

Title	Newfoundland Oligo-Miocene sediment drifts: understanding the transition from the Paleogene greenhouse to the modern icehouse		
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### Abstract

The Newfoundland sediment drifts accumulated under the Deep Western Boundary Current (DWBC) that transports deep waters formed in the North Atlantic into the global ocean. Consequently, they record a global 'end member' of deep-water overturning and cryosphere evolution; at the same time, they preserve a detailed history of terrestrial and marine high-latitude ecosystems from the middle Eocene (~48 Ma) onwards. They are therefore ideally suited to test hypotheses on the global and regional evolution of the carbonate compensation depth (CCD), the origin of major 'biogenic blooms', and the role of gateways, nutrient recycling and latitudinal habitat differentiation in radiation of different biota.

Well-resolved marine records of the Oligo-Miocene are scarce in the Northern Hemisphere, which limits our understanding of the early transition into glacial climates and ecosystems. The Newfoundland sediment drifts comprise an exceptionally thick, quasi-continuous Oligo-Miocene succession containing well-preserved calcareous, siliceous and organic-walled microfossils, biomarkers, and magnetostratigraphic signals. Drilling these sediments will allow to test hypotheses about the interaction between deep-water circulation, global temperature, atmospheric pCO<sub>2</sub>, ice-sheet dynamics, and ecosystems, all of which experience state changes across the Oligo-Miocene. For deep-water circulation, a high-quality record of the DWBC history will be established, allowing reconstruction of North Atlantic deep-water production and the onset of quasi-modern AMOC. A new Oligo-Miocene depth transect (of ~1400–1600 m depth range) will capture the dynamics of southern component waters and northern-sourced deep waters through major climatic episodes of the Oligo-Miocene. Further, the new records will allow completion of a Paleocene to Miocene series of depth transects drilled during Expedition 342 in order to reconstruct the Cenozoic CCD for comparison with the well-resolved Pacific CCD.

Unlike most places in the Atlantic, bottom currents flowing over the Newfoundland Ridges have prevented the Oligo-Miocene sequence from becoming buried under a thick Plio-Pleistocene sedimentary blanket; hence, these sediments can be readily piston cored and have not been subject to diagenesis resulting from deep burial. Our drilling plan is designed around initially drilling a single, logged borehole on the crest of the drift sequence through the entire, ~900-m-thick Oligo-Miocene succession; this will provide a reference site that ties the reflector stratigraphy into all other drill sites. We will then drill a series of shallow-penetration, triple-APC-cored sites to recover the entire Oligo-Miocene record. Finally, we will drill two deep-penetration sites near the Oligo-Miocene CCD. Altogether, we have identified eight primary sites to achieve the science objectives outlined for the expedition.

## Scientific Objectives

The proposed drilling of Oligo-Miocene sediment drifts deposited on the Southeast Newfoundland Ridge can be used to address the following three key research questions that will allow a rigorous test of leading and sometimes contradictory hypotheses:

- 1) Do the CCD fluctuations and biogenic blooms of the Oligo-Miocene reflect primarily global changes in weathering or are they driven by large-scale changes in ocean circulation and/or regional tectonics (such as gateway dynamics)?
- 2) What is the role of tectonics, productivity, and North Atlantic overturning circulation as potential drivers of the Middle Miocene Climatic Optimum (MMCO)?
- 3) Is the establishment of distinctive polar ecosystems linked to major changes in overturning circulation in the North Atlantic, or is it primarily driven by a decline in pCO<sub>2</sub>?

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

none

## Proposed Sites (Total proposed sites: 25; pri: 8; alt: 17; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
NFR-01A (Primary)	40.835245 -47.721541	3320	900	0	900	Stratigraphic test site to identify the ages of the major and minor reflectors from the Pleistocene to the upper Eocene; data used to plan shallow penetration, offset sites. Site is located on a crossing of MCS Lines 43 and 56 making it possible to extend the seismic stratigraphy throughout SENR.
NFR-02A (Primary)	40.889215 -47.643687	3380	300	0	300	Lower Pliocene through upper Miocene; shallow penetration site (300 m); This site, together with NFR-03A, 04A, and 05A, will collect a composite ~750 m sequence of Miocene-Oligocene sediments with APC to maximize core quality, microfossil preservation and magnetic stratigraphy.
NFR-03A (Primary)	40.926778 -47.589625	3500	300	0	300	Middle Miocene; shallow penetration site (300 m); This site, together with NFR-02A, 04A, and 05A, will collect a composite ~750 m sequence of Miocene-Oligocene sediments with APC to maximize core quality, microfossil preservation and magnetic stratigraphy.
NFR-04A (Primary)	40.967666 -47.530591	3550	250	0	250	Lower Miocene; shallow penetration site (250 m); This site, together with NFR-02A, 03A, and 05A, will collect a composite ~750 m sequence of Miocene-Oligocene sediments with APC to maximize core quality, microfossil preservation and magnetic stratigraphy.
NFR-05A (Primary)	41.038692 -47.516385	3550	250	0	250	Lower Miocene through the Oligocene (to E/O boundary); shallow penetration site (250 m); This site, together with NFR-02A, 03A, and 04A, will collect a composite ~750 m sequence of Miocene-Oligocene sediments with APC to maximize core quality, microfossil preservation and magnetic stratigraphy.
NFR-06A (Primary)	40.085712 -47.745961	4250	300	0	300	Oligocene deep water section through the E/O boundary; represents the lower end of the Oligocene depth transect (together with NFR-05A and Leg 342 sites) designed to reconstruct the Oligocene CCD
NFR-07A (Primary)	40.312480 -49.670012	4420	700	0	700	Deep water Miocene section largely above the CCD; should capture primarily a carbonate-bearing section above the CCD with occasional excursions of carbonate poor sediments during CCD shoaling events.
NFR-08A (Primary)	40.185178 -49.834010	4925	700	0	700	Miocene deep water sequence straddling the CCD; This site is intended to evaluate fine-scale variations in the Miocene CCD by detecting occurrences (or absence) of carbonate sediments. The site is expected to be partly carbonate-free but the chronology of the site will be transferred from shallower water sites by use of log-to-log correlations and biostratigraphic control in the intervals where carbonate is present or through the use of dinocysts and siliceous microfossils.
NFR-09A (Alternate)	41.099113 -47.485762	3800	250	0	250	Oligocene to the E/O boundary; mid depth site that pins the shallow water excursions of the CCD in the Oligocene; forms depth transect to reconstruct the CCD in combination with Site NFR-06A and Leg 342 sites. This site penetrates a sequence similar in seismic character to IODP U1411 so it also represents an opportunity to obtain a 3 APC-cored E/O record; IODP U1411 was only double-cored owing to time and weather constraints. Site NFR-09A is an alternate for primary Site NFR-06A
NFR-10A (Alternate)	40.864283 -47.880816	3280	250	0	250	Shallow water (3280 m) Pleistocene-Miocene section with expanded Pleistocene record; intended to recover an expanded Pleistocene-upper Miocene record in combination with Site NFR-11A. Site NFR-10A is an alternate for primary Site NFR-02A
NFR-11A (Alternate)	40.875400 -47.943644	3370	400	0	400	Recover an expanded Pliocene and upper Miocene record on crest of the SENR. Drilling to 400 m would allow to capture the entire Pliocene sequence at shallow (3360 m) water depth. Site in combination to NFR-10A to recover (in combination) an expanded Pleistocene-upper Miocene section. Site NFR-11A is an alternate for primary Site NFR-02A
NFR-12A (Alternate)	40.868711 -47.601645	3400	250	0	250	Very expanded upper to middle Miocene section accessible through APC coring. Represents an alternate in the depth transect of offset boreholes represented by primary sites NFR-02A to -05A. Site NFR-12A is an alternate for primary Site NFR-03A

## Proposed Sites (Continued; total proposed sites: 25; pri: 8; alt: 17; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
NFR-13A (Alternate)	40.978834 -47.514364	3540	250	0	250	Lower Miocene to upper Oligocene section available through APC coring; represents an alternate for the basal Miocene in the depth transect of offset boreholes in Primary sites NFR-02A to -05A Site NFR-13A is an alternate for primary Site NFR-03A
NFR-14A (Alternate)	40.390731 -48.763151	3830	500	0	500	Middle of the proposed Miocene depth transect (at 3830 m). Carbonate content of sediments is expected to be variable, reflecting variations in the CCD. Section expected to be mainly middle and upper Miocene. Site NFR-14A is an alternate for primary Site NFR-03A
NFR-15A (Alternate)	40.653000 -46.975398	3720	250	0	250	Pliocene to upper Miocene at moderate depth (3720 m); drilling to ~500 m would capture most of the Miocene section Site NFR-15A is an alternate for primary Site NFR-03A
NFR-16A (Alternate)	40.714483 -49.503335	3750	250	0	250	Expanded Eocene section with E/O at shallow burial depth. Also expanded lower to middle Oligocene to get middle part of depth transect. Site NFR-16A is an alternate for primary Site NFR-05A
NFR-17A (Alternate)	40.173750 -49.848685	5000	500	0	500	This site represents the lower end of the Miocene depth transect. Minimal carbonate content expected to recover the deep end of Miocene CCD excursions; alternate to deep water primary site NFR-08A.
NFR-18A (Alternate)	40.098820 -47.789333	4200	400	0	400	Expanded lower to middle Miocene and Oligocene to the E/O Boundary Site NFR-18A is an alternate for primary Site NFR-06A
NFR-19A (Alternate)	40.098776 -47.680846	4260	250	0	250	Recovery of an expanded mid depth (4260 m) Oligocene succession to complete the middle of an Oligocene depth transect. Site NFR-19A is an alternate for primary Site NFR-04A
NFR-20A (Alternate)	39.968619 -48.959689	4620	500	0	500	Expanded Miocene record in deep water (4620 m) just above the Miocene CCD; should capture record of CCD shoaling but largely be above the CCD and so record good biostratigraphy and magnetostratigraphy; alternative site to deep-water primary site NFR-07A
NFR-21A (Alternate)	40.608510 -47.032209	3600	250	0	250	Pliocene-upper Miocene sequence for offset coring; alternative to primary sites (NFR-02A to -05A) that are used to capture a full Miocene-Oligocene sequence in APC cored sites Site NFR-21A is an alternate for primary Site NFR-03A
NFR-22A (Alternate)	40.301233 -47.423836	3920	250	0	250	Middle and Upper Miocene at a mid depth site (3920 m); mid part of Miocene depth transect for Miocene CCD reconstruction Site NFR-22A is an alternate for primary Site NFR-02A
NFR-23A (Alternate)	40.195797 -47.557755	4120	250	0	250	Lower Miocene to the O/M boundary and upper Oligocene. Mid-depth transect (4120 m) for Miocene-Oligocene CCD reconstruction Site NFR-23A is an alternate for primary Site NFR-06A
NFR-24A (Alternate)	40.269925 -49.724799	4550	500	0	500	Expanded middle and lower Miocene sequence just above Miocene CCD; alternative site to NFR-07A to pin the shallow excursions of the Miocene CCD
NFR-25A (Alternate)	39.873587 -49.097721	5070	500	0	500	Alternate to Primary site NFR-08A for Miocene deep water (5070 m) at the Miocene CCD; used to reconstruct short-term depressions of the CCD; dated by transferring biostratigraphy and magnetic chronology from shallower water sites using core-based logs; given available time, this site could also be logged, enabling correlation using downhole logs. Site expected to contain intervals of carbonate that can provide calcareous biostratigraphy; dinocysts and siliceous microfossils also provide chronology.