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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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, late Cretaceous-Cenozoic rifting, alongside Neogene erosion, has led to widespread subsidence in West Antarctica. A more elevated West Antarctica in the Early 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 also has formed large sedimentary basins that capture and preserve climatic records at high latitudes in Antarctica since Late Cretaceous times. We target three 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.

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 three 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.

These three new sites are designed to be drilled alongside two sites that were not drilled during IODP Expedition 374 (due to the early termination resulting from a mechanical failure) - for a total of five sites. The new sites in this proposal have standalone, but complimentary, objectives. This proposal directly address Challenges 1 and 2 of the IODP Science Plan.

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

Proposed Sites (Total proposed sites: 14; pri: 3; alt: 11; 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 aboveRSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to mid Miocene (~16 Ma) record of EAIS advance. 2) Reconstruction “pre-icehouse” climates in East Antarctica during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-28Ma). 3) Constrain timing of late rift phases in the Western Ross Sea. This will be achieved by dating RSU6 and coring syn-rift strata.
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 aboveRSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to mid Miocene (~16 Ma) record of EAIS advance. 2) Reconstruction “pre-icehouse” climates in East Antarctica during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-28Ma). 3) Constrain timing of late rift phases in the Western Ross Sea. This will be achieved by dating RSU6 and coring syn-rift strata
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 aboveRSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to mid Miocene (~16 Ma) record of EAIS advance. 2) Reconstruction “pre-icehouse” climates in East Antarctica during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-28Ma). 3) Constrain timing of late rift phases in the Western Ross Sea. This will be achieved by dating RSU6 and coring syn-rift strata
CENCS-01A (Primary)	-77.4516 -177.8407	616	1185	15	1200	1) Obtain direct geological evidence of the earliest history of ice sheets in East Antarctica, by sampling strata aboveRSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to Early Miocene (20 Ma) record of marine environments, with influence of combined EAIS/WAIS or local ice cap advance in central Ross Sea. 2) Reconstruction “pre-icehouse” climates in Central Ross Sea during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-28Ma). 3) Constrain timing of late rift phases in the Central Ross Sea. This will be achieved by dating RSU6 and coring syn-rift strata.
CENCS-02A (Alternate)	-77.6402 -179.2478	648	850	50	900	1) Obtain direct geological evidence of the earliest history of ice sheets in East Antarctica, by sampling strata aboveRSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to Early Miocene (20 Ma) record of marine environments, with influence of combined EAIS/WAIS or local ice cap advance in central Ross Sea. 2) Reconstruction “pre-icehouse” climates in Central Ross Sea during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-28Ma). 3) Constrain timing of late rift phases in the Central Ross Sea. This will be achieved by dating RSU6 and coring syn-rift strata.
CENCS-03A (Alternate)	-77.2200 -178.6336	645	1050	0	1050	1) Obtain direct geological evidence of the earliest history of ice sheets in East Antarctica, by sampling strata aboveRSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to late Oligocene (25 Ma) record of marine environments, with influence of combined EAIS/WAIS or local ice cap advance in central Ross Sea. 2) Reconstruction “pre-icehouse” climates in Central Ross Sea during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-28Ma). 3) Constrain timing of late rift phases in the Central Ross Sea. This will be achieved by dating RSU6 and coring syn-rift strata.
ERSCS-01A (Alternate)	-77.61010423 -160.84500232	620	1050	0	1050	1) Obtain direct geological evidence of the earliest history of ice sheets in West Antarctica, by sampling strata above RSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to Early Miocene (20 Ma) record of WAIS advance in Marie Byrd Land 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?) 3) Constrain timing of late rift phases in the Eastern Ross Sea. This will be achieved by dating syn-rift strata below RSU7.

Proposed Sites (Continued; total proposed sites: 14; pri: 3; alt: 11; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
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 34-28 Ma). Will obtain a Oligocene (~34 Ma) to Early Miocene (20 Ma) record of WAIS advance in Marie Byrd Land 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?) 3) Constrain timing of late rift phases in the Eastern Ross Sea. This will be achieved by dating syn-rift strata below RSU7.
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, by sampling strata above RSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to Early Miocene (20 Ma) record of WAIS advance in Marie Byrd Land 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?) 3) Constrain timing of late rift phases in the Eastern Ross Sea. This will be achieved by dating syn-rift strata below RSU7.
ERSCS-04A (Alternate)	-78.3509 -162.5913	706	1134	16	1150	1) Obtain direct geological evidence of the earliest history of ice sheets in West Antarctica, by sampling strata above RSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to Early Miocene (20 Ma) record of WAIS advance in Marie Byrd Land 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?) 3) Constrain timing of late rift phases in the Eastern Ross Sea. This will be achieved by dating syn-rift strata below RSU7.
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 34-28 Ma). Will obtain a Oligocene (~34 Ma) to Early Miocene (20 Ma) record of WAIS advance in Marie Byrd Land 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)
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 34-28 Ma). Will obtain a Oligocene (~34 Ma) to Early Miocene (20 Ma) record of WAIS advance in Marie Byrd Land 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?) 3) Constrain timing of late rift phases in the Eastern Ross Sea. This will be achieved by dating syn-rift strata below RSU7.
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)
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 1. 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). Site is alternate in case, ERSCS site are ice covered in an extreme sea ice year (other shelf sites in CHCS and CENCS regions are always open water in summer)

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Proponent List

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Christopher	Sorlien	University of California Santa Barbara	New Zealand	Other Lead	Seismic Stratigraphy
Richard	Levy	GNS Science	New Zealand	Other Lead	Stratigraphy
Amelia	Shevenell	University of South Florida	United States	Other Lead	Sedimentology, geochemistry
Doug	Wilson	University of California Santa Barbara	United States	Other Lead	Seismic Stratigraphy
Bruce	Luyendyk	University of California Santa Barbara	United States	Other Lead	Seismic Stratigraphy, tectonics
Sookwan	Kim	Korea Polar Research Institute	Korea, Republic of	Other Proponent	Seismic Stratigraphy
Karsten	Gohl	Alfred-Wegener-Institut	Germany	Other Proponent	Seismic Stratigraphy
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Rupert	Sutherland	Victoria University of Wellington	New Zealand	Other Proponent	Tectonics
Tina	van de Flierdt	Imperial College London	United Kingdom	Other Proponent	Geochemistry, paleooceanography
David	Harwood	University of Nebraska-Lincoln	United States	Other Proponent	Biostratigraphy
Denise	Kulhanek	International Ocean Discovery Program, Texas A&M University	United States	Other Proponent	Biostratigraphy, logistics
Tim	Naish	Victoria University of Wellington	New Zealand	Other Proponent	Sedimentology and Stratigraphy
Robert	De Conto	University of Massachusetts-Amherst	United States	Other Proponent	Ice Sheet/Climate Modelling
Jongkuk	Hong	Korea Polar Research Institute	Korea, Republic of	Other Proponent	Seismic Stratigraphy
Yusuke	Suganuma	National Institute of Polar Research	Japan	Other Proponent	Paleomagnetics and paleoclimate
Gerhard	Kuhn	Alfred-Wegener-Institut	Germany	Other Proponent	Geochemistry, physcial properties

1. Introduction

Direct records of the early history of growth of large Antarctica Ice Sheets (AIS) during the latest Eocene to early Oligocene come from rare and disparate rock outcrop and ~two dozen drill holes that are mostly located around the periphery of the East Antarctic Ice Sheet (EAIS)(McKay et al., 2016; Escutia et al., 2019). There are only a sparse number of "snapshot" records of pre-icehouse climate in Antarctica, with high latitude records limited to glacial erratics and short sediment cores (Harwood and Levy, 2000; Gulick et al., 2017) and drill cores that just capture the latest Eocene (Barrett, 1989; Hambrey et al., 1991). More continuous Eocene records are restricted to the Antarctic Peninsula region, or deep-sea settings at off East Antarctica (Bowman et al., 2014; Ivany et al., 2008; Pross et al., 2012). Consequently, estimates of long-term Cenozoic climate and polar ice volume have largely been derived from far-field records, most notably in the deep-sea or the continental margins in low- to mid-latitudes. Whereas, these remote proxies are useful, they remain subject to uncertainties and assumptions when assessing high-latitude climatic change (McKay et al., 2016). To best understand Antarctic glacial history and the influence of high-latitude processes on climate and sea level, direct records from the Antarctic margin are essential.

An important control on AIS development is thought to be the tectonic break-up of Gondwana, which resulted in the formation of the Southern Ocean - an essential component of the modern overturning circulation. Resultant changes in global carbon cycling and the thermal isolation of the continent likely drove the Cenozic expansion of Antarctica's continental ice sheets (DeConto and Pollard, 2003; Kennett, 1977; Kennett et al., 1974).

Development of the West Antarctic Rift System (WARS), which encompasses much of the modern Ross Sea (Behrendt et al., 1991; Cooper and Davey, 1985; LeMasurier, 1990; Luyendyk et al., 2001; Wilson and Luyendyk, 2009), has influenced the timing and amount of West Antarctic subsidence, Transantarctic Mountain (TAM) uplift, and crustal heat flux – all of which influence EAIS and West Antarctic Ice Sheet (WAIS) evolution (Wilson et al., 2013). The WARS comprises three large sedimentary basins in the Ross Sea: the Victoria Land Basin; Central Trough and the Eastern Basin. By constraining the relative timing of rifting in each basins, we will test hypotheses regarding the role of Ross Sea rifting on global plate kinematics, thereby reducing existing uncertainty in deciphering Pacific plate motions (Matthews et al., 2015; Müller, 2019; Sutherland, 2007). Critically, the basins also contain archives of both Antarctic environmental change since the Late Cretaceous, including the early history of the Cenozoic Antarctic Ice Sheets (Brancolini et al., 1995; Decesari et al., 2007; Fielding et al., 2008; Sorlien et al., 2007) (Figure 1).

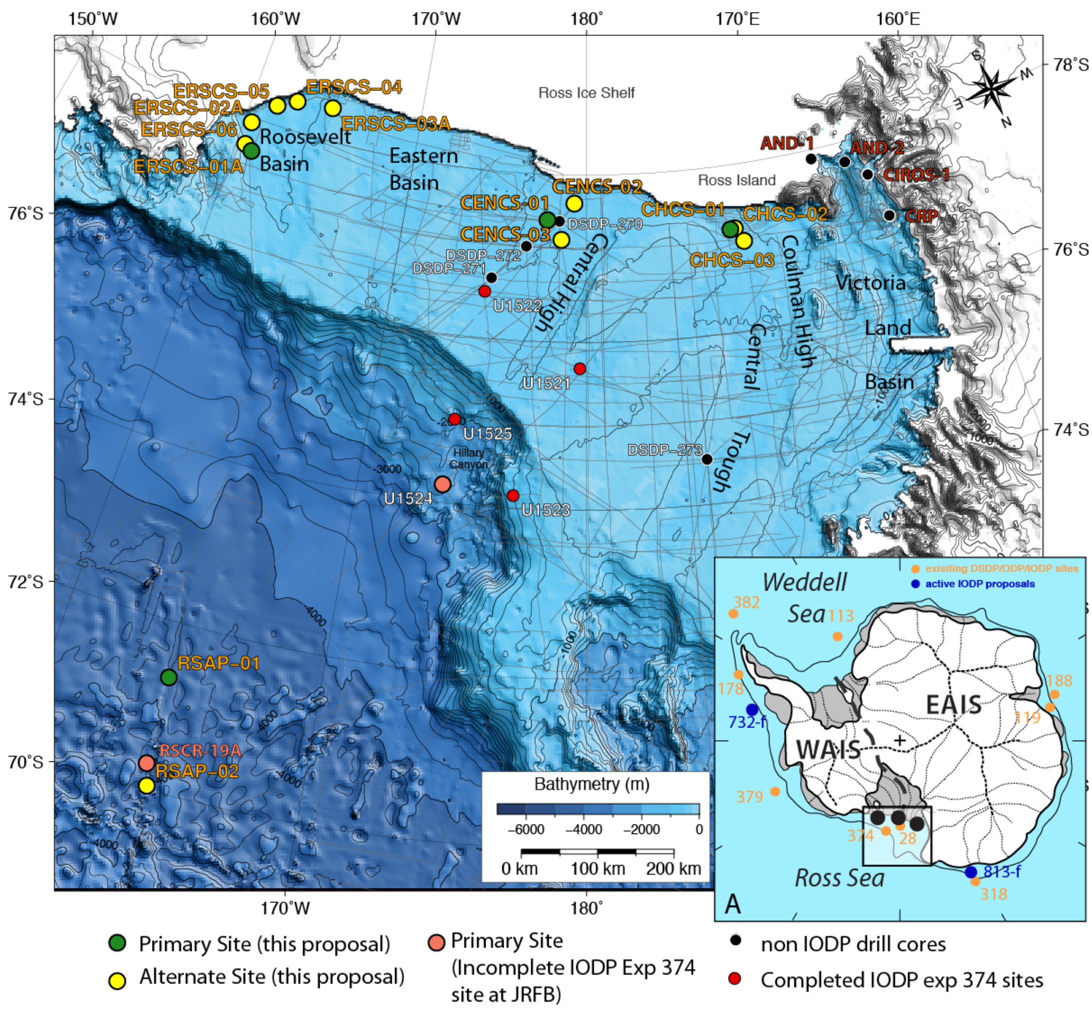


Figure 1: Ross Sea bathymetry with locations of proposed drill sites (including alternates); existing drill sites; and incomplete primary sites from IODP Expedition 374 (alternates from IODP Expedition 374 not shown). Major basins discussed in proposal are labeled. Insert map show major ice flow pathways of the West Antarctic Ice Sheet (WAIS) and East Antarctic Ice Sheet (EAIS), and previous drilling legs (orange dots), active proposals (blue dots) and the sites proposed herein (black dots). Note how the sites in this proposal are strategically located to capture sedimentary archives of WAIS and EAIS ice flow into the Ross Sea (thick dashed line represents the dividing line between these ice sheet sources).

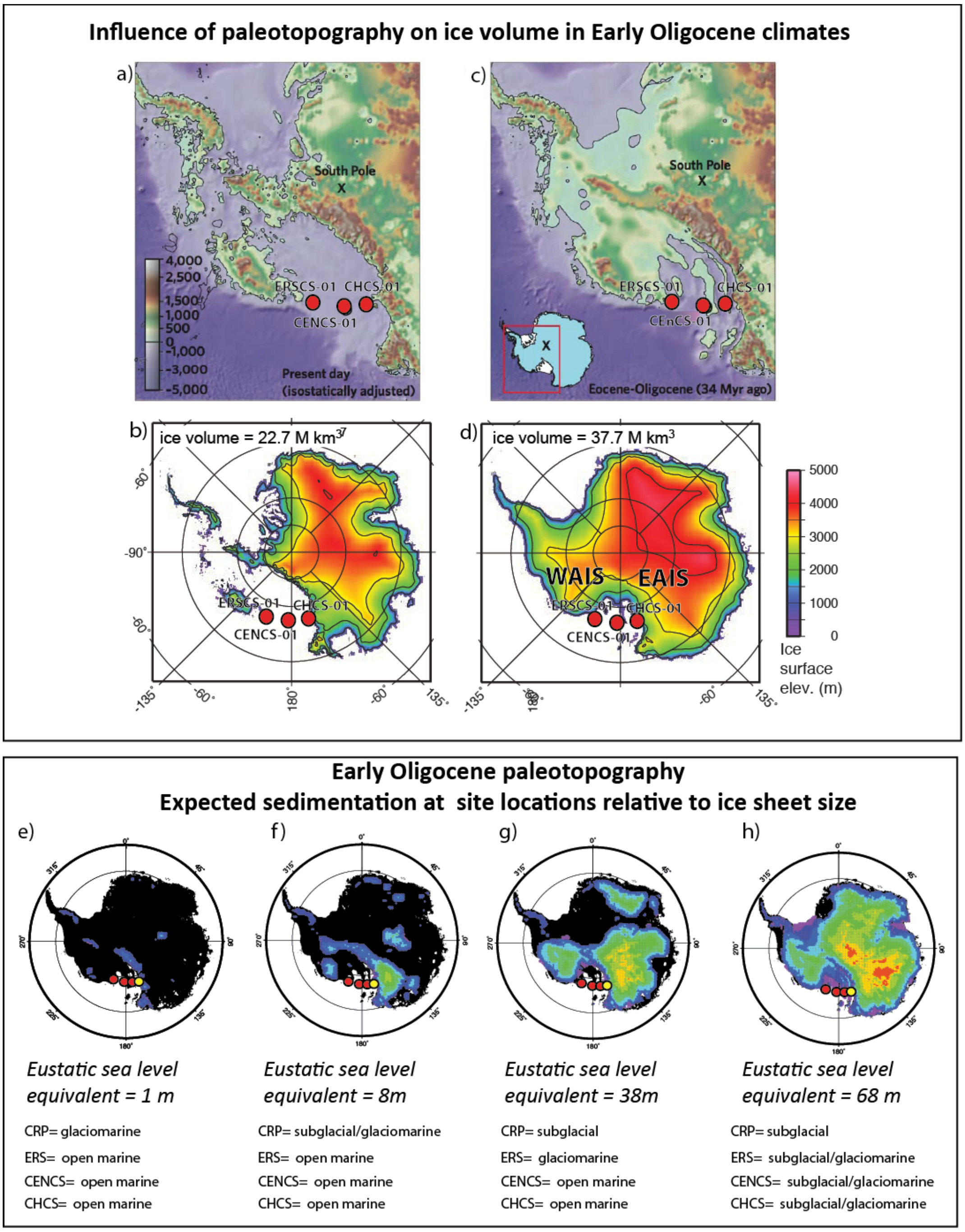


*Figure 2: **Upper panel**: a) Modern topography of West Antarctica, with b) modeled ice sheet volume under an E/O boundary climate state (700 ppm CO_2) indicating a lack of ice in West Antarctica as marine ice sheet does not form in this warmer-than-present climate state. c) Reconstructed E/O topography of West Antarctica, with modeled ice sheet volume run in same climate as shown in panel b. Note almost doubling of ice volume due to this topographic change, as terrestrial ice sheets can grow in West Antarctica under E/O climate states. **Lower Panels:** Ice sheet model evolution across the E/O transition using reconstruction shown in Figure 2c. This model indicates: (e) small alpine glaciers or (f) ice caps in TAM could result in glacial deposition at the CRP core records (yellow dot), but only contributing 1-8 m of eustatic sea level fall. Large advances from WAIS and EAIS into the Ross Sea (g, h) will be captured at the proposed sites herein (red dots)- and represent continental scale ice sheets up to 68 m sea level equivalent (model run from Stocchi et al., 2013)).*

2. Why the Ross Sea?

We submit that the Ross Sea region is the best location to use ship-based drilling to test hypotheses relating to Antarctic feedbacks on Cenozoic climate history, and WARS influence on global plate tectonic motions. DSDP Leg 28 and IODP Expedition 374 demonstrated the accessibility of the Ross Sea for drilling and exploited the region's extensive seismic stratigraphic framework in Antarctica (Figure 1) (Brancolini et al., 1995; Decesari et al., 2007). Rifting in West Antarctica likely initiated across in Marie Byrd Land (between the Amundsen and Ross Sea sectors) ~104 Ma and continued through the Cenozoic into Central then western Ross Sea Embayment (Decesari et al., 2007; Eagles et al., 2004; Wilson and Luyendyk, 2009; Wobbe et al., 2012). Alternate models suggest different patterns and timing, but all are unconstrained by geological drilling (Bart and De Santis, 2012; Decesari et al., 2007; De Santis et al., 1995; Luyendyk et al., 2001). We plan an east-to-west transect to target distinct intervals of rift-fill strata to examine high-latitude paleoclimatic evolution since Late Cretaceous times, and constrain rift history.

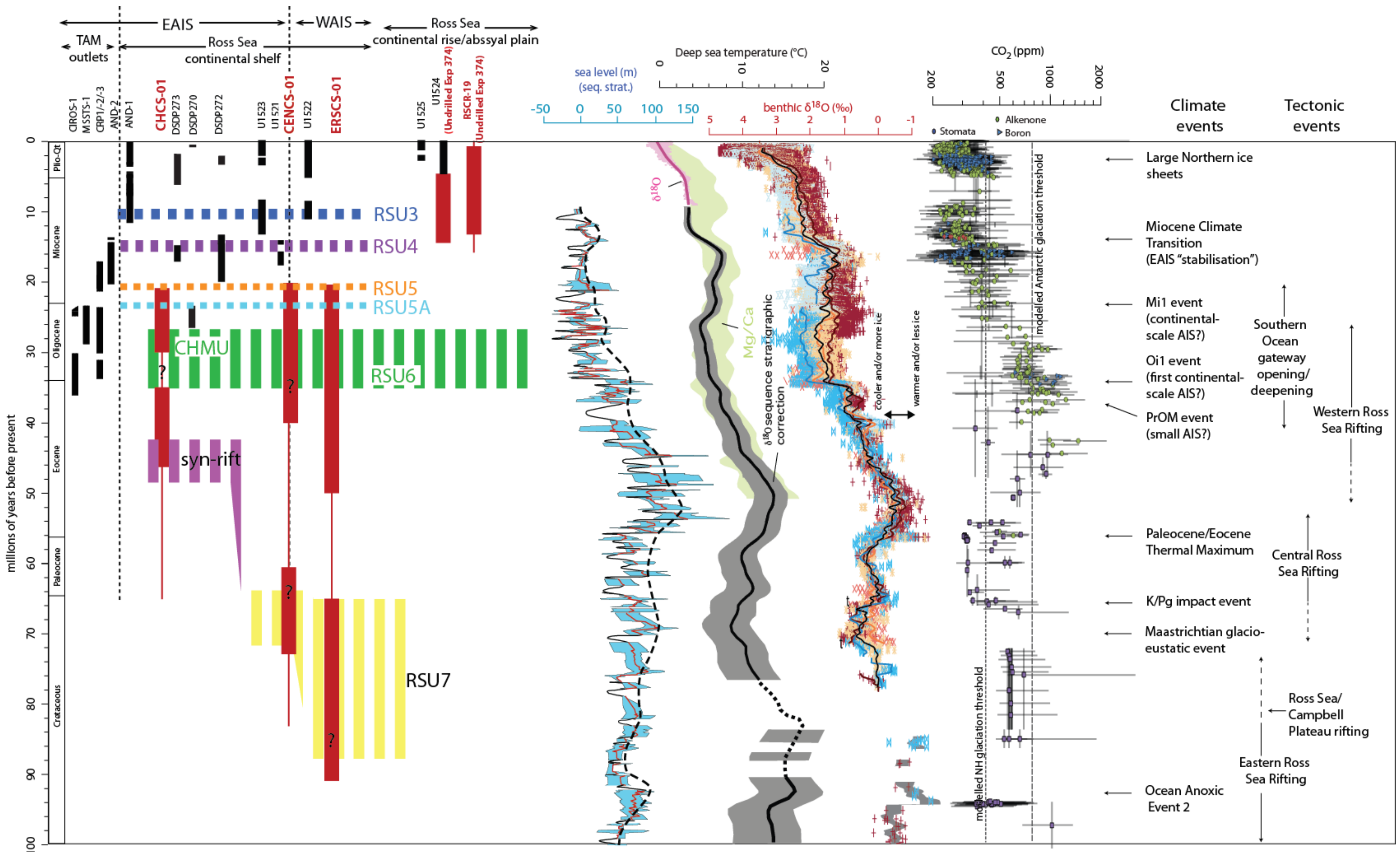
A critical component of drilling success on the Antarctic continental shelves is ice-free access. Annually, a large open-water polynya forms over the Ross Sea continental shelf, south of major storm tracks, which allows for stable drilling conditions and recovery rates that exceed other Antarctica's continental shelf regions (Hayes et al., 1975; McKay et al., 2018) (Figure 8). Sea ice free conditions in this polynya (Figure 9) allow ships to reach the highest possible southern latitudes (up to 78°S). Records recovered will offer the high-latitude end-member that, when integrated with existing data sets (Hollis et al., 2019), will complete trans-hemispheric transects that will allow a more complete examination of changing temperature gradients and variations in polar amplification. These new high-latitude data will also allow us to examine the role of feedbacks through the Early Cenozoic cooling and initiation of glaciation in Antarctica.

Finally, the location of our continental shelf drill sites affords a unique opportunity to constrain the earliest ice sheet advance sourced from both the EAIS and WAIS (Figures 1-2), and identify key environmental and tectonic boundary conditions that influenced the earliest phases of continental-scale ice sheet development.

3. Scientific rationale and drilling approach

The Cretaceous to Oligocene is a period when Earth transitioned through several major climate episodes; from a warm Cretaceous to a relatively cool Paleocene, into the high-CO_2 "hothouse" worlds of the early to mid-Eocene, and then into the lower-CO_2 "icehouse" world of the Oligocene when large Antarctic ice sheets first formed (DeConto et al., 2008; Foster and Rohling, 2013; Liu et al., 2009; Zachos et al., 2001). Obtaining a high-latitude record through these major climatic episodes has been a longstanding goal of the paleoclimate community. Records from locations directly adjacent to the Antarctic continent that document the earliest onset of continental-scale glaciation, as well as climatic, vegetation, carbon cycle and tectonic changes since the Cretaceous are considered a holy grail. Such archives offer a means to examine high-latitude environmental conditions during peak warmth of the Early Eocene Climatic Optimum (~53-49 Ma) and assess the potential for episodes of ice sheet growth during cooler climatic intervals in the Paleocene-late Eocene, that are inferred from far-field sea level records (Hollis et al., 2012; Miller et al., 2005; Scher et al., 2014).

Figure 3 (NEXT PAGE): Chronostratigraphic summary of existing and proposed Ross Sea drilling (Modified from McKay et al., 2018). Seismic stratigraphy below RSU4 is constrained by drilling in the Victoria Land Basin, but not in the Central and Eastern basins Seismic stratigraphy below CHMU/RSU6 (28-34 Ma) or lower is not constrained in any basin. Red lines indicate predicted stratigraphies to be recovered in the proposed sites. These predictions are based on hypothesized rift histories within each basin, as presented in Figure 5, although this can only be constrained by drilling. Far-field sea level records (Kominz et al., 2008), climate proxies ($\delta^{18}O$; Cramer et al., 2009)), atmospheric CO_2, (Foster et al., 2017), and relevant Cenozoic climate and tectonic events also shown.



EAIS
WAIS
TAM outlets
Ross Sea continental shelf
Ross Sea continental rise/abyssal plain
CIROS-1
MSSTS-1
CRP1/-2/-3
AND-2
AND-1
CHCS-01
DSDP273
DSDP270
DSDP272
U1523
U1521
CENCS-01
U1522
ERSCS-01
U1525
U1524 (Undrilled Exp 374)
RSCR-19 (Undrilled Exp 374)
millions of years before present
Plio-Qt
Miocene
Oligocene
Eocene
Paleocene
Cretaceous
RSU3
RSU4
RSU5
RSU5A
CHMU
RSU6
syn-rift
RSU7
sea level (m) (seq. strat.)
-50 0 50 100 150
Deep sea temperature (°C)
benthic $\delta^{18}O$ (‰)
$\delta^{18}O$
Mg/Ca
$\delta^{18}O$ sequence stratigraphic correction
cooler and/or more ice
warmer and/or less ice
CO_2 (ppm)
Stomata
Alkenone
Boron
modelled Antarctic glaciation threshold
modelled NH glaciation threshold
Climate events
Tectonic events
Large Northern ice sheets
Miocene Climate Transition (EAIS "stabilisation")
Mi1 event (continental-scale AIS?)
Oi1 event (first continental-scale AIS?)
PrOM event (small AIS?)
Paleocene/Eocene Thermal Maximum
K/Pg impact event
Maastrichtian glacio-eustatic event
Ocean Anoxic Event 2
Southern Ocean gateway opening/ deepening
Western Ross Sea Rifting
Central Ross Sea Rifting
Ross Sea/ Campbell Plateau rifting
Eastern Ross Sea Rifting

4. Linkages to previous drilling and active proposals in the Ross Sea

Most of the key new drill sites and scientific rationale presented herein were previously assessed through SEP, International Continental Drilling Programme (ICDP), and NSF processes. Positive outcomes from these reviews contributed to our decision to submit a full-proposal to IODP. The scientific rationale of the Eastern Ross Sea sites (ERSCS) were assessed by the IODP Science Evaluation Panel for 812-pre, which planned to use a seafloor drill system to obtain short (<100 m cores) (invited to develop full-proposal).

Sites in the western Ross Sea (CHCS) are based on those proposed in the ANDRILL Coulman High project (peer-review through NSF and ICDP proposals, but not drilled due to funding constraints). Modified ANDRILL sites (shifted to locations away from the ice shelf) were included in IODP Expedition 374 as alternates for extreme sea ice scenarios (see IODP751-Add2). We have further adjusted the location of these sites to target older geological strata.

These new sites compliment two sites that are currently at the JRFB awaiting rescheduling (Site U1524 and RSCR-19A), and allow us to complete a full five site expedition (See Table 3). The two approved sites were not completed during Expedition 374 due to the early termination and loss of 39% of the operational time due to a mechanical failure.

IODP Expedition 374 had exceptional success, including record recovery rates for the Antarctic continental shelf (section 9.1; Figure 8). Recovery of sediment at sites U1524 and RSCR-19A will complete the planned continental shelf to deep sea transect aspect of Expedition 374.

5. Cretaceous to Eocene climate history

5.1. Global climate during the Late Cretaceous to Oligocene.

Low- and mid-latitude passive margins record high-amplitude sea level variations (40-100 m) since Cretaceous times, implying substantial ice sheets on Antarctica long before the assumed first glaciation in the earliest Oligocene (Hollis et al., 2014; Kominz et al., 2008; Miller et al., 2008, 2005, 1991). However, mantle dynamics may exert a significant influence that overwhelms a eustatic signal in the far-field sequence stratigraphic record (Moucha et al., 2008; Raymo et al., 2011). It remains equivocal whether significant Antarctic Ice Sheets (AIS) existed during the Late Cretaceous to Eocene.

The Eocene epoch was the last period when atmospheric CO_2 exceeded 3-5x Pre industrial concentrations (Anagnostou et al., 2016; Foster et al., 2017; Jagniecki et al., 2015; Liu et al., 2009; Pagani et al., 2011, 2005). Ocean modeling studies indicate that poleward heat transport in the Eocene was similar to today, but polar sea-surface temperatures (SSTs) were up to ~14°C warmer (Hollis et al., 2019, 2012; Huber et al., 2004). An ice free and vegetated Antarctica may have exerted a significant control on the global carbon cycle, by thawing of organic-rich permafrost soils during rapid and extreme warming event (hyperthermals) of the Eocene, including the Paleocene Eocene Thermal (PETM) (DeConto et al., 2012). Consequently, a direct record of the Antarctic terrestrial environment during the Paleogene - either though sampling of terrestrial deposits, or terrestrial runoff in a shallow marine environment - are essential to test this hypothesis of Antarctic carbon sources to the PETM.

High-resolution deep-sea $\delta^{18}O$ records, paleontological studies, and modeling experiments suggest the growth of the first ice sheets were triggered at the Eocene/Oligocene boundary by an optimally cold orbital configuration (Coxall et al., 2005), following the tectonic opening of Southern Ocean gateways (Bijl et al., 2013a; Kennett, 1977) and was associated with a decrease in atmospheric CO_2 below a threshold value (DeConto et al., 2008). Once initiated, the height-albedo feedback ensured that the first ice remained as a nucleus, from which the ice sheet expanded and contracted in response to orbital forcing (DeConto and Pollard, 2003). However, seismic data and short core evidence from East Antarctica suggest glaciers may have advanced into marine settings prior to Eocene/Oligocene boundary (Carter et al., 2017; Gulick et al., 2017). Continuous high-latitude records are needed to evaluate ice sheet variability prior to the Eocene/Oligocene (E/O) boundary.

5.2. Antarctic records of the Late Cretaceous to Oligocene

The only *in situ* Antarctic continental shelf records obtained for the Late Cretaceous to earliest Paleogene are exposed on Seymour Island in the Antarctic Peninsula (Ivany et al., 2008), which at the time of deposition was an emergent volcanic arc at paleolatitude of ~65°S, rather than part of continental Antarctica (Elliot, 1988; Lawver et al., 1992). Pollen assemblages indicate a cool to warm temperate coastal vegetation in the Late Cretaceous, with Mean Annual Temperatures of ~10-15°C, and dinoflagellate assemblages suggesting the possibility of winter sea ice (Bowman et al., 2014, 2013).

Late Cretaceous and Paleocene strata are yet to be sampled *in situ* at higher latitudes in the Antarctic, such as the Ross Sea (paleolatitude of ~80°S), although a recent seafloor drill core recovered short intervals of possible terrigenous Cretaceous to Paleocene(?) sandstone from the Amundsen Sea region of West Antarctica (Gohl et al., 2017). The oldest known WARS infill sediments are mid-Eocene glacial erratics deposited in moraine in the western Ross Sea (Askin, 2000; Levy and Harwood, 2000). However, rifting in the Ross Sea sector may have initiated during the Late Cretaceous in the eastern Ross Sea (Luyendyk et al., 2001; Wilson and Luyendyk, 2009). Reworked terrestrial Cretaceous palynomorphs are observed in surface sediments from the eastern Ross Sea, suggesting Cretaceous sediments are present in the rift basins (Kemp and Barrett, 1975; Truswell and Drewry, 1984).

Isotope studies on mollusks in the Antarctic Peninsula region suggest SSTs reached ~15°C in the early Eocene and cooled to ~5°C by the late Eocene (Ivany et al., 2008). Proxies from early Eocene strata off Wilkes Land indicate much warmer summer temperatures (~25°C) and frost-free winters (~10°C) despite polar winter darkness (Pross et al., 2012), and SSTs >15°C warmer than present (Bijl et al., 2013a). Despite these temperatures, modelling indicates ice caps on interior mountains are possible, depending on atmospheric CO_2 levels (DeConto et al., 2008). Most modeling studies fail to produce extreme Eocene Antarctic temperatures, unless CO_2 levels are significantly higher than current proxy records suggest (Hollis et al., 2012, 2009), implying that models might be under-sensitive and lack some processes critical for simulation of polar climates.

New data from continuous to semi-continuous *in situ* strata at very high latitudes, will allow temperature gradients to be reconstructed and provide a more complete assessment of polar amplification of temperature during the Paleogene greenhouse world (Hollis et al., 2019). Importantly, the proto-Ross Sea region was open to the Pacific Ocean during the Paleocene-Eocene and thus provides a high-latitude end member of Pacific Ocean oceanography at this time (Figure 5). Previously drilled sites in Wilkes Land (sited along the Australian conjugate margin) and Seymour Island (in close proximity to South America) (Cande and Stock, 2004) were likely strongly influenced by local oceanographic and continental controls (Bijl et al., 2013a).

Paleotopographic reconstruction reveals that West Antarctic was largely above sea level at 34 Ma. Therefore, Antarctica could hold more terrestrial ice in Oligocene than it can today, even though the climate was warmer than present (Wilson et al., 2013). This is because the cooling threshold required for the development of a terrestrial-based ice sheet is lower than that of a marine-based ice sheet, which is highly sensitive to changes in oceanic heat flux. Consequently, models indicate a largely terrestrial West Antarctica could accommodate an extra ~13 million km^2 of grounded ice (i.e. ~30 m SLE) during the early Oligocene, while the increased buttressing provided by a larger WAIS also leads to a larger and higher EAIS (Bart et al., 2016; Colleoni et al., 2018; Wilson et al., 2013). In addition, marine ice sheets also displace some of their mass in the ocean, so even if the volumes of a marine versus terrestrial ice sheet are the same, the resulting sea level changes are less for marine ice sheets (Gasson et al., 2016) (Figure 2). Constraining West Antarctica's paleotopography is critical for determining AIS contributions to eustatic sea level variance and ice volume through the Cenozoic.

During the earliest Oligocene (and potentially late Eocene), marine-terminating glaciers episodically extended beyond the present day coastline in the Prydz Bay, Wilkes Land, and Ross Sea regions (Barrett, 1989; Escutia and Brinkhuis, 2014; Galeotti et al., 2016; Hambrey et al., 1991; Levy et al., 2019). However, much of this evidence either comes from 1) sedimentological data from the deep-sea margin of Antarctica which only indicates presence (rather than size) of marine terminating glaciers; and 2) sites in close proximity to the TAM (e.g. CIROS-1 and Cape Roberts Project), that are highly discontinuous and potentially recording smaller-scale alpine glacial advances. Our transect approach is designed to document larger-scale ice caps and sheets advancing into a marine marginal setting well away from the influences of local TAM outlets (Figures 2-3).

6. Geology and stratigraphy of the Ross Sea

Extension associated with the WARS likely occurred in several phases over the Late Cretaceous and Cenozoic, and led to the opening of the Ross Sea and the development of three major sedimentary basins in the Ross Sea (Figure 4) (Cooper et al., 1991; Wilson and Luyendyk, 2009)). The western-most Victoria Land Basin (VLB) has been the focus of most previous geological drilling in the Ross Sea region (e.g. DVDP, MSSTS-1, CIROS-1 and -2, Cape Roberts Project (CRP) and ANDRILL). This proposal focuses on the unsampled Early Cenozoic sequences in the Central Trough and the Eastern Basin, which contain up to ~8 km of Cenozoic sediment infill (Figures 4-5) (Brancolini et al., 1995; Busetti et al., 1999).

6.1. Seismic Stratigraphy

Within the Eastern Basin and Central Trough, eight major Ross Sea Sequence (RSS1-8) units and seven major Ross Sea Unconformities (RSU1-7) are mapped, and represent major steps in Antarctica's tectonic and climatic evolution (Table 1). The oldest and deepest unit is RSS-1, which consists of graben-bound rift-fill strata and is separated into two units, representing early- (RSS-1 Lower) and late-rift (RSS-1 Upper) sequences bounded by unconformity RSU7. These units are probably diachronous across basins, a consequence of rifting propagating toward the west (Figures 4-5). To highlight this different timing, we refer to this surface as "top-syn rift" in the Central Trough to Coulman High region, rather than RSU7. Unit RSS-1-lower is likely Late Cretaceous in age in the Eastern Basin, and is characterized by dipping and disrupted reflectors. RSS-1-lower may represent a fluvial terrestrial setting and potentially provide a unique opportunity to sample terrestrial Antarctic environments during the Cretaceous (Luyendyk et al., 2001). RSU7 is inferred have formed during regional extension during breakup of the continent (Decesari et al., 2007; Luyendyk et al., 2001). Unit RSS-1 upper is a thicker sequence of flat lying, faulted strata onlapping onto RSU7, and inferred to contain marine strata deposited during marine transgression across thermally subsiding crust (Decesari et al., 2007).

RSU6 is a prominent seismic unconformity across the Ross Sea but its origin and age is enigmatic. It is possible that RSU6 was cored at CRP and CIROS-1 (Figures 1 and 3), but its age at these sites is highly ambiguous due to extensive truncated unconformities by alpine TAM glaciation at these sites, making correlations to the broader Ross Sea seismic stratigraphy tenuous (Davey et al., 2000). DSDP Site 270 provides a minimum constraint for RSU6 of >26.5 Ma, but this site cored into a basement high and likely postdates RSU6 (Figure 6). An early Oligocene age (>28 Ma) is consistent with the hypothesis that RSU6 represents either the transition from the Eocene “greenhouse” to early Oligocene “icehouse”, or early Oligocene grounding of ice sheets on the Ross Sea continental shelf, and related sea level falls associated with ice sheet growth (Anderson and Bartek, 1992; Bartek et al., 1991; De Santis et al., 1995) However, Glacio Isostatic Adjustment (GIA) theory and experiments indicate initial ice sheet growth would result in rising sea levels in the near field Antarctic (Stocchi et al., 2013).

Sequence	Sequence seismic character	Age	Bottom unconformity
RSS-8	Aggradational topset beds underlying (locally backstepping grounding zone wedge)	Pleistocene	RSU1 (0.7 Ma?)
RSS-7	Aggradational, topset beds	Pliocene	RSU2 (?4 Ma)
RSS-6	Shelf topset beds and prograding trough mouth fan at the shelf edge	Late Miocene	RSU3 (?12 Ma)
RSS-5	Alternating subsequences made of grounding zone prograding wedges and subhorizontal strata packages	Mid Miocene	RSU4 (14-16 Ma)
RSS-4	Grounding zone prograding wedges and subhorizontal strata packages	Early Miocene	RSU4a (18.5 Ma?)
RSS-3	Alternating subsequences made of grounding zone prograding wedges and subhorizontal strata packages	Early Miocene	RSU5 (21 Ma?)
RSS-2	Alternating subsequences made of grounding zone prograding wedges and subhorizontal strata packages	(Early?)Late Oligocene- early Miocene	RSU6 (28-34 Ma?)
RSS-1-upper	Subhorizontal strata filling basement basins	Late Eocene- early Oligocene	RSU7 (>34 Ma?)
RSS-1-lower	Subhorizontal and dipping strata filling basement basins	?Late Cretaceous	Basement

Table 1: Seismic stratigraphic framework for Ross Sea. Modified from (Brancolini et al., 1995).

In the Coulman High region, RSU6 is truncated and possibly amalgamated over the structural highs by the younger Coulman High Major Unconformity (CHMU) which separates rift fill strata (RSS-1) from overlying post-rift, glaciomarine strata of RSS-2. The age of CHMU and the rift-fill strata are likely younger than the RSU6 unconformity in the Central and Eastern Ross Sea. Noting this caveat, we classify this truncated surface at the CHCS-01A site (and alternates) as RSU6 in the presentation of our site forms, although it is likely younger than in the Eastern Basin. This can be made by comparison of the seismic stratigraphy with ages obtained from CENCS-01A and ERS-CS-01A (Figure 7).

Overlying RSU6, glacial-influenced marine sediment dominates RSS-2, and provides a record of the early to Late Oligocene and early Miocene history of the AIS, although this unit is still only sparsely sampled. The CRP and CIROS-1 records obtained discontinuous records influenced by deposition of local TAM alpine glaciers since the earliest Oligocene (Figure 2), whereas DSDP Site 270 only sampled the upper part of RSS-2, but with several large hiatus, including one near the O/M boundary (Kulhanek et al., in review). Site CENCS-01A provides a much more complete section of RSS-2 (Figure 6) (see detail in Section 8.2).

The recent IODP Expedition 374 drilled sediments post-dating 18 Ma (RSS-4 and younger) in the Central Ross Sea, to document the evolution of the marine-based ice sheets in the Ross Sea, as glacial erosion resulted in a transition from a seaward dipping shallow continental shelf to an overdeepened continental shelf.

The early history of WAIS expansion in the central to Eastern Ross Sea is currently unsampled, despite seismic evidence of large WAIS expansion sometime during the Early to Late Oligocene (Sorlien et al., 2007). As noted earlier, expansion of WAIS during the relatively warmer climates (compared to today) of the Early Oligocene is possible if West Antarctic was more elevated at that time (Wilson et al., 2013) (Figure 2). Consequently, the ice sheet evolution of the Ross Sea is hypothesized to be strongly-coupled to ice sheet evolution tectonic and subsidence evolution of West Antarctica, rather than climate forcing alone (see Guiding Hypothesis 3 in Section 7).

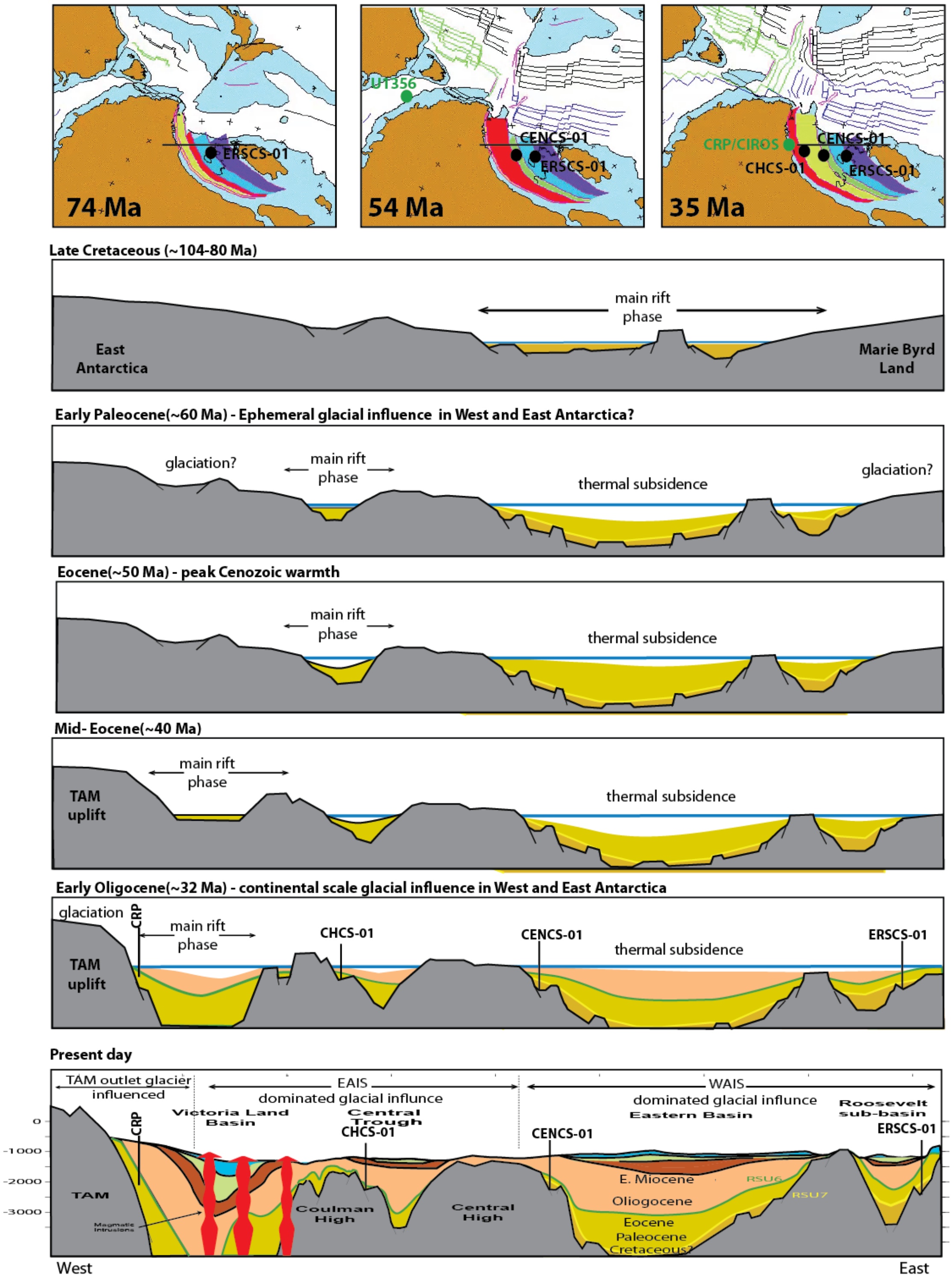


Figure 4: Rift history and relationship to basin infill and ice sheet/TAM outlet glacier influences through time (c.f. ice sheet models in Figure 2e-h). It is based on the rift model presented in Figure 5. Targeted drilling at each continental shelf will assess the timing of active rift termination. This model results in the ERSCS-02A obtaining the oldest rift fill and climate records (back to Cretaceous?), and site CHCS-01A will contain the youngest rift fill and paleoclimate record (back to Middle Eocene?).

7. Scientific Objectives

Objective 1: Obtain direct evidence of the earliest ice sheets in East and West Antarctica expanding into the Ross Sea.

Guiding hypothesis 1: West Antarctica accommodated terrestrial ice sheets, which episodically expanded across shallow regions of the Ross Sea in the Latest Eocene and Oligocene driving sea level variation of 10s of metres.

It is generally assumed the first large ice sheets in Antarctica formed at the E/O boundary, as a consequence of the opening of Southern Ocean gateways and declining atmospheric CO_2 values (see section 5). A prominent Southern Ocean cooling, associated with a short lived $\delta^{18}O$ excursion (Priabonian Oxygen Istope Maximum; PrOM), has been identified in microfossil assemblages at ~37 Ma, and linked to an early AIS glaciation through fossil assemblages and the presence of ice rafted debris in the southern Ocean and East Antarctic margin (Carter et al., 2017; Pascher et al., 2015; Passchier et al., 2017; Scher et al., 2014). Glacimarine deposits are also interpreted from early to mid-Eocene continental shelf cores from the Sabrina Coast region on the East Antarctic margin, although determining the scale of marine-terminating glaciation at this time is ambiguous owing to the lack of equivalent datasets from other parts of Antarctica (Gulick et al., 2017).

The 1.0 to 1.5‰ enrichment in benthic foraminiferal $\delta^{18}O$ across the E/O boundary (Oi-1 event) implies a significant Antarctic ice sheet volume increase at 34 Ma (Coxall et al., 2005; Lear et al., 2000; Zachos et al., 2001), while Early Oligocene glaciation has been unequivocally identified from coastal CRP and CIROS-1 core (Barrett, 2007, 1989; Galeotti et al., 2016), that document fluctuations of TAM glaciations at orbital-scale periods. If ice only grew on East Antarctica at this time, its ice volume would have been 25-50% too small to account for the marine benthic isotope shift (Figure 2). This requires significant ice in the Northern Hemisphere during this cooling event, a deep sea cooling of 4°C (Liu et al., 2009), or an Antarctic continent that was capable of storing more ice during the Oligocene than the Last Glacial Maximum (DeConto et al., 2008). As noted in Section 5.2, tectonic and pre-erosional reconstructions of West Antarctica could accommodate much larger ice sheets (~20 m sea level equivalent) in warmer-than-present climates due to its more subaerial setting (Figure 2), and significantly reduces the discrepancy between proxy inferences of ice volume based on oxygen isotopes and sea level records (Liu et al., 2009; Miller et al., 2008).

Once ice sheets were more fully established during the Oligocene period, atmospheric CO_2 levels ranged between 400-800 ppm (Foster and Rohling, 2013; Pagani et al., 2011; Zhang et al., 2013) (Figure 3). We hypothesize that these concentrations precluded the formation of widespread marine-based ice sheets, except in a very shallow marine setting (e.g. terrestrial ice sheets can still have marine terminating margins, as they do today in parts of East Antarctica and Greenland). It this is correct, then we anticipate recovering a mostly continuous Oligocene glacimarine sequence largely devoid of ice sheet grounding events at Sites ERSCS-02, CENCS-01A and CHCS-01A (c.f. Figure 2). If present, hiatuses will be diagnostically important, as they may be associated with sea level changes or grounded ice sheet overriding during the largest transient glaciations. Indeed, the transient nature of large Oligocene glaciations have been difficult to rectify in a climate- and ice-sheet modeling context (Pollard and DeConto, 2005). This is mainly because AIS hysteresis is very strong, and once a high elevation, terrestrial ice sheet covers the continent, orbital forcing alone cannot provide enough surface melt to drive a retreat, even at CO_2 levels >4x PAL (Huybrechts, 1994; Pollard and DeConto, 2005), much higher than Oligocene estimates from paleo CO_2 proxies (DeConto et al., 2008; Foster and Rohling, 2013; Pagani et al., 2011, 2005).

Resolving these issues will require new data from sites located in sites influenced by past WAIS (e.g., ERSCS-02A) and EAIS (e.g.,CHCS-01A) advance and retreat into the Ross Sea proposed here. To test guiding hypothesis 1, we will recover strata above and below RSU6 and the CHMU to investigate spatial distribution of glacimarine and subglacial sediment across the marine continental shelf when it was much shallower than today and could have hosted the marine terminating margins of ice sheets/caps.

Guiding hypothesis 2: Substantial ephemeral ice caps were present in West Antarctica during proposed cooler "greenhouse" climates of the Late Eocene and Paleocene

The ocean gateway hypothesis proposes that widespread Late Cenozoic glaciation in Antarctic was driven by thermal isolation of the Antarctic continent after the tectonic opening of the Southern Ocean "gateways" to the south of Australia and South America during the Late Eocene (Bijl et al., 2013a; Kennett, 1977). However, this hypothesis has been challenged by ice sheet models that propose ice sheet response was primarily driven by declining CO_2, and changes in oceanic heat flux changes driven by gateway opening played a lesser role (DeConto and Pollard, 2003).

Far-field studies provide equivocal evidence of glaciation during the Paleocene (see Section 5) (Hollis et al., 2014; Miller et al., 2005), and obtaining direct evidence of marine-terminating glaciation at a time preceding gateway opening will help test existing models and hypotheses for ice sheet development. If glacial or glacimarine lithofacies or other geochemical/seismic indicators indicating glacial transport/erosion are present at any of our sites during the Cretaceous to middle Eocene, this may point towards a dominant greenhouse gas forcing for ice sheet development in Antarctica, with the caveat tectonic changes may ultimately drive carbon cycle changes. These data will be augmented with environmental proxies for temperature, sea ice and changes in the hydrological and carbon cycles (see Table 2) that can be used to test model-based hypothesis for thresholds of ice sheet development in the Cenozoic (DeConto et al., 2008). This hypothesis will be tested by obtaining strata below RSU6 and RSU7 at sites CHCS-01A, CENCS-01A, and ERSCS-02A to assess for the presence of glacimarine indicators (Table 2).

Guiding hypothesis 3: Tectonic subsidence and erosion of WANT led to a decoupling of Antarctic ice volume to global climate state through the Cenozoic.

As noted in guiding hypothesis 1, larger than present ice sheets can be sustained in Antarctica during warmer-than-present climates if West Antarctica was largely elevated above sea level. Given that benthic foraminiferal oxygen isotopes are a function of both deep-sea temperature and ice volume, the common assumption that a cooling global ocean would directly relate to larger ice volumes requires reassessment. Differentiating climatic versus tectonic influences on Antarctic climate evolution and ice volume during the Cenozoic may help to reconcile interpretations of the non-linear relationship between oxygen isotope-based assessments of global climate/ice volume with that of past atmospheric CO_2 concentrations (Figure 3).

The integration of our new Cretaceous to early Miocene records with existing younger records obtained from previous drilling (Figure 3) will enable a complete stratigraphic record of both WAIS and EAIS evolution through the entire Cenozoic in the Ross Sea, with a constraint of spatial extent of these ice sheets determined by our longitudinal transect approach and model-data integration (Figure 2).

Objective 2: Obtain geological reconstructions of "pre-icehouse" climates at high latitudes in Antarctica during the Late Cretaceous to Eocene

Guiding hypothesis 4: High levels of atmospheric CO_2 and associated polar amplification during the early to mid-Eocene "greenhouse" maintained mostly ice-free climates at high southern latitudes.

As noted in section 5, modeling studies fail to produce extreme Eocene Antarctic temperatures under scenarios of high CO_2 implied by proxies, suggesting that models might be under-sensitive and lack some processes critical for simulation of polar climates (Hollis et al., 2009).

In contrast to the apparent warmth of the Eocene, sea level records from low-latitude passive margins in the Paleocene to Eocene record large amplitude variations, which could relate to episodic growth of substantial ice sheets on Antarctica or mantle dynamics affecting these relative sea level records (Kominz et al., 2008; Miller et al., 2005; Moucha et al., 2008). These far-field sea level records contradict the current model of Cenozoic cryosphere evolution and AIS expansion at 34 Ma (Coxall et al., 2005), but they have never been tested against direct records proximal to the Antarctic continent, although short cores collected in Sabrina Coast and Prydz Bay regions of East Antarctica and the Weddell Sea suggest the presence of some marine terminating glaciers in the Early Eocene (Carter et al., 2017; Gulick et al., 2017; Passchier et al., 2017). Obtaining paleoenvironmental data from our transect sites will directly test competing hypothesis of widespread glaciation in the early Cenozoic, climate sensitivity to

GHG forcing and strength of polar amplification, and the role of global heat-transport mechanisms during past extreme greenhouse climates.

Guiding hypothesis 5: Terrestrial environments in the Cretaceous and Paleocene provided a significant carbon source for Eocene hyperthermal events.

Drilling on the Ross Sea continental shelf is anticipated to recover *in situ* Paleocene to Eocene marine strata, and maybe Cretaceous to Paleocene terrestrial sediments (Figures 4-6). Very little is known about the Antarctic terrestrial environment and its role in the global carbon cycling during this interval, but the thawing of organic rich permafrost deposits have been implicated in Eocene hyperthermal events, including the Paleocene Eocene Thermal Maxima (DeConto et al., 2012). Consequently, assessing the terrestrial and marine marginal Antarctic paleoenvironments during the Cretaceous to Eocene will help test this hypothesis, as will the identification of permafrost conditions during the Paleocene and Eocene (e.g. freeze-thaw features). Testing this hypothesis does not require direct sampling of the hyperthermals, but only an assessment of the potential carbon source and climatic conditions (e.g. thawing permafrost) which may have contributed to them. However, there is a possibility some of the Eocene hyperthermals could be sampled *in situ* (and indeed other significant "events" such as the K-Pg boundary). However, this hypothesis test is designed around identifying "carbon sources" though sampling either terrestrial deposits or shallow marine sediment capturing terrestrial runoff in pre-RSU6/RSU7 strata.

Objective 3: Constrain the timing of late rift phases in the Ross Sea to resolve mechanisms for crustal extension in the Ross Sea, in order to test hypotheses of global plate tectonic models, and understand tectonic controls on ice sheet evolution

Guiding hypothesis 6: WARS rifting and basin development propagated in an East to West pattern – from Late Cretaceous in the EB; to the early Cenozoic in CB and adjacent CMH/CH; and Eocene to Oligocene in the VLB. Alternatively, extension is of Cretaceous age, except for the VLB and NB.

Combined, the TAM and WARS form one of the largest extensional provenances on Earth, with a over 500 km of crustal extension thought to have occurred in the Ross Sea (Wilson and Luyendyk, 2009). In the western Ross Sea (e.g., the Victoria Land Basin (VLB) adjacent to the TAM) the main rift phase is believed to be 43-28 Ma (Cande et al., 2000; Granot et al., 2013; Wilson and Luyendyk, 2009), although extension has continued through to the present day in the Terror Rift in the westernmost Ross Sea (Fielding et al., 2008; Hall et al., 2007). However, it is unclear when the remainder of the WARS formed, and hence created the subdued basin morphology and seaway of the Ross Sea?

Several hypotheses exist, including:

(1) Rifting across the region occurred in two phases, with a stage of diffuse extension across the entire Ross Sea beginning in the Late Cretaceous (~100 Ma), which became focused in the VLB by 60 Ma (Huerta and Harry, 2007);

(2) Initial rifting concentrated in the Eastern Basin was primarily older than 83 Ma, and was a precursor to continental breakup; and Central Trough and VLB rifting largely occurred after 83 Ma (Wilson and Luyendyk, 2009) (Figure 5)

(3) The majority of rifting in the Eastern Basin occurred after breakup of Marie Byrd Land from Campbell Plateau, but before 44 Ma (Sutherland, 2007).

Each hypothesis has implications for the timing of when low-lying land or seaways were created, which are critical factors to consider regarding climatic thresholds for early ice sheet evolution (Figure 2). The timing of rifting has significant implications for global plate kinematic models, because Antarctica connects the Indo-Atlantic hemisphere with the Pacific hemisphere via a route that crosses no subduction systems, and hence provides the best opportunity to quantify global plate motion history (Sutherland, 2007). Sampling syn-rift strata in the Ross Sea continental shelf provides the most direct means of testing alternate tectonic/paleogeographic models.

To test guiding hypothesis 6, we aim to date strata above and below RSU6 and RSU7 (sites CHCS-01A, CENCS-01A and ERSCS-02) to constrain the age of the termination of active rifting in the Central Trough and Eastern Basin, with VLB timing largely already constrained by previous drilling. The east to west transect approach will assess if syn-rift strata in Central Trough and RSU 7 in the Eastern

Basin are diachronous, and therefore consistent with the propagating rift model presented in Figures 4-5.

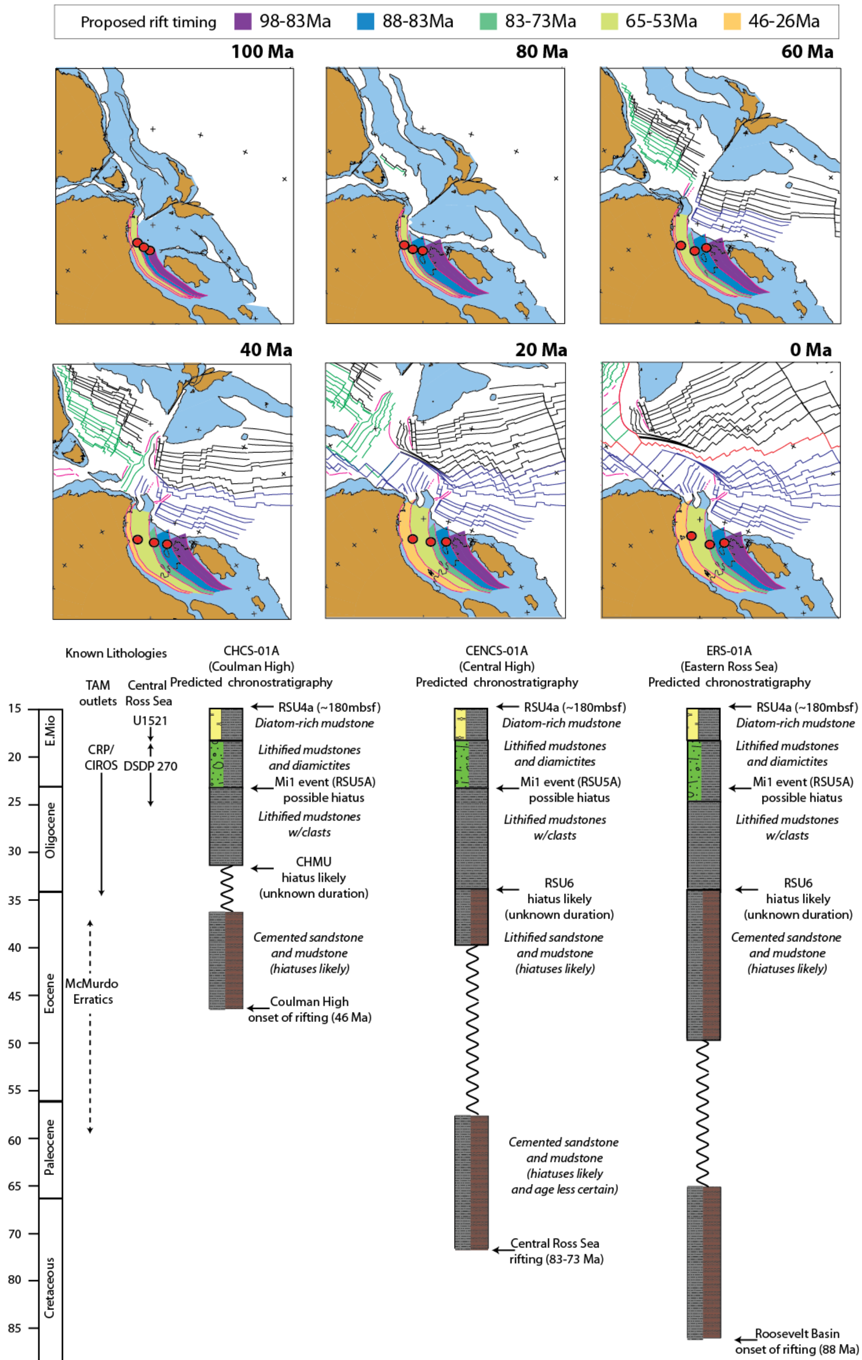


Figure 5: Upper panels show tectonic model used to guide drilling plan (Wilson and Luyendyk, 2009). Bottom panels show predicted stratigraphies based on the tectonic model above, with lithologies based on correlative examples from drill core data of Oligocene glacimarine strata near the TAM (possible alpine glacier influenced), and pre-greenhouse climates obtained from glacial erratics obtained from moraine near the TAM.

4. Methods to constrain ice sheet margin variability, reconstruct past Antarctica environments, and date continental margin sequences

Following ANDRILL/CRP and IODP Expedition 374 methodology, sedimentologic analyses at Sites CHCS-01, CENCS-01 and ERSCS-02A will enable us to identify deposition under grounded ice, glacimarine, and open marine conditions (Fielding et al., 2000; McKay et al., 2009; R.M. McKay et al., 2018; Naish et al., 2001; Passchier et al., 2011; Powell and Cooper, 2002). Establishing the timing of marine transgression, and paleo-water depth will be achieved through sedimentology and macro and micro- (e.g. benthic foraminifera and diatoms) faunal assemblages (Beu and Taviani, 2014; Patterson and Ishman, 2012). Magneto-, bio-, and tephro-chronology will enable identification of orbital-scale ice sheet variations, and has been employed in discontinuous Antarctic margin sequences (e.g.(Naish et al., 2009, 2001). Furthermore, new quantitative techniques have greatly enhanced the biostratigraphic framework of the Southern Ocean (Bijl et al., 2013b; Cody et al., 2012, 2008)). Radiometrically datable felsic ashes from Marie Byrd Land, which has been volcanically active since at least 36-34 Ma, may be used to provide age control (e.g. Wilch and McIntosh, 2000). Climate snapshots near magnetic reversals will be targeted, as these events can be traced to more continuous records from the continental rise (e.g. IODP site U1356), and global sea level records (Figure 3). Biogenic carbonate proxies are rare in Antarctica, but more common in Miocene and older strata (Harwood and Levy, 2000; Levy et al., 2016; R.M. McKay et al., 2018). Sediment provenance studies (clast/sand petrology, individual mineral grain geo/thermochronology, fine-grained/bulk radiogenic isotope composition) will enable understanding of the changes in the origin of sediments – e.g. local ice caps vs ice sheet expansion (Cook et al., 2013; Licht et al., 2005; Licht and Palmer, 2013; Monien et al., 2012; Simões Pereira et al., 2018; Wilson et al., 2018). A list of example paleoenvironmental proxies used to achieve our objectives at each site are given in Table 2, and these follow previous methodologies successfully applied in Antarctic sediments.

		Anticipated ages	Proxies (primary methods)
Continental shelf	CHCS-01/CENCS-01/ERSCS-01	Late Cretaceous (?) to early Miocene (ERSCS-01) Paleocene to Early Miocene (CENCS-01) Mid Eocene (?) to Early Miocene (CHCS-01)	• AIS extent and catchments using facies analysis (McKay et al., 2009; Passchier et al., 2011), geochemistry provenance ((Cook et al., 2013), seismic stratigraphy (Brancolini et al., 1995; Sorlien et al., 2007) • Sea Surface/subsurface water temperature (TEX_{86}), and microfossil assemblages (diatoms, radiolaria, marine palynomorphs; foraminifera) (Bijl et al., 2013a; Lazarus et al., 2008; Levy and Harwood, 2000; McKay et al., 2012; Patterson and Ishman, 2012; Scherer et al., 2000) • Bottom Water Temperature (clumped isotope on molluscs), and Mg/Ca on benthic foraminifera (if suitable species) (Levy et al., 2016; Shevenell et al., 2004) • Terrestrial temperatures (pollen, MBT/CBT, leaf wax isotopes)(Feakins et al., 2014, 2012; Pross et al., 2012) • Surface stratification relating to glacial/sea ice meltwater and terrestrial hydrology (δ^2H isotopes on marine algal biomarkers (Pagani et al., 2006), microfossil assemblages (McKay et al., 2012; Whitehead et al., 2005). • Bottom Water conditions (redox sensitive metals from XRF and ICP-MS/ICP-OES)(Jaccard et al., 2016)

Table 2: Examples of proxies used to reconstruct past environments in previous high-latitude studies.

8. Logisitical considertions

8.1. Drilling plan

The three continental shelf sites will penetrate between 800 and 1200 m to obtain rift fill strata that pre-date seismic unconformities RSU7 (or top syn-rift in Central Trough) and RSU6. However, key objectives (penetrating RSU6 and syn-rift strata) can be obtained at ~1000mbsf at most sites. Alternates are provided with shallower penetrations if time is restricted due to delays (e.g. RSU6 is penetrated at ~300 mbsf at CENCS-02A). Where feasible, basement rocks will be sampled at all continental sites (informing objective 3).

Site	# of holes	Water depth (m)	Penetration (mbsf)	Time to core one hole and trip pipe (days)	time logging (days)	Priority	Alternates (in order of priority)
Shelf sites							
CHCS-01A	1	695	1200	9	1.5	1	CHCS-02A ,CHCS-03A
CENCS-01A	1	616	1200	9	1.5	3	CENCS-02A CENCS-03A
ERSCS-02A	1	660	800	4.5	1	2	ERSCS-01A, ERSCS-06A,ERSCS-03A, ERSCS-04A, ERSC-05A
Completion of Expedition 374 sites (priority ranked separately)							
U1524	1 RCB (280 to 1000mbsf)	2401	1000	6.7	1.5	2	See IODP Exp 374 prospectus
	1 APC		250	1.9			
RSCR-19A	1APC 1APC/XCB	4261	250 465	2.5 4.1		1	See IODP Exp 374 prospectus
Drill DAYS:				37.7	5.6		

Transit days (including between sites) =19. Total expedition days = 62

Table 3: Proposed primary drill sites and drilling plan (number of holes) and estimated time drilling and logging on sites. We have prioritized the continental shelf sites (1=highest priority) based on importance of site in achieving the science objectives, and also polynya opening times (e.g. CHCS-01 will open earlier than ERSCS-01). The Expedition 374 sites that were not completed due to mechanical breakdown of the JOIDES Resolution are also show to highlight how a full leg could be completed with these newly proposed sites. There are priortised separately, but would be drilled at the end of the expedition regardless (when exiting the Ross Sea) as these site clear of sea ice later in the season than the continental shelf (i.e. they cannot be drilled in Early January). N.b. IODP Expedition was scheduled for 63 days.

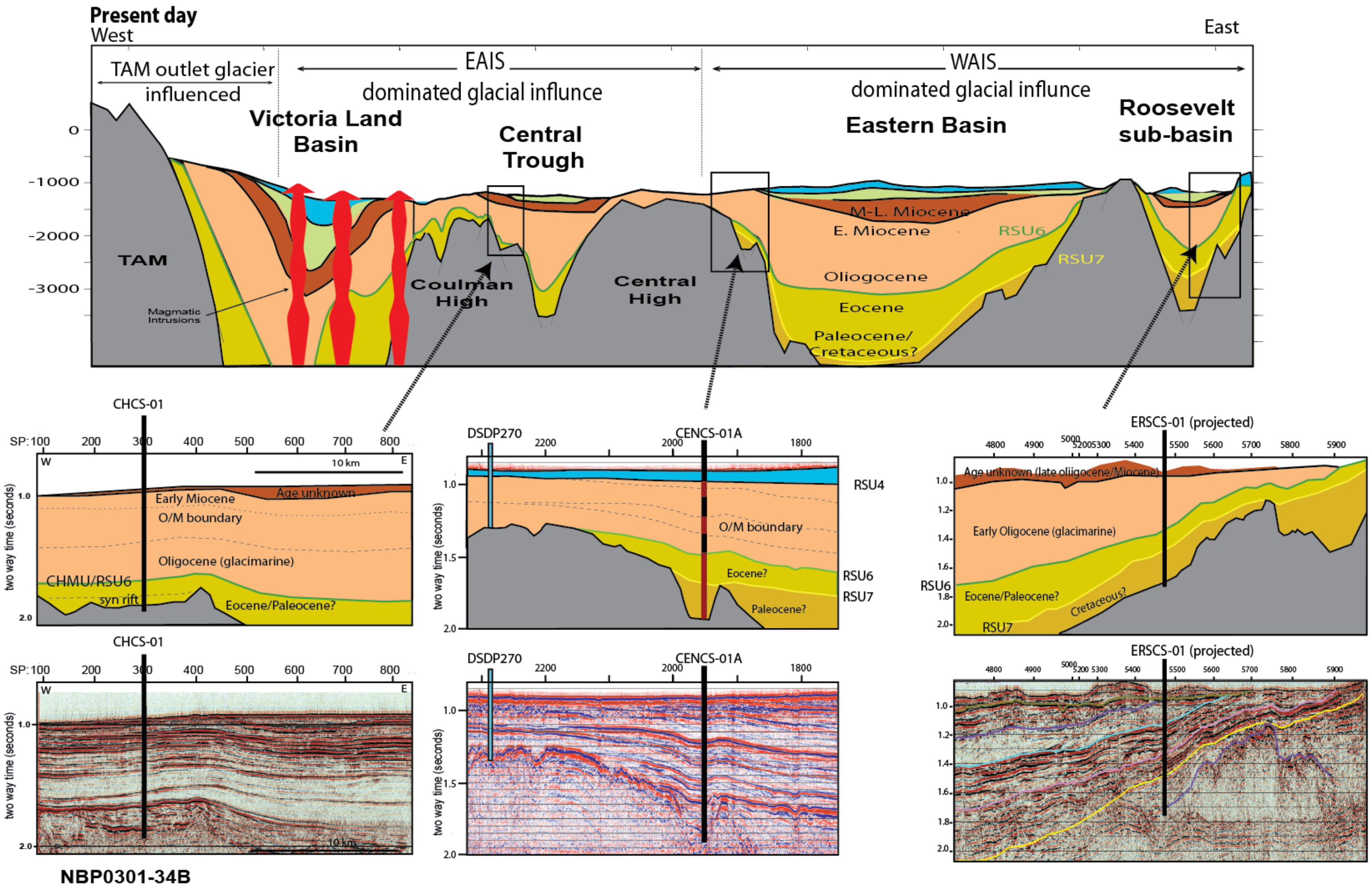


Figure 6: Simplified seismic stratigraphy of the Ross Sea (cross section lines shown in Figure 9), with detailed inserts of each site location. Note proposed diachronous nature of rifting is likely to have resulted in different rift fill ages within each basin, and all sites capture thick sequences of pre- and post-RSU6 sediment.

Details of proposed Sites

8.2. Continental Shelf sites

Site CHCS-01A: Coulman High

This site will sample an expanded EAIS-influenced glacimarine sequence above the RSU6 reflector (ages between ~30-34 Ma and ~18 Ma), and earliest glacial and syn-rift material below RSU6 for a snapshot record of latest Oliogence/early Eocene climate and paleoenvironment in the western Ross Sea. This site differs from earlier drilling at CIROS-1 and CRP as: 1) it is likely to penetrate into strata older than 36 Ma; 2) the presence of glacial sediments infers larger ice sheet responses, rather than TAM alpine glaciations (as recorded in CIROS/CRP) (Figure 2); and 3) ice sheet models indicate it is close to the margin during EAIS advances, but may not be overridden regularly by grounded ice sheet, and thus will provide a more continuous stratigraphic sequences of glacially influenced-marine environments than the highly truncated, glacial eroded CIROS/CRP records influenced by smaller scale alpine/ice cap glaciations (Figure 2e-f).

The top of the post RSU6 sequence is bounded by RSU4a, correlated to site DSDP Site 272 and IODP Site U1521 which has an age of ~18 Ma (McKay et al., 2018). Consequently, we anticipate a snapshot climate record of pre- and early icehouse climates prior to >28(34?) Ma below RSU6 (likely to be mid- to late Eocene; Figure 5) and a semi-continuous record of glacimarine sedimentation between 34-30 Ma and 18 Ma, punctuated by likely hiatuses during the largest ice sheet advance events. We also note the caveat that the top of the syn-rift interval (c.f. RSU7 in the Eastern Basin) is interpreted to represent a significant time gap, and as such does not compromise our objectives. Determining the paleoenvironments above and below this hiatus and its timing relative to global events has important implications for our interpretation of ice sheet and tectonic evolution in the Ross Sea. However, it is also possible it does not represent a hiatus and a record of this transition would be highly valuable.

Site CENCS-01: Central High Region.

This proposed site targets a perched rift basin on the western flank of the Eastern Basin. It is located in a deeper part of the same sedimentary basin in which DSDP Site 270 was drilled (~15 km to the west), which allows for high confidence in determining the age of the target strata in the upper part of the record. However, this site is designed to target both younger and older sediments than recovered at DSDP Site 270 (26.5 to 20 Ma; where hiatuses were identified at 24-23 Ma and 22.5-20.7 Ma); the site was drilled to basement, which consisted of foliated marbles and calcsilicate gneiss (Hayes et al., 1975). However, seismic mapping indicates thick packages of sediment associated with these hiatuses are deposited at CENCS-01A, in particular across the Oligocene/Miocene (O/M) boundary, when the EAIS advanced across the Cape Robert Project sites (Naish et al., 2001). Although the deep-sea oxygen isotope records reveal a substantial $\delta^{18}O$ increase at the O/M boundary, we have not yet constrained the extent of this event in the circum-Antarctic.

We anticipate a semi-continuous expanded Oligocene record that documents ice sheet dynamics in the central Ross Sea. Glacial sediments may be associated with either local ice caps on the Central High, or reflecting coalescing WAIS and EAIS advances (Figure 2e-h). Hiatuses are likely throughout the section and are diagnostically important as they may reflect ice sheet advances, either through direct erosion by grounded ice or changing sea levels. These scenarios can be constrained through seismic stratigraphy and sediment provenance studies.

This location is distinguished from the alpine TAM and EAIS glaciation records recovered at CRP sites and proposed site CHCS-01, respectively (Figure 2e-h). Although much of the inorganic geochemistry and physical properties of DSDP site 270 is compromised by *in situ* salt growth and desiccation since their recovery in 1973 (Kraus, 2016), organic chemistry and paleontological markers of this legacy DSDP 270 core indicate excellent potential for paleoenvironmental analysis (Kulhanek et al., in review; Duncan, 2017). However, we emphasize that site CENCS-01 targets a more complete Oligocene to early Miocene sequence and, more critically, penetrates RSU6 and RSU7 in the depocentre of a perched basin, which is interpreted as a rift valley (Figure 6). We anticipate that this rift-fill sequence will provide a snapshot assessment of pre-icehouse climates of the Cretaceous and Paleocene and constrain the timing of the final phase of active rifting in this sector of the Ross Sea, relative to the Eastern (ERSCS-02) and Western Ross Sites (CHCS-01).

Site ERSCS-02A: Eastern Ross Sea.

Site ERCS-02A targets a ~430 m thick early to mid-Oligocene glacimarine influenced sequence (Seismic Unit RSS2 lower) overlying early and late rift-fill sediments. Beneath Unit RSS2 lower, we aim to penetrate both RSU6 and RSU7 (Units RSS1 upper and lower), to capture the dynamics of ice caps nucleating on Marie Bryd Land (Figure 2g-h). Seismic evidence infers glacial expansion in this region sometime prior to 25 Ma (Sorlien et al., 2007), which requires validation by drilling. The site also targets a ~120 m thick sequence that may have been deposited during the greenhouse climates of the Paleocene and Eocene (RSS-1 upper, bounded by RSU6 and RSU7); strata beneath RSU7 (~230m thick) may be *in situ* Late Cretaceous early rift fill deposits that will enable us to constrain timing of early phase rift termination in this region. We anticipate that this site will provide the most expanded sequence of greenhouse climates (pre-RSU6).

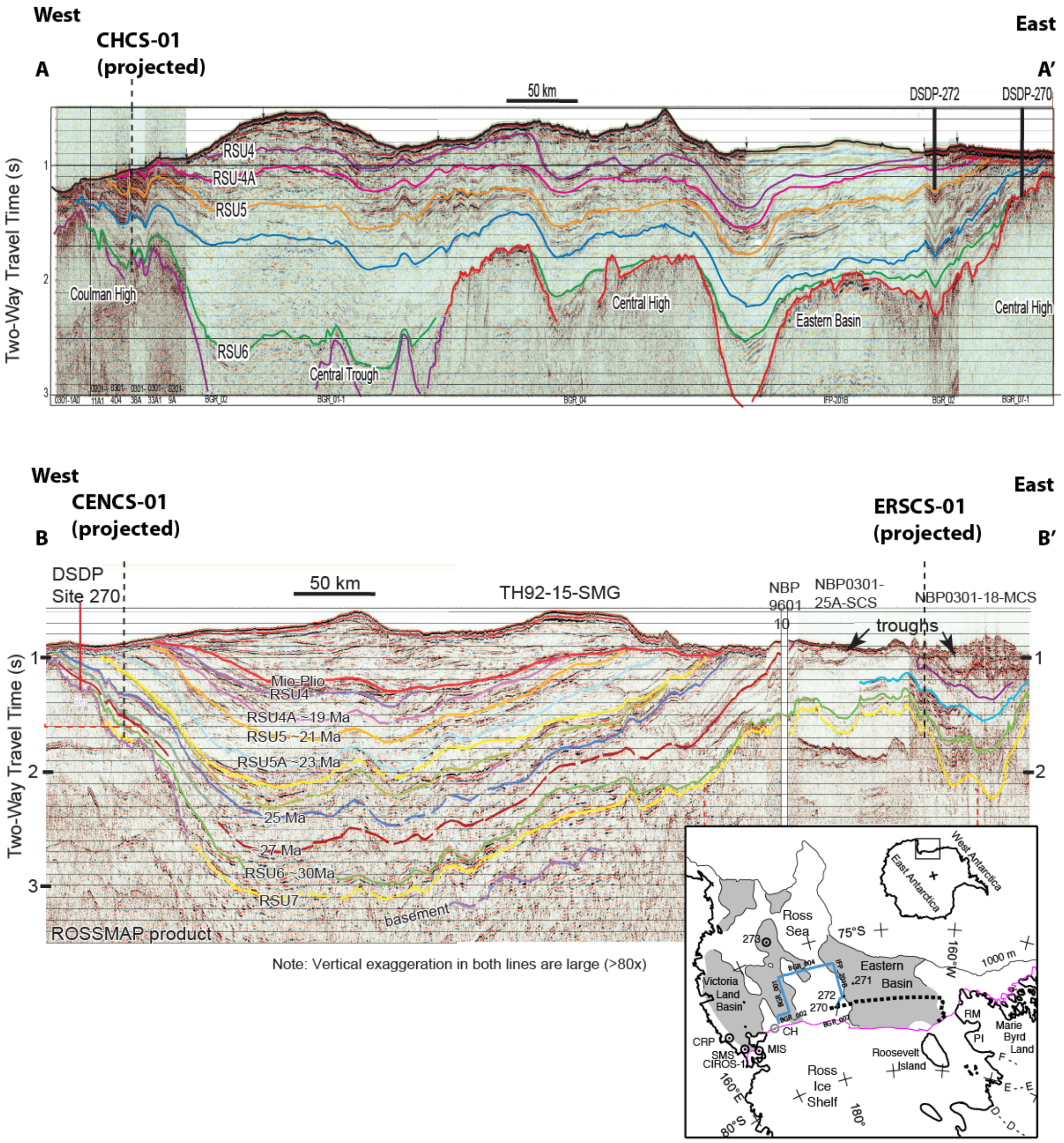


Figure 7: Detailed seismic cross sections and correlations of major unconformities and ties to DSDP Leg 28 sites (Sites 270, 272) from: Top) the Central Trough to western flank of the Eastern Basin (blue line in insert map); Bottom) the western flank to Eastern Flank of the Eastern Basin (dotted line in insert map). Approximate location of projected primary drill sites shown.

8.3. Abyssal Plain sites – alternates in case of extreme sea ice year in Eastern Ross Sea region

RSAP-01A: Ross Sea Abyssal Plain

We identify two abyssal plain sites (RSAP-01A and RSAP-02A) as alternates in case of an extreme sea ice year that affects the ERSCS-01 site (this is a rare event, while sites CENCS-01A and CHCS-01A site are consistently ice free as they are in the primary polynya formation region). The RSAP sites are on a drift located in the outer eastern Ross Sea to the south of approved site RSCR-19A (complementary IODP Expedition 374 site, and not discussed in detail here, as it is already at JRFB for rescheduling). Consequently, we located RSAP-01A to obtain the stratigraphically older section below RSCR-19A, as older strata are at depths closer to the seafloor at site RSAP-01A (see Site Form image). Obtaining these deep-water sites will provide continuous records of offshore oceanographic change to changing climate and cryosphere on the Antarctic continental shelf, thereby linking the objectives of these deep-water sites to the early icehouse records obtained from sites ERSCS-01A, CENCS-01 and CHCS-01. Anticipated core at RSAP-01A is likely to be more consolidated than RSCR-19A (which is planned to be an APC/XCB core), and we will proceed directly with RCB coring.

9. Risks and risk planning

9.1. Recovering glacial sediments in the Ross Sea.

Previous ship-based drilling on Antarctica's continental shelves yielded variable core recovery due to 1) rotary coring of unconsolidated sediments; 2) poor recovery in the upper 50 to 100 m of each hole, until weight on the bit stabilizes drilling; and 3) adverse weather and ice conditions resulting in ship heave and site abandonment in the upper 100 mbsf.

Low heave is anticipated in the Ross Sea, (e.g., DSDP Leg 28, IODP Exp 374, and annual international vessel experience) relative to other Antarctic regions. Both previous expeditions to the Ross Sea (DSDP Leg 28 and IODP Expedition 374) demonstrate that good core recovery (e.g., up to 64% total recovery, and higher in targeted sediments at depth) is a realistic expectation for our proposed continental shelf sites (Figure 8). Where section is not recovered, downhole logging has proven valuable. All IODP Expedition 374 continental shelf sites obtained borehole logs, and the cohesive diamictite of Site U1521 provided exceptional quality (i.e. highly stable) borehole conditions that allowing logging to within 40 m of the seafloor (McKay et al., 2019) (Figure 8). An identical methodology to that employed in Expedition 374 will be used the proposed expedition.

Although diamict lithologies are perceived as the largest issue for drilling recovery in Antarctic, this is incorrect. Unconsolidated diamict is difficult to recover (e.g.

Plio-Pleistocene strata) but drilling lithified glacial diamictites with a hard mud matrix is much easier as it is homogenous and cohesive (Figure 8). Site U1521 obtained a total of 64% recovery, but recovery rates were much higher below 100 m once weight could be placed on bit (>80%; Figure 8). These rates are much higher than the average recovery using RCB coring elsewhere globally, and we anticipate similar lithologies to DSDP site 270 and IODP site U1521 at all our continental shelf sites (e.g. muddier, and more consolidated than U1522; Figure 8). Furthermore, the Paleocene to Eocene erratics observed in McMurdo Sound (and provisionally identified at Site U1522), are cemented sandstones and mudstones (Harwood and Levy, 2000; R.M. McKay et al., 2018), and thus should be easily recovered. However, we have designed the drilling plan such that all objectives will achievable even with very low recovery rates, as they are all dependent only on obtaining "snapshot" glimpses into Cretaceous to early Cenozoic Antarctic environment.

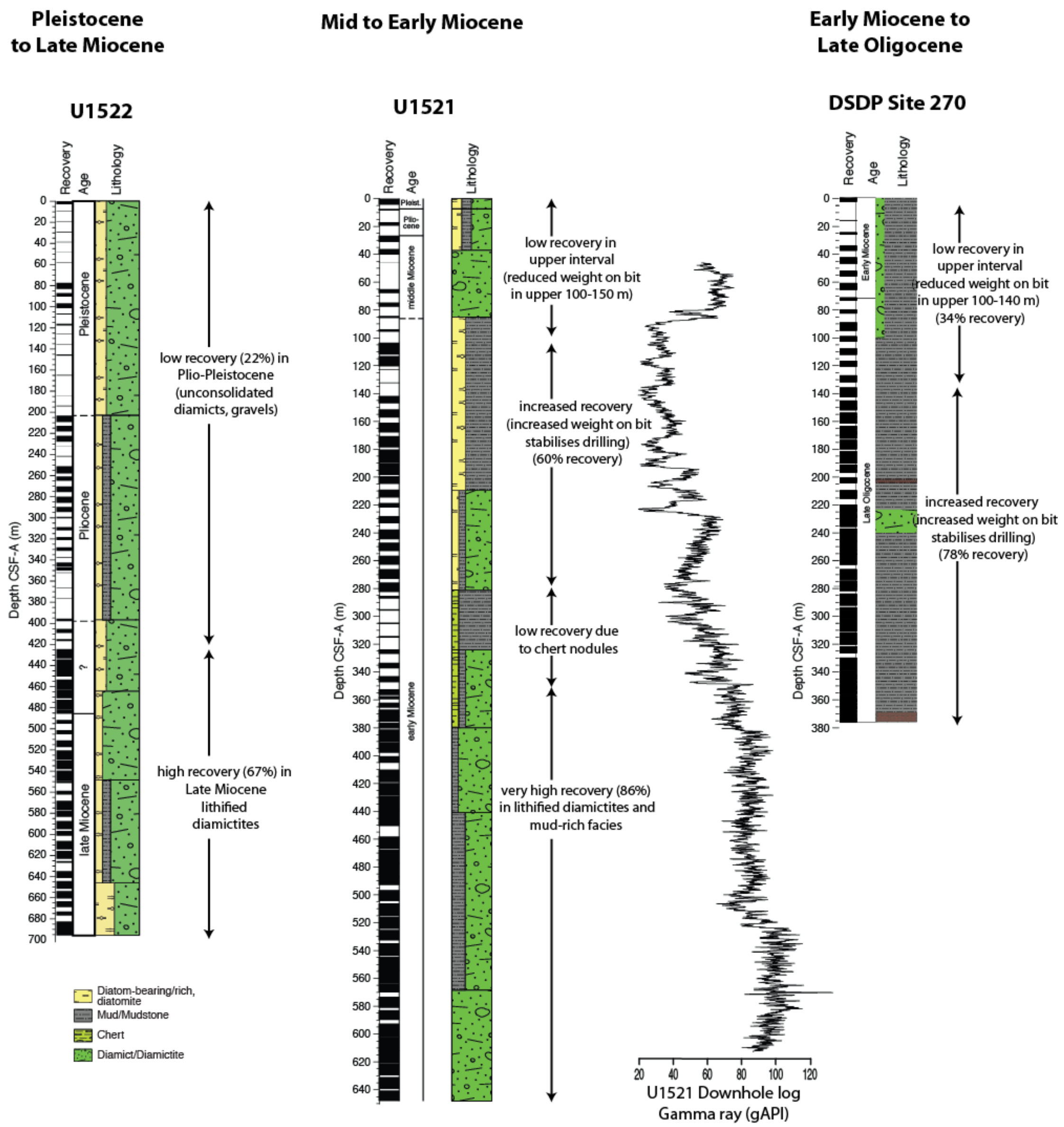


Figure 8: Previous drilling recovery in Ross Sea continental shelf settings. Note high recovery in Late Miocene and older strata, and below 150 mbsf when weight can be placed on bit to stabilize drilling. Previous drilling in Antarctic rarely penetrated to depths below 150 mbsf due to ice risks and frequent storms (which are greatly reduced in the Ross Sea). Also shown for Site U1521, are the continuous down-hole logs (gamma ray) that help complete missing stratigraphy. We anticipate lithologies similar to DSDP site 270 and U1521.

9.2. Incomplete records due to hiatuses.

Targeting hiatuses is a primary objective at all continental shelf sites, and we anticipate missing section at all continental shelf sites. Dates across these unconformities constrain the history of ice advance and retreat or associated isostatic/sea level adjustments (Levy et al., 2019). High-resolution orbital-scale records of ice variations were recovered from ANDRILL (Fielding et al., 2011; Levy et al., 2016; Naish et al., 2009) and Cape Roberts sites (Naish et al., 2001).

However, the core will also contain continuous intervals of sedimentation, with site U1521 during IODP expedition 374, obtaining a high-resolution record of pelagic sediments deposited during the Miocene Climate Optimum that demonstrated a strong cyclicity (McKay et al., 2018). (Figure 8)

9.3. Hydrocarbon and safety considerations relating to ice risk

Full hydrocarbon risk assessment have previously been undertaken for the entire Ross Sea as part of the EPSP safety assessment for the ANDRILL Coulman High Project and IODP Expedition 374, and hydrocarbon risk was deemed low.

Icebergs are rare within the Ross Sea continental shelf region we propose to drill (there were no iceberg incursions on as with IODP Expedition 374), and all three continental shelf sites occur in region off the Ross Sea where the open water polynya is very predictable (open water from Late December to mid February) and has been drillable for every year for the past decade (Figure 9). A full sea ice and iceberg risk assessment will be provided for the EPSP report following the same methodology as Expedition 374. To gain access to the polynya, we recommend that the JOIDES Resolution follow the path of the icebreaker from one of the various icebreakers that operate in the Ross Sea each year (USA, Italian, Korean, China). Ice observers are also essential.

We provide a wide spatial coverage of primary and alternates that mitigates against variable sea ice conditions - as well as those alternates for RSCR-19 and U1524 that are currently with the JRFB due to early termination of IODP Expedition 374, and are proposed to be drilled concurrently with these proposed sites. Re-entry cones have been successfully utilized in the Antarctic (e.g. IODP Exp 318, ODP Leg 188) but were not required during IODP Expedition 374 to the Ross Sea.

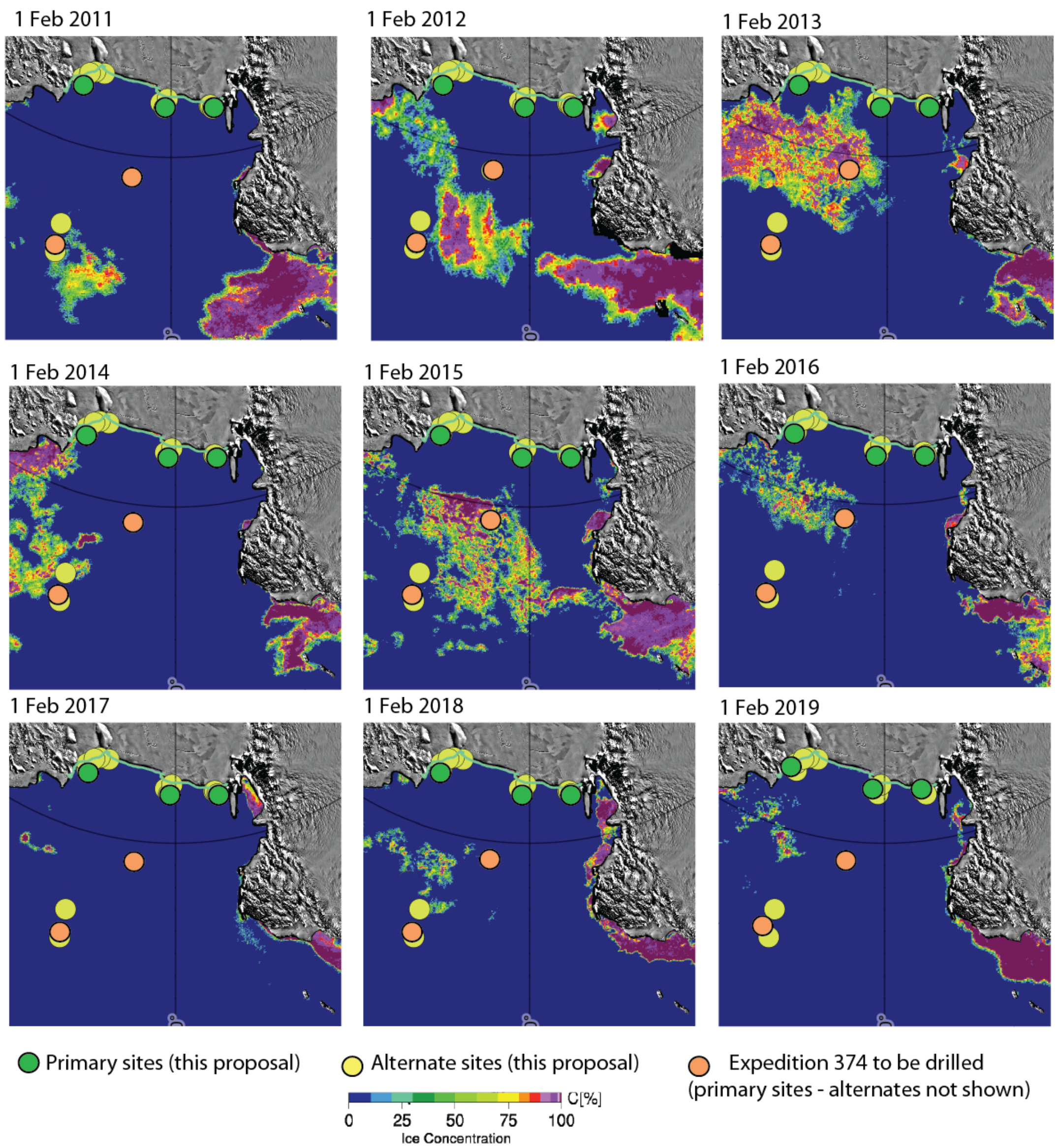


Figure 9: Map showing sea ice concentrations on 1 February (middle of drilling window). Sites CHCS-01A and CENCS-01A are open from late November and are consistently ice free. In only a singe year (2013) are the ERSCS-01A site difficult to access (despite being in open water). In such a year, we would drill an alternate RSAP-01A (or require icebreaker support in the region). For site numbers refer to Figure 1.

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Stocchi, P., Escutia, C., Houben, A.J.P., Vermeersen, B.L.A., Bijl, P.K., Brinkhuis, H., DeConto, R.M., Galeotti, S., Passchier, S., Pollard, D., Brinkhuis, H., Escutia, C., Klaus, A., Fehr, A., Williams, T., Bendle, J.A.P., Bijl, P.K., Bohaty, S.M., Carr, S.A., Dunbar, R.B., Flores, J.A., Gonzàlez, J.J., Hayden, T.G., Iwai, M., Jimenez-Espejo, F.J., Katsuki, K., Kong, G.S., McKay, R.M., Nakai, M., Olney, M.P., Passchier, S., Pekar, S.F., Pross, J., Riesselman, C., Röhl, U., Sakai, T., Shrivastava, P.K., Stickley, C.E., Sugisaki, S., Tauxe, L., Tuo, S., van de Flierdt, T., Welsh, K., Yamane, M., 2013. Relative sea-level rise around East Antarctica during Oligocene glaciation. Nat. Geosci. advance online publication. https://doi.org/10.1038/ngeo1783
Sutherland, R., 2007. The significance of Antarctica for studies of global geodynamics (Report No. 2007-1047-KP-10), Open-File Report. Washington, DC.
Truswell, E.M., Drewry, D.J., 1984. Distribution and provenance of recycled palynomorphs in surficial sediments of the Ross Sea, Antarctica. Mar. Geol. 59, 187–214. https://doi.org/10.1016/0025-3227(84)90093-8
Whitehead, J.M., Wotherspoon, S., Bohaty, S.M., 2005. Minimal Antarctic sea ice during the Pliocene. Geology 33, 137–140. https://doi.org/10.1130/G21013.1
Wilch, T.I., McIntosh, W.C., 2000. Eocene and Oligocene volcanism at Mount Petras, Marie Byrd Land: implications for middle Cenozoic ice sheet reconstructions in West Antarctica. Antarct. Sci. 12, 477–491. https://doi.org/10.1017/S0954102000000560

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Wilson, D.S., Luyendyk, B.P., 2009. West Antarctic paleotopography estimated at the Eocene-Oligocene climate transition. Geophys. Res. Lett. 36, 4 PP. https://doi.org/200910.1029/2009GL039297
Wilson, D.S., Pollard, D., DeConto, R.M., Jamieson, S.S.R., Luyendyk, B.P., 2013. Initiation of the West Antarctic Ice Sheet and estimates of total Antarctic ice volume in the earliest Oligocene. Geophys. Res. Lett. 40, 4305–4309. https://doi.org/10.1002/grl.50797
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Zachos, J., Pagani, M., Sloan, L., Thomas, E., Billups, K., 2001. Trends, Rhythms, and Aberrations in Global Climate 65 Ma to Present. Science 292, 686–693. https://doi.org/10.1126/science.1059412
Zhang, Y.G., Pagani, M., Liu, Z., Bohaty, S.M., DeConto, R., 2013. A 40-million-year history of atmospheric CO2. Philos. Trans. R. Soc. Math. Phys. Eng. Sci. 371, 20130096. https://doi.org/10.1098/rsta.2013.0096

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RESEARCH INTERESTS

Paleoclimate, paleooceanography, glacial and marine geology, ice sheet histories.

PROFESSIONAL PREPARATION

2008 PhD in Geology, Victoria University of Wellington

CURRENT EMPLOYMENT

2013-present Associate Professor, Antarctic Research Centre, Victoria University of Wellington, New Zealand

FIVE DIRECTLY RELEVANT PEER-REVEIWED PUBLICATIONS

*corresponding author/student advisee paper

McKay, R., Golledge, N.R., Maas, S., Naish, T., Levy, R., Dunbar, G., Kuhn, G., **(2016).** Antarctic marine ice-sheet retreat in the Ross Sea during the early Holocene. *Geology.*

*Patterson, M.O., **McKay, R.,** and 36 others. **(2014)** Orbital forcing of the East Antarctic ice sheet during the Pliocene and Early Pleistocene *Nature Geoscience*, 7 (11), pp. 841-847.

McKay, R., Naish, T., Carter, L., Riesselman, C., Dunbar, R., Sjunneskog, C., Winter, D., Sangiorgi, F., Warren, C., Pagani, M., Schouten, S., Willmott, V., Levy, R., DeConto, R., and Powell., R., (2012). Antarctic and Southern Ocean influences on Late Pliocene global cooling, *Proceedings National Academy of Sciences* 109(17), 6423-6428.

McKay, R., Naish,T., Powell, R., Barrett, P., Talarico, F., Kyle, P., Monien, D., Kuhn, G., Jackolski, C., Williams, T., (2012). Pleistocene variability of Antarctic Ice Sheet extent in the Ross Embayment. *Quaternary Science Reviews*.

McKay, R.M., et al., (2009). The stratigraphic signature of Late Cenozoic oscillations of the West Antarctic Ice Sheet in Ross Embayment. *Bulletin of the Geological Society of America* 121, pp. 1537–1561.

FIVE OTHER PUBLICATION

*corresponding author/student advisee paper

McKay, R.M., De Santis, L., Kulhanek, D.K., and the Expedition 374 Science Team, 2018. Ross Sea West Antarctic Ice Sheet history ocean-ice sheet interactions and West Antarctic Ice Sheet vulnerability: Clues from the Neogene and Quaternary record of the outer Ross Sea continental margin. International Ocean Discovery Program Preliminary Reports 374.

McKay R.M., Barrett P.J., Levy R.S., Naish T.R., Golledge N.R., Pyne A. **(2016)** Antarctic Cenozoic climate history from sedimentary records: ANDRILL and beyond. *Phil. Trans. R. Soc. A* 374: 20140301.

McKay, R. (2014) Did Antarctica initiate the ice age cycles? *Science,* 346, 812-813.

Wilson, D.J., Bertram, R.A., Needham, E.F., van de Fleirdt, T., Welsh, K.J., **McKay, R.M,** Mazumder, A., Riesselman, C.R., Jimenez-Espejo, F.J., Escutia., C.,2018. Ice loss from the East Antarctic Ice Sheet during late Pleistocene interglacials. Nature.

*Patterson, M.O., **McKay, R.,** Naish, T., Bostock, H.C., Dunbar, R., Ohneiser, C., Woodard, S.C., Wilson, G. & Caballero-Gill, R. 2018, "A Southwest Pacific Perspective on Long-Term Global Trends in Pliocene-Pleistocene Stable Isotope Records", Paleoceanography and Paleoclimatology, vol. 33, no. 7, pp. 825-839.

PROFESSIONAL DISTINCTIONS AND MEMBERSHIPS

2018 Co-chief scientist on IODP Expedition 374 – Ross Sea West Antarctic Ice Sheet History

2017 Lead Scientific convenor: Australasian IODP Regional Planning workshop: Developing community-based scientific priorities and new IODP proposals

2016 Lead International convenor for IODP workshop: Antarctica's Cenozoic Ice And Climate History, New Science and New Challenges of Drilling in Antarctic Waters, Texas, USA (May 2016)

2016-2018 NZ representative on the IODP Science Evaluation Panel

2014-2018 Chair of the ANZIC (Australia New Zealand Implementation Committee) Science Committee for the International Ocean Discovery Program

2014-2019 Rutherford Discovery Fellow

2013-17 Lead Proponent on Integrated Ocean Drilling Programme proposal 751 to drill in the Ross Sea for a climate, ocean and ice sheet history (approved)

2013 -2019 Steering committee for the Past Ice Sheet program (PAIS) for the Scientific Committee on Antarctic Research (SCAR)

2013-2018 Committee Member (Treasurer) for ANDRILL Scientific Committee.

2012 Chair (climate theme) for Southwest Pacific IODP Workshop, Sydney Australia (October 2012)

2011 Prime Minister's MacDiarmid Emerging Scientist, for New Zealand's top emerging researcher (across all disciplines) ($NZ200k)

2010 Sedimentology team leader for IODP Leg 318 to Wilkes Land, Antarctica.

2006 Sedimentologist for ANDRILL McMurdo Ice Shelf Project.

FUNDED PROPOSALS

2019-2022 Principal Investigator in $0.96M RSNZ Marsden Fund grant "Antarctic Ice Sheet interactions with the ocean during past warm climates'

2015-2018 Principal Investigator in $0.81M RSNZ Marsden Fund grant "Predicting a Sea Change: Antarctic ice-ocean interactions in a warming world, Collaborative with Principal Investigator A/Prof. N Bertler

2014-2017 Associate Investigator in $0.78M RSNZ Marsden Fund grant "Drilling back to the Pliocene in search of Earth's future high tide". Collaborative with Principal Investigator Prof. Tim Naish (VUW),

2013 to present: Rutherford Discovery Fellowship ($800K), Royal Society of New Zealand "Antarctic Ice Sheet-Southern Ocean interactions during greenhouse worlds of the past 23 million years - and consequences for New Zealand climate".

2013 to present: Principal Investigator ($107K), New Zealand Antarctic Research Institute grant."Southern Ocean and Antarctic climate response to high atmospheric CO2 forcing"

2008–2012 :Foundation for Research,Science and Technology (FRST) Postdoctoral Research Fellowship ($260K). "Climatic shifts at the East Antarctic Ice Sheet: Implications of Antarctic ice sheet variability for the Southern Ocean".

2009-2012:Associate Investigator in ($0.77M) RSNZ Marsden Fund grant "Does Antarctic ride the Milankovitch Cycle". Collaborative with Principal Investigators Prof. Tim Naish (VUW), Dr Lionel Carter (VUW).

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RESEARCH INTERESTS

Paleoclimate, glacial and marine geophysics, ice sheet histories.

PROFESSIONAL PREPARATION

1995 PhD in Geology, University of Parma, Italy

CURRENT EMPLOYMENT

2003-present Researcher at OGS

FIVE DIRECTLY RELEVANT PEER-REVEIWED PUBLICATIONS

*corresponding author/student advisee paper

*S. Kim, L. De Santis, et al. Seismic stratigraphy of the Central Basin in northwestern Ross Sea slope and rise, Antarctica: Clues to the late Cenozoic ice-sheet dynamics and bottom-current activity. Marine Geology, 2018. Volume 395, Pages 363-379

Colleoni, F., De Santis, et al. 2018. Past continental shelf evolution increased Antarctic ice sheet sensitivity to climatic conditions. Scientific Reports. volume 8, Article number: 11323

Böhm G., Ocakoğlu N., Picotti S., De Santis L., 2009. West Antarctic Ice Sheet evolution: new insights from a seismic tomographic 3D depth model in the Eastern Ross Sea (Antarctica) Marine Geology, 266, 109-128

Levy R.H., Meyers S.R., Naish T.R., Golledge N.R., McKay R.M., Crampton J.S., DeConto R.M., De Santis L., Florindo, F, Gasson, E.G.W, Harwood, D.M., Luyendyk, B.P, Powell, R.D., Clowes, C., Kulhanek D.K. (2019) Antarctic ice-sheet sensitivity to obliquity forcing enhanced through ocean connections. 2018. Nature Geoscience, 12 (2) , pp. 132-137. 10.1038/s41561-018-0284-4

De Santis L., et al. 1999. *The eastern Ross Sea continental shelf during the Cenozoic: implications for the West Antarctic Ice Sheet development.* Global and Planetary Change, vol. 23, n. 1-4, 173-196.

FIVE OTHER PUBLICATION

Bart, P.J., and L. De Santis. 2012. Glacial intensification during the Neogene: A review of seismic stratigraphic evidence from the Ross Sea, Antarctica, continental shelf. *Oceanography* 25(3):166–183

Sauli C. , M. Busetti, L. De Santis, N. Wardell. Late Neogene geomorphological and glacial reconstruction of the northern Victoria Land coast, western Ross Sea (Antarctica). 2014. Marine Geology , 355, 297-309.

Anderson, J.B., 2018, Simkins, L.M., Bart, P.J., De Santis, L., Halberstadt, R.W., Olivo, E., and Greenwood, S., Seismic and geomorphic records of Antarctic Ice Sheet evolution in the Ross Sea and controlling factors in its behaviour. Geological Society Special Publications, 475.

Brancolini G., Busetti M., Marchetti A., De Santis L., Zanolla C., Cooper A. K., Cochrane G. R., Zayatz I., Belyaev V., Knyazev M., Vinnikovskaya O., Davey F. J., and Hinz K., *Descriptive text for the Seismic Stratigraphic Atlas of the Ross Sea*. In: vol. 68 "Geology and Seismic Stratigraphy of the Antarctic Margin, Antarctic Research Series, edito da: Alan K. Cooper, Peter F. Barker e Giuliano Brancolini, AGU, Washington, D.C., A271-A268, 1995.

De Santis L., Anderson J. B, Brancolini G., Zayatz I. 1999*Seismic record of the late Oligocene through Miocene glaciation on the central eastern continental shelf of the Ross Sea*, vol. 68 "Geology and Seismic Stratigraphy of the Antarctic Margin, Antarctic Research Series, edito da: Alan K. Cooper, Peter F. Barker e Giuliano Brancolini, AGU, Washington, D.C., 235-260,

PROFESSIONAL MEMBERSHIPS

2019 XXXVI SCAR-Open Science Conference (OSC), Hobart, Tasmania (Australia) 31 July to 11 August 2020: member of the International Organization Scientific Committee

2019 International Symposium of Earth Science (ISAES) 2019 15-23 July 2019: member of the International Scientific Committee (ISC)
2019 member of the organizing committee IODP-PAIS school for Antarctic , Texas AM Univ. (College Station, Texas, USA) June 10-14 2019 :
Since 2016: co-chief officer SCAR Geoscience program PAIS (Past Antarctic Ice Sheet dynamics).
2008-2015: member of PNRA/CSNA Antarctic National Research Program scientific and strategy advisory board for the Italian Ministry of Research.
2008-2017: member of the scientific review panel, and chair of the Polar regional call 2013. EU-FP7/Eurofleets 1 and 2 projects
2008-2012: Member of the technical steering committee and Science support unit of the EU-FP7/ERICON-AB (European Polar Research Icebreaker Consortium (ERICON) - AURORA BOREALIS) project.
Since 2014: Italian delegate (head officer in 2016) for the SCAR Standing Scientific Group on Geosciences.
2019 Co-editor of the Elsevier new edition of the book "Antarctic Climate Evolution"
2003 Co-Editor of the Deep Sea Research II "Recent Investigations of the Mertz Polynya and George Vth Land continental margin, East Antarctica", *Special Volume* n. 50, Issues 8-9, (May 2003). Elsevier Publ.
Co-chief of IODP Expedition 374 (2018) Ross Sea (Antarctica)
2015-2018: Italian delegate (Alternate) at the ECORD Council
2004-2018: member of the IODP Italian Coordination Group
Since 1995: co-proponent and seismic site survey data manager of the IODP, full2-proposal 751
Since 2000: co-proponent and seismic site survey data manager of the IODP, full-proposal 482
Since 2013: co-proponent and seismic site survey data manager of the IODP, Mission Specific Platform MSP full-proposal 813

FUNDED PROPOSALS

1991-1995: Programma Nazionale delle Ricerche in Antartide – PNRA/Ross Sea Atlas maps, under the ANTOSTRAT (Antarctic Offshore Acoustic Stratigraphy) SCAR Geoscience project. 40 kEuro.
1999-2001: PNRA CAPE ROBERTS PROJECT CRP (Ross Sea, Antarctica). Deep Drilling project from fast ice, Funds received: 10 kEuro.
1999-2001: PNRA. Joint project AUS-Italy/WEGA - Wilkes Basin Glacial History 90 kEuro (and 28 days of ship time in 1999/2000
2002-2004: PNRA (2002-2004). MOGAM - MOrphology and Geology of Antarctic Margins. 52 kEuro and 10 days ship time in 2006 with OGS Explora, Italy
2000-2003: Energy Environment and Sustainable Development EU 5th Framework (2000-2003), STRATAGEM Stratigraphical Development of the Glaciated European Margin. Coordinated by Dan Evans (BGS-UK). 140 kEuro.
2006-2007: EU-Marie Curie European Re-Integration Grant (ERG). "HoloSed" HOLOocene SEDdiment record of Antarctic deep water production project linked to the IMAGES X° – CADO (Coring Adélie Diatom Oozes) 2003 project. 40 k Euro.
2016-2018: Italy-USA bilateral projects (Foreigner Affair Minister funding agency) – GSLAISS Global Sea Level Rise and Antarctic Ice Sheet stability prediction: guessing future by learning from past. 95 k Euro
2008-2012: Research Infrastructures EU 7th Framework (2008-2012), 3 yrs duration. European Polar Research Icebreaker Consortium (ERICON) - AURORA BOREALIS Project. Coordinated by the European Science Foundation, Polar Board (EPB). 160 kEuro.
2016-2018: PNRA/WHISPERS (West Antarctic Ice Sheet HIstory from Slope Processes – Eastern Ross Sea) 158 kEuro and 6 days ship time in 2017
ECORD/Magellan workshop "Antarctica's Cenozoic Ice and Climate History: New Science and New Challenges of drilling in Antarctic Waters" 2006 at Texas AM Univ. and IODP, College Station (TX, USA). 15 kEuro

Christopher Sorlien

Professional Preparation:

- B.A. – Geology – University of Rhode Island, Kingston, R.I. with distinction, 1982.
- D.E.A. – Structural Geology – Universite Pierre et Marie Curie, (Paris VI), France, 1985:
- M.S. – Geophysical Sciences – Georgia Institute of Technology, Atlanta, Georgia, 1988:
- Ph.D. – Geology, University of California, Santa Barbara, Santa Barbara CA, 1994

Appointments:

- Registered Geologist #5205, State of California.
- Research Geologist, Earth Research Institute, UC Santa Barbara 2014-present
- Associate Research Geologist, Earth Research Institute, UC Santa Barbara since 2006-2014;
- Adjunct Research Professor, Dept. Geological Sciences, University of Missouri 2006-2012;
- Adjunct Assistant Research Geologist at Lamont-Doherty Earth Observatory 1995-2007;
- Assistant Research Geologist, Institute for Crustal Studies, UC Santa Barbara, 1995-2005;
- Graduate Research Assistant, University of California at Santa Barbara, January 1988-1992:
- Geophysicist, Mobil Oil Corporation, Bakersfield, June-September 1989:
- Petroleum Geophysicist, Gulf Oil Company, New Orleans, February 1982 - July 1984:

Publications

Sorlien, C. C., B. P. Luyendyk, D. Wilson, R. Decesari, L Bartek, and J. Diebold, Oligocene development of the West Antarctic Ice Sheet recorded in eastern Ross Sea strata, Geology, v. 35, p. 467-470, doi: 10.1130/G23387A.1.

Decesari, R.C., C.C. Sorlien, B.P. Luyendyk, D.S. Wilson, L. Bartek, J, Diebold and S.E. Hopkins. (2007), Regional seismic stratigraphic correlations of the Ross Sea: Implications for the tectonic history of the West Antarctic Rift System, in Antarctica: A Keystone in a Changing World – Online Proceedings of the 10th ISAES, edited by A.K. Cooper and C.R. Raymond et al., USGS Open File Report 2007-1047, Short Research Paper 052, 4 p.; doi:10.3133/of2007-1047.srp052

Luyendyk, B. P., Sorlien, C. C., Wilson, D., Bartek L., and Siddoway C.H., 2001, Structural and tectonic evolution of the Ross Sea rift in the Cape Colbeck region, Eastern Ross Sea, Antarctica, Tectonics, v. 20, p.933-958.

Sorlien, C. C., L. Seeber, K. G. Broderick, B. P. Luyendyk, M. A. Fisher, R. W. Sliter, and W. R. Normark, 2013, The Palos Verdes Anticlinorium along the Los Angeles, California coast: Implications for underlying thrust faulting, Geochemistry, Geophysics, Geosystems. http://onlinelibrary.wiley.com/doi/10.1002/ggge.20112/pdf DOI: 10.1002/ggge.20112

Hamilton, R. J., Luyendyk, B. P., Sorlien, C. C., and Bartek, L. R., 2001, Cenozoic Tectonics of the Cape Roberts Rift Basin, and Transantarctic Mountains Front, Southwestern Ross Sea, Antarctica, Tectonics, v. 20 , p. 325-342

Five Other Publications

Kurt, H., C. Sorlien, L. Seeber, M. Steckler, D. Shillington, G. Cifci, M.-H. Cormier, J.-X. Dessa, O. Atgin, D. Dondurur, E. Demirbag, S. Okay, C. Imren, S. Gurcay and H. Carton, Steady

late Quaternary slip rate on the Cinarcik section of the North Anatolian fault near Istanbul, Turkey, 2013, Geophysical Research Letters, 40, doi: 0.1002/grl.50882.
Sorlien, C. C., J. T. Bennett, M.-H. Cormier, B. A. Campbell, C. Nicholson , and R. L. Bauer, 2015, Late Miocene-Quaternary fault evolution and interaction in the Southern California Inner Continental Borderland, Geosphere, v. 11, no. X, doi: 10.1130/GES01118.1.
Sorlien, C . C., S. D. Akhun, L. Seeber, M. Steckler, D. Shillington, H. Kurt, G. Çifçi, D. T. Poyraz, S. Gürçay, D. Dondurur, C. İmren, E. Perincek, M. Kucuk, J. B. Diebold, 2012, Uniform basin growth over the last 500 ka, North Anatolian Fault, Marmara Sea, Turkey, Tectonophysics doi:10.1016/j.tecto.2011.10.006.
Pinter, N., Sorlien, C. C., and Scott, A. T., 2003, Fault-related fold growth and isostatic subsidence, California Channel Islands, American Journal of Science, v. 303, p. 300-318
Dean, W. E., J. P. Kennett, R. J. Behl, C. Nicholson, and C. C. Sorlien, 2015, Abrupt termination of Marine Isotope Stage 16 (Termination VII) at 631.5 ka in Santa Barbara basin, California, Paleoceanography, 30, 1373-1390, doi:10.1002/2014PA002756.

Synergistic activities: Co-organizer, 2006 international workshop “Comparative studies of the North Anatolia fault (northwest Turkey) and the San Andreas fault (southern California), Istanbul, Turkey. NSF Panel Member. Co-convened special session AGU, 1999, 2011, 2016; co-chaired sessions at AGU.

List of collaborators (no co-editors): 28

Kenan Akbayram, MTA, Turkey, Louis Bartek-U. North Carolina, Philip Bart-LSU, Rick Behl-CSULB, Anne Becel-LDEO, Gunay Cifci- D.E.U. , Izmir, Turkey, Marie-Helene Cormier-URI, Walt Dean-USGS, Laura De Santis, OGS, Italy, Celine Grall-LDEO, Sean Gulick-UTIG, Pierre Henry, U. Aix-Marseille, France; Matt Hornbach-UTIG, Samuel Johnson- USGS, Kaj Johnson, Indiana Univ., James Kennett-UCSB, Hulya Kurt-Istanbul Technical Univ.**,** Bruce Luyendyk-UCSB**,** Cecilia McHugh-Queens College**,** Craig Nicholson-UCSB**,** Seda Okay-D.E.U. Izmir, Turkey**,** Aral Okay, ITU, Turkey**;** Chiara Sauli, OGS, Italy, Leonardo Seeber-LDEO**,** Donna Shillington-LDEO**,** Ray Sliter-USGS**,** Mike Steckler-LDEO**,** Nigel Wardell, OGS, Italy, Douglas Wilson-UCSB

Advisees 15: (for SCEC internship, senior theses, and for Masters & PhD theses): Erick McWayne, UCSB; Rhea Hamilton, UCSB/UBC; Andrew Scott, SIU; Robert Decesari, UCSB; Kris Broderick, UCSB; Sarah Hopkins, UCSB, Sarah Schindler, CSUB, Joe Green, CSUN, Courtney Marshall, CSULB, Greg De Hoogh, CSULB; Jon Bennett, U. Missouri; Celine Grall, U. Aix-Marseille, France; Nelson Doris, CSULB, Sierra Davis, IUP, Seth Brazell, UNC-Chapel Hill
Plus trained four Turkish graduate students for 4 to 6 weeks each.

Advisors Tanya Atwater (UCSB), Jean Chorowicz (University of Paris 6), Phil Gans (UCSB), L. Tim Long (Georgia Tech), and Bruce Luyendyk (UCSB, PhD thesis advisor)

BIOGRAPHICAL SKETCH:

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New Zealand
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r.levy@gns.cri.nz

Professional Preparation

Institution	*Major*	*Degree*	*Year*
Victoria University of Wellington, New Zealand	Geology	B.S.	1990
Victoria University of Wellington, New Zealand	Geology	M.S.	1993
University of Nebraska-Lincoln, USA	Geoscience	PhD	1998
University of Nebraska-Lincoln, USA	Curriculum and Instruction	MST	2001

Appointments

Year(s)	*Title*
2019 – present	Theme Leader, Environment and Climate, GNS Science, New Zealand
2018 - present	Associate Professor, Victoria University of Wellington (0.2 FTE), New Zealand
2008 – present	Senior Scientist, Paleontology Department, GNS Science, New Zealand
2003 – 2008	Assistant Research Professor, University of Nebraska-Lincoln, USA
2002 - 2008	Staff Scientist, ANDRILL Science Management Office, University of Nebraska-Lincoln, USA
2001 - 2002	Teacher, Dawes Middle School, Lincoln, Nebraska, USA
1999 – 2001	Research Associate, University of Nebraska – Lincoln, USA
1998 - 1999	Petroleum Geologist, Mobil, Dallas, Texas, USA

Products

Five products most closely related to the proposed project

Levy, R.H.; Meyers, S.R.; Naish, T.R.; McKay, R.M.; Golledge, N.R.; Crampton, J.S.; DeConto, R.M.; De Santis, L.; Florindo, F.; Gasson, E.G.W.; Harwood, D.M.; Luyendyk, B.P.; Powell, R.D.; Clowes, C.D.; Kulhanek, D.K. 2019. Antarctic ice-sheet sensitivity to obliquity forcing enhanced through ocean connections. Nature Geoscience, http://dx.doi.org/10.1038/s41561-018-0284-4.

Levy, R.H.; Harwood, D.; Florindo, F.; Sangiorgi, F.; Tripati, R.; von Eynatten, H.; Gasson, E.; Kuhn, G.; Tripati, A.; DeConto, R.; et al. 2016. Antarctic ice sheet sensitivity to atmospheric CO2 variations in the early to mid-Miocene. Proceedings of the National Academy of Sciences of the United States of America, 113(13): 3453–3458

Golledge, N.R.; Kowalewski, D.E.; Naish, T.R.; Levy, R.H.; Fogwill, C.J.; Gasson, E.G.W. 2015. The multi-millennial Antarctic commitment to future sea-level rise. Nature, 526(7573): 421-425; doi: 10.1038/nature15706

Levy, R.H.; Cody, R.D.; Crampton, J.S.; Fielding, C.; Golledge, N.R.; Harwood, D.M.; Henrys, S.A.; McKay, R.; Naish, T.R.; Ohneiser, C.; et al. 2012. Late Neogene climate and glacial history of the Southern Victoria Land coast from integrated drill core, seismic and outcrop data. Global and Planetary Change, 80: 61-84

Naish, T.R.; Powell, R.; Levy, R.H.; Wilson, G.; Scherer, R.; Talarico, F.; Krissek, L.; Niessen, F.; Pompilio, M.; Wilson, T.; et al. 2009. Obliquity-paced Pliocene West Antarctic ice sheet oscillations. Nature, 458(7236): 322-328; doi: 10.1038/nature07867

Five other significant products

Levy, R. H., Dunbar, G. B., Vandergoes, M. J., Howarth, J. D., et al., 2018. A high-resolution climate record spanning the past 17 000 years recovered from Lake Ohau, South Island, New Zealand, Sci. Drilling.

Golledge, N.R.; Levy, R.H.; McKay, R.M.; Naish, T.R. 2017. East Antarctic ice sheet most vulnerable to Weddell Sea warming. Geophysical Research Letters, 10.1002/2016GL072422.

Crampton, J.S.; Cody, R.D.; Levy, R.H.; Harwood, D.; McKay, R.; Naish, T.R. 2016. Southern Ocean phytoplankton turnover in response to stepwise Antarctic cooling over the past 15 million years. Proceedings of the National Academy of Sciences of the United States of America, 113(25): 6868-6873; doi: 10.1073/pnas.1600318113

Gasson, E.; DeConto, R.M.; Pollard, D.; Levy, R.H. 2016. Dynamic Antarctic ice sheet during the early to mid-Miocene. Proceedings of the National Academy of Sciences of the United States of America, 113(13): 3459-3464; doi: 10.1073/pnas.1516130113

Cody, R.D.; Levy, R.H.; Harwood, D.M.; Sadler, P.M. 2008. Thinking outside the zone: high-resolution quantitative diatom biochronology for the Antarctic Neogene. Palaeogeography, Palaeoclimatology, Palaeoecology, 260(1/2): 92-121

Synergistic Activities

1. Lead and managed several international drilling projects in Antarctica and New Zealand;
2. Lead the NZ Ministry of Business, Innovation, and Employment funded Past Antarctic Climate research programme;
3. Published papers on Antarctic climate and stratigraphic studies in international scientific journals;
4. Developed the ANDRILL Research Immersion for Science Educators (ARISE) Program (http://andrill.org/education/arise/index.html), which is designed to facilitate development of mechanisms and materials to effectively connect ANDRILL with the public;
5. Facilitated implementation of a state-of-the-art data visualization system (CoreWall) for ANDRILL to enhance data sharing capability;
6. Chaired and organized Antarctic sessions and workshops at international scientific meetings;
7. Presented research results to a range of audiences through a variety of media (public speaking, film/tv, popular magazines, radio, and world-wide-web).
8. Developed and implemented authentic field-based science experiences for educators and school students

Collaborators:

Acton, G.; Cossu, R.; DeConto, R.; Dunbar, G.B.; Fielding, C.; Field, B.D.; Fitzsimons, S.; Florindo, F.; Forrest, A.;Gasson, E.; Golledge, N.R.; Harwood, D.; Howarth, J.D.; Kuhn, G.; McKay, R.M.; Moy, C.; Naish, T.R.; Olney, M.; Panter, K.; Paulsen, T.; Pollard, D.; Pyne, A.R.; Sangiorgi, F.; Taviani, M; Tripati, R.; Schouten, S.; Talarico, F.; Vandergoes, M.J.; von Eynatten, H.; Warny, S.;Willmott, V.

PhD and MSc students supervised:

PhD, Heidi Roop, current, VUW, NZ; PhD, Eva Tuzzi, University of Nebraska – Lincoln, USA; MS, Rosemary Cody, University of Nebraska - Lincoln, USA

Biographical Sketch

Amelia Endicott Shevenell
Associate Professor
University of South Florida
College of Marine Science
140 7th Ave South, St Petersburg, FL 33701
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Professional Preparation

Hamilton College	Geology	B.A., 1996
University of California Santa Barbara	Marine Science	M.Sc., 2001
University of California Santa Barbara	Marine Science	Ph.D., 2004
University of Washington	Oceanography	2005-2007

Appointments

2017- ***Associate Professor*****,** College of Marine Science, *University of South Florida*, St. Petersburg, Florida, USA

2011-2017 ***Assistant Professor,*** College of Marine Science, *University of South Florida*, St. Petersburg, Florida, USA

2011-2014 ***Research Associate,*** Department of Earth Sciences, *University College London*, London, UK

2008-2011 ***Lecturer (Assistant Professor),*** Departments of Geography (60%) and Earth Sciences (40%), *University College London*, London, UK.

2005-2007 ***Postdoctoral Fellow,*** Program On Climate Change, JISAO/ School of Oceanography, *University of Washington*, Seattle, Washington, USA.

1998-2004 ***Research and Teaching Assistant***: Department of Geological Science, *University of California Santa Barbara*, Santa Barbara, California, USA.

Five Most Closely Related Publications

- Gulick, S.P.S, **Shevenell, A.E**., *et al*. 2017. Initiation and long-term instability of the East Antarctic Ice Sheet. *Nature*, **552**, 225-229.
- *Smith, C., Warny, S., **Shevenell, A.E.,** Gulick, S.P.S., and A. Leventer, 2018. New species from the Sabrina Flora: An early Paleogene pollen and spore assemblage from the Sabrina Coast, East Antarctica. *Palynology,* DOI: 10.1080/01916122.2018.1471422.
- **Shevenell, A.E.,** Ingalls, A.E., Domack, E.W., & C. Kelly. 2011. Holocene Southern Ocean surface temperature variability west of the Antarctic Peninsula. *Nature,* **470**, 250-254.
- **Shevenell, A.E.**, Kennett, J.P., & D.W. Lea. 2008. Middle Miocene ice sheet dynamics, deep-sea temperatures, and carbon cycling: A Southern Ocean perspective. *Geochem.Geophys. Geosystem.* **9**, doi:10.1029/2007GC1736.

- **Shevenell, A.E.**, Kennett, J.P., & D.W. Lea. 2004. Middle Miocene Southern Ocean Cooling and Antarctic Cryosphere Expansion. *Science* **305**, 1766-1770.

Five Other Significant Publications

- Escutia, C., DeConto, R., Dunbar, R., De Santis, L., **Shevenell, A.E**., and T. Naish, 2019. Keeping an eye on ice sheet stability. Celebrating 50 years of Scientific Ocean Drilling, *Oceanography,* **32** (1), 32-46.
- McKay, R.M., De Santis, L., Kulhanek, D.K., and the **Expedition 374 Scientists**, 2018. Expedition 374 Preliminary Report: Ross Sea West Antarctic Ice Sheet History. International Ocean Discovery Program, 374, https://doi.org/10.14379/iodp.pr.374.2018
- **Shevenell, A.E.** 2016. Commentary: Drilling exposes Antarctica's Miocene secrets. *Proc. Natl. Acad. Sci. U.S.A.* **113**(13), 3419-3421.
- **Shevenell, A.E.** & S.M. Bohaty. 2012. Southern exposure: New paleoclimate insights from Southern Ocean and Antarctic margin sediments. *Oceanography* **25**(3), 106–117.
- **Shevenell, A.E.** and J.P. Kennett, 2007. Cenozoic Antarctic cryosphere evolution: Tales from deep-sea sedimentary records. *Deep Sea Research II* **54***,* 2308-2324.

*Student author

Synergistic Activities

- ***Elected Geological Oceanography Council Member*****,** The Oceanography Society **(**2019-2022)
- ***Proponent/Steering Committee Member,*** Antarctica's Cenozoic Ice and Climate History: New science and new challenges of drilling in Antarctic waters, IODP USSSP workshop, Texas A&M (May 9-11, 2016).
- ***Advisory Committee Member,*** US Advisory Committee for Scientific Ocean Drilling (USAC), Consortium for Ocean Leadership. (2014-2018)
- ***IODP Distinguished Lecturer,*** nominated by colleagues and invited by Ocean Leadership/US Science Support Program. The Distinguished Lecturer Series brings the scientific explorations and discoveries of IODP to students at both undergraduate and graduate levels and to the geoscience community. (2014-2015)
- ***Panel Member/ Climate and Ocean Section Co-Chair,*** IODP Proposal Evaluation Panel (PEP)/Science Evaluation Panel (SEP). (2011-2014)

Douglas S. Wilson
University of California, Santa Barbara
Dept. Earth Science & Marine Science Inst
Santa Barbara, CA 93106-9630
dwilson@ ucsb.edu

Professional Preparation:

B.S., Geophysics, Stanford University, 1978.
M.S., Geophysics, Stanford University, 1979.
Ph.D., Geophysics, Stanford University, 1985.
NRC Post-doc, USGS, Menlo Park, 1985-1987.

Appointments:

Research Geophysicist, University of California, Santa Barbara, 2010-present.
Associate Research Geophysicist, University of California, Santa Barbara, 1993-2010.
Assistant Research Geophysicist, University of California, Santa Barbara, 1988-1993.
Geophysicist, U.S. Geological Survey, 1987.
Research Associate, National Research Council/USGS, 1985-1987.
Research and Teaching Assistant, Stanford University, 1981-1985.
Research Associate, Hawaii Institute of Geophysics, 1979-1981.
Teaching and Research Assistant, Stanford University, 1977-1978.
Undergraduate Research Asst, Lamont-Doherty Geological Observatory, summer, 1976.

Selected Publications:

Wilson, D. S. Confirmation of the astronomical calibration of the magnetic polarity time scale from rates of sea-floor spreading, *Nature, 364,* 788-790, 1993.
Luyendyk, B.P., C.C. Sorlien, D.S. Wilson, L.R. Bartek, and C.S. Siddoway, Structural and tectonic evolution of the Ross Sea rift in the Cape Colbeck region, Eastern Ross Sea, Antarctica, *Tectonics, 20*, 933-958, 2001.
Luyendyk, B.P., D.S. Wilson, and C.S. Siddoway, Eastern margin of the Ross Sea Rift in western Marie Byrd Land, Antarctica: Crustal structure and tectonic development, *Geochem. Geophys. Geosyst.*, *4*(10), 1090, doi:10.1029/2002GC000462, 2003.
Lourens, L., F.J. Hilgen, J. Laskar, N.J. Shackleton, and D. Wilson, The Neogene Period, in *A Geologic Time Scale 2004*, ed. F. Gradstein, J. Ogg, and A. Smith, Cambridge Univ. Press, pp. 409-440, 2004.
Wilson, D.S., P.A. McCrory, and R.G. Stanley, Implications of volcanism in coastal California for the Neogene deformation history of western North America, *Tectonics, 24(3),* TC3008, doi:10.1029/2003TC001621, 2005.
Wilson, D.S., D.A.H. Teagle, J.C. Alt, N.R. Banerjee, S. Umino, S. Miyashita, and 45 others, Drilling to gabbro in intact ocean crust, *Science, 312*, 1016–1020, 2006.
Sorlien, C.C., B.P. Luyendyk, D.S. Wilson, R.C. Decesari, L.R. Bartek, and J.B. Diebold, Oligocene development of the West Antarctic Ice Sheet recorded in eastern Ross Sea strata, *Geology, 35*, 467-470, 2007.
Wilson, D.S., and B.P. Luyendyk, West Antarctic paleotopography estimated at the Eocene-Oligocene climate transition, *Geophysical Res. Lett., 36*, L16302, 2009
Wilson, D.S., S.S.R. Jamieson, P.J. Barrett, G. Leitchenkov, K. Gohl, and R.D. Larter, Antarctic Topography at the Eocene-Oligocene Boundary, *Palaeogeography, Palaeoclimatology, Palaeoecology, 335-336,* 24-34, 2012.

Wilson, D.S., D. Pollard, R.M. DeConto, S.S.R. Jamieson, and B.P. Luyendyk, Initiation of the West Antarctic Ice Sheet and estimates of total Antarctic ice volume in the earliest Oligocene, *Geophysical Res. Lett., 36*, doi:10.1002/ grl.50797.

Selected Seagoing Experience

1999 R/V M. Ewing, Guatemala Basin (Chief Scientist for EW9903 ODP site survey)
2002 D/V JOIDES Resolution, Guatemala Basin (Co-chief Scientist for ODP Leg 206)
2004 RVIB N.B. Palmer, Ross Sea (Co-chief Scientist NBP0306)
2005 D/V JOIDES Resolution, Guatemala Basin (IODP Expeditions 309 & 312)
2011 D/V JOIDES Resolution, Guatemala Basin (IODP Expedition 335)

Synergystic activities:

Member, JOIDES (ODP) Lithosphere Panel, 1992-1995
Member, NSF review panel, Marine Geology and Geophysics, 1992-1994, 1998-2001, 2004.
IODP/COL Distinguished Lecturer, 2012-2013.
Guest editor: ODP Leg 206; IODP Exp 309/312; Tectonophysics special issue on slab windows (published 2009); G-Cubed theme on fast-spread ocean crust (2006-2009).

February, 2013

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http://www.geol.ucsb.edu/people/emeriti/bruce-luyendyk

Professional Preparation

Institution	*Major*	*Degree*	*Year*
San Diego State Univ. (College)	Geology (Geophysics)	B.S.	1965
Scripps Inst. of Oceanography (UCSD)	Oceanography (Marine Geophysics)	Ph.D.	1969
Woods Hole Oceanographic Institution	Marine Geophysics	Postdoc	1970

Appointments

Year(s)	*Title*
2011-present	Adjunct Research Professor, Dept. Earth and Atmospheric Sciences, Univ. Nebraska
2010-present	Research Professor, Earth Research Inst., UC Santa Barbara
2010-present	Professor Emeritus, Department of Earth Science, UC, Santa Barbara
2005-2010	Associate Dean, Div. Math., Life, Physical Sciences, UC Santa Barbara
1981-2010	Professor, Department of Earth Science (was Geological Sciences), UC, Santa Barbara
1997-2003	Chair, Department of Geological Sciences, UC, Santa Barbara
1987-1997	Director, Institute for Crustal Studies, UC, Santa Barbara
1975-1981	Assoc. Professor, Department of Geological Sciences, UC, Santa Barbara
1973-1975	Assist. Professor, Department of Geological Sciences, UC, Santa Barbara
1969-1975	Postdoc and Assist. Scientist, Dept. of Geol. and Geophysics, Woods Hole Oceanog Inst.
1969	Postgraduate Research Geologist, Scripps Institution of Oceanography, UCSD

Honors and Distinctions:

1975	Fellow of the Geological Society of America
1980	Co-Recipient, Newcomb Cleveland Prize of AAAS
1983	Distinguished Alumni Award, Department of Geological Sciences, San Diego State University
1990	Antarctic Service Medal, U. S. National Science Foundation, and Department of the Navy
1991	Contributor to Encyclopedia Britannica, 15th edition; article "Ocean Basins"
1984 -	Named to Who's Who in Technology, American Men and Women of Science
1994 -	Named to Who's Who in America; Who's Who in Science and Engineering.
2002	Fellow of the American Geophysical Union

Products

Five most closely related to the proposed project

Levy, R. H., et al. Levy, R. H., Meyers, S. R., Naish, T. R., Golledge, N. R., McKay, R. M., Crampton, J. S., DeConto, R. M., Santis, L. De, Florindo, F., Gasson, E. G. W., Harwood, D. M., **Luyendyk**, B. P., Powell, R. D., Clowes, C., Kulhanek, D. K. 2019, Antarctic ice-sheet sensitivity to obliquity forcing enhanced through ocean connections, Nature Geosci., 12(2), 132-137, doi:10.1038/s41561-018-0284-4.

Fretwell, P., Pritchard, H. D., Vaughan, D. G., … **Luyendyk**, B. P.,… (57 coauthors in alphab order), 2013, Bedmap2: improved ice bed, surface and thickness datasets for Antarctica: The Cryosphere, v. in press.

Hamilton, Rhea, B. P. **Luyendyk**, C. C. Sorlien, and L. R. Bartek, 2001, Cenozoic Tectonics of the Cape Roberts Rift Basin, and Transantarctic Mountains Front, Southwestern Ross Sea, Antarctica, *Tectonics*, 20, 325-342.

Luyendyk, B.P., C. C. Sorlien, D. Wilson, L. Bartek, and C.H. Siddoway, 2001, Structural and tectonic evolution of the Ross Sea rift in the Cape Colbeck region, Eastern Ross Sea, Antarctica, *Tectonics*, v. 20, # 6, pp. 933-958.

Wilson, D. S., and B. P. **Luyendyk**, 2009, West Antarctic paleotopography estimated at the Eocene-Oligocene climate transition, Geophysical Research Letters, 36 (L16302), doi:10.1029/2009GL039297.

Five other

Luyendyk, B. P., D. S. Wilson, and C. S. Siddoway, 2003, Eastern margin of the Ross Sea Rift in western Marie Byrd Land, Antarctica: Crustal structure and tectonic development, *Geochem. Geophys. Geosyst.*, 4(10), 1090, doi:10.1029/2002GC000462.

Richard, S.M., Smith, C.H., Kimbrough, D.L., Fitzgerald, P.G., **Luyendyk**, B.P., and McWilliams, M.O., 1994, Cooling history of the northern Ford Ranges, Marie Byrd Land, West Antarctica, *Tectonics*, v. 13, 837-857.

Siddoway, C.S., S.L. Baldwin, P.G. Fitzgerald, C.M. Fanning, and B.P. **Luyendyk**, 2004, Ross Sea mylonites and the timing of continental extension between East and West Antarctica, *Geology*, *32* (1), 57-60.

Sorlien, C. C., B. P. **Luyendyk**, D. S. Wilson, R. C. Decesari, L. R. Bartek, and J. B. Diebold, 2007, Oligocene development of the West Antarctic Ice Sheet recorded in eastern Ross Sea strata, *Geology*, 35 (5), 467-470.

Wilson, D. S., and B. P. **Luyendyk**, 2006, Bedrock platforms within the Ross Embayment, West Antarctica: Hypotheses for ice sheet history, wave erosion, Cenozoic extension, and thermal subsidence, *Geochem., Geophys., Geosyst*., 7, Q12011, doi:12010.11029/12006GC001294.

Synergistic Activities

1) Founding director of Institute for Crustal Studies UCSB, (1987-1997). 2) Contributor to Encyclopedia Britannica, 15th edition; article "Ocean Basins" (1990). 3) Developed programs and funding to include undergraduates on marine expeditions to Antarctica (1996, 2003, 2004), to equatorial Pacific (1998), and to Chatham Rise (2006). 4) Symposium Manager, 10th Int'l. Symp. Antarctic Earth Sci. (2007). 5) a proponent for the Coulman High International Drilling Project under ANDRILL (2006-present).

Collaborators & Other Affiliations

Collaborators and Co-editors: Bartek, L. R. III UNC, Chapel Hill, Clayton, R., Caltech, DeConto, R., UMA, Amherst, Fischbein, S. A. UNE, Lincoln, Harwood, D. M., UNE, Lincoln, Jamieson, S., Durham U, U.K., Kamerling, M. J., Venoco, Santa Barbara, Kennett, J. P., UCSB, Leifer, I., UCSB, Levy, R. H., GNS, Wellington, NZ, Pollard, D., Penn State, Rack, F., UNE, Lincoln, Shevenell, A., USFLA, Tampa, Sorlien, C. C., UCSB, Stock, J., Caltech, Stubbs, C., Terrasond, Seattle, Wilson, D. S., UCSB, Wise, S. W., FSU, Tallahassee

Graduate Advisors and Postdoctoral Sponsors: All deceased

Thesis Advisor and Postgraduate-Scholar Sponsor: Robert Decesari (Exxon Mobil, Houston), Tonya Del Sontro (ETH, Zurich), Sarah Hopkins (Houston), Christopher Stubbs (Terrasond, Seattle).

Total number of graduate students advised: 28
Total number of postdoctoral scholars sponsored: 3

Suggested Reviewers

John Barron
US Geological Survey, Menlo Park, CA
Micropaleontologist, marine geology, paleoclimate, paleooceanography

Alan Haywood
University of Leeds, Leeds, United Kingdom
Palaeoclimate and Ice Sheet Modelling

Philip O'Brien
Macquarie University, Sydney, Australia.
Antarctic marine geology and geophysics, seismic stratigraphy, paleoclimate.

Carlota Escutia
Instituto Andaluz de Ciencias de la Tierra, Spain
Antarctic marine geology and geophysics, seismic stratigraphy, paleoclimate.

Peter Bijl
Utrecht University, Netherlands
Paleooceanography, Southern Ocean biostratigraphy, Greenhouse climates

John Jaeger
University of Florida, United States
Coastal and marine sedimentology, glacial sedimentary processes, and continental margin stratigraphy
Jane Francis
British Antarctic Survey, Cambridge, United Kingdom
Palaeoclimatology, paleobotany (Antarctica and Arctic)

IODP Site Forms

Form 1 – General Site Information

964 - Full

Section A: Proposal Information

Proposal Title	Tracing Antarctic Cryosphere Origins to Climate And Tectonics
Date Form Submitted	2019-04-02 21:51:48
Site-Specific Objectives with Priority (Must include general objectives in proposal)	1) Obtain direct geological evidence of the earliest history of ice sheets in East Antarctica, by sampling strata aboveRSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to mid Miocene (~16 Ma) record of EAIS advance. 2) Reconstruction “pre-icehouse” climates in East Antarctica during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-28Ma). 3) Constrain timing of late rift phases in the Western Ross Sea. This will be achieved by dating RSU6 and coring syn-rift strata.
List Previous Drilling in Area	Cape Roberts Project, CIROS-1, AND-1B, AND-2A

Section B: General Site Information

Site Name:	CHCS-01A
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#	
Latitude:	Deg: -77.2315
Longitude:	Deg: 172.2051
Coordinate System:	WGS 84
Priority of Site:	Primary: ✓ Alternate: ☐

Area or Location:	SW Ross Sea continental shelf
Jurisdiction:	Antarctica
Distance to Land: (km)	78
Water Depth (m):	693

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1200	0
	Total Sediment Thickness (m) 1500	
		Total Penetration (m): 1200
General Lithologies:	Diamictite, mudstone, cemented sandstones	unknown (schist, granite, marble, sandstone)

Coring Plan: (Specify or check)

RCB throughout, as strata are lithified near seafloor. Recovery and drill rate anticipate to improve below 100 mbsf as drill bit stabilizes.

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		Other tools:
WL	☑	Magnetic Susceptibility	☐	
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☑			

Other Measurements:

Estimated Days:	Drilling/Coring: 9.1	Logging: 1.6	Total On-site: 10.7

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	January to Feburary is best ice free window
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					
Sensitive marine habitat (e.g., reefs, vents)						

Other: Full hydrocarbon assessment have previously been conducted in these basins for ANDRILL Coulman High and IODP Exp 374

Proposal #: 964 - Full	Site #: CHCS-01A	Date Form Submitted: 2019-04-02 21:51:48

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: NBP0301-34B Position: SP300
2b Deep penetration seismic reflection (crossing)	yes	Line: NBP0301-09A Position: SP4886 nearest crossing line
3 Seismic Velocity	yes	Its own velocity model from stack velocities
4 Seismic Grid	yes	The Antarctic Seismic Data Library System includes many kilometers of multichannel seismic profiles publically available online. We have set up a Kingdom project including also several regional single channel surveys (Polar Duke (PD) 1990, Nathaniel B. Palmer (NBP) 1994, 1995, 2003, 2008). The Kingdom project was already uploaded into the IODP SDSB for prop. 751 in 2016.
5a Refraction (surface)	no	Refraction data exist for the region (Cochrane, G.R.,1995; Antarctic Research Series 68 AGU, Washington, DC, pp. 261–270)
5b Refraction (bottom)	no	N/A
6 3.5 kHz	no	
7 Swath bathymetry	no	Regional swath data is available
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	The list of heat flow stations in the Ross Sea. Can be found from the International Heat Flow Commission http://www.geophysik.rwth-aachen.de/IHFC/heatflow.html Heat flow measurements in the Ross Sea have been carried out since 1970s but are not enough to describe the regional heat flow distribution due to sparse data and restricted location compared to complicated tectonic history. All data were obtained by using a heat probe at shallow subsurface except for the IODP Exp 374 and the ones from McMurdo Sound drill sites such as CRP and DVDP sites.
11a Magnetics	no	Magnetic data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on
11b Gravity	no	Gravity data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on A Free Air gravity Ross Sea map is in the ANTOSTRAT Ross Sea Atlas map AGU vol. 68 (Brancolini et al., 1995)
12 Sediment cores		100s of piston and gravity cores have been collected from the Ross Sea continental shelf and are archived at the AMGRF in Florida.
13 Rock sampling		N/A
14a Water current data		N/A
14b Ice Conditions		open water conditions in polynya region from December to February
15 OBS microseismicity		N/A
16 Navigation	yes	
17 Other		

Proposal #: 964 - Full	Site #: CHCS-01A	Date Form Submitted: 2019-04-02 21:51:48

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single RCB hole, with logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	No shows on IODP Exp 374. Biogenic gas observed at some sites on DSDP Leg 28
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	nonen
4. Indications of gas hydrates at this location	no
5. Are there reasons to expect hydrocarbon accumulations at this site?	
6. What "special" precautions will be taken during drilling?	Sea ice and iceberg present minor risk. Ice observers needed and free fall funnells can be used in case on encroaching ice.
7. What abandonment procedures need to be followed?	standard iceberg encroachment procedures
8. Natural or manmade hazards which may affect ship's operations	ice - see special precautions
9. Summary: What do you consider the major risks in drilling at this site?	ice - see special precautions. A full risk assessment as done for Exp 374 will be conducted. Ice conditions will be similiar to Exp 374 which experienced very few issues with this.

Proposal #: 964 - Full	Site #: CHCS-01A	Date Form Submitted: 2019-04-02 21:51:48

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 20	Strata between seafloor and RSU4A	<18.5	1.55	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
20 - 126	Strata between RSU4A and RSU5	18.5-21	1.600	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
126 - 815	Strata between RSU5 and RSU6 reflector	21-28 (34?)	1.632	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
814 - 1114	Strata between RSU6 and top syn-rift	28(34?) - 40(?)	2.6	mudstone	open marine		
1114 - 1200	syn-rift strata	>40(?)	2.9	Indurated Sandstone, mudstone	shallow marine		

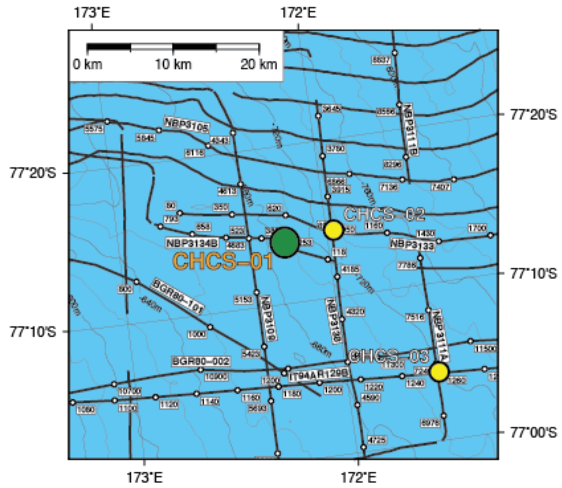
Site Summary Form 6

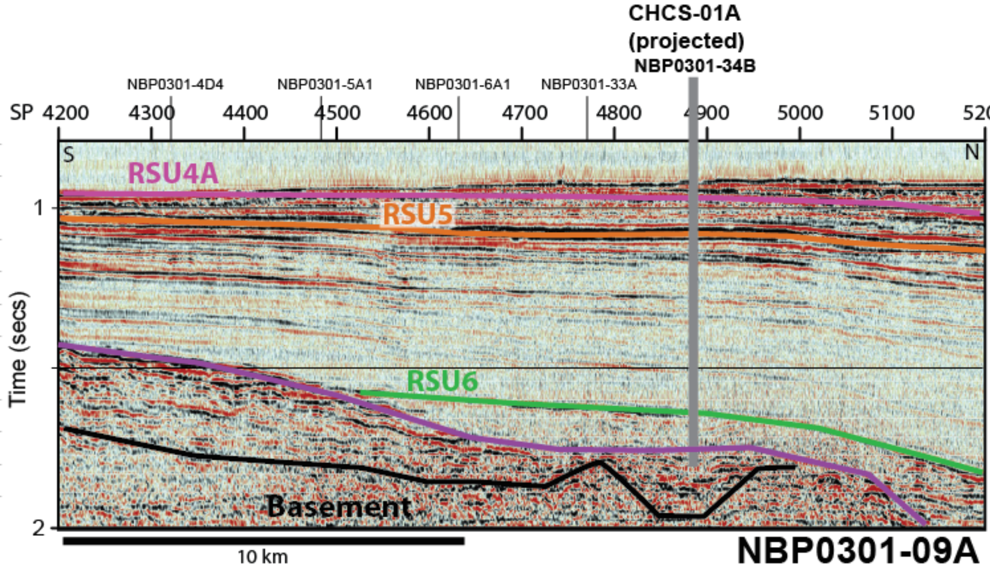
CHCS-01A

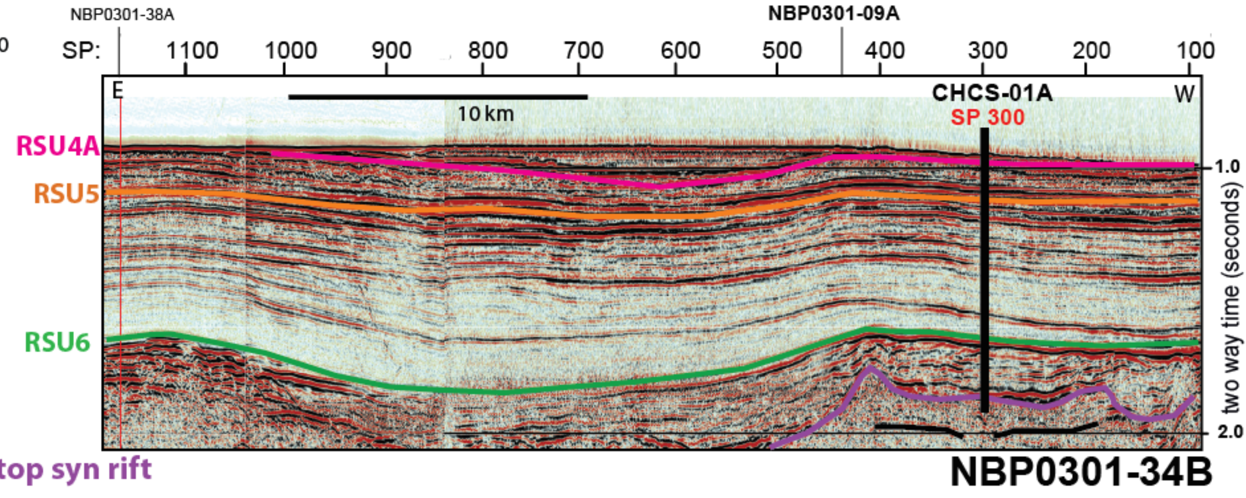
SP300 on NBP03010_34B
nearest crossing line
(SP4886 on NBP03010_09A)
Lat:-77.23154915
Long:172.2050731
Water depth:693 m

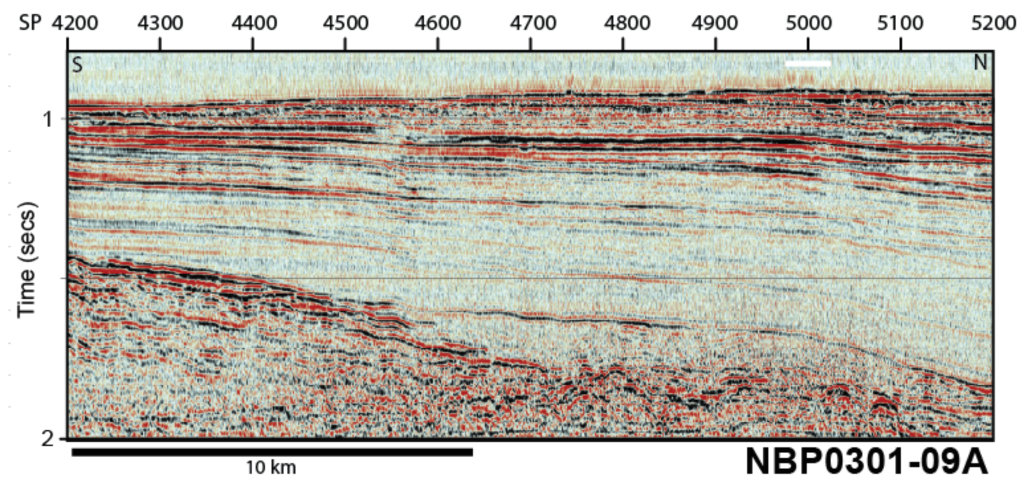
RSU4A (~15Ma)
RSU5 (~21 Ma)
RSU6 (~28-34 Ma?)

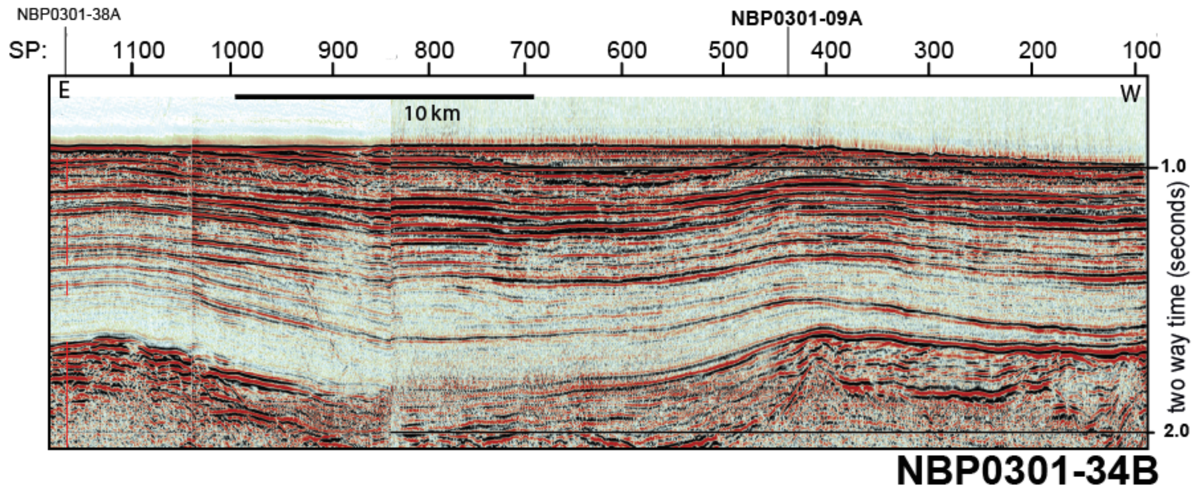
Data files in SSDB (to be upload by 1 May 2019)
NBP03010_34B.segy, NBP03010_34B.nav
NBP03010_09A.segy, NBP03010_09A.nav
Velocity information.doc











IODP Site Forms

Form 1 – General Site Information

964 - Full

Section A: Proposal Information

Proposal Title	Tracing Antarctic Cryosphere Origins to Climate And Tectonics
Date Form Submitted	2019-04-02 21:51:48
Site-Specific Objectives with Priority (Must include general objectives in proposal)	1) Obtain direct geological evidence of the earliest history of ice sheets in East Antarctica, by sampling strata aboveRSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to mid Miocene (~16 Ma) record of EAIS advance. 2) Reconstruction "pre-icehouse" climates in East Antarctica during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-28Ma). 3) Constrain timing of late rift phases in the Western Ross Sea. This will be achieved by dating RSU6 and coring syn-rift strata
List Previous Drilling in Area	Cape Roberts Project, CIROS-1, AND-1B, AND-2A

Section B: General Site Information

Site Name:	CHCS-02A	Area or Location:	SW Ross Sea continental shelf
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: -77.31783122	Jurisdiction:	Antarctica
Longitude:	Deg: 171.95787093	Distance to Land: (km)	64
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	740

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1200	0
	Total Sediment Thickness (m) 1774	
		Total Penetration (m): 1200
General Lithologies:	Diamictite, mudstone, cemented sandstones	unknown (schist, granite, marble, sandstone)

Coring Plan:
(Specify or check)

RCB throughout, as strata are lithified near seafloor. Recovery and drill rate anticipate to improve below 100 mbsf as drill bit stabilizes.

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		Other tools:
WL	☑	Magnetic Susceptibility	☐	
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☑			

Other Measurements:

Estimated Days:	Drilling/Coring: 9	Logging: 1.6	Total On-site: 10.6

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	January to Feburary is best ice free window
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					
Sensitive marine habitat (e.g., reefs, vents)						

Other: Full hydrocarbon assessment have previously been conducted in these basins for ANDRILL Coulman High and IODP Exp 374

Generated: 2019-05-03T19:01:55+00:00

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 964 - Full	Site #: CHCS-02A	Date Form Submitted: 2019-04-02 21:51:48

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: NBP03010-38A Position: SP3779
2b Deep penetration seismic reflection (crossing)	yes	Line: NBP0301-05A Position: SP 6739 nearest line, not crossing. it's located 8 km to the north of the site
3 Seismic Velocity	yes	Its own velocity model from stack velocities
4 Seismic Grid	yes	The Antarctic Seismic Data Library System includes many kilometers of multichannel seismic profiles publically available online. We have set up a Kingdom project including also several regional single channel surveys (Polar Duke (PD) 1990, Nathaniel B. Palmer (NBP) 1994, 1995, 2003, 2008). The Kingdom project was already uploaded into the IODP SDSB for prop. 751 in 2016.
5a Refraction (surface)	no	Refraction data exist for the region (Cochrane, G.R.,1995; Antarctic Research Series 68 AGU, Washington, DC, pp. 261–270)
5b Refraction (bottom)	no	N/A
6 3.5 kHz	no	
7 Swath bathymetry	no	Regional swath data is available
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	The list of heat flow stations in the Ross Sea. Can be found from the International Heat Flow Commission http://www.geophysik.rwth-aachen.de/IHFC/heatflow.html Heat flow measurements in the Ross Sea have been carried out since 1970s but are not enough to describe the regional heat flow distribution due to sparse data and restricted location compared to complicated tectonic history. All data were obtained by using a heat probe at shallow subsurface except for the IODP Exp 374 and the ones from McMurdo Sound drill sites such as CRP and DVDP sites.
11a Magnetics	no	Magnetic data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on
11b Gravity	no	Gravity data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on A Free Air gravity Ross Sea map is in the ANTOSTRAT Ross Sea Atlas map AGU vol. 68 (Brancolini et al., 1995)
12 Sediment cores		100s of piston and gravity cores have been collected from the Ross Sea continental shelf and are archived at the AMGRF in Florida.
13 Rock sampling		N/A
14a Water current data		N/A
14b Ice Conditions		open water conditions in polynya region from December to February
15 OBS microseismicity		N/A
16 Navigation	yes	
17 Other		

Proposal #: 964 - Full	Site #: CHCS-02A	Date Form Submitted: 2019-04-02 21:51:48

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single RCB hole, with logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	No shows on IODP Exp 374. Biogenic gas observed at some sites on DSDP Leg 28
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	nonen
4. Indications of gas hydrates at this location	no
5. Are there reasons to expect hydrocarbon accumulations at this site?	
6. What "special" precautions will be taken during drilling?	Sea ice and iceberg present minor risk. Ice observers needed and free fall funnells can be used in case on encroaching ice.
7. What abandonment procedures need to be followed?	standard iceberg encroachment procedures
8. Natural or manmade hazards which may affect ship's operations	ice - see special precautions
9. Summary: What do you consider the major risks in drilling at this site?	ice - see special precautions. A full risk assessment as done for Exp 374 will be conducted. Ice conditions will be similiar to Exp 374 which experienced very few issues with this.

Proposal #: 964 - Full	Site #: CHCS-02A	Date Form Submitted: 2019-04-02 21:51:48

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 181	Strata between sea floor and RSU5	18.5-21	2.6	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
181 - 1050	Strata between RSU5 and RSU6 reflector	21-28 (34?)	2.8	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
1050 - 1190	Strata between RSU6 and top syn-rift	28 (34?)-40 (?)	3.1	mudstone	open marine		
1190 - 1200	syn-rift strata	>40(?)	4.0	Indurated Sandstone, mudstone	shallow marine		

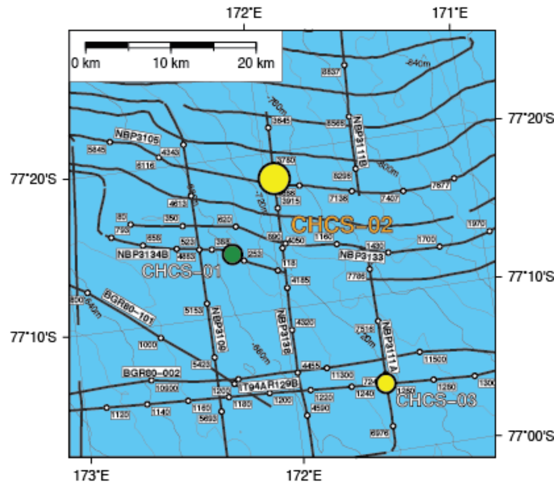
Site Summary Form 6

Site CHCS-02A

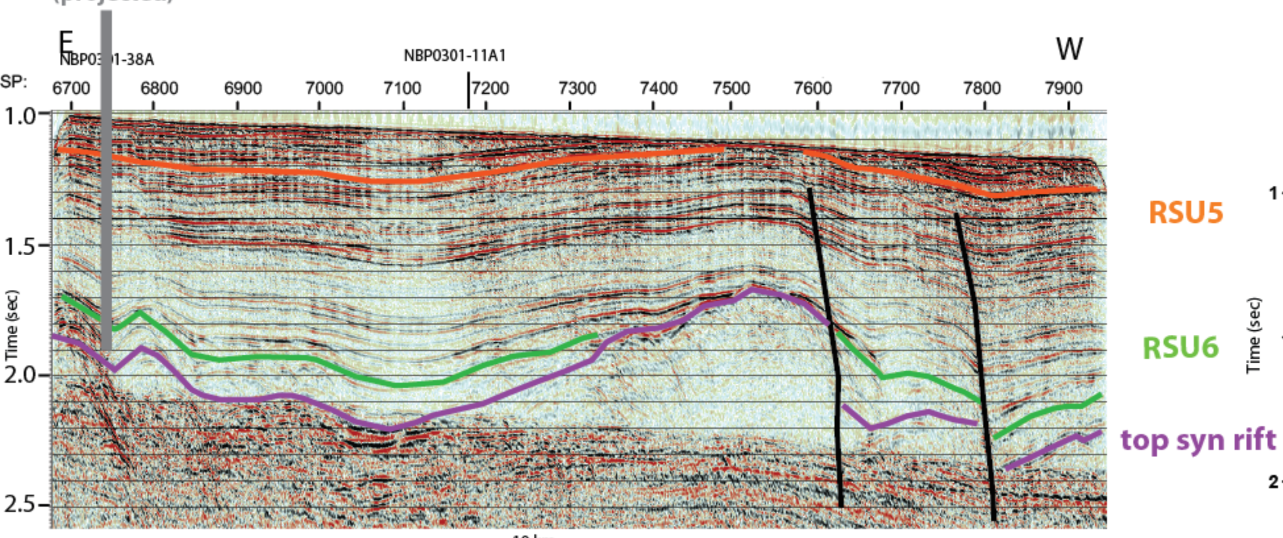
SP3779 on NBP03010_38A1
SP6739 on NBP0301-5A1 (nearest)

Lat:-77.3178
Long:171.9578
Waterdepth 740m

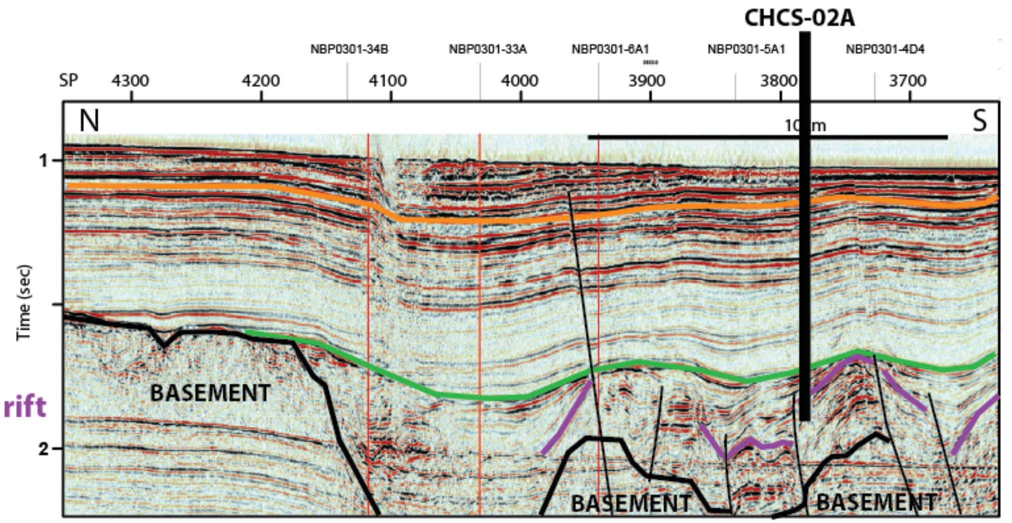
Data files in SSDB (to be upload by 1 May 2019)
NBP03010_33A1.segy,NBP03010_33A1.nav
NBP0301-5A1.segy, NBP0301-5A1.nav
Velocity information.doc



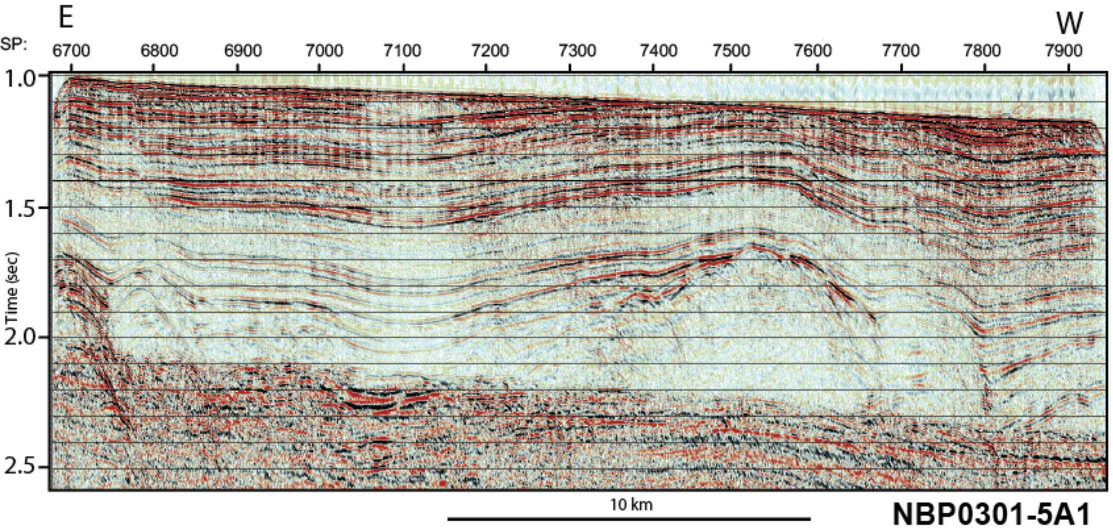
RSU5 (~21 Ma - orange)
RSU6 (~28-34 Ma? - green)
Top syn rift (unknown age (Eocene??)- purple)



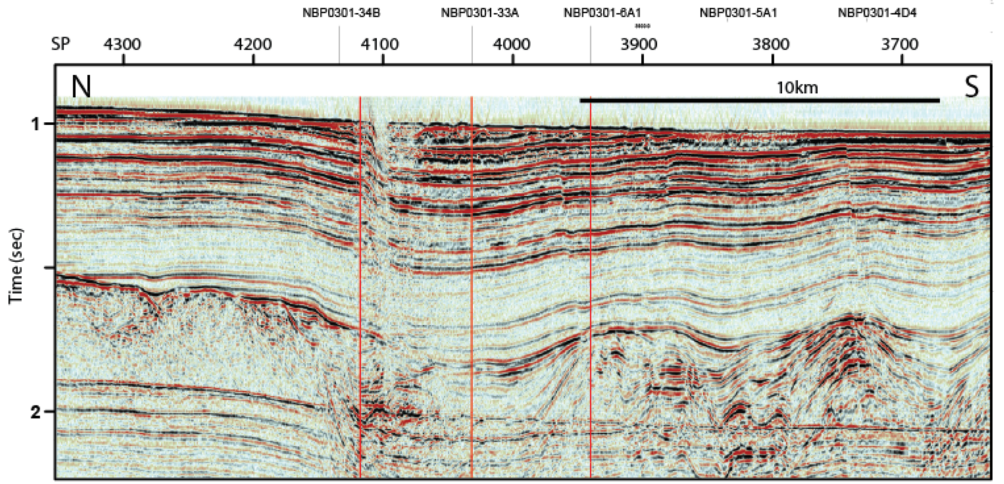
NBP0301-5A1



NBP0301-38A



NBP0301-5A1



NBP0301-38A

IODP Site Forms

Form 1 – General Site Information

964 - Full

Section A: Proposal Information

Proposal Title	Tracing Antarctic Cryosphere Origins to Climate And Tectonics
Date Form Submitted	2019-04-02 21:51:48
Site-Specific Objectives with Priority (Must include general objectives in proposal)	1) Obtain direct geological evidence of the earliest history of ice sheets in East Antarctica, by sampling strata aboveRSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to mid Miocene (~16 Ma) record of EAIS advance. 2) Reconstruction "pre-icehouse" climates in East Antarctica during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-28Ma). 3) Constrain timing of late rift phases in the Western Ross Sea. This will be achieved by dating RSU6 and coring syn-rift strata
List Previous Drilling in Area	Cape Roberts Project, CIROS-1, AND-1B, AND-2A

Section B: General Site Information

Site Name:	CHCS-03A	Area or Location:	SW Ross Sea continental shelf
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: -77.0727	Jurisdiction:	Antarctica
Longitude:	Deg: 171.5629	Distance to Land: (km)	69
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	712

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1300	0
	Total Sediment Thickness (m): 1588	
		Total Penetration (m): 1300
General Lithologies:	Diamictite, mudstone, cemented sandstones	unknown (schist, granite, marble, sandstone)

Coring Plan: (Specify or check)

RCB throughout, as strata are lithified near seafloor. Recovery and drill rate anticipate to improve below 100 mbsf as drill bit stabilizes.

- [ ] APC
- [ ] XCB
- [x] RCB
- [ ] Re-entry
- [ ] PCS

Wireline Logging Plan:

Standard Measurements		Special Tools		Other tools:
WL	✓	Magnetic Susceptibility	☐	
Porosity	✓	Borehole Temperature	☐	
Density	✓	Formation Image (Acoustic)	☐	
Gamma Ray	✓	VSP (walkaway)	☐	
Resistivity	✓	LWD	☐	
Sonic (Δt)	✓			
Formation Image (Res)	✓			
VSP (zero offset)	✓			
Formation Temperature & Pressure	✓			

Other Measurements:

Estimated Days:

Drilling/Coring:	Logging:	Total On-site:
10	2	12

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

Potential Hazards/ Weather:

Shallow Gas	✓	Complicated Seabed Condition	☐	Hydrothermal Activity	☐
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐
H_2S	☐	High Dip Angle	☐	Ice Conditions	✓
CO_2	☐				

Sensitive marine habitat (e.g., reefs, vents):

Preferred weather window: January to Feburary is best ice free window

Other: Full hydrocarbon assessment have previously been conducted in these basins for ANDRILL Coulman High and IODP Exp 374

Proposal #: 964 - Full	Site #: CHCS-03A	Date Form Submitted: 2019-04-02 21:51:48

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: NBP0301-11A Position: 7200
2b Deep penetration seismic reflection (crossing)	yes	Line: IT94AR129 Position: 1257
3 Seismic Velocity	yes	Its own velocity model from stack velocities
4 Seismic Grid	yes	The Antarctic Seismic Data Library System includes many kilometers of multichannel seismic profiles publically available online. We have set up a Kingdom project including also several regional single channel surveys (Polar Duke (PD) 1990, Nathaniel B. Palmer (NBP) 1994, 1995, 2003, 2008). The Kingdom project was already uploaded into the IODP SDSB for prop. 751 in 2016.
5a Refraction (surface)	no	Refraction data exist for the region (Cochrane, G.R.,1995; Antarctic Research Series 68 AGU, Washington, DC, pp. 261–270)
5b Refraction (bottom)		
6 3.5 kHz		
7 Swath bathymetry	no	N/A
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	The list of heat flow stations in the Ross Sea. Can be found from the International Heat Flow Commission http://www.geophysik.rwth-aachen.de/IHFC/heatflow.html Heat flow measurements in the Ross Sea have been carried out since 1970s but are not enough to describe the regional heat flow distribution due to sparse data and restricted location compared to complicated tectonic history. All data were obtained by using a heat probe at shallow subsurface except for the IODP Exp 374 and the ones from McMurdo Sound drill sites such as CRP and DVDP sites.
11a Magnetics	no	Magnetic data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on
11b Gravity	no	Gravity data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on A Free Air gravity Ross Sea map is in the ANTOSTRAT Ross Sea Atlas map AGU vol. 68 (Brancolini et al., 1995)
12 Sediment cores	no	100s of piston and gravity cores have been collected from the Ross Sea continental shelf and are archived at the AMGRF in Florida.
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions		open water conditions in polynya region from December to February
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other	no	

Proposal #: 964 - Full	Site #: CHCS-03A	Date Form Submitted: 2019-04-02 21:51:48

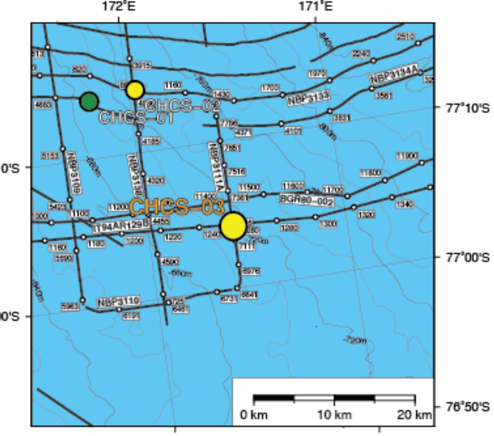
Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single RCB hole, with logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	No shows on IODP Exp 374. Biogenic gas observed at some sites on DSDP Leg 28
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	none
4. Indications of gas hydrates at this location	no
5. Are there reasons to expect hydrocarbon accumulations at this site?	No
6. What "special" precautions will be taken during drilling?	Sea ice and iceberg present minor risk. Ice observers needed and free fall funnells can be used in case on encroaching ice.
7. What abandonment procedures need to be followed?	standard iceberg encroachment procedures
8. Natural or manmade hazards which may affect ship's operations	ice - see special precautions
9. Summary: What do you consider the major risks in drilling at this site?	ice - see special precautions. A full risk assessment as done for Exp 374 will be conducted. Ice conditions will be similiar to Exp 374 which experienced very few issues with this.

Proposal #: 964 - Full	Site #: CHCS-03A	Date Form Submitted: 2019-04-02 21:51:48

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 138	Strata between seafloor and RSU4a	0-18	2.5	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
138 - 320	Strata between RSU4a and RSU5 reflector	18-21	2.5	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
320 - 1080	RSU5-RSU6 reflectors	21-28(? 34)	2.7	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
1080 - 1287	Strata between RSU6 and top of syn rift	28(34?) - >34Ma?	3.0	Indurated Sandstone, mudstone	open marine, marginal marine		
1287 - 1300	syn rift strata	>40 ?	3.3	Indurated Sandstone, mudstone	shallow marine		

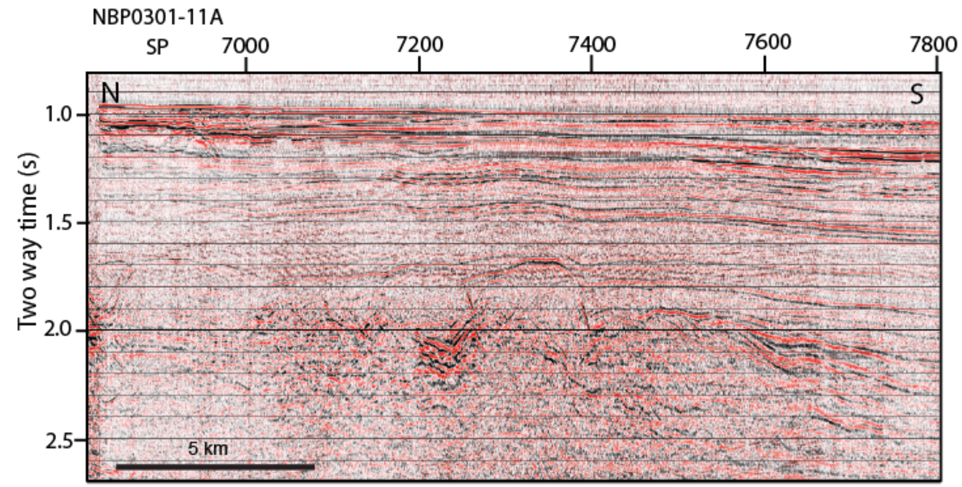
Site Summary Form 6
CHCS-03A

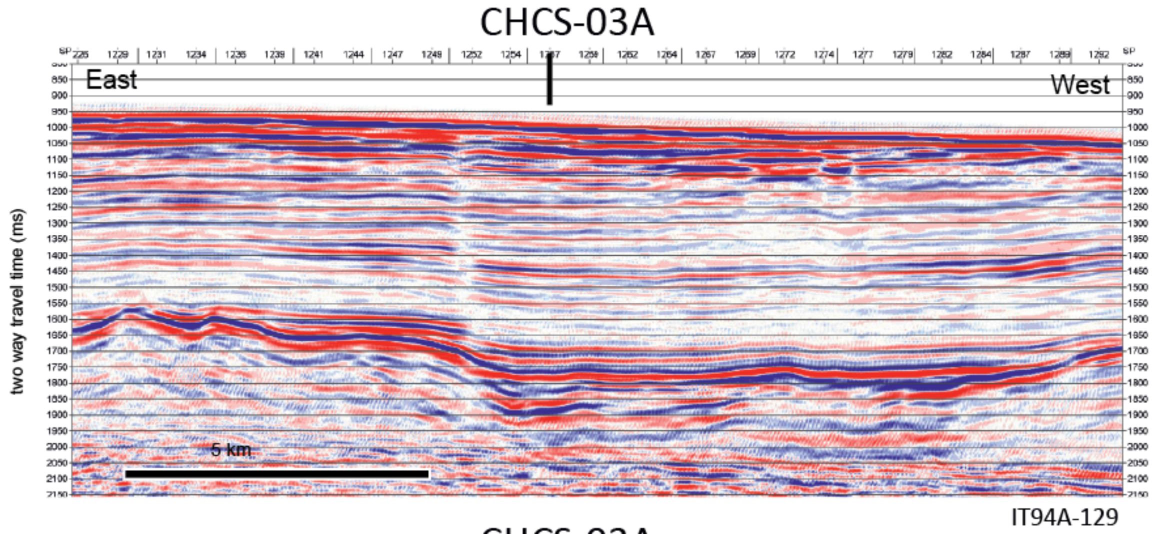
Data files in SSDB (to be upload by 1 May 2019)
IT94AR129.segy, IT94AR129.nav
NBP0301-11A.segy, NBP0301-11A.nav
Velocity information.doc

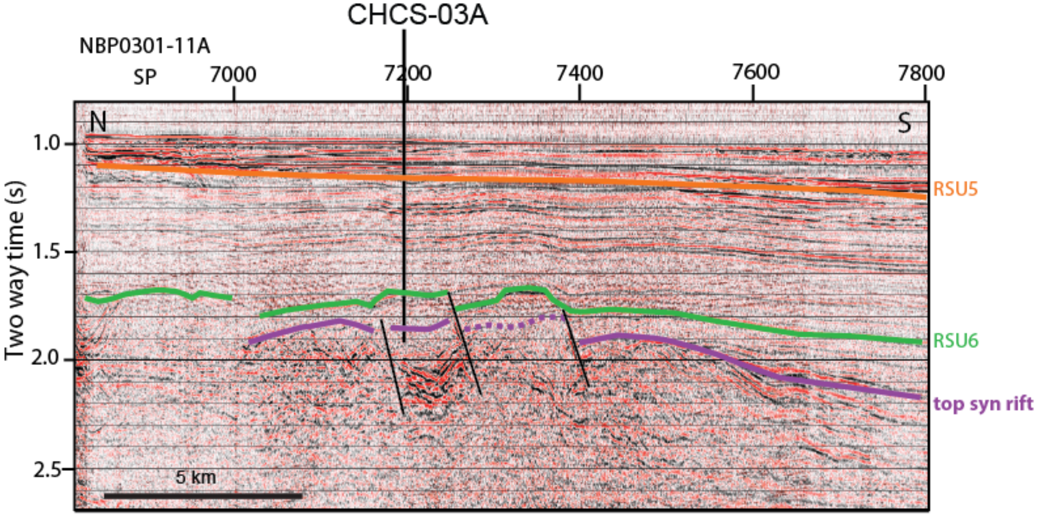


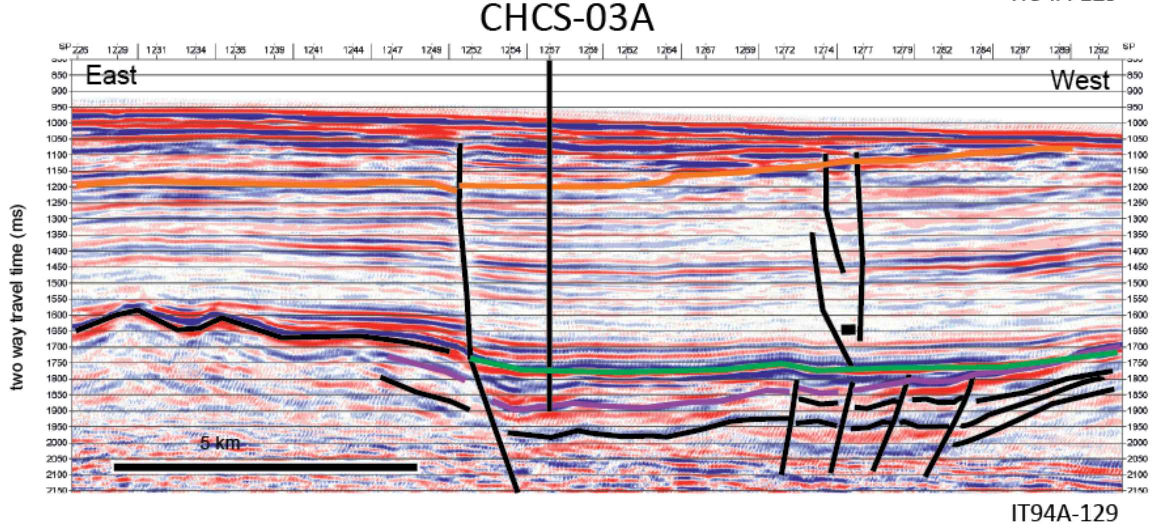
SP7200 on NBP0301-11A
SP1257 on IT94AR129
Lat:-77.07257
Long:171.5629
water depth: 712 m

RSU5 (~21 Ma - orange)
RSU6 (~28-34 Ma? - green)
Top syn rift (unknown age (Eocene??)- purple)









IODP Site Forms

Form 1 – General Site Information

964 - Full

Section A: Proposal Information

Proposal Title	Tracing Antarctic Cryosphere Origins to Climate And Tectonics
Date Form Submitted	2019-04-02 21:51:48
Site-Specific Objectives with Priority (Must include general objectives in proposal)	1) Obtain direct geological evidence of the earliest history of ice sheets in East Antarctica, by sampling strata aboveRSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to Early Miocene (20 Ma) record of marine environments, with influence of combined EAIS/WAIS or local ice cap advance in central Ross Sea. 2) Reconstruction “pre-icehouse” climates in Central Ross Sea during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-28Ma). 3) Constrain timing of late rift phases in the Central Ross Sea. This will be achieved by dating RSU6 and coring syn-rift strata.
List Previous Drilling in Area	DSDP Site 270

Section B: General Site Information

Site Name:	CENCS-01A	Area or Location:	Central Ross Sea continental shelf
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: -77.4516	Jurisdiction:	Antarctica
Longitude:	Deg: -177.8407	Distance to Land: (km)	300
Coordinate System:	WGS 84		
Priority of Site:	Primary: ✓ Alternate: ☐	Water Depth (m):	616

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1185	15
	Total Sediment Thickness (m) 1185	
		Total Penetration (m): 1200
General Lithologies:	Diamictite, mudstone, cemented sandstones	unknown (schist, granite, marble, sandstone)

Coring Plan: (Specify or check)

RCB throughout, as strata are lithified near seafloor. Recovery and drill rate anticipate to improve below 100 mbsf as drill bit stabilizes.

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☐	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☑			

Other Measurements:

Estimated Days:	Drilling/Coring: 9	Logging: 1.6	Total On-site: 10.6

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	January to Feburary is best ice free window
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					
Sensitive marine habitat (e.g., reefs, vents)						

Other: Full hydrocarbon assessment have previously been conducted in these basins for ANDRILL Coulman High and IODP Exp 374

Proposal #: 964 - Full	Site #: CENCS-01A	Date Form Submitted: 2019-04-02 21:51:48

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	yes	Line: PD90-026 Position: SP166
2a Deep penetration seismic reflection (primary)	yes	Line: IT89A-33 Position: SP1964
2b Deep penetration seismic reflection (crossing)	no	nearest crossing line (1 km to south)
3 Seismic Velocity	yes	Its own velocity model from stack velocities
4 Seismic Grid	yes	The Antarctic Seismic Data Library System includes many kilometers of multichannel seismic profiles publically available online. We have set up a Kingdom project including also several regional single channel surveys (Polar Duke (PD) 1990, Nathaniel B. Palmer (NBP) 1994, 1995, 2003, 2008). The Kingdom project was already uploaded into the IODP SDSB for prop. 751 in 2016.
5a Refraction (surface)	no	Refraction data exist for the region (Cochrane, G.R.,1995; Antarctic Research Series 68 AGU, Washington, DC, pp. 261–270)
5b Refraction (bottom)	no	N/A
6 3.5 kHz	no	
7 Swath bathymetry	no	Regional swath data is available
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	The list of heat flow stations in the Ross Sea. Can be found from the International Heat Flow Commission http://www.geophysik.rwth-aachen.de/IHFC/heatflow.html Heat flow measurements in the Ross Sea have been carried out since 1970s but are not enough to describe the regional heat flow distribution due to sparse data and restricted location compared to complicated tectonic history. All data were obtained by using a heat probe at shallow subsurface except for the IODP Exp 374 and the ones from McMurdo Sound drill sites such as CRP and DVDP sites.
11a Magnetics	no	Magnetic data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on
11b Gravity	no	Gravity data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on A Free Air gravity Ross Sea map is in the ANTOSTRAT Ross Sea Atlas map AGU vol. 68 (Brancolini et al., 1995)
12 Sediment cores		100s of piston and gravity cores have been collected from the Ross Sea continental shelf and are archived at the AMGRF in Florida.
13 Rock sampling		N/A
14a Water current data		N/A
14b Ice Conditions		open water conditions in polynya region from December to February
15 OBS microseismicity		N/A
16 Navigation	yes	
17 Other		

Proposal #: 964 - Full	Site #: CENCS-01A	Date Form Submitted: 2019-04-02 21:51:48

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single RCB hole, with logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	No shows on IODP Exp 374. Biogenic gas observed at some sites on DSDP Leg 28
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	none
4. Indications of gas hydrates at this location	no
5. Are there reasons to expect hydrocarbon accumulations at this site?	no
6. What "special" precautions will be taken during drilling?	Sea ice and iceberg present minor risk. Ice observers needed and free fall funnells can be used in case on encroaching ice.
7. What abandonment procedures need to be followed?	standard iceberg encroachment procedures
8. Natural or manmade hazards which may affect ship's operations	ice - see special precautions
9. Summary: What do you consider the major risks in drilling at this site?	ice - see special precautions. A full risk assessment as done for Exp 374 will be conducted. Ice conditions will be similiar to Exp 374 which experienced very few issues with this.

Proposal #: 964 - Full	Site #: CENCS-01A	Date Form Submitted: 2019-04-02 21:51:48

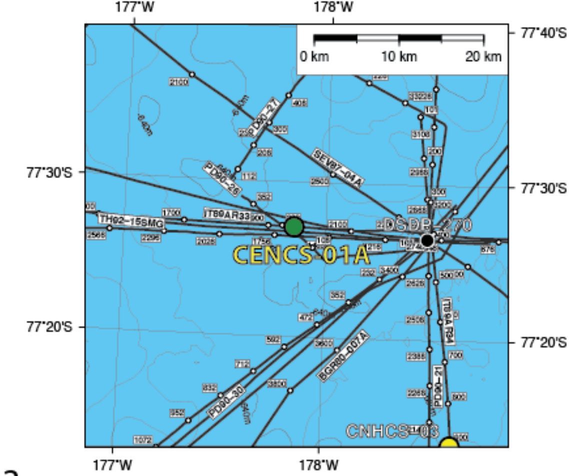
Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 135	Strata between seafloor and RSU5A	20-23	2.0	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
135 - 745	Strata between RSU5A and RSU6 reflector	21-34(?)	2.34	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
745 - 985	Strata between RSU6 and RSU7	21-30	2.8	Indurated Sandstone, mudstone	open marine/ marginal marine		
985 - 1185	Strata between RSU7 and basement	>50Ma (?)	2.8	Indurated Sandstone, mudstone	open marine, marginal marine		
1185 - 1200	basement		3.0	unknown (gneiss, sandstone, granite, marble?)			

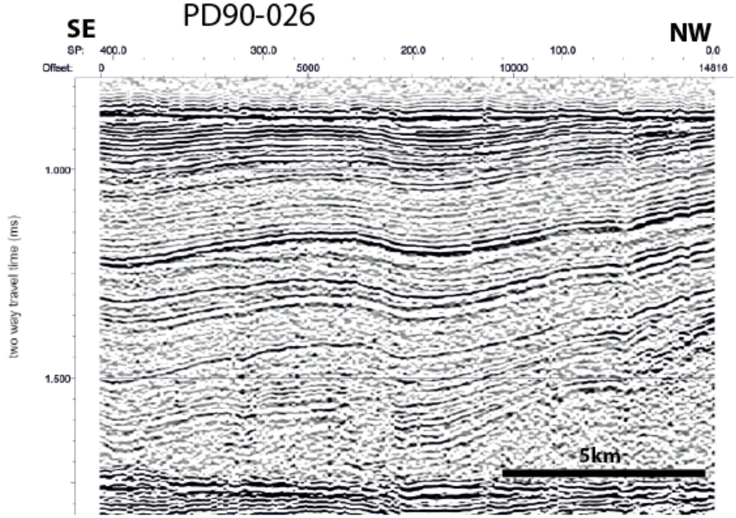
Site CENCS-01A

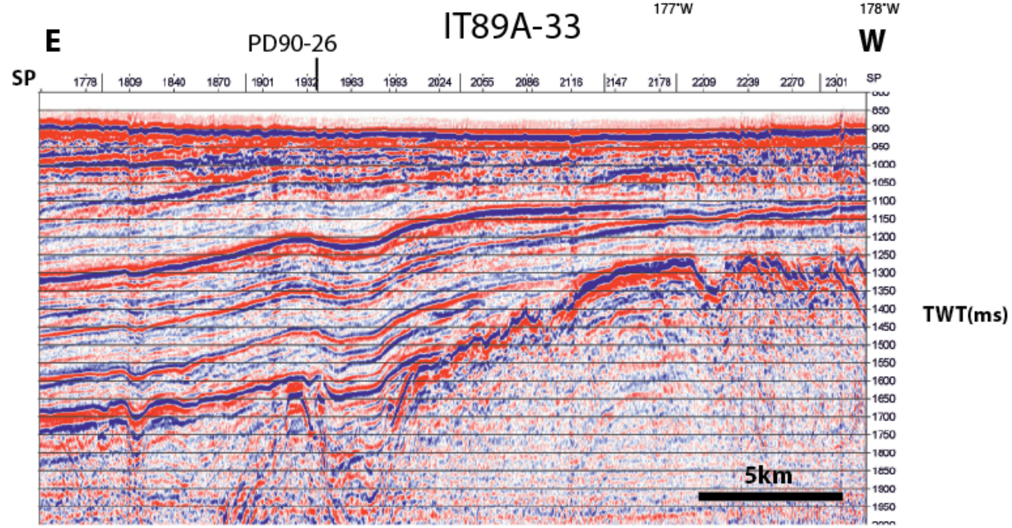
shotpoint 1964 on IT89A-33
shotpoint 166 on PD90-026 (nearest - 1km tosouth)
Lat:-77.4516
Long: -177.8407
Water depth:616m

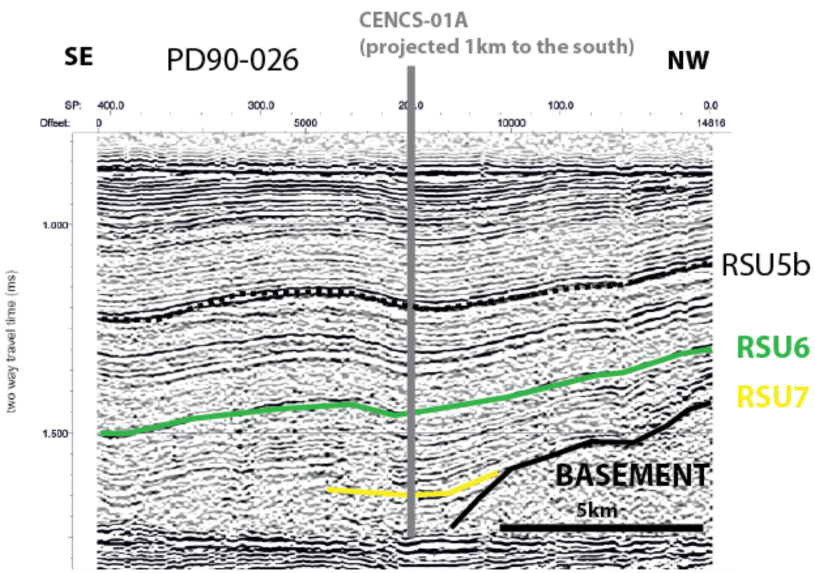
Data files in SSDB (to be upload by 1 May 2019)
IT89A-33.segy, IT89A-33.nav
PD90-026.segy, PD90-026.nav
Velocity information.doc

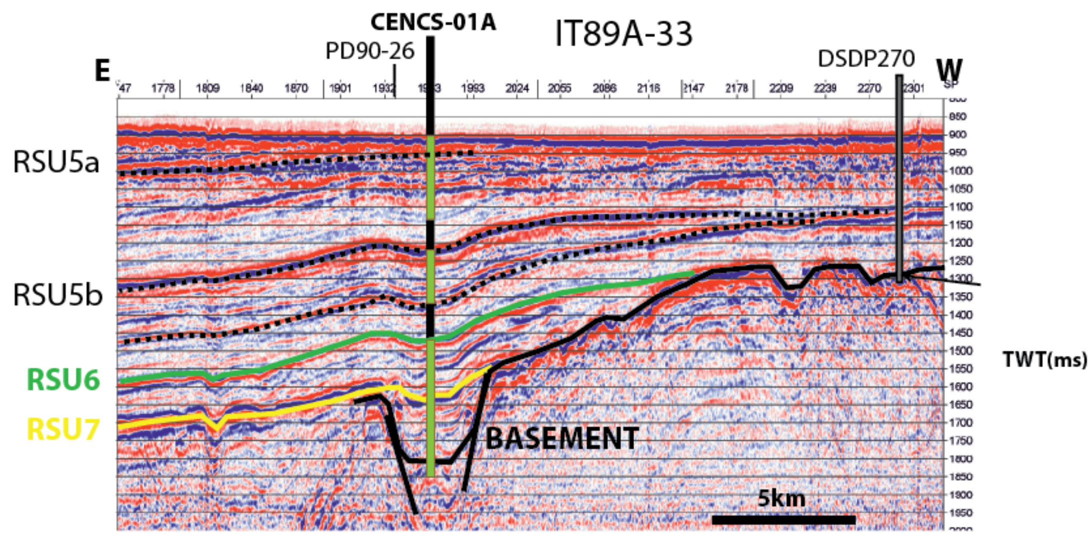
RSU6 (~28-34 Ma?)
RSU7 (age unknown)











n.b. green core intervals = sections not deposited at DSDP site270

IODP Site Forms

Form 1 – General Site Information

964 - Full

Section A: Proposal Information

Proposal Title	Tracing Antarctic Cryosphere Origins to Climate And Tectonics
Date Form Submitted	2019-04-02 21:51:48
Site-Specific Objectives with Priority (Must include general objectives in proposal)	1) Obtain direct geological evidence of the earliest history of ice sheets in East Antarctica, by sampling strata aboveRSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to Early Miocene (20 Ma) record of marine environments, with influence of combined EAIS/WAIS or local ice cap advance in central Ross Sea. 2) Reconstruction “pre-icehouse” climates in Central Ross Sea during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-28Ma). 3) Constrain timing of late rift phases in the Central Ross Sea. This will be achieved by dating RSU6 and coring syn-rift strata.
List Previous Drilling in Area	DSDP Site 270

Section B: General Site Information

Site Name:	CENCS-02A	Area or Location:	Central Ross Sea continental shelf
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#	268		
Latitude:	Deg: -77.6402	Jurisdiction:	Antarctica
Longitude:	Deg: -179.2478	Distance to Land: (km)	
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	648

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	850	50
	Total Sediment Thickness (m) 850	
		Total Penetration (m): 900
General Lithologies:	Diamictite, mudstone, cemented sandstones	unknown (schist, granite, marble, sandstone)

Coring Plan: (Specify or check)

RCB throughout, as strata are lithified near seafloor. Recovery and drill rate anticipate to improve below 100 mbsf as drill bit stabilizes.

- [ ] APC
- [ ] XCB
- [x] RCB
- [ ] Re-entry
- [ ] PCS

Wireline Logging Plan:

Standard Measurements		Special Tools		Other tools:
WL	✓	Magnetic Susceptibility	☐	
Porosity	✓	Borehole Temperature	☐	
Density	✓	Formation Image (Acoustic)	☐	
Gamma Ray	✓	VSP (walkaway)	☐	
Resistivity	✓	LWD	☐	
Sonic (Δt)	✓			
Formation Image (Res)	✓			
VSP (zero offset)	✓			
Formation Temperature & Pressure	✓			

Other Measurements:

Estimated Days:

Drilling/Coring:	Logging:	Total On-site:
5.1	1.5	6.6

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	✓	Complicated Seabed Condition	☐	Hydrothermal Activity	☐
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐
H_2S	☐	High Dip Angle	☐	Ice Conditions	✓
CO_2	☐				

Sensitive marine habitat (e.g., reefs, vents):

Preferred weather window: January to Feburary is best ice free window

Other: Full hydrocarbon assessment have previously been conducted in these basins for ANDRILL Coulman High and IODP Exp 374

Proposal #: 964 - Full	Site #: CENCS-02A	Date Form Submitted: 2019-04-02 21:51:48

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	yes	Line: PD90-21 Position: SP3500
2a Deep penetration seismic reflection (primary)	yes	Line: BGR80-007A Position: SP2745
2b Deep penetration seismic reflection (crossing)	no	nearest crossing line
3 Seismic Velocity	yes	Its own velocity model from stack velocities
4 Seismic Grid	yes	The Antarctic Seismic Data Library System includes many kilometers of multichannel seismic profiles publically available online. We have set up a Kingdom project including also several regional single channel surveys (Polar Duke (PD) 1990, Nathaniel B. Palmer (NBP) 1994, 1995, 2003, 2008). The Kingdom project was already uploaded into the IODP SDSB for prop. 751 in 2016.
5a Refraction (surface)	no	Refraction data exist for the region (Cochrane, G.R.,1995; Antarctic Research Series 68 AGU, Washington, DC, pp. 261–270)
5b Refraction (bottom)	no	N/A
6 3.5 kHz	no	
7 Swath bathymetry	no	Regional swath data is available
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	The list of heat flow stations in the Ross Sea. Can be found from the International Heat Flow Commission http://www.geophysik.rwth-aachen.de/IHFC/heatflow.html Heat flow measurements in the Ross Sea have been carried out since 1970s but are not enough to describe the regional heat flow distribution due to sparse data and restricted location compared to complicated tectonic history. All data were obtained by using a heat probe at shallow subsurface except for the IODP Exp 374 and the ones from McMurdo Sound drill sites such as CRP and DVDP sites.
11a Magnetics	no	Magnetic data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on
11b Gravity	no	Gravity data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on A Free Air gravity Ross Sea map is in the ANTOSTRAT Ross Sea Atlas map AGU vol. 68 (Brancolini et al., 1995)
12 Sediment cores		100s of piston and gravity cores have been collected from the Ross Sea continental shelf and are archived at the AMGRF in Florida.
13 Rock sampling		N/A
14a Water current data		N/A
14b Ice Conditions		open water conditions in polynya region from December to February
15 OBS microseismicity		N/A
16 Navigation	yes	
17 Other		

Proposal #: 964 - Full	Site #: CENCS-02A	Date Form Submitted: 2019-04-02 21:51:48

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single RCB hole, with logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	No shows on IODP Exp 374. Biogenic gas observed at some sites on DSDP Leg 28
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	none
4. Indications of gas hydrates at this location	no
5. Are there reasons to expect hydrocarbon accumulations at this site?	No
6. What "special" precautions will be taken during drilling?	Sea ice and iceberg present minor risk. Ice observers needed and free fall funnells can be used in case on encroaching ice.
7. What abandonment procedures need to be followed?	standard iceberg encroachment procedures
8. Natural or manmade hazards which may affect ship's operations	ice - see special precautions
9. Summary: What do you consider the major risks in drilling at this site?	ice - see special precautions. A full risk assessment as done for Exp 374 will be conducted. Ice conditions will be similiar to Exp 374 which experienced very few issues with this.

Proposal #: 964 - Full	Site #: CENCS-02A	Date Form Submitted: 2019-04-02 21:51:48

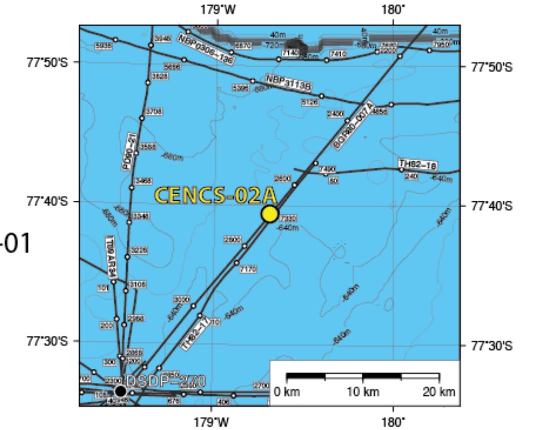
Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 300	Strata between seafloor and RSU6	23-34(?)	1.8	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
300 - 630	Strata between RSU6 and RSU7	34 (?)-40?	2.3	Indurated Sandstone, mudstone	open marine, marginal marine		
630 - 850	Strata between RSU7 and basement	>50Ma (?)	2.3	Indurated Sandstone, mudstone	open marine, marginal marine		
850 - 900	basement		3.0	unknown (gneiss, sandstone, granite, marble?)			

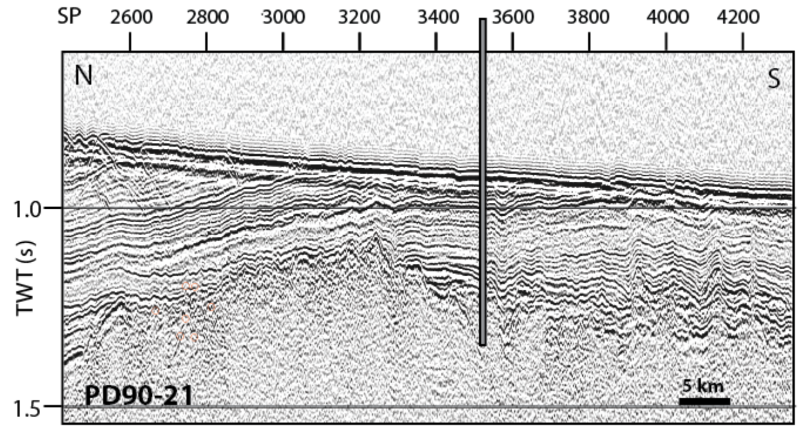
Site CENCS-02A

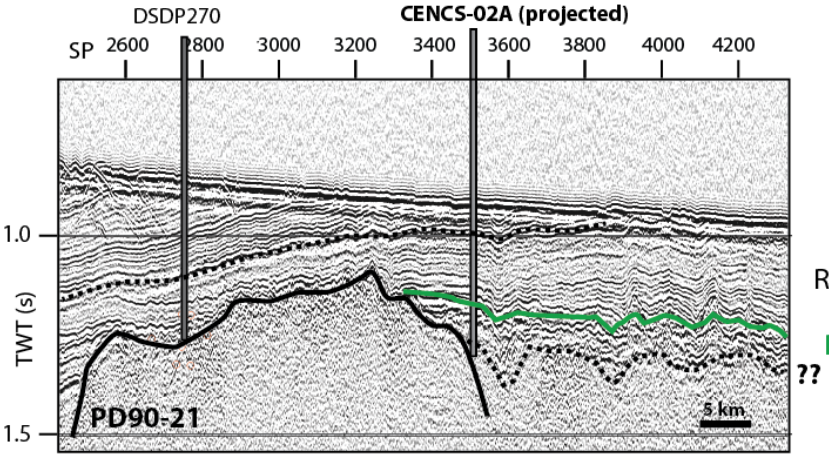
Shotpoint 2745 on BGR80-007A
Shotpoint 3500 on PD90-21
Lat:-77.6402
Long:-179.2478
Water Depth:648m

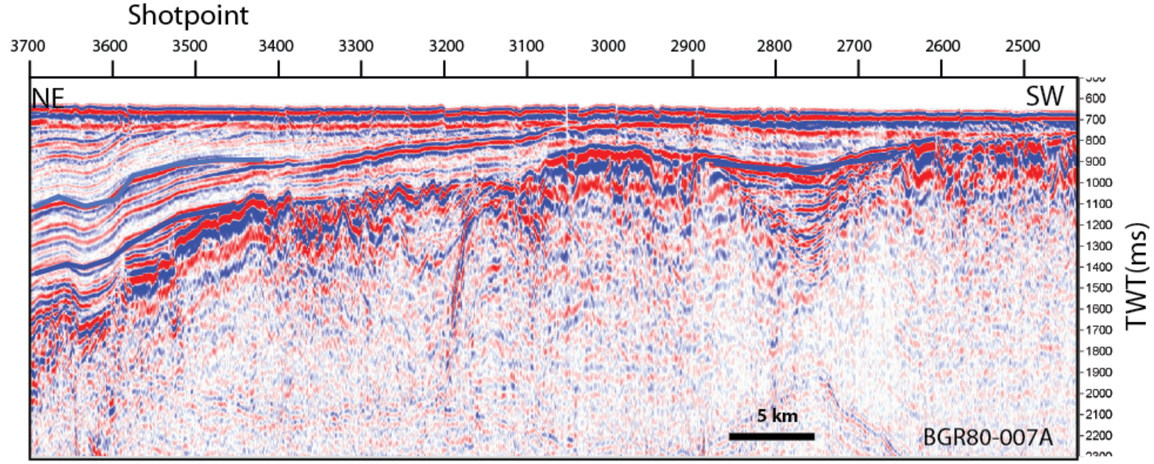
Data files in SSDB (to be upload by 1 May 2019)
BGR80-007A.segy, BGR80-007.nav
PD90-21.segy, PD90-21.nav
Velocity information.doc

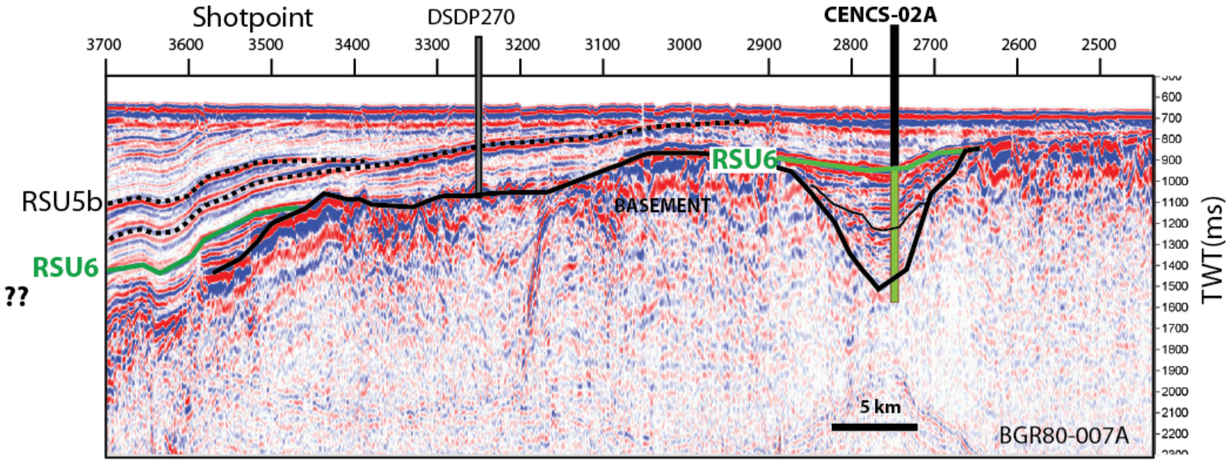
RSU6 (~28-34 Ma?)
This site targets RSU6 at a much shallow depth, and is an alternate to CENCS-01 if there are time restrictions due to drilling











n.b. green core intervals = sections not preserved at DSDP 270

IODP Site Forms

Form 1 – General Site Information

964 - Full

Section A: Proposal Information

Proposal Title	Tracing Antarctic Cryosphere Origins to Climate And Tectonics
Date Form Submitted	2019-04-02 21:51:48
Site-Specific Objectives with Priority (Must include general objectives in proposal)	1) Obtain direct geological evidence of the earliest history of ice sheets in East Antarctica, by sampling strata aboveRSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to late Oligocene (25 Ma) record of marine environments, with influence of combined EAIS/WAIS or local ice cap advance in central Ross Sea. 2) Reconstruction "pre-icehouse" climates in Central Ross Sea during the Late Cretaceous to Eocene, by sampling material below RSU6 (thought to be ~34-28Ma). 3) Constrain timing of late rift phases in the Central Ross Sea. This will be achieved by dating RSU6 and coring syn-rift strata.
List Previous Drilling in Area	DSDP Site 270

Section B: General Site Information

Site Name:	CENCS-03A
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#	
Latitude:	Deg: -77.2200
Longitude:	Deg: -178.6336
Coordinate System:	WGS 84
Priority of Site:	Primary: ☐ Alternate: ☑
Area or Location:	Central Ross Sea continental shelf
Jurisdiction:	Antarctica
Distance to Land: (km)	288
Water Depth (m):	645

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1050	0
	Total Sediment Thickness (m): 1050	
		Total Penetration (m): 1050
General Lithologies:	Diamictite, mudstone, cemented sandstones	unknown (schist, granite, marble, sandstone)

Coring Plan: (Specify or check)

RCB throughout, as strata are lithified near seafloor. Recovery and drill rate anticipate to improve below 100 mbsf as drill bit stabilizes.

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		Other tools:
WL	☑	Magnetic Susceptibility	☐	
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☑			

Other Measurements:

Estimated Days: Drilling/Coring: 7 | Logging: 1.5 | Total On-site: 8.5

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑
CO_2	☐				

Sensitive marine habitat (e.g., reefs, vents):

Preferred weather window: January to Feburary is best ice free window

Other: Full hydrocarbon assessment have previously been conducted in these basins for ANDRILL Coulman High and IODP Exp 374

Generated: 2019-05-03T19:01:55+00:00

Proposal #: 964 - Full	Site #: CENCS-03A	Date Form Submitted: 2019-04-02 21:51:48

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: IT89A-34 Position: SP907
2b Deep penetration seismic reflection (crossing)	yes	Line: BGR80-002 Position: SP6550 nearest crossing line
3 Seismic Velocity	yes	Its own velocity model from stack velocities
4 Seismic Grid	yes	The Antarctic Seismic Data Library System includes many kilometers of multichannel seismic profiles publically available online. We have set up a Kingdom project including also several regional single channel surveys (Polar Duke (PD) 1990, Nathaniel B. Palmer (NBP) 1994, 1995, 2003, 2008). The Kingdom project was already uploaded into the IODP SDSB for prop. 751 in 2016.
5a Refraction (surface)	no	Refraction data exist for the region (Cochrane, G.R.,1995; Antarctic Research Series 68 AGU, Washington, DC, pp. 261–270)
5b Refraction (bottom)	no	N/A
6 3.5 kHz	no	
7 Swath bathymetry	no	Regional swath data is available
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	The list of heat flow stations in the Ross Sea. Can be found from the International Heat Flow Commission http://www.geophysik.rwth-aachen.de/IHFC/heatflow.html Heat flow measurements in the Ross Sea have been carried out since 1970s but are not enough to describe the regional heat flow distribution due to sparse data and restricted location compared to complicated tectonic history. All data were obtained by using a heat probe at shallow subsurface except for the IODP Exp 374 and the ones from McMurdo Sound drill sites such as CRP and DVDP sites
11a Magnetics	no	Magnetic data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on
11b Gravity	no	Gravity data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on A Free Air gravity Ross Sea map is in the ANTOSTRAT Ross Sea Atlas map AGU vol. 68 (Brancolini et al., 1995)
12 Sediment cores		100s of piston and gravity cores have been collected from the Ross Sea continental shelf and are archived at the AMGRF in Florida.
13 Rock sampling		N/A
14a Water current data		N/A
14b Ice Conditions		open water conditions in polynya region from December to February
15 OBS microseismicity		N/A
16 Navigation	yes	
17 Other		

Proposal #: 964 - Full	Site #: CENCS-03A	Date Form Submitted: 2019-04-02 21:51:48

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single RCB hole, with logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	No shows on IODP Exp 374. Biogenic gas observed at some sites on DSDP Leg 28
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	none
4. Indications of gas hydrates at this location	no
5. Are there reasons to expect hydrocarbon accumulations at this site?	No
6. What "special" precautions will be taken during drilling?	Sea ice and iceberg present minor risk. Ice observers needed and free fall funnells can be used in case on encroaching ice.
7. What abandonment procedures need to be followed?	standard iceberg encroachment procedures
8. Natural or manmade hazards which may affect ship's operations	ice - see special precautions
9. Summary: What do you consider the major risks in drilling at this site?	ice - see special precautions. A full risk assessment as done for Exp 374 will be conducted. Ice conditions will be similiar to Exp 374 which experienced very few issues with this.

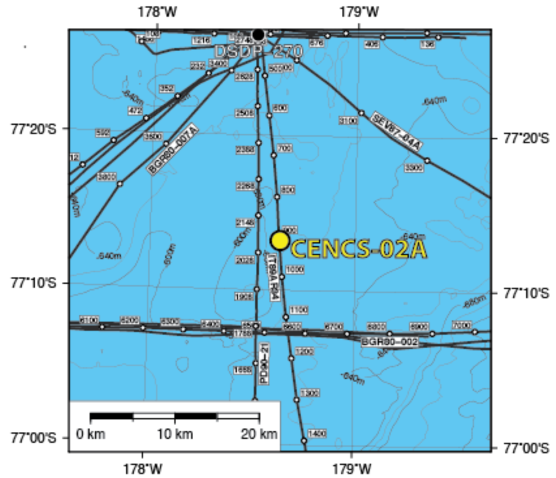
Proposal #: 964 - Full	Site #: CENCS-03A	Date Form Submitted: 2019-04-02 21:51:48

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 206	Strata between seafloor and RSU5A	20-23	1.7	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
206 - 555	Strata between RSU5A and RSU6	23-34(?)	2.15	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
555 - 705	Strata between RSU6 and RSU7	34 (?)-40?	2.4	Indurated Sandstone, mudstone	open marine/ marginal marine		
705 - 1050	Strata between RSU7 and basement	>50Ma (?)	2.7	Indurated Sandstone, mudstone	open marine, marginal marine, (terrestrial?)		

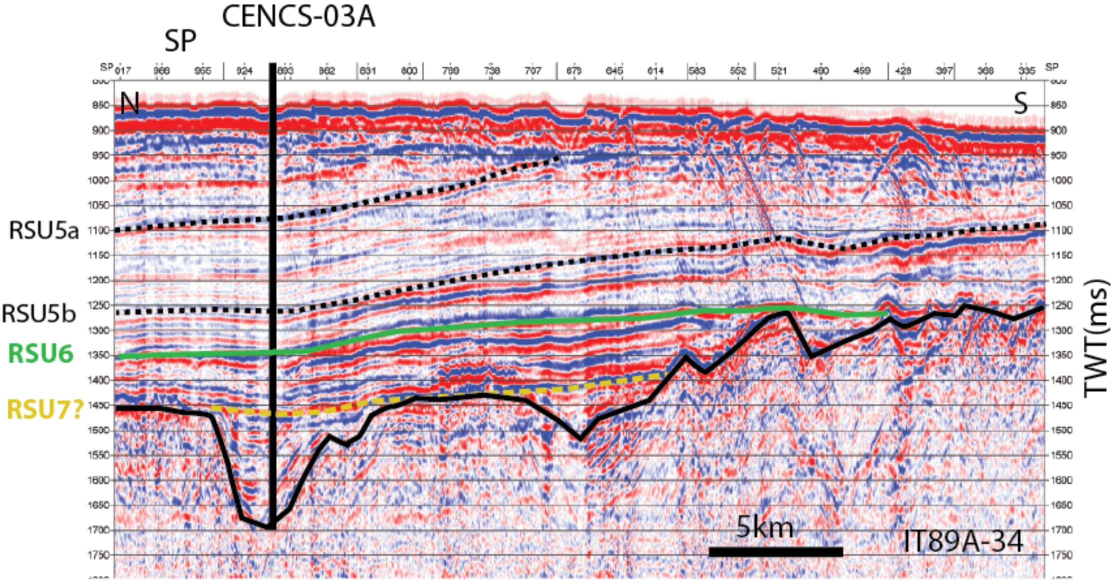
Site CENCS-03A

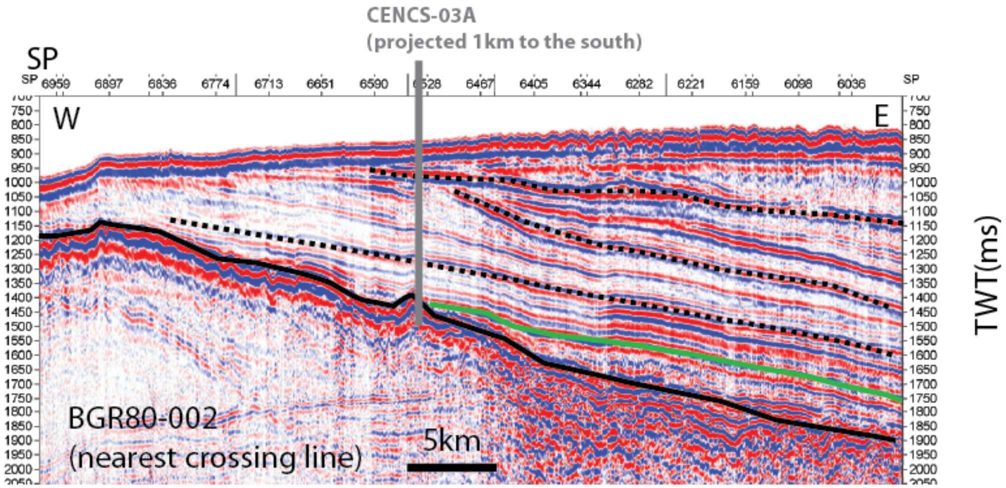
shotpoint 907 on IT89A-34
shotpoint 6550 on BGR80-002 (nearest - 10 km to north)
Lat:-77.2200
Long: -178.6336
Water depth:645m

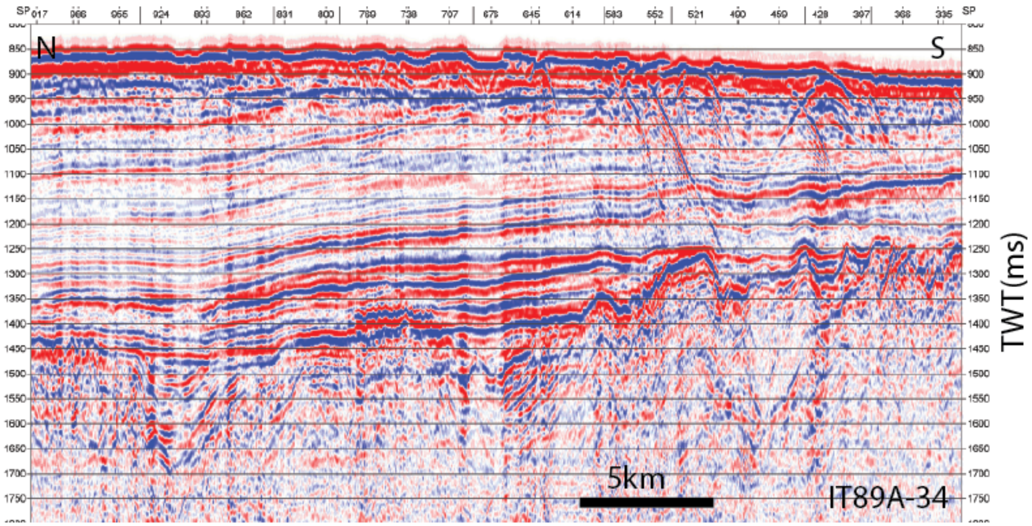
Data files in SSDB (to be upload by 1 May 2019)
IT89A-34.segy, IT89A-34.nav
BGR80-002.segy, BGR80-0026.nav
Velocity information.doc

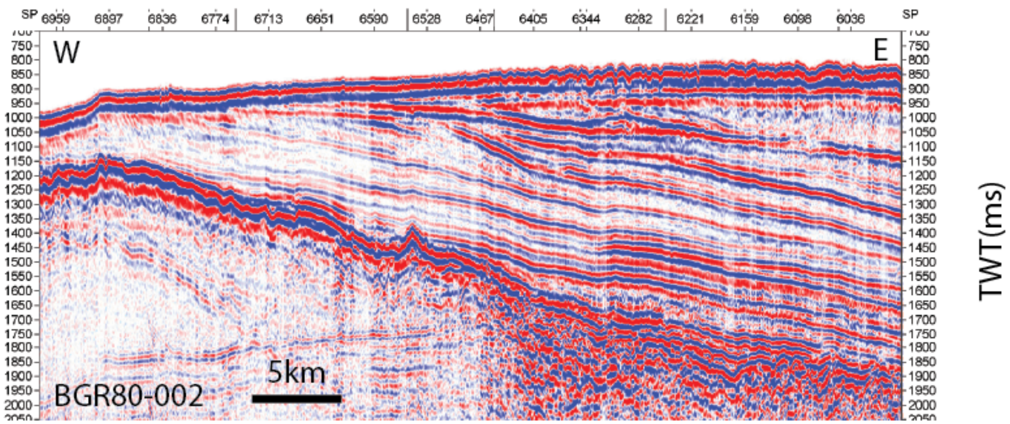


RSU6 (~28-34 Ma?)
RSU7 (age unknown- n.b. alternate interpretation is glacial trough predating RSU6?)









IODP Site Forms

Form 1 – General Site Information

964 - Full

Section A: Proposal Information

Proposal Title	Tracing Antarctic Cryosphere Origins to Climate And Tectonics
Date Form Submitted	2019-04-02 21:51:48
Site-Specific Objectives with Priority (Must include general objectives in proposal)	1) Obtain direct geological evidence of the earliest history of ice sheets in West Antarctica, by sampling strata above RSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to Early Miocene (20 Ma) record of WAIS advance in Marie Byrd Land 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?) 3) Constrain timing of late rift phases in the Eastern Ross Sea. This will be achieved by dating syn-rift strata below RSU7.
List Previous Drilling in Area	

Section B: General Site Information

Site Name:	ERSCS-01A	Area or Location:	Eastern Ross Sea continental shelf
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: -77.61010423	Jurisdiction:	Antarctica
Longitude:	Deg: -160.84500232	Distance to Land: (km)	70
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	620

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1050	0
	Total Sediment Thickness (m): 1050	
		Total Penetration (m): 1050
General Lithologies:	diamictite, mudstone and cemented sandstone	unknown (schist, granite, marble, sandstone)

Coring Plan:
(Specify or check)

RCB throughout, as strata are lithified near seafloor. Recovery and drill rate anticipate to improve below 100 mbsf as drill bit stabilizes.

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		Other tools:
WL	☑	Magnetic Susceptibility	☐	
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☑			

Other Measurements:

Estimated Days: Drilling/Coring: 7 | Logging: 1.5 | Total On-site: 8.5

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑
CO_2	☐				

Sensitive marine habitat (e.g., reefs, vents)

Preferred weather window: January to Feburary is best ice free window

Other: Full hydrocarbon assessment have previously been conducted in these basins for ANDRILL Coulman High and IODP Exp 374

Proposal #: 964 - Full	Site #: ERSCS-01A	Date Form Submitted: 2019-04-02 21:51:48

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: NBP0301-25A Position: SP890
2b Deep penetration seismic reflection (crossing)	yes	Line: NBP9601L011A Position: SP176
3 Seismic Velocity	yes	Its own velocity model from stack velocities
4 Seismic Grid	yes	The Antarctic Seismic Data Library System includes many kilometers of multichannel seismic profiles publically available online. We have set up a Kingdom project including also several regional single channel surveys (Polar Duke (PD) 1990, Nathaniel B. Palmer (NBP) 1994, 1995, 2003, 2008). The Kingdom project was already uploaded into the IODP SDSB for prop. 751 in 2016.
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry		Regional swath data is available
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	The list of heat flow stations in the Ross Sea. Can be found from the International Heat Flow Commission http://www.geophysik.rwth-aachen.de/IHFC/heatflow.html Heat flow measurements in the Ross Sea have been carried out since 1970s but are not enough to describe the regional heat flow distribution due to sparse data and restricted location compared to complicated tectonic history. All data were obtained by using a heat probe at shallow subsurface except for the IODP Exp 374 and the ones from McMurdo Sound drill sites such as CRP and DVDP sites
11a Magnetics	no	Magnetic data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on
11b Gravity	no	Gravity data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on A Free Air gravity Ross Sea map is in the ANTOSTRAT Ross Sea Atlas map AGU vol. 68 (Brancolini et al., 1995)
12 Sediment cores		100s of piston and gravity cores have been collected from the Ross Sea continental shelf and are archived at the AMGRF in Florida.
13 Rock sampling	no	N/A
14a Water current data	no	
14b Ice Conditions		open water conditions in polynya region from December to February
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other	no	

Proposal #: 964 - Full	Site #: ERSCS-01A	Date Form Submitted: 2019-04-02 21:51:48

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single RCB hole, with logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	No shows on IODP Exp 374. Biogenic gas observed at some sites on DSDP Leg 28
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	none
4. Indications of gas hydrates at this location	no
5. Are there reasons to expect hydrocarbon accumulations at this site?	No
6. What "special" precautions will be taken during drilling?	Sea ice and iceberg present risk. Ice observers needed and free fall funnells can be used in case on encroaching ice.
7. What abandonment procedures need to be followed?	standard iceberg encroachment procedures
8. Natural or manmade hazards which may affect ship's operations	ice - see special precautions
9. Summary: What do you consider the major risks in drilling at this site?	ice - see special precautions. A full risk assessment as done for Exp 374 will be conducted. Ice conditions will be similiar to Exp 374 which experienced very few issues with this.

Proposal #: 964 - Full	Site #: ERSCS-01A	Date Form Submitted: 2019-04-02 21:51:48

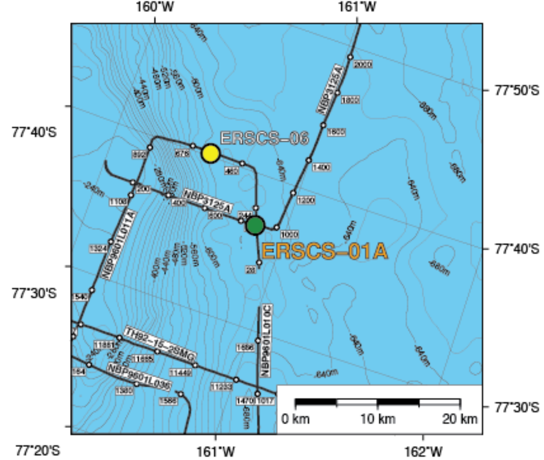
Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 190	Top of progradation	<14 Ma?	1.7	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
195 - 485	Strata between top progradation and RSU6	25(?)-28 (34?)	2.0	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
485 - 660	Strata between RSU6 and RSU7	>28 (34?) - 60 (?)	2.7	Indurated Sandstone, mudstone	open marine, marginal marine		
660 - 1055	Strata between RSU7 and basement	>60Ma (?)	2.8	Indurated Sandstone, mudstone	open marine, marginal marine, (terrestrial?)		

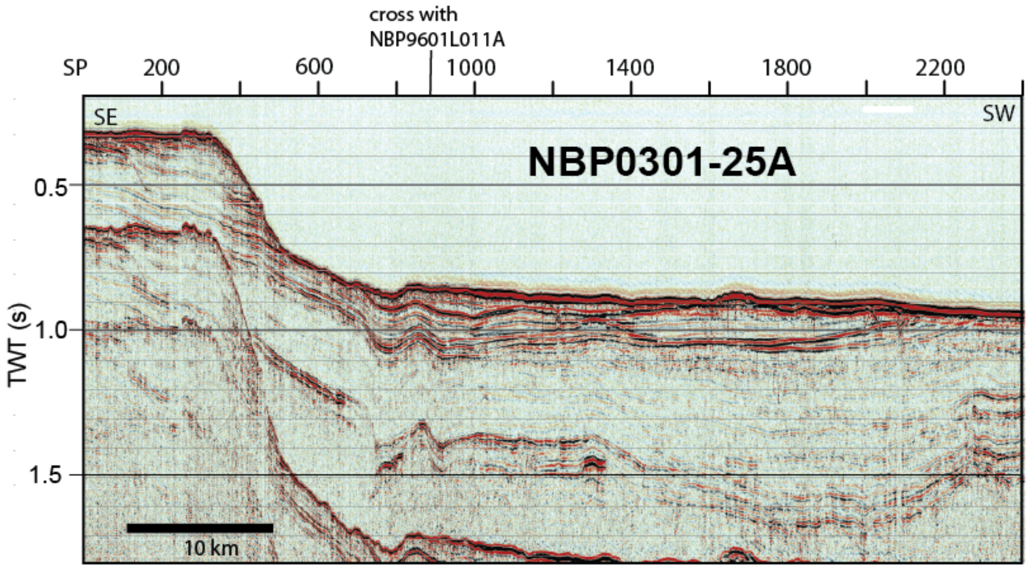
Site ERSCS-01A

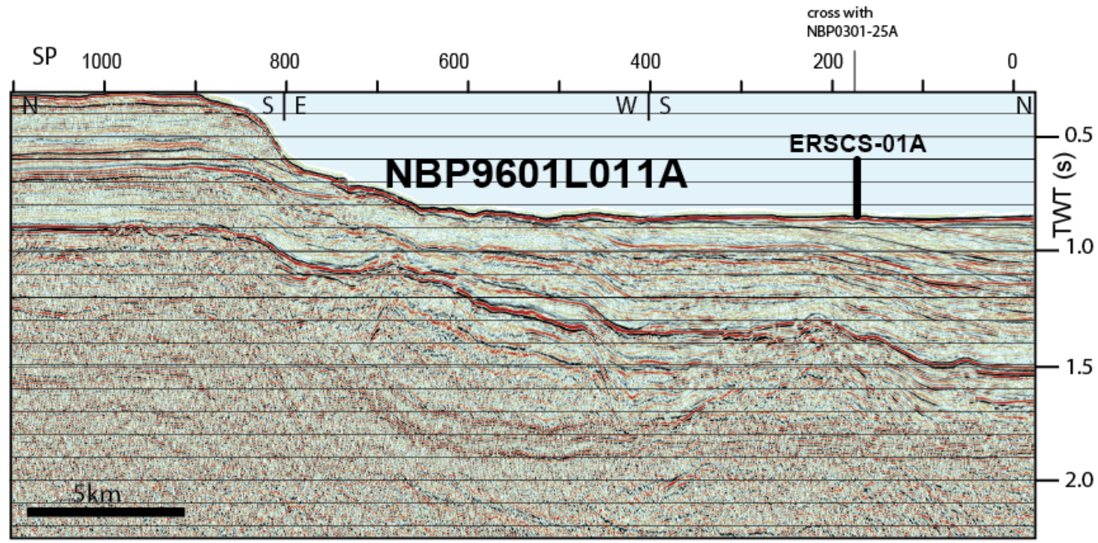
shotpoint 176 on NBP9601L011A
shotpoint 890 on NBP0301-25A
Lat:-77.6101
Long: -160.8450
Water depth:620

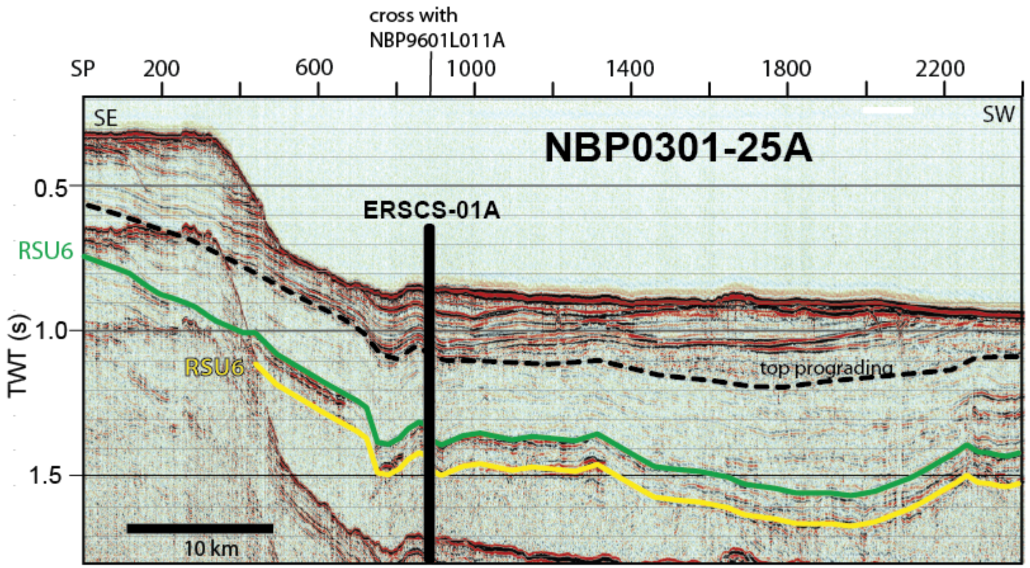
Data files in SSDB (to be upload by 1 May 2019)
NBP0301-25A.segy, NBP0301-25A.nav
NBP9601L011A .segy, NBP9601L011A .nav
Velocity information.doc

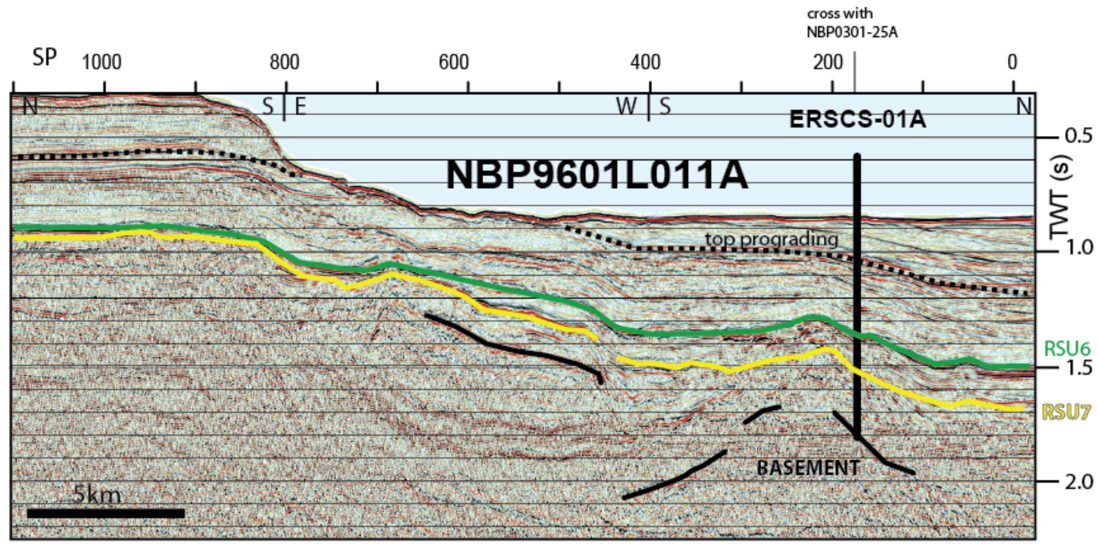
RSU6 (~28-34 Ma?)
RSU7 (age unknown)











IODP Site Forms

Form 1 – General Site Information

964 - Full

Section A: Proposal Information

Proposal Title	Tracing Antarctic Cryosphere Origins to Climate And Tectonics
Date Form Submitted	2019-04-02 21:51:48
Site-Specific Objectives with Priority (Must include general objectives in proposal)	1) Obtain direct geological evidence of the earliest history of ice sheets in West Antarctica, by sampling strata above RSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to Early Miocene (20 Ma) record of WAIS advance in Marie Byrd Land 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?) 3) Constrain timing of late rift phases in the Eastern Ross Sea. This will be achieved by dating syn-rift strata below RSU7.
List Previous Drilling in Area	

Section B: General Site Information

Site Name:	ERSCS-02A	Area or Location:	Eastern Ross Sea continental shelf
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: -77.9402	Jurisdiction:	Antarctica
Longitude:	Deg: -160.4316	Distance to Land: (km)	65
Coordinate System:	WGS 84		
Priority of Site:	Primary: ✓ Alternate: ☐	Water Depth (m):	660

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	775	25
	Total Sediment Thickness (m) 775	
		Total Penetration (m): 800
General Lithologies:	Sediment lithologies: diamictite, mudstone and cemented sandstone	unknown (schist, granite, marble, sandstone)

Coring Plan: (Specify or check)

RCB throughout, as strata are lithified near seafloor. Recovery and drill rate anticipate to improve below 100 mbsf as drill bit stabilizes

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☐	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☑			

Other Measurements:

Estimated Days:

Drilling/Coring:	Logging:	Total On-site:
4.5	1.2	5.7

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents)

Other:

Proposal #: 964 - Full	Site #: ERSCS-02A	Date Form Submitted: 2019-04-02 21:51:48

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: NBP0301-22A23A-MCS Position: SP500
1b High resolution seismic seismic reflection (crossing)		
2a Deep penetration seismic reflection (primary)	yes	Line: NBP0301-23A-SCS Position: SP167
2b Deep penetration seismic reflection (crossing)	yes	Line: NBP0301-27A-SCS Position: SP100
3 Seismic Velocity	yes	Its own velocity model from stack velocities
4 Seismic Grid	yes	ANTOSTRAT data base (Brancolini, et al. 1995) includes many kilometers of multichannel seismic plus several regional single channel surveys (Polar Duke (PD) 1990, Nathaniel B. Palmer (NBP) 1994, 1995, 2003, 2008). The Kingdom project was already uploaded into the IODP SDSB for prop. 751 in 2016.
5a Refraction (surface)		Refraction data exist for the region (Cochrane, G.R.,1995; Antarctic Research Series 68 AGU, Washington, DC, pp. 261–270)
5b Refraction (bottom)		N/A
6 3.5 kHz	no	
7 Swath bathymetry		Regional swath data is available
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	The list of heat flow stations in the Ross Sea. Can be found from the International Heat Flow Commission http://www.geophysik.rwth-aachen.de/IHFC/heatflow.html Heat flow measurements in the Ross Sea have been carried out since 1970s but are not enough to describe the regional heat flow distribution due to sparse data and restricted location compared to complicated tectonic history. All data were obtained by using a heat probe at shallow subsurface except for the IODP Exp 374 and the ones from McMurdo Sound drill sites such as CRP and DVDP sites.
11a Magnetics	no	Magnetic data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on
11b Gravity	no	Gravity data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on A Free Air gravity Ross Sea map is in the ANTOSTRAT Ross Sea Atlas map AGU vol. 68 (Brancolini et al., 1995)
12 Sediment cores		100s of piston and gravity cores have been collected from the Ross Sea continental shelf and are archived at the AMGRF in Florida.
13 Rock sampling		
14a Water current data	no	
14b Ice Conditions		open water conditions in polynya region from December to February
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other	no	

Proposal #: 964 - Full	Site #: ERSCS-02A	Date Form Submitted: 2019-04-02 21:51:48

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single RCB hole, with logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	No shows on IODP Exp 374. Biogenic gas observed at some sites on DSDP Leg 28
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	none
4. Indications of gas hydrates at this location	no
5. Are there reasons to expect hydrocarbon accumulations at this site?	No
6. What "special" precautions will be taken during drilling?	Sea ice and iceberg present risk. Ice observers needed and free fall funnells can be used in case on encroaching ice.
7. What abandonment procedures need to be followed?	
8. Natural or manmade hazards which may affect ship's operations	ice - see special precautions
9. Summary: What do you consider the major risks in drilling at this site?	ice - see special precautions. A full risk assessment as done for Exp 374 will be conducted. Ice conditions will be similiar to Exp 374 which experienced very few issues with this.

Proposal #: 964 - Full	Site #: ERSCS-02A	Date Form Submitted: 2019-04-02 21:51:48

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 80	Strata betwen seafloor and top of progradation	<14 Ma?	1.45	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
80 - 427	Strata between top progradation and RSU6	23-34(?)	1.6	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
427 - 548	Strata between RSU6 and RSU7	34 (?)-50?	2.0	Indurated Sandstone, mudstone	open marine, marginal marine, (terrestrial?)		
542 - 775	[BASEMENT/TOP SYN RIFT DEPTH??]Strata below RSU7	>60Ma (?)	2.5	Indurated Sandstone, mudstone	open marine, marginal marine, (terrestrial?)		
775 - 800	basement		3.0	unknown (gneiss, sandstone, granite, marble?)			

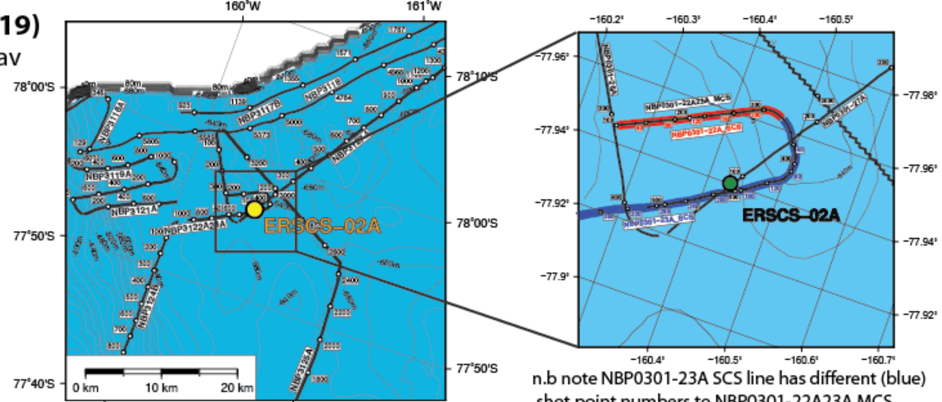
Site ERSCS-02A

NBP0301-22A23A-MCS (SP500)
NBP0301-23A-SCS (SP167)
NBP0301-27A-SCS (SP100 - nearest crossing -200 m)
Lat:-77.9402
Long: -160.4316
Water depth:660m

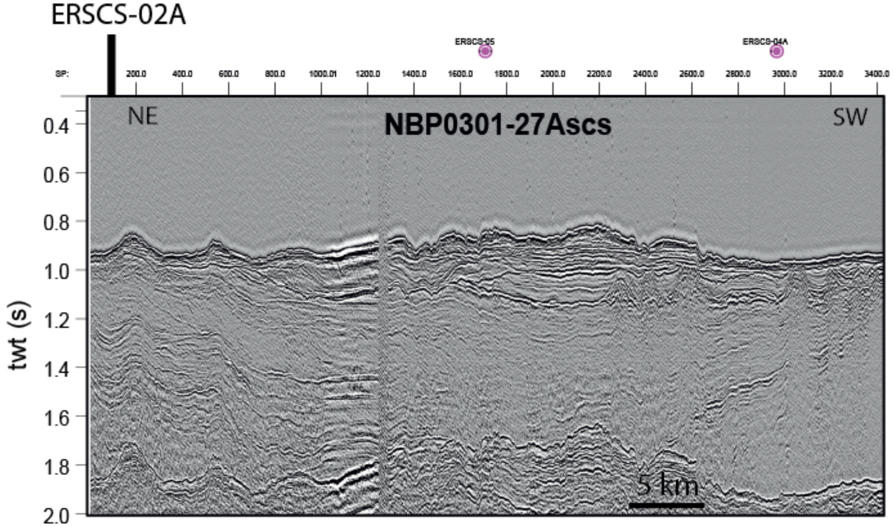
Data files in SSDB (to be upload by 1 May 2019)

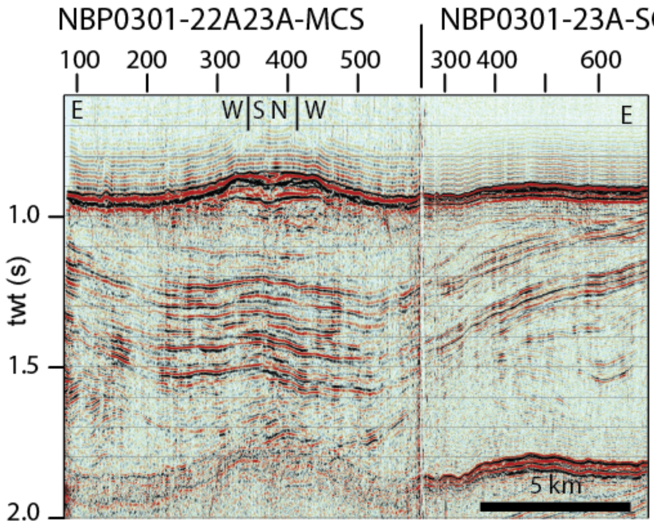
NBP0301-22A23A-MCS.segy, NBP0301-22A23A-MCS.nav
NBP0301-23A-SCS .segy, NBP0301-23A-SCS .nav
NBP0301-27A-SCS .segy, NBP0301-27A-SCS .nav
Velocity information.doc

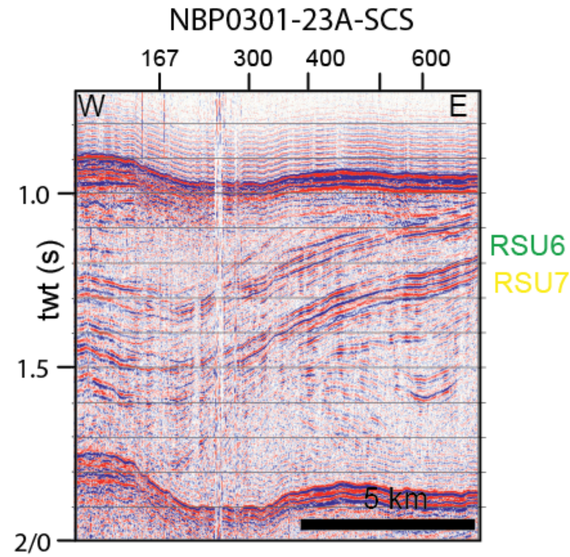
RSU6 (~27-34 Ma?)
RSU7 (age unknown)

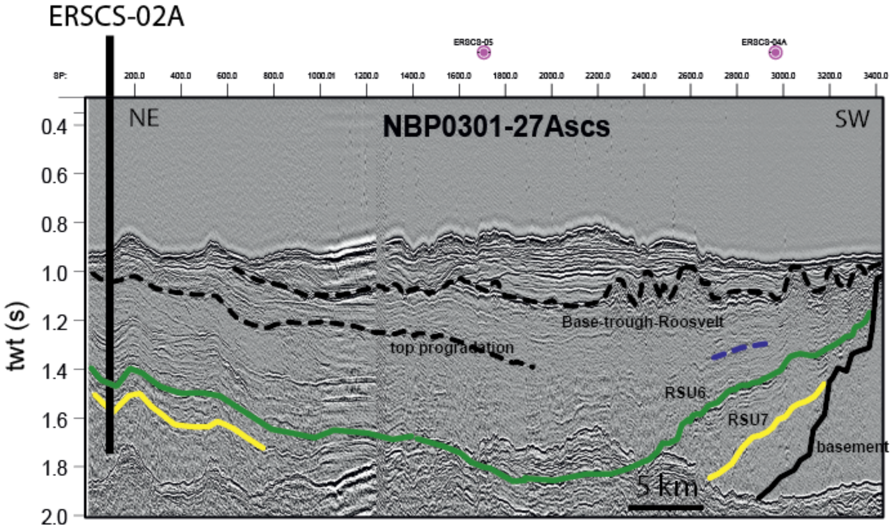


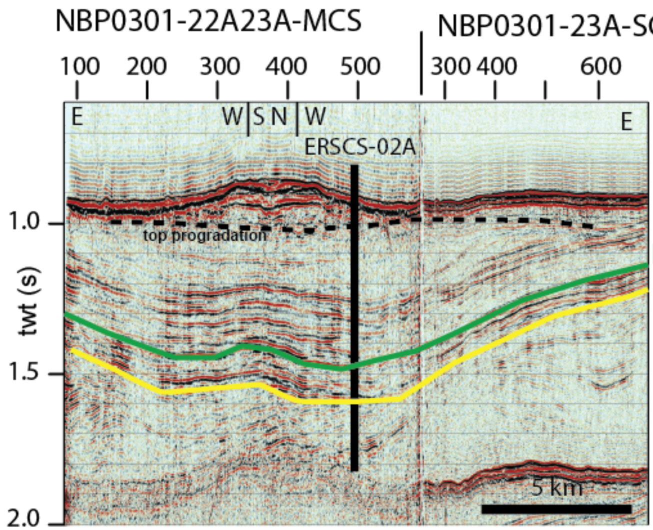
n.b note NBP0301-23A SCS line has different (blue) shot point numbers to NBP0301-22A23A MCS

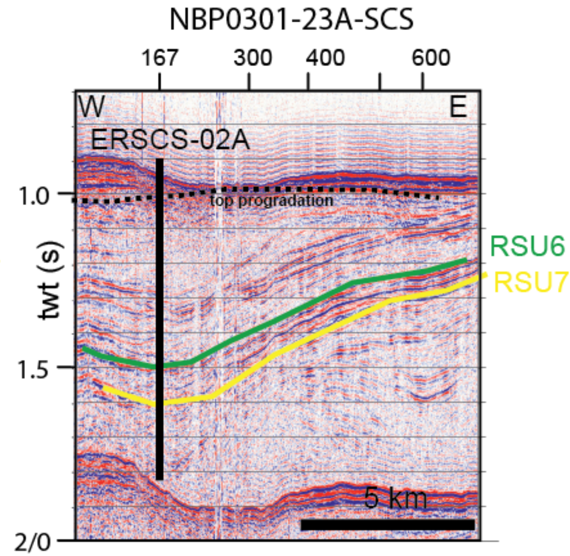












IODP Site Forms

Form 1 – General Site Information

964 - Full

Section A: Proposal Information

Proposal Title	Tracing Antarctic Cryosphere Origins to Climate And Tectonics
Date Form Submitted	2019-04-02 21:51:48
Site-Specific Objectives with Priority (Must include general objectives in proposal)	1) Obtain direct geological evidence of the earliest history of ice sheets in West Antarctica, by sampling strata above RSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to Early Miocene (20 Ma) record of WAIS advance in Marie Byrd Land 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?) 3) Constrain timing of late rift phases in the Eastern Ross Sea. This will be achieved by dating syn-rift strata below RSU7.
List Previous Drilling in Area	

Section B: General Site Information

Site Name:	ERSCS-03A	Area or Location:	Eastern Ross Sea continental shelf
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: -78.3925	Jurisdiction:	Antarctica
Longitude:	Deg: -164.7040	Distance to Land: (km)	84
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	541

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1200	0
	Total Sediment Thickness (m) 1550	
		Total Penetration (m): 1200
General Lithologies:	diamictite, mudstone and cemented sandstone	unknown (schist, granite, marble, sandstone)

Coring Plan:
(Specify or check)

RCB throughout, as strata are lithified near seafloor. Recovery and drill rate anticipate to improve below 100 mbsf as drill bit stabilizes.

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☐	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☑			

Other Measurements:

Estimated Days: Drilling/Coring: 9 | Logging: 1.6 | Total On-site: 10.6

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Preferred weather window: January to Feburary is best ice free window
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					
Sensitive marine habitat (e.g., reefs, vents)						

Other: Full hydrocarbon assessment have previously been conducted in these basins for ANDRILL Coulman High and IODP Exp 374

Proposal #: 964 - Full	Site #: ERSCS-03A	Date Form Submitted: 2019-04-02 21:51:48

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	yes	Line: PD90-22 Position: SP8600
2a Deep penetration seismic reflection (primary)	yes	Line: NBP0301-30A Position: SP2700
2b Deep penetration seismic reflection (crossing)	no	
3 Seismic Velocity	yes	Its own velocity model from stack velocities
4 Seismic Grid	no	The Antarctic Seismic Data Library System includes many kilometers of multichannel seismic profiles publically available online. We have set up a Kingdom project including also several regional single channel surveys (Polar Duke (PD) 1990, Nathaniel B. Palmer (NBP) 1994, 1995, 2003, 2008). The Kingdom project was already uploaded into the IODP SDSB for prop. 751 in 2016.
5a Refraction (surface)	yes	AGU, Washington, DC, pp. 261–270)
5b Refraction (bottom)	no	N/A
6 3.5 kHz	no	
7 Swath bathymetry	yes	Regional swath data is available
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	The list of heat flow stations in the Ross Sea. Can be found from the International Heat Flow Commission http://www.geophysik.rwth-aachen.de/IHFC/heatflow.html Heat flow measurements in the Ross Sea have been carried out since 1970s but are not enough to describe the regional heat flow distribution due to sparse data and restricted location compared to complicated tectonic history. All data were obtained by using a heat probe at shallow subsurface except for the IODP Exp 374 and the ones from McMurdo Sound drill sites such as CRP and DVDP sites.
11a Magnetics	no	Magnetic data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on
11b Gravity	no	Gravity data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on A Free Air gravity Ross Sea map is in the ANTOSTRAT Ross Sea Atlas map AGU vol. 68 (Brancolini et al., 1995)
12 Sediment cores	no	100s of piston and gravity cores have been collected from the Ross Sea continental shelf and are archived at the AMGRF in Florida (USA) and in the Italian repository (Trieste, Italy).
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions		open water conditions in polynya region from December to February
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other		

Proposal #: 964 - Full	Site #: ERSCS-03A	Date Form Submitted: 2019-04-02 21:51:48

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single RCB hole, with logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	No shows on IODP Exp 374. Biogenic gas observed at some sites on DSDP Leg 28
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	none
4. Indications of gas hydrates at this location	no
5. Are there reasons to expect hydrocarbon accumulations at this site?	No
6. What "special" precautions will be taken during drilling?	Sea ice and iceberg present risk. Ice observers needed and free fall funnells can be used in case on encroaching ice.
7. What abandonment procedures need to be followed?	
8. Natural or manmade hazards which may affect ship's operations	ice - see special precautions
9. Summary: What do you consider the major risks in drilling at this site?	ice - see special precautions. A full risk assessment as done for Exp 374 will be conducted. Ice conditions will be similiar to Exp 374 which experienced very few issues with this.

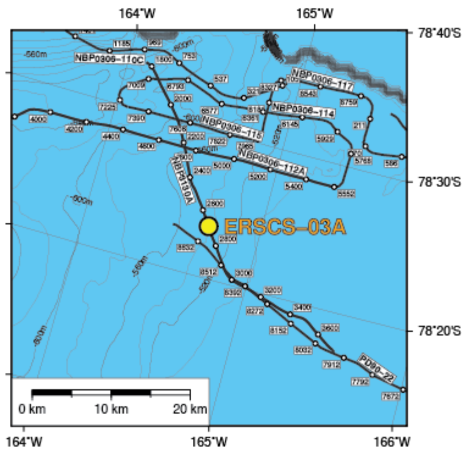
Proposal #: 964 - Full	Site #: ERSCS-03A	Date Form Submitted: 2019-04-02 21:51:48

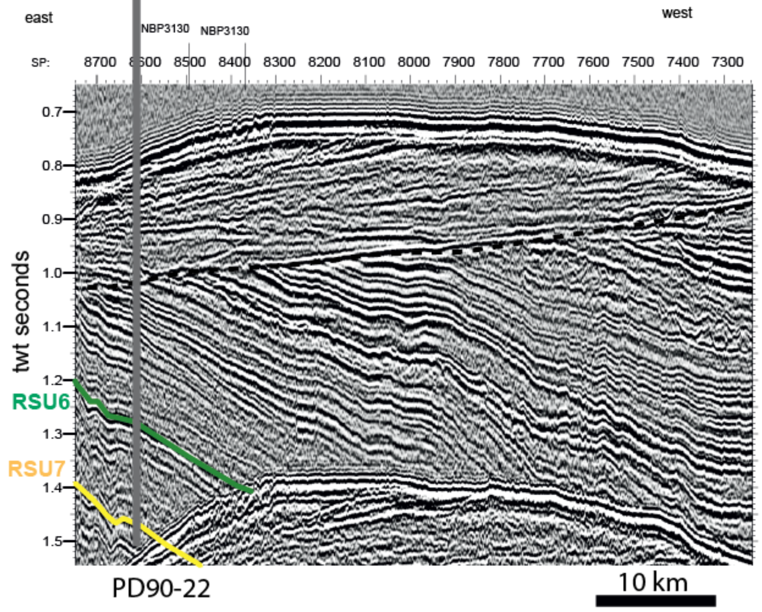
Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 279	Strata between seafloor and a major unconformity likely several erosional amalgamated surfaces of possible late Miocene age	0-10(?)	1.600	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
279 - 542	Strata below a major unconformity (of possible late Miocene age) and early Miocene-Oligocene strata	23-28(? 34)	2.1	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
542 - 754	Strata between RSU6 and RSU7	34 (?)-50?	2.5	Indurated Sandstone, mudstone	open marine, marginal marine, (terrestrial?)		
754 - 1200	Strata below RSU7	>60Ma (?)	2.5	Indurated Sandstone, mudstone	open marine, marginal marine, (terrestrial?)		

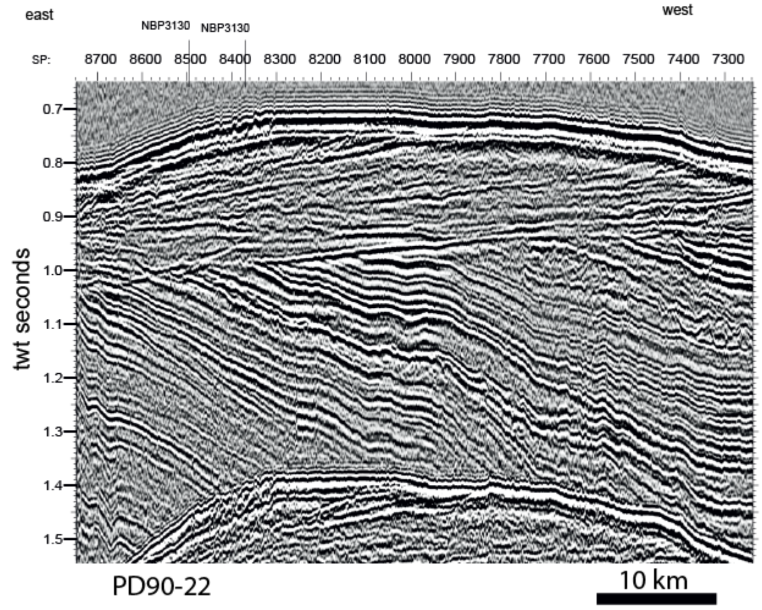
Site ERSCS-03A

NBP0301-30A (SP2700)
PD90-22 (SP8600) nearest
Lat:-78.3925
Long: -164.7040
Water depth: 541 m

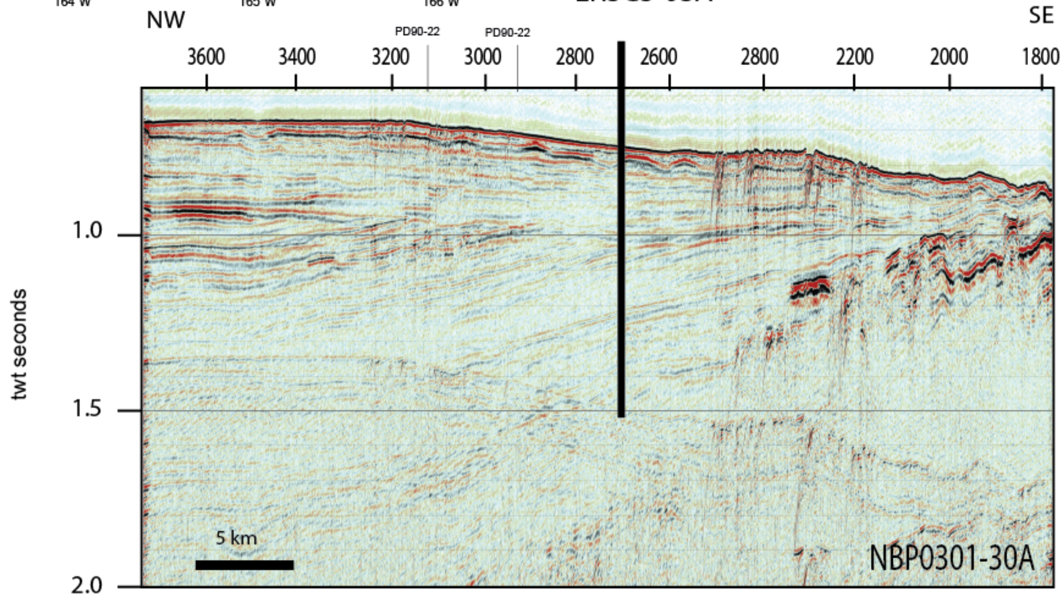
Data files in SSDB (upload by 1 May 2019)
NBP0301-30A.segy, NBP0301-30A.nav
PD90-22.segy, PD90-22 .nav
Velocity information.doc

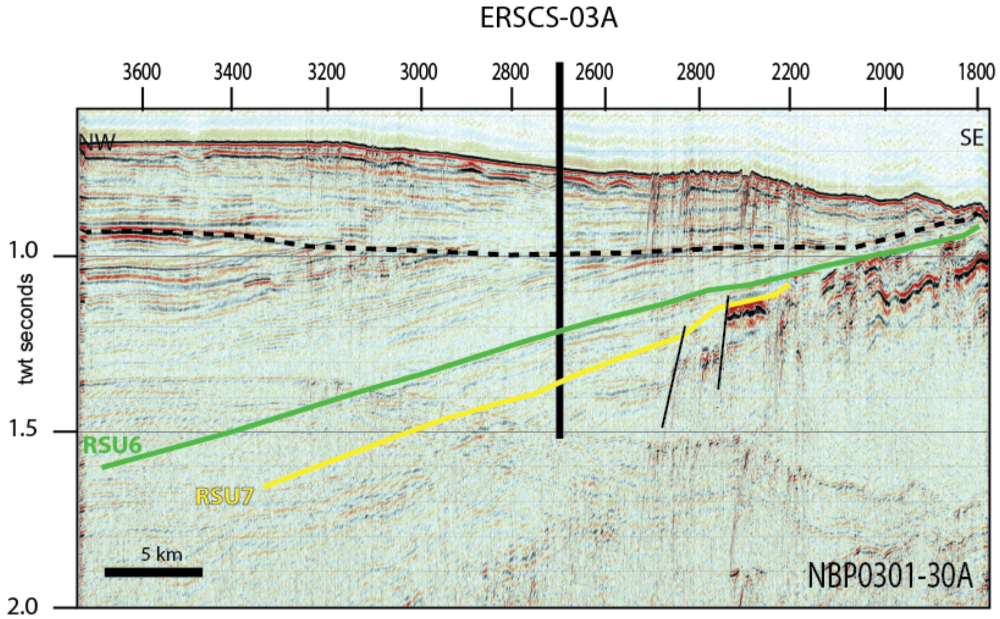






RSU6 (~28-34 Ma?)
RSU7 (age unknown)





IODP Site Forms

Form 1 – General Site Information

964 - Full

Section A: Proposal Information

Proposal Title	Tracing Antarctic Cryosphere Origins to Climate And Tectonics
Date Form Submitted	2019-04-02 21:51:48
Site-Specific Objectives with Priority (Must include general objectives in proposal)	1) Obtain direct geological evidence of the earliest history of ice sheets in West Antarctica, by sampling strata above RSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to Early Miocene (20 Ma) record of WAIS advance in Marie Byrd Land 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?) 3) Constrain timing of late rift phases in the Eastern Ross Sea. This will be achieved by dating syn-rift strata below RSU7.
List Previous Drilling in Area	

Section B: General Site Information

Site Name:	ERSCS-04A	Area or Location:	Eastern Ross Sea continental shelf
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: -78.3509	Jurisdiction:	Antarctica
Longitude:	Deg: -162.5913	Distance to Land: (km)	90
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	706

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1134	16
	Total Sediment Thickness (m) 1134	
		Total Penetration (m): 1150
General Lithologies:	diamictite, mudstone and cemented sandstone	unknown (schist, granite, marble, sandstone)

Coring Plan:
(Specify or check)

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☐	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☑			

Other Measurements:

Estimated Days:

Drilling/Coring:	Logging:	Total On-site:
8.1	2.1	10.2

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	January to Feburary is best ice free window
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					
Sensitive marine habitat (e.g., reefs, vents)						

Other: Full hydrocarbon assessment have previously been conducted in these basins for ANDRILL Coulman High and IODP Exp 374

Proposal #: 964 - Full	Site #: ERSCS-04A	Date Form Submitted: 2019-04-02 21:51:48

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: NBP0301-27A1B Position: SP8209
2b Deep penetration seismic reflection (crossing)	yes	Line: NBP0306-111A Position: SP2956
3 Seismic Velocity	yes	Its own velocity model from stack velocities
4 Seismic Grid	yes	The Antarctic Seismic Data Library System includes many kilometers of multichannel seismic profiles publically available online. We have set up a Kingdom project including also several regional single channel surveys (Polar Duke (PD) 1990, Nathaniel B. Palmer (NBP) 1994, 1995, 2003, 2008). The Kingdom project was already uploaded into the IODP SDSB for prop. 751 in 2016.
5a Refraction (surface)		Refraction data exist for the region (Cochrane, G.R.,1995; Antarctic Research Series 68 AGU, Washington, DC, pp. 261–270)
5b Refraction (bottom)	no	N/A
6 3.5 kHz	no	
7 Swath bathymetry		Regional swath data is available
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	The list of heat flow stations in the Ross Sea. Can be found from the International Heat Flow Commission http://www.geophysik.rwth-aachen.de/IHFC/heatflow.html Heat flow measurements in the Ross Sea have been carried out since 1970s but are not enough to describe the regional heat flow distribution due to sparse data and restricted location compared to complicated tectonic history. All data were obtained by using a heat probe at shallow subsurface except for the IODP Exp 374 and the ones from McMurdo Sound drill sites such as CRP and DVDP sites.
11a Magnetics	no	Magnetic data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on
11b Gravity	no	Gravity data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on A Free Air gravity Ross Sea map is in the ANTOSTRAT Ross Sea Atlas map AGU vol. 68 (Brancolini et al., 1995)
12 Sediment cores	no	100s of piston and gravity cores have been collected from the Ross Sea continental shelf and are archived at the AMGRF in Florida.
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions		open water conditions in polynya region from December to February
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other	no	

Proposal #: 964 - Full	Site #: ERSCS-04A	Date Form Submitted: 2019-04-02 21:51:48

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single RCB hole, with logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	No shows on IODP Exp 374. Biogenic gas observed at some sites on DSDP Leg 28
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	none
4. Indications of gas hydrates at this location	no
5. Are there reasons to expect hydrocarbon accumulations at this site?	No
6. What "special" precautions will be taken during drilling?	Sea ice and iceberg present risk. Ice observers needed and free fall funnells can be used in case on encroaching ice.
7. What abandonment procedures need to be followed?	
8. Natural or manmade hazards which may affect ship's operations	ice - see special precautions
9. Summary: What do you consider the major risks in drilling at this site?	ice - see special precautions. A full risk assessment as done for Exp 374 will be conducted. Ice conditions will be similiar to Exp 374 which experienced very few issues with this.

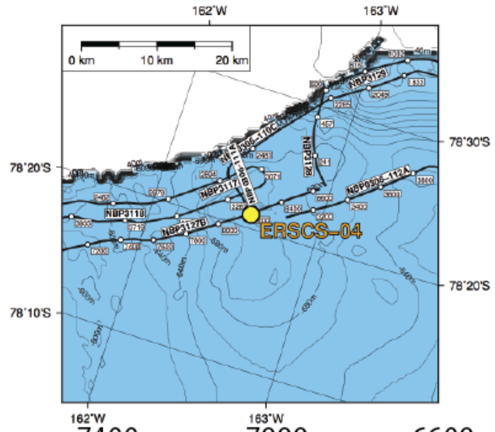
Proposal #: 964 - Full	Site #: ERSCS-04A	Date Form Submitted: 2019-04-02 21:51:48

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 114	Strata betwen seafloor and base of glacial trough	<14 Ma?	1.5	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
114 - 461	Strata between base of glacial trough and RSU6	23-34(?)	2.2	Diamictite, mudstone with clasts, diatomite	glacimarine/open marine		
461 - 751	Strata between RSU6 and RSU7	34 (?)-50?	2.2	Indurated Sandstone, mudstone	open marine, marginal marine, (terrestrial?)		
751 - 1134	Strata between RSU7 and basement	>60Ma (?)	3.2	Indurated Sandstone, mudstone	open marine, marginal marine, (terrestrial?)		
1134 - 1150	basement		3.0	unknown (gneiss, sandstone, granite, marble?)			

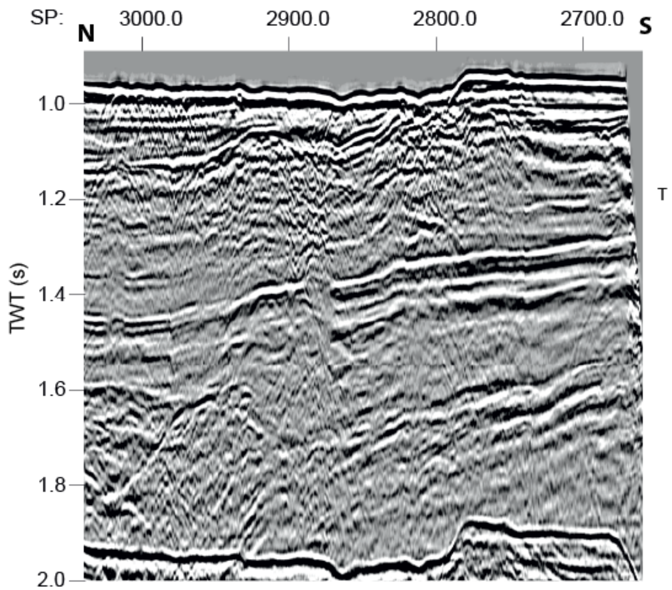
Data files in SSDB
(to be upload by 1 May 2019)
NBP0301-27A1B.segy, NBP0301-27A1B.nav
NBP0306-111A .segy, NBP0306-111A .nav
Velocity information.doc

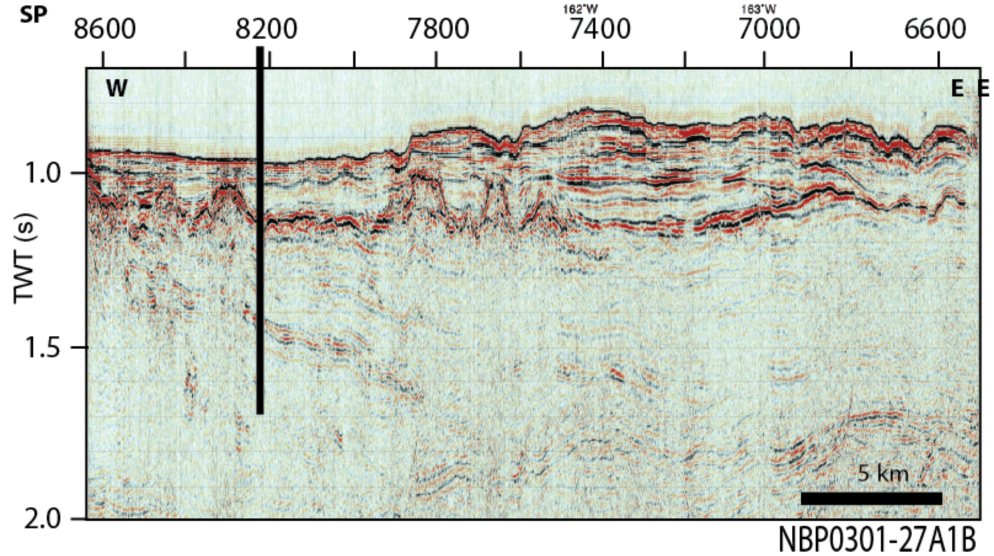
Site ERSCS-04A

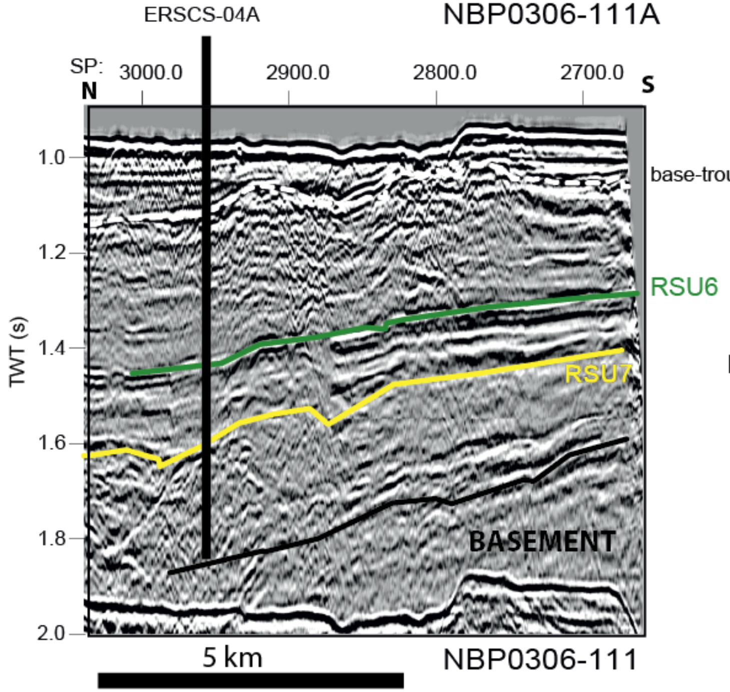
NBP0301-27A1B (SP 8209)
NBP0306-111A(SP2956)
Lat:-78.3509
Long: -162.5913
Water depth: 706 m

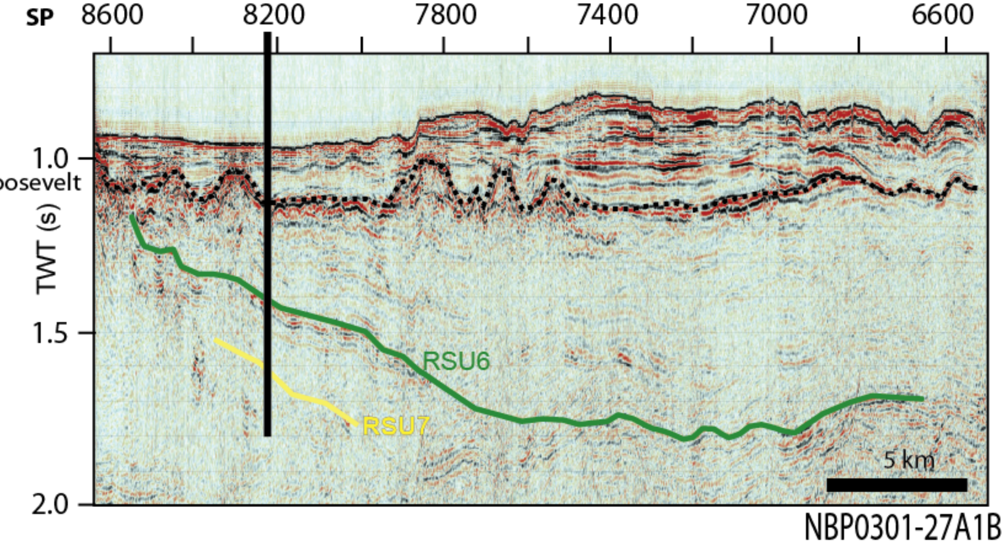


RSU6 (~28-34 Ma?)
RSU7 (age unknown)









IODP Site Forms

Form 1 – General Site Information

964 - Full

Section A: Proposal Information

Proposal Title	Tracing Antarctic Cryosphere Origins to Climate And Tectonics
Date Form Submitted	2019-04-02 21:51:48
Site-Specific Objectives with Priority (Must include general objectives in proposal)	1) Obtain direct geological evidence of the earliest history of ice sheets in West Antarctica, by sampling strata above RSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to Early Miocene (20 Ma) record of WAIS advance in Marie Byrd Land 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)
List Previous Drilling in Area	

Section B: General Site Information

Site Name:	ERSCS-05A	Area or Location:	Eastern Ross Sea continental shelf
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: -78.2274	Jurisdiction:	Antarctica
Longitude:	Deg: -161.5268	Distance to Land: (km)	57
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	615

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1200	0
	Total Sediment Thickness (m) 2500	
		Total Penetration (m): 1200
General Lithologies:	diamictite, mudstone and cemented sandstone	unknown (schist, granite, marble, sandstone)

Coring Plan:
(Specify or check)

RCB throughout, as strata are lithified near seafloor. Recovery and drill rate anticipate to improve below 100 mbsf as drill bit stabilizes.

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☐	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☑			

Other Measurements:

Estimated Days:

Drilling/Coring:	Logging:	Total On-site:
9	1.6	10.6

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	January to Feburary is best ice free window
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					
Sensitive marine habitat (e.g., reefs, vents)						

Other: Full hydrocarbon assessment have previously been conducted in these basins for ANDRILL Coulman High and IODP Exp 374

Proposal #: 964 - Full	Site #: ERSCS-05A	Date Form Submitted: 2019-04-02 21:51:48

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: NBP0301-27A1B Position: SP6950
2b Deep penetration seismic reflection (crossing)	yes	Line: NBP0301-27A-SCS Position: SP1708
3 Seismic Velocity	yes	Its own velocity model from stack velocities
4 Seismic Grid	yes	The Antarctic Seismic Data Library System includes many kilometers of multichannel seismic profiles publically available online. We have set up a Kingdom project including also several regional single channel surveys (Polar Duke (PD) 1990, Nathaniel B. Palmer (NBP) 1994, 1995, 2003, 2008). The Kingdom project was already uploaded into the IODP SDSB for prop. 751 in 2016.
5a Refraction (surface)	no	Refraction data exist for the region (Cochrane, G.R.,1995; Antarctic Research Series 68 AGU, Washington, DC, pp. 261–270)
5b Refraction (bottom)	no	N/A
6 3.5 kHz	no	N/A
7 Swath bathymetry	no	Regional swath data is available
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	The list of heat flow stations in the Ross Sea. Can be found from the International Heat Flow Commission http://www.geophysik.rwth-aachen.de/IHFC/heatflow.html Heat flow measurements in the Ross Sea have been carried out since 1970s but are not enough to describe the regional heat flow distribution due to sparse data and restricted location compared to complicated tectonic history. All data were obtained by using a heat probe at shallow subsurface except for the IODP Exp 374 and the ones from McMurdo Sound drill sites such as CRP and DVDP sites.
11a Magnetics	no	Magnetic data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on
11b Gravity	no	Gravity data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on A Free Air gravity Ross Sea map is in the ANTOSTRAT Ross Sea Atlas map AGU vol. 68 (Brancolini et al., 1995)
12 Sediment cores		100s of piston and gravity cores have been collected from the Ross Sea continental shelf and are archived at the AMGRF in Florida.
13 Rock sampling		N/A
14a Water current data	no	
14b Ice Conditions		open water conditions in polynya region from December to February
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other	no	

Proposal #: 964 - Full	Site #: ERSCS-05A	Date Form Submitted: 2019-04-02 21:51:48

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single RCB hole, with logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	No shows on IODP Exp 374. Biogenic gas observed at some sites on DSDP Leg 28
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	none
4. Indications of gas hydrates at this location	no
5. Are there reasons to expect hydrocarbon accumulations at this site?	No
6. What "special" precautions will be taken during drilling?	Sea ice and iceberg present risk. Ice observers needed and free fall funnells can be used in case on encroaching ice.
7. What abandonment procedures need to be followed?	
8. Natural or manmade hazards which may affect ship's operations	ice - see special precautions
9. Summary: What do you consider the major risks in drilling at this site?	ice - see special precautions. A full risk assessment as done for Exp 374 will be conducted. Ice conditions will be similiar to Exp 374 which experienced very few issues with this.

Proposal #: 964 - Full	Site #: ERSCS-05A	Date Form Submitted: 2019-04-02 21:51:48

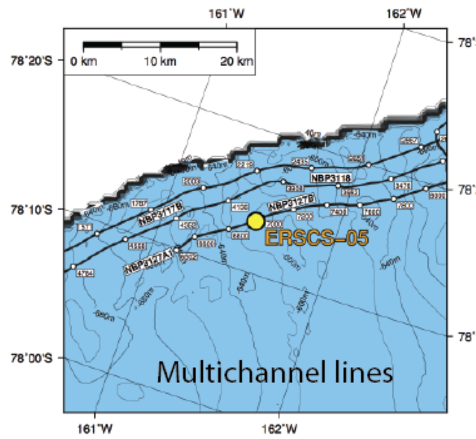
Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 206	Seafloor to base of glacial troughs	<14 Ma?	1.71	Diamictite, mudstone with clasts, diatomite	glacial, glacimarine, open marine		
206 - 481	Strata between base glacial troughs and top progradation strata	<23Ma?	2.3	Diamictite, mudstone with clasts, diatomite	glacial, glacimarine, open marine		
481 - 1132	Strata between top progradation and RSU6	23-34(?)	2.7	Diamictite, mudstone with clasts, diatomite	glacial, glacimarine, open marine		
1132 - 1200	strata under RSU6	34 (?)-50?	3.6	Indurated Sandstone, mudstone	open marine, marginal marine		

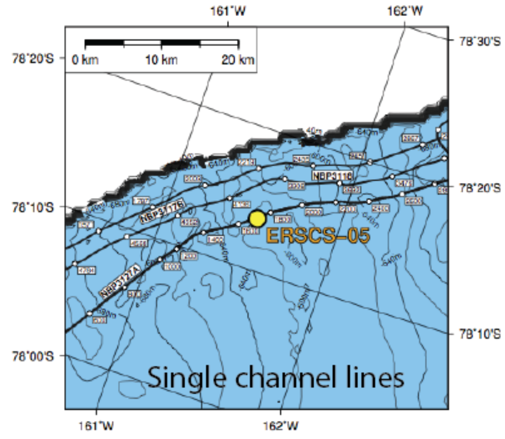
Site ERSCS-05A

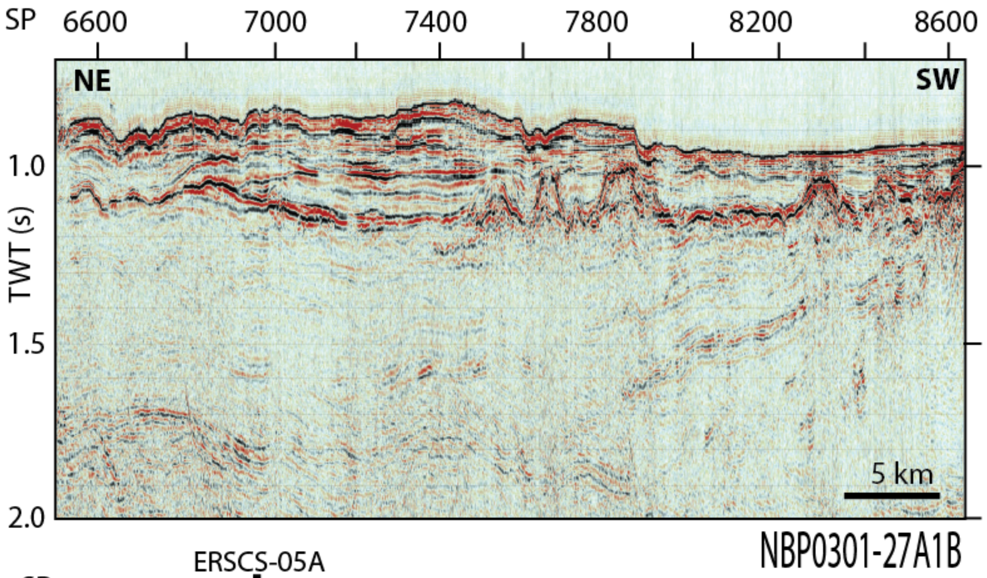
NBP0301-27A1B (SP 6950)
NBP0301-27A-SCS(SP1708)
Lat:-78.2274
Long: -161.5268
Water depth: 615 m

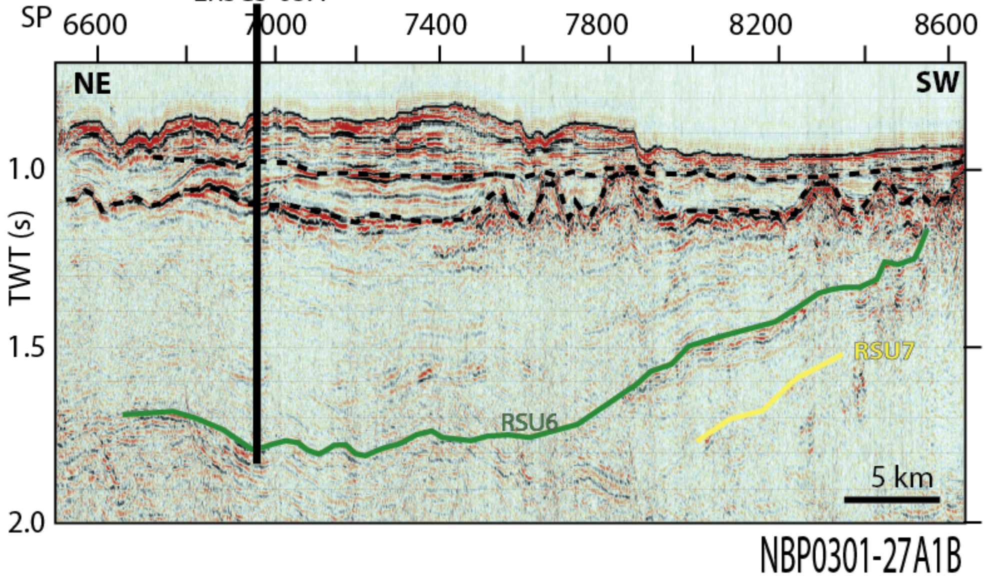
Data files in SSDB (to be upload by 1 May 2019)
NBP0301-27A1B.segy, NBP0301-27A1B.nav
NBP0301-27A-SCS .segy, NBP0301-27A-SCS .nav
Velocity information.doc

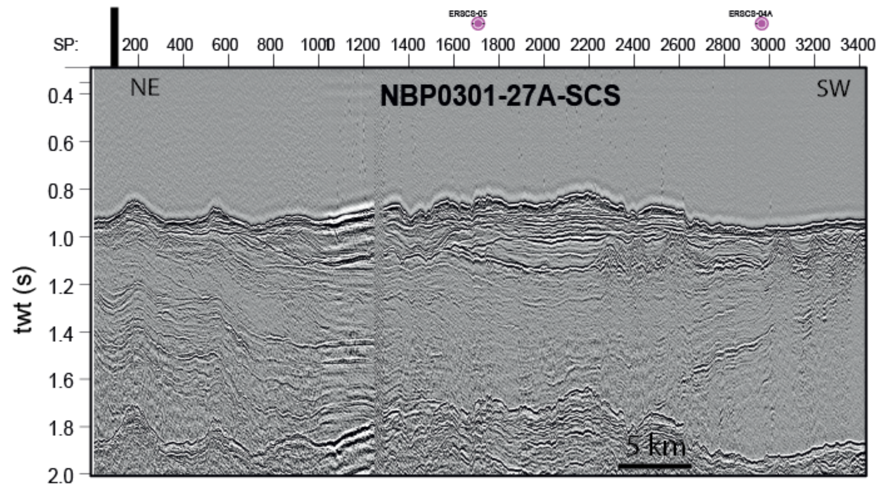
RSU6 (~28-34 Ma?)
RSU7 - too deep to recover - site is lower priority but will recover expanded post RSU6 section)

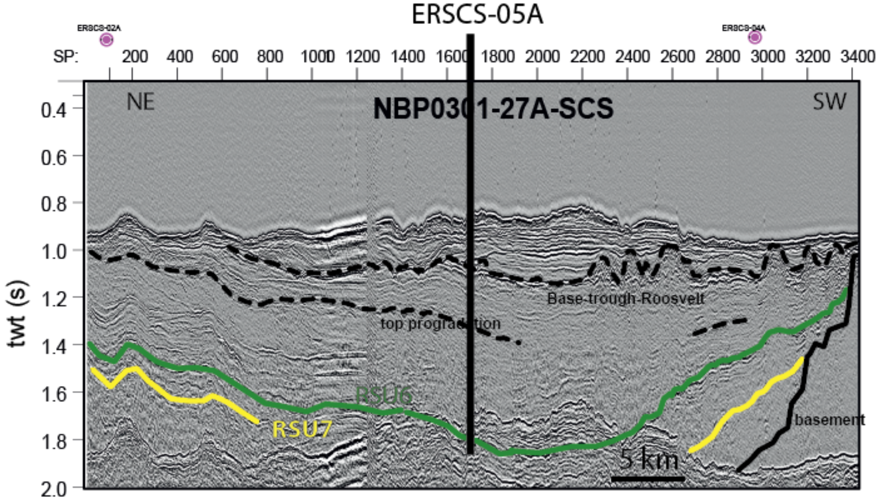












IODP Site Forms

Form 1 – General Site Information

964 - Full

Section A: Proposal Information

Proposal Title	Tracing Antarctic Cryosphere Origins to Climate And Tectonics
Date Form Submitted	2019-04-02 21:51:48
Site-Specific Objectives with Priority (Must include general objectives in proposal)	1) Obtain direct geological evidence of the earliest history of ice sheets in West Antarctica, by sampling strata above RSU6 (thought to be 34-28 Ma). Will obtain a Oligocene (~34 Ma) to Early Miocene (20 Ma) record of WAIS advance in Marie Byrd Land 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?) 3) Constrain timing of late rift phases in the Eastern Ross Sea. This will be achieved by dating syn-rift strata below RSU7.
List Previous Drilling in Area	

Section B: General Site Information

Site Name:	ERSCS-06A	Area or Location:	Eastern Ross Sea continental shelf
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: -77.668106299	Jurisdiction:	Antarctica
Longitude:	Deg: -160.740589980	Distance to Land: (km)	65
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	620

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1300	0
	Total Sediment Thickness (m) 1500	
		Total Penetration (m): 1300
General Lithologies:	diamictite, mudstone and cemented sandstone	unknown (schist, granite, marble, sandstone)

Coring Plan: (Specify or check)

RCB throughout, as strata are lithified near seafloor. Recovery and drill rate anticipate to improve below 100 mbsf as drill bit stabilizes.

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		Other tools:
WL	☑	Magnetic Susceptibility	☐	
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☑			

Other Measurements:

Estimated Days: Drilling/Coring: 10 | Logging: 2.5 | Total On-site: 12.5

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	January to Feburary is best ice free window
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					
Sensitive marine habitat (e.g., reefs, vents)						

Other: Full hydrocarbon assessment have previously been conducted in these basins for ANDRILL Coulman High and IODP Exp 374

Proposal #: 964 - Full	Site #: ERSCS-06A	Date Form Submitted: 2019-04-02 21:51:48

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: NBP9601L011A Position: SP400
2b Deep penetration seismic reflection (crossing)	yes	Line: NBP0301-25A Position: SP810 nearest crossling line
3 Seismic Velocity	yes	Its own velocity model from stack velocities
4 Seismic Grid	yes	The Antarctic Seismic Data Library System includes many kilometers of multichannel seismic profiles publically available online. We have set up a Kingdom project including also several regional single channel surveys (Polar Duke (PD) 1990, Nathaniel B. Palmer (NBP) 1994, 1995, 2003, 2008). The Kingdom project was already uploaded into the IODP SDSB for prop. 751 in 2016.
5a Refraction (surface)		Refraction data exist for the region (Cochrane, G.R.,1995; Antarctic Research Series 68 AGU, Washington, DC, pp. 261–270)
5b Refraction (bottom)		N/A
6 3.5 kHz		N/A
7 Swath bathymetry	no	Regional swath data is available
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	The list of heat flow stations in the Ross Sea. Can be found from the International Heat Flow Commission http://www.geophysik.rwth-aachen.de/IHFC/heatflow.html Heat flow measurements in the Ross Sea have been carried out since 1970s but are not enough to describe the regional heat flow distribution due to sparse data and restricted location compared to complicated tectonic history. All data were obtained by using a heat probe at shallow subsurface except for the IODP Exp 374 and the ones from McMurdo Sound drill sites such as CRP and DVDP sites.
11a Magnetics	no	Magnetic data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on
11b Gravity	no	Gravity data were collected during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on A Free Air gravity Ross Sea map is in the ANTOSTRAT Ross Sea Atlas map AGU vol. 68 (Brancolini et al., 1995)
12 Sediment cores		100s of piston and gravity cores have been collected from the Ross Sea continental shelf and are archived at the AMGRF in Florida.
13 Rock sampling		N/A
14a Water current data	no	
14b Ice Conditions		open water conditions in polynya region from December to February
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other	no	

Proposal #: 964 - Full	Site #: ERSCS-06A	Date Form Submitted: 2019-04-02 21:51:48

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single RCB hole, with logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	No shows on IODP Exp 374. Biogenic gas observed at some sites on DSDP Leg 28
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	none
4. Indications of gas hydrates at this location	no
5. Are there reasons to expect hydrocarbon accumulations at this site?	No
6. What "special" precautions will be taken during drilling?	Sea ice and iceberg present risk. Ice observers needed and free fall funnells can be used in case on encroaching ice.
7. What abandonment procedures need to be followed?	
8. Natural or manmade hazards which may affect ship's operations	ice - see special precautions
9. Summary: What do you consider the major risks in drilling at this site?	ice - see special precautions. A full risk assessment as done for Exp 374 will be conducted. Ice conditions will be similiar to Exp 374 which experienced very few issues with this.

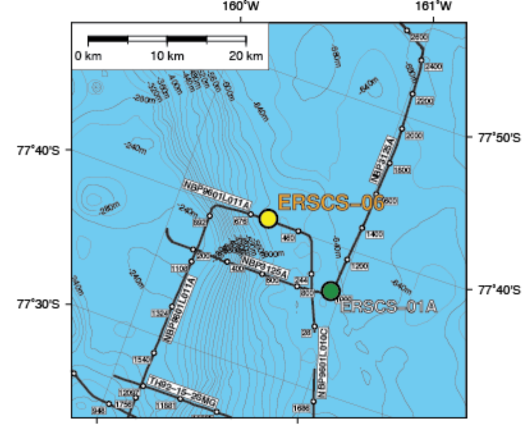
Proposal #: 964 - Full	Site #: ERSCS-06A	Date Form Submitted: 2019-04-02 21:51:48

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 150	Seafloor to top prograding	<14 Ma?	1.7	Diamictite, mudstone with clasts, diatomite	glacial, glacimarine, open marine		
150 - 470	Strata between top progradation and RSU6	<23Ma?	2.0	Diamictite, mudstone with clasts, diatomite	glacial, glacimarine, open marine		
481 - 1132	Strata between RSU6 and RSU7	23-34(?)	2.3	Diamictite, mudstone with clasts, diatomite	glacial, glacimarine, open marine		
1132 - 1300	strata below RSU7	34 (?)-50?	2.4	Indurated Sandstone, mudstone	open marine, marginal marine		

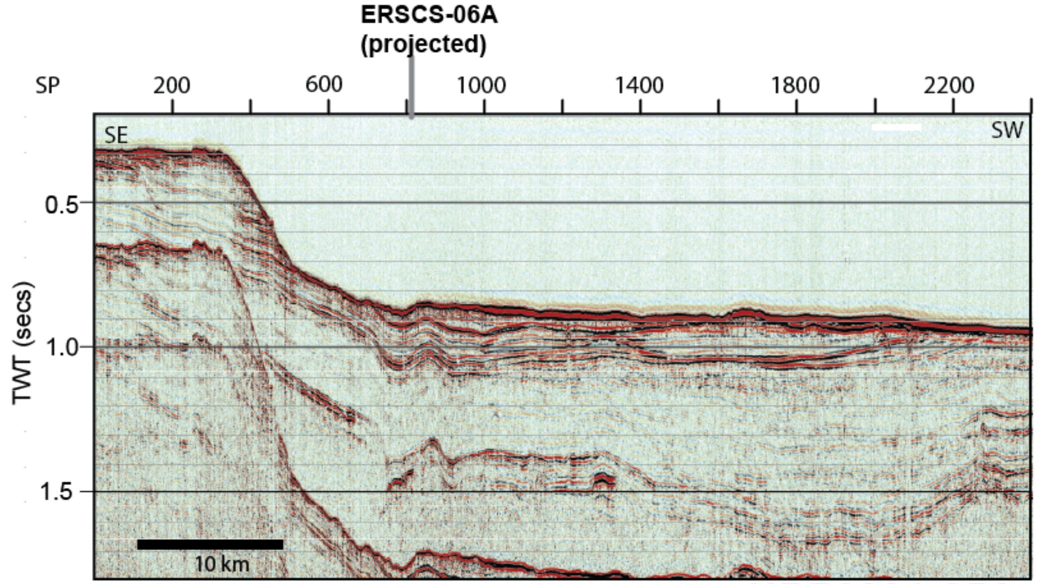
Site ERSCS-06A

shotpoint 400 on NBP9601L011A
shotpoint 810 on NBP0301-25A (nearest crossing)
Lat:-77.66810630
Long: -160.74058998

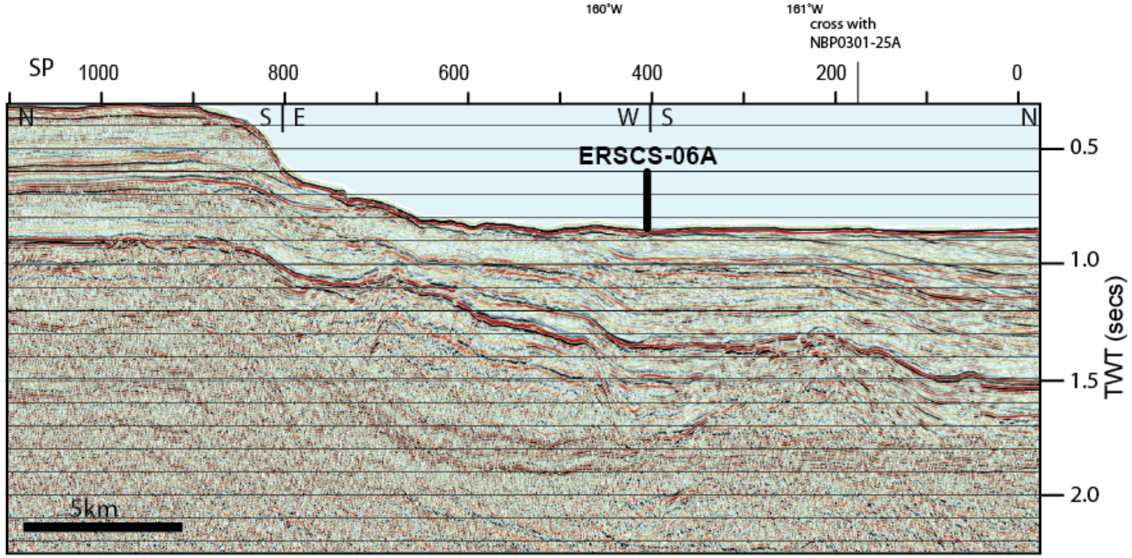
Data files in SSDB (to be upload by 1 May 2019)
NBP0301-25A.segy, NBP0301-25A.nav
NBP9601L011A .segy, NBP9601L011A .nav
Velocity information.doc



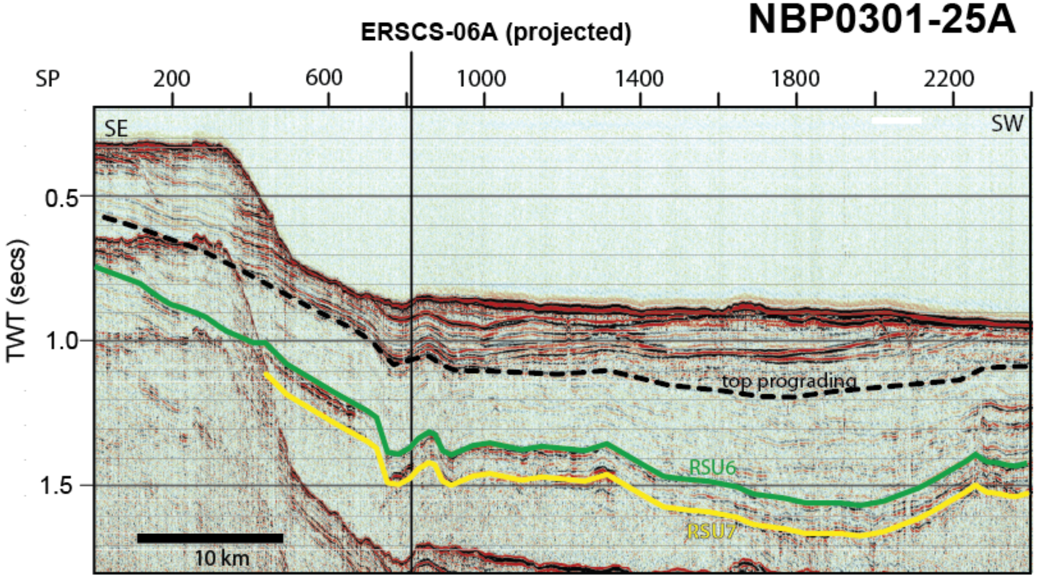
RSU6 (~28-34 Ma?)
RSU7 (age unknown)



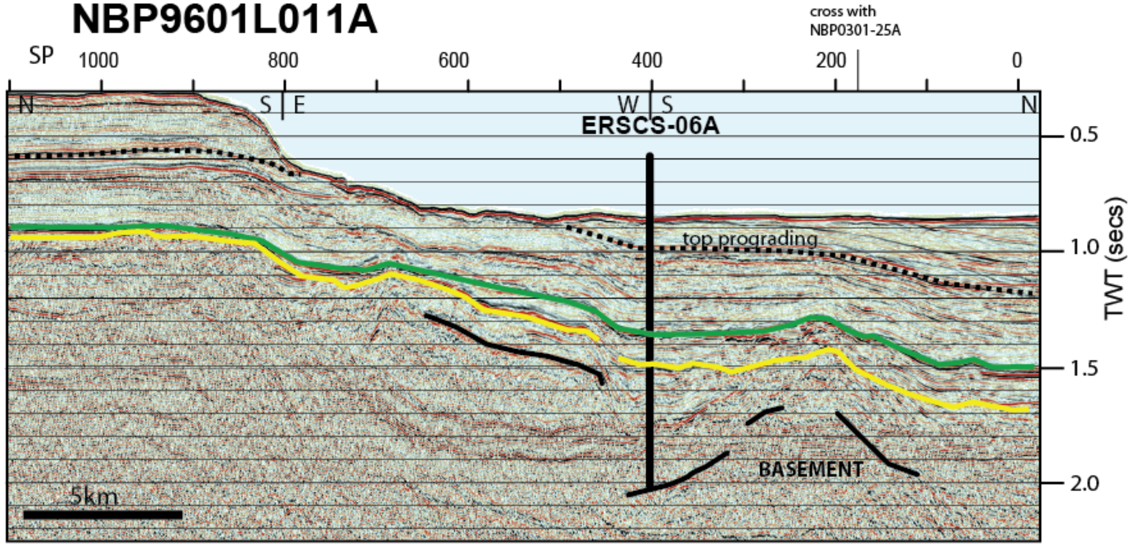
NBP0301-25A



NBP9601L011A



NBP0301-25A



NBP9601L011A

IODP Site Forms

Form 1 – General Site Information

964 - Full

Section A: Proposal Information

Proposal Title	Tracing Antarctic Cryosphere Origins to Climate And Tectonics
Date Form Submitted	2019-04-02 21:51:48
Site-Specific Objectives with Priority (Must include general objectives in proposal)	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)
List Previous Drilling in Area	IODP Exp 374

Section B: General Site Information

Site Name:	RSAP-01A	Area or Location:	Ross Sea Abyssal Plain
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: -71.3435	Jurisdiction:	Antarctica
Longitude:	Deg: -164.4160	Distance to Land: (km)	860
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	4133

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1090	10
	Total Sediment Thickness (m) 1090	
		Total Penetration (m): 1100
General Lithologies:	diatom ooze and mudstone	basalt

Coring Plan:
(Specify or check)

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☐	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☑			

Other Measurements:

Estimated Days: Drilling/Coring: 16 Logging: 2.4 Total On-site: 18.4

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Feburary is best ice free window (sea ice clears later than other sites)
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					
Sensitive marine habitat (e.g., reefs, vents)						

Other:

Proposal #: 964 - Full	Site #: RSAP-01A	Date Form Submitted: 2019-04-02 21:51:48

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)		
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: AWI20100107 Position: CDP11550
2b Deep penetration seismic reflection (crossing)	no	
3 Seismic Velocity	yes	
4 Seismic Grid	no	The Antarctic Seismic Data Library System includes many kilometers of multichannel seismic profiles publically available online. We have set up a Kingdom project including also several regional single channel surveys (Polar Duke (PD) 1990, Nathaniel B. Palmer (NBP) 1994, 1995, 2003, 2008). The Kingdom project was already uploaded into the IODP SDSB for prop. 751 in 2016.
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry	no	
8a Side looking sonar (surface)		
8b Side looking sonar (bottom)		
9 Photography or video	no	
10 Heat Flow	no	The list of heat flow stations in the Ross Sea. Can be found from the International Heat Flow Commission http://www.geophysik.rwth-aachen.de/IHFC/heatflow.html Heat flow measurements in the Ross Sea have been carried out since 1970s but are not enough to describe the regional heat flow distribution due to sparse data and restricted location compared to complicated tectonic history. All data were obtained by using a heat probe at shallow subsurface except for the IODP Exp 374 and the ones from McMurdo Sound drill sites such as CRP and DVDP sites.
11a Magnetics	no	Magnetic data were collected during the AWI cruise 2010 and during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on
11b Gravity	no	Gravity data were collected during the AWI cruise 2010 and during each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on A Free Air gravity Ross Sea map is in the ANTOSTRAT Ross Sea Atlas map AGU vol. 68 (Brancolini et al., 1995)
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions		open water conditions in region later in season than other site (February). ice covered in some years (note this is an alternate)
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other	no	

Proposal #: 964 - Full	Site #: RSAP-01A	Date Form Submitted: 2019-04-02 21:51:48

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single RCB hole, with logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	No shows on IODP Exp 374. Biogenic gas observed at some sites on DSDP Leg 28
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	none
4. Indications of gas hydrates at this location	no
5. Are there reasons to expect hydrocarbon accumulations at this site?	No
6. What "special" precautions will be taken during drilling?	Sea ice and iceberg present risk. Ice observers needed and free fall funnells can be used in case on encroaching ice.
7. What abandonment procedures need to be followed?	
8. Natural or manmade hazards which may affect ship's operations	ice - see special precautions
9. Summary: What do you consider the major risks in drilling at this site?	ice - see special precautions. A full risk assessment as done for Exp 374 will be conducted. Ice conditions will be similiar to Exp 374 which experienced very few issues with this.

Proposal #: 964 - Full	Site #: RSAP-01A	Date Form Submitted: 2019-04-02 21:51:48

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 500	strata above RSU4	2-16 Ma	1.710	mudstone, diatomites	open marine		
500 - 800	Strata between RSU4 and RSU6	16-34 Ma	1.760	mudstone, diatomites	open marine		
800 - 1090	Strata under RSU6	>34 Ma		mudstone, diatomites	open marine	2.082	
1090 - 1100	Basement			Basalt		4	

Site RSAP-01A

CDP 11550 on Line AWI-20100107

Lat:-71.3435

Long: -164.416

water depth: 4133 m

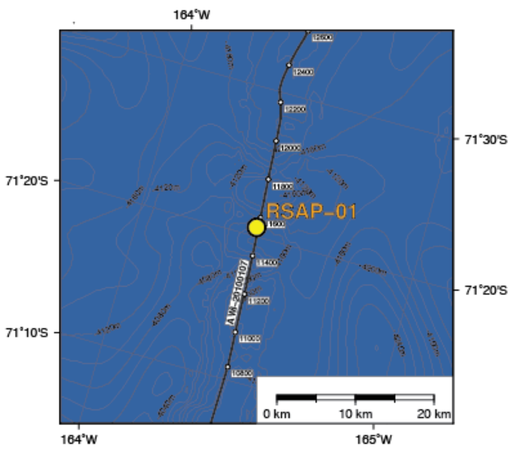
Data files in SSDB (to be uploaded by 1 May 2019)

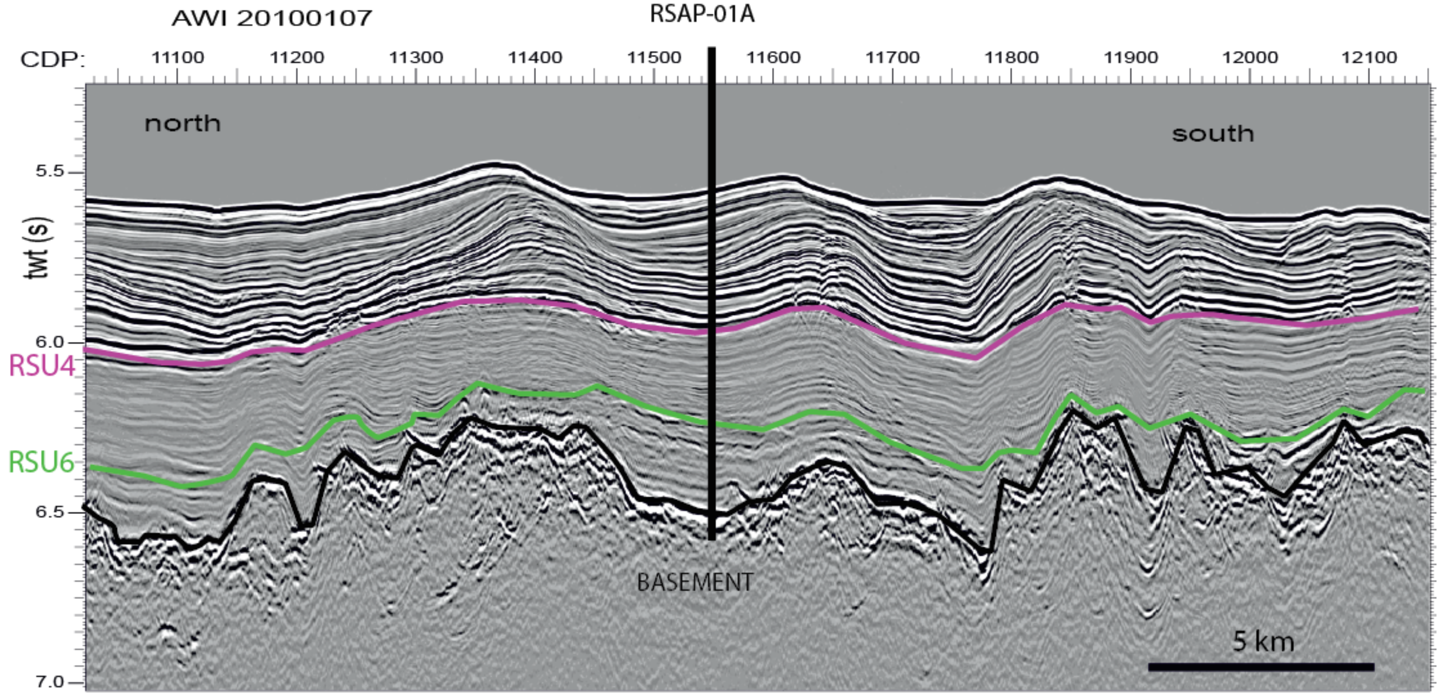
AWI-20100107.segy,AWI-20100107.nav

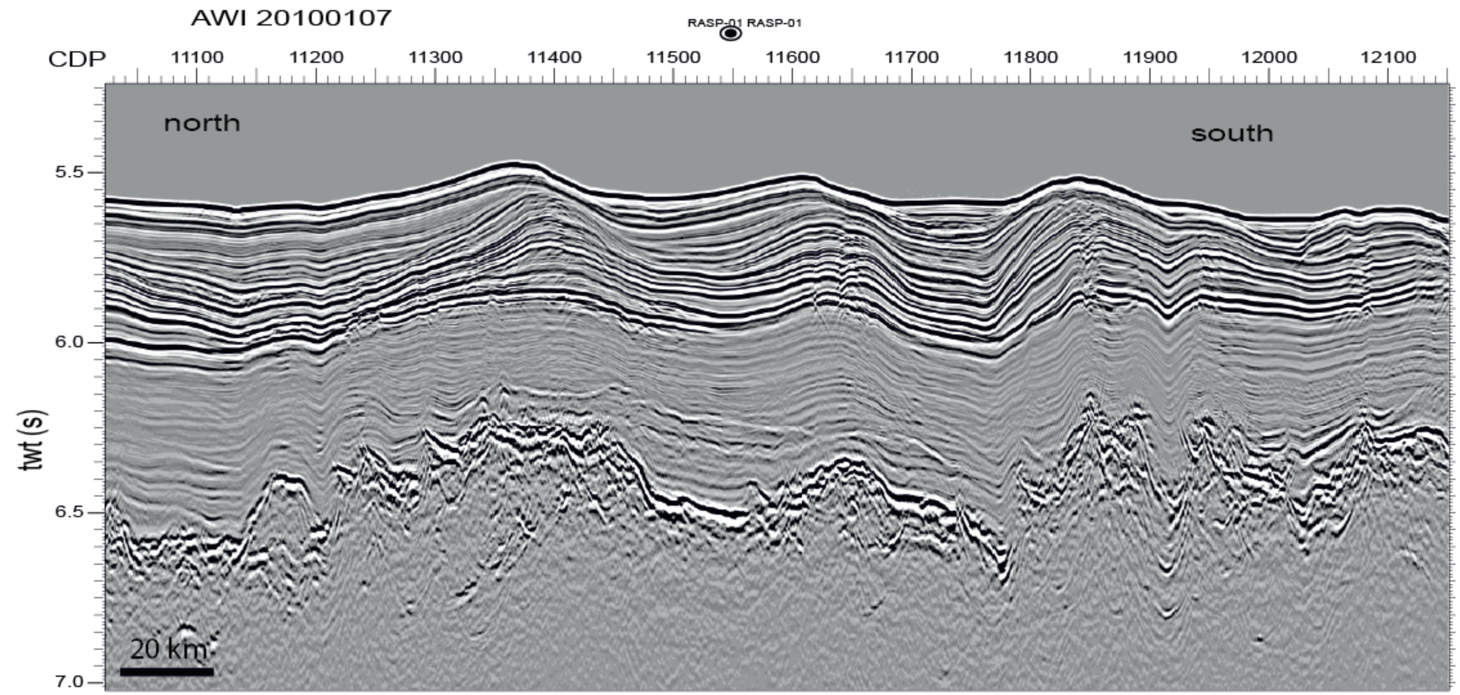
Velocity information.doc

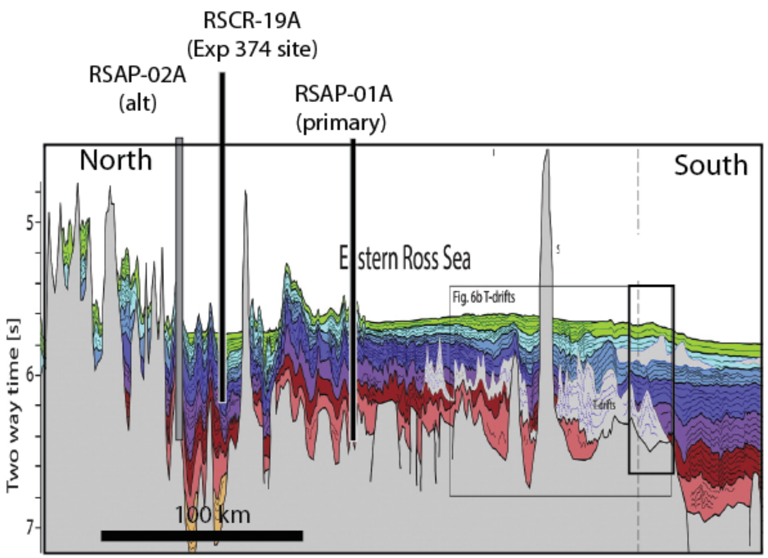
RSU4 (~16 Ma)

RSU6 (~28-34 Ma)









AWI-20100107

Relationship to IOPD Exp 374 proposed site RSCR19A (at JRFB for reconsideration of scehduling)

Image from Lindeque et al., 2016

IODP Site Forms

Form 1 – General Site Information

964 - Full

Section A: Proposal Information

Proposal Title	Tracing Antarctic Cryosphere Origins to Climate And Tectonics
Date Form Submitted	2019-04-02 21:51:48
Site-Specific Objectives with Priority (Must include general objectives in proposal)	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 1. 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). Site is alternate in case, ERSCS site are ice covered in an extreme sea ice year (other shelf sites in CHCS and CENCS regions are always open water in summer)
List Previous Drilling in Area	IODP Expedition 374

Section B: General Site Information

Site Name:	RSAP-02A	Area or Location:	Ross Sea Abyssal Plain
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: -69.99544571	Jurisdiction:	Antarctica
Longitude:	Deg: -164.67600	Distance to Land: (km)	920
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	4075

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1200	0
	Total Sediment Thickness (m) 1420	
		Total Penetration (m): 1200
General Lithologies:	diatom ooze and mudstone	basalt

Coring Plan: (Specify or check)

RCB coring, as APC core will collect softer/younger sediments at Exp 374 site RSCR-19A - upper units not mission critical at this site. Site is alternate in case ERSCS site are ice covered in an extreme sea ice year

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		Other tools:
WL	☑	Magnetic Susceptibility	☐	
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☑			

Other Measurements:

Estimated Days:

Drilling/Coring:	Logging:	Total On-site:
15	2.4	17.4

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	January to Feburary is best ice free window
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents)

Other:

Generated: 2019-05-03T19:01:56+00:00

Proposal #: 964 - Full	Site #: RSAP-02A	Date Form Submitted: 2019-04-02 21:51:48

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)		
1b High resolution seismic seismic reflection (crossing)		
2a Deep penetration seismic reflection (primary)	yes	Line: AWI20100107 Position: CDP5440
2b Deep penetration seismic reflection (crossing)		
3 Seismic Velocity	yes	
4 Seismic Grid	no	The Antarctic Seismic Data Library System includes many kilometers of multichannel seismic profiles publically available online. We have set up a Kingdom project including also several regional single channel surveys (Polar Duke (PD) 1990, Nathaniel B. Palmer (NBP) 1994, 1995, 2003, 2008). The Kingdom project was already uploaded into the IODP SDSB for prop. 751 in 2016.
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry	no	
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	The list of heat flow stations in the Ross Sea. Can be found from the International Heat Flow Commission http://www.geophysik.rwth-aachen.de/IHFC/heatflow.html Heat flow measurements in the Ross Sea have been carried out since 1970s but are not enough to describe the regional heat flow distribution due to sparse data and restricted location compared to complicated tectonic history. All data were obtained by using a heat probe at shallow subsurface except for the IODP Exp 374 and the ones from McMurdo Sound drill sites such as CRP and DVDP sites.
11a Magnetics	no	Magnetic data were collected during the AWI cruise and each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on
11b Gravity		Gravity data were collected during the AWI 2010 cruise and each of the Italian and US seismic cruises and are available via the OGS repository and via the Marine Geoscience Data System MGDC http://www.marine-geo.org/tools/new_search/index.php?&all_field=1&all_compilation=1&funding=USAP&output_info_all=on A Free Air gravity Ross Sea map is in the ANTOSTRAT Ross Sea Atlas map AGU vol. 68 (Brancolini et al., 1995)
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions		open water conditions in region later in season than other site (February). ice covered in some years (note this is an alternate)
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other	no	

Proposal #: 964 - Full	Site #: RSAP-02A	Date Form Submitted: 2019-04-02 21:51:48

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single RCB hole, with logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	No shows on IODP Exp 374. Biogenic gas observed at some sites on DSDP Leg 28
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	none
4. Indications of gas hydrates at this location	no
5. Are there reasons to expect hydrocarbon accumulations at this site?	No
6. What "special" precautions will be taken during drilling?	Sea ice and iceberg present risk. Ice observers needed and free fall funnells can be used in case on encroaching ice.
7. What abandonment procedures need to be followed?	
8. Natural or manmade hazards which may affect ship's operations	ice - see special precautions
9. Summary: What do you consider the major risks in drilling at this site?	ice - see special precautions. A full risk assessment as done for Exp 374 will be conducted. Ice conditions will be similiar to Exp 374 which experienced very few issues with this.

Proposal #: 964 - Full	Site #: RSAP-02A	Date Form Submitted: 2019-04-02 21:51:48

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 451	Strata between seafloor and RSU4	2-16 Ma	1.600	mudstone, diatomites	open marine		
451 - 700	Strata between RSU4 and RSU4a	16-18.5	1.635	mudstone, diatomites	open marine		
700 - 930	Strata between RSU4a and RSU5	18.5-21	1.84	mudstone, diatomites	open marine		
930 - 1200	srata between RSU5 and Basement	>21	2.0	mudstone, diatomite	open marine		

Site RSAP-02A

CDP 5440 on Line AWI-20100107

Lat:-69.9955

Long: -164.6760

water depth: 4075 m

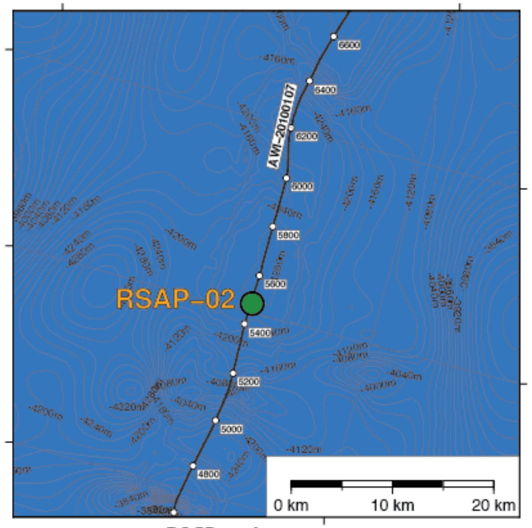
Data files in SSDB (to be uploaded by 1 May 2019)

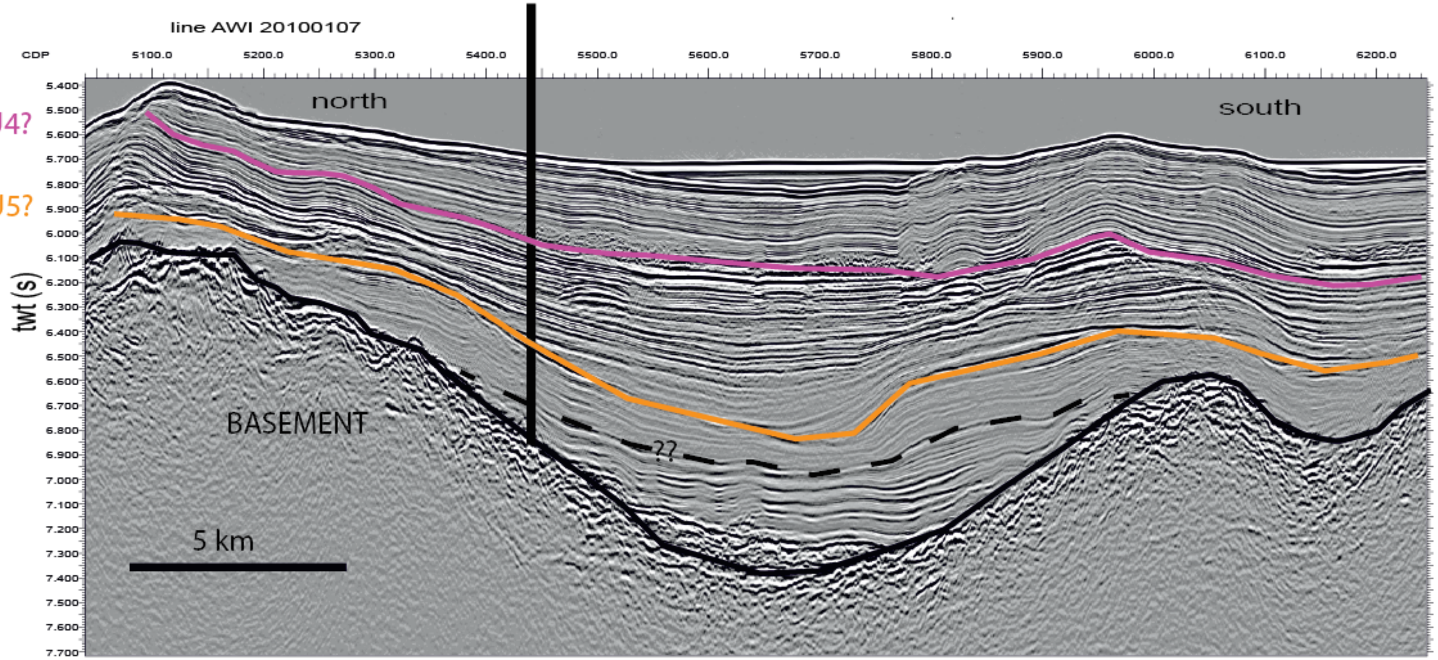
AWI-20100107.segy,AWI-20100107.nav

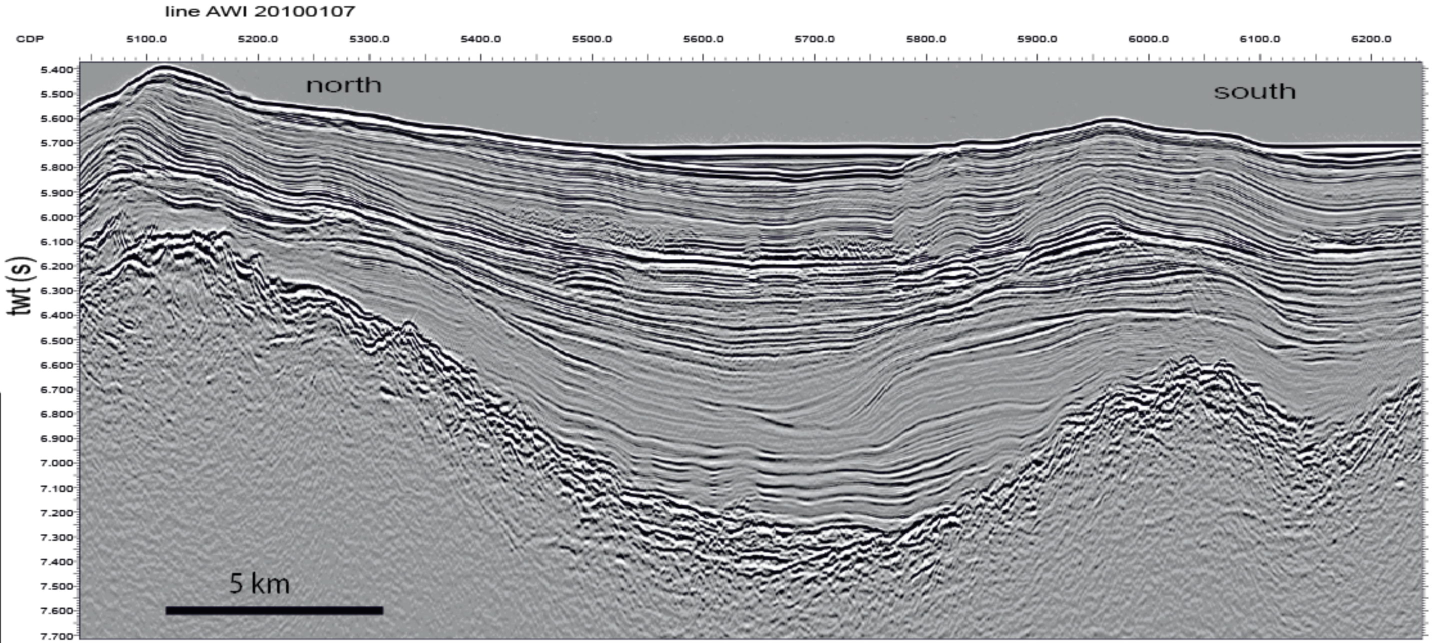
Velocity information.doc

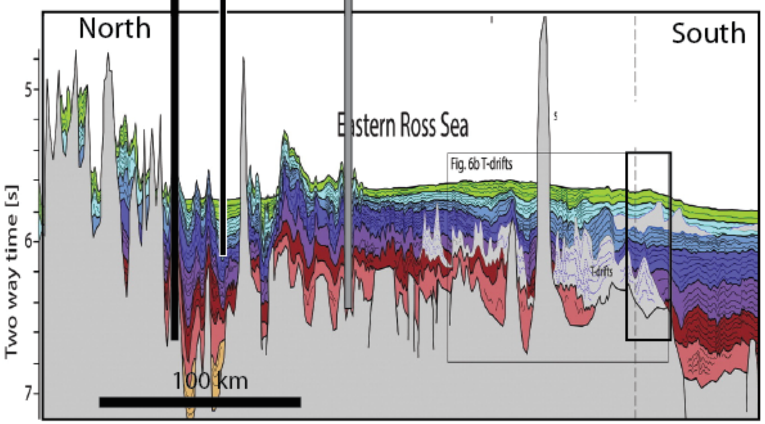
RSU4 (~16 Ma)

RSU5 (~21 Ma)









Relationship to IOPD Exp 374 proposed site RSCR19A (at JRFB for reconsideration of scehduling)

Image from Lindeque et al., 2016