Early initiation of Arctic sea-ice formation

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Significant sea ice formation occurred in the Arctic earlier than previously thought is the conclusion of a study published this week in *Nature*. "The results are also especially exciting because they suggest that sea ice formed in the Arctic before it did in Antarctica, which goes against scientific expectation," says scientific team member Dr Richard Pearce of the University of Southampton's School of Ocean and Earth Science based at the National Oceanography Centre, Southampton (NOCS).

The international collaborative research team led by Dr Catherine Stickley and Professor Nalân Koç of the University of Tromsø and Norwegian Polar Insitute (Tromsø) analysed oceanic sediment cores collected from the Lomonosov ridge in the central Arctic by Integrated Ocean Drilling Program Expedition 302 ('ACEX'). Previous analyses of cores drilled in this region revealed ice-rafted debris dating back to the middle Eocene epoch, prompting suggestions that ice appeared in the Arctic about 46 million years ago. But records of ice-rafted debris do not differentiate sea ice from glacial (continental) ice, which is important because sea ice influences climate by directly affecting ocean-atmosphere exchanges, whereas land-based ice affects sea level and consequently ocean acidity.

Instead of focusing solely on ice-rafted debris, Stickley and her colleagues also garner information about ancient climate by analysing fossilised remains of tiny single-celled plants called diatoms in the sediment cores. Today, different living diatom species are adapted to particular environmental conditions. Assuming that this was also true in the past - for which there is ample evidence - the presence of particular diatom species in sediment cores is diagnostic of conditions prevailing at the time.

Coincident with ice-rafted debris in the cores, the researchers found high abundances of delicately silicified diatoms belong to the genus *Synedropsis*. "We were astonished by this", said team member Richard Pearce of NOCS, who imaged the samples using a scanning electron microscope at the NOCS: "Weakly silicified diatoms are preserved only under exceptional circumstances, so to find fossilised *Synedropsis* species so well preserved and in such abundance is truly remarkable." In fact, the ACEX *Synedropsis* species represent the earliest known fossil record of sea-ice diatoms.

The researchers attribute the presence of *Synedropsis* fossils in these sediments to the presence of sea ice, and silica-enriched waters that favour their preservation. They propose that, like *Synedropsis* species found in polar regions today, the ACEX species were also sea-ice specialists uniquely adapted for surviving the lengthy polar darkness and freezing temperatures. "These diatoms provide the most compelling evidence for ancient sea ice, as they rely on this medium for their survival," said Catherine Stickley. Moreover, their analysis of quartz grain textural characteristics further supports sea ice as the dominant transporter of ice-rafted debris at this time.

"It is likely that sea ice formed in autumn and winter and melted in spring and summer, as seasonal sea ice does today," they say. *Synedropsis* species probably over-wintered within the sea ice and then bloomed there in the spring when there was enough sunlight. They would have been released into stratified surface waters as the ice melted, rapidly sinking to the sea bottom as aggregates, leaving other diatom species to dominate summer production. And, indeed, these seasonal changes can be discerned in the sediment cores.

The researchers conclude from their analysis, which cover a two-million year period, that episodic sea ice formation in marginal shelf areas of the Arctic started around 47.5 million years ago, about a million years earlier than previous estimates based on ice-raft debris evidence only. This appears to have been followed half a million years later by the onset of seasonal sea-ice formation in offshore areas of the central Arctic, and about 24 million years before major ice-sheet expansion in the region.

The findings have potentially important implications for climate. Spring sea ice and summer cloud formation would have reduced oceanic heat loss to the atmosphere and increased the amount of solar radiation reflected back out into space. "A stable sea-ice regime also suggests the possibility of concomitant glacial ice," say the researchers, and indeed they find some evidence for the presence of small isolated glaciers at the time.

Furthermore, their data indicate that sea ice formed in the Arctic before it did in Antarctica. Atmospheric levels of the greenhouse gas carbon dioxide were declining in the middle Eocene, one of the reasons postulated in causing the Earth to cool. However, the new findings imply that the threshold for sea-ice formation was first crossed in the Arctic, which, say the authors, is "a hypothesis opposite to that modelled for glacial ice, whereby Antarctica is shown to glaciate much earlier (that is, at higher levels of carbon dioxide) than circum-Arctic continents."

Source: National Oceanography Centre, Southampton