Earth sciences

Growing stromatolites

from Peter J. Smith

CONTRARY to popular belief, terrestrial life did not begin at the start of the Cambrian, about 600 million years (Myr) ago, or even during the few hundred million years immediately preceding it. The Precambrian–Cambrian boundary simply represents the time at which abundant organisms developed hard parts capable of leaving fossil remains. Evidence for what meagre life there was during most of the Precambrian exists not as skeletons and shells but largely as stromatolites, sedimentary structures produced by the activity of blue-green algae. A new discovery by Gomes (*Trans. geol. Soc. S. Afr.* **88**, 1; 1985) reminds us that stromatolites differ from many organisms in the fossil record in that they are still being produced in limited numbers today, giving some insight into the Precambrian conditions under which they developed.

It is highly probable that the most primitive terrestrial organisms originated as long ago as the Hadean, the interval between the creation of the Earth and the formation of the oldest known rocks (about 4,600–3,800 Myr ago): there is certainly evidence for very ancient life in the form of microscopic filaments and cells of bacteria and blue-green algae in South African chert deposits at least 3,200 Myr old. Stromatolites are more important than these insofar as, having hard (albeit inorganic) parts, they have greater survival potential and are thus more common. Walter (*Stromatolites* Elsevier, Amsterdam; 1976) defined them formally as "organo-sedimentary structures produced by sediment trapping, binding and/or precipitation as a result of the growth and metabolic activity of micro-organisms". In other words, they are not fossils at all in the conventional sense in that they are not primary organic remains, although without organisms they would not have been able to form. They are traces of past life much as burrows and tracks are, although more substantial than either.

The organisms involved in the generation of stromatolites are usually blue-green algae which, being filamentous, attract and bind surrounding particles of carbonate into an algal mat. The algae then extend their filaments throughout the newly accreted carbonate layer, attract more particles, and thus expand into thinly laminated structures which can be of considerable overall size. (The largest known forms are mounds hundreds of metres across and tens of metres high.) The algal layers themselves are seldom preserved, of course; but the carbonate accretions often survive in various distinctive forms, such as tabular, domed, branch-like and columnar.

Stromatolites were produced during the Archaean (earlier than 2,500 Myr ago), reached their peak of abundance and diversity during the Proterozoic (2,500–600 Myr), and thereafter declined, although they are sometimes encountered in the Phanerozoic. Indeed, they are still being generated today in a few suitable marine and freshwater environments; modern examples are not so common that new discoveries are of merely routine interest. Despite a resurgence of interest in stromatolites during the past 20 years, the influences on their formation are still unclear, a point worth remembering in view of the many problems to which stromatolite data have been offered as solutions. Claims for the use of such data have been made in almost every branch of the earth sciences and even in astronomy, but as Hofmann (*Earth-Sci. Rev.* **9**, 339; 1973) has pointed out, not all the conclusions rest on sufficiently strong evidence to warrant their acceptance.

The new discovery by Gomes of two types of stromatolite currently growing in South Africa is thus of considerable interest, not least because the study reveals in detail the conditions under which growth is taking place. The site in question is a collapse sinkhole, Wondergat, in dolomite sediments in the western Transvaal. The hole has a cross-sectional area of about 2,000 m^2 and is about 50 m deep at the centre, although two long caves running off from the bottom edge extend the overall depth to about 70 m. More crucially, running off from the side wall at a depth of about 20 m is a smaller cave that has been dissolved into the boundary between the dolomites of the upper 20 m and the dolomitic limestone (with chert bands) underlying them.

The sinkhole contains fresh, clear water at a depth of about 10 m and a temperature of 21 ± 4°C. The *p*H value of the upper 15 m of water (the depths at which stromatolites grow) is between 7.38 and 7.76, the Ca^{2+} concentrations vary from 53 to 68 p.p.m (parts per million) and Mg^{2+} concentrations range from 2.7 to 3.4 p.p.m. Water movement is slight, and natural visibility is high at distances of 10–15 km.

It is not possible to tell which of these chemical characteristics are necessary for stromatolite growth. For example, if all other circumstance were to remain unchanged, would stromatolites grow if the *p*H of the water were, say, 7.2 or 7.9? Or to put the question in a slightly different way, is the greatest depth of stromatolite growth governed solely by the ability of sunlight to penetrate and hence to allow the photosynthesis necessary for the production of the algae, or is it also defined or limited by one or more of the chemical properties of the water?

As for the stromatolites themselves, tabular 'crinkled' forms grow abundantly on the dolomite side walls of the sinkhole in the upper 15 m of water. They are 15–20 mm thick; light-brown to greenish in colour; soft and spongy; and, apart from the living algae, consist mainly of $CaCO_3$. Columnar stromatolites grow on the roof, walls and floor of the first 20 m of the smaller cave and in crevices in the wall of the main sinkhole. These vary in thickness from a few millimetres to a few centimetres; are the same colour as the tabular forms; and similarly consist mainly of $CaCO_3$, although they are hard, in contrast to the tabular stromatolites. The form of stromatolite appears to be governed by the range of genera involved, which is in turn influenced by the degree of sunlight available. Tabular forms grow where the light is brightest and columnar forms where it is relatively dim.

One curiosity of the Wondergat stromatolites is that they seem to need permanent submersion for survival and growth. If the water level falls, the exposed stromatolites rapidly desiccate. In this respect they differ from 'typical' stromatolites, which are thought to form with episodic immersions to allow the alternating layers of algae-rich and carbonate-rich material to be built up. There seems little doubt that most known stromatolites were generated in shallow-water zones where tides are the clearly recognizable agents for the periodic transport of sedimentary particles into the algal mats.

There have been previous claims for the discovery of deep-water stromatolites. Achauer and Johnson (*J. sedim. Petrol.* **39**, 1466; 1969), for example, concluded that stromatolites associated with a late Cretaceous reef in Texas must have been generated in deep water. In such a case, the influx of carbonate particles would not necessarily be sedimentary in nature. It is well established that photosynthesis by algal colonies can, by removing CO_2 from the water, increase the *p*H and accentuate the precipitation of $CaCO_3$ which then intermingles with the algae.

Gomes himself makes little comment on the wider implications of his data, which is perhaps wise. Modern stromatolites are quite rare, and freshwater occurrences make up only a very small fraction of the total, calling into question whether the Wondergat find is in fact typical of stromatolites. □

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