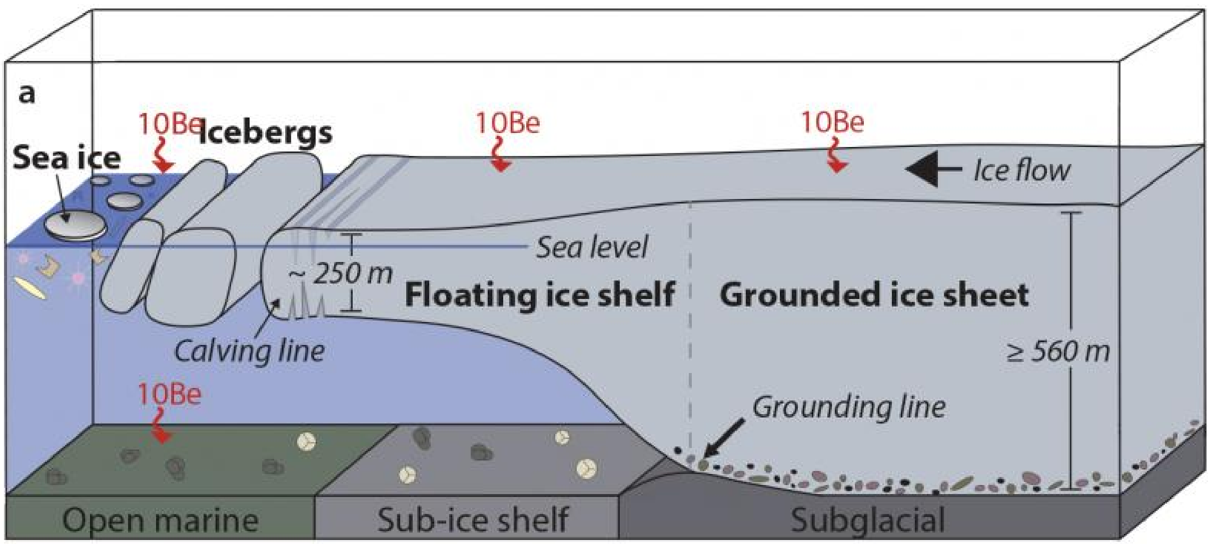
Colossal Antarctic ice-shelf collapse followed last ice age

February 18 2016



This infographic depicts a grounded ice sheet (right), floating ice shelf (center) and open sea that is partially covered by ice (left). The isotope beryllium-10 (10Be) forms in the atmosphere and does not fall to the seafloor beneath ice shelves or ice sheets. Credit: L. Simkins/Rice University

In a new study that provides clues about how Antarctica's nation-sized Ross Ice Shelf might respond to a warming climate, U.S. and Japanese oceanographers have shown that a 100,000-square-mile section of the ice shelf broke apart within 1,500 years during a warming period after the last ice age.

The Ross Ice Shelf is the world's largest ice shelf, a vast floating extension of the West Antarctic Ice Sheet that is about the size of France. But at the end of the last ice age, it extended much farther north and covered the entire Ross Sea.

A study in this week's *Proceedings of the National Academy of Sciences* details how the ice shelf shrank during a period of climate warming following the ice age. The paper was co-authored by Rice University oceanographer John Anderson, postdoctoral research associate Lauren Simkins, graduate student Lindsay Prothro and colleagues at the University of Tokyo.

"At the height of the last ice age, we know that the sheet of ice covering the Antarctic continent was larger and thicker than it is today," said Anderson, Rice's Maurice Ewing Professor of Oceanography and professor of Earth science. "This continent-enveloping ice sheet extended all the way to the continental shelf, and in western Antarctica it filled the entire Ross Sea basin."

While people typically think of continents as landmasses that rise above the sea, the margins of all continents, including Antarctica, extend well beyond their shores to include continental shelves, subsea aprons that are far more shallow than the deep ocean abysses that mark the continental boundary.

Rice University students Brian Demet (left) and Ruthie Halberstadt study a seafloor sediment sample aboard the NSF research vessel Nathaniel B. Palmer in the Ross Sea in 2015. Credit: L. Simkins/Rice University

In western Antarctica, the Ross Sea is characterized by a continental shelf that extends nearly 1,000 miles from the coast and is as much as 3,500 feet deep. Anderson said the geologic record shows that as recently as 18,000 years ago the entire Ross basin was filled with ice that was so thick and heavy it was grounded on the seafloor all the way to the edge of the continental shelf.

"We found that about 10,000 years ago, this thick, grounded ice sheet broke apart in dramatic fashion," Anderson said. "The evidence shows that an armada of icebergs—each at least twice as tall as the Empire

State Building—was pushed out en masse. We know this because this part of the Ross Sea is about 550 meters (1,804 feet) deep, and the icebergs were so large and so tightly packed that they gouged huge furrows into the seafloor as they moved north."

Researchers measured the furrows using a seafloor mapping system—the most sensitive ever employed in the Antarctic—during a 2015 cruise by the U.S. research vessel Nathaniel B. Palmer, which is operated by the National Science Foundation.

Simkins, who helped gather data during the 56-day cruise, said other features preserved on the seafloor, formed by the retreating ice, showed that the margin of the grounded ice sheet retreated rapidly after the initial collapse and fell back hundreds of miles in stair-step fashion.

The Ross Ice Shelf appeared after the breakup of the ice sheet. An ice shelf is the floating, seaward extension of an ice sheet and marks the point at which the ice is thin enough to float.

"The grounding line is the location where the ice actually sits on the seafloor," Simkins said. "Following ice-shelf break up, the grounding line is left exposed to marine processes, such as ocean warming, which can erode the grounding line and cause it to move back toward the shore."

The retreat was halted when the grounding line reached a series of shallow banks that acted as anchors and stabilized the ice shelf for about 5,000 years.

Anderson said, "Throughout this period, the ice shelf was pinned atop these shallow banks. On the surface, ice still covered large portions of the Ross Sea, but there was open water beneath the ice shelf."

The researchers know the times when the seafloor was partially or fully ice-covered, thanks to painstaking geochemical analyses of seafloor sediments that were overseen by study lead author Yusuke Yokoyama, a professor at the University of Tokyo who was also a Wiess Visiting Professor in Rice's Department of Earth Science in 2014-2015. The geochemical analyses also relied on evidence gathered by the Palmer, which is capable of drilling and recovering sediment cores from the seafloor. Such cores contain a geological record that can extend thousands of years, and Yokoyama's team used Ross Sea core samples that were recovered during a 1999 Palmer cruise as well as 2015 cores and seafloor imagery to pinpoint the timing of the ice-shelf breakup.

"The really big breakup began around 3000 B.C.," Anderson said. "We believe it was similar, in many respects, to the breakup of the Larsen B Ice Shelf in 2002. The Larsen is far smaller than the Ross Ice Shelf, but satellite imagery that year showed the Larsen dramatically breaking apart in just a few weeks. We believe the large breakup of the Ross Ice Shelf occurred at roughly this same pace, but the area involved was so much larger—about the size of the state of Colorado—that it took several centuries to complete."

A sediment core from the Ross Sea floor is raised onto the deck of the NSF research vessel Nathaniel B. Palmer in 2015. Credit: L. Simkins/Rice University

By 1500 B.C. the breakup had exposed about 100,000 square miles of the Ross Sea that had been either wholly or largely ice-covered for many millennia, Anderson said.

To pinpoint the timing, Yokoyama's team used two novel geochemical approaches: measurement of the isotope beryllium 10, which forms in the atmosphere and does not fall to the seafloor beneath ice shelves, and "compound-specific radiocarbon dating," a painstaking technique that involves identifying and ascertaining the age of specific organic molecules in sediments. Yokoyama said each compound-specific radiocarbon dating measurement took several weeks to perform, and more than a dozen were needed for the study, which marked the first systematic use of the technique in Antarctic science.

"Our radiocarbon dating work alone took more than a year to complete," Yokoyama said. "The results of those tests, as well as the beryllium tests, provided conclusive evidence that the main breakup of the ice shelf occurred between 5,000 and 3,500 years ago."

Anderson said knowledge about the past behavior of the ice sheet and ice shelf, in particular their rate of response to atmospheric and oceanic warming, informs scientists about how present-day ice sheets and ice shelves may respond to future warming.

"There are similarities to what we see the modern Ross Ice Shelf doing," Anderson said. "The farthest boundary of the ice shelf extends nearly 1,000 kilometers (621 miles) from the grounding line, where the ice sheet is grounded in about 800 meters (2,625 feet) of water. That's a condition that most glaciologists consider unstable, and it is not unlike the situation that existed prior to the big breakup that began 5,000 years ago."

The present Ross Ice Shelf is about 500 miles wide and several hundred feet thick. Because the ice shelf is already floating, its breakup and melting would not, by itself, pose a risk of raising global sea level, Anderson said. However, he pointed out that the ice shelf acts as a brake to dozens of Antarctic ice streams and outlet glaciers, and ice flowing into the ocean from those would contribute to global sea level rise.

"The ice shelf slows the flow of grounded ice from the glaciers, and as we saw after the Larsen B breakup, once you pull the stopper out of the bottle, the glaciers move much faster, in some cases about 10 times faster," Anderson said.

More information: Yusuke Yokoyama et al. Widespread collapse of the Ross Ice Shelf during the late Holocene, *Proceedings of the National Academy of Sciences* (2016). DOI: 10.1073/pnas.1516908113

Provided by Rice University