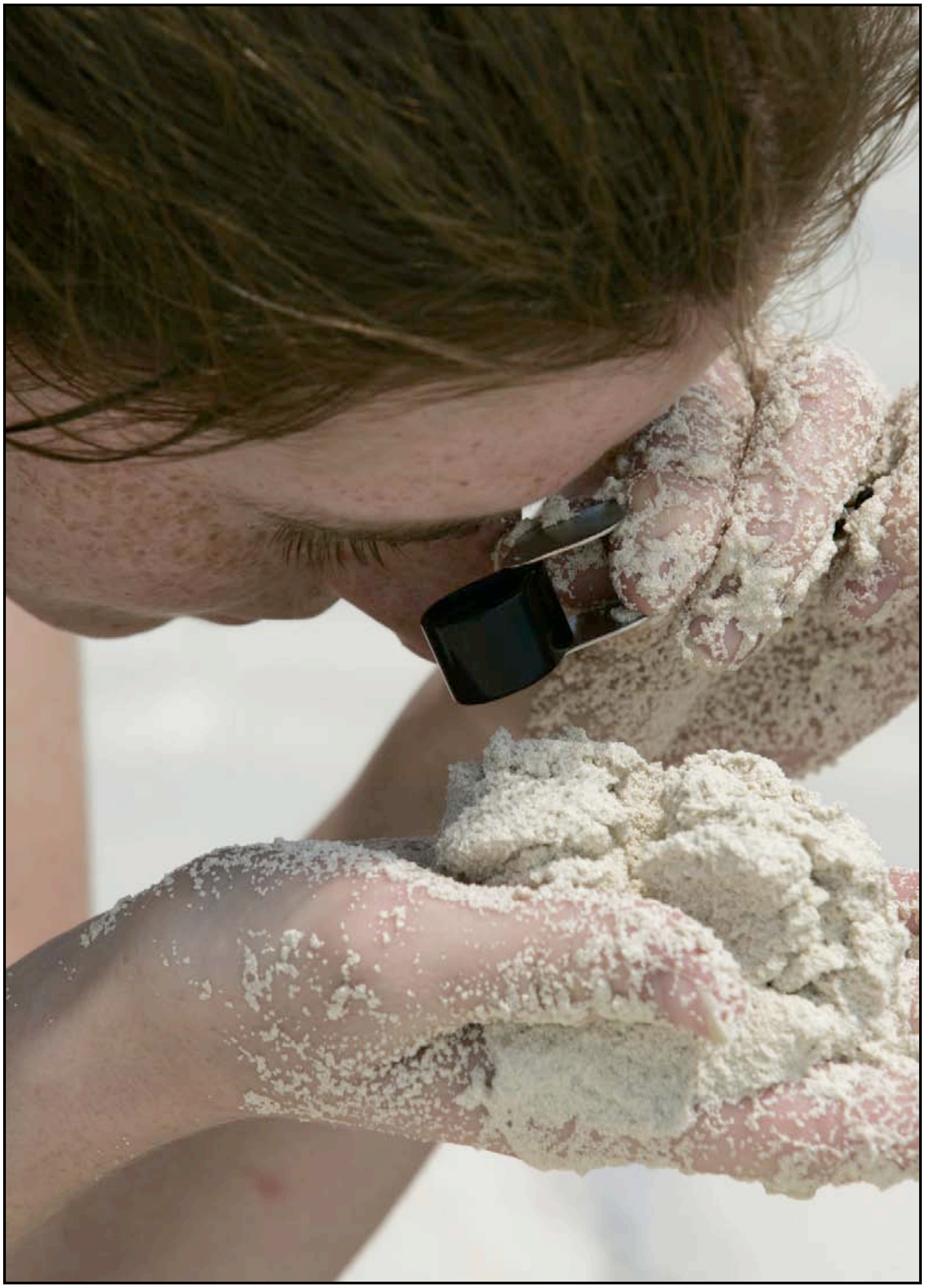
The map above shows some of the stromatolite study sites located on the margin of Exuma Sound: 1. Stocking Island; 2. Lee Stocking Island; 3. Highborne Cay; and 4. Schooner Cays (Macintyre, et al., 2000).

The "high-stress" environment of the Exuma Cays is created by the tremendous tidal currents and the 3 feet (1 m) tall sand waves they produce that regularly bury the Bahamian stromatolites. Shown above are stromatolite domes in a tidal channel off Lee Stocking Island that are half buried by carbonate sand. The giant Bahaman stromatolites are composed primarily of fine-grained carbonate sand (ooid sand) that is trapped and bound by the filamentous cyanobacteria *Schizothrix sp*..

The shoals off the south end of Andros Island (below and left of center above), include sand banks roughly 15 miles by 10 miles across composed of ooid sands. Carbonate rock forms from ooid sands. It is ooid sand that settles and hardens between the plant and animal remains (including stromatolites) on reefs, fossilizing them into carbonate rock. Stromatolites themselves are layered deposits of calcium carbonate.

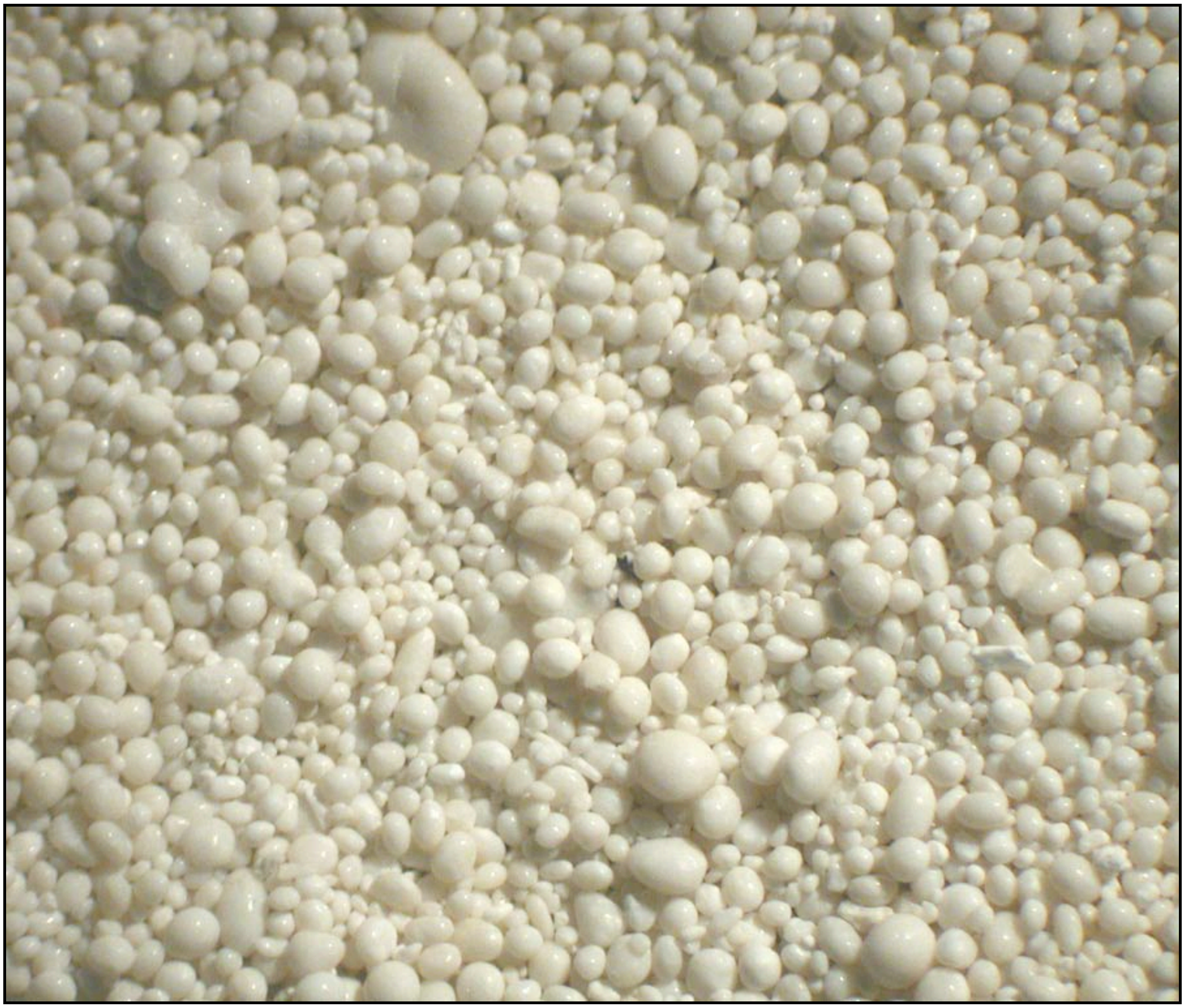
(NASA image courtesy of Christopher Kendall)

Geology students walking across a slightly submerged ooid sand bank off Andros Island. As its name suggests, ooid sand is round, having formed around a nucleus of bone or shell particles. Organic material mainly composed of calcium carbonate coats the nucleus over time as it's washed about, in a process similar to that of a pearl’s formation.



Ooid sands are composed of fine granule no larger than 2 millimeters in diameter.

Individual ooid granules are barely visible to the unaided eye.



A Microscopic View of Ooid Sand Granules

Web References
http://www.gly.uga.edu/railsback/sands/sandscarbonate.html

http://www.gly.uga.edu/railsback/sands/sand300.html

Shark Bay in Western Australia

Shark Bay is home to an astounding diversity of marine life. The bay is also the home of the one of the oldest forms of photosynthetic life on the planet, stromatolite forming cyanobacteria.

(November 6, 2004, MODIS/Terra image courtesy of NASA)

The stromatolites of Shark Bay are found in Hamelin Pool. In this map of the area, Hamelin Pool is shown in the southeast corner of Shark Bay. Faure Island is the location of the underwater sill that separates Hamelin Pool from the rest of Shark Bay.

Stromatolites in Hamlin Pool, Shark Bay, Australia

Hamelin Pool, at the south end of Shark Bay, is one of only two places in the world (the other being the Bahamas) with living marine stromatolites. Stromatolites are able to survive in the area because Hamelin Pool's water is twice as saline as normal sea water and sea grasses and many other forms of life cannot survive there. Hamelin Pool is actually a landlocked marine basin partially separated from Shark Bay by the Faure sill. This has helped to produce the hypersalination which in turn has ensured that the cyanobacteria remained isolated from fish and other animals that would feed on them.

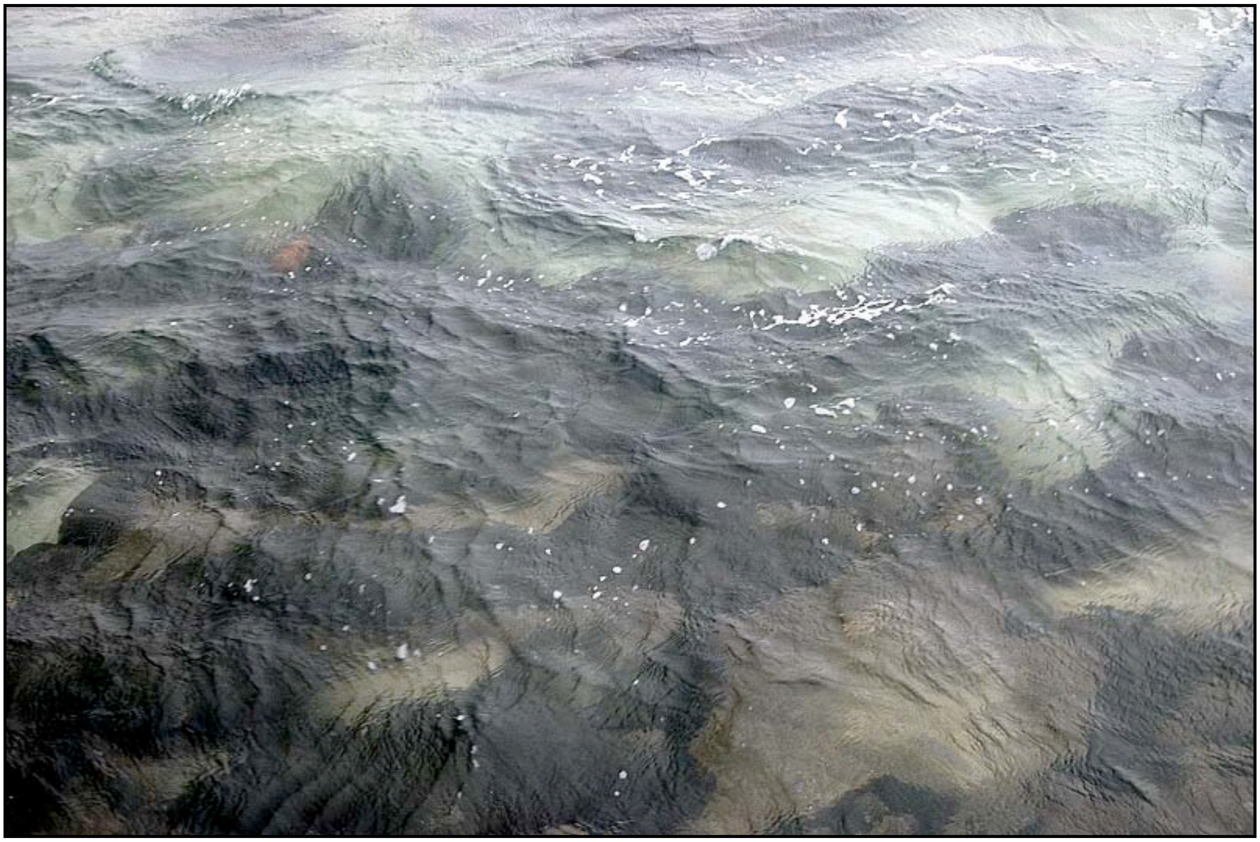
(Photograph by Guido Claessen)

Stromatolites are one of the most important features of Shark Bay. They look like rocky lumps strewn around the beach but are actually built by cyanobacteria. Within the structures are communities of diverse microbes with population densities of 3000 million individuals per square meter. The organisms combine with sediments and organic material to build stromatolites up to 5 feet (1.5 m) high—up to 10 million times their size. Because they grow very slowly, a 3 foot (1 m) high stromatolite could be as much as 2000 years old.

Web Reference
http://www.lpi.usra.edu/education/EPO/yellowstone2002/workshop/stromatolite/

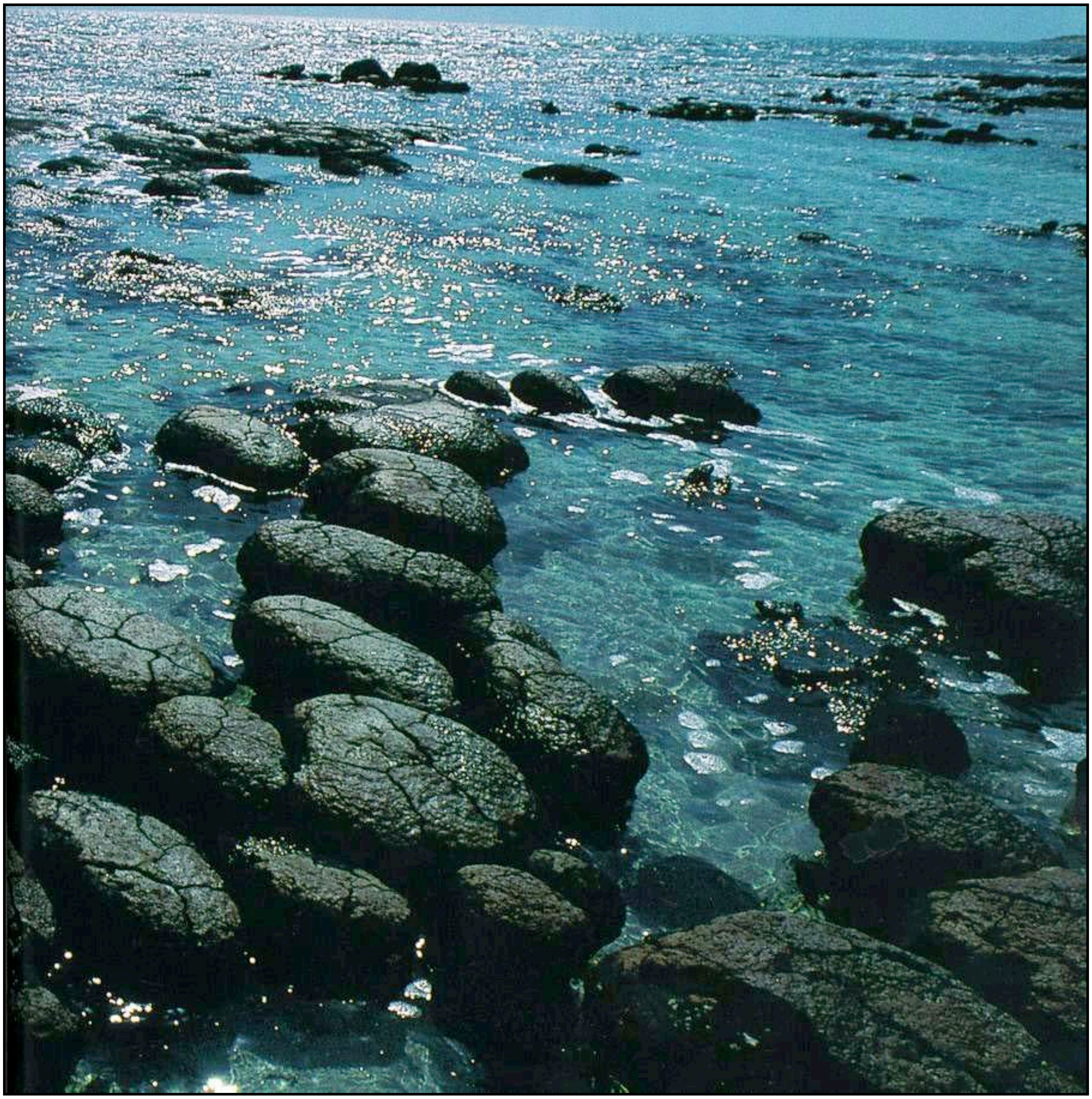
Taking up the top few inches, a velvety bacterial mat grows in fine layers that include a crown of photosynthetic bacteria. This image shows the stromatolites in Shark Bay at low tide.

(Photograph courtesy of Cambridge Carbonates Ltd.)



When the tides return the stromatolites are once again covered with sea water and sediments continuing the slow process that forms these ancient structures.

(Photograph by A. Avanes)



When the Shark Bay stromatolites were discovered by scientists in 1956, they were the first growing examples known of structures found fossilized in very old rocks that had puzzled geologists for more than a century.

A Fossilized Stromatolite Reef

The Petrified Sea Garden, National Natural Landmark, and adjacent Lester Park, just west of Saratoga Springs in New York State, are home to almost an acre of exposed stromatolite fossils approximately 500 million years old. The stromatolites of Lester Park were the first in North America to be described scientifically.

Shown above is a cross section of this fossil stromatolite reef. This huge slab of fossils was once part of an ocean-reef existing when the area was in the southern hemisphere at the edge of a warm tropical sea in the early Cambrian. This fossilized reef in New York State is nearly identical to the living stromatolite reefs found in Shark Bay, Australia. But they are separated in time by half a billion years.

(Photographs courtesy of the Petrified Sea Garden Inc.)

Above is a closer view of this cross section of fossil reef showing two individual stromatolite "heads". Note the 50mm camera lens cover for scale.

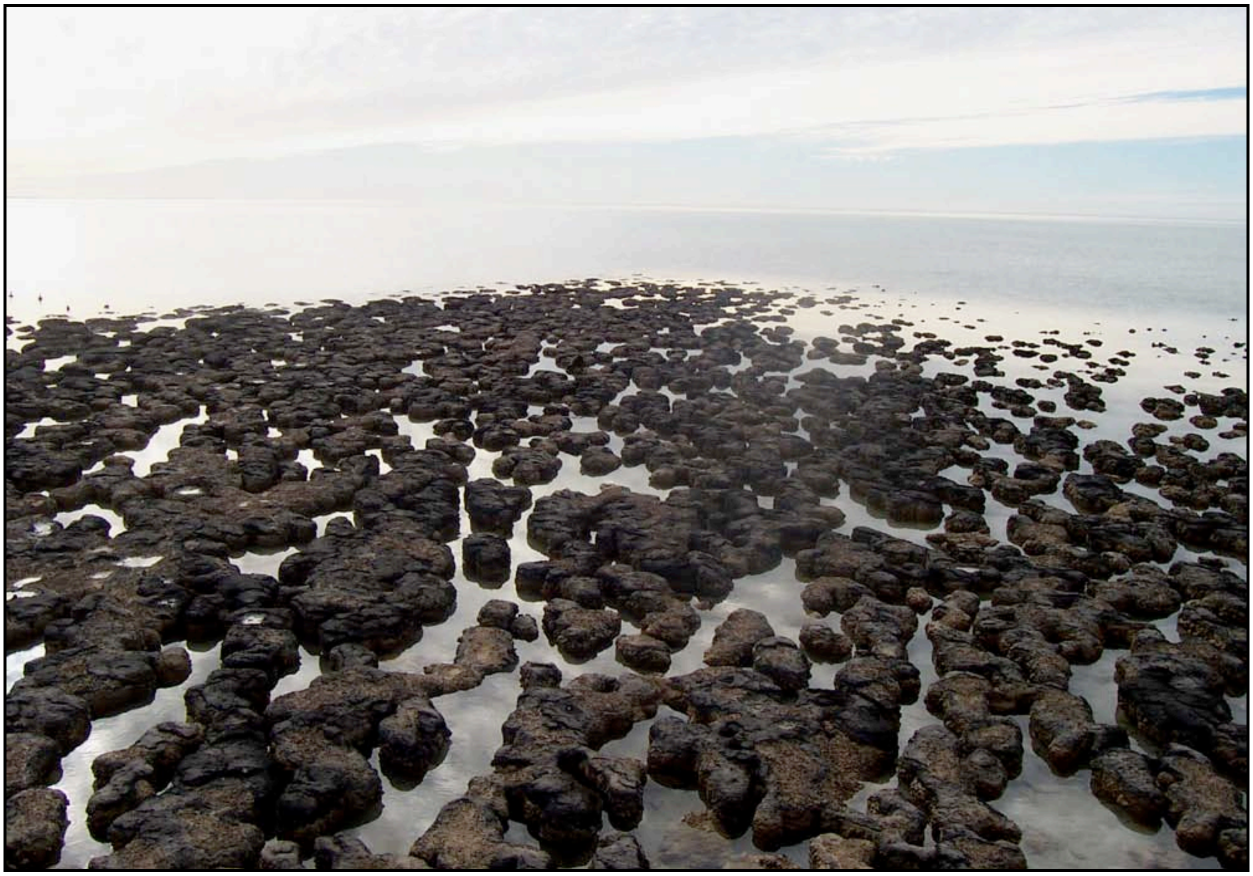
(Photograph by Bret Bennington)

A close-up of a stromatolite in the fossil reef shows the fine cemented layers of sediments. Note the pine needles for scale.

(Photograph courtesy of the Petrified Sea Garden Inc.)

This image shows a fossil stromatolite reef in Morocco that formed in a shallow sea some 600 million years ago and then was buried by volcanic ash. The stromatolites were later exposed through uplift and erosion of the Atlas Mountains. Their remarkable preservation is due to the modern-day arid climate, making it appear that the sea has just receded.

(Photograph courtesy of Bill Burton, U.S. Geological Survey)



Stromatolites in Shark Bay

For billions of years single celled, microscopic organisms have been creating the stony structures that we call stromatolites. At one time stromatolites were the dominate life form on this planet. The oxygen-rich atmosphere that made complex life on our planet possible was largely a result of stromatolites (cyanobacteria) photosynthesizing during the late Archean and Proterozoic Eons (2.7 - 0.5 bya). In addition, stromatolites created the first reef environments on Earth. And, although stromatolites are no longer a dominant form of life on Earth, they still survive as "living fossils" from the Earth's distant past. They are thus both a reminder of how fragile life on Earth is and yet how enduring.

Today there is a growing scientific consensus that 3.5 billion year old (bya) stromatolites found in the fossil record are the oldest macro-fossils of life on Earth (Allwood, et al., 2006; Awramik, 2006; Simpson, 2003).

(Photograph by Susan Rhoades)

Web Reference
http://en.wikipedia.org/wiki/Stromatolite

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