IODP Proposal Cover Sheet

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Reykjanes Mantle Convection

Received for: 2018-03-05

Title	Mantle Dynamics, Paleoceanography and Climate Evolution in the North Atlantic Ocean
Proponents	Ross Parnell-Turner, Tim Henstock, Stephen Jones, John Maclennan, I. Nick McCave, Bramley Murton, John Rudge, Oliver Shorttle, Nicky White, Steve Barker, Bryndis Brandsdottir, Anne Briais, James Channell, Roz Coggon, Deborah Eason, Javier Escartin, David Graham, Richard Hey, David Hodell, Emilie Hooft, Matt Huber, Carrie Lear, Jian Lin, Dan Lizarralde, Dan Lunt, Fernando Martinez, Maureen Raymo, Michele Rebesco, Neil Ribe, Ros Rickaby, Roger Searle, Yang Shen, Bernhard Steinberger, Andreas Stracke, Gabriele Uenzelmann-Neben
Keywords	Mantle heterogeneity, climate, hydrothermal alteration
Area	Iceland Basin

Proponent Information

Proponent	Ross Parnell-Turner
Affiliation	Woods Hole Oceanographic Institution
Country	United States

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Abstract

The intersection between the Mid-Atlantic Ridge and Iceland hotspot provides us with a natural laboratory where the composition and dynamics of Earth's upper mantle can be observed. Plume-ridge interaction drives variations in the melting regime, resulting in a range of crustal types including a series of V-shaped ridges and troughs south of Iceland. Time-dependent mantle upwelling beneath Iceland dynamically supports regional bathymetry, leading to changes in the height of oceanic gateways which control the strength of deep-water flow over geologic timescales. We propose a drilling program that contains three objectives: (1) to test contrasting hypotheses for the formation of V-shaped ridges; (2) to understand temporal changes in ocean circulation, and explore connections with plume activity; (3) to reconstruct the evolving chemistry of hydrothermal fluids with increasing crustal age, varying sediment thickness and crustal architecture. This drilling program will recover basaltic samples from crust that is blanketed by thick sediments and is thus inaccessible with dredging. Major, trace and isotope geochemistry of basalts will allow us to observe spatial and temporal variations in mantle melting processes. We will test the hypothesis that the Iceland plume thermally pulses on two timescales (5-10 Ma, and ~30 Ma), leading to fundamental changes in crustal architecture. This idea will be tested against alternative hypotheses involving propagating rifts and buoyant mantle upwelling. Millennial-scale paleoclimate records are contained within rapidly accumulated sediments of contourite drifts in this region. The accumulation rate of these sediments is a proxy for current strength, which is moderated by dynamic support of oceanic gateways such as the Greenland-Scotland Ridge. These sediments also provide constraints for climatic events including Pliocene warmth, the onset of Northern Hemisphere Glaciation and abrupt Late Pleistocene climate change. Our combined approach will explore relationships between deep Earth processes, ocean circulation and climate. Our objectives can only be addressed by recovering sedimentary and basaltic cores, and we plan to penetrate 200 m into igneous basement at five sites east of Reykjanes Ridge. Four sites intersect V-shaped ridges/troughs pairs, one of which coincides with Bjorn Drift. A fifth site is located over 32.4 Ma oceanic crust devoid of V-shaped features, chosen to intersect Oligo-Miocene sediments of Gardar Drift. Sediments and basalts recovered during this program will provide a major advance in our understanding of mantle dynamics, and of the coupled nature of Earth's deep and surfical domains.

Scientific Objectives

Objective 1: Crustal Accretion and Mantle Plume Behavior
We will use the composition of drilled basalts to understand crustal formation south of Iceland at two temporal scales. On 5-10 Ma timescales we will test three hypotheses for V-shaped ridge formation: 1) thermal pulsing; 2) propagating rifts; and 3) buoyant mantle upwelling. These models predict differing depths, temperatures and degrees of melting between V-shaped ridges and troughs, expected to be reflected in basalt composition. On 30-40 Ma timescales, we aim to test the controls on crustal architecture by comparing basalts from smooth and fractured seafloor types, which are thought to arise from different melting regimes relating to plume activity.

Objective 2: Ocean Circulation and Sedimentation
We plan to quantify how oceanic circulation in the North Atlantic Ocean has varied since Oligocene times. These observations will allow us to test the hypothesis that deep-water flow in the North Atlantic Ocean has been moderated by transient activity of the Iceland mantle plume. This program will extend the high-resolution climate record into late Pliocene times. Thus, we aim to evaluate both the millennial- and million-year scale variability in Neogene climate during important intervals when temperatures were warmer than today.

Objective 3: Time-Dependent Hydrothermal Alteration of Oceanic Crust
We will investigate the nature, extent, timing and duration of hydrothermal alteration within the upper Reykjanes Ridge flank. Drilling will enable us to quantify the timing and extent of hydrothermal fluid-rock exchange, to assess the hydrothermal contributions from a rapidly sedimented slow-spreading ridge flank to global geochemical budgets.

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

None

Proposed Sites (Total proposed sites: 2; pri: 1; alt: 1; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
REYK-03B (Primary)	60.10501 -26.50174	2001	465	130	595	Sample 15 flow units, or ~130 m of basalt at V-shaped ridge 3. Primary site.
REYK-04B (Alternate)	60.10094 -26.46111	2109	415	130	545	Sample 15 flow units, or ~130 m of basalt at V-shaped ridge 3. Alternate site.

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Contact Information

Contact Person:	Ross Parnell-Turner
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Proponent List

First Name	Last Name	Affiliation	Country	Role	Expertise
Ross	Parnell-Turner	Woods Hole Oceanographic Institution	United States	Principal Lead and Data Lead	Geophysics
Tim	Henstock	University of Southampton	United Kingdom	Other Lead	Geophysics
Stephen	Jones	University of Birmingham	United Kingdom	Other Lead	Geophysics
John	Maclennan	University of Cambridge	United Kingdom	Other Lead	Igneous Petrology
I. Nick	McCave	University of Cambridge	United Kingdom	Other Lead	Sedimentology
Bramley	Murton	National Oceanography Centre, Southampton	United Kingdom	Other Lead	Igneous Petrology
John	Rudge	University of Cambridge	United Kingdom	Other Lead	Geodynamics
Oliver	Shorttle	University of Cambridge	United Kingdom	Other Lead	Igneous Petrology
Nicky	White	University of Cambridge	United Kingdom	Other Lead	Geophysics
Steve	Barker	University of Cardiff	United Kingdom	Other Proponent	Paleoclimate
Bryndis	Brandsdottir	University of Iceland	Iceland	Other Proponent	Geophysics
Anne	Briais	University of Toulouse	France	Other Proponent	Geophysics
James	Channell	University of Florida	United States	Other Proponent	Paleomagnetism
Roz	Coggon	University of Southampton	United Kingdom	Other Proponent	Geochemistry
Deborah	Eason	University of Hawaii	United States	Other Proponent	Igneous Petrology
Javier	Escartin	IPGP, Paris	France	Other Proponent	Geophysics
David	Graham	Oregon State University	United States	Other Proponent	Igneous Petrology
Richard	Hey	University of Hawaii	United States	Other Proponent	Geophysics
David	Hodell	University of Cambridge	United Kingdom	Other Proponent	Paleoclimate
Emilie	Hooft	University of Oregon	United States	Other Proponent	Geophysics
Matt	Huber	Purdue University	United States	Other Proponent	Paleoclimate

Proponent List (Continued)

First Name	Last Name	Affiliation	Country	Role	Expertise
Carrie	Lear	University of Cardiff	United Kingdom	Other Proponent	Sedimentology
Jian	Lin	Woods Hole Oceanographic Institution	United States	Other Proponent	Geophysics
Dan	Lizarralde	Woods Hole Oceanographic Institution	United States	Other Proponent	Geophysics
Dan	Lunt	University of Bristol	United Kingdom	Other Proponent	Paleoclimate
Fernando	Martinez	University of Hawaii	United States	Other Proponent	Geophysics
Maureen	Raymo	Lamont-Doherty Earth Observatory	United States	Other Proponent	Paleoclimate
Michele	Rebesco	OGS, Trieste	Italy	Other Proponent	Sedimentology
Neil	Ribe	University of Paris-Sud	France	Other Proponent	Geodynamics
Ros	Rickaby	University of Oxford	United Kingdom	Other Proponent	Biogeochemistry
Roger	Searle	University of Durham	United Kingdom	Other Proponent	Geophysics
Yang	Shen	University of Rhode Island	United States	Other Proponent	Geophysics
Bernhard	Steinberger	GFZ-Potsdam	Germany	Other Proponent	Geodynamics
Andreas	Stracke	University of Münster	Germany	Other Proponent	Igneous Petrology
Gabriele	Uenzelmann-Neben	Alfred Wegener Institute	Germany	Other Proponent	Geophysics

Addendum: Proposal 892-Full2

We thank SEP for their continued support and constructive feedback, and below we address the two questions raised at the January 2018 SEP meeting, and give details of two relocated sites.

SEP Comments

(1) *The SEP panel would like the proponents to consider the challenges of basement recovery. For instance, what if they recover only 10 m of basement rocks before bit destruction? Can the science objectives be still accomplished with such a basement sample?*

The five-site program provides multiple opportunities to achieve the three main project objectives, so that if problems such as low recovery are encountered at any single site, there is another site later in the program which will allow the objective to be accomplished, illustrated in our suggested decision tree (Figure 1).

Our basement objectives require recovery of samples from ~15 lava flow units, in order to obtain a space- and time-averaged geochemical record of basalt composition. Leg 49 targeted V-shaped ridges (VSRs) near to Iceland, and encountered flow units that were 3–8 m thick. Our proposed operations plan includes up to 130 m of basement penetration at each site, and using a conservative estimate of 8 m average flow unit thickness, this penetration depth will allow us to intersect ~16 flow units. If flow units are on average thinner than 8 m, we will use this redundancy to make up for unforeseen delays in the schedule elsewhere. Basement recovery rates with a single bit during Leg 49 were 25% at site 407 (which penetrated 177 m into basement) and 24% at site 409 (which penetrated 239 m into basement). Our objectives can be achieved if we recover material from a sufficient number of distinct flow units, even if the overall recovery rate is lower than that of Leg 49.

Since our objective is to obtain a sufficient number of flow units (rather than a specific basement penetration depth), we will stop basement coring once 15 flow units have been encountered. Flow units will be identified onboard based upon changes in rate of penetration, grain size, presence of interlayered sediments, and petrographic characteristics including phenocryst assemblages and groundmass texture. This approach will ensure that a sufficient number of flows have been sampled, while not spending more time than necessary at a given site.

Variations in rate of penetration provided a near real-time estimate of flow unit boundaries during Leg 49 (see Figure 2), however we acknowledge that this method assumes a constant weight on the drill bit, which may not be achievable in variable sea conditions. This approach also requires a sufficient thickness of sediments or rubble between flows. Nonetheless, once the cores are split (about 3 to 5 hours after the core arrives on deck), it should be relatively fast for the shipboard petrologists to count the flow units, in order to make a timely decision about whether to continue drilling ahead or not.

(2) *The drilling program, as planned, has very little margin for error. The SEP would appreciate comments from the proponents about their highest priorities for drilling, redundancy among the various primary sites and possible "Plan B" programs that might permit them to meet the objectives defined for the five primary sites by drilling alternate sites.*

Our chosen sites have multiple objectives, with targets both in the sediment and basement intervals, which address different aspects of our scientific priorities. Below we summarize how the three main objectives will be achieved in case of unforeseen operational difficulties, by identifying redundancies that lead to our decision-making logic.

Objective 1: Crustal Accretion and Mantle Plume Behavior (all sites)
Testing the three competing V-shapes ridge formation hypotheses requires drilling sites at V-shaped ridge/trough pairs. We have two such pairs in the program (each with alternates), therefore will still be able to test this hypothesis should there be a delay in the program. We have accounted for 130 m of basement penetration in the operations plan (Table 1), however should 15 flow units be encountered before this point, we will stop coring and move to the next site in order to conserve time (Figure 1).

Objective 2: Ocean Circulation and Sedimentation (REYK-2A and REYK-6A)
Obtaining millennial-scale climate records, and tracing deep-water current activity through Neogene times can be achieved by successful triple APC-coring at one or both of these sites. This triple APC program is considered high priority. Additional paleoclimate constraints can be obtained by single APC at REYK-3B, REYK-11A and REYK-13A, however these activities are lower priority, and can be removed from the program should drilling be behind schedule (Figure 1). The option of reducing these three sites to single holes gives a combined contingency of 2.9 additional days in our operations plan (Table 1 and Figure 1).

Objective 3: Time-Dependent Hydrothermal Alteration of Oceanic Crust (all sites)
Investigation of the progressive alteration of recovered cores has similar flow unit recovery requirements as Objective 1, therefore our flexible approach to penetration depth is a compromise between basement recovery and time management.

Two sites, REYK-2A and REYK-6A, carry higher risk of hole instability due to increased target depth, which we have mitigated with the inclusion of casing. REYK-6A targets a V-shaped trough (VST), and since we also have a second, shallower VST site later in the program (REYK-13A), we will still be able to test the VSR/VST pair hypothesis even if basement recovery at REYK-6A is insufficient. If basement recovery at REYK-2A is insufficient, then obtaining a basalt sample from segmented crust may not be possible. Since REYK-2A is the deepest hole with most time allotted (18 days), we would be unlikely to be able to drill its alternate (REYK-1A) and still have time for the other VSR/VST sites. Therefore the basement objective at REYK-2A is a lower priority if unforeseen problems mean that we exceed our planned time at that site.

Site Relocations

Sites REYK-4A (primary) and REYK-3A (alternate) target VSR-3, and are both too close to a fault near common midpoint (CMP) 39400 on seismic profile JC50-1 (Figure 3). These sites will be replaced by REYK-4B (alternate) and REYK-3B (primary)

REYK-3B is located ~3.2 km west of seismic crossline JC50-2, at CMP 39920 on profile JC50-1.

This site intersects a continuous, unambiguous single basement reflection, clear of any obvious faults, and is therefore chosen as the primary site for sampling VSR-3. There are no sedimentary objectives at this site, therefore the presence of what appears to be an erosion surface at 2.9 s two-way travel time (TWTT) is not significant. Although sediments at REYK-3B are 50 m thicker than at REYK-4B, this difference will not add a significant amount of drilling time to the program.

REYK-4B is located ~1.3 km west of seismic crossline JC50-2, at CMP 39550 on profile JC50-1. Although away from any visible faults, this site intersects a basement reflection that is more ambiguous than at REYK-3A, and makes an accurate prediction of basement depth difficult. Hence we have chosen this site as an alternate.

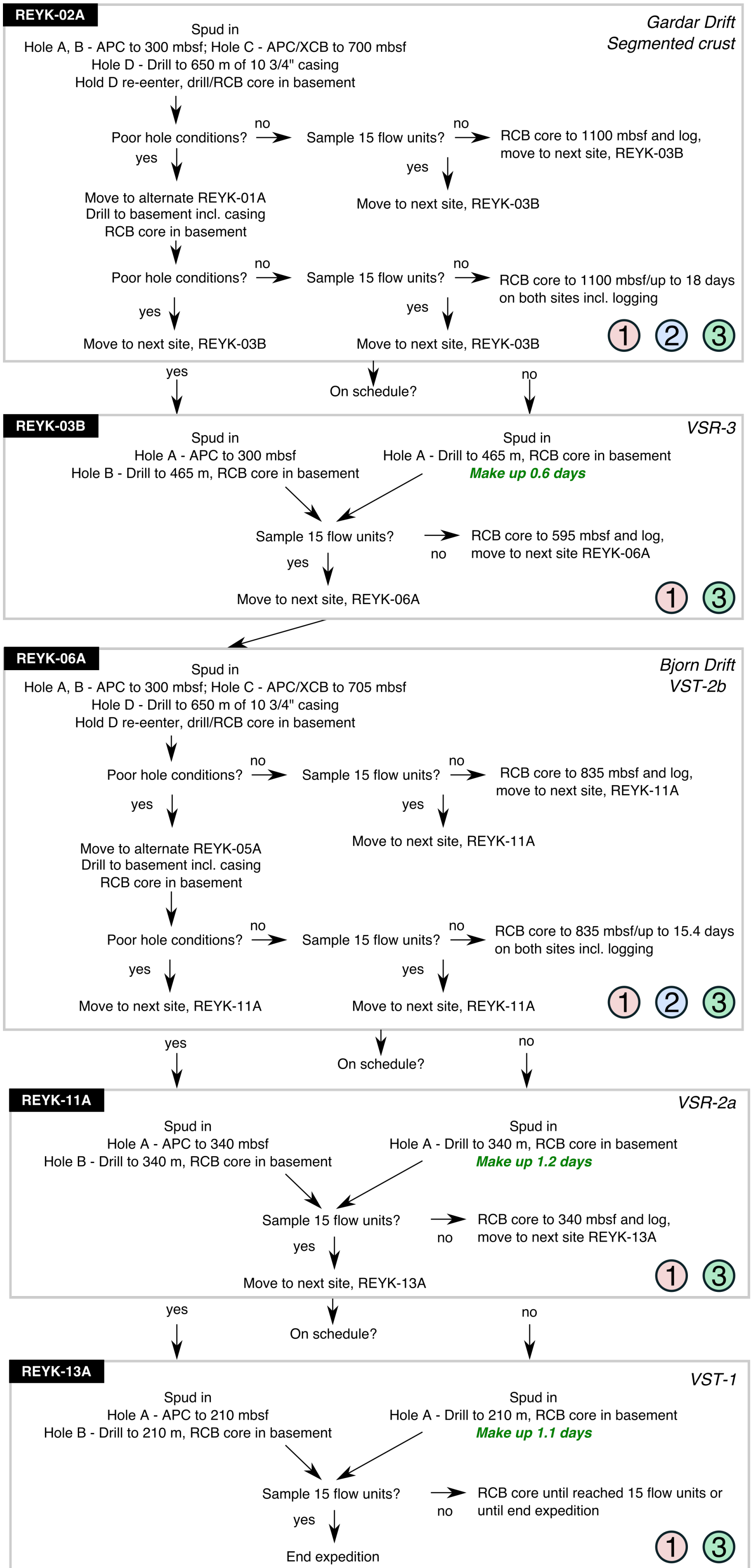


Figure 1. Decision tree with contingencies for poor hole conditions and schedule delays (green text). Circled numbers indicate project objectives at each site

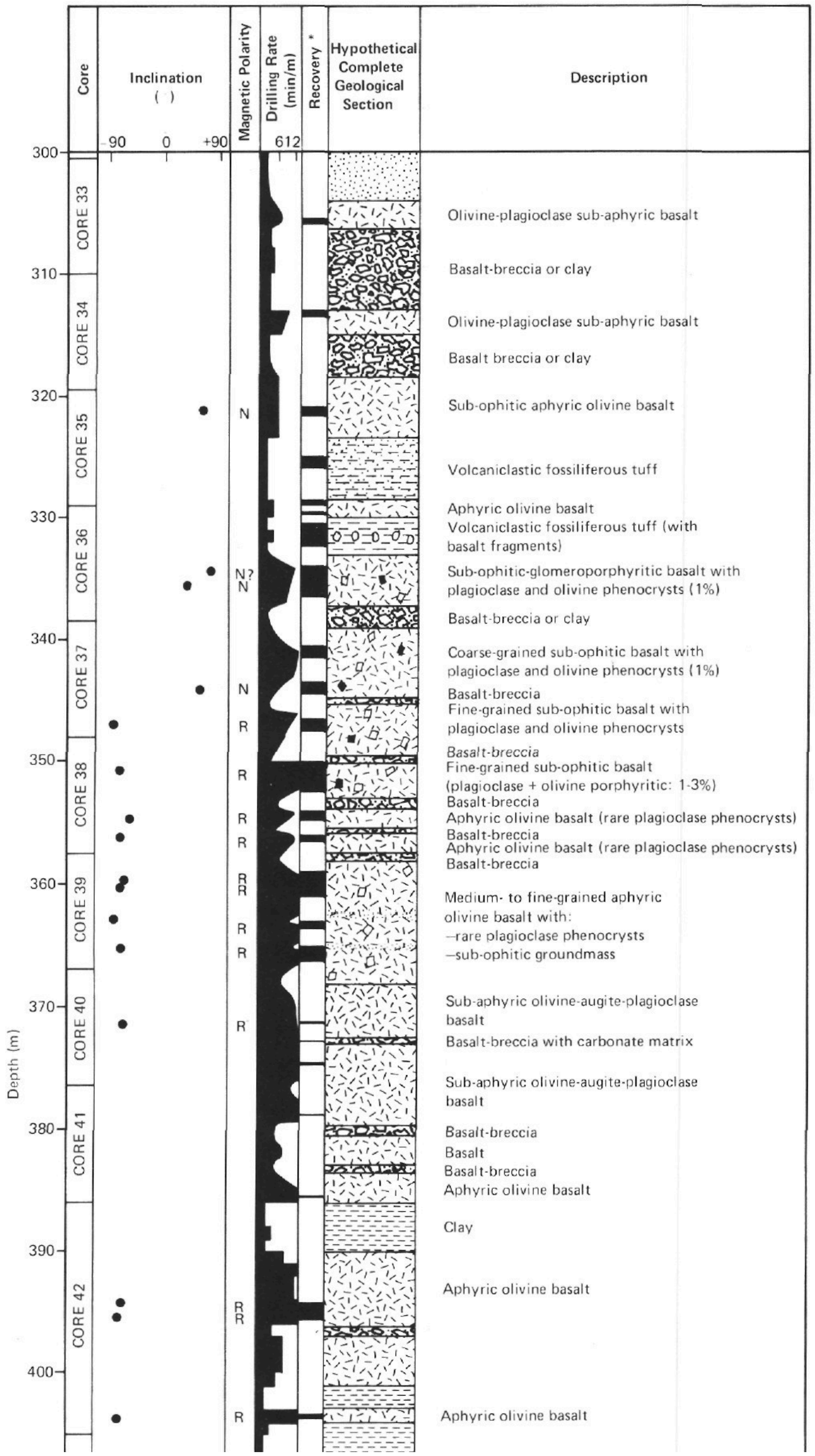


Figure 2. Portion of stratigraphic column for cored basement section, Leg 49 site 407 (Shipboard Scientific Party, 1979). Note variations in drilling rate correlate well with flow unit boundaries, which were later confirmed with aid of petrological interpretation of recovered core.

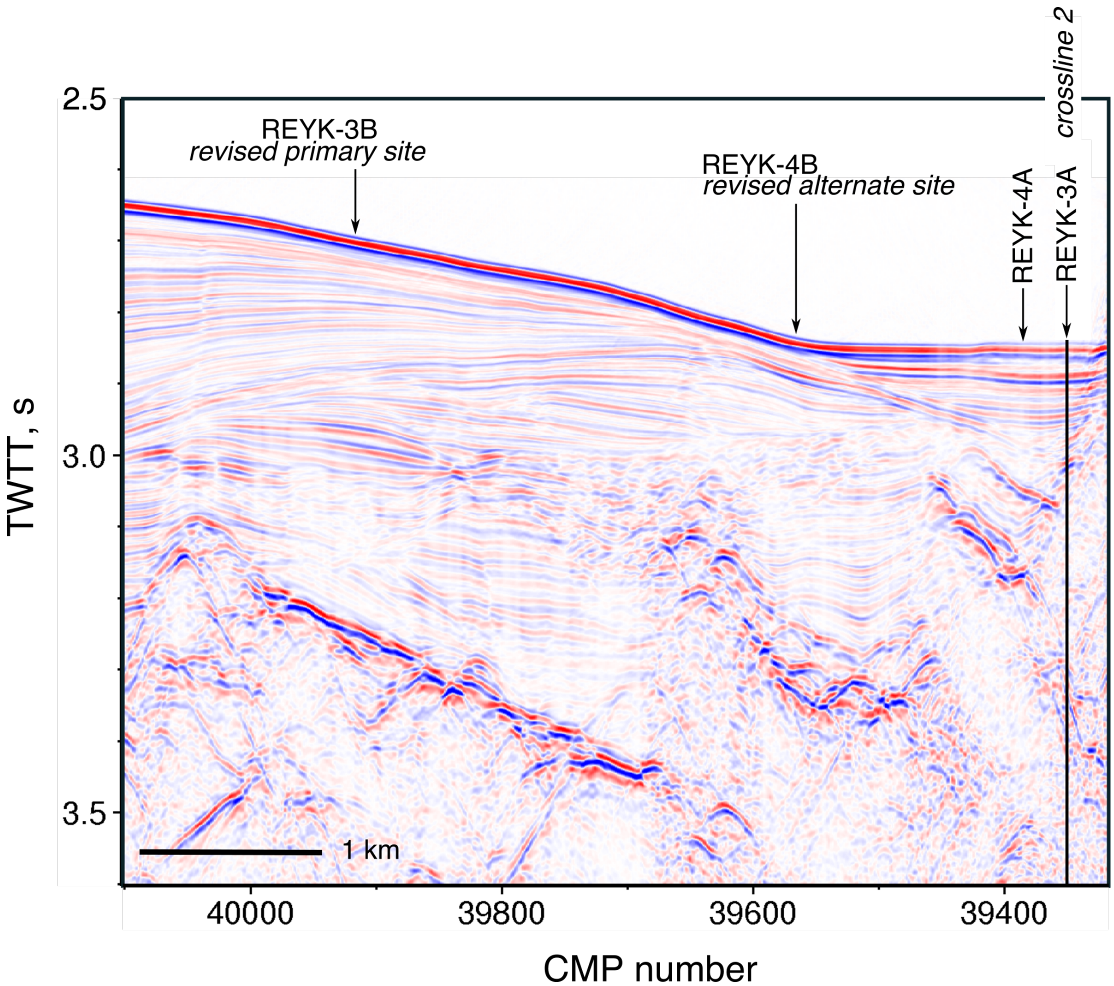


Figure 3. Portion of seismic profile JC50-1, showing relocated sites REYK-3B and REYK-4B, both targeting VSR-3. Note relatively continuous, single basement reflection at REYK-3B, avoiding visible faults; REYK-3A is located at the crossing point between profiles JC50-1 and crossline 2.

North Atlantic Mantle Convection and Climate (P892)
Operations Plan Summary - 130 m Basement, no 1xAPC
Grigar, 27 February 2018

Site No.	Location (Latitude Longitude)	Seafloor Depth (mbrf)	Operations Description	Transit (days)	Drilling Coring (days)	LWD/MWD Log (days)
Reykjavik			Begin Expedition 5.0 port call days			
			Transit ~282 nmi toREYK-2A@ 10.5	1.1		
REYK-2A	59° 51.0360' N	2217	Hole A - APC to 300 mbsf	0.0	1.8	0.0
	23° 15.9840' W		Hole B - APC to 300 mbsf	0.0	1.4	0.0
			Hole C - APC/XCB to 700 mbsf - Log with triple combo and FMS Sonic	0.0	3.9	1.1
			Hole D - Drill in 650 m of 10 3/4" casing	0.0	3.1	0.0
			Hole D - Reenter Hole D, drill down to 700 mbsf and RCB core to 1100 mbsf and log with triple combo and FMS Sonic	0.0	5.4	1.1
			Sub-Total Days On-Site: 17.8			
			Transit ~98 nmi toREYK-3B@ 10.5	0.4		
REYK-3B	60° 6.3006' N	2001	Hole A - RCB core to 595 mbsf and log with triple combo and FMS Sonic	0.0	5.4	0.9
	26° 30.1044' W					
			Sub-Total Days On-Site: 6.3			
			Transit ~6 nmi toREYK-6A@ 10.5	0.0		
REYK-6A	60° 7.5060' N	1882	Hole A - APC to 300 mbsf	0.0	1.7	0.0
	26° 42.0960' W		Hole B - APC to 300 mbsf	0.0	1.3	0.0
			Hole C - APC/XCB to 705 mbsf - Log with triple combo and FMS Sonic	0.0	3.8	1.1
			Hole D - Drill in 650 m of 10 3/4" casing	0.0	3.0	0.0
			Hole D - Reenter Hole D, drill down to 700 mbsf and RCB core to 835 mbsf and log with triple combo and FMS Sonic	0.0	3.3	0.9
			Sub-Total Days On-Site: 15.2			
			Transit ~39 nmi toREYK-11A@ 10.5	0.2		
REYK-11A	60° 11.9940' N	1426	Hole A - RCB core to 470 mbsf and log with triple combo and FMS Sonic	0.0	4.2	0.8
	28° 0.0000' W					
			Sub-Total Days On-Site: 5.0			
			Transit ~15 nmi toREYK-13A@ 10.5	0.1		
REYK-13A	60° 13.6920' N	1531	Hole A - RCB core to 340 mbsf and log with triple combo and FMS Sonic	0.0	3.6	0.8
	28° 30.0240' W					
			Sub-Total Days On-Site: 4.4			
			Transit ~283 nmi toREYK-2A@ 10.5	1.2		
Reykjavik			End Expedition	3.0	42.0	6.7

Port Call:	5.0	Total Operating Days:	51.6
Sub-Total On-Site:	48.6	Total Expedition:	56.6

Table 1. Operations plan summary, with single APC holes omitted from REYK-3B, REYK-11A and REYK-13A, in order to provide contingency if time is lost elsewhere in program, saving a total of 2.9 days. Prepared by JRSO Science Services.

References

Shipboard Scientific Party, 1979. Site 407, in: Luyendyk, B.P., Cann, J.R., et al. (Eds.), Init. Rep. Deep Sea Drill. Proj. 49. U.S. Govt. Printing Office, Washington, pp. 21–100.

IODP Site Forms

Form 1 – General Site Information

892 - Add

Section A: Proposal Information

Proposal Title	Mantle Dynamics, Paleoceanography and Climate Evolution in the North Atlantic Ocean
Date Form Submitted	2018-03-02 16:20:08
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Sample 15 flow units, or ~130 m of basalt at V-shaped ridge 3. Primary site.
List Previous Drilling in Area	Leg 162 Sites 983 and 984

Section B: General Site Information

Site Name:	REYK-03B	Area or Location:	North Atlantic Ocean
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 60.10501	Jurisdiction:	International
Longitude:	Deg: -26.50174	Distance to Land: (km)	147
Coordinate System:	WGS 84		
Priority of Site:	Primary: ✓ Alternate: ☐	Water Depth (m):	2001

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	465	130
	Total Sediment Thickness (m) 465	
		Total Penetration (m): 595
General Lithologies:	Nannofossil ooze, clay and mud	Vesicular basalt

Coring Plan: (Specify or check)

APC to basement or refusal, RCB to target depth ~130 m within oceanic crustal basement.

APC ☑ XCB ☑ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

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

Other Measurements:

Estimated Days:

Drilling/Coring:	Logging:	Total On-site:
6	0.9	6.9

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

N/A

Potential Hazards/ Weather:

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

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

Preferred weather window: Summer required as North Atlantic weather poor in Winter

Other:

Proposal #: 892 - Add	Site #: REYK-03B	Date Form Submitted: 2018-03-02 16:20:08

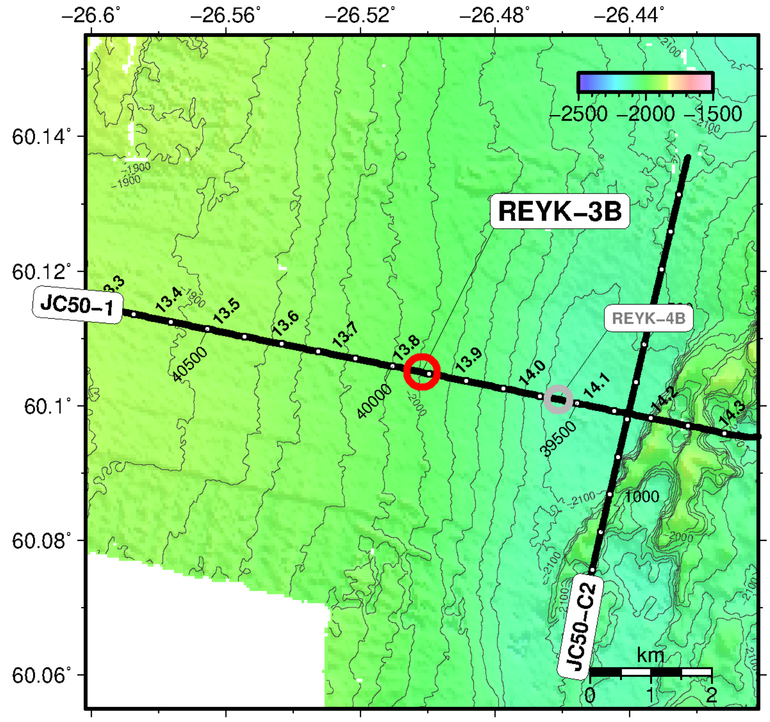
Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: Profile JC50-1 Position: 39920 In fault block ~2.3 km west of seismic crossing point, where basement reflection is clearly defined, and away from visible faults.
1b High resolution seismic seismic reflection (crossing)	yes	Line: Profile JC50-C2 Position: 685
2a Deep penetration seismic reflection (primary)		
2b Deep penetration seismic reflection (crossing)		
3 Seismic Velocity	yes	
4 Seismic Grid		
5a Refraction (surface)		
5b Refraction (bottom)		
6 3.5 kHz		
7 Swath bathymetry	yes	Cruise JC50 EM120 multibeam survey
8a Side looking sonar (surface)		
8b Side looking sonar (bottom)		
9 Photography or video		
10 Heat Flow		
11a Magnetics	yes	Regional magnetic data compilation and chron interpretation
11b Gravity	yes	Satellite free-air gravity anomaly
12 Sediment cores		
13 Rock sampling		
14a Water current data		
14b Ice Conditions		
15 OBS microseismicity		
16 Navigation	yes	JC50 cruise navigation
17 Other		

Proposal #: 892 - Add	Site #: REYK-03B	Date Form Submitted: 2018-03-02 16:20:08

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single APC to basement at 317 m. RCB 130 m into basement, log as shown on form 3
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	None
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	None
4. Indications of gas hydrates at this location	None
5. Are there reasons to expect hydrocarbon accumulations at this site?	None
6. What "special" precautions will be taken during drilling?	None
7. What abandonment procedures need to be followed?	Not applicable
8. Natural or manmade hazards which may affect ship's operations	None
9. Summary: What do you consider the major risks in drilling at this site?	Poor weather

Proposal #: 892 - Add	Site #: REYK-03B	Date Form Submitted: 2018-03-02 16:20:08

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 12	Seabed to reflection B2	0.47	1.55	Nannofossil clay	Pelagic	245	Age based upon reflection R2 at Site 984
12 - 60	Reflection B2 to reflection B4	0.47-2.63	1.63	Silty clay	Pelagic	42	Age and lithology based on results from Site 984
60 - 166	Reflection B4 to reflection B5	2.63-3.7	1.63	Silty clay	Pelagic	17	
166 - 465	Reflection B5 to basement	3.7-13.9	1760	Silty clay	Pelagic	29	
465 - 595	Acoustic basement	13.9 and older	2000	Basalt	Volcanic	NA	

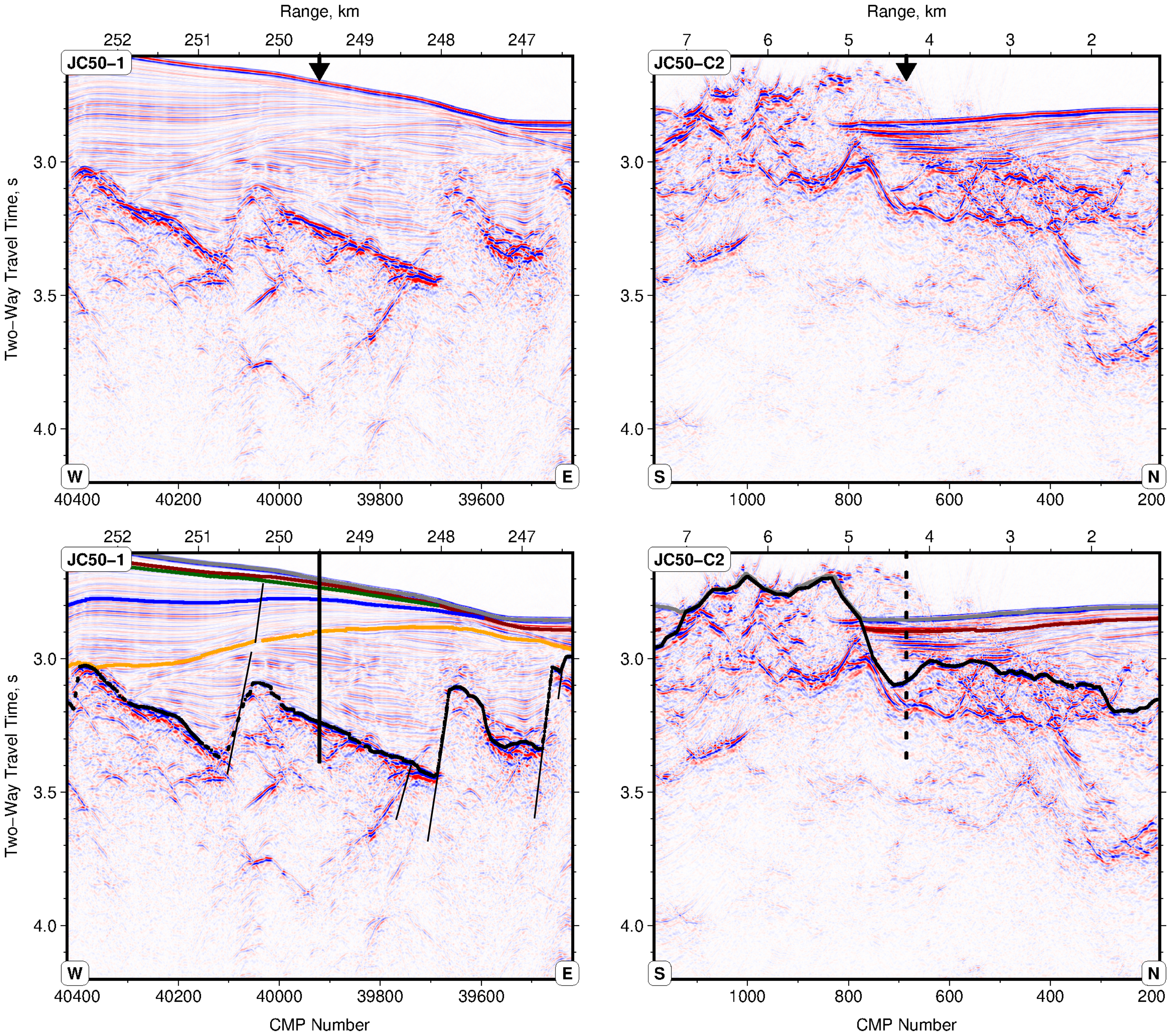


Site Summary Figure: Proposal P892–Full Site REYK–3B

Location: –26.50174 W, 60.10501 N
CMP 39920 on JC50–1; CMP 685 on JC50–C2
Water depth: 2001 m / 2.702 s TWTT
Basement depth: 465 mbsf / 3.237 s TWTT
Target depth: 595 mbsf / 3.385 s TWTT
Basement age: 13.86 Ma

Figures and supporting data in SSDB:
Location map: REYK–3B_site_sum_fig_map.pdf
Seismic images: REYK–3B_site_sum_fig_JC50–1.pdf & REYK–3B_site_sum_fig_JC50–C2.pdf
SEGY data / Navigation: JC50–1_stolt_trbal.segy / JC50–1.xy & JC50–C2_stolt_trbal.segy / JC50–C2.xy

Interpretation:
Gray = seabed ; red = B2 (0.47 Ma); green = B3 (2.15 Ma); blue = B4 (2.63 Ma); orange = B5 (3.7 Ma); black = basement



IODP Site Forms

Form 1 – General Site Information

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Section A: Proposal Information

Proposal Title	Mantle Dynamics, Paleoceanography and Climate Evolution in the North Atlantic Ocean
Date Form Submitted	2018-03-02 16:20:08
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Sample 15 flow units, or ~130 m of basalt at V-shaped ridge 3. Alternate site.
List Previous Drilling in Area	Leg 162 Sites 983 and 984

Section B: General Site Information

Site Name:	REYK-04B	Area or Location:	North Atlantic Ocean
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 60.10094	Jurisdiction:	International
Longitude:	Deg: -26.46111	Distance to Land: (km)	147
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	2109

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Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	415	130
	Total Sediment Thickness (m) 415	
		Total Penetration (m): 545
General Lithologies:	Nannofossil ooze, clay and mud	Vesicular basalt

Coring Plan: (Specify or check)

APC to basement or refusal, RCB to target depth ~130 m within oceanic crustal basement.

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: 4.9	Logging: 0.8	Total On-site: 5.7

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

N/A

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Summer required as North Atlantic weather poor in Winter
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:

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Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: Profile JC50-1 Position: 39550
1b High resolution seismic seismic reflection (crossing)	yes	Line: Profile JC50-C2 Position: 685 Site located 1.3 km west of crossing point in order to avoid possible basement fault
2a Deep penetration seismic reflection (primary)		
2b Deep penetration seismic reflection (crossing)		
3 Seismic Velocity	yes	
4 Seismic Grid		
5a Refraction (surface)		
5b Refraction (bottom)		
6 3.5 kHz		
7 Swath bathymetry	yes	Cruise JC50 EM120 multibeam survey
8a Side looking sonar (surface)		
8b Side looking sonar (bottom)		
9 Photography or video		
10 Heat Flow		
11a Magnetics	yes	Regional magnetic data compilation and chron interpretation
11b Gravity	yes	Satellite free-air gravity anomaly
12 Sediment cores		
13 Rock sampling		
14a Water current data		
14b Ice Conditions		
15 OBS microseismicity		
16 Navigation	yes	JC50 cruise navigation
17 Other		

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Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single APC to basement at 187 m. RCB 130 m into basement, log as shown on form 3
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	None
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	None
4. Indications of gas hydrates at this location	None
5. Are there reasons to expect hydrocarbon accumulations at this site?	None
6. What "special" precautions will be taken during drilling?	None
7. What abandonment procedures need to be followed?	Not applicable
8. Natural or manmade hazards which may affect ship's operations	None
9. Summary: What do you consider the major risks in drilling at this site?	Poor weather

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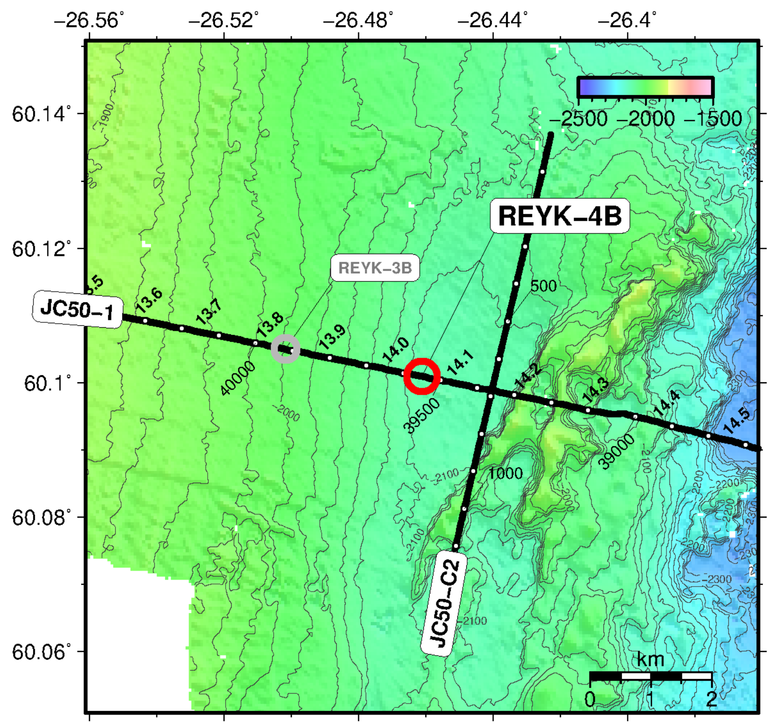
Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 16	Seabed to reflection B2	0.47	1.55	Nannofossil clay	Pelagic	138	Age based upon reflection R2 at Site 984
16 - 57	Reflection B2 to reflection B5	0.47-3.7	1.63	Silty clay	Pelagic	22	Age and lithology based on results from Site 984
57 - 415	Reflection B5 to acoustic basement	3.7-14.2	1.76	Silty clay	Pelagic	5	
415 - 545	Acoustic basement	14.2 and older	2.7	Vesicular basalt	Pelagic	NA	



Site Summary Figure: Proposal P892–Full Site REYK–4B

Location: –26.46111 W, 60.10094 N
CMP 39550 on JC50–1; CMP 685 on JC50–C2
Water depth: 2109 m / 2.849 s TWTT
Basement depth: 415 mbsf / 3.329 s TWTT
Target depth: 545 mbsf / 3.477 s TWTT
Basement age: 14.08 Ma

Figures and supporting data in SSDB:
Location map: REYK–4B_site_sum_fig_map.pdf
Seismic images: REYK–4B_site_sum_fig_JC50–1.pdf &
REYK–4B_site_sum_fig_JC50–C2.pdf
SEGY data / Navigation: JC50–1_stolt_trbal.segy / JC50–1.xy &
JC50–C2_stolt_trbal.segy / JC50–C2.xy

Interpretation:
Gray = seabed ; red = B2 (0.47 Ma); green = B3 (2.15 Ma);
blue = B4 (2.63 Ma); orange = B5 (3.7 Ma); black = basement