Integrated Ocean Drilling Program
Expedition 338 Scientific Prospectus

NanTroSEIZE Stage 3: NanTroSEIZE plate boundary deep riser 2

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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.

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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. During Integrated Ocean Drilling Program (IODP) Expedition 338, drilling is planned to extend riser Hole C0002F, which was started during IODP Expedition 326 in 2010, from 856 to ~3600 meters below the seafloor (mbsf) over a 4 month period beginning in late September 2012 and ending in early January 2013. IODP Site C0002 is located in the Kumano forearc basin in the upper plate above the seismogenic, and presumably locked, portion of the plate boundary thrust system. The Kumano Basin sedimentary sequence and uppermost most part of the accretionary prism has been sampled and analyzed during IODP Expeditions 314 (logging while drilling [LWD] to 1401.5 mbsf) and 315 (coring to 1057 mbsf). The proposed extension would access the deep interior of the Miocene accretionary prism and would allow characterization of a unique tectonic environment that has never been sampled in situ by ocean drilling. The primary goals for Expedition 338 Site C0002 are riser drilling, analyses of cuttings and limited cores (100 m from 2300 to 2400 mbsf), LWD, and casing to the target depth of 3600 mbsf. This will allow addressing the primary scientific objectives such as (1) determining the composition, stratigraphy, and internal style of deformation of the Miocene accretionary complex; (2) reconstructing its thermal, diagenetic, and metamorphic history (3) determining orientation of minimal horizontal stress within the deep interior of the inner wedge; (4) investigating the mechanical state and behavior of the formation; and (5) showing how Objectives 1–4 relate to overall structural evolution of the Nankai accretionary prism and the current state of the upper plate above seismogenic plate boundary thrust. The hole is planned to be deepened during operations later in 2013. This *Scientific Prospectus* outlines the scientific rationale, objectives, and operational plans for drilling this site and contingency options.

Schedule for Expedition 338

The operations schedule for Integrated Ocean Drilling Program (IODP) Expedition 338 is derived from the original IODP drilling Proposals 603-CDP3 and 603C-Full (available at **www.iodp.org/600/**). Following ranking by the IODP Scientific Advisory Structure, the IODP Operations Task Force charged the Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) Project Management Team (PMT) with formulating a strategy to achieve the overall scientific objectives outlined in all of the NanTroSEIZE program proposals. The overarching goals and multistage implementation strategy are described in Tobin and Kinoshita (2006a, 2006b). For "Phase 2" of the NanTroSEIZE project described in Proposals 603B and 603D, the IODP Operations Task Force scheduled one Stage 1 expedition and one Stage 2 expedition on the D/V *Chikyu*, operating under contract with the Japanese Implementing Organization, the Center for Deep Earth Exploration (CDEX) (**www.jamstec.go.jp/chikyu/eng/Expedition/index.html**).

Expedition 338 is the second expedition of NanTroSEIZE Stage 3 and is currently scheduled to begin at Shingu, Japan, on 19 September 2012. Details of the operational schedule, updates to the drilling schedule, and operational and layout details of the *Chikyu* can be found at **www.jamstec.go.jp/chikyu/eng/CHIKYU/index.html.** The science party is scheduled to board the *Chikyu* on 6 October 2012 and disembark at Shingu, Japan, on 6 January 2013; the science party itself will consist of two groups, which will rotate on/off the week of 17–23 November 2012; 1 week will be spent in crossover with Specialty Coordinator participation. The entire expedition comprises a total of 102 days, including 20 days of contingency time, that will be available for drilling, coring, logging, and casing operations during Expedition 338, as described in this *Scientific Prospectus*.

Introduction

Overview of the NanTroSEIZE drilling project

Subduction zones account for 90% of the global seismic moment release and generate damaging earthquakes and tsunamis with potentially disastrous effects on heavily populated coastal areas (e.g., Lay et al., 2005; Moreno et al., 2010; Simons et al., 2011). 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, measurement of in situ conditions, and shore-based laboratory experiments is a fundamental and societally relevant goal of modern earth science. To this end, several recent and ongoing drilling programs have targeted portions of active plate boundary faults that either slipped coseismically during large earthquakes or nucleated smaller events. These efforts include the San Andreas Fault Observatory at Depth (SAFOD) (Hickman et al., 2004), the Taiwan-Chelungpu Drilling Project (Ma, 2005), IODP NanTroSEIZE drilling (Tobin and Kinoshita, 2006a, 2006b), and Japan Trench Fast Earthquake Drilling Project (Mori et al., 2012).

NanTroSEIZE is a multiexpedition, multistage IODP drilling project focused on understanding the mechanics of seismogenesis and rupture propagation along subduction plate boundary faults. The drilling program includes a coordinated effort to sample and instrument the plate boundary system at several locations offshore the Kii Peninsula (Tobin and Kinoshita, 2006b) (Figs. **F1, F2**). The main objectives are to understand

- The mechanisms and processes controlling the updip aseismic–seismic transition of the megathrust fault system,
- Processes of earthquake and tsunami generation,
- Mechanics of strain accumulation and release,
- The absolute mechanical strength of the plate boundary fault, and
- The potential role of a major upper plate fault system (termed the “megasplay” fault) in seismogenesis and tsunamigenesis.

The multiexpedition drilling program will evaluate a set of core hypotheses through 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 frictional 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 Mw ~8.0+ (Ruff and Kanamori, 1983). Although the causal mechanisms are not well understood (e.g., Byrne et al., 1988; Moore and Saffer, 2001; Saffer and Marone, 2003) and great earthquakes are also known to occur within sediment-starved subduction zones such as the Japan Trench, 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). Along the Nankai margin, high-resolution seismic reflection profiles across the outer rise clearly document a large out-of-sequence-thrust fault system (the megasplay fault, after Park et al., 2002) that branches from the plate boundary décollement close to the updip limit of inferred coseismic rupture in the 1944 Tonankai Mw 8.2 earthquake (Fig. **F2**).

Several lines of evidence indicate that the megasplay system is active and that it may accommodate an appreciable component of plate boundary motion. However, the partitioning of strain between the lower plate interface (the décollement zone) and the megasplay system and the nature and mechanisms of fault slip as a function of depth and time on the megasplay are not understood. As stated in the fifth hypothesis above, one of the first-order goals in characterizing the seismogenic zone along the Nankai Trough, which bears on both understanding subduction zone megathrust behavior globally and defining tsunami hazards, is to document the role of the megasplay fault in accommodating plate motion (both seismically and interseismically) and to characterize its mechanical and hydrologic behavior.

In late 2007 through early 2008, IODP Expeditions 314, 315, and 316 were carried out as a unified program of drilling collectively known as NanTroSEIZE Stage 1 (Tobin et al., 2009). A transect of eight sites was selected for riserless drilling to target the frontal thrust region, the midslope megasplay fault region, and the Kumano forearc basin region (Figs. **F1, F2**). Two of these sites are preparatory pilot holes for planned deep riser drilling operations, whereas the other sites primarily targeted fault zones in the shallow, presumed aseismic, portions of the accretionary complex (Tobin et al., 2009). Expedition 314 was dedicated to in situ measurement of physical properties and borehole imaging through logging while drilling (LWD) in holes drilled specifically for that purpose, including IODP Site C0002 (Expedition 314 Scientists, 2009). Expedition 315 was devoted to core sampling and downhole temperature measurements at a site in the megasplay region and Site C0002 in the forearc basin (Expedition 315 Scientists, 2009b). Expedition 316 targeted the frontal thrust and megasplay fault in their shallow, aseismic portions (Screaton et al., 2009).

Stage 2 of NanTroSEIZE comprised four IODP expeditions (319, 322, 332, and 333) (Expedition 319 Scientists, 2010; Underwood et al., 2010; Kopf et al., 2011; Expedition 333 Scientists, 2011), with the aims of building on the results of Stage 1, characterizing the subduction inputs on the Philippine Sea plate, and preparing for later observatory installations for long-term monitoring of deformation at the updip limit of the seismogenic zone. IODP Expedition 326 started Stage 3 by installing the first casing string in Hole C0002F to 860 meters below seafloor (mbsf) (Expedition 326 Scientists, 2011). Expedition 338 will deepen the hole to investigate the properties, structure, and state of stress within the hanging wall above the locked plate boundary at Site C0002. The borehole will be further deepened later in 2013, with the ultimate goal of penetrating the megasplay fault and for future installation of a long-term observatory (Fig. **F3**).

Site C0002 is the deep centerpiece of the NanTroSEIZE project, as it is planned to access the plate interface fault system at a location where the fault system is believed to be capable of seismogenic locking and slip and to have slipped coseismically in the 1944 Tonankai earthquake (e.g., Ichinose et al., 2003). This zone also coincides with the location where a cluster of very low frequency (VLF) seismic events occurred in 2004–2005 (Ito and Obara, 2006) and the first tectonic tremor recorded in an accretionary prism setting has been found (Obana and Kodaira, 2009). The primary targets for Site C0002 include both the basal décollement and the reflector known as the megasplay fault (Tobin and Kinoshita, 2006b). The megasplay fault reflection lies at an estimated depth of 5200 mbsf, and the top of subducting basement is estimated to lie at ~6800 mbsf (Fig. **F2**). The planned ultimate target depth for this site is 7000 mbsf, to be reached during future operations.

Background

Geological setting

The Nankai Trough is formed by subduction of the Philippine Sea plate to the northwest beneath the Eurasian plate at a rate of ~4.1–6.5 cm/y (Seno et al., 1993; Miyazaki and Heki, 2001). The convergence direction is slightly oblique to the trench and sediments of the Shikoku Basin are actively accreting at the deformation front. The Nankai Trough is among the most extensively studied subduction zones in the world, and great earthquakes during the past 1300 years or more are well documented in historical and archeological records (e.g., Ando, 1975). The Nankai Trough has been one of the focus sites for studies of seismogenesis by both the IODP and the U.S. MARGINS initiative, based on the wealth of geological and geophysical data available. A better understanding of seismic and tsunami behavior at margins such as Nankai is highly relevant to heavily populated coastal areas.

Subduction zones like the Nankai Trough, where most of the great earthquakes (Mw > 8.0) occur, are especially favorable for study because the entire downdip width of the seismogenic zone ruptures in each event, suggesting that the zone of coseismic rupture in future large earthquakes may be more predictable than for smaller earthquakes. The Nankai Trough region has a 1300 year historical record of recurring great earthquakes that are typically tsunamigenic, including the 1944 Tonankai Mw 8.2 and 1946 Nankaido Mw 8.3 earthquakes (Ando, 1975; Hori et al., 2004). The rupture area and zone of tsunami generation for the 1944 event (within which this expedition is located) are now reasonably well understood (Ichinose et al., 2003; Baba et al., 2005). Land-based geodetic studies suggest that currently the plate boundary thrust is strongly locked (Miyazaki and Heki, 2001). Similarly, the relatively low level of microseismicity near the updip limits of the 1940s earthquakes (Obana et al., 2001) implies significant interseismic strain accumulation on the megathrust. However, recent observations of VLF earthquakes within or just below the accretionary prism in the drilling area (Obara and Ito, 2005) demonstrate that interseismic strain is not confined to slow elastic strain accumulation. Slow slip phenomena, referred to as episodic tremor and slip, including episodic slow slip events and nonvolcanic tremor (Schwartz and Rokosky, 2007), are also widely known to occur in the downdip part of the rupture zone (Ito et al., 2007). In the subducting Philippine Sea plate mantle below the rupture zone, weak seismicity is observed (Obana et al., 2005). Seaward of the subduction zone, deformation of the incoming ocean crust is suggested by microearthquakes as documented by ocean-bottom seismometer (OBS) studies (Obana et al., 2005).

The region offshore the Kii Peninsula on Honshu Island was selected for seismogenic zone drilling for several reasons. First, the rupture area of the most recent great earthquake, the 1944 Mw 8.2 Tonankai event, is well constrained by recent seismic and tsunami waveform inversions (e.g., Tanioka and Satake, 2001; Kikuchi et al., 2003). Slip inversion studies suggest that only in this region did past coseismic rupture clearly extend shallow enough for drilling (Ichinose et al., 2003; Baba and Cummins, 2005), and an updip zone of large slip has been identified and targeted (Figs. **F2, F3**). Notably, coseismic slip during events like the 1944 Tonankai earthquake may have occurred on the megasplay fault in addition to the plate boundary décollement (Ichinose et al., 2003; Baba et al., 2006). The megasplay fault is therefore a primary drilling target equal in importance to the basal décollement. Second, OBS campaigns and onshore high-resolution geodetic studies (though of short duration) indicate significant interseismic strain accumulation (e.g., Miyazaki and Heki, 2001; Obana et al., 2001). Third, the region offshore the Kii Peninsula is generally typical of the Nankai margin in terms of heat flow and sediment on the incoming plate. This is in contrast to the area offshore Cape Muroto (the location of previous Deep Sea Drilling Project and Ocean Drilling Program [ODP] drilling), where both local stratigraphic variation associated with basement topography and anomalously high heat flow have been documented (Moore et al., 2001, 2005; Moore, Taira, Klaus, et al., 2001). Finally, the drilling targets are within the operational limits of riser drilling by the *Chikyu* (i.e., maximum of 2500 m water depth and 7000 m subseafloor penetration). In the seaward portions of the Kumano Basin, the seismogenic zone lies ~6000 m beneath the seafloor (Nakanishi et al., 2002).

Seismic studies/Site survey data

A significant volume of site survey data has been collected in the drilling area over many years, including multiple generations of 2-D seismic reflection (e.g., Park et al., 2002), wide-angle refraction (Nakanishi et al., 2002), passive seismicity (e.g., Obara et al., 2004), heat flow (Yamano et al., 2003), side-scan sonar, swath bathymetry, and submersible and remotely operated vehicle dive studies (Ashi et al., 2002). In 2006, Japan and the United States conducted a joint, 3-D seismic reflection survey over a ~11 km × 55 km area, acquired by PGS Geophysical, an industry service company (Moore et al., 2009). This 3-D data volume is the first deep-penetration, fully 3-D marine survey ever acquired for basic research purposes and has been used to (1) refine selection of drill sites and targets in the complex megasplay fault region, (2) define the 3-D regional structure and seismic stratigraphy, (3) analyze physical properties of the subsurface through seismic attribute studies, and (4) assess drilling safety (Moore et al., 2007; Moore et al., 2009). These high-resolution, 3-D data will be used in conjunction with physical properties, petrophysical, and geophysical data obtained from core analyses and both wireline and LWD logging to allow extensive and high-resolution integration of core, logs, and seismic data.

The supporting site survey data for Expedition338 are archived at the **IODP Site Survey Data Bank.**

Long-term observatories

During future IODP expeditions, a series of long-term borehole observatories will be installed at IODP Sites C0002, C0009, and C0010. The three sites are located within and above regions of contrasting behavior of the megasplay fault zone and plate boundary as a whole (i.e., a site ~6–7 km above the locked seismogenic plate boundary [Site C0009], a site above the updip edge of the locked zone [Site C0002], and a shallow site in the megasplay fault zone and footwall where slip is presumed to be aseismic [Site C0010]). These observatories have the potential of capturing seismic activity, slow slip behavior, and possibly interseismic strain accumulation on the plate boundary and megasplay faults across a range of seismogenic settings. These temporal and spatial observations are necessary to understand how each part of the plate boundary functions through the seismic cycle of megathrust earthquakes.

Currently, the planned observation system for the boreholes consists of an array of sensors designed to monitor slow crustal deformation (e.g., strain, tilt, and pore pressure as a proxy for strain), seismic events including VLF earthquakes, hydrologic transients associated with strain events, ambient pore pressure, and temperature. To ensure the long-term and continuous monitoring necessary to capture events occurring over a wide range of timescales, these borehole observatories will be connected to a submarine cabled observation network called Dense Oceanfloor Network System for Earthquakes and Tsunamis (DONET) (**www.jamstec.go.jp/jamstec-e/maritec/donet/**), which will be constructed in and around the drilling target area.

Scientific objectives

Site C0002 background

The primary drilling plan for Expedition 338 is to extend Hole C0002F to ~3600 mbsf through riser drilling with the *Chikyu*. The hole will be suspended after casing is installed and cemented at the 13⅜ inch casing set point (Fig. F2). During Expedition 326 in 2010, the wellhead was installed and a 20 inch casing string was cemented in place to 860 mbsf.

The uppermost 1400 mbsf section at Site C0002 was previously logged with a comprehensive LWD program during Expedition 314 (Expedition 314 Scientists, 2009). The intervals 0–204 and 475–1057 mbsf were cored during Expedition 315 (Expedition 315 Scientists, 2009b). The Kumano forearc basin sedimentary package composes the interval from 0 to 940 mbsf, and it is underlain by the “inner wedge” deformed accretionary wedge package. The seismic reflection character of the entire zone from ~940 mbsf to the megasplay reflector at ~5200 mbsf exhibits virtually no coherent reflections that would indicate intact stratal packages, which is in contrast to the outer accretionary wedge seaward of the megasplay fault system (Figs. F2, F3) (also see Moore et al., 2009). This seismic character is thought to indicate complex deformation within the inner wedge, perhaps best characterized as a subduction mélange or protomélange. The anticipated lithology to be encountered during Expedition 338 is Miocene age hemipelagic mudstone and sand/silt turbidites with sparse volcanic ash, judging from the core recoveries and logs recovered during Expeditions 314 and 315. Whether the deeper accreted strata represent trench-wedge deposits, Shikoku Basin deposits, or both remains to be determined.

Site C0002 objectives

Accordingly, the main research objectives for this interval are to (1) sample the interior of the accretionary complex in the midslope region beneath the Kumano forearc basin with both cores and drill cuttings and (2) collect an extensive suite of LWD to characterize the formation. Sampling this previously unsampled interval will allow the (1) determination of the composition, age, stratigraphy, and internal style of deformation of the Miocene accretionary complex; (2) reconstruction of its thermal, diagenetic, and metamorphic history and comparison with present pressure-temperature (P-T) conditions; (3) determination of minimal horizontal stress within the deep interior of the inner wedge; (4) investigation of the mechanical state and behavior of the formation; and (5) characterization of the overall structural evolution of the Nankai accretionary prism and the current state of the upper plate above seismogenic plate boundary thrust.

The interval from 856 mbsf to target depth (proposed to be 3600 mbsf) will be drilled with continuous LWD resistivity, gamma radiation, and annulus fluid pressure data. During this riser drilling, mud return will allow for comprehensive analysis of drill cuttings and mud gas, as was performed at Site C0009 and described in the Expedition 319 *Preliminary Report* (Saffer et al., 2009). Coring (100 m total) is also planned to sample the inner wedge but is restricted to one interval from 2300 to 2400 mbsf.

Site C0002 drilling will therefore access the interior of the landward region of an active accretionary prism for the first time by scientific ocean drilling, testing hypotheses for the transition from aseismic prism growth to a strong hanging wall regime defining the outer edge of the geodetically locked or partially locked seismogenic plate boundary. Additionally, it will shed light on the nature of prism formation and evolution. The data collected will also define the physical properties of the sediments that create the discontinuous seismic signature. At the end of Expedition 338, the borehole will be suspended for reentry and further deepening to the planned plate boundary target during the 2013–2014 IODP riser drilling season.

Specific questions to be addressed by drilling into the deep interior of the inner wedge include

- What is the thermal, diagenetic, and metamorphic history of the sedimentary rock below the Kumano Basin?
- What is the budget for hydrous minerals (e.g., smectite group clays) and the extent of dehydration reaction progress as a function of depth?
- What is the mechanical and structural evolution of the inner wedge?
- Are there indicators of low effective stress, high pore pressure zones related to deformation?
- How do the properties of the inner wedge sediments compare with the Shikoku Basin sediments that are input to the wedge?
- What is the orientation of minimal horizontal stress within the deep interior of the inner wedge? How does the stress orientation relate to the current state of the earthquake cycle?
- What is the mechanical state and behavior of the formation and how does it relate to the current state of the upper plate above seismogenic plate boundary thrust?

- What are faulting processes and mechanisms and how do they vary with depth in the inner accretionary wedge?

Answering these questions will allow for inferences on the structural style (subduction mélange or protomélange versus deformed former outer wedge), connections between sediment dewatering and fluid pressure, and thus long-term evolution of the Nankai accretionary prism. The answers also provide a robust characterization of the inner wedge, which will ultimately be related to the deep section near the megasplay and plate boundary faults.

Performing experiments using cuttings at presumably in situ conditions, we can constrain mechanical and hydrological properties of the inner wedge materials. Analyses of continuous series of cuttings, even with poor resolution from mixing, would also provide information on the lithologic constituents and their variation with depth in the inner accretionary wedge and also compare them with those properties estimated by LWD.

Drilling strategy, operations plan, and downhole measurements

To meet the scientific and engineering objectives, primary operations in Hole C0002F will be to drill using LWD/measurement while drilling (MWD) until the 16 inch casing is set at 2300 mbsf (Fig. **F4**). Cuttings and mud gas will be collected and analyzed during riser drilling from 860.3 (bottom of 20 inch casing) to 2300 mbsf. Wireline coring will be conducted in Hole C0002F between 2300 and 2400 mbsf using a rotary core barrel (RCB) to obtain the highest quality and most complete core samples. Drilling and LWD/MWD logging and cuttings and mud gas analysis will continue to 3600 mbsf where the 13⅜ inch casing will be set.

Operations plan

The operations plan and time estimate (Table **T1**) are based on formations and depths inferred from seismic and regional geological interpretations combined with data from previous drilling operations at nearby sites. We will use these operations and data to guide the operations described during Expedition 338. The primary operational plan is to conduct operations in one hole at Site C0002 (Fig. **F3**); however, contingency plans have been developed. An abbreviated list of primary sites, holes, drilling depths, and contingency plans can be found in **"Contingency plans."**

Hole C0002F

During Expedition 326 in 2009, a 36 inch conductor casing was run and cemented to 54 mbsf. Following this, a 26 inch hole was drilled to 860.3 mbsf, cased with 20 inch casing, and then cemented. During Expedition 338, we will use reaming-while-drilling (RWD) technology, which allows for LWD/MWD analysis behind a 10⅝ or 12¼ inch bit while simultaneously opening the hole behind the LWD/MWD bottom-hole assembly to 20 or 17.5 inches (Fig. **F5**). The first drilling interval will be from 860.3 to 2300 mbsf, and we will set and cement the 16 inch casing (Fig. **F4**). We will then RCB core from 2300 to 2400 mbsf. A second RWD/MWD interval will extend the hole to 3600 mbsf, where the 13⅜ inch casing will be set and cemented. If there is enough time after setting the 13⅜ inch casing, a second coring interval may be added as a contingency option.

Logging/downhole measurements strategy

Hole C0002F

During drilling of Hole C0002F, MWD/LWD tools will be run between 860.3 and 3600 mbsf. This provides the ability to monitor drilling parameters and conditions and to collect gamma ray and resistivity logs to define major lithologic changes in real time (MWD) as well as record high-resolution borehole and formation conditions (LWD). The MWD tool suite will include annular pressure while drilling, weight on bit, torque, hole inclination, and gamma radiation. The geoVISION LWD tool will be added to this suite to obtain LWD azimuthal resistivity data and borehole resistivity images in order to further define stratigraphic boundaries and to characterize bedding, minor faults, and any breakouts or tensile fractures induced by drilling. In addition, and pending tool and budget availability, a sonicVISION LWD tool or a proVISION tool will be included in the logging suite. SonicVISION would provide compressional velocity data during drilling. ProVISION (nuclear magnetic resonance) would provide mineralogy-independent porosity, fluid volumes, and permeability data on the formation during drilling. Feasibility studies to assess the impact of RWD on data fidelity are ongoing.

Sampling and sample coordination

Expedition 338 will sample cuttings and mud gas from riser drilling intervals that are not cored (860–2300 and 2400–3600 mbsf) as well as a limited number of sediment cores (2300–2400 mbsf). Sampling and sample coordination for cuttings and mud gas will involve a combination of shipboard analysis, sample collection, and sample archiving based on the approach that was first used at Site C0009 during Expedition 319. This approach built on experience transferred from the oil industry and from the International Continental Scientific Drilling Program SAFOD drilling program. The core and cuttings sampling strategy was developed by the PMT and Specialty Coordinators in consultation with the Sample Allocation Committee (SAC) (see **"Sample requests and coordination"** below) to best meet the drilling project's objectives and the needs of the science party. Sampling of cores will include whole-round and discrete sampling following traditional IODP sample policies. Basic shipboard sampling, community samples, and individual sample requests will be coordinated by the SAC and exact numbers and location of samples will be based on core recovery. A short review of core sampling and archiving is provided below followed by a more detailed discussion of sampling and archiving of cuttings. Shipboard and shore-based researchers should also refer to the IODP Sample, Data, and Obligations Policy (**www.iodp.org/program-policies/**) for additional details about obtaining and using samples.

Sampling sediment cores

Prior to any whole-round or discrete sampling of cores, all cores will be imaged with X-ray computed tomography (CT). Time-sensitive sample (e.g., interstitial water, microbiology, and anelastic strain recovery) whole rounds will then be subsampled (Fig. **F6**). Whole-round core sections will then be nondestructively analyzed in the multisensor core logger. After nondestructive logging, nontime-sensitive whole-round samples (e.g., community whole rounds and science party research samples) will be taken as approved by the Co-Chief Scientists. Then cores will be 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 used for stratigraphic and structural characterization and archived to preserve retrieved material while providing flexibility and broader access to important material postexpedition.

The unique, multiexpedition nature of NanTroSEIZE has also required the modification of traditional IODP sampling policy and routines in sampling sediment cores. Specifically, these include: (1) community whole-round samples that are archived (at the Kochi Core Repository [KCC]) for postexpedition distribution as approved by the SAC and (2) cluster samples taken for a suite of basic scientific measurements collected onboard and shore-based from a much smaller (1–2 cm thick) whole-round core. These basic measurements consist of carbonate content, moisture and density (MAD), grain size, bulk X-ray fluorescence (XRF), bulk X-ray diffraction (XRD), and clay-size XRD. Community whole-round cores and sample clusters are typically adjacently located and collected approximately one or two per core. We note that, due to the highly lithified core expected at these depths, squeezing for pore water will be impossible, so fluid chemistry will have to follow the GRIND method (Expedition 315 Scientists, 2009a).

Community whole-round core samples

As usual, individual scientists will collect samples for shipboard analyses and their postexpedition research. In addition, we intend to collect "community" archive samples, especially whole-round samples. These community samples will augment and/or provide redundancy for whole-round core samples requested by shipboard and shore-based scientists. The goal is to preserve a wide range of sample material for geotechnical characterization to help achieve the overall science objectives after the expedition and over the duration of the NanTroSEIZE project. Community whole-round cores are typically collected from each core after X-ray CT imaging as determined by the Co-Chief Scientists.

Cluster samples

To ensure achievement of overall NanTroSEIZE scientific objectives and maximize the ability to correlate different shipboard and shore-based data sets, it will be essential to co-locate suites of essential data types (pore water, calcium carbonate content, MAD, bulk XRD, grain size, bulk chemistry, cation exchange capacity, and clay mineral XRD). This will be done with appropriate and consistent sample spacing throughout each site's stratigraphic succession. Sample clusters are normally collected from each section. In addition, a cluster sample is taken adjacent to each whole-round sample.

Sampling and archiving drill cuttings

Unwashed drill cuttings are delivered continuously to the shale shaker, where they are sampled by the "Sample Catcher" at a frequency equivalent to every 5 m of drilling penetration (Fig. F7). The Sample Catcher then splits the cuttings into two splits: one for the Mud Logger and the second for IODP scientific analysis. The IODP cuttings sample has a volume of ~1.5 L, depending on the volume of total sample requests, and is transferred to the Laboratory Roof Deck (by a Mantle Quest Japan "Roustabout"), where it is again split into two portions: a 400 cm^3 portion for archiving (the "archive portion") and a 1000 cm^3 portion for analysis and sampling (the "working portion"). The working portion is available for scientific sampling and analysis at any stage of the cleaning, sieving, and preliminary analysis shown in Figure F7 (potential sampling intervals are noted with diamonds). A portion of the archived cuttings (designated as a "temporary archive") is also available for sampling and analysis after the moratorium and approval of the SAC. Shipboard analysis of the "working portion" normally includes gamma ray, MAD, lithologic and structural (microstructures) descriptions (through smear slides and thin sections, respectively), XRD and XRF analyses, magnetic susceptibility, total carbonate (using carbonate analyzer), and total carbon and nitrogen (using CHNS/O elemental analyzer). If possible, pore fluids will also be extracted from cuttings using the GRIND method (Expedition 315 Scientists, 2009a). The archive portion will be separated into an unwashed split and a washed split, both of which will be archived at KCC. Samples will be sorted, when possible, by lithology after sieving with magnets and seawater.

Sample requests and coordination

Because NanTroSEIZE is a long-term, multiexpedition drilling project that includes multiple 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 the role 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 the overall NanTroSEIZE goals. Specialty Coordinators, in collaboration with Co-Chief Scientists, are responsible for facilitating collaborations between all of the participants on the two parts of Expedition 338, as well as identifying research or sampling gaps or collaborations across the project that are needed to achieve the overall NanTroSEIZE scientific goals. They will also provide technical and scientific guidance to each science party before, during, and after the expedition to ensure uniform and consistent data sets and nomenclature. The NanTroSEIZE PMT has identified six specific research areas that require special effort over the project's duration:

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

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, planned, or ongoing expedition. In this context, all Expedition 338 scientists are required to submit a request for data/samples from other IODP expeditions, including Expedition 315 (which cored the upper part of Site C0002), if they are interested in conducting postexpedition research that furthers the science objectives of those expeditions. Expedition 338 participants are also encouraged to review the postexpedition science of NanTroSEIZE Stages 1 and 2 to identify potential collaborative projects or research gaps that they can help address. In the broader scientific context of NanTroSEIZE, it is also possible that drilling or scientific objectives will overlap across two or more expeditions and science parties to such an extent that the expeditions will be treated as one project in terms of shipboard data and samples. In cases of formal merger of expeditions by the PMT, 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 SAC and the Co-Chiefs of the involved expeditions. This is somewhat different than most previous ODP and IODP expeditions but will follow the precedent and procedures defined during NanTroSEIZE Stage 1 drilling (Kinoshita, Tobin, Ashi, Kimura, Lallemant, Screaton, Curewitz, Masago, Moe, and the Expedition 314/315/316 Scientists, 2009).

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 before, during, or after the expedition as necessary to acquire samples or data that will help address fundamental questions of Expedition 338 or individual research projects. Requests will also be submitted by shore-based participants, but in cases of overlap or potential conflict, the shipboard scientists will be given higher priority. The initial sample requests provide the basis for the SAC and Specialty Coordinators to develop an integrated sampling program of both shipboard and shore-based sample requests to meet all of the essential postexpedition research objectives and avoid unnecessary duplication of effort. 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, sample requests are due by 1 June 2012.

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/**) to submit their requests.

Additional sampling guidelines

The SAC is composed of the expedition Co-Chief Scientists, Expedition Project Managers (EPMs), the shipboard curatorial representative, and the IODP curator on shore. Specialty Coordinators provide advice to the SAC, but the SAC is responsible for all decisions. The SAC for the expedition(s) must approve access to data and core/cuttings samples requested during the expedition and during the 1 year 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/cuttings 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' postexpedition research may be conducted during the expedition, or may be deferred to postexpedition.

Contingency plans

Contingency operational options

The details of possible operational priorities or contingencies will be determined by the Co-Chief Scientists, EPMs, Chief Project Scientists, PMT, and Operation Superintendents; however, current preliminary discussion includes (Fig. **F8**)

- Coring Hole C0002F beyond 3600 mbsf,
- Logging at Site C0012 (input site) with LWD, and
- Logging at Site C0007 (frontal thrust site) with LWD.

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Table T1. Expedition 338 operations and time estimates.

Operation	Depth (mbsf)	Days	Subtotal (d)	Total (d)
Transit, deploy transponders, retrieve corrosion cap, preparation for spud	—	5.0	5.0	5.0
Run and set BOP and riser, test BOP	—	11.0	11.0	16.0
Set 16 inch casing				
DOC and LOT	850	2.0		
Drill RWD (LWD) to 2300 mbsf	2300	9.0		
Run and cement 16 inch casing	2300	6.0		
Test BOP	—	2.0	19.0	35.0
Set 13-3/8 inch casing				
DOC and LOT	2300	2.0		
Cut core from 2300 to 2400 mbsf	2400	4.0		
Underream (LWD) to 17 inch hole from 2300 to 3600 mbsf	3600	16.0		
Run and cement 13-3/8 inch casing to 3600 mbsf	3600	6.0		
Test BOP (2 times)	—	4.0	32.0	67.0
Suspend hole				
Set cement plug or bridge plug in hole	—	3.0		
Retrieve BOP and marine riser	—	9.0	12.0	79.0
Set corrosion cap, retrieve transponders	—	2.0	3.0	82.0
Transit to Shingu	—	1.0		
Contingency	—	20.0	20.0	102.0
Mechanical down time (operation time × 3%)				
Wait on weather (operation time × 1.5%)				
Typhoon evacuation (4 times × 4 days)				

Water depth = 1968 m. BOP = blowout preventer. DOC = drill out cement. LOT = leak-off test. RWD = reaming while drilling, LWD = logging while drilling.

Figure F1. Map of NanTroSEIZE region, showing all Stage 1 and 2 sites. Box = region with 3-D seismic data, diamond = Expedition 338 site, circles = Stage 1 and 2 sites.

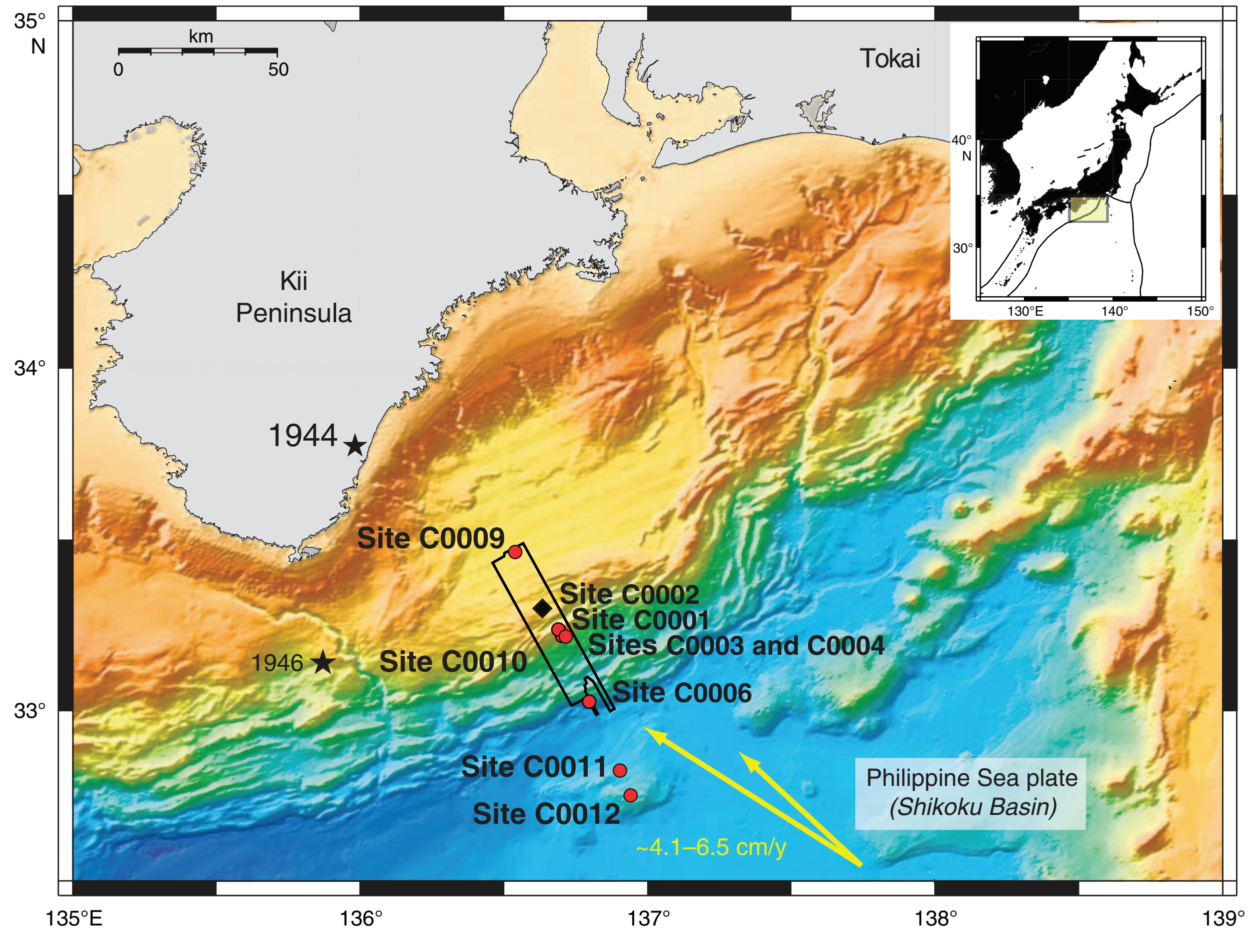


Figure F2. In-line (IL) 2529 extracted from 3-D seismic volume, showing Hole C0002F in relation to Stage 1 Sites C0001, C0003, and C0004. Dashed extension below the green box = ultimate planned plate boundary interception at ~7000 mbsf, red box = 20 inch casing to 856 mbsf, yellow box = planned casing set point for 16 inch casing, green box = planned casing set point for 13-3/8 inch casing. Target depth for Expedition 338 is 3600 mbsf at the planned 13-3/8 inch casing shoe position. VE = vertical exaggeration.

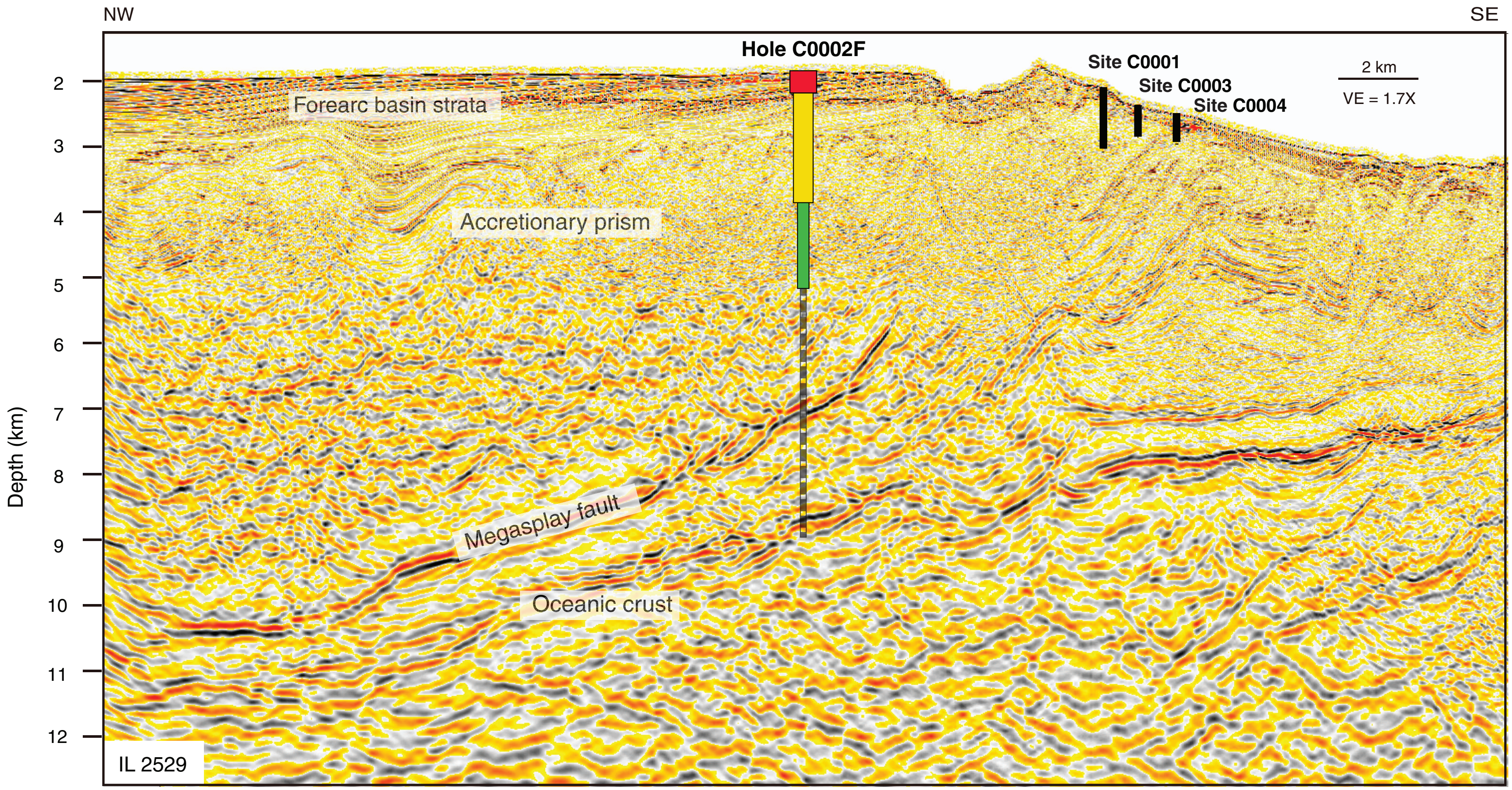


Figure F3. Schematic of the planned final configuration of Hole C0002F. The planned total depth of Expedition 338 (~3600 mbsf, and casing strings, shown in red) is indicated in relation to the long-term borehole monitoring system (LTBMS) observatory installed (Expedition 332) in a riserless hole in the top 1000 m of the formation. Final operations include coring sidetracks planned at the megasplay fault and the plate boundary. Green = previously drilled and cased section, red = Expedition 338 targets, blue = future deep riser targets. BSR = bottom-simulating reflector, LWD = logging while drilling.

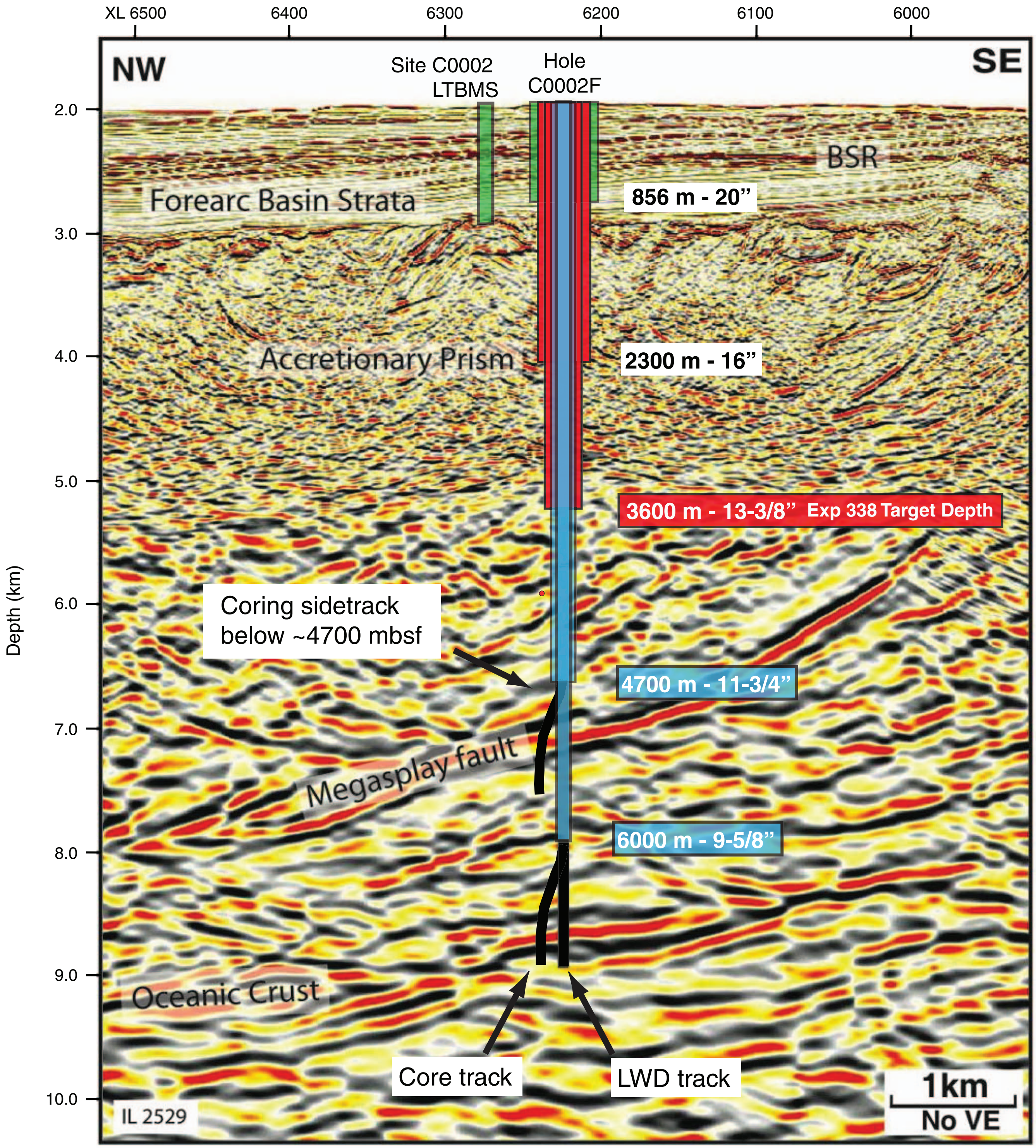


Figure F4. Schematic diagram showing drilling operations sequence, Hole C0002F. BOP = blowout preventer, LWD = logging while drilling.

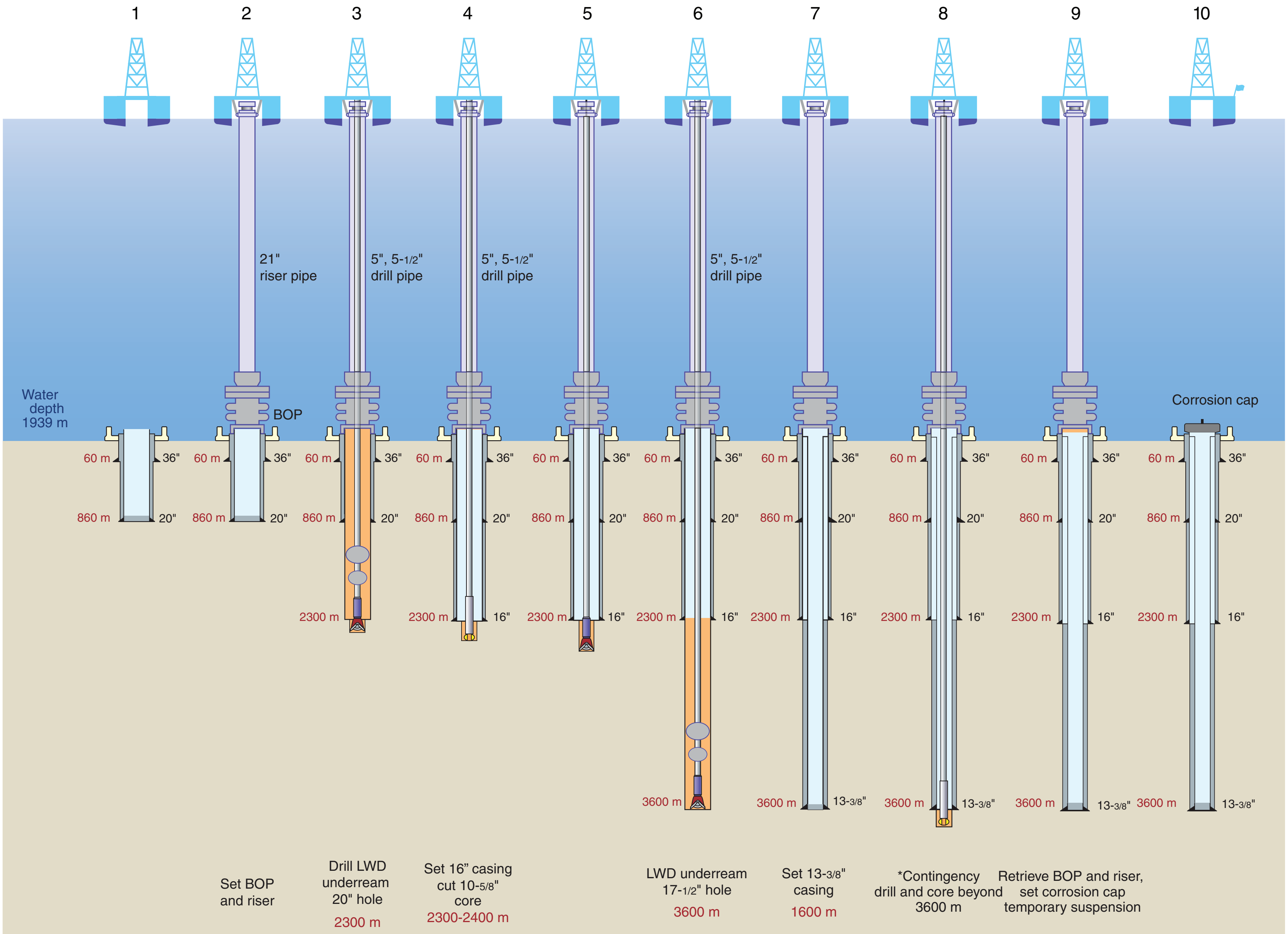


Figure F5. Schematic diagram of reaming while drilling. A tool to drill a pilot hole, which enlarges the hole diameter. Tool can be installed with the logging-while-drilling (LWD) and measurement-while-drilling (MWD) tools. NMDC = nonmagnetic drill collar.

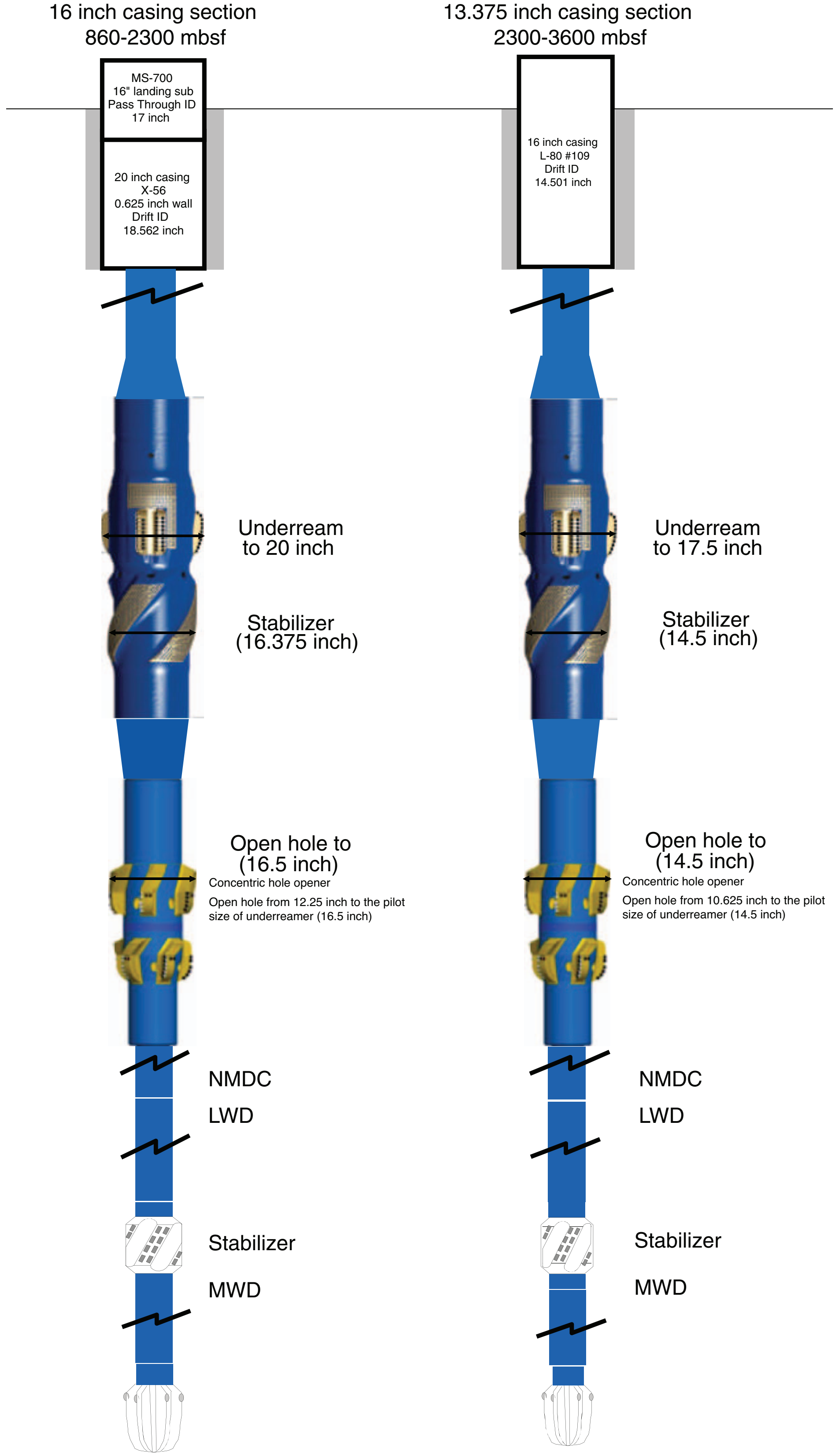


Figure F6. Schematic diagram of core flow. CT = computed tomography, WR = whole round, IW = interstitial water, RMS = routine microbiology sample, MSCL-W = whole-round multisensor core logger, AMS = anisotropy of magnetic susceptibility, SQUID = superconducting quantum interference device, TIC = total inorganic carbon, CA = carbonate analyzer, TC = total carbon, EA = elemental analyzer, XRD = X-ray diffraction, XRF = X-ray fluorescence.

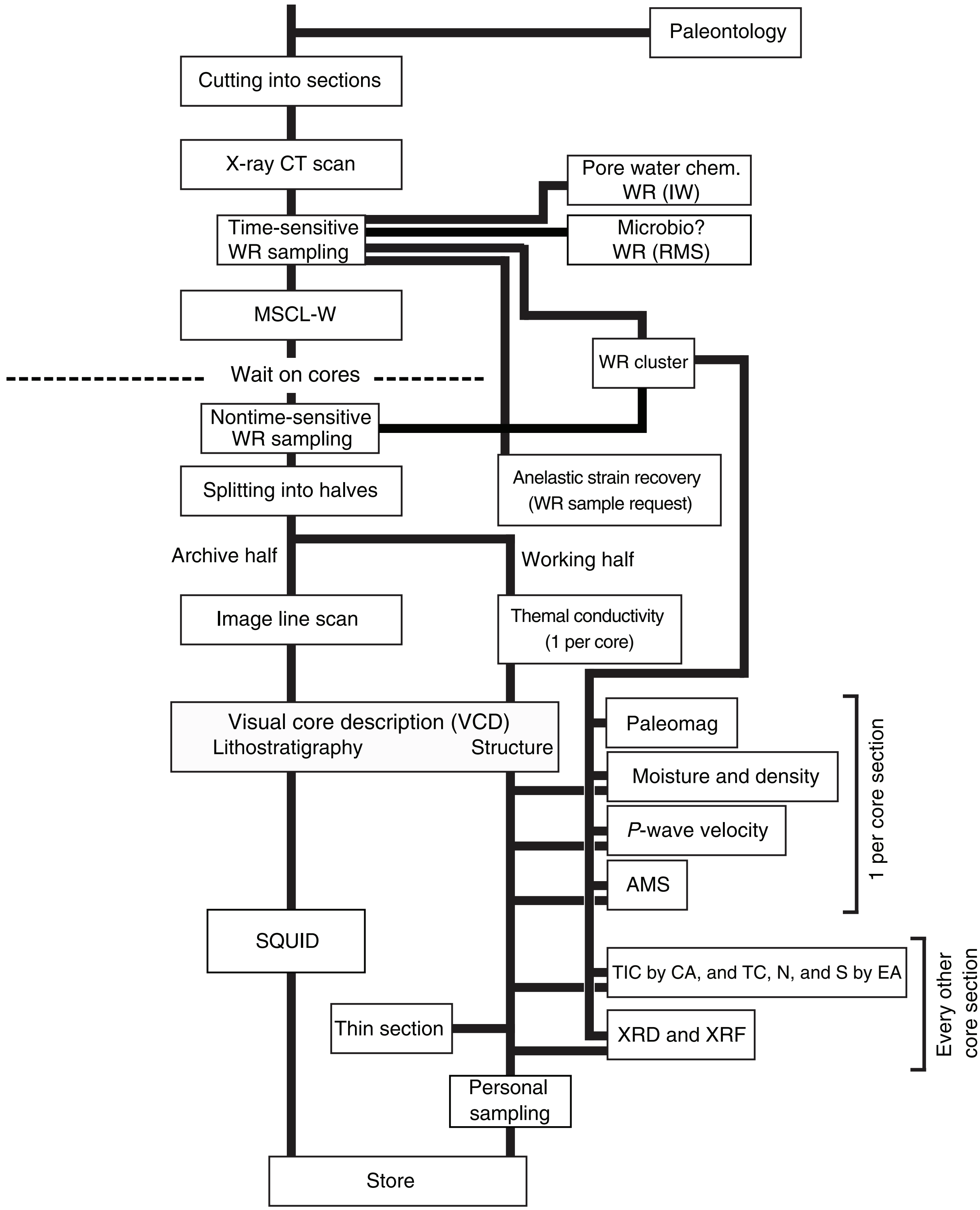


Figure F7. Washed cuttings work flow (from Expedition 319). EPM = Expedition Project Manager, CC = Co-Chief Scientist, LO = Laboratory Officer, PA = Publications Assistant, CU = Curator, A, B, C, D = scientists, a, b, c, d, e = lab techs/scientists. NGR = natural gamma ray, QA/QC = quality assurance/quality control, MAD = moisture and density, XRD = X-ray diffraction, XRF = X-ray fluorescence, TCC = total carbonate content, CA = carbonate analyzer, TC = total carbon, EA = elemental analyzer.

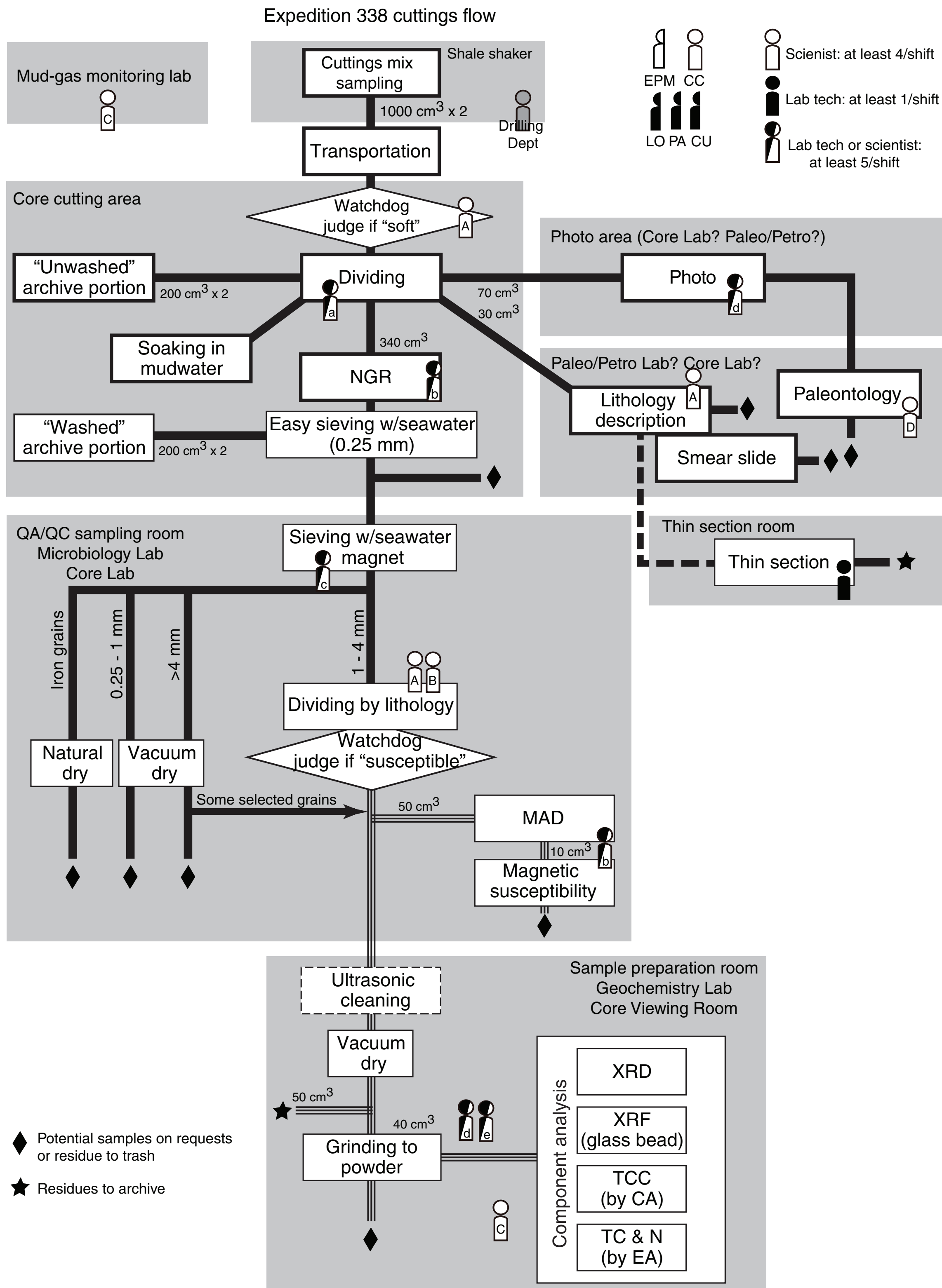
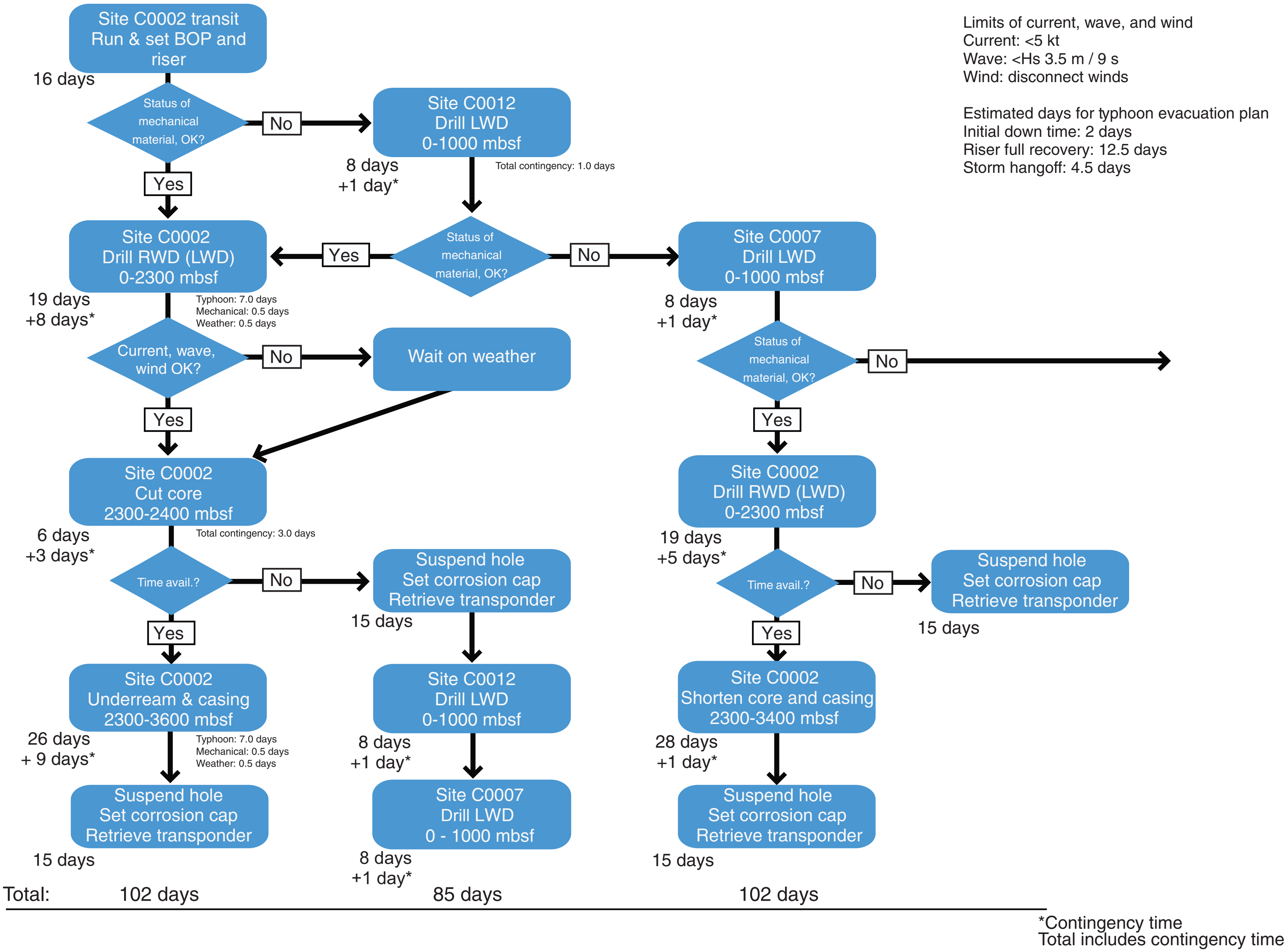


Figure F8. Operations contingency plan, Expedition 338. Time required for operational segments, decision points, and decision point conditions as described in the legends. BOP = blowout preventer, LWD = logging while drilling, RWD = reaming while drilling.



Site summaries

Hole C0002F

Priority:	Primary: *Chikyu* Expedition 338 (riser)
Position:	33°18.507′N, 136°38.2029′E
Water depth (m):	1968
Target drilling depth (mbsf):	3600
Approved maximum penetration (mbsf):	7000
Survey coverage:	Extensive data from 3-D seismic data: • In-line 2553 • Cross-line 6228
Objective:	• Drill and case hole • Take cuttings and core samples to define lithostratigraphy, physical properties, and composition • Constrain in situ stress and pore pressure
Drilling, coring, and downhole measurement program:	*Chikyu* Expedition 338: • RCB coring (2300–2400 mbsf) • LWD/MWD • Cuttings analysis
Anticipated lithology:	Hemipelagic mud, mudstone, and siltstone/sandstone

Site C0007

Priority:	Expedition 338 contingency
Position:	33°01.2326′N, 136°47.9485′E
Water depth (m):	4081.0
Approved penetration depth (mbsf):	1400
Objective:	• Collect logging data to complement core samples collected during Expedition 316
Drilling program:	• Logging with LWD
Anticipated lithology:	• 0–440 mbsf: alternating mud and sand layers (accreted trench strata) • 440–1400 mbsf: interbedded mud and sand layers (trench wedge)

Site summaries (continued)

Site C0012

Priority:	Expedition 338 contingency
Position:	32°44.888′N , 136°55.024′E
Water depth (m):	3510.7
Total depth (DRF, m):	4115.0
Approved penetration depth (mbsf):	800
Objective:	• Collect logging data to complement core samples collected during Expedition 322
Drilling program:	• Logging with LWD
Anticipated lithology:	• 0–600 mbsf: Shikoku Basin hemipelagic sediments • >600 mbsf: volcaniclastic sediments and basalt

Scientific participants

The current list of participants for Expedition 338 can be found at **www.jamstec.go.jp/chikyu/eng/Expedition/.**