IODP Expedition 326 Operations: First Stage of Nankai Trough Plate Boundary Deep Riser Drilling

by Masataka Kinoshita, Harold Tobin, Nobuhisa Eguchi, and Simon Nielsen

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Introduction

Expedition 326 Ultra Deep Riser Top Hole was the first stage of drilling and coring of the Integrated Ocean Drilling Program (IODP) Hole C0002F to the boundary zone between the Philippine Sea and Eurasian Plates in the Nankai accretionary margin, one of the main objectives of the Nankai Trough SEIsmogenic Zone Experiments (NanTroSEIZE) Complex Drilling Program. The expedition objectives were purely operational, with the goal being installation of the wellhead assembly and drilling and casing the uppermost 800 m of the planned 7-km deep hole. Accordingly, no science party was on board during the expedition, and no scientific results are reported. Scientific objectives for the top 1400 m of this Site were previously fulfilled during NanTroSEIZE Stage 1 Expeditions 314 and 315 (Kinoshita et al., 2009).

After a one month operation in July–August 2010, Hole C0002F had been drilled to 872.5 m below sea floor (mbsf), and the hole was lined with cemented-in 20-inch casing. A corrosion cap was set in preparation for return to continue drilling in 2012. We confirm that Hole C0002F is now ready for deep riser drilling to the plate boundary fault zone.

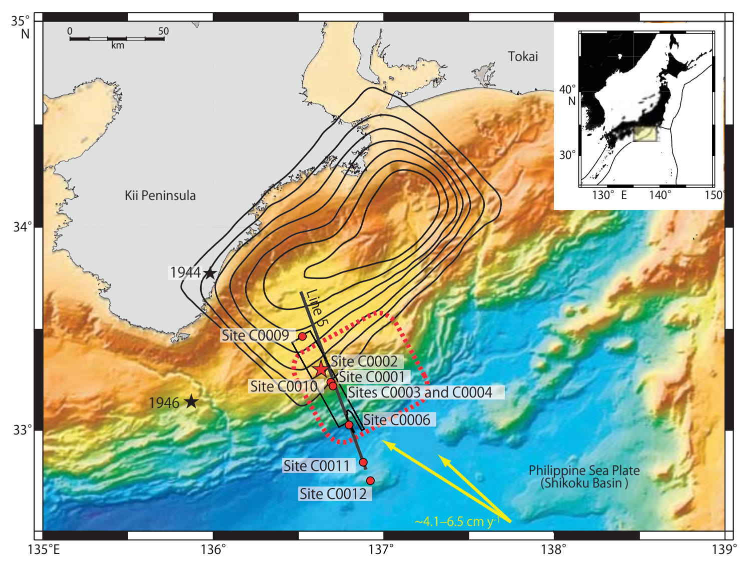

Figure 1. Map of Nankai accretionary complex off Kumano, showing NanTroSEIZE drill sites. Yellow arrows=computed far-field convergence vectors between the Philippine Sea Plate and Japan (Seno et al., 1993; Heki, 2007). Contours indicate estimated slip during the 1944 event (0.5-m intervals). Red box outlines region of recorded very low frequency events (Obara and Ito, 2005). Red circles=NanTroSEIZE drill sites. C0002 is marked with a red star.

NanTroSEIZE Complex Drilling Project

NanTroSEIZE is a multiexpedition, multistage IODP drilling program focused overall on understanding the mechanics of seismogenesis and rupture propagation along subduction plate boundary faults (Tobin and Kinoshita, 2006). This program includes a coordinated effort to characterize (through integrating core/log with seismic images), sample (core/cuttings), and instrument (borehole observatory) the plate boundary fault system near the updip limit of the locked zone of Tonankai great earthquakes at 5–7 km below seafloor (Figs. 1, 2; Tobin and Kinoshita, 2006).

The main objectives are to understand (1) the mechanisms controlling the updip aseismic–seismic transition along the megathrust fault systems; (2) processes of earthquake and tsunami generation and strain accumulation and release, including the role of recently discovered slow slip and very low frequency earthquake (Ito and Obara, 2006); (3) the absolute mechanical strength of the plate boundary fault and its degree of interseismic locking; and (4) the potential role of a major upper plate fault system (termed the “megasplay” fault) in seismogenesis and tsunamigenesis. This drilling program approaches these objectives through a combination of riser and riserless drilling, long-term observatories, and associated geophysical, laboratory, and numerical modeling efforts.

At Nankai Trough, high-resolution seismic reflection profiles 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 M 8.2 earthquake (Fig. 1). Several lines of evidence indicate that the megasplay system is active and may accommodate a significant fraction of plate boundary motion (Moore et al., 2007, 2009). However, the partitioning of strain between the lower plate interface above the oceanic basement and the megasplay system is not understood, and neither are the nature and mechanisms of fault

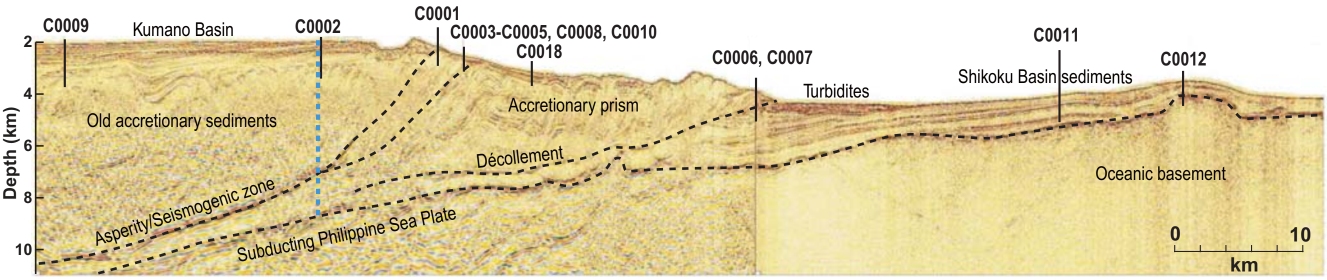

Figure 2. Spliced composite profile of a representative depth section from the NanTroSEIZE 3D seismic data volume (Moore et al., 2009) and Line 95 from IFREE mini-3D seismic survey (Park et al., 2008). Projected positions of Stage 1 and 2 drilling sites, including C0009, C0010, C0011, and C0012.

slip as a function of depth and time on the megasplay. One of the first-order goals in characterizing the seismogenic zone along the Nankai Trough—and which bears 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.

IODP Site C0002 is the centerpiece of the NanTroSEIZE project, intended to access the plate interface fault system at a location where it is believed to be capable of seismogenic locking and slip, and to have slipped coseismically during the 1944 Tonankai earthquake. The primary targets include both the basal décollement and the reflector known as the “megasplay fault” (Tobin and Kinoshita, 2006). The megasplay fault zone and the accretionary prism domain are the location of a newly identified class of earthquakes known as very low frequency () earthquakes (Ito and Obara, 2006) as well as the first observation of shallow tectonic tremor (Obana and Kodaira, 2009). The megasplay fault reflector lies at an estimated depth of 5000–5200 mbsf, and the top of the subducting basement is estimated to lie at 6800–7000 mbsf (Fig. 3).

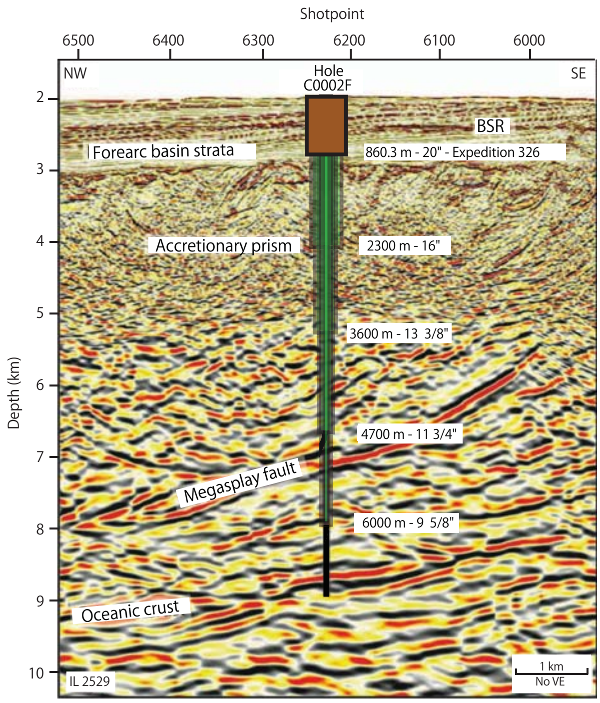

Figure 3. Seismic section of In-line 2529, showing the current status and planned trace for the deep riser Hole C0002F. Brown rectangle denotes the progress made by Expedition 326. Note that the operational options shown here in green are only suggested by the Project Management Team (PMT). BSR=Bottom Simulating Reflector, LWD=Logging-While-Drilling.

During Expedition 314, Site C0002 was drilled to 1401 mbsf with *in situ* measurement of physical properties and borehole imaging through logging while drilling (LWD) but no coring (Expedition 314 Scientists, 2009). Several months later, portions of Site C0002 were cored over the intervals 0–204 mbsf and 475–1057 mbsf on Expedition 315 (Expedition 315 Scientists, 2009). Lithostratigraphy at Site C0002 is characterized by turbiditic sediments to ~830 mbsf, underlain by older rocks of the accretionary prism and/or early slope basin sediments deposited prior to the development of the megasplay fault.

Further background, objectives, and accomplishments to date for the NanTroSEIZE project are discussed in Tobin et al. (2009), Expedition 319 Scientists (2010), and Underwood et al. (2010).

Summary of Operations at Site C0002 Ultra Deep Riser Top Hole

The Expedition 326 was carried out during 19 July to 20 August 2010. Hole C0002F is located at 33° 18.0507' N, 136° 38.2029' E (Fig. 4) and its water depth is 1968 m. Total drilling depth was 872.5 mbsf.

Our drilling plan for Expedition 326 was to run a mudmat (a steel plate deployed on the seafloor) and a Guidelineless Reentry Assembly (GRA) to the seafloor, and jet in 36-inch conductor casing to 60 mbsf (Fig. 5). The 36-inch conductor pipe and jetting Bore Hole Assembly (BHA) were made up and run, and by 21 July the guide horn was installed, and the vessel started drifting to site. Hole C0002F was spudded on 25 July, jetting the 36-inch conductor pipe in to 54 mbsf. After the casing angle was confirmed by Write Remotely Operated Vehicle (ROV) to be within 1.5° of vertical, the

BHA was exchanged to a 26-inch drill-ahead assembly. Releasing the Drill Ahead Tool (DAT) went smoothly, followed by drilling with 26-inch bit to target depth of 856.5 mbsf on 27 July.

The subsequent wiper trip encountered a few tight spots, including one too close to total depth (TD) that could endanger the cement job for the casing operation. We decided to deepen the hole slightly, to reach a more stable interval at 868.5 mbsf. By 30 July we were able to clear the hole and move upstream to prepare for casing operations.

The lowering of the 20-inch casing began on 31 July, and by 1 August deep sea drilling vessel (D/V) *Chikyu* could drift back towards Hole C0002F with 72 joints of 20-inch casing trailing underneath. However, during the afternoon of 1 August, probably due to a sudden intensifying of the current, the string sheared off just above the Casing Running Tool (CART), and most of the casing was lost on the seafloor. The decision was made to return to the port of Shingu to load up new casing and try again.

The port call lasted less than a day, and by 3 August *Chikyu* returned to sea to stand by, while decisions were made on shore about how to proceed. It was decided to procure a sturdier but untested CART, which was delivered by the supply boat on 7 August. While decisions were still being made onshore, we surveyed current conditions with the help from the tanker ship *Heisei-maru*. Currents sometimes exceeded 4 knots, with an average around 3 knots.

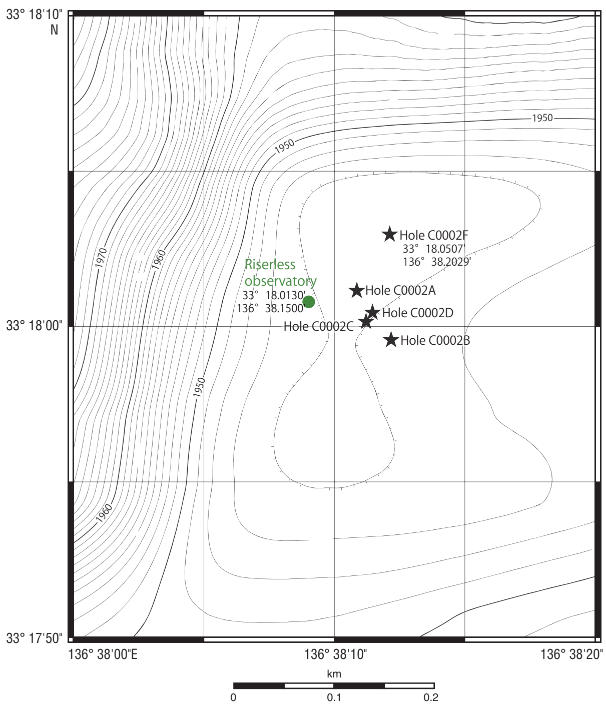

Figure 4. Bathymetric map of Site C0002. Black stars=holes drilled, green circle=proposed hole for Expedition 332 riserless observatory.

Preparations for the second casing operation were completed by 12 August. We reamed down another 4 m (to 872.5 mbsf) and continued wiper trips until 14 August, then returned upstream to a low current area to prepare for setting casing. On 15 August, the new casing was lowered, with four ropes attached to the drill pipe to reduce the Vortex-Induced Vibration (VIV). Use of the rope is proven very effective to suppress VIV (Kitada et al., 2011), thus this option was adopted for the second casing operation.

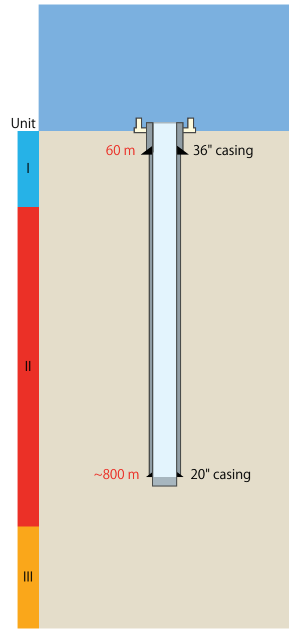

Figure 5. Casing plan for top hole portion of the riser hole, C0002F. The 36-inch conductor casing was set at 54 mbsf, and the 20-inch casing was run to 856.6 mbsf.

Drifting downstream was successfully followed by the casing stabbed into Hole C0002F under the current speeds of >4 knots. On 18 August, the casing was successfully set and cemented, and the drill pipe could be tripped back up. The casing shoe is at 860.3 mbsf. Finally, a steel lid, called the "corrosion cap", was set at the top of the hole by the ROV on 19 August. This completed mission of Expedition 326 to set the wellhead, 36-inch conductor, and 20-inch casing, and to cement to 860.3 mbsf, satisfying the requirement for this tophole portion of the planned riser borehole. The *Chikyu* arrived in Shimizu, Japan, and Expedition 326 concluded on 20 August 2010.

The loss of a substantial length of 20-inch casing in the water column, presumably due to the strong current and VIV, was a costly problem. However, the lesson learned about how to deploy casing and other pipe through the Kuroshio current using the vibration-dampening rope coils proved to be successful in the second attempt.

Plan Toward the Completion of Hole C0002F

In October 2012, Hole C0002F will be revisited to extend the hole from ~900 mbsf to 3600 mbsf during IODP Expedition 338 "NanTroSEIZE Plate Boundary Deep Riser – 2" (Fig. 3). The proposed extension would access the deep interior of the Miocene accretionary prism. In addition to continuous cutting analyses, mud-gas and logging while drilling (LWD) data will be acquired throughout the interval, whereas the core sampling is planned for a limited interval (2300–2400 mbsf). The hole will be cased with

16-inch casing for the upper 2300 m, then with 13 3/8 inch casing down to 3600 mbsf.

In the following year, this hole is planned to be deepened to ~4700 mbsf for the next casing, followed by the drilling/coring ahead toward the megasplay fault system that is expected at 5000–5200 mbsf.

References

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

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

Expedition 319 Scientists, 2010. Expedition 319 summary. *In* Saffer, D., McNeill, L., Byrne, T., Araki, E., Toczko, S., Eguchi, N., Takahashi, K., and the Expedition 319 Scientists, *Proc. IODP,* 319: Washington, DC (Integrated Ocean Drilling Program Management International, Inc.). doi:10.2204/iodp.proc.319.101.2010

Heki, K., 2007. Secular, transient and seasonal crustal movements in Japan from a dense GPS array: Implication for plate dynamics in convergent boundaries. *In* Dixon, T., and Moore, C. (Eds.), *The Seismogenic Zone of Subduction Thrust Faults:* New York (Columbia University Press), 512–539.

Ito, Y., and Obara, K., 2006. Dynamic deformation of the accretionary prism excites very low frequency earthquakes. *Geophys. Res. Lett.*, 33(2):LO2311, doi:10.1029/2005GL025270

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

Kitada, K., Araki, E., Kimura, T., Kinoshita, M., Kopf, A., Hammerschmidt, S., Toczko, S., et al., 2011. Drill pipe monitoring of vortex-induced vibration during IODP Expedition 332 observatory installations. *In* Kopf, A., Araki, E., Toczko, S., and the Expedition 332 Scientists, *Proc. IODP,* 332: Washington, DC (Integrated Ocean Drilling Program Management International, Inc.). doi:10.2204/iodp.proc.332.106.2011

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

Moore, G.F., Park, J.-O., Bangs, N.L., Gulick, S.P., Tobin, H.J., Nakamura, Y., Sato, S., et al., 2009. Structural and seismic stratigraphic framework of the NanTroSEIZE Stage 1 transect. *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.314315316.102.2009

Obana, K., and Kodaira, S., 2009. Low-frequency tremors associated with reverse faults in a shallow accretionary prism. *Earth Planet. Sci. Lett.*, 287(1–2):168–174. doi:10.1016/j.epsl.2009.08.005

Obara, K., and Ito, Y., 2005. Very low frequency earthquake excited by the 2004 off the Kii peninsula earthquake: A dynamic deformation process in the large accretionary prism. *Earth Planets Space*, 57:321–326.

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

Park, J.-O., Tsuru, T., No, T., Takizawa, K., Sato, S., and Kaneda, Y., 2008. High-resolution 3D seismic reflection survey and prestack depth imaging in the Nankai Trough off southeast Kii Peninsula. *Butsuri Tansa*, 61:231–241. (in Japanese with English abstract).

Seno, T., Stein, S., and Gripp, A.E., 1993. A model for the motion of the Philippine Sea plate consistent with NUVEL-1 and geological data. *J. Geophys. Res*., 98:17941–17948.

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

Tobin, H., Kinoshita, M., Ashi, J., Lallemant, S., Kimura, G., Screaton, E., Moe, K.T., Masago, H., Curewitz, D., and the Expedition 314/315/316 Scientists, 2009. NanTroSEIZE Stage 1 expeditions: Introduction and synthesis of key results. *In* Kinoshita, M., Tobin, H., Ashi, J., Kimura, G., Lallement, 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.314315316.101.2009

Underwood, M.B., Saito, S., Kubo, Y., and the Expedition 322 Scientists, 2010. Expedition 322 summary. *In* Saito, S., Underwood, M.B., Kubo, Y., and the Expedition 322 Scientists, *Proc. IODP,* 322: Washington, DC (Integrated Ocean Drilling Program Management International, Inc.). doi:10.2204/iodp.proc.322.101.2010

Authors

Masa (Masataka) Kinoshita, Japan Agency for Marine-Earth Science and Technology–Kochi Core Center (JAMSTEC-KCC), Monobe-B200, Nankoku-City, Kochi, 783-8502 Japan, e-mail: masa@jamstec.go.jp

Harold Tobin, Department of Geology and Geophysics, University of Wisconsin-Madison, 1215 West Dayton Street, Madison, WI 53706, U.S.A., e-mail: htobin@wisc.edu

Nobuhisa Eguchi and **Simon Nielsen**, Center for Deep Earth Exploration–Japan Agency for Marine-Earth Science and Technology (CDEX-JAMSTEC), 3173-25 Showa-machi, Kanazawa-ku, Yokohama, Kanagawa 236-0001, Japan