LESSONS OF THE PAST

Back to the future:
productivity upheaval in a warming ocean

Helen Neil

Cores of sediment from the ocean floor hold a record of past algal blooms in the ocean. What can this tell us about previous changes to the climate?

WITH CONCERN MOUNTING over global climate change one big question is: what will be the response of the ocean environment to such change?

Some of our best clues come from information on past periods which we know were warmer than today. These periods provide a reference for identifying human-induced change. When making comparisons, scientists must take some key features into account. These are: natural cycles that cause variations in climate; links between the carbon cycle and global temperature (see *Water & Atmosphere 8*(1): 14–16); and the impact of increasing global temperature on ice caps and sea level. Many studies focus on a time around 120,000 years ago – the Last **Interglacial** – when sea level was 4 m higher and temperatures were about 2°C warmer than now.

A New Zealand record

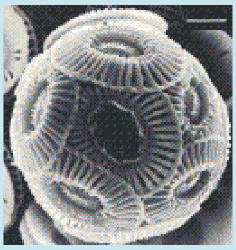
NIWA-based research on waters and sediments on Campbell Plateau, southeast of New Zealand, has shown that during the Last Interglacial this area was bathed by warmer Southern Ocean waters, with sea-surface temperatures up to 2°C higher than present. The area received more heat from the sun and for longer, leading to increased light and **stratification** in surface waters and a very stable water column. The dominant feature of ocean circulation was the **Antarctic Circumpolar Current**, just as it is today. Back then, however, this flow was relaxed, even sluggish, as were the ocean **conveyor belt** and atmospheric winds. Today, Campbell Plateau is a region of quiet circulation that exhibits strong temperature stratification of its surface waters due to seasonal heating in summer.

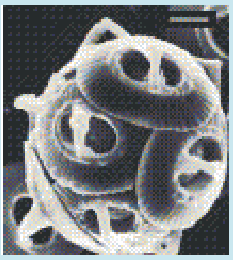
These differences in ocean circulation, temperature and stability may not appear dramatic, but they resulted in a striking change in sediment deposited during that time. Sediment cores retrieved from the Campbell Plateau region contain modern grey-to-brown sediment, rich in the calcium carbonate remains of small marine plankton such as **foraminifera** and **coccolithophores**. (This makes up about 60% of the core.) However, in parts of the core corresponding to the peak of the Last Interglacial the sediment is a distinctive bright, white, sticky deposit composed almost entirely of the carbonate remains of plankton. The debris of coccolithophores increased almost five times. With only a 2°C increase in ocean temperature why should this minute coccolithophore flora bloom and appear to swamp the Campbell Plateau region?

Microscopic climate regulators?

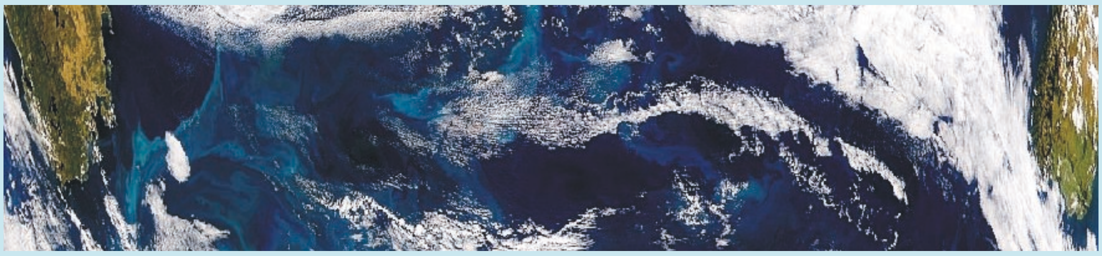
Coccolithophores are microscopic single-celled marine algae, each only about one-hundredth of a mm in diameter. The cells are armoured with intricate carbonate plates known as coccoliths (see photos, left) and drift freely in the upper, sunlit areas of the ocean. In association with other phytoplankton, they form a major food source and the basis of the marine food web (see pages 28–30, this issue). Coccolithophores are abundant all over the world, occurring in all but the cold polar oceans. Their abundance suggests that they may affect climate on a global scale. As the organisms die, the plates accumulate on the bottom of the ocean. Marine sediments and their uplifted ancient counterparts, such as the chalk White Cliffs of Dover, are the resting place of multitudes of once living phyto-plankton, mostly coccolithophores.

Under favourable conditions massive coccolithophore blooms can occur over large expanses of ocean, up to 100,000 km^2. The resulting milky waters contain over 100 million cells per litre (see photo below).





above:
Among living cocco-lithophores, Emiliana huxleyi *(top) has the widest distribution and dominates assem-blages worldwide.* E. huxleyi *may have taken over the niche formerly dominated by* Gephyrocapsa *spp., with* G. oceanica *(bottom) occurring today in inland seas and upwelling regions. Scale bar = 0.001 mm.*



Coccolithophores can thrive when the nutrient phosphate is in short supply in the water, when light intensity is high, and when surface layers are well stratified – all these being responses to calm, sunny weather. These conditions were common across Campbell Plateau during the Last Interglacial, and led to continual annual blooms on a scale not recorded in modern times.

Thus vast quantities of coccoliths accumulated in the Plateau sediments. If a warming climate brought a return of these massive annual blooms would this enhance or reduce global warming?

Coccolithophore cells are major producers of three substances that can affect climate. One of these – calcium carbonate – is discussed below. The others are organic carbon (see pages 28–30, this issue) and **dimethylsulfide (DMS)** – a sulfur bearing gas (see pages 26–27, this issue).

Calcium carbonate and climate

As coccolithophores grow by photosynthesising, they take up carbon dioxide (CO_2) and other chemicals from sea water in order to produce their calcium carbonate armour. During large blooms most of the CO_2 in the surface waters is used up. To compensate, the ocean absorbs more CO_2 from the atmosphere, thus reducing one agent of global warming. Much of this CO_2 is returned to the atmosphere when the cells die and decompose within the surface waters. However, a small percentage of the plates sinks into the deep ocean and can remain out of contact with the atmosphere for 1,000 years or so. An even smaller fraction sinks to the seafloor and becomes part of the sediment cover and, ultimately, becomes rock, which may remain out of the atmosphere for millions of years. Taking this process into account alone, coccolithophore blooms apparently cause a small net loss of CO_2 from the atmosphere.

But there are many twists to this tale of the microscopic climate regulator. Coccoliths can act as minute mirrors reflecting heat and light. This has two effects. First, they reflect sunlight back into the atmosphere. Second, they trap more heat in the ocean's surface rather than allowing the heat to mix into deeper water. Hence, over a long period, coccolithophore blooms may cool the overall water column. A similar negative feedback is the emission of DMS (see page 27, this issue). On the other hand, during the process of locking carbon into solid calcium carbonate plates, dissolved CO_2 is also released into the ocean's surface waters. This means that coccolithophore blooms might enhance global warming by increasing atmospheric CO_2 rather than decreasing it by trapping dissolved CO_2.

Whatever the case, coccolith plates are very dense and sink rapidly, along with other organic matter adhered to their surfaces. This provides a faster-than-normal exit for carbon from surface to deep waters and may offset the CO_2 increase caused by the bloom. In fact, blooms of coccolithophores may oppose global warming, rather than to intensify it.

Coccolithophores in a warming world

Will the large and natural oscillations of climate eventually override global warming and plummet us back into a cooler age? Or will the effects of anthropogenic emissions increase the rate of change, forcing us towards a climate similar to 120,000 years ago and a recurrence of massive blooms of coccolithophores? Would the occurrence of large blooms of phytoplankton in the future reduce or increase warming? These are burning issues that need to be answered with continued research of modern and past ocean cycling systems. ■

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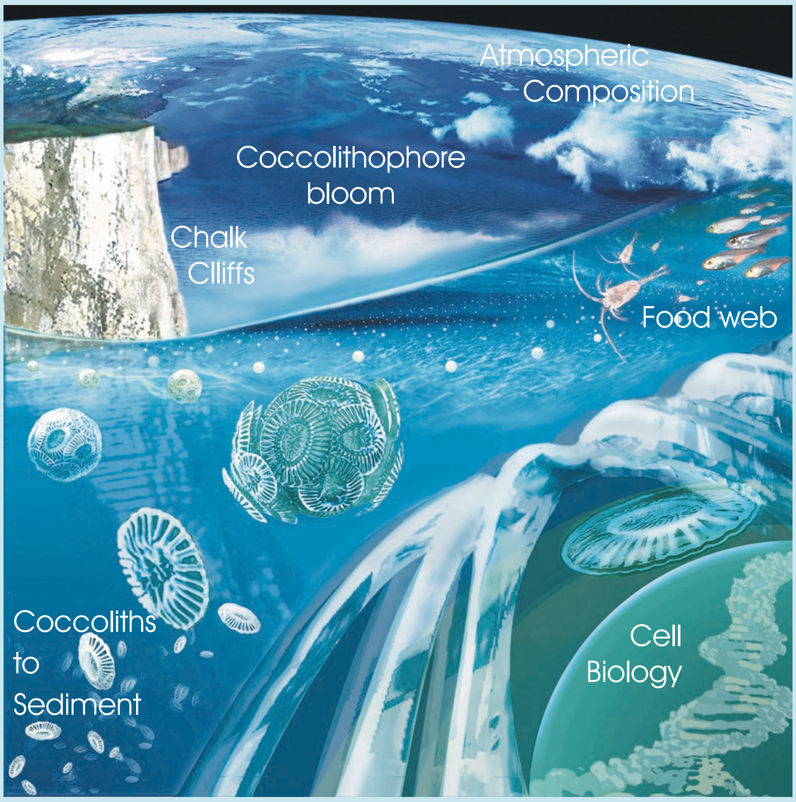
For explanations of words in **bold** in the text, refer to Glossary on page 31.

left:
Pale milky swirls of a coccolithophore bloom, probably Emiliana huxleyi, *on the ocean surface beneath the cloud cover between Tasmania and New Zealand on 17 January 1999. The swirls reflect the physical nature of the surface water masses. (Image from SeaWiFS, NASA)*



Coccolithophore blooms remove dissolved CO_2 and nutrients from the water, at the same time introducing other products such as dimethylsulfide (DMS) into the water, which feed through to the atmosphere. The marine food web processes the coccolithophores, subsequently pumping large volumes of organic matter and calcium carbonate into the deep ocean and to the ocean floor, where the calcium carbonate eventually ends up as marine sedimentary rocks. (Copyright Glynn Gorick, www.gorick.u-net.com)