IODP Proposal Cover Sheet

708 - Add 3

Central Arctic Paleoceanography

Received for:

Title	Arctic Ocean Paleoceanography: Towards a Continuous Cenozoic Record from a Greenhouse to an Icehouse World (ArcOP)
Proponents	Ruediger Stein, Estella Weigelt, Frank Niessen, Wilfried Jokat, Jens Matthiessen, Seung-il Nam, Kristen St. John, Martin Jakobsson, Matthew O'Regan, Matthias Forwick, Alexey Krylov, Catalina Gebhardt, Bernard Coakley, Henk Brinkhuis, Leon Clarke
Keywords	Arctic Ocean, Paleoceanography, Cenozoic
Area	Lomonosov Ridge

Proponent Information

Proponent	Ruediger Stein
Affiliation	Alfred Wegener Institute Bremerhaven
Country	Germany

☑ Permission is granted to post the coversheet/site table on www.iodp.org

Abstract

Prior to 2004, geological sampling in the Arctic Ocean was mainly restricted to near-surface Quaternary sediments. Thus, the long-term Pre-Quaternary geological history is still poorly known. With the successful completion of the Arctic Coring Expedition - ACEX (IODP Expedition 302) in 2004, a new era in Arctic research has begun. Employing a novel multi-vessel approach, the first Mission Specific Platform (MSP) expedition of IODP has proven that drilling in permanently ice-covered regions is possible. During ACEX, 428 meters of Quaternary, Neogene, Paleogene and Campanian sediment on Lomonosov Ridge were penetrated, providing new unique insights into the Cenozoic Arctic paleo-oceanographic and climatic history. While highly successful, ACEX also has three important limitations. The ACEX sequence possibly contains a large hiatus spanning the time interval from late Eocene to middle Miocene (based on the original biostratigraphic age model) or an interval of strongly reduced sedimentation rates (new Os-Re-isotope-based age model). This is a critical time interval, as it spans the time when prominent changes in global climate took place during the transition from the early Cenozoic Greenhouse world to the late Cenozoic Icehouse world. Furthermore, generally poor recovery during ACEX prevented detailed and continuous reconstruction of Cenozoic climate history. Finally, a higher-resolution reconstruction of Arctic rapid climate change during Neogene to Pleistocene times, could not be reached during ACEX. We believe, this justifies a return to the Lomonosov Ridge for a second MSP - type drilling campaign within IODP to fill these major gaps in our knowledge on Arctic Ocean paleoenvironmental history through Cenozoic times and its relationship to the global climate history.

Overall goal of the proposed drilling campaign is the recovery of a complete stratigraphic sedimentary record on southern Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continuous long-term Cenozoic climate history of the central Arctic Ocean. Furthermore, sedimentation rates two to four times higher than those of ACEX permit higher-resolution studies of Arctic climate change. As demonstrated in the proposal, this goal can be achieved by careful site selection, appropriate drilling technology, and applying multi-proxy approaches to paleoceanographic, paleoclimatic, and age-model reconstructions. We propose one primary deep drill site (LR-11B) with three APC/XCB/RCB holes, supplemented by a short APC drill site (LR-10B), to recover multiple sections of the sediment sequence to ensure complete recovery for construction of a composite section.

ArcOP objectives are key elements in the IODP New Science Plan, Theme 1 Climate and Ocean Change

708 - Add 3

Scientific Objectives

A complete stratigraphic sedimentary sequence representing the continuous Cenozoic climate history of the central Arctic Ocean will be studied to answer the following key questions:

- Did the Arctic Ocean climate follow the global climate evolution during its course from early Cenozoic Greenhouse to late Cenozoic Icehouse conditions?
- Are the Early Eocene Climate Optimum (poor recovery in the ACEX record) and the Oligocene and Mid-Miocene warmings also reflected in Arctic Ocean records?
- Did extensive glaciations (e.g., the OI-1 and Mi-1 glaciations) develop synchronously in both the Northern and Southern Hemispheres?
- What is the timing of repeated major (Plio-)Pleistocene Arctic glaciations as postulated from sediment echosounding and multi-channel seismic reflection profiling?
- What was the variability of sea-ice in terms of frequency, extent and magnitude?
- When and how did the change from a warm, fresh-water-influenced, biosilica-rich and poorly ventilated Eocene ocean to a cold, fossil-poor, and oxygenated Neogene ocean occur?
- What is the history of Siberian river discharge and how critical is it for sea-ice formation, water mass circulation and climate change?
- How did the Arctic Ocean evolve during the Pliocene warm period and succeeding cooling?
- How do the new ArcOP record correlate with the terrestrial record from the Siberian Lake El'gygytgyn?
- What is the cause of the major hiatus recovered in the ACEX record? Does this hiatus in fact exist?

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

The sites are located in the seasonally ice-covered central Arctic Ocean (southern Lomonosov Ridge), and will need mission specific vessels to perform the drilling in the pack ice (marginal ice zone). A well organized ice-management strategy and support by an icebreaker (e.g., Oden) are needed.

708 - Add 3

Proposed Sites (Total proposed sites: 12; pri: 2; alt: 10; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
LR-11B (Primary)	81.4365 140.8405	794	900	0	900	Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest-priority paleoceanographic objective, the continous long-term Cenozoic climate history of the central Arctic Ocean
LR-10B (Primary)	81.4836 140.5855	890	50	0	50	Recovery of the undisturbed uppermost (Quaternary) sedimentary section
LR-01A (Alternate)	80.9502 142.9717	1402	1225	0	1225	Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continuous long-term Cenozoic climate history of the central Arctic Ocean (Alternate site)
LR-02A (Alternate)	80.9650 142.4717	1458	1300	0	1300	Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continous long-term Cenozoic climate history of the central Arctic Ocean (Alternate Site)
LR-03A (Alternate)	81.1825 142.0918	1013	1180	0	1180	Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continuous long-term Cenozoic climate history of the central Arctic Ocean (Alternate site)
LR-04C (Alternate)	81.3531 141.2484	875	930	0	930	Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continuous long-term Cenozoic climate history of the central Arctic Ocean (Alternate site)
LR-05B (Alternate)	81.3256 141.4248	906	1050	0	1050	Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continuous long-term Cenozoic climate history of the central Arctic Ocean (Alternate site)
LR-06A (Alternate)	81.4568 140.7299	779	970	0	970	Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continuous long-term Cenozoic climate history of the central Arctic Ocean (Alternate site)
LR-07A (Alternate)	81.6851 142.3074	764	740	0	740	Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continuous long-term Cenozoic climate history of the central Arctic Ocean (Alternate site)
LR-08A (Alternate)	82.4215 142.1678	1450	875	0	875	Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continuous long-term Cenozoic climate history of the central Arctic Ocean (Alternate site)
LR-09A (Alternate)	82.8274 142.4677	1251	750	0	750	Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continuous long-term Cenozoic climate history of the central Arctic Ocean (Alternate site)
LORI-5B (Alternate)	83.8005 146.4750	1334	1100	0	1100	Recovery of a complete stratigraphic sedimentary record on the central Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continous long-term Cenozoic climate history of the central Arctic Ocean. (Alternate Site)

708 - Add 3

Contact Information

Contact Person:	Ruediger Stein
Department:	Geosciences
Organization:	Alfred Wegener Institute for Polar and Marine Research
Address:	Am Alten Hafen 26 Bremerhaven Bremen 27568 Germany
E-mail/Phone:	Ruediger.Stein@awi.de; Phone: +4947148311576

Proponent List

First Name	Last Name	Affiliation	Country	Role	Expertise
Ruediger	Stein	Alfred Wegener Institute Bremerhaven	Germany	Principal Lead	Organic geochemistry
Estella	Weigelt	Alfred Wegener Institute Bremerhaven	Germany	Data Lead	Geophysics
Frank	Niessen	Alfred Wegener Institute Bremerhaven	Germany	Other Proponent	Physical properties
Wilfried	Jokat	Alfred Wegener Institute Bremerhaven	Germany	Other Proponent	Geophysics
Jens	Matthiessen	Alfred Wegener Institute Bremerhaven	Germany	Other Proponent	Paleoceanography
Seung-il	Nam	Korea Polar Research Institute, Incheon	Korea, Democratic People's Republic of	Other Proponent	Paleoceanography
Kristen	St. John	James Madison University Virginia	United States	Other Proponent	Sedimentology
Martin	Jakobsson	Stockholm University	Sweden	Other Proponent	Bathymetry
Matthew	O'Regan	Stockholm University	Sweden	Other Proponent	Physical properties
Matthias	Forwick	Department of Geology, Tromsø University	Norway	Other Proponent	Sedimentology, XRF scanning
Alexey	Krylov	VNIIOkeangeologia, St. Petersburg	Russian Federation	Other Proponent	Sedimentology, Sediment provenances
Catalina	Gebhardt	Alfred Wegener Institute, Bremerhaven	Germany	Other Proponent	Geophysics; Physical properties
Bernard	Coakley	University of Fairbanks Alaska	United States	Other Proponent	Geophysics
Henk	Brinkhuis	Utrecht University	Netherlands	Other Proponent	Palynology
Leon	Clarke	Bangor University Wales	United Kingdom	Other Proponent	Inorganic geochemistry

Generated: 2020-03-06T09:01:04+00:00

Addendum to Proposal 708-Full1 ("Add4"; 06 March 2020)

Arctic Ocean Paleoceanography: Towards a Continuous Cenozoic Record from a Greenhouse to an Icehouse World (ArcOP)

Proponents:
R. Stein, E. Weigelt, F. Niessen, W. Jokat, J. Matthiessen, S.-I. Nam, K. St. John, M. Jakobsson, M. O´Regan, M. Forwick, A. Krylov, C. Gebhardt, B. Coakley, H. Brinkhuis, L. Clarke

This addendum is an update of the previous Addendum (708-Add3). It is to slightly relocate the sites LR-04B and LR-10A, responding to EPSP review on 18/19 February 2020. The names of these relocated sites have been changed into LR-04C and LR-10B. No further changes have been made.

The updates of sites LR-04C and LR-10B (for location see Fig. 1) are included in Table 1, summarizing the data of all our proposed sites. We select the new Site LR-11B as primary deep site and LR-10A as primary shallow site, all other sites (i.e., LR-01A, LR-02A, LR-03A, LR-04C, LR-05B, LR-06A, LR-07A, LR-08A, LR-09A, and LORI-5B) remain active alternate sites. All alternate sites at which the target depth can be reached with total drill pipe length no longer than 2000 m, are highlighted in Table 1 in yellow. For the relocated and renamed sites LR-04C and LR-10B the revised "Form 6" are included here as Figures 2 and 3, respectively.

Again and in summary, we can reach all objectives outlined in the 708 proposal by drilling **one deep primary site LR-11B plus a "1-day add" for drilling/coring the uppermost 40-50 m at a close-by location (LR-10B)**, i.e., during Expedition 377 and under reduced costs. That means, Expedition 377 (ArcOP) remains a "stand-alone expedition". By this, Expedition 377 (ArcOP) can be carried out as approved by EFB/SEP.

All new seismic data, forms and/or tables will be uploaded no later than 09 March 2020.

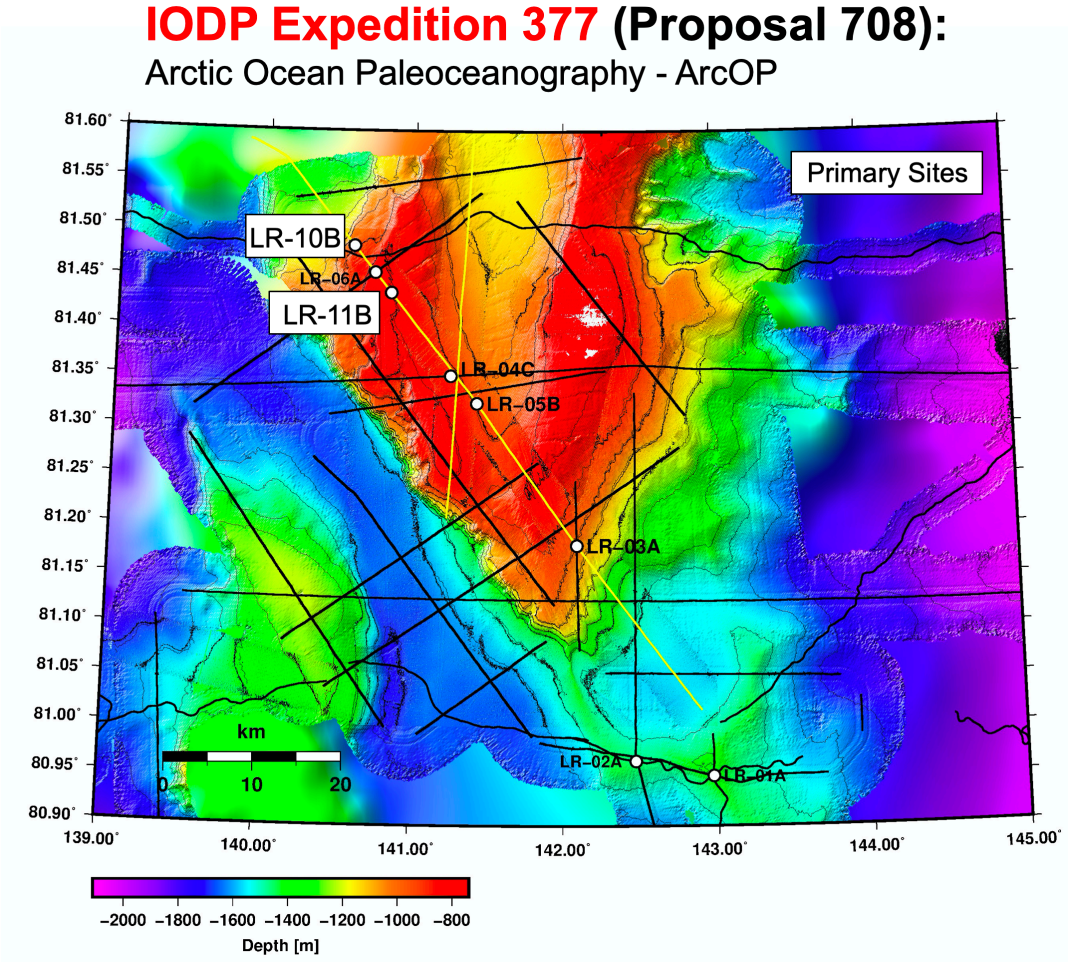
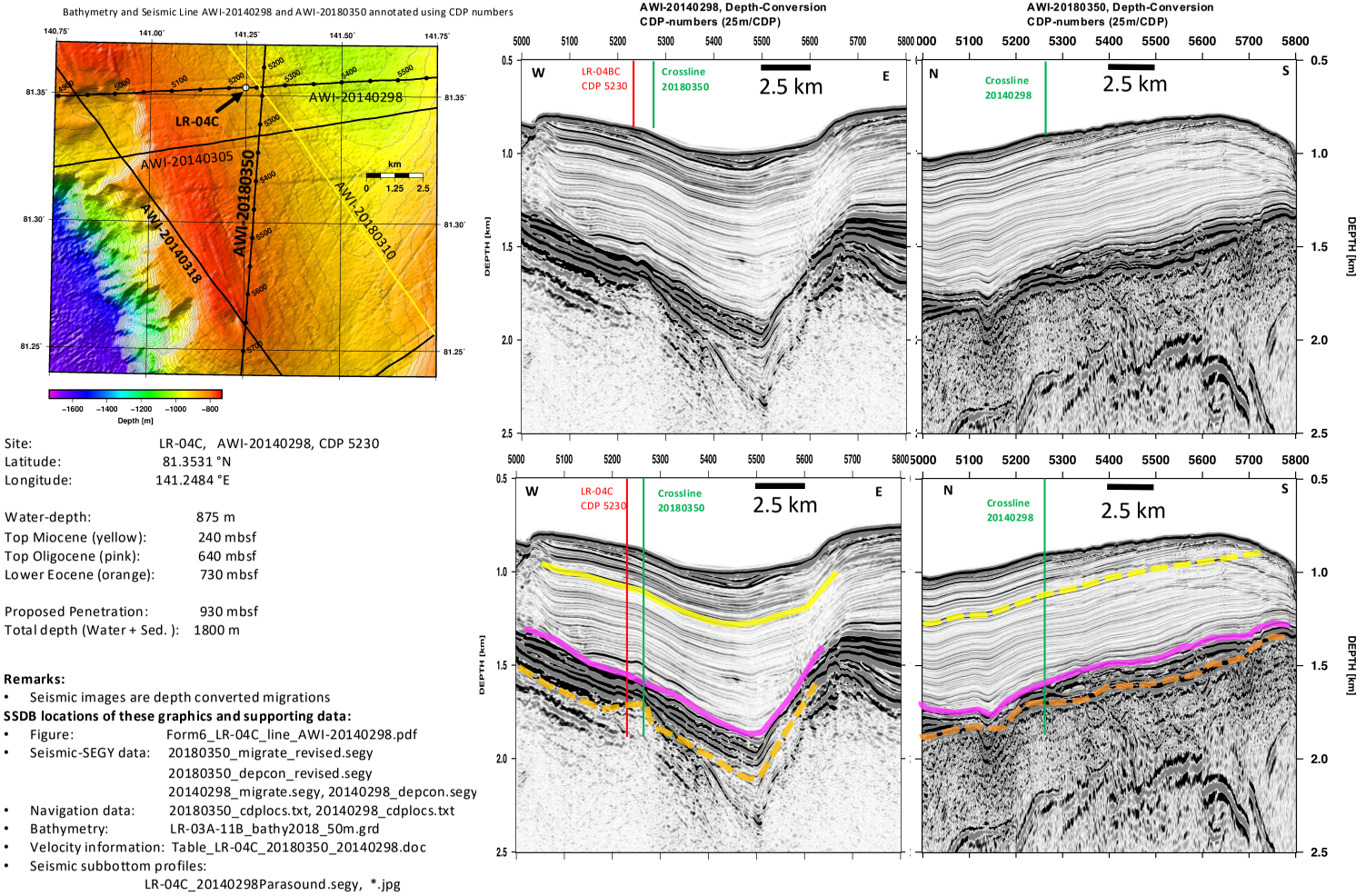


Figure 1.
Southern Lomonosov Ridge with locations of proposed drill sites

Figure 2. Form 6 of Site LR-04C

Site Summary Form 6: IODP Proposal 708 Site LR-04C



Site: LR-04C, AWI-20140298, CDP 5230
Latitude: 81.3531 °N
Longitude: 141.2484 °E

Water-depth: 875 m
Top Miocene (yellow): 240 mbsf
Top Oligocene (pink): 640 mbsf
Lower Eocene (orange): 730 mbsf

Proposed Penetration: 930 mbsf
Total depth (Water + Sed.): 1800 m

Remarks:

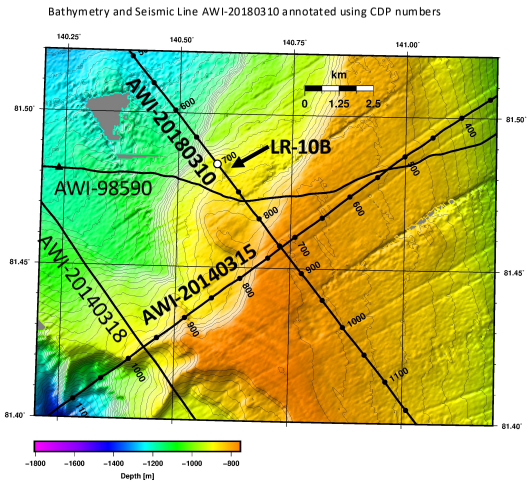
- Seismic images are depth converted migrations

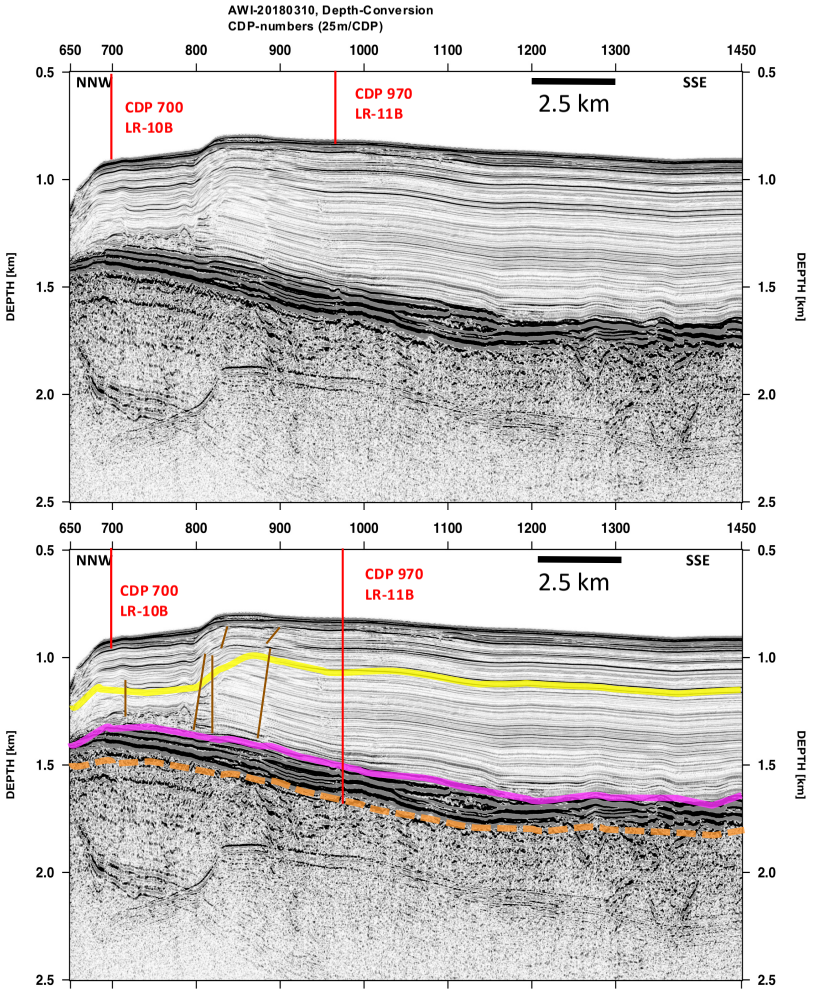
SSDB locations of these graphics and supporting data:

- Figure: Form6_LR-04C_line_AWI-20140298.pdf
- Seismic-SEGY data: 20180350_migrate_revised.segy
  20180350_depcon_revised.segy
  20140298_migrate.segy, 20140298_depcon.segy
- Navigation data: 20180350_cdplocs.txt, 20140298_cdplocs.txt
- Bathymetry: LR-03A-11B_bathy2018_50m.grd
- Velocity information: Table_LR-04C_20180350_20140298.doc
- Seismic subbottom profiles:
  LR-04C_20140298Parasound.segy, *.jpg

Figure 3. Form 6 of Site LR-10B

Site Summary Form 6: IODP Proposal 708 Site LR-10B





Site: LR-10B, AWI-20180310, CDP 700
Latitude: 81.4836°N
Longitude: 140.5855°E
Water-depth: 890 m

Proposed Penetration: 50 mbsf
Total depth (Water + Sed.): 940 m

Remarks:

- Seismic images are depth converted migrations

SSDB locations of these graphics and supporting data:

- Figure: Form6-LR-10B_line_AWI-20180310.pdf
- Seismic-SEGY data: 20180310_migrate.segy, 20180310_depcon.segy
- Navigation data: 20180310_cdplocs.txt
- Bathymetry: LR-03A-11B_bathy2018_50m.grd
- Seismic subbottom profiles: LR-06A-10A-11B_20180310Parasound.segy, LR-10B-11B_20180310Parasound.jpg

Table 1

Site	LR-01A	LR-02A	LR-03A	LR-04C	LR-05B	LR-06A	LR-11B	LR-10B	LR-07A	LR-08A	LR-09A	LORI-5B
Location	80.9502° N 142.9717° E	80.965° N 142.4717° E	81.1825°N 142.0918°E	81.3531°N 141.2484° E	81.3256°N 141.4248°E	81.4568°N 140.7299°E	81.4365°N 140.8405°E	81.48363°N 140.5855°E	81.6851°N 142.3074°E	82.4215°N 142.1678°E	82.8274°N 142.4677°E	83.8005° N 146.475° E
Line	20080160	20140304,307	20140310	20140298	20180310	20140315	20180310	20180310	20140321	20140292	20140324,290	565,260,279
CDP	475	2147, 567	600	5230	1600	725	970	700	220	1720	135, 1615	2582,650 1004
	depth[m]	depth[m]	depth[m]	depth[m]	depth[m]	depth[m]	depth (m)	depth (m)	depth[m]	depth[m]	depth[m]	depth[m]
Seafloor Bathymetry	1402	1458	1013	875	906	779	794	890	764	1450	1251	1333
Seafloor Seismic	1405	1460	1013-1022	860-880	910-917	776-782	795-810	890-910 **904**	760-765	1435 - 1450	1244-1251	1334
Top Miocene (yellow)	1570 - 1580	1600 - 1650 (1670)	1219 - 1225 **1220**	1090-1110 **1100**	1120-1180 **1180**	975-1000 **980**	1045		950-960	1570	1375	1610 - 1670
Thin Reflector Band	2080	2190 - 2200	1620 - 1650 **1630**	1490-1510 **1500**	1530-1555 **1550**	1280-1300 **1300**	1420		1015-1030	1920 - 1935	1700-1715	
Top Oligocene HARS (pink)	**2170** - 2240	2300 - 2330	1705 - 1730 **1725**	1580-1600 **1590**	1635-1660 **1655**	1375-1390 **1375**	1480		1040-1060	1990 - 2020	1750-1755	1970 – 1995
Lower Eocene (orange)	**2450** - 2550	2610 - 2650	2150 - 2195 **2180**	1780-1800 **1790**	1920-1985 **1930**	1563-1700 **1565**	1680		1480-1490	2290 - 2325	1940-**1945** (2045-2055)	2490 – 2600
Basement (purple)	3070 - 3090 (3180-3290)	3160 - 3270	2590 - 3340 (3000)						1800-2000	2600 - 2620	2750-2770	3100 – 3200
Proposed Penetration	1225 mbsf	1300 mbsf	1185 mbsf (old:1180)	930 mbsf	1050 mbsf (old:1050)	800 mbsf (old: 970)	900 mbsf	Short Log 50 mbsf	740 mbsf	865 mbsf	750 mbsf	1250 mbsf
Proposed total (WD+seds)	2630 m	2750 m	2200 m (old:2200)	1800 m	1960 m (old:1950)	1600 m (old:1750)	1750 m	Short Log 940 m	1500 m	2315 m	2000 m	2580 m
Ranking	Alternate	Alternate	Alternate	Alternate	Alternate	Alternate	**Primary**	**Primary**	Alternate	Alternate	Alternate	Alternate

Table_with basic data of ArcOP sites. Depths: Overview over the expected drilling depth [m] for the main horizons at the proposed sites. Differences in depths result from the inaccuracies of velocity-models or ambiguous course of marker reflectors. The most likely depths are marked bold. The colours refer to coloured lines marking the horizons of interest in the seismic sections (see Figures for Form 6). At sites marked in yellow the target depth can be reached with total drill pipe length no longer than 2000 m.
As demanded, the locations of sites LR-04B and LR-10A were shifted to LR-04C and LR-10B, respectively. New or revised values are marked in green.

IODP Site Forms

Form 1 – General Site Information

708 - Add 3

Section A: Proposal Information

Proposal Title	Arctic Ocean Paleoceanography: Towards a Continuous Cenozoic Record from a Greenhouse to an Icehouse World (ArcOP)
Date Form Submitted	
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest-priority paleoceanographic objective, the continous long-term Cenozoic climate history of the central Arctic Ocean
List Previous Drilling in Area	IODP Expedition 302 (ACEX)

Section B: General Site Information

Site Name:	LR-11B	Area or Location:	southern Lomonosov Ridge
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 81.4365	Jurisdiction:	International waters
Longitude:	Deg: 140.8405	Distance to Land: (km)	640
Coordinate System:	WGS 84		
Priority of Site:	Primary: ✓ Alternate:	Water Depth (m):	794

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	900	0
Total Sediment Thickness (m)	900	
Total Penetration (m):	900	

General Lithologies: Silty clays, clays, biosiliceous ooze, siltstone, claystone; some ice-rafted debris

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: 22 | Logging: 2 | Total On-site: 24

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

Potential Hazards/ Weather:

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Preferred weather window: late August-September-early October
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: some sea ice

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 708 - Add 3	Site #: LR-11B	Date Form Submitted:

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: line AWI-20180310 Position: CDP 970
1b High resolution seismic seismic reflection (crossing)	yes	
2a Deep penetration seismic reflection (primary)	yes	
2b Deep penetration seismic reflection (crossing)	yes	
3 Seismic Velocity	yes	
4 Seismic Grid	yes	
5a Refraction (surface)		
5b Refraction (bottom)	yes	
6 3.5 kHz		
7 Swath bathymetry		
8a Side looking sonar (surface)		
8b Side looking sonar (bottom)		
9 Photography or video		
10 Heat Flow		
11a Magnetics		
11b Gravity		
12 Sediment cores		
13 Rock sampling		
14a Water current data		
14b Ice Conditions		
15 OBS microseismicity		
16 Navigation		
17 Other		

IODP Site Forms

Form 4 - Environmental Protection

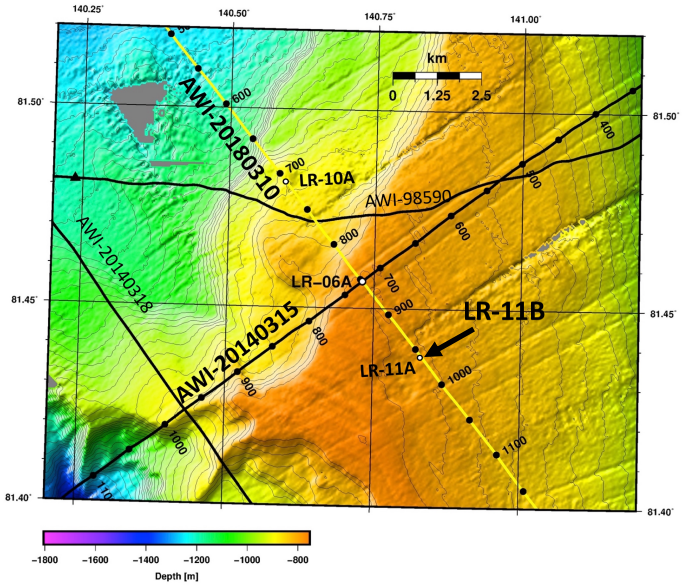
Proposal #: 708 - Add 3	Site #: LR-11B	Date Form Submitted:

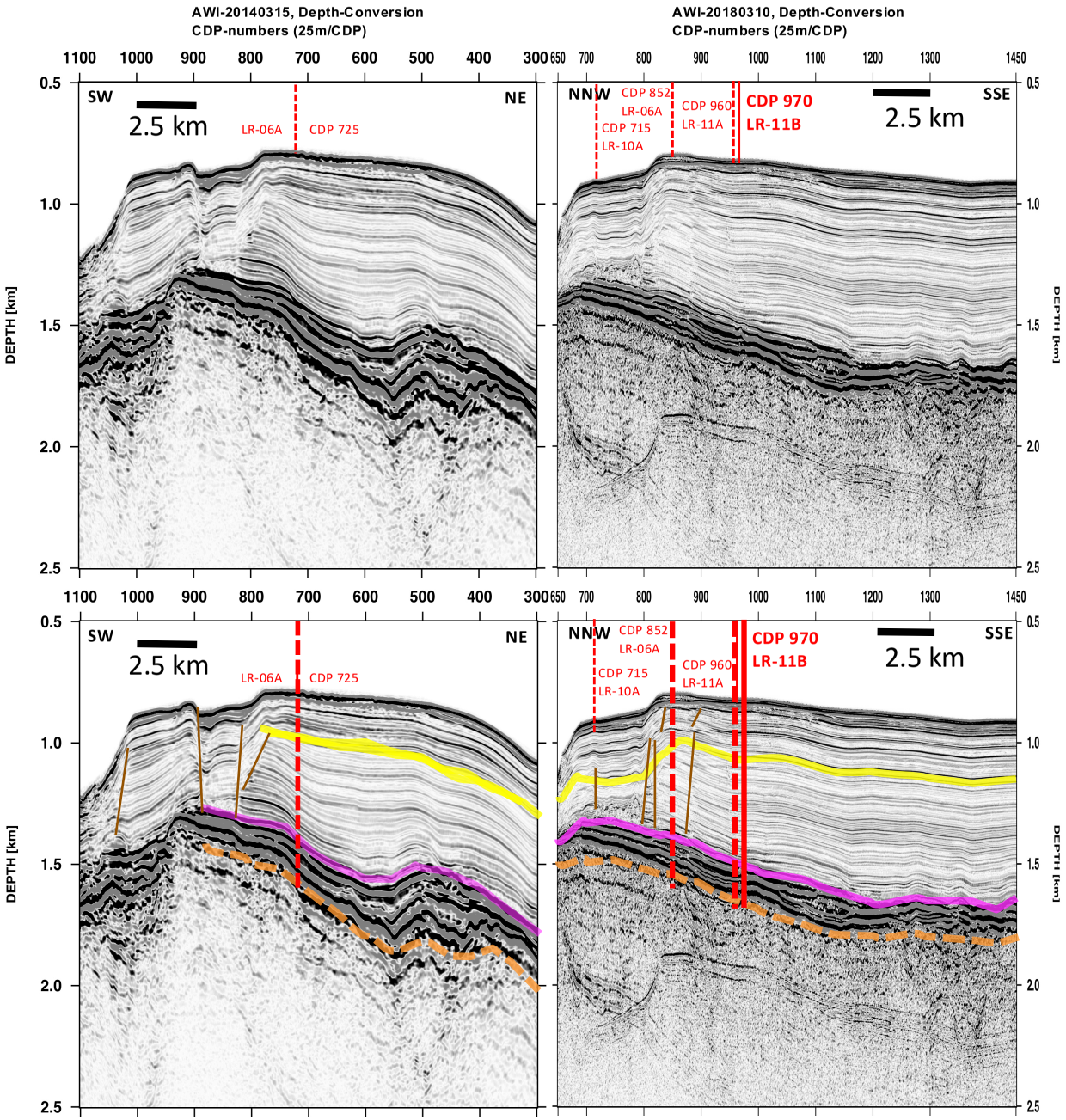
Pollution & Safety Hazard	Comment
1. Summary of operations at site	Triple/double APC to refusal, continued by XCB and RCB to final depth
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	N/A
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	N/A
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
7. What abandonment procedures need to be followed?	Ice management
8. Natural or manmade hazards which may affect ship's operations	No
9. Summary: What do you consider the major risks in drilling at this site?	sea ice conditions

Proposal #: 708 - Add 3	Site #: LR-11B	Date Form Submitted:

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 245	Yellow reflector	5.3	1.6	Silty Clay	pelagic	40	
245 - 680	Pink Reflector	223.8	2.2	Silty clay	pelagic	20	
680 - 880	Orange Reflector	54	2.2	Silte clay, biosiliceous ooze	pelagic, euxinic	10	

Site Summary Form 6: IODP Proposal 708 Site LR-11B





Site:	LR-11B	LR-11A
	CDP 970	CDP 960
Latitude:	81.4365°N	81.4381 °N
Longitude:	140.8405°E	140.8320°E
Water-depth:	800 m	815 m
Top Miocene (yellow):	245 mbsf	230 mbsf
Top Oligocene (pink):	680 mbsf	690 mbsf
Lower Eocene (orange):	880 mbsf	890 mbsf
Proposed Penetration:	900 mbsf	900 mbsf
Penetration total:	1750 m	1750 m

Remarks:

- Seismic images are depth converted migrations

SSDB locations of these graphics and supporting data:

- Figure: Form6-LR-11B_line_AWI-20180310.pdf
- Seismic-SEGY data: 20180310_migrate.segy, 20180310_depcon.segy
- Navigation data: 20180310_cdplocs.txt
- Bathymetry: LR-03A-11B_bathy2018_50m.grd
- Velocity information: Table_LR-11B_20180310_20140315.pdf
- Seismic subbottom profiles: LR-06A-10A-11B_20180310Parasound.segy, *.jpg

IODP Site Forms

Form 1 – General Site Information

708 - Add 3

Section A: Proposal Information

Proposal Title	Arctic Ocean Paleoceanography: Towards a Continuous Cenozoic Record from a Greenhouse to an Icehouse World (ArcOP)
Date Form Submitted	
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recovery of the undisturbed uppermost (Quaternary) sedimentary section
List Previous Drilling in Area	IODP Expedition 302 (ACEX)

Section B: General Site Information

Site Name:	LR-10B	Area or Location:	southern Lomonosov Ridge
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#		Jurisdiction:	International waters
Latitude:	Deg: 81.4836	Distance to Land: (km)	640
Longitude:	Deg: 140.5855		
Coordinate System:	WGS 84		
Priority of Site:	Primary: ✓ Alternate: ☐	Water Depth (m):	890

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	50	0
Total Sediment Thickness (m)	50	
Total Penetration (m):	50	

General Lithologies: Silty Clay

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: 1 | Logging: | Total On-site: 1

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

Potential Hazards/ Weather:

Shallow Gas ☐	Complicated Seabed Condition ☐	Hydrothermal Activity ☐	Preferred weather window: late August - September - early October
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: sea ice

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 708 - Add 3	Site #: LR-10B	Date Form Submitted:

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: AWI-20180310 Position: CDP700
1b High resolution seismic seismic reflection (crossing)	yes	
2a Deep penetration seismic reflection (primary)	yes	
2b Deep penetration seismic reflection (crossing)	yes	
3 Seismic Velocity		
4 Seismic Grid		
5a Refraction (surface)		
5b Refraction (bottom)		
6 3.5 kHz		
7 Swath bathymetry		
8a Side looking sonar (surface)		
8b Side looking sonar (bottom)		
9 Photography or video		
10 Heat Flow		
11a Magnetics		
11b Gravity		
12 Sediment cores		
13 Rock sampling		
14a Water current data		
14b Ice Conditions		
15 OBS microseismicity		
16 Navigation		
17 Other		

IODP Site Forms

Form 4 - Environmental Protection

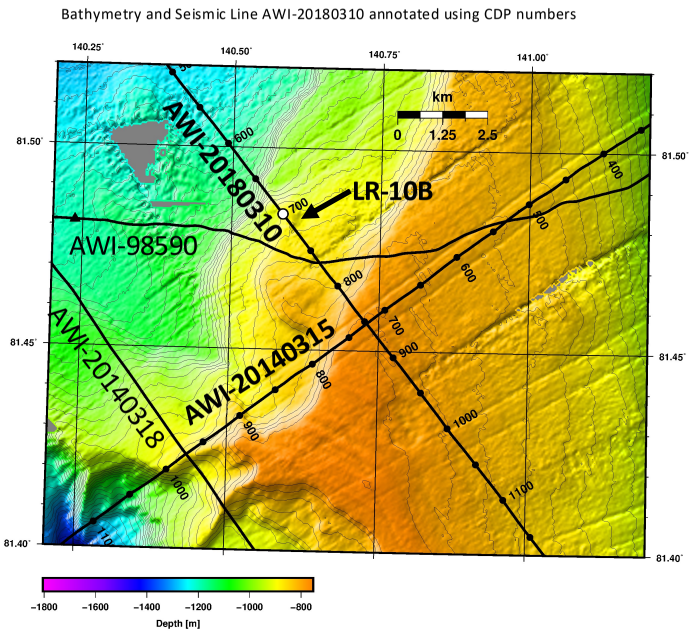
Proposal #: 708 - Add 3	Site #: LR-10B	Date Form Submitted:

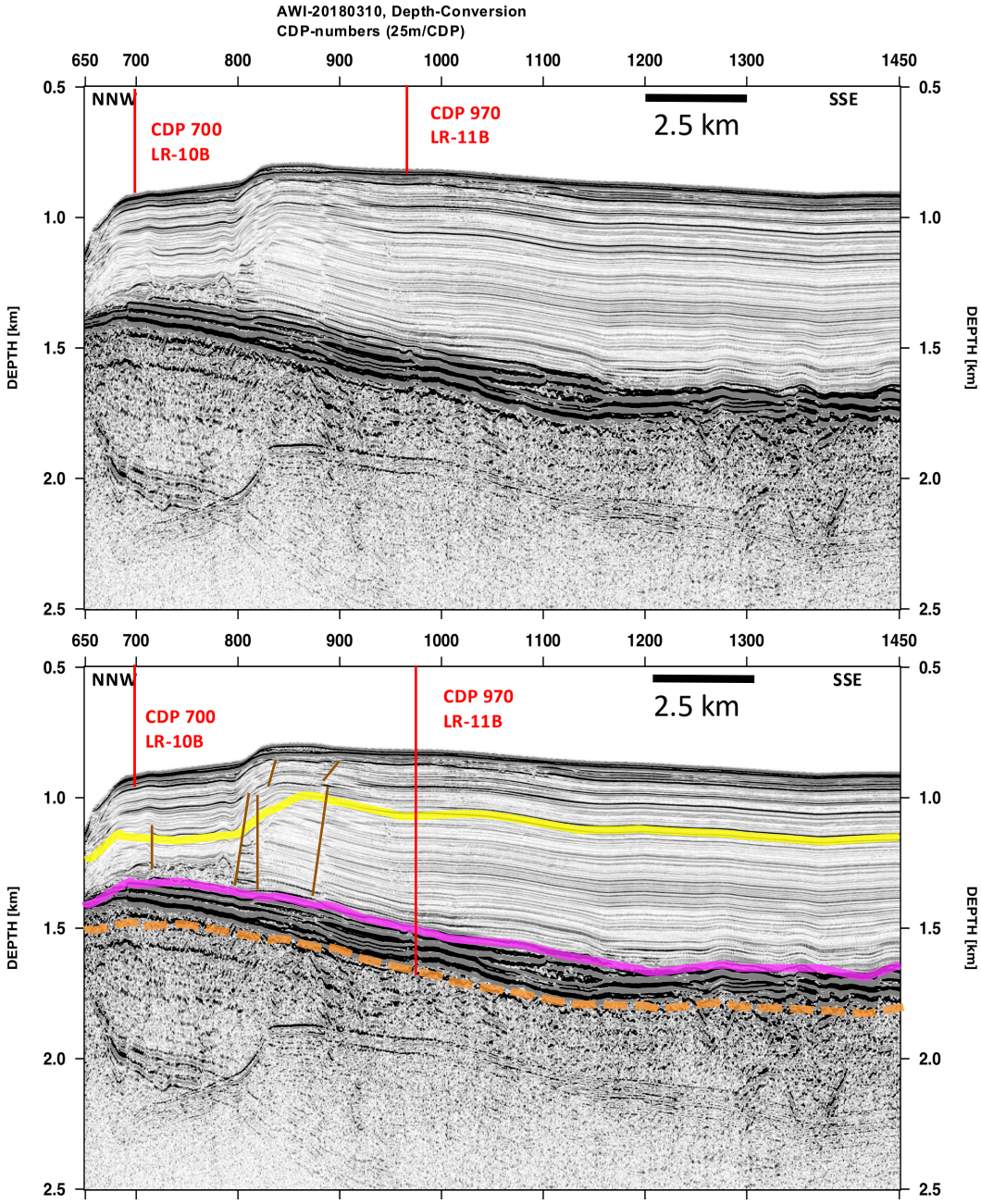
Pollution & Safety Hazard	Comment
1. Summary of operations at site	APC
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	N/A
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	N/A
4. Indications of gas hydrates at this location	No
5. Are there reasons to expect hydrocarbon accumulations at this site?	No
6. What "special" precautions will be taken during drilling?	sea ice
7. What abandonment procedures need to be followed?	Ice management
8. Natural or manmade hazards which may affect ship's operations	sea ice
9. Summary: What do you consider the major risks in drilling at this site?	sea ice conditions

Proposal #: 708 - Add 3	Site #: LR-10B	Date Form Submitted:

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 50	uppermost undisturbed sedimentary section	1	1.6	Silty clay	Pelagic	50	

Site Summary Form 6: IODP Proposal 708 Site LR-10B





Site: LR-10B, AWI-20180310, CDP 700
Latitude: 81.4836°N
Longitude: 140.5855°E
Water-depth: 890 m

Proposed Penetration: 50 mbsf
Total depth (Water + Sed.): 940 m

Remarks:

- Seismic images are depth converted migrations

SSDB locations of these graphics and supporting data:

- Figure: Form6-LR-10B_line_AWI-20180310.pdf
- Seismic-SEGY data: 20180310_migrate.segy, 20180310_depcon.segy
- Navigation data: 20180310_cdplocs.txt
- Bathymetry: LR-03A-11B_bathy2018_50m.grd
- Seismic subbottom profiles:
  LR-06A-10A-11B_20180310Parasound.segy,
  LR-10B-11B_20180310Parasound.jpg

IODP Site Forms

Form 1 – General Site Information

708 - Add 3

Section A: Proposal Information

Proposal Title	Arctic Ocean Paleoceanography: Towards a Continuous Cenozoic Record from a Greenhouse to an Icehouse World (ArcOP)
Date Form Submitted	
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continuous long-term Cenozoic climate history of the central Arctic Ocean (Alternate site)
List Previous Drilling in Area	IODP Expedition 302 (ACEX)

Section B: General Site Information

Site Name:	LR-01A	Area or Location:	Southern Lomonosov Ridge
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 80.9502	Jurisdiction:	International waters
Longitude:	Deg: 142.9717	Distance to Land: (km)	590
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ✓	Water Depth (m):	1402

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1225	0
Total Sediment Thickness (m)	1225	
Total Penetration (m):	1225	

General Lithologies: Silty clays, clays, biosiliceous ooze; siltsone, claystone; some ice-rafted debris

Coring Plan: (Specify or check): one primary drill site with three APC/XCB/RCB holes down to about 1225 mbsf to recover multiple sections of the sediment sequence to ensure complete recovery for construction of a composite section (Primary site)

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: 22 | Logging: 2 | Total On-site: 24

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

Potential Hazards/ Weather:

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Preferred weather window	
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	August-September (time interval of minimum ice conditions)	
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 #: 708 - Add 3	Site #: LR-01A	Date Form Submitted:

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	Line: line AWI-20080160 Position: CDP 475 Additional high-resolution seismic reflection, line AWI-98597 (CDP 184)
1b High resolution seismic seismic reflection (crossing)	yes	Line: line AWI-20140307 Position: CDP 933 Additional high-resolution seismic reflection, line AWI-98597 (CDP 184)
2a Deep penetration seismic reflection (primary)		
2b Deep penetration seismic reflection (crossing)		
3 Seismic Velocity		
4 Seismic Grid		
5a Refraction (surface)		
5b Refraction (bottom)		
6 3.5 kHz	no	Parasound profile
7 Swath bathymetry	no	Hydrosweep profile
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video		
10 Heat Flow		
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	Numerous sediment cores from Polarstern expeditions 1995 and 2008
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	no	Navigation data for seismic lines AWI-20080160, AWI-20140307 and AWI-98597 exist
17 Other		

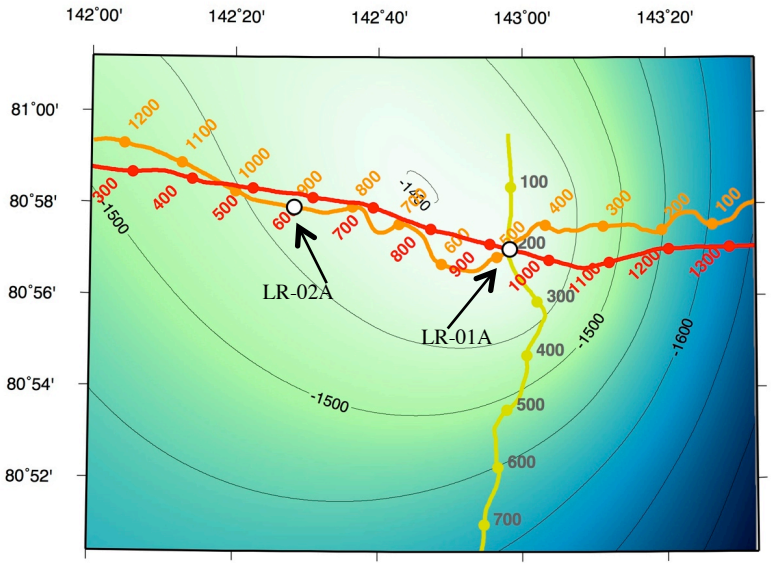
Proposal #: 708 - Add 3	Site #: LR-01A	Date Form Submitted:

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Triple APC to refusal, continued by XCB and RCB to final depth
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	N/A
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	N/A
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?	Ice management
7. What abandonment procedures need to be followed?	support by an icebreaker (e.g., RV Polarstern)
8. Natural or manmade hazards which may affect ship's operations	ice
9. Summary: What do you consider the major risks in drilling at this site?	ice could delay operations

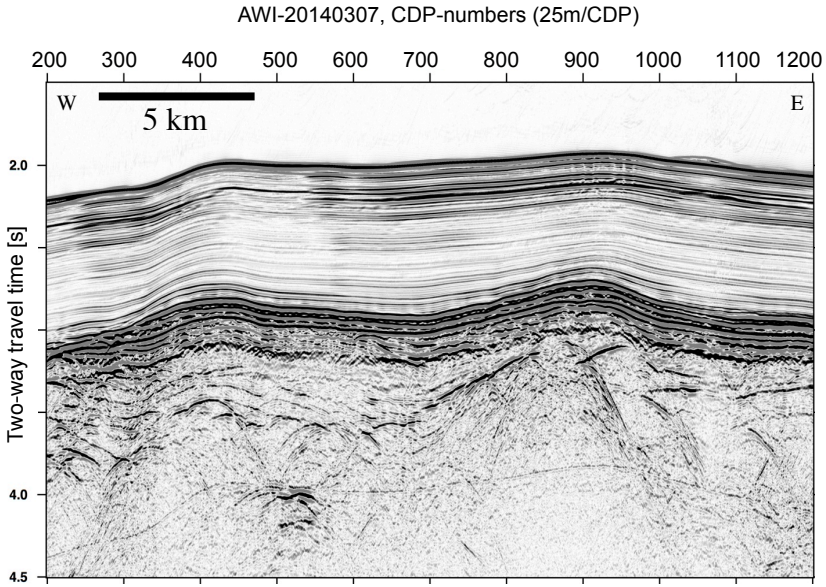
Proposal #: 708 - Add 3	Site #: LR-01A	Date Form Submitted:

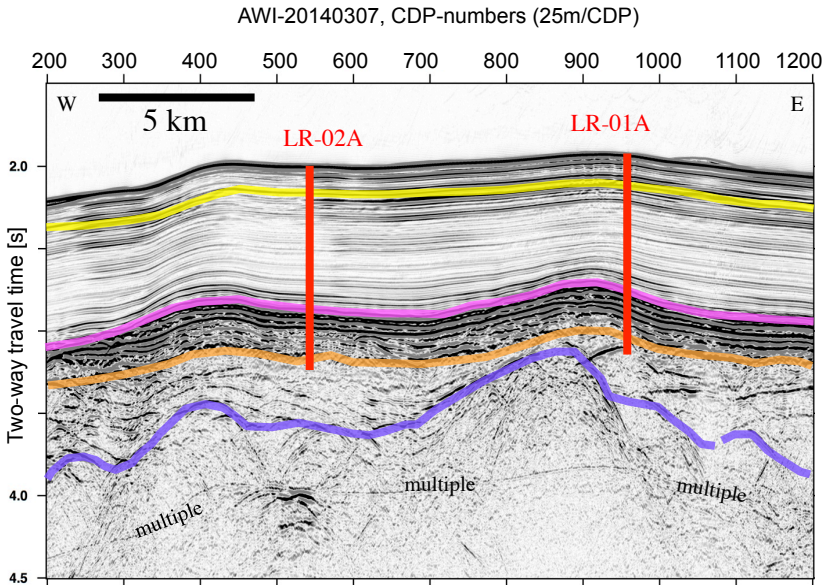
Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 170	Reflector "yellow"	5.3	1.6	silty clay	pelagic	32	
170 - 800	Reflector "pink"	23.8	2.2	silty clay	pelagic	34	
800 - 1029	Reflector "orange"	54	3.4	silty clay, biosiliceous ooze	pelagic	7	
1029 - 1879	Reflector "purple"	?65	5	Slity clay, clay-/ siltstones	(hemi-) pelagic		

IODP Proposal 708 Sites LR-01A and LR-02A



Profiles AWI-98597 (yellow), AWI-20080160 (orange), and AWI-20140307 (red) annotated using CDP numbers





Site:	LR-01A	LR-02A
Latitude:	80.95 °N	80.97 °N
Longitude:	142.97 °E	142.47 °E
Water-depth:	1405 m	1454 m
Top Miocene (yellow):	170 mbsf	218 mbsf
Top Oligocene (pink):	800 mbsf	920 mbsf
Lower Eocene (orange):	1029 mbsf	1211 mbsf
Basement (purple):	1879 mbsf	1882 mbsf
Penetration total:	1225 m	1300 m

SSDB locations of these graphics and supporting data:

-Location map: LR-01A_LR-02A_map.pdf
-Seismic figures: LR-01A_LR-02A_AWI-20140307.pdf
-SEGY data: AWI-20140307stack.sgy
-Navigation data: 20140307_cdplocs.asc

Fig. 6. Enlarged section of line AWI-20140307. Red bars show the location of the proposed drilling sites LR-01A and LR-02A. Coloured lines mark horizons of interest (yellow: top Miocene, pink: top Oligocene, orange: Lower Eocene, purple: acoustic basement).

IODP Site Forms

Form 1 – General Site Information

708 - Add 3

Section A: Proposal Information

Proposal Title	Arctic Ocean Paleoceanography: Towards a Continuous Cenozoic Record from a Greenhouse to an Icehouse World (ArcOP)
Date Form Submitted	
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continous long-term Cenozoic climate history of the central Arctic Ocean (Alternate Site)
List Previous Drilling in Area	IODP Expedition 302 (ACEX)

Section B: General Site Information

Site Name:	LR-02A	Area or Location:	Southern Lomonosov Ridge
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 80.9650	Jurisdiction:	International waters
Longitude:	Deg: 142.4717	Distance to Land: (km)	590
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	1458

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1300	0
Total Sediment Thickness (m)	2150	
Total Penetration (m):	1300	

General Lithologies: Silty clay, clay, biosiliceous ooze; siltstone, claystone; some ice-rafted debris | 0

Coring Plan: (Specify or check): one drill site with three APC/XCB/RCB holes down to about 1300 mbsf to recover multiple sections of the sediment sequence to ensure complete recovery for construction of a composite section (Alternate Site)

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: 22 | Logging: 2 | Total On-site: 24

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

Potential Hazards/ Weather:

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Preferred weather window: August-September (time interval of minimum ice extent)
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 #: 708 - Add 3	Site #: LR-02A	Date Form Submitted:

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: line AWI-20080160 Position: CDP 900 Site location close to crossing point AWI-20080160 and AWI-98597
1b High resolution seismic seismic reflection (crossing)	yes	Line: line AWI-20140307 Position: CDP 567 Site location close to crossing point AWI-20080160 and AWI-98597
2a Deep penetration seismic reflection (primary)	no	
2b Deep penetration seismic reflection (crossing)	no	
3 Seismic Velocity	no	
4 Seismic Grid	no	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	Parasound profile
7 Swath bathymetry	no	Hydrosweep profile
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores		Numerous sediment cores from Polarstern expeditions 1995 and 2008
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	seasonal sea ice
15 OBS microseismicity	no	
16 Navigation	no	
17 Other	no	

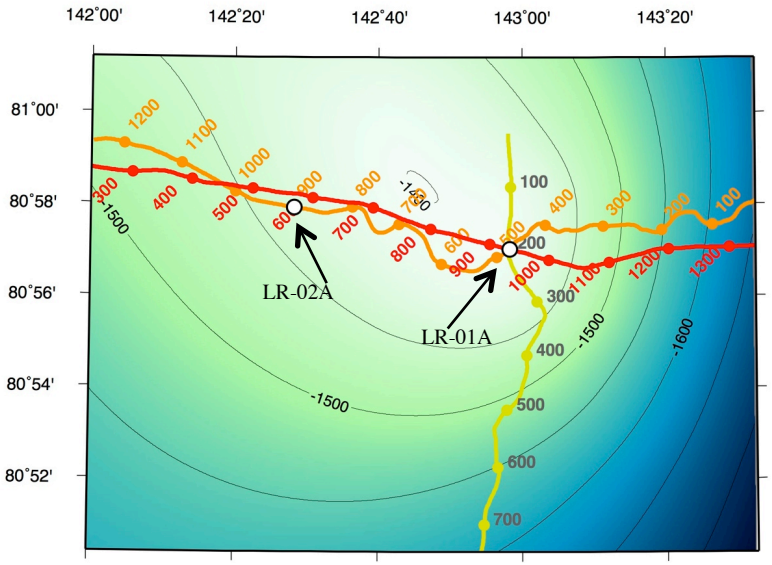
Proposal #: 708 - Add 3	Site #: LR-02A	Date Form Submitted:

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Triple APC to refusal, continued by XCB and RCB to final depth
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	N/A
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	N/A
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?	ice management
7. What abandonment procedures need to be followed?	Support by an icebreaker (e.g., RV Polarstern)
8. Natural or manmade hazards which may affect ship's operations	ice
9. Summary: What do you consider the major risks in drilling at this site?	ice could delay operations

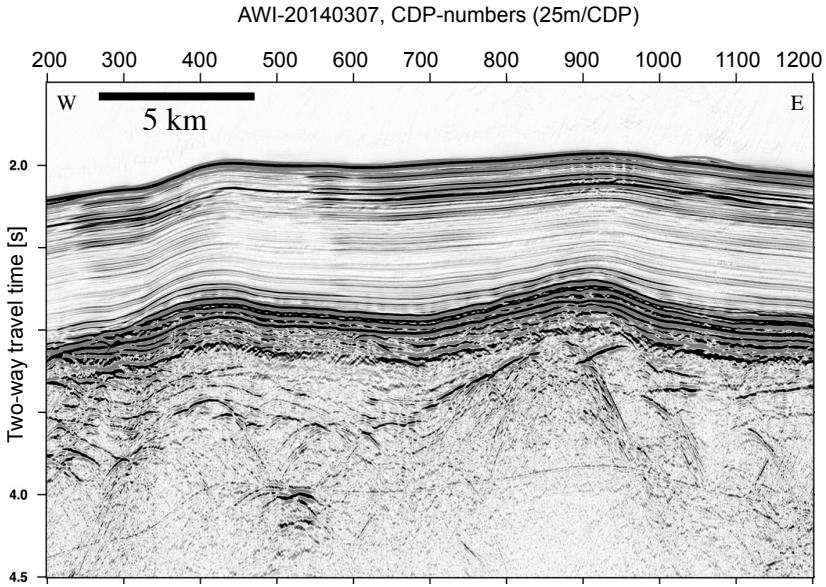
Proposal #: 708 - Add 3	Site #: LR-02A	Date Form Submitted:

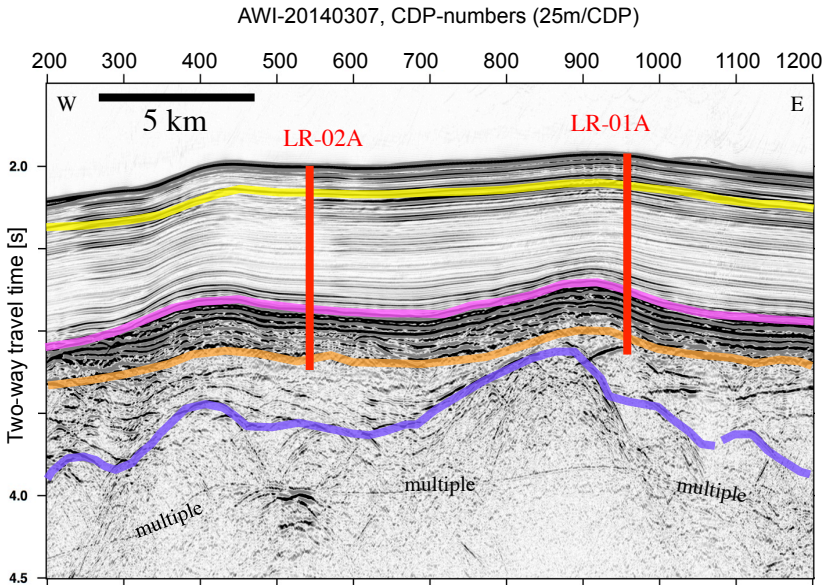
Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 218	Reflector "yellow"	5.3	1.6	silty clay	pelagic	41	
218 - 920	Reflector "pink"	23.8	2.2	silty clay	pelagic	38	
920 - 1211	Reflector "orange"	54	3.4	silty clay, biosiliceous ooze	pelagic	9	

IODP Proposal 708 Sites LR-01A and LR-02A



Profiles AWI-98597 (yellow), AWI-20080160 (orange), and AWI-20140307 (red) annotated using CDP numbers





Site:	LR-01A	LR-02A
Latitude:	80.95 °N	80.97 °N
Longitude:	142.97 °E	142.47 °E
Water-depth:	1405 m	1454 m
Top Miocene (yellow):	170 mbsf	218 mbsf
Top Oligocene (pink):	800 mbsf	920 mbsf
Lower Eocene (orange):	1029 mbsf	1211 mbsf
Basement (purple):	1879 mbsf	1882 mbsf
Penetration total:	1225 m	1300 m

SSDB locations of these graphics and supporting data:

-Location map: LR-01A_LR-02A_map.pdf
-Seismic figures: LR-01A_LR-02A_AWI-20140307.pdf
-SEGY data: AWI-20140307stack.sgy
-Navigation data: 20140307_cdplocs.asc

Fig. 6. Enlarged section of line AWI-20140307. Red bars show the location of the proposed drilling sites LR-01A and LR-02A. Coloured lines mark horizons of interest (yellow: top Miocene, pink: top Oligocene, orange: Lower Eocene, purple: acoustic basement).

IODP Site Forms

Form 1 – General Site Information

708 - Add 3

Section A: Proposal Information

Proposal Title	Arctic Ocean Paleoceanography: Towards a Continuous Cenozoic Record from a Greenhouse to an Icehouse World (ArcOP)
Date Form Submitted	
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continuous long-term Cenozoic climate history of the central Arctic Ocean (Alternate site)
List Previous Drilling in Area	IODP Expedition 302 (ACEX)

Section B: General Site Information

Site Name:	LR-03A	Area or Location:	southern Lomonosov Ridge
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 81.1825	Jurisdiction:	international waters
Longitude:	Deg: 142.0918	Distance to Land: (km)	610
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	1013

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1180	0
Total Sediment Thickness (m)	1180	
Total Penetration (m):	1180	

General Lithologies: Silty clays, clays, biosiliceous ooze; siltsone, claystone; some ice-rafted debris

Coring Plan: (Specify or check): one drill site with three APC/XCB/RCB holes down to about 1180 mbsf to recover multiple sections of the sediment sequence to ensure complete recovery for construction of a composite section (Alternate site)

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: 22 | Logging: 2 | Total On-site: 24

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

Potential Hazards/ Weather:

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Preferred weather window	
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	August-September (time interval of minimum ice extent)	
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 #: 708 - Add 3	Site #: LR-03A	Date Form Submitted:

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: line AWI-20140310 Position: CDP 600 Additional high-resolution seismic reflection closeby, line AWI-20140313
1b High resolution seismic seismic reflection (crossing)		
2a Deep penetration seismic reflection (primary)		
2b Deep penetration seismic reflection (crossing)		
3 Seismic Velocity		
4 Seismic Grid		
5a Refraction (surface)		
5b Refraction (bottom)		
6 3.5 kHz	yes	Parasound
7 Swath bathymetry	yes	Hydrosweep profile
8a Side looking sonar (surface)		
8b Side looking sonar (bottom)		
9 Photography or video		
10 Heat Flow		
11a Magnetics		
11b Gravity		
12 Sediment cores		
13 Rock sampling		
14a Water current data		
14b Ice Conditions		
15 OBS microseismicity		
16 Navigation		Navigation data for seismic lines AWI-20140310 exist
17 Other		

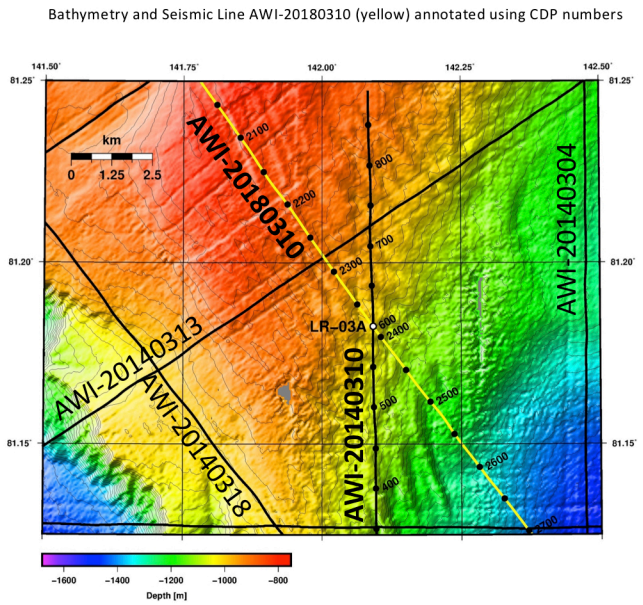
Proposal #: 708 - Add 3	Site #: LR-03A	Date Form Submitted:

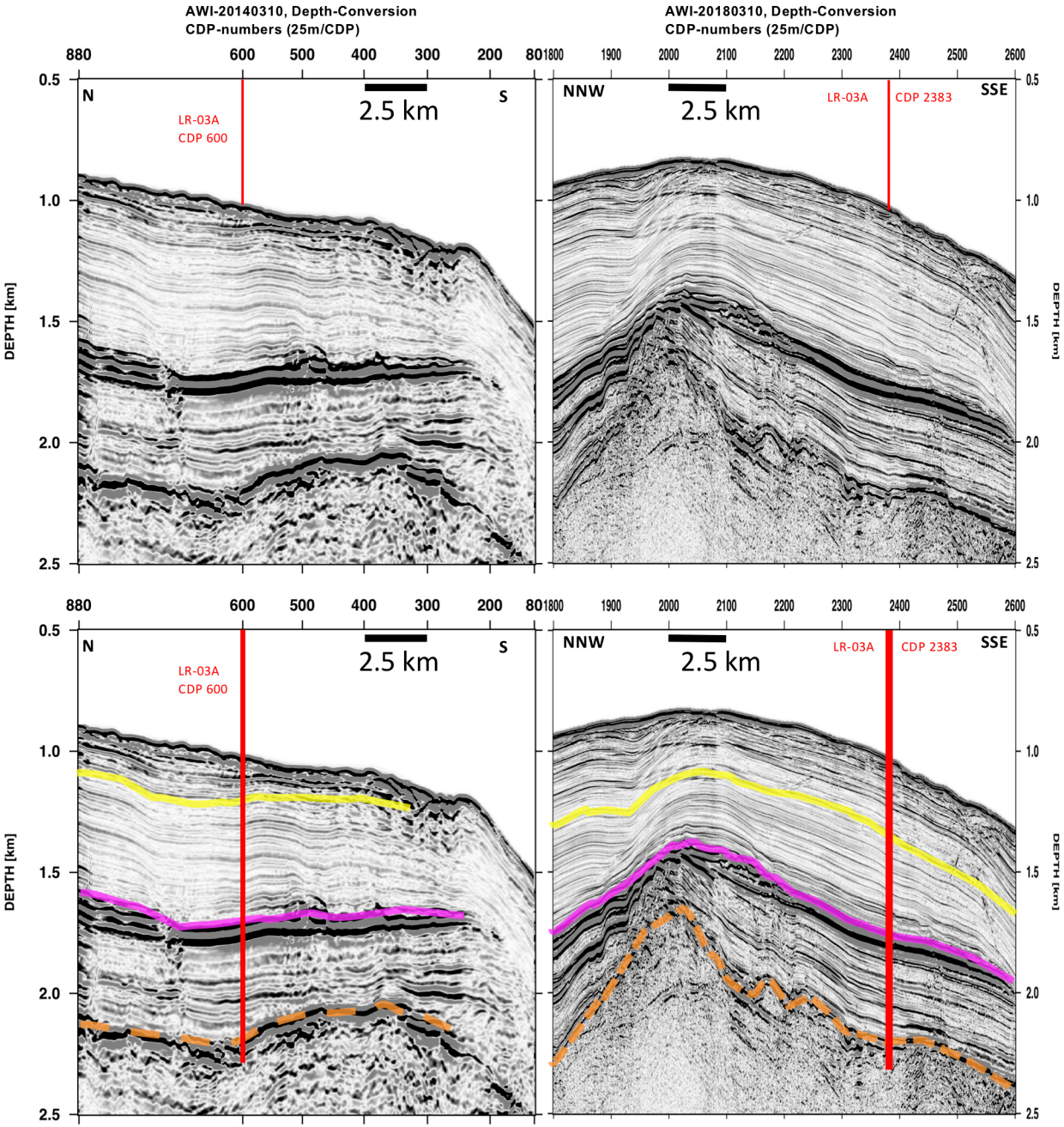
Pollution & Safety Hazard	Comment
1. Summary of operations at site	
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	
4. Indications of gas hydrates at this location	
5. Are there reasons to expect hydrocarbon accumulations at this site?	
6. What "special" precautions will be taken during drilling?	
7. What abandonment procedures need to be followed?	
8. Natural or manmade hazards which may affect ship's operations	
9. Summary: What do you consider the major risks in drilling at this site?	

Proposal #: 708 - Add 3	Site #: LR-03A	Date Form Submitted:

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	Reflector "yellow"	5.3	1.6	Silty clay		36	
190 - 690	Reflector "pink"	23.8	2.2	Silty clay		27	
690 - 1140	Reflector "orange"	54	2.6	Silty clay, biosiliceous ooze		14	

Site Summary Form 6: IODP Proposal 708 Site LR-03A





Site: LR-03A
Latitude: 81.1825 °N
Longitude: 142.0912 °E

Water-depth: 1015 m
Top Miocene (yellow): 205 mbsf
Top Oligocene (pink): 710 mbsf
Lower Eocene (orange): 1165 mbsf

Proposed Penetration: 1185 mbsf
Penetration total: 2200 m

Remarks:

- Seismic images are depth converted migrations

SSDB locations of these graphics and supporting data:

- Figure: LR-03A_line_AWI-20180310.pdf
- Seismic-SEGY data: 20180310_migrate.seg, 20180310_depcon.segy
- Navigation data: 20180310_cdplocs.txt
- Bathymetry: LR-03A-06A_bathy2018_50m.grd
- Velocity information: 20180310_vt_LR-03A.pdf
- Seismic subbottom profiles: LR-03A-20180310para.sgy, -"-.txt

IODP Site Forms

Form 1 – General Site Information

708 - Add 3

Section A: Proposal Information

Proposal Title	Arctic Ocean Paleoceanography: Towards a Continuous Cenozoic Record from a Greenhouse to an Icehouse World (ArcOP)
Date Form Submitted	
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continuous long-term Cenozoic climate history of the central Arctic Ocean (Alternate site)
List Previous Drilling in Area	IODP Expedition 302 (ACEX)

Section B: General Site Information

Site Name:	LR-04C	Area or Location:	southern Lomonosov Ridge
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 81.3531	Jurisdiction:	international waters
Longitude:	Deg: 141.2484	Distance to Land: (km)	620
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ✓	Water Depth (m):	875

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	930	0
Total Sediment Thickness (m)	930	
Total Penetration (m):	930	

General Lithologies: Silty clays, clays, biosiliceous ooze; siltsone, claystone; some ice-rafted debris

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: 22 | Logging: 2 | Total On-site: 24

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

one drill site with three APC/XCB/RCB holes down to about 930 mbsf to recover multiple sections of the sediment sequence to ensure complete recovery for construction of a composite section (Alternate site)

Potential Hazards/ Weather:

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Preferred weather window	
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	August-September (time interval of minimum ice extent)	
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:

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 708 - Add 3	Site #: LR-04C	Date Form Submitted:

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: line AWI-20180350 Position: CDP 5230
1b High resolution seismic seismic reflection (crossing)	yes	Line: line AWI-20140298 Position: CDP 5260
2a Deep penetration seismic reflection (primary)		
2b Deep penetration seismic reflection (crossing)		
3 Seismic Velocity		
4 Seismic Grid		
5a Refraction (surface)		
5b Refraction (bottom)		
6 3.5 kHz		Parasound profile
7 Swath bathymetry		Hydrosweep profile
8a Side looking sonar (surface)		
8b Side looking sonar (bottom)		
9 Photography or video		
10 Heat Flow		
11a Magnetics		
11b Gravity		
12 Sediment cores		
13 Rock sampling		
14a Water current data		
14b Ice Conditions		
15 OBS microseismicity		
16 Navigation		Navigation data for seismic lines AWI-20140318 exist
17 Other		

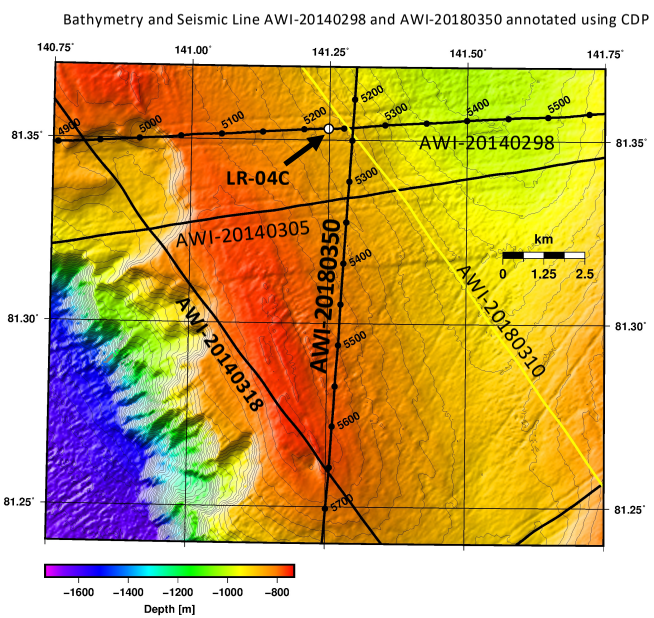
Proposal #: 708 - Add 3	Site #: LR-04C	Date Form Submitted:

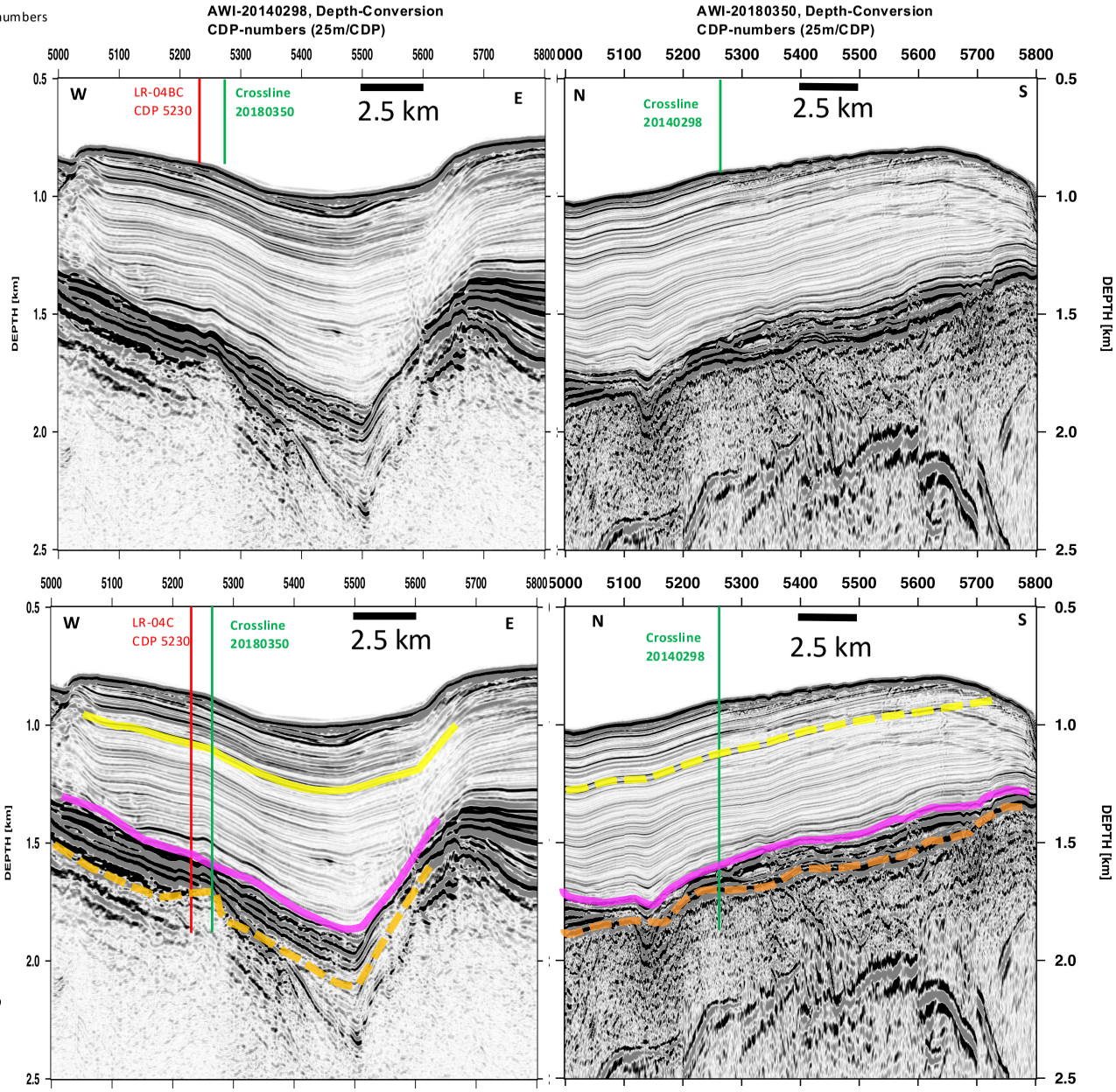
Pollution & Safety Hazard	Comment
1. Summary of operations at site	Triple APC to refusal, continued by XCB and RCB to final depth
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	N/A
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	N/A
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?	Ice management
7. What abandonment procedures need to be followed?	Support by an icebreaker (e.g., Polarstern)
8. Natural or manmade hazards which may affect ship's operations	Ice
9. Summary: What do you consider the major risks in drilling at this site?	ice could delay operations

Proposal #: 708 - Add 3	Site #: LR-04C	Date Form Submitted:

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 240	Reflector "yellow"	5.3	1.6	Silty clay	pelagic	12	
240 - 640	Reflector "pink"	23.8	2.1	Silty clay	pelagic	19	
640 - 730	Reflector "orange"	54	2.1	Silty clay, biosiliceous ooze	pelagic	12	

Site Summary Form 6: IODP Proposal 708 Site LR-04C





Site: LR-04C, AWI-20140298, CDP 5230
Latitude: 81.3531 °N
Longitude: 141.2484 °E

Water-depth: 875 m
Top Miocene (yellow): 240 mbsf
Top Oligocene (pink): 640 mbsf
Lower Eocene (orange): 730 mbsf

Proposed Penetration: 930 mbsf
Total depth (Water + Sed.): 1800 m

Remarks:

- Seismic images are depth converted migrations

SSDB locations of these graphics and supporting data:

- Figure: Form6_LR-04C_line_AWI-20140298.pdf
- Seismic-SEGY data: 20180350_migrate_revised.segy
  20180350_depcon_revised.segy
  20140298_migrate.segy, 20140298_depcon.segy
- Navigation data: 20180350_cdplocs.txt, 20140298_cdplocs.txt
- Bathymetry: LR-03A-11B_bathy2018_50m.grd
- Velocity information: Table_LR-04C_20180350_20140298.doc
- Seismic subbottom profiles:
  LR-04C_20140298Parasound.segy, *.jpg

IODP Site Forms

Form 1 – General Site Information

708 - Add 3

Section A: Proposal Information

Proposal Title	Arctic Ocean Paleoceanography: Towards a Continuous Cenozoic Record from a Greenhouse to an Icehouse World (ArcOP)
Date Form Submitted	
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continuous long-term Cenozoic climate history of the central Arctic Ocean (Alternate site)
List Previous Drilling in Area	IODP Expedition 302 (ACEX)

Section B: General Site Information

Site Name:	LR-05B	Area or Location:	southern Lomonosov Ridge
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 81.3256	Jurisdiction:	international waters
Longitude:	Deg: 141.4248	Distance to Land: (km)	630
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	906

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1050	0
Total Sediment Thickness (m)	1050	
Total Penetration (m):	1050	

General Lithologies: Silty clays, clays, biosiliceous ooze; siltsone, claystone; some ice-rafted debris

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: 22 | Logging: 2 | Total On-site: 24

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

one drill site with three APC/XCB/RCB holes down to about 1150 mbsf to recover multiple sections of the sediment sequence to ensure complete recovery for construction of a composite section (Alternate site)

Potential Hazards/ Weather:

Shallow Gas ☐	Complicated Seabed Condition ☐	Hydrothermal Activity ☐	Preferred weather window: August-September (time interval of minimum ice extent)
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 #: 708 - Add 3	Site #: LR-05B	Date Form Submitted:

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: line AWI-20180310 Position: CDP 1600 Additional high-resolution seismic reflection closeby, line AWI-20140298
1b High resolution seismic seismic reflection (crossing)		
2a Deep penetration seismic reflection (primary)		
2b Deep penetration seismic reflection (crossing)		
3 Seismic Velocity		
4 Seismic Grid		
5a Refraction (surface)		
5b Refraction (bottom)		
6 3.5 kHz		Parasound profile
7 Swath bathymetry		Hydrosweep profile
8a Side looking sonar (surface)		
8b Side looking sonar (bottom)		
9 Photography or video		
10 Heat Flow		
11a Magnetics		
11b Gravity		
12 Sediment cores		
13 Rock sampling		
14a Water current data		
14b Ice Conditions		
15 OBS microseismicity		
16 Navigation		Navigation data for seismic lines AWI-20140305 exist
17 Other		

Proposal #: 708 - Add 3	Site #: LR-05B	Date Form Submitted:

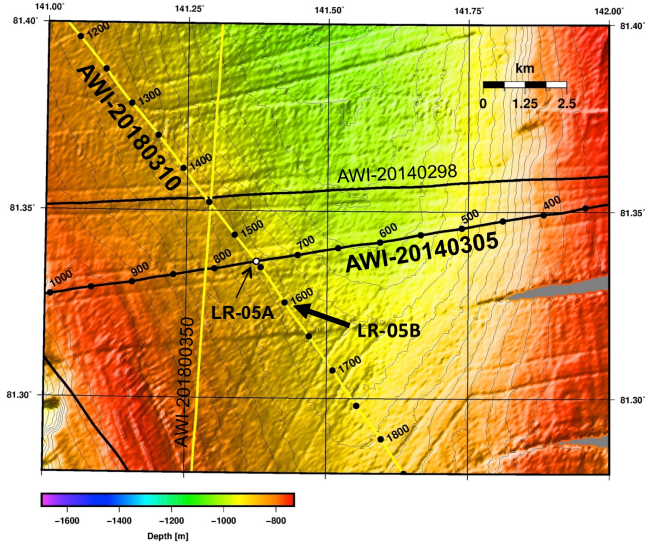
Pollution & Safety Hazard	Comment
1. Summary of operations at site	Triple APC to refusal, continued by XCB and RCB to final depth
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	N/A
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	N/A
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?	Ice management
7. What abandonment procedures need to be followed?	Support by an icebreaker (e.g., Polarstern)
8. Natural or manmade hazards which may affect ship's operations	Ice
9. Summary: What do you consider the major risks in drilling at this site?	ice could delay operations

Proposal #: 708 - Add 3	Site #: LR-05B	Date Form Submitted:

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 270	Reflector "yellow"	5.3	1.6	Silty clay	pelagic	44	
270 - 745	Reflector "pink"	23.8	2.3	Silty clay	pelagic	28	
745 - 1020	Reflector "orange"	54	2.4	Silty clay, biosiliceous ooze	pelagic	13	

Site Summary Form 6: IODP Proposal 708 Site LR-05B

Bathymetry and Seismic Line AWI-20180310 (yellow) annotated using CDP numbers



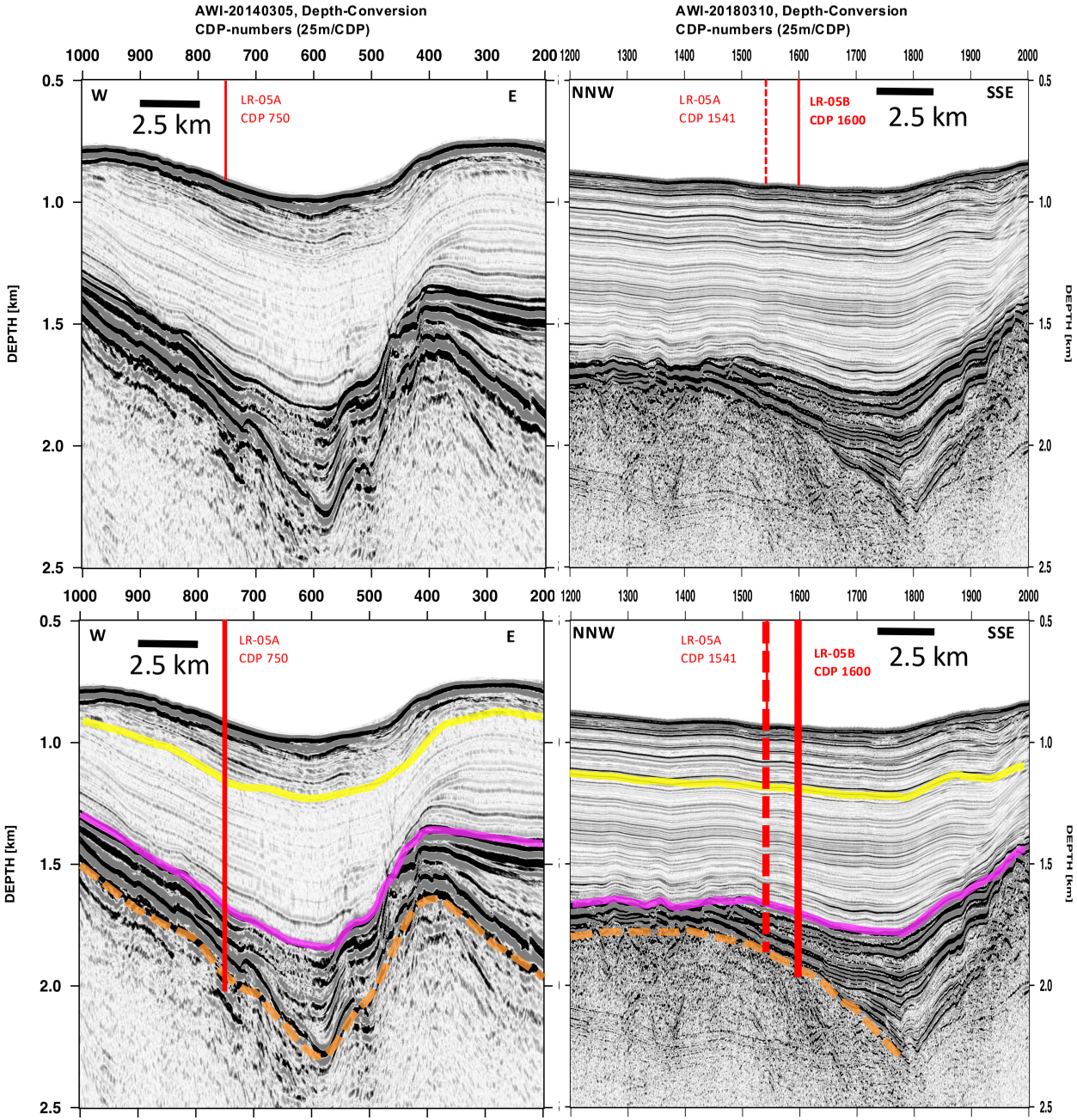
Site:	LR-05B	LR-05A
	CDP 1600	CDP 1541
Latitude:	81.3256 °N	81.3365 °N
Longitude:	141.4248 °E	141.3738 °E
Water-depth:	910 m	900 m
Top Miocene (yellow):	270 mbsf	275 mbsf
Top Oligocene (pink):	745 mbsf	750 mbsf
Lower Eocene (orange):	1020 mbsf	1020 mbsf
Proposed Penetration:	1050 mbsf	1050 mbsf
Penetration total:	1960 m	1950 mbsf

Remarks:

- Seismic images are depth converted migrations

SSDB locations of these graphics and supporting data:

- Figure: Form6-LR-05B_line_AWI-20180310.pdf
- Seismic-SEGY data: 20180310_migrate.seg, 20180310_depcon.segy
- Navigation data: 20180310_cdplocs.txt
- Bathymetry: LR-03A-11B_bathy2018_50m.grd
- Velocity information: Table_LR-05B_20180310-20140305.pdf
- Seismic subbottom profiles: LR-03A-04B-05B_20180310Parasound.segy, *.jpg



IODP Site Forms

Form 1 – General Site Information

708 - Add 3

Section A: Proposal Information

Proposal Title	Arctic Ocean Paleoceanography: Towards a Continuous Cenozoic Record from a Greenhouse to an Icehouse World (ArcOP)
Date Form Submitted	
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continuous long-term Cenozoic climate history of the central Arctic Ocean (Alternate site)
List Previous Drilling in Area	IODP Expedition 302 (ACEX)

Section B: General Site Information

Site Name:	LR-06A	Area or Location:	southern Lomonosov Ridge
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 81.4568	Jurisdiction:	international waters
Longitude:	Deg: 140.7299	Distance to Land: (km)	640
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	779

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	970	0
Total Sediment Thickness (m)	970	
Total Penetration (m):	970	

General Lithologies: Silty clays, clays, biosiliceous ooze; siltsone, claystone; some ice-rafted debris

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: 22 | Logging: 2 | Total On-site: 24

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

one drill site with three APC/XCB/RCB holes down to about 970 mbsf to recover multiple sections of the sediment sequence to ensure complete recovery for construction of a composite section (Alternate site)

Potential Hazards/ Weather:

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Preferred weather window: August-September (time interval of minimum ice extent)
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:

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 708 - Add 3	Site #: LR-06A	Date Form Submitted:

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: line AWI-20140315 Position: CDP 725 Additional high-resolution seismic reflection closeby, line AWI-20140318
1b High resolution seismic seismic reflection (crossing)		
2a Deep penetration seismic reflection (primary)		
2b Deep penetration seismic reflection (crossing)		
3 Seismic Velocity		
4 Seismic Grid		
5a Refraction (surface)		
5b Refraction (bottom)		
6 3.5 kHz		Parasound profile
7 Swath bathymetry		Hydrosweep profile
8a Side looking sonar (surface)		
8b Side looking sonar (bottom)		
9 Photography or video		
10 Heat Flow		
11a Magnetics		
11b Gravity		
12 Sediment cores		
13 Rock sampling		
14a Water current data		
14b Ice Conditions		
15 OBS microseismicity		
16 Navigation		Navigation data for seismic lines AWI-20140315 exist
17 Other		

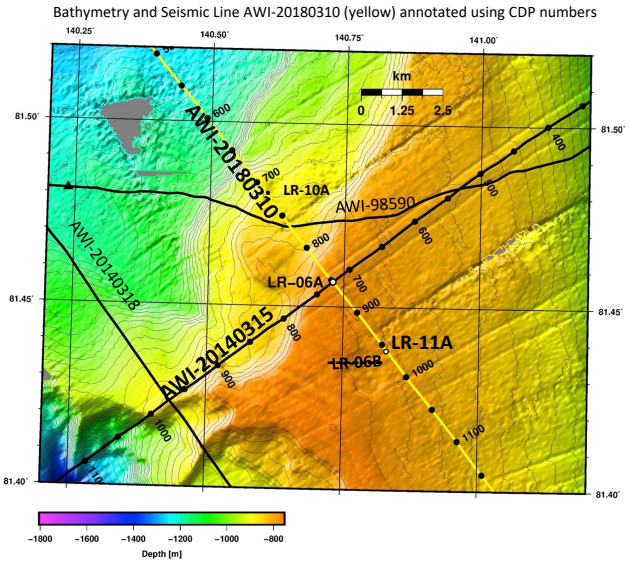
Proposal #: 708 - Add 3	Site #: LR-06A	Date Form Submitted:

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Triple APC to refusal, continued by XCB and RCB to final depth
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	N/A
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	N/A
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?	Ice management
7. What abandonment procedures need to be followed?	Support by an icebreaker (e.g., Polarstern)
8. Natural or manmade hazards which may affect ship's operations	Ice
9. Summary: What do you consider the major risks in drilling at this site?	ice could delay operations

Proposal #: 708 - Add 3	Site #: LR-06A	Date Form Submitted:

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 220	Reflector "yellow"	5.3	1.6	Silty clay		42	
220 - 610		23.8	2.2	Silty clay		21	
610 - 920	Reflector "orange"	54	2.2	Silty clay, biosiliceous ooze		10	

Site Summary Form 6: IODP Proposal 708 Site LR-06A and LR-11A



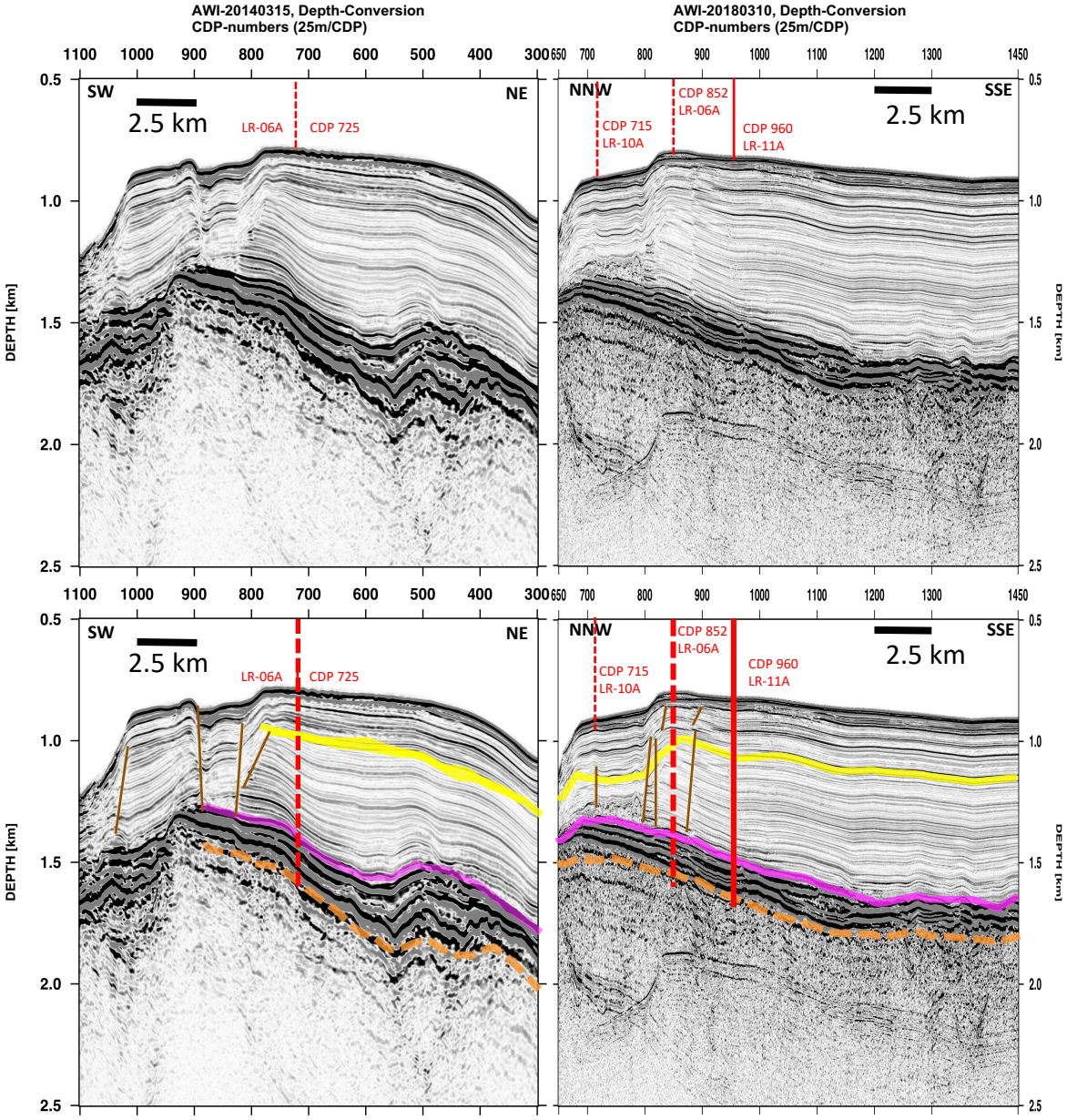
Site:	LR-06A	LR-11A	LR-10A
Latitude:	81.4568 °N	81.4381°N	81.4810°N
Longitude:	140.7295 °E	140.8320°E	140.5997°E
Water-depth:	780 m	815 m	904 m
Top Miocene (yellow):	200 mbsf	230 mbsf	short
Top Oligocene (pink):	600 mbsf	690 mbsf	log
Lower Eocene (orange):	790 mbsf	890 mbsf	
Proposed Penetration:	800 mbsf	900 mbsf	
Penetration total:	1600 m	1750 m	

Remarks:

- Seismic images are depth converted migrations

SSDB locations of these graphics and supporting data:

- Figure: LR-06A+LR-11A_line_AWI-20180310.pdf
- Seismic-SEGY data: 20180310_migrate.seg, 20180310_depcon.segy
- Navigation data: 20180310_cdplocs.txt
- Bathymetry: LR-03A-11A_bathy2018_50m.grd
- Velocity information: 20180310_vt_LR-11A.pdf
- Seismic subbottom profiles: LR-06A+LR-10A+LR-11A-20180310.pdf



IODP Site Forms

Form 1 – General Site Information

708 - Add 3

Section A: Proposal Information

Proposal Title	Arctic Ocean Paleoceanography: Towards a Continuous Cenozoic Record from a Greenhouse to an Icehouse World (ArcOP)
Date Form Submitted	
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continuous long-term Cenozoic climate history of the central Arctic Ocean (Alternate site)
List Previous Drilling in Area	IODP Expedition 302 (ACEX)

Section B: General Site Information

Site Name:	LR-07A	Area or Location:	southern Lomonosov Ridge
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 81.6851	Jurisdiction:	international waters
Longitude:	Deg: 142.3074	Distance to Land: (km)	670
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ✓	Water Depth (m):	764

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	740	0
Total Sediment Thickness (m)	740	
Total Penetration (m):	740	

General Lithologies: Silty clays, clays, biosiliceous ooze; siltsone, claystone; some ice-rafted debris

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: 18 | Logging: 2 | Total On-site: 20

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

one drill site with three APC/XCB/RCB holes down to about 740 mbsf to recover multiple sections of the sediment sequence to ensure complete recovery for construction of a composite section (Alternate site)

Potential Hazards/ Weather:

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Preferred weather window	
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	August-September (time interval of minimum ice extent)	
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:

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 708 - Add 3	Site #: LR-07A	Date Form Submitted:

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: line AWI-20140321 Position: CDP 220 Additional high-resolution crossing seismic reflection closeby, line AWI-20140296
1b High resolution seismic seismic reflection (crossing)		
2a Deep penetration seismic reflection (primary)		
2b Deep penetration seismic reflection (crossing)		
3 Seismic Velocity		
4 Seismic Grid		
5a Refraction (surface)		
5b Refraction (bottom)		
6 3.5 kHz		Parasound profile
7 Swath bathymetry		Hydrosweep profile
8a Side looking sonar (surface)		
8b Side looking sonar (bottom)		
9 Photography or video		
10 Heat Flow		
11a Magnetics		
11b Gravity		
12 Sediment cores		
13 Rock sampling		
14a Water current data		
14b Ice Conditions		
15 OBS microseismicity		
16 Navigation		Navigation data for seismic lines AWI-20140321 exist
17 Other		

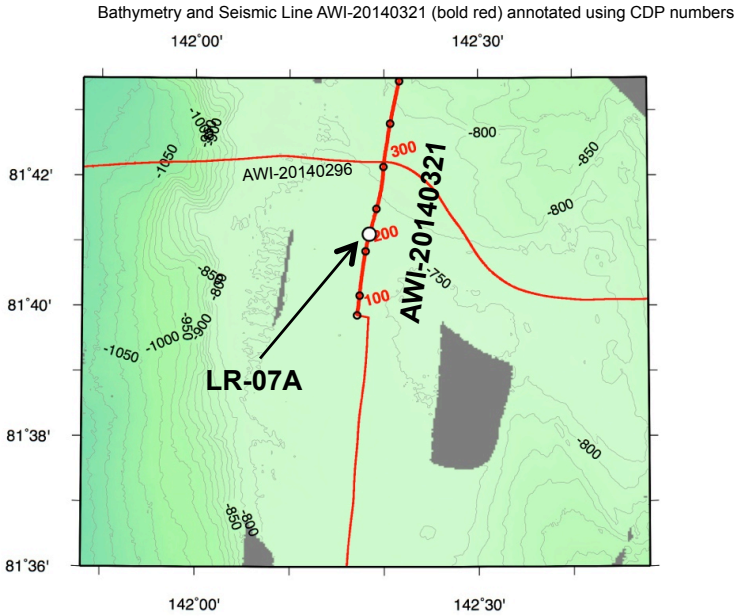
Proposal #: 708 - Add 3	Site #: LR-07A	Date Form Submitted:

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Triple APC to refusal, continued by XCB and RCB to final depth
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	N/A
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	N/A
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?	Ice management
7. What abandonment procedures need to be followed?	Support by an icebreaker (e.g., Polarstern)
8. Natural or manmade hazards which may affect ship's operations	Ice
9. Summary: What do you consider the major risks in drilling at this site?	ice could delay operations

Proposal #: 708 - Add 3	Site #: LR-07A	Date Form Submitted:

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 195	Reflector "yellow"	5.3	1.5	Silty clay		38	
195 - 300	Reflector "pink"	23.8	1.7	Silty clay		6	
300 - 725	Reflector "orange"	54	2.0	Silty clay, biosiliceous ooze		14	

Site Summary Form 6: IODP Proposal 708 Site LR-07A



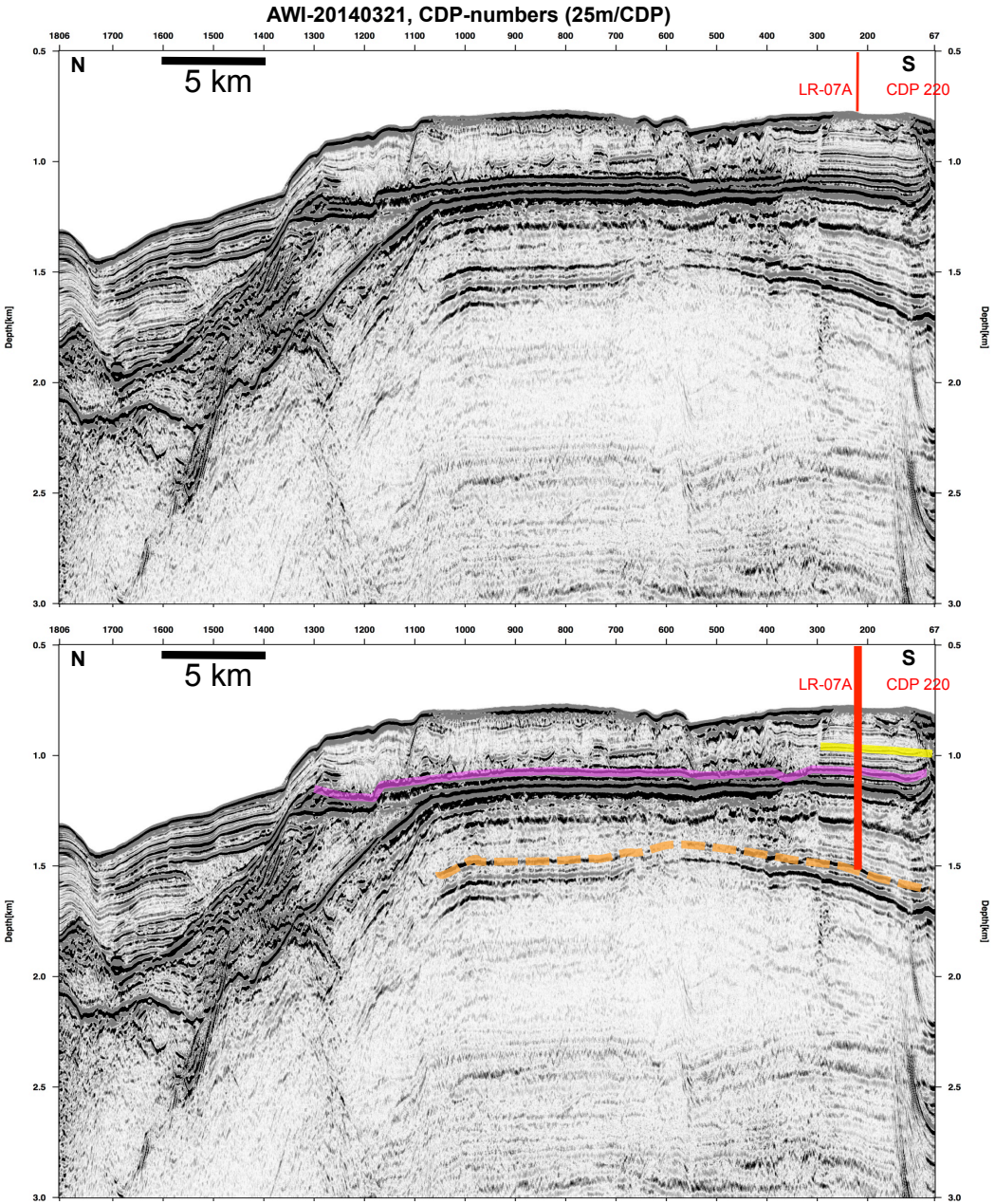
Site: LR-07A
Latitude: 81.6851 °N
Longitude: 142.3074 °E

Water-depth: 764 m
Top Miocene (yellow): 195 mbsf
Top Oligocene (pink): 300 mbsf
Lower Eocene (orange): 725 mbsf

Proposed Penetration: 740 mbsf
Penetration total: 1500 m

Remarks:
- Seismic images are depth converted migrations

SSDB locations of these graphics and supporting data:
- Figure: LR-07A_line_AWI-20140321.pdf
- Seismic-SEGY data: 20140321_stack.seg, 20140321_migrate.segy 20140321_depcon.segy
- Navigation data: 20140321_cdplocs.txt
- Bathymetry: LR-07A_50.grd
- Velocity information: 20140321_vt.pdf
- Seismic subbottom profiles: LR-07A-20140321para.sgy, -"-.txt



IODP Site Forms

Form 1 – General Site Information

708 - Add 3

Section A: Proposal Information

Proposal Title	Arctic Ocean Paleoceanography: Towards a Continuous Cenozoic Record from a Greenhouse to an Icehouse World (ArcOP)
Date Form Submitted	
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continuous long-term Cenozoic climate history of the central Arctic Ocean (Alternate site)
List Previous Drilling in Area	IODP Expedition 302 (ACEX)

Section B: General Site Information

Site Name:	LR-08A	Area or Location:	Lomonosov Ridge
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#		Jurisdiction:	international waters
Latitude:	Deg: 82.4215	Distance to Land: (km)	750
Longitude:	Deg: 142.1678		
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ✓	Water Depth (m):	1450

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	875	0
Total Sediment Thickness (m)	875	
Total Penetration (m):	875	

General Lithologies: Silty clays, clays, biosiliceous ooze; siltsone, claystone; some ice-rafted debris

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: 18 | Logging: 2 | Total On-site: 20

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

one drill site with three APC/XCB/RCB holes down to about 875 mbsf to recover multiple sections of the sediment sequence to ensure complete recovery for construction of a composite section (Alternate site)

Potential Hazards/ Weather:

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Preferred weather window	
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	August-September (time interval of minimum ice extent)	
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 #: 708 - Add 3	Site #: LR-08A	Date Form Submitted:

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: line AWI-20140292 Position: CDP 1720 Additional high-resolution seismic reflection closeby, line AWI-20140323
1b High resolution seismic seismic reflection (crossing)		
2a Deep penetration seismic reflection (primary)		
2b Deep penetration seismic reflection (crossing)		
3 Seismic Velocity		
4 Seismic Grid		
5a Refraction (surface)		
5b Refraction (bottom)		
6 3.5 kHz		Parasound profile
7 Swath bathymetry		Hydrosweep profile
8a Side looking sonar (surface)		
8b Side looking sonar (bottom)		
9 Photography or video		
10 Heat Flow		
11a Magnetics		
11b Gravity		
12 Sediment cores		
13 Rock sampling		
14a Water current data		
14b Ice Conditions		
15 OBS microseismicity		
16 Navigation		Navigation data for seismic lines AWI-20140292 exist
17 Other		

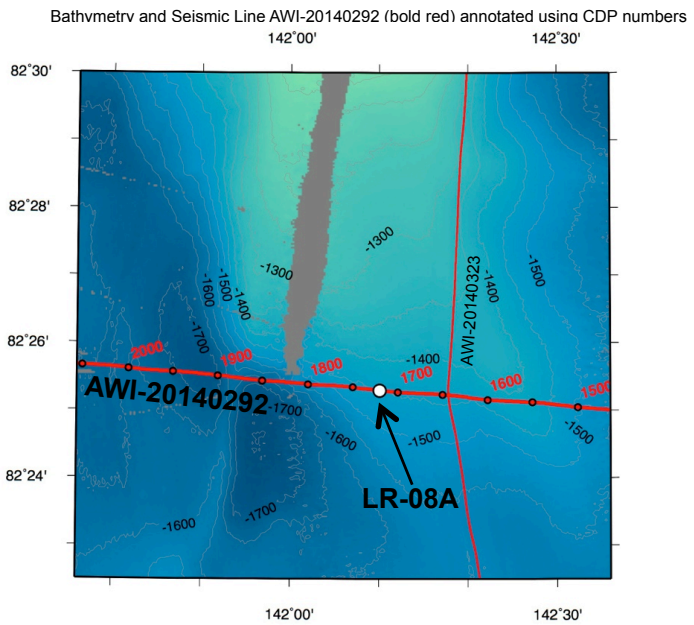
Proposal #: 708 - Add 3	Site #: LR-08A	Date Form Submitted:

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Triple APC to refusal, continued by XCB and RCB to final depth
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	N/A
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	N/A
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?	Ice management
7. What abandonment procedures need to be followed?	Support by an icebreaker (e.g., Polarstern)
8. Natural or manmade hazards which may affect ship's operations	Ice
9. Summary: What do you consider the major risks in drilling at this site?	ice could delay operations

Proposal #: 708 - Add 3	Site #: LR-08A	Date Form Submitted:

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 120	Reflector "yellow"	5.3	1.5	Silty clay		23	
120 - 570	Reflector "pink"	23.8	2.2	Silty clay		24	
570 - 875	Reflector "orange"	54	2.3	Silty clay, biosiliceous ooze		10	

Site Summary Form 6: IODP Proposal 708 Site LR-08A



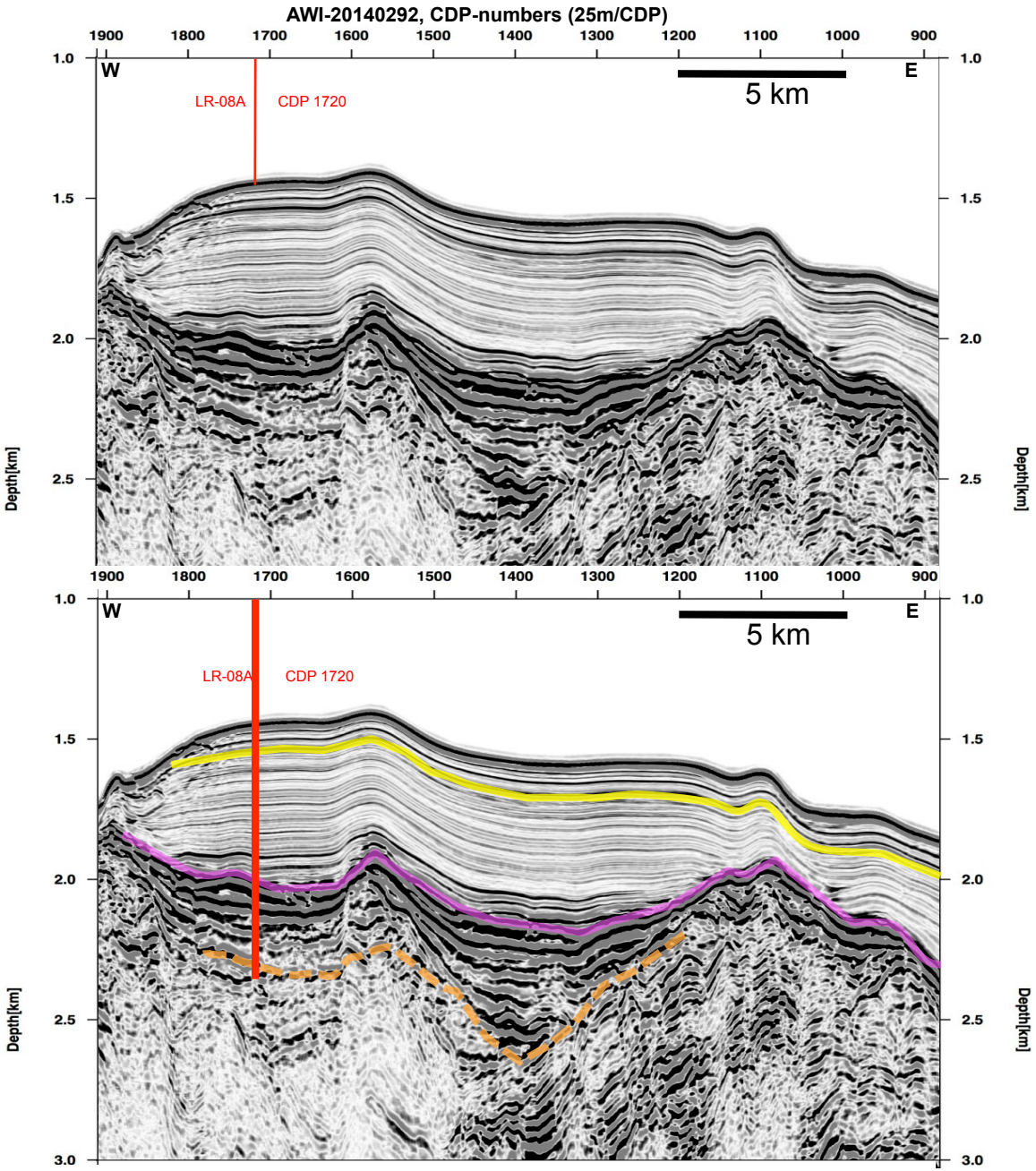
Site: LR-08A
Latitude: 82.4215 °N
Longitude: 142.1678 °E

Water-depth: 1450 m
Top Miocene (yellow): 120 mbsf
Top Oligocene (pink): 570 mbsf
Lower Eocene (orange): 875 mbsf

Proposed Penetration: 865 mbsf
Penetration total: 2315 m

Remarks:
- Seismic images are depth converted migrations

SSDB locations of these graphics and supporting data:
- Figure: LR-08A_line_AWI-20140292.pdf
- Seismic-SEGY data: 20140292_stack.seg, 20140292_migrate.segy 20140292_depcon.segy
- Navigation data: 20140292_cdplocs.txt
- Bathymetry: LR-08A_50.grd
- Velocity information: 20140292_vt.pdf
- Seismic subbottom profiles: LR-08A-20140292para.sgy, -"-.txt



IODP Site Forms

Form 1 – General Site Information

708 - Add 3

Section A: Proposal Information

Proposal Title	Arctic Ocean Paleoceanography: Towards a Continuous Cenozoic Record from a Greenhouse to an Icehouse World (ArcOP)
Date Form Submitted	
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recovery of a complete stratigraphic sedimentary record on the southern Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continuous long-term Cenozoic climate history of the central Arctic Ocean (Alternate site)
List Previous Drilling in Area	IODP Expedition 302 (ACEX)

Section B: General Site Information

Site Name:	LR-09A	Area or Location:	Lomonosov Ridge
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 82.8274	Jurisdiction:	international waters
Longitude:	Deg: 142.4677	Distance to Land: (km)	790
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ✓	Water Depth (m):	1251

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	750	0
Total Sediment Thickness (m)	750	
Total Penetration (m):	750	

General Lithologies: Silty clays, clays, biosiliceous ooze; siltsone, claystone; some ice-rafted debris

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: 18 | Logging: 2 | Total On-site: 20

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

one drill site with three APC/XCB/RCB holes down to about 1020 mbsf to recover multiple sections of the sediment sequence to ensure complete recovery for construction of a composite section (Alternate site)

Potential Hazards/ Weather:

Shallow Gas ☐	Complicated Seabed Condition ☐	Hydrothermal Activity ☐	Preferred weather window: August-September (time interval of minimum ice extent)
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:

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 708 - Add 3	Site #: LR-09A	Date Form Submitted:

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: line AWI-20140290 Position: CDP 1615
1b High resolution seismic seismic reflection (crossing)	yes	Line: line AWI-20140324 Position: CDP 135
2a Deep penetration seismic reflection (primary)		
2b Deep penetration seismic reflection (crossing)		
3 Seismic Velocity		
4 Seismic Grid		
5a Refraction (surface)		
5b Refraction (bottom)		
6 3.5 kHz		Parasound profile
7 Swath bathymetry		Hydrosweep profile
8a Side looking sonar (surface)		
8b Side looking sonar (bottom)		
9 Photography or video		
10 Heat Flow		
11a Magnetics		
11b Gravity		
12 Sediment cores		
13 Rock sampling		
14a Water current data		
14b Ice Conditions		
15 OBS microseismicity		
16 Navigation		Navigation data for seismic lines AWI-20140290 and AWI-20140324 exist
17 Other		

Proposal #: 708 - Add 3	Site #: LR-09A	Date Form Submitted:

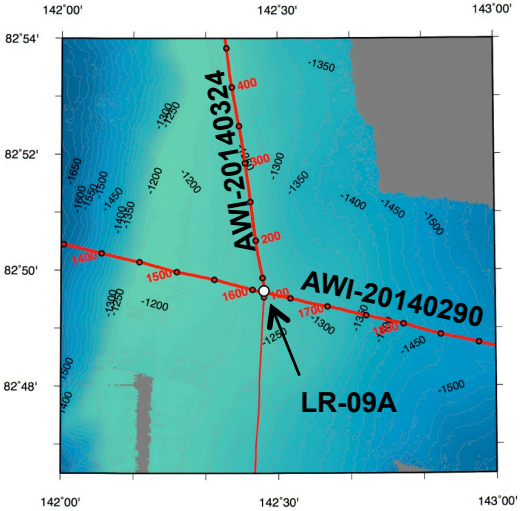
Pollution & Safety Hazard	Comment
1. Summary of operations at site	Triple APC to refusal, continued by XCB and RCB to final depth
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	N/A
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	N/A
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?	Ice management
7. What abandonment procedures need to be followed?	Support by an icebreaker (e.g., Polarstern)
8. Natural or manmade hazards which may affect ship's operations	Ice
9. Summary: What do you consider the major risks in drilling at this site?	ice could delay operations

Proposal #: 708 - Add 3	Site #: LR-09A	Date Form Submitted:

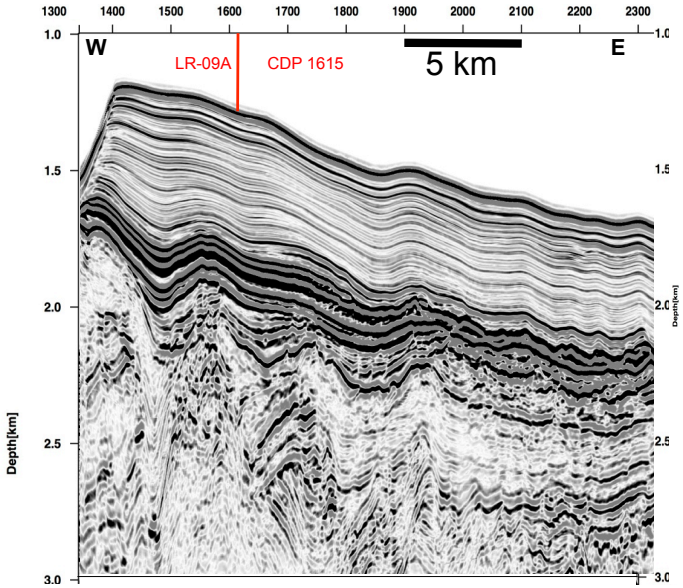
Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 125	Reflector "yellow"	5.3	1.6	Silty clay		24	
125 - 505	Reflector "pink"	23.8	2.1	Silty clay		21	
505 - 700	Reflector "orange"	54	2.2	Silty clay, biosiliceous ooze		6	

Site Summary Form 6: IODP Proposal 708 Site LR-09A

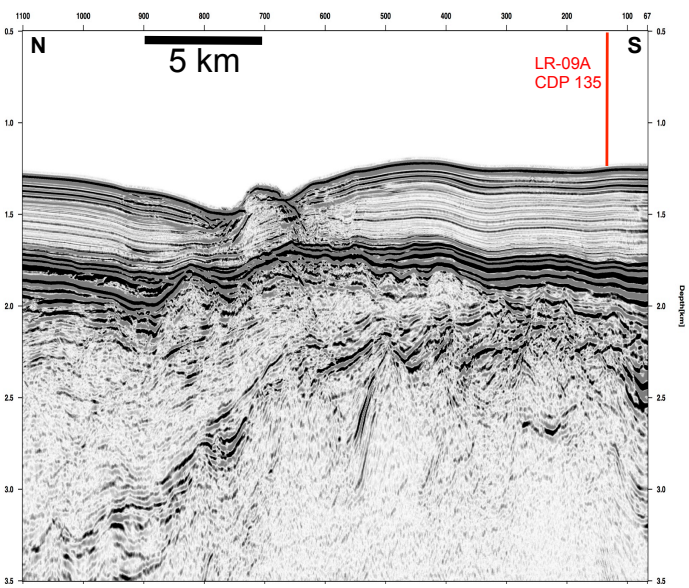
Bathymetry and Seismic Lines AWI-20140292 and 20140324 annotated using CDPs

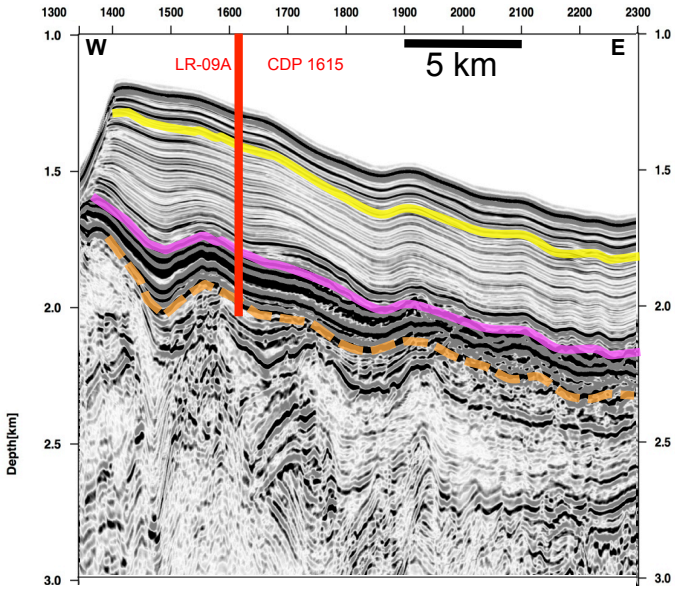


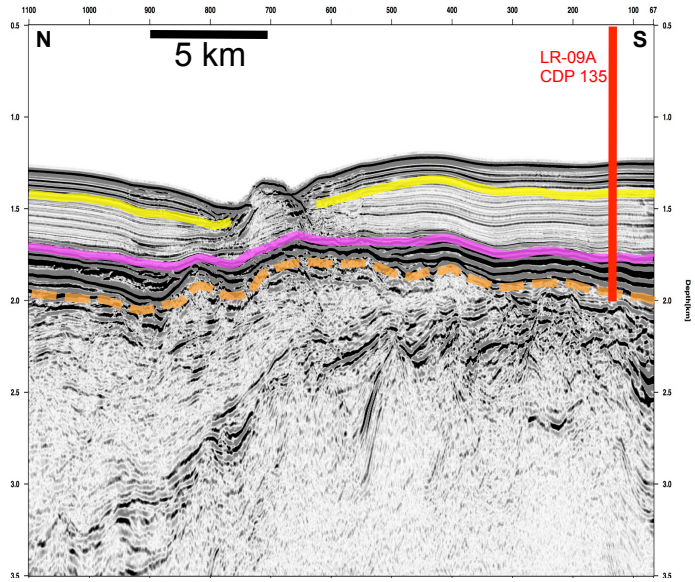
AWI-20140290, CDP-numbers (25m/CDP)



AWI-20140324, CDP-numbers (25m/CDP)







Site: LR-09A
Latitude: 82.8274 °N
Longitude: 142.4677 °E

Water-depth: 1251 m
Top Miocene (yellow): 125 mbsf
Top Oligocene (pink): 505 mbsf
Lower Eocene (orange): 700 mbsf

Proposed Penetration: 750 mbsf
Penetration total: 2000 m

Remarks:

- Seismic images are depth converted migrations

SSDB locations of these graphics and supporting data:

- Figure: LR-09A_line_AWI-20140324.pdf
- Seismic-SEGY data:
  20140324_stack.seg, 20140324_migrate.segy,
  20140324_depcon.segy
  20140290_stack.seg, 20140290_migrate.segy,
  20140290_depcony.segy
- Navigation data: 20140290_cdplocs.txt, 20140324_
- Bathymetry: LR-08A_50.grd
- Velocity information: 20140324_vt.pdf
- Seismic subbottom profiles: LR-09A-20140324para.sgy, -"-.txt

IODP Site Forms

Form 1 – General Site Information

708 - Add 3

Section A: Proposal Information

Proposal Title	Arctic Ocean Paleoceanography: Towards a Continuous Cenozoic Record from a Greenhouse to an Icehouse World (ArcOP)
Date Form Submitted	
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recovery of a complete stratigraphic sedimentary record on the central Lomonosov Ridge to meet our highest priority paleoceanographic objective, the continous long-term Cenozoic climate history of the central Arctic Ocean. (Alternate Site)
List Previous Drilling in Area	IODP Expedition 302 (ACEX)

Section B: General Site Information

Site Name:	LORI-5B	Area or Location:	central Lomonosov Ridge
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#		Jurisdiction:	International waters
Latitude:	Deg: 83.8005	Distance to Land: (km)	900
Longitude:	Deg: 146.4750		
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	1334

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1100	0
Total Sediment Thickness (m)	1750	
Total Penetration (m):	1100	

General Lithologies: Silty clay, clay, biosiliceous ooze; siltstone, claystone; some ice-rafted debris

Coring Plan: (Specify or check): one drill site with three APC/XCB/RCB holes down to about 970 mbsf to recover multiple sections of the sediment sequence to ensure complete recovery for construction of a composite section (Alternate Site)

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: 20 | Logging: 2 | Total On-site: 22

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

Potential Hazards/ Weather:

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Preferred weather window: August-September (time interval of minimum ice extent)
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:

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 708 - Add 3	Site #: LORI-5B	Date Form Submitted:

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: line AWI-20140260 Position: CDP 650 already uploaded to the SSBD
1b High resolution seismic seismic reflection (crossing)	yes	Line: line AWI-20140279 Position: CDP 1004 already uploaded to the SSBD
2a Deep penetration seismic reflection (primary)	no	
2b Deep penetration seismic reflection (crossing)	no	
3 Seismic Velocity	no	
4 Seismic Grid	no	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	AWI Parasound profile
7 Swath bathymetry	no	AWI Hydrosweep profile
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	sediment cores from Polarstern expeditions 1991 and 2007
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	more perennial sea ice (8-9/10)
15 OBS microseismicity	no	
16 Navigation	yes	Navigation data for seismic lines AWI-98565, AWI-20140260, and AWI-20140279 exist and were uploaded
17 Other	no	

Proposal #: 708 - Add 3	Site #: LORI-5B	Date Form Submitted:

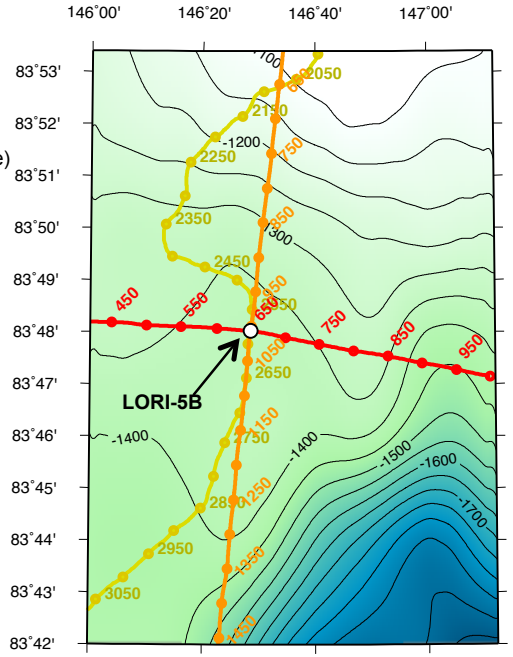
Pollution & Safety Hazard	Comment
1. Summary of operations at site	Triple APC to refusal, continued by XCB and RCB to final depth
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	N/A
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	N/A
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?	severe/perennial ice conditions
7. What abandonment procedures need to be followed?	support by an icebreaker needed (e.g., RV Polarstern)
8. Natural or manmade hazards which may affect ship's operations	ice
9. Summary: What do you consider the major risks in drilling at this site?	ice could delay operations

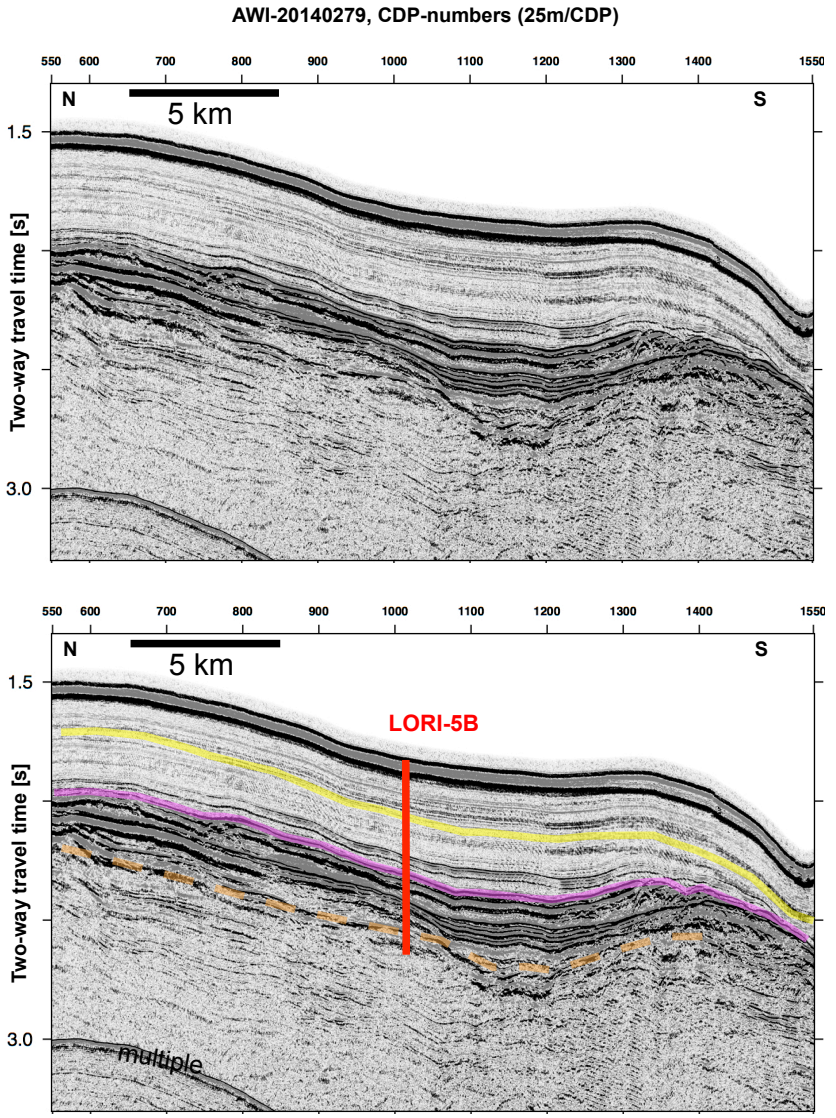
Proposal #: 708 - Add 3	Site #: LORI-5B	Date Form Submitted:

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 330	Reflector "yellow"	5.3	1.6	silty clay	pelagic	62	
330 - 650	Reflector "pink"	23.8	2.2	silty clay	pelagic	17	
650 - 1060	Reflector "orange"	54.8	3.4	silty clay, biosiliceous ooze	pelagic	13	
1060 - 1150	below Reflector "orange"	>54.8		silty clay	pelagic		

IODP Proposal 708 Site LORI-5B

Seismic Profiles
AWI-98597 (yellow),
AWI-20140260 (red)
AWI-20140279 (orange)
annotated using
CDP numbers





Site: LORI-5B
Latitude: 83.80 °N
Longitude: 146.475 °E
Water-depth: 1334 m
Top Miocene (yellow): 330 mbsf
Top Oligocene (pink): 650 mbsf
Lower Eocene (orange): 1060 mbsf

Penetration total: 1100 m

SSDB locations of these graphics and supporting data:
-Location map: LORI-5B_map.pdf
-Seismic figures: LORI-5B_AWI-20140279.pdf
-SEGY data: AWI-20140279stack.segy
-Navigation data: 20140279_cdplocs.asc

708-Full1-Addendum (Stein et al.)

Fig. 8. Enlarged section of line AWI-20140279. Red bars show the location of the proposed drilling Site LORI-5B. Coloured lines mark horizons of interest (yellow: top Miocene, pink: top Oligocene, orange: Lower Eocene).