

What triggered the onset of the northern hemisphere glaciation 2.7 million years ago? **Melanie Leng** and **Hilary Sloane** with colleagues **George Swann** and **Mark Maslin** (University College London) have evidence that conditions in the Pacific Ocean played a significant part.

# How an ice age began

During much of the Earth's recent geological history, the northern hemisphere has remained warm compared to the modern day. The first recorded glaciation in the northern hemisphere occurred in Greenland between 10 and 6 million years ago. From this point, a period of gradual global climatic cooling began. This culminated about 2.7 million years ago with a sudden intensification of ice ages which resulted in the growth of ice sheets over the northernmost areas of both North America and Eurasia.

Scientists hypothesise that the climate transition known as the onset of the major northern hemisphere glaciation was caused by long-term changes in the Earth's tectonic plates. The cooling resulted from the closure of the Panama ocean gateway between North and South America, together with natural decreases in the amount of solar radiation received by the Earth. The latter could have been caused by changes in the tilt of the Earth's axis and the distance from the Earth to the Sun during the summer months. What remains unknown about this period is where all the water and snow came from to build the huge expanses of ice in North America.

We analysed fossil diatoms — small algae that have lived in the surface waters of the Pacific Ocean for millions of years — to see if we could find an answer. The fossils contain two major oxygen isotopes, the ratio of these isotopes tells us about the oxygen isotope composition of the water in which the diatoms lived. Changes within this ratio

in the ocean water are directly related to changes in the ocean's temperature and

salinity, which is largely controlled by glacial–interglacial cycles.

The oxygen isotope compositions of 2.7 million-year-old diatoms from the north-west Pacific Ocean reveal that the ocean became significantly warmer and less salty during the autumn and early winter months. These unusual results contrast with previous ideas which



*The extraction of the oxygen isotopes from diatom silica ( $\text{SiO}_2 \cdot n\text{H}_2\text{O}$ ) involves using readily reactive chemicals and high temperatures to disassociate the oxygen (O) from the silicon (Si). The process is done in an airtight stainless steel vessel and the oxygen gas is purified by moving it along a series of tubes where waste compounds formed in the reaction are removed. The oxygen isotope composition of the purified gas is measured by mass spectrometry.*

## Diatoms

Diatoms are photosynthetic algae (from 2 to 200 microns in size) that form a shell, or frustule, composed of opaline or biogenic silica ( $\text{SiO}_2 \cdot n\text{H}_2\text{O}$ ). Diatoms are ubiquitous in most aquatic environments (rivers, lakes, oceans) wherever the macronutrients of silica (Si), nitrogen (N) and phosphorus (P) are sufficient to sustain productivity. Diatoms are successful in turbulent water where their buoyant cells, often augmented by free-floating organic threads, enable them to keep within the photic zone better than many other algae. Some species are able to withstand deep mixing and low light levels. A survival strategy used by diatoms is to produce long-lived resting spores to buffer environmental deterioration. Diatoms are found in a variety of life forms including free-floating planktonic, benthic and attached to rocks and plants. Diatom productivity follows a seasonal pattern, controlled by the variability of climate, nutrient supply, mixing regimes, and in northern latitudes the period of ice cover. Diatoms will therefore acquire their isotope signature during their major growing seasons.

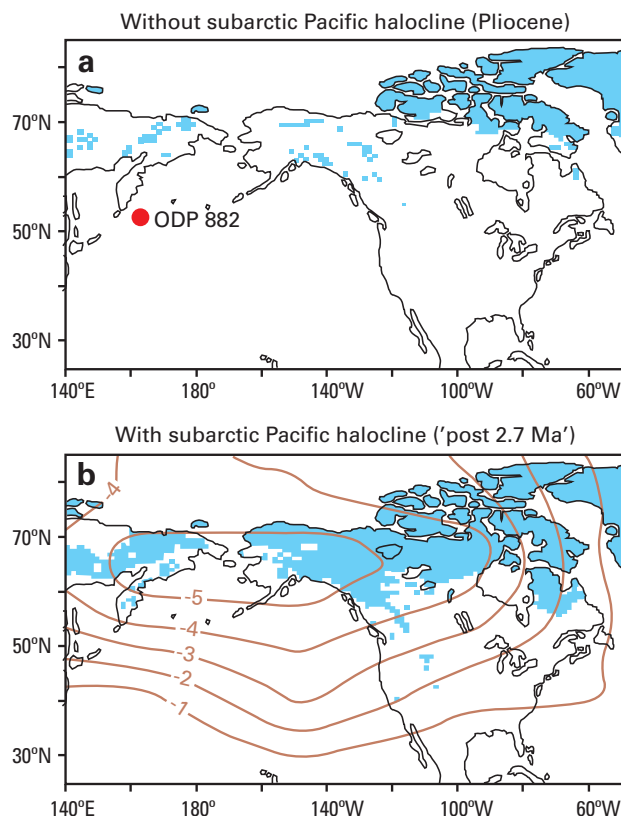


*The diatom frustule Coscinodiscus radiatus found in marine sediments at the onset of the northern hemisphere glaciation. (Reproduced with permission from George Swann).*

suggested that the oceans might have been significantly colder at this time.

The new data help to explain how more rain came to fall on North America. The fresher water in the region, which mainly originated from newly formed ice-sheets, would have floated on top of the salty seawater. This would have caused the ocean to stratify with freshwater lying on top of the more salty water. If the two layers did not mix, the top fresher layer would have warmed and, critically, would then have stayed relatively warm until the late autumn or early winter months. This warmer water would also evaporate more easily than cold water, increasing the air moisture content in this region. Winds would have carried the moisture eastwards

## Model ice-sheet development



*Extent of permanent snow cover (blue) in North America prior to the development of the halocline in the north-west Pacific (a) and following the development of the halocline stratification in the north-west Pacific (b). Marine sediments for this study were collected from ODP site 882. (Figure based on Haug, G H, et al., Nature, 433, 821–825).*

towards North America, bringing increased rain and snow to feed the region's ice sheets and make them grow.

## Isotopes

The oxygen isotope composition (ratio of  $^{16}\text{O}/^{18}\text{O}$ ) of diatom frustules is a function of the ocean water's temperature and salinity. The relationship with temperature is well understood, the diatom–water fractionation, for example, is about  $-0.2\text{‰}^{\circ}\text{C}^{-1}$ . Decreases in the isotope composition occur during warm periods, while increases occur in cooler periods.

It seems, therefore, that the moister air originating from the North Pacific combined with colder winters were the triggers for the huge expansion of ice-sheets across the North American continent. Thus, it seems that processes in the north-west Pacific Ocean were the triggers for the onset of the northern hemisphere glaciation.

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