OCEAN DRILLING PROGRAM

LEG 210 SCIENTIFIC PROSPECTUS

DRILLING THE NEWFOUNDLAND HALF OF THE NEWFOUNDLAND–IBERIA TRANSECT: THE FIRST CONJUGATE MARGIN DRILLING IN A NON-VOLCANIC RIFT

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This Scientific Prospectus is based on precruise JOIDES panel discussions and scientific input from the designated Co-chief Scientists on behalf of the drilling proponents. The operational plans within reflect JOIDES Planning Committee and thematic panel priorities. During the course of the cruise, actual site operations may indicate to the Co-chief Scientists and the Operations Manager that it would be scientifically or operationally advantageous to amend the plan detailed in this prospectus. It should be understood that any proposed changes to the plan presented here are contingent upon the approval of the Director of the Ocean Drilling Program in consultation with the Science and Operations Committees (successors to the Planning Committee) and the Pollution Prevention and Safety Panel.

ABSTRACT

The underlying premise of many empirical, analytical, and numerical models of continental rifting is that mantle melt supply and/or temperatures prior to and during extension govern structural architecture and magmatic construction in the rift. However, drilling on the Iberia margin (Ocean Drilling Program [ODP] Legs 149 and 173) has documented extreme extension with little or no decompression melting of the asthenospheric mantle, defying model predictions. The puzzles raised by Iberia drilling are compounded by observations from geophysical studies on the conjugate Newfoundland margin, which document significant cross-rift asymmetries in basement depth, character of tectonic extension, and other deep structure. These results raise fundamental, overarching questions about rifting of non-volcanic margins, including the cause and extent of mantle unroofing, the presence or absence of decompression melting, the origin of the deep and crustal asymmetry between conjugates, the age-subsidence and strain-partitioning history, and the relation of rift events to development of shallow-water unconformities and the stratigraphic record. We propose three competing hypotheses for development of the Newfoundland–Iberia rift in which these questions are subsumed and which make specific predictions that can be tested by ocean drilling on the Newfoundland margin. The planned drilling is in a position exactly conjugate to the Iberia Abyssal Plain drilling transect and is based on a detailed grid of multichannel seismic and ocean borehole seismometer surveys that we conducted in 2000. The single most productive and direct test of our hypotheses can be accomplished by drilling a deep hole (~2200 m) in the central Newfoundland Basin (proposed Site NNB-01A), which is the primary target for drilling during ODP Leg 210. At this site we will also recover an extensive Cretaceous–Paleogene (and possibly Neogene) sedimentary record in the "gateway" between the Arctic/sub-Arctic seas and the main North Atlantic Basin. In the event that basement and deep sedimentary objectives cannot be achieved at proposed Site NNB-01A and sufficient time remains during the leg, alternate sites that extend seaward to known oceanic crust will be cored to partially meet our scientific objectives.

OVERVIEW OF SCIENTIFIC OBJECTIVES

The Newfoundland–Iberia rift (Fig. F1) is a non-volcanic rift that is an ideal location to examine overarching questions about the structure and evolution of non-volcanic rifted margins. Proposed Site NNB-01A in the central Newfoundland Basin, the prime site planned for drilling, is on "transitional" crust of uncertain composition between continental crust to the west and ocean crust exhibiting M-series (M0 and ?M3) magnetic anomalies to the east. Alternate sites in positions farther east along the transect (Fig. F2) are designed to obtain information about basement composition and structure at the seaward edge of the transition zone and onto probable ocean crust.

The primary objectives of Leg 210 drilling are

1. To determine whether the perceived asymmetry in deep and basement structure between the Newfoundland and Iberia margins is real, and if so, what mechanisms account for the deformation (e.g., simple shear?);
2. To understand the mechanical process responsible for pervasive unroofing of upper mantle off Iberia by constraining basement structure and evolution on the Newfoundland conjugate;
3. To investigate whether lithospheric thinning and removal of the continental crust occur with or without decompression melting of the asthenospheric mantle (e.g., was the entire rift amagmatic?);

4. To determine the nature and timing of rift events (e.g., end of rifting, subsidence, and initial seafloor spreading) in the Newfoundland Basin and to test correlations with events on the Iberia margin;
5. To relate spatial and temporal strain partitioning predicted from these events to features including symmetric or asymmetric extension, distribution of melt products in the rift, development of stratigraphic sequences, and well-documented synrift and "break-up" unconformities on the shallow margins;
6. To examine whether strain rates were sufficiently slow that conductive cooling suppressed melting of the rising asthenospheric mantle; and
7. To document the post-rift paleoceanographic history in this "gateway" between the North Atlantic and the sub-Arctic and Arctic Oceans.

GEOLOGICAL BACKGROUND AND HYPOTHESES FOR ORIGIN OF TRANSITIONAL CRUST

Geological Background

The Newfoundland–Iberia rift first experienced significant extension in the Late Triassic, when basins initially formed within the Grand Banks and accumulated clastics and evaporites (e.g., Jansa and Wade, 1975). A second rift phase in the Late Jurassic through Early Cretaceous focused extension between the Grand Banks and Iberia, culminating in breakup and formation of the first oceanic crust no later than Barremian to Aptian time (Fig. F1). Excepting the Southeast Newfoundland Ridge at the southernmost edge of the rift, no significant thickness of volcanic rocks or magmatic underplating are known to be present, and the system is considered to be a non-volcanic rift.

Plate reconstruction of the Newfoundland–Iberia conjugate margins at the time of Anomaly M0 (early Aptian; ~121 Ma) (Fig. F1) provides a regional overview of the rift and the conjugate margins. At this time, thick continental crust of Flemish Cap was opposite extended continental crust of Galicia Bank at the northern end of the rift. To the south, geophysical studies and magnetic anomaly identifications suggest that ocean crust was present, extending landward from a seafloor-spreading axis to at least Anomaly M3 (shaded area in Fig. F1). Off Iberia, the seaward edge of known continental crust is near the western margin of Galicia Bank, and to the south it passes near Ocean Drilling Program (ODP) Site 1069, then east and south toward Estremadure Spur. On the Newfoundland margin, continental crust is thought to reach seaward to at least the Flemish Hinge in the north and to a hinge line at the eastern edge of Salar-Bonnition Basin in the south.

On both margins, seafloor between Anomaly M3 and the most-seaward "known" continental crust is considered "transitional crust," and its origin is a matter of intense debate. Structural trends of basement in this zone are oriented north-northeast to northeast, subparallel to the Anomaly M0 rift axis. In the area of the Iberia Abyssal Plain, ODP coring recovered serpentinized peridotites from basement in the transition zone (Fig. F2). In seismic data to the south, a thin (1.0–2.5 km) acoustically unreflective basement layer is observed overlying a more reflective layer (Pickup et al., 1996), and this has been interpreted to be serpentinized upper mantle peridotite grading downward into unaltered peridotite. Velocities in the Iberia transition zone define a "crust" that is only a few kilometers thick and that has velocity values and gradients characteristic of neither extended continental nor oceanic crust (Whitmarsh et al., 1990; Pinheiro et al., 1992).

Similar "crustal" thicknesses and unusual velocity structure were indicated along the landward margin of the transition zone in the Newfoundland Basin (Todd and Reid, 1989; Reid, 1994; Srivastava et al., 2000). In 2000, detailed multichannel seismic (MCS) and ocean borehole seismometer (OBH/S) surveys were conducted across the entire Newfoundland transition zone on the *Ewing* cruise 00-07, including drill site surveys in a corridor conjugate to the Leg 149 and 173 drilling (Transect 2 in Fig. F3). Results show that crustal thickness averages only ~3 km. However, the crustal velocity structure appears to differ from that off Iberia. It seems to be more similar to Layer 3 of ocean crust, with Layer 2 either extremely thin or absent.

Despite the similarity of "crustal" thicknesses in the Newfoundland and Iberia transition zones, there are significant asymmetries in deep and basement structure between the two margins (Fig. F2). Newfoundland transitional basement averages a kilometer or more shallower than Iberia basement, and it is comparatively smooth compared to ~1- to 2-km basement relief off Iberia. Off Newfoundland, landward of Anomaly ~M3, there is also a very flat, high-amplitude, basin-wide reflection (U), which closely overlies or intersects the underlying basement; there is no known counterpart to this horizon in the transition zone off Iberia. In the central and southern Newfoundland Basin the U reflection appears locally to truncate the underlying basement, and where traced landward it merges with the mid-Cretaceous Avalon unconformity on the Grand Banks. Because of these characteristics, Tucholke et al. (1989) suggested that the reflection is an unconformity that was eroded at sea level on extended continental crust. Thermal-mechanical modeling, however, shows that such sea level erosion would have to be on continental crust up to ~20 km thick, so if the reflection is a subaerial unconformity it must be a synrift unconformity and not a "breakup unconformity" (B. Tucholke and N. Driscoll, unpubl. data.).

Hypotheses for Origin of Transitional Crust

We have posed three hypotheses to explain crustal structure in the Newfoundland and Iberia transition zones and the cross-rift asymmetries between these zones (Fig. F4):

1. The Newfoundland transition zone is strongly thinned continental crust. Newfoundland crust is shallower and smoother than Iberia crust, and it could be the upper plate in an asymmetric detachment system (Fig. F4B). The lower Iberia plate east of Anomaly ~M3 would be exhumed lower continental crust and mantle. Strong thinning of the Newfoundland crust without significant brittle extension might be explained by ductile flow of the lower crust (e.g., Driscoll and Karner, 1998) (Fig. F4A). This should be reflected in rapid synrift subsidence, and it would be recorded in the sedimentary section above reflection U if we interpret U as a subaerially eroded unconformity. An alternate explanation of reflection U is that it is the top of basalt flows, emplaced either subaerially (synrift on continental crust) or on the seafloor. If melt was extracted from the rising lower plate and emplaced in the Newfoundland upper plate, the exhumed Iberia mantle would be virtually melt-free, as is suggested by existing Iberia drilling.
2. The transition zones reflect extreme extension in an amagmatic rift. According to this hypothesis, continental extension proceeded under nearly amagmatic conditions to a state where only mantle was exposed, and at some point an asymmetric shear developed within the exposed mantle (Fig. F4C). This hypothesis differs from the one above in that Newfoundland transitional crust would be (serpentinized) mantle, and the U reflection cannot be a subaerial unconformity because it would be impossible to uplift extending mantle to sea level. The reflection U–basement interval could consist of basalt flows, with melt generated from the rising lower plate in an asymmetric extensional system as noted above.

3. Transitional crust was formed by ultra-slow seafloor spreading. Slow seafloor spreading (Fig. F4D) is known to expose lower crust and mantle (e.g., in the Labrador Sea), and it could explain the transitional crust in the Newfoundland Basin. However, symmetrical ultra-slow seafloor spreading in the rift (Fig. F4D) seems unlikely because it does not explain the extensive mantle exposures off Iberia, nor does it explain the asymmetries in crustal structure between the conjugate transition zones. It is possible that extension first exposed mantle in the rift, that ultra-slow seafloor spreading then occurred on the Newfoundland side of the rift, and that this ocean crust was then isolated on the Newfoundland margin by an eastward jump of the spreading axis. This hypothesis precludes reflection U from being a subaerial unconformity because it would overlie thin ocean crust and thus it could not have been exposed at sea level. The U reflection could prove to have another, unknown origin, perhaps as a basin-wide sedimentary event that was restricted to the Grand Banks side of the rift.

SCIENTIFIC OBJECTIVES AND OPERATIONAL STRATEGY

Broad-Based Objectives

To test the above hypotheses, critical data will be provided by drilling in the Newfoundland transition zone. These data include (1) the structure and composition of basement, (2) the origin and composition of the interval between basement and the U reflection, (3) the origin of the U reflection, and (4) the subsidence history of crust recorded in the basement–U and post-U sedimentary sequence. In addition, coring the post-U sequence will determine the evolution of paleoceanographic conditions in this developing ocean basin, which is a critical gateway between the North Atlantic and the sub-Arctic and Arctic Ocean Basins.

Leg 210 drill sites are arrayed along *Ewing* line 2MCS (Figs. F2, F3, F5, F6, F7, F8), which is conjugate to the drilling transect of ODP Legs 149 and 173 on the Iberia margin. The prime drill site for ODP Leg 210 is proposed Site NNB-01A. This is a deep hole (~2080 m to basement) which is designed to penetrate a complete stratigraphic sequence below ~800 meters below seafloor (mbsf) (including the U reflection and the U–basement interval) and to penetrate as deeply as possible into basement. Alternate Sites NNB-01B and NNB-01C have the same objectives but they require deeper penetration; it is unlikely that either of these sites will be drilled. Other sites along the transect are designed to sample across the interval from transition zone crust at Site NNB-01A seaward to probable "normal" ocean crust (proposed Sites NNB0-5A and NNB-06B). These sites are outside the limits where the U reflection is observed, and they consequently have lower priority than Site NNB-01A. The order in which these alternate sites might be drilled will depend on the time that each requires balanced against scientific priorities and time remaining during the leg. Site-specific objectives, expected lithologies, and drilling strategies are described below.

Site-Specific Operational Strategy

Primary Site: Proposed Site NNB-01A

This is the primary site for Leg 210 operations (Figs. F2, F3, F5, F7; Table T1). Major objectives are (1) to sample reflection U, the U–basement interval, and basement (penetration of at least 100 m) in order to test hypotheses about crustal origin and evolution; and (2) to obtain as much of the record of the overlying deep sedimentary section as possible in order to examine subsidence history and paleoceanographic evolution in the Newfoundland Basin. On line 2MCS, the site is located slightly east of the crest of a crustal block and basement depth is ~2080 mbsf. On the crossing line 303, basement rises ~500 m within 10 km to the south (see Fig. F7). Reflection U is ~200 m above basement at the drill site and dips southeast on line 2MCS. On the crossing line 303, reflection U forms a gentle swale, rising slightly to the south where it laps onto the shoaling basement. To the north, reflection U is initially nearly flat and then slowly rises.

The nature of the section between reflection U and basement is unknown, and our three working hypotheses predict different lithologies. If the basement is thinned continental crust, the basement–U section could be prerift to synrift sediments (middle Cretaceous and older), possibly including Kimmeridgian beds like the Egret formation source rock in the Jeanne d'Arc Basin ~300 km to the west on the Grand Banks. However, analysis of OBH/S data currently in progress suggests that it is unlikely that the basement is continental. The crust is thin (a few kilometers) and it has velocities and velocity gradients similar to oceanic Layer 3.

The hypothesis that basement is exhumed serpentinized mantle would indicate that the basement–U section must have been deposited in deep water because of isostatic considerations. The section could be basalts, or it could be a sedimentary sequence peculiar to the Newfoundland margin. If the basement is ultra-slow-spreading ocean crust, the basement–U section could also be basaltic or sedimentary, although the depth of the seafloor probably would have been shallower than if it had been over exhumed mantle. OBH/S analyses suggest that the crust has velocity and velocity gradients similar to oceanic Layer 3. If the crust is oceanic, the U–basement section would probably have been deposited in deep water.

Overlying U, and up to reflection A^u, we expect the following ascending series: black claystones equivalent to the Hatteras formation (Barremian–Cenomanian) drilled in the western North Atlantic, multicolored claystones (±limestones) equivalent to the Plantagenet formation (Turonian–Paleocene), siliceous claystones (possibly cherty) equivalent to the Bermuda Rise formation (Paleocene–Eocene), and, possibly, claystones equivalent to the Blake Ridge formation (Eocene and younger). Because the black claystones in the western North Atlantic can contain significant amounts of organic matter and because any equivalent in the Newfoundland Basin is buried up to ~1800 m, we must consider the potential in this interval for hydrocarbon generation. Within the Newfoundland–Iberia rift, black claystones of Barremian–Albian age were drilled at Deep Sea Drilling Project Site 398 (water depth = 3900 m) on the conjugate Iberia margin at subbottom depths of ~1180–1670 m. These sediments presumably were deposited under conditions similar to those in the Newfoundland Basin. Although the sediments contain up to 3% organic matter, Kendrick et al. (1979) considered the sequence to have low petroleum-generating potential. Nonetheless, the environment may have been different in the Newfoundland Basin and it will be important to monitor continuously for any hydrocarbons during drilling at this site.

The shallowest part of the hole has a thin turbidite sequence, and there is the possibility of sand in this section that could cause hole instability. Because proposed Site NNB-01A is located at the western feather edge of this sequence, this possibility is minimized.

Previous drilling results on the conjugate Iberian margin (Legs 149 and 173) have been used to predict drilling conditions and penetration rates at Leg 210 sites, including Site NNB-01A. As these previous legs encountered substantial hole stability problems (unconsolidated turbidites and unstable deep sediments and basement), we are prepared to use multiple casing strings to stabilize the entire sedimentary cover and uppermost basement at Site NNB-01A. Operations at Site NNB-01A are expected to occupy the entire leg. To be able to achieve the prime objectives of the leg (sampling the deepest sediment section, the U reflection, and basement) in the time allotted, coring the uppermost sediments (0–800 mbsf) will be deferred until achieving the main goals of the cruise.

Our first operation will be to drill-in a reentry cone with ~80 m of 20-in casing (Table T1). Next, we will drill without coring from 80 to 800 mbsf and install 16-in casing to 775 mbsf. Rotary core barrel (RCB) coring will start at 800 mbsf and continue down to ~1375 mbsf; the hole will be logged and a $13^3/_8$-in casing liner set to ~1350 mbsf. We will core from ~1375 mbsf down to basement (~2080 mbsf) and possibly into the upper few tens of meters of basement, hole conditions permitting. This section will be logged before setting a $10^3/_4$-in casing liner to ~2080 mbsf. Then basement will be penetrated 100–200 m, depending on hole and drill-bit conditions as well as time available (see Table T1). Logging will be conducted in the same sections that are cored and will consist of three runs (triple combination [triple combo] and Formation MicroScanner [FMS]-sonic tool strings and the Well Seismic Tool [WST]). After the primary deep objectives have been achieved, if time permits, we may core the upper ~800 m of section in a second hole to obtain a complete sedimentary record at this site.

Alternate Site: Proposed Site NNB-01B

This site is an alternate to drilling at proposed Site NNB-01A (Figs. F2, F3, F5, F7; Table T2). The uppermost turbidite section at Site NNB-01B is slightly thicker than that at Site NNB-01A. Based on recent time migration of MCS data and velocity analyses, basement depth is picked at ~7.90 s (~2177 m subbottom), ~100 m deeper than at Site NNB-01A. The Site NNB-01B basement depth is shallower than indicated by recent analysis of the other alternate (proposed Site NNB-01C), and thus Site NNB-01B is the preferred alternate. The site is located on a small basement rise on line 2MCS. On the crossing line 108, basement is depressed at the site, rising both to the north and the south. The overlying U reflection is flat to gently depressed, with a small rise to the south side of the drill site.

The objectives, the stratigraphic section, and the drilling, logging, and monitoring procedures are similar to those for proposed Site NNB-01A, but they are outlined in Table T2 as a three casing string scenario.

Alternate Site: Proposed Site NNB-01C

This site is a second alternate to Site NNB-01A (Figs. F2, F3, F5, F7; Table T2). There is no turbidite section at the top of Site NNB-01C. Based on recent time migration of MCS data and velocity analyses, basement depth is picked at ~7.76 s (~2358 m subbottom), requiring ~280 m more penetration than at Site NNB-01A. Proposed Site NNB-01C is located just east of the crest of a basement high on line 2MCS, and on the crossing line 305 it is in a basement swale. The overlying U reflection dips eastward on line 2MCS and forms a local swale in the crossing line 305.

The objectives, the stratigraphic section, and the drilling, logging, and monitoring procedures are similar to those for proposed Site NNB-01B.

Alternate Site: Proposed Site NNB-03A

Proposed Site NNB-03A is 22 km seaward of Site NNB-01A (Figs. F2, F3, F5, F8; Table T2). It is our next highest priority for drilling if there are problems at Site NNB-01A and enough time remains to drill at the site. Proposed Site NNB-03A lies over a flattened basement block that the U reflection laps onto and partially circumscribes. Thus the block predates the formation of reflection U, and a key objective is to determine the nature of this pre-U crust. The block is near magnetic Anomaly M3, the interpreted age of the oldest ocean crust on the conjugate Iberia margin. However, the block exhibits reflections that are significantly more coherent and lower frequency than large basement ridges farther to the east and closer to Anomaly M0. This might indicate that the Site NNB-03A crust contains a continental component, or, like the basement ridge drilled at Site 1070 near Anomaly M3 off Iberia, that it consists of serpentinized peridotite ± gabbroic intrusions. Other key objectives are to determine the subsidence history of the basement and the paleoceanographic history from the overlying sedimentary section.

On line 2MCS, the site is east of the crest of a basement high, and on the crossing line 208 it is on the flank of the basement high. Reflection U is not present at the site. The sedimentary section over basement, up to reflection A^u, probably consists of claystones and siliceous/cherty claystones of Late Cretaceous to Eocene age. There may be a thin interval of black shales (Hatteras formation equivalent) immediately above basement. Turbidites are present from the seafloor to a depth of ~400 mbsf.

The drilling/logging plan consists of a two-casing string strategy with a $10^3/_4$-in liner as contingency to ensure we can obtain deep sediments and basement (Table T2). We will drill 20-in casing in to ~80 mbsf and then 16-in casing to ~475 mbsf. RCB coring will extend from 500 mbsf down to, and into, basement. Logging will consist of the two standard logging strings and a checkshot with the WST. After the primary deep objectives have been achieved, if time permits, we will core the upper ~500 m of section in order to obtain a complete sedimentary record at this site.

Alternate Site: Proposed Site NNB-04A

Seaward of Site NNB-03A out to just beyond Anomaly M0 is a set of three large basement ridges (Figs. F2, F5, F6). These ridges are much higher amplitude than any other basement blocks known either landward or seaward, but they are similar to the large peridotite ridges drilled on the conjugate Iberia margin. Proposed Sites NNB-04A to NNB-06B are located on these large ridges, and a primary drilling objective is to determine whether they are normal ocean crust, serpentinized peridotite as off Iberia, or possibly some other composition. Site NNB-04A is the highest priority for drilling in this group, and it is also a short hole (~6 days).

Basement at Site NNB-04A is picked on line 2MCS at 6.27 s (~136 m subbottom) at the top of a basement high. In the crossing line 206 (Fig. F8), an elongated ridgelike character of the basement high is apparent and basement rises southward nearly to the seafloor. Overlying sediments are Pleistocene turbidites.

Coring/logging at this site will be RCB to basement, plus at least 100-m basement penetration (Table T2). Logging will consist of the two standard logging strings and a checkshot with the WST.

Alternate Site: Proposed Site NNB-05A

This site is located to the side of the crest of a basement high which is elongated in a northeast-southwest direction (Figs. F2, F6, F8). Basement depth at the drill site is ~355 m. The overlying sediments are turbidites, fan sediments, and contourites, probably of Pliocene (?Miocene) to Pleistocene age.

In the first hole we will use the advanced piston corer/extended core barrel (APC/XCB) to core to basement (Table T2). In the second hole we will drill without coring to ~355 mbsf (just above basement) and then core at least 100 m in basement. Logging will consist of the two standard logging strings and a checkshot with the WST.

Alternate Site: Proposed Site NNB-06B

This site also is located to the side of the crest of a basement high which is elongated in a northeast-southwest direction (Figs. F2, F6, F8). Basement depth at the drill site is ~760 m. The overlying sediments are turbidites, fan sediments, and contourites, probably of Oligocene–Miocene to Pleistocene age. Horizon A^u is interpreted to be at ~650 mbsf, and Eocene sediments are presumably present below this reflection.

Coring/logging at this site includes APC/XCB coring to ~500 mbsf (Table T2). The second hole will be drilled without coring to just above ~500 mbsf and then cored downward to at least 100 m into basement. Logging will consist of the two standard logging strings and a checkshot with the WST.

Logging Plan

Downhole logging will constrain in situ formation properties and is an essential component for achieving Leg 210 scientific objectives. We are planning three logging runs in each of the cored intervals at proposed Site NNB-01A and other sites that may be drilled: (1) triple combo tool string (including the QSST checkshot tool, pending funding), (2) FMS-sonic tool string, and (3) a checkshot with the WST.

The Leg 210 logging plan for proposed Site NNB-01A has been designed to achieve the following objectives:

1. Core-log-seismic correlation. A detailed correlation between cores, logs, and the extensive suite of high-quality seismic reflection data is critical for understanding the succession of basement and sedimentary rocks and for compiling a detailed sequence stratigraphy. Accordingly, checkshot (WST) surveys, at ~50 m spacing, will be run.
2. Detailed description of cored sequences and sedimentary features. Integrated interpretation of the FMS and geophysical logs (triple combo) will provide an essential compliment to cores for describing the lithostratigraphy, particularly in intervals where core recovery is incomplete. Fine-scale sedimentary features like bedding, bioturbation, and slumps can be seen on FMS images and this data will help in understanding the paleoenvironment.
3. Structural analysis of fracture and fault networks by integrating FMS images, log, and core data.

The characteristics of the logging tools are as follows (additional information on these tool strings can be found at http://www.ldeo.columbia.edu/BRG):

1. The triple combo tool string includes the Dual Induction Tool (DITE), which measures resistivity from deep and shallow induction, the Accelerator Porosity Sonde (APS), which measures porosity from epithermal neutron measurements, and the Hostile Environment Litho-Density Sonde (HLDS), which measures bulk density from Compton scattering and provides an indication of general lithology from the photoelectric effect. The Hostile Environment Gamma Ray Sonde (HNGS) is added to the top of this tool string.
2. The FMS-sonic tool string includes the Formation MicroScanner, which measures resistivity at centimeter-scale resolution on four pads moving along the borehole, the General Purpose Inclinometer Tool (GPIT), and the Dipole Sonic Imager (DSI), which measures compressional and shear wave velocity as well as cross-dipole and Stoneley waveforms.
3. The WST is a checkshot tool used for zero-offset vertical seismic profiles (VSPs). It consists of a single geophone that is used to record acoustic waves generated by a seismic source located near the sea surface. We have also requested use of the QSST tool to obtain a checkshot at total depth when running the triple combo tool string.

Sampling Strategy

The Sample Distribution, Data Distribution, and Publications Policy is posted at www-odp.tamu.edu/publications/policy.html. As part of this policy, any access to data and core sampling to be conducted during Leg 210 or during the 1-yr moratorium following the end of the leg must be approved by the Sampling Allocation Committee (SAC). The SAC members are the co-chief scientists, the staff scientist, and the curatorial representative. The SAC will work with the scientific party to formulate a formal a leg-specific sampling plan for shipboard and postcruise sampling.

Sample and data requests may be submitted by shipboard and shore-based scientists no later than 3 months before the cruise via the electronic form (www-odp.tamu.edu/curation/subsfrm.htm). Prior to the cruise, the SAC will prepare a temporary sampling plan, which will be revised on the ship as needed. Minimizing redundancy of measurements among the science party, both shipboard and shore-based scientists, will be a factor in evaluating sample requests. The sampling plan will be subject to modification depending upon the actual material recovered and collaborations that may evolve between scientists during the leg.

The minimum permanent archive will be the standard archive half of each core. All sample frequencies and sizes must be justified on a scientific basis and will depend on core recovery, the full spectrum of other requests, and the cruise objectives. Some redundancy of measurement is unavoidable, but minimizing the duplication of measurements among the shipboard party and identified shore-based collaborators will be a factor in evaluating sample requests.

As we intend to core only one hole at proposed Site NNB-01A during Leg 210, there will only be one lithologic section available for core description and sampling. In some critical intervals (e.g., Cretaceous/Tertiary boundary, ocean anoxic events, basement contact, faults, veins, etc.) there may be considerable demand for samples from a limited amount of recovered core material. These intervals may require special handling, a higher sampling density, or reduced sample size. A coordinated sampling plan may be required before critical intervals are sampled.

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TABLE CAPTIONS

Table T1. Leg 210 operations plan and time estimate for the primary site.

Table T2. Leg 210 operations plan and time estimate for alternate sites.

FIGURE CAPTIONS

Figure F1. Reconstruction of the Newfoundland–Iberia rift at Anomaly M0 (Newfoundland plate is fixed in present geographic coordinates), based on the reconstruction pole of Srivastava et al. (2000). Tectonic and other data are compiled from numerous sources (structural data from *Ewing* Cruise 00-07 in 2000 [Fig. F3] are not included). Ocean crust (center, shaded) is presumed to have formed beginning near Anomaly M3. South-to-north zipperlike opening would account for the observed splayed tectonic trends between the two margins and the northward-narrowing zone of ocean crust. On the Newfoundland side, the U reflection extends throughout the Newfoundland Basin and pinches out seaward near Anomaly M3. *Ewing* MCS/OBH/S transects across the Newfoundland margin (Fig. F3) are indicated by bold lines labeled with circled numbers. ODP Leg 210 drill sites are along Transect 2. F.Z. = fracture zone, T.Z. = transfer zone, A.P. = abyssal plain.

Figure F2. **A.** Reconstruction of conjugate seismic sections from the Newfoundland and Iberia margins to the time of Anomaly ~M1. Left: Preliminary interpretation of *Ewing* line 2MCS (location in Fig. F3). Interpreted postrift sediments are shaded. The deep U reflection is highlighted and labeled. Proposed drill sites landward of Anomaly M1 are shown. Right: Composite seismic section (LG-12) along the conjugate Iberia drilling transect, adapted from ODP Leg 173 Scientific Party (1998). Drill sites are numbered, and recovery at the bottom of holes is indicated. **B.** *Conrad* MCS line NB1 (location in Fig. F3) ~150 km south of *Ewing* line 2MCS, showing another view of Newfoundland Basin basement structure and the overlying U reflection. **C.** IAM-9 MCS line ~50 km south of LG-12 off Iberia. In A–C, note the marked asymmetries in basement depth and roughness between the Newfoundland and Iberia sides of the rift. **D.** Preliminary interpretation of the full length of *Ewing* line 2MCS with magnetic anomaly locations of Srivastava et al. (2000) and proposed drill site locations. TWT = two-way traveltime.

Figure F3. **A.** Track map showing partial coverage of multichannel seismic (MCS) and single-channel seismic (SCS) reflection profiles, northern Newfoundland Basin (*Ewing* Cruise 00-07 lines in bold). Bathymetry in meters (1000-m contours). **B.** *Ewing* Cruise 00-07 MCS and ocean borehole seismometer (OBH/S) survey on Transect 2 (labeled every 1000 common midpoint [CMP]). Proposed drill sites are indicated by solid circles and labeling. Bathymetry in meters (100-m contour interval).

Figure F4. Schematic models to explain observed deep structural asymmetries between the Newfoundland (left) and Iberia (right) margins. **A.** Synrift extension of continental crust. In the central part of the rift, lower crust is thinned ductilely (dashes) but brittle upper crust has limited tectonic extension (e.g., Driscoll and Karner, 1998). **B.** At the time of Anomaly ~M3. The rift evolves asymmetrically, with a thin remnant of continental crust forming an upper Newfoundland plate and serpentinized peridotite and remnants of ductilely thinned lower crust forming a lower Iberia plate. Bending stresses may account for faulting in the cold brittle mantle footwall as it is exhumed. Basement depth differences on the two margins reflect buoyancy of thin continental crust vs. serpentinized mantle. The U reflection may be a synrift unconformity developed near sea level. **C.** Anomaly ~M3. Mantle is exposed on both sides of the rift at an early stage, but an asymmetric shear then develops.

Melt extracted from the lower plate may permeate the Newfoundland upper plate and flood its surface to form the U-to-basement sequence in a submarine setting (dark gray). Basement depth differences reflect buoyancy differences caused by melt intrusion/extrusion on the Newfoundland side. **D.** Anomaly ~M3: ultra-slow seafloor spreading. Symmetrical spreading as depicted here is unlikely because it would not account for extensive exposure of serpentinized mantle on the Iberia side or the asymmetry in basement structure of the transition zones on the two margins. Rather, ocean crust may have formed in the western part of the rift by seafloor spreading after the initial exposure of mantle, with the ocean crust subsequently being isolated on the Newfoundland side by an eastward jump of the spreading axis. The U–basement sequence might be explained (e.g., by basalt flows capping the ocean crust or as a sedimentary phenomenon peculiar to the Grand Banks side of the rift). The Newfoundland ocean crust would be more buoyant, and thus shallower, than serpentinized mantle on the Iberia side; differences in basement roughness would reflect differing effects and degrees of tectonic extension in ultra-slow-spreading ocean crust (Newfoundland side) and serpentinized mantle (Iberia side). MOHO = Mohorovicic seismic discontinuity.

Figure F5. Section of *Ewing* line 2MCS showing proposed drill Sites NNB-01A, NNB-01B, NNB-01C, NNB-03A, and NNB-04A. Locations are shown in Figure F3. Crossing profiles are shown in Figures F7 and F8. Arrows at the bottom indicate depths of basement picks. Holes are planned for at least 100-m basement penetration. CMP = common midpoint.

Figure F6. Section of *Ewing* line 2MCS extending east of the section in Figure F5, showing proposed drill Site NNB-05A. Site NNB-06B is on line 202 ~8 km southwest of the indicated crossing of this line. Location is shown in Figure F3. Crossing profiles are shown in Figure F8. Arrows at bottom of sites locate basement picks. Holes are planned for at least 100-m basement penetration. CMP = common midpoint.

Figure F7. *Ewing* MCS profiles crossing at proposed drill Sites NNB-01A, NNB-01B, and NNB-01C. Locations are shown in Figure F3. The main profile (2MCS) is shown in Figure F5. Arrows at the bottom indicate depths of basement picks. Holes are planned for at least 100-m basement penetration. CMP = common midpoint.

Figure F8. *Ewing* MCS crossing lines for proposed drill Sites NNB-03A, NNB-04A, and NNB-05A and profile through proposed Site NNB-06B. Locations are shown in Figure F3. Arrows at the bottom indicate basement picks. Holes are planned for at least 100-m basement penetration. CMP = common midpoint.

Table T1. Leg 210 operations plan and time estimate for the primary site.

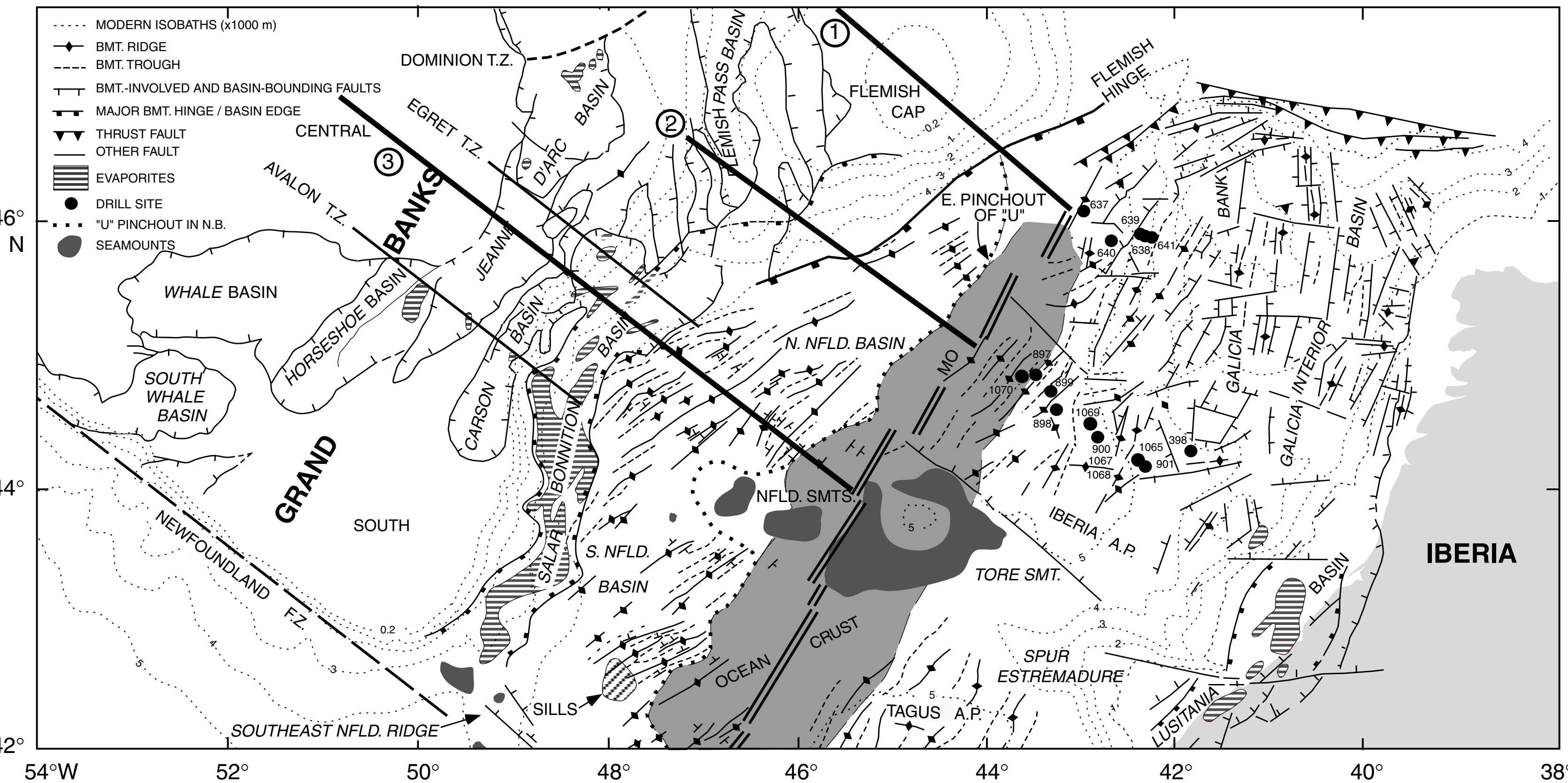
Site	Location (lat/long)	Water depth (mbrf)	Operations description	Transit (days)	Drilling (days)	Logging (days)
Bermuda	32.18°N, 64.48°W		Sea voyage from starting port to site, 1210 nmi @ 10.5 kt	4.8		
NNB-01A	45.40500°N	4559	Four casing strings (reentry cone, 20, 16, 13-3/8, and 10-3/4 inch)			
(4 casings)	44.78500°W	4559	Hole A: Drill-in 80 m 20" casing with reentry cone		1.9	
			Drill with 20-in underreamer ~80 to 800 mbsf in sediment and			
			Set 16-in casing at 775 mbsf, cement		6.2	
			RCB 800-1375 mbsf		7.8	
			Log: triple combo/FMS-sonic/WST-VSP			2.0
			Underream with 14-3/4-in tricone bit ~800 to 1375 mbsf			
			and set 13-3/8-in casing liner to 1350 mbsf, cement		6.0	
			RCB 1375-2080 mbsf		15.2	
			Log: triple combo/FMS-sonic/WST-VSP			2.3
			Underream with 12-1/4-in tricone bit ~1350 to 2080 mbsf			
			and set 760 m 10-3/4-in liner at 2060 mbsf, cement		7.3	
			Basement @ 2080 mbsf			
			RCB basement 2080-2180 mbsf		4.1	
			Log: triple combo/FMS-sonic/WST-VSP			1.6
St. John's	47.34°N, 52.41°W		Sea voyage from last site to ending port, 336 nmi @ 10.5 kt	1.3		
			SUBTOTAL:	6.1	48.5	5.9
			TOTAL OPERATING DAYS (56 days available):	60.5		
			NNB-01A ALTERNATE OPERATIONS			
NNB-01A	45.40500°N	4559	Hole B: drill to 350 mbsf, RCB 350-800 mbsf		5.8	
(4 casings)	44.78500°W		Log: triple combo/FMS-sonic			2.0
			Hole C: APC to ref. ~250 mbsf, XCB to ref. ~500 mbsf		4.8	
			Log: triple combo/FMS-sonic			1.4

Table T2. Leg 210 operations plan and time estimate for alternate sites.

Site	Location (lat/long)	Site depth (mbrf)	Operations description	Transit (days)	Drilling (days)	Logging (days)
NNB-03A	45.3267°N	4553	Two casing strings (reentry cone, 20, and 16 in)			
(2 casings)	44.6317°W		with 10-3/4-in liner as contingency			
			Hole A: drill-in 80 m 20-in casing with reentry cone		**1.8**	
			Drill with 22-in underreamer ~80 to 500 mbsf			
			set 475 m 16-in casing, cement		**4.8**	
			RCB 500-1240 mbsf (sediment)		**8.2**	
			RCB 1240-1340 mbsf (basement at 1240 mbsf)		**3.5**	
			Log: triple combo/FMS-sonic/WST-VSP			**2.2**
			SUBTOTAL:	**0.0**	**18.3**	**2.2**
			TOTAL OPERATING DAYS (56 days available):	**20.5**		
			NNB-03A ALTERNATE OPERATIONS:			
NNB-03A		4553	Hole A: underream to 18-in ~525 to 1240 mbsf			
(3 casings)			and set 740 m 10-3/4-in liner @ 1215 mbsf, cement		**5.5**	
			Hole A: RCB basement 1240-1480 mbsf		**11.8**	
			Log: triple combo/FMS-sonic/WST-VSP			**1.7**
			Hole B: APC to refusal ~250 mbsf, XCB to refusal ~500 mbsf		**4.7**	
			Log: triple combo/FMS-sonic			**1.4**
NNB-01B	45.3917°N	4563	Three casing strings (reentry cone, 20, 16, and 13-3/8 in)			
(3 casings)	44.7583°W		with 10-3/4-in casing as contingency			
			Hole A: drill-in 60 m 20-in casing with reentry cone		**1.8**	
			Drill with 20-in underreamer ~60 to 800 mbsf			
			set 775 m 16-in casing, cement		**6.2**	
			RCB 800-1375 mbsf		**7.7**	
			Log: triple combo/FMS-sonic/WST-VSP			**2.0**
			Underream with 14-3/4-in tricone bit ~800 to 1375 mbsf			
			and set 725 m 13-3/8-in liner @ 1350 mbsf, cement		**6.5**	
			RCB sediment 1375-2180 mbsf		**17.7**	
			RCB basement 2180-2280 mbsf		**4.3**	
			Log: triple combo/FMS-sonic/WST-VSP			**2.3**
			SUBTOTAL:	**0.0**	**44.2**	**4.3**
			TOTAL OPERATING DAYS (56 days available):	**48.5**		
NNB-01C	45.4661°N	4412	Three casing strings (reentry cone, 20, 16, and 13-3/8 in)			
(3 casings)	44.9050°W		with 10-3/4-in casing as contingency			
			Hole A: drill-in 60 m 20-in casing with reentry cone		1.8	
			Drill with 20-in underreamer ~60 to 800 mbsf			
			set 775 m 16-in casing, cement		6.2	
			RCB 800-1375 mbsf		7.7	
			Log: triple combo/FMS-sonic/WST-VSP			2.0
			Underream with 14-3/4-in tricone bit ~800 to 1375 mbsf			
			and set 725 m 13-3/8in liner @ 1350 mbsf, cement		6.4	
			RCB sediment 1375-2360 mbsf		21.8	
			RCB basement 2360-2460 mbsf		4.3	
			Log: triple combo/FMS-sonic/WST-VSP			2.3
			SUBTOTAL:	**0.0**	**48.2**	**4.3**
			TOTAL OPERATING DAYS (56 days available):	**52.5**		

Table T2 (continued).

Site	Location (lat/long)	Site depth (mbrf)	Operations description	Transit (days)	Drilling (days)	Logging (days)
			Log: triple combo/FMS-sonic/WST-VSP			1.4
			SUBTOTAL:	0.0	0.0	1.4
			TOTAL OPERATING DAYS (56 days available):	1.4		
NNB-05A	45.1967°N	4695	Hole A: APC to 250 mbsf, XCB to 355 mbsf		3.4	
	44.3767°W		Hole B: drill ahead 335 mbsf,			
			RCB 335 to 435 mbsf (basement at 355 mbsf)		4.9	
			Log: triple combo/FMS-sonic/WST			1.7
			SUBTOTAL:	0.0	8.3	1.7
			TOTAL OPERATING DAYS (56 days available):	10.0		
NNB-06B	45.1033°N	4727	Hole A: APC to 250 mbsf, XCB to 500 mbsf		4.6	
	44.1967°W		Hole B: drill ahead 490 mbsf,			
			RCB 490 to 858 mbsf (basement at 758 mbsf)		7.5	
			Log: triple combo/FMS-sonic/WST			1.8
			SUBTOTAL:	0.0	12.1	1.8
			TOTAL OPERATING DAYS (56 days available):	13.9		


MODERN ISOBATHS (x1000 m)
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BMT. TROUGH
BMT.-INVOLVED AND BASIN-BOUNDING FAULTS
MAJOR BMT. HINGE / BASIN EDGE
THRUST FAULT
OTHER FAULT
EVAPORITES
DRILL SITE
"U" PINCHOUT IN N.B.
SEAMOUNTS
DOMINION T.Z.
EGRET T.Z.
AVALON T.Z.
CENTRAL
GRAND
BANKS
SOUTH
WHALE BASIN
SOUTH WHALE BASIN
HORSESHOE BASIN
JEANNE D'ARC BASIN
FLEMISH PASS BASIN
FLEMISH CAP
FLEMISH HINGE
E. PINCHOUT OF "U"
CARSON BASIN
BONNITION BASIN
SALAR BASIN
N. NFLD. BASIN
S. NFLD. BASIN
NFLD. SMTS.
NEWFOUNDLAND F.Z.
SOUTHEAST NFLD. RIDGE
SILLS
MO
OCEAN CRUST
TORE SMT.
IBERIA A.P.
TAGUS A.P.
SPUR ESTREMADURE
LUSITANIA BASIN
GALICIA BANK
GALICIA INTERIOR BASIN
IBERIA
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639
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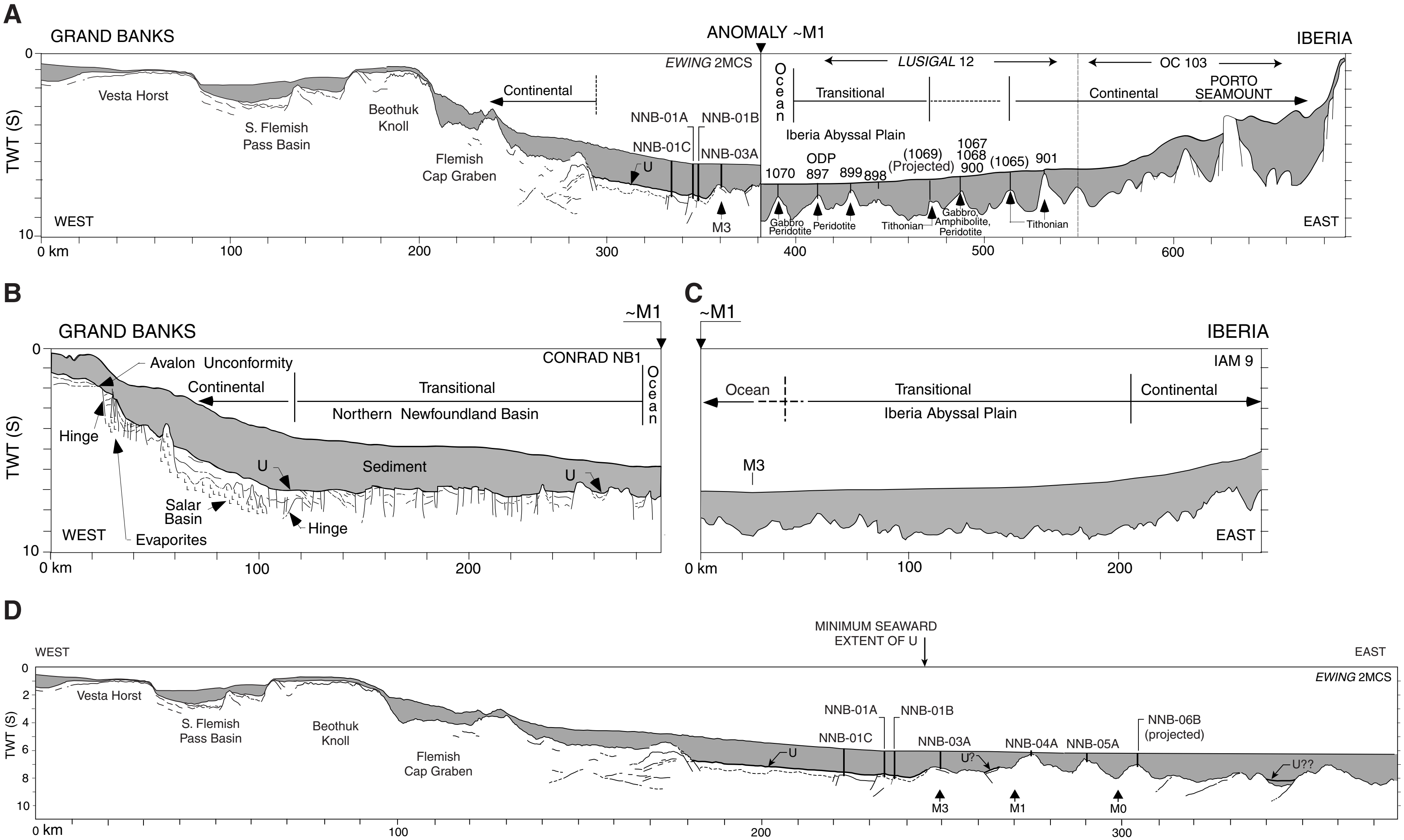
Figure F1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S. Flemish Pass Basin
Beothuk Knoll
Flemish Cap Graben
NNB-01A
NNB-01B
NNB-01C
NNB-03A
U
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Iberia Abyssal Plain
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898
(1069) (Projected)
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900
(1065)
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Gabbro Peridotite
Peridotite
Tithonian
Gabbro, Amphibolite, Peridotite
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Avalon Unconformity
Continental
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Salar Basin
Evaporites
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IBERIA
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Ocean
Transitional
Continental
Iberia Abyssal Plain
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MINIMUM SEAWARD EXTENT OF U
NNB-04A
NNB-05A
NNB-06B (projected)
U?
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M1
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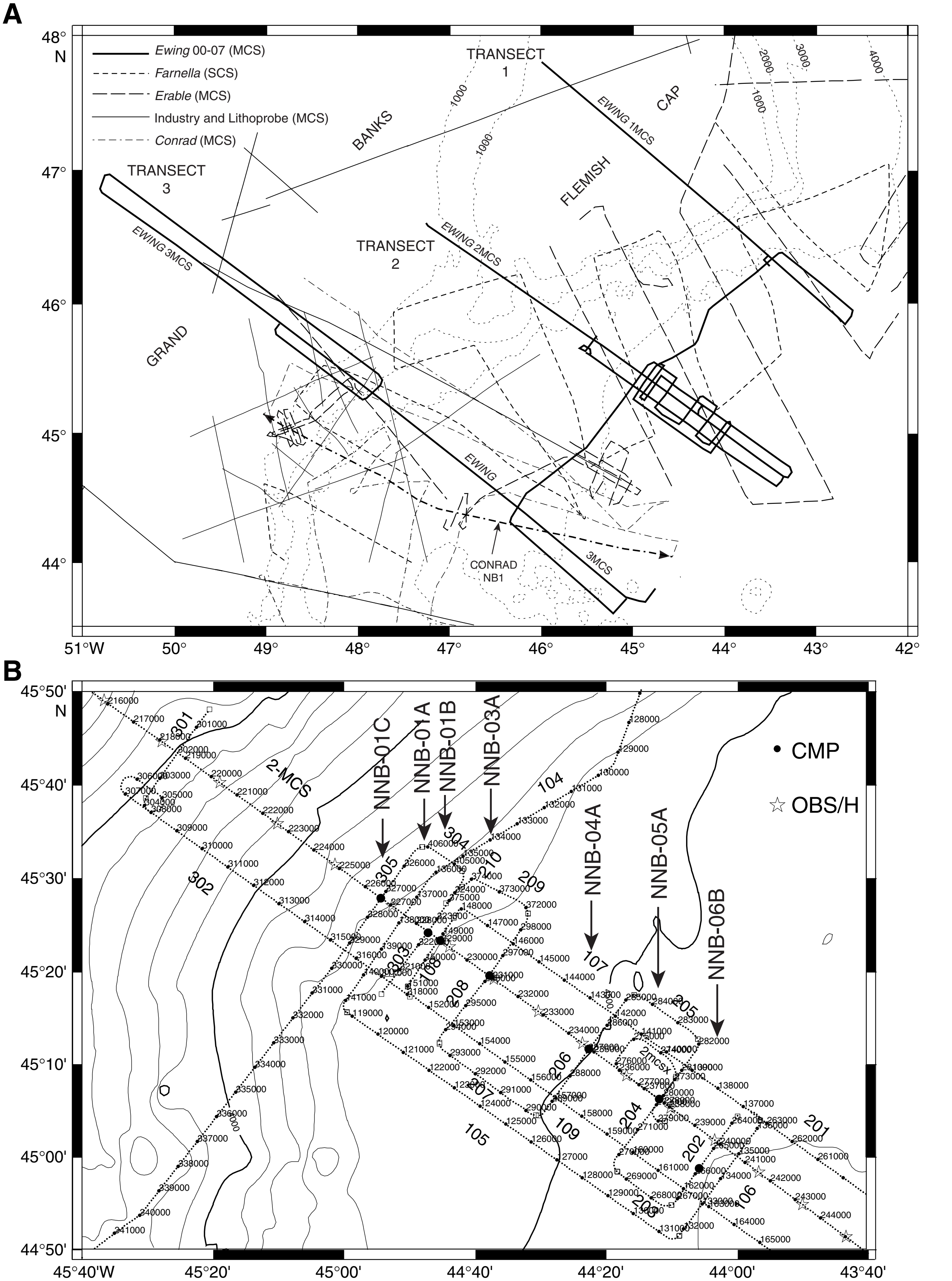
Figure F2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TRANSECT 3
EWING 1MCS
EWING 2MCS
EWING 3MCS
EWING
3MCS
CONRAD NB1
GRAND
BANKS
FLEMISH
CAP
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2-MCS
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44°40'
44°20'
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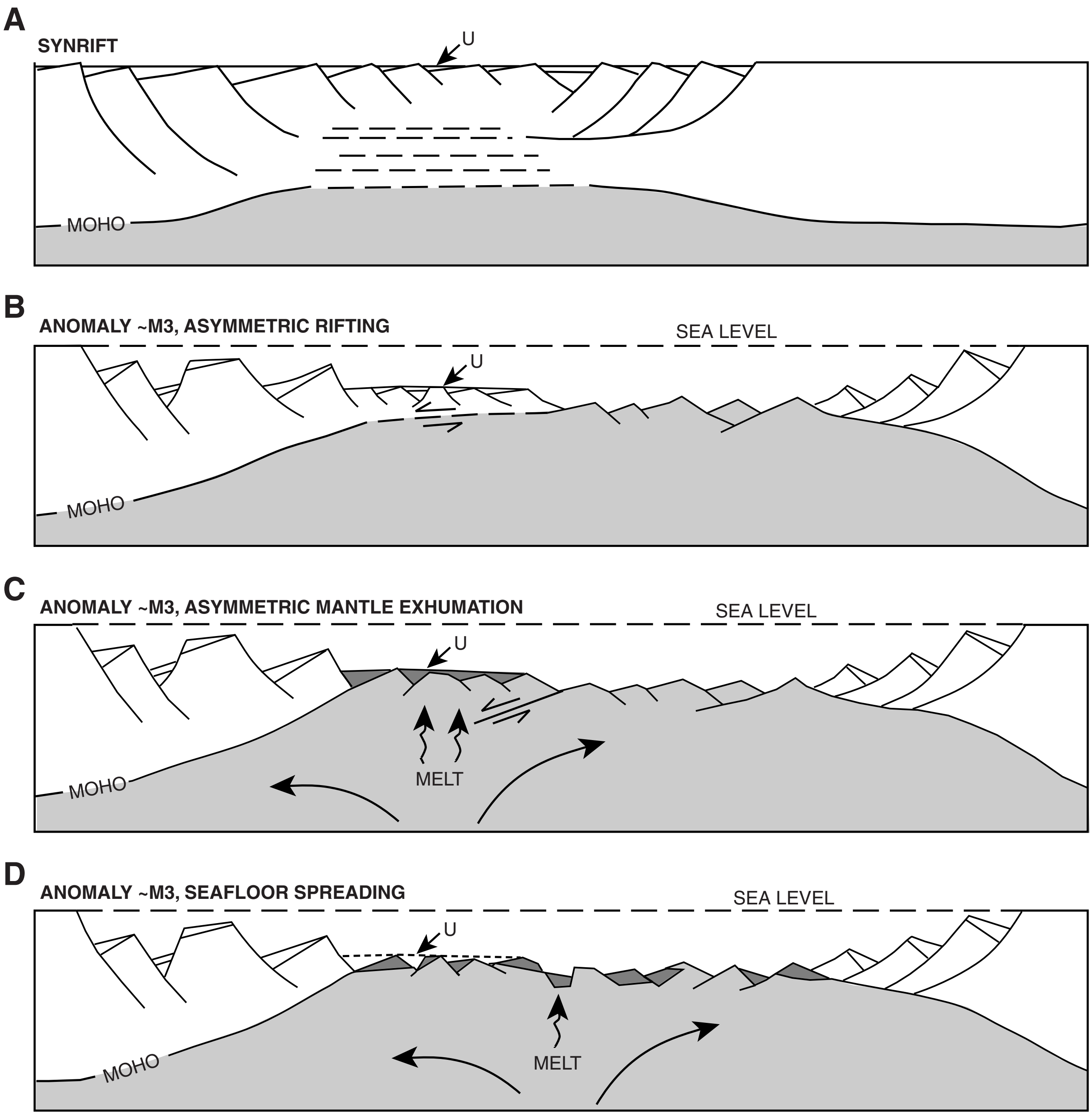
43°40'

Figure F3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SEA LEVEL
U
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MELT
MOHO
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ANOMALY ~M3, SEAFLOOR SPREADING
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U
MELT
MOHO

Figure F4

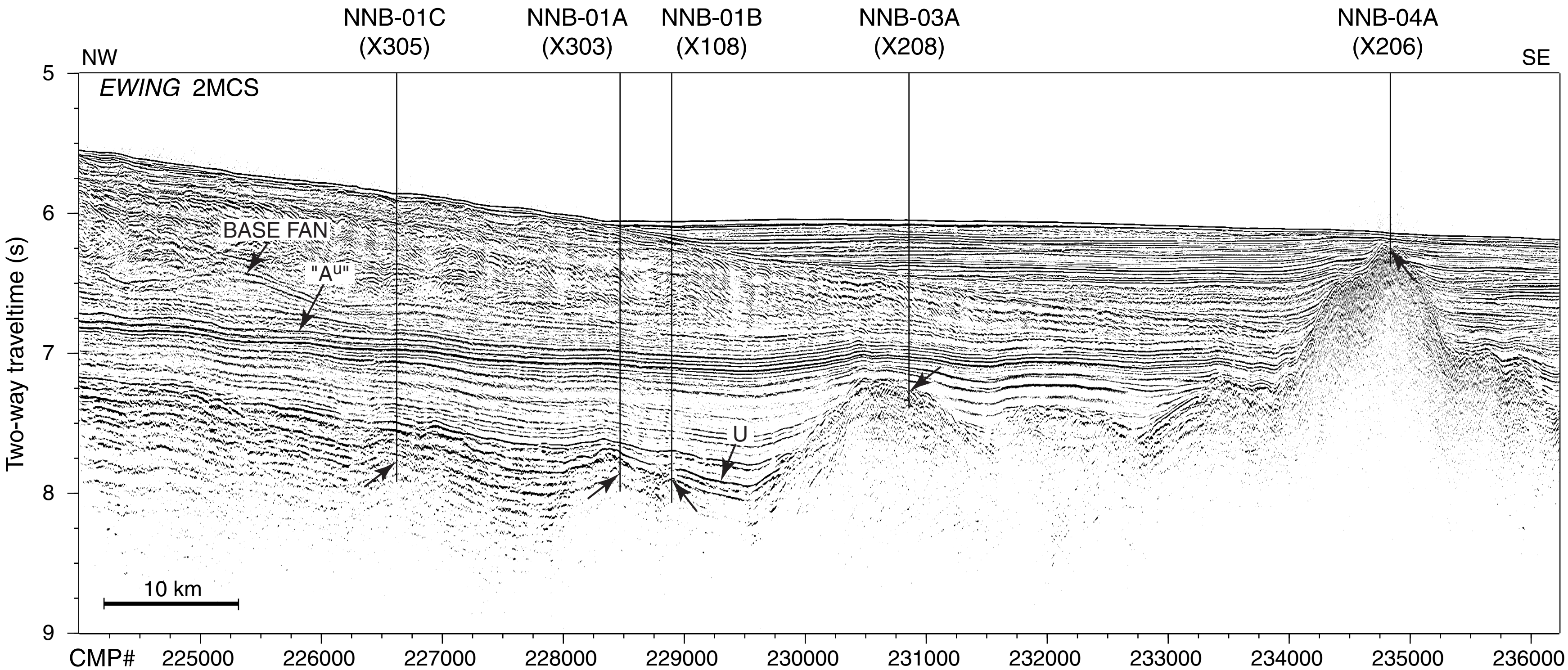
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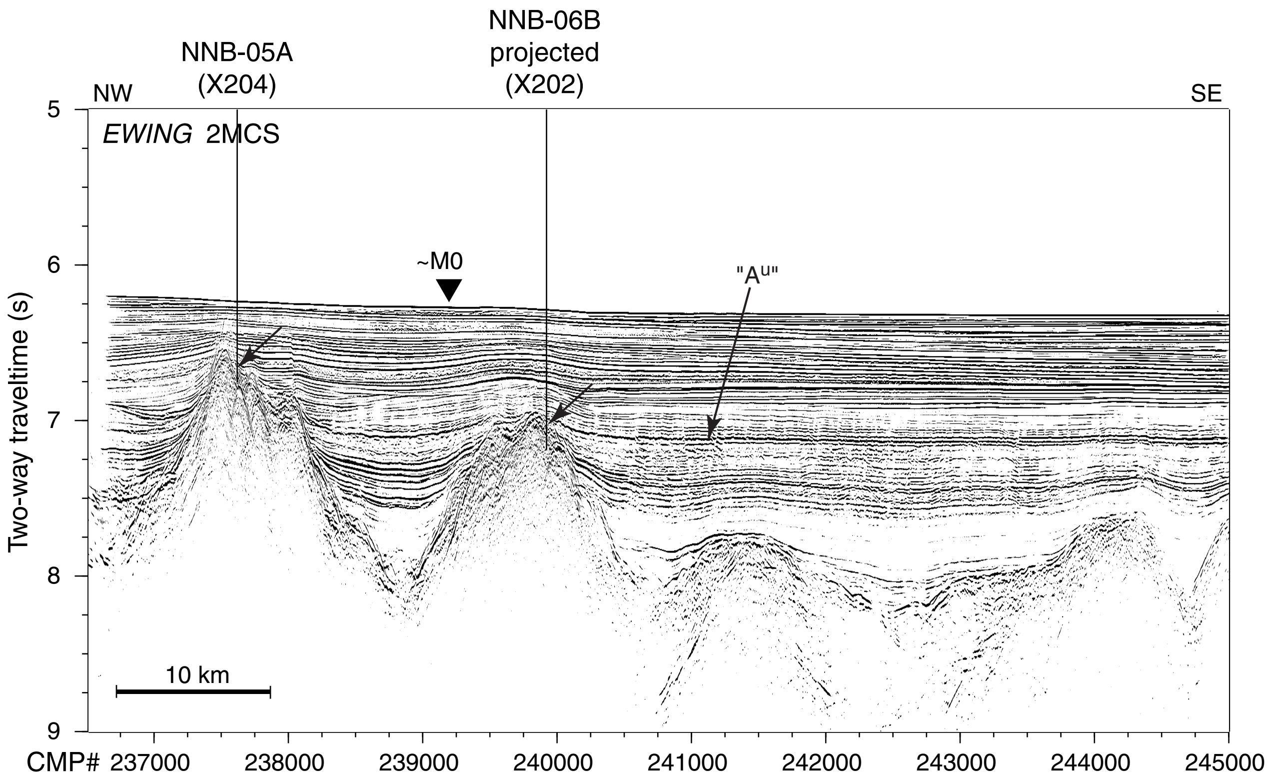
Figure F5


NNB-05A
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projected
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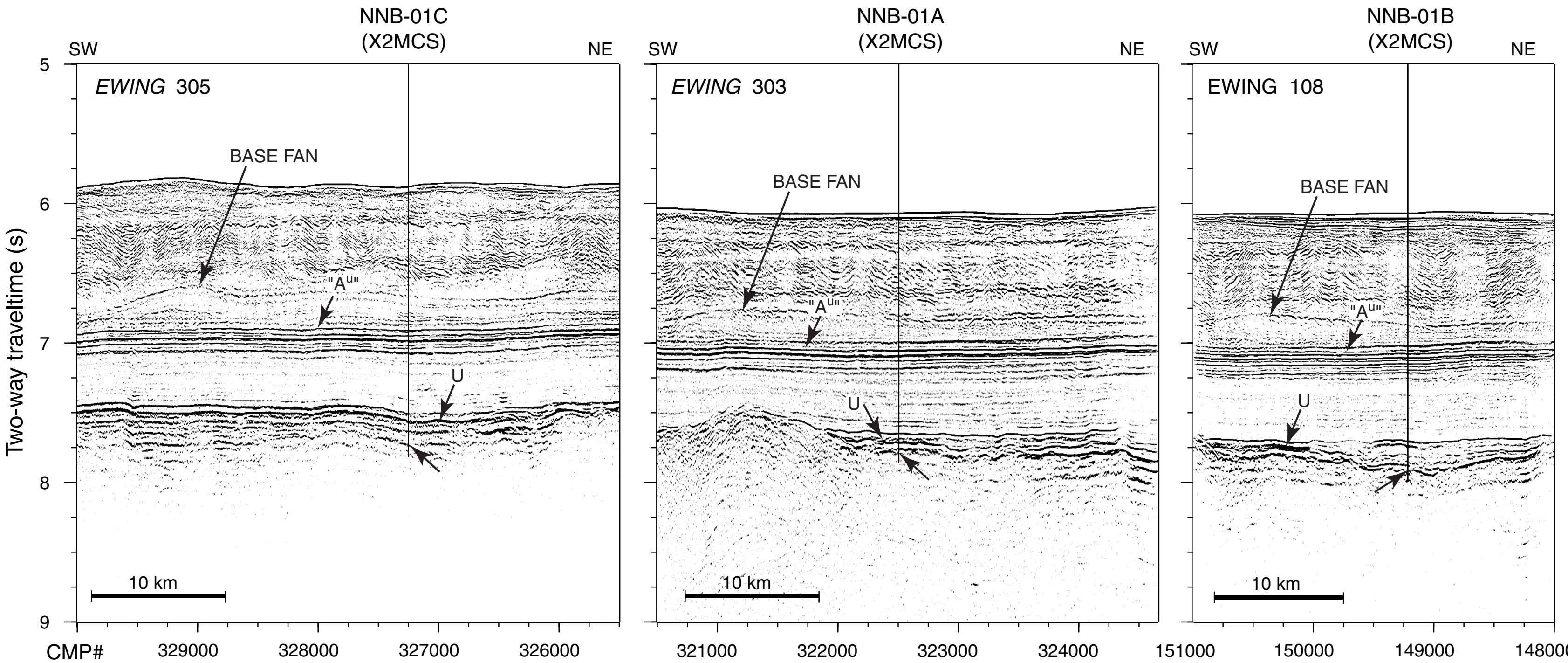
CMP# 237000 238000 239000 240000 241000 242000 243000 244000 245000

Figure F6


NNB-01C
(X2MCS)
SW
NE
EWING 305
BASE FAN
"A^U"
U
10 km
NNB-01A
(X2MCS)
SW
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EWING 303
BASE FAN
"A^U"
U
10 km
NNB-01B
(X2MCS)
SW
NE
EWING 108
BASE FAN
"A^U"
U
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Two-way traveltime (s)
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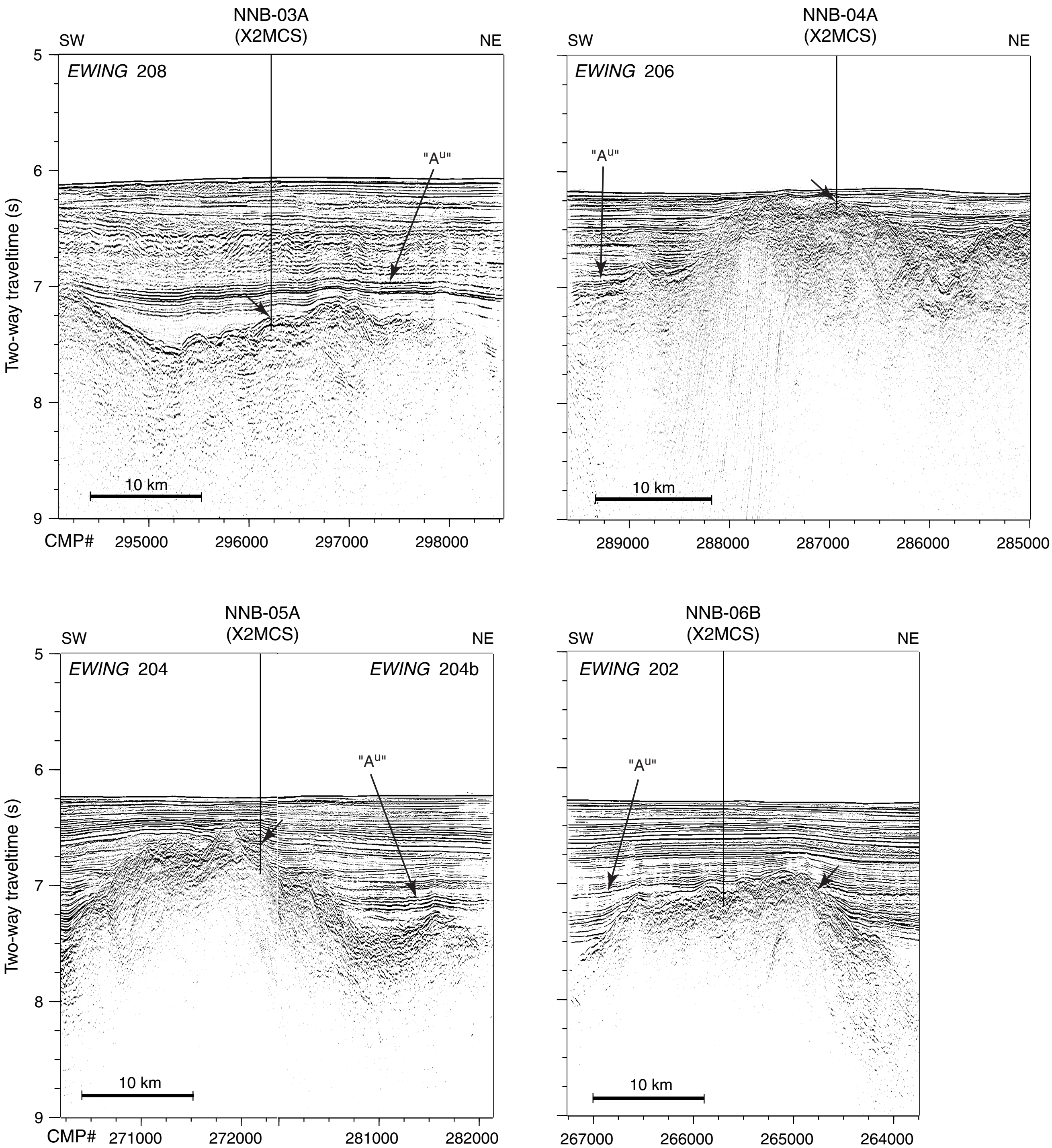
Figure F7


NNB-03A
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EWING 208
"Au"
Two-way traveltime (s)
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NNB-04A
(X2MCS)
SW
NE
EWING 206
"Au"
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NNB-05A
(X2MCS)
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282000
NNB-06B
(X2MCS)
SW
NE
EWING 202
"Au"
10 km
267000
266000
265000
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Figure F8

SITE SUMMARIES

Site NNB-01A

Priority: 1
Position: 45°24.3′N; 44°47.1′W
Water Depth: 4559 m
Sediment Thickness: 2080 m, from stacking and wide-angle velocity models
Target Drilling Depth: 2180 mbsf
Approved Maximum Penetration: 2500 mbsf; drill without coring to 800 mbsf

Seismic Coverage: *Ewing* 00-07 line 2 MCS; SP 28433 (CMP 228470) (see Figs. F3, F5, F7)

Objectives:

1. Primary objective: Composition and igneous/tectonic history of basement. The nature of the U reflection and the composition and origin of the high-velocity interval between U and basement. Subsidence history of the stratigraphic sequence immediately above reflection U.
2. Secondary objective: Age of a prominent reflection (horizon A^u?) which marks the initiation of abyssal current-controlled deposition in the basin, implications for a northern Atlantic gateway, and sedimentary characteristics of subsequent current-controlled sedimentation. Stratigraphic sequence development compared to development of synchronously deposited, formally defined formations that are widely developed in the western North Atlantic.

Operational Program: See "Primary Site: Proposed Site NNB-01A" section and Table T1. Drill-in a reentry cone with ~80 m of 20-in casing. Drill without coring from 80 to 800 mbsf and install 16-in casing to ~775 mbsf. RCB coring 800 mbsf down to ~1375 mbsf and then set a $13^3/_8$-in casing liner to ~1350 mbsf. RCB core from ~1375 mbsf down to basement (~2080 mbsf) and possibly into the upper few tens of meters of basement, hole conditions permitting, before setting a $10^3/_4$-in casing liner to ~2080 mbsf. Then basement will be penetrated 100–200 m, depending on hole and drill-bit conditions as well as time available (see Table T1). Logging will be conducted in each of the cored sections and will consist of three runs (triple combo and FMS-sonic tool strings and WST). After the primary deep objectives have been achieved, if time permits, we will core the upper ~800 m of section in order to obtain a complete sedimentary record at this site.

Logging and Downhole: Three logging runs (1) triple combo tool string, (2) FMS-sonic tool string, and (3) checkshot with WST. Core orientation and temperature tools if alternate plan for shallow coring occurs.

Nature of Rock Anticipated: From top to base: clays, silty clays, and claystones (equivalent to Blake Ridge formation); siliceous and/or cherty claystones (equivalent to Bermuda Rise formation); multicolored claystones ± limestones (equivalent to Plantagenet formation); black shales (equivalent to Hatteras formation); possible limestone beds (?Blake-Bahama formation).

Site NNB-01B

Priority: 2
Position: 45°23.5′N; 44°45.5′W
Water Depth: 4563 m
Sediment Thickness: 2180 m, from stacking and wide-angle velocity models
Target Drilling Depth: 2280 mbsf
Approved Maximum Penetration: 2600 mbsf; drill without coring to 800 mbsf

Seismic Coverage: *Ewing* 00-07 line 2 MCS; SP 28486 (CMP 228893) (see Figs. F3, F5, F7)

Objectives:

1. Primary objective: Composition and igneous/tectonic history of basement. The nature of the U reflection and the composition and origin of the high-velocity interval between U and basement. Subsidence history of the stratigraphic sequence immediately above reflector U.
2. Secondary Objective: Age of a prominent reflection (horizon A^u?) which marks the initiation of abyssal current-controlled deposition in the basin, implications for a northern Atlantic gateway, and sedimentary characteristics of subsequent current-controlled sedimentation. Stratigraphic sequence development compared to development of synchronously deposited, formally defined formations that are widely developed in the western North Atlantic.

Operational Program: Same as at proposed Site NNB-01A, but with a three-casing string. See "Alternate Sites: Proposed Site NNB-01B" section and Table T2.

Logging and Downhole: Three logging runs (1) triple combo tool string, (2) FMS-sonic tool string, and (3) checkshot with WST. Core orientation and temperature tools if alternate plan for shallow coring occurs.

Nature of Rock Anticipated: From top to base: clays, silty clays, and claystones (equivalent to Blake Ridge formation); siliceous and/or cherty claystones (equivalent to Bermuda Rise formation); multicolored claysontes ± limetones (equivalent to Plantagenet formation); black shales (equivalent to Hatteras formation); possible limestone beds (?Blake-Bahama formation).

Site NNB-01C

Priority: 2
Position: 45°28.0′N; 44°54.3′W
Water Depth: 4412 m
Sediment Thickness: 2360 m, from stacking and wide-angle velocity models
Target Drilling Depth: 2460 mbsf
Approved Maximum Penetration: 2650 mbsf; drill without coring to 800 mbsf

Seismic Coverage: *Ewing* 00-07 line 2 MCS; SP 28202 (CMP 226628) (see Figs. F3, F5, F7)

Objectives:

1. Primary objective: Composition and igneous/tectonic history of basement. The nature of the U reflection and the composition and origin of the high-velocity interval between U and basement. Subsidence history of the stratigraphic sequence immediately above reflector U.
2. Secondary objective: Age of a prominent reflection (horizon A^u?) which marks the initiation of abyssal current-controlled deposition in the basin, implications for a northern Atlantic gateway, and sedimentary characteristics of subsequent current-controlled sedimentation. Stratigraphic sequence development compared to development of synchronously deposited, formally defined formations that are widely developed in the western North Atlantic.

Operational Program: Same as at proposed Site NNB-01A. See "Alternate Sites: Proposed Site NNB-01C" section and Table T2.

Logging and Downhole: Three logging runs (1) triple combo tool string, (2) FMS-sonic tool string, and (3) checkshot with WST. Core orientation and temperature tools if alternate plan for shallow coring occurs.

Nature of Rock Anticipated: From top to base: clays, silty clays, and claystones (equivalent to Blake Ridge formation); siliceous and/or cherty claystones (equivalent to Bermuda Rise formation); multicolored claystones ± limestones (equivalent to Plantagenet formation); black shales (equivalent to Hatteras formation); possible limestone beds (?Blake-Bahama formation).

Site NNB-03A

Priority: 2
Position: 45°19.6′N; 44°37.9′W
Water Depth: 4553 m
Sediment Thickness: 1240 m, from stacking and wide-angle velocity models
Target Drilling Depth: 1340 mbsf
Approved Maximum Penetration: 1600 mbsf; drill without coring to 500 mbsf

Seismic Coverage: *Ewing* 00-07 line 2 MCS; SP 28731 (CMP 230858) (see Figs. F3, F5, F8)

Objectives:

1. Primary objective: Composition and igneous/tectonic history of basement. Subsidence history of the stratigraphic sequence immediately above basement.
2. Secondary objective: Age of a prominent reflection (horizon A^u?) marks the initiation of abyssal current-controlled deposition in the basin, implications for a northern Atlantic gateway, and sedimentary characteristics of subsequent current-controlled sedimentation. Stratigraphic sequence development compared to development of synchronously deposited, formally defined formations that are widely developed in the western North Atlantic.

Operational Program: The drilling/logging plan consists of a two–casing string strategy with a $10^3/_4$-in casing liner as contingency to ensure we can obtain deep sediments and basement. We will drill 20-in casing in to ~80 mbsf and then 16-in casing to ~475 mbsf. RCB coring will extend from 500 mbsf down to, and into, basement. Logging will consist of the two standard logging strings and a checkshot with the WST. After the primary deep objectives have been achieved, if time permits, we will core the upper ~500 m of section in order to obtain a complete sedimentary record at this site. see "Alternate Sites: Proposed Site NNB-03A" section and Table T2.

Logging and Downhole: Three logging runs (1) triple combo tool string, (2) FMS-sonic tool string, and (3) checkshot with WST. Core orientation and temperature tools if alternate plan for shallow coring occurs.

Nature of Rock Anticipated: From top to base: clays, silty clays, and claystones (equivalent to Blake Ridge formation); siliceous and/or cherty claystones (equivalent to Bermuda Rise formation); multicolored claystones ± limestones (equivalent to Plantagenet formation); possibly black shales (equivalent to Hatteras formation).

Site NNB-04A

Priority: 2
Position: 45°11.8′N; 44°22.6′W
Water Depth: 4624 m
Sediment Thickness: 135 m, from stacking and wide-angle velocity models
Target Drilling Depth: 235 mbsf
Approved Maximum Penetration: 500 mbsf

Seismic Coverage: *Ewing* 00-07 line 2 MCS; SP 29227 (CMP 234827) (see Figs. F3, F5, F8)

Objectives:

1. Primary objective: Composition and igneous/tectonic history of basement. If Site NNB-01 samples continental basement, then Sites NNB-03A to NNB-06A will systematically sample basement eastward to define the maximum seaward limit of continental crust, landward limit of ocean crust, and the character of any intervening transition. If this basement high is serpentinite, this hole might be deepened to bit destruction in order to investigate the variation in composition, alteration, and possible melt interaction with depth.

Operational Program: see "Alternate Sites: Proposed Site NNB-04A" section and Table T2.

Logging and Downhole: Three logging runs (1) triple combo tool string, (2) FMS-sonic tool string, and (3) checkshot with WST. Core orientation and temperature tools if alternate plan for shallow coring occurs.

Nature of Rock Anticipated: From top to base: clays and silty clays.

Site NNB-05A

Priority: 2
Position: 45°06.2′N; 44°11.8′W
Water Depth: 4695 m
Sediment Thickness: 355 m, from stacking and wide-angle velocity models
Target Drilling Depth: 455 mbsf
Approved Maximum Penetration: 700 mbsf

Seismic Coverage: *Ewing* 00-07 line 2 MCS; SP 29576 (CMP 237616) (see Figs. F3, F6, F8)

Objectives:

1. Primary objective: Composition and igneous/tectonic history of basement. If Site NNB-01 samples continental basement, then Sites NNB-03A to NNB-06A will systematically sample basement eastward to define the maximum seaward limit of continental crust, landward limit of ocean crust, and the character of any intervening transition. If this basement high is serpentinite, this hole might be deepened to bit destruction in order to investigate the variation in composition, alteration, and possible melt interaction with depth.

Operational Program: see "Alternate Sites: Proposed Site NNB-05A" section and Table T2.

Logging and Downhole: Three logging runs (1) triple combo tool string, (2) FMS-sonic tool string, and (3) checkshot with WST. Core orientation and temperature tools if alternate plan for shallow coring occurs.

Nature of Rock Anticipated: From top to base: clays, silty clays and claystones.

Site NNB-06B

Priority: 2
Position: 44°59.0′N; 44°05.5′W
Water Depth: 4727 m
Sediment Thickness: 760 m, from stacking and wide-angle velocity models
Target Drilling Depth: 858 mbsf
Approved Maximum Penetration: 1100 mbsf

Seismic Coverage: *Ewing* 00-07 line 202 (CMP 265700) (see Figs. F3, F6, F8)

Objectives:

1. Primary objective: Composition and igneous/tectonic history of basement. If Site NNB-01 samples continental basement, then Sites NNB-03A to NNB-06A will systematically sample basement eastward to define the maximum seaward limit of continental crust, landward limit of ocean crust, and the character of any intervening transition. If this basement high is serpentinite, this hole might be deepened to bit destruction in order to investigate the variation in composition, alteration, and possible melt interaction with depth.

Operational Program: see "Alternate Sites: Proposed Site NNB-06B" section and Table T2.

Logging and Downhole: Three logging runs (1) triple combo tool string, (2) FMS-sonic tool string, and (3) checkshot with WST. Core orientation and temperature tools if alternate plan for shallow coring occurs.

Nature of Rock Anticipated: From top to base: clays, silty clays, and claystones; cherty/siliceous claystones.

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