The Microbes That Loved the Sun

Awramik

Columnar stromatolites in Hamelin Pool, western Australia, are growing toward the rays of sunlight that pierce the water.

Some very tiny organisms living millions of years ago recorded the heavenly interactions among some very large bodies: the earth, the sun and the moon

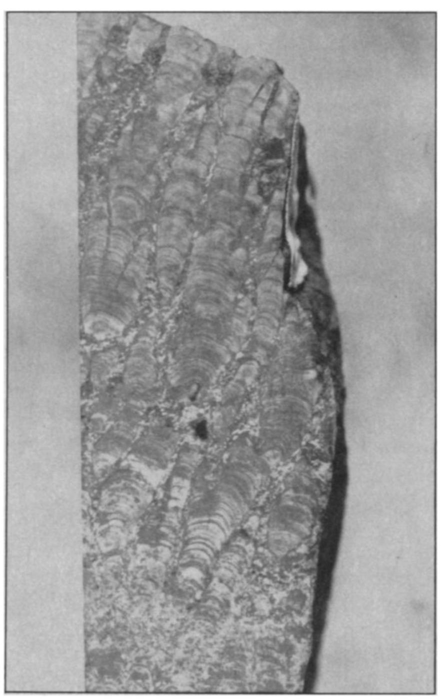
By STEFI WEISBURD

Among the larger species of plants and animals, it's easy to spot those individuals that worship the sun. Every winter, for example, New Yorkers can be seen flocking to Florida, where they follow the sun's every move. And a houseplant turned away from the window in the morning will most assuredly be found bending back toward the luxuriant rays in the afternoon.

But homing in on the really devout solar trackers among much smaller organisms is not always an easy task. In order to find evidence of movement toward the sun in groups of photosynthetic microorganisms such as blue-green algae, Stanley M. Awramik and James Vanyo had to get on their hands and knees in shallow-water pools and tidal flats. They peered intently at the orientation of the centimeter-high stromatolites—columns or tufts constructed by sticky mats of these microorganisms as they trap passing sediments and cement them into layers.

As the two University of California at Santa Barbara scientists report in upcoming issues of SCIENCE and EOS, they discovered a number of stromatolites tilting toward the sun and not, like most of their neighbors, in the direction of sediment-rich current flow. This is the first report of heliotropism—the inclination of a structure toward the average direction of sunlight — in stromatolites being formed today, says Vanyo.

The finding of heliotropism in modern stromatolites not only sheds light on the behavior of living microorganisms but also helps to confirm an earlier geologic theory linking the tiny architectures of ancient stromatolites to the much larger dynamics of the ancient solar system.



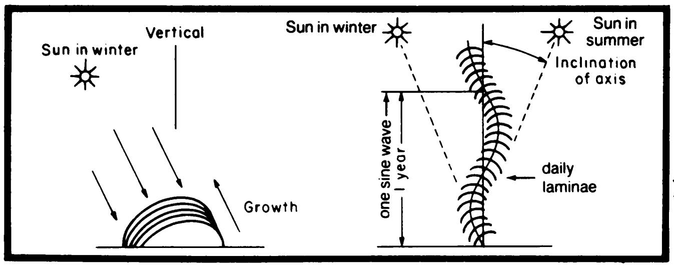
Awramik

The growth pattern of stromatolites constructed by microorganisms 850 million years ago follows a sine wave. This specimen of Anabaria juvensis *was found in the Bitter Springs Formation in Australia.*

According to the researchers, most of the scientific thinking about the interaction between the earth, sun and moon comes from the last few thousand years of historical records of observations and from studies of distant stars, from which scientists can glean something about the beginnings of our own system 5 billion years ago. But for the several billions of years in between the system's beginnings and the recent past, there is little direct information; theoretical models are needed to estimate, for example, how the gravitational tug of the moon has slowed the rotation of the earth, causing the number of days per year to decline with time.

Because organisms are sensitive to such things as the amount and direction of sunlight, researchers like Awramik, a paleobiologist, and Vanyo, an astronomer and engineer, have turned to the fossil record on earth for traces of earth-moon-sun dynamics. Some scientists have used the growth rings of ancient corals, for instance, to estimate periods such as the number of days that made up a year in the distant past. However, fossils of corals and other invertebrates date back only to the Cambrian period, about 570 million years ago. Stromatolites, on the other hand, extend back in the fossil record to 3.5 billion years ago—almost as old as the earth itself.

But the use of stromatolites as paleontological clocks has not been straightforward. A few researchers have suggested that the sediment layers, or laminae, in



A stromatolite that grows near the equator and follows the seasonal movement of the sun can develop a growth pattern in the form of a sine wave. If the stromatolite is built up of sediment layers constructed each day, then the number of these layers appearing in one wavelength of the sine wave represents the number of days in the year in which the stromatolite grew. From the stromatolite structure, scientists can also infer the angle made by the earth's spin axis with respect to the plane of the earth's orbit when the stromatolite was constructed.

fossil stromatolites could be used to estimate past lunar and annual periods; others have proposed that the tilt of a stromatolite column could be used to deduce the latitude of the structure when it was formed. However, these suggestions were discredited, say Awramik and Vanyo, by studies showing that stromatolite patterns were often driven by the patterns of current flow and not by the orientation of the sun relative to the earth.

More recently, Awramik and Vanyo came across some stromatolites with growth patterns that could not easily be attributed to current flow. The *Anabaria juvensis* stromatolites, taken from the Bitter Springs formation in central Australia, snaked upward in the 850-million-year-old fossil record in the distinct pattern of sine waves.

The researchers proposed that the microorganisms that made the stromatolites produced a new lamina each day by binding sediments and then working their way up toward the top of the new lamina to get the most of the sun's rays. The sinusoidal pattern resulted, they argued, because the microorganisms were building toward the sun, which, from the microorganisms' point of view, moved in the sky with the change in season. To microorganisms sitting just north of the equator, the sun would move toward the south during the winter and toward the north in the summer.

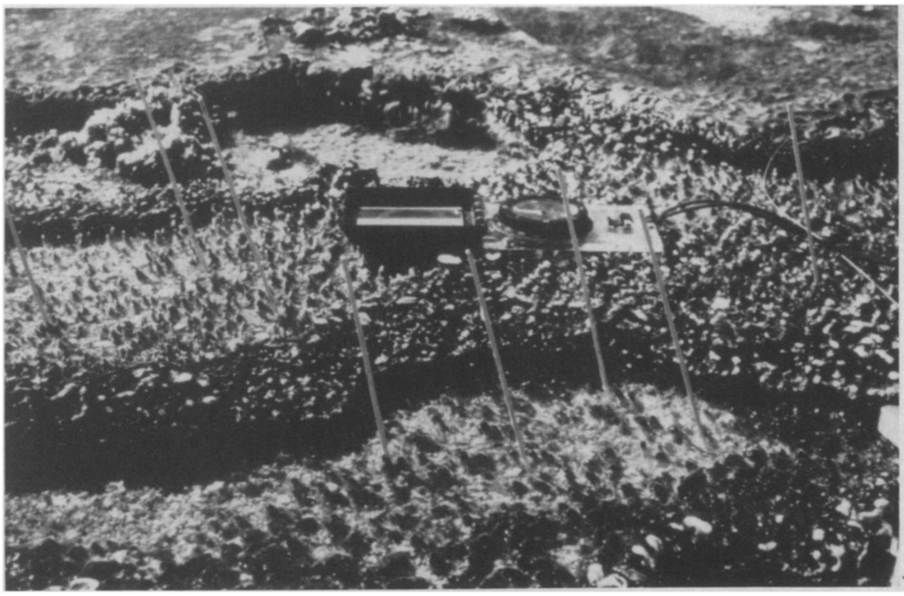
By counting the number of laminae in one cycle of a sine wave, Awramik and Vanyo estimate there were 435 days per year during the late Proterozoic. "Our results agree well both with estimates extrapolated from the Paleozoic [570 million to 245 million years ago] fossil invertebrate data and with the theoretical estimates using geophysics," says Awramik.

In addition to the number of days in a year, the sine wave pattern of the ancient stromatolites contains information about another important astronomical parameter called the obliquity of the ecliptic, or the angle between the planes of the earth's equator and the planet's orbit around the sun. Scientists think this angle might have been decreasing over time, but studies estimating values for this angle in the past have produced differing results. By measuring the maximum angle at which the sine wave deviates from the average direction of the column, Awramik and Vanyo obtained a value of 26 degrees 30 minutes.

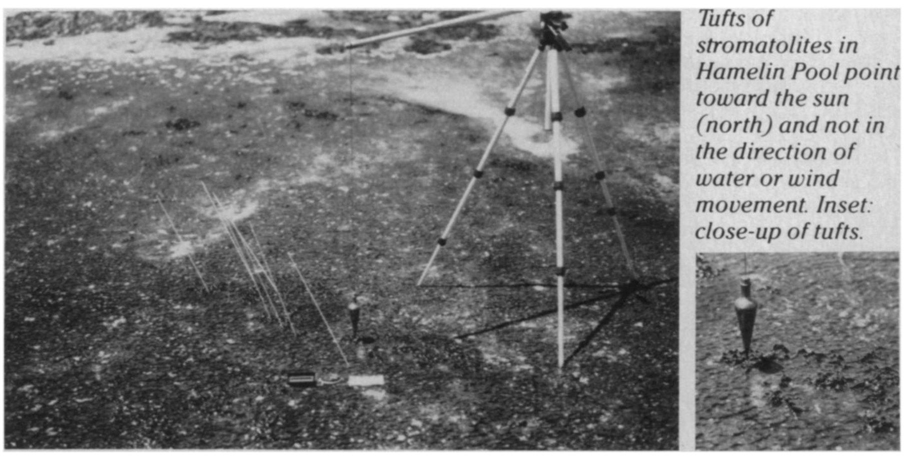
The researchers also were able to estimate the angle of the earth's magnetic field with respect to its spin axis during the late Proterozoic. They did this by looking at paleomagnetic studies of the rocks to determine the direction of the past field, and by using the plane along which the stromatolitic sine waves grew to define the past north-south plane of the earth and its spin axis. "The value we got indicates that at least back 850 million years ago the magnetic pole closely approximated the axis of rotation — something that was just assumed in geophysical studies," says Awramik.

In order for Awramik and Vanyo to extract astronomical information from the fossil patterns of stromatolites they had to assume, among other things, that the microorganisms lived near the equator and that they produced laminae each day. But the most important assumption was that stromatolite growth was heliotropic. And on this point the researchers were on shaky ground, because no modern examples of heliotropism in stromatolites had ever been reported.

So the researchers went on a heliotropism hunt. Vanyo and Rick Hutchinson, a


Vanyo

The metal rods in this photograph have been inserted parallel to the axes of stromatolitic cones growing in thermal pools of Yellowstone National Park. The cones are oriented toward the south (white part of the compass needle points south), or toward the general direction of the sun and not in the direction of current flow.



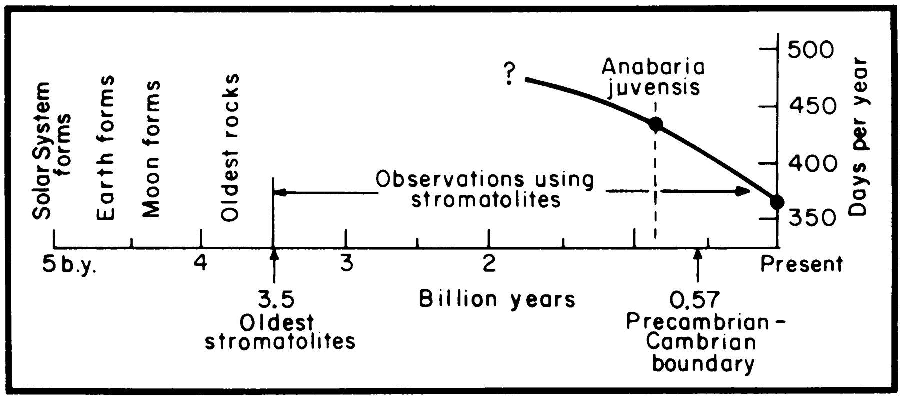
Tufts of stromatolites in Hamelin Pool point toward the sun (north) and not in the direction of water or wind movement. Inset: close-up of tufts.

Awramik

research geologist at Yellowstone National Park, looked in the thermal effluents from geysers and hot springs in Yellowstone. In six thermal springs they found conical and pillar-shaped stromatolites that were oriented not with the flow of water but toward the south, which is the general direction of the sun as viewed from the northern hemisphere.

Awramik, searching in the highly saline Hamelin Pool in Shark Bay, western Australia, met with success as well. At two sites exposed to the tides, he found small tufts inclined to the north, the general direction of the sun as seen from the southern hemisphere. The tufts were not leaning in either the east-west direction of the tidal currents or the general direction of the winds from the south. He also discovered dozens of much larger stromatolite columns in an area permanently submerged below the water's surface. These columns were tilted toward the north; ripples in the sandy bottom again showed that the current moved in a east-west direction. Awramik says that most recently he's also found evidence for heliotropism in millimeter-sized stromatolite tufts in the Caribbean.

"We're not saying that [heliotropism] is a common phenomenon in either ancient or modern stromatolites, but it's probably more common than people previously thought," observes Awramik.



Vanyo and Awramik, *Precambrian Research*, 29 © 1985 Elsevier Science Pub. B.V., Amsterdam

Because the stromatolite record spans much more of the earth's history than do skeletal fossils, which go back only 570 million years, it might hold important clues to the past dynamics among the earth, sun and moon. Here, for example, a stromatolite indicates the number of days in a year 850 million years ago.

Vanyo adds that only a few sinusoidal patterns have been found in the stromatolite fossil record, in part because people have not looked for them. "The cost and effort of digging up these things and then cutting the rocks in the correct way to expose the sine waves is huge," he says.

As for modern stromatolites, the researchers are not sure why some structures are heliotropic while others in the same region are not. The architecture of a stromatolite depends on a mosaic of different factors, including temperature, water chemistry, sediment flow and other organisms in addition to sunlight, they say. Heliotropism occurs when the influence of these other factors is suppressed in some way. The effects of competing organisms, for example, might be damped in both the Yellowstone National Park and Shark Bay areas, says Awramik, because these environments are stressed by either high water temperatures or salinity, which discourage other species from settling there. The researchers plan to conduct laboratory experiments this year to better understand what controls the blueprint of stromatolite growth. □

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