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EARTH DISCOVERY

Special Topic

September 2007–*Chikyu* is a Go

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Special Topic

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6,000 meters below the seafloor of the Nankai Trough—a world never before reached by mankind. An international scientific project to reveal the mechanisms behind earthquakes becomes operational.

Chikyu, a deep-sea drilling vessel, is in the final stage of preconditioning before departure for the Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) in September 2007, after numerous successful shakedown cruises. During the East Offshore Shimokita Peninsular Drilling Test and the Drilling Shakedown off Kenya in 2005 and 2006, we experienced many hardships, such as typhoons; however, by overcoming these trials, we became more confident in the abilities of *Chikyu*.

It is not an easy task to reach sub-ocean floor depths never before seen, due to such environmental challenges such as weather conditions and ocean currents, but the high spirits of the participating scientists will make NanTroSEIZE a success and break new ground in discovering unknown aspects of great earthquakes.

4 Stage Drilling Program to Attain Scientific Objectives

NanTroSEIZE is the most ambitious and challenging project among various scientific research projects in the world. We will take core samples from seismogenic faults and place monitoring equipment in the subduction zone of plates where great earthquakes of magnitude 8 or more have taken place throughout history. The Integrated Ocean Drilling Program (IODP) has identified the Nankai Trough as the most important target for investigating the subduction zone of the Philippine Plate, which is recognized as one of the world's most active seismogenic zones.

Most of the energy released in earthquakes comes from earthquakes occurring at the plate boundaries, while the energy released due to volcanic earthquakes is quite limited. Among such plate boundaries, places where great earthquakes with a magnitude scale 8 or more are limited. Along the Nankai Trough, three seismogenic zones—Tokai, Tonankai, and Nankai—are arranged in a series where such strong earthquakes have occurred, with historical records of such great earthquakes going back more than 1,300 years, including such details as "when" and "at what magnitude." There are no other places in the world where such detailed records of historic earthquakes are available. Furthermore, the seismic centers for these great earthquakes are within reach of the *Chikyu*. For all these reasons, no place other than the Nankai Trough is suitable for investigating the origin of earthquakes.

In 2004, a clear demonstration of the power of these subduction zone earthquakes was shown by the more than 200,000 deaths due to the Sumatra earthquake and tsunami in the Indian Ocean. This clearly demonstrated that great earthquakes in these zones are among the largest natural disasters on Earth. It is the objective of the NanTroSEIZE to reveal the mechanisms of such great earthquakes and to predict the timing and magnitude of the earthquake and tsunami. Because of such objectives, drilling is planned, in shallow regions off the Kii Peninsula, to various depths reaching to the seismogenic zone.

A total of 4 stages as shown below are projected in the overall NanTroSEIZE project.

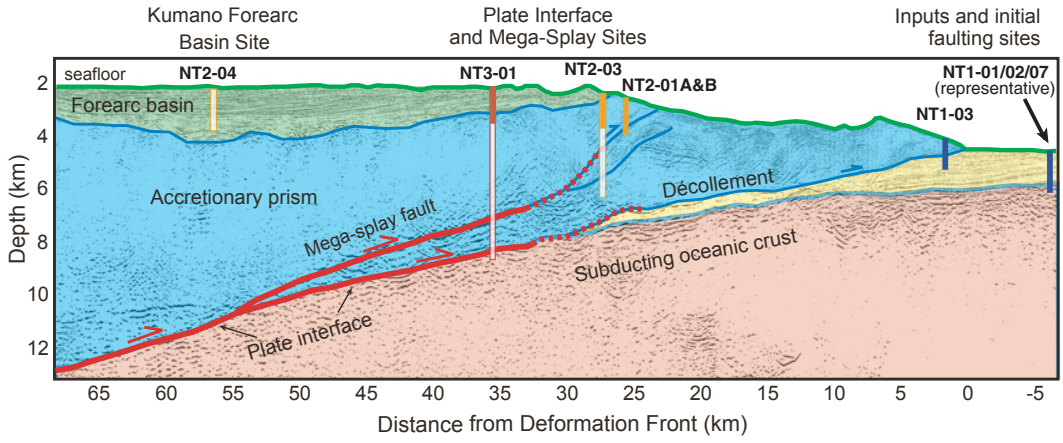
Stage 1 : Riserless drilling of six sites, from the sediment layer ahead of the plate subduction region, to the accretionary fault and to the forearc sea basin. Logging While Drilling (LWD) will be used to monitor the characteristics of the sediment layer and the characteristics of the fault, and samples will be taken at each site.

Stage 2 : Riser drilling targeting the splay fault located approximately 3,500 m below the seafloor, this is a scientific first for undersea drilling.

Stage 3 : Riser drilling into the seismogenic fault to a depth of 6,000 m under the seafloor.

Stage 4 : Projected installation of a long-term monitoring system in the drilled hole to measure strain, earthquakes, temperature, inclination, etc.

NanTroSEIZE is a long-term project. Stage 1 will continue until February 2008, and its primary objective will be to establish a bridgehead for the subsequent stages. A strong ocean current (the Kuroshio) exists off the Kumano coast, and it is expected that the riser pipes will be subject to significant stresses. The soft and fragile alternated layers of sandstone and mudstone are also expected to impede drilling operations. There are many unknowns involved in drilling to depths below the seafloor never before reached by mankind, but scientists are confident that they will overcome such difficulties and will obtain significant scientific results.



At NT1-01 and NT1-07, the plan is to drill through the sediment layer accumulated on the plate just before subduction to reach the basement (basalt layer), and at NT1-03, the plan is to drill through the décollement (horizontal fault) created by subduction of the plate. At NT3-01, NT2-01 and NT2-03, the plan is to drill through the mega-splay faults and the surrounding structure, and at NT3-01, the plan is to drill to a depth of 6,000 m to reach the seismogenic region of great earthquakes for the subsequent Stage 3. At NT2-04, we will work to solve the history of the accretionary prism formation engraved in the sediment in the forearc basin.

The Challenge of Penetrating the Active Plate Boundary

In recent years, interest in drilling and research of active faults has increased. Onshore projects, such as the San Andreas Fault Observatory at Depth on the west coast of the USA, the Chelungpu Fault Drilling Project in Taiwan, the Corinth Rift Laboratory in Greece, and seafloor projects like NanTroSEIZE and the Costa Rica Seismogenesis Project (CRISP) in Central America, have all been initiated because of such interest. While advances in research fields, such as seismology, geodesy, and friction dynamics have contributed to raising such interest, the mechanisms of earthquakes still remain a mystery. To answer such questions, it is required to examine detailed characteristics of deep faults and to identify the coefficient of friction with the surrounding substances and elastic strengths, collect core samples, and observe the seismogenic zone. In this, NanTroSEIZE will greatly contribute to the establishment of new theories.

The purpose of NanTroSEIZE is extensive monitoring of the upper portion of the seismogenic and tsunami generation region of the subduction zone, which is the doorway to the seismogenic area of great earthquakes at the depth of the plate boundary. Furthermore, an important target is to penetrate the active plate boundary, which is a rupture zone from the Tonankai Earthquake in 1944 and considered related to tsunami generation at the ultra-depth of 6,000 m below the seafloor.

"What makes drilling difficult is the fact that this is the first expedition for *Chikyu*," said Masataka Kinoshita, a group leader, who was assigned as a Co-Chief Scientist in the first expedition. Even though *Chikyu* has world-class drilling capacity, it is difficult to determine how drilling should continue depending on weather conditions and geological formations due to a shortage of experience in scientific drilling.

Therefore, Stage 1 consists of drilling at six sites for the first 2 months of the approximately 5-months for the 3 expeditions, measuring by LWD but without collecting core samples. The drilling depth will be 600 m below the seafloor at the site for the shallower depth and 1,400 m for the deeper depth. "It is our intension to find out how much we can actually drill before collecting core samples," says Masataka Kinoshita.

Subsequently in Stage 2, the first riser drilling by *Chikyu* for scientific purposes will drill to 3,500 m below the seafloor. This is at the mega-splay fault where rupturing took place during the Tonankai Earthquake. This Stage 2 will take place in 2008 or 2009.

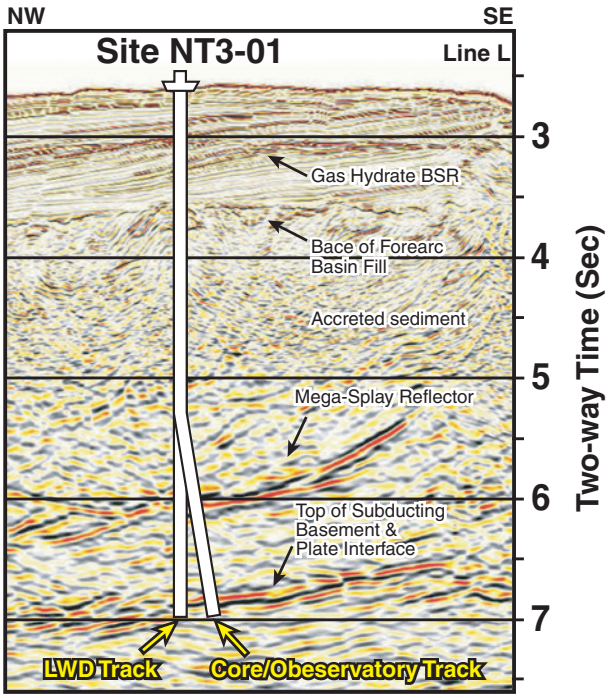
In Stage 3, the drilling target is the seismogenic zone lying 6,000 m below the seafloor. This will be an unprecedented deep drilling endeavor to reach the subducting ocean crust after penetrating the plate boundary forming the fault that causes earthquakes. At this moment we can't estimate how much time will be needed to drill to such a depth. Even drilling continually, it will take more than a year to complete. We plan to install a monitoring system in the borehole, but

Precise Temperature Measurement from Cross-Section of Seismogenic Area to Resolve Fault Evolution

Masataka Kinoshita
Group Leader
NanTroSEIZE
Co-Chief Project Scientist
Institute for Research on Earth Evolution, JAMSTEC

"It is time to see, with my own eyes, the evolution of physical properties and deformation of the surface layers of the seabed in the Sea of Kumano where a great earthquake will occur. Temperature is an important factor in defining changes in matter. It will provide us the information we need to know how the fault at the seismogenic area will change by measuring temperature at the fault plane more precisely that has been estimated from the data on the surface."

"NanTroSEIZE is a drilling project by a Japanese vessel off the coast of Japan. I'm proud of this, and in my participation as a Japanese."



A conceptual diagram of NT3-01, which is the deepest drilling point in NanTroSEIZE. Both LWD and coring will be performed, and core sampling from the major fault and placement of the monitoring equipment are planned. Please note that the angles and dimensions are not to scale.

this system is still under development. Therefore, this stage will be started depending on the progress in developing the monitoring system.

Stage 4, the final stage, will install the long-term monitoring system in the borehole at depths of 3,500 m and 6,000 m. By monitoring strain, earthquakes, temperature, pressure, and the like, and their changes at the plate boundary with this measuring system, behavior of the earthquake-causing fault can be directly recorded in real time. Development of a system that can withstand such severe environmental conditions at 6,000 m below the seafloor at temperatures of 170℃ is currently underway.

In parallel with this project, installation of a submarine optical cable network for the monitoring of earthquakes in Kumano basin is in progress in Japan. Once the monitoring system is installed in Stage 4 of this project and the network is connected, an ideal setting for real-time collection of the monitoring data will be established. Preparation of the fundamental equipment is underway in high gear, and commissioning is scheduled in 2012 or 2013.

"The first thing we have to do is to drill the hole to the depth as planned, and collect data and take core samples. Then, our science will start," says Masataka Kinoshita. The science on earthquakes will evolve with the number of expeditions of *Chikyu*.

Expectations are rising as NanTroSEIZE comes closer to reality.

Harold Tobin

NanTroSEIZE
Co-Chief Project Scientist
University of Wisconsin-Madison

Stage 1 of the Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) project is about to begin, and I am excited to be finally getting the chance to put our long-awaited plan into action. While we submitted the first NanTroSEIZE proposal to IODP in October of 2001, the planning for it had already been in the works for several years before that, so it has been a long road to the first expedition. The goal was an obvious, but challenging, one – to drill into, sample, and monitor the actual plate boundary faults that are involved in great subduction earthquakes. The reason for this is simple: we geophysicists have a very incomplete understanding of the processes that control the occurrence of earthquakes. One reason for that lack may be that we have not had enough samples and measurements from inside the active "live" faults where those earthquakes take place. NanTroSEIZE promises to change that.

Stage 1 begins with a IODP Expedition 314, a nearly 60 day long program of drilling using state-of-the art "Logging-While-Drilling" tools and instruments collectively called "LWD." Geophysical logging is the process of measuring properties of the rock directly as the hole is drilled, using properties such as the speed of sound waves, electrical signals, or the signature of natural radioactivity that is present in all rocks. LWD can even produce an image of the inside of the borehole, so scientists can observe the layers of rock and the faults and fractures. Using these very advanced instruments, we will learn much more about the real conditions inside these faults.

Expedition 314 will be a real challenge because we are drilling into an environment that is tectonically very dynamic, and the rock formations are likely to be unstable, thus creating difficult drilling conditions. We will be sampling truly unknown geology, sampling a new part of the Earth's, and Japan's, plates for the first time. However, I am optimistic that both the drilling and science will be successful. We have an outstanding international scientific team that will all be working together, and the drilling and technical teams are world-class. The NanTroSEIZE team will follow Exp. 314 with two additional expeditions to take core samples of the same locations, completing our studies of the shallow parts of the fault system. The next year, we will begin the very deep drilling to the seismogenic zone that is the ultimate objective of NanTroSEIZE.

Many people may have the impression that the goal of NanTroSEIZE is the short-term prediction of the next potentially damaging Tonankai earthquake. However, at this time, we don't even know if that is at all possible, for any future earthquakes. The real goal is much more basic, in a way – we seek to learn much more about the stresses, strength, and nature of rocks and water inside the faults, to test our hypotheses about how faults work. In this way, the Nankai Trough of Japan is the "model" for subduction earthquakes and tsunami all over the world. It is my hope that what we learn here will be a fundamental contribution to our science, and to developing a strategy to respond to the challenges presented by earthquakes.

The First Step toward Success: Stage 1 to Resolve Mega-splay Fault

As explained earlier, Stage 1 also involves pilot drilling for subsequent Stages 2 through 4, and collection of data is also necessary in order to help the subsequent expeditions progress smoothly. This is one reason why all six sites where drilling is scheduled in NanTroSEIZE are being shallow-drilled in Stage 1. The first expedition in Stage 1, Expedition 314, will last 2 months. While no core samples will be collected, measurements by the LWD will be performed during drilling at all sites. In LWD, various data can be measured through the logging tool set positioned at a few meters behind the drill bit, with a time-lag after drilling of a few minutes to a few hours, and drilling can be continued with real-time measurement of structural properties and physical properties.

Even without deep drilling, certain facts can be identified by comparing shallow-boreholes at the six sites. For example, evolution of the accretionary prism can be traced by drilling the sites where the stages of evolution are different, such as before and after deformation in the accretionary prism, the exit from the splay fault to the main fault, and the non-seismogenic area in the shallow area to the seismogenic area at the depth of the plate boundary where great earthquakes take place. Many investigations were made on the accretionary prism off Muroto and at the Middle America Trench, but for the first time, drilling of the accretionary prism at Nankai Trough off the Sea of Kumano is being performed. Studies of the accretionary prism, which will provide valuable information and is a key to resolve the mechanisms of a great earthquake, will be a significant step forward.

Success of the Project Depends on the Accuracy of Research Data

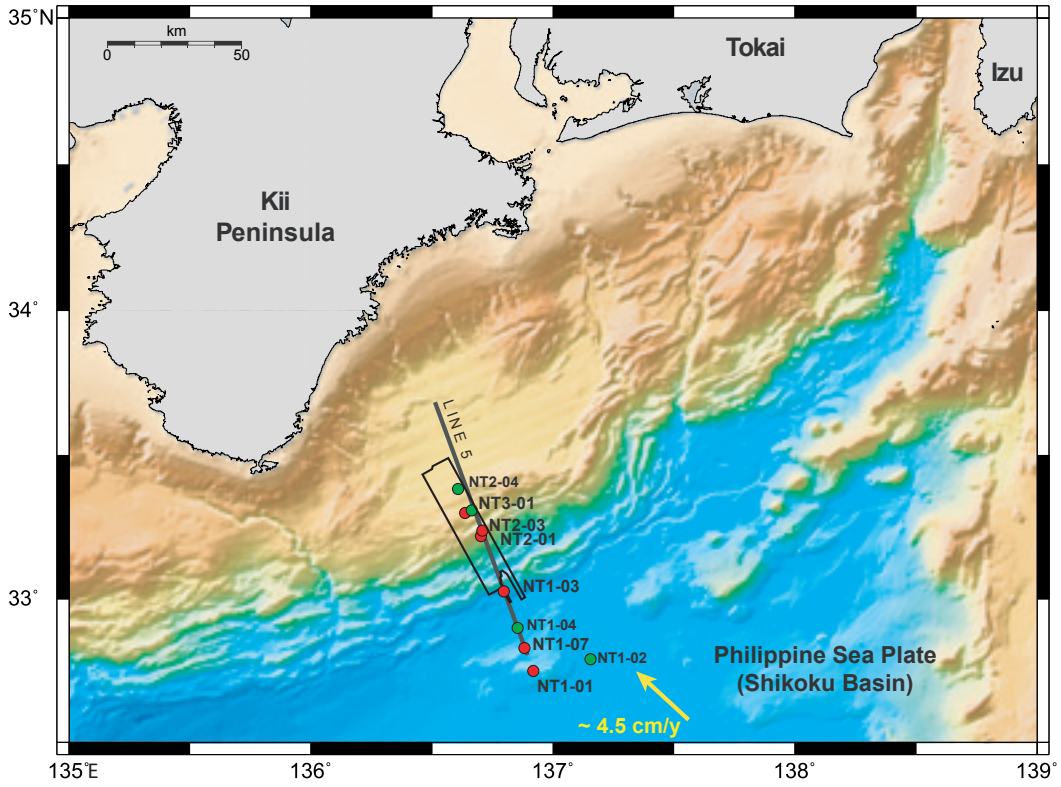
Gaku Kimura

NanTroSEIZE Specialty Coordinator
Expedition316 Co-Chief Scientist

Univ. Tokyo / IFREE, JAMSTEC

My assignment is the standardization of the description of the drilling data on such categories as faults, geological structures, and deformation. Because of the size of the project, the researchers on-board will change in each expedition, and scientists from many countries will be involved. For example, clear standards are required for measuring data, such as whether significant figures should be one or two digits to prevent collection of unorganized data. It is very important that every person performs his/her individual role under the standardized procedure. Remarkable progress will be only possible with the provisions of accurate data.

Drilling points for Stage 1 of NanTroSEIZE shown on a topographic map of the Kii Peninsula and the Sea of Kumano (red circles indicate principal sites and green circles indicate backup sites). Area enclosed in the black frame is where the 3D seismic survey was performed in 2006. The straight black line (LINE5) indicates where the 2D seismic survey was performed.



Following the first expedition is the approximately one-month Expedition 315, the first NanTroSEIZE expedition where core samples will be collected. The target drilling depth is 1,000 m below the seafloor, based on the data obtained by LWD. Because collection of core samples will be performed for the first time this expedition will be an opportunity for training, including confirmation of staff assignments on board the vessel. The borehole will be used for riser drilling in Stage 2 to a depth of 3,500 m below the seafloor and will serve as a pilot drilling. At this site, sediments will be collected from submarine landslides that are generated due to motion of the fault by earthquakes. It is believed that it will be possible to identify when the fault moved caused the landslide by analyzing the sediment core.

In Expedition 316, two sites will be drilled in 2 months. One site is located at the edge of the accretionary prism where the sediment on the surface starts to deform due to subduction of the plate. At this site pore water leaving and solidification taking place will be able to be observed. At the other site, the splay fault will be drilled to a shallow depth. It is close to the site drilled in Expedition 315, and will observe how the accretionary prism can grow by observing a hole penetrating the main fault and splay faults 800 m below. This borehole will serve as the guide for installation of the LTBMS (long term borehole measurement system) in Stage 2.

Stage 1 consists of 3 expeditions, each expedition having an individual purpose, and the study targets are different. Researchers on board each expedition will also be different, but it is important to achieve each individual target one-by-one. Prof. Kimura, a NanTroSEIZE Specialty Coordinator and who has been involved in this project from the planning stage explains the meaning of this project, as follows:

"If compared to medical science, observation of the earth so far is like dissection in the Edo period of Japan in which a doctor has to visualize the inside of a human with only a stethoscope. This drilling project is like incising a living body to directly examine the inside of the body, and it is a turning point in geological science. This is the point why the scientists in the world are so interested in the project. It can be simply said that the depth of drilling of 1 km or 2 km increases to 6 km, but the depth differences of such magnitude brings significant differences. If the results are as expected, it is still exciting and such facts are important: however, the most exciting thing in science is unexpected results, and unexpected facts will bring remarkable progress of the science," says Prof. Kimura.

In the early 1990s, subduction of plates was a hot topic in academic circles, and many scientists dreamed of drilling directly into them. These wishes have been finally realized and this is why scientists are so excited about this project. The outcome of this project must be properly passed to the scientists in the next generation. For this purpose, students of graduate schools are also accepted as on-board NanTroSEIZE researchers in all related areas. Asuka Yamaguchi studies under the guidance of Prof. Kimura at the Graduate School of Science, The University of Tokyo, and will be on board Chikyu for the Stage 1 expedition. Ayumu Miyagawa is the youngest researcher participating in the LWD expedition and studies at the Graduate School of Engineering, Kyoto University. Prof. Kimura says, "What I expect of young researchers like Yamaguchi and Miyagawa is to think about the overall earth." In geological science, most research requires pinpointing a selected subject; however, it is necessary to apply what is found in the Nankai Trough to other geographical areas or to view the earth overall without restricting the research to a narrow view. He encourages them by saying, "Earthquake research in Japan is well ahead of the world. I wish they make efforts to become confident world leaders in earthquake science."

Stage 1 CDEX Chikyu Operation Schedule

	Expedition	Date (at Sea)	Co-Chief Scientists
314	NanTroSEIZE Stage 1 **LWD Transect**	21 Sep., 2007 ⟩ 16 Nov., 2007 57 days	Masataka Kinoshita (JAMSTEC; JP) Harold Tobin (U. Wisconsin; US)
315	NanTroSEIZE Stage 1 **Megasplay Riser Pilot**	17 Nov., 2007 ⟩ 19 Dec., 2007 33 days	Juichiro Ashi (ORI, U. Tokyo; JP) Siegfried Lallemant (U. Cergy-Pontoise; FR)
316	NanTroSEIZE Stage 1 **Thrust Faults**	20 Dec., 2007 ⟩ 5 Feb., 2008 48 days	Gaku Kimura (U. Tokyo; JP) Elizabeth Screaton (U. Florida; US)

Remarks:
All expedition schedules are subject to change.

Great Results Possible from Active Seismogenic Fault Study

Asuka Yamaguchi

Shipboard Scientist, Expedition 316

Univ. Tokyo

"Experiencing the Great Hanshin Awaji Earthquake made me start research on the earthquake. Thus, the earthquake is a very close research subject to me. My research subjects were the products of past earthquakes; however, in NanTroSEIZE, I can see the status of the live faults and core samples. It is a precious experience to directly observe the process that will take place in the future. I want to substantiate the difference from the onshore faults that I observed by observing live rocks."

Expectation and Confidence grow on Chikyu After Completing Shakedowns

July 29, 2005 is the day that *Chikyu* was completed and delivered. Since then, two years have been spent on preparation and tests for NanTroSEIZE due to start in September of this year. State-of–the-art equipment never used in similar applications was installed on *Chikyu*, a 6th generation scientific drilling vessel, and it takes time before such equipment can function properly as designed. Preparations were made in scheduling and one result was the shakedown held off Shimokita Peninsular in August to October 2005. Although there was some initial trouble with the system, it performed within expectations. Hajime Saga, Director, CDEX Chikyu Operations Department, regarded the shakedown off Shimokita as a "learning period." It was intended to reveal all the problems and to test the designed functions during the first expedition in the integrated system tests.

From November 2005, drilling shakedowns at 9 sites off Kenya and northwest off Australia were performed to experience drilling in different conditions (depth, soil, ocean currents, etc.) from that off the Shimokita Peninsula. At 3 sites, riser drilling was performed, and especially at the site off Kenya, we succeeded in drilling in depths of 2,200 m to 2,700 m below the seafloor under a strong ocean current. Initial troubles encountered at the Shimokita Peninsula were mostly eliminated, and down time in which the drilling system temporarily stops was substantially reduced from approximately 60% off Shimokita Peninsula to approximately 10% at off-Kenya and then less than 5% off Australia. *Chikyu* demonstrated its potential as a drilling vessel.

In these shakedowns, a variety of testing, such as installation of the Blow Out Preventer (BOP) on the 2,200 m from sea level, operation checks, and drilling under complex geological conditions containing alternated layer of sandstone, mudstone, and limestone, were carried out, and they were successfully completed. Saga says with confidence, "Compared with the Shimokita operation where everything was just beginning, *Chikyu* is now much more reliable." It is not only *Chikyu* itself that is making achievements. Crewmembers who will be on-board *Chikyu* in NanTroSEIZE could also effectively acquire know-how and proficiency necessary for operations through these shakedowns.

Preparations for actual expeditions are at the final stage. A series of meetings between the scientists and the engineers are held every day based on the outcome of two shakedowns, because various alternatives should be prepared with multiple simulations on a case-by-case basis. Operational standards were improved to enable effective achievement of scientific results, while also ensuring crew safety. The fully prepared *Chikyu* will soon sail out to Nankai Trough, based on experiences from the Shimokita Peninsula, Kenya, and Australia.

Drilling Responding to the Request of the Scientists

Hajime Saga
Director,
CDEX Chikyu Operations Department

"Drilling in the Nankai Trough is, technically, a very difficult mission. The seafloor geography is rugged and the geological formations are highly anisotropic and unstable. Furthermore, Stage 1 is running during typhoon season. But even in such adverse conditions, it is our ultimate mission in the operation side to collect data in the borehole and core samples according to the request of the scientists. We wish to provide as much high-quality data as possible, and the best way to do this is to drill a well-formed borehole."

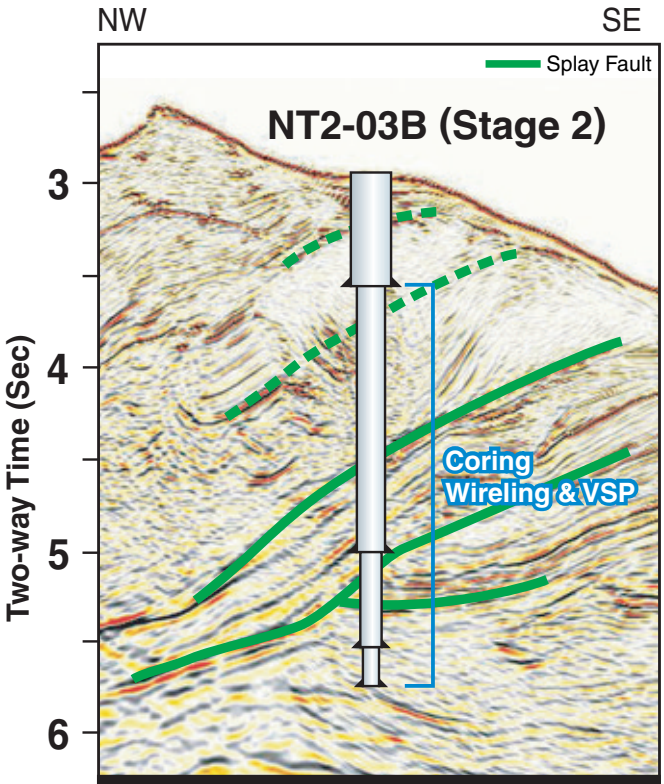
Crews retrieving core samples during test drilling carried out east of the Shimokita Peninsula.

Some core samples collected just beneath the sea floor are not completely solid (fluid).

Stage 2 Reaching for the Splay Fault 3,500 m Below the Seafloor

Compared with Stage 1, where we will be drilling 1 km borehole at six sites, in Stage 2, a single deep borehole will be drilled over a 150-day period. To reach 3,500 m, penetrating the splay fault, is a difficult task. In terms of depth, some industrial drilling vessels have already drilled to such depths or beyond, but it will be the first time to drill at the Nankai Trough site, with strong ocean currents. Continuously collecting core samples from unstable formations in the mobile belt and drilling a borehole suitable for the future long-term monitoring in Stage 2 will be a very challenging expedition.

Drilling to 3,500 m depth will be carried out at site NT2-03, where 1,000 m will be drilled in Stage 1 by riserless drilling for core sampling, and a 700 m borehole for Stage 2 will be drilled and turned over to Stage 2 with steel pipes installed to prevent collapse of the borehole. The first 1,000 m will be drilled without stopping, and after that drilling will be performed stepwise at 1,500 m, over 2,000 m, before 3,000 m, and over 3,000 m. At each step, coring to collect core samples, logging to measure the borehole wall by pulling up the monitoring tool at a constant speed, and casing to insert steel pipes in the borehole will be repeated until the destination borehole. Five splay faults have been identified at the site in the preliminary investigation, and it will be unveiled which splay fault is most active by penetrating these faults at different depths. It will be possible to identify various features of the faults, such as thickness, deformation structure, or existence of fluid.



NT2-03 site will be drilled in Stage 2. The first 700 m will be drilled by riserless drilling, and after that the work of coring, logging and casing will be repeated by riser drilling until the target depth of 3,500 m. Casing pipe will be set three times during drilling.

It was not possible to drill to such depths by conventional drilling vessels: however, when drilling to depths never experienced before becomes possible with *Chikyu*, unexpected issues arise. Because of this, the assistance to scientists by the more advanced fault research of onshore geology is needed. It will be possible to predict substances that constitute the fault zone under the seafloor from studying similar onshore faults, for example. In Stage 2, approximately 100 researchers will be on board *Chikyu* in 4 expeditions, approximately 25 for each expedition, and among them, participation of many researchers from the field of onshore geology and specialists on faults is required and projected. Additionally, research on subterranean microorganisms will make progress based on the core samples from large depths. So far, life in the deepest zone is bacteria found 1,000 m below the seafloor. When we drill down to 3,500 m, unknown bacteria that can live in such extremes of temperature and pressure may be found. Although not directly related with earthquakes, it will also be interesting.

"I want to form a strong team gathering talents in various fields," says Saneatsu Saito, Co-Chief Scientist of Stage 2. Drilling to great depths will advance the research of various fields of science. Although we have longer to wait for Stage 2, anticipation is growing about drilling a single borehole for 150 days.

Bring NanTroSEIZE into Success with the Leadership of Japan

Saneatsu Saito
NanTroSEIZE Co-Chief Scientist
Institute for Research on Earth Evolution, JAMSTEC

"The principal object of Stage 2, the first riser drilling of IODP, is to investigate the splay faults derived from the seismogenic zone. With the concentration of knowledge from around the world and under the leadership of Japan, we want to make Stage 2 successfully continue to Stage 3, where we will look at the plate boundary directly where great earthquakes take place. We will participate in NanTroSEIZE with the resolve that we have to be successful."

Subsea-System

World-class technology and systems taking on the challenge of drilling in 4,000 m depths and another 7,500 m below the sea floor

The hole at the center of the deck below the drilling tower (derrick) is called a moon pool, a feature peculiar to drilling vessels. From there, we can look down into the ocean's surface and reach straight down to the sea floor. Riser pipes lowered into the sea from the moon pool for drilling, the blow out preventer (BOP), and other equipment lowered into the sea and equipment on deck like the riser tensioner, which supports the riser pipe, are collectively called the *sub-sea system*.

Equipment, like the riser pipe and BOP, are critical elements that determine the drilling capacity of the riser drilling system. While the riser drilling system is widely used technology for offshore oil development, the *Chikyu* drilling operations will be performed not only where oil is likely to be, but also in seas around the world where no oil is expected. Therefore, development of the equipment had to be based on unique specifications, and as a result, it was built as a world-class sub-sea system.

Riser pipe, made of 30 mm-thick high tensile strength steel, is about 27 m long and weighs about 28 tons. Riser pipes hung vertically above the drill floor are connected with large bolts one by one and then let down into the sea. A riser tensioner hangs all the connected risers on the *Chikyu*. A riser tensioner prevents transmission of motion from the vessel to the riser pipe using the telescopic motion of six air cylinders, like air-shocks, that cancel the vertical movement of the vessel imparted by the wind and ocean waves.

The riser tensioner suspends the riser pipe by six air cylinders that isolate the riser pipe from the motion of the *Chikyu*. The amount of play in each of the rods is approximately 15 m. Using the cushioning effect of these rods, the riser pipe is effectively stationary relative to the *Chikyu's* motion for smooth drilling operations.

In the riser drilling system, drilling is made more efficient by injecting slurry (called "mud") through the drilling pipe and circulating it back to the vessel through the space between the riser pipe and the drill pipe. Mud, a mixture of seawater and clay with the density and viscosity effectively adjusted, removes drilled earth and rock and reinforces the drilled hole by forming a mud layer.

Gas and oil are trapped in reservoirs created by geological formations. When the drill hits a gas layer, the pressurized gas rushes to the surface through riser pipes connected to the vessel. The BOP plays an important role in the sub-sea system by preventing disasters due to gas blow out and contamination of seawater from blown out oil.

The BOP on the *Chikyu* is 16 m high, weighs as much as 380 tons, and withstands pressure up to 1,000 times atmospheric pressure. The size and capacity of this BOP is one of the world's largest.

Casing pipes will be inserted to prevent the drilled hole from collapsing after the hole reaches a few hundred meters from the sea floor; a wellhead is then installed at the top of the casing pipe on the sea floor. The BOP is connected to the wellhead, and the riser pipes connect the BOP to the vessel. Hydraulic equipment, such as a pipe ram that closes the hole with a drill pipe and a shear ram that closes the hole by cutting the drill pipe in an emergency or when the vessel has to be moved, are incorporated in the BOP.

Mud rising through the riser pipe is continuously monitored, and if the volume of mud or the gas in the gas mixture increases, the space between the riser pipe and the drill pipe closes using the pipe ram in the BOP. The density of mud will be adjusted to control the intrusion of gas into the drilled hole.

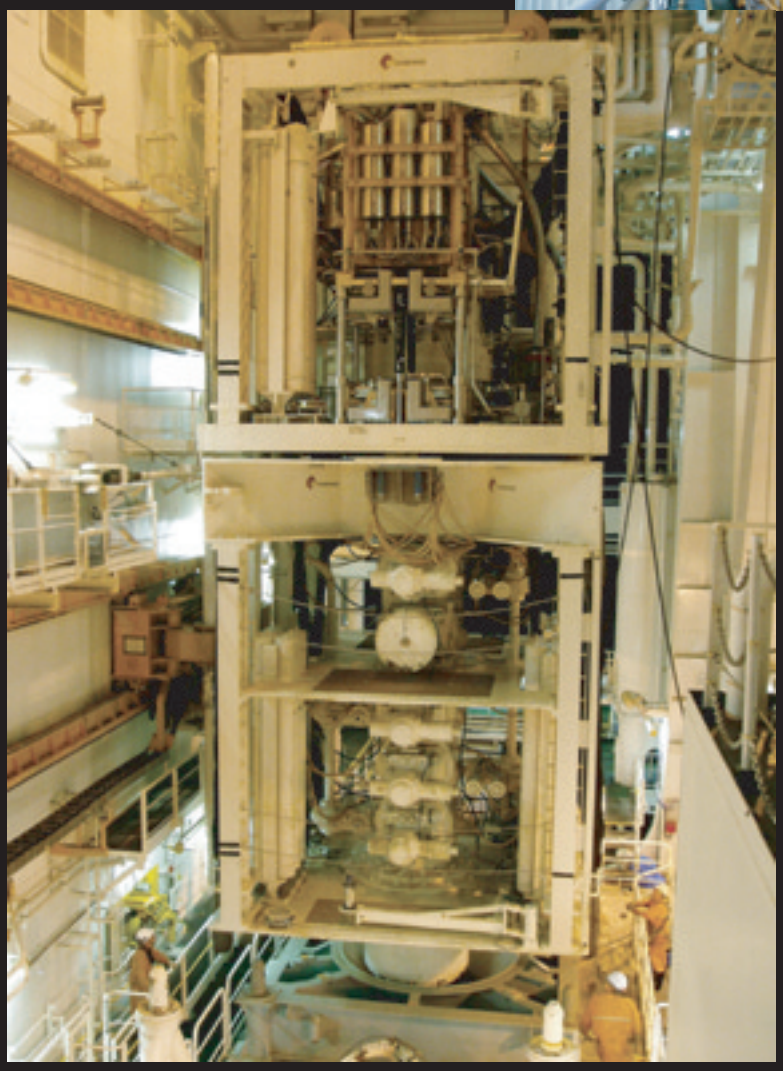
The BOP from the vessel is controlled through dual optical fiber systems. Control power on the vessel is backed up with a UPS, and the system has multiple means to ensure that the drilled hole can be closed regardless of what may occur. If a problem develops with the transmission of the optical signal, a backup acoustic signal system will activate the BOP.

The BOP can be separated into two parts, the upper part called the *lower marine riser package* (LMRP), and the lower part called the *lower BOP stack*. When the vessel has to evacuate the site due to major typhoons, it is possible to move the vessel and leave the lower BOP stack on the sea floor. The reason the *Chikyu* sub-sea system is world class is not only because of its size but also because of its inherent safety even in severe weather conditions.

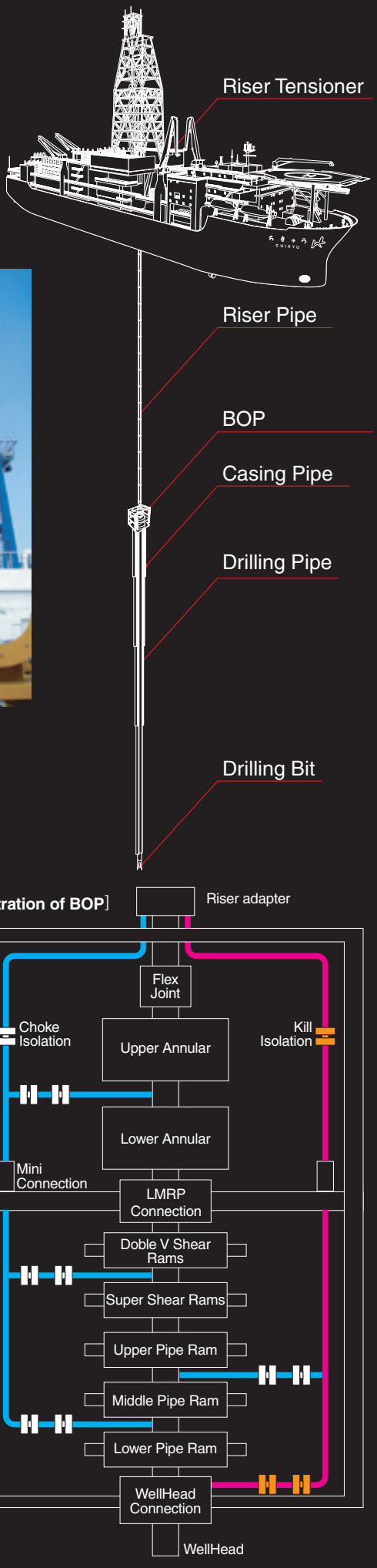
A collaborative report by Eigo Miyazaki, Subsea Engineering Development Technology Development Group, CDEX Engineering Department

Riser pipes with a flotation device stored in the rack. It weighs about 28 tons each in the air but reduces to about 4 tons in seawater.

A riser pipe set vertically in the derrick. It is lowered to the ocean floor from the moon pool.



Blow Out Preventer (BOP) is hydraulically controlled by signals transmitted from the vessel through optical fiber. When the mud and gas mixture is shut in, the gas in the hole must be released. In such cases, the gas is released into the atmosphere at the top of the derrick through the choke line.



Kumano-nada 3D Seismic Cruise Completed

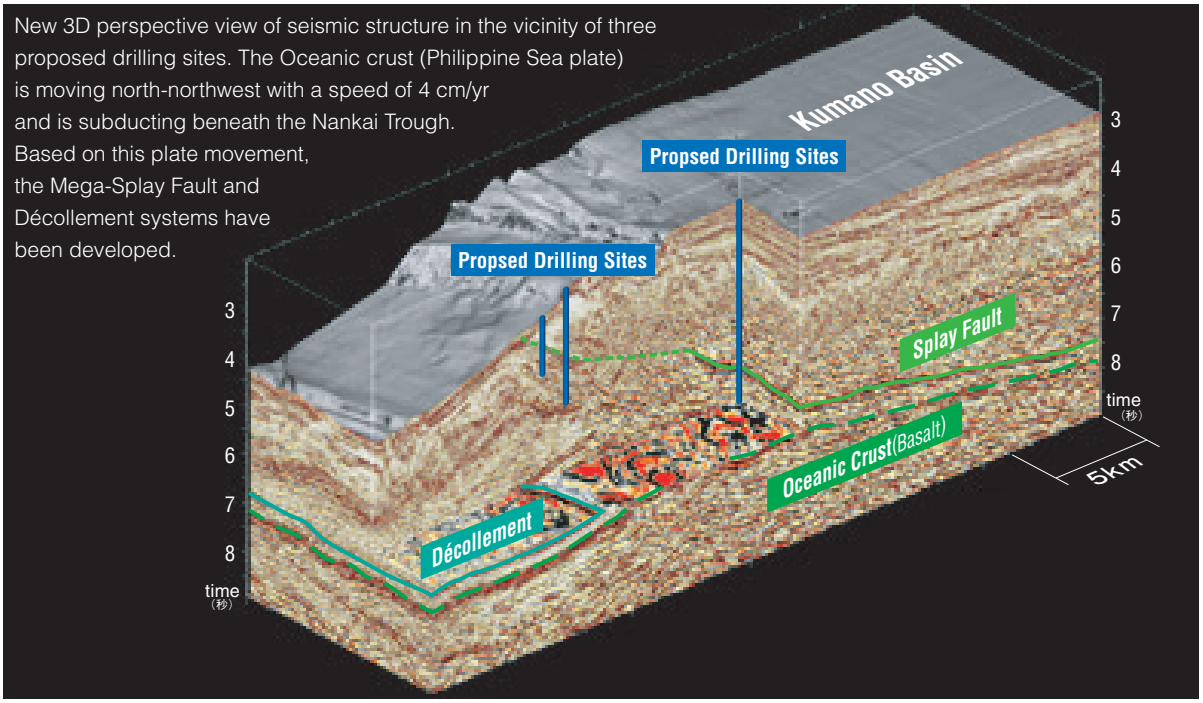
Gregory Moore NanTroSEIZE Specialty Coordinator CDEX Principal Technical Scientist

In preparation for the Nankai Trough SEIzmogenic Zone Experiment (NanTroSEIZE) IODP drilling campaign, CDEX contracted a three-dimensional (3D) seismic reflection survey in the Kumano Basin, Nankai Tough, Japan. Our survey was the first ever to be conducted by a commercial seismic contractor specifically for scientific research and was carried out during April-May, 2006 by Petroleum Geo Services (PGS). We used the *S/V Nordic Explorer* to survey an area of approximately 585 km^2. The ship towed four hydrophone cables each 4,500 m long with 360 receiver channels. They were spaced 150 m apart. We fired two G-gun arrays of 3,090 in^3 alternately, thus enabling us to collect 8 Common Mid-Point (CMP) lines for every sail line. The resulting 3D volume has 6.25 m x 37.5 m CMP spacing. The Kuroshio Current caused acquisition difficulties related to strong feathering of the hydrophone cables. The seaward portion of the survey had to be abandoned because the current was strongest along the deep part of the Nankai Trough.

The seismic reflection data volume was processed by Compagnie Générale de Géophysique (CGG) in Kuala Lumpur, Malaysia They applied swell noise and multiple attenuation, cross-line interpolation, bin centering and regularization, high-density velocity analysis, 3D anisotropic pre-stack time migration (PSTM), residual move-out (RMO), PSTM stack and post stack multiple attenuation. The final processing produced 620 inlines at 18.75 m spacing and 5500 cross-lines at 12.5 m spacing. The most challenging part of the processing was to eliminate the very strong sea-floor multiple reflections that obscured important splay falult reflections.

The 3D volume has already been used to choose the locations of four primary and several alternate sites for NanTroSEIZE drilling. The most important targets are one site that will penetrate the frontal thrust fault at the toe of the accretionary prism and three sites that will drill into a fault that splays off the main plate boundary fault. The megasplay fault rises from the oceanic crust at > 7.5 sec (~10 km) depth, cutting across the older part of the accretionary prism all the way to the seafloor in the frontal accretioanary thrust region. This splay fault reflection exhibits areas of reverse-polarity, possibly reflecting fluid flow from the seismogenic zone to the surface. More than 1.5 km of sediment in the Kumano forearc basin will be penetrated at our deepest riser drilling site. The oldest part of the section is strongly folded, while the seaward portion is progressively tilted landward due to repeated motion on the magasplay fault.

New 3D perspective view of seismic structure in the vicinity of three proposed drilling sites. The Oceanic crust (Philippine Sea plate) is moving north-northwest with a speed of 4 cm/yr and is subducting beneath the Nankai Trough. Based on this plate movement, the Mega-Splay Fault and Décollement systems have been developed.



Logistics personnel supporting drilling operations of *Chikyu* behind the scenes

Provide guidance to researchers (customers) from around the world for safe, smooth embarkation to *Chikyu* through first-class coordination

Many researchers are expected to participate from Japan, the United States, and other countries in the Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE), which will be fully operational in September 2007. The enthusiasm of the researchers for this project is overwhelming, considering the fact that they are going to explore depths of the earth that have never been seen by humans before. Three people, J. Fukutomi, K. Matagawa, and A. Fuse of CDEX, are assigned as contacts for handling matters related to embarkation applications, written oaths for embarkation, and to provide guidance to all people, including the researchers, for a smooth embarkation.

"It is our mission to ensure the success of NanTroSEIZE, which is the Integrated Ocean Drilling Program under the initiatives of Japan and the United States," says Jun Fukutomi of the IODP Department. He continues, "This is a good opportunity to showcase the ability of Japanese to manage large, international projects."

Takashi Matagawa from the *Chikyu* Operations Department of CDEX, who is the contact person for operation management for all persons on board says, "I am continuously aware of the importance of my role as mission support staff to efficiently guide researchers until they are onboard *Chikyu*, while their expectations grow and they look forward to seeing unknown places." He is confident about the progress of preparations despite the pressure of the approaching schedule, relying on the well-known precision and thoroughness of the Japanese.

Akiko Fuse of the IODP Department handles all the paperwork for managing the schedule of embarkation and disembarkation of the researchers. "I hope the project will be successful with many achievements by the researchers. The researchers are looking forward to start of the project and so am I," she says, believing that hospitality will be the key to success.

The first thing they did prior to full scale deployment of the project in September was to prepare access information for boarding *Chikyu*. The embarkation port for the first group of researchers for the drilling programs is the port of Shingu, Wakayama Prefecture. For the second and subsequent boarding groups, transport helicopters will be based in the town of Minami-Ise, Mie Prefecture, accessing *Chikyu*, which will be positioned on the Sea of Kumano off Kii Peninsula during the drilling operation. Neither of the two locations are convenient for international travelers arriving at Narita or Kansai airports from outside Japan. Matagawa

From left to right:
Takashi Matagawa,
Marine Affairs Group, CDEX Chikyu Operations Department;
Jun Fukutomi,
Program Coordination Group, CDEX IODP Department;
Akiko Fuse,
Program Coordination Group, CDEX IODP Department

prepared a detailed route guide showing the access routes to these destinations, including railroad fares, times required from each arrival airport, and a location map that clearly indicates the destinations. "Even for Japanese people, unless they live close to Shingu, it is almost impossible to give directions to Shingu. I think that a guide describing the routes and transit information in detail is essential for a foreigner visiting Japan for the first time," Matagawa says. When asked if he often feels like a tour guide, he smiled; "Yes I do!"

Checklists showing personal items that researchers must prepare, the paperwork required before embarkation, or documents to be filed are also available. For instance, once *Chikyu* leaves port, all embarkations and disembarkations will be made by helicopter; thus, all members on board *Chikyu* are required to participate in an emergency escape drill. "It is essential to ensure the safety of the researchers. They can practice the drills in their own countries, and we also provide training sessions in Japan before embarkation," Matagawa says. The guidebook incorporates all the necessary details for the researchers.

Guides for embarkation were already forwarded but their assignments are not finished. "We will soon reach the busiest time," says Fukutomi. "This project is not a project to be completed within a few months but it is a project to be constructed over several years. We will have to watch for the time being so that the first step of the project is successful."

Let's learn about *Chikyu* at the Science Museum!

We are holding many events across Japan in order to promote the Integrated Ocean Drilling Program (IODP) before the Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) begins this September. Here are two examples of such events.

Final countdown to NanTroSEIZE!
Talk events Earth×Underground×Future by researchers of IODP

Just before the *Chikyu's* IODP expedition kicks off, five sessions of talks with some of the scientists involved in the IODP research themes will be held at the Miraikan (Odaiba, Tokyo) from August to September. IODP research themes, such as the mechanism of great earthquakes that cause large tsunami, as well as mysterious life found deep underground, will be introduced with the keyword "Underground" preceding the special Underground exhibition at Miraikan. Scientists who will soon be aboard *Chikyu* during NanTroSEIZE will be the presenters. The event is an opportunity to experience the enthusiasm that the scientists have for the project and learn about the difficult-to-see underground world, assisted by simple experiments and demonstrations. For details about the events and an application for admission, visit the Miraikan website at: **www.miraikan.jst.go.jp/index_e.html** or our *Chikyu* Hakken website: **www.jamstec.go.jp/chikyu/eng/**

Talk Event : Earth×Underground×Future, at Miraikan (The National Museum of Emerging Science and Innovation), Odaiba, Tokyo

First Session : Saturday, August 18, 2007, "Underground World—It is more distant than you imagine"
Juichiro Ashi The University of Tokyo; IODP NanTroSEIZE, Expedition 315 Co-Chief Scientist

No.2 : Sunday, August 19, 2007, "Mysterious Species—Life we can find underground"
Ken Takai Program Director; Deep Subsurface Extremophiles Research Program, Extremobiosphere Research Center, JAMSTEC

No.3 : Sunday, August 26, 2007, "Great Earthquake—It will hit someday"
Masataka Kinoshita Institute for Research on Earth Evolution, JAMSTEC; Co-Chief Project Scientist, IODP NanTroSEIZE

No.4 : Sunday, September 2, 2007, "NanTroSEIZE—*Chikyu* drills into the Earth (*chikyu*)"
Gaku Kimura The University of Tokyo; IODP NanTroSEIZE, Expedition 316 Co-Chief Scientist

No. 5: Saturday, September 8, 2007, "Its' Fascinating Underground—Uncover the mysteries and secrets of our earth"
Asahiko Taira Executive Director, JAMSTEC; Director-General of CDEX

Also visit the exhibition "System of the Earth Revealed by Deep sea Drilling" at The Earth Environment and Frontiers section (5F, EX5).

The National Museum of Emerging Science and Innovation
Web site: http://www.miraikan.jst.go.jp/index_e.html Address:2-41, Aomi,Koto-ku Tokyo

2007 Summer Holidays Science Square
Experience the "Expedition to the Place Where Earthquakes originate (Nankai Trough)" at the National Museum of Nature and Science

We manned a JAMSTEC held booth exhibition during the 2007 Summer Holidays Science Square held at the National Museum of Nature and Science in Ueno, Tokyo, on 1 – 5 August. Under this year's theme, "Expedition to Where Earthquakes originate (Nankai Trough)," an exhibit and a quiz game featuring the deep-sea drilling vessel *Chikyu* and NanTroSEIZE were presented. The prominent use of illustrations and models were of great benefit in the exhibit in promoting understanding, and children visiting the booth during their summer holiday seemed to be excited about our program.

Also visit the *Chikyu* Exhibition at the "History of the Japanese Islands" section (North Wing 3F, Japan Building).

National Museum of Nature and Science
Web site: http://www.kahaku.go.jp/english/ Address: 7-20 Ueno Park, Taito-ku, Tokyo

Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) should advance the study on earthquakes!

Planning, Equipment, and Support Organization are all a "Go" after Overseas Drilling Shakedowns

Since the commissioning of *Chikyu*, we have been conducting shakedown cruises for two years, such as system integration tests off Shimokita Peninsula and overseas shakedowns off Kenya in Africa and off Australia. Generally, we are able to achieve our objectives, despite occasional stormy weather. We are proud that *Chikyu* has the world's number one drilling capacity, and the size and level of the equipment and devices on-board are exceeding the conventional ones. In order to smoothly operate them, it is necessary to confirm how many staff people and what competencies of those staff people are required by experiencing actual operations. After completion of the shakedown cruises, such questions concerning staff requirements are all cleared. Preparations including adjustment of personnel to be on-board *Chikyu* and onshore support teams are in the final stages, and we will soon be able to declare that everything is a "Go" for Stage 1.

This project will need to continue for another ten to twenty years. It is necessary to accumulate technical experience as well as to educate new talent, and therefore, the end of this project will not be upon us for several years. We will, however, always have to consider the next step without slowing down our efforts.

Scientific Drilling Using LWD – First in the World

The most remarkable aspect in NanTroSEIZE Stage 1 is the drilling that is fully utilizing LWD technology, which is the first in scientific drilling. In NanTroSEIZE, we are going to drill at six sites. In this first expedition of Stage 1, we will drill all six sites measuring with LWD. The drilling depth at all sites should be approximately 600 m to 1,400 m under the sea floor, and by collecting common data from all sites drilled according to the same procedure, we will be able to obtain an overview of the geological formations of the Nankai Trough in this sea area. Collecting such data in the plate boundary where a great earthquake will take place is the first undertaking. It is expected that many characteristics that are supposed to be closely related to the occurrence of earthquakes, such as geological history and toughness of rocks, direction of the crevices, and conditions and flow of water present in the crevices in the Kumano Basin, will be disclosed and will provide a plethora of information.

Historical Turning Point Drawing the Attention of Scientists Across the World

So far, studies on the earthquake have been divided into two aspects: a study of the earthquake as a natural phenomenon and a social study on its impact on our lives and disaster prevention; however, no coordination has been made between these two aspects. It will not be considered a success if only scientists are satisfied with the results of drillings in this project. By looking back through history, it is believed that Nankai Earthquake will definitely hit us in the near future. There is an increasing anxiety among people about earthquakes, and Japan should become a country that is resistant to natural hazards. In NanTroSEIZE, the objectives of scientific research should of course be satisfied, but the ultimate goal is to construct a country resistant to natural hazards.

Although it is true that we do not yet understand the mechanisms of great earthquakes, we do have the ability, for the first time in history, to actually see the scene where the tsunami attacked in the Off-Sumatra Earthquake in 2004. The first step to prevent a disaster is to understand the mechanism of how and where an earthquake takes place and how it expands. Scientists must take the initiative to establish solid answers about the mechanisms of earthquakes. Although prevention of earthquakes will not be possible in the foreseeable future, the grand design of Japan for the future will be impossible without knowing the mechanisms of earthquakes.

Scientists across the world are moving ahead to cooperate in this project. Messages from scientists, including myself, have been consolidated into one voice converging in this project for the overall success of the project. It will be necessary that the attention of the public be focused on this project so that such convergence will be utilized in a variety of fields.

Because of the commissioning of *Chikyu*, our understanding of the earthquake will definitely change. It will be an historical turning point from ante-*Chikyu* to post-*Chikyu*. We will put forth all our efforts for the success of this project as geoscientists.

Asahiko Taira produced a T-shirt design commemorating ODP drilling leg 131 in the Nankai Trough in 1990.

Close Up

IODP Expedition Setting Sail from the Port of Shingu!

This bird's eye view shows the NanTroSEIZE material depot in the port of Shingu assigned to *Chikyu* for the upcoming mission. The city of Shingu, Wakayama Prefecture, is located at the south end of the Kii Peninsula and is known for the Ancient Road of Kumano, a registered UNESCO World Heritage site, and for the mountains which were a focus of worship in ancient times. The area is covered by igneous rocks called *Kumano acidic rocks* that were formed about 15 million years ago during the igneous activity that formed the Japan Islands. *Chikyu* will sail from this beautiful port, where the history of the Earth's geology and human culture are engraved.

CHIKYU HAKKEN
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3173-25 Showa-machi, Kanazawa-ku, Yokohama, 236-0001 JAPAN, TEL:+81-45-778-5643 FAX:+81-45-778-5704
EMAIL : cdex@jamstec.go.jp Website : http://www.jamstec.go.jp/chikyu/