Integrated Ocean Drilling Program
Expedition 332 Scientific Prospectus

NanTroSEIZE Stage 2: riserless observatory

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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. 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). The primary goals for Integrated Ocean Drilling Program (IODP) Expedition 332 are: (1) drilling and casing a riserless hole at Site C0002 (0–1000 mbsf), followed by installation of a circulation obviation retrofit kit observatory system, and (2) retrieving and replacing the SmartPlug installed at Site C0010 during IODP Expedition 319 with an upgraded version, the GENIUSPlug.

Schedule for Expedition 332

Integrated Ocean Drilling Program (IODP) Expedition 332 is based on drilling Proposal 603 (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, Japan, on 25 October 2010 and to end at sea on 12 December 2010. A total of 49 days will be available for the drilling and casing of IODP Site C0002, IODP Site C0010 sensor package retrieval/installation, and CORK deployment 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 Kuroshio Current conditions at the proposed drill sites.

The ultimate objective for Site C0002 is to drill to a total depth (TD) of ~7000 meters below seafloor (mbsf) and thereby penetrate the plate interface. For this expedition, the plan is to drill down to 1000 mbsf and set 9⅝ inch casing in preparation for deployment of a circulation obviation retrofit kit (CORK) observatory. 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 limited LWD will be performed at riser Site C0002. Additional plans include sensor package retrieval/installation at Site C0010 (splay fault site).

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 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 societal 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 (OOST) 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 twelve sites along a transect across the incoming subducting Philippine Sea plate, 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 et al., 2008).

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. 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 and 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 in the Kumano Basin, IODP Sites C0006 and C0007 at the main frontal thrust at the seaward edge of the accretionary wedge, and IODP Site C0008 in the basin seaward of the splay fault. For more details, see Kinoshita et al. (2008), Ashi et al. (2008), and Kimura et al. (2008).

IODP Expeditions 319 and 322 followed this first stage in 2009, as NanTroSEIZE Stage 2. Expedition 319 prepared boreholes at IODP Sites C0009 and C0010 for future installation of long-term borehole monitoring systems. At Site C0009, Expedition 319 conducted the first riser operation and walkaway vertical seismic profile (VSP) experiment in IODP history. Expedition 322 cored IODP Sites C0011 and C0012 in the Shikoku Basin to evaluate the composition of sediment that eventually will be transported to 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 4–6.5 cm/y along an azimuth of 300°–315°N (Seno et al., 1993; Miyazaki and Heki, 2001) down an interface dipping 3°–7° (Kodaira et al., 2000). The subducting lithosphere of the Shikoku Basin was formed by backarc spreading by 15–25 Ma (Okino et al., 1994). The Nankai subduction zone forms an example of a sediment-dominated accretionary prism end-member. In the toe region off the Muroto transect, a sediment section ~1 km thick is accreted to or underthrusts below the margin (Moore, Taira, Klaus, et al., 2001).

The three major seismic stratigraphic sequences identified in the northern Shikoku Basin are the lower and upper Shikoku Basin sequences and the Quaternary turbidite sequences (Kinoshita, Tobin, Ashi, Kimura, Lallemant, Screaton, Curewitz, Masago, Moe, and the Expedition 314/315/316 Scientists, 2009). The upper Shikoku Basin facies off the Kumano Basin pinches out toward the north, whereas the lower succession has a more complicated geometry resulting from basement topographic influence (Le Pichon et al., 1987a, 1987b; Mazzotti et al., 2000; Moore, Taira, Klaus, et al., 2001): seismic thickness decreases above large basement highs, and acoustically transparent units indicate local absence of the sand packages that characterize most other parts of the lower Shikoku Basin. The mechanical differences between subducting basement highs and plains could be significant for fault zone dynamics and earthquake rupture behavior.

The deformation front behavior off the Kumano Basin is fundamentally different than that at previous targets of Ocean Drilling Program (ODP) drilling off the Muroto and Ashizuri transects, several hundred kilometers to the southwest. Seismic reflection data off the Kumano Basin clearly delineate the frontal fault near the prism toe. However, there is little evidence for seaward propagation of the décollement within the deeper Shikoku Basin strata (see Proposal 603A-Full2 at www.iodp.org/600/). One interpretation of the seismic profile is that the décollement steps up to the seafloor, thereby thrusting older accretionary prism strata over the upper Quaternary trench-wedge facies (Fig. F2). Manned submersible observations also indicate that semilithified strata of unknown age have been uplifted and exposed along a fault scarp at the prism toe (Ashi et al., 2002). Farther in board, the fault ramps down into the lower Shikoku Basin facies (Park et al., 2002).

The lower forearc slope consists of a series of thrust faults that have shortened the accreted sedimentary units of the prism. A combination of swath bathymetric and multichannel seismic data show a pronounced and continuous outer ridge (outer arc high) of topography extending >120 km along strike, which may be related to the megasplay fault slip, including the 1944 Tonankai M 8.2 earthquake and repeated previous earthquakes. 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. This we term the megasplay because it is a feature that traverses the entire wedge and has had a protracted history shown by the thick forearc basin sedimentary successions trapped behind its leading edge (Moore et al., 2007).

The megasplay 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 is 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 Expedition 314.

The most direct evidence for activity in the megasplay during geologically recent times comes from Kumano forearc basin stratigraphy. The Kumano Basin is characterized by flat topography at ~2000 m and is filled with turbiditic sediments to a maximum thickness of ~2 km. Little is known regarding the detailed stratigraphy of the Kumano Basin, but several remarkable features are recognized in the seismic profiles (Fig. **F3**): the overall sedimentary sequences filling the basin can be divided into four main lithologic units (I–IV) by unconformities based on the seismic stratigraphy as well as LWD during Expedition 314. The sediments in the southern part of the basin are tilted northward, truncated by a flat erosional surface, and subsequently cut by normal faults (Park et al., 2002). The depositional center appears to have migrated northward after each successive unconformity.

The sequences above the unconformities are tilted less than those below them; all of the sediments pinch out toward the north. All these features appear to be caused by uplift of the outer rise and potentially by postseismic relaxation after coseismic slip on the splay faults (Park et al., 2002).

Previous drilling achievements

Site C0002

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 (MWD) tools. Despite strong Kuroshio Current conditions, the expedition retrieved an excellent series of logs and seismic VSP data. They drilled and logged four units, separated by unconformities:

- 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 lithologic 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 C0010

Operations at Site C0010 during Expedition 319 in 2009 included drilling with LWD/MWD across the megasplay fault to a TD of 555 m LWD depth below seafloor, casing the borehole (with casing screens at the fault), conducting an observatory dummy run to test strainmeter and seismometer deployment procedures, and installation of a simple pore pressure and temperature monitoring system (SmartPlug).

Although the SmartPlug is relatively simple, it marks the first observatory placement in NanTroSEIZE. All of the planned science objectives for Site C0010 were achieved, although casing operations were adjusted to fit hole conditions after drilling to TD

(560 m drilling depth below seafloor [DSF]) with casing to 500 m DSF instead of the planned 525 mbsf outlined in the Expedition 319 *Scientific Prospectus* (Saffer et al., 2009). LWD/MWD data (gamma ray and resistivity, including resistivity-at-the-bit images, see Fig. **F4**) were collected allowing (1) definition of major lithologic unit boundaries and of the shallow megasplay fault zone and (2) determination of the preferred placement of the screened joints interval within the fracture zone interval for the temporary observatory. Through comparison with previously drilled Site C0004 (Kinoshita, Tobin, Ashi, Kimura, Lallemant, Screaton, Curewitz, Masago, Moe, and the Expedition 314/315/316 Scientists, 2009) these data also provide insights into along-strike differences in the architecture of the megasplay fault and hanging wall.

After drilling the hole and in preparation for a future permanent observatory installation, a sensor dummy run test was carried out to evaluate reentry operations during instrument deployment. After casing was completed and the borehole was cemented, two dummy run tests were conducted, including adjustments for the effects of the Kuroshio Current, which reached speeds of 4.5 kt during the experiment.

After the dummy run reentry simulations were completed, the SmartPlug instrument package was installed for short-term (1–2 y) data collection and storage to monitor temperature and pore pressure within the megasplay fault zone. It was installed just beneath a mechanically set retrievable casing packer. The retrievable packer was set inside casing above two screened casing joints; the SmartPlug and screen placement in the casing were configured to continuously monitor pore pressure and temperature in an isolated interval of formation including the splay fault and to also monitor hydrostatic pressure as a reference. The SmartPlug contains two high-precision pressure transducers with period counters and four temperature sensors (one as part of each pressure gauge for compensation, one platinum chip thermistor, and one stand-alone miniature temperature logger) in a shockproof housing. The self-contained instrument has a recording lifetime of ~7 y.

The SmartPlug entered the hole and the packer was set at 364 m DSF. Retrieval of the bridge plug and instrument package is anticipated as a contingency plan during this expedition, where a more sophisticated temporary monitoring system will replace the SmartPlug.

Site survey data

The supporting site survey data for Expedition 332 are archived at the **IODP Site Survey Data Bank.**

NanTroSEIZE overall scientific objectives

Tobin and Kinoshita (2006a, 2006b) provide the overall goals and plans of the NanTroSEIZE project as a whole. The reader is referred to those publications for details. Here, we briefly summarize the overall goals of NanTroSEIZE, focusing on Stage 3.

IODP will attempt to drill, sample, and instrument the seismogenic portion of a plate boundary fault, or megathrust, within the Nankai Trough subduction zone offshore the Kii Peninsula of Honshu Island (Fig. **F1**). This is a multistage, multiobjective project, now nearing completion of Stage 2. Stage 3 is the focus of the most ambitious objective: to access, sample, and instrument the Nankai plate interface within the seismogenic zone using riser drilling at Site C0002 (target depth = 7000 mbsf).

Sampling/Data acquisition plan

Expedition 332 will most likely be recovering data from the previously installed SmartPlug observatory at Site C0010; these data are currently acquired using third-party instruments and will be made available upon request to members the science party from Expedition 332 or shore-based researchers. Limited LWD/MWD drilling will be conducted at Site C0002, with no other sampling or data collection planned for Expedition 332. Shipboard and shore-based researchers should also refer to the IODP Sample, Data, and Obligations Policy (**www.iodp.org/program-policies/**) as well as to the following text.

Sample/Data requests and coordination

Because NanTroSEIZE is a long-term multiexpedition drilling project that includes several linked expeditions over several years that share overarching scientific objectives, sampling and coordination of individual samples and data requests are somewhat different than for single expeditions. These differences include the recognition of Specialty Coordinators, unique data sharing opportunities, and a more integrated sample and data request program. Key aspects of these differences are described below.

Specialty coordinators

Unlike traditional stand-alone ODP/IODP legs and expeditions, unusual amounts of coordination and collaboration must occur among science parties across expeditions and within the framework of overall NanTroSEIZE goals. Specialty Coordinators, in collaboration with Co-Chief Scientists, are usually responsible for facilitating collaborations between the participants aboard the *Chikyu* during Expedition 332 and shore-based science party members, as well as identifying research or sampling gaps or collaborations in addition to those planned by shipboard science parties but needed to advance the overall NanTroSEIZE scientific goals. They will also provide technical and scientific guidance to each science party. The NanTroSEIZE Project Management Team (PMT) has identified six specific research areas that require special effort over the project's duration:

1. Lithology and sedimentary petrology.
2. Structural geology.
3. Geotechnical properties and hydrogeology.
4. Geochemistry.
5. Core-log-seismic integration.
6. Paleomagnetism and biostratigraphy.

No Specialty Coordinator for observatories has been nominated or assigned so far. However, the PMT observatory team assists the PMT in decision-making concerning long-term monitoring strategies, instruments, and associated issues.

Data/Sample sharing

Data sharing across expeditions is normally accommodated through a formal data/sample request; that is, scientists from one expedition can apply as a shore-based scientist for shipboard data/samples from a completed or planned expedition. In the case of NanTroSEIZE, it is also possible that drilling or scientific objectives will overlap across two or more expeditions to such an extent that the expeditions will be considered one expedition in terms of shipboard data and samples. In these cases, data can be shared without a separate data/sample request. This may occur, for example, for scientific or logistical reasons during preexpedition planning or during the expedition, if contingency sites are drilled that overlap with a planned expedition. The decision as to whether an expedition is a stand-alone expedition in terms of data/samples or is part of a suite of expeditions is made by the PMT in consultation with the Sample Allocation Committee (SAC) and the Co-Chiefs of the involved expeditions.

Sample and data requests (research proposals)

All shipboard scientists must submit at least one data or sample request in advance of the drilling expedition. Since Expedition 332 will most likely only recover data, sample requests would have to be for other NanTroSEIZE expeditions. 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. 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). Modifications to the sampling plan during the expedition require the approval of the SAC. To provide time for the SAC and Specialty Coordinators to develop a detailed and integrated sampling strategy, data requests are due by 15 October 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/data handling 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.

All sample frequencies and sizes must be justified on a scientific basis and 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. The SAC may require an additional formal sampling plan before critical intervals are sampled.

All sampling to acquire ephemeral data types or to achieve essential sample preservation will be conducted during the expedition. Sampling for individual scientists' postcruise research may be conducted during the expedition, or may be deferred to postcruise.

For third-party experiments (e.g., VSP, etc.) or instruments such as components of CORKs or miniCORKS, a different strategy and moratorium period applies. Those data or samples (in case of OsmoSamplers, flow-through osmo colonization system [FLOCS] modules, etc.) will generally be associated with research proposals by the primary investigators (PIs) of the projects that funded the instruments. In a situation where several researchers request samples and/or data from a third-party instrument/experiment, the following prioritization will be applicable: third-party researcher/PI, shipboard scientist, shore-based scientist. The SAC will oversee that this order is enforced. After the 24 month moratorium period has expired, the data/samples will be available for the public for anybody's request.

Expedition 332 drilling and observatory installation plan

Contingency operations for Expedition 332 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 Expedition 332 based on continuing PMT discussions. The Expedition 332 drilling schedule is shown in Figure **F5A** and **F5B.** The following operations are planned:

1. Install riserless CORK observatory at Site C0002.
2. Replace SmartPlug at Site C0010 with its improved version (GENIUSPlug).

Site C0002 riserless observatory

Site C0002 will be the location of the first CORK installation during NanTroSEIZE. The suite of sensors for the downhole portion of the observatory includes (1) pressure ports, (2) a volumetric strainmeter, (3) a broadband seismometer, (4) a tiltmeter, (5) three-component geophones, (6) three-component accelerometers, and (7) a thermometer array (Fig. F6). The set of sensors is designed to collect, as a whole, multiparameter observations in wide period range from months to 1/100 s and a wide dynamic range covering events from local microearthquakes, very low frequency earthquakes, to the largest, earthquake slips of the Tonankai plate boundary 6 km below the sensors. A 20 inch conductor pipe will be run to 36 mbsf, and then 9⅝ inch casing will be run to ~955 mbsf. To ensure good coupling of the strainmeter to the formation and to eliminate local fluid motion around seismic sensors and tiltmeter, the sensors will be cemented in the open hole section below the 9⅝ inch casing shoe in Unit III. One pressure port will be installed in Unit IV below the strainmeter to sample pore fluid pressure in the accretionary prism. Above the cemented sensors in the open hole, the 9⅝ inch casing has a screened interval to sample pore fluid pressure in Unit II below a swellable packer to isolate the interval from the seafloor. The downhole sensors are digitally connected to the seafloor where power is supplied and data are recovered, whereas pore fluid pressure is transmitted through hydraulic tubing to be recorded in the seafloor recorder. The observatory will be linked to the Dense Oceanfloor Network System for Earthquakes and Tsunamis (DONET) submarine cable observatory network so that measurements can be observed in real time from a shore-based monitoring station, though it will be initially operated by seafloor installed batteries and data recorders, with data recovery by subsequent ROV operations.

As a fallback option in case of unforeseeable problems during installation of the long-term borehole monitoring system (LTBMS), a Baker-Hughes retrievable mechanical bridge plug instrumented with a GENIUSPlug (see **"Site C0010 riserless observatory"**) is available to temporarily complete the hole.

Drilling strategy

The plan for riserless drilling at Site C0002 is to proceed in several steps (Table T1).

The uppermost 0–1401 mbsf at Site C0002 was logged with a comprehensive LWD program during Expedition 314 (Expedition 314 Scientists, 2009), and intervals 0–

204 mbsf and 475–1057 mbsf were cored during Expedition 315 (Expedition 315 Scientists, 2009).

Logging/Downhole measurements strategy

Since Hole C0002A was previously drilled with LWD/MWD tools, no logging (other than with basic LWD) is planned for the tophole section of the proposed new hole (0–800 mbsf). Records from Expedition 314 LWD composite logging data and Expedition 315 core measurements can be detectable to the Unit II/III boundary at 830.4 mbsf and the Unit III/IV boundary at 935.6 mbsf.

The LTBMS will be set just above the Unit II/III boundary, and the strainmeter will be set just below the Unit III/IV boundary. Resistivity and gamma ray values at both the upper and lower boundaries showed sharp and clear higher to lower values to identify this section.

Logging while drilling/measuring while drilling

Drilling with LWD will be performed to monitor drilling conditions and define major lithologic and structural changes in real time, primarily to identify the best target depths for installation of the observatory components. Tools include the TeleScope MWD, located on the main body of the arcVISION LWD tool string (Fig. **F7**), which measures drilling parameters and transmits these data in real time and also stores data in onboard memory for later downloading on deck. Because of a gap of several meters from the top of the bit and sensors, there is a time delay between bit drilling and the sensors collecting data and transferring them to memory. During Expedition 314 LWD data, there was a 10–15 min delay, whereas during Expedition 332, we anticipate a much faster resistivity and natural gamma ray data update rate.

Site C0010 riserless observatory

C0010 SmartPlug recovery/GENIUSPlug deployment

Site C0010, completed during Expedition 319, is located 3.5 km along strike of previously drilled and cored Site C0004 (Fig. **F4**). Hole C0010A penetrated a major splay fault (megasplay) at ~410 mbsf. During Expedition 319, Site C0010 was drilled with MWD and a basic suite of LWD tools (geoVISION resistivity tool and gamma ray) to penetrate the megasplay fault at ~410 meters below seafloor (mbsf) and into the footwall to a TD of 560 mbsf. Observatory operations included installing a temporary monitoring package to monitor pore pressure and temperature within the fault zone accessed through a screened casing.

Scientific objectives

The scientific objectives at Site C0010 during Expedition 332 are to retrieve the SmartPlug sensor and packer assembly (see Davis et al., 2009, for details) and to install another temporary monitoring system (Table **T2**). The retrieval of the SmartPlug will allow the collection of the first observatory data (pressure and temperature) from the shallow section of the megasplay fault as well as allow evaluation of observatory installation procedures in the rough Kuroshio Current. These data will be invaluable in planning for the permanent observatory, due for installation before 2013. After the recovery of the SmartPlug (Fig. **F8A**), its upgraded version containing an OsmoSampler (Jannasch et al., 2003) as well as a FLOCS microbiology unit (Orcutt et al., 2010), a GENIUSPlug (Fig. **F8B**), will be installed for continued observations until the deployment of the permanent observatory in the shallow updip end of the megasplay fault.

Operational plan

The SmartPlug was installed during Expedition 319 and will be recovered during this expedition (Saffer et al., 2009) (Fig. **F5B**). An improved running tool will be used to recover the SmartPlug and for the running in and deployment of the GENIUSPlug.

Contingency plan

The go/no-go decision for installation of the permanent observatory (CORK) will occur on the turning point of 5 December 2010. If the casing is completed by that date but installation of the permanent CORK has not significantly progressed, we will then ask for an additional 12 days to safely complete installation. If, however, casing installation is still ongoing on 5 December, we will ask for 5 additional days to complete casing operations and SmartPlug installation. The worst-case situation will leave Site C0002 cased, cemented, and capped but with no observatory installation at all.

References

Ashi, J., Kuramoto, S., Morita, S., Tsunogai, U., Goto, S., Kojima, S., Okamoto, T., Ishimura, T., Ijiri, A., Toki, T., Kudo, S., Asai, S., and Utsumi, M., 2002. Structure and cold seep of the Nankai accretionary prism off Kumano—outline of the off Kumano survey during YK01-04 Leg 2 cruise. *JAMSTEC J. Deep Sea Res.,* 20:1–8. (in Japanese, with abstract in English)

Ashi, J., Lallemant, S., Masago, H., and the Expedition 315 Scientists, 2008. NanTroSEIZE Stage 1A: NanTroSEIZE megasplay riser pilot. *IODP Prel. Rept.,* 315. **doi:10.2204/iodp.pr.315.2008**

Byrne, D.E., Davis, D.M., and Sykes, L.R., 1988. Loci and maximum size of thrust earthquakes and the mechanics of the shallow region of subduction zones. *Tectonics,* 7(4):833–857. **doi:10.1029/TC007i004p00833**

Davis, E.E., Saffer, D.M., Kopf, A., Macdonald, R., LaBonte, A., Bennest, J., Meldrum, R., and Toczko, S., 2009. A “mini-CORK” “smart bridge plug” for initial NanTroSEIZE borehole monitoring. *Eos, Trans. Am. Geophys. Union,* 90(52)(Suppl.):NH31A-1102. (Abstract) **http://www.agu.org/meetings/fm09/waisfm09.html**

Expedition 314 Scientists, 2009. Expedition 314 Site C0002. *In* Kinoshita, M., Tobin, H., Ashi, J., Kimura, G., Lallemant, S., Screaton, E.J., Curewitz, D., Masago, H., Moe, K.T., and the Expedition 314/315/316 Scientists, *Proc. IODP,* 314/315/316: Washington, DC (Integrated Ocean Drilling Program Management International, Inc.). **doi:10.2204/iodp.proc.314315316.114.2009**

Expedition 315 Scientists, 2009. Expedition 315 Site C0002. *In* Kinoshita, M., Tobin, H., Ashi, J., Kimura, G., Lallemant, S., Screaton, E.J., Curewitz, D., Masago, H., Moe, K.T., and the Expedition 314/315/316 Scientists, *Proc. IODP,* 314/315/316: Washington, DC (Integrated Ocean Drilling Program Management International, Inc.). **doi:10.2204/iodp.proc.314315316.124.2009**

Expedition 319 Scientists, 2010. Site C0010. *In* Saffer, D., McNeill, L., Byrne, T., Araki, E., Toczko, S., Eguchi, N., Takahashi, K., and the Expedition 319 Scientists, *Proc. IODP,* 319: Tokyo (Integrated Ocean Drilling Program Management International, Inc.). **doi:10.2204/iodp.proc.319.104.2010**

Hickman, S., Zoback, M., and Ellsworth, W., 2004. Introduction to special section: preparing for the San Andreas Fault Observatory at Depth. *Geophys. Res. Lett.,* 31(12):L12S01. **doi:10.1029/2004GL020688**

Jannasch, H.W., Davis, E.E., Kastner, M., Morris, J.D., Pettigrew, T.L., Plant, J.N., Solomon, E.A., Villinger, H.W., and Wheat, C.G., 2003. CORK-II: long-term monitoring of fluid chemistry, fluxes, and hydrology in instrumented boreholes at the Costa Rica subduction zone. *In* Morris, J.D., Villinger, H.W., Klaus, A., *Proc. ODP, Init. Repts.,* 205: College Station, TX (Ocean Drilling Program), 1–36. **doi:10.2973/odp.proc.ir.205.102.2003**

Kimura, G., Screaton, E.J., Curewitz, D., and the Expedition 316 Scientists, 2008. NanTroSEIZE Stage 1A: NanTroSEIZE shallow megasplay and frontal thrusts. *IODP Prel. Rept.,* 316. **doi:10.2204/iodp.pr.316.2008**

Kinoshita, M., Tobin, H., Ashi, J., Kimura, G., Lallemant, S., Screaton, E.J., Curewitz, D., Masago, H., Moe, K.T., and the Expedition 314/315/316 Scientists, 2009. *Proc. IODP,* 314/315/316: Washington, DC (Integrated Ocean Drilling Program Management International, Inc.). **doi:10.2204/iodp.proc.314315316.2009**

Kinoshita, M., Tobin, H., Moe, K.T., and the Expedition 314 Scientists, 2008. NanTroSEIZE Stage 1A: NanTroSEIZE LWD transect. *IODP Prel. Rept.,* 314. **doi:10.2204/iodp.pr.314.2008**

Kodaira, S., Takahashi, N., Park, J.-O., Mochizuki, K., Shinohara, M., and Kimura, S., 2000. Western Nankai Trough seismogenic zone: results from a wide-angle ocean bottom seismic survey. *J. Geophys. Res., [Solid Earth],* 105(B3):5887–5905. **doi:10.1029/1999JB900394**

Lay, T., Kanamori, H., Ammon, C.J., Nettles, M., Ward, S.N., Aster, R.C., Beck, S.L., Bilek, S.L., Brudzinski, M.R., Butler, R., DeShon, H.R., Ekström, G., Satake, K., and Sipkin, S., 2005. The great Sumatra-Andaman earthquake of 26 December 2004. *Science,* 308(5725):1127–1133. **doi:10.1126/science.1112250**

Le Pichon, X., Iiyama, T., Chamley, H., Charvet, J., Faure, M., Fujimoto, H., Furuta, T., Ida, Y., Kagami, H., Lallemant, S., Leggett, J., Murata, A., Okada, H., Rangin, C., Renard, V., Taira, A., and Tokuyama, H., 1987a. Nankai Trough and the fossil Shikoku Ridge: results of Box 6 *Kaiko* survey. *Earth Planet. Sci. Lett.,* 83(1–4):186–198. **doi:10.1016/0012-821X(87)90065-3**

Le Pichon, X., Iiyama, T., Chamley, H., Charvet, J., Faure, M., Fujimoto, H., Furuta, T., Ida, Y., Kagami, H., Lallemant, S., Leggett, J., Murata, A., Okada, H., Rangin, C., Renard, V., Taira, A., and Tokuyama, H., 1987b. The eastern and western ends of Nankai Trough: results of Box 5 and Box 7 Kaiko survey. *Earth Planet. Sci. Lett.,* 83(1–4):199–213. **doi:10.1016/0012-821X(87)90066-5**

Ma, K., 2005. Slip zone and energetic of a large earthquake from seismological modeling and fault core of TCDP. *Eos, Trans. Am. Geophys. Union,* 86(52):T43D-02. (Abstract) **http://www.agu.org/meetings/fm05/waisfm05.html**

Mazzotti, S., Le Pichon, X., Henry, P., and Miyazaki, S.-I., 2000. Full interseismic locking of the Nankai and Japan-West Kuril subduction zones: an analysis of uniform elastic strain accumulation in Japan constrained by permanent GPS. *J. Geophys. Res., [Solid Earth],* 105(B6):13159–13178. **doi:10.1029/2000JB900060**

Miyazaki, S., and Heki, K., 2001. Crustal velocity field of southwest Japan: subduction and arc-arc collision. *J. Geophys. Res., [Solid Earth],* 106(B3):4305–4326. **doi:10.1029/2000JB900312**

Moore, G.F., Bangs, N.L., Taira, A., Kuramoto, S., Pangborn, E., and Tobin, H.J., 2007. Three-dimensional splay fault geometry and implications for tsunami generation. *Science,* 318(5853):1128–1131. **doi:10.1126/science.1147195**

Moore, G.F., Taira, A., Klaus, A., et al., 2001. *Proc. ODP, Init. Repts.,* 190: College Station, TX (Ocean Drilling Program). **doi:10.2973/odp.proc.ir.190.2001**

Moore, J.C., and Saffer, D., 2001. Updip limit of the seismogenic zone beneath the accretionary prism of southwest Japan: an effect of diagenetic to low-grade metamorphic processes and increasing effective stress. *Geology,* 29(2):183–186. **doi:10.1130/0091-7613(2001)029<0183:ULOTSZ>2.0.CO;2**

Okino, K., Shimakawa, Y., and Nagaoka, S., 1994. Evolution of the Shikoku Basin. *J. Geomagn. Geoelectr.,* 46(6):463–479.

Orcutt, B., Wheat, C.G., and Edwards, K.J., 2010. Subseafloor ocean crust microbial observatories: development of FLOCS (flow-through osmo colonization system) and evaluation of borehole construction materials. *Geomicrobiol. J.,* 27(2):143–157. **doi:10.1080/01490450903456772**

Park, J.-O., Tsuru, T., Kodaira, S., Cummins, P.R., and Kaneda, Y., 2002. Splay fault branching along the Nankai subduction zone. *Science,* 297(5584):1157–1160. **doi:10.1126/science.1074111**

Ruff, L., and Kanamori, H., 1983. Seismic coupling and uncoupling at subduction zones. *Tectonophysics,* 99(2–4):99–117. **doi:10.1016/0040-1951(83)90097-5**

Saffer, D., McNeill, L., Araki, E., Byrne, T., Eguchi, N., Toczko, S., Takahashi, K., and the Expedition 319 Scientists, 2009. NanTroSEIZE Stage 2: NanTroSEIZE riser/riserless observatory. *IODP Prel. Rept.,* 319. **doi:10.2204/iodp.pr.319.2009**

Saffer, D.M., and Marone, C., 2003. Comparison of smectite- and illite-rich gouge frictional properties: application to the updip limit of the seismogenic zone along subduction megathrusts. *Earth Planet. Sci. Lett.,* 215(1–2):219–235. **doi:10.1016/S0012-821X(03)00424-2**

Seno, T., Stein, S., and Gripp, A.E., 1993. A model for the motion of the Philippine Sea plate consistent with NUVEL-1 and geological data. *J. Geophys. Res., [Solid Earth],* 98(B10):17941–17948. **doi:10.1029/93JB00782**

Tobin, H.J., and Kinoshita, M., 2006a. Investigations of seismogenesis at the Nankai Trough, Japan. *IODP Sci. Prosp.,* NanTroSEIZE Stage 1. **doi:10.2204/iodp.sp.nantroseize1.2006**

Tobin, H.J., and Kinoshita, M., 2006b. NanTroSEIZE: the IODP Nankai Trough Seismogenic Zone Experiment. *Sci. Drill.,* 2:23–27. **doi:10.2204/iodp.sd.2.06.2006**

Wang, K., and Hu, Y., 2006. Accretionary prisms in subduction earthquake cycles: the theory of dynamic Coulomb wedge. *J. Geophys. Res., [Solid Earth],* 111(B6):B06410. **doi:10.1029/2005JB004094**

Table T1. Operations and time estimates for Expedition 332, Site C0010 riserless. (See table notes.)

Site	PTD (mbsf)	Water depth (m)	Total (mbsf)	Operation	Estimated days	Total days	Number of cores
C0010							
	555	2523.7	555	Move to site, deploy transponders, retrieve corrosion cap:			
				• Move to site	0.5		
				• Set transponders, ROV survey	0.5		
				• Retrieve corrosion cap	1.0	**2.0**	
				Prep for running RBP tool:			
				• Install guidehorn	2.0		
				• Make up and run RBP tool	1.0		
				• Retrieve RBP and SmartPlug	1.0	**6.0**	
				Wireline logging:			
				• Run 8-1/2 inch bit and scraper assembly to top of cement	1.5		
				• Run guide drill pipe for wireline log	0.5		
				• Run CBL, POOH	0.5	**8.5**	
				Make up and run RBP with probe	2.0	**10.5**	
				Set corrosion cap and retrieve transponders	1.5	**12.0**	
				Contingency:			
				• Typhoon evacuation	—		
				• Equipment downtime	2.0		
				• Wait on weather	1.0	**15.0**	
				Move to other site	0.5		
					Total days:	**15.5**	

Notes: PTD = proposed total depth. ROV = remotely operated vehicle. RBP = Retrievable Bridge Plug. CBL = cement-bond log. POOH = pull out of hole.

Table T2. Operations and time estimates for Expedition 332, Site C0002 riserless. (**See table notes.**)

Site	PTD (mbsf)	Water depth (m)	Total (mbsf)	Operation	Estimated days	Subtotal days	Total days	Number of cores
C0002								
	1000	1936	1400	Prepare for running 20 inch casing:				
				• Move to site, ROV survey	0.5			
				• Preparation for running 20 inch casing	1.0			
				• Move to low current area	0.5	2.0	**2.0**	
				Set 20 inch casing:				
				• Rig up 20 inch conductor	0.5			
				• Make up and run 20 inch casing, low current area	1.0			
				• Drift to location	1.5			
				• Run and jet-in 20 inch conductor to 36 mbsf	1.0	4.0	**6.0**	
				Drill 12-1/4 inch hole:				
				• Install guidehorn	0.5			
				• Makeup and run 12-1/4 inch drilling assembly with drifting	1.5			
				• Drill 12-1/4 inch hole to 900 msbf with LWD	2.5			
				• POOH and RIH 10-5/8 inch drilling assembly, drill 10-5/8 inch hole to 955 mbsf TD	1.0			
				• Wiper trip, POOH	1.0	6.5	**12.5**	
				Set 9-5/8 inch casing:				
				• Move to low current area, unset guidehorn, rig up 9-5/8 inch casing	1.0			
				• Make up and run 9-5/8 inch casing at low current area	1.0			
				• Drifting to location	1.5			
				• Run and cement 9-5/8 inch casing to 890 mbsf	1.5	5.0	**17.5**	
				Drill out cement and scraping:				
				• Make up and run drill out cement assembly, drill out cement, POOH	2.0			
				• Run scraper assembly to above float collar, POOH	1.0	3.0	**20.5**	
				Wiper trip:				
				• Install guidehorn, run wiper trip assembly, ream to bottom, spot cross-linked gel, POOH	1.0	1.0	**21.5**	
				Completion:				
				• Preparation of completion, make up and run 3-1/2 inch tubing completion assembly with drifting, test sensor, cement and set strainmeter and POOH running tool	8.5	8.5	**30.0**	
				Retrieve transponders, test pressure logger with ROV	2.0	2.0	**32.0**	
						Total days	**32.0**	

Notes: PTD = proposed total depth. ROV = remotely operated vehicle. LWD = logging while drilling. POOH = pull out of hole, RIH = run in hole. TD = total depth.

Figure F1. Map of Kumano Basin region showing NanTroSEIZE drill sites. Red circles = Sites C0002 and C0010.

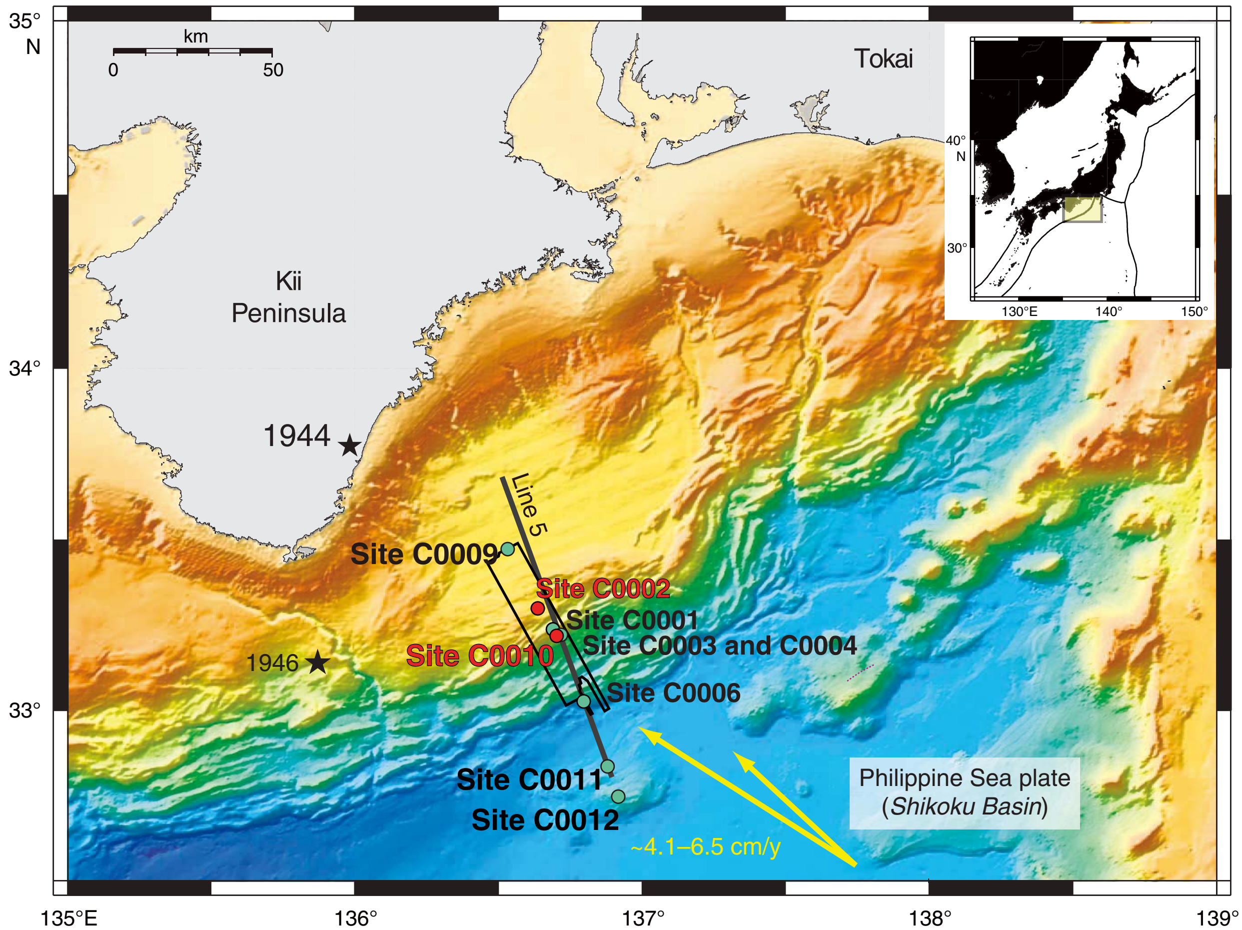


Figure F2. Seismic diagram at regional scale showing interpretation by Park et al. (2002) and drill sites. The updip of the megasplay fault is shown in relation to observatory Sites C0002 and C0010. Red = Sites C0002 and C0010, orange = sites drilled in 2009.

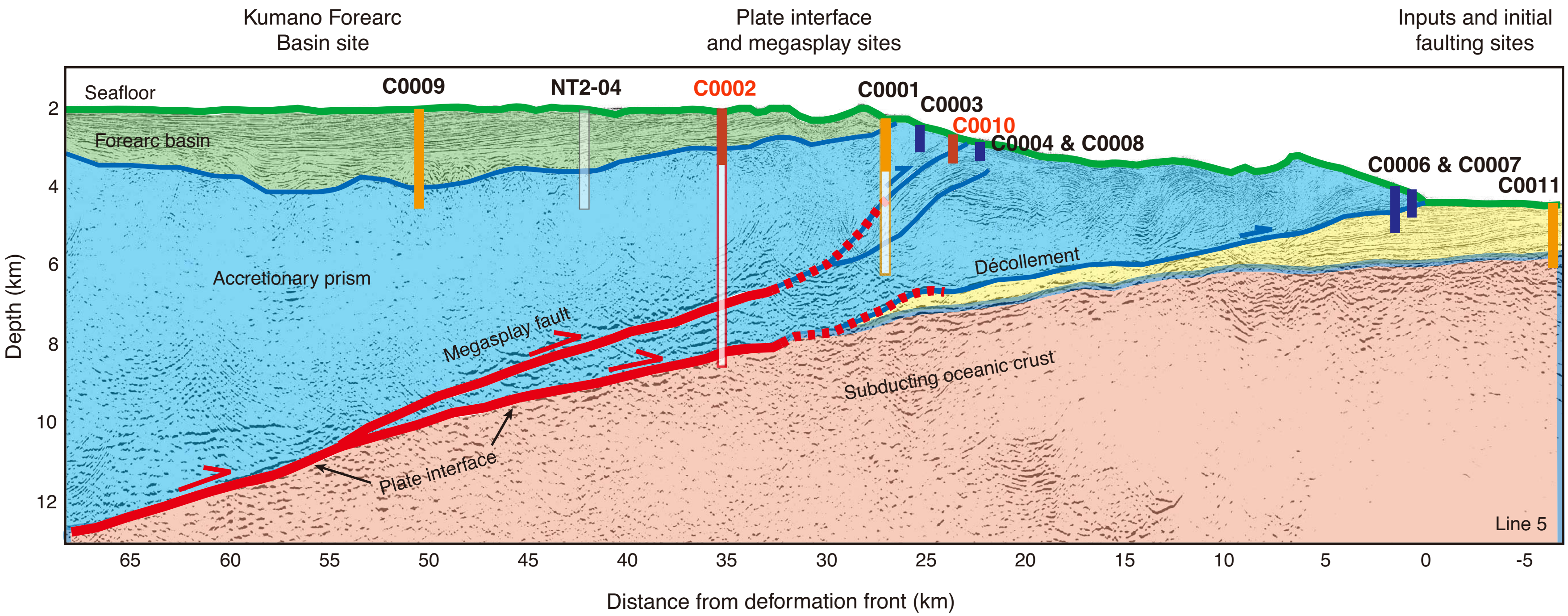


Figure F3. Seismic profile along the Nankai Trough axis, showing major geologic features along the transect encompassing all NanTroSEIZE drill sites.

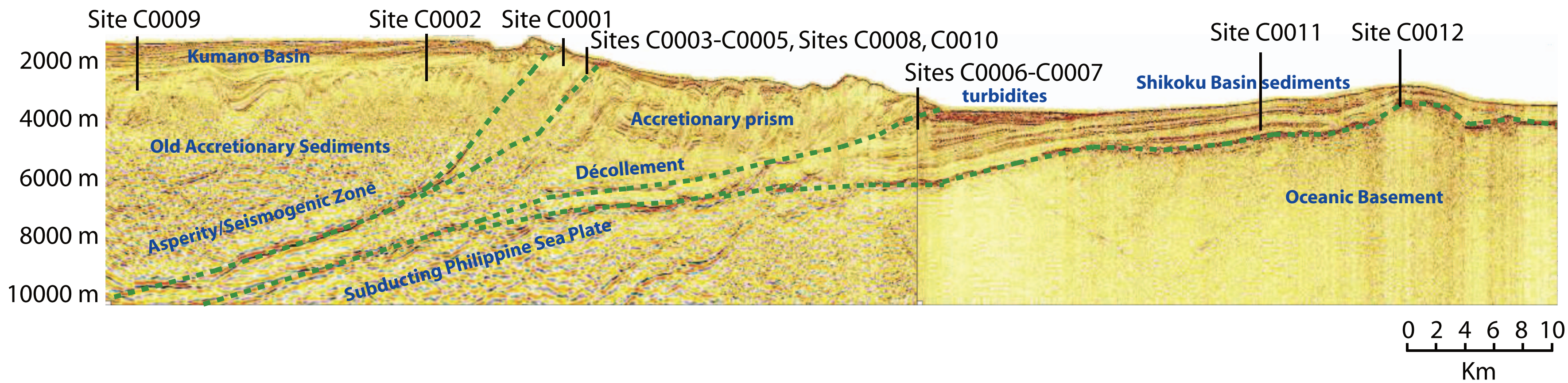


Figure F4. Log-Seismic integration figure showing lithologic units and resistivity data for Site C0010 from Expedition 319 Scientists (2010).

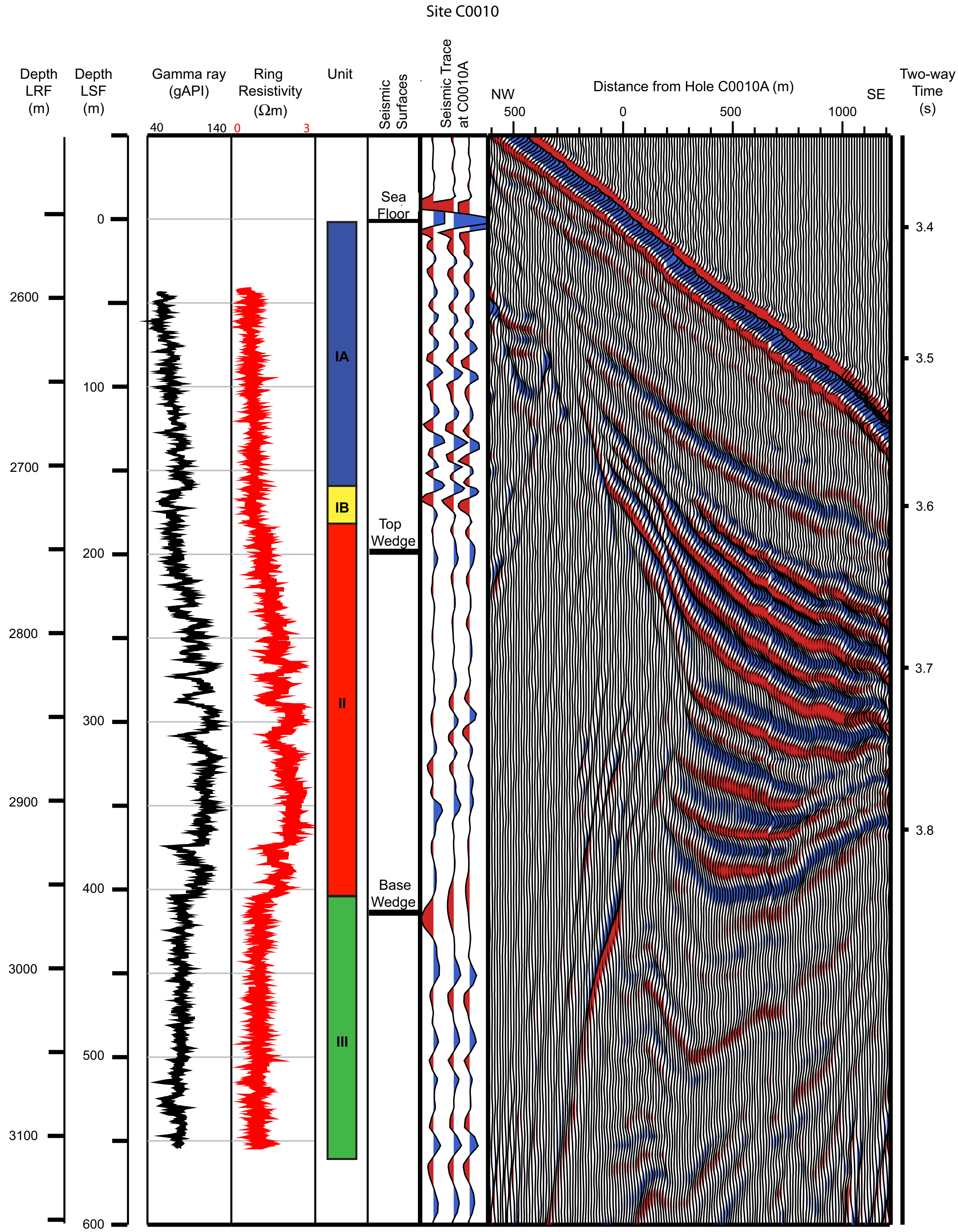


Figure F5. Drilling schedule. **A.** Site C0002, riserless circulation obviation retrofit kit (CORK). LWD = logging while drilling, POOH = pull out of hole. (**Continued on next page.**)

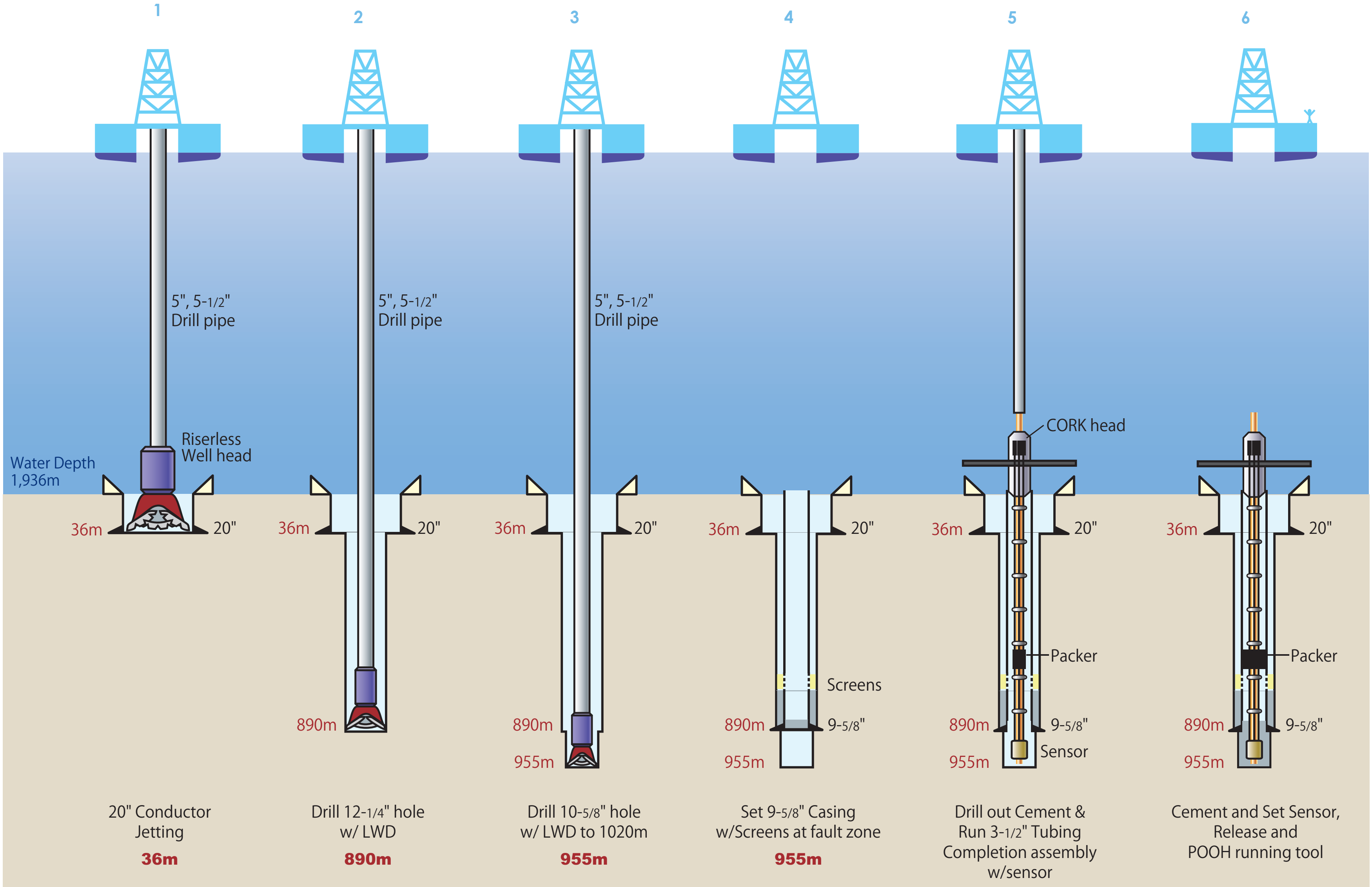


Figure F5 (continued). B. Site C0010, SmartPlug/GENIUSPlug recovery/deployment.

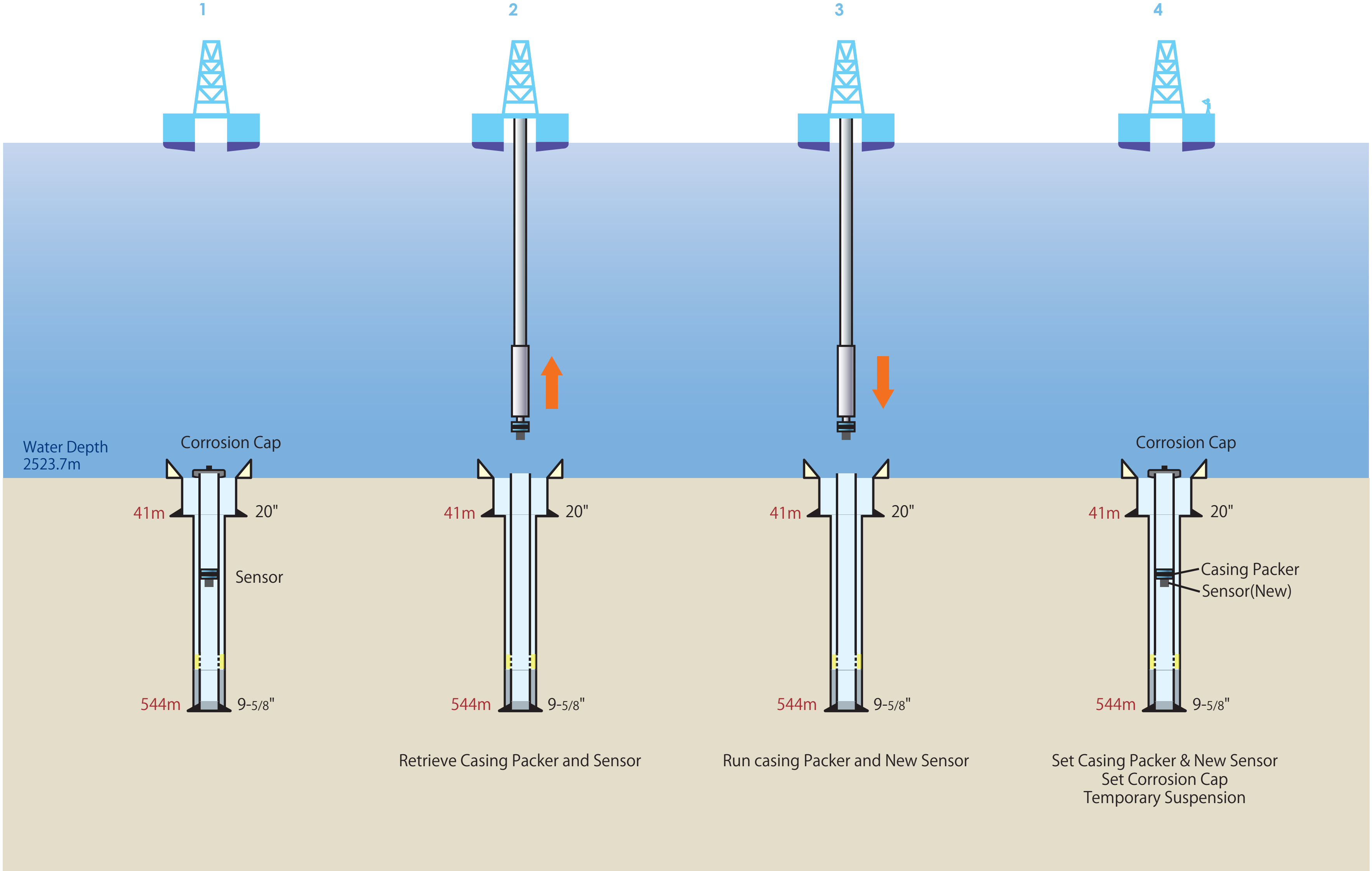


Figure F6. Circulation obviation retrofit kit (CORK) schematic showing instruments and sensor packages, deployment depths, and final configuration. ROV = remotely operated vehicle.

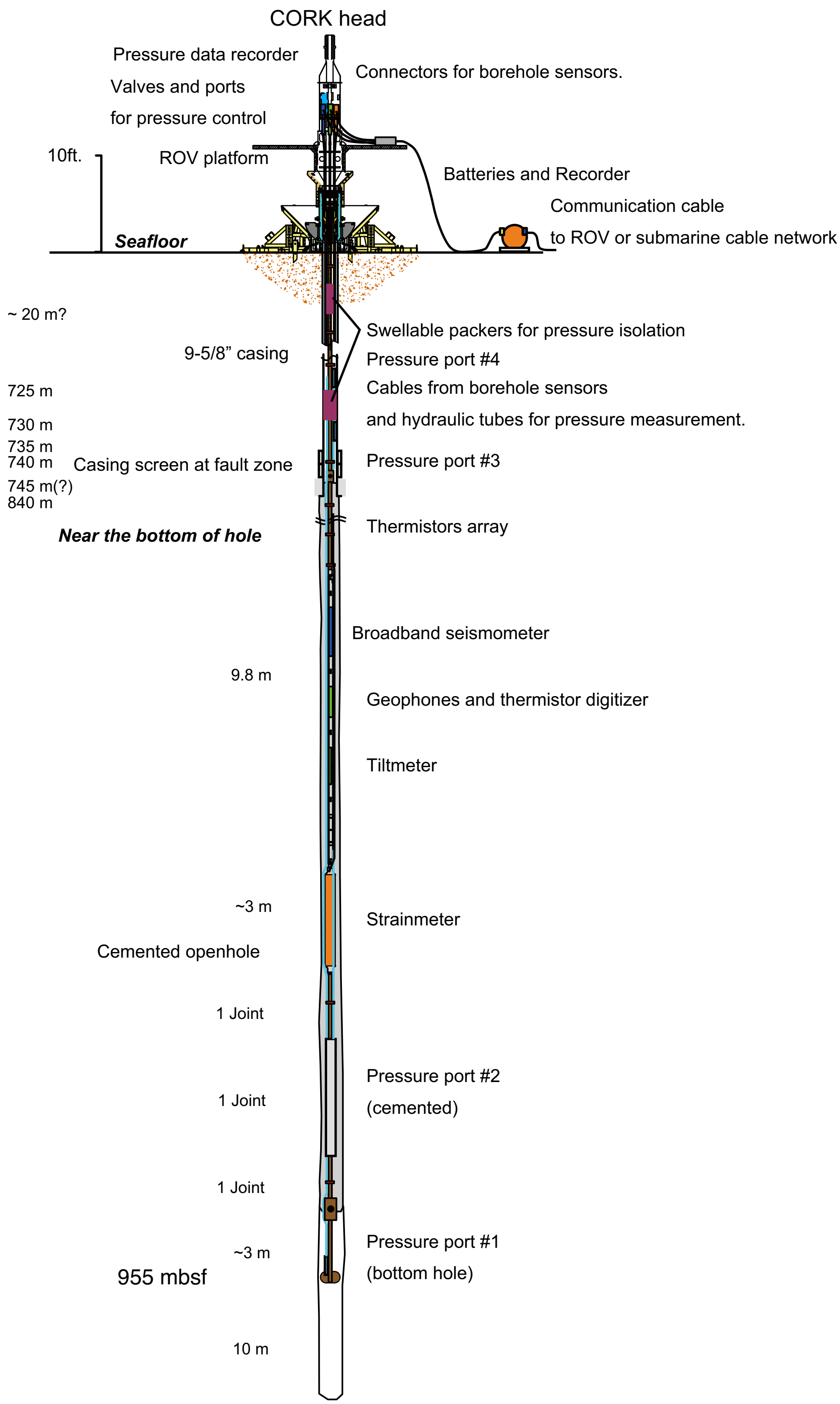


Figure F7. LWD tool string, ARC825 tool on the left, arcVISION tool on the right. XO = crossover, NMDC = nonmagnetic drill collar, HF = high flow.

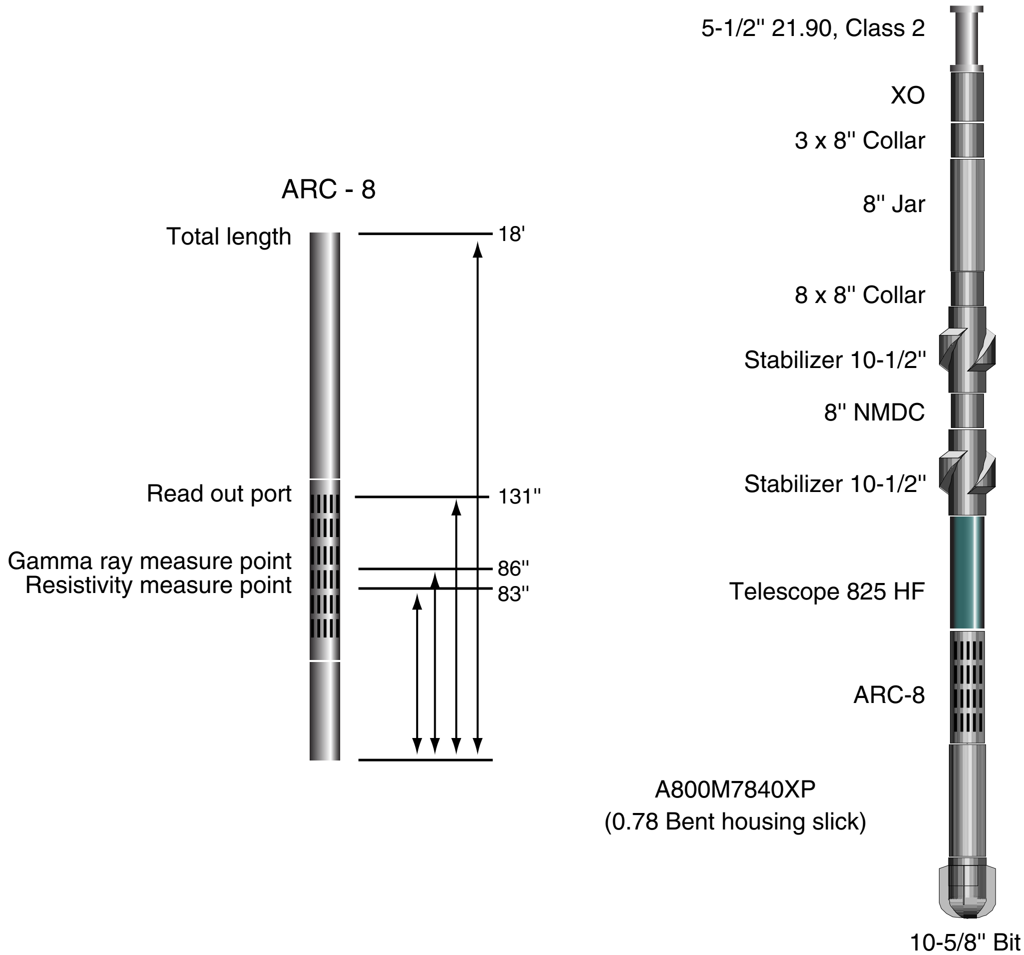


Figure F8. Diagrams and schematics. **A.** Site C0010 SmartPlug. (**Continued on next page.**)

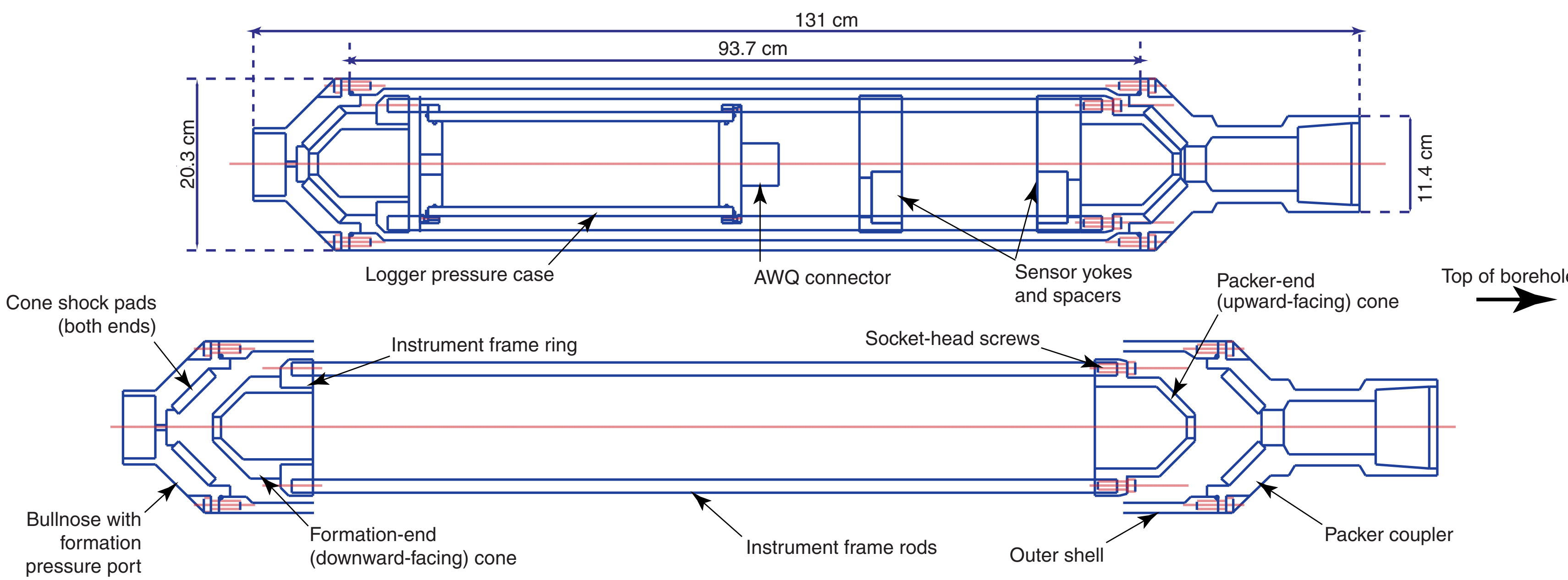
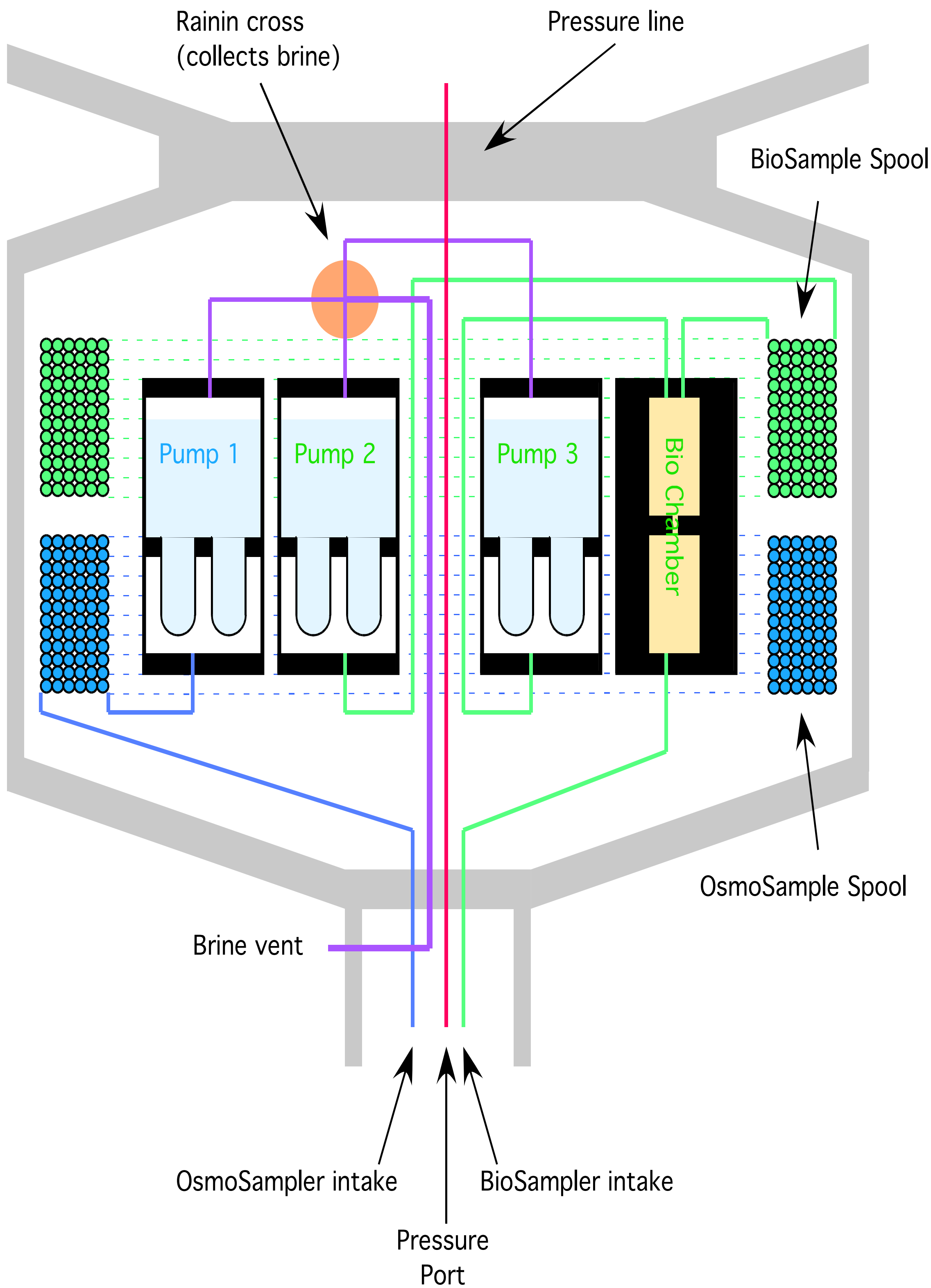


Figure F8 (continued). B. Site C0010 GENIUSPlug extension. A unit containing OsmoSamplers as well as a biochamber (so-called FLOCS; see Orcutt et al., 2010) is added at the lower bullnose of the SmartPlug to monitor pore fluid chemistry in the fault and assess microbial turnover rates.



Site summary

Hole C0002C–riserless observatory

Priority:	Contingency: *Chikyu* Expedition 326 (NanTroSEIZE Stage 3: plate boundary deep riser: top hole engineering)
Position:	33°18.02′N, 136°38.18′E
Water depth (m):	1936
Target drilling depth (mbsf):	1000
Approved maximum penetration (mbsf):	1400
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 riserless hole to 1000 mbsf in preparation for future permanent observatory installation
Drilling, coring, and downhole measurement program:	• Set 20 inch casing to 36 mbsf • Drill 12-1/4 inch hole to 1000 mbsf • Set 9-5/8 inch casing to 1000 mbsf • MWD, cement-bond log
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 332 can be found at **www.jamstec.go.jp/chikyu/eng/Expedition/NantroSEIZE/exp332.html.**