Fossil hunters occasionally chance upon small, glossy red to amber-coloured, roughly circular objects on bedding planes when they crack open shales that were deposited in ancient swamps and rivers. These curious fossils range from about a millimetre in diameter up to the size of a fingernail (Fig. 1). When well preserved, they are egg-shaped, but, in most cases, they have been flattened to a thin flake in the rock by the weight of the overlying strata. Some specimens appear to have a net-like coating on the surface but, otherwise, they offer few clues as to their identity. Indeed palaeontologists have reported these objects for over 150 years and have variously interpreted them as the eggs of insects, parts of lichens, the food-catching devices of ancient invertebrates, the membranous coatings of seeds, or the linings of clubmoss sporangia. Many early palaeobiologists simply labelled them as 'red eggs' and avoided assigning them to any particular biological group.

New Antarctic discovery

Recently, one of us (TM) recovered a few new specimens of these strange fossils after sieving Eocene (50myr-old) sediments collected on Seymour Island, Antarctica (Fig. 2). Using a high-powered light microscope, it was clear that several varieties of fossil cocoons were present - some with solid walls and a variable coating of entangled threads (Fig. 3), and another with a rigid mesh-like wall, covering an inner layer of thread-like material (Figs. 4 and 5). We have report was largely overlooked by later researchers, probably because it was published as a brief communication in the German language. These strange fossils are now known to have a record extending back to the Triassic, but DNA-dating of modern cocoon-producing annelids (earthworms, leeches and their relatives) suggests that this group has an even earlier origin - perhaps in the early Palaeozoic.
Fig. 6. Earthworm with saddle (clitellum) around which the cocoon is secreted.

Fig. 7. Formation of a leech cocoon: (A) mating; (B) the leech begins to secrete a cocoon around the clitellum; (C) the leech retracts its body through the cocoon and lays eggs inside it, while the cocoon wall is still soft and sticky, which allows some spermatozoa and micro-organisms to be entrapped in the cocoon wall; (D) the cocoon is deposited on the substrate, and spermatozoa and microbes become entombed and fossilised as the cocoon wall hardens.

Fig. 8. A Vorticella-like protozoan (a 'bell-animal') entombed in the wall of a Triassic leech cocoon from Antarctica.

Fig. 9. The inner surface of a cocoon wall from the Eocene of Seymour Island, showing scattered rod-shaped bacterial bacilli and entombed spermatozoa with whip-like tails.

Fig. 10. The nuclear region and tail of the world's oldest known fossil animal sperm cell, entombed in the wall of a 50myr-old worm cocoon from Seymour Island.

now formally described these tiny fossils and assigned them to several new species. However, the significance of these fossils does not end with their identification as palaeontological curiosities. They also tell us something about the evolutionary history of worms and their relatives, and they potentially reveal a hidden world of fossil microbes.

To fully appreciate these fossils, one must understand a few things about worm biology. There are three major classes of modern annelids: Echiura (spoon worms), which are entirely marine; Polychaeta (bristle worms), which are mostly marine; and Clitellata (earthworms, leeches and crayfish worms), of which some occur in marine waters, but others have widely colonised freshwater and terrestrial environments. Only members of Clitellata produce cocoons to protect their eggs. Members of this group are hermaphrodites—they have both pairs of sex organs. During reproduction, they generally exchange sperm between individuals and some species can store the sperm cells in specialised sacs for several months. At the time of egg laying, earthworms, leeches and their relatives secrete a mucus-like material from glands on the clitellum, which is a series of specialised body segments situated in the front half of the body. The clitellum is best seen in earthworms, where it forms a thickened 'saddle' (Fig. 6). The initial mucus-like secretion acts as a scaffold onto which the worm secretes additional threads of more robust material that may build up into several distinct layers to form a cylindrical cocoon around the clitellum. These secretions are initially soft and jelly-like, but, over the course of a few hours to days, they harden into a rigid and extremely durable coating. In the meantime, eggs are deposited into the cocoon, sperm are released for fertilisation, and the cocoon is
eventually sealed by a cap (operculum) as the animal withdraws, and then deposited on the substrate. Once the embryos have matured, the egg hatch and the cocoon’s operculum detaches to release the young worms.

A hidden world of fossil microbes

It is the early stage of cocoon secretion that is important for palaeontology, because it is during this time that micro-organisms from the surrounding environment can become entrapped and entombed in the sticky threads of the cocoon wall, so escaping decay and ultimately becoming part of the fossil record (Fig. 7). This type of preservation is somewhat like bugs becoming entombed in amber. Manum and his colleagues noted not only such unexpected occurrence of a nematode entombed in the wall of a fossil leech cocoon from the Cretaceous of Spitsbergen. More recently, one of us (BB) discovered a microscopic fossil Vorticella (a bell-shaped ciliate protozoan) preserved in the wall of a leech cocoon from the Triassic of Antarctica (Fig. 8).

Given these previous records of entrapped micro-organisms, we recently discovered Eocene cocoons from Seymour Island offered the chance for us to search for additional fossil microbes. Such microbes are best seen on the smooth inner surface of the cocoon. Therefore, we studied the inner surface of a broken cocoon using a scanning electron microscope. Sure enough, embedded within the innermost layer of the cocoon were numerous fossilised spherical and rod-shaped bacteria (Fig. 9). More curiously, however, we observed numerous elongate structures with long whip-like tails preserved among the bacteria (Fig. 10). These turned out to be the sperm cells of the cocoon-producer itself that had become trapped in the sticky wall material, before they could fertilise an egg. In many cases, these spermatozoa were broken - probably as a consequence of their efforts to wriggle free of the sticky cocoon lining. When complete, they have a long coiled ‘drill-bit’-shaped front part (the acrosome), followed by a granular region that contains the nucleus. In turn, this is followed by a striate region containing the mitochondria, and then a very long and slender whip-like tail. The finer details revealed similarities to the sperm cells of modern branchiobdellids (crayfish worms) - a group of leech relatives that live in a symbiotic relationship with freshwater crayfish hosts.

If these are indeed the fossil cocoons of crayfish worms, this implies that branchiobdellids had a much greater geographic range in the Eocene compared to their modern relatives, which are restricted to the Northern Hemisphere. However, research on such fossil cocoons is at a very early stage. Once the full extent of diversity and the stratigraphic ranges of these fossils are clarified, they may even have value for correlating and dating sedimentary rocks.

We now have collections of fossil clitellate annelid cocoons from several localities around the world and it will involve some challenging detective work to see if any of these specimens have further identifiable micro-organisms trapped in their walls. Potentially, these cocoons could open up a new gallery of fossil soft-bodied micro-organisms from soil and freshwater environments for which, previously, we have had a very meagre fossil record. Groups - such as tardigrades, rotifers, euglenoids, flatworms and nematodes - are all candidates for becoming entrapped in the sticky walls of newly secreted annelid cocoons. Perhaps, in the future, annelid cocoons will become a valuable resource for understanding the evolution of soft-bodied micro-organisms, as amber is for revealing the fossil record of insects.

About the authors

The authors are all from the Swedish Museum of Natural History in Stockholm.

Further reading


News snippets

Aust closed to the public until Spring 2017

We have been contacted by the National Grid to highlight to readers that the Aust location along the River Severn is closed to the public until 2017, due to works being carried out at the site. Several collectors have been seen scaling the fences, which is extremely dangerous. Any questions regarding the work should be directed to the National Grid.

Crocodile sized animal was the first vegetarian reptile

Two important fossils found in China of a crocodile sized creature living 242 million years ago are the first records of a vegetarian reptile. The animal lived in the sea, and had a hammer-shaped skull, which helped it feed on underwater plants.

Extinct vegetarian reptiles are actually very rare. The information came to light when scientists made models of the jaw from modelling clay. Remains of the animal first surfaced a few years ago and it has been named, Atopodentatus unicus, which is Latin for ‘unique strangely toothed’.

Dinosaur fossils from Antarctica are a major find

The recent discovery of over a ton of dinosaur fossils from the James Ross Island of Antarctica could provide important clues on how they became extinct. Dated at 71myrs old, the dinosaurs, together with reptile remains of plesiosaurs and mosasaurs, and birds (including the earliest ducks), are creating a clear picture of the environment of the Antarctica before the extinction. The sheer number of finds means that they will take a few years to study, but could provide some major breakthroughs in our understanding of this period.

4,800 year old mother and baby from Taiwan

Archaeologists have uncovered the extraordinary remains of a mother looking down at an infant in her arms in Taichung City. This is the oldest human fossil of a mother and baby from Taiwan. The bones came from a set of remains unearthed from graves of the earliest traces of human activity in Central Taiwan. The mother and baby find was quite shocking, as the mother was looking down at the baby in her hands. Carbon dating was used to determine the ages of the fossils, which included five children.

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