Integrated Ocean Drilling Program
Expedition 343 Scientific Prospectus

Japan Trench Fast Earthquake Drilling Project (JFAST)

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Disclaimer

This IODP *Scientific Prospectus* is based on precruise Science Advisory Structure panel discussions and scientific input from the designated Co-Chief Scientists on behalf of the drilling proponents. During the course of the cruise, actual site operations may indicate to the Co-Chief Scientists, the Expedition Project Manager, and the Operations Superintendent that it would be scientifically or operationally advantageous to amend the plan detailed in this prospectus. It should be understood that any proposed changes to the science deliverables outlined in the plan presented here are contingent upon the approval of the CDEX Science Operator Science Manager in consultation with IODP-MI.

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Abstract

The 2011 Tohoku earthquake (Mw 9.0) off the Pacific coast of Japan produced huge slip (~50 m) on the shallow portion of the fault close to the toe of the megathrust. The large displacement on this portion of the subduction zone and the magnitude of the devastating tsunami that took more than 19,000 lives and inflicted massive damage along the northeast coast of Honshu was unexpected by earthquake scientists. The main science goal of the Japan Trench Fast Earthquake Drilling Project (JFAST) is to understand the physical mechanisms and dynamics of large slip earthquakes, which is a fundamental issue that is currently poorly understood. Specifically, the level of frictional stress during the earthquake rupture and the physical characteristics of the fault zone will be investigated. This topic has obvious social consequences globally for evaluating severe shaking and large tsunamis from future earthquakes at subduction zones. The scientific objectives of JFAST include characterizing the fault and wall-rock composition, fault architecture, and the nature of heat and pressure within and around the fault zone, located approximately 1000 m below seafloor. Two riserless holes will be drilled during Integrated Ocean Drilling Program (IODP) Expedition 343: one logging-while-drilling hole to determine in situ stress and locate the fault zone and one hole to acquire core samples from the fault zone. Each hole will be completed with an observatory deployment comprising a suite of temperature and pressure sensors.

Schedule for Expedition 343

Integrated Ocean Drilling Program (IODP) Expedition 343 is based largely on IODP drilling Proposal 787 (available at **www.iodp.org/700/**). The expedition is scheduled for the D/V *Chikyu*, operated under contract with the Japanese Implementing Organization, Center for Deep Earth Exploration (CDEX). At the time of publication of this *Scientific Prospectus*, the expedition is scheduled to depart Shimizu, Japan, on 1 April 2012 and return to the same port on 24 May 2012. A total of 48 days (plus 6 days of transit time) will be available for drilling, logging, coring, and deployment of borehole instrumentation (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.**

Background

The Tohoku Mw 9.0 earthquake and tsunami devastated northern Japan and the catastrophe highlighted many of the gaping unknowns in earthquake science. The largest slip ever recorded in an earthquake occurred in a largely unexpected location. On the basis of historical records of seismicity and previous studies of the rheology and behavior of the shallow subduction megathrusts, earthquake scientists did not anticipate a Mw 9.0 earthquake near Japan that ruptured to the trench with slip magnitudes of ~50 m (Ozawa et al., 2011; Avouac, 2011; Ito et al., 2011; Ide et al., 2011; Sato et al., 2011).

The scientific community has an obligation to learn as much as possible from this extreme event about the forces that operate during and immediately after an earthquake. Specifically, we need to observe the effects of the earthquake on the fault zone so that we can recognize such an event elsewhere in the geological record. Furthermore, we need to determine the processes that resist slip so that we can predict the circumstances under which large slip is likely to happen at the seafloor where devastating tsunamis could be generated. The extreme slip of the Tohoku earthquake and the extraordinary monitoring data available in Japan together provide an unprecedented ability to address these questions.

Expedition 343 will drill into the Tohoku subduction zone in order to measure the fault zone physical properties, recover fault zone material, and directly record the temperature anomaly from coseismic frictional slip, which is the best method to determine the absolute resistive strength of a fault during dynamic slip (Brodsky et al., 2009). All of these observations have bearing on the most important observational gap inhibiting progress on physical models of faults: measures of stress. If the stresses are known, we can predict the behavior of a rupture and understand the conditions under which slip progresses over the complex geometry of the fault.

Stress both during and after the earthquake can be determined from a variety of observations accessible through a borehole (e.g., Lin et al., 2011). Stress measurements from breakouts and core relaxation measure the postseismic stress field. Geological textures and their relationship to laboratory experiments constrain the processes governing stress during the earthquake (e.g., Ujiie and Tsutsumi, 2010). Temperature records the absolute value of stress during the high-speed slip of the earthquake itself, which is perhaps the stage of stress least well known at this time. The frictional stress during the earthquake results in heating of the fault that persists after the earthquake.

Stress-related measurements need to be acquired soon after an earthquake to be useful. Expectations of fault stress vary widely (thus necessitating direct constraints), and several recent laboratory experiments suggest that during a large earthquake the frictional strength can be so low that the thermal signature would be small and decay to unobservable levels within 5 y. Since the drilling process itself temporarily disturbs the temperature field, a few months must pass after the completion of drilling for successful measurements. Furthermore, interpretation of the thermal anomaly can be greatly improved if the rate of temperature change is monitored for at least 1 y and initial measurements are taken within 1–2 y after the earthquake (Fulton et al., 2010). To obtain data within 2 y of the 11 March 2011 earthquake, drilling of the borehole must be completed by January 2013, allow thermal stabilization for 2 months, and then observe temperatures prior to March 2013 (continuous measurements will actually begin earlier, when the borehole is completed). Therefore, this project has been fast-tracked by the Science Planning Committee to begin as soon as possible to maximize the opportunity to capture this important and fleeting signal.

Geological setting

The 2011 Tohoku earthquake and tsunami originated from slip on the megathrust fault surface west of the Japan Trench where the Pacific plate of Cretaceous age subducts below Honshu Island (Fig. **F1**). The subduction zone is characterized by a relatively rapid convergence rate of ~8 cm/y (e.g., Apel et al., 2006), much seismic activity, and a deep trench. The convergent margin of the Japan Trench displays the features generally associated with subduction erosion (von Huene et al., 1994, 2004; Tsuru et al., 2000), specifically, evidence of subsidence in the Neogene with associated extensional faulting in the middle slope region, horst, and graben structure in the upper portion of the subducting plate and a relatively small frontal prism (5–15 km wide) containing landward-dipping reflectors and a backstop bounding the frontal prism on the landward side.

The structure and lithology of the forearc region of northern Japan was investigated during previous ocean drilling, specifically by Deep Sea Drilling Project (DSDP) Legs 56 and 57 and later drilling to establish observatories during Ocean Drilling Program Leg 186. Leg 186 Sites 1150 and 1151 are located above the slipped area of the Tohoku earthquake ~100 km north of the epicenter and the region of maximum slip at the trench, and Leg 56 and 57 Sites 434–441 are located approximately 50–100 km further north. In this region, the Japan Trench system consists of a deep-sea terrace, inner trench slope, midslope terrace, trench lower slope, the trench, and outer trench slope

(Arthur and Adelseck, 1980). A forearc basin formed at the deep-sea terrace contains a sequence as thick as 5 km of Neogene sediments overlying a Cretaceous unconformity that correlates with the regional unconformity and geologic relations on land. The overlying sediments extend trenchward through the midslope terrace to the backstop boundary, with the frontal prism forming the trench lower slope (e.g., Tsuru et al., 2000). Seismic profiling indicates the structure in the northern Japan Trench is similar through the region to the south that ruptured during the Tohoku event (Tsuru et al., 2002).

The frontal prism is characterized by lower seismic velocity than just landward of the backstop, and the prism displays only disrupted-to-chaotic reflection patterns that likely indicate strong deformation (e.g., Tsuru et al., 2000). Coring of the toe region of the frontal prism at DSDP Site 434 revealed the prism is composed of a highly disrupted, very uniform hemipelagic deposit (Shipboard Scientific Party, 1980). The major constituents are terrigenous silty clay, biogenic silica, and vitric ash. Biostratigraphic observations indicate structural complexity in the prism, with repletion of assemblages that could record slumping, sliding, and faulting. Significant induration of the sediments occurs at depths below ~100 m, and the mudstones recovered are highly fractured with slickensided faces. The highly fractured and disrupted structure contributed to the difficulties of coring and poor core recovery at the site.

Seismic studies and site survey

The offshore Tohoku region is well characterized from decades of data collection, including some high-resolution surveys of bathymetric and seismic reflection data taken after the 2011 Tohoku earthquake (Fig. **F2**). A differential bathymetry analysis across the trench axis eastward of the hypocentral area, using bathymetric data collected along the same track before and after the earthquake, demonstrates considerable topographical changes on the landward side of the trench. From this analysis, Fujiwara et al. (2011) demonstrate movement of 50 m horizontal toward the southeast and 10 m vertically upward. In addition, a large submarine landslide scarp on the lower trench wall and associated slump deposits in the trench are indicated by the distinct negative and positive seafloor elevation changes at the trench. A critical result is that the coseismic displacement of the 2011 Tohoku earthquake extended all the way to the landslide scarp, if not to the trench axis proper (Fig. **F2**). The pervasive and similar magnitude of displacement eastward along the profile shows that the frontal prism was displaced as a unit along a fairly uniform dipping detachment surface.

Analysis of other data sets also points to coseismic slip on the order of 50 m that extends to the trench (e.g., Ito et al., 2011; Ide et al., 2011; Simons et al., 2011).

Based on existing seismic data sets, three possible fault interfaces that may have experienced coseismic slip have been identified as potential targets for rapid response drilling:

- The interface near the trench between the subducting plate and the overriding frontal wedge (hereafter referred to as the plate interface or detachment surface),
- Backstop interface, including other reverse faults imaged in the wedge-shaped, low-velocity frontal prism between the plate interface and the Cretaceous unit to the west, and
- Normal faults cutting the unconformity at the top of Cretaceous unit.

All these interfaces occur at depths that can be reached with riserless drilling. Based on the differential bathymetry (Fig. F2) and the geometric continuity with the deeper main detachment surface, the plate interface is considered to be the most likely fault surface of large displacement during the earthquake. This fault is seen as the weak reflector located ~100 m above the strong reflector at ~900 meters below seafloor (mbsf) (Fig. F2). The strong reflector is interpreted as the sediment/basement interface of the subducting Pacific plate.

In general, the plate interface shallows toward the trench, but the water deepens. Based on technical information from CDEX engineers, the maximum water depth for drilling of the proposed borehole and observatory is 7000 m. Generally, the plate interface at a water depth of ~7000 m is shallower near 38°N and deeper further north. On the basis of existing seismic data, a primary site (JFAST-3) and an alternate site (JFAST-4) have been identified that minimize both water depth and depth below the seafloor.

The supporting site survey data for Expedition 343 are archived at the **IODP Site Survey Data Bank.**

Science objectives

The science objectives are closely aligned with the overall goals of IODP. In the IODP Initial Science Plan, research concerning solid earth cycles and geodynamics highlights the seismogenic zone initiative, which advocates subduction zone studies that include investigating the behavior of rocks and sediments to better understand the fault zone and integration with studies of earthquake mechanics. Deformation microstructures and physical rock properties at in situ conditions, along with observatory monitoring of temperature, pore pressure, and stress, are also emphasized in the plan. These are all key components of the Japan Trench Fast Earthquake Drilling Project (JFAST). Furthermore, JFAST directly addresses Challenge 12 of the IODP Science Plan for 2013–2023: "What mechanisms control the occurrence of destructive earthquakes, landslides, and tsunami?'"

The prioritization of science objectives reflects the unique possibilities provided by rapid response drilling into a slipped fault following an earthquake. The shallow distribution of large slip for the Tohoku earthquake provides an unprecedented ability to directly access a fault that has recently moved tens of meters. As outlined in the report from the International Continental Scientific Drilling Program/Southern California Earthquake Center international workshop on rapid response drilling (Brodsky et al., 2009), fundamental questions regarding stress, faulting-related fluid flow, and the structural and mechanical characteristics of the earthquake rupture zone can be addressed uniquely through rapid response drilling.

Specifically, the science objectives and strategies for achieving them are as follows:

1. What was the stress state on the fault that controls rupture during the earthquake and was the stress completely released?
    - Dynamic friction during the rupture: potentially the most significant result of this project will be a value for the dynamic frictional stress. Time decaying temperature measurements will be used to estimate the frictional heat produced at the time of the earthquake, which can be used to infer the level of dynamic friction.
    - Rupture to the toe of the accretionary wedge: past thinking was that sediments in this region are weak and rate strengthening, so earthquake instability should not nucleate or easily propagate through this region. Measurements of current stress and stress during the earthquake can be used to explore different models to explain how dynamic slip occurred. Hydrogeological measurements can constrain the healing of the fault.
2. What are the characteristics of large earthquakes in the fault zone, and how can we distinguish present and past events in fault zone cores?
    - Core analyses: detailed analyses of textures and small-scale structures of core samples of the fault zone will be used to infer the role of fluids and pressuriza-

tion during rupture. We will look for evidence of melting and other processes that contribute to dynamic strength reduction. Trace elements will be used to estimate the thermal history of the recent and past events.

- Laboratory experiments: high-speed friction and petrophysical experiments on fault material can be used to characterize the frictional behavior of the fault.

Secondary science objectives include carrying out other geological, geochemical, and microbiological observations to the greatest extent possible during drilling in accordance with the IODP Measurements document (**www.iodp.org/program-policies/**). As a specific example, there is some evidence that great amounts of hydrogen may be released at the time of large faulting (e.g., Kita et al., 1982). The massive amounts of hydrogen may greatly stimulate microbiological activity; thus, samples of the fault may contain records of biogeochemical and microbiological processes.

Drilling, coring, and instrumentation plan

The general operations plan and time estimates are provided in Table **T1** and Figure **F3A** and **F3B.** Although site survey data analysis, contingency planning, engineering, and working out the technical details for placing instruments in the boreholes are ongoing at the time of writing this *Scientific Prospectus*, the prioritization of the main activities and overall sequencing is not expected to change. However, given the compressed time frame for planning the project and the likelihood of encountering difficult drill site conditions, we expect that some details of the operational plan will be modified before and during the expedition. Purposefully including some redundancy in the instrumentation plan, contingency planning, and identification of alternate drill sites will greatly contribute to successfully meeting the scientific goals of the expedition.

The main operations to be completed during Expedition 343 consist of drilling two boreholes (Holes A and B) at a single location (e.g., proposed Site JFAST-3); the first hole is dedicated to collecting downhole geophysical data, and the second hole is dedicated to retrieving core samples from across the Tohoku earthquake slip surface. An observatory will be established to acquire temperature within each borehole from across the fault and fluid pressure data in one hole from inside and outside the fault zone. The sequencing of operations reflects the prioritization of the activities and engineering constraints.

The most important goal of the project is to gather repeated temperature measurements across the fault zone to determine the amount of frictional heat generated by the earthquake and constrain the dynamic frictional strength of the fault. Accordingly, each borehole will be instrumented with a multisensor temperature measurement string. Observations of a decaying temperature signal will be used to estimate the level of dynamic friction during the large rupture. To obtain good resolution of the thermal signal, calculations show that initial measurements need to be started within about 2 y following the earthquake, with measurements continued over subsequent years. In addition to the temperature observations, other time-sensitive measurements such as borehole stress provide insights on the rupture mechanics. Observatory data that are recorded in the borehole will be retrieved later using the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) remotely operated vehicle (ROV) *Kaiko*.

The sequence of operations to be completed during Expedition 343 consist of

1. Drilling the pilot hole with logging while drilling (LWD)/measurement while drilling (MWD) to total depth (TD), currently planned for ~900 mbsf;
2. Running casing and completion assembly (including long-term temperature monitoring with the autonomous string) in LWD/MWD hole to ~900 mbsf (casing to 100 m below fault, ~900 m);
3. Drilling second hole with rotary coring barrel (RCB) drilling (with center bit) to ~500 mbsf and continuation with RCB coring to ~900 mbsf; and
4. Running casing and completion assembly for the second hole (including long-term temperature and pressure monitoring with the telemetered string) to ~900 mbsf (casing to 100 m below fault, ~900 m).

Proposed Sites JFAST-3 and JFAST-4

The drilling target is the top of the oceanic basement below the plate interface at the toe of the frontal prism. At the proposed sites, the target is the seismic reflector that is interpreted as the top of the Pacific plate basaltic crust. Based on experience drilling other accretionary wedge settings (e.g., Barbados, Costa Rica, and Nankai) and the Taiwan Chelungpu Fault Drilling Project, we anticipate that identifying one or more plate boundary fault(s) that slipped during the Tohoku event will be possible on the basis of cores and logs. While drilling Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) holes through the toe regions of the frontal and splay thrust, the main faults were located slightly above the strong reflector imaged by multichannel seismic data (Expedition 316 Scientists, 2009). Logistic plans are not affected if the exact depth of the target fault is unknown until logging and coring is completed.

Preliminary analysis of seismic data indicates the primary site (JFAST-3) is located at a water depth of 6910 m along seismic Lines HD33B and HS41B, and the target fault lies at ~800 mbsf (Fig. **F4**). The alternate site (JFAST-4) is located at a water depth of 6830 m along seismic Lines HD33B and HS40B, and the target fault lies at ~880 mbsf.

Hole A

The first borehole will be rotary drilled with LWD and MWD tools to TD, currently planned for ~900 mbsf. LWD/MWD will acquire important geophysical data and provide information on the location of the fault zone (e.g., IODP Expedition 314 [Kinoshita et al., 2008]). LWD-derived resistivity is an effective way to identify the depth and width of a frontal megathrust fault zone, which will be used to refine strategies for coring in the second borehole. Resistivity images with 360° coverage of the borehole are also essential for identifying the geometry of faults and measuring in situ stress by stress-induced borehole compressive failures (borehole breakouts) and drilling-induced tensile fractures (DITFs). Other key LWD measurements could characterize important fault physical properties.

After completing LWD/MWD drilling operations, casing and a completion assembly (including a temporary temperature observatory) will be run in the LWD/MWD hole (8.5 inch diameter) to ~900 mbsf.

Hole B

The second borehole will be drilled using an RCB bit (10⅝ inch diameter) to a TD of ~900 mbsf. The second highest priority for the expedition is to retrieve core samples from across the slipped fault zone. However, the time required for running casing and placing observatory instruments in both boreholes will not allow enough time to core the entire length of the second borehole. Accordingly, we plan continuous RCB coring only over a 300–400 m interval spanning the fault zone. The remainder of the borehole (the top 500 m) will be drilled using RCB with a center bit. The exact depth range for coring will be determined on the basis of high-resolution seismic site survey data and LWD/MWD data from the first borehole. Successful RCB coring will allow for careful analysis of fault zone structures, as well as provide fault rock samples for experimentation designed to determine the mechanical properties that allowed such large slip to occur to the trench. Core studies will characterize important attributes of the fault including composition, mineralogy, grain size and fabric, as well as damage zone fracture density. Several different techniques will be employed to identify the main slip zone, which may be as thin as several millimeters and may occur within a damage zone as wide as several hundred meters. As was done during IODP Expedition 316 in the Nankai accretionary margin, X-ray computed tomography (CT) scans, visual core study, and microscopy will be used to identify the location of the recent rupture (Expedition 316 Scientists, 2009). Evidence in the core of coseismic slip may include structures indicative of fault gouge fluidization and injection of gouge into wall rock, grain size segregations and other fault rock textures, and petrographic, geochemical or geophysical signatures of transient heating. Detailed multisensor core logger (MSCL) profiles will provide important complementary information about physical properties such as density and magnetic susceptibility across the slip zone. Core-based, 3-D anelastic strain recovery measurements will be used to augment the determination of in situ stress conditions from geophysical data. Biostratigraphic age analysis may also play a critical role in detecting a stratigraphic age gap expected across the main slip zone.

If there is excellent core recovery, including capturing an identifiable rupture zone from the Tohoku earthquake, then various onshore core analyses and experiments will be performed, particularly to determine petrophysical and friction properties. Even if core recovery does not include an identifiable rupture zone, experiments can still be performed on in situ sediments that will characterize useful frictional parameters of the sediments within the fault zone.

Observatory plan

The highest priority is to gather temperature measurements across the fault zone to determine the amount of frictional heat generated by the earthquake. Observations of a decaying temperature signal will be used to estimate the level of dynamic friction during the large rupture. To obtain good resolution of the thermal signal, calculations show that initial measurements need to be started within about 2 y following the earthquake with measurements continued over several months to years. Temperature and pressure data will be collected in both boreholes with observatory instrumentation as described below.

Hole A

The 4.5 inch diameter casing will extend 100 m below the fault, (~900 mbsf) to provide temperature measurements mainly above the fault. A string will be constructed by attaching ANTARES temperature loggers and RBR temperature and temperature/pressure loggers to a Vectran rope. The string of ~50 sensors will have a miniature temperature logger (MTL) hangar attachment on the top and will be fixed to the wellhead for later retrieval in September 2012 by the ROV *Kaiko* (Fig. **F5**). The spacing is closer in the depth range where the fault-related temperature anomaly is expected. The exact length of the temperature string will be decided on board after looking at the results of LWD/MWD.

LWD/MWD is expected to acquire important data in the first stages of drilling and provide the first information on the location of the fault zone (e.g., Expedition 314 [Kinoshita et al., 2008]). LWD-derived resistivity is an effective way to identify the depth and thickness of the fractured zone associated with the plate interface fault zone. Resistivity images with 360° coverage of borehole are also essential for identifying geometry of fractures, stress-induced borehole compressive failures (borehole breakouts), and DITFs. Changes in fracture and in situ stress may be expected to change at the slipped interface.

Of particular concern is the possibility of afterslip from the Tohoku event occurring along the fault at the drill site, which could deform or collapse the casing sufficiently to clamp the MTL string and prevent retrieval. Portions of the string are being connected with weak links, which are expected to break at the time of retrieval if the lower portion of the string becomes stuck.

Hole B

After completing the coring operation, 3.5 inch casing and a circulation obviation retrofit kit (CORK)-type (Becker and Davis, 2005) observatory completion assembly will be run in the second borehole, extending approximately 100 m below the fault (~900 mbsf) to permit temperature and pressure measurements from the fault zone. A temperature and pressure measurement string will be installed in the borehole. This system will comprise an internal string of 20–30 thermistors with data telemetered to a data logger at the wellhead (Fig. **F6**). Three pressure ports along the outside of the casing will be used to measure pore fluid pressure inside and outside of the fault zone. Pressure lines using a flatpack will be connected to a pressure data logger at the wellhead. The battery life of the data loggers is expected to be about 5 y. Observatory data recorded in this hole also will be retrieved later using the ROV *Kaiko*. The system will allow data retrieval without physical recovery of the thermistor string for as long as the string remains functional. A robust cable will be used so that if there is a break in any portion of the cable (possibly due to afterslip), data will still recorded for portions above the break.

The exact depth of the sensors will be decided on board before deployment. As is the case for the observatory in the first borehole, it is critical to accurately determine the exact location of the slipped fault in order to place the temperature measurement string in the proper location. Locating the fault in the second borehole will benefit from the geophysical data from the first borehole and from analysis of core samples in the second borehole. Analysis of core sample data, including micropaleontological data, will be carried out during the time associated with preparing and running casing in the second borehole after coring is completed.

Logging/downhole measurements strategy

The best target depths for installation of the observatory components can be identified via LWD, which is performed to monitor drilling conditions and to define lithological and structural changes in real time. The LWD tools selected for Expedition 343 include the TeleScope 675 MWD, located above the geoVISION 675 (Fig. **F7**), which not only measures drilling parameters and transmits these data in real time but also stores data on the tool memory recorder for later downloading once recovered on deck. A gap of several meters from the top of the bit and the sensor pads causes a time delay between the bit drilling and the sensors collecting data and transferring them to memory. The geoVISION has five resistivity measurements, three-azimuth electrical imaging, and gamma ray measurement. The resistivity tool is based on resistivity-at-the-bit technology to provide real-time at-bit resistivity data and azimuthally focused laterolog measurements for detailed geological imaging on the borehole wall. The geoVISION tool also contains a scintillation counter that provides a total gamma ray measurement. Current plans also include the provision tool, which uses magnetic resonance techniques to independently constrain the quantities of the fluids in the sediment, the properties of the fluids, and the sizes of the pores that contain the fluids. However, actual tools used during the expedition may change according to availability.

TeleScope MWD tools include the capability to transmit annular pressure while drilling (APWD) and MWD data and provide information to optimize well placement, improve drilling efficiency, and reduce risk. APWD measurements also include weight on bit and torque on bit data, which are valuable data sets for drilling safety and efficiency.

Sampling and data sharing

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 343 will not recover any observatory monitoring data until the observatories are revisited, sample requests for observatory data should be submitted in collaboration with other research vessels following this expedition. Currently, the first observatory data retrieval expedition is planned for a non-IODP cruise.

A Sample Allocation Committee (SAC) composed of co-chief scientists, expedition project manager, and IODP curator on shore (and curatorial representative on board ship) will work with the entire scientific party to formulate a formal expedition-specific sampling plan for shipboard and postcruise sampling. The SAC must approve access to data and core samples requested during the expedition and during the one-year moratorium period, which starts at the end of the drilling expedition. Modifications to the sampling plan during the expedition require the approval of the SAC.

Additional requests also may be submitted during or after the expedition if appropriate.

The initial sample requests provide the basis for the SAC 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. To provide time for the SAC and Specialty Coordinators to develop a detailed and integrated sampling strategy, data requests are due by the end of February 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 ship board and shore-based scientists. Both groups of scientists should also use the Sample/Data Request form (**smcs.iodp.org:8080/smcs/**) in submitting their requests.

Core flow for onboard measurements, sampling, and storage

We will follow IODP standard measurements and archival sampling procedures in the shipboard laboratory. Upon recovery, core will be cut into 1.5 m sections and will be sampled for interstitial water (whole round 20–50 cm in length, from Section 4) and archival routine microbiological sample (RMS) (whole round from next to the interstitial water sample as recommended by the Subseafloor Life Task Force), for micropaleontology (from core catcher), and for safety monitoring (headspace). The RMS will be sampled at a frequency of 1 every 20 m, core recovery permitting. All core sections will be scanned using the X-ray CT facility; X-ray CT image analysis will be used to identify critical intervals (e.g., localized fault zones) and for planning any whole-round core measurement and sampling for microbiological study, interstitial water extraction, geotechnical testing, anelastic strain recovery measurements, and thermal conductivity measurements. All whole-round samples will be taken after completing whole-round sample measurements (e.g., whole-round multisensor core logging [MSCL-W]) unless whole-round sampling is time sensitive (e.g., microbiological). Standard cluster samples for physical properties and mineralogical/chemical analyses will be taken from adjacent to whole-round samples if possible.

After whole-round sampling is completed, cores will be split into working and archive halves per standard procedures. Archive halves will be used for visual core descriptions and image/color scan. Working halves will be used for physical properties measurements, such as thermal conductivity and shear strength. Additional discrete samples will be used for measurements of moisture and density, *P*-wave velocity, and bulk chemistry.

Additional sampling/data handling guidelines

Acquiring core samples from the slipped fault zone is a high priority of the expedition, but there may be a limited amount of core material and high demand for samples, particularly in critical intervals. For these intervals (e.g., highly sheared zones of the fault) special handling and sampling plans may be required, and it will not be possible to finalize plans until after core recovery occurs. The SAC may require an additional formal sampling plan before critical intervals are sampled for postcruise studies.

The working half is available for sampling by shipboard and shore-based scientists, which will likely be completed shipboard. Samples of whole-round cores can be requested following IODP policy. Sampling whole rounds is particularly valuable for geotechnical and rock mechanical testing (e.g., permeability, consolidation, triaxial, ring shear, etc.), for study of ephemeral features or properties (e.g., pore fluid chemistry and microbiological studies), and for special preservation and study of sediment and rock structures (e.g., delicate shear zones) that would be destroyed by conventional splitting of cores in working and archive halves. Use of X-ray CT imaging has proven particularly useful for selecting intervals ideal for whole-round sampling and informing sample planning.

The overarching science goals of Expedition 343 focus primarily of the mechanics of earthquake faulting, secondly on thermal and fluid flow processes, and thirdly on microbiological activity associated with fault zone environments. As such, sample plans will follow this prioritization in resolving sampling conflicts. Ideally, core recovery will allow extensive sampling to achieve research objectives within a range of disciplines. If core recovery permits, it would be ideal to make as many measurements as possible on common (or nearly colocated) samples, thus maximizing correlation of different data types (e.g., physical and mechanical properties, pore water, carbon carbonate, moisture and density, bulk X-ray diffraction, clay X-ray diffraction, and bulk chemistry).

Risk and contingency

Contingency

Contingency operations for Expedition 343 are based on the current state of knowledge at the time of writing this *Scientific Prospectus*. These plans may be modified both before and during the expedition, based on continuing JFAST Project Management Team discussions. The Expedition 343 drilling schedule is shown in Table **T1.** The following operations are planned:

- Install riserless MTL observatory at proposed Site JFAST-3, Hole A, comprising an internal string suspending a mix of RBR and ANTARES MTLs; and

- Install riserless CORK observatory at proposed Site JFAST-3, Hole B, comprising external pressure sensors and internal thermistor string.

Risks

There are significant technical and logistical challenges for this project, including drilling in 7000 m water depth and conducting long-term monitoring of temperature and pressure. The drilling and monitoring plans presented are the result of extensive discussions, including the platform operators, and are considered to be feasible operations. A decision tree of operations for the various successes and failures of the operational plan is shown in Figure **F8.**

If operational difficulties prohibit completion of the primary borehole goals of the project, plans for drilling alternative sites have also been prepared for any remaining ship time. Boreholes of ~200 m can be drilled with LWD to obtain estimates of absolute stress levels from observations of borehole breakouts. Four possible sites (JFAST-5, JFAST-6, JFAST-7, and JFAST-8) are located at site survey crossing points, as shown in Figure **F9.** Estimates of the stress levels are important for evaluations of models of the fault coupling along the tip of the shallow megathrust. These sites can also be considered for drilling. If all the operations for the primary goals are completed ahead of schedule, these drilling sites will also be considered.

References

Apel, E.V., Bürgmann, R., Steblov, G., Vasilenko, N., King, R., and Prytkov, A., 2006. Independent active microplate tectonics of northeast Asia from GPS velocities and block modeling. *Geophys. Res. Lett.,* 33(11):L11303. **doi:10.1029/2006GL026077**

Arthur, M.A., and Adelseck, C.G., Jr., 1980. Acknowledgments, introduction, and explanatory notes: the Japan Trench transect, Legs 56 and 57, Deep Sea Drilling Project. *In* Scientific Party, *Init. Repts. DSDP,* 56, 57 (Pt. 1): Washington, DC (U.S. Govt. Printing Office), 3–21. **doi:10.2973/dsdp.proc.5657.101.1980**

Avouac, J.-P., 2011. Earthquakes: the lessons of Tohoku-Oki. *Nature (London, U. K.),* 473(7356):300. **doi:10.1038/nature10265**

Becker, K., and Davis, E.E., 2005. A review of CORK designs and operations during the Ocean Drilling Program. *In* Fisher, A.T., Urabe, T., Klaus, A., and the Expedition 301 Scientists, *Proc. IODP,* 301: College Station, TX (Integrated Ocean Drilling Program Management International, Inc.). **doi:10.2204/iodp.proc.301.104.2005**

Brodsky, E.E., Ma, K.-F., Mori, J., Saffer, D.M., and the participants of the ICDP/SCEC International Workshop, 2009. Rapid response fault drilling: past, present, and future. *Sci. Drill.,* 8:66–74. **doi:10.2204/iodp.sd.8.11.2009**

Expedition 316 Scientists, 2009. Expedition 316 Site C0004. *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.314315316.133.2009**

Fujiwara, T., Kodaira, S., No, T., Kaiho, Y., Takahashi, N., and Kaneda, Y., 2011. The 2011 Tohoku-Oki earthquake: displacement reaching the trench axis. *Science,* 334(6060):1240. **doi:10.1126/science.1211554**

Fulton, P.M., Harris, R.N., Saffer, D.M., and Brodsky, E.E., 2010. Does hydrologic circulation mask frictional heat on faults after large earthquakes? *J. Geophys. Res., [Solid Earth],* 115(B9):B09402. **doi:10.1029/2009JB007103**

Ide, S., Baltay, A., and Beroza, G.C., 2011. Shallow dynamic overshoot and energetic deep rupture in the 2011 Mw 9.0 Tohoku-Oki earthquake. *Science,* 332(6036):1426–1429. **doi:10.1126/science.1207020**

Ito Y., Tsuji, T., Osada, Y., Kido, M., Inazu, D., Hayashi, Y., Tsushima, H., Hino, R., and Fujimoto, H., 2011. Frontal wedge deformation near the source region of the 2011 Tohoku-Oki earthquake. *Geophys. Res. Lett.,* 38(15):L00G05. **doi:10.1029/2011GL048355**

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**

Kita, I., Matsuo, S., and Wakita, H., 1982. H_2 generation by reaction between H_2O and crushed rock: an experimental study on H_2 degassing from the active fault zone. *J. Geophys. Res., [Solid Earth],* 87(B13):10789–10795. **doi:10.1029/JB087iB13p10789**

Lin, W., Saito, S., Sanada, Y., Yamamoto, Y., Hashimoto, Y., and Kanamatsu, T., 2011. Principal horizontal stress orientations prior to the 2011 Mw 9.0 Tohoku-Oki, Japan, earthquake in its source area. *Geophys. Res. Lett.,* 38(17):L00G10. **doi:10.1029/2011GL049097**

Ozawa, S., Nishimura, T., Suito, H., Kobayashi, T., Tobita, M., and Imakiire, T., 2011. Coseismic and postseismic slip of the 2011 magnitude-9 Tohoku-Oki earthquake. *Nature (London, U. K.),* 475(7356):373–376. **doi:10.1038/nature10227**

Sato, M., Ishikawa, T., Ujihara, N., Yoshida, S., Fujita, M., Mochizuki M., and Asada, A., 2011. Displacement above the hypocenter of the 2011 Tohoku-Oki earthquake. *Science,* 332(6036):1395. **doi:10.1126/science.1207401**

Shipboard Scientific Party, 1980. Site 434: the lower trench slope, Leg 56. *In* Scientific Party, *Init. Repts. DSDP,* 56, 57 (Pt. 1): Washington, DC (U.S. Govt. Printing Office), 355–398. **doi:10.2973/dsdp.proc.5657.106.1980**

Simons, M., Minson, S.E., Sladen, A., Ortega, F., Jiang, J., Owen, S.E., Meng, L., Ampuero, J.-P., Wei, S., Chu, R., Helmberger, D.V., Kanamori, H., Hetland, E., Moore, A.W., and Webb, F.H., 2011. The 2011 magnitude 9.0 Tohoku-Oki earthquake: mosaicking the megathrust from seconds to centuries. *Science,* 332(6036):1421–1425. **doi:10.1126/science.1206731**

Tsuru, T., Park, J.-O., Miura, S., Kodaira, S., Kido, Y., and Hayashi, T., 2002. Along-arc structural variation of the plate boundary at the Japan Trench margin: implication of interplate coupling. *J. Geophys. Res., [Solid Earth],* 107(B12):2357. **doi:10.1029/2001JB001664**

Tsuru, T., Park, J.-O., Takahashi, N., Kodaira, S., Kido, Y., Kaneda, Y., and Kono, Y., 2000. Tectonic features of the Japan Trench convergent margin off Sanriku, northeastern Japan, revealed by multichannel seismic reflection data. *J. Geophys. Res., [Solid Earth],* 105(B7):16403–16413. **doi:10.1029/2000JB900132**

Ujiie, K., and Tsutsumi, A., 2010. High-velocity frictional properties of clay-rich fault gouge in a megasplay fault zone, Nankai subduction zone. *Geophys. Res. Lett.,* 37(24):L24310. **doi:10.1029/2010GL046002**

von Huene, R., Klaeschen, D., Cropp, B., and Miller, J., 1994. Tectonic structure across the accretionary and erosional parts of the Japan Trench margin. *J. Geophys. Res., [Solid Earth],* 99(B11):22349–22361. **doi:10.1029/94JB01198**

von Huene, R., Ranero, C.R., and Vannucchi, P., 2004. Generic model of subduction erosion. *Geology*, 32(10):913–916. **doi:10.1130/G20563.1**

Table T1. Expedition 343 operations schedule.

Task	Depth (mbsf)	Section length (m)	Daily progress (m/day)	Days	Subtotal (days)	Total (days)
Transit						
Transit from Shimizu to the site.				3.00	3.00	3.00
Set guide base						
Prepare for spud, free fall UWTV cable to 7000 m.						
Deploy transponders, DP calibration.						
Make up drill pipe and rack back in derrick.						
Prepare and set guide base.				3.00	5.50	8.50
Run guide base and set on the seabed w/UWTV.						
Recover UWTV; POOH running tool.						
LWD pilot hole to 900 mbsf						
Make up and run LWD BHA w/UWTV.				2.00	2.00	
Tag seabed and recover UWTV prior to starting drilling.						
Drill 8-1/2 inch LWD hole from 0 to 800 mbsf.	740	740	300	2.50	4.50	
Wiper trip, bit change.				3.00	7.50	
Drill 8-1/2 inch LWD hole from 800 to 900 mbsf.	840	100	100	1.00	8.50	
Wiper trip, POOH, rig down BHA.				1.50	10.00	18.50
Run casing and completion assembly						
Run 4.5 inch tubing to 900 m w/MTL assembly.				4.00	4.00	22.50
Run UWTV, enter guide base and recover UWTV.						
RIH to 900 mbsf, recover casing running tool.						
Set guide base						
Prepare and set guide base.				3.00	3.00	25.50
Run guide base and set on the seabed w/UWTV.						
Recover UWTV; POOH running tool.						
RCB core 500–900 mbsf						
Prepare				0.50	0.50	
Rig up RCB BHA.						
Make up and run RCB coring BHA w/UWTV.				2.00	2.50	
Enter guide base and recover UWTV prior to start coring.						
Drill down w/center bit to 500 mbsf.	500	500	250	2.00	4.50	
Cut core from 500 to 800 mbsf.	740	240	40	6.00	10.50	
Wiper trip, bit change.				3.00	13.50	
Cut core from 800 to 900 mbsf.	840	100	35	3.00	16.50	
Spot kill mud; POOH, rig down BHA.				1.50	18.00	43.50
Run casing and completion assembly						
Run 3.5 inch tubing 900 m w/completion assembly.				6.00	6.00	
Run UWTV, enter guide base and recover UWTV.						
RIH to 900 mbsf, recover casing running tool.						
Recover transponders.				1.50	7.50	51.00
Transit						
Transit from the site to port.				3.00	3.00	54.00
				Total:		54.00

Water depth = 6910 m. UWTV = underwater television. DP = dynamic positioning. POOH = pull out of hole. LWD = logging while drilling, BHA = bottom-hole assembly, MTL = miniature temperature logger, RCB = rotary core barrel. RIH = run in hole.

Figure F1. **A.** Large-scale map showing Tohoku region and epicenter of 11 March 2011 Tohoku earthquake (red star) along with the survey lines and IODP Expedition 343 proposed drill site (in box). **B.** Close-up map, showing proposed Sites JFAST-3 and JFAST-4.

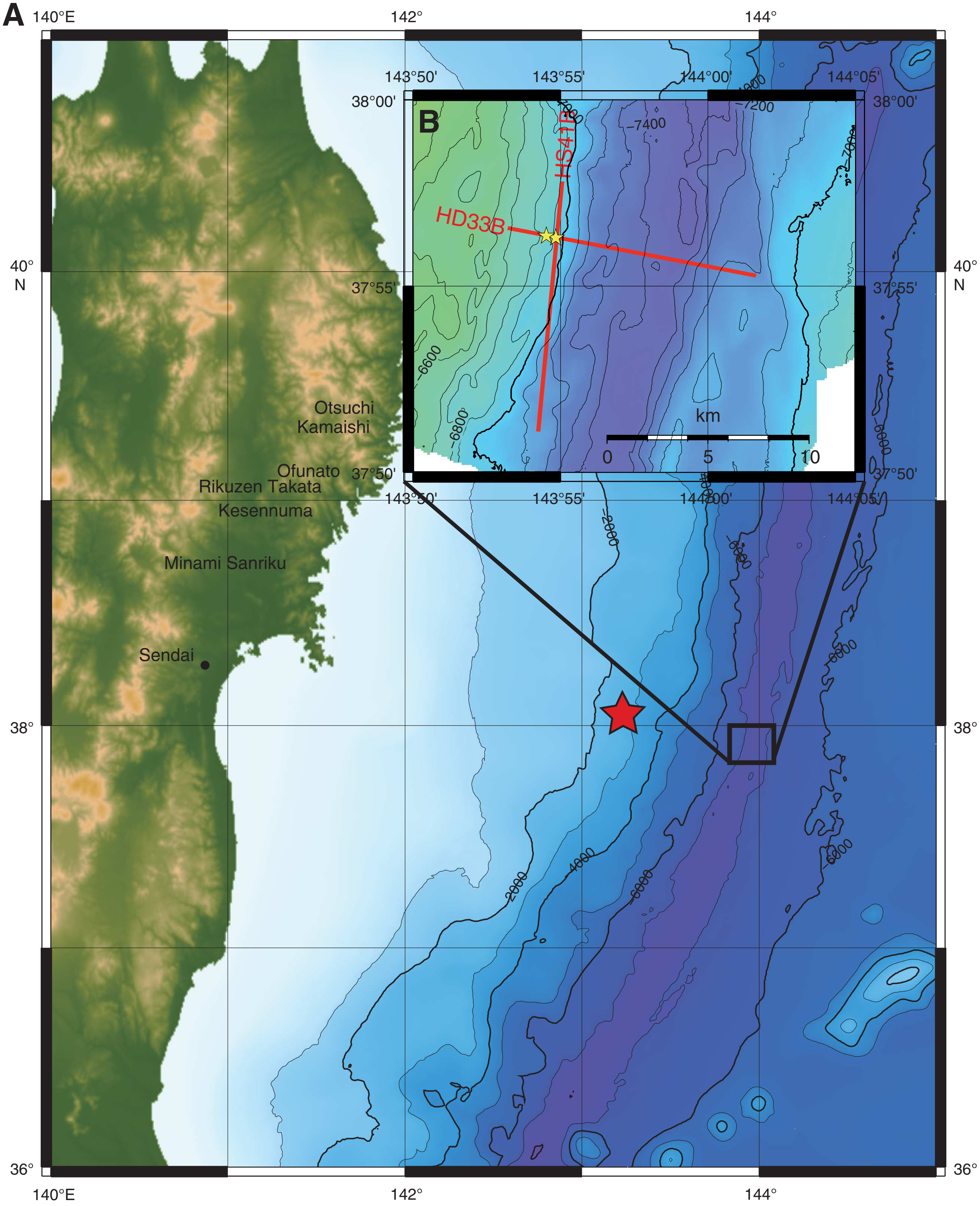


Figure F2. Coseismic displacement of the 2011 Tohoku earthquake extended all the way to the trench axis (Fujiwara et al., 2011). **A.** Bathymetric data along Line TH03. **B.** Difference between the bathymetric data acquired before (1999) and after (2011) the earthquake. **C.** Time-migrated multichannel seismic (MCS) section along Line TH03. Comparing B and C suggests that coseismic fault slip reached to the trench axis along the top of the basaltic layer (or an interface slightly above it) because the top of the basaltic layer and an interface slightly above it are the only visible interfaces in the MCS section (see Fig. F3).

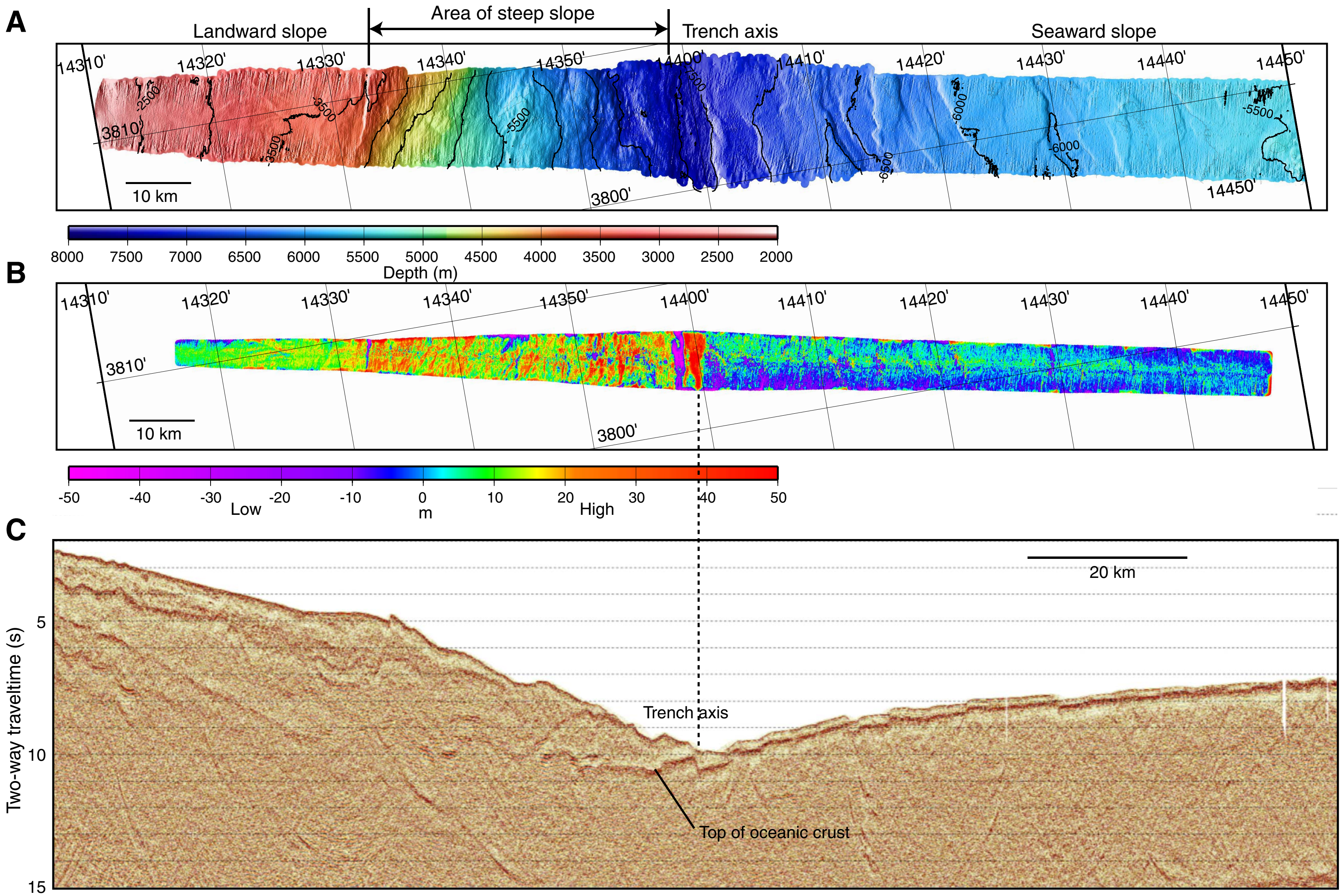


Figure F3. General operations plan and time estimates. **A.** Proposed Site JFAST-3, Hole A. LWD = logging while drilling, MTL = miniature temperature logger. (Continued on next page.)

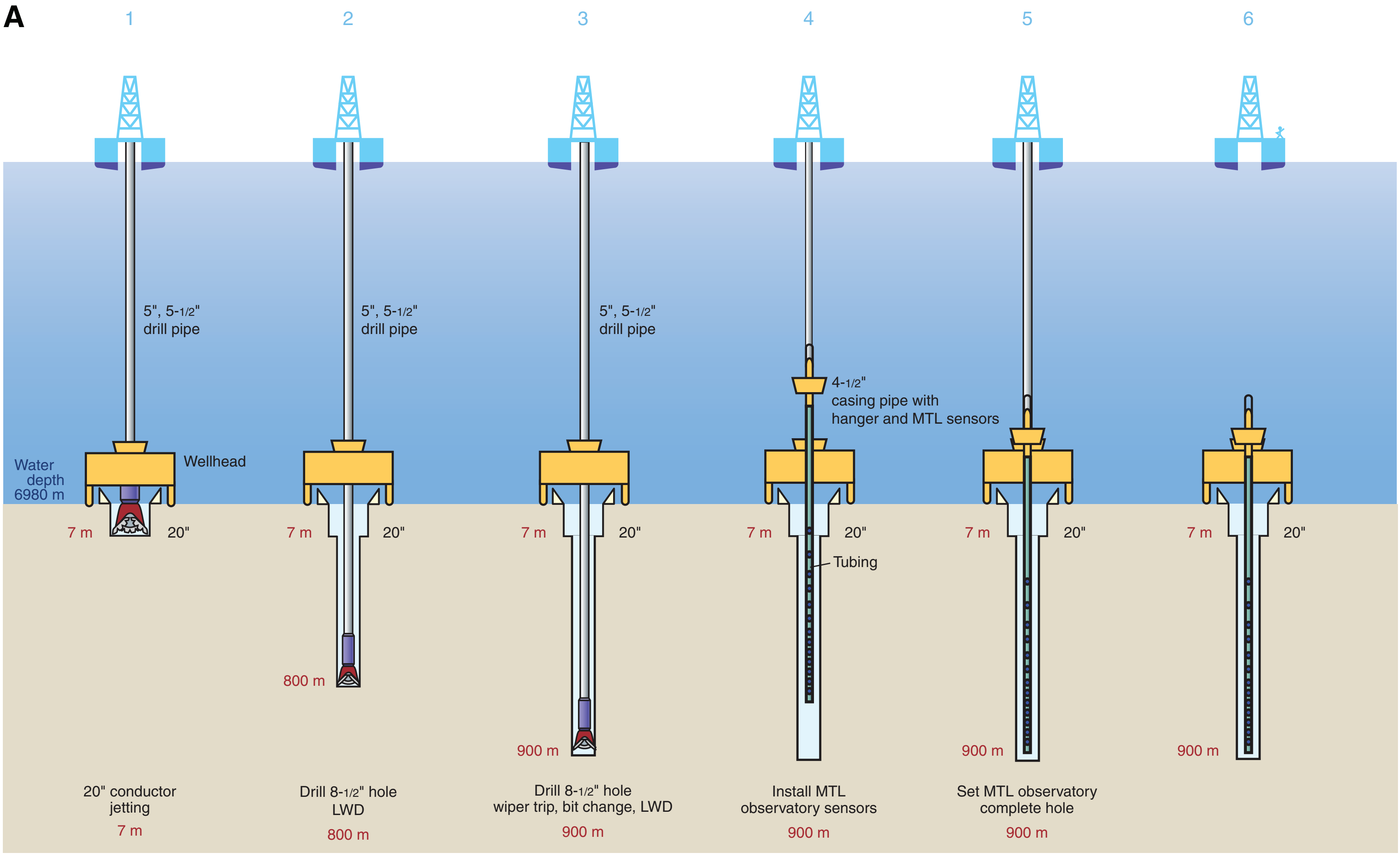


Figure F3 (continued). **B.** Proposed Site JFAST-3, Hole B. CORK = circulation obviation retrofit kit, PSU = pressure sensor unit.

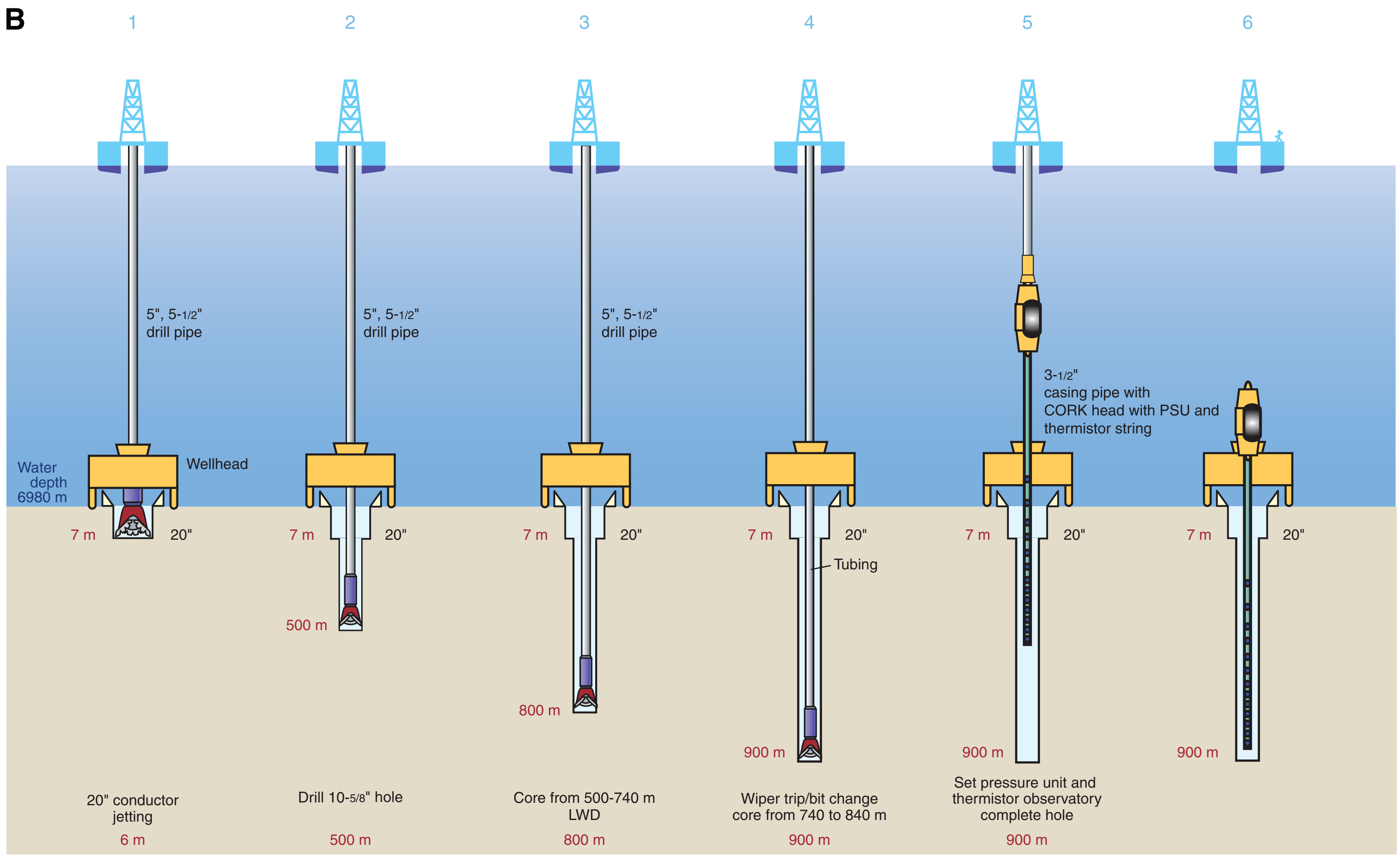


Figure F4. Proposed Sites JFAST-3 (primary) and JFAST-4 (alternate) seismic line and cross-line.

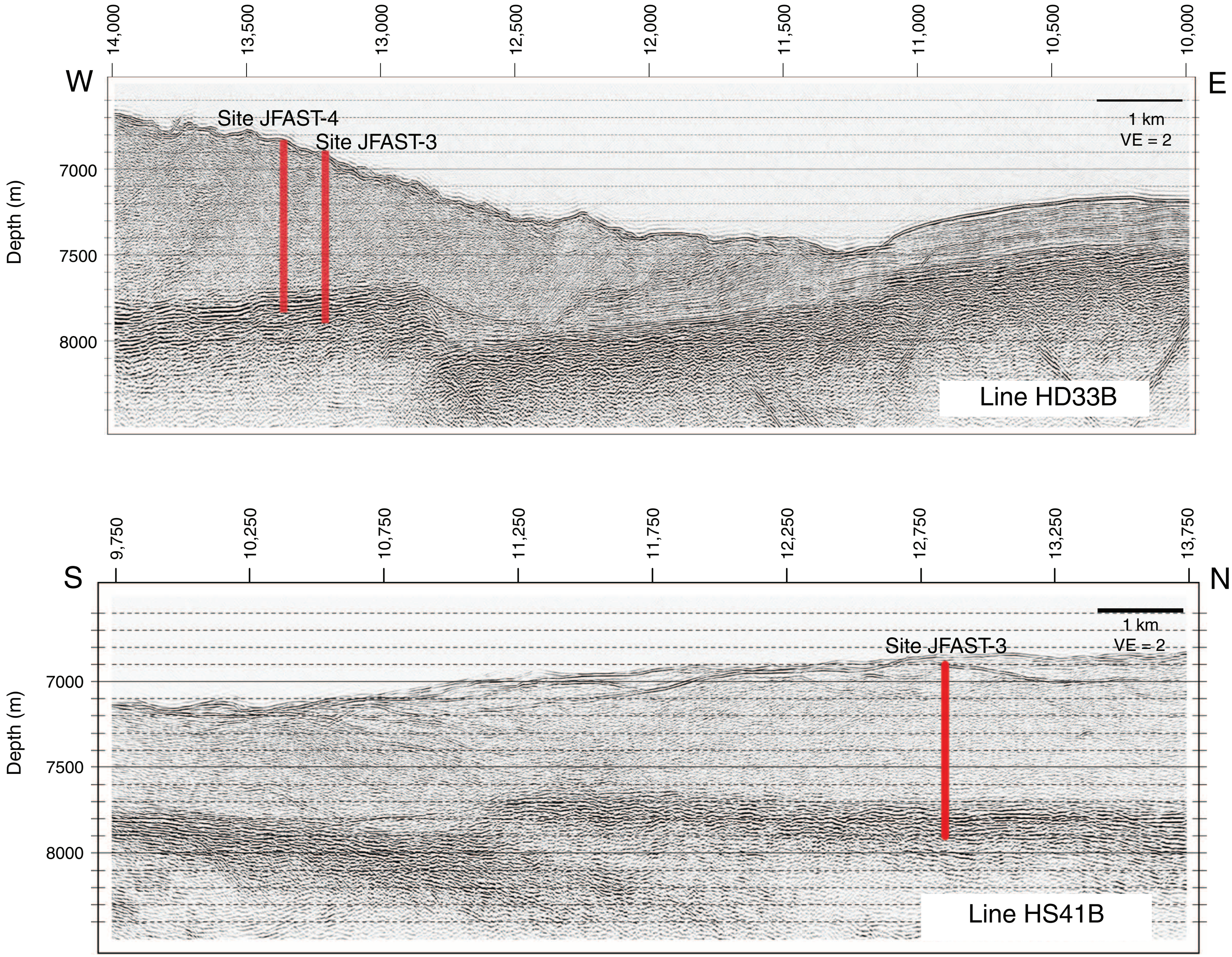


Figure F5. Miniature temperature logger (MTL) string temporary observatory planned for installation at proposed Site JFAST-3, Hole A. UWTV = underwater television, WH = wellhead, CSG = casing, OH = open hole, CAM = cam actuated running tool, HGR = hanger.

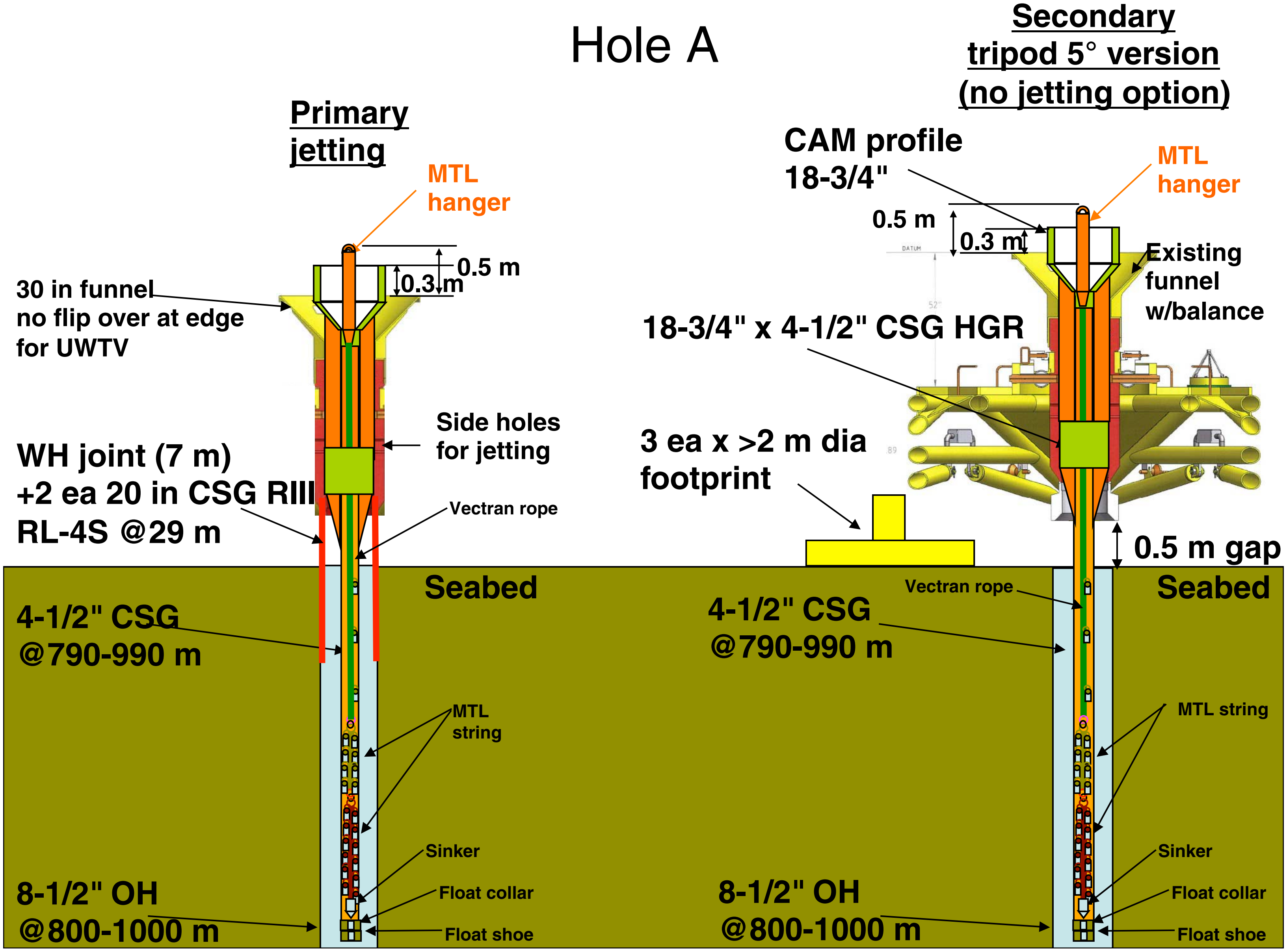


Figure F6. Pressure and thermistor string strap-CORK observatory planned for installation at proposed Site JFAST-3, Hole B. ROV = remotely operated vehicle, WH = wellhead, CSG = casing, OH = open hole, MTL = miniature temperature logger, CAM = cam actuated running tool, CORK = circulation obivation retrofit kit, HGR = hanger, TBG = tubing.

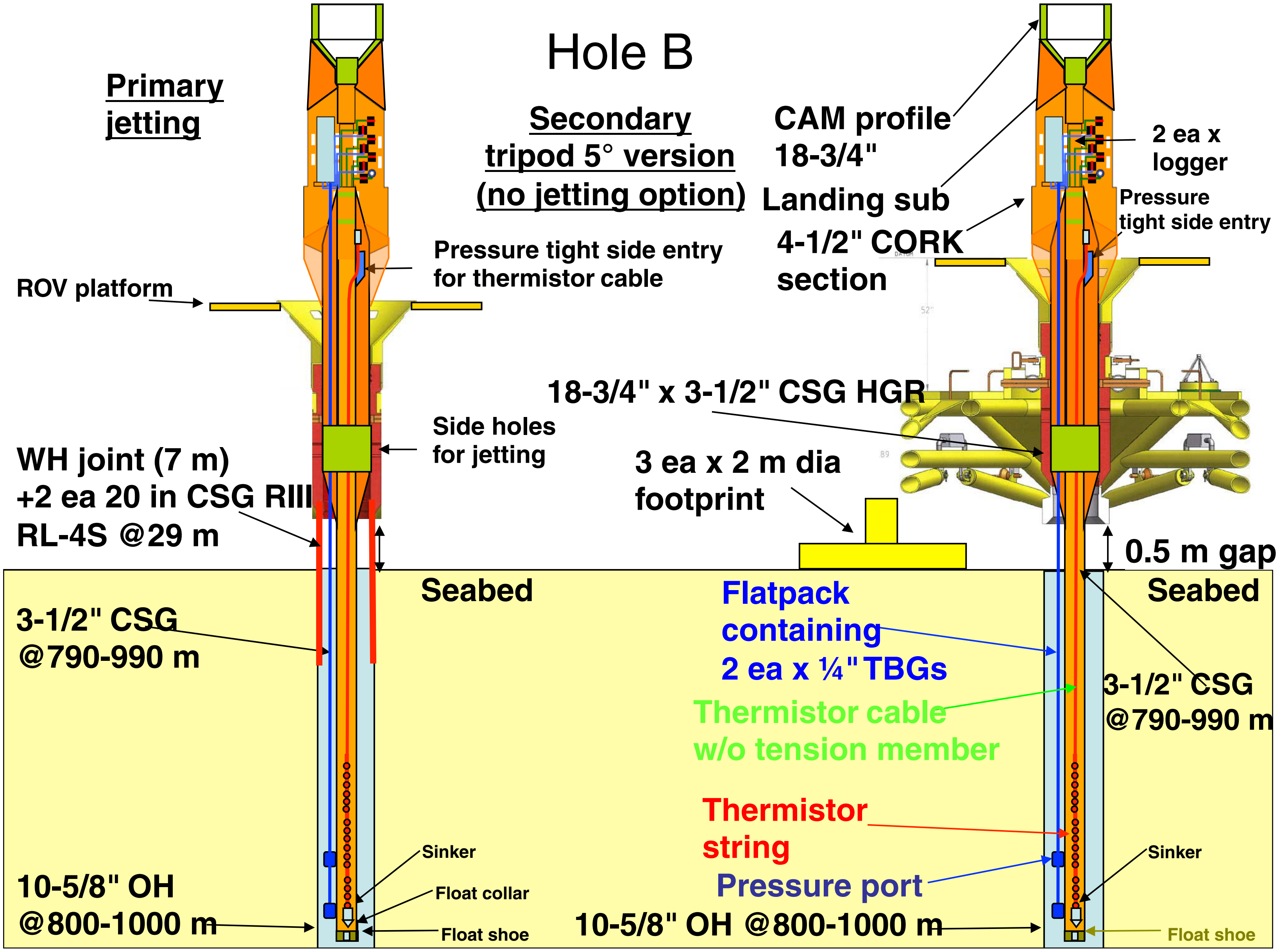


Figure F7. LWD tool bottom-hole assembly diagram. The whole borehole assembly is on the left (105 m total length), and geoVISION 675 is on the right with measurement points of gamma ray and resistivity. DPG = drill pipe guide, NMDC = nonmagnetic drill collar, GVR = geoVISION resistivity tool, APWD = annular pressure while drilling. Bit size = 8½ inch.

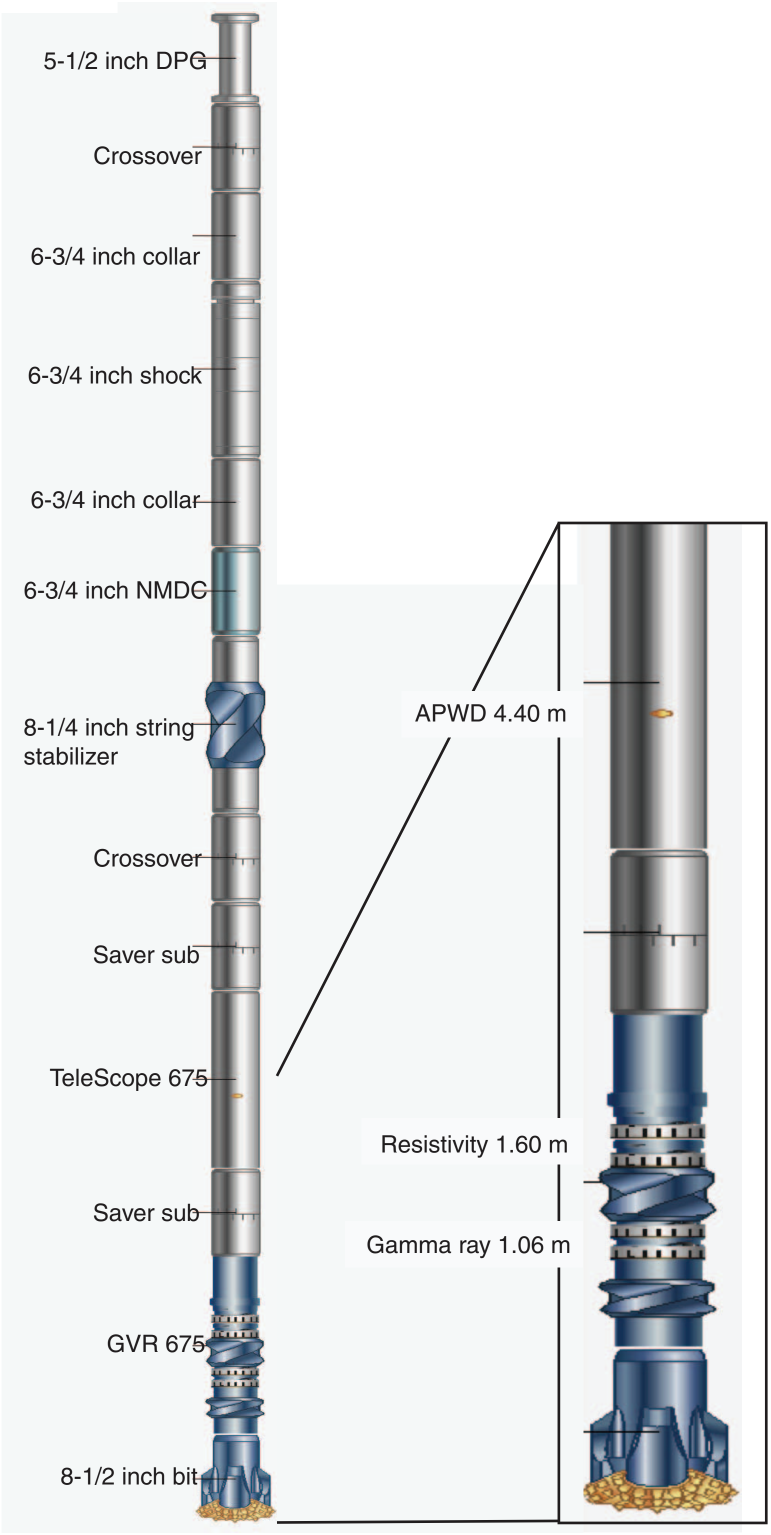
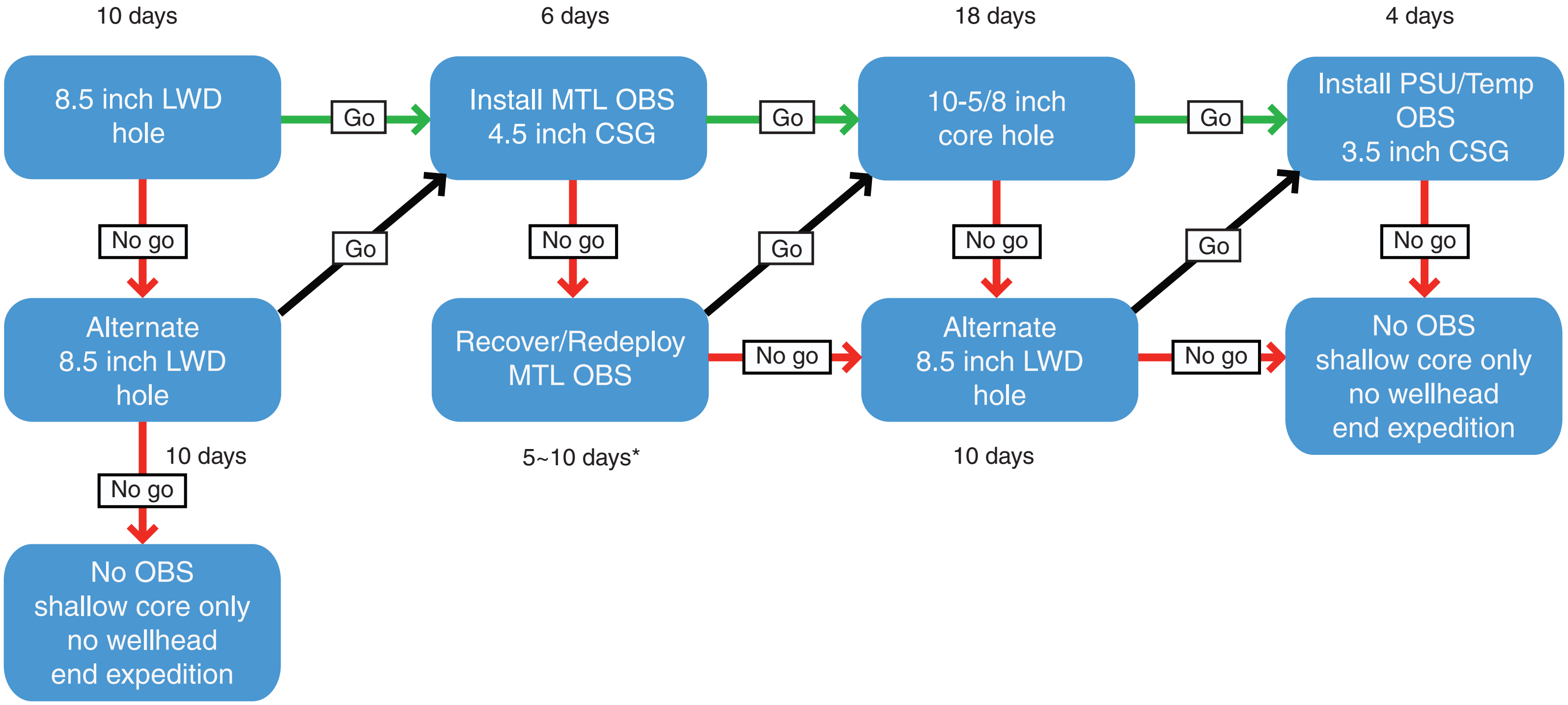
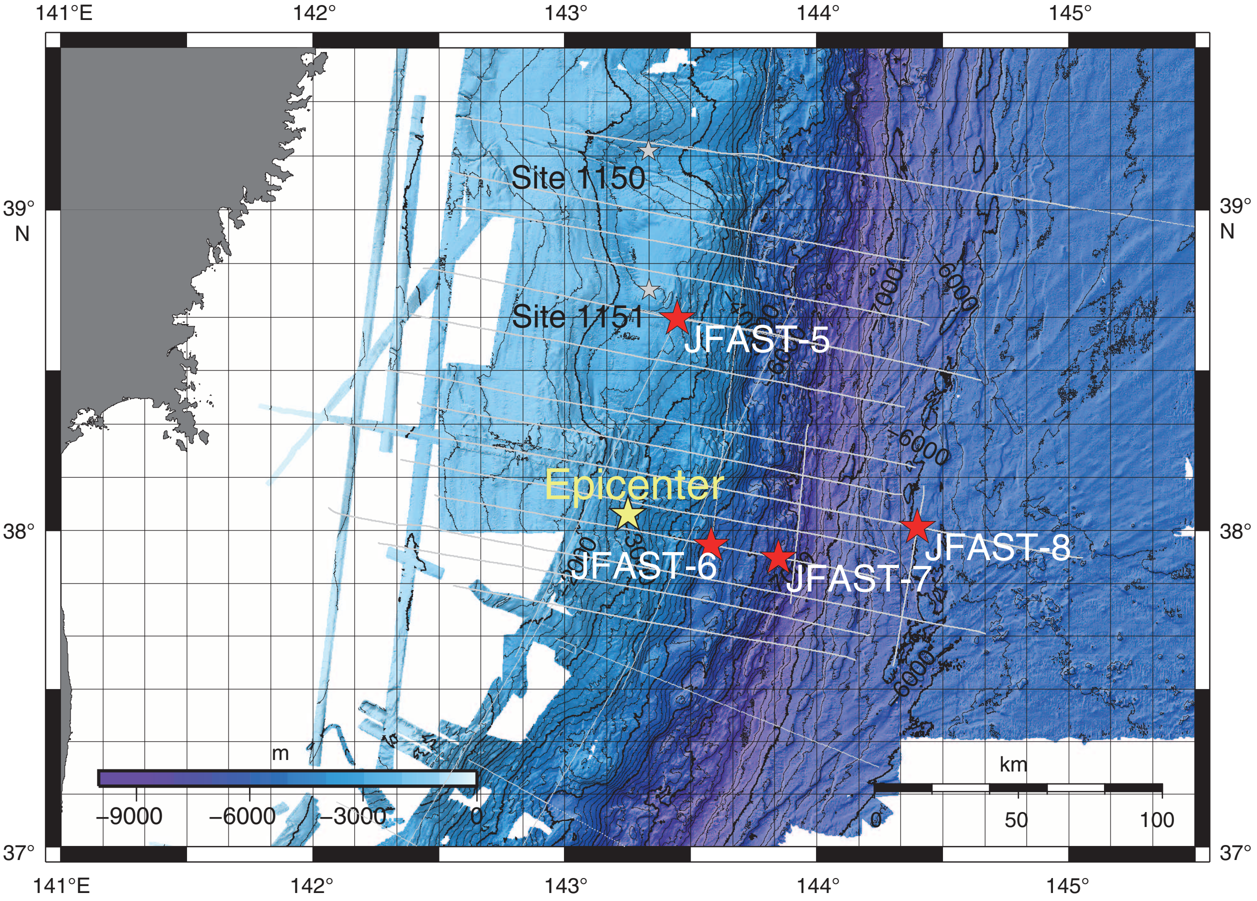


Figure F8. Contingency operations and decision tree. LWD = logging while drilling, OBS = observatory, MTL = miniature temperature logger, CSG = caging, PSU = pressure sensor unit.



*Time estimates depend on whether guide horn needs to be removed or not.

Figure F9. Possible contingency sites.



Site summaries

Site JFAST-3

Priority:	Primary
Position:	~37°56.3022′N, 143°54.8405′E
Water depth (m):	6910
Target drilling depth (mbsf):	~1000
Survey coverage (track map; seismic profile):	Lines HD33B and HS41B; Figure **F1B**
Objective:	Determine stress state on the fault Characterize large earthquakes in the fault zone
Drilling program:	Hole A: LWD to ~950 mbsf; install casing/temperature monitoring string to ~950 mbsf Hole B: RCB to ~950 mbsf; install casing/temperature and pressure monitoring string to ~850 mbsf
Logging/downhole measurements program:	Hole A: LWD/MWD to ~950 mbsf LWD: resistivity, electrical imaging, gamma ray MWD: annular pressure while drilling, temperature
Nature of rock anticipated:	Highly disrupted hemipelagic deposits. A chert layer is anticipated within a 100 m zone above TD.

Site summaries (continued)

Site JFAST-4

Priority:	Alternate
Position:	~37°56.3528′N, 143°54.5075′E
Water depth (m):	6830
Target drilling depth (mbsf):	~1100
Survey coverage (track map; seismic profile):	Lines HD33B and HS40B; Figure **F1B**
Objective:	Determine stress state on the fault Characterize large earthquakes in the fault zone
Drilling program:	Hole A: LWD to ~950 mbsf; install casing/temperature monitoring string to ~950 mbsf Hole B: RCB to ~950 mbsf; install casing/temperature and pressure monitoring string to ~850 mbsf
Logging/downhole measurements program:	Hole A: LWD/MWD to ~950 mbsf LWD: resistivity, electrical imaging, gamma ray MWD: annular pressure while drilling, temperature
Nature of rock anticipated:	Highly disrupted hemipelagic deposits. A chert layer is anticipated within a 100 m zone above TD.

Scientific participants

The current list of participants for Expedition 343 can be found at **www.jamstec.go.jp/chikyu/eng/Expedition/exp343.html.**