The Arctic Ocean was covered by a shelf ice and filled with freshwater

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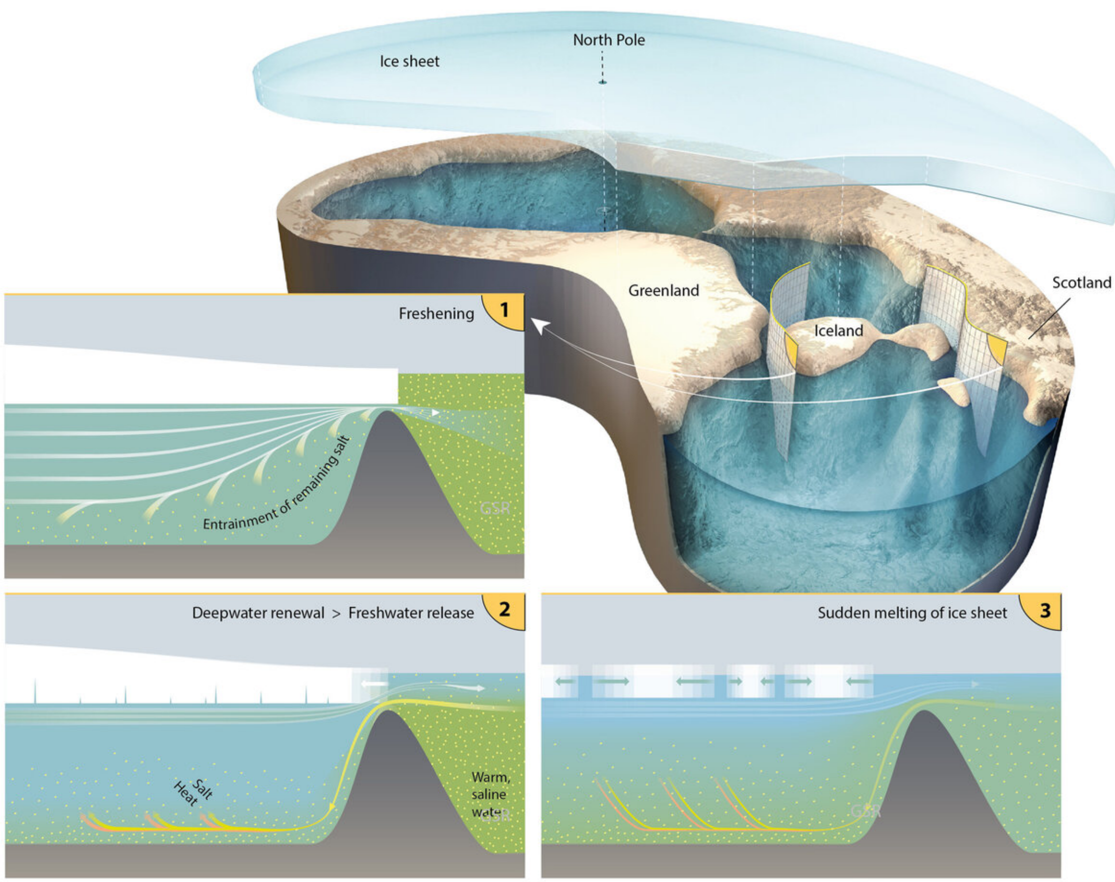

In glacial periods with low sea levels, exchange with the Pacific was halted and exchange with the North Atlantic was extremely reduced, while the Arctic basin was still receiving freshwater input. Exchange could only occur through narrow gateways in the Greenland-Scotland-Ridge. The sequence of three sketches shows (1) a period of freshening of the Arctic Ocean followed by (2) the release of freshwater to the North Atlantic, when saline water entered the Arctic Ocean and (3) sudden melting of the Arctic ice sheet upon contact with the relatively warm and salty Atlantic water. Credit: Alfred Wegener Institute/Martin Künsting

The Arctic Ocean was covered by up to 900-meter-thick shelf ice and was filled entirely with freshwater at least twice in the last 150,000 years. This surprising finding, reported in the latest issue of the journal *Nature*, is the result of long-term research by scientists from the Alfred Wegener Institute and the MARUM. With a detailed analysis of the composition of marine deposits, the scientists could demonstrate that the Arctic Ocean as well as the Nordic Seas did not contain sea-salt in at least two glacial periods. Instead, these oceans were filled with large amounts of freshwater under a thick ice shield. This water could then be released into the North Atlantic in very short periods of time. Such sudden freshwater inputs could explain rapid climate oscillations for which no satisfying explanation had been previously found.

About 60,000 to 70,000 years ago, in a particularly cold part of the last glacial period, large parts of Northern Europe and North America were covered by ice sheets. The European ice sheet spanned a distance of more than 5000 kilometers, from Ireland and Scotland via Scandinavia to the Eastern rim of the Kara Sea (Arctic Ocean). In North America, large parts of what is now known as Canada were buried under two large ice sheets. Greenland and parts of the Bering Sea coastline were glaciated too. What was the ice situation like even further North, in the Arctic Ocean? Was it covered by thick sea-ice, or maybe with the tongues of these vast ice sheets were floating on it, far beyond the North Pole?

Scientific answers to these questions have been more or less hypothetical so far. In contrast to deposits on land, where erratic boulders, moraines and glacial valleys are the obvious landmarks of glaciers, only few traces of vast ice shelves had been found so far in the Arctic Ocean. Geoscientists from the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI) and MARUM Center for Marine Environmental Sciences at the University of Bremen have now compiled existing evidence from the Arctic Ocean and the Nordic Seas, and combined it with new data to arrive at a surprising conclusion.

According to their study, the floating parts of the northern ice sheets covered large parts of the Arctic Ocean in the past 150,000 years. Once about 70,000-60,000 years ago and also about 150,000-130,000 years ago. In both periods, freshwater accumulated under the ice, creating a completely fresh Arctic Ocean for thousands of years.

"These results mean a real change to our understanding of the Arctic Ocean in glacial climates. To our knowledge, this is the first time that a complete freshening of the Arctic Ocean and the Nordic Seas has been considered—happening not just once, but twice," says the first author, Dr. Walter Geibert, geochemist at the Alfred Wegener Institute.

Thorium is absent in the sediments, so saline water must have been absent

Their finding is based on geological analyses of ten sediment cores from different parts of the Arctic Ocean, Fram Strait and the Nordic Seas. The stacked deposits mirror the climate history of the past glacials. When investigating and comparing the sediment records, the geoscientists found that an important indicator was missing, always in the same two intervals. "In saline sea water, the decay of naturally occurring uranium always results in the production of the isotope thorium-230. This substance accumulates at the sea floor, where it remains detectable for a very long time due to its half-life of 75,000 years," Walter Geibert explains.

Therefore, geologists often use this thorium-isotope as a natural clock. "Here, its repeated and wide-spread absence is the giveaway that reveals to us what happened. According to our knowledge, the only reasonable explanation for this pattern is that the Arctic Ocean was filled with freshwater twice in its younger history- in frozen and liquid form," co-author and micropalaeontologist Dr. Jutta Wollenburg, also from the AWI, explains.

A new picture of the Arctic Ocean

How can a large ocean basin, connected by several straits with the North Atlantic and the Pacific Ocean, turn entirely fresh? "Such a scenario is perceivable if we realize that in glacial periods, global sea levels were up to 130 m lower than today, and ice masses in the Arctic may have restricted ocean circulation even further," states co-author Professor Ruediger Stein, geologist at the AWI and the MARUM.

Shallow connections like Bering Strait or the sounds of the Canadian Archipelago were above sea level at the time, cutting off the connection with the Pacific Ocean entirely. In the Nordic Seas, large icebergs or ice sheets extending onto the sea floor restricted the exchange of water masses. The flow of glaciers, ice melt in summer, and rivers draining into the Arctic Ocean kept delivering large amounts of fresh water to the system, at least 1200 cubic kilometers per year. A part of this amount would have been forced via the Nordic Seas through the sparse narrow deeper connections in the Greenland-Scotland Ridge into the North Atlantic, hindering saline water from penetrating further north. This resulted in the freshening of the Arctic Ocean.

"Once the mechanism of ice barriers failed, heavier saline water could fill the Arctic Ocean again," Walter Geibert says. "We believe that it could then quickly displace the lighter freshwater, resulting in a sudden discharge of the accumulated amount of freshwater over the shallow southern boundary of the Nordic Seas, the Greenland-Scotland-Ridge, into the North Atlantic."

A concept that assumes that enormous amounts of freshwater were stored in the Arctic Ocean and available for rapid release would help understanding the connection between a range of past climate fluctuations. It would also offer an explanation for some apparent discrepancies between different ways of reconstructing past sea levels. "The remains of coral reefs have pointed to a somewhat higher sea level in certain cold periods than reconstructions from Antarctic ice cores, or reconstructions from the calcareous shells of small marine organisms, would suggest," explains Walter Geibert. "If we now accept that freshwater may not only have been stored in solid form on land, but some of it also in liquid form in the ocean, the different sea level reconstructions agree better and we can reconcile the location of the coral reefs with calculations of the freshwater budget."

Freshwater release from the Arctic Ocean might also serve as an explanation for some abrupt climate change events during the last glacial period. During such events, temperatures in Greenland could rise by 8-10 degree centigrade within a few years, only returning to the original cold glacial temperatures over the course of hundreds or thousands of years. "We see an example here of a past Arctic climate tipping point of the Earth system. Now we need to investigate in more detail how these processes were interconnected, and evaluate how this new concept of the Arctic Ocean helps in closing further gaps in our knowledge, in particular in view of the risks of manmade climate change," says Walter Geibert.

More information: Glacial episodes of a freshwater Arctic Ocean covered by a thick ice shelf, *Nature* (2021). DOI: 10.1038/s41586-021-03186-y , www.nature.com/articles/s41586-021-03186-y

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