Integrated Ocean Drilling Program Expedition 333 Scientific Prospectus

NanTroSEIZE Stage 2: subduction inputs 2 and heat flow

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Abstract

The Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) program is a coordinated, multiexpedition drilling project designed to investigate fault mechanics and seismogenesis along subduction megathrusts through direct sampling, in situ measurements, and long-term monitoring in conjunction with allied laboratory and numerical modeling studies. Some of the fundamental scientific objectives of the NanTroSEIZE drilling project include characterizing the nature of fault slip and strain accumulation, fault and wall rock composition, fault architecture, and state variables throughout the active plate boundary system to a depth of 7000 meters below seafloor. It is also important to show how such properties evolve from shallow, presubduction conditions in the Shikoku Basin to greater depths of the accretionary prism where fault slip is seismogenic. Within this context, the primary goals for Integrated Ocean Drilling Program (IODP) Expedition 333 are: (1) drilling and coring of previously unsampled intervals of sediment and basalt at IODP Sites C0011 and C0012 in the Shikoku Basin and (2) drilling and coring an Ancillary Project Letter (738-APL: Nankai Trough Submarine Landslide History [NanTroSLIDE]) at a site near the updip terminus of the megasplay fault.

Schedule for Expedition 333

Integrated Ocean Drilling Program (IODP) Expedition 333 is based largely on Integrated Ocean Drilling Program drilling Proposals 603A and 603D (available at **www.iodp.org/600/**) and Ancillary Project Letter 738-APL (available at **www.igcp585.org/documents/738-APL_NanTroSLIDE.pdf?attredirects=0&d=1**). Most of the scientific objectives are follow-ups to what was achieved during IODP Expedition 322 (Underwood et al., 2009). Following ranking by the IODP Scientific Advisory Structure, the expedition was scheduled for the D/V *Chikyu*, operating under contract with the Japanese Implementing Organization Center for Deep Earth Exploration (CDEX). At the time of publication of this *Scientific Prospectus,* the expedition is scheduled to begin at sea on 13 December 2010 and to end at Shingu, Japan, on 10 January 2011. A total of 29 days will be available for the additional drilling and coring at IODP Sites C0011 and C0012 and to drill the Nankai Trough Submarine Landslide History (NanTroSLIDE) proposed Site NTS-1A described in Ancillary Project Letter 738-APL (for the current detailed schedule, see **www.iodp.org/expeditions/**) (Fig. **F1**). Further details on the *Chikyu* can be found at **www.jamstec.go.jp/chikyu/eng/CHIKYU/index.html.**

Introduction

CDEX is implementing three Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) expeditions during 2010 and early 2011: Expedition 326 (NanTroSEIZE Stage 3: plate boundary deep riser: top hole engineering), Expedition 332 (NanTroSEIZE Stage 2: riserless observatory), and Expedition 333 (NanTroSEIZE Stage 2: subduction inputs 2 and heat flow).

The objectives for Expedition 333 are to core and measure temperature within the shallow intervals at Sites C0011 and C0012 that were not sampled during Expedition 322 and to collect up to 220 m of additional basement material from Site C0012 (Fig. **F1**). These are the two subduction inputs sites for the transect, positioned above and on the northwest flank of a prominent basement high in the Shikoku Basin. Additionally, the coring objectives of an Ancillary Project Letter (738-APL), NanTroSLIDE, will be attempted to help constrain the history of submarine landslides along the lower forearc slope as it may relate to slip along the megasplay fault.

Overview of the NanTroSEIZE complex drilling project

Subduction zones account for 90% of global seismic moment release, generating damaging earthquakes and tsunamis with potential disastrous effects on heavily populated areas (e.g., Lay et al., 2005). Understanding the processes that govern the strength, nature, and distribution of slip along these plate boundary fault systems is crucial for evaluating earthquake and tsunami hazards. Sediment-dominated subduction zones such as the Eastern Aleutian, Cascadia, Sumatra, and Nankai margins are characterized by repeated great earthquakes of magnitude M ~8.0+ (Ruff and Kanamori, 1983). Although the causative mechanisms are not well understood (e.g., Byrne et al., 1988; Moore and Saffer, 2001; Saffer and Marone, 2003), the updip limit of the seismogenic zones at these margins is thought to correlate with a topographic break, often associated with the outer rise of the forearc (e.g., Byrne et al., 1988; Wang and Hu, 2006). At Nankai, seismic reflection profiles across the forearc outer rise document an out-of-sequence thrust (OOST) fault system (the megasplay fault) that branches from the plate boundary décollement close to the updip limit of inferred coseismic rupture of the 1944 Tonankai M 8.2 earthquake (Moore et al., 2007) (Fig. **F2**).

The NanTroSEIZE Project is a complex drilling project (CDP): a multiexpedition, multistage component of IODP focused on understanding the mechanics of seismogenics and rupture propagation along subduction plate boundary faults. NanTroSEIZE is a coordinated effort to sample and instrument the plate boundary system at several locations offshore the Kii Peninsula, Japan (Tobin and Kinoshita, 2006b) (Fig. **F1**). The main objectives are to understand

- The mechanisms and properties governing the updip aseismic–seismic transition of the megathrust and plate interface fault systems;
- Processes of earthquake and tsunami generation, as well as strain accumulation and release; and
- The mechanical strength and hydrogeologic behavior of the plate boundary fault and megasplay.

The following hypotheses are paraphrased from the original IODP proposals and outlined in Tobin and Kinoshita (2006a, 2006b):

1. Systematic, progressive material and state changes control the onset of seismogenic behavior on subduction thrust faults.
2. Subduction megathrusts are weak faults.
3. Plate motion is accommodated primarily by coseismic slip in a concentrated zone (i.e., the fault is locked during the interseismic period).
4. Physical properties of the plate boundary system (including the fault system and its hanging wall and footwall) change with time during the earthquake cycle.
5. A significant, laterally extensive upper plate fault system (the megasplay) slips in discrete events that may include tsunamigenic slip during great earthquakes. It remains locked during the interseismic period and accumulates strain.

To address Hypothesis 1 above, it is essential to document the composition and geotechnical/frictional/hydrogeological properties of the subduction inputs (i.e., the initial conditions) before the rocks reach the deformation front and begin to change. As stated in Hypothesis 5 above, two of the first-order goals in characterizing the seismogenic zone along the Nankai Trough are to document the role of the megasplay fault in accommodating plate motion (both seismically and interseismically) and to characterize the fault's mechanical and hydrological behavior. This research bears on understanding both fault behavior and tsunami hazards.

Presently, the NanTroSEIZE CDP encompasses twelve sites along a transect that extends from the northwest edge of the Shikoku Basin across the frontal thrust region, the midslope megasplay region, and into the Kumano Basin forearc region (Figs. **F1, F2**). One of these sites (IODP Site C0002) currently includes a pilot hole for the planned deep riser drilling operations. The other sites targeted fault zones in the shallow, aseismic portions of the accretionary complex (Kinoshita et al., 2008b) and the subduction inputs (Underwood et al., 2009).

From late 2007 through early 2008, IODP Expeditions 314, 315, and 316 were carried out as a unified program known as NanTroSEIZE Stage 1. Expedition 314 was dedicated to downhole measurement of physical properties and borehole imaging through logging while drilling (LWD). Expedition 315 was devoted to core sampling and downhole temperature measurement at two sites in the hanging wall: IODP Site C0001 just seaward of the outer rise and Site C0002 in the Kumano Basin. Expedition 316 targeted the frontal thrust region and megasplay in their shallow aseismic portions: IODP Site C0004 near the surface expression of the megasplay in the Kumano Basin, IODP Sites C0006 and C0007 at the frontal thrust of the accretionary wedge, and IODP Site C0008 in a trench-slope basin seaward of the splay fault. For more details, see Kinoshita et al. (2008b), Ashi et al. (2008), and Kimura et al. (2008).

IODP Expeditions 319 and 322 followed in 2009, as NanTroSEIZE Stage 2. Expedition 319 prepared boreholes at IODP Sites C0009 and C0010 for future installation of long-term monitoring systems. At Site C0009, Expedition 319 also conducted the first riser operation in IODP history, as well as a walkaway vertical seismic profile experiment. Expedition 322 cored Sites C0011 and C0012 in the Shikoku Basin to document the composition and material properties of sediment and uppermost igneous basement that eventually enters the Nankai subduction zone.

Background

Geological setting

The Nankai Trough is a convergent plate boundary where the Philippine Sea plate underthrusts the southwestern Japan margin at rates of 4.0–6.0 cm/y along an azimuth of 300°–315°N (Seno et al., 1993; Miyazaki and Heki, 2001; Mazzotti et al., 2000; Henry et al., 2001) down an interface dipping 3°–7° (Kodaira et al., 2000a). The subducting lithosphere of the Shikoku Basin was formed by backarc spreading during a time period of approximately 15–25 Ma (Okino et al., 1994).

The three major seismic stratigraphic sequences identified in the northern Shikoku Basin are the lower and upper Shikoku Basin facies and local spillover of Quaternary trench-wedge turbidites (Fig. **F3**). The upper Shikoku Basin facies off the Kumano Basin thins toward the north, whereas the lower succession has a more complicated isopach geometry influenced by basement topography (Le Pichon et al., 1987a, 1987b; Mazzotti et al., 2002; Moore, Taira, Klaus, et al., 2001; Moore et al., 2001; Ike et al., 2008b). Throughout the basin, seismic thickness decreases above large basement highs and sand packages of the lower Shikoku Basin pinch out against basement highs. Basement highs are imaged within the subduction zone (Kodaira et al., 2003, Dessa et al., 2004) and influence margin structure (Lallemand et al., 1992) and seismicity (Kodaira et al., 2000b; Park et al., 2004). The mechanical and hydrogeological differences between strata above subducting basement highs and regions with smooth basement topography could be significant for fault zone dynamics and earthquake rupture behavior.

The lower forearc slope of the Nankai Trough consists of a series of thrust faults that have shortened the accreted sedimentary units of the prism (e.g., Moore et al., 2009; Screaton et al., 2009). Swath bathymetry and multichannel seismic (MCS) data show a pronounced and continuous outer arc high extending >120 km along strike, which may be related to slip on the megasplay fault (Moore et al., 2009; Martin et al., 2010). Remotely operated vehicle (ROV) and manned submersible surveys along this feature reveal a very steep slope on both sides of the ridge (Ashi et al., 2002). The other arc high coincides with the updip end of the splaying system of thrust faults that branch from a strong seismic reflector interpreted by Park et al. (2002) as a major OOST. The megasplay fault is hypothesized to represent the mechanical boundary between the inner and outer accretionary wedge and between aseismic and seismogenic fault behavior (Wang and Hu, 2006). At depth, this megasplay produces a high-amplitude reflector (Fig. **F2**). It branches into a family of thrust splays in the upper few kilometers below the seafloor, including the thrust splay drilled during Stage 1 Expeditions 314, 315, and 316 (Moore et al., 2007, 2009).

The plate boundary, when traced in the downdip direction, eventually ramps down from a sediment/sediment interface to the sediment/basalt or an intrabasalt interface (Figs. **F2, F3**). This shift in lithologic position of the fault must coincide with fundamental changes in the rock's mechanical and/or hydrologic properties, but how so? Shore-based studies indicate that systematic fragmentation of upper basement and incorporation of basalt slabs into shear-zone mélanges could be controlled by primary layering of the igneous rock (Kimura and Ludden, 1995). Our challenge will be to discriminate between the presubduction features in basement inherited from backarc spreading in the Shikoku Basin (documented during this expedition) and the changes imparted by increasing pressure-temperature (P-T) conditions and stress changes at depth (documented in the future by deep riser drilling).

Previous drilling achievements

Sites C0011 and C0012

Expedition 322 was designed to document characteristics of incoming sedimentary strata and uppermost igneous basement prior to their arrival at the subduction front (Saito et al., 2009). To accomplish those objectives, coring was conducted at two sites on the subducting Philippine Sea plate. Site C0011 is located on the northwest flank of a prominent bathymetric high (the Kashinosaki Knoll; Ike et al., 2008a), whereas Site C0012 is located near the crest of the knoll (Fig. **F2**).

The resulting data, which include LWD during Expedition 319, provide a great deal of new information on presubduction equivalents of the seismogenic zone (Figs. **F3**, **F4**) (Underwood et al., 2009). Core samples at Site C0011 were obtained by rotary core barrel (RCB) from 340 to 876 m core depth below seafloor (CSF) where the hole was abandoned because of failure of the drill bit. After jetting-in to ~70 meters below seafloor (mbsf), RCB coring at Site C0012 penetrated almost 23 m into igneous basement and recovered the sediment/basalt interface intact at 537.81 m CSF (Fig. **F4**). This incomplete coring program left major gaps in the stratigraphic coverage, particularly within intervals of the upper Shikoku Basin facies. Nevertheless, the merger of lithofacies and age-depth models shows how correlative units change from an expanded section at Site C0011 to a condensed section at Site C0012. The composite section also captures most of the important ingredients of basin evolution, including a previously unrecognized interval of late Miocene volcaniclastic sandstone designated the middle Shikoku Basin facies. An older (early–middle Miocene) turbidite sandstone/siltstone facies with mixed volcaniclastic-siliciclastic detrital provenance occurs in the lower Shikoku Basin; this unit may be broadly correlative with superficially similar Miocene turbidites on the western side of the basin (Underwood, 2007). The age of basal sediment (reddish-brown pelagic claystone) at Site C0012 is older than 18.9 Ma.

Geochemical analyses of pore fluids on top of the basement high show clear evidence of a seawater-like source (Underwood et al., 2009). The depth of the sulfate reduction zone is also anomalously deep at Site C0012. Chlorinity values increase toward basement because of hydration reactions in the sediment and diffusional exchange with basement fluids. In contrast to Site C0011, where chlorinity decreases with depth, the fluids are largely unchanged by the effects of focused flow and/or in situ dehydration reactions associated with rapid burial beneath the trench wedge and frontal accretionary prism. Thus, Site C0012 finally provides a reliable geochemical reference site, unaffected by subduction processes.

Seismic studies/site survey data

Site survey data have been collected in the drilling area over many years, including multiple generations of two-dimensional seismic reflection (e.g., Park et al., 2002), wide-angle refraction (Nakanishi et al., 2002), passive seismicity (e.g., Obana et al., 2004; Obara and Ito, 2005; Ito and Obara, 2006), heat flow (Yamano et al., 2003), side-scan sonar, swath bathymetry, and visual observations from submersible and ROV dives (Ashi et al., 2002). In 2006, Japan and the United States conducted a joint three-dimensional (3-D) seismic reflection survey over a ~11 km × 55 km area, acquired by PGS Geophysical, an industry service company (Moore et al., 2007). This 3-D data volume was used to refine selection of drill sites and targets in the complicated megasplay fault region, define the regional structure and seismic stratigraphy, analyze physical properties of the subsurface through seismic attribute studies in order to extend information away from boreholes, and assess drilling safety (Moore et al., 2009). A smaller 3-D survey was conducted over proposed Sites NT1-01A (C0012) and NT1-07A (C0011) in 2006 by the Japan Agency for Marine-Earth Science and Technology–Institute for Research on Earth Evolution (JAMSTEC-IFREE) (Park et al., 2008) (Figs. **F3, F5, F6**). Prestack depth migration of those data led to refined velocity models and revised estimates of sediment thickness and total drilling depths.

The supporting site survey data for Expedition 333 are archived at the **IODP Site Survey Data Bank.**

Drilling, coring, and temperature measurements plan

Operations for Expedition 333 are based on the current state of knowledge at the time of writing this *Scientific Prospectus*. These plans may be modified both before and during the expedition, based on continuing NanTroSEIZE Project Management Team (PMT) discussions. The Expedition 333 operation plan and drilling sequence is shown in Table **T1** and Figure **F7.** The following operations are planned:

1. NanTroSLIDE coring at proposed Site NTS-1A.

2. Formation temperature measurements with advanced piston corer temperature tool (APCT-3), together with hydraulic piston coring system (HPCS), extended shoe coring system (ESCS), and extended punch coring system (EPCS) coring at the two subduction input Sites C0011 and C0012.
3. Basement coring at Site C0012.

Sites C0011 and C0012

Scientific objectives

As mentioned previously, the upper stratigraphic intervals (upper Shikoku Basin facies) were not adequately sampled during Expedition 322. Therefore, one of the priorities for Expedition 333 is to fill in the coring gaps and expand the age-depth models into the Pliocene and Quaternary (Fig. **F4**). The shallow section is also important for comprehensive profiles of organic and interstitial water geochemistry. Thermal structure, including the effects of fluid circulation in the basement, is another of the critical input variables to document because of its influence on sediment diagenesis and fluid chemistry (Spinelli and Underwood, 2005; Saffer and McKiernan, 2009; Spinelli and Wang, 2008). The age of subducting lithosphere within the Kumano transect area is ~20 Ma (Okino et al., 1994), as verified by coring at Site C0012 (Underwood et al., 2009). The Kashinosaki Knoll lies west of the Zenisu Ridge intraoceanic thrust, which brings backarc basin crust to outcrop at the seafloor (Lallemant et al., 1989; Henry et al., 1997). However, the contribution of active compressive tectonics to the Kashinosaki Knoll morphology is unclear, and the exact timing of volcanic activity responsible for the birth of Kashinosaki Knoll (Ike et al., 2008a) still needs to be established by radiometric dating of the basalt. Dense surface heat flow measurement around the Kashinosaki Knoll indicates significantly higher value than the theoretical value estimated from the age of the Shikoku Basin (Kinoshita et al., 2008a) (Fig. **F8**). We must study deep thermal structure to document the entire heat flow pattern around the sites with high-quality borehole temperature measurement. As subduction carries Shikoku Basin strata toward and beneath the accretionary prism, we expect fluids and physical properties to change downsection and downdip in response to hydration reactions (e.g., volcanic glass to zeolite + smectite), dehydration reactions (e.g., opal-to-quartz and smectite-to-illite), and crystalline cement precipitation (carbonates, zeolites, and silica). Documenting such changes is an essential ingredient of the NanTroSEIZE science plan. Sharp diagenetic fronts (especially opal-to-quartz) have been linked to anomalous offsets in profiles of porosity, *P*-wave velocity, and other geotechnical properties (Spinelli et al., 2007). Alteration of dispersed volcanic glass is also potentially important during diagenesis but, as yet, this component of the sediment budget is poorly understood (Scudder et al., 2009). Similarly, hydrous authigenic phases in the basalt (e.g., saponite from ridge-flank hydrothermal alteration) are susceptible to diagenetic reactions at higher temperatures. Updip migration of fluids (including hydrocarbons) toward the Shikoku Basin from landward zones of deeper seated dehydration reactions is a distinct possibility (Saffer et al., 2008), and this idea can be tested through a comprehensive program of geochemical analyses. Interpretation of the geochemistry, however, requires constraints on the in situ temperature.

Characterization of basement composition and structure is a high priority for NanTroSEIZE. Permeability and fluid flow within oceanic basalt are affected by many variables (Fisher, 1998). A long-term goal is to monitor and sample fluids using subseafloor observatories but design of those experiments hinges on coring and logging results. As a prelude, we plan to concentrate first on documenting the basement's structural architecture, hydrologic properties, and early alteration products. Products of early alteration within the uppermost basalt (e.g., saponite and calcite) change the rock's bulk chemistry and physical properties (porosity and permeability). The extent of this alteration is important for constraining the volatile content of subducting crust. In addition, coring at least 200 m into basement and wireline logging during a future expedition will capture heterogeneities in fracture patterns and porosity that might be involved in delamination of the basalt downdip in the seismogenic zone.

The specific set of questions addressed by drilling at input sites are

- Is fluid circulation in basement and permeable sedimentary layers influencing heat flow and diagenesis at Sites C0011 and C0012?
- How does contrasting pore fluid chemistry at Sites C0011 and C0012 relate with in situ diagenesis and fluid flow?
- Can a change of physical properties between 200 and 250 mbsf at Site C0011 (Fig. **F9**) be related to lithologic variation or diagenesis? Does the same transition occur at Site C0012?
- Is magmatic activity heterogeneous in composition and age on a backarc basin basement high?
- Is alteration of the upper oceanic basement heterogeneous and how does it influence geochemical and fluid budgets?

Understanding relationships between the physical and chemical evolution of basement and sediment is a key objective of Expedition 333, relevant both to seismogenic zone and subduction factory studies.

Drilling strategy

At Sites C0011 and C0012, HPCS cores with APCT-3 measurements will be collected from the seafloor to refusal, and ESCS/EPCS coring will continue as time permits to the target depths of 350 mbsf at proposed Hole C0011C and 150 mbsf at proposed Hole C0012C or to the refusal depths (Figs. **F5, F6, F10, F11**). RCB coring will collect basement cores at proposed Hole C0012D from 520 to 740 mbsf after washing down to 520 mbsf.

Time was insufficient to deploy HPCS coring during Expedition 322, so temperature measurements were not made at Sites C0011 and C0012. The sediment temperature-pressure tool was successfully tested in the drill string but was not deployed in the formation. Expedition 333 plans to make formation temperature measurements using the APCT-3 during HPCS coring operations at a target spacing of every third core.

NanTroSLIDE Ancillary Project Letter

Scientific objectives

Expedition 333 will drill and sample the slope basin seaward of the megasplay that is characterized in 3-D seismic data by stacked mass transport deposits (MTDs) (Strasser et al., 2009) (Figs. **F12, F13, F14**). This coring has the aim of establishing the submarine landslide history and reconstructing transport dynamics. Core from proposed Site NTS-1A will be integrated with 3-D seismic interpretation and data from nearby NanTroSEIZE sites to determine the relation of submarine landslides to the tectonic evolution. By establishing a better physical understanding of tectonic processes and slope failures, we will also gain a general understanding of failure-related sedimentation patterns and the significance of episodic mass transport events. Ultimately, this could help us assess the tsunamigenic potential of tectonic landslides. The primary goals of drilling the proposed site (NTS-1A) are

1. To establish a well-dated Quaternary mass-movement event stratigraphy and
2. To sample the distal part of an exceptionally thick MTD for analyzing its rheological behavior to constrain sliding dynamics and tsunamigenic potential.

These aim at providing answers to the following questions:

1. What is the frequency of submarine landslides?
2. What is the source materials of the MTDs?
3. What is the importance of accretionary wedge remobilization versus surficial processes?
4. What controls type, size, and magnitude of turbitides and MTDs and how do they change through time?
5. How do large MTDs relate to the timing of splay fault activity as inferred from NanTroSEIZE Stage 1 drilling (Strasser et al., 2009)?
6. What are the dynamics of large submarine landslides and can we infer their tsunamigenic potential?

By addressing these questions, we aim to isolate tectonic processes influencing magnitude and occurrence of submarine landslides along active subduction zone margins and to understand their potential for triggering catastrophic events in terms of both hazards (tsunamigenic landslides) and sediment mass transfer within the context of margin evolution.

Drilling strategy

Proposed Site NTS-1A (water depth = 3100 m) is located on a margin-perpendicular transect 4.5 km southwest of the NanTroSEIZE Stage 1 drilling transect (Fig. **F12**). It is located 5 km south-southwest of Site C0008, which was drilled into a small slope basin seaward of the megasplay fault (Kimura et al., 2008). Site C0008 results show the utility of using the ages of MTDs to reconstruct slope failure activity related to megasplay fault movements (Strasser et al., 2009). Apart from the deepest section, Site C0008 lacks clear evidence for MTDs, potentially due to a significant hiatus in its upper part, suggesting erosion or nondeposition likely related to a prominent slope collapse structure seaward of the megasplay fault (Kimura et al., 2008). On the basis of new 3-D seismic data interpretation, the Ancillary Project Letter proponents have identified a lower slope basin that (1) better represents the depocenter for downslope mass transport, (2) is clearly characterized by stacked MTDs as seismically imaged by acoustically transparent to chaotic bodies with ponded geometries (Fig. **F12**), and (3) includes a large, as thick as 150 m, MTD. Expedition 333 will drill at a location where the MTD bodies wedge out and where basal erosion is minimal. Continuous coring with HPCS and ESCS/EPCS to ~350 mbsf will allow for sampling the MTDs across the most complete and longest stratigraphic succession.

Sampling plan

Expedition 333 will sample retrieved cores following traditional IODP policy, including discrete samples, whole-round samples (both individual requests and "community whole rounds"), and sample clusters (see additional explanation of community whole rounds and sample clusters in **"Sampling sediment cores"**). The sampling strategy was developed by the NanTroSEIZE PMT in consultation with the Sample Allocation Committee (SAC) (see **"Sample requests and coordination"**) to best meet the project's objectives and the individual desires of the science party. A short review of core sampling and archiving is provided below. Shipboard and shore-based researchers should also refer to the IODP Sample, Data, and Obligations Policy (**www.iodp.org/program-policies/**).

Sampling sediment cores

Cores are typically split into a "working half" and "archive half," with the working half being available for sampling by shipboard and shore-based scientists. Although the archive half is also available for sampling in certain circumstances, it is primarily designed to preserve retrieved material while providing flexibility and broader access to important material postcruise. Samples of whole-round cores can also be requested following IODP policy. The multiexpedition nature of NanTroSEIZE requires modification of normal IODP sampling policy and routines in sampling sediment cores. Specifically, these include: (1) community whole-round cores that are archived (at the Kochi Core Center [KCC]) for postcruise distribution and (2) co-located sample clusters taken as a suite from slices (1–2 cm thick) next to all whole rounds.

Sampling basement cores

Sampling of basement cores is typically handled in a more deliberate manner, particularly if recovery is limited. Once the cores are split, interested scientists will be able to identify specific pieces or features (e.g., veins) for sampling, and adjustments will be made if more than one request is made for the same piece. If the amount of time available for basement sampling is insufficient because it is planned as a later part of the expedition, this part of the sampling plan could be implemented after the expedition at the KCC.

Community whole-round samples

As usual, individual scientists will be able to collect whole-round samples for their postcruise research. In addition, however, we will collect “community” archive whole-round samples to augment and/or provide redundancy for those requested by shipboard scientists. The goal is to preserve samples for a wide range of overall science objectives over the duration of NanTroSEIZE. Community whole-round samples are typically collected from each core, depending on the length of each recovery. This strategy, for example, will enable additional analyses of critical intervals once those zones are identified from initial shore-based laboratory tests.

Sample clusters

To maximize the project’s ability to correlate different shipboard and shore-based data sets, it will be essential to co-locate suites of basic data types (pore water, organic geochemistry, carbon/carbonate, moisture and density, bulk-powder X-ray diffraction [XRD], and bulk chemistry X-ray fluorescence). Sample clusters are normally collected next to each whole-round specimen, including those used for interstitial water geochemistry. Clusters will also include subsamples for shore-based measurements of grain size, clay mineral XRD, microfabric, and cation exchange capacity as specified by individual sample/data requests.

Sample requests and coordination

NanTroSEIZE is a long-term drilling project with several linked expeditions over several years. Consequently, sampling and coordination of individual samples and data requests are somewhat different than for single expeditions. These differences include the role of Specialty Coordinators, data sharing opportunities, and a more integrated sample/data request program that includes use of designated labs for some shore-based analyses. Key aspects of these differences are described below.

Specialty Coordinators

Unlike traditional stand-alone Ocean Drilling Program/IODP legs and expeditions, unusual amounts of coordination and collaboration must occur among different science parties to achieve NanTroSEIZE goals. Specialty Coordinators, in collaboration with Co-Chief Scientists, will be responsible for facilitating collaborations between the participants of Expeditions 322 and 333. They will also identify research or sampling gaps, help organize efficient sampling strategies (to minimize redundancy and overlap), and facilitate collaborations beyond those planned by the shipboard science party for Expedition 333. The Specialty Coordinators will also provide technical and scientific guidance to the science party before and during the expedition to ensure seamless data sets, particularly with respect to existing shipboard data from Expedition 322. The NanTroSEIZE PMT has identified six specific research areas that require the oversight of Specialty Coordinators over the project's duration:

- Lithology and sedimentary petrology,
- Structural geology,
- Geotechnical properties and hydrogeology,
- Geochemistry,
- Core-log-seismic integration, and
- Paleomagnetism and biostratigraphy.

Data/Sample sharing between expeditions

Data sharing across expeditions is normally accommodated through a formal data/sample request; that is, a scientist from one expedition can apply as a shore-based scientist for data/samples from a completed or planned expedition. In the case of NanTroSEIZE, contingency operations sometimes overlap across two or more expeditions to such an extent that the expeditions are considered one expedition in terms of shipboard data and samples. In such cases, data can be shared without a separate data/sample request. This type of merger may occur, for example, for scientific or logistical reasons during preexpedition planning. It could also occur during an expedition if contingency sites are drilled that overlap with another planned expedition. The decision as to whether an expedition is a stand-alone or merged in terms of data/samples is made by the NanTroSEIZE PMT in consultation with the SAC and the Co-Chiefs of the involved expeditions. In the case of Expedition 333, it is also important to realize that members of the science party for Expedition 322 will be interested in collaborative postcruise research using samples from intervals that had not been cored before. Balancing the research interests of individual scientists from both expeditions against the project’s needs for seamless data sets at each site will be a responsibility of the Specialty Coordinators. The desire will be to enhance opportunities for fruitful collaboration.

Community labs for postexpedition analyses

Whereas many analyses can and will be conducted at sea, others require state-of-the-art instrumentation that is only available on shore. We are particularly concerned about stable isotopic measurements that depend on dedicated instruments not found at all universities and government laboratories. For example, we expect to collect pore water to measure at least Sr, B, Li, O, H, Cl, and C stable isotopic compositions. It is doubtful that any individual scientist has the on-site capability to make all of the measurements listed above. Issues regarding quality assurance/quality control become significant. To get the most consistent and reliable data for all Stage 1 expeditions, the NanTroSEIZE PMT proposed that all samples for each category of geochemical analysis go to a single laboratory. Several laboratories (to be determined) will have to be involved. For example, one laboratory might measure O, H, and C isotopes while another might measure Cl isotopes or Li. The choice of a particular laboratory (and analytical technique) will be reached by consensus of the inorganic geochemists who sail on Expedition 333, mediated by the Specialty Coordinator for Geochemistry and approved by expedition SACs. We anticipate that data generated from each laboratory will be shared by all members of the Expedition 322 and 333 scientific parties for use as defined by the approved research plans. Similarly, shore-based collaborators who are part of the community team will be granted access to the results of shipboard geochemical analyses at the earliest convenience (i.e., as site reports are completed). This strategy was implemented successfully during the postexpedition phase of NanTroSEIZE Stage 1.

Sample and data requests (research proposals)

All shipboard scientists must submit at least one data or sample request in advance of the drilling expedition. Additional requests also may be submitted during or after the expedition if appropriate. The initial sample requests provide the basis for the SAC and Specialty Coordinators to develop an integrated sampling program of both shipboard and postcruise sample requests. Careful planning and vertical mapping of sample distributions is particularly important for whole-round sampling. The initial sampling plan, of course, will be subject to modification depending upon the actual material/data recovered and on collaborations that may evolve between scientists before and during the expedition(s). Substantial modifications to the sampling plan during the expedition require the approval of the SAC. To provide enough time for the SAC and Specialty Coordinators to develop a detailed and integrated sampling strategy, sample requests are due by 15 November 2010.

The IODP Sample, Data, and Obligations Policy (**www.iodp.org/program-policies/**) outlines the policy for distributing IODP samples and data and defines the obligations incurred by both shipboard and shore-based scientists. Both groups of scientists should also use the Sample/Data Request form (**smcs.iodp.org/**) in submitting their requests.

Additional sampling guidelines

The SAC is composed of Co-Chief Scientists, Expedition Project Managers, the shipboard curatorial representative, and the IODP curator on shore; the SAC for the expedition(s) must approve access to data and core samples requested during the expedition and during the 1 y moratorium, which starts at the end of the drilling expedition. It is important to note that Specialty Coordinators merely provide advice to the SAC within their fields of expertise; they are not responsible for the decisions to approve/revise/reject the sample/data requests.

All sample frequencies, spacing, and sizes must be justified on a scientific basis. Implementation of the sampling plan will depend on core recovery, the full spectrum of other sample/data requests, the expedition objectives, and project-wide NanTroSEIZE objectives. When critical or volumetrically limited intervals are recovered, there may be considerable demand for samples because of the limited amount of cored material. These intervals (e.g., highly deformed fault zone) may require special handling, a higher sampling density, reduced sample size, or continuous core sampling for a set of particular high-priority research objectives. With advice from Specialty Coordinators, the SAC may request an additional formal sampling plan before critical intervals are sampled. All sampling to acquire ephemeral data types (e.g., for microbiology) or to achieve essential sample preservation will be conducted during the expedition. Most sampling for each individual scientist's postcruise research will be conducted during the expedition, but some sampling could be deferred to postcruise. A postexpedition sampling party is particularly likely for cores collected during the final days of the expedition.

Risks and contingency

Unforeseen circumstances, collapse of a borehole from unstable sands, adverse environmental conditions, hardware failures, or unusually slow penetration could result in insufficient time being available to complete the entire operations plan for Expedition 333. In anticipation of challenging and fluctuating environmental conditions, we have included a range of contingency options for the entire expedition in the operations plan and time estimate. To balance all of the priorities, each site is allocated a fixed limit for the maximum number of operational days. In addition, one possibility is that a maximum of eight days delay in the start date of Expedition 333 may occur, in case of severe delay during installing the long-term borehole monitoring system (LTBMS) at Site C0002 during Expedition 332. Even if this happens at the beginning of the expedition, the Expedition 333 science party will board the ship as scheduled and prepare for the expedition while Expedition 332 scientists finish working on installing the LTBMS.

Figures **F7** and **F15** show the drilling sequence and decision trees for contingencies if Expedition 332 finishes early or is delayed at the beginning of Expedition 333 or any of expedition targets finish ahead of or behind the planned schedule during the expedition period. It is important to note that this contingency plan is based on our state of knowledge at the time of this writing and modification may be required as additional information becomes available, including recommendations from the NanTroSEIZE PMT. Within our primary operations plan, we have identified several potential contingency options in the case of hole problems and/or time constraints (Fig. **F15**). If coring operations at any of the three sites require significantly more time than allocated to reach the total depth target, we do not plan to rebalance any of the remaining scientific objectives.

Kuroshio Current

The Kuroshio Current is a swift western boundary current that presents substantial risk to all expedition operations. If we encounter the maximum Kuroshio Current strengths at any given drill site, any operations and measurements may be risky as previous work in the region demonstrated that current related vibrations are potentially damaging to all hardware and tools deployed. The axis of the current migrates and meanders significantly and unpredictably (Fig. **F16**), so efforts will be made to monitor its location and velocity using available online resources with forecasts for a few months in advance without accurate and precise predictions.

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Table T1. Operations plan and time estimate, Expedition 333. (See table notes.)

Site	Location	Water depth (m)	Operation	Duration (days) Transit/ position	Drilling/ coring	Subtotal
			Move to Site NTS-1A from Site C0002 (Expedition 332)	0.5		
NTS-1A	136° 40.8888'N 33° 09.4195'E	3100	Deploy transponders, move up current for running BHA	1		
			Make up and running coring assembly		0.5	
			Hole A: Drilling with HPCS to refusal, changes to ESCS/EPCS to 350 mbsf or refusal		4.5	
			Spot weighted mud and pull out of hole		0.5	
			Retrieve transponders and move to Site C0011		1	
			Subtotal days on site			8
C0011C	136° 52.9250'N 32° 49.7436'E	4051	Deploy transponders, seafloor survey, move up current for running BHA	1.5		
			Make up and running coring assembly		0.5	
			Hole C: Drilling with HPCS to refusal, change to ESCS/EPCS to 350 mbsf or refusal		5	
			Spot weighted mud, pull out of hole and retrieve transponders		1	
			Subtotal days on site			8
C0012C	136° 55.0417'N 32° 44.8947'E	3514	Move to Site C0012, deploy transponders, move up current for running BHA	2		
			Make up and running coring assembly		0.5	
			Hole C: Drilling with HPCS to refusal or ~150 mbsf, APCT-3/3 cores		1.5	
			Spot weighted mud and pull out of hole		0.5	
			Subtotal days on site			4.5
C0012D	136° 55.0066'N 32° 44.6815'E	3512	Move up current for running BHA, make up and running coring assembly		0.5	
			Hole D: Drilling 10-5/8" hole with RCB center bit to 520 mbsf		1	
			Retreive center bit and core RCB to 740 mbsf		3.5	
			Spot weighted mud and pull out of hole		0.5	
			Retrieve transponders and transit to Shingu port	2		
			Subtotal days on site			7.5
			Total expedition days			**28**

Notes: BHA = bottom-hole assembly. HPCS = hydraulic piston coring system, ESCS = extended shoe coring system, EPCS = extended punch coring system. mbsf = meters below seafloor. APCT-3 = advanced piston corer temperature tool. RCB = rotary core barrel.

Figure F1. Bathymetric map, with two-dimensional MCS profile locations and NanTroSEIZE Stage 1 and 2 drill sites (white circles) and planned drill sites for Expedition 333 (red circles). White barbed line = position of deformation front of accretionary prism, yellow arrow = estimated far-field vectors between Philippine Sea plate and Japan (Seno et al. 1993; Heki, 2007).

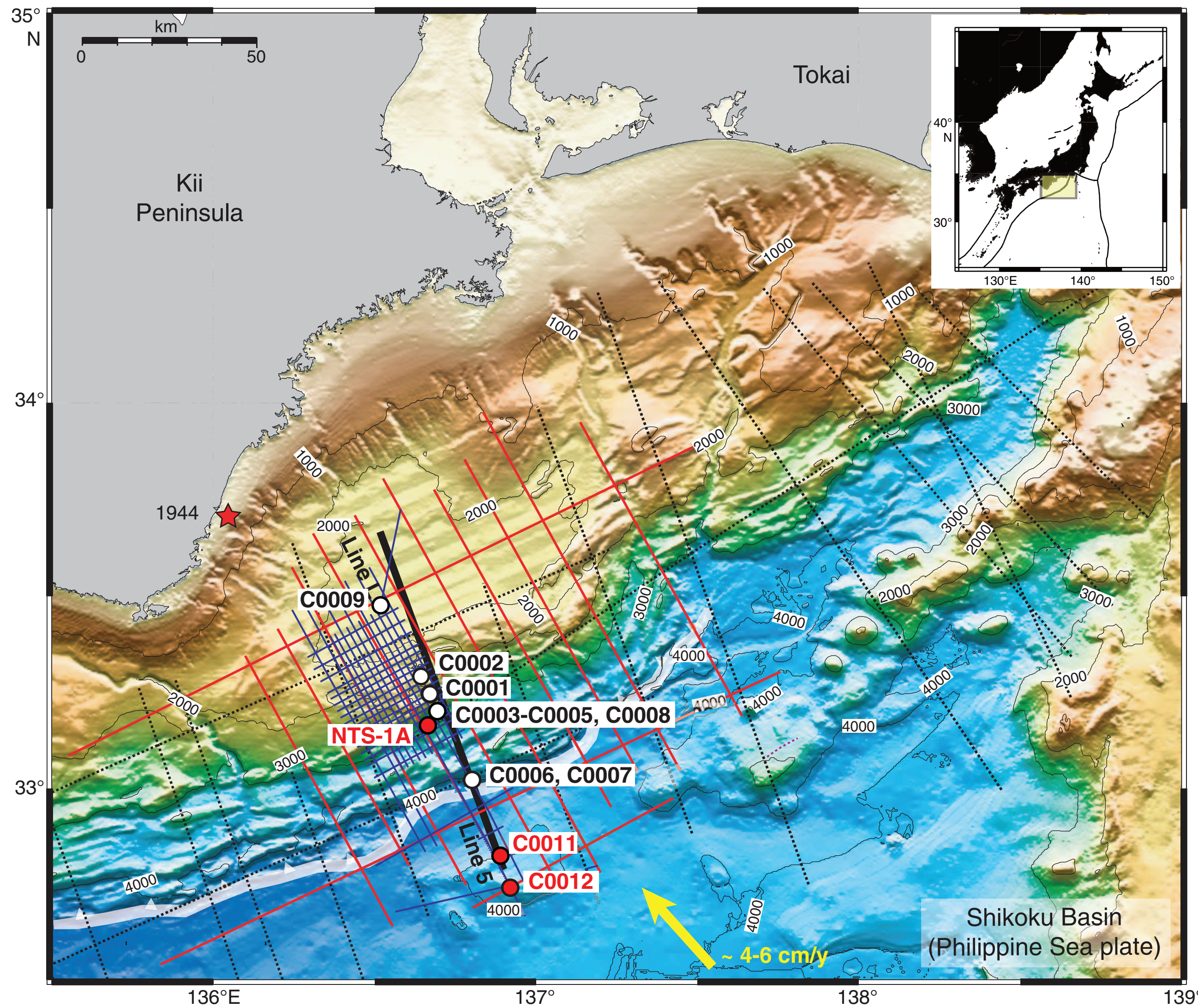


Figure F2. Spliced composite profile of a representative depth section from NanTroSEIZE 3-D data volume (Moore et al., 2009) and Line 95 from IFREE mini-3-D seismic survey (Park et al., 2008). Projected positions of Stage 1 and 2 drilling sites, including Sites C0011 and C0012, are shown together with major geologic features.

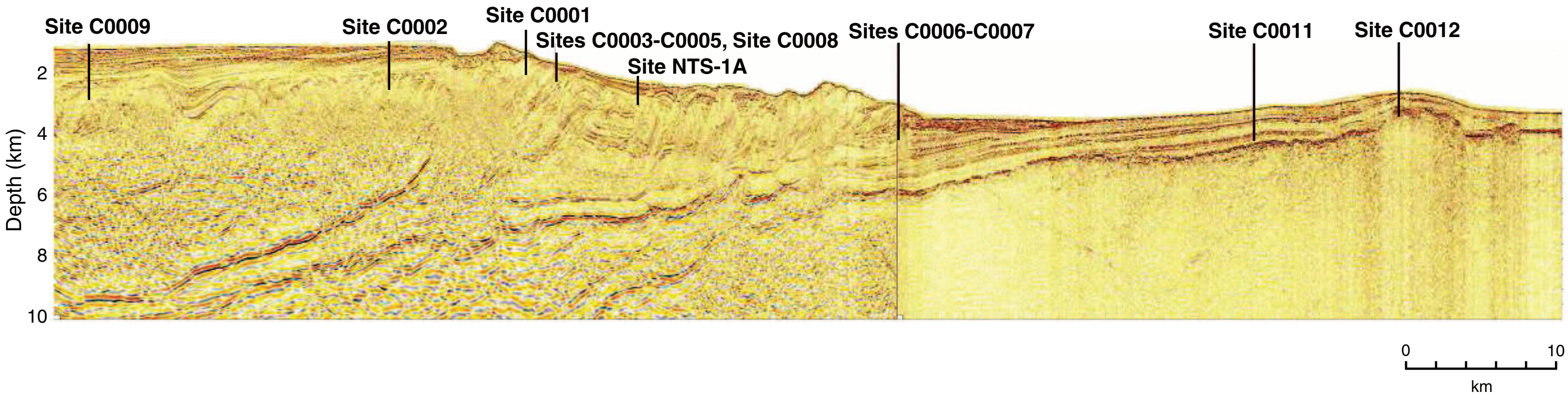


Figure F3. Lithologic columns on seismic background, Sites C0011 and C0012. Portion of IFREE 3-D seismic reflection Line 95 showing Sites C0011 and C0012. Depth section corrected during Expedition 322 after adjustments to velocity model following acquisition of LWD data at Site C0011. VE = vertical exaggeration.

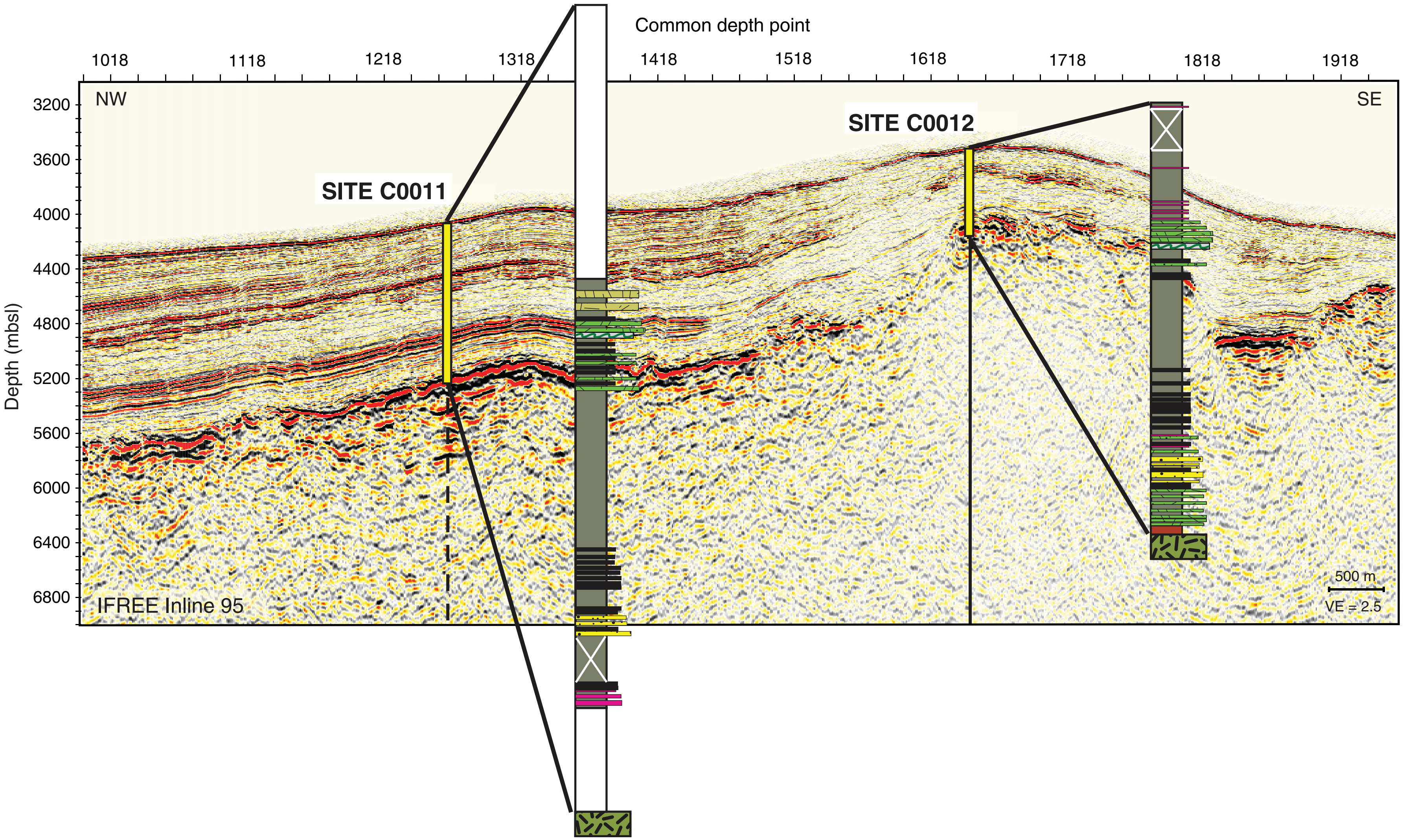


Figure F4. Stratigraphic correlation between Sites C0011 and C0012. For Site C0011, only logging-while-drilling data from 0 to 340 m LWD depth below seafloor (LSF) are available. Unit boundary ages taken from integrated age-depth models.

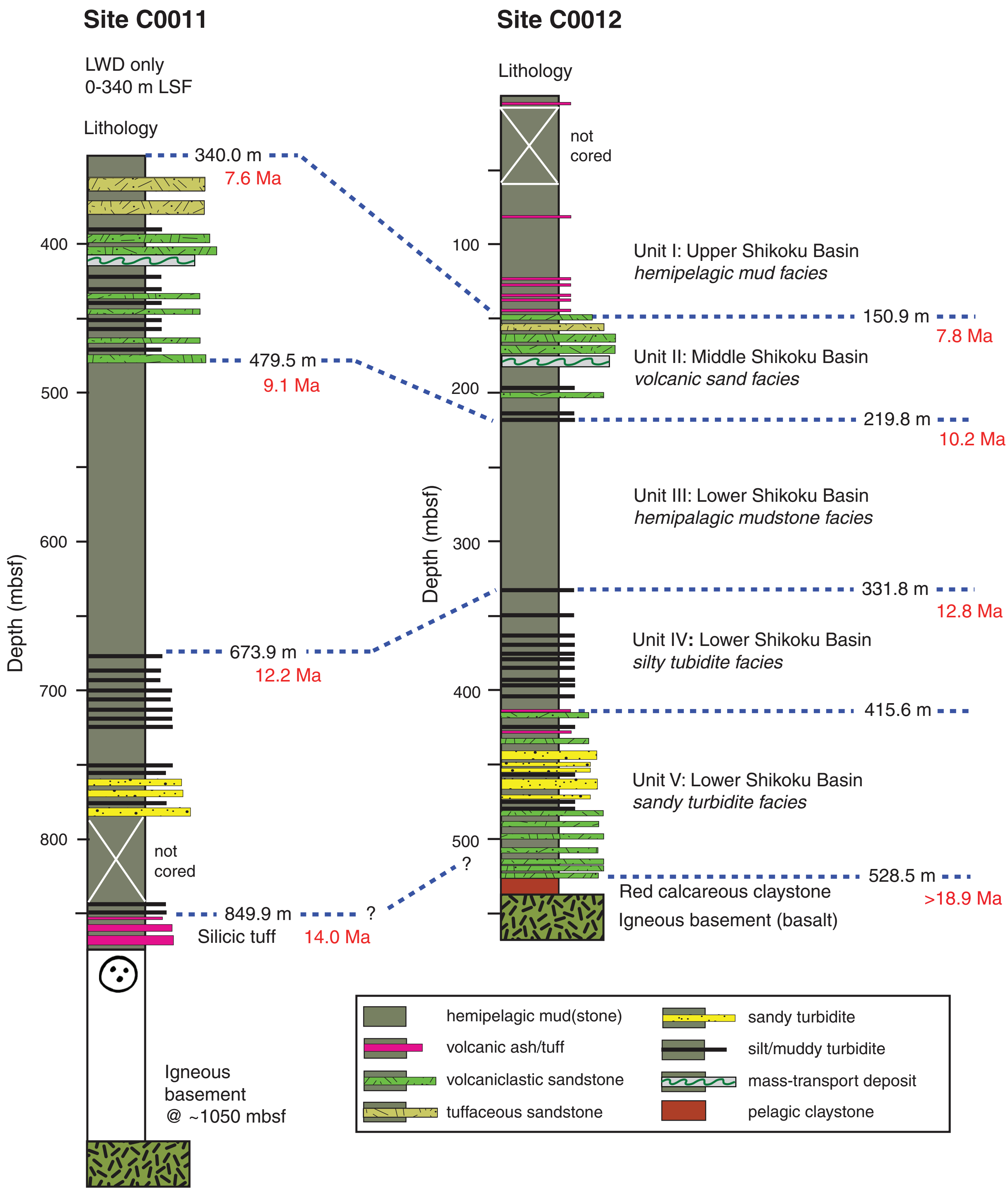


Figure F5. Seismic stratigraphy over IFREE 3-D seismic reflection Line 95, Site C0011. VE = vertical exaggeration.

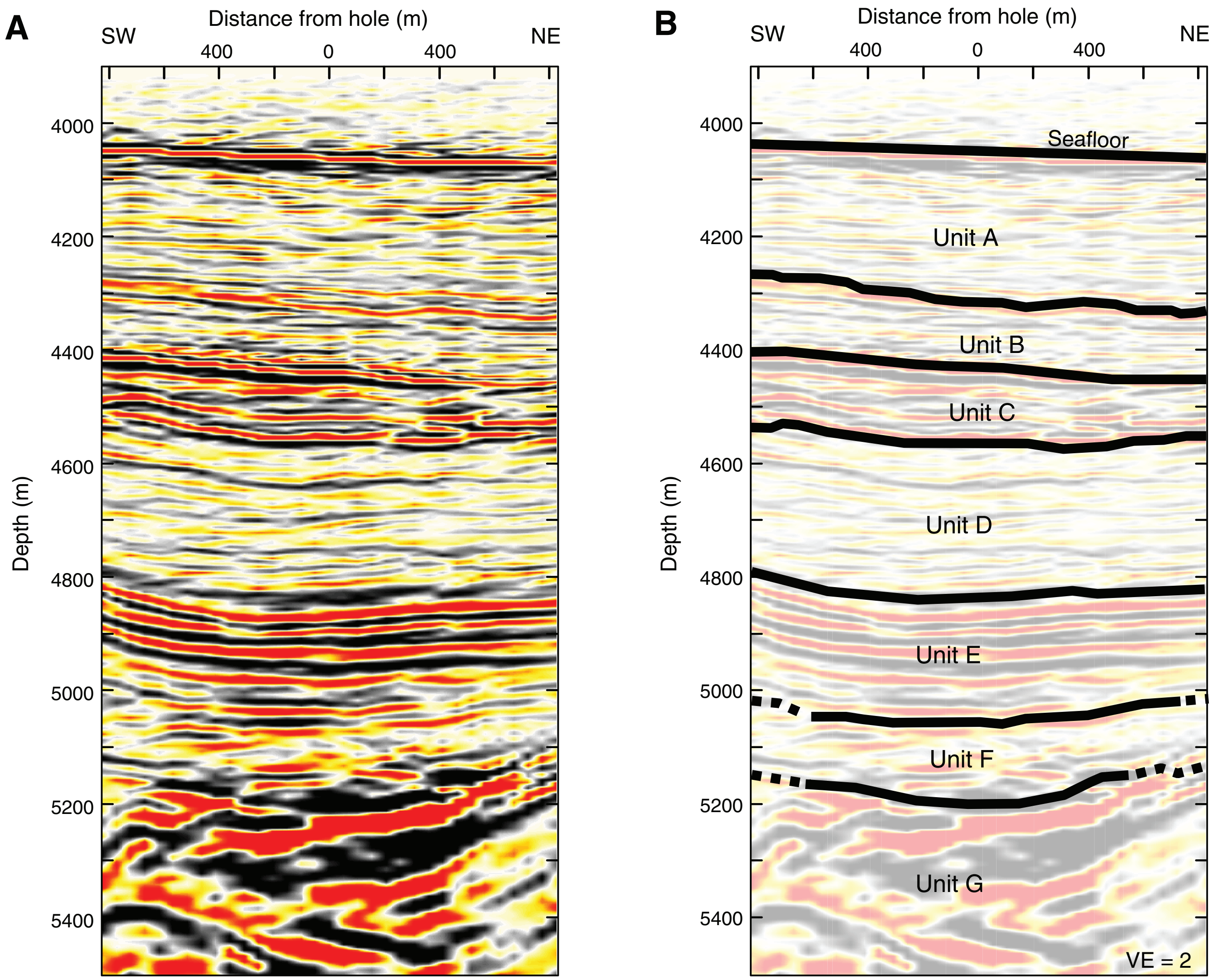


Figure F6. Seismic stratigraphy over IFREE 3-D seismic reflection Line 95, Hole C0012A. VE = vertical exaggeration.

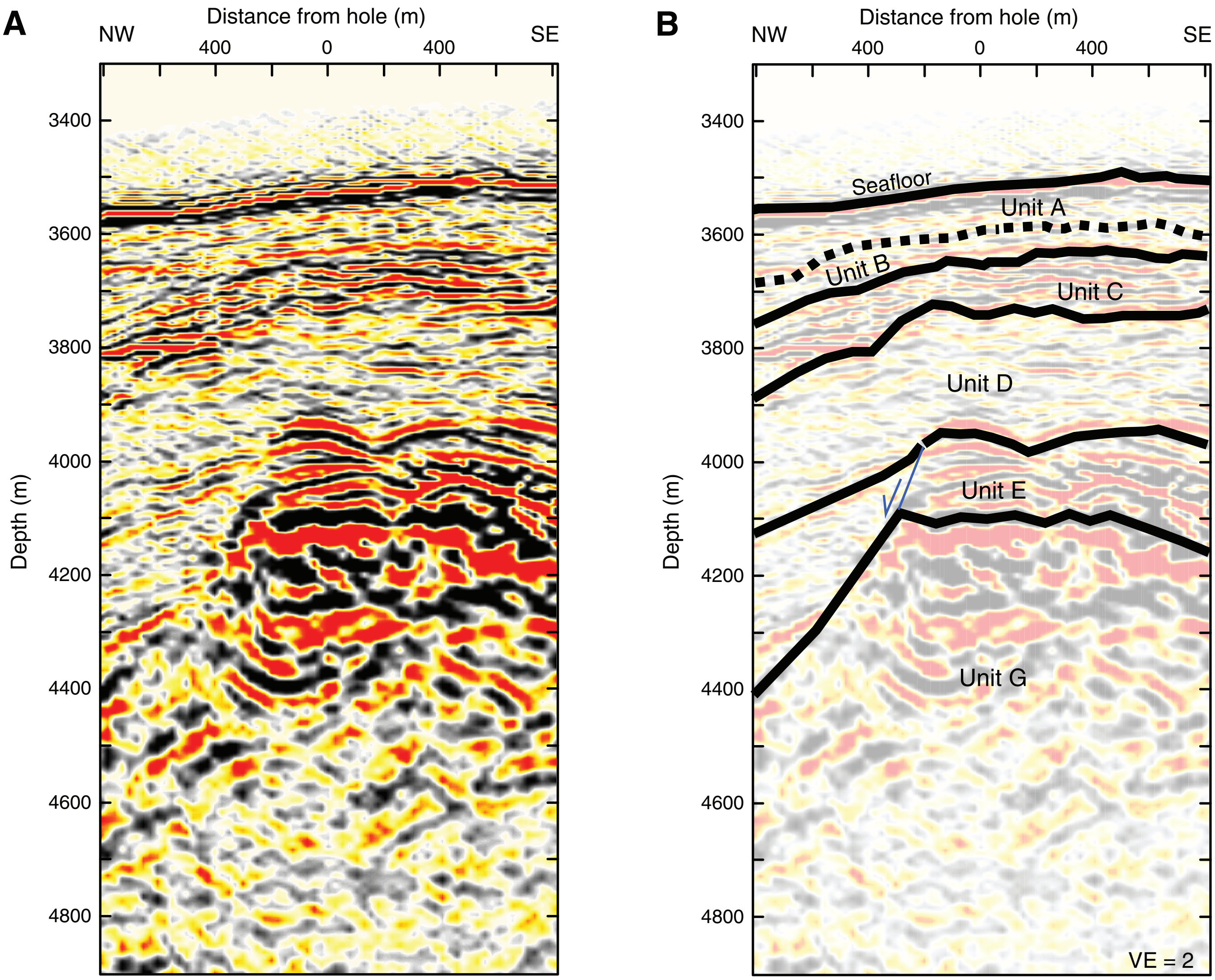


Figure F7. Operation plan (drilling sequence) of Expedition 333 in the Shikoku Basin. See **"Drilling, coring, and temperature measurements plan"** for more detailed descriptions of drilling operations at proposed Site NTS-1A and proposed Holes C0011C, C0012C and C0012D.

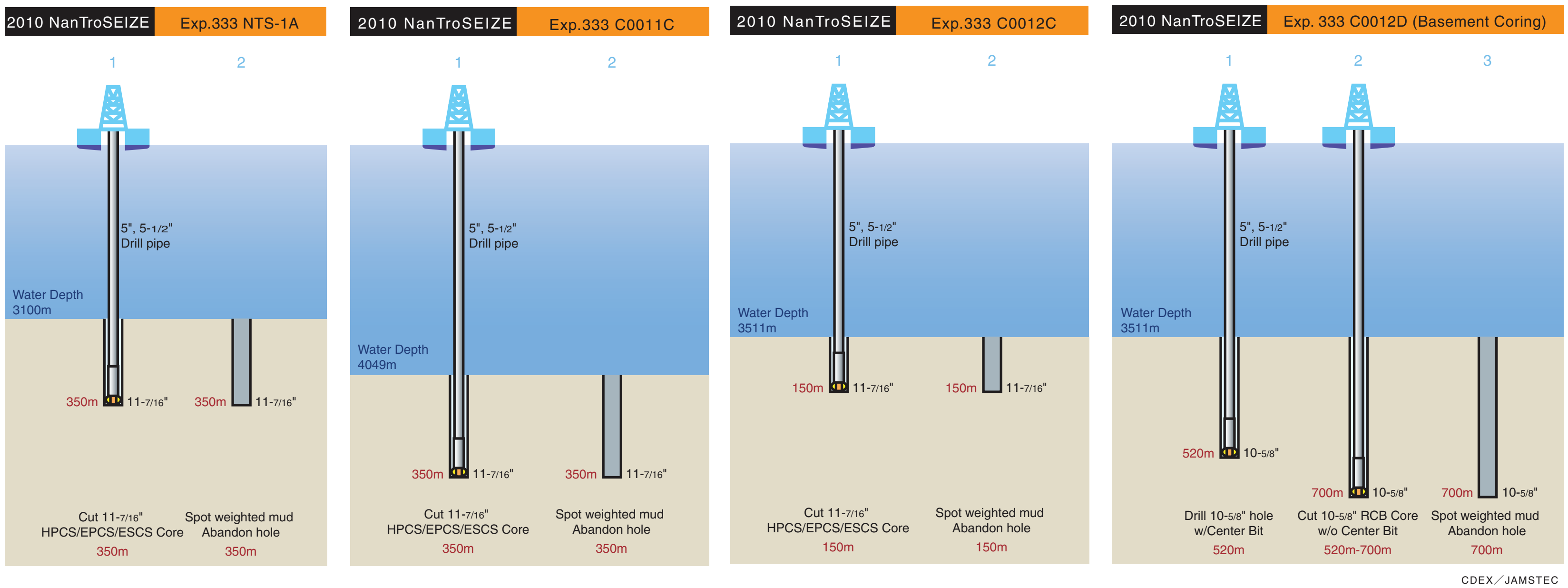


Figure F8. A. Heat flow distribution on the floor of the Nankai Trough plotted on area bathymetry. Heat flow values are indicated by the color code on the right. **B.** Heat flow distribution in the Nankai Trough off Kumano together with depth-converted multichannel seismic (MCS) profile. Dashed line = theoretical heat flow (110 mW/m^2) corresponding to 20 Ma age ocean crust. Squares (in A) and large solid circles (in B) = heat flow values obtained during research Cruises KY03-14, KY07-01, and KY08-01 (Kinoshita et al., 2008a); small circles = other studies (Yamano et al., 2003; H. Hamamoto et al., unpubl. data); crosses = estimates from gas hydrate bottom-simulating reflectors (Ashi et al., 2002). (**Figure shown on following page.**)

Figure F8 (continued). (Caption shown on previous page.)

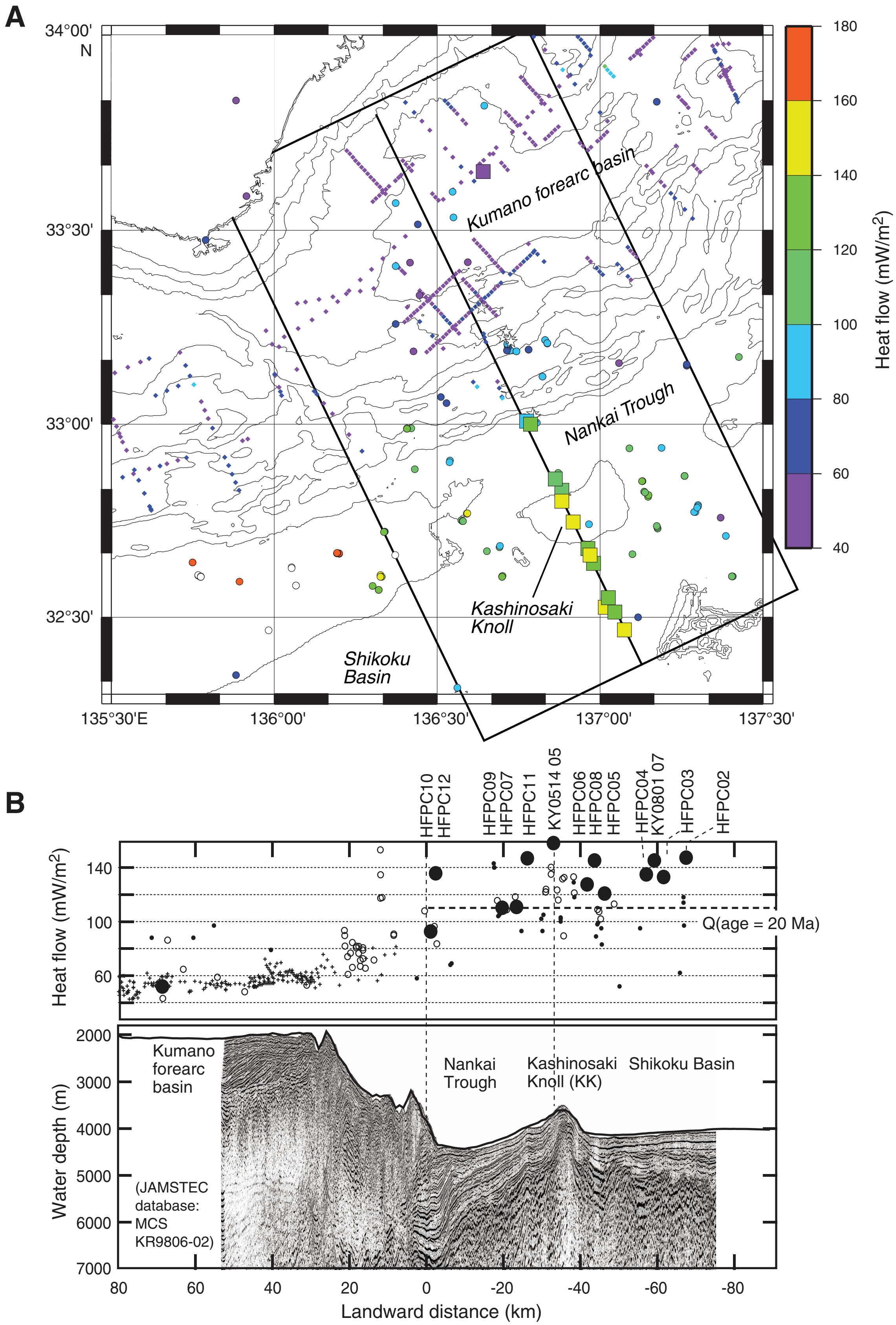


Figure F9. LWD log summary and log-seismic integration, Hole C0011A. Interpretations of lithology are based on log character. VE = vertical exaggeration.

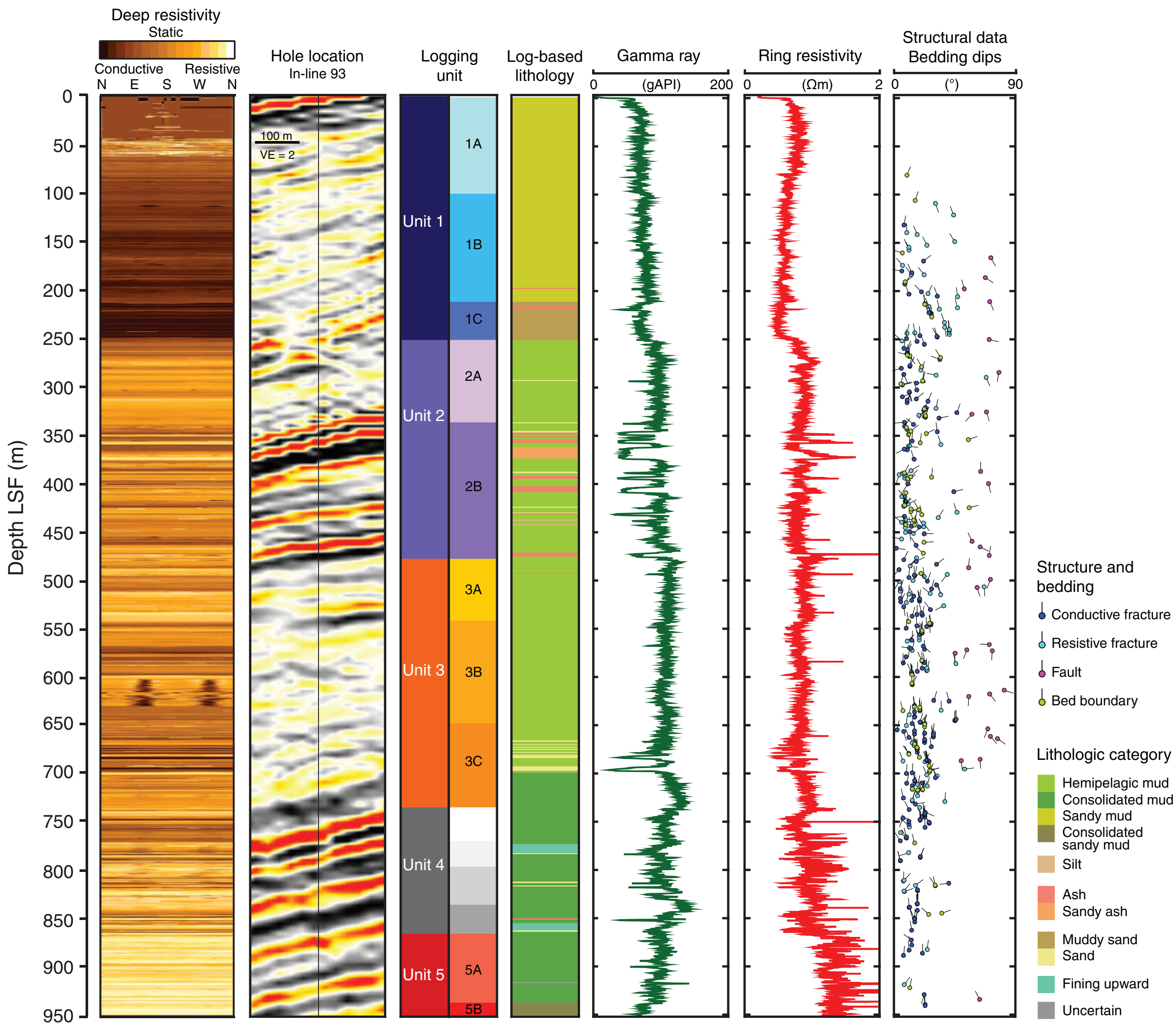


Figure F10. Map, proposed Hole C0011C.

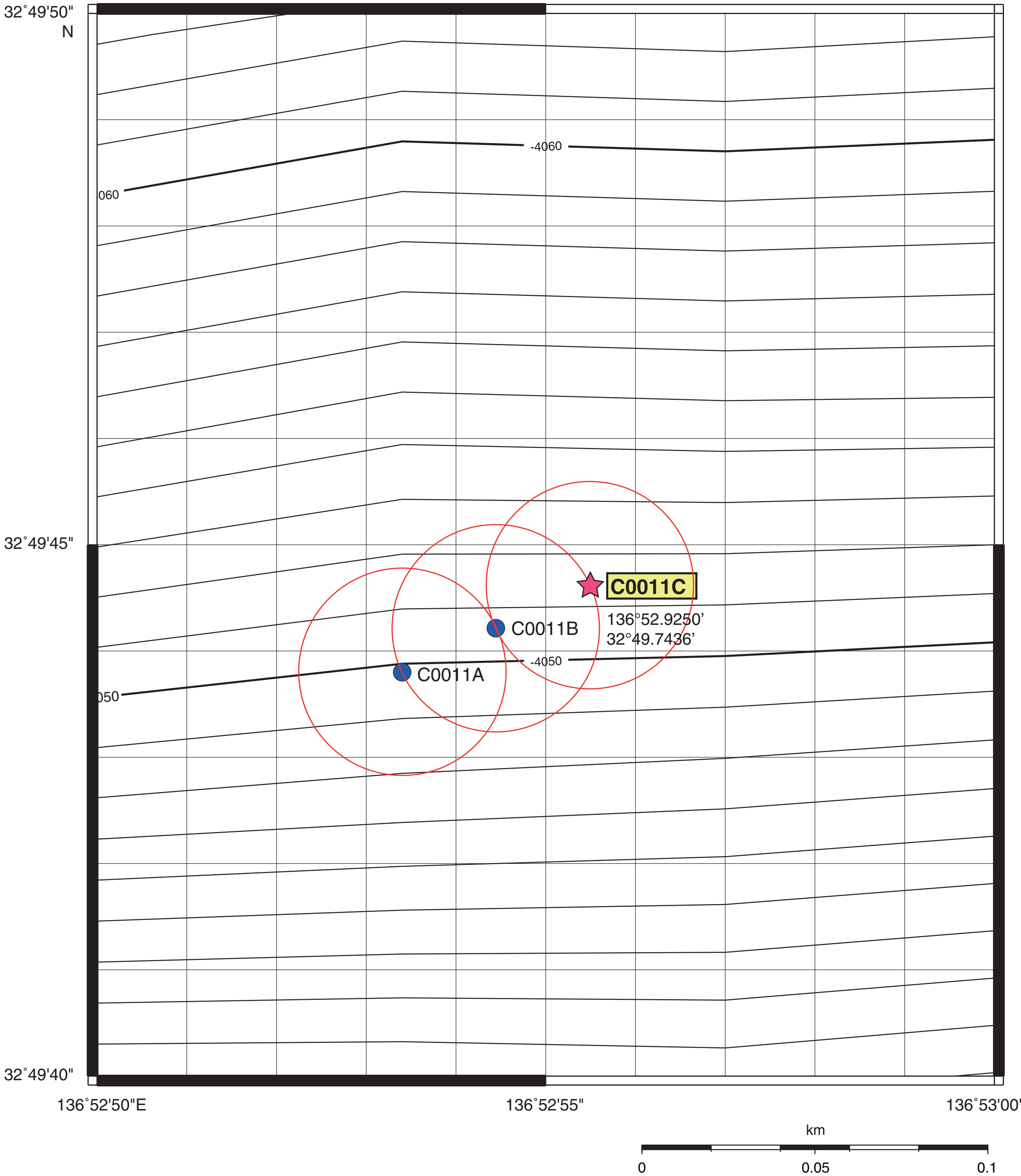


Figure F11. Map, proposed Holes C0012C and C0012D.

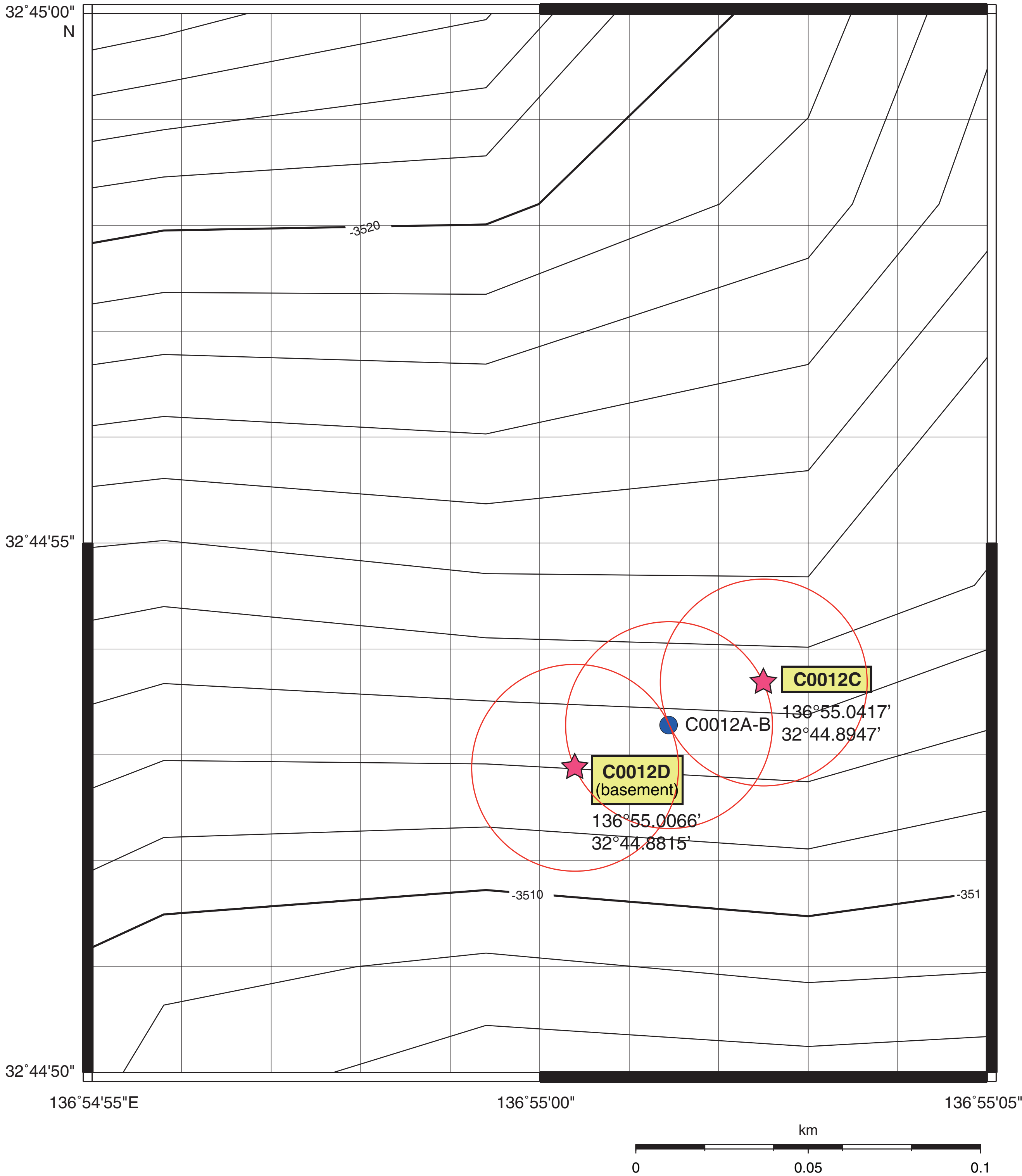


Figure F12. A. Colored bathymetry of the study area showing location of proposed drill Site NTS-1A and Sites C0001, C0004, and C0008. Bold black lines = location of 3-D seismic in-line (IL) and cross-line (XL) shown in (**B**) along strike oriented seismic profile and (**C**) dip-oriented seismic reflection profile. **D, E.** Seismic profiles with interpretation showing mass transport deposits (MTDs). Vertical gray and black lines = location of proposed Site NTS-1A and penetration depths to 350 mbsf (first priority target depth) and 225 mbsf (second priority target depth), respectively.

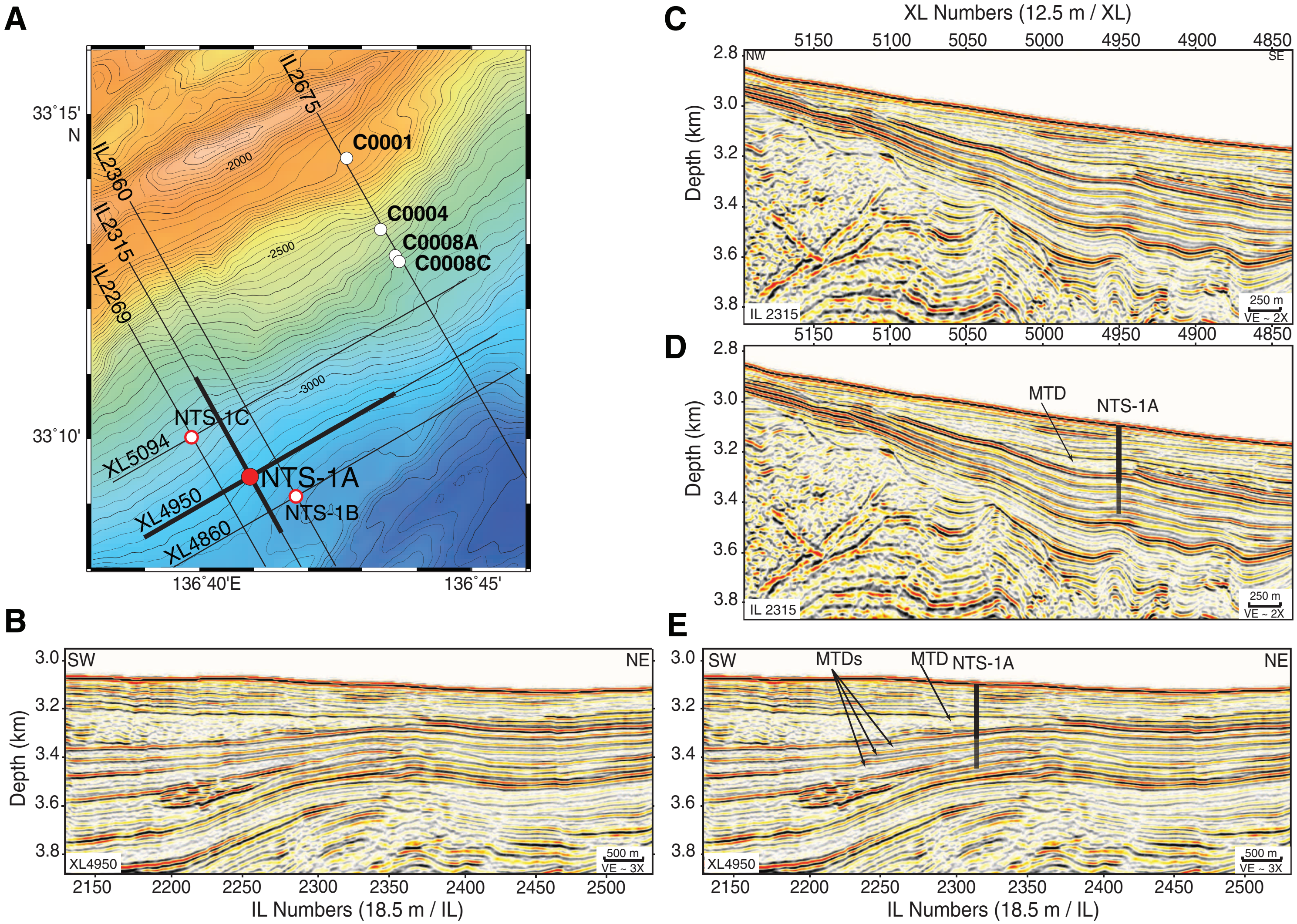


Figure F13. **A.** Colored bathymetry of the study area showing location of proposed alternate drill Site NTS-1B and Sites C0001, C0004, and C0008. Bold black lines = location of 3-D seismic in-line (IL) and cross-line (XL) shown in (**B**) along strike oriented seismic profile and (**C**) dip-oriented seismic reflection profile. **D, E.** Seismic profiles with interpretation showing mass transport deposits (MTDs). Vertical gray and black lines show location of proposed Site NTS-1B and penetration depths to 350 mbsf (first priority target depth) and 200 mbsf (second priority target depth), respectively.

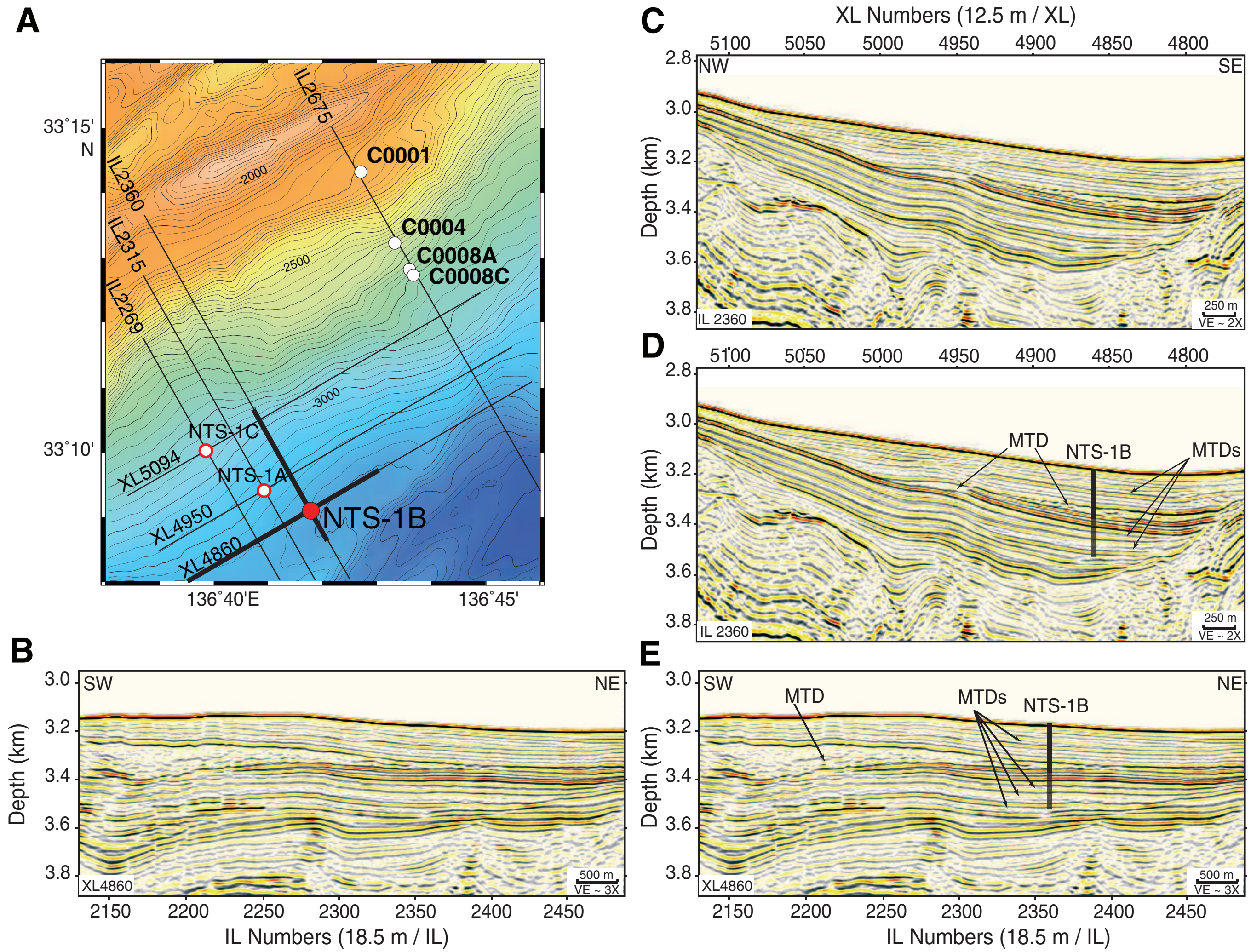


Figure F14. **A.** Colored bathymetry of the study area showing location of proposed alternate drill Site NTS-1C and Sites C0001, C0004, and C0008. Bold black lines = location of 3-D seismic in-line (IL) and cross-line (XL) shown in (**B**) along strike oriented seismic profile and (**C**) dip-oriented seismic reflection profile. **D, E.** Seismic profiles with interpretation showing mass transport deposits (MTDs). Vertical gray and black lines = location of proposed Site NTS-1C and penetration depths to 300 mbsf (first priority target depth) and 205 mbsf (second priority target depth), respectively.

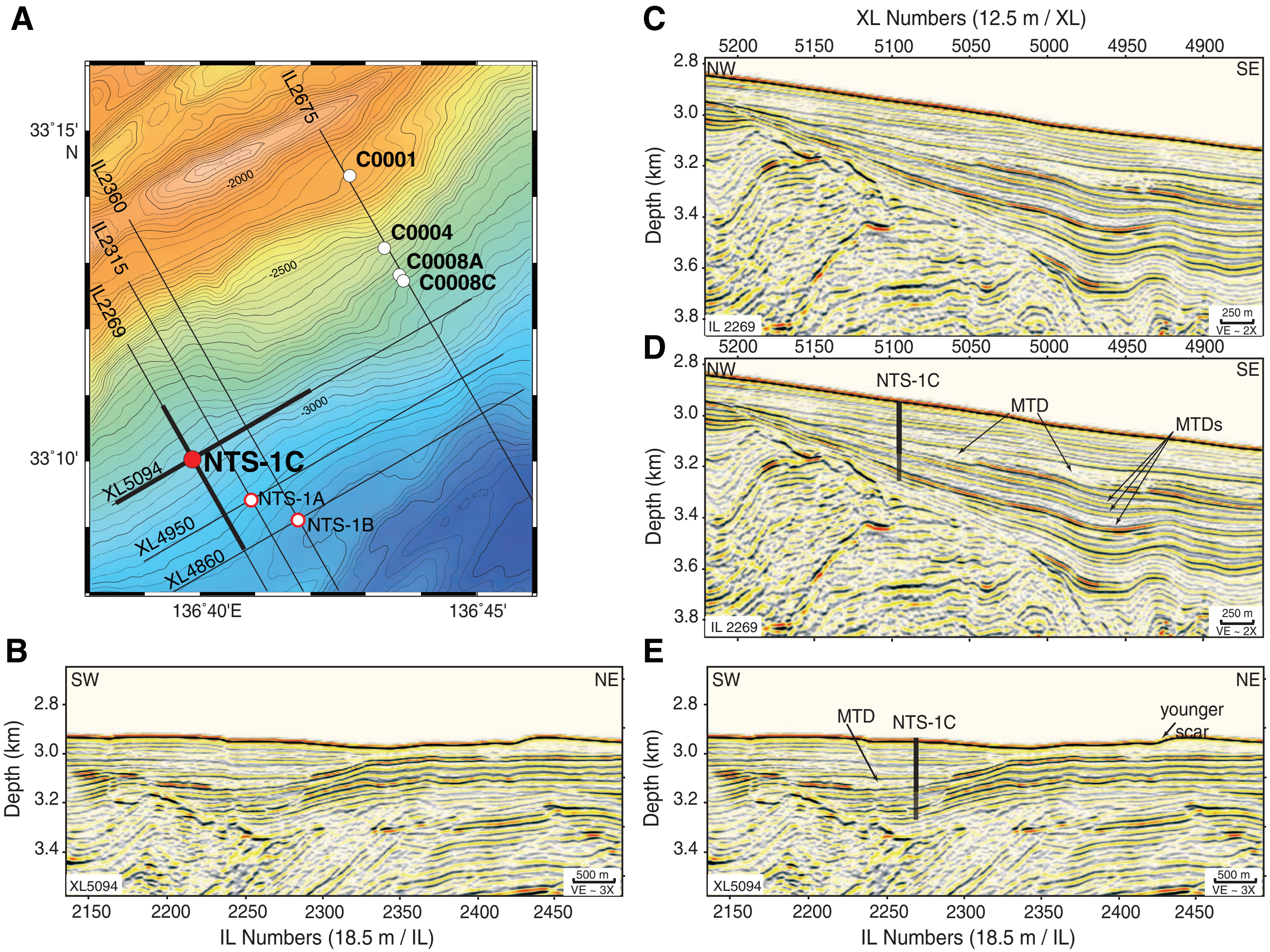


Figure F15. Expedition 333 decision tree based on original schedule without considering delays or ahead of time. HPCS = hydraulic piston coring system, ESCS = extended shoe coring system, EPCS = extended punch coring system, RCB = rotary core barrel, APCT-3 = advanced piston corer temperature tool, POOH = pull out of hole.

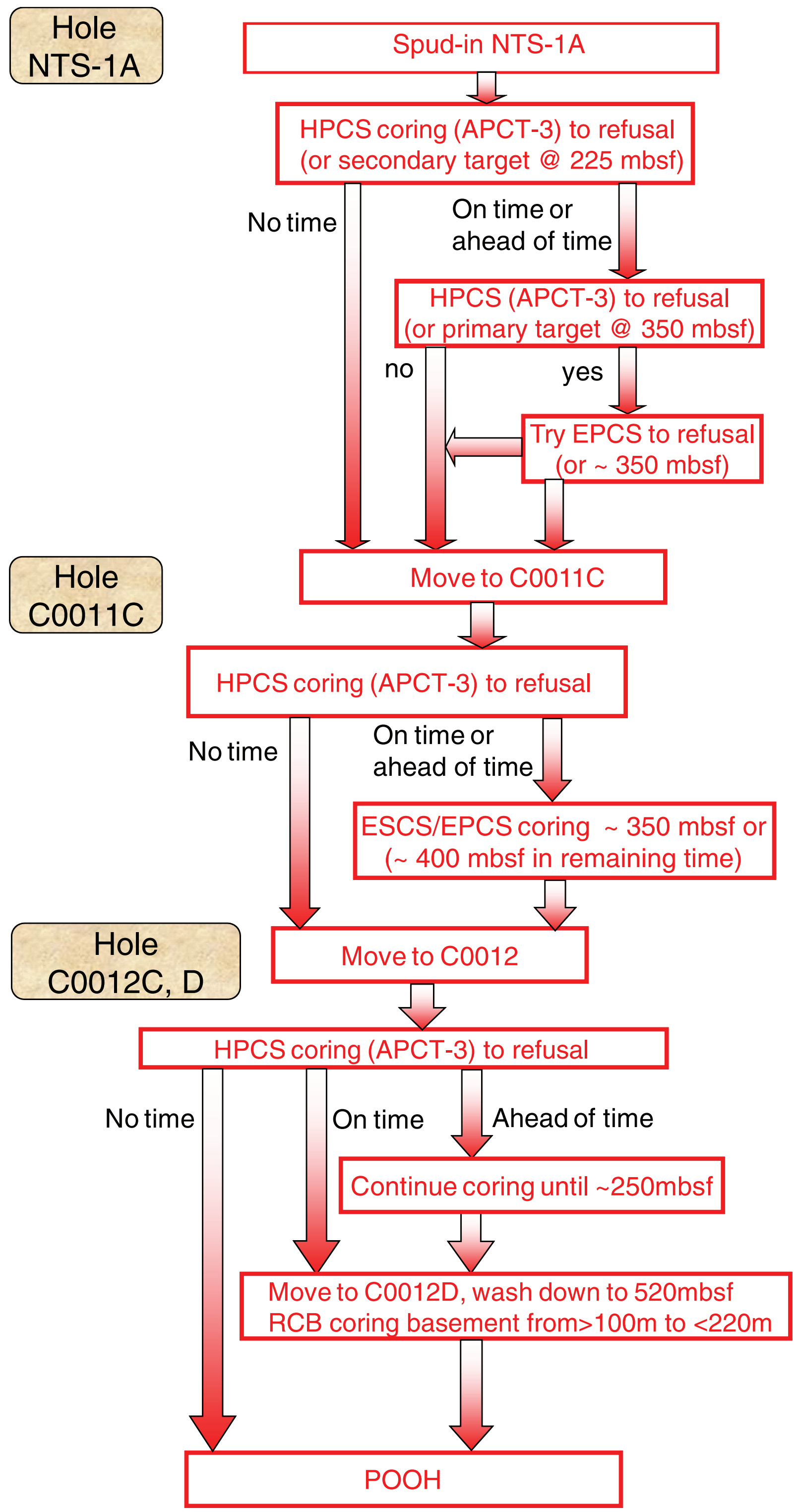
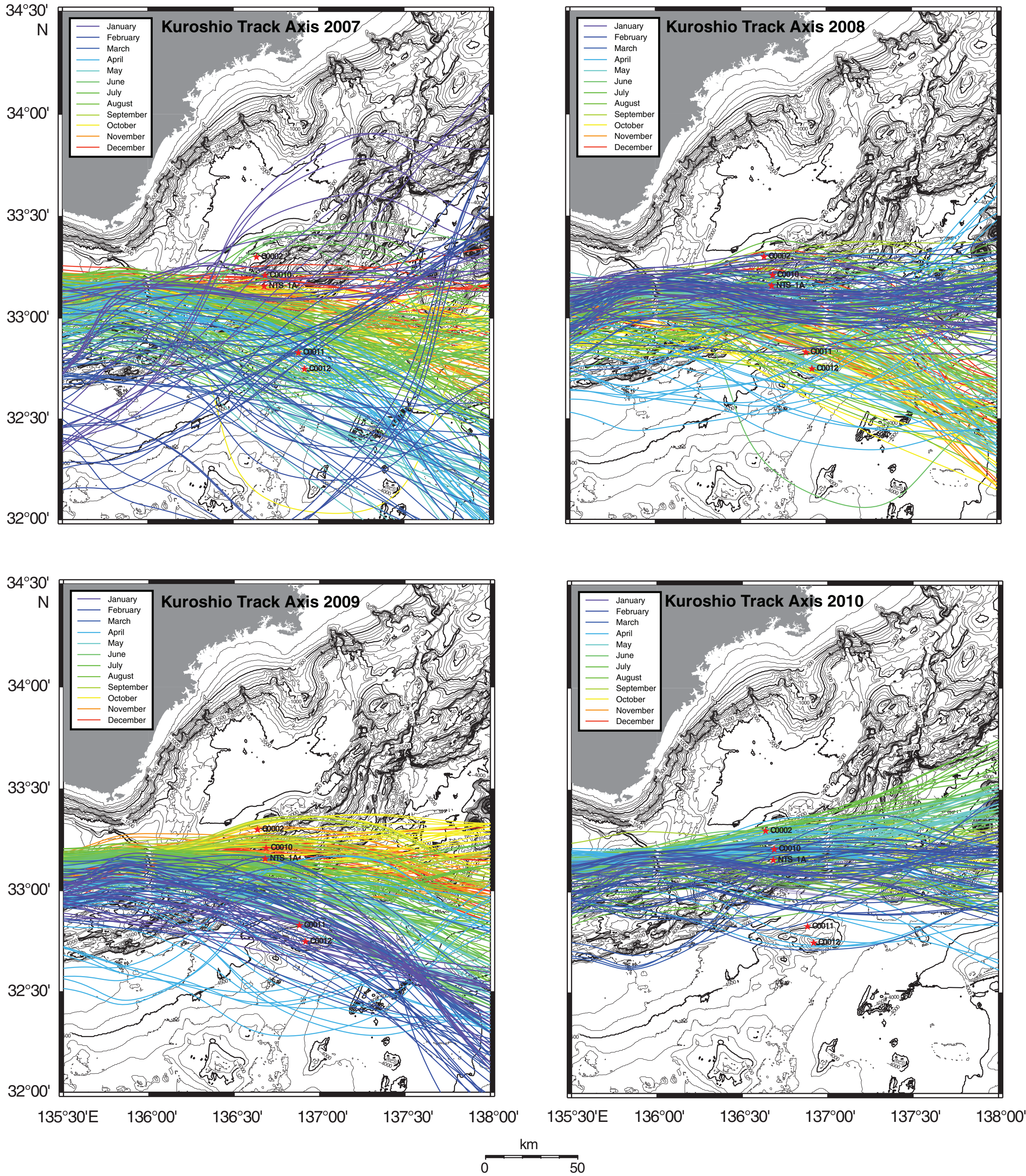


Figure F16. Map showing migration pattern of the Kuroshio track axis from 2007 through 2010.



Site summaries

Proposed Site NTS-1A

Priority:	Primary: *Chikyu* Expedition 333 (NanTroSEIZE Stage 2: subduction inputs 2 and heat flow)
Position:	33°09.4195′N, 136°40.8888′E
Water depth (m):	3100
Target drilling depth (mbsf):	350
Approved maximum penetration (mbsf):	350
Survey coverage:	Extensive survey data outlined in Proposal 603A-Full2: • Primary line, CDEX 2006 3-D In-line 2315 at Cross-line 4950 • Crossing line, CDEX 2006 3-D Cross-line 4950 at In-line 2315
Objective:	Collect core to characterize depositional dynamics of MTDs for use in analyzing sliding dynamics and tsunamigenic potential from sediments in the top 350 m
Drilling, coring, and downhole measurement program:	HPCS/ESCS/EPCS coring, APCT-3
Anticipated lithology:	0–140 mbsf: slope apron hemipelagic sediments 140–210 mbsf: MTDs 210–350 mbsf: hemipelagic slope basin sediments intercalated with MTDs

Site summaries (continued)

Proposed Site NTS-1B

Priority:	Primary: *Chikyu* Expedition 333 (NanTroSEIZE Stage 2: subduction inputs 2 and heat flow)
Position:	33°09.1098′N, 136°41.7144′E
Water depth (m):	3180
Target drilling depth (mbsf):	350
Approved maximum penetration (mbsf):	350
Survey coverage:	Extensive survey data outlined in Proposal 603A-Full2: • Primary line, CDEX 2006 3-D In-line 2360 at Cross-line 4860 • Crossing line, CDEX 2006 3-D Cross-line 4860 at In-line 2360
Objective:	Collect core to characterize depositional dynamics of MTDs for use in analyzing sliding dynamics and tsunamigenic potential from sediments in the top 350 m
Drilling, coring, and downhole measurement program:	HPCS/ESCS/EPCS coring, APCT-3
Anticipated lithology:	0–150 mbsf: slope apron hemipelagic sediments 150–185 mbsf: MTDs 185–350 mbsf: hemipelagic slope basin sediments intercalated with MTDs

Site summaries (continued)

Proposed Site NTS-1C

Priority:	Primary: *Chikyu* Expedition 333 (NanTroSEIZE Stage 2: subduction inputs 2 and heat flow)
Position:	33°10.0482′N, 136°39.8454′E
Water depth (m):	2950
Target drilling depth (mbsf):	300
Approved maximum penetration (mbsf):	350
Survey coverage:	Extensive survey data outlined in Proposal 603A-Full2: • Primary line, CDEX 2006 3-D In-line 2269 at Cross-line 5094 • Crossing line, CDEX 2006 3-D Cross-line 5094 at In-line 2269
Objective:	Collect core to characterize depositional dynamics of MTDs for use in analyzing sliding dynamics and tsunamigenic potential from sediments in the top 350 m
Drilling, coring, and downhole measurement program:	HPCS/ESCS/EPCS coring, APCT-3
Anticipated lithology:	0–150 mbsf: slope apron hemipelagic sediments 150–190 mbsf: MTDs 190–300 mbsf: hemipelagic slope basin sediments intercalated with MTDs

Site summaries (continued)

Proposed Hole C0011C

Priority:	Primary: *Chikyu* Expedition 333 (NanTroSEIZE Stage 2: subduction inputs 2 and heat flow)
Position:	32°49.7436′N, 136°52.925′E
Water depth (m):	4051
Target drilling depth (mbsf):	350
Approved maximum penetration (mbsf):	350
Survey coverage:	Extensive survey data outlined in Proposal 603A-Full2: • Track map (Fig. **AF1**) • Line ODKM03-101 Shotpoint 2524 (Fig. **AF2**) • IFREE 3-D Line 95 (Fig. **AF3**)
Objective:	Core top of hole for portion not cored during *Chikyu* Expedition 322
Drilling, coring, and downhole measurement program:	HPCS/ESCS from 0 to 350 m, APCT-3
Anticipated lithology:	0–250 mbsf: upper Shikoku Basin hemipelagics and volcanic ash 250–400 mbsf: lower Shikoku Basin hemipelagics and volcanic ash 400–1200 mbsf: lower Shikoku Basin hemipelagics and turbidite sands >1200 mbsf: volcaniclastic sediments and basalt

Site summaries (continued)

Proposed Hole C0012C–top hole

Priority:	Primary: *Chikyu* Expedition 333 (NanTroSEIZE Stage 2: subduction inputs 2 and heat flow)
Position:	32°44.8878′N, 136°55.0417′E
Water depth (m):	3514
Target drilling depth (mbsf):	150
Approved maximum penetration (mbsf):	150
Survey coverage:	Extensive survey data outlined in Proposal 603A-Full2: • Track map (Fig. **AF4**) • Line ODKM03-AB Shotpoint 2795 (Fig. **AF5**) • Crossing Line ODKM03-22 Shotpoint 1685 (Fig. **AF6**) • IFREE 3-D Line 95 (Fig. **AF7**)
Objective:	Core top of hole for portion not cored during *Chikyu* Expedition 322
Drilling, coring, and downhole measurement program:	HPCS/ESCS/EPCS from 0 to 120 m, APCT-3 every 30 m
Anticipated lithology:	0–600 mbsf: Shikoku Basin hemipelagic sediments >600 mbsf: volcaniclastic sediments and basalt

Site summaries (continued)

Proposed Hole C0012D–basement

Priority:	Primary: *Chikyu* Expedition 333 (NanTroSEIZE Stage 2: subduction inputs 2 and heat flow)
Position:	32°44.6815′N, 136°55.0066′E
Water depth (m):	3512
Target drilling depth (mbsf):	740
Approved maximum penetration (mbsf):	800
Survey coverage:	Extensive survey data outlined in Proposal 603A-Full2: • Track map (Fig. **AF4**) • Line ODKM03-AB Shotpoint 2795 (Fig. **AF5**) • Crossing Line ODKM03-22 Shotpoint 1685 (Fig. **AF6**) • IFREE 3-D Line 95 (Fig. **AF7**)
Objective:	Core basement of hole for portion not cored during *Chikyu* Expedition 322
Drilling, coring, and downhole measurement program:	Drill from 0 to 520 mbsf, no coring RCB core from 520 to 740 mbsf
Anticipated lithology:	0–600 mbsf: Shikoku Basin hemipelagic sediments >600 mbsf: volcaniclastic sediments and basalt

Figure AF1. Site C0011 track map.

Figure AF2. CDEX seismic reflection profile of Line ODKM03-101, oriented perpendicular to IFREE seismic reflection Line 95 (see Fig. AF3).

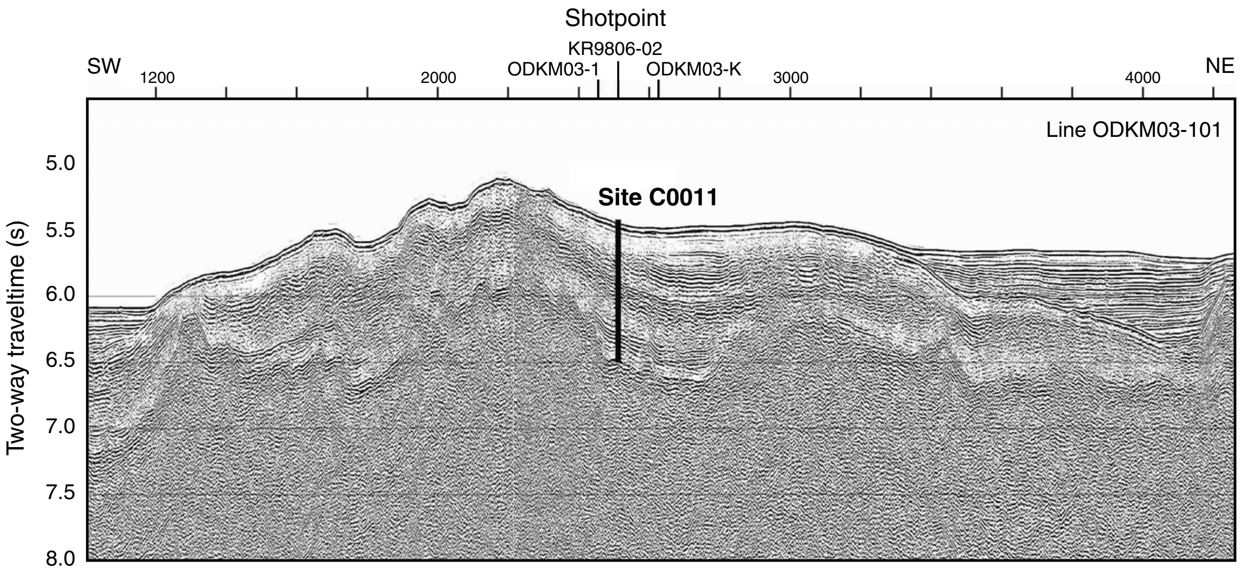


Figure AF3. IFREE 3-D seismic reflection Line 95 showing location of Site C0011. VE = vertical exaggeration.

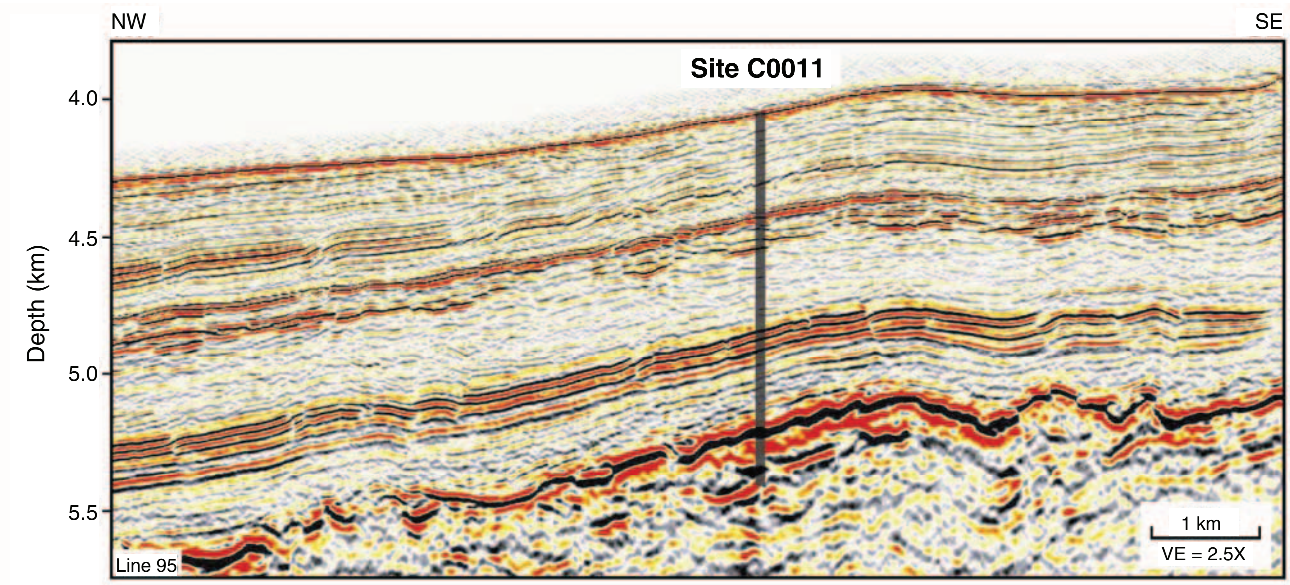


Figure AF4. Site C0012 track map.

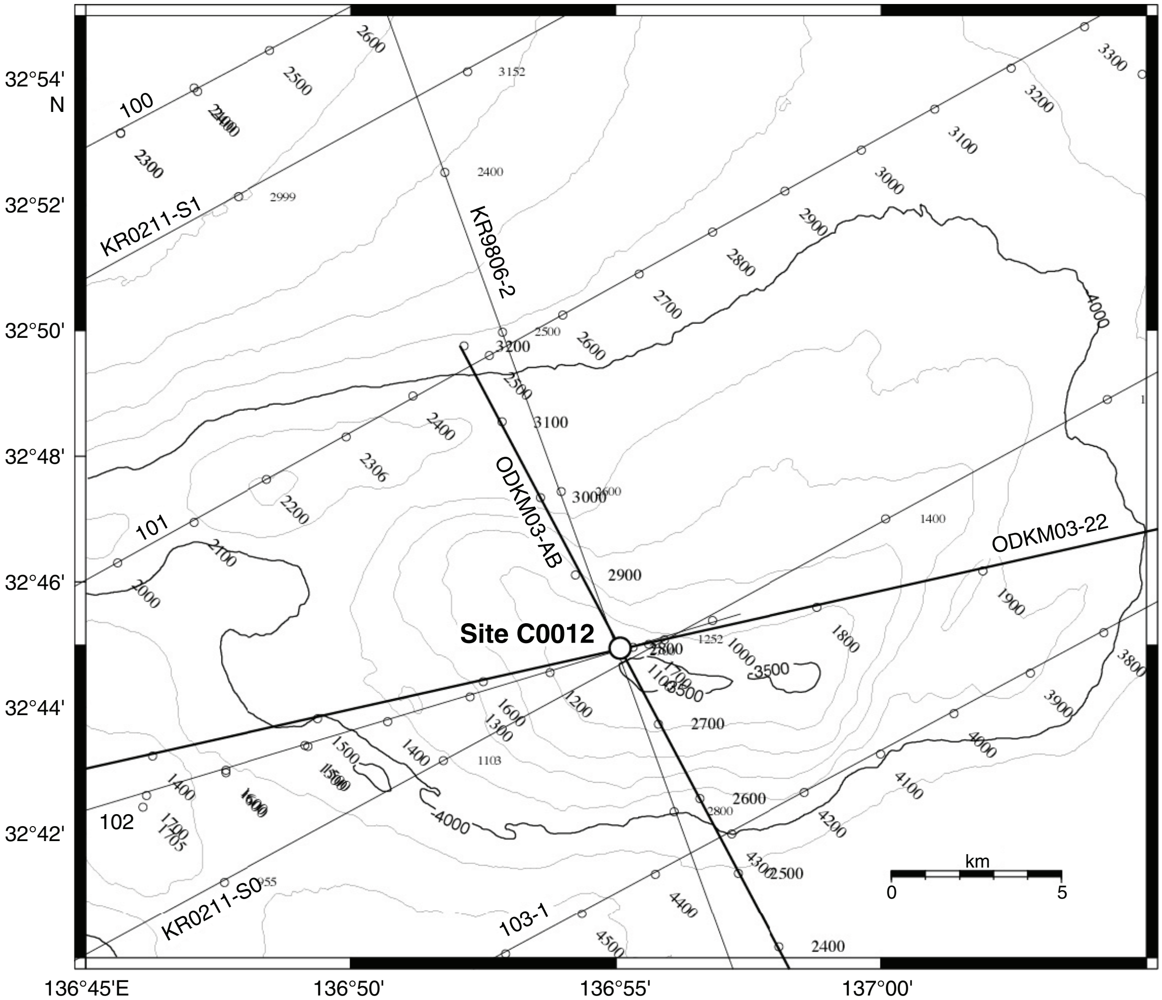


Figure AF5. Line ODKM03-AB seismic reflection profile. VE = vertical exaggeration.

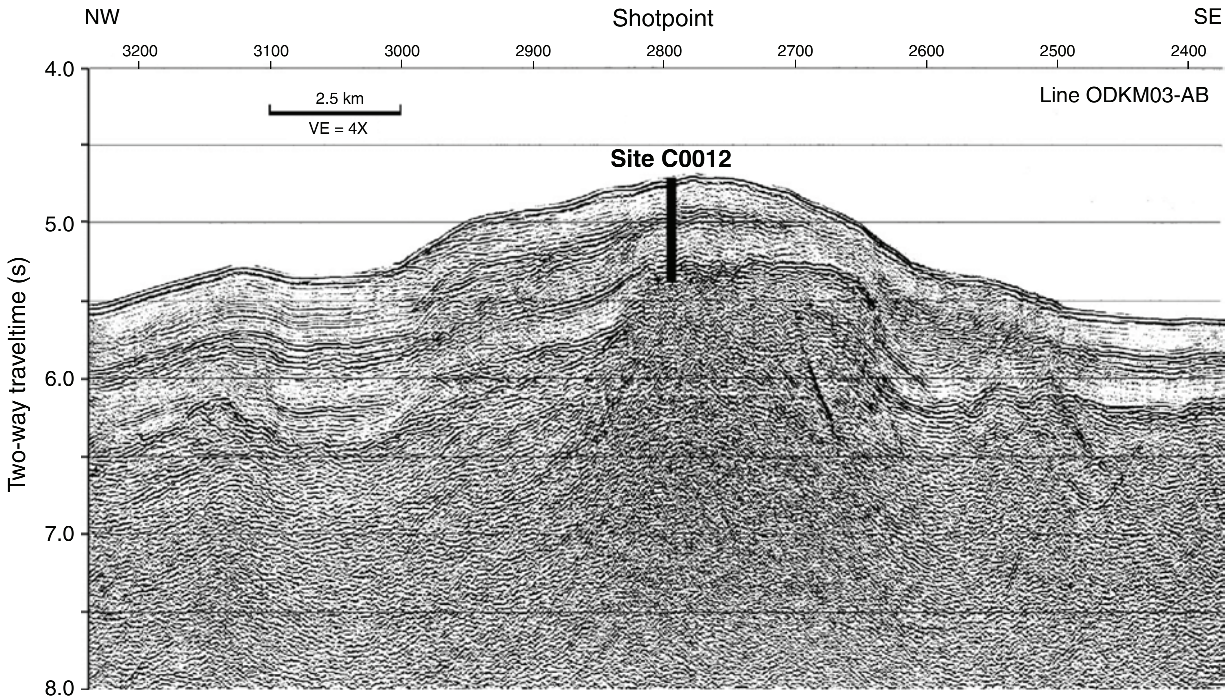


Figure AF6. CDEX seismic reflection profile of Line ODKM03-22, located perpendicular to IFREE seismic reflection Line 95 (see Fig. AF7) VE = vertical exaggeration.

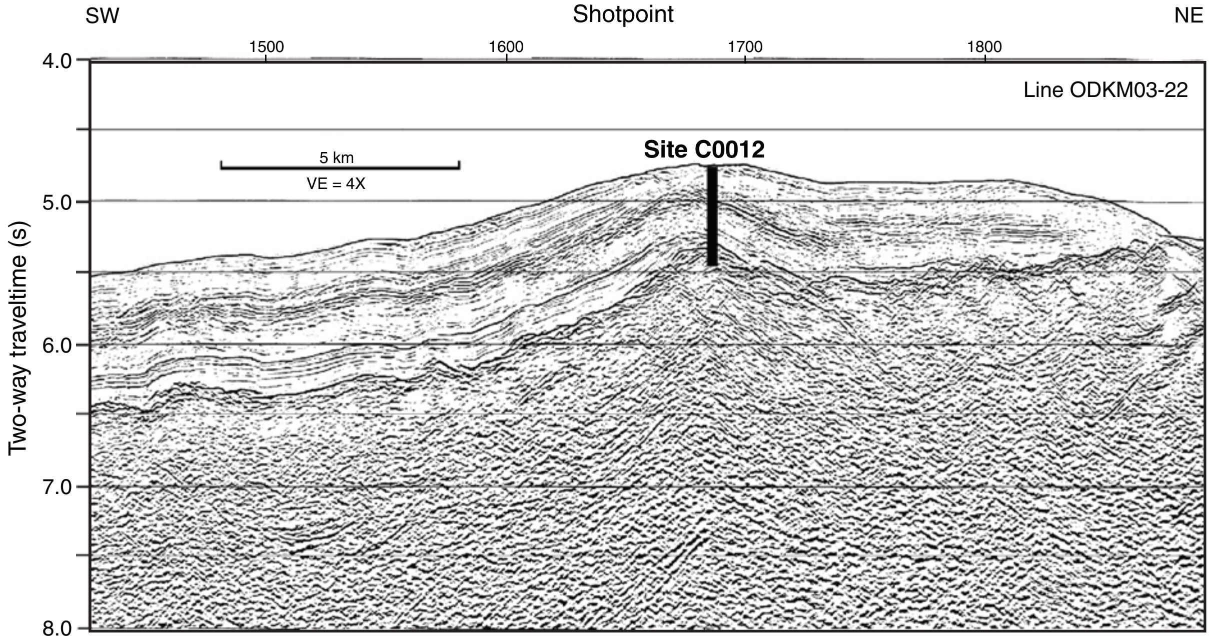
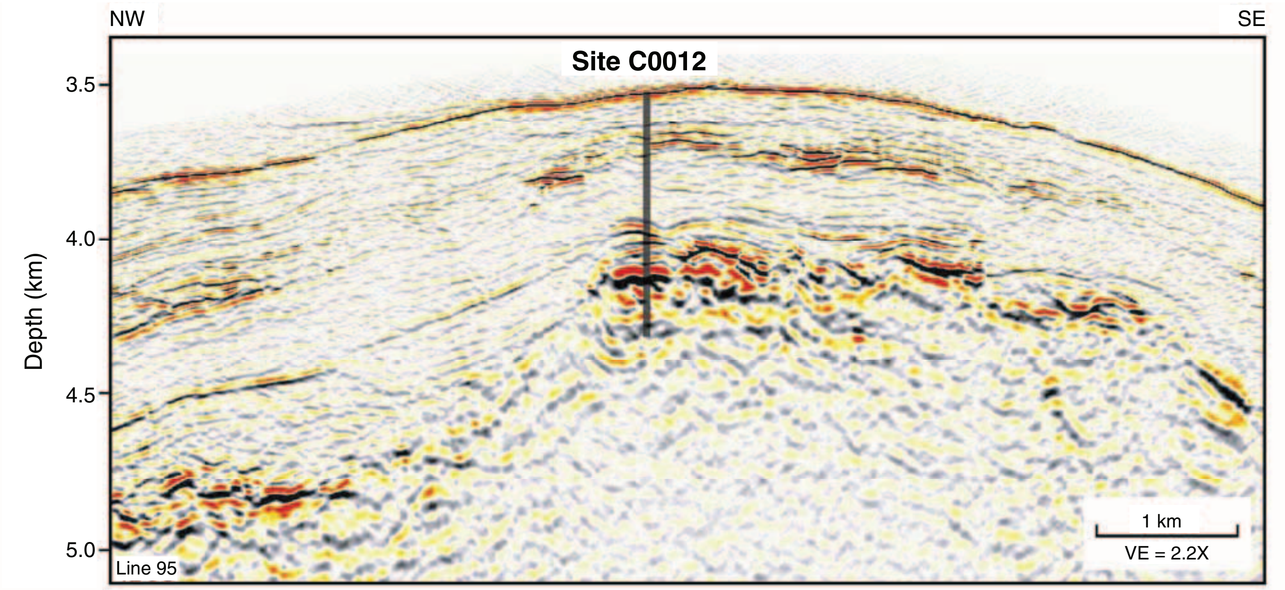


Figure AF7. IFREE 3-D seismic reflection Line 95 showing location of Site C0012. VE = vertical exaggeration.



Scientific participants

The current list of participants for Expedition 333 can be found at **www.jamstec.go.jp/chikyu/eng/Expedition/NantroSEIZE/exp333.html.**