

Celebrating First Decade of IODP Core Curation Services at Kochi Core Center, Japan

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Under the auspices of the Integrated Ocean Drilling Program (IODP), Kochi Core Center (KCC) was designated as one of the 3 IODP core repositories in the world. The KCC is in-charge of curating core materials collected/to be collected from most of the Indian Ocean, west Pacific Ocean and Bering Sea. Curation of the IODP core material in the KCC began in 2007 as it started receiving core material from other two IODP core repositories. This core material was collected under the DSDP (Deep Sea Drilling Program) and ODP (Ocean Drilling Program) that preceded the IODP. With the development of various new analytical techniques and geochemical tracers, and ever-going refinement of environmental record based on traditional indices, the core material collected under the DSDP and ODP (also known as 'Legacy core') continuously attract science community. The KCC has not only maintained high curatorial standards of the IODP for providing core samples free of cost, but also added many unique services like curation of cuttings and deep frozen aliquots of cores, open access to logging equipment for core measurements, virtual core library to provide quick online access to 3-D XCT images of the cores collected by the D/V Chikyu, online summary of the cores being curated in the KCC, and up-to-date online images of working half of recently sampled cores to show status of samples available for research. A huge new reefer building was added to the KCC in August 2014 that raised the capacity of the KCC to store 250 km of core. With its current stock of 121 km of the IODP cores, that has built up over last decade, and the cores to be collected under new IODP (International Ocean Discovery Program), the KCC continues to play a significant role in promoting earth and biogeosciences throughout the world.

Keywords: Marine core, Drilling Science, DSDP, ODP, IODP, KCC

Discussion on gamma ray, temperature, and pressure downhole logging data at sea-floor hydrothermal deposit in Izena Hole off-shore Okinawa

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CK16-05 cruise was carried out to understand origin and development process of the sea-floor hydrothermal deposit in Izena Hole off-shore Okinawa on November to December in 2016. It is one of the research cruise under an umbrella of Cross-ministerial Strategic Innovation Promotion Program (SIP), "Next-generation technology for ocean resources exploration (Zipangu in the Ocean)". Natural gamma ray and temperature downhole logging data was acquired at the five wells. It is difficult to take high quality and recovery cores in hydrothermal brittle formation. The continuous natural gamma ray logging data allows us to describe continuous vertical formation profile. The temperature logging indicates potential of hydrothermal deposit activity. The pressure data does not show significant features. We compile the gamma ray, temperature, and pressure data, and discuss its geological and geophysical features.

Keywords: Sea-floor hydrothermal deposit, downhole logging

Estimation of in-situ stress by a new analysis method of Diametrical Core Deformation Analysis (DCDA)

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Determination both direction and magnitude of in-situ stress is very important for many geoscience and geoenvironmental problems. Diametrical Core Deformation Analysis (DCDA) was developed to determine the difference of maximum and minimum stress and the stress orientations on the plane perpendicular to borehole. In case of vertical borehole, they are maximum horizontal stress (SHmax) and minimum horizontal stress (Shmin). It is based on measurement of diametrical core deformation accompanied with stress release caused by drilling. This method has simple and clear principle, and is a non-destructive method. However, it cannot provide the individual SHmax and Shmin magnitudes. Therefore, we propose a new analysis method using the same core diameter data as the conventional method, the new method enables us to estimate SHmax and Shmin magnitudes and their orientations in both vertical and deviated borehole. To examine this new analysis method, we applied it for estimation in-situ stress using the DCDA data of core samples retrieved from the IODP Expedition 319.

The new analysis method is based on an assumption that principal stresses are in horizontal plane and a vertical direction. Then circumference distribution of core diameter is given by a theoretic equation with SHmax, Shmin and vertical stress (Sv). We can get the optimum SHmax and Shmin values and the azimuth analytically by fitting to the observed core diameter by this equation. In this study, we adopted this new method to three cores from a vertical borehole at depths of ~1540 mbsf in site C0009 drilled during the IODP Expedition 319 and estimated the principal stress magnitudes and orientation. Moreover, we compared this result to other results measured by other methods at same depth.

As a result, azimuth of SHmax was N140°, SHmax and Shmin magnitudes were ~65MPa, 42MPa (average of three cores), respectively. The result of SHmax azimuth was consistent to that from breakout. In particular, the SHmax and Shmin magnitudes estimated by the new method were reasonable, and showed the same stress regime with the others. It suggests the new analysis method may be valid.

Keywords: DCDA, core sample, principal stress

Driling experiment

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Drilling can provide more useful subsurface information which has not been realized. We are planning drilling experiments, as a first step, to explore how this approach can be achieved. This presentation outlines our initiatives.

Keywords: drilling, experiments

Calibration of the borehole pressure gauges installed in the C0002G observatory in the Nankai trough

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In the Nankai Trough region, several large interplate earthquakes with magnitudes of 8 have occurred repeatedly due to a subduction of the Philippine Sea Plate beneath the Eurasian Plate at a rate of 4-6 cm/year. In this area, Japan Agency for Marine-Earth Science and Technology (JAMSTEC) deployed a long-term borehole monitoring system (LTBMS) into the C0002G boreholes during the IODP expedition 332 in 2010 to understand a seismogenic process of large interplate earthquakes. The LTBMS incorporates four pressure sensors, a volumetric strainmeter, a tiltmeter, a geophone, a broadband seismometer, accelerometers, and a thermistor string. Among the sensors, the pressure measurements are important for detections of long-term and small crustal deformations associated with the occurrence of large earthquakes. However pressure measurements contain instrumental drifts in the sensors in addition to the pressure changes associated with crustal deformations. Therefore calibrations for the pressure sensors are indispensable.

All pressure sensors are deployed on the ROV platform of the C0002G observatory, but each pressure sensor measure different water pressure depending on its pressure port depth (0 ~ 948 mbsf). One pressure port is located on the ROV platform (seafloor), the others are distributed inside the C0002G borehole and are connected by steel hydraulic lines with valve systems. The valve systems are manually operated by ROV manipulator, and switch target pressures from the pore fluid pressure in the C0002G borehole to the pressure on the seafloor. The valve systems are used for calibrations of the pressure sensors. Changes in relative instrumental drifts are estimated using the data during recording the seafloor pressure, because all the pressure sensors measure a reference seafloor pressure.

We repeatedly calibrated the pressure sensors in the C0002G borehole in the KY14-04, the KY15-05, and the KY15-16 cruise. Because all valve system were not switched during the cruises, instrumental drifts of the two pressure sensors in the borehole were estimated relative to the seafloor pressure sensor. The relative drift rates were estimated to be -3.88 and 2.37 hPa/year, respectively.

Absolute instrumental drifts are necessary to understand long-term and small pressure change. We are developing a mobile pressure gauge to calibrate a pressure sensor on the seafloor. A target accuracy of the gauge is less than 1 hPa. The absolute instrumental drift rates of all pressure sensors in the borehole will be estimated using the data.

Keywords: LTBMS, C0002, Nankai trough, pressure sensors, calibration

Episodic tectonic uplifting / erosion and sedimentation offshore southern Taiwan, a possible target of scientific ocean drilling

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Taiwan has been known as of high uplift rate and the uplifted mountain region provides huge amount of sediments that buries carbon in the surrounding oceanic basins. The uplifting process has been episodic, suggested by several evidences, and this may be associated with episodic accretion and collision process at the eastern and western margins offshore Taiwan. If the uplift is produced as a pop-up structure between these two convergent margins, strength of the two detachment zones may play a key role to determine the uplifting amount. In southern Taiwan, part of the sediments from the retro-wedge is ponded in the ~1000-m deep Southern Longitudinal Trough, a part of the deformed Luzon fore-arc basin. Off SW Taiwan, coarser-grained sediments from the pro-wedge are delivered into the South China Sea through a few canyon winding through the accretionary wedge. The study area is ideal for study links and interplay among mountain building, erosion, sedimentation and efficiency of organic carbon burial. We will introduce outline of our potential targets of offshore scientific drilling to examine such hypothesis, based on our interpretation of seismic profiles.

Keywords: Taiwan, IODP, episodic uplift

Initiation process of frontal thrust at accretionary prism

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This talk explains the thrust initiation process at accretionary prism based on geologic modeling studies and compares with actual deformation features observed at a frontal thrust of Nankai Trough, IODP370.

Physical properties of the Nankai accretionary prism, off Cape Muroto: Preliminary results of IODP Expedition 370

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International Ocean Discovery Program (IODP) Expedition 370 was carried out to explore the limits of life in the deep seafloor biosphere at a location where temperature exceeds the known temperature maximum of microbial life ($\sim 120^{\circ}\text{C}$) at the sediment/basement interface ~ 1.2 km below the seafloor. Drilling Site C0023 is located in the vicinity of Ocean Drilling Program (ODP) Sites 808 and 1174 at the protothrust zone in the Nankai Trough off Cape Muroto at a water depth of 4776 m. Continuous physical property measurements on cores were performed to identify the occurrence of the accretionary prism and plate boundary fault and to characterize the habitat of seafloor microbial communities. In the presentation, we will report our preliminary physical properties of the Nankai accretionary prism at Site C0023.

Physical property measurements on shipboard, including moisture and density (MAD), thermal conductivity, electrical resistivity, *P*-wave velocity, natural gamma radiation, and magnetic susceptibility were carried out on core samples from 204 to 1176 mbsf under room temperature and pressure conditions. Porosities through the wedge facies (Unit II) to the upper Shikoku Basin facies (Unit III) are characterized by high variability and generally decrease from 45% to 37% in average with increasing depth. Within the lower Shikoku Basin facies (Unit IV), porosities continue to decrease with depth to 33% at the top of the décollement zone at ~ 760 mbsf. However, deeper than 760 mbsf, they turn to increase gradually by 5%–7% with depth to ~ 830 mbsf. This porosity increase is accompanied by a decrease in *P*-wave velocity and apparent formation factor (i.e., electrical resistivity). Deeper than ~ 830 mbsf, porosities resume a general compaction trend to the base of Unit IV and then rapidly increase within Unit V, where tuffaceous mud becomes the dominant lithology. Basaltic rocks in the basement exhibit a range of porosity between 5.5% and 25%. Similar porosity depth profiles were reported at Sites 808 and 1174 (Taira et al., 1991; Moore et al., 2001). However, in contrast to these sites, porosities at Site C0023 begin to elevate gradually within the décollement zone.

In situ temperature measurements between 189 and 408 mbsf and laboratory thermal conductivity measurements indicate a heat flow of 140 mW/m^2 . Assuming that the heat flow is purely conductive and steady state, temperatures of 86° and 120°C are projected for the top of the décollement and the bottom of the hole, respectively.

Keywords: Nankai, Décollement

Reorientation of cored samples for stress-state analyses: IODP Expedition 370

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In the Nankai Trough subduction zone, SW Japan, moment magnitude (Mw) 8 class great earthquakes have occurred repeatedly at intervals of 100~200 years. To determine the present-day stress state at the toe of the plate subduction zone penetrated during the IODP (Integrated Ocean Discovery Program) Expedition 370, we conducted stress measurements using core samples recovered from Site C0023 by Anelastic Strain Recovery (ASR) method. In order to determine the in-situ stress directions, we need to reorient the samples to the geographic coordinate using the paleomagnetic method.

Experimental procedure is as follows: we first cut a disc-shaped sample with a thickness of 2 cm from a whole round core sample and then further cut it into 9 specimens. To avoid drying of the specimens, they were subsequently wrapped by a parafilm. Progressive alternating field demagnetization (AFD) was conducted on each specimen by 80 mT to extract a primary component of the natural remanent magnetization (NRM). We were able to determine a paleomagnetic direction of each specimen by applying the principal component analysis (Kirschvink, 1980) or the great circle analysis (McFadden and McElhinny, 1988) to the demagnetization results of NRM. The primary component was acquired when the rock formed and records the direction of the geomagnetic field at that time. Therefore this direction corresponds to magnetic north and can be used to reorient the sample.

In this study, we succeeded in the reorientation of 9 out of 15 whole round core samples to geographic coordinates. Specimens from 6 cores had heavy magnetic overprints associated with the drilling and have not been reoriented.

Keywords: Paleomagnetism, Core reorientation, Anelastic Strain Recovery

A new method for measurement of core quality using X-ray CT data of IODP Expedition 370

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Geological drilling aims to obtain high-quality cores for various purposes, such as the studies of mineralogy, physical properties and subsurface biogeochemistry. It is critical to quickly evaluate the quality of the drilled cores to assess the level of recovery, decide drilling methods, identify intervals for subsampling and estimate the extent of contamination by drilling mud or seawater. X-ray computed tomography (CT) is a powerful tool which shows the distribution of materials, drilling disturbance and geological structures throughout the core in three dimensions. X-ray CT can be carried out without splitting the cores or opening core liners and hence is efficient for core evaluation and desirable for studies sensitive to contamination and disturbance. X-ray CT is generally used as a qualitative method so far. Here we introduce the Core Quality Factor (CQF) as a quantitative method for analyzing and comparing core qualities using X-ray CT data.

Each pixel in X-ray CT images gives a CT number depending on the density of the material, for example, 0 for air (unrecovered area) and 2500 for standard aluminium. The CQF method first examines a cross-sectional slice of the core section at one depth, producing a histogram of numbers of pixels against CT numbers for the slice. The major material in the slice gives a dominant CT number and produces a peak in the histogram. Pixels with CT numbers higher than a threshold (e.g. 70% of the dominant CT number) are considered 'high-quality slice'. We repeat this at intervals of 0.625 mm throughout the entire core section. Then we can calculate the CQF score which is the percentage of 'high-quality slice' among all slices in the section.

We applied the new method to the X-ray CT data at Site C0023 of IODP Expedition 370. The X-ray CT measurements were made on 598 sections from 189 to 1177 mbsf. The X-ray CT instrument on the *Chikyu* is a Discovery CT 750HD (GE Medical Systems) capable of generating thirty-two 0.625 mm thick slice images every 0.4 s, the time for one revolution of the X-ray source around the sample. The CQF scores are lower than 70% at intervals 189–430 mbsf and 1100–1177 mbsf, matching the shipboard geological observation of sandy or soupy sediments and heavy drilling disturbance at these intervals. The CQF scores are above 80% at intervals 540–630 mbsf, 710–790 mbsf, and 860–1080 mbsf. The high CQF scores representing high core quality are in line with geological description of firm sediments and minor drilling disturbance at these intervals.

Keywords: X-ray CT, Nankai Trough

Detection of microbial life in the oceanic crust aged 13-100 million years

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Microbial life is widely distributed in extremely oligotrophic habitats. However, the extent and microbiological nature of such oligotrophic habitats are poorly constrained due to the lack of scientific knowledge of the oceanic crust, which has been estimated to be the largest but least accessible microbial habitat. Several lines of evidence previously suggest that seafloor microbial life exists within young ocean crusts on the flanks of mid-ocean ridge systems where fluid circulation is thermally driven. As the oceanic crust is aged, the deposition of sediment cover and the heat loss appear to dramatically alter the physicochemical properties of the oceanic crust after 10–15 Myr. Despite the fact that the oceanic crust older than 10 Ma covers >50% of Earth's lithosphere, microbial life in the vast crustal habitat has been poorly explored mainly due to microbial contamination from drilling fluid made from surface seawater. 13.5–100 Ma basaltic rocks in the oceanic crust distributed with South Pacific Gyre were explored through Integrated Ocean Drilling Project Expedition 329, where primary productivity in the surface seawater is exceedingly low. By undertaking the routine evaluation of microbiological contamination with fluorescent microspheres added to drilling fluid, 11 out of 15 core samples were found to be undetectable for fluorescent microspheres from the core interior. 16S rRNA-based molecular phylogenetic analysis was conducted by pyrosequencing of the 15 core samples, drilling fluid samples and a negative control from the laboratory manipulation was conducted. As a result, pyrosequencing was successful for five core samples undetected for microsphere contamination, one contaminated core sample and one drilling fluid sample and the laboratory control. After carefully excluding contamination sequences, 92–370 sequences and 18–134 operational taxonomic units (OTUs) based on >97% similarity were obtained from the five core samples and subjected to further phylogenetic affiliation. Microbial community structures were shifted in shallow pillow lavas thinly covered with oxygenated sediments from the ϵ -proteobacterial dominance at 13.5 Ma and the β -proteobacterial dominance at 33.5-Ma, which is also represented by the inferred metabolic shift from chemoautotrophy to heterotrophy. In the ~100-Ma lava flows, methanotrophy in basaltic rocks with fractures filled with secondary minerals was indicated by the phylogenetic relationship to known methane-oxidizing bacteria and archaea. Although more research is needed to clarify the biomass, biodiversity and metabolic activities of microbial life in the upper oceanic crust, microbial communities revealed in this study might be widely distributed and playing important roles in the global carbon cycling in previously unrecognized pathways.

IODP Expedition 361 –Southern African Climates and Agulhas LGM Density Profile

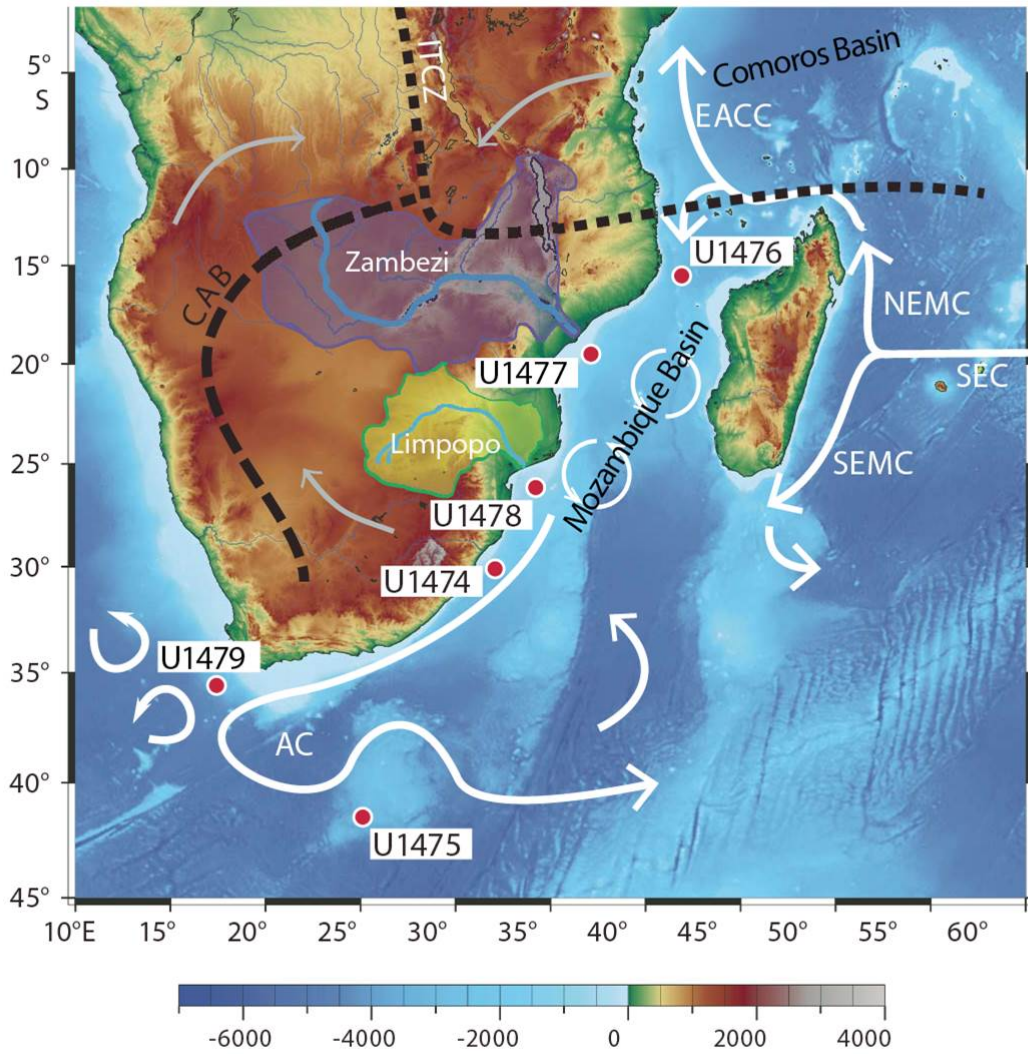
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The Agulhas Current constitutes the largest western boundary current system in the Southern Hemisphere and is a key component of the global oceanic thermohaline circulation. IODP Expedition 361 (January-March 2016) was planned to reveal the sensitivity of the Agulhas Current to climate changes over the past ~5 million years, to determine the dynamics of the Indian-Atlantic gateway, and to examine the connection between the Agulhas leakage and the Atlantic Meridional Overturning Circulation. Other scientific objectives included evaluation of the effect of the Agulhas Current on African terrestrial climates (especially rainfall patterns and river runoff) and potential linkages to hominid evolution. Additionally, Ancillary Project Letter aimed at high-resolution sediment-pore fluid sampling in order to constrain deep ocean temperature and salinities during the last glacial maximum was completed.

During the IODP Exp. 361, six sites (Site U1474 –U1479) were drilled and 5,175 m of sediment core was recovered (average recovery 102 %), spanning the time-interval between ~0.13 and 7 million years. Initial results of chronostratigraphic and paleoenvironmental information of both shipboard and post-cruise measurements by IODP Exp. 361 will be presented.

Keywords: IODP Exp. 361, Agulhas Current , Southern Africa Climates



Mineralogical and geochemical characteristics of micro-mineral particles in the South Pacific Gyre sediment (IODP Exp. 329)

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Ferromanganese minerals widely occur on the seafloor of abyssal plains as nodules consisting of manganese, iron and various trace metal elements. Accumulation and dissolution of the vast mineral deposits play important roles in the global element cycle. However, no clear picture has yet emerged as to the nature of these mineral deposits in deep subseafloor oxic sediments. During the Integrated Ocean Drilling Program (IODP) Expedition 329, we drilled the entire sedimentary sequence at 6 sites in the ultra-oligotrophic region of the South Pacific Gyre (SPG), where dissolved O₂ and aerobic microbial communities are present from the seafloor to the sediment-basement interface [1]. We observed abundant micrometer-scale particles of ferromanganese minerals (Mn-microparticles) in oxic pelagic clay sediments of the SPG over 100 million years. Three-dimensional micro-texture and elemental composition analyses using mass-spectrometric, flow cytometry and synchrotron-based approaches revealed that most Mn-microparticles are poorly crystalline ferromanganese minerals that consist of various trace metals and carbon species, indicating that Mn-microparticles are possibly derived from the past hydrothermal activity and widespread buried in the open-ocean gyre.

[1] D' Hondt et al., Presence of oxygen and aerobic communities from seafloor to basement in deep-sea sediment. *Nature Geosciences*, 8(4), 299-304, 2015.

Keywords: micro-mineral particle, pelagic clay, South Pacific Gyre

High-resolution Petrophysical, Geophysical & Chemical Properties Characterization across Crustal-Mantle Transition in Oman

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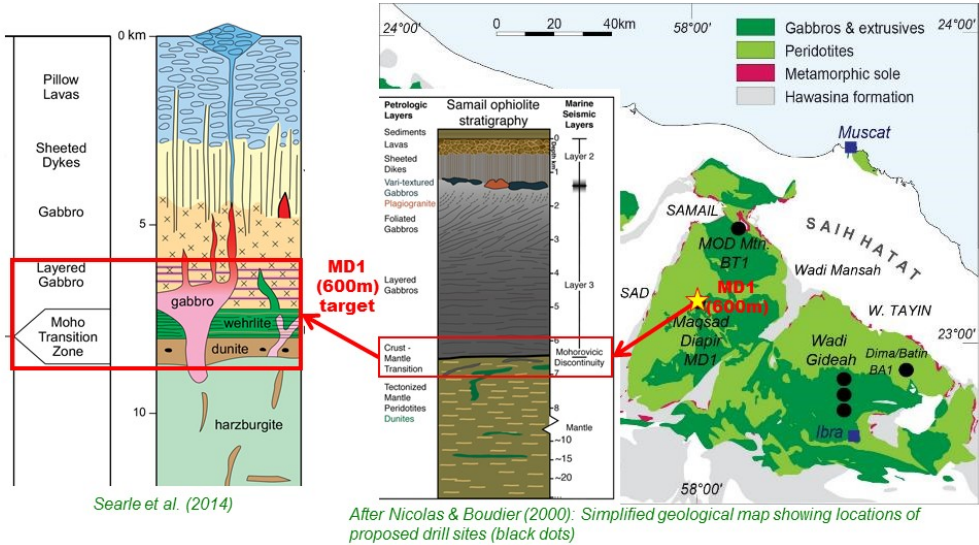
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To clarify the actual condition of the Mohole discontinuity which was first identified in 1909 as step in the velocity of the seismic wave, it is necessary to drill and sample across crustal-mantle transition and that was original idea of the scientific ocean drilling more than four decades ago. This study is aiming to maximize the understanding on the petrophysical, geophysical and chemical nature across crustal-mantle transition, and to support in realistic planning for D/V Chikyu drilling and sampling fresh mantle in the future.

Since the full proposal approved in 2014 and overcoming some delays, Oman drilling operations began in early December, 2016 in the Samail Ophiolite, the largest and best-exposed section of oceanic crust and upper mantle in the World. Among several sites to drill, core, log and experiment, this study targets at the crustal-mantle transition site to collect as much data and sample as possible. Hence, two wells are planned to drill up to 600 m where slim well is for the high quality coring and slim wireline logging, and rotary well is for conventional logging with most advanced tools in the industry. In addition to the scientific core measurements onboard Chikyu, core scratch test will carry out to collect continuous high resolution rock strength (UCS), wireline logging will take various petrophysical measurements from slim logging tools and density-porosity, resistivity image, sonic velocity and various element-mineralogy data from the most advanced logging tool from industry.

As part of the “drilling informatics science” that Center for Ocean Drilling Science is working for three years, all geological samples and petrophysical, chemical and geophysical logging data are planned to process, analyze and integrate to achieve world's first high-resolution petrophysical and chemical properties across the Mohole transition.

Keywords: Oman drilling, Mohole, Drilling Informatics



Physical properties and chemical compositions of fore-arc basalt and boninite in Bonin forearc recovered by IODP Expedition 352

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The Izu-Bonin-Mariana (IBM) arc is a typical intraoceanic arc system and is the type locality for subduction initiation. IODP (International Ocean Discovery Program)-IBM project is aimed to understand subduction initiation, arc evolution, and continental crust formation. Expedition 352 is one of the IBM projects and that has the 4 drilled sites at the Bonin fore-arc (Reagan et al., 2015, Proceeding of IODP). Expedition 352 has successfully recovered fore-arc basalts and boninites. Fore-arc basalts and related rocks were collected from the sites U1440 and U1441 (the eastern deeper trench slope sites), whereas the boninites and related rocks were mainly recovered from sites U1439 and U1442 (the wearn shallower slope sites) (Reagan et al., 2015, Proceeding of IODP; Reagan et al., 2017, Int. Geol. Rev.).

We studied physical properties and bulk chemical composition of both the fore-arc basalt and the boninite samples. For the physical properties, we measured P-wave velocity, density, porosity, low-field magnetic susceptibility. Elastic wave velocities are affected by rock type, porosity, fluid saturation, temperature and pressure: in this study, we measured P-wave velocities under water-saturated condition at ordinary temperature and pressure.

As a result, the bulk densities of boninite group (U1439 and U1442) are 1.98~2.67 g/cm³. The porosities are in a range between 7.0 and 37.9 %. The P-wave velocities are in a wide range from 3.1 to 5.4 km/s and have a positive correlation to the bulk densities. The fore-arc basalt group (U1440 and U1441) has 2.13~2.90 g/cm³ of bulk density with 5.2 -35.6 % of porosity and 3.0-5.5 km/s of P-wave velocity. The P-wave velocity represent similar to boninite group and have a positive correlation to the densities.

The low-field magnetic susceptibilities showed bimodal distributions so that the physical properties of boninite were classified into two groups: a high magnetic susceptibility group ($0.2 \sim 2 \times 10^{-2} \text{ m}^3/\text{kg}$) and a low magnetic susceptibility group ($0.01 \sim 0.7 \times 10^{-2} \text{ m}^3/\text{kg}$). The former is almost identical with the fore-arc basalt and boninite group samples with the higher correlation trend between the P-wave velocities and the densities, whereas the latter is only the boninite group samples with the lower correlation trend.

The bulk chemical compositions of boninite group samples that SiO₂ contents are between 43.8 and 62.4 wt.%, FeO* contents are from 4.6 to 9.0 wt.% and K₂O contents are 0.1~3.3 wt.%. SiO₂ contents of fore-arc basalt group rocks are between 46.7~53.6 wt.%, FeO* contents are from 8.1 to 13.2 wt.% and K₂O contents are 0.1~4.0 wt.%. The FeO* contents are similar to both magnetic susceptibility groups.

Moreover, some high K₂O contents samples have low P-wave velocity, suggesting that P-wave velocities of these rocks had been reduced by alteration.

Keywords: Izu-Bonin-Mariana, drilling, boninite, velocity, magnetic susceptibility

Preliminary results of multichannel seismic reflection survey in the northern Kyushu-Palau Ridge: Site survey cruise (KH-16-6 Leg 2) for IODP proposal

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Multichannel seismic (MCS) reflection survey was conducted on northern Kyushu-Palau Ridge during the KH-16-6 Leg 2 cruise. Obtained data will provide indispensable information to understand the geological structure in the surveyed area, and contribute to the future development of the IODP (International Ocean Discovery Program) proposal as the site survey data for the proposal.

Keywords: Kyushu-Palau Ridge, Multichannel seismic (MCS) reflection survey, IODP proposal, paleoceanography