Integrated Ocean Drilling Program
Expedition 326 Scientific Prospectus

NanTroSEIZE Stage 3: plate boundary deep riser: top hole engineering

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Disclaimer

This IODP *Scientific Prospectus* is based on precruise Science Advisory Structure panel discussions and scientific input from the designated Co-Chief Scientists on behalf of the drilling proponents. During the course of the cruise, actual site operations may indicate to the Co-Chief Scientists, the Expedition Project Manager, and the Operations Superintendent 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 science deliverables outlined in the plan presented here are contingent upon the approval of the CDEX Science Operator Science Manager in consultation with IODP-MI.

August 2010

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. 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 (mbsf). Integrated Ocean Drilling Program (IODP) Expedition 326 is slated to begin drilling the main ultradeep borehole with "top hole" operations to pilot the hole, set casing to ~800 mbsf, and install the wellhead to be used in later deep riser drilling at Site C0002.

Schedule for Expedition 326

Integrated Ocean Drilling Program (IODP) Expedition 326 is based on IODP drilling Proposal 603-C (available at **www.iodp.org/600/**). Following ranking by the IODP Scientific Advisory Structure, the expedition was scheduled for the research vessel D/V *Chikyu,* operating under contract with the Japanese Implementing Organization, Center for Deep Earth Exploration (CDEX). At the time of publication of the *Scientific Prospectus,* the expedition is scheduled to depart Shingu on 19 July 2010 and to end in Shingu on 8 August 2010. A total of 24 days will be available for the drilling, wellhead deployment, and casing program described in this report (for the current detailed schedule, see **www.iodp.org/expeditions/**). 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: 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 expedition schedule and planned operations are subject to changes

based on final budget and operational time decisions, as well as the Kuroshio Current and weather conditions at the proposed drill sites.

The ultimate objective for IODP Site C0002 is to drill to a total depth (TD) of ~7000 meters below seafloor (mbsf) and thereby penetrate the entire plate boundary fault zone to the subducting oceanic crust. For this expedition, the plan is to jet in 36 inch conductor casing to ~60 mbsf, and then drill down to ~800 mbsf and set 20 inch casing in the borehole. The borehole will then be suspended with a cement plug and a cap, awaiting further drilling during a subsequent expedition. Since the upper 1000 m at Site C0002 was already logged with logging while drilling (LWD) and cored during NanTroSEIZE Stage 1 (Kinoshita, Tobin, Ashi, Kimura, Lallemant, Screaton, Curewitz, Masago, Moe, and the Expedition 314/315/316 Scientists, 2009), only riserless drilling and casing will be performed at riser Site C0002 during Expedition 326, and no coring, logging, or other scientific operations are planned. The TD of the 20 inch casing installation may be extended to 830 mbsf or deeper, depending on hole conditions and available casing hardware.

Overview of the NanTroSEIZE complex drilling project

Subduction zones account for 90% of global seismic moment release, generating damaging earthquakes and tsunamis with potentially 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 a crucial step toward evaluating earthquake and tsunami hazards. More generally, characterizing fault slip behavior and mechanical state at all plate boundary types through direct sampling, near-field geophysical observations, and measurement of in situ conditions is a fundamental and societally relevant goal of modern earth science.

Several recent and ongoing drilling programs have targeted portions of active plate boundary faults that have either slipped coseismically during large earthquakes or nucleated smaller events. These efforts include the San Andreas Fault Observatory at Depth (Hickman et al., 2004), the Taiwan-Chelungpu Drilling Project (Ma, 2005), and IODP NanTroSEIZE (Tobin and Kinoshita, 2006a, 2006b).

The NanTroSEIZE project is a complex drilling project (CDP): a multiexpedition, multistage IODP drilling program focused on understanding the mechanics of seismogenics and rupture propagation along subduction plate boundary faults. NanTroSEIZE includes 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 processes governing the updip aseismic–seismic transition of the megathrust fault system;
- Processes of earthquake and tsunami generation, as well as strain accumulation and release;
- The absolute mechanical strength of the plate boundary fault, and
- The potential role of a major upper fault system (termed the "megasplay" fault) in seismogenesis and tsunamigenesis.

The drilling program will evaluate a set of core hypotheses through a combination of riser and riserless drilling, long-term observatories, and associated geophysical, laboratory, and numerical modeling efforts. 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 fault; Park et al., 2002) slips in discrete events that may include tsunamigenic slip during great earthquakes. It remains locked during the interseismic period and accumulates strain.

Sediment-dominated subduction zones such as the East 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 (e.g., Byrne et al., 1988; Wang and Hu, 2006). At Nankai, high-resolution seismic reflection profiles across the outer rise clearly document a large out-of-sequence thrust fault system (the megasplay

fault). This system branches from the plate boundary décollement close to the updip limit of inferred coseismic rupture in the 1944 Tonankai M 8.2 earthquake (Fig. **F2**).

Several lines of evidence indicate that the megasplay system as well as the nature and mechanics of fault slip as a function of depth and time are not well understood. As stated in the fifth hypothesis above, one of the first-order goals in characterizing the seismogenic zone along the Nankai Trough is to document the role of the megasplay fault in accommodating plate motion (both seismically and interseismically) and to characterize its mechanical and hydrological behavior. This bears both on understanding subduction zone megathrust behavior and on defining tsunami hazards.

Presently, the overall CDP encompasses eight sites along a transect across the frontal thrust region, the midslope megasplay region, and the Kumano forearc basin region (Fig. **F1**). Two of these already occupied sites are preparatory pilot holes for planned deep riser drilling operations, including Site C0002. The other sites primarily targeted fault zones in the shallow, presumed aseismic portions of the accretionary complex (Kinoshita, Tobin, Ashi, Kimura, Lallemant, Screaton, Curewitz, Masago, Moe, and the Expedition 314/315/316 Scientists, 2009).

In late 2007 through early 2008, IODP Expeditions 314, 315, and 316 were carried out as a unified program of oceanic drilling collectively known as NanTroSEIZE Stage 1. Expedition 314 was dedicated to downhole measurement of physical properties and borehole imaging through LWD in holes drilled specifically for that purpose, including one at Site C0002 that reached 1401 mbsf. Expedition 315 was devoted to core sampling and downhole temperature measurements at two sites in the hanging wall: IODP Site C0001 just seaward of the outer rise into indurated thrust sheet of the megasplay fault and to a depth of 1057 mbsf at Site C0002 in the Kumano Basin. Expedition 316 targeted the frontal thrust and megasplay in their shallow, aseismic portion: IODP Site C0004 near the surface expression of the megasplay, IODP Sites C0006 and C0007 at the main frontal thrust at the seaward edge of the accretionary wedge, and IODP Site C0008 in the slope basin seaward of the megasplay fault. For more details, see Kinoshita, Tobin, Ashi, Kimura, Lallemant, Screaton, Curewitz, Masago, Moe, and the Expedition 314/315/316 Scientists (2009).

IODP Expeditions 319 and 322 followed this first stage in 2009 as NanTroSEIZE Stage 2. Expedition 319 was dedicated to preparing boreholes at IODP Sites C0009 and C0010 for future installation of long-term borehole monitoring systems. Site C0009 was drilled to ~1600 mbsf as the first IODP riser drilling operation and included a

walkaway vertical seismic profile (VSP) experiment. The hole was cased and left ready for future observatory installation work. During Expedition 322, IODP Sites C0011 and C0012 in the Shikoku Basin, seaward of the trench axis and deformation front, were cored and logged to evaluate the composition and properties of sediment and fluids entering the subduction zone.

Previous Site C0002 drilling achievements

Site C0002 was previously drilled during Expedition 314, as Hole C0002A, in which 1401 m of Kumano forearc basin and accretionary prism sediments were successfully drilled and logged with a full suite of LWD and measurement-while-drilling tools. Despite strong Kuroshio Current conditions, the expedition retrieved an excellent series of logs and zero-offset VSP data. They drilled and logged four units, separated by unconformities (Fig. **F3**):

- Logging Unit I: slope basin deposits;
- Logging Unit II: basin fill comprised of repeating turbidite deposits (contains two potentially gas-bearing sandy intervals);
- Logging Unit III: basin fill consisting of homogeneous clay-rich mudstone; an angular unconformity cuts Unit III, but with no discernible lithological changes across the boundary; and
- Logging Unit IV: accretionary prism sediment with very variable responses in the downhole logs.

Expedition 315 cored the 475–1057 mbsf interval (middle of logging Unit I to top of logging Unit IV), confirming the boundaries of the logging units and adding lithologic detail through core description as well as preliminary nannofossil-based biostratigraphy. Unit II is of Pleistocene age, Unit III is from the Pliocene, and Unit IV is of late Miocene age. Paleomagnetic measurements support this age model by placing the Bruhnes/Matayuama border at 850 m core depth below seafloor. Unit IV has a strongly varied dip and azimuth, confirming the presence of highly deformed strata as suggested by the reflection profiles.

Site survey data

The supporting site survey data for Expedition 326 are archived at the **IODP Site Survey Data Bank.**

Drilling plan and contingency

Contingency operations for Expedition 326 are based on the current state of knowledge at the time of publication of the *Scientific Prospectus*. These plans may be modified both before and during the expedition, based on continuing NanTroSEIZE Project Management Team (PMT) discussions. The Expedition 326 drilling and casing plan is shown in Figure **F4.** The following operations are planned:

Planned Hole C0002F is located ~60 m northwest of Hole C0002A (Fig. **F5**); a position chosen on the basis of the surrounding relatively flat seafloor topography and to maximize the distance from the planned riserless observatory currently scheduled for installation later this year during IODP Expedition 332. Top hole operations will begin with deploying the transponders, setting the guidehorn, and jetting in the 36 inch conductor pipe to 60 mbsf. Drilling will proceed to a minimum of 800 mbsf with a 26 inch bit. After reaching TD, 20 inch casing will be run in and cemented. Operations will be completed with setting a corrosion cap on the wellhead and retrieving the transponders.

Site C0002 ultradeep riser top hole

IODP Site C0002 is the centerpiece of the NanTroSEIZE project, intended to access the plate interface fault system at a location where it is believed to be capable of seismogenic locking and slip and to have slipped coseismically in the 1944 Tonankai earthquake. The primary targets include both the basal décollement and the reflector known as the "megasplay fault" (Tobin and Kinoshita, 2006b). The megasplay fault zone and the accretionary prism block are the location of a newly identified class of earthquakes known as very low frequency (VLF) earthquakes (Ito and Obara, 2006) as well as the first observation of shallow tectonic tremor (Obana and Kodaira, 2009). The megasplay fault reflector lies at an estimated depth of 5000~5200 mbsf, and the top of the subducting basement is estimated to lie at 6800~7000 mbsf (Fig. **F6**).

The top ~800 mbsf will be drilled and cased during Expedition 326, while a real-time vibration monitoring system is tested and fielded. No new scientific data are expected to be collected during this engineering expedition.

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Table T1. Operations and time estimates for Expedition 326, riser Site C0002.

Site	Proposed total depth (mbsf)	Water depth (m)	Total (mbsf)	Operation	Estimated days	Total days
				Loading at Shingu	4.0	4.0
C0002	3300	1939	3300	Move to site, preparation for spud, deploy transponders	5.0	9.0
				Run and jet in 36 inch conductor to 60 mbsf	4.0	13.0
				Set 20 inch casing:		
				• Drill 26 inch hole from 60 to 800 mbsf	3.0	
				• Run and cement 20 inch casing	5.0	
				• Set corrosion cap, retrieve transponders	2.0	23.0
				Move back to Shingu	1.0	24.0
					Total days:	24.0

Figure F1. Map of Nankai accretionary complex off Kumano showing drill sites. Yellow arrows = computed far-field convergence vectors between Philippine Sea plate and Japan (Seno et al., 1993; Heki, 2007), contours = estimated slip during the 1944 event (0.5 m intervals) (Kikuchi et al., 2003), red box = region of recorded VLFs (Obara and Ito, 2005), red circles = NanTroSEIZE boreholes (as of 2010).

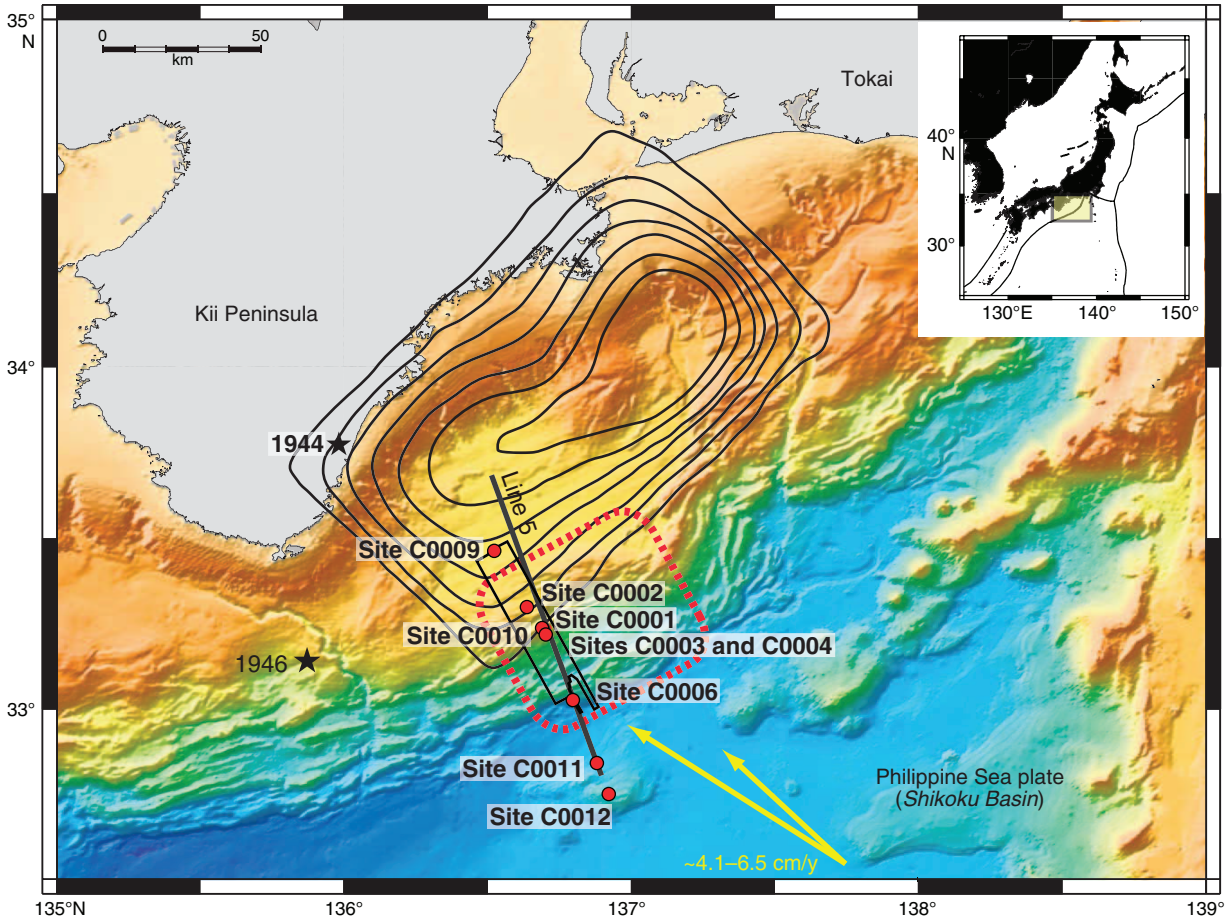


Figure F2. Spliced composite profile of a representative depth section from NanTroSEIZE three-dimensional (3-D) data volume (Moore et al., 2009) and Line 95 from Institute for Research on Earth Evolution mini-3-D seismic survey (Park et al., 2008). Projected positions of Stage 1 and 2 drilling sites, including Sites C0009, C0010, C0011, and C0012.

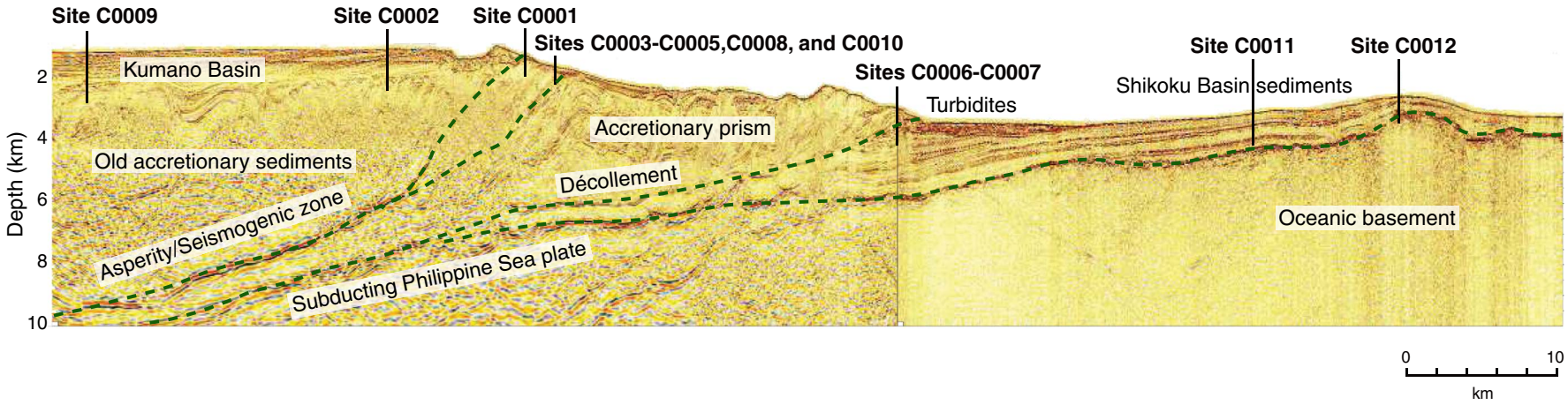


Figure F3. Interpreted three-dimensional seismic profile In-line 2645 across Kumano forearc basin, showing four major unconformities (colored lines). Regional seismic line showing correlation between Sites C0009 and C0002, including stratigraphic columns. VE = vertical exaggeration.

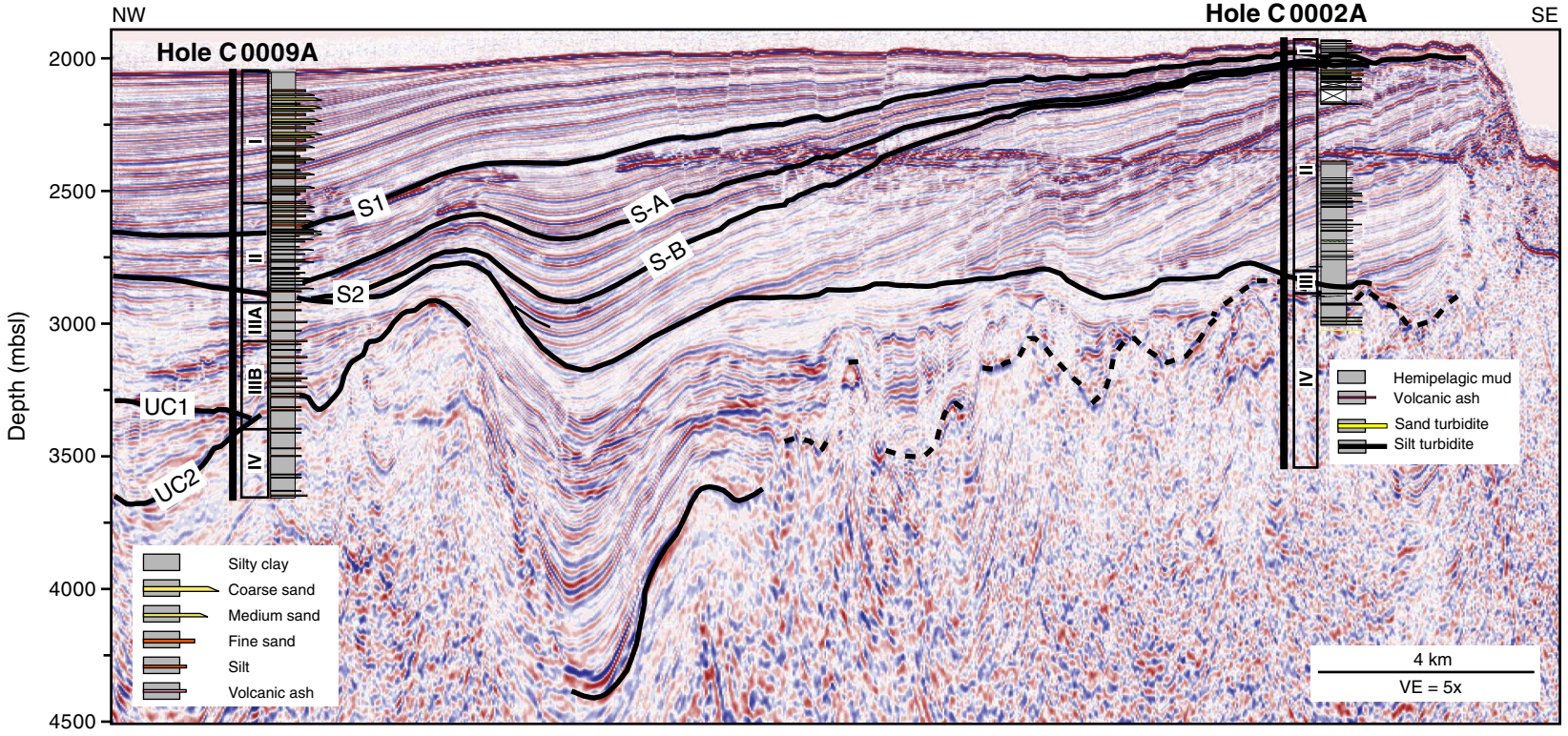


Figure F4. Casing plan for top hole portion of riser hole, Site C0002. Hole will be suspended after 36 inch casing is set at 60 mbsf and 20 inch casing is run, set, and cemented at ~800 mbsf. If possible, casing will be run deeper than 800 mbsf to maximum possible depth.

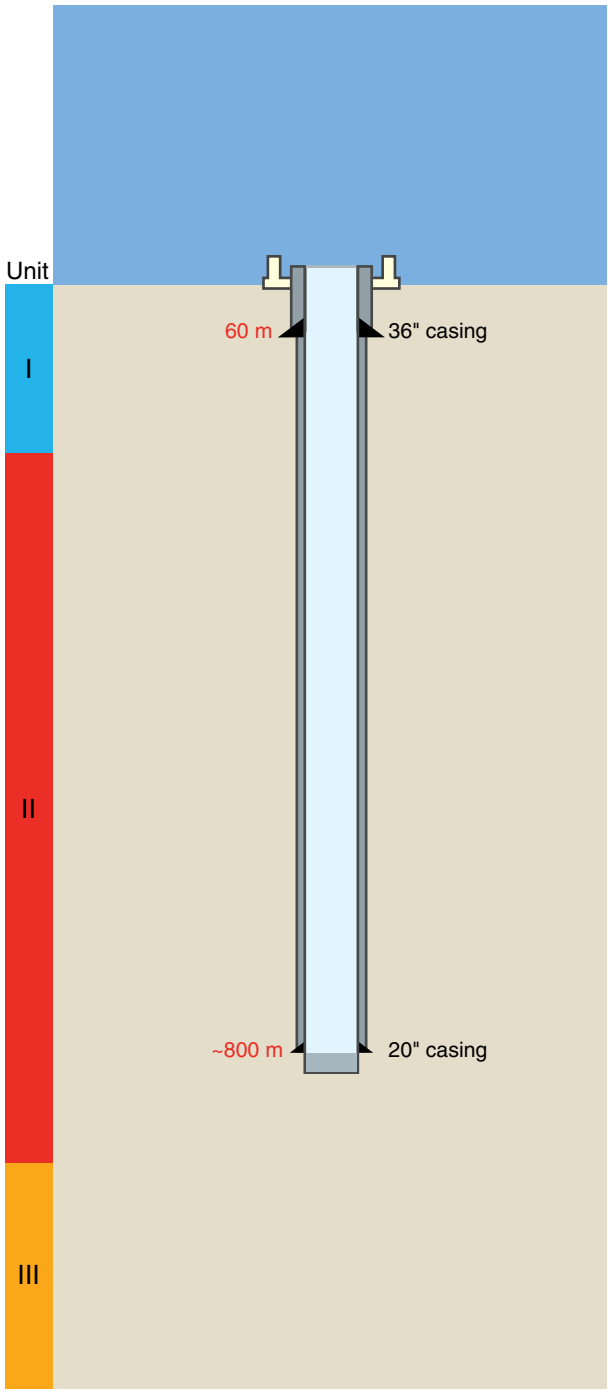


Figure F5. Bathymetric map, Site C0002. Black stars = holes drilled during previous NanTroSEIZE expeditions, red circles = 50 m radius from each hole, green circles = proposed holes for 2010 (Expedition 326 riser top hole and Expedition 332 riserless observatory).

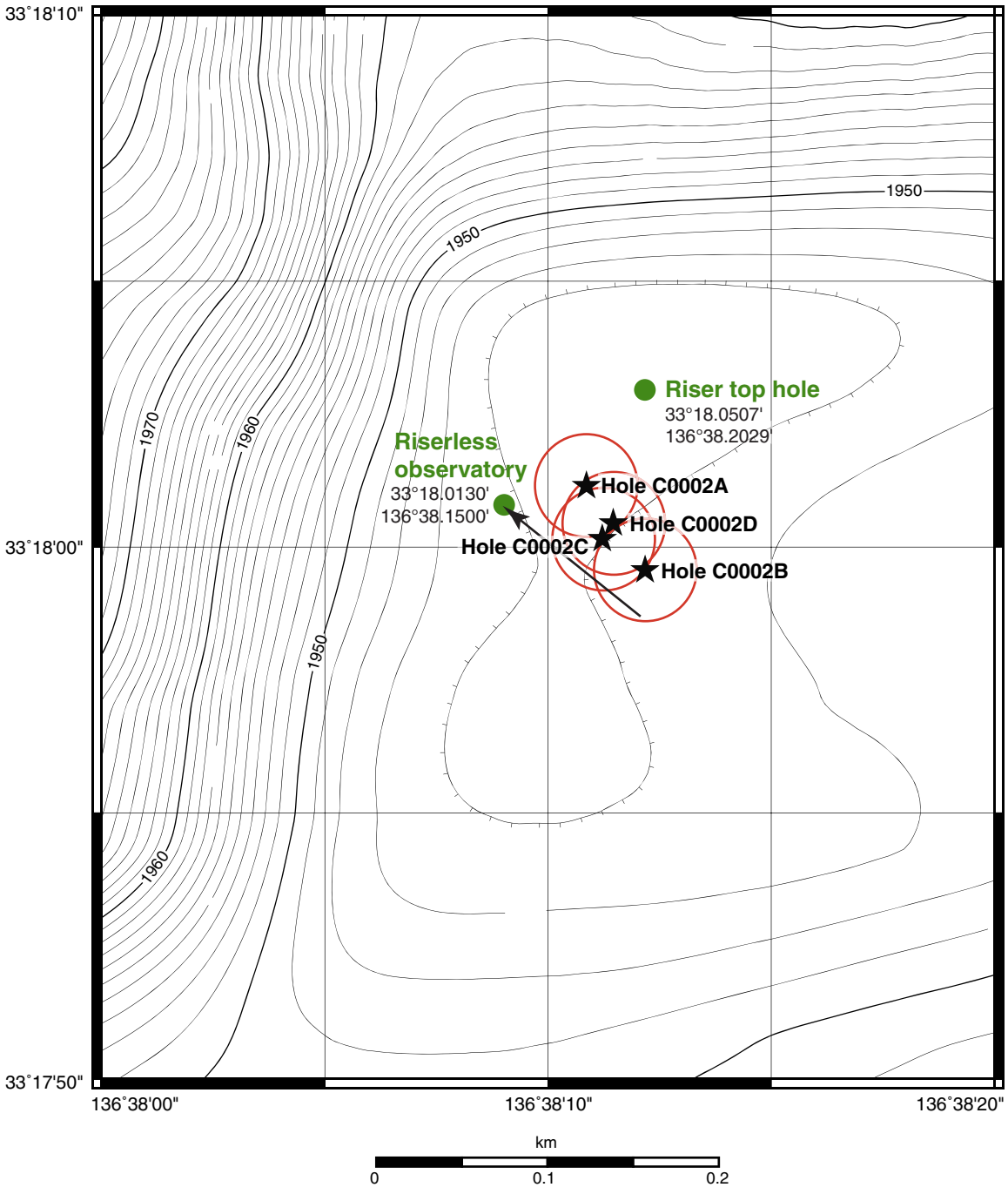
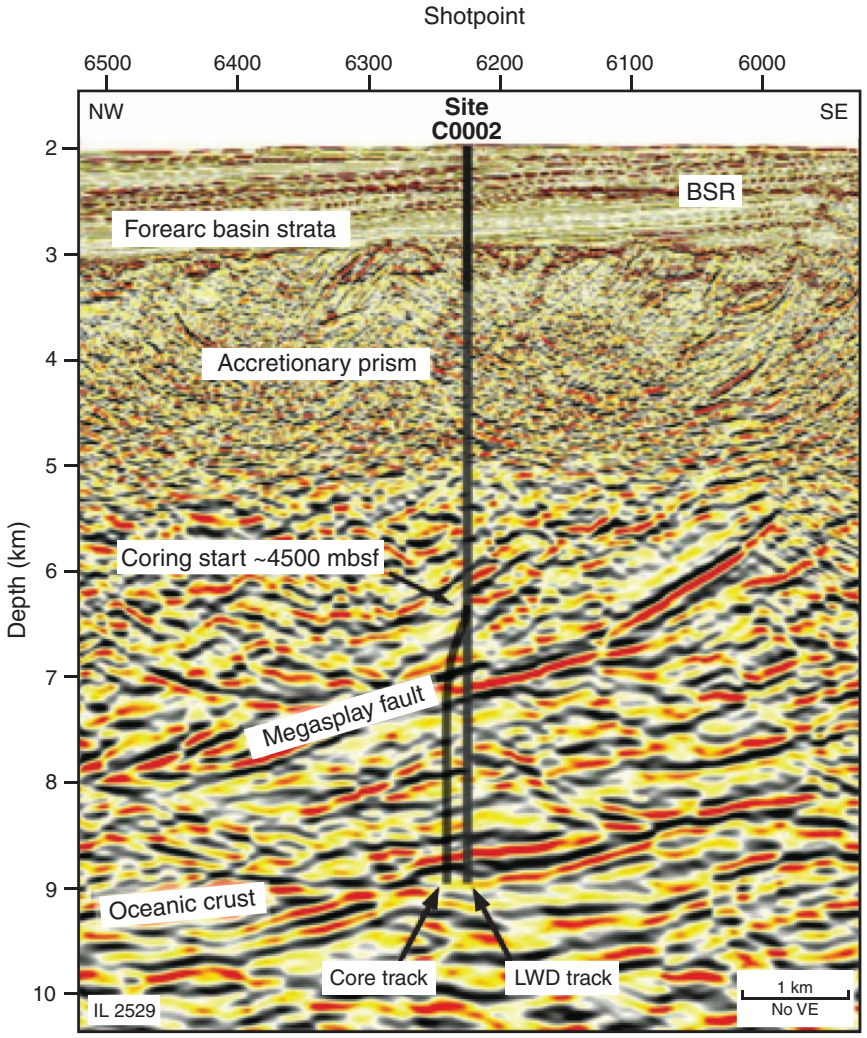


Figure F6. Seismic section of In-line (IL) 2529, showing planned trace for deep riser site, Site C0002. Note that operational options shown here are only temporary suggested by NanTroSEIZE PMT. BSR = bottom-simulating reflector, LWD = logging-while-drilling, VE = vertical exaggeration.



Site summary

Site C0002 (riser top hole)

Priority:	Primary: *Chikyu* Expedition 326 (NanTroSEIZE Stage 3: plate boundary deep riser: top hole engineering)
Position:	33°18.0507′N, 136°38.2029′E
Water depth (m):	2060
Target drilling depth (mbsf):	800
Approved maximum penetration (mbsf):	7000
Survey coverage:	CDEX 2006 3-D MCS; extensive survey data outlined in Proposal 603C-Full: • 3-D In-line 2529 • 3-D Cross-line 6225
Objective (see text for full details):	• Case riser hole to 3300 mbsf in preparation for future extension to 7000 mbsf, for future permanent observatory installation • Determine nature of the plate boundary below the drill site
Drilling, coring, and downhole measurement program:	• Set 36 inch casing to 60 mbsf • Set 20 inch casing to 800 mbsf
Anticipated lithology:	0–150 mbsf: Kumano forearc basin sediments 150–910 mbsf: lower sediments 910–1400 mbsf: accretionary prism

Scientific participants

The current list of participants for Expedition 326 can be found at **www.jamstec.go.jp/chikyu/eng/Expedition/NantroSEIZE/exp326.html.**