IODP Proposal Cover Sheet

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Totten Glacier Climate Vulnerability

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Title	Totten Glacier Climate Vulnerability under varying Neogene climate conditions: Lessons for East Antarctic Ice Sheet climate sensitivity
Proponents	Taryn Noble, Federica Donda, Yair Rosenthal, Amy Leventer, Alan Aitken, Linda Armbrecht, Peter Bijl, Giuseppe Cortese, Edward Gasson, Georgia Grant, Jacqueline Halpin, Sidney Hemming, Stephen Meyers, German Leitchenkov, Renata Lucchi, Philip O'Brien, Bradley Opdyke, Eelco Rohling, Francesca Sangiorgi, Sophie Warny, Trevor Williams, Yusuke Yokoyama
Keywords	Antarctica, Paleoclimate, Ice sheet history
Area	East Antarctic margin; Indian sector of the Southern Ocean

Proponent Information

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Abstract

The Totten Glacier (TG) is the main outlet draining the low-lying Sabrina and Aurora Subglacial Basins and is susceptible to marine ice sheet instability due to the landward sloping topography. Current melting rates of the TG are among the fastest in East Antarctica, due to incursions of relatively warm modified Circumpolar Deep Water to the glacier grounding line. Like glaciers in West Antarctica, the present-day observations suggest that the TG is sensitive to climate warming. However, there is insufficient proximal paleoenvironmental data to contextualise these sensitivities. Existing evidence suggests that the ice sheet in the Aurora Basin sector was less sensitive to past climate warming compared to other vulnerable regions of East Antarctica. We propose to reconstruct the response of the TG to climate changes since the mid-Miocene, targeting both warmer than present intervals, such as the Mid-Miocene Climate Optimum, Pliocene warm period, Pleistocene super interglacials, and the major EAIS expansions during the mid-Miocene Climate transition and the transition to the Pleistocene ice ages.

Existing cores and seismic sections on the Sabrina continental margin reveal glacial-interglacial variability and deep seismic unconformities, which are hypothesised to record major ice sheet events of the Neogene. Furthermore, seismic stratigraphic correlation with other sites along the EAIS margin, suggest that the TG history might have been different from that of other East Antarctic glaciers. We take advantage of unique features of the Sabrina Coast including 1) Well bedded, glaciomarine sediments with higher Plio-Pleistocene sedimentation rates relative to sites previously cored on the East Antarctic margin; 2) High-resolution seismic data providing detailed images of the sites' seismostratigraphy; 3) advances in astrochronology to date the cores allowing correlation among sites with global climate events; 4) multiple organic biomarkers allowing for paleoceanographic reconstructions; 5) multiple coring sites outside the summer sea ice front.

This proposal is relevant to the flagship initiative Ground Truthing Future Climate Change of the 2050 Science Framework. The drilling targets end member archives for different climate states. In particular, we will establish the presence/absence of ice in the Sabrina-Aurora Basin during the Mid-Miocene, to extensive glacial advance during the Late Miocene and Plio-Pleistocene.

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Scientific Objectives

The overarching goal of this proposal is to improve our understanding of the vulnerable East Antarctic Ice Sheet (EAIS) marine basins to climate change through the reconstruction of the ocean and Aurora Basin ice sheet history under varying climate conditions during the Neogene, with primary emphasis on warmer than pre-industrial climate states, specifically:

1. Assess the response of the EAIS to the major climate transitions across the Neogene, including the mid-Miocene climate transition (MMCT), Late Miocene/Early Pliocene change in the ice sheet's thermal regime (from sub-polar to polar), Northern Hemisphere Glaciation (NHG) and mid-Pleistocene Transition as well as to major glaciations of the Pleistocene.
2. Reconstruct the Totten Glacier (TG) melting history at warm intervals from the Miocene Climate Optimum (MCO), mid-Pliocene Warm Period (MPWP), and Pleistocene super interglacials (such as MIS31 and MIS11), by recovering discrete and continuous sedimentary records at variable temporal resolutions.
3. Evaluate the contribution of the Wilkes Land EAIS to past global sea level change during both cool climate (e.g., MMCT, late Pliocene glacial expansion) and warm climate states (e.g., MPWP).
4. Assess the mechanisms and processes affecting TG melting e.g., global temperatures, sea level rise, changes in water-mass circulation, and sea ice on the Wilkes Land margin.
5. Determine the relative sensitivity of the TG to past climate warming relative to other vulnerable locations in East Antarctica, e.g., Wilkes Subglacial Basin.
6. Investigate changes in past sea-ice extent, the biological responses to such change, and the linkages with past ocean and climate conditions.

Non-standard measurements technology needed to achieve the proposed scientific objectives

Have you contacted the appropriate IODP Science Operator about this proposal to discuss drilling platform capabilities, the feasibility of your proposed drilling plan and strategies, and the required overall timetable for transiting, drilling, coring, logging, and other downhole measurements?

no

Science Communications Plain Language Summary

Using simple terms, describe in 500 words or less your proposed research and its broader impacts in a way that can be understood by a general audience.

The East Antarctic Ice Sheet holds the world's largest volume of freshwater locked up as ice. The Sabrina and Aurora Basins are vast low-lying areas of East Antarctica where the ice rests on bedrock that is below sea level. The Totten Glacier is the main outlet for ice flowing from the Sabrina and Aurora basins and is showing some of the highest melting rates of all the glaciers in East Antarctica, due to warm ocean waters melting the base of the ice. If the Totten Glacier melts and retreats back sufficiently the glacier will become unstable due to the landward deepening topography and contribute to raising sea levels around the world. Ice sheets can take hundreds to thousands of years to adjust to the surrounding environmental conditions, so we don't know how the Totten Glacier will respond as the climate continues to warm. This drilling proposal aims to recover sediment cores from around 200km seaward of the Totten Glacier to provide a record of how the ice sheet and ocean responded to past climate changes. The proposed expedition fills a gap in the regional coverage of Antarctica, and These sediments are time capsules that allow scientists to travel back to periods in Earth's history when the climate fluctuated between warm and cold conditions. New records will be used in collaboration with climate and ice sheet modellers to reveal the sensitivity of the ice sheet to climate changes. New knowledge will further our understanding of the interactions and feedbacks within the Earth system and identify regions of vulnerable regions of East Antarctica that may contribute to global sea-level rise. The proposal contributes to the ocean end of a land-to-sea transect that links with proposal 931 (Shevenell) on the Sabrina continental shelf, and future subglacial drilling in the Sabrina-Aurora Basin by US and Australian rapid access ice and bedrock drilling programs.

Proposal History

Submission Type: Resubmission from previously submitted proposal

Review Response

This 1002-Full proposal addresses comments (as numbered) in the July 30, 2021 SEP review:
1) We explained how new IODP cores are required to explore the sensitivity of the Totten Glacier to climate changes based on present-day observations of (i) high Totten Glacier ice loss relative to other East Antarctic glaciers (Rignoit et al., 2019), (ii) increasing incursions of warm modified circumpolar deep water to the base of the ice sheet (Rintoul et al 2016), and (iii) the susceptibility to marine ice sheet instability due to the Sabrina and Aurora Subglacial Basin sitting >1000 m below sea level (Morlighem et al., 2020). We also highlight the uncertainty in ice sheet retreat scenarios into the Sabrina-Aurora Basin for both future climate warming scenarios (e.g., Golledge et al., 2015; DeConto and Pollard, 2016) and past warm climate simulations for the Miocene (e.g., Gasson et al., 2016b; Halberstadt et al., 2021).
2) Including Antarctic Ice sheet modeller Edward Gasson and geophysical modeller Alan Aitken.
3) We have incorporated the insights and approaches developed from other Antarctic IODP expeditions, besides Exp 318.
4) We have included a section that highlights future opportunities for this proposal to complement a land-to-sea transect.
5) We have included a new site TSS17A that targets WL-5 and WL-6 hypothesized to be Early to Mid Miocene. This site, (and alternate TSS18A) targets a mega debris flow which we posit may be linked to a major advance of the ice sheet during the MMCT.
6) The hypotheses have also been redrafted from the original preproposal and better linked to core sites and approaches to test them.
7) Georgia Grant (CONOP) and Stephen Meyers (astrochronology) have joined the proposal and will ensure the development of robust stratigraphy.
8) Issues raised in this point around proxies have been addressed in both the hypotheses and section on methodology.
9) We have included Renata Lucchi (Italy).
10) We have changed the leadership, with as much attention as possible given to the issues raised by SEP as the circumstances would allow.

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Proposed Sites (Total proposed sites: 14; pri: 5; alt: 9; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
TSS-01B (Primary)	-64.7262 114.5499	1660	344	0	344	1) This site targets seismic unconformities WL7, WL8, WL9 to recover ? late Miocene/Early Pliocene to Plio-Pleistocene sediments 2) This site is the shallowest location (1660 m) with best chance of preserving calcareous fossils 3) This site is the most proximal site to the Totten Glacier and will recover WL9, which is only found in the western study region (see isobath maps)
TSS-06B (Primary)	-64.3619 115.0697	1920	456	0	456	1) This site targets Mid-Miocene sediments in the western study region
TSS-10B (Primary)	-64.2558 116.0001	2250	400	0	400	1) Acquire expanded Plio-Pleistocene section in the western-most ridge seaward of the Totten Glacier 2) Date surfaces WL-9, WL-8, and WL-7 to understand the timing of local (WL-9) events and regional changes
TSS-15B (Primary)	-64.5448 119.2201	3250	542	0	542	1) Acquire Plio-Pleistocene section at the eastern edge of the study area which likely receives detritus from the Moscow University Ice Shelf outlet of the Aurora Basin for comparison with sites sampling sediment derived from the Totten Glacier 2) Date surfaces WL-8 and WL-7 to test if these surfaces are of the same age as further West.
TSS-17A (Primary)	-64.4932 121.0277	3220	800	0	800	1) Date surfaces WL5 and WL6, which bound the giant debris flow deposits, which has been linked to the evolution of EAIS (Donda et al., 2008)
TSS-09B (Alternate)	-64.5540 116.6386	2100	850	0	850	1) Expanded Plio-Pleistocene section to show sub-orbital scale temporal changes of ice sheet and ocean change response to climate forcing 2) Date surfaces WL-8 and WL-7 to understand timing of major changes in regional sedimentation and environment.
TSS-04B (Alternate)	-64.4033 116.0067	2220	550	0	550	1) Acquire expanded Plio-Pleistocene section 2) Date surfaces WL-9, WL-8 and WL-7 understand timing of local (WL-9) events and regional changes
TSS-14B (Alternate)	-64.6551 119.7894	3050	375	0	375	1) Acquire expanded Plio-Pleistocene section at the eastern edge of the study area which likely receives detritus from the Moscow University Ice Shelf outlet of the Aurora Basin for comparison with sites sampling sediment derived from the Totten Glacier 2) Date surface WL-7 to test if this surface is the same age as further west.
TSS-18A (Alternate)	-64.4840 119.5072	3250	660	0	660	1) Acquire Early Miocene to Plio-Pleistocene section at the eastern sector of the study area which likely receives detritus from the Moscow University Ice Shelf outlet of the Aurora Basin for comparison with sites sampling sediment derived from the Totten Glacier, and is currently affected by mCDW incursion (Bensi et al., 2022) 2) Date the debris flow deposits between WL6 and WL7, younger than that at site TSS17A but still occurring within the seismic sequences belonging to Phase 2, when a temperate ice sheet was highly fluctuating on the shelf (Donda et al., 2020)
TSS-16A (Alternate)	-65.0134 119.9846	2804	850	0	850	1) Acquire expanded Plio-Pleistocene section at the eastern edge of the study area which likely receives detritus from the Moscow University Ice Shelf outlet of the Aurora Basin for comparison with sites sampling sediment derived from the Totten Glacier 2) Date surfaces WL-8 and WL-7 to test if these surfaces are of the same age as further West.
TSS-11A (Alternate)	-64.2510 115.6518	2159	350	0	350	1) Acquire expanded Plio-Pleistocene section in western-most ridge seawarad of the Totten Glacier 2) Date surfaces WL-9, WL-8 and WL-7 understand timing of local (WL-9) events and regional changes

Proposed Sites (Continued; total proposed sites: 14; pri: 5; alt: 9; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
TSS-13A (Alternate)	-64.6215 119.6420	3107	300	0	300	1) Acquire Plio-Pleistocene section at the eastern edge of the study area which likely receives detritus from the Moscow University Ice Shelf outlet of the Aurora Basin for comparison with sites sampling sediment derived from the Totten Glacier 2) Date surfaces WL-8 and WL-7 to test if these surfaces are of the same age as further West.
TSS-02A (Alternate)	-64.625733 114.915883	1877	200	0	200	1) Acquire Plio-Pleistocene section in shallowest location with best chance of preserving calcareous fossils 2) Acquire sediment from the most inshore and westward location to see if local paleoceanographic effects are detectable
TSS-03A (Alternate)	-64.61125 115.21107	2074	250	0	250	1) Acquire Plio-Pleistocene section in shallowest location with best chance of preserving calcareous fossils 2) Acquire sediment from the most inshore and westward location to see if local paleoceanographic effects are detectable