

Spongy but not glassy: Ediacaran fossil provides insight into early animal evolution

Sea sponges were among the first animals to evolve. But, perplexingly, they left few early fossils despite having dense yet porous bodies. The Ediacaran fossil *Helicolocellus cantori* is interpreted as having been a glass sponge without biomineralized spicules (little spikes made of glass) to support its body.

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The problem

Molecular clocks, which use the mutation rate of biomolecules to deduce how long ago two species diverged, and phylogenetics (the evolutionary relationships between species) can tell us when sea sponges must have emerged. We know that they evolved no later than the Ediacaran period (635 million to 539 million years ago, the most recent part of the Precambrian), but we have few sponge fossils from the Precambrian as a whole.

Biomineralization is the formation of minerals by living organisms. Most living sponges have either siliceous (glassy) or calcareous (chalky) spikes called spicules that support their porous bodies. Previous studies have therefore suggested that biomineralized spicules were present in the last common ancestor of sponges¹. The lack of Ediacaran sponge fossils might have been a result of unfavourable conditions for spicule fossilization. By contrast, molecular and phylogenetic data indicate that ancestral sponges were non-biomineralizing animals and that sponges independently evolved biomineralized skeletons later². If this is the case, Precambrian sponges might not have had biomineralized spicules. However, this needs to be confirmed in the fossil record.

The discovery

We investigated the rocks of the late Ediacaran Shibantan Member (formed between 551 million and 539 million years ago) in southern China to assess the prediction of non-biomineralizing ancestral sponges and independent origins of biomineralized spicules. The Shibantan Member consists of marine carbonate rocks, or limestone, that are known to preserve abundant animal trace fossils and non-biomineralizing macrofossils, including animals capable of locomotion^{3,4}. It therefore could have captured non-biomineralizing sponge animals if they existed in late Ediacaran oceans.

Indeed, *Helicolocellus cantori*, a newly described fossil from the Shibantan Member, could represent a non-biomineralizing sponge animal. To test this theory, we compared *H. cantori* with a variety of living and fossil animals.

We found that *H. cantori* shares some key structural features with fossil and living glass sponges, or hexactinellids. It had a conical body with radial symmetry, and it is inferred to have had a spongocoel, or central cavity, and an osculum, which is a large opening at the end farthest from its centre (Fig. 1a). This body construction

helps living sea sponges to pump water into and out of the spongocoel during filter feeding. The body wall of *H. cantori* is similar to those of hexactinellids. However, there is no evidence of a biomineralized skeleton in *H. cantori*; instead, it seems to have had an organic skeleton. A phylogenetic analysis places *H. cantori* in the sponge phylum, and it is more closely related to hexactinellids than to any other sponges (Fig. 1b).

The implications

The discovery of *H. cantori* indicates that non-biomineralizing sponge animals did exist and can be preserved in Precambrian rocks. Importantly, it suggests that palaeontologists should broaden their search for Precambrian sponge fossils, because early sponges might not have had biomineralized spicules² and might not look like later sponges in one or more aspects⁵.

Because *H. cantori* is grouped with Palaeozoic hexactinellids, it does not unambiguously support the theory that biomineralized spicules evolved independently in distinct sponge classes – an idea that is based mainly on phylogenetic analyses of the biomineralization proteins of living sponges².

The phylogenetic analysis of sponge fossils is still in its infancy. An expanded search for Precambrian sponge fossils is needed to understand the origins of biomineralization in these animals. If several Precambrian sponge fossils with organic skeletons were to populate the basal part of the phylogenetic tree beyond the divergence of sponge classes, then the fossil record would provide strong support for multiple independent origins of sponge biomineralization. This would also mean that the Cambrian explosion – when a huge number of complex animal groups started appearing in the fossil record around 538.8 million years ago – was a biomineralization event, during which several animal groups evolved biominerals, presumably to avoid heavy predation.

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EXPERT OPINION



Sponges are regarded by many as the most basal animal type.

However, their early fossil record is fraught with an abundance of controversy and opinions, yet there is almost no physical evidence. Thus, every scrap of possibly

relevant fossil material is exquisitely precious. Finding readily identifiable crown-group sponges from the late Ediacaran period is therefore stupendous.” (CC BY 4.0)

A reviewer

FIGURE

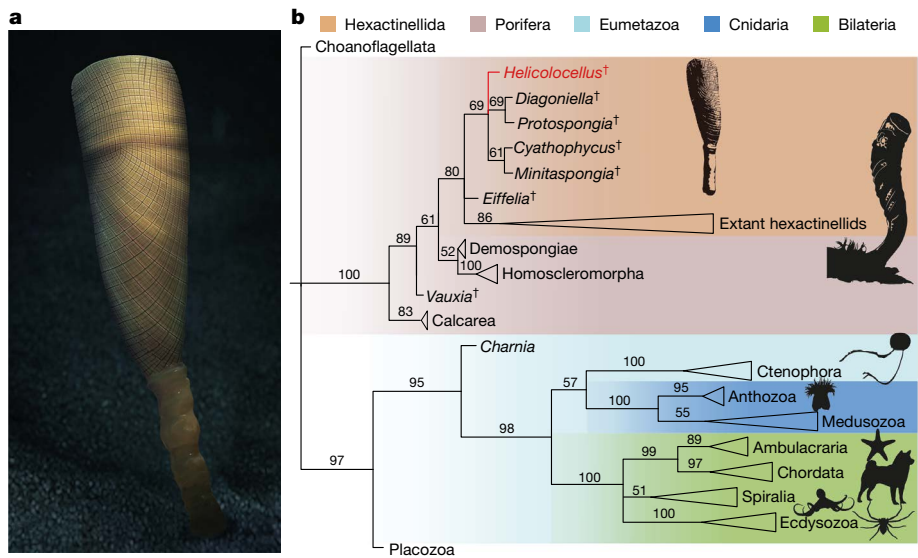


Figure 1 | Structure and interpretation of the early sea sponge *Helicolocellus cantori*. **a**, Morphological (structural) reconstruction of *H. cantori* on the Ediacaran sea floor. The sponge was around 40 centimetres high. Artwork by Dinghua Yang. **b**, A Bayesian (statistical) phylogenetic analysis of metazoans shows that *H. cantori* must have been a sponge animal related to hexactinellids and a close relative of Palaeozoic animals such as *Diagoniella*, *Protospongia*, *Cyathophycus* and *Minitaspongia*. †Extinct. Numbers represent adjusted probabilities (as percentages) for branching points.

BEHIND THE PAPER

The Shibantan project was a collaborative research endeavour that involved the Chinese Academy of Sciences in Nanjing, Virginia Tech in Blacksburg and, for the past two years, the University of Cambridge, UK. Initially, much of our fieldwork involved gazing at the rooftops of local farmhouses, and in particular the pig pens that had rooftops visible to geologists walking by with a hand lens. Local farmers quarried the shallowly buried limestones of the Shibantan Member to make roof tiles, many of which bear fossils obscured by modern lichens and mosses. We later began

to systematically quarry the Shibantan Member so that freshly exposed fossils were collected in their geological and stratigraphic contexts. When *H. cantori* came to light, the research team intensely debated its possible affinities with sponges, cnidarians (jellyfish and sea anemones) and tunicates (sea squirts), before ultimately settling on the sponge interpretation, which was confirmed by a Bayesian phylogenetic analysis.

S.X.

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FROM THE EDITOR

Sponges are thought to have existed way back in the Precambrian. But claims for Precambrian sponge fossils are notoriously debatable. The discovery of impressions made by something like a hexactinellid — a glass sponge — in Ediacaran rocks (around 540 million years in age) won’t end the debate, but it tips the scales in favour of the view that sponges already had a long history as soft-bodied creatures before they became mineralized in the Cambrian period.

Henry Gee, Senior Editor, *Nature*