ISSN 1880-3261

CHIKYU 地球 HAKKEN 発見

EARTH DISCOVERY

SPECIAL TOPIC 1 :

First permanent Borehole Observatory in the NanTroSEIZE Project Successfully Installed

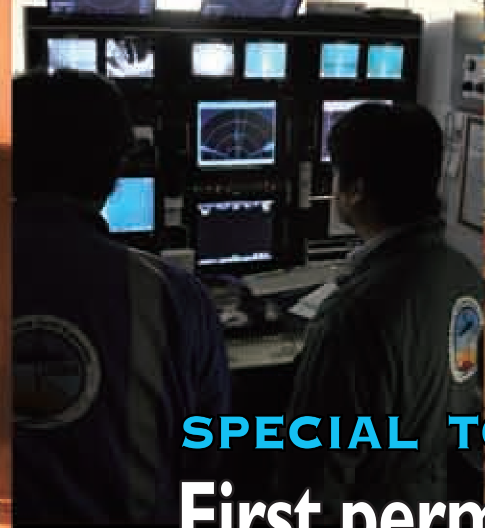
SPECIAL TOPIC 2 :

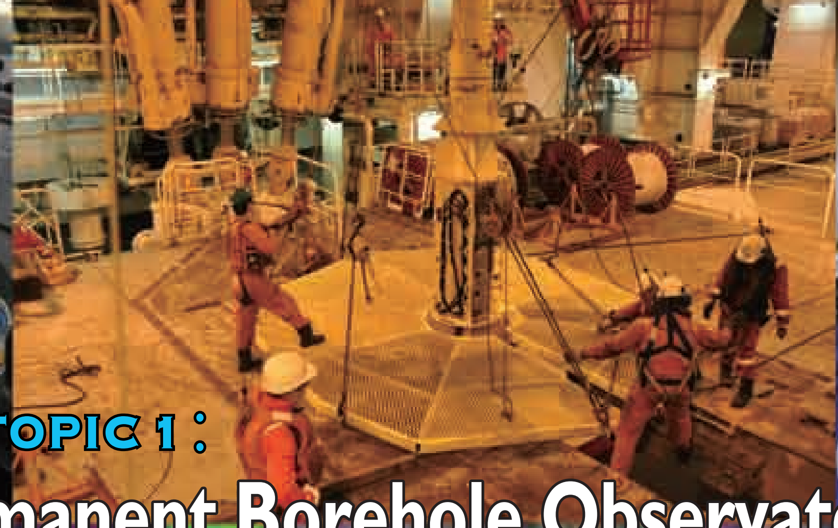
Numerous Results Achieved in Drilling the Okinawa Hydrothermal Field

March 2011
Volume
11

CHIKYU HAKKEN
Volume 11

CONTENTS



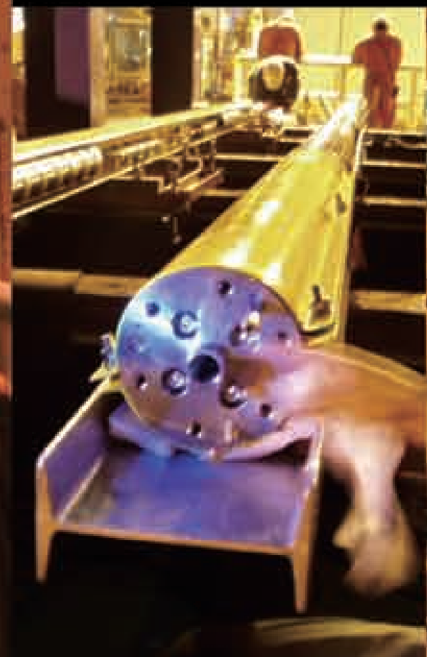


SPECIAL TOPIC 1:

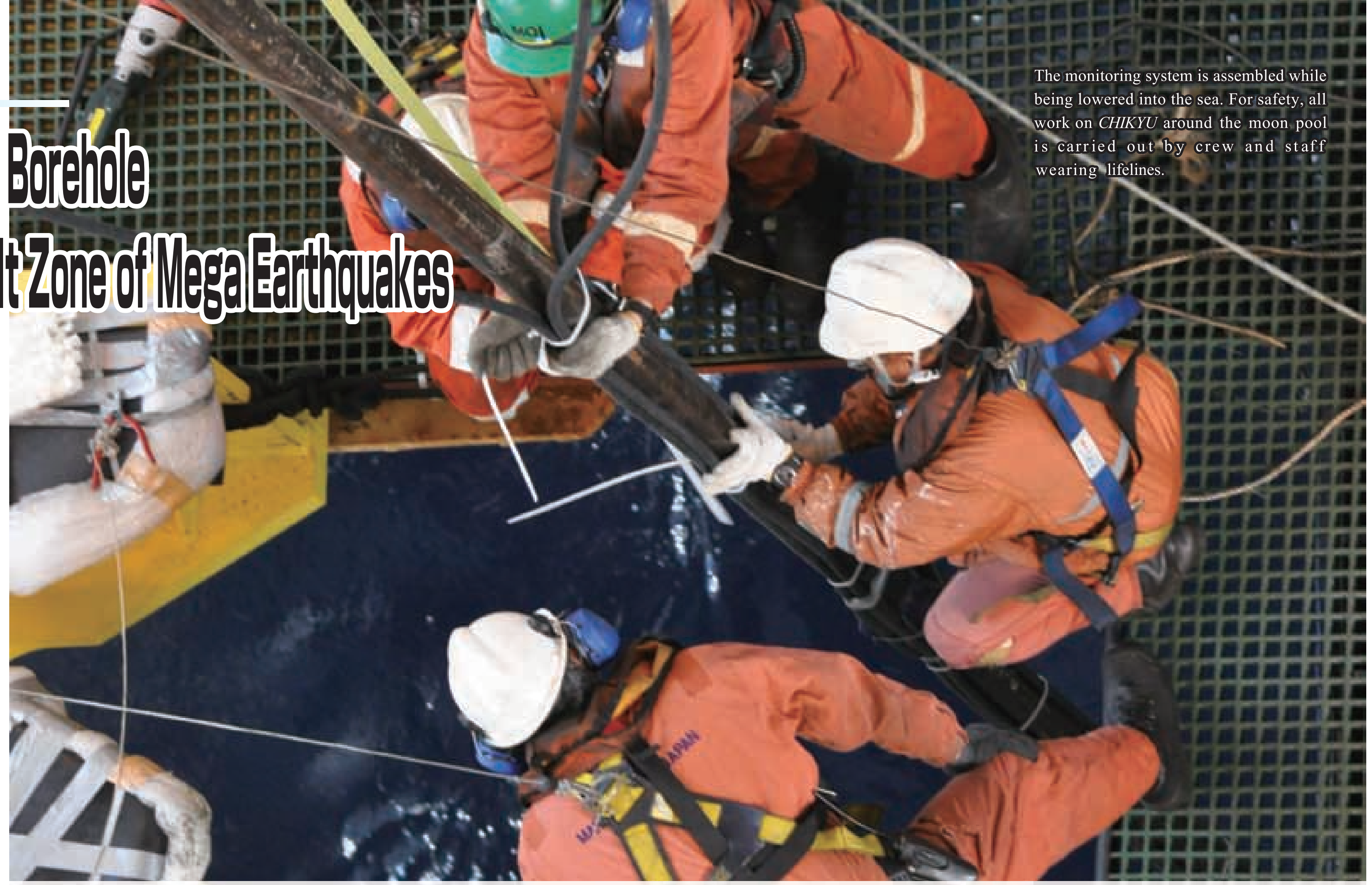
First permanent Borehole Observatory in the NanTroSEIZE Project Successfully Installed

From October through December 2010, as part of Integrated Ocean Drilling Program (IODP) Expedition 332 "Riserless Observatory", the Deep Sea Drilling Vessel *CHIKYU* drilled and cased a riserless borehole up to 980 m below the seafloor at the subduction end of the Tonankai Earthquake's focal region (Site C0002) off the Kii Peninsula. The expedition also successfully carried out the difficult operation of installing within the cased borehole a long-term observatory, which will help monitor seismic changes within the shallow region of the accretionary prism with very high sensitivity and precision.

Interviewee:
Dr. Eiichiro Araki
JAMSTEC Technical Development Group, Earthquake and Tsunami Research Project for Disaster Prevention



Long-term Observatory Installed in the Borehole
Great Progress toward Monitoring Fault Zone of Mega Earthquakes



The monitoring system is assembled while being lowered into the sea. For safety, all work on *CHIKYU* around the moon pool is carried out by crew and staff wearing lifelines.

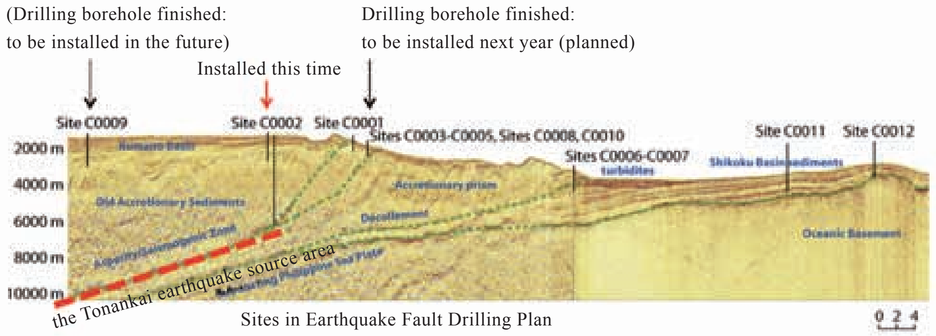
New Challenges in NanTroSEIZE

IODP Expedition 332 was carried out over a period of about 50 days from late October 2010, as part of 'Stage 2' of Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE).

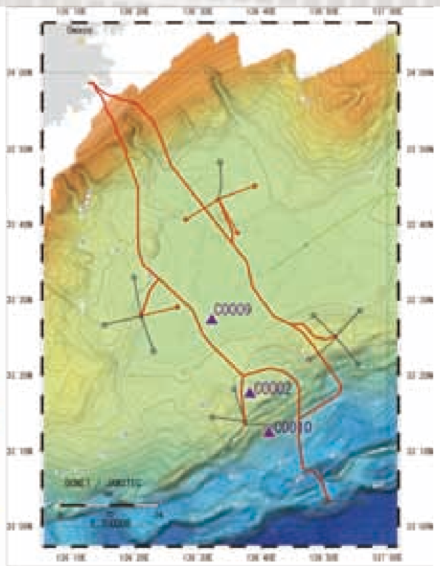
The expedition's goals were two-fold: one was to recover and replace the temporary observatory installed into a borehole (Site C0010, water depth: 2,523.7 m) drilled during IODP Expedition 319 (May through August 2009) with a new temporary observatory. The other was to drill, case, and deploy the first permanent observatory, at Site C0002 (water depth: 1,937.5 m). The Expedition 319 Site C0010 borehole (casing depth: 544.3 m below seafloor) is located at the shallowest area of the megasplay fault so that it intersects the fault extending from the seismogenic zone (Site C0010).

The old temporary observatory was installed below a retrievable plug in the casing, and comprised a monitoring package for pore fluid pressure and temperature measurement in the megasplay fault. IODP Expedition 332 recovered this observatory with a tool at the end of the drill pipe from *CHIKYU*. The data recovered from the observatory included robust and valuable pore fluid pressure and temperature data from over a period of about 15 months since installation. Significantly, the recorded data not only showed isolation of the borehole by the plug, but also showed a tidal response of pore fluid pressure in the formation, as well as signs of past earthquake and tsunami occurrences in the Pacific Basin and crustal deformation associated with them. The new temporary observatory, deployed in the same borehole at Site C0010, is equipped with an osmosampler to detect changes in pore fluid chemistry, in addition to pore fluid pressure and temperature measurement. The instrument package also includes a bio-sampler and an in-situ incubator.

IODP Expedition 332 installed a Long-Term Borehole Monitoring System permanent observatory in a new cased borehole reaching approximately 1,000 m below seafloor. This site (C0002) is located in the Kumano Basin, off the Kii Peninsula, directly above the region believed to be responsible for Magnitude-8 class mega-earthquakes that historically occur at intervals of between every 100 and 150 years. This is also the site of the future ultra-deep riser borehole planned for Site C0002. To help monitor seismic activity within the fault zone and the surrounding accretionary prism with much higher sensitivity and precision, the permanent observatory was installed at Site C0002. This monitoring system consists of sensors, such as a broadband seismometer, a volumetric strainmeter, a tiltmeter, a thermometer array, pressure ports and three-component geophones. It is also to be connected with the Dense Oceanfloor Network System for Earthquakes and Tsunamis (DONET), which is currently being deployed in this area.



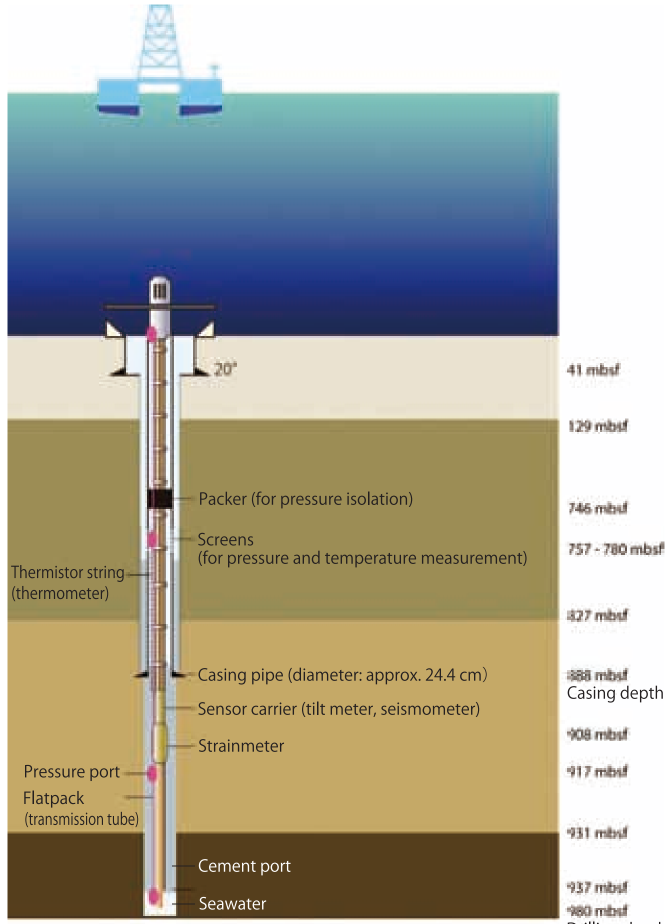
Sites in Earthquake Fault Drilling Plan



During IODP Expedition 332, a permanent long-term borehole observatory was installed approximately 1,000 m below the seafloor at Site C0002.

Adapting to the Kuroshio Current

In mid-November, *CHIKYU* completed the retrieval and installation of the temporary observatories at Site C0010, after which *CHIKYU* made a 24-hour port call in Shimizu, leaving on November 27 for Site C0002. Finally, work to install the long-term observatory began. "The instrument package is installed about 800 m below the seafloor (mbsf), the deepest point in the borehole which is about 1,000 mbsf. To do this, the package is attached to the end of a series of steel pipes called tubing; therefore, the package is suspended from the wellhead down through the borehole casing pipes into the seafloor. The inner diameter of the borehole casing is approximately 21 cm, and the tubing is about 9 cm in diameter. Electrical power and data cables, and hydraulic tubing are all run down along the outside of the 3.5 inch tubing. These cables and tubing are very delicate; any contact with the borehole wall has the potential to sever or damage them, therefore great care was taken with attaching and running the entire system down into the water and the borehole. Additionally, the accretionary prism strata are unstable, and safely installing the monitoring system into the well is demanding work by itself", says Dr. Eiichiro Araki, one Co-Chief Scientist of IODP Expedition 332. Furthermore, the Kuroshio Current, a strong western boundary current that flows through the research area, is another obstacle in the way of Long-Term Borehole Monitoring System operations, hampering Dr. Araki and the scientists.



Long-term Observatory Schematic

In March 2010, tests were conducted to examine ways to reduce the harmful effects caused by Vortex-Induced-Vibration (VIV) that the Kuroshio Current has on scientific equipment and tools, discovered during operations during IODP Expedition 319. During that expedition, it was discovered that the vibration caused by the Kuroshio Current was strong enough to destroy scientific instruments attached to 3.5 inch tubing at the end of the drill string, necessitating a redesign of the tools and instruments before deployment during Expedition 332.

"Until that point, our focus had been on refining the design of the instruments so as to collect the best data, but this proved that there were, in fact, major obstacles before that. We had a little over one year, during which something had to be done", Dr. Araki recalled. Dr. Araki, together with CDEX's Technical Development Group and the IODP Observatory team discussed the situation and methods to address the VIV problem. In March 2010, half a year to go before the actual expedition, a trial experiment was conducted on board *CHIKYU* to test various methods for reducing the vivration. The ultimate solution was somewhat unexpected; attaching ropes to the drill pipe. "Detailed analysis is necessary as to why vibration is reduced when the rope is placed along the pipe. Still I think that the rope may interfere, making the vortex generation difficult", says Dr. Araki.

Furthermore, various other plans were developed to help reduce possible damage to the observatory during installation. These included working with the manufacturer of the well head and running tool to

Working to attach monitoring instruments, such as seismometer and tilt meter, to the frame.

With the instrument package attached, the assembly of the almost 7 m frame is finished (in front).

Vibrations caused by the Kuroshio Current can be suppressed by attaching 4 lengths of rope along the drill pipe.

The ROV platform and the top of the Long-Term Borehole Monitoring System observatory being connected together. These sections sit on top of the wellhead at the sea floor. The diameter of the platform is approximately 5 m.

redesign and strengthen them, and also work with the CDEX and JAMSTEC engineers to redesign the observatory sensor carrier. All the components were tested and checked for resistance to vibration in preparation for the expedition start date of 25 October 2010.

Good Teamwork Makes for Success

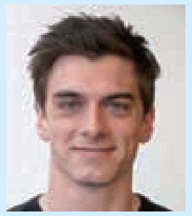
To begin installation operations at Site C0002, *CHIKYU* began assembling and lowering the LTBMS tools and sensors into the water at a point 40 km "upstream" of C0002. This was done to reduce the amount of time the instruments would be exposed to the VIV, before drifting into the Kuroshio Current. The length of the entire LTBMS monitoring system is 980 m, from the well head to the bottom bull-nose in the deepest part of the well. The sensor carrier and other instruments is located at approximately 800 m from the CORK (Circulation Obviation Retrofit Kit) head at the top of the well, and there are cables and hydraulic lines running from the bottom of the LTBMS to the very top. As each part of the LTBMS was assembled and checked, it was lowered gradually in to the sea, whereupon the drift back "downstream" towards Site C0002 began. To further minimize the effects of VIV, *CHIKYU* moved at a maximum on 0.5 knots (almost 1 km per hour). The rope system of reducing VIV was very successful.

After *CHIKYU* arrived in position at Site C0002, the DPS (Dynamic Positioning System) was engaged to maintain a steady position above the C0002 well head. The drill pipe, with running tool, CORK head and Long-Term Borehole Monitoring System tools at the very bottom, was gradually and carefully lowered into the cased well. Many people nervously watched the images carried back by a camera installed on ROV (Remotely Operated Vehicles) as operations unfolded 2000 m below the sea's surface. Operations continued day and night, with scheduled breaks to run checks on the sensors and tools, to ensure that they continued to operate as planned. Once the Long-Term Borehole Monitoring System was set into the hole, cement was pumped through the drill string to "couple" it to the formation. This is done so that there is a complete seal around the sensors, eliminating any possible gaps where water may freely flow. This helps reduce ambient noise caused by the movement of water, and also helps the sensors collect good data from the formation below the cased sections of the well. All work on the installation was completed at 4:00 AM on 9 December 2010.

"I think I can give a 100% score, no, a 120% score on the installation. We ran into stonewalls many times in the preparation stage, but we could overcome them. That was because of our teamwork, I think. Everyone shared the goals and contributed their good ideas; the power was so strong. In my opinion, the reason *CHIKYU* has gotten over various difficulties and made progress is that such teamwork is solidly built", comments Dr. Araki. "Having said that, for us who are in charge of developing the monitoring system, the successful installation is nothing but one milestone. Above all, it is only when the highly precise monitoring is realized and its data is useful that what we have done becomes meaningful", says Dr. Araki.

Full-fledged monitoring is due to begin in March 2011, when the oceanographic research vessel, *KAIYO* and the *HYPER DOLPHIN* ROV, connect recorders to the long-term observatory. Experiments within the borehole, using air guns from the ocean's surface are also planned for the future. In the near future, the observatory will also be connected to the Dense Oceanfloor Network System for Earthquakes and Tsunamis (DONET) deployed in this region. Installations of more long-term observatories are also planned; at Site C0010 where a temporary observatory is currently installed, and at the riser borehole at Site C0009 which was drilled up to 1,603.7 m below seafloor. In particular, when these observatories start supplying the DONET network with real-time data from below the sea floor, combined with the DONET seafloor observatories, combining all these data into one a data analysis system will greatly enhance our capability to monitor earthquakes and tsunamis.

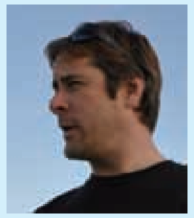
Comments from Science Participants of IODP Expedition 332



Sebastian Hammerschmidt

Onboard Scientist
University of Bremen (Germany)

One of my main tasks was the accurate evaluation of LWD/MWD (Logging While Drilling and Measurements While Drilling) parameters for the installation of the Long-Term Borehole Monitoring System. This not only helped the engineers in their demanding task to deploy such a highly sophisticated borehole observatory, but also allowed me to broaden my technical and geological horizons. IODP Expedition 332 with *CHIKYU* was one fantastic experience; I hope that other students will also have the opportunity to participate in the future.



Sean Toczko

JAMSTEC/CDEX
Expedition Project Manager

"We really had some ground-breaking advances for IODP and *CHIKYU* during this expedition. We installed the first permanent observatory in the history of the NanTroSEIZE project, and we also recovered the first long-term pressure and temperature data from the temporary observatory deployed last year. Both observatory platforms have performed well so far, and we are excited about the link-up of the permanent observatory to the DONET network next year, and the geochemical/biological data we expect to recover from the upgraded temporary observatory deployed this expedition. These are exciting times!"

Yasuhiro Namba

JAMSTEC/CDEX
Long-Term Borehole Monitoring System Engineer

"In this Expedition, we installed the long-term observatory to help elucidate the mechanisms of mega-thrust earthquake occurrence and collect observations via real-time data when earthquakes occur. We lowered the almost 950 m long observatory assembly down below the sea floor, itself almost 2000 meters deep, while working in difficult and strong sea currents. The work was very difficult, but during that time, we kept up-to-date notifications of our work progress through the internet and people tracking our postings gave us a lot of support. We were so glad and encouraged."

Numerous Results Achieved in Drilling the Okinawa Hydrothermal Field

Whereas all the previous deep-sea hydrothermal field drilling ended up with recovering insufficient cores, Deep Hot Biosphere (IODP Expedition 331) succeeded in collecting cores at a rate of nearly 50%. Expedition 331 achieved results which would lead to finding black ore and elucidating the whole picture of hydrothermal fields.

Interviewee:
Dr. Ken Takai
Japan Agency for Marine-Earth Science and Technology
Institute of Biogeosciences
Extremobiosphere Research Program

Core Recovery Succeeded with the Highest Rate Ever

Drilling a deep-sea hydrothermal field is extremely difficult. Scientific drilling operations were conducted four times in the past, but the core recovery rate is less than 10% as a whole. The recovered samples were also unfavorable. However, in the hydrothermal field drilling expedition carried out in the Iheya North in Okinawa, the core recovery rate increased to nearly 50%. This success is first attributable to the fact that the science team led by Dr. Ken Takai had selected sites through careful preliminary research on where drilling and core recovery would be possible. Another reason was *CHIKYU*'s advanced drilling capabilities. 'There were a lot of options available in drilling methods; when some method went wrong, we switched to another method. We could take such a strategy. The integration of *CHIKYU*'s own capabilities of drilling target points properly and the good on-site judgment contributed to the success of this expedition', summarizes Dr. Takai.

However, it was very hard to deal with the drilling and coring in high-temperature layers containing a lot of hydrogen sulfide. The typical site is Hole G at Drill site C0014. As initially expected, the Hole was difficult to drill, where hard layers and soft layers appeared alternately. So the drilling proceeded little by little, by making the cores shorter. Dr. Takai says, "When the cores are made shorter and the number of drilling is increased, it takes more time. But if the cores are made longer, no recoveries of the cores will increase. We must expect what kind of state the next layer is in and take the best measure. The concerted efforts of the drillers and scientists bore fruit, which enabled us to drill through the layers, the most formidable foe for drilling".

Unexpected situations also occurred: due to too high temperature, the plastic liner in the Hydraulic Piston Core Sampling System(HPCS) melted, so the aluminum liner was hastily transported from Shingu, Wakayama Prefecture; and the blade of the drill bit which was finally pulled up was badly damaged. In addition, the importance of wire line system got much attention in this expedition, which offered a valuable experience for the future coring.

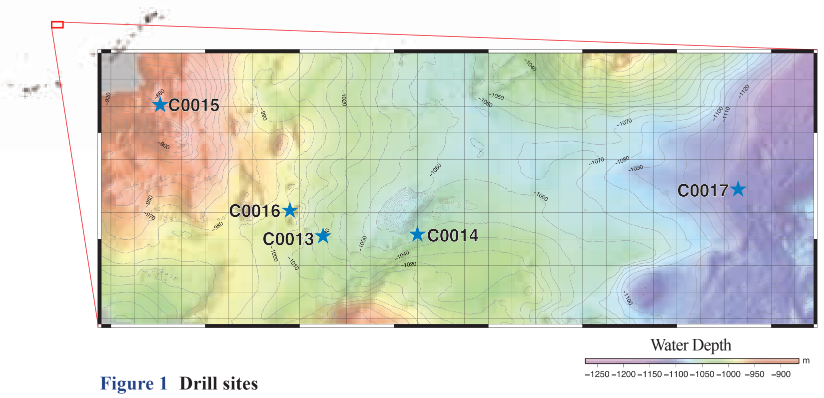


Figure 1 Drill sites
The five sites, C0013 ～ 0017 are the drill sites for this expedition.

Finding Massive 'Hydrothermal Fluid Reservoir' beyond Expectations

As the drilling proceeded, the first hard layer, called 'caprock' appeared and after drilling through the layer, thermal fluids gushed out. Prior to the drilling, it was expected that thermal fluids would appear and disappear repeatedly on starting the drilling, and that microbes would exist between the gaps of thermal fluids which spread like mesh. But in fact, high temperature thermal fluids or hydrothermal alternation zone spread below seafloor. The chemical composition also revealed that thermal fluids filled all the gaps between many layers of caprock which appeared under the first caprock, indicating that there was a massive subs-seafloor 'hydrothermal fluid reservoir'. Assuming from the subseafloor temperature, the hydrothermal fluid reservoir also exists under C0017, which is nearly 2km away from the hydrothermal vent and it is undoubtedly conceivable that there is a subseafloor thermal lake covering 2km in radius. In the initial expectation, the image of hydrothermal fluids rising like mesh through rock gaps, flowing out into the seafloor was compared with the Amazon River. However, the actual drilling started to show the structure as if the Amazon River had an estuary weir, where large amounts of water accumulated.

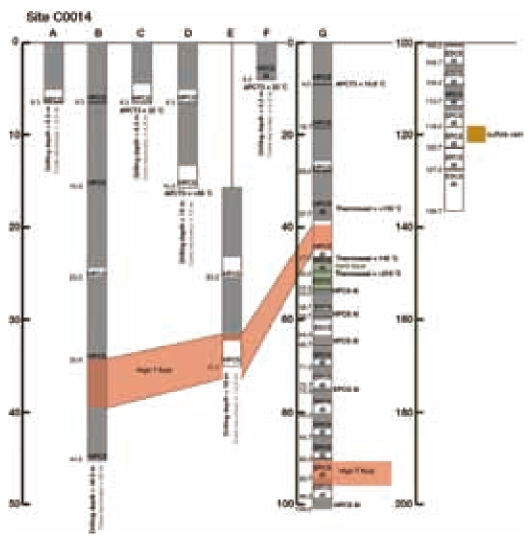


Figure 2 Drill status of C0014
The gray color indicates where the cores could be recovered and the black lines show the number of coring. The red color represents the area where the hydrothermal fluids gushed out. At Hole B, the layers were relatively soft, which enabled HPCS to recover the cores smoothly. However, the drilling was difficult at Hole G, so in order to recover the cores, they were made shorter by making full use of various methods.

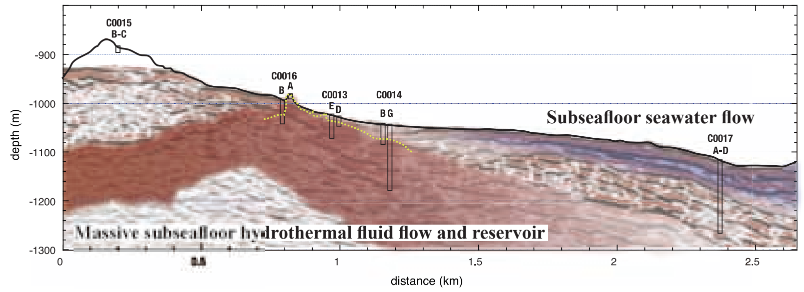


Figure 3 The world's largest subseafloor lake
Cross section of the five drill sites. C0013 is 100m away from the thermal fluids and C0014 500m. At C0013, several meters below subseafloor and at C0014 about 20m below subseafloor, the first hard layer called caprock appears, and there is a massive hydrothermal fluid reservoir underneath the caprock. At C0013, C0014 and C0016, gushing hydrothermal fluids are observed and the flow of hydrothermal fluids exists. At C0017, nearly 2km away from these sites, when drilling was conducted 150m down, the temperature went up and exceeded 30℃ immediately. It is thus expected that there is also a structure underneath C0017, similar to the one observed at C0013 and C0014, where hydrothermal fluids accumulate.

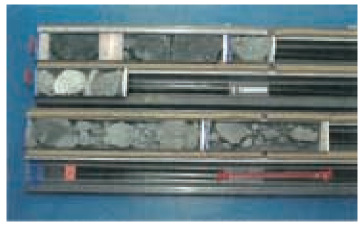


Figure 4 Black ore generated below seafloor
Subseafloor black ore found in the recovered cores.
It is considered that black ore deposits are just being generated by hydrothermal fluids.

Furthermore, the examination of hydrothermal fluids contained in the cores recovered at a certain level of depth indicated the presence of relatively low-salinity water in the upper portion of the cores and relatively high-salinity water at the bottom.

The phenomenon of stratification by the density gradient also occurs in this subseafloor thermal lake. It had been assumed that the hydrothermal fluids in the Iheya North might boil around 310°C and separate into steam and water and the water might have slightly higher salinity. However, the previous hydrothermal expeditions had failed to ascertain the presence of high-salinity thermal fluids under seafloor and its presence had remained a mystery. This expedition could grasp such phenomenon for the first time in the world.

Unraveling the Mystery of Black Ore Deposit Generation

In the drilling at C0016, located just next to the hydrothermal mound※, approx. 1.5m-long black ore was contained in the first recovered 9m-long core. Black ore means minerals which contain iron, zinc, lead and copper as major components and even gold, silver and rare metals as minor components. The black ore, found at approx. 7～8m below seafloor, in the neighborhood of the top caprock, was connected to the whole chimney. Although the core from the hydrothermal mound itself could not be recovered, drilling caused belching black smokers, indicating that the mound is a mass of black ore. Furthermore, black ore was also recovered from the area corresponding to the 'root' of the mound. The current hydrothermal fluids in the Iheya North are clear smoker, which seems incapable of generating ore deposits. But still now, black ore is accumulating underneath. When multiplying the amount of minerals contained in the recovered cores and the expanse of the hydrothermal fluids together, there should be the world's largest black ore deposits underneath the hydrothermal fluids of the Iheya North and it should be growing even now.

Figure 5 Artificial hydrothermal vents

There is an area called Black Ore Belt (Green Tuff) on the west side of the Tohoku Region, northern Honshu, the largest island of Japan. But its generation mechanism was not clearly explained. The major premise was the theory, 'When this area used to be on the seafloor, a chain of many hydrothermal activities formed ore deposits. Subsequent volcanic activities covered the ore deposits, thus keeping them from being melt by oxidative seawater'. The drilling results of the Iheya North show a different generation mechanism than this theory. Even though there are black ore mounds on the seafloor in the Okinawa Trough, ore deposits are actually growing more under seafloor.

It is possible that this kind of hydrothermal fluid reservoir occurs in an area with a radius of 10～20km. Therefore, if hydrothermal fluids continuously occur at every 20km or 30 km distance interval, a black ore belt as seen in the Tohoku Region can be generated. That the mechanism of ore deposit generation could be almost revealed in this drilling expedition is another great achievement.

Expectations toward the Future Researches

The boreholes were fitted with casings so that hydrothermal fluids may flow horizontally at a certain depth. The formation of controllable artificial hydrothermal vents is also the world's first. As the gushing hydrothermal fluids could not be recovered during this expedition, hydrothermal fluids will be recovered for analysis from the artificial hydrothermal vents in February 2011.

Dr. Takai explains the use for the artificial hydrothermal vents, 'Two of them are fitted with casings, one of them is in a natural state and one of them is fitted with a cap only. What is interesting is how much difference exists between these hydrothermal fluids and naturally gashing hydrothermal fluids. The tips of the wellhead caps should be inhabited by galatheid crabs and deep-sea mussels which live near the hydrothermal fluids. The artificial hydrothermal vents can be utilized for long-term studies and we plan to go on expeditions there once in every six months in the future'.

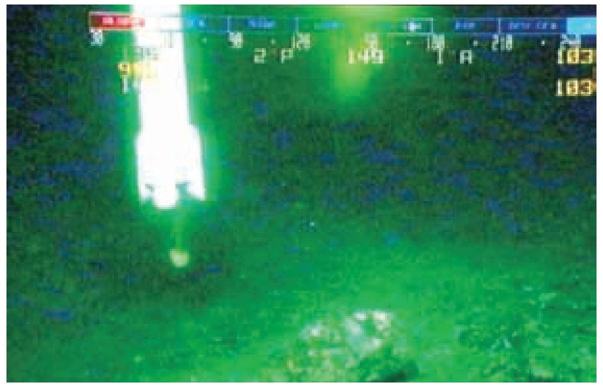
Even though the scale of the subseafloor biosphere became smaller in proportion to the difference from the expectation, the microbes research has begun to produce good results. There has been a possibility that the world of microbes depending on hydrothermal fluids exists above several caprocks. It is likely that within one year, new findings will be gained on the microbe world in the subseafloor hydrothermal field.

※ **hydrothermal mound**…a small hill-like topography generated around subseafloor hydrothermal vents

Recovering Cores from the Earth's Mantle

Coring System

Drilling in deep oceanic formations requires a sophisticated technological system and equipment since formations become harder while temperatures and pressures rise as drilling goes deeper. Constant development is being carried out to efficiently recover cores of good quality and quantity even under such extreme conditions.



Tip of coring system lowered into the seafloor

Mr. Shinmoto holding the plate of the Best Paper Award.

In the current coring system, there are two main methods: a Hydraulic Piston Coring System (HPCS) mainly used for relatively shallow and soft sedimentary layers which utilizes piston action movements to thrust the core barrel into the seafloor to recover core samples and the Rotary Core Barrel (RCB) which is mainly used for hard formations, rotating the core barrel to retrieve cores. A core bit is mounted to the tip of the core barrel to drill into the rocks and a wireline enables the recovery of the inner tube within which the scraped cores are stored. Cores can thus be recovered continuously and stably, even with variations in the layers, by a Wireline Coring System.

Even with such advanced coring equipment, cores of high quality are not always recovered. In some cases, the cores are damaged or sand and gravel layers are washed away by drilling fluid from the coring tool, leaving only gravel. We are now working on improvements to the core bit to address these problems. First, the number of bid blades was reduced so that the cores would not be damaged from contact with the blades. The tip was sharpened to prevent cores from being washed away and also to ensure that drilling fluid would not flow into the core side, preventing core jam. When the core bit was thus improved, these problems could be resolved, enabling recovery of cores in good condition even from sandstone or mudstone. The paper describing this improved core bit by Yuichi Shinmoto, Technical Engineer of the CDEX Engineer Department, was awarded Best Paper at the 15th Formation Evaluation Symposium of Japan.

The main objective of the deep-sea drilling vessel, *CHIKYU*, is to carry out scientific drilling and eventually reach the Earth's mantle. However, temperatures at the mantle exceed 250°C with pressures of 1000 atm. The mantle is also expected to be extremely hard so that a durable, efficient system will be required to drill for extended periods under the most extreme conditions.

Currently, an 'ultra-deep core bit', 'Turbine Driven Coring System (TDCS)' and more advanced 'Measurement-while-Coring (MWC)/ Logging-while-Coring (LWC) tools' are under development. In molding the ultra-deep core bit, diamond particles are evenly mixed into its body. During drilling, the diamonds attached to the blades wear off, however, with this newly improved bit, new diamond particles continue to appear on the surface, making the bit more durable over extended periods.

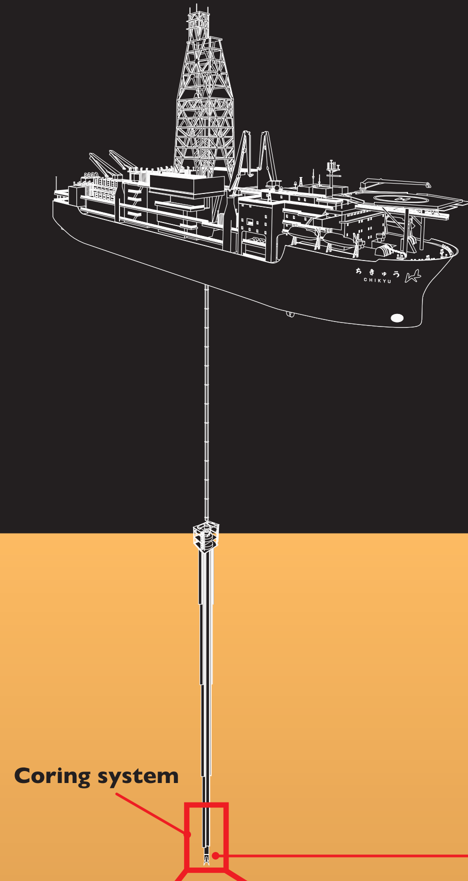
With the TDCS, the turbine is rotated by drilling fluid to cut the cores. When drilling fluid flows into the turbine unit, the rotor blades rotate at a maximum speed of 8000 rotation per minute (rpm) which reduction gear converts into rotational power or torque. A piston is installed further down, rotating and pushing out the small core bit located at the tip of the inner tube. The outer tube is rotated by a top drive system in order to ream down after the core is recovered.

The deeper the system drills in, the more difficult it becomes to check the positions where cores have been recovered so that highly advanced Measurement-while-Coring (MWC) / Logging-while-Coring (LWC) tools to measure borehole inclination and directional data to be sent in real time to the surface vessel through pressure waves (mud pulse telemetry) are essential. This will also enable accurate measurements of the direction of the cores themselves at the time of recovery, which can only be assumed at present by using paleomagnetism. Moreover, the weight-on-bit, rotary speed of the core bit, temperature and pressure inside the borehole can also be accurately monitored. The development of a system capable of measuring the natural gamma-ray, electrical resistance of layers, even when cores cannot be recovered, is underway and expected to be completed within five years.

'Fundamentals and Applications of Drilling the Ocean Floor' Awarded

Shoichi Sumita Encouragement Award of the Marine Engineering

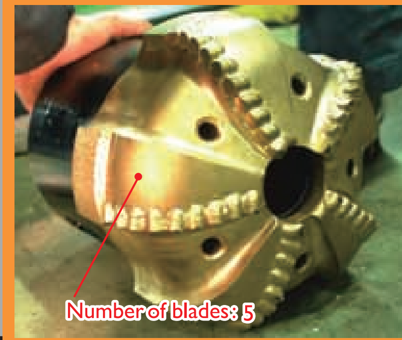
'Fundamentals and Applications of Drilling the Ocean Floor' (Seizando Shoten), a book covering all the drilling engineering at the ocean floor, written by a scientist of CDEX at JAMSTEC, in addition to the writing assistance from five staffs at JAMSTEC, was awarded 2010 'Shoichi Sumita Encouragement Award of the Marine Engineering'.



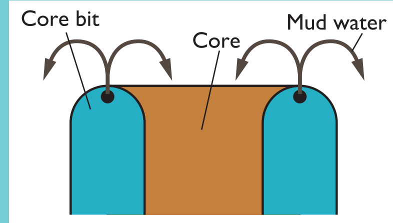
Improvements on core bit

Present / **Newly developed**

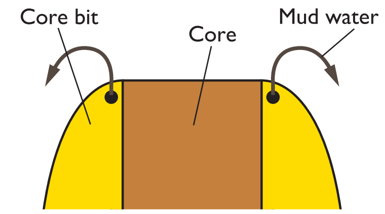
Core bit



Cross section of core bit



Shortcomings: The internal blades damage cores being recovered and drilling fluid flows into the core side.



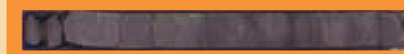
After the number of the blades was reduced and the blades on the core side were removed, the shape was modified in order to prevent drilling fluid from flowing into the core.

Examples of recovered cores

Core damaged in RCB core recovery

Recovered core of sand and gravel layer

The core surface is damaged by internal blades, as shown in the photo. When drilling through sand and gravel layers, drilling fluid washes away the sand.

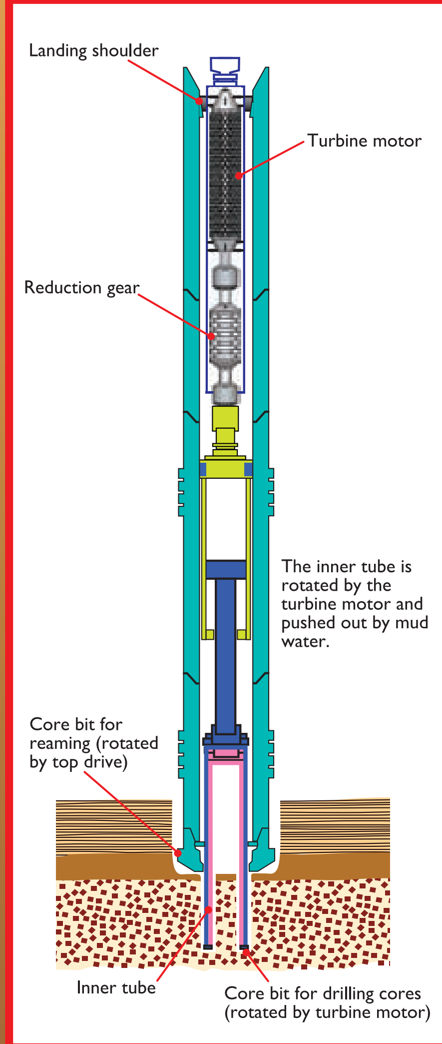


Sandstone

Mudstone (containing sand and gravel layer)

Drilling with the new core bit suppressed damage to the cores and washing away of sand, enabling more complete core recovery.

● Turbine drive coring system



● Measurement-while-Coring (MWC) / Logging-while-Coring (LWC) tools

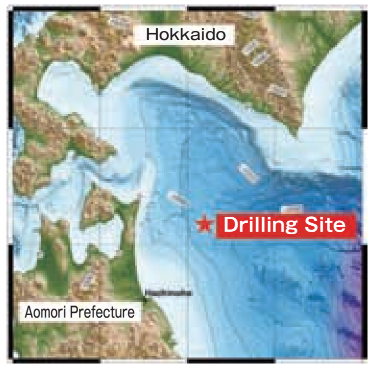
A direct visible check is not possible during coring so that the deeper the system drills in, the more difficult it becomes to check the status of the equipment and condition of the cores recovered. For example, the coring system may be assumed to be drilling in a vertical direction, however, the direction may actually have inclined. Sophisticated Measurement-while-Coring (MWC)/Logging-while-Coring (LWC) systems would thus be vital in monitoring inclination and direction and other data which would be sent to the surface by mud pulse telemetry. In addition to the direction of the drilling equipment, measurement of the direction of cores themselves, the actual status of the weight-on-bit and rotary speed for the core bit in the borehole as well as temperatures and pressures in the borehole could all be monitored in real time.

● Ultra-deep core bit

V-shaped grooves are attached to the blades for easier elimination of cuttings. Moreover, the area of tips for drilling has been widened in order to distribute the load for increased durability. The drilling fluid flows through the grooves.

Riser Drilling to be Conducted over 2,000meters off the Shimokita Peninsula

Exploring the Biological Activities of Lignite Coal Layers in the Deep Subsurface



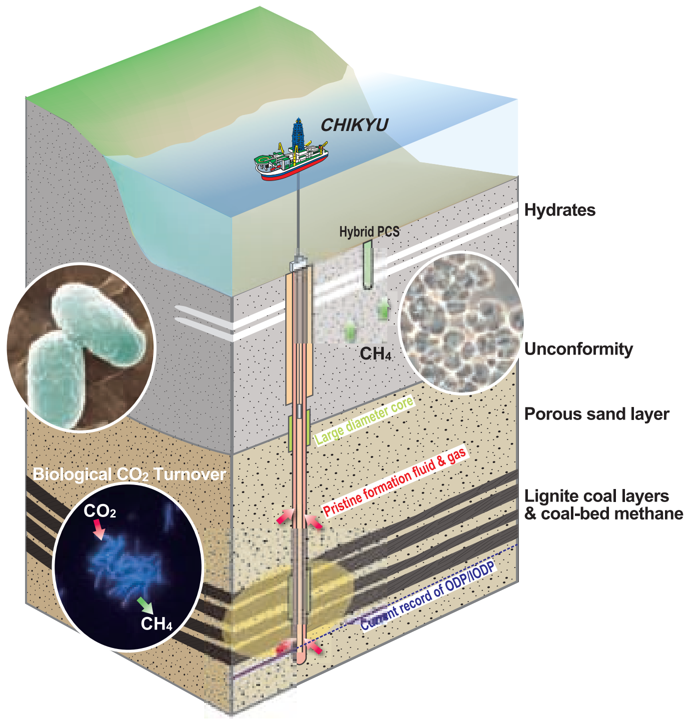
Interviewee:
Dr. Fumio Inagaki
Geomicrobiology Group of the Kochi Institute for Core Sample Research

In the spring of 2011, *CHIKYU* conducts riser drilling in the sea area approx. 80km off the Shimokita Peninsula (IODP Expedition 337), aiming at 2,200meters below seafloor, deeper than 2,111m, the drilling depth record in ocean drilling science. A lot of results are expected by drilling through biosphere in gas-rich and coal layers, including new findings.

Aiming at Renewing the Drilling Depth Record with Riser Drilling

In 2006, *CHIKYU* conducted drilling down to about 650meters below seafloor to the east of the Shimokita Peninsula (water depth: approx. 1,200m) during the shakedown cruise (Site C9001: Pilot Hole). In mid-March 2011, *CHIKYU* further drills deeper through the C9001 Hole by riser drilling, aiming at reaching 2,200meters, the depth unexplored in scientific ocean drilling. In this neighborhood, there is an immature coal (lignite) layers about 50million years ago (the Paleogene-Eocene in the Cenozoic Era), above which a natural gas area exists. As these strata have been difficult for riserless drilling, no scientific drilling has been conducted.

'By drilling through the natural gas field and drilling down until the lignite coal layers deeply buried in the subseafloor, the whole picture of the energy cycle system of hydrocarbon, where the lignite coal layers are the mother rocks, should be revealed. In addition, we hope to elucidate the actual conditions of biological activities, that is, how many microbes exist there and what kinds of roles they perform', Dr. Fumio Inagaki, Co-Chief Scientist, talks about the purpose of the research. 'However, to that end, there is a major challenge', says Dr. Inagaki. That is to collect core samples with good quality'. The depth around the unconformity (approx. 1,800meters) which forms the boundary between the marine sediments and terrigenous sediments below them is an important place for the research. But the strata are brittle in the place, which creates the problem of whether clean core samples with less contamination can be collected. It is expected that the lignite coal layers, where sandstone and lignite forms layer structure, are also brittle. Collecting high-quality core samples in such a place greatly influence the study at a laboratory with real subseafloor environment planned after the coring expedition.



Subseafloor structure of the drilling sea area off the Shomokita

Challenges toward a New Frontier, to which Scientific Ocean Drilling Contributes

In order to study with the use of core samples to be obtained during Expedition 337, in situ subseafloor environment has been developed in the laboratory. For the maximum use of the new facility, fresh and high-quality core samples are required. Furthermore, during Expedition 337, mud-gas and cuttings contained in drilling mud collected on board by riser drilling are to be monitored minutely and continuously which will be used as valuable data to reproduce the actual environment.

To explore the possibility of CCS (Carbon Capture and Storage) by which carbon dioxide is captured and stored within subseafloor strata is also expected as one of the big outcome in this project. 'Given Japan's geographical conditions, subseafloor lignite coal layers can become a very effective space as a storage place for carbon dioxide. In addition, we think that metabolic activities of microbes can process carbon dioxide into energy substrates, such as methane (natural gas) and organic matters. If this 'Bio CCS' hypothesis is proven, it should be possible to utilize lignite coal layers as 'Subseafloor Forests', Dr. Inagaki explains. The new geo-bio-engineering approach new challenge for scientific ocean drilling, such as developing energy processing and cycle technology by utilizing biological activities below seafloor, has received significant interest, including future collaboration with the industrial circles.

＊ The current schedule of Expedition 337 has been cancelled due to one of six *CHIKYU*'s thrusters suffered damage by Tsunami caused by the 2011 Tohoku Earthquake and Tsunami.

Superintendent Taking Charge for Smooth Drilling

Tool Pusher

Interviewee:
Tool Pusher Masayuki Kawasaki
Mantle Quest Japan Company Ltd.

The role of the Tool Pusher is to make thorough preparations for drilling so as to execute operations and achieve the objectives within a tight timeframe. Such efforts to 'do one's best in making the preparations and aim for full marks' result in the ability to deal with unexpected circumstances.

Tool Pusher keeps watch on the entire drilling operations from their preparations.

The drilling operations of Deep Sea Drilling Vessel *CHIKYU* are mainly performed in an area of the vessel called the 'drill floor'. This is one of the vital operations areas of the *CHIKYU* and a location that is heavy with activity and full of drilling equipment, including many kilometers worth of drill pipe. Above this area there is dynamic activity and heavy hanging machinery. It is a potentially dangerous area, and as such is off-limits to non-essential personnel, even during open house events. Thus it has less public exposure than other areas of *CHIKYU*.

Personnel who work on the drill floor are proud, physically strong, and of posses sound judgment, all attributes refined on-site. Drill pipe must be lifted, lowered, and rotated by the Driller controlling equipment from the Driller's House. The Tool Pusher supervises general drilling operations, including managing the drilling schedule, maintaining machinery, and ensuring the safety of the drilling crew.

Typically, the Tool Pusher works his way up the career ladder, starting at what is known as in the industry vernacular, Roughneck, and proceeding through to Derrick Man handling drilling mud, Assistant Driller assisting drillers, and then Toll Pusher.

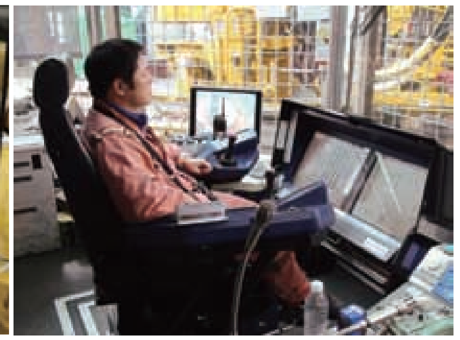
Kawasaki Masayuki served as Assistant Driller at a different drilling operation, and was then transferred to shore-based activities where he was responsible for the improvement plan of the coring tool, which *CHIKYU* currently uses. He has subsequently been aboard *CHIKYU* as a Tool Pusher since it has been operated by Mantle Quest Japan Company.

Time is a premium commodity during coring expeditions. Scientists hope to retrieve as much core sample as possible during these expeditions and eventually capitalize on the research results. The Tool Pusher carefully organizes tasks and closely monitors activities so as to avoid time losses caused by unexpected incidents or machinery failure. 'Carelessness and over-familiarity can easily lead to incidents. Attention and alertness must be aroused every day', says Kawasaki.

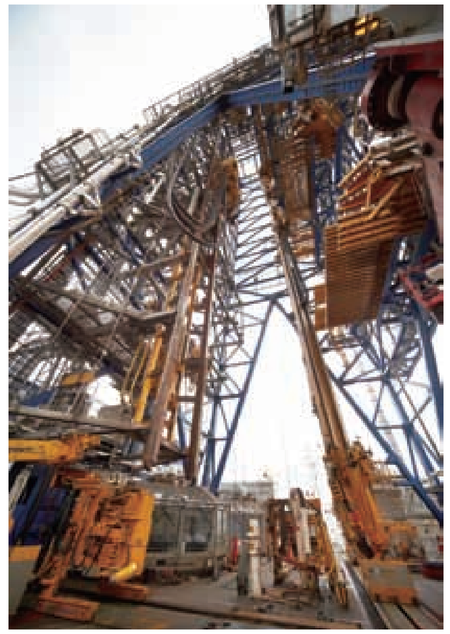
The Tool Pusher is attentive to nipping trouble in the bud. "Preventative Maintenance" programs are used to manage control equipment, which requires especially close attention since it cannot be readily replaced. Such continual efforts are essential for successful coring expeditions.

"I take pride in and feel good about my job, using world-class equipment aboard *CHIKYU*. When work proceeds without downtime or other inefficiencies, nothing is more rewarding", comments Kawasaki. Research drilling has many phases in which new challenges and unexpected situations arise. They are an inherent part of the job. For that reason, preparations are repeated and alternatives, in case of emergency, are readied.

The Tool Pusher must keep watch on the entire drilling operation, from job preparation, through to execution, to contingency planning.



Drill floor operations require full attention (left).
Masayuki Kawasaki working in the driller's house (right).



Machinery hanging from the derrick. At-height operations are continual.

Let More People See and Realize How *CHIKYU* Take on Challenges!

The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) introduces the activities of *CHIKYU* which develops a new era of earth science in various ways, including open house of *CHIKYU* , lectures and internet video streaming.

Open House of *CHIKYU* The Total Number of Visitors Exceeded 100,000!

Azuma, the Director-General of CDEX (left) and Captain Minoura (right) welcoming the family who became the 100,000th visitor in total.

The scene of a tour of *CHIKYU*'s bridge.

In the Port of Kobe, *YOKOSUKA* and *SHINKAI 6500* were also open to the public, together with *CHIKYU*.

In 2010, open house events of *CHIKYU* were held in the Port of Nakagusuku, Okinawa Prefecture on October 9 and 10, and in the Port of Kobe, Hyogo Prefecture on October 16. There was a tour of various onboard facilities, such as the bridge and the research compartment, as well as the explanations of how to dig beneath the seafloor and the exhibitions of core samples collected by drilling. At Open house in Okinawa, there was a happy occasion where the total number of visitors so far exceeded 100,000. Furthermore, during a port call at the Port of Shimizu, Shizuoka Prefecture in January 2011, a symposium was carried out for people involved in education at high schools/universities and researchers, so that they could deepen their understanding toward *CHIKYU*.

Talk Event Held Featuring Dr. Ken Takai, Geomicrobiologist

Dr. Takai (right) talking enthusiastically about how the Expedition went.
On the left is the facilitator, Sascha, navigator of "Chikyu TV".

'Chikyu TV Special Talk Event' was held at Science Museum in Tokyo on October 9, 2010, featuring Co-Chief Scientist, Dr. Ken Takai (JAMSTEC) who returned home after completing IODP Expedition 331 'Deep Hot Biosphere'. The visitors enjoyed his various topics and easy explanation, including the results of the Expedition and his researches as well as his first impression on board *Chikyu*. The content of the talk event is also available on 'Chikyu TV'.
'Chikyu TV' Deep Hot Biosphere Vol.6
http://www.jamstec.go.jp/okinawa2010

'Chikyu TV' Podcasting Named 'iTunes Rewind 2010' Top 25 Podcast

'JAMSTEC Discover the Future Chikyu TV' was named one of 'the top 25 new video' by Apple Inc.'s iTunes Rewind 2010 Podcast. Please do access 'Chikyu TV' which introduces the work on board *CHIKYU* and the research contents of scientific drilling in an easily understandable way.

How to View: : iTunes-->Podcast-->Science/Medicine-->Video or http://www.youtube.com/user/jamstecchannel

Overcoming Obstacles in Subseafloor Drilling for Greater Scientific Results

CHIKYU has achieved big results in the Expeditions of the Okinawa Trough Hydrothermal Fields and the Nankai Trough. Wataru Azuma, the Director-General of CDEX tells us about the operational achievements for the year 2010.

Toward Realizing the Dreams of Earth Sciences

CHIKYU, which marked the 5th year in 2010 since its completion, had various happenings. In summer, there was an accident where a casing pipe fell off, but eventually the mission could be completed successfully. And by drawing a lesson from the accident, security measures could be enhanced in order to prevent recurrence. The subsequent Deep Hot Biosphere (IODP Expedition 331) could generate many results which should contribute to uncovering subseafloor biosphere. In addition, we can say that new discoveries about hydrothermal mineral deposits gained in the Expedition are important and hopeful achievements, also related to Japan's future resources exploration and development.

The installation of a long-term borehole observatory in the Kumano Basin, off the Kii Peninsula (IODP Expedition 332), conducted in October through December, was the expedition which made us nervous most in 2010. Of course, all expeditions are new challenges and everything always makes us nervous. Still, as you can see in Special Topic of this issue, considerable difficulties were expected of this Expedition from the beginning. Whether we would successfully install sensitive sensors within the small borehole in the seafloor of approx. 2,000m water depth, amid rapid tidal currents of the Kuroshio current of the North Pacific region. That made us feel continuously nervous to the very end. The successful installation was all the more joyful above all else. There are a lot of factors in the success, but I realize the biggest factor of all is that the scientists, engineers and crew got united to tackle the difficult task and achieved it through their remarkable teamwork.

In March 2011, we will use ROVs to check if the sensors installed this time work properly. In 2011, the observatory is to be connected with a submarine cabled system, the Dense Oceanfloor Network System for Earthquakes and Tsunamis (DONET) deployed in the Kumano Basin in our plan. As a result, real-time observation and monitoring will be realized not only in the seafloor but also in the subseafloor around the Tonankai magnitude 8 class earthquake source area, which should be effective in the prevention and mitigation of disasters when earthquakes or tsunamis happen. Also, such as in helping to elucidate the mechanism generating slow slip events (slip phenomena with much slower velocity and longer duration than slips caused by earthquakes) which have been attracting attention, new findings may be produced by analyzing detailed data sent from the subseafloor, which will overturn the conventional wisdom about massive trench-type earthquakes. We greatly anticipate that the long-term borehole observatories will play an active part.

'Chikyu TV'
http://www.jamstec.go.jp/chikyu/nantroseize2010/e/

'Chikyu TV' to Respond to Growing Interest

In 2010, the number of visitors to the open house events of *CHIKYU* exceeded 100,000 in total. We are thrilled to know that a lot of people express such interest in *CHIKYU*. However, in the past it was difficult to show the public how *CHIKYU* conducted drilling operations, that is, its on-site work at sea. So, in 2010, we started a new initiative, called 'Chikyu TV'. Its purpose is to realistically convey the situations of scientific drilling, what kinds of things are going onboard *CHIKYU*, through videos sprinkled with expressions and actual voices of scientists and engineers. Thanks for everyone's support, 'Chikyu TV' has been so popular as to get 120,000 ～ 130,000 visitor number per month. We hope to continue to put effort into such promotional activities so that a lot of people may deepen the understanding toward the activities of *CHIKYU*.

CLOSE UP

One scene of *CHIKYU* in New Year

The scientists of 'IODP Expedition 333 : NanTroSEIZE Stage 2' greeted the New Year of 2011 on board *CHIKYU*. While finishing a normal work shift even during New Year holidays, they held New Year Calligraphy event.

The calligraphy examples were '新春 (New Spring)' and 'ちきゅう (*CHIKYU*)'. In spare moments from their busy work, they tried new year calligraphy after a long time or the first brush writing, which made them feel refreshed.

CDEX
CENTER FOR DEEP EARTH EXPLORATION
JAMSTEC
http://www.jamstec.go.jp/chikyu/

CHIKYU HAKKEN
– EARTH DISCOVERY –
IODP Japan Implementing Organization Report
Volume 11 March, 2011
IODP INTEGRATED OCEAN DRILLING PROGRAM

Publisher
Center for Deep Earth Exploration, Japan Agency for Marine-Earth Science and Technology
3173-25 Showa-machi, Kanazawa-ku Yokohama Kanagawa 236-0001 JAPAN
TEL: +81-45-778-5647, FAX: +81-45-778-5704
EMAIL: cdex@jamstec.go.jp URL: http://www.jamstec.go.jp/chikyu/