IODP Proposal Cover Sheet

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Antarctic Cryosphere Origins

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Title	Tracing Antarctic Cryosphere Origins to Climate And Tectonics
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Area	Ross Sea

Proponent Information

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Abstract

Antarctica's ice sheets profoundly influence the global climate system and carbon cycle by impacting ocean and atmospheric circulation, biogeochemical cycles, and sea level. Large ice sheets developed in Antarctica as the Earth transitioned from the warm, high-CO2 Greenhouse world of the Paleocene and Eocene, into the moderate-CO2 world of the Oligocene to early Miocene. However, constraints regarding the timing and magnitude of Antarctica's earliest ice sheets come mostly from indirect inferences based on distant marine geochemical records rather than a direct, ice-proximal, perspective from the Antarctic continental shelf. Additionally, there are very few direct records of Eocene-Cretaceous climates at high latitudes in Antarctica, and new records will provide important constraints of the magnitude of polar amplification during greenhouse climates.

Several mechanisms exist to explain Antarctic glacial onset, including declining atmospheric CO2 and the tectonic opening of the Southern Ocean. It is also generally assumed that initial ice sheet expansion near the Eocene/Oligocene boundary was limited to terrestrial ice sheets in East Antarctica, because ice could not easily expand across a marine-inundated West Antarctica in the moderate-CO2 worlds and warmer climates of the Oligocene. However, Cretaceous-Cenozoic rifting, alongside Neogene erosion, has led to widespread subsidence in West Antarctica. A more elevated West Antarctica in the Oligocene could hold more terrestrial ice than today, even though the climate was warmer than present. Consequently, the ice sheet evolution of the Ross Sea is hypothesized to be strongly-coupled to the tectonic and subsidence history of West Antarctica, rather than climate forcings alone. Therefore,obtaining direct records of rift timing and climate/glacial history is required to understand these competing influences. A further implication of understanding the tectonic history of West Antarctica, is that active rifting in the Ross Sea is thought to be a keystone in resolving models of Cenozoic global plate motion circuits.

The Ross Sea is perfectly situated to obtain new perspectives on the tectonic influences on Antarctica's climatic and ice sheet evolution. It is located within West Antarctic Rift System, which allows for direct assessment of rift timing, but has formed large sedimentary basins that capture and preserve climatic records at high latitudes in Antarctica since Late Cretaceous times. We target four continental shelf drill sites in the Ross Sea, which form a longitudinal-transect designed to capture this integrated history of tectonic, climate and glacial influences from both East and West Antarctica.

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Scientific Objectives

Objective 1: Obtain direct evidence of the earliest ice sheets in East and West Antarctica expanding into the Ross Sea.
Objective 2: Obtain geological reconstructions of “pre-icehouse” climates at high latitudes in Antarctica during the Late Cretaceous to Eocene.
Objective 3: Constrain the timing of late rift phases in the Ross Sea to resolve mechanisms of crustal extension in the Ross Sea, in order to test hypotheses of global plate tectonic models, and understand tectonic controls on ice sheet evolution.

We will achieve these objectives by:
A) Drilling a total of four sites, as part of an East to West transect on the Ross Sea continental shelf, that will provide records of early ice sheet histories sourced from both East and West Antarctica.
B) Drill into syn-rift strata (Cretaceous- late Eocene), and post-rift strata (Eocene-early Miocene) at each site to obtain climate archives. We aim to core above and below unconformities formed near the Eocene/Oligocene boundary, when the first large-continental scale Antarctic ice sheets are proposed to have formed.
C) Date syn-rift strata in separate continental shelf basins, to provide minimum constraints of the time of active Ross Sea rift propagation.

This proposal directly address Challenges 1 and 2 of the IODP Science Plan.

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

Proposal History

Submission Type: Resubmission from declined proposal

Declined Proposal Number: 964-Full

Review Response

The SEP stated "there is a very strong scientific rationale for the proposed drilling". We were strongly encouraged to resubmit, even though it was deactivated.

SEP had several high order requests.

1) submit a pre-proposal (instead of full proposal) to allow more opportunity to nurture the proposal prior through to the peer review stage. DONE

2) remove link to undrilled IODP Exp 374 sites. That expedition terminated early, so several sites went back to JRFB. We submitted the last proposal (964) as a shorter duration expedition to allow remaining 374 sites to be drilled. This confused SEP, who found it difficult to prioritize between objectives between this new proposal and IODP 374. We also overlooked port call time that the drilling timeline to include the 374 unfeasible. This new proposal is entirely standalone in it objectives and is now a full expedition. JRFB can decide on the best procedure to prioritize the undrilled 374 sites. DONE

3) Prioritize objectives between obtaining rift history or climate/ice sheet history. It was perceived our first priority was the deepest, highest risk strata below RSU7 to obtain rift timing, and therefore we could have achieved our objectives by drilling at shallower sites. This was not intended. Our priority is the greenhouse and early icehouse records above and below RSU6 and expanded records of this period are higher priority than dating RSU7 (which highly useful, but more snapshot in nature). This prioritization is much clearer in this revised proposal. DONE

3) Add results of Exp 374 to inform on margin stratigraphy, and paleoclimate or optimum methodologies or operational strategies can be integrated.
-This was a somewhat confusing request as we had a lot of details of operation strategies/methods from 374 in this new proposal, and had several figures dedicated to this. Importantly, 374 has no bearing on margin stratigraphy relevant to this new proposal - as our targets much older than anything 374 drilled (see Figure 3). Therefore, existing published drill core studies in the Ross Sea we cited are more relevant and already published (ANDRILL, Cape Robert, CIROS-1, DSDP 28). Results from these expeditions are far more relevant than 374 (and we explain paleoclimate/methods from these in a table). These earlier projects are what guided our hypothesis development and strategy for drilling/analysis. We have made this more clear in this revised proposal, but we do point to the relevant methodological/dirlling successes from 374 proceeding volumes in this revised proposal (esp drilling recovery/risks). IMPROVED AND CLARIFIED

4) Consider relocating some sites to shallower target for RSU7, and if RSU7 is primary target we may need addition seismic lines due to the complex rifting structures. See comment 2.This request was based on the view RSU7 was our higher priority than early ice house/greenhouse records - which was not intended. If RSU7 was not the highest priority, then SEP suggested existing site are ok. We make it clear this is not our priority and expanded sequences are more important. Shallow targets are only presented as contingency if drilling window time are short due to delays etc. CLARIFIED.

Proposed Sites (Total proposed sites: 16; pri: 4; alt: 12; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
CHCS-01A (Primary)	-77.2315 172.2051	693	1200	0	1200	1) Obtain direct geological evidence of the earliest history of ice sheets in East Antarctica, by sampling strata above RSU6 (thought to be 34-26.5 Ma). Will obtain a Oligocene (~34 Ma) to mid Miocene (~16 Ma) record of EAIS advance. (high priority) 2) Reconstruction “pre-icehouse” climates in East Antarctica during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-26.5Ma). (medium priority) 3) Constrain timing of late rift phases in the Western Ross Sea. This will be achieved by dating RSU6 and coring syn-rift strata. (lower priority)
CHCS-02A (Alternate)	-77.31783122 171.95787093	740	1200	0	1200	1) Obtain direct geological evidence of the earliest history of ice sheets in East Antarctica, by sampling strata above RSU6 (thought to be 34-26.5 Ma). Will obtain a Oligocene (~34 Ma) to mid Miocene (~16 Ma) record of EAIS advance. (high priority) 2) Reconstruction “pre-icehouse” climates in East Antarctica during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-26.5Ma). (medium priority) 3) Constrain timing of late rift phases in the Western Ross Sea. This will be achieved by dating RSU6 and coring syn-rift strata. (lower priority)
CHCS-03A (Alternate)	-77.0727 171.5629	712	1300	0	1300	1) Obtain direct geological evidence of the earliest history of ice sheets in East Antarctica, by sampling strata above RSU6 (thought to be 34-26.5 Ma). Will obtain a Oligocene (~34 Ma) to mid Miocene (~16 Ma) record of EAIS advance. (high priority) 2) Reconstruction “pre-icehouse” climates in East Antarctica during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-26.5 Ma). (medium priority) 3) Constrain timing of late rift phases in the Western Ross Sea. This will be achieved by dating RSU6 and coring syn-rift strata. (lower priority)
CENCS-01A (Primary)	-77.4516 -177.8407	616	1185	15	1200	1) Obtain direct geological evidence of the earliest history of ice sheets coalescing from West and East Antarctica, by sampling strata above RSU6 (thought to be 34-26.5 Ma). Will obtain a Oligocene (~34 Ma) to mid Miocene (~16 Ma) record of EAIS advance. (high priority) 2) Reconstruction “pre-icehouse” climates in West Antarctica during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-26.5 Ma). (high priority) 3) Constrain timing of late rift phases in the Western Ross Sea. This will be achieved by dating RSU6 and coring syn-rift strata. (lower priority).
CENCS-02A (Alternate)	-77.6402 -179.2478	648	850	50	900	1) Obtain direct geological evidence of the earliest ice sheets coalescing from West/East Antarctica, by sampling strata above RSU6 (~34-26.5 Ma). A Oligocene (~34 Ma) to mid Miocene (~16 Ma) record of EAIS advance. (low priority at this site, as section is condensed compared to CENCS-01A) 2) Reconstruct “pre-icehouse” climates in West Antarctica (Late Cretaceous to Eocene), by sampling material below RSU6 (thought to be ~34-26.5Ma). (high priority) 3) Constrain late rift phase timing in the Western Ross Sea, by dating RSU6 and coring syn-rift strata. (moderate priority). ALTERNATE IN CASE OF REDUCED DRILLING TIME DUE TO LOGISTIC DELAYS AT OTHER SITES.
CENCS-03A (Alternate)	-77.2200 -178.6336	645	1050	0	1050	1) Obtain direct geological evidence of the earliest history of ice sheets coalescing from West and East Antarctica, by sampling strata above RSU6 (thought to be 34-26.5 Ma). Will obtain a Oligocene (~34 Ma) to mid Miocene (~16 Ma) record of EAIS advance. (high priority) 2) Reconstruction “pre-icehouse” climates in West Antarctica during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-26.5Ma). (high priority) 3) Constrain timing of late rift phases in the Western Ross Sea. This will be achieved by dating RSU6 and coring syn-rift strata. (lower priority).
CENCS-04A (Primary)	-73.99148766 -177.28643477	700	1070	0	1070	1) Reconstruction “pre-icehouse” climates in West Antarctica during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-26.5Ma). (high priority) 2) Constrain timing of late rift phases in the Western Ross Sea. This will be achieved by dating RSU6 and coring syn-rift strata. (medium priority).
CENCS-05A (Alternate)	-73.99713175 177.15819239	385	1000	0	1000	1) Reconstruction “pre-icehouse” climates in West Antarctica during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-26.5Ma). (high priority) 2) Constrain timing of late rift phases in the Western Ross Sea. This will be achieved by dating RSU6 and coring syn-rift strata. (medium priority).

Proposed Sites (Continued; total proposed sites: 16; pri: 4; alt: 12; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
ERSCS-01A (Alternate)	-77.61010423 -160.84500232	620	1050	10	1060	1) Obtain direct geological evidence of the earliest history of ice sheets in West Antarctica, by sampling strata above RSU6 (thought to be 34-26.5 Ma). Will obtain a Oligocene (~34 Ma) to Early Miocene (20 Ma) record of WAIS advance in Marie Byrd Land (high priority) 2) Reconstruction “pre-icehouse” climates in Eastern Ross Sea/ Marie Byrd Land during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-28Ma) and RSU7 (Late Cretaceous to Eocene?) (high priority) 3) Constrain timing of late rift phases in the Eastern Ross Sea. This will be achieved by dating syn-rift strata below RSU7. (lowest priority)
ERSCS-02A (Primary)	-77.9402 -160.4316	660	775	25	800	1) Obtain direct geological evidence of the earliest history of ice sheets in West Antarctica, by sampling strata above RSU6 (thought to be 34-26.5 Ma). Will obtain a Oligocene (~34 Ma) to Early Miocene (20 Ma) record of WAIS advance in Marie Byrd Land (high priority) 2) Reconstruction “pre-icehouse” climates in Eastern Ross Sea/ Marie Byrd Land during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-28Ma) and RSU7 (Late Cretaceous to Eocene?) (high priority) 3) Constrain timing of late rift phases in the Eastern Ross Sea. This will be achieved by dating syn-rift strata below RSU7. (lowest priority)
ERSCS-03A (Alternate)	-78.3925 -164.7040	541	1200	0	1200	1) Obtain direct geological evidence of the earliest history of ice sheets in West Antarctica (strata above RSU6; 34-26.5 Ma). Will obtain a Oligocene-Early Miocene (~34-20 Ma) record of WAIS advance in Marie Byrd Land. (moderate priority, as top of sequence truncated by younger strata) 2) Reconstruct “pre-icehouse” climates in Eastern Ross Sea/Marie Byrd Land during the Late Cretaceous to Eocene; strata below RSU6 (~34-28Ma) and RSU7 (Late Cretaceous to Eocene?). (high priority-expanded at this site) 3) Constrain timing of late rift phases in the Eastern Ross Sea. This will be achieved by dating syn-rift strata below RSU7. (lowest priority)
ERSCS-04A (Alternate)	-78.3509 -162.5913	706	1134	20	1154	1) Obtain direct geological evidence of the earliest history of ice sheets in West Antarctica, by sampling strata above RSU6 (thought to be 34-26.5 Ma). Will obtain a Oligocene (~34 Ma) to Early Miocene (20 Ma) record of WAIS advance in Marie Byrd Land (high priority) 2) Reconstruction “pre-icehouse” climates in Eastern Ross Sea/ Marie Byrd Land during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-28Ma) and RSU7 (Late Cretaceous to Eocene?) (high priority) 3) Constrain timing of late rift phases in the Eastern Ross Sea. This will be achieved by dating syn-rift strata below RSU7. (lowest priority)
ERSCS-05A (Alternate)	-78.2274 -161.5268	615	1200	0	1200	1) Obtain direct geological evidence of the earliest history of ice sheets in West Antarctica, by sampling strata above RSU6 (thought to be 34-26.5 Ma). Will obtain a Oligocene-Early Miocene (~34-20 Ma) record of WAIS advance in Marie Byrd Land (high priority) 2) Reconstruction “pre-icehouse” climates in Eastern Ross Sea/ Marie Byrd Land during the Late Cretaceous to Eocene, by sampling material below RSU6 (~34-26.5Ma) and RSU7 (Late Cretaceous to Eocene?) (low priority -as strata to deep) 3) Constrain timing of late rift phases in the Eastern Ross Sea. This will be achieved by dating syn-rift strata below RSU7. (lowest priority)
ERSCS-06A (Alternate)	-77.668106299 -160.740589980	620	1300	0	1300	1) Obtain direct geological evidence of the earliest history of ice sheets in West Antarctica, by sampling strata above RSU6 (thought to be 34-26.5 Ma). Will obtain a Oligocene-early Miocene (~34-20 Ma) record of WAIS advance in Marie Byrd Land. (high priority) 2) Reconstruct “pre-icehouse” climates in Eastern Ross Sea/ Marie Byrd Land during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-28Ma) and RSU7 (Late Cretaceous-Eocene?) (high priority - expanded sequence at this site) 3) Constrain timing of late rift phases in Eastern Ross Sea, by dating syn-rift strata below RSU7. (moderate priority)
RSAP-01A (Alternate)	-71.3435 -164.4160	4133	1090	10	1100	1) obtain continuous record of Early Miocene to Oligocene oceanographic change relating to ice sheet variance on continent. Site complements RSCR-19A from IODP Exp 374 to obtain an older stratigraphic record links Exp 374 and this new proposals objective. It is lower priority than the continental shelf site and RSCR-19A, as it is RCB only and will obtain lower recovery than shelf site (less lithified) and RSCR-19A (APC/XCB core). alternate in case of poor sea ice year in ERSCS sites (other shelf site in CHCS and CENCS regions are always open water in summer)

Proposed Sites (Continued; total proposed sites: 16; pri: 4; alt: 12; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
RSAP-02A (Alternate)	-69.99544571 -164.67600	4075	1200	0	1200	1) obtain continuous record of Early Miocene to Oligocene oceanographic change relating to ice sheet variance on continent. Site complements RSCR-19A from IODP Exp 374 to obtain an older stratigraphic record links Exp 374 and this new proposals objective. It is lower priority than the continental shelf sites. Provides an alternate in case of poor sea ice year in ERSCS sites (other shelf site in CHCS and CENCS regions are always open water in summer)