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Expedition 365 Preliminary Report

NanTroSEIZE Stage 3: Shallow Megasplay Long-Term Borehole Monitoring System (LTBMS)

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Core samples and the wider set of data from the science program covered in this report are under moratorium and accessible only to Science Party members until 5 August 2017.

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Abstract

The Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) is a coordinated, multiexpedition International Ocean Discovery Program (IODP) 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. IODP Expedition 365 is part of NanTroSEIZE Stage 3, with the following primary objectives: (1) retrieval of a temporary observatory at Site C0010 that has been monitoring temperature and pore pressure within the major splay thrust fault (termed the "megasplay") at 400 meters below seafloor since November 2010 and (2) deployment of a complex long-term borehole monitoring system (LTBMS) that will be connected to the Dense Oceanfloor Network System for Earthquakes and Tsunamis (DONET) seafloor cabled observatory network postexpedition (anticipated June 2016). The LTBMS incorporates multilevel pore pressure sensing, a volumetric strainmeter, tiltmeter, geophone, broadband seismometer, accelerometer, and thermistor string. Together with an existing observatory at Integrated Ocean Drilling Program Site C0002 and a possible future installation near the trench, the Site C0010 observatory will allow monitoring within and above regions of contrasting behavior of the megasplay fault and the plate boundary as a whole. These include a site above the updip edge of the locked zone (Site C0002), a shallow site in the megasplay fault zone and its footwall (Site C0010), and a site at the tip of the accretionary prism (Integrated Ocean Drilling Program Site C0006). Together, this suite of observatories has the potential to capture deformation spanning a wide range of timescales (e.g., seismic and microseismic activity, slow slip, and interseismic strain accumulation) across a transect from near-trench to the seismogenic zone. Site C0010 is located 3.5 km along strike to the southwest of Integrated Ocean Drilling Program Site C0004. The site was drilled and cased during Integrated Ocean Drilling Program Expedition 319, with casing screens spanning a ~20 m interval that includes the megasplay fault, and suspended with a temporary instrument package (a "SmartPlug"). During Integrated Ocean Drilling Program Expedition 332 in late 2010, the instrument package was replaced with an upgraded sensor package (the "GeniusPlug"), which included pressure and temperature sensors and a set of geochemical and biological experiments.

Expedition 365 achieved its primary scientific and operational objectives, including recovery of the GeniusPlug with a >5 y record of pressure and temperature conditions within the shallow megasplay fault zone, geochemical samples, and its in situ microbial colonization experiment; and installation of the LTBMS. The pressure records from the GeniusPlug include high-quality records of formation and seafloor responses to multiple fault slip events, including the 11 March 2011 Tohoku M9 and 1 April 2016 Mie-ken Nanto-oki M6 earthquakes. The geochemical sampling coils yielded in situ pore fluids from the splay fault zone, and microbes were successfully cultivated from the colonization unit. The complex sensor array, in combination with the multilevel hole completion, is one of the most ambitious and sophisticated observatory installations in scientific ocean drilling (similar to that in Hole C0002G, deployed in 2010). Overall, the installation went smoothly, efficiently, and ahead of schedule. The extra time afforded by the efficient observatory deployment was used for coring in Holes C0010B–C0010E. Despite challenging hole conditions, the depth interval corresponding to the screened casing across the megasplay fault was successfully sampled in Hole C0010C, and the footwall of the megasplay was sampled in Hole C0010E, with >50% recovery for both zones.

In the hanging wall of the megasplay fault (Holes C0010C and C0010D), we recovered indurated silty clay with occasional ash layers and sedimentary breccias. Some of the deposits show burrows and zones of diagenetic alteration/colored patches. Mudstones show different degrees of deformation spanning from occasional fractures to intervals of densely fractured scaly claystones of up to >10 cm thickness. Sparse faulting with low displacement (usually <2 cm) is seen in core and exhibits primarily normal and, rarely, reversed sense of slip. When present, ash was entrained along fractures and faults. On one occasion, a ~10 cm thick ash layer was found, which showed a fining-downward gradation into a mottled zone with clasts of the underlying silty claystones.

In Hole C0010E, the footwall to the megasplay fault was recovered. Sediments are horizontally to gently dipping and mainly comprise silt of olive-gray color. The deposits of the underthrust sediment prism are less indurated than the hanging wall mudstones and show lamination on a centimeter scale. The material is less intensely deformed than the mudstones, and apart from occasional fracturation (some of it being drilling disturbance), evidence of structural features is absent.

Introduction

Subduction zones account for 90% of 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 have either slipped coseismically during large earthquakes or have nucleated smaller events. These efforts include the San Andreas Fault Observatory at Depth (Hickman et al., 2004), the Taiwan-Chelungpu Drilling Project (Ma, 2005), and Integrated Ocean Drilling Program drilling in the Nankai Trough (Nankai Trough Seismogenic Zone Experiment [NanTroSEIZE]; Tobin and Kinoshita, 2006a, 2006b) and in the high-slip region of the March 2011 Tohoku earthquake (Japan Trench Fast Drilling Project; Chester et al., 2012).

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 ~40–60 mm/y (Figure **F1**; 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 are well documented in historical and archaeological records (e.g., Ando, 1975). It has been one of the focus sites for studies of seismogenesis by both the Integrated Ocean Drilling Program and the U.S. MARGINS initiative, based on the wealth of geological and geophysical data available.

The Nankai Trough region has a 1300 y historical record of recurring great earthquakes that are typically tsunamigenic, including the 1944 Tonankai M8.2 and 1946 Nankaido M8.3 earthquakes (Ando, 1975; Hori et al., 2004). The rupture area and zone of tsunami generation for the 1944 event (within which the site of International Ocean Discovery Program [IODP] Expedition 365 is located) are now reasonably well understood (Ichinose et al., 2003; Baba et al., 2005, 2006). 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 very low frequency (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 Tonankai M8.2 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 (Figure **F2**). Notably, coseismic slip during events such as 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 scientific ocean drilling) where both local stratigraphic variations associated with basement topography and anomalously high heat flow have been documented (Moore, Taira, Klaus, et al., 2001; Moore et al., 2005; Moore and Saffer, 2001). Finally, the drilling targets are within the operational limits of riser drilling by the D/V *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 ~4700–6000 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, heat flow (Yamano et al., 2003), side-scan sonar, swath bathymetry, and submersible and remotely operated vehicle (ROV) 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 was 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, 2009). These high-resolution, 3-D data are being used in conjunction with physical property, petrophysical, and geophysical data obtained from core analyses and both wireline and logging-while-drilling (LWD) logging to allow extensive and high-resolution integration of core, logs, and seismic data.

NanTroSEIZE drilling project

The NanTroSEIZE project 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, 2006a, 2006b; Figures **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 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 Integrated Ocean Drilling Program 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 occurrences of great earthquakes of ~M8.0+ (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 M8.2 earthquake (Figures **F1**, **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, as well as 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 both on understanding subduction zone megathrust behavior globally and on 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.

NanTroSEIZE Phase 1, conducted in 2007–2008, included three riserless drilling expeditions targeting the incoming sediments and ocean crust to characterize their physical properties, composition, and state (pore pressure and temperature). Phase 2, conducted in 2009–2011, included (1) the first riser drilling in the Integrated Ocean Drilling Program at Site C0009 in the Kumano Basin, (2) observatory installations at Integrated Ocean Drilling Program Sites C0002 (long-term borehole observatory) and C0010 (temporary instrument package), and (3) additional riserless coring of subduction inputs and mass wasting deposits on the continental slope (Expedition 319 Scientists, 2010; Kopf, Araki, Toczko, and the Expedition 332 Scientists, 2011; Underwood et al., 2010; Henry, Kanamatsu, Moe, and the Expedition 333 Scientists, 2012). Phase 3, begun in 2010 and continuing with this expedition, includes riser drilling in Holes C0002F, C0002N, and C0002P and installation of long-term observatories in Holes C0002G and C0010A (Kopf, Araki, Toczko, and the Expedition 332 Scientists, 2011). To date, the NanTroSEIZE Project has included 10 expeditions, encompassing a diverse suite of operations and lengths of individual expeditions, all conducted by the *Chikyu*.

NanTroSEIZE Stage 1 included three coordinated riserless drilling expeditions (Integrated Ocean Drilling Program Expeditions 314, 315, and 316). Eight sites were drilled across the continental slope and rise offshore the Kii Peninsula, many above the inferred coseismic slip region of the 1944 Tonankai M8.2 earthquake. The first Stage 1 expedition (314; LWD Transect) used LWD to define physical properties, lithostratigraphy, and structures in advance of coring operations (Kinoshita, Tobin, Ashi, Kimura, Lallemant, Screaton, Curewitz, Masago, Moe, and the Expedition 314/315/316 Scientists, 2009). This was followed by the first Center for Deep Earth Exploration (CDEX) coring expedition (315; Mega-Splay Riser Pilot) aimed at sampling the materials and characterizing in situ conditions within the hanging wall of the megasplay fault to a depth of 1000 meters below seafloor (mbsf) at Integrated Ocean Drilling Program Site C0001 and in the Kumano Basin fill and underlying accretionary wedge to a depth of 1057 mbsf at Site C0002 (Ashi et al., 2008). The third riserless expedition (316; Shallow Megasplay and Frontal Thrusts) targeted the megasplay at a depth of 350–400 mbsf (Integrated Ocean Drilling Program Site C0004) as well as the frontal thrust at the toe of the young accretionary prism (Integrated Ocean Drilling Program Sites C0006 and C0007) (Kimura et al., 2008).

NanTroSEIZE Stage 2 operations began in 2009 with Integrated Ocean Drilling Program Expedition 319 (Riser/Riserless Observatory 1) followed by Integrated Ocean Drilling Program Expeditions 322 (Subduction Inputs), 332 (Riserless Observatory), and 333 (Subduction Inputs 2 and Heat Flow). Expedition 319 included (1) the first riser drilling in the Integrated Ocean Drilling Program, at Site C0009, which penetrated the Kumano Basin fill and into accreted strata of the Nankai wedge overlying the locked subduction thrust, and (2) drilling across the shallow megasplay fault with LWD to a total depth (TD) of 555 mbsf at Site C0010 and installation of casing with screens positioned to span the megasplay at 407 mbsf (Expedition 319 Scientists, 2010). This hole was suspended with a temporary observatory attached to a retrievable bridge plug (termed the “SmartPlug”) to monitor temperature and pore pressure at the fault zone. Expedition 322 characterized the subduction inputs at Integrated Ocean Drilling Program Sites C0011 and C0012 (Underwood et al., 2010). Two more Stage 2 expeditions followed a year later. Expedition 332 recovered and replaced the temporary observatory at Site C0010 and deployed the first permanent long-term borehole monitoring system (LTBMS) in Hole C0002G. Expedition 333 then conducted additional coring operations to complete the original objectives of Expedition 322 and to sample mass wasting complexes on the continental slope.

NanTroSEIZE Stage 3 operations comprise three expeditions: Integrated Ocean Drilling Program Expeditions 326 (Plate Boundary Deep Riser 1), 338 (Plate Boundary Deep Riser 2), and 348 (Plate Boundary Deep Riser 3). To date, Stage 3 has focused on riser drilling, with the ultimate objective of penetrating the megasplay fault at ~5000 mbsf. Expedition 326 drilled Hole C0002F to 827.5 mbsf to set shallow casing (Kinoshita et al., 2010). Expedition 338 extended the hole to 2005 mbsf with LWD and also conducted riserless coring operations at Integrated Ocean Drilling Program Sites C0002, C0022, and C0021 (Moore et al., 2013). Expedition 348 deepened Site C0002 in Holes C0002N and C0002P to a depth of 3056 mbsf (Tobin, Hirose, Saffer, Toczko, Maeda, Kubo, and the Expedition 348 Scientists, 2015) and included LWD as well as sampling cuttings and limited coring.

Expedition 365 is part of NanTroSEIZE Stage 3, with the primary objectives of (1) retrieving the temporary observatory at Site C0010 and (2) deployment of a complex long-term observatory, which will eventually be connected to the Dense Oceanfloor Network System for Earthquakes and Tsunamis (DONET) seafloor cabled observatory network (anticipated June 2016). Together with the existing observatory at Site C0002 and a possible future installation at Site C0006 (Figures **F1**, **F2**), the Site C0010 LTBMS will allow monitoring within and above regions of contrasting behavior of the megasplay fault zone and plate boundary as a whole. These include a site above the updip edge of the "locked" zone (Site C0002), a shallow site in the megasplay fault zone and footwall (this expedition; Site C0010), and a site at the tip of the accretionary prism (Site C0006), where possible monitoring has been motivated by observed slip in the 11 March 2011 Tohoku earthquake that indicates coseismic rupture may propagate to the trench at some margins (e.g., Fujiwara et al., 2011). Together, the suite of NanTroSEIZE observatories has the potential to capture seismic and microseismic activity, slow slip, and interseismic strain accumulation across a transect from near-trench to the seismogenic zone. Such temporally continuous and spatially distributed observations are necessary to understand how each part of the plate boundary functions through the seismic cycle of megathrust earthquakes.

Scientific objectives and operational strategy

Background

Site C0010, located above the shallow megasplay fault and sited 3.5 km southwest of previously drilled Site C0004 (Figures **F1**, **F2**, **F3**), was originally drilled with LWD and cased during Expedition 319. Operations included drilling with measurement while drilling (MWD)/LWD across the megasplay fault to a TD of 555 mbsf, casing the borehole (with casing screens spanning the fault), conducting an observatory "dummy run" to test strainmeter and seismometer deployment procedures, and installation of a simple pore pressure and temperature monitoring system (SmartPlug) attached to a retrievable bridge plug (Expedition 319 Scientists, 2010). The hole was revisited during Expedition 332, when the SmartPlug was recovered and replaced with a similar temporary instrument package, which also included geochemical and microbiological sampling coils and an in situ microbiological colonization experiment; this temporary instrument package is termed the "GeniusPlug" (Kopf, Araki, Toczko, and the Expedition 332 Scientists, 2011; Figures **F4**, **F5**). Drilling during Expedition 319 identified three distinct lithologic packages at Site C0010, defined on the basis of LWD data, combined with coring and LWD at nearby Site C0004 (located 3.5 to the northeast along strike). From top to bottom, these lithologic packages are hemipelagic slope deposits composed primarily of mud with minor distal turbidite interbeds (Unit I, 0–182.5 m LWD depth below seafloor [LSF]), a thrust wedge composed of overconsolidated and fractured clay- and mudstones (Unit II, 182.5–407 m LSF), and overridden slope deposits (Unit III, 407 m LSF to TD). At Site C0010, Unit I is divided into two subunits: Subunit IA (0–161.5 m LSF), characterized by gamma ray and resistivity patterns similar to those observed in Unit I at Site C0004 (Expedition 314 Scientists, 2009), and Subunit IB (161.5–182.8 m LSF), interpreted as slope sediments composed of material reworked from the underlying thrust wedge.

For Expedition 365, the observatory system at Site C0010 consisted of an array of sensors (Figure **F6**) designed to monitor crustal deformation and hydrologic processes in the offshore portion of the subduction system over a wide range of timescales. These monitoring targets include seismicity and microseismicity, slow slip events and VLF earthquakes, hydrologic transients, ambient pore pressure, and temperature. To allow the high sampling rates and ensure power delivery for the long-term and continuous monitoring necessary to capture this full range of events, the borehole observatory plans called for the observatory to be connected to the DONET submarine cable network (**http://www.jamstec.go.jp/donet/e**) after the drilling expedition in June 2016. The LTBMS installed at Site C0002 is already connected to this network, and the formation pressure data can be viewed and downloaded at an open-access observatory data portal (**http://offshore.geosc.psu.edu**).

Scientific objectives

The primary plan for Expedition 365 was to recover the GeniusPlug installed in Hole C0010A during Expedition 332 (shown in Figure **F5**), deepen the hole from 555 to 655 mbsf, underream the hole below the 9⅝ inch casing to 10 inch diameter, and install the LTBMS. Site C0010 constitutes the second LTBMS installation during NanTroSEIZE. The downhole configuration of the observatory includes (1) pressure ports, (2) a volumetric strainmeter, (3) a broadband seismometer, (4) a tiltmeter, (5) three-component geophones, (6) three-component accelerometers, and (7) a thermometer array (Figure **F6**). The set of sensors is designed to collect, as a whole, multiparameter observations in a wide period range from months to 0.01 s and over a wide dynamic range to sense tectonic and hydrologic events that include responses to local microearthquakes, VLF earthquakes, and the largest potential earthquake slips of the Tonankai plate boundary 6 km below the sensors. The observatory installation was planned to operate initially in a standalone mode at the wellhead, using batteries and data recorders, with data recovery by subsequent ROV operations. Following the expedition, an ROV cruise was planned for June 2016 to download initial data, conduct hydrostatic sensor checks for the pressure transducers, and connect the system to DONET so that measurements can be observed in real time from a shore-based monitoring station.

Observatory operations went smoothly and faster than planned, enabling us to conduct coring operations. This degree of contingency was not anticipated at the time of expedition planning, and as such, was not described in Kopf et al. (2015), and the expedition was not originally staffed for core sampling, measurements, or description. As a result, description and analysis of the cores was deferred to a shore-based sampling party on board the *Chikyu* in the port of Shimizu, Japan, in July–August 2016. The opportunity to collect cores introduced new science objectives for the expedition, including sampling of material from the hanging wall and footwall of the megasplay fault both for standard shipboard analyses and for subsequent shore-based study and characterization of the formation and interstitial fluids spanning the depth range of the screened casing. The latter of these objectives, in particular, has the potential to greatly enhance interpretations of the LTBMS and GeniusPlug data.

Specific objectives for Site C0010 during Expedition 365 were to

1. Recover the GeniusPlug installed in 2010 and conduct initial shipboard analyses of the recovered pore pressure and temperature data, fluids sampled by the sampling coils, and microbiological colonization experiment.
2. Drill out the cement plug at the casing shoe, extend the borehole to a TD of 655 mbsf, and conduct reaming to prepare the hole for observatory installation.
3. Deploy a long-term borehole monitoring system that includes pore pressure ports at three levels, a thermistor string, and a suite of geophysical instruments (strainmeter, tiltmeter, and seismometer) in a configuration like that in Hole C0002G (Kopf, Araki, Toczko, and the Expedition 332 Scientists, 2011).
4. Drill, collect, and analyze core samples across the megasplay fault and spanning the interval of screened casing in Hole C0010A.

Operational strategy

Planned work during Expedition 365 included two main operations, both at the cased borehole in Hole C0010A (Figure F7). The first operation was the recovery of the GeniusPlug autonomous sampling unit. This was to begin following transit from Shimizu harbor to Site C0010 and after ROV dives to conduct a seafloor survey, set transponders, and remove the Hole C0010A well corrosion cap. Once complete, the vessel was to move away from the Kuroshio Current to a low-current area (LCA) to make up the GeniusPlug recovery bottom-hole assembly (BHA). The BHA consisted of the L-10 on/off tool, designed to recover the retrievable bridge plug from which the GeniusPlug was suspended. Once recovered from Hole C0010A, the vessel was to return to the LCA while the BHA was pulled out of the hole to the rig floor, the GeniusPlug would then be moved to the laboratory for data download, and the OsmoSampler/Flow-through Osmo Colonization System (FLOCS) experiment would be moved to the microbiology laboratory for sampling and analysis.

The next operation was to extend previously drilled Hole C0010A from 555 to 655 mbsf using a combination drill bit and underreamer BHA. Once drilling was finished, the drilling/underreaming BHA was to be pulled out of the hole and replaced with a scraper BHA to ensure the cased section of the well was clear of any obstructions. The expedition science objectives would be completed with operations to deploy the LTBMS. This involved considerable moonpool preparation using newly developed guide rollers to run the completion.

A major impediment to observatory deployment in the Nankai region is the extremely strong Kuroshio Current. Current speeds up to 6 kt are possible, and the current flow past the drill string commonly results in vortex-induced vibration (VIV), which has caused lost drill pipe, dropped casing, and destroyed electronic sensors during past Integrated Ocean Drilling Program expeditions (Expedition 319 Scientists, 2010). CDEX has developed a series of mitigation techniques and equipment to minimize or suppress VIV. These include the attachment of ropes to drill string sections exposed to the current, preventing the formation of vortices as the current flows past the drill string. Other newly developed tools are the moonpool guide rollers, which support the drill string in the moonpool and provide a safe platform for moonpool work, and guides for attaching the VIV-suppressing ropes, cables, and hydraulic flatpack lines to the LTBMS observatory instruments.

The operational plan called for the LTBMS to be made up from the bottom bullnose to the seafloor LTBMS head as the completion was run into the moonpool. A series of system checks on the status of the strainmeter, tiltmeter, broadband seismometer, and pressure sensor unit (PSU) were to be performed at set stages as the LTBMS and sensors were assembled. Once the LTBMS was completed and run into the water, the *Chikyu* would then drift back into the Kuroshio Current to run the LTBMS into Hole C0010A. After checking that all systems were working, the LTBMS would be cemented in place, and the vessel would release the LTBMS running tool and recover the drill string.

Coring operations were planned to maximize limited available time in order to target the key interval spanning the megasplay fault and the screened casing zone and to penetrate and sample the footwall. For this reason, in Hole C0010B (abandoned due to bad hole conditions after a single core with no recovery) and subsequently in Hole C0010C we planned to drill without coring to 300 mbsf and to then core across the fault (located at 407 mbsf in Hole C0010A as identified by LWD data). In Hole C0010C, coring reached 395 mbsf before hole conditions deteriorated, requiring that we abandon the hole. For Holes C0010D and C0010E, the coring strategy was modified in light of limited remaining operational time. For these holes, we planned to drill without coring to a depth closer to the anticipated fault and then begin coring from ~15 to 20 m above the megasplay and into the footwall. This depth was 385 mbsf in Hole C0010D and 360 mbsf in Hole C0010E, where the megasplay was shallower because the hole was located ~100 m updip of Holes C0010A–C0010D (cf. Figure F3).

Operations

Port call and transit to Site C0010

Expedition 365 began in the port of Shimizu, Shizuoka Prefecture, Japan, on 26 March 2016. The first few days were spent quayside, loading cargo and supplies. The science party boarded the *Chikyu* on 27 March and participated in the shipboard prespud meeting on 28 March. The *Chikyu* sailed from Shimizu at 0900 h on 29 March (Table T1), lowered the azimuth thrusters, and arrived on location at Site C0010 at 0330 h on 30 March.

Site C0010

While the supply boat searched for the Kuroshio Current edge (LCA), the ROV dove to survey the seabed, set transponders, and remove the corrosion cap. The *Chikyu* moved to the LCA to begin running the BHA in the hole (Table T2) from 2145 h. The science party placed an accelerometer on the drill string to evaluate the Kuroshio Current VIV as preparation for GeniusPlug recovery and LTBMS running operations.

The *Chikyu* reached the LCA 12 nmi northwest of Site C0010 at 0000 h on 31 March 2016 and began drifting back to the well center. At 1136 h on 1 April, an M6.0 earthquake struck, with the reported hypocenter ~10 nmi to the northwest of Site C0010 and 15 km deep. The quake was felt aboard the ship. Running drill pipe resumed, and on 1 April, the L-10 BHA was over the wellhead and was stabbed in. The BHA landed on the bridge plug and the drill string rotated to release the mechanical seal. The bridge plug and the GeniusPlug successfully cleared the wellhead at 2040 h. The L-10 BHA was pulled out of the hole as the *Chikyu* moved toward the LCA to recover the BHA and GeniusPlug on deck. The L-10 tool, the bridge plug, and the GeniusPlug were recovered on deck at 0500 h on 3 April. The OsmoSampler portion of the GeniusPlug was opened, and the FLOCS and OsmoSampler experiments were moved to the microbiology laboratory.

The *Chikyu* began drifting to the LCA 8 nmi west of Site C0010 and began rigging up the guide horn in preparation for drilling out the cement plug. From early on 4 April (0100 h) the drilling and underreaming BHA (Table T2) was assembled and run in the hole. Drilling out the cement started from 1200 h on 4 April. Once drilling out cement was completed, the underreamer was activated and opened the hole until reaching TD (654 mbsf; 3206 m below rotary table [BRT]) at 1945 h. A short wiper trip confirmed no excessive overpull or torque. The underreamer BHA was pulled out of the hole, reaching the deck by 5 April. The 9⅝ inch casing scraper BHA was made up and run in the hole (Table T2). The BHA was stabbed into the Hole C0010A wellhead and scraped to 2934 m BRT. The scraper BHA was pulled out of the hole and laid down by 0900 h on 6 April. The guide horn was rigged down, and preparations for running the LTBMS completion began. However, the approach of a cold front necessitated waiting on weather until 0245 h on 8 April. At that time, LTBMS preparations were restarted. The LTBMS completion string was run in the hole, and miniscreens for pressure Port P1, cables, and sensors were attached to the completion string. On the morning of 9 April, the sensor cables were connected to the strainmeter, seismometer, and thermistor. Testing revealed that the strainmeter and seismometer were faulty, so the LTBMS was pulled out of the hole to the rig floor so that the faulty sensors could be replaced with standby instruments. The testing cable also turned out to be faulty, so it was also replaced. The replacement sensors and LTBMS assembly was completed by 1615 h, and the LTBMS completion was run in the hole. The LTBMS assembly continued to be run, pausing on 10 April to install the swellable packer in the moonpool from 1815 h. The LTBMS head and hydraulically activated running tool (HART) (Table **T2**) were picked up then made up to the rest of the LTBMS completion assembly and lowered into the moonpool by 1700 h on 11 April. There, the stainless steel hydraulic ¼ inch lines leading from the PSU mounted on the LTBMS head were connected to the flatpack running down to the pressure ports. The PSU valves were kept "open" to prevent damage during running. The sensor cables were measured and prepared for termination at Teledyne Oil and Gas ODI connectors by 12 April. A data logger and battery unit were mounted on the ROV platform to collect data until the planned connection to the DONET undersea cable network in June 2016.

The LTBMS completion assembly was run into the water, and by 1000 h on 14 April the vessel was back at Site C0010. The LTBMS completion assembly reentered the Hole C0010A wellhead. The ROV moved the PSU 2-way valves from open to "closed" to protect the lines from fouling during landing, circulation, and cementing. The LTBMS head was landed by 0515 h on 15 April. Cementing was finished by 1045 h. The HART was released from the LTBMS and pulled out of the hole, and on 15 April the BHA was laid down on the rig floor by 2300 h. The moonpool completion guide, completion guide roller, and VIV-suppression rope drums were removed from the working cart and blowout preventer cart so that rigging up the guide horn could begin for contingency coring operations at Site C0010.

A series of 10 sensor health checks (Table **T1**) were run on the sensors at specific stages during the assembly and running of the LTBMS. Except for the sensor failure noted above, all health checks were positive.

Contingency coring operations were originally planned to test the Turbine Driven Coring System developed by CDEX in preparation for deep coring operations. However, after considering the large amount of time remaining to the expedition, the Co-Chief Scientists, Expedition Project Manager, and Operations Superintendent (OSI) all agreed to move forward with rotary core barrel (RCB) coring in order to maximize potential science returns. Coring was conducted in four holes, all of which were drilled down without coring to ≥300 mbsf: Holes C0010B (300–309.5 mbsf), C0010C (300–395 mbsf), C0010D (385–394.5 mbsf), and C0010E (360–391 mbsf). Coring was most successful in Hole C0010C (Table **T3**) with 52.6 m of core collected for a 95 m advance (55.4% recovery). Core recovery rates tended to increase with depth in both Holes C0010C and C0010E. There were problems with borehole stability, and these required abandoning each hole with the exception of Hole C0010E. Core recovery continued to be high at this site, but with the drawworks needing maintenance, the consensus was to halt coring operations once major coring targets, including the footwall at Site C0010, were recovered. With the recovery of the RCB BHA on deck, science operations for Expedition 365 were completed (Table **T4**). The *Chikyu* returned to Shimizu harbor on 27 April and lowered the gangplank at 1030 h.

Because of the core recovered, a shore-based sample party was held aboard the *Chikyu* while quayside in Shimizu, Japan, from 25 July to 5 August 2016.

Principal results

GeniusPlug

One of the primary objectives of Expedition 365 was to recover the GeniusPlug temporary observatory from Hole C0010A (Figures **F8**, **F9**; see also Figure **F4**) and conduct initial analyses of the pressure and temperature data, fluid geochemical samples collected in both chemical and biological sampling coils, and FLOCS for microbiology. All of these data and samples were successfully recovered from the instrument package, although a significant fraction of fluids in the chemical and biological sampling coils was lost upon depressurization and on the rig floor.

The pressure and temperature records clearly document several key events during the 5.3 y deployment period (November 2010 through April 2016). Initial analysis of the data illustrates two key results. First, on the basis of hydraulic isolation of the formation (downward looking) and hydrostatic reference (upward looking) sensors, it is clear that the bridge plug successfully sealed, and thus that the downward-looking sensor provides a meaningful record of formation pressure. This is most evident at the start and end of the deployment when the bridge plug was set and retrieved, respectively. In both cases, the hydrostatic pressure record exhibits large perturbations associated with drill string movement and attaching/detaching the running tool, whereas the downward-looking pressure record is stable (Figure **F10**). Additionally, initial review of the pressure-time series documents clear responses to regional and local earthquakes. These include the 11 March 2011 Tohoku M9 event and the 1 April 2016 Mie-ken Nanto-oki M6 earthquake (Figures **F11**, **F12**). The latter event occurred below and slightly landward of Site C0010 and is manifested as the arrival of a wavetrain followed by a distinct pressure increase of ~0.4 kPa, likely indicating compressional coseismic strain. For both events, the subsequent tsunami wave is also clearly recorded in both the seafloor and formation sensors. These examples serve to highlight the ability of offshore borehole observatory systems to sense a wide range of crustal strain processes and in detailed characterization of events enabled by monitoring in the near-field.

Analysis of the GeniusPlug fluid samples indicates that, for many elements (e.g., Cl, K, Ca, and Br), the fluids sampled by the OsmoSampler coils are broadly consistent with formation pore fluids measured from cores at both Sites C0004 and C0010 (Figure **F13**). However, some key differences were also observed between the two sets of samples and between the GeniusPlug fluid samples and previously collected interstitial pore waters. The biology coils, which drew fluid from the screened interval of the borehole then through the FLOCS unit (Figure **F13**) and into the sampling coil, exhibit elevated B and SO_4 and reduced Ba concentrations relative to the chemical coils, which drew water directly from the borehole. The higher SO_4 (similar to interstitial waters at Site C0004) and reduced Ba are consistent with barite precipitation in the FLOCS unit, whereas the lower SO_4 in the chemistry coil may reflect microbial uptake of sulfate in the chemical coil due to unanticipated colonization of the membrane itself. Gradually increasing salinity in the chemical coil toward the inlet may reflect an artifact caused by leakage across the membrane in the chemistry unit's pump.

The OsmoSampler and FLOCS provided a an opportunity to sample native microbial communities living in the pervasively fractured thrust wedge, with the advantage that pristine in situ fluids and microbes could be collected without drilling-induced contamination. This marked the first deployment of a FLOCS unit in a sedimentary environment (Figure **F14A**). When the OsmoSampler and FLOCS unit were recovered, substrates were subsampled for DNA analyses, microscopy, and culture experiments. The culture experiments were initiated on board and inoculated with substrates of the FLOCS. The observed growth from these cultures—and not the controls—suggests that the FLOCS successfully collected viable microorganisms (Figure **F14B–F14G**), validating the use of OsmoSampler and FLOCS technology in sedimentary environments. Future shore-based DNA analyses will further characterize these microbial communities and their metabolic potentials.

LTBMS installation

As described in **Scientific objectives**, from bottom to top the LTBMS included (see Figure **F6**) hydraulic ports to monitor pore fluid pressure in an open hole interval spanning from 602 mbsf to the TD of 655 mbsf; a volumetric strainmeter (572–580.6 mbsf); a tilt combo package that includes a broadband seismometer, geophone, accelerometer, tiltmeter, and a thermistor string mounted on a sensor carrier (565–572 mbsf); and an upper hydraulic port to monitor pore pressure in a screened interval spanning the megasplay fault (Figures **F15**, **F16**, **F17**). The thermistor string data logger was mounted on the sensor carrier; however, the string itself consisted of 5 thermistors spanning from 396 to 563 mbsf. In addition, a hydraulic port was included in the instrument carrier-strainmeter assembly, which was to be cemented in the hole (Figure **F6**). The three hydraulic lines were encased in urethane within a single umbilical flatpack and broken out for termination at each of the three downhole port locations. A swellable packer set above the screened casing interval provides hydraulic isolation between the upper pressure port and the overlying ocean. Taken together, the suite of instruments will enable measurement of crustal deformation over a wide bandwidth (from 0.01 s to several months or longer) with the high precision needed to detect earthquakes, microseismicity, low frequency earthquakes, and slow slip events.

The locations of the sensors in the array were chosen on the basis of logging data from Expedition 319, in combination with coring results from Site C0004 located 3.5 km to the east-northeast along strike (Kimura et al., 2008; Expedition 319 Scientists, 2010) (Figure **F6**). The lowermost pressure port is located within overridden slope sediments in the footwall of the megasplay fault (Unit III). The strainmeter and instrument carrier are also installed within Unit III. The total thermistor string length is 175 m, with the two uppermost nodes located within the screened casing interval, two more below the screened interval, and the bottom node just above the instrument carrier.

The completion string for the LTBMS was prepared by attaching the sensors, cables, pressure ports, and hydraulic lines to 3½ inch tubing. The top of the string was terminated at the LTBMS head where underwater mateable connectors (UMC) and hydraulic lines with valves and the pressure sensing unit were mounted (Figure **F15**). An ROV platform was attached to the wellhead prior to lowering the wellhead into water. A titanium sphere data recorder and communications unit with three UMC hoses connected to each downhole sensor was also installed on the ROV platform. At the time of initial assembly, the PSU began continuous recording to its stand-alone data logger with a 1 min sampling interval. The hydraulic valves on the LTBMS head were set to connect the pressure gauges in the PSU to the overlying ocean but isolated from the formation hydraulic lines to avoid potential damage to the sensors due to pressure fluctuations during landing and cementing operations. The other sensors were not recording at this time.

Assembly was conducted in a LCA to avoid potential vibration and damage caused by lowering the string through the Kuroshio Current. VIV was also suppressed by attaching ropes to the drill string while deploying and drifting (Kopf, Araki, Toczko, and the Expedition 332 Scientists, 2011). Additionally, newly developed moonpool equipment, including guide rollers and completion guide rollers, were used to more efficiently and smoothly attach the hydraulic umbilical and cables (guide roller) and ropes (completion guide roller). Throughout the deployment sequence (i.e., string assembly, lowering, drifting, reentry, landing, and cementing), a series of communication tests were conducted with the borehole instruments to verify sensor and cable function.

After landing the LTBMS, we initialized the data recorder to start data acquisition for the tilt combo package and strainmeter. The ROV maintained a connection to the data recorder at this time to monitor the status of the sensors during cementing. Temperature records during this period document cooling of the borehole due to circulation. Pressure recorded at the strainmeter port indicates a pressure increase of ~0.7 MPa during cementing, indicating that 78 m of seawater above the pressure sensor was displaced by the denser cement. After cementing was complete, the hydraulic valves at the LTBMS head were turned to connect the pressure gauges to the formation hydraulic lines, and initial pressure data spanning the descent through the water column and LTBMS head landing were recovered by the ROV. The PSU logger memory was then cleared, and valve configurations and positions of all instruments installed on the ROV platform were checked by visual inspection prior to leaving the site.

Coring

Coring operations were conducted in four holes: C0010B–C0010D, located within 30 m and offset along strike from Hole C0010A, and Hole C0010E, offset 95 m to the south-southeast in the updip direction where the thrust wedge is thinner and the megasplay fault is shallower (Figures **F1A**, **F3**). Because coring operations were not anticipated and were not part of the primary expedition plan, the shipboard laboratory technical and science party was not staffed to split, describe, or sample cores. For this reason, whole (unsplit) cores were sampled for gas analyses and immediately scanned with X-ray computed tomography to identify candidate intervals for whole-round sampling. After taking whole-round samples for interstitial water and microbiology, the cores were run through the whole-round multisensor core logger and then refrigerated. All further shipboard analyses and sampling were deferred until a sampling party conducted on the *Chikyu* while in port in Shimizu, Japan, from 25 July to 5 August 2016.

Coring in Holes C0010C and C0010D recovered fractured silty claystone from depths corresponding to the hanging wall of the megasplay (<400 mbsf). Core samples collected from Hole C0010E span the interval from 366 to 391 mbsf and primarily recovered clayey siltstones from the footwall of the fault (Figure **F18**). The hanging wall to the megasplay fault (Holes C0010C and C0010D) is dominated by indurated, gray to greenish gray silty claystone. The silty claystone is mottled by bioturbation where intact but more typically overprinted by deformation and coring disturbance, with many intervals of dense fractures and drill breccia. Subordinate lithologies include thin beds of gray vitric ash. The ash is locally entrained along fractures and faults. This unit also contains intervals of sedimentary breccia with subrounded to subangular clasts of remobilized mudstone supported by a mudstone matrix. X-ray diffraction (XRD) data show high percentages of total clay minerals relative to quartz and feldspar.

The footwall to the megasplay fault contains olive-gray clayey siltstone that is weakly indurated and consistently coarser grained than strata in the hanging wall. Bioturbation and faint laminae are widespread. Thin interbeds of dark gray silt are common, typically with sharp bases, normal size grading, and plane-parallel laminae. Thin interbeds of light to medium gray vitric ash are also common. Some intervals in the footwall display contorted soft-sediment deformation, with highly variable dips to laminae, clasts of remobilized mudstone, and pebble- to granule-sized lithic fragments and pumice supported by a matrix of silty claystone. XRD data show consistent increases in the relative percentages of quartz and feldspar relative to the hanging wall.

Bedding in Holes C0010C and C0010D, in the hanging wall of the megasplay fault, is near horizontal or gently dipping from 300 to ~350 mbsf. Dips steepen and are up to 50°–60° in the ~50 m above the fault, likely related to deformation caused by slip on the megasplay. Faults and shear zones in the hanging wall also dip moderately. High-angle faults, one of which is identified as a reverse fault, are only observed at ~375 mbsf. Bedding in Hole C0010E in the footwall of the fault is horizontal or gently dipping; unlike the hanging wall, low-angle (<30°) anastomosing shear zones are common.

Porosity within the hanging wall ranges from 40% to 50% and averages ~42% (Figure **F19**). Although scattered, there is a distinct increase in porosity in the footwall cored in Hole C0010E, with values ranging from 45% to 50% and averaging 48%. *P*-wave velocity in all orientations increases gradually with depth in the hanging wall in Holes C0010C and C0010D from ~1900 m/s to ~2000 m/s in the interval 300–395 mbsf. In the footwall (Hole C0010E), *P*-wave velocity is nearly constant with depth at ~1880 m/s. Average thermal conductivities are 1.37, 1.47, and 1.3 W/(m·K) for Holes C0010C, C0010D, and C0010E, respectively. In general, thermal conductivity in the hanging wall is higher than in the footwall. The higher *P*-wave velocity and thermal conductivity in the hanging wall relative to the footwall is consistent with its lower porosity.

Preliminary scientific assessment

Expedition 365 achieved its two primary scientific and operational objectives, including (1) recovery of the GeniusPlug temporary monitoring system with a >5 y record of pressure and temperature conditions within the shallow megasplay fault zone, geochemical samples, and an in situ microbial colonization experiment (Figures **F8**, **F9**) and (2) installation of a permanent LTBMS with a suite of instruments to monitor seismicity, deformation, and hydrogeological processes. The complex LTBMS sensor array, in combination with the multilevel hole completion, is one of the most ambitious and sophisticated observatory installations in scientific ocean drilling (similar to that in Hole C0002G, deployed in 2010). Additional operational challenges to deployment of the observatory string are presented by the 2500 m water depth and the strong Kuroshio Current (reaching speeds >5 kt during the expedition). Overall, the installation went smoothly, efficiently, and ahead of schedule. The extra time afforded by the efficient observatory deployment was used for coring at Site C0010. Despite challenging hole conditions, the depth interval corresponding to the screened casing across the megasplay fault was successfully sampled in Hole C0010C, and the footwall of the megasplay was sampled in Hole C0010E, with >50% recovery for both zones. Taken together with promising initial results from the GeniusPlug, this represents a clear success in meeting—and exceeding—Expedition 365 objectives.

Notably, many of the previous problems related to running complex observatory arrays in the Kuroshio Current have been successfully mitigated. During deployment “dummy runs” in this area during Expedition 319, VIV of the drill pipe in the water column caused extensive damage to sensors and led to the loss of instruments (Expedition 319 Scientists, 2010). During the most recent NanTroSEIZE LTBMS installation during Expedition 332 (Hole C0002G), VIV was mitigated with the use of ropes attached to the upper portion of the drill pipe, which reduced vibration by disrupting the flow of water around the pipe and prevented the formation of a low-pressure region behind (downstream) of the pipe. However, attachment of ropes, umbilical flatpack, and cables to the pipe still presents an operational challenge and requires considerable time because the lines need to be gathered and strapped to the pipe every ~2 m. During Expedition 365, newly developed moonpool equipment, including a guide roller and completion guide roller, vastly increased efficiency and safety by providing guides to align the umbilical and cables (guide roller) and ropes (completion guide roller) for attachment to the pipe as it was lowered through the moonpool. We attribute much of the operation’s success during the expedition to these advances. The increased efficiency afforded extra days for science operations; as a result, we were able to collect core samples that will provide crucial data to aid in interpretation of the observatory data. The increased efficiency also minimized the time spent suspending sensitive instrumentation in the water column, which in turn minimized the risk of damage due to heave and vibration in the current.

Initial analysis of the GeniusPlug pressure, temperature, chemical, and microbiological experiments has provided promising results. Coring of the thrust wedge immediately above the megasplay fault has yielded key samples for postexpedition analyses and for comparison of pore fluid geochemistry with that sampled by the GeniusPlug. The key outcomes of the expedition include

- Complete recovery of continuous pressure and temperature records from the GeniusPlug, which include high-quality records of formation and seafloor responses to multiple fault slip events, including the 2011 Tohoku M9 earthquake (Figure **F11**), the 1 April 2016 Mie-Ken Nanto-oki M6 earthquake (Figure **F12**), and additional tentatively identified slip events associated with VLF earthquakes (one possibly triggered by the Tohoku earthquake and another in October 2015) (Tobin, Hirose, Saffer, Toczko, Maeda, Kubo, and the Expedition 348 Scientists, 2015);
- Recovery of the FLOCS unit and geochemical sampling coils and successful cultivation of microbes from the FLOCS unit (Figure **F14**);
- Successful deployment of the LTBMS string and completion of the hole (Figure **F6**); and
- Coring in the deepest part of the thrust wedge above the megasplay fault (Holes C0010C and C0010D) and into the footwall of the fault (Hole C0010E), with >50% recovery of the formation; these samples provide valuable context for the formation physical properties and interstitial water geochemistry and will greatly enhance interpretation of the GeniusPlug and LTBMS data sets.

The GeniusPlug record of the Mie-ken Nanto-oki earthquake documents a positive offset in pressure following the event, indicating compressional strain, and is consistent with observations from the previously installed LTBMS in Hole C0002G. This is important because together these data can uniquely distinguish between the two potential focal mechanisms identified by seismological data (a steeply southeast-dipping nodal plane vs. a shallow northwest-dipping one) and provide key evidence supporting a thrusting event either within the accretionary wedge or at the plate interface. We anticipate that future analysis of other earthquakes in the pressure record will produce similar insights.

The GeniusPlug chemistry coils provide fluid samples that are, to first order, consistent with interstitial pore fluids collected across the megathrust at nearby Site C0004 (Kimura et al., 2008). However, loss of substantial fluid during recovery (possibly related to gas exsolution and expansion in the coils) in combination with cracking of the membranes for the chemical sampling coils preclude a detailed analysis of the time series data. Additional targeted analysis of samples and review of the data postexpedition may provide further insights. Care should be taken in future deployments to develop a mechanism to seal the sampling coils and to improve access to the coils on the rig floor to prevent depressurization and/or minimize fluid loss during recovery and transport of the coils to the shipboard laboratories.

The second primary objective of Expedition 365 was to install a permanent LTBMS (Figures **F6**, **F15**, **F16**, **F17**). This was completed successfully and ahead of schedule. All observatory components were tested at several stages before, during, and after reentry and final deployment. These tests verify that all cables, data transmission, and instruments were not damaged during the deployment procedure and were functioning at the time of cementing and hole completion. After Expedition 365, the LTBMS, including multilevel pressure sensors and the full suite of geodetic and seismological instruments, was connected successfully to DONET during a Japan Agency for Marine-Earth Science and Technology cruise on 19 June 2016. From that time onward, power has been supplied by the cabled network and the data sampling rate for pressure has increased from 60 s to 1 s.

In addition to accomplishing the planned expedition objectives noted above, efficient observatory operations afforded contingency time that was used to core the hanging wall and footwall of the megasplay fault and recover materials representative of the formation where observatory instruments are placed (Figure **F4**). The hanging wall is characterized by fractured claystones, whereas the footwall is characterized by relatively less deformed and slightly coarser grained overridden slope apron deposits. These siltstones are similar to those cored at Sites C0001 and C0004 (Figure **F18**, **F19**) with some key differences, notably: (1) the hanging wall at Site C0010 has slightly lower porosity and higher *P*-wave velocity than the hanging wall at Site C0004, consistent with differences in LWD data sets between the two sites and suggesting that the thrust wedge at Site C0010 is slightly more consolidated and/or clay rich than its counterpart along strike and (2) higher calcite content (up to 15 wt%) indicative of deeper environment of deposition closer to the carbonate compensation depth (CCD) and thinner mass transport deposits.

Overall, the expedition was a clear success. All of the scientific and operational goals were achieved and completed well ahead of schedule, allowing for ~5 days of contingency operations that included coring at Site C0010. This is noteworthy because the sites had been logged with LWD during Expedition 319 at the time the casing was emplaced (Expedition 319 Scientists, 2010) but had not been cored. Collection of samples will provide key constraints on rock properties and provide valuable context (i.e., pore fluid geochemistry and physical properties) for interpretation of observatory and GeniusPlug data. For the earthquake events analyzed in our preliminary review of the data set, the borehole measurements, together with data from the previously installed borehole observatory in Hole C0002G, provide important and unique constraints on both slow earthquakes and the details of rupture in the Mie-ken Nanto-oki earthquake. These examples underscore the essential value of borehole observatories in understanding earthquake and tsunami processes through monitoring in boreholes that place instruments nearby, within, and directly above the earthquake-generating faults.

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Table T1. Expedition 365 operations summary. ROV = remotely operated vehicle. LCA = low-current area, VIV = vortex-induced vibration. BOP = blowout preventer, BHA = bottom-hole assembly, HART = hydraulic assist running tool, RTS = rail transport system, HPU = high pressure unit, HPS = Hydralift Power Swivel. POOH = pull out of hole, RIH = run in hole, NG = no go. LTBMS = long-term borehole monitoring system, PSU = pressure sensor unit. WOW = wait on weather. spm = strokes per minute. SUS = steel use stainless. SWG = saltwater gel. RCB = rotary core barrel. (Continued on next page.)

Operation	Date (2016)	Start time (UTC h)	Finish time (UTC h)	Notes	Total operations time (h)	Cumulative time (h)	Cumulative time (days)
Science party boards ship at Shimizu harbor.	27–28 Mar	0000	2400		48.00	48.00	2.0
D/V *Chikyu* sails from Shimizu to Site C0010.	29 Mar	0900	2400	Leave Shimizu harbor at 0900 h.	15.00	72.00	3.0
Arrive at Site C0010.	30 Mar	0000	0330		3.50	75.50	3.1
ROV operations.	30 Mar	0330	1530	Dive ROV, set transponders, remove corrosion cap.	12.00	87.50	3.6
Make up retrieval tool, move to LCA.	30 Mar	1530	0245	Run L-10 A-3 packer retrieval tool with accelerometer. Attach at 550 m BRT and ROV tow rope at 800 m BRT. LCA (1 kt current) located 12 nmi NW of Site C0010.	11.25	98.75	4.1
Begin drifting to Site C0010 from LCA; attach anti-VIV ropes to drill string.	31 Mar	0245	0430	Attaching VIV-suppression ropes with smart bands.	1.75	100.50	4.2
Arrive at well center of Hole C0010A.	1 Apr	0000	0200		2.00	102.50	4.3
Shift BOP cart; install work platform in moonpool.	1 Apr	0200	1715	Resume running L-10 BHA, prepare for stab-in. Mie-ken Nanto-oki M6.0 earthquake at 1139 h.	15.25	117.75	4.9
L-10 on/off tool BHA stabbed in Hole C0010A wellhead.	1 Apr	1715	1730	A-3 packer top at 2928.22 m BRT, 3.5 m lower than set.	0.25	118.00	4.9
POOH L-10 BHA with GeniusPlug; drift to LCA.	1 Apr	1730	2000		26.50	144.50	6.0
Resume POOH L-10 BHA and GeniusPlug.	2 Apr	2000	2315	POOH L-10 BHA to 800 m BRT.	3.25	147.75	6.2
Stop work to fix burst hydraulic line on iron roughneck.	2 Apr	2315	2400		0.75	148.50	6.2
Resume POOH with manual tongs from 670 m BRT.	3 Apr	0000	0100		1.00	149.50	6.2
Remove master bushing/accelerometer from drill pipe.	3 Apr	0100	0115		0.25	149.75	6.2
Resume POOH L-10 BHA and GeniusPlug; lay down packer and tubing.	3 Apr	0115	0930		8.25	158.00	6.6
Drift vessel to LCA 8 nmi north, rig up guide horn.	3 Apr	0930	0100	Drift vessel to LCA 8 nmi west-northwest of Site C0010.	15.50	173.50	7.2
Make up and RIH 8-1/2 inch drilling and 9-7/8 inch underreamer BHA.	4 Apr	0100	1945	Drill out cement, drill pilot hole (8-1/2 inch), activate underreamer (9-7/8 inch), drill to 3206 m BRT.	18.75	192.25	8.0
Wiper trip 3206–3099.5 m BRT.	4 Apr	1945	1430	9-5/8 inch casing shoe at 3099.5 m BRT. Wiper trip, spot protect zone (3.7 kL; 3206–3156 m BRT), POOH underreamer BHA.	18.75	211.00	8.8
Make up and RIH 9-5/8 inch casing scraper while drifting.	5 Apr	1430	0900	Drift at 0.5 kt to well center. RIH and scrape casing to 2934 m BRT. POOH scraper BHA.	18.50	229.50	9.6
Rig down guide horn.	6 Apr	0900	0730	Rig down guide horn; begin LTBMS run preparation.	22.50	252.00	10.5
Evacuation for cold front passage.	7–8 Apr	0730	0730	WOW. Move to 33 nmi NW of Site C0010 by 2400 h.	48.00	300.00	12.5
Run LTBMS with sensor tests.	8 Apr	0730	2400	Finish sensor tests, move strainmeter/sensor carrier to middle pipe rack. Install miniscreens and 1/4-inch hydraulic line on tubing with SUS bands.	16.50	316.50	13.2
Continue sensor cables set up to each sensor (strainmeter, seismometer, thermistor).	9 Apr	0000	0630		6.50	323.00	13.5
Test sensor cables at the moonpool.	9 Apr	0630	0930	Tiltmeter pass; seismometer and strainmeter both NG; both to be replaced.	3.00	326.00	13.6
POOH LTBMS to 30.6 m BRT to remove cables and lay down strainmeter and sensor carrier.	9 Apr	0930	1615	NG sensor test on middle pipe rack; replace with sensor backups.	6.75	332.75	13.9
Restart running LTBMS completion assembly.	9 Apr	1615	1900	Conduct 3 tests of sensors.	2.75	335.50	14.0
Prepare moonpool for packer installation.	9–10 Apr	1900	2215	Conduct sensor communication Test 2. All good.	27.25	362.75	15.1
Install sensor cables and flatpack to swellable packer.	10 Apr	2215	2400	Rig up swellable packer; terminate thermistor cable end onto tubing. Conduct sensor Test 3. All good.	1.75	364.50	15.2
Continue running completion assembly.	11 Apr	0000	1430	Swellable packer in water from 0015 h. Pick up HART at drill floor; pick up LTBMS CORK and move to RTS after PSU testing complete.	14.50	379.00	15.8
Pick up HART and lock to LTBMS CORK on RTS.	11 Apr	1430	1530	Set moonpool for running LTBMS CORK head.	1.00	380.00	15.8
Make up LTBMS CORK head; lower to moonpool.	11 Apr	1530	2115	PSU 2-way valves: "open"; 3-way valves: "ocean."	5.75	385.75	16.1
Arrange position of ODI connector plate on LTBMS CORK.	11 Apr	2115	2300		1.75	387.50	16.1
Prepare moonpool set up for ODI termination; terminate 3 each sensor cables to ODI connectors.	11–12 Apr	2300	2315		24.25	411.75	17.2
Sensor test.	12 Apr	2315	2400	Conduct sensor Test 4.	00.75	412.50	17.2
Install ROV platform and data logger on LTBMS CORK.	13 Apr	0000	0100	Transfer 20 ft test container to aft pipe rack.	1.00	413.50	17.2
Bind sensor cables and connectors to LTBMS CORK head.	13 Apr	0100	1330	Conduct sensor Tests 5 and 6.	12.50	426.00	17.8
Resume running completion assembly into water; conduct ODI wet test.	13–14 Apr	1330	1000	Conduct sensor Test 7 at 1800 m BRT; add VIV ropes while drifting.	20.50	446.50	18.6
Sensor test; resume running LTBMS completion.	14 Apr	1000	2100	Conduct sensor Test 8 at end of drift.	11.00	457.50	19.1
Troubleshoot HPU on drawworks after brake fluid spill.	14 Apr	2100	2200	Hydraulic hose break released brake fluid.	1.00	458.50	19.1
Resume RIH LTBMS completion to 2552 m BRT.	14 Apr	2200	2230		0.50	459.00	19.1
Reenter Hole C0010A.	14–15 Apr	2230	0330	RIH LTBMS completion to 3094 m BRT.	5.00	464.00	19.3
ROV changes PSU 2-way valves from "open" to "ocean."	15 Apr	0330	0345	Confirm direction of ODI connector bay (220°).	0.25	464.25	19.3
Land LTBMS onto wellhead at 3167 m BRT.	15 Apr	0345	0530	40 spm × 2 MPa at 3094 m BRT.	1.75	466.00	19.4
Sensor test.	15 Apr	0530	1045	Conduct sensor Test 9 at end of drift. Run cement.	5.25	471.25	19.6
Release HART.	15 Apr	1045	1215	Drop sponge after release; flush with 100 spm × 2 MPa.	1.50	472.75	19.7
POOH running BHA while removing VIV-suppression ropes to 690 m BRT.	15 Apr	1215	2300	ROV recovered corrosion cap from seafloor. Recover ROV by 2230 h. Lay down HART by 2300 h.	10.75	483.50	20.1

Table T1 (continued).

Operation	Date (2016)	Start time (UTC h)	Finish time (UTC h)	Notes	Total operations time (h)	Cumulative time (h)	Cumulative time (days)
Remove guide roller, completion guide roller, and VIV-suppression rope drums from moonpool.	15–16 Apr	2300	0215		3.25	486.75	20.3
Rig up guide horn on moonpool carts.	16 Apr	0215	1000	Prepare RCB coring at auxiliary well. Install mouseholes on rig floor.	7.75	494.50	20.6
Prepare RCB coring BHA.	16 Apr	1000	2400	Space out RCB inner barrels, set center bit level with bit bottom, set deplugger 70 mm out from bit bottom. Make up 10-5/8 inch RCB BHA. RIH while drifting.	14.00	508.50	21.2
Continue drifting while RIH 10-5/8 inch RCB BHA.	17 Apr	0000	0330	Drift at 1.2 kt, seabed ROV survey; confirm spud-in position.	3.50	512.00	21.3
Tag seabed at 2554 m BRT.	17 Apr	0330	0830	Wash down with 30 spm at 0.7 MPa to 2587 m BRT (33 mbsf). Drill down to 2663 m BRT.	5.00	517.00	21.5
WOW.	17 Apr	0830	0945		1.25	518.25	21.6
Resume drilling down 2663–2854 m BRT.	17–18 Apr	0945	0445	Sweep out 5 m^3 SWG every stand; 1 ream each stand.	19.00	537.25	22.4
Cut Core 365-C0010B-1R.	18 Apr	0445	0800	RCB: 2854.0–2863.5 m BRT; 9.5 m advance. HPS torque/pump pressure indicate pack-off (12 kN/m, 4.5 MPa). Abandon hole.	3.25	540.50	22.5
POOH 10-5/8 inch RCB BHA 2850–2544 m BRT.	18 Apr	0800	0900	10 m above seabed.	1.00	541.50	22.6
Move vessel to Hole C0010C.	18 Apr	0900	1000	Tag seabed at 2553 m BRT.	1.00	542.50	22.6
Spud-in Hole C0010C and drill down 10-5/8 inch RCB BHA to 2853 m BRT.	18 Apr	1000	2400	Jet down to 2588 m BRT. Run sinker bar to recover center bit at 2355 h.	14.00	556.50	23.2
Continue running sinker bar to recover center bit.	19 Apr	0000	0130		1.50	558.00	23.3
Cut 12 RCB cores in Hole C0010C.	19–20 Apr	0130	2400	Cut RCB Cores 365-C0010C-1R to 13R, 300–395 mbsf; 55.4% recovery. Core 13R; drop inner barrel and attempt coring. Pipe stall (high torque 18 kN/m). Abandon Hole C0010C.	46.50	604.50	25.2
Start POOH RCB BHA 2948–2510 m BRT.	21 Apr	0000	0145	10 m above seabed.	1.75	606.25	25.3
Move vessel to Hole C0010D.	21 Apr	0145	0630	Tag seabed at 2555 m BRT.	4.75	611.00	25.5
Spud-in Hole C0010D and drill down 10-5/8 inch RCB BHA to 2589 m BRT.	21 Apr	0630	2300	Reach 2589 m BRT by 1000 h, DP status changes from "green" to "yellow" at 2250 h from cold front passage (winds ~18 m/s) and Kuroshio Current (5.2 kt). Decide to POOH near seabed.	16.50	627.50	26.1
POOH 10-5/8 inch RCB BHA to 2585 m BRT (30 mbsf).	21 Apr	2300	2400	WOW.	1.00	628.50	26.2
WOW.	22 Apr	0000	0600	DP returned to "advisory" at 0550 h.	6.00	634.50	26.4
RIH 2585–2940 m BRT.	22 Apr	0600	1915	No excessive drag observed. Sweep out 5 kL of SWG and 5 kL of guar gum every stand.	13.25	647.75	27.0
Cut Core 365-C0010D-1R.	22 Apr	1915	1930		0.25	648.00	27.0
Sweep 20 m^3 of SWG and guar gum; recover inner barrel.	22 Apr	1930	2100	120 spm × 12.0~8.0 MPa.	1.50	649.50	27.1
Sweep out SWG and guar gum without inner barrel.	22 Apr	2100	2230	Abnormal pressure does not improve after 3 sweeps.	1.50	651.00	27.1
Drop inner barrel to cut core.	22 Apr	2230	2245		0.25	651.25	27.1
Make up connection to begin coring; drill pipe becomes stuck.	22 Apr	2245	2345	Massive flow-back observed, trapped pressure holding at 3 MPa. Pipe freed with rotation at 2932 m BRT.	1.00	652.25	27.2
POOH 10-5/8 inch RCB BHA with excessive drag.	22 Apr	2345	2400		0.25	652.50	27.2
POOH 10-5/8 inch RCB BHA to 2550 m BRT (5 m above seabed).	23 Apr	0000	0130	Occasional overpull (150–200 kN).	1.50	654.00	27.3
Recover sinker bar; move to Hole C0010E, drop center bit.	23 Apr	0130	0330		2.00	656.00	27.3
Seabed survey.	23 Apr	0330	0430	Tag seabed at 2566.5 m BRT.	1.00	657.00	27.4
Spud-in Hole C0010E; drill down 10-5/8 inch RCB BHA to 2778 m BRT.	23 Apr	0430	1345		9.25	666.25	27.8
Ream up/down to open hole (2778–2740 m BRT).	23 Apr	1345	1445	No excessive drag observed.	1.00	667.25	27.8
Drill down 2778–2926.5 m BRT.	23 Apr	1445	2100		6.25	673.50	28.1
Load sinker bar, retrieve center bit, drop inner barrel.	23 Apr	2100	2215		1.25	674.75	28.1
Cut Core 365-C0010E-1R.	23–24 Apr	2215	0445	Cut RCB Cores 365-C0010E-1R to 4R, 360–391 mbsf; 71.2% recovery. Finish coring in Hole C0010E.	6.50	681.25	28.4
POOH 10-5/8 inch RCB BHA to surface.	24 Apr	0445	1430	No excessive overpull.	9.75	691.00	28.8
Lay out RCB BHA.	24 Apr	1430	1500		0.50	691.50	28.8
Rig down upper guide horn; move BOP cart aft.	24 Apr	1500	2145	Move vessel 1.5 nmi W-NW of Hole C0010A. Check LTBMS sensor, observe no flow from Hole C0010D.	6.75	698.25	29.1
End of Expedition 365 operations.	24 Apr	2145	2400	Ship maintenance/slow return to Shimizu harbor.	2.25	700.50	29.2
Sail back to Shimizu harbor.	25–27 Apr	0000	2400		48.00	748.50	31.2

Table T2. Site C0010 bottom-hole assemblies (BHAs). Recovery is top of A-3 Baker-Hughes bridge plug. MSL = from mean sea level. TD = total depth. NA = not applicable. LTBMS = long-term borehole monitoring system, HART = hydraulic assist running tool. RCB = rotary core barrel. DC = drill collar, DP = drill pipe, PDC = polycrystalline diamond compact, stab = stabilizer, std = stand, XO = crossover sub.

Hole	Drilling type	Water depth BRT (m)	Water depth MSL (m)	TD (mbsf)	TD BRT (m)	Bit size (inch)	BHA
C0010A	Recovery	2552	2523.5	372	2924	NA	L-10 on/off tool × port sub (3-1/2 inch IF pin × 5-1/2 inch FH DSTJ box) × 5-1/2 inch DP S-140 pup joint (3 m) × 5-1/2 inch DP S-140 (1 std) × XO × 6-3/4 inch DC (12) × XO × 5-1/2 inch DP S-140 (37 stds) × XO × 5-1/2 inch DP S-150
	Drill and underream			654	3728	8-1/2	8-1/2 inch PDC bit × NBR800 underreamer (8-1/2 inch × 9-7/8 inch) × bit sub w/float × XO × 8-1/2 inch stab × XO × 6-3/4 inch DC (9) × 6-3/4 inch HM jar × 6-3/4 inch DC (3) × XO × 5-1/2 inch DP S-140 (38 stds) × 5-1/2 inch DP S-150
	Casing scraping tool			525	3077	8-1/2	8-1/2 inch insert bit × 9-5/8 inch casing scraper × XO × 6-3/4 inch DC (9) × HM jar × 6-3/4 inch DC (3) × XO × Churchill drift catcher sub × 5-1/2 inch DP S-140 (38 stds) × XO × 5-1/2 inch DP S-150
	LTBMS running tool			0	2552		HART
C0010B	RCB coring	2554	2525.5	309.5	2864.5	10-5/8	10-5/8 inch core bit × long bit sub w/stab × 8-1/2 inch core barrel × top sub × head sub × 10-5/8 inch stab × 8-1/2 inch core DC (2) × XO × 10-5/8 inch stab × XO × 8-1/2 inch core DC (6) × XO × 5-1/2 inch DP S-140 (38 stds) × XO × 5-1/2 inch DP S-150
C0010C	RCB coring	2553	2524.5	395.5	2948.5	10-5/8	10-5/8 inch core bit × long bit sub w/stab × 8-1/2 inch core barrel × top sub × head sub × 10-5/8 inch stab × 8-1/2 inch core DC (2) × XO × 10-5/8 inch stab × XO × 8-1/2 inch core DC (6) × XO × 5-1/2 inch DP S-140 (38 stds) × XO × 5-1/2 inch DP S-150
C0010D	RCB coring	2555	2526.5	394.5	2949.5	10-5/8	10-5/8 inch core bit × long bit sub w/stab × 8-1/2 inch core barrel × top sub × head sub × 10-5/8 inch stab × 8-1/2 inch core DC (2) × XO × 10-5/8 inch stab × XO × 8-1/2 inch core DC (6) × XO × 5-1/2 inch DP S-140 (38 stds) × XO × 5-1/2 inch DP S-150
C0010E	RCB coring	2566.5	2538	391	2957.5	10-5/8	10-5/8 inch core bit × long bit sub w/stab × 8-1/2 inch core barrel × top sub × head sub × 10-5/8 inch stab × 8-1/2 inch core DC (2) × XO × 10-5/8 inch stab × XO × 8-1/2 inch core DC (6) × XO × 5-1/2 inch DP S-140 (38 stds) × XO × 5-1/2 inch DP S-150

Table T3. Site C0010 coring details.

Hole	Longitude	Latitude	Seafloor depth BRT (m)	Water depth MSL (m)	Core	Core on deck date (2016)	Core on deck time (h)	Top depth BRT (m)	Bottom depth BRT (m)	Top depth (mbsf)	Bottom depth (mbsf)	Advance (m)	Recovery (m)	Recovery (%)	Time on hole (h)
C0010B	33°12.5930′N	136°41.1806′E	2554.0	2525.5	1R	17 Apr	0930	2854.0	2863.5	300.0	309.5	9.5	0	0	
						Hole C0010B totals:		2854.0	2863.5	300.0	309.5	9.5	0	0	3.25
C0010C	33°12.5899′N	136°41.1748′E	2553.0	2524.5	1R	18 Apr	0417	2853.0	2862.5	300.0	309.5	9.5	5.49	57.8	
					2R	19 Apr	0655	2862.5	2872.0	309.5	319.0	9.5	5.18	54.5	
					3R	19 Apr	0925	2872.0	2881.5	319.0	328.5	9.5	3.85	40.5	
					4R	19 Apr	1216	2881.5	2891.0	328.5	338.0	9.5	3.34	35.2	
					5R	19 Apr	1533	2891.0	2900.5	338.0	347.5	9.5	3.81	40.1	
					6R	19 Apr	1855	2900.5	2910.0	347.5	357.0	9.5	5.18	54.5	
					7R	20 Apr	0045	2910.0	2919.5	357.0	366.5	9.5	6.78	71.4	
					8R	20 Apr	0419	2919.5	2929.0	366.5	376.0	9.5	3.41	35.9	
					9R	20 Apr	0706	2929.0	2933.5	376.0	380.5	4.5	3.88	86.2	
					10R	20 Apr	1027	2933.5	2938.0	380.5	385.0	4.5	5.22	116.0	
					11R	20 Apr	1404	2938.0	2943.0	385.0	390.0	5.0	4.07	81.4	
					12R	20 Apr	1912	2943.0	2948.0	390.0	395.0	5.0	2.38	47.6	
						Hole C0010C totals:		2943.0	2948.0	390.0	395.0	95.0	52.6	55.4	46.50
C0010D	33°12.6024′N	136°41.2042′E	2555.0	2526.5	1R	22 Apr	2054	2940.0	2949.5	385.0	394.5	9.5	7.22	76.0	
						Hole C0010D totals:		2940.0	2949.5	385.0	394.5	9.5	7.22	76.0	0.25
C0010E	33°12.5500′N	136°41.2223′E	2566.5	2538.0	1R	23 Apr	2316	2926.5	2932.5	360.0	366.0	6.0	0.22	3.7	
					2R	24 Apr	0048	2932.5	2938.5	366.0	372.0	6.0	3.03	50.5	
					3R	24 Apr	0230	2938.5	2948.0	372.0	381.5	9.5	10.1	106.3	
					4R	24 Apr	0407	2948.0	2957.5	381.5	391.0	9.5	8.73	91.9	
						Hole C0010E totals:		2948.0	2957.5	381.5	391.0	31.0	22.1	71.2	7.25
						Site C0010 coring totals:		2943.0	2949.5	390.0	395.0	145.0	81.9	56.5	57.25

Table T4. Summary of drilling, long-term borehole monitoring system (LTBMS) installation, and coring during Expedition 365. RCB = rotary core barrel. NA = not applicable.

Hole	Latitude	Longitude	Water depth BRT (m)	Water depth MSL (m)	Operation	Drilled interval (mbsf)	Cased interval (mbsf)	Total penetration (m)	Cores (*N*)	Interval cored (m)	Core recovered (m)	Recovery (%)	Time on hole (days)
C0010A	33°12.5981′N	136°41.1924′E	2552	2523.5	GeniusPlug recovery	0.0	544.3	0.0	NA	NA	NA	NA	3
					Hole extension, LTBMS deployment	129.0	NA	654.0	NA	NA	NA	NA	13.7
C0010B	33°12.5930′N	136°41.1806′E	2554	2525.5	Coring (RCB)	309.5	NA	309.5	1	9.5	0.0	0.0	2.3
C0010C	33°12.5899′N	136°41.1748′E	2553	2524.5	Coring (RCB)	300.0	NA	395.0	12	95.0	52.6	55.4	2.7
C0010D	33°12.6024′N	136°41.2042′E	2555	2526.5	Coring (RCB)	380.0	NA	394.5	1	9.5	7.2	76.0	2
C0010E	33°12.5500′N	136°41.2223′E	2566.5	2538.0	Coring (RCB)	360.0	NA	391.0	4	31.0	22.1	71.2	1.5
Expedition 365 totals:						1118.5	544.3	1753.0	18	145.0	81.9	56.5	25

Figure F1. A. Map showing locations of NanTroSEIZE drill sites (red = locations of existing and planned borehole observatory installations) (from Kopf, Araki, Toczko, and the Expedition 332 Scientists, 2011). Expedition 365 focuses on Site C0010, which penetrates the megasplay fault at 407 mbsf. B. Detail map showing location of Site C0010. IL = in-line, XL = cross-line.

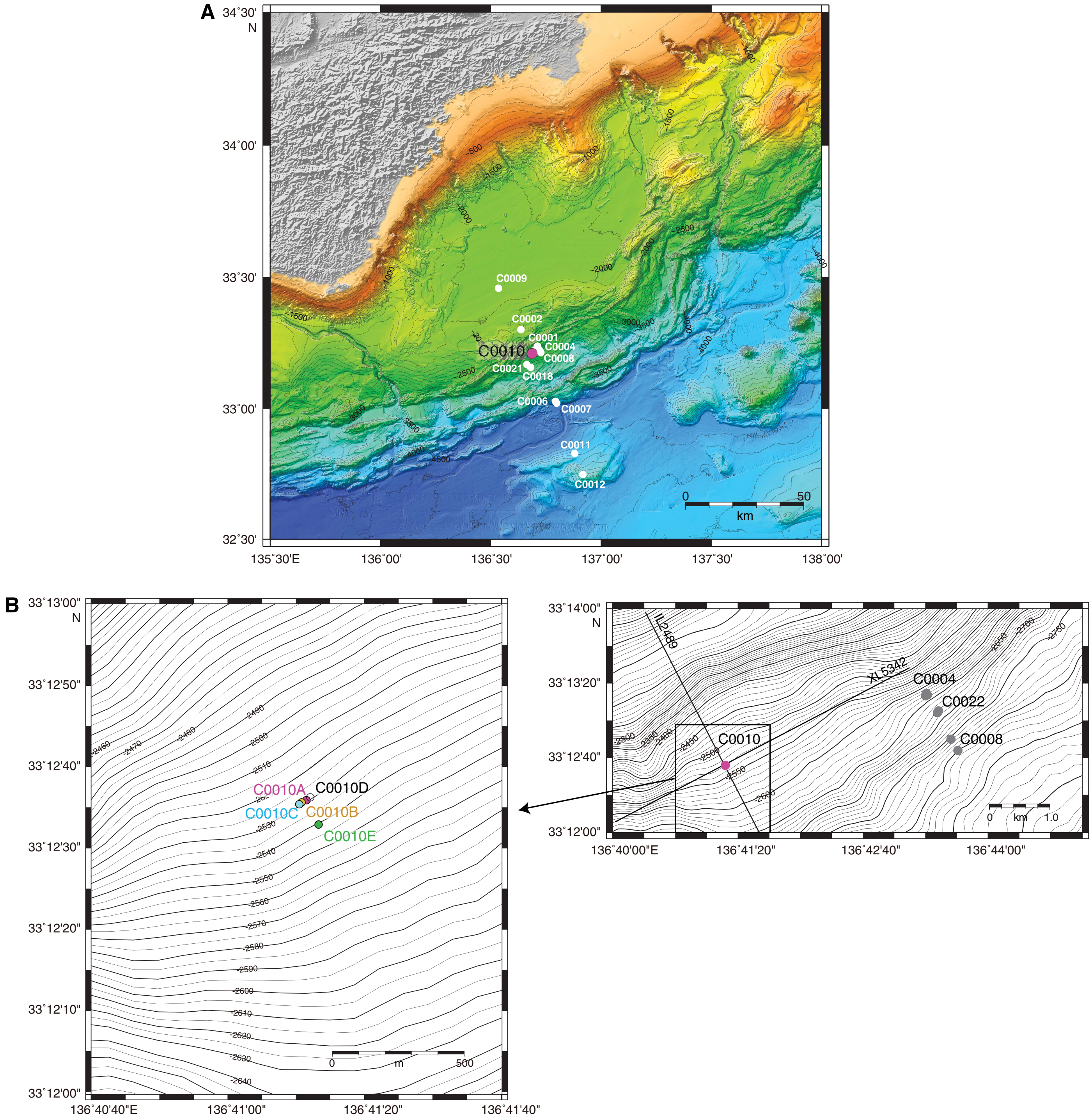

Figure F2. Interpreted seismic cross section of Kumano transect offshore and southeast of Kii Peninsula (modified from Moore et al., 2009; after Moore et al., 2013). Starting with the trench, the transect is separated into six morphotectonic domains: protothrust zone, frontal thrust zone, imbricate thrust zone, megasplay fault zone, Kumano Basin edge fault zone, and Kumano fore-arc basin. Drill sites on incoming Philippine Sea plate are not shown. VE = vertical exaggeration.

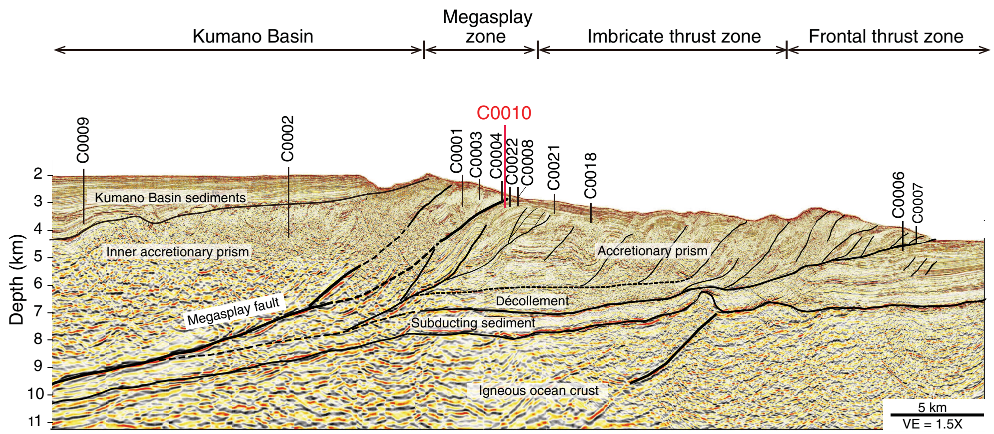

Figure F3. Detailed seismic reflection lines showing locations of Holes C0010A–C0010E. A. Dip line. B. Strike line. Line locations are shown in Figure **F1B**. mbsl = meters below sea level.

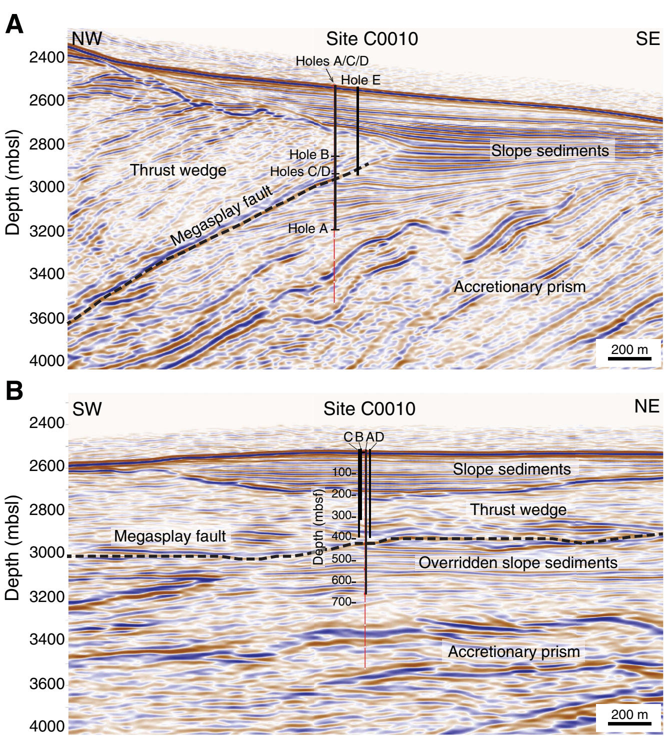

Figure F4. Schematic showing configuration of Hole C0010A and depths of GeniusPlug and key components of hole completion, Expedition 332.

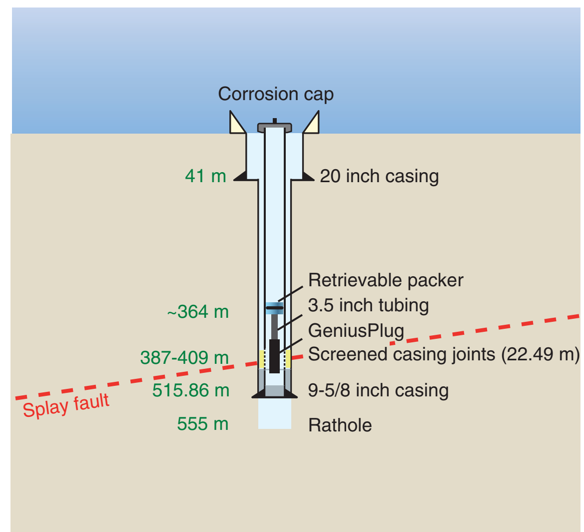

Figure F5. GeniusPlug components. MTL = miniature temperature logger, RTC-PPC = real-time clock pressure period counter.

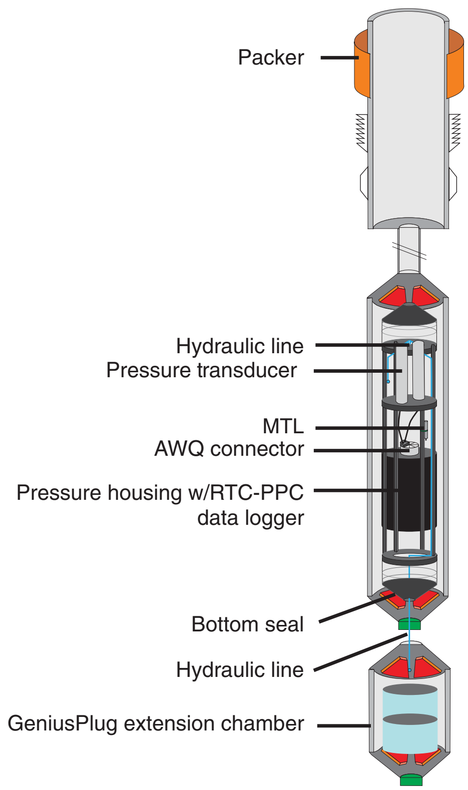

Figure F6. Schematic of LTBMS string installed in Hole C0010A after recovery of GeniusPlug. BRT = below rotary table.

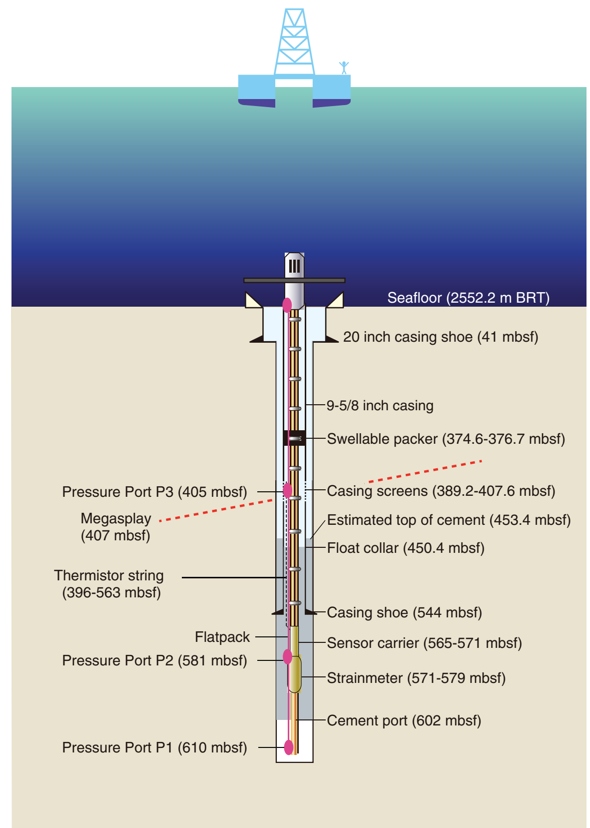

Figure F7. Planned operations sequence, Hole C0010A. POOH = pull out of hole.

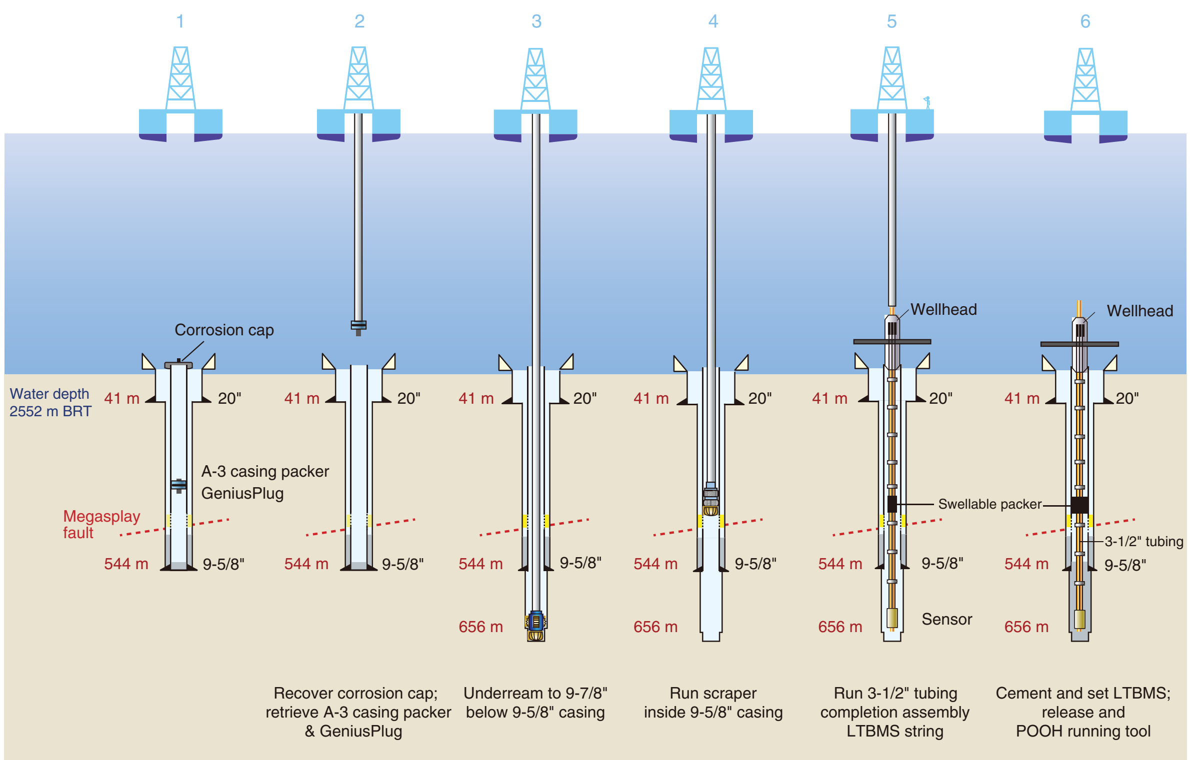

Figure F8. GeniusPlug. MTL = miniature temperature logger (Antares), P sensor = pressure sensor.

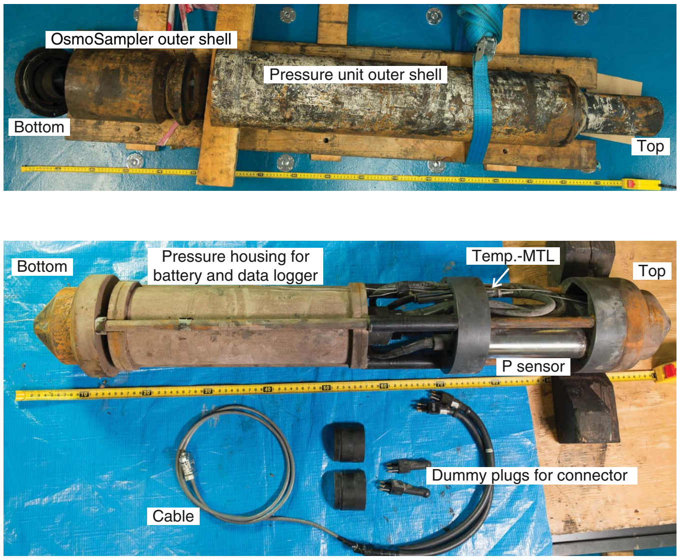

Figure F9. OsmoSampler coils. FLOCS = Flow-through Osmo Colonization System.

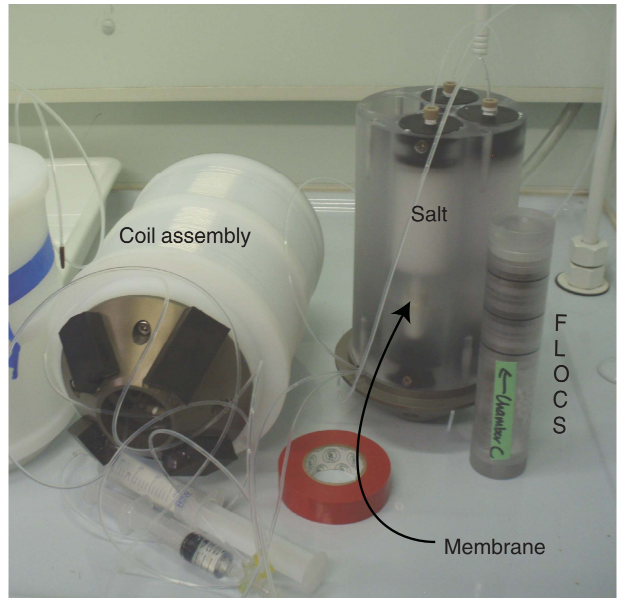

Figure F10 Pressure (P) record from GeniusPlug deployment. A. Overview of entire deployment period. B. Installation time window. C. Instrument recovery period.

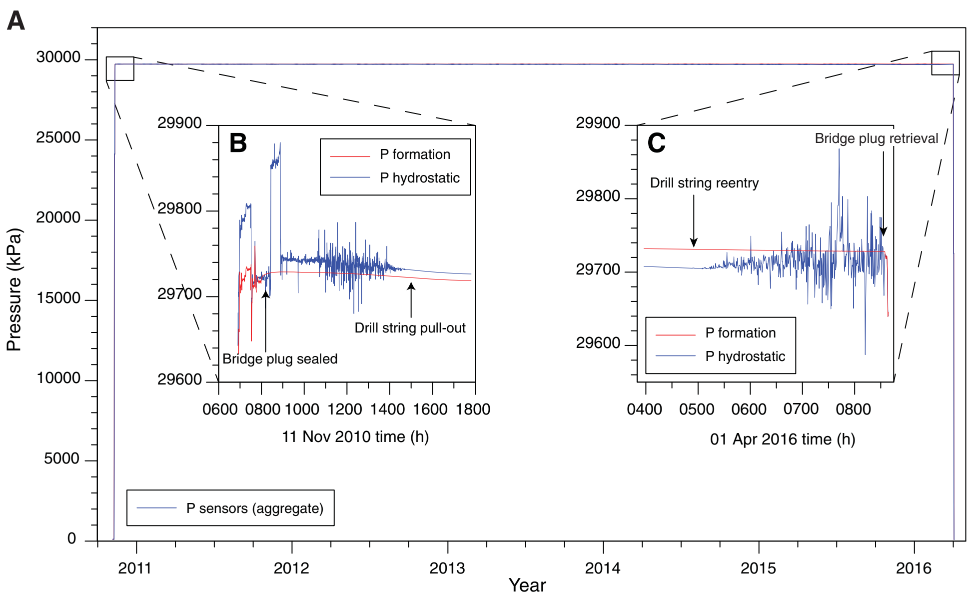

Figure F11. Pressure (P) record for the 11 March 2011 Tohoku M9 earthquake. A. Data from 9 to 15 March. B. Earthquake record on 11 March.

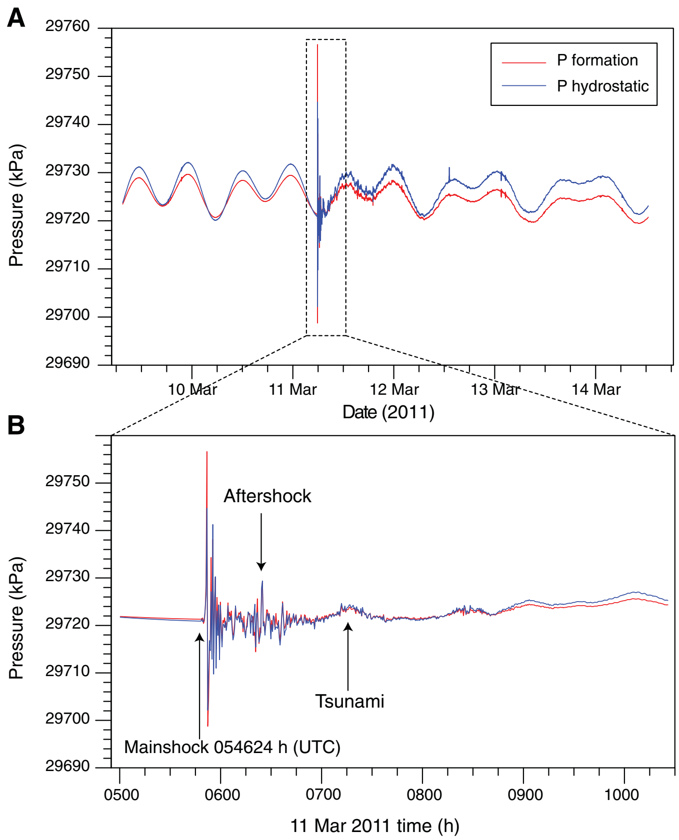

Figure F12. Pressure (P) record for the 1 April 2016 Mie-ken Nanto-oki M6 earthquake (EQ). A. 2.3 day period from 30 March to 1 April. B. Time window of earthquake.

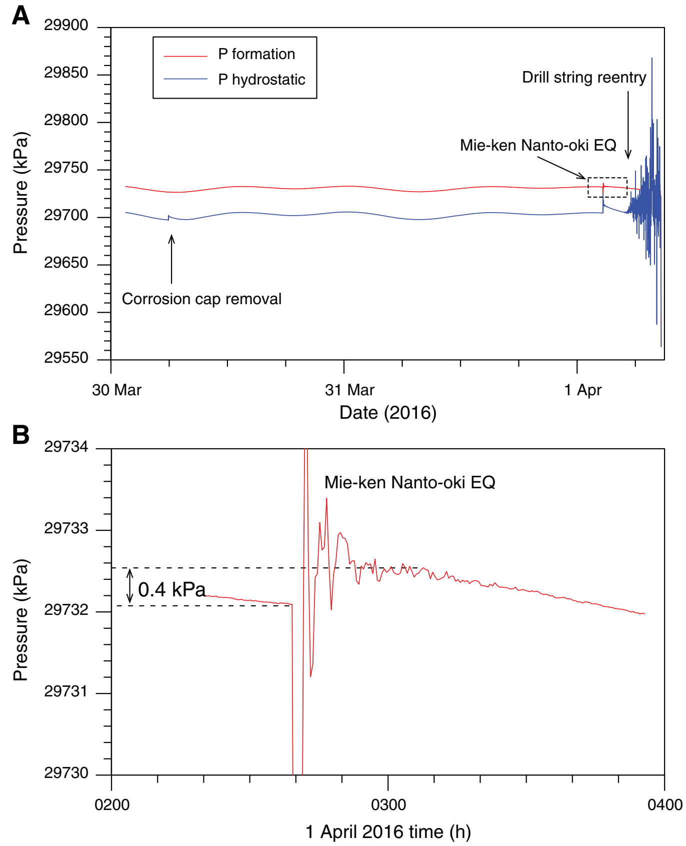

Figure F13. Chlorinity data from GeniusPlug chemistry (chem) and biology (bio) coils. Interstitial water (IW) results for Sites C0004 and C0010 are shown for comparison.

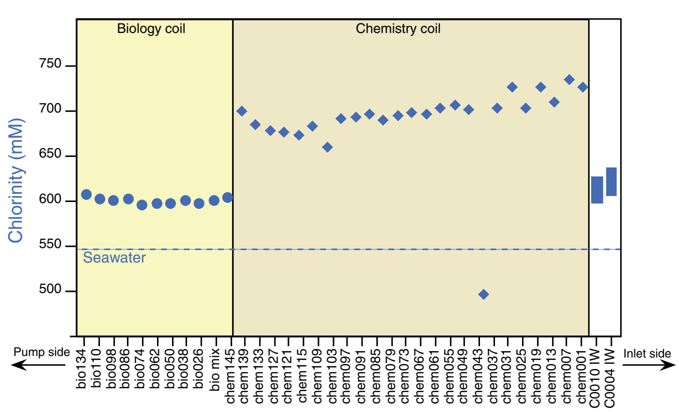

Figure F14. A. Schematic of FLOCS unit. B–G. Microscope images of microbiology cultures. 250 µL of each culture was filtered onto a 0.2 µM filter, stained with SYBR green, and viewed with an epifluorescent microscope. Inoculum for each culture: (B) FLOCS fluids, (C) crushed barite, (D) Site C0004 sediment, (E) olivine, (F) rust from GeniusPlug casing, and (G) control.

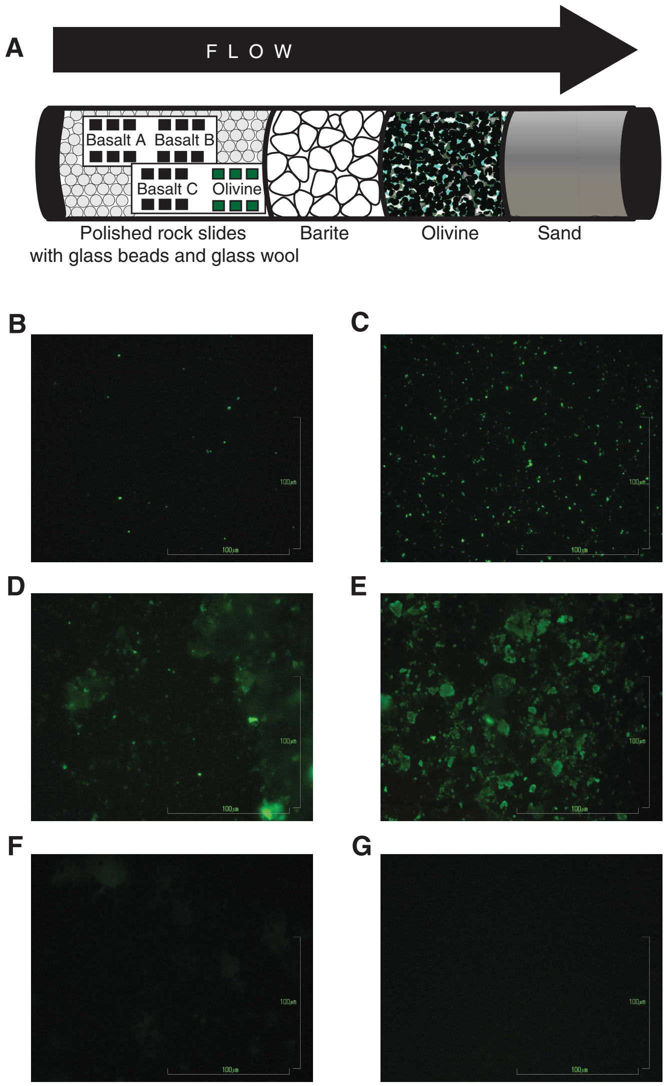

Figure F15. LTBMS head, showing configuration of each bay (top) and ROV platform and data recorder (bottom). UMC = underwater mateable connectors.

Figure F16. Miniscreens used to terminate hydraulic line at the lowermost pressure port.

Figure F17. A. Instrument carrier. B. Strainmeter suspended in moonpool.

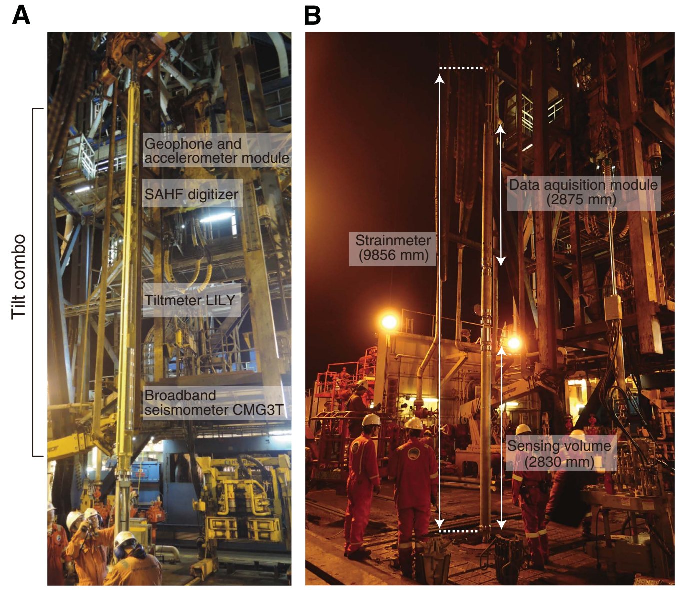

Figure F18. Generalized stratigraphic columns for Holes C0010C and C0010D (hanging wall) and Hole C0010E (footwall).

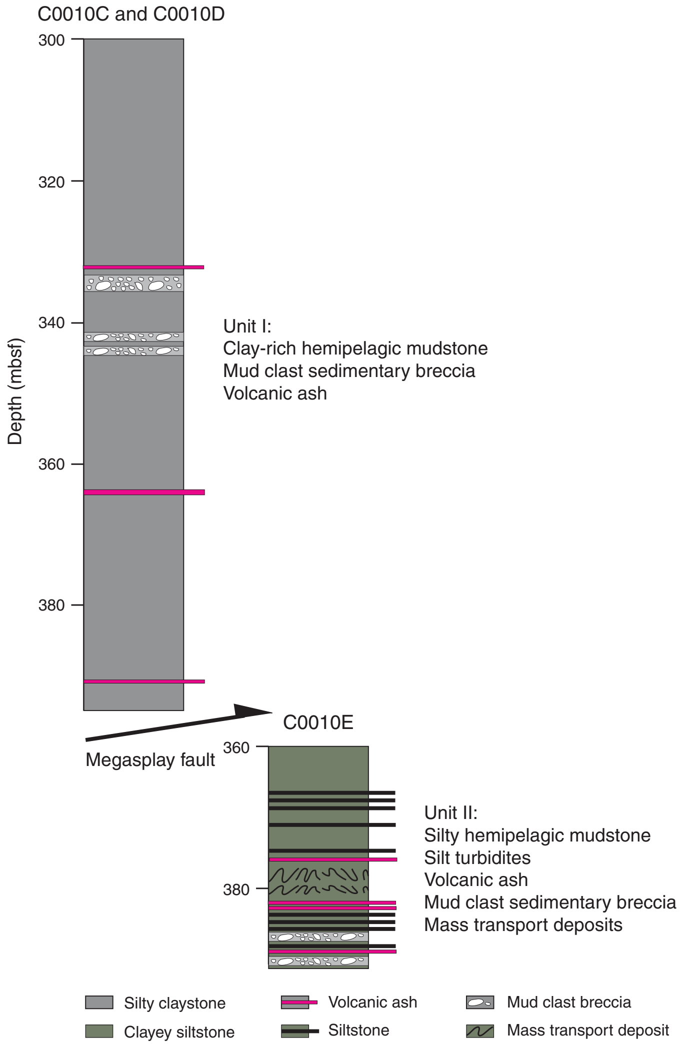

Figure F19. Porosity and *P*-wave velocity data, Holes C0010A–C0010E.