Naturhistoriska riksmuseet

Press release

Relates to article: S.M. Slater, P. Bown, R.J. Twitchett, S. Danise, V. Vajda. Global record of "ghost" nannofossils reveals plankton resilience to high CO_2 and warming. *Science* **376** (2022). doi:10.1126/science.abm7330

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Discovery of "ghost" fossils reveals plankton resilience to past global warming events

Scientists have found masses of microscopic imprints, or "ghost" fossils, of single-celled plankton, called coccolithophores, that lived in the seas millions of years ago. Their discovery from three global warming events in Earth's history shows that the normal fossil record of coccolithophores has been severely distorted, and suggests that these plankton were more resilient than was previously thought.

Plankton are a fundamental component of marine ecosystems, and coccolithophores, a type of photosynthetic nannoplankton, are important in today's oceans, providing much of the oxygen we breathe, supporting food webs, and locking carbon away in seafloor sediments. Coccolithophores produce hard plates made of calcium carbonate, called coccoliths. These are often extremely abundant in the fossil record and are what palaeontologists generally look for when studying nannoplankton.

During three past global warming events, ~183, ~120 and ~94 million years ago, substantial declines in the abundance of coccoliths and other types of nannoplankton have been documented in the fossil record. These signals have previously been interpreted as crises of the living nannoplankton, in response to global warming and ocean acidification. However, a new study published on May 20th 2022, in the journal *Science*, challenges this view.

"In our study, we present a new global record of an almost entirely overlooked form of fossil preservation – imprints, or ghost fossils, of nannoplankton preserved on organic matter. We found the fossils within rocks from intervals in the geological record where normal coccoliths are rare or absent, this was a total surprise!" says Dr. Sam Slater, from the Swedish Museum of Natural History. "These unusual fossils are exquisitely preserved and reveal a previously hidden record of nannoplankton communities through several past global warming events, showing us that these plankton were more resilient than the traditional fossil record would suggest."

Perfectly visible using powerful microscopes

The researchers discovered the ghost fossils, using powerful microscopes, in rocks from three intervals of rapid warming that took place during the Jurassic and Cretaceous periods, in the age of the dinosaurs. The international team of researchers included Dr. Sam Slater and Prof. Vivi Vajda (Swedish Museum of Natural History), Prof. Paul Bown (University College London), Prof. Silvia Danise (University of Florence) and Prof. Richard Twitchett (Natural History Museum, London).

Despite their microscopic size, when coccolithophores multiply rapidly, they can become so abundant that they form blooms in the ocean that be seen from space. After the plankton die, their exoskeletons sink to the seafloor, accumulating in vast numbers, forming rocks such as chalk.

"The preservation of these ghost nannofossils is truly remarkable," says Prof. Paul Bown. "The ghost fossils are extremely small – their length is approximately five thousandths of a millimetre, 15 times smaller than the width of a human hair! – but the detail of the original plates is still perfectly visible,

even though the plates themselves have dissolved away, so we can easily tell which species were present".

Dissolved fossils left imprints

The ghost fossils formed while the sediments at the seafloor were being buried and turned into rock. As more mud was gradually deposited on top, the resulting pressure squashed the coccolith plates and other organic remains together, and the hard coccoliths were pressed into the surfaces of pollen, spores and other soft organic matter in the sediments. Later, acidic waters inside the pore spaces of the rock dissolved away the hard coccoliths, leaving behind just their impressions – the ghosts.

"Normally, palaeontologists only search for the fossil coccoliths themselves, and if they don't find any then they often assume that these ancient plankton communities collapsed," explains Prof. Vivi Vajda. "These ghost fossils show us that sometimes the fossil record plays tricks on us and there are other ways that these calcareous nannoplankton may be preserved, which need to be taken into account when trying to understand responses to past climate change".

Useful today

Prof. Silvia Danise says, "Ghost nannofossils are likely common in the fossil record, but they have been overlooked due to their tiny size and cryptic mode of preservation. We think that this peculiar type of fossilization will be useful in the future, particularly when studying geological intervals where the original coccoliths are missing from the fossil record".

The study focused on the Toarcian Oceanic Anoxic Event (T-OAE), an interval of rapid global warming in the Early Jurassic (~183 million years ago), caused by an increase in CO_2-levels in the atmosphere from massive volcanism in the Southern Hemisphere. The researchers found ghost nannofossils associated with the T-OAE from the UK, Germany, Japan and New Zealand, but also from two similar global warming events in the Cretaceous: Oceanic Anoxic Event 1a (~120 million years ago) of Sweden, and Oceanic Anoxic Event 2 (~94 million years ago) of Italy.

"The ghost fossils show that nannoplankton were abundant, diverse and thriving during past warming events in the Jurassic and Cretaceous, where previous records have assumed that plankton collapsed due to ocean acidification," explains Prof. Richard Twitchett. "These fossils are rewriting our understanding of how the calcareous nannoplankton respond to warming events."

The study also suggests that the proliferation of plankton throughout the warming events contributed to the development of marine dead zones, regions where oxygen-levels are too low for most species to survive. When planktonic algae bloom, after they die and sink, their decomposition uses up oxygen from the water. In extreme circumstances, this can lead to the development of dead zones. Today, climate change and increased nutrient input into coastal seas from human activity are causing dead zones to expand.

Dr. Sam Slater explains, "The ghost fossils indicate that nannoplankton, as well as other types of algae, fuelled the development of marine dead zones during the Jurassic and Cretaceous warming events. However, these fossils also suggest that in the long-term, nannoplankton likely helped to cool the climate following the warming episodes, by drawing down CO_2 from the atmosphere. The discovery of this global record of ghost fossils further shows us that there are potentially many more cryptic fossil records out there waiting to be found!"

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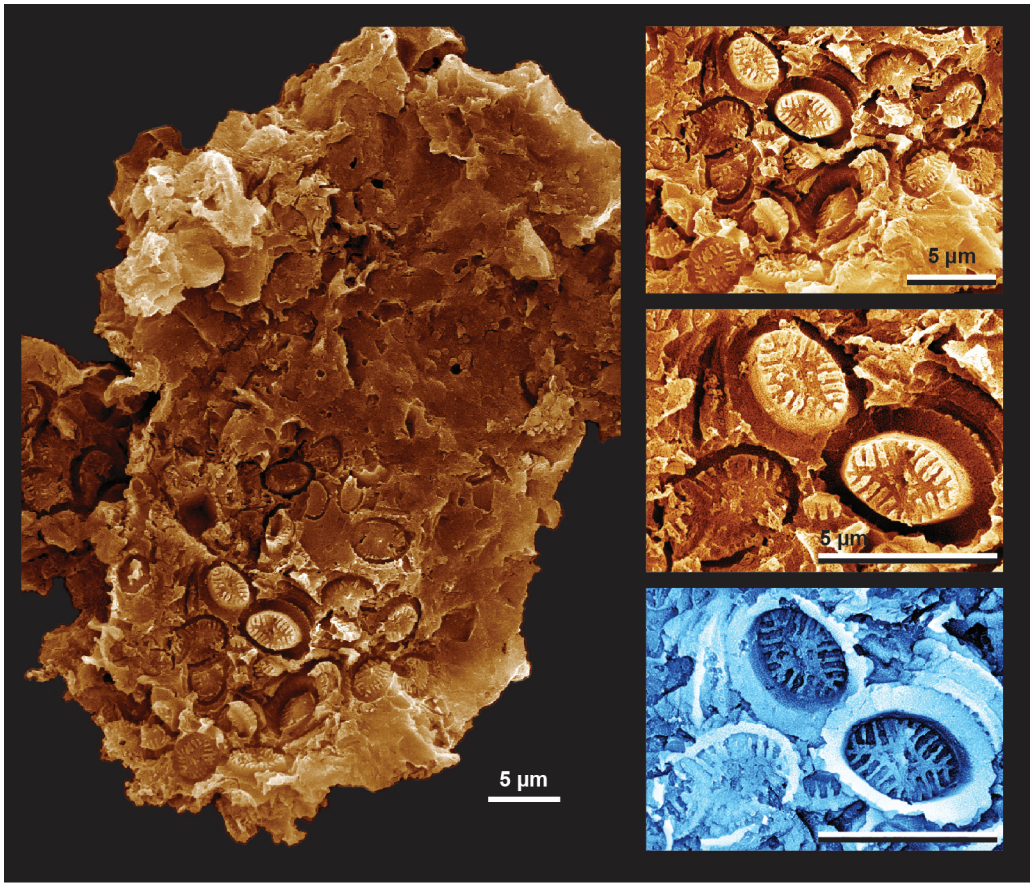
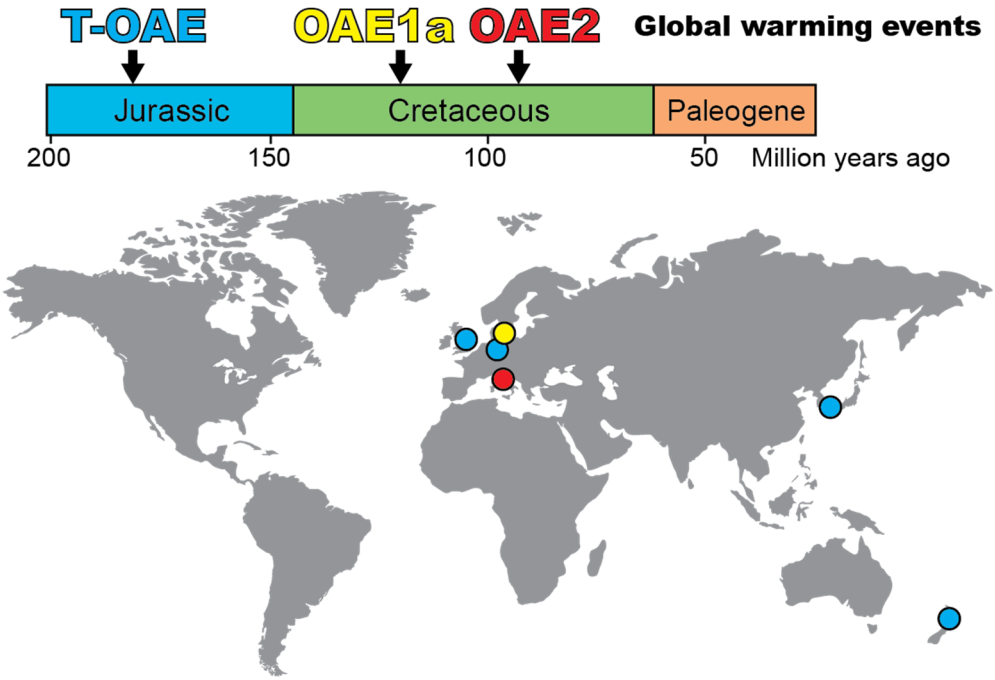
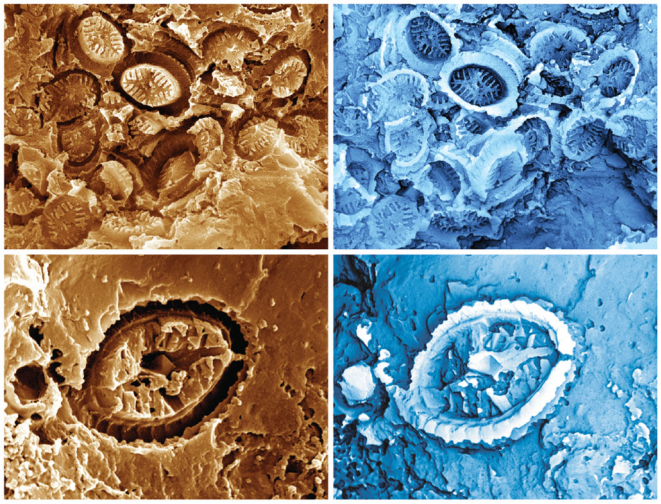


Caption (above): Microscopic plankton cell-wall coverings preserved as "ghost" fossil impressions, pressed into the surface of ancient organic matter (183 million years old). The images show the impressions of a collapsed cell-wall covering (a coccosphere) on the surface of a fragment of ancient organic matter (left) with the individual plates (coccoliths) enlarged to show the exquisite preservation of sub-micron-scale structures (right). The blue image is inverted to give a virtual fossil cast, i.e., to show the original three-dimensional form. The original plates have been removed from the sediment by dissolution, leaving behind only the ghost imprints.

Caption (above): Ghost nannofossil from the Jurassic rocks of Yorkshire, UK.



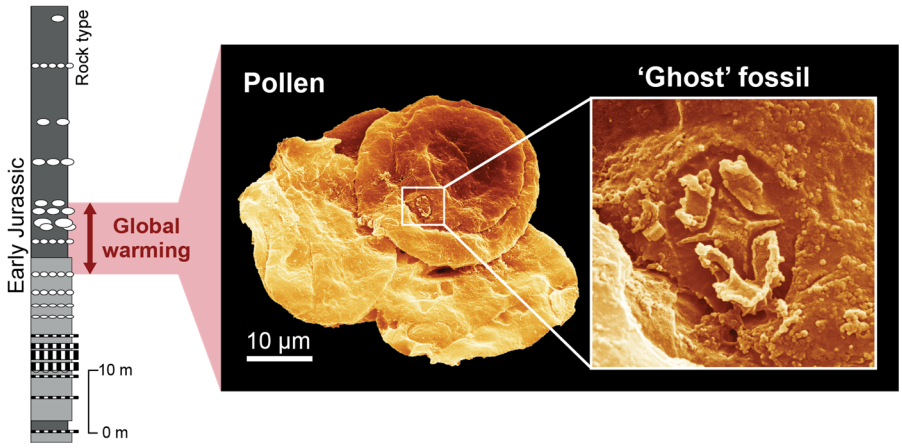
Caption (above): Ghost nannofossils were found globally, in rocks from three rapid warming events in Earth's history (the T-OAE, OAE1a and OAE2).



Caption (above): Ghost nannofossils (left) with virtual casts (right). The fossils are approximately 5 µm in length, 15 times smaller than the width of a human hair.

Caption (above): Modern (left) and Jurassic (right) coccolithophore exoskeletons. The individual plates are coccoliths.

Caption (above): The ghost fossils were found using a scanning electron microscope at the Swedish Museum of Natural History.



Caption (above): Ghost nannofossils were found in rocks from global warming intervals where normal coccolithophore fossils were rare or absent.