PRESS RELEASE

Toyama, December 23, 2025

Clues from the Past Reveal the West Antarctic Ice Sheet's Vulnerability to Warming

Ancient sediment records show the ice sheet retreated at least five times during warmer periods millions of years ago

A record of repeated retreat of the West Antarctic Ice Sheet during the past warm climates has been identified by IODP Exp379 Scientists. By analyzing deep-sea sediments from the Amundsen Sea and tracing their geochemical signatures, the study shows that the ice sheet retreated far inland at least five times during the warm Pliocene Epoch. The findings highlight the ice sheet's sensitivity to warming and its potential to drive future sea-level rise.

The Thwaites and Pine Island glaciers, located in the Amundsen Sea sector of the West Antarctic Ice Sheet (WAIS), are among the fastest-melting glaciers on Earth. Together, they are losing ice more rapidly than any other part of Antarctica, raising serious concerns about the long-term stability of the ice sheet and its contribution to future sea-level rise.

To better understand the risks that warmer conditions pose to the WAIS, researchers are looking back to the Pliocene Epoch (5.3–2.58 million years ago), when global temperatures were about 3–4 °C higher than today and sea levels stood more than 15 meters higher, with melted ice from Antarctica contributing to much of that rise.

Now, examining a deep-sea sediment from this region, researchers from the IODP Exp379 Scientists, found that the WAIS margin retreated far inland at least five times during the Pliocene period.

The study was led by Professor Keiji Horikawa from the Faculty of Science, University of Toyama, Japan, and included Masao Iwai (Kochi University), Claus-Dieter Hillenbrand (British Antarctic Survey), Christine S. Siddoway (Colorado College), and Anna Ruth Halberstadt (University of Texas at Austin). The findings, made available online on December 22, 2025, and published in Vol. 123 of the journal *PNAS* on January 6, 2026, highlight the vulnerability of the WAIS to future warming.

"We wanted to investigate whether the WAIS fully disintegrated during the Pliocene, how often such events occurred, and what triggered them," says Prof. Horikawa.

The team analyzed marine sediments collected during the IODP Expedition 379. The sediments recovered from the Site U1532 on the Amundsen Sea continental rise act as a historical archive, recording changes in ice sheets and ocean conditions over millions of years.

They identified two distinct sediment layers reflecting alternating cold and warm climate phases: thick, gray, and finely laminated clays from cold glacial periods, when ice extended across much of the continental shelf; and thinner, greenish layers formed during warmer interglacial periods. The green color comes from the microscopic algae, indicating open, ice-free ocean waters. Crucially, these warm-period layers also contain iceberg-rafted debris (IRD), small rock fragments carried by icebergs, that broke off from the Antarctic continent. As these icebergs drifted across the Amundsen Sea and melted, they released this debris onto the seafloor.

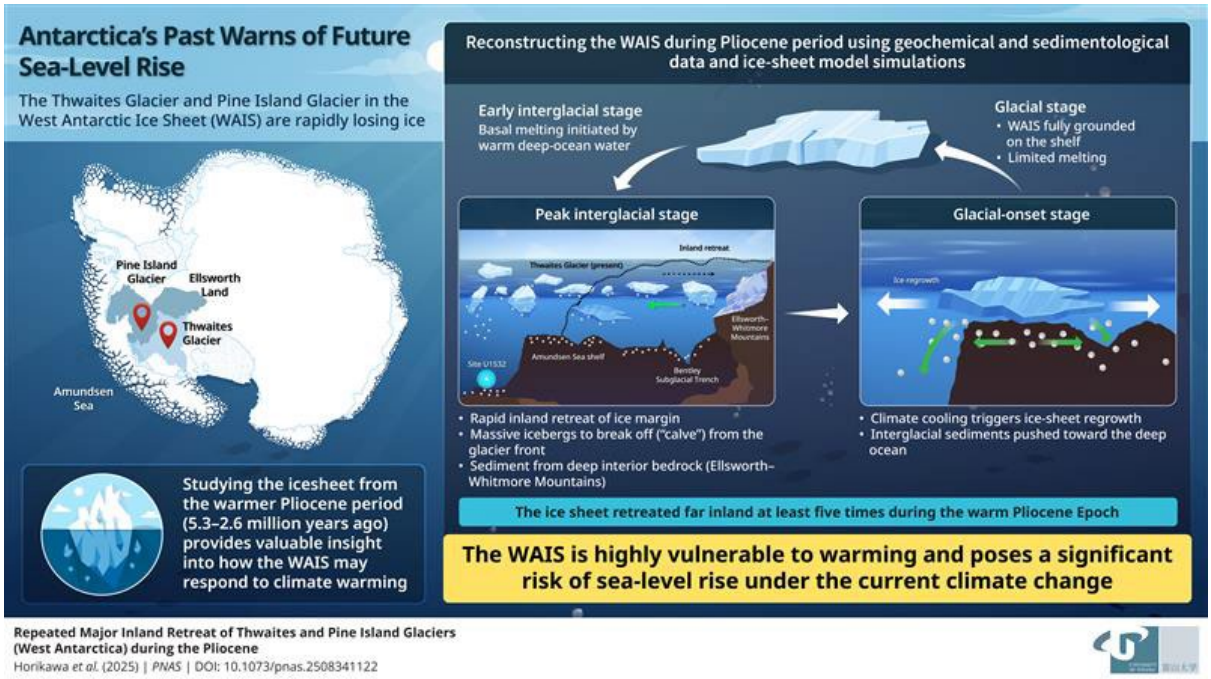
The team identified 14 prominent IRD-rich intervals between 4.65 and 3.33 million years ago, each interpreted as a major melt event when the WAIS partially retreated.

To determine how far inland the ice had retreated, the researchers analyzed the chemical "fingerprints" of the sediments. They measured isotopes of strontium, neodymium, and lead, which vary depending on the age and type of the source rock. By comparing these signatures with those of modern seafloor sediments and bedrock samples from across West Antarctica, the team traced much of the debris to the continental interior, particularly the Ellsworth-Whitmore Mountains.

The sediment record reveals a consistent four-stage cycle of warming and cooling. During cold glacial periods, the ice sheet was extensive and stable, covering the continent. As the climate warmed, during the early interglacial stage, basal melting began, leading to the inland retreat of the ice sheet. At peak warmth, during the peak interglacial stage, large icebergs calved from the retreating ice margin and transported sediment from the Antarctic interior across the Amundsen Sea. As temperatures cooled again, during the glacial-onset stage, the ice sheet rapidly regrew, pushing previously deposited sediments toward the shelf edge and transporting them further downslope into deeper waters.

"Our data and model results suggest that the Amundsen Sea sector of the WAIS persisted on the shelf throughout the Pliocene, punctuated by episodic but rapid retreat into the Byrd Subglacial Basin or farther inland, rather than undergoing permanent collapse," says Prof. Horikawa

The findings indicate that the WAIS has undergone retreats far beyond its current extent, underscoring its extreme vulnerability to future warming and its potential to drive substantial sea-level rise.



Title: Tracking the West Antarctic Ice Sheet during the Pliocene
Caption: By studying Pliocene sediments deposited when Earth was warmer than today, the researchers found that the West Antarctic Ice Sheet retreated far inland at least five times. These findings provide critical insight into how the ice sheet may respond to ongoing climate warming and the potential scale of future sea-level rise.
Credit: Professor Keiji Horikawa from the University of Toyama, Japan
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Reference

Title of original paper: Repeated major inland retreat of Thwaites and Pine Island glaciers (West Antarctica) during the Pliocene

Journal: *PNAS*

DOI: 10.1073/pnas.2508341122

Additional information for EurekAlert

Latest Article Publication Date:	6 January 2026
Method of Research:	Observational study
Subject of Research:	Not Applicable
Conflicts of Interest Statement:	The authors declare no competing interest.

About University of Toyama, Japan

University of Toyama is a leading national university located in Toyama Prefecture, Japan, with campuses in Toyama City and Takaoka City. Formed in 2005 through the integration of three former national institutions, the university brings together a broad spectrum of disciplines across its 9 undergraduate schools, 8 graduate schools, and a range of specialized

institutes. With more than 9,000 students, including a growing international cohort, the university is dedicated to high-quality education, cutting-edge research, and meaningful social contribution. Guided by the mission to cultivate individuals with creativity, ethical awareness, and a strong sense of purpose, the University of Toyama fosters learning that integrates the humanities, social sciences, natural sciences, and life sciences. The university emphasizes a global standard of education while remaining deeply engaged with the local community.

Website: https://www.u-toyama.ac.jp/en/

About Professor Keiji Horikawa from the University of Toyama, Japan

Keiji Horikawa is a Professor in the Faculty of Science at the University of Toyama, Japan, and a geochemist specializing in paleoceanography and paleoclimate research. His work focuses on reconstructing past climate and ocean conditions through geochemical analyses of marine sediment cores. He participated in the International Ocean Discovery Program Expedition 379 to the Amundsen Sea in 2019 and studies the response of the West Antarctic Ice Sheet to warm Pliocene climates. He heads the Horikawa Lab for Paleoceanography and Geochemistry, which aims to improve understanding of Earth's climate system.

Funding information

This work was supported by JSPS KAKENHI Grant Numbers JP21H04924 and JP25H01181 and JP21H03590, JP23K21746, and JP25K03252 and was conducted by the support of Joint Research Grant for the Environmental Isotope Study of Research Institute for Humanity and Nature, and partly carried out under the Joint Research Program of the Institute of Low Temperature Science, Hokkaido University (23G056).

C. Siddoway's contributions were supported by U.S. NSF awards 1917176 and 1939146 was funded through the Natural Environment Research Council (NERC) UK IODP grant NE/T010975/1. E.A. Cowan was supported by a postexpedition award from the U.S. Science Support Program of IODP.

Media contact: Yumiko Kato
E-mail: ykato@ctg.u-toyama.ac.jp