

## Digest of first part of IODP NanTro SEIZE project

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The IODP Nankai trough seismogenic zone drilling project (NanTro SEIZE) aims to understand the earthquake mechanics from fault rock analysis, borehole logging and long term monitoring. This project has been doing since 2007, and deep riser drilling to reach seismogenic depth will start on 2012. We introduce three topics of (1) Identification of earthquake fault of 1944 Tonankai, (2) In-situ stress at seismogenic area and (3) Seismic rupture propagation to the unexpected shallow portion.

Two major thrusts of plate boundary and mega-splay faults are developed off Kumano area. It was hard to know earthquake history of abyssal plate subduction faults. Strong seismic shaking originated mud-breccia was found around mega-splay fault. The 210Pb method revealed that the formation of latest mud-breccia is concordant with the 1944 Tonankai earthquake (Sakaguchi et al., 2011). This is a direct evidence of the earthquake fault as 1944 Tonankai earthquake.

Stress distribution across the Tonankai earthquake are was revealed using the technique of Borehole breakout, Borehole hydrofracturing test and Anelastic strain recovery. In the result, most of area affects compression stress concordant with pate convergent direction except the area of hanging wall of the mega-splay fault. Though this is still controversy, local stress difference may be due to thrust related hanging wall deformation and/or is limited in shallow portion (Byrne, et al 2009).

The geothermometric analysis of the fault core sample reveals that the two examined fault zones underwent localized high temperature though the toe of the accretionary wedge has classically been considered aseismic zone.. This suggests that coseismic slip must have propagated to the up-dip end of the megasplay fault and to the toe of the accretionary wedge (Sakaguchi, et al., 2011).

Keywords: Nankai, Seismogenic, Plate subduction, Fault

## Hydrate content estimated from Chlorinity and insitu temperature anomalies at IODP Site C0008

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During the IODP Expedition 316 (NanTroSEIZE Stage 1) in 2007, significant negative anomalies in the pore fluid chlorinity were reported from the core samples taken 100m below the seafloor at IODP Site C0008 in the slope sediment seaward of the mega-splay fault zone. We estimated the total contents of methane hydrate from this Cl anomaly and the porosity measured for core samples. The maximum content percentage is 40% at a horizon with strong reflectivity, suggesting a sandy interval.

In the vicinity of Cl anomaly interval, we discovered a negative temperature anomaly of up to 1K, measured insitu using the APC-T tool attached to the shoe of the hydraulic piston corer. Although our preferred interpretation for this negative excursions is a dissociation of hydrate at the time of coring, the amount of dissolved hydrates estimated from the latent heat of fusion is only at most 2% (total content). This may be due to the localized distribution of hydrate.

We will propose a hypothetical model that the methane gas was originally formed beneath the base of hydrate stability when the mega-splay fault uplifted, and was transferred to Site C0008 through the fault zone and the sandy horizon.

Keywords: NanTroSEIZE, methane hydrate, splay fault, submarine landslide

## Deep Fault Drilling Project -Alpine Fault

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The Alpine Fault (South Island, New Zealand) is one of the largest active fault zones on earth. It ruptures every 200-400 years in a magnitude ~7.9 earthquake, and is thought to have last ruptured in AD 1717, which implies a significant geohazard potential. For understanding the seismogenesis and the habitat of earthquakes, ductile and brittle deformation mechanisms and their interaction, and evolution of a transpressive orogenic system, the "Deep Fault Drilling Project - Alpine Fault (DFDP-AF) was started from January 2011. The first, phase (DFDP-1), which targeted to drill to 150 m, has completed on February 2011, and the samples have already been provided to international scientific community. DFDP-2 is planed to drill to 1500 m through the Alpine Fault as one of the International Continental Scientific Drilling Program (ICDP), and is now working. In this presentation, we outline this drilling project.

## Consolidated nano-polycrystalline diamond and its potential applications to deep-Earth drilling

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We have been developing technology to synthesize ultrahard nano-polycrystalline diamond (NPD = HIME-DIAMOND), using multianvil high-pressure technology. Now, we are able to make such NPD rods with dimensions of up to 1 cm in both diameter and length on a routine basis. NPD is known to have exceptional hardness and toughness, which withstands even high temperatures exceeding 1300K. Here, I will report current status of the synthesis, properties, and some applications of NPD. NPD should also be potentially important as a drilling tool, because of its ultrahardness and high toughness at high temperature, which are far superior to those of conventional hard materials such as tungsten carbide or sintered polycrystalline diamond with some binders.

Keywords: ultrahard material, diamond, polycrystalline material, deep Earth drilling, mantle, high pressure



## Stress and strain analyses in the Costa Rica subduction margin, IODP Expedition 334

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The Costa Rica Seismogenesis Project (CRISP) is designed to understand the processes that control nucleation and seismic rupture of large earthquakes at erosional subduction zones. Integrated Ocean Drilling Program (IODP) Expedition 334 drilled and cored at the middle slope (Sites U1378 and U1380), upper slope (Site U1379), and input site (Site U1381).

Stress and strain analyses using anelastic strain recovery (ASR), fault kinematics, and anisotropy of magnetic susceptibility (AMS) have been conducted in the middle and the upper slope. Based on ASR analyses, clear difference in present-days stress state between the slope sediments and the basement was identified in the Site U1379: A normal-fault stress regime characterizes the slope sediments, whereas a strike-slip regime corresponds to the basement. On the other hand, the stress-states in the slope sediments in the Sites U1378 and U1380 are characterized by a strike-slip regime that Sigma 2 has oriented vertically. The Sigma 1 direction oriented NNW-SSE, which is corresponding to the Sigma Hmax direction identified in the LWD, parallel to the present GPS direction. In contrast to the present-day stress state, the ancient stress and strain based on kinematics of faults and AMS were controlled by direction of plate subduction. The spatial and time variations in stress state along the CRISP transect is a key to examining the onset of subduction erosion along the subduction channel.

Keywords: Subduction erosion, ASR, AMS, CRISP, Expedition 334, IODP

## Limited Mantle Plume Motion for the Louisville Hotspot

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Deep Earth convection can be understood by studying hotspot volcanoes that form where mantle plumes rise up and intersect the lithosphere, the Earth's rigid outer layer. For many years it has been widely assumed that these narrow diapirs generate stationary hotspots within an overall convective mantle regime, but it is apparent now that the Hawaiian mantle plume moved approximately 15 degrees south between about 80 and 50 million years ago. In this presentation we show that the Louisville hotspot in the South Pacific behaved in a different way over the same time period, experiencing only a limited latitudinal motion, using drill cores of Integrated Ocean Drilling Program Expedition 330. Our findings demonstrate that the motions of the Louisville and Hawaiian hotspots are incompatible and that mantle plumes are moving independently.

Keywords: hotspot, plume motion, seamount, paleolatitude, paleomagnetism, IODP

## Petrographical and geochemical characteristics of the sheeted dyke-gabbro transition zone in ODP/IODP Hole 1256D

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During IODP Expedition 335, high grade granoblastic hornfels were extensively recovered as drilling cuttings at the gabbro-sheeted dyke transition zone of ODP Hole 1256D (East Pacific Rise, 6°44.163'N, 91°56.061'W). This lithology probably results from high-temperature metamorphism of previously hydrothermally altered diabbases and/or basalts; the heat source likely stems from the melt lens located at the top of the magmatic chambers imaged along present-day fast-spreading ridges. This lithology, associated with gabbroic bodies, characterises the transition zone between the sheeted dyke complex and the uppermost gabbroic section and represents the interface between magmatic and hydrothermal convecting systems in an oceanic crust formed at fast-spreading ridges. In this study, 14 samples from the junk basket (cuttings) and 2 samples from cores obtained during Expedition 335 were observed and analysed. The petrological and chemical characteristics of 5 granoblastic samples collected during Expedition 312 at the root of the sheeted dyke complex and between two gabbroic horizons were also acquired for comparison.

Samples collected during IODP Expedition 335 are mainly fine grained oxide gabbroites composed of two pyroxenes, plagioclases and oxides (ilmenite, magnetite) with more or less amphiboles, sulphides, quartz and accessory minerals. Orthopyroxene Shape (roundish or anhedral), the amount of oxides inclusions in clinopyroxene and plagioclase morphology (laths or triple-junction mosaic) indicate various recrystallisation degrees. Plagioclases show a strong zoning in the less recrystallised samples, which tend to disappear with increasing recrystallisation degree. Samples show usually low alteration (less than 10%) with moderate transformation of pyroxenes into talc and actinolite. Samples from Expedition 312 show finer grains, higher degree of alteration (up to 30%), and weaker recrystallisation. They are mainly composed of plagioclases, amphibole and oxides (ilmenite, magnetite) with more or less pyroxenes, quartz and alteration phases. Samples from the higher stratigraphic level (root of the sheeted dyke complex above the shallowest gabbro) are virtually free of pyroxenes while the strongly recrystallised samples from the bottom of the hole (i.e. closer to the gabbroic section) contain only episodic amphibole and are rich in pyroxenes. The composition of plagioclase ranges from An<sub>12</sub> to An<sub>85</sub>, with higher anorthite contents observed in the most recrystallised samples. Pyroxenes composition ranges from Wo<sub>37</sub>En<sub>46</sub>Fs<sub>17</sub> to Wo<sub>46</sub>En<sub>38</sub>Fs<sub>16</sub> for Cpx and Wo<sub>4</sub>En<sub>59</sub>Fs<sub>37</sub> to Wo<sub>2</sub>En<sub>65</sub>Fs<sub>33</sub> for Opx, and does not show any significant variation with the recrystallisation degree. Temperatures of recrystallisation were estimated between 902 and 980°C using the two-pyroxenes geothermometer.

Heating and probable partial melting resulting from magmatic activity below hydrothermally altered sheeted dyke complex would lead to metamorphism and recrystallisation associated with light elements migration resulting in variations in the modal composition of the rock and in the chemical composition of the minerals stable in hydrothermal and magmatic conditions.

Keywords: ODP/IODP Hole 1256D, Beerbachites, Granoblastic dykes, Fast-spreading ridge, East pacific Rise, IODP Exp. 335

## Origin and distribution of chloride in pore water beneath the New Jersey Shallow Shelf, IODP Exp.313

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IODP Exp. 313 was conducted in the mid New Jersey Shallow Shelf (NJSS) in 2009. This expedition focuses on geological structure and history of sedimentological environment with sea level change. Three holes were drilled along the MAT (Mid-Atlantic Transect) and the maximum depth was 750 mbsf.

On the other hand, in the NJSS, previous expeditions and oil explorations have found that the pore water beneath sea floor has very wide range of chloride concentration. This variation of Cl concentration is considered to reflect the history of salinization and desalinization of pore water with sea level change. However, process and mechanism of Cl distribution is not clarified. Objective of this study is to understand origin and behavior of pore water and chloride using pore water samples taken by Exp. 313.

Cl concentration of pore water samples were from about 20 to 995 mmol/kg (4 to 190% of seawater). "Fresh" pore water (Cl < 100 mmol/kg) were distributed from about 15 to 420 mbsf and were mainly in silty layers. This result suggests that pore water in low permeable layers such as silt and clay were relatively not susceptible to salinization by seawater.

Considering the stable isotopic ratios of oxygen and hydrogen and Cl concentration of pore water, origins of pore water should be meteoric water, present sea water and paleo sea water. Also, origins of chloride were considered to be present and paleo sea water and brine. From the sea floor to 250~350mbsf, chloride in pore water was originated from mixing of the meteoric water and present/paleo sea water. On the contrary, chloride was originated from mixing of the meteoric water and brine.

This study is supported by CDEX/JAMSTEC.

Keywords: IODP, New Jersey, continental shelf, sea level change, pore water, chloride



## Onset, evolution and effects of the Mediterranean Outflow: An overview of IODP Expedition 339

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We will present the preliminary results of IODP Expedition 339, Mediterranean Outflow (from 17 November 2011 to 17 January 2012). This expedition has drilled five sites in the Gulf of Cadiz and two sites offshore the west Iberian margin, and recovered 5.5 km of core with an average recovery of 86.4%. The Gulf of Cadiz was targeted for drilling as a key location for the investigation of Mediterranean Outflow Water (MOW) through the Straits of Gibraltar and its influence on global circulation and climate. It is also a prime area for understanding the effects of tectonic activity on evolution of the Gibraltar Gateway and on margin sedimentation.

We penetrated into the Miocene at two different sites and established a strong signal of MOW in the sedimentary record of the Gulf of Cadiz following opening of the Gibraltar Gateway. Preliminary results show contourite deposition from 4.2-4.5 Ma, although subsequent research will establish whether this dates from the first onset of MOW. The Pliocene succession, penetrated at four sites, shows low bottom current activity linked with a weak MOW. Significant widespread unconformities, present in all sites but with hiatuses of variable duration, are interpreted as a signal of intensified MOW, coupled with flow confinement. The Quaternary succession shows a much more pronounced phase of contourite drift development, with two periods of MOW intensification separated by a widespread unconformity. Following this, the final phase of drift evolution established the contourite depositional system (CDS) architecture we see today.

There is a significant climate control on this evolution of MOW and bottom-current activity. However, from the closure of the Atlantic-Mediterranean gateways in Spain and Morocco just over 6 Ma and the opening of the Gibraltar Gateway at 5.3 Ma, there has been an even stronger tectonic control on margin development, downslope sediment transport and contourite drift evolution. Based on the timing of events recorded in the sedimentary record, we propose a tectonic pulsing in the region, linked with asthenosphere activity.

The Gulf of Cadiz is the world's premier contourite laboratory and thus presented an ideal testing ground for the contourite paradigm. Following examination of over 4.5 km of contourite cores, the existing models for contourite deposition are found to be in good working order. Their further study will allow us to resolve outstanding issues of depositional processes, drift budgets, and recognition of fossil contourites in the ancient record onshore. The expedition also verified an enormous quantity and extensive distribution of contourite sands that are clean and well sorted. These represent a completely new and important exploration target for potential oil and gas reservoirs. Preliminary work has shown a remarkable record of orbital-scale variation in bulk sediment properties of contourites at several of the drift sites and a good correlation between all sites. The climate control on contourite sedimentation is clearly significant at this scale; further work will determine the nature of controls at the millennial scale.

<sup>#</sup>IODP Expedition 339 Scientists: Acton, G., Bahr, A., Balestra, B., Ducassou, E., Flood, R., Flores, J-A., Grunert, P., Hodell, D., Kim, J. K., Krissek, L., Li, B., Llave, E., Lofi, J., Lourens, L., Miller, M., Richter, C., Roque, C., Sanchez Goni, M., Siervo Sanchez, F., Singh, A., Sloss, C., Tzanova, A., Voelker, A., Williams, T., Xuan, C.

Keywords: IODP Expedition 339, Gulf of Cadiz, Mediterranean Outflow Water

## Radiolarian biostratigraphy from the early Eocene to early Miocene at IODP Leg 320, Sites U1331, U1332, and U1333

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Early Eocene-early Miocene 228 radiolarian datum events are identified and correlated with the geochronologic time scale at Sites U1331, U1332, and U1333 in the equatorial Pacific Ocean. Seven new Oligocene subzones are proposed for the low latitude radiolarian zonal scheme: *Eucyrtidium diaphanes* Interval Subzone (RP22b); *Calocycletta robusta* Interval Subzone (RP22a); *Lychnocanoma apodora* Interval Subzone (RP21b); *Theocyrtis annosa* Interval Subzone (RP21a); *Eucyrtidium ple-siodiaphanes* Interval Subzone (RP20c); *Dorcadospyrus pseudopapilio* Interval Subzone (RP20b); *Lithocyclia angusta* Interval Subzone (RP20a). These subdivisions materially improve the biostratigraphic/biochronologic resolution within the relatively short zone/subzone (~1.6 my). The Oligocene zonal boundary events are synchronous in the low latitude Pacific Ocean based on new data and previous literature. Four Eocene zones, *Cryptocarpium ornatum* (RP19), *Calocyclus bandyca* (RP18), *Phormocyrtis striata striata* (RP9), and *Buryella clinata* (RP8) are emended.

Keywords: equatorial Pacific, eEocene, EOligocene, radiolarian biostratigraphy, IODP, PEAT I

## Variations in SST and primary production revealed from long-chain diols in the Neogene equatorial Pacific sediments

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The eastern equatorial Pacific Ocean today sustains significant amounts of global marine productivity, and the region is one of the largest marine sources of carbon dioxide to the atmosphere. Nevertheless, geological time-scale variations of marine productivity and ecological / biogeochemical systems in the equatorial Pacific have been still unclear. It was obtained rough knowledge that marine productivity in the region was characterized by abundant diatoms since the late Oligocene to early Miocene. In this study, we reconstruct more detailed variations of primary productions by new diatom biomarker (long-chain diols) proxies from 'Pacific Equatorial Age Transect (PEAT)' sediments, and discuss evolution of the diatom-dominant ecosystem and the related paleoceanographic and paleoclimatic systems during the Neogene. In addition, we reconstruct variations in sea surface temperature (SST) by long chain alkenone and the newest long-chain diol thermometers in these sediments.

Integrated Ocean Drilling Program (IODP) Expeditions 320/321, 'PEAT', recovered a Cenozoic sediment record from the equatorial Pacific by coring above the palaeoposition of the Equator at successive crustal ages on the Pacific plate. We used the cores U1335, U1336, U1337 and U1338 of the Neogene 'PEAT' sediments. The long-chain diols in marine sediments are mainly derived from diatom, and 28 carbon numbers (C<sub>28</sub>) and C<sub>30</sub> 1,14-diols are peculiar biomarkers of specific diatom genus *Proboscia*. These long-chain diols are used as upwelling indicator, diol index, which is the ratio of C<sub>28</sub> and C<sub>30</sub> 1, 14-diols to C<sub>30</sub> 1,15-diols (Rampen et al., 2008, *Earth Planet. Sci. Lett.* 276, 207). Furthermore, Eustigmatophyceae are also known to have C<sub>28</sub> and C<sub>30</sub> 1, 13-diols, and more recently, these biomarkers are proposed as paleothermometer, which is the ratios of C<sub>30</sub> 1, 15-diols to C<sub>28</sub> and C<sub>30</sub> 1,13-diols, called 'diol isomer index (DIX)' (Rampen et al., 2011, IMOG abstract).

We identify saturated C<sub>28</sub> and C<sub>30</sub> 1,13-diols, C<sub>28</sub> and C<sub>30</sub> 1,14-diols, and C<sub>30</sub> 1,15-diol from almost all the early Miocene to Pleistocene PEAT sediments (23-0.23 Ma; cores U1335, U1336, U1337 and U1338). This indicates that diatom and eustigmatophyte algae productions were consistently significant in the equatorial Pacific throughout the Neogene. In particular, the diatom productions recorded by total diol concentrations increased at paleolatitude 2 °N-4 °N during 6 and 5-3 Ma, and at paleolatitude 2 °S-2 °N during 10-7 and 5-4 Ma. The diol (1,14/1,15) indices also varied, and higher diol index values suggest that upwelling more efficiently occurred in sea surface layers at paleolatitude 2 °S-4 °N since 16 Ma. However, their decreasing spikes appeared at 2 °S-2 °N during 8 Ma and 4 Ma and at 2 °N-4 °N during 4-3 Ma. The horizons of higher diol concentrations do not correspond to those of higher diol indices. Therefore, the increase of diatom production cannot be explained by only more efficient occurrence of upwelling in the equatorial zone. Diatom is known to need silica (Si) for its production, and Si is thought to be transported from land to ocean. Thus, the increase of diatom production in this study might be caused by increasing amount of terrigenous matter transported via atmosphere from land to the pelagic areas of the equatorial Pacific. From these insights, we suggest that variations of diatom productions are presumably attributed to changes in efficiency of upwelling and terrigenous input by aeolian transport in the equatorial Pacific during the Neogene.

The diol thermometer, DIX, values varied in the Neogene PEAT sediments. Variations in DIX-based SSTs were quite different from those in alkenone-based SSTs, which were nearly constant over the 15 Ma. The DIX-based temperatures might vary controlling by occurrence of cooler upwelling in the equatorial Pacific areas. These trends are concordant with that of the Neogene global paleoclimatic variation.

**Keywords:** Pacific Equatorial Age Transect (PEAT), marine primary production, sea surface temperature, diol paleothermometer, diatom production, Neogene paleoceanography

## Paleoenvironmental changes of the continental shelf in the Canterbury Basin based on benthic foraminiferal assemblages

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### Introduction

The Quaternary benthic foraminiferal assemblages in top 74 m of two cores, Hole U1353B (hole depth; 211.48 m) and Hole U1354B (hole depth; 77.52 m) of IODP Exp. 317, were examined to understand the paleobathymetric and paleoclimatic history at the Canterbury Basin, New Zealand. The purpose of IODP Exp. 317 is to understand the relative importance of eustasy and tectonic and sedimentary processes in controlling the development of continental margin sedimentary cycles (sequences). Sites U1353 and U1354 provide a high resolution record of recent glacial cycles covering the middle to late Quaternary in a continental shelf setting (Expedition 317 Scientists, 2011). Top 74 m of these cores have the glacial-deglacial records since 0.5 Ma based on the datums of microfossils and the oxygen isotope curves.

### Foraminiferal taxa group

We identified 50 genera and 95 species of fossil benthic foraminifera (>0.125 mm) in 120 samples of these core, and recognized 4 taxa groups, with different depth ranges in the present ocean around New Zealand (Hayward et al., 1999).

Taxa group 1 - *Bulimina marginata*, *Cassidulina carinata*, *Anomalinoidea sphericus*, *Notorotalia zealandica* and *Sphaeroidina bulloides* - deep inner shelf to outer shelf (about 20-200 m in water depth)

Taxa group 2 - *Nonionellina flemingi* and *Angulogerina angulosa* - deep inner shelf to mid shelf (about 20-100 m in water depth)

Taxa group 3 - *Notorotalia finlayi*, *Notorotalia aucklandica*, *Quinqueloculina* spp. and *Cibicides* spp. - inner shelf (about 0-50 m in water depth)

Taxa group 4 - *Zeaflorilus parri*, *Elphidium charlottense*, *Haynesina depressula* and *Virgulopsis turris* - shallow inner shelf (about 0-20 m in water depth)

### Paleoenvironmental changes

Based on the paleo-water depth estimated by benthic foraminiferal assemblages, the sediments of U1353B and U1354B since 0.5 Ma were divided to 7 bio-cycles. 1 bio-cycle represents from shallower taxa group to next shallower group via deeper taxa group. And each cycle may correlate to a glacial-deglacial cycle.

Subtropical benthic species, *Bulimina marginata*, is abundant during the three warmer periods (MIS 1, MIS 11, MIS 13). This species indicates that Canterbury Basin was warmer than modern in climate.

According to the previous studies on the Tertiary stratigraphy in Oamaru (Hornibrook et al., 1961), *Bolivina parri*, *Bolivina wanganuiensis* and *Siphonotexturalia wairoana* were extinct at the boundary of Haweran and Castlecliffian in NZ stages, corresponding to 0.34 Ma. However, the present study represent that these highest occurrences were not the same, and seem to be controlled by the paleoenvironmental changes related to glacial-deglacial cycles.

Keywords: benthic foraminifera, paleobathymetry, continental shelf, Canterbury Basin, Pleistocene, IODP Exp. 317

## Sedimentary and diagenetic history of Kita-daito-jima atoll for the last 25 million years

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An old borehole, 432.7 m deep, drilled in 1934 and 1936 on Kita-daito-jima, northern Philippine Sea, reveals the reef evolution on this island during the Late Oligocene to Miocene. Four depositional units have been defined by lithological changes and are numbered sequentially from the top of the hole downward. The major lithology varies from bioclastic packstone/grainstone (unit C4) to coral rudstone (unit C3) to coral bafflestone (unit C2), implying a gradual shallowing of the lagoon. However, the coral fauna suggests that unit C1, above, formed on a submerged platform. Reef formation on Kita-daito-jima was controlled by the combined effects of sea-level changes and tectonic movements (subsidence and uplift). Two modes of reef formation have been recognized: growth that kept pace with the subsidence of the island; and rapid reef formation that commenced at sea-level falls. The latter indicated that sea-level falls are key events that revived drowned reefs. Dolomites extend in Kita-daito-jima from the island surface to a depth of 100 m below the ground surface (units C1 and C2). X-ray diffraction analysis indicates that the island-surface and borehole dolomites comprise variable mixtures of multiple dolomite crystal phases. Deconvolution of whole-rock isotopic and elemental compositions based on the relative abundance of phases reveals that each phase has a distinct chemical and isotopic composition. Oxygen isotopic compositions of the island surface and borehole dolomites suggest that all dolomite phases formed in seawater.

**Keywords:** Kita-daito-jima, shallow-water carbonate, dolomite, oxygen-isotope composition, strontium-isotope composition, seawater dolomitization

## IODP Expedition 331 Deep Hot Biosphere

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The Iheya North hydrothermal field is located in the middle Okinawa Trough, an actively spreading backarc basin that extends for 1200 km between the Ryukyu arc-trench system and the Asian continent, in a transitional region between continental and oceanic crust. Because the Okinawa Trough contains both hemipelagic and volcanic sediment, in some places >1000 m thick, its hydrothermal systems provide abundant H<sub>2</sub>, CO<sub>2</sub>, CH<sub>4</sub>, NH<sub>4</sub>, H<sub>2</sub>S, and CO derived from sedimentary organic matter and from magmatic gases that could feed a variety of microbial communities, sustained by different chemolithoautotrophic primary producers within a range of sub-seafloor habitats. Integrated Ocean Drilling Program (IODP) Expedition 331, the Deep Hot Biosphere project, drilled into the Iheya North hydrothermal system in order to investigate metabolically diverse subseafloor microbial ecosystems and their physical and chemical settings.

We drilled five sites during Expedition 331: the active hydrothermal vent site and sulfide-sulfate mound at North Big Chimney (NBC) (Site C0016); three sites east of NBC at distances of ~100, 450, and 1550 m from the active vents (Sites C0013, C0014, and C0017, respectively); and one site on a hill ~600 m northwest of the active vents that represents a potential migration path for hydrothermal fluid (Site C0015). Our maximum penetration was 151 meters below seafloor (mbsf) at recharge Site C0017. We will introduce summary of the drilling, geochemistry, mineralogy and microbiology among the sites, and discuss about the sub-vent hydrogeology of the hydrothermal field.

Keywords: IODP, Okinawa Trough, hydrothermal, subsurface biosphere, sub-vent biosphere

## Summary of IODP Expedition 336

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We will present the outline of the Integrated Ocean Drilling Project Expedition 336.

Keywords: IODP, North Pond, Mid-Atlantic Ridge, sub-surface ocean, deep biosphere

## Impacts of results from IODP Expedition 324 (Shatsky Rise) on solid-earth science and Cretaceous paleoceanography

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IODP Expedition 324 to Shatsky Rise was primarily aimed at elucidating the processes of the formation and evolution of oceanic plateaus based on the integrated analysis of the basement basaltic rocks by means of petrology, geochemistry, volcanology, radiometric geochronology, etc., with a special emphasis on testing the two competing hypotheses for the mechanism of oceanic plateau emplacement (mantle plume vs. peculiar plate tectonics). In terms of solid-earth science, several important new findings have already been made, including a large variety of magma chemistry, magma evolution at shallow magma chambers, and the deep origin for primary magma. On the other hand, this expedition was initially deemed to be unsuitable for the study of sediments/sedimentary rocks because of various restrictions from the drilling strategy, and actually the cored sedimentary materials were rather limited in quantity. Unexpectedly, postcruise study has brought about important new insights into Cretaceous paleoceanography, the outline of which is presented herein.

Through the drilling at Site U1348 on the northern summit of Tamu Massif, the presence of unconsolidated Cretaceous pelagic sediment cover was revealed, and paleoceanographically important intervals were captured, though poor in recovery. Of these, a short 1.4 m-thick interval of calcareous ooze in Site U1348-Core 2 has been accurately dated to be the Santonian-Campanian (S-C) transition, based on shore-based integrated stratigraphy of planktonic foraminifera, Sr isotopes and paleomagnetism. This finding is significant, because a major obstacle in Late Cretaceous paleoceanography has long been the lack of deep-sea sedimentary records across the S/C boundary resulting from the spatiotemporally extensive hiatus. The ooze lithology allows the acquisition of stable isotope data from very well-preserved, taxon-specific separates of foraminifera for the first time for the deep-sea S-C transition. The detailed benthic foraminiferal oxygen isotope data predict a sustained supergreenhouse condition until the end of the Santonian and a subsequent relatively rapid cooling (+1.0 per mil shift) within the early Campanian, opposing the preconceived view for a gradual cooling trend during this period.

In Site U1348-Core 10, another short interval (22 cm-thick) of calcareous ooze was recovered and dated onboard to be the early Aptian in age, thus representing the oldest known record of unconsolidated pelagic sediments recovered through the history of scientific deep-sea drilling. Detailed shore-based chronological assessments by means of planktonic foraminifera, carbon isotopes and Sr isotopes have been successful in placing the rigorous age constraints upon this interval at around the early/late Aptian boundary. Accordingly, it is certain that the deposition took place just after Oceanic Anoxic Event (OAE) 1a, and that the extension of the global stable isotopic compilation of deep-sea benthic foraminifera is possible to as old as ~120 Ma. It is noteworthy that seismic interpretation indicates that the expanded, older pelagic sedimentary strata are present just to the south of Site U1348. Consequently, northern Tamu Massif of Shatsky Rise, where pelagic sediments are unconsolidated, thick and potentially dating back to the earliest Cretaceous (spanning the OAE1a interval), would be the ideal target area for future paleoceanographic IODP expedition.

This study is partly supported by IODP After Cruise Research Program, JAMSTEC.



## Southern Ocean drilling proposal: Antarctic Cryosphere evolution project (AnCEP)

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The Southern Ocean has played a significant role in the global climate system during the geologic past. In order to understand the paleoceanographic variations with the polar front system and Antarctic Circumpolar Current (ACC), we conducted two cruises KH-07-4 and KH-10-7 in the Indian sector of the Southern Ocean. Two piston cores were collected from the Conrad Rise. We examined centennial-scale changes of diatom assemblages and stable isotopic ratios in planktic foraminifera during the Holocene in a high-accumulation-rate sediment core from the Conrad Rise. Although abundances of dominant diatom taxa (*Fragilariopsis kerguelensis* and *Thalassiothrix antarctica*) are comparatively constant, relative abundances of secondary taxa fluctuate. Before ca 9900 cal. yr BP, winter sea-ice and cold water covered the Conrad Rise. Following deglaciation the sea-ice retreated from the Conrad Rise. The Polar Front moved southward during the early Holocene optimum and north Antarctic Zone waters covered the Conrad Rise for about 650 yr. After 9300 cal. yr BP, solar insolation strongly influenced sea surface temperature and primary productivity in the Southern Ocean. In the high-latitude Indian Sector, productivity increased 1500 yr after the onset of late Holocene neoglaciation. Periodic  $\delta^{18}O$  and cold-water diatom taxa spikes (at intervals of 200 and 300-500 yr, respectively) occurred after 9300 cal. yr BP, probably associated with solar activity. Fluctuations in short-term sea surface temperature and cold-water taxa are synchronous with changes in  $\delta D$  observed in an east Antarctic ice core.

Keywords: Southern Ocean, Earth drilling science, paleoceanography, Antarctic Cryosphere, Antarctic Circumpolar Current, sea ice

## IODP Exp. 346(Asian Monsoon): Return of JR to the Japan Sea and a new visit to East China Sea

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In the summer of 1989, during the phase of DSDP cruises Leg 127/128 were organized to drill the Japan Sea. It was a memorial in the respect that the cruises were led by two Japanese co-chiefs and 10 Japanese scientists in total participated. One of unexpected findings of the cruises was the occurrence of dark and light layers that were alternated throughout the Quaternary. These dark and light layers are correlatable basin-wide and deposited synchronously. The dark layers are org-C rich, partly laminated, and somehow resemble sapropels of Mediterranean. However, their sedimentary rhythm is more complicated than that of Mediterranean sapropels the latter basically reflect orbital cycles. The origin of the rhythm of the dark and light layers was mystery for some time until Tada et al. (1995, 1999) found that the rhythm resembles that of  $\delta^{18}O$  variations of Greenland ice cores in millennium time scale, so-called Dansgaard-Oeschger Cycles [DOC]. Subsequent studies on piston cores suggested that deposition of the dark and light layers reflects changes in properties of water influx through the Tsushima Strait due to the changes in contribution of the East China Sea coastal water relative to Kuroshio-derived water. Tada et al. (1999) hypothesized that changes in the relative contribution of the East China Sea coastal water reflected changes in discharge of Yangtze River which, in turn, reflected changes in EASM precipitation over the Yangtze River drainage. Recent provenance study of eolian dust in the cores from the Japan Sea further suggests that westerly jet axis over the Japan Sea oscillates in association with DOC (Nagashima et al., 2011). Because the westerly jet is bounding the northern limit of EASM front, it is likely that N-S oscillation of the westerly jet axis caused N-S movement of the northern limit of EASM front that resulted in the changes in EASM precipitation over the Yangtze River drainage in association with DOC. Thus, we further hypothesized that oscillation in westerly jet paths played a role of tele-connecting climatic changes in north Atlantic with changes in EASM intensity.

Expedition 346 is aimed to test these hypotheses. In addition, the expedition aims to specify the timing of onset of DOC type millennial-scale variability of EASM, its mode of evolution, and changes in mode, frequency, and amplitude of variability of EASM in association with glacial-interglacial cycles. The relation between East Asian summer and winter monsoons and its changes through time will be another interesting objective of the expedition. The paleoceanographic condition of the Japan Sea has been very sensitive to the nature (e.g., salinity, temperature, nutrients, and etc.) and the amount of the influx to the sea as well as sea level and climate in the surrounding region, and drastically changed in various time scales throughout its history. Consequently, there will be many interesting topics other than the major objectives of the expedition. IODP cruise will provide a rare opportunity to work with international community who share similar scientific interests. Participation of young generation with innovative ideas is welcome.

Keywords: IODP, Exp. 346, Asian Monsoon, Japan Sea, East China Sea, Abrupt climate change

## Rotation Angle of Shikoku Basin: Discremination of drilling induced magnetization from VRM by great circle analysis

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The IODP Expedition 322 penetrated sediments-basement boundary and recovered successive cores at Site C0012, subduction input in Nankai Subduction Zone. The collected basement samples are composed of alternating beds of pillow basalts and hyaroclastite and were retrieved by rotary core barrel drilling system. Paleomagnetic measurements were conducted to understand the polarity, paleolatitude and tectonic rotation. In total, 29 minicores or blocks were collected from the basaltic basement rocks. Paleomagnetic results suffers from intense secondary magnetization during drilling. AF demagnetization field up to 10 mT was generally enough to remove the overprint to allow interpretation of polarity of magnetization.

Paleomagnetic measurements on basaltic basement rocks from Site C0012 (538-561m CSF) show that the stable magnetization has reversed polarity. Paleolatitude was calculated from 7 samples as 28.0+-7.6 degrees N and the expected latitudinal translation is 522+-844km. Magnetic anomaly map can be produced using the recently compiled dataset by Quesnel et al. (2009). Preliminary interpretation based on the simple magnetization model assuming the constant thickness of the magnetized layer (Okino, personal communication), the magnetic anomaly crossing the Kashinosaki Knoll corresponds to anomaly C6Ar (20.7-21.1Ma; ATNTS2004).

We also attempted to reconstruct tectonic rotation related to the development of Shikoku Basin using secondary magnetization component acquired during Brunhes normal polarity chron. A whole round sample used for anelastic strain recovery (ASR) is the best sample for that purpose allowing us to measure a block collected from the center of the core, which has least drilling overprint. We collected multiple sub-samples from the center of ASR sample and carefully measured with stepwise AF demagnetization and thermal demagnetization experiments. However, the results indicate that the secondary magnetization is not directing the magnetic north during the Brunhes chron. In order to extract the information carried by the viscous remanent magnetization (VRM) acquired during the Brunhes, we conducted great circle analysis described by Kirschvink (1980). This allowed us to recognize four components including the VRM. The results shows that the angles between VRM and primarly component of reversed polarity are around 10~20 degrees suggesting no significant rotation since the formation Shikoku Basin.

Keywords: Shikoku Basin, drilling induced magnetization, viscous remanent magnetization, great circle regression analysis, IODP Hole C0012A, Basaltic Basement

## Stress-drop estimation from geophysical logs in Shikoku basin of Exp. 322-C0011, NanTro-SEIZ

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<sup>1</sup>JAMSTEC

Nankai Trough region in southeast Japan is invested the comprehensive studies of the subduction zones. For understanding the stress state and geological properties in the shallower Shikoku basin, two sites were drilled in open-ocean sediments. The resistivity Logging while Drilling was run in C0011A and full cored was applied in C0011B which preparing for the measurements of physical prosperities (MultiSensory Core Log, MSCL.). In the LWD logging, the notability breakout anomaly was observed in the depth 615 mbsf. NanTroSEIZE scientists developed many researches about the stress orientation and magnitude estimation by logging data in Nankai Trough. In this study, we constrained the possible horizontal principal stress azimuth and magnitude in entire C0011A borehole. The dislocation of breakout orientation indicated this drilling drilled through the fault and stress drop can be determined by the fault geometry. The close 90 degree rotation implied the 100% stress drop which the magnitude equal to 2.5 MPa. Our simulation displays the magnitude of horizontal principal stresses before and after the fault slip. The low rock strength (0~20MPa) and weak fault would be the necessary conditions to satisfy the dislocation model and the observations.

Keywords: stress drop, breakout, logging, Logging while drilling, stress polygon

## Evaluation of the Present Stress Field for the Nankai area through the Slip DeFicit Model

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After the 2011 Tohoku-Oki, Japan, earthquake, many studies have investigated the stress state in the Nankai trough area, where is one of the possible area for the next devastating earthquake. For understanding the stress state and geological properties in Nankai, several drilling projects have been conducted in the shallow part of the Kumano and Shikoku basin. Among them, the Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) has involved in many studies on the stress orientation and magnitude estimation by logging datum in the Nankai Trough. Due to limitation by the technology and the processing of drilling, the real stress orientation and magnitude in Nankai near the subduction zones is still controversial. In this study, we develop the Slip DeFicit Model (SDM) to estimate the stress tensor and associated with the Fine-scale boreholes datum. SDM is assumed that the regional stress is dominated by the slip deFicit during aseismic period. The tectonic loading in the rest part of the system has been released through other aseismic behaviors, such as creeping or small earthquakes. Using this model, the stress tensor can be analyzed at different depths in the drilling sites. Comparing to the logging data, the modeled stress tensors in terms of magnitude and orientation are consistent with the stress states in the site C0009, C00012, C0002, and C0006. Based on SDM, the stress tensor at deeper depth in the drill sites can be evaluated.

Keywords: Slip DeFicit model, Nankai trough, stress tensor, subductiuon zone, logging

## Provenance change in around 3Ma at IODP Site C0011, off Nankai Trough

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Sr-Nd-Pb isotope ratios and chemistry of silicate portion of hemipelagic mud taken from IODP site C0011 suggest that Asian dust flux had rapidly decreased since 3 Ma. Asian dust is known to originate from soils of inland China, which are characterized by much higher Sr, Pb and much lower Nd isotope ratios than those of Japanese rocks and sediments. Results of isotopic analysis of silicate portion show that the isotope ratios of Sr and Pb decrease, and that of Nd increases upward rapidly across the horizon corresponding to 3Ma in age. This indicates the rational decrease of Asian dust particles in the sediments since 3Ma. Because the paleomagnetostratigraphy of C0011 shows that the sedimentary rate had rapidly decreased since 3 Ma (Expedition 333 Scientists, 2011), the rational decrease of Asian dust in the sediments means the decrease of its flux to this site at that time. Decrease of biogenic flux of silica or carbonates cannot explain the slowed depositional rate considering the fact that there is no increase in bulk  $Al_2O_3/SiO_2$  at around 3 Ma, and that bulk CaO and content of calcium carbonate had rather increased since 3Ma. Because there is no period of significant decrease in Asian dust flux to the North Pacific since its rapid increase at 3.6 Ma (Rea, 1994), the decrease of the flux at Site C0011 may reflect some local events around Shikoku Basin. Such events considerable include cutoff of the dust path to Shikoku Basin by the uplifted Japan island arc and the entrainment of surficial suspended particles by the Kuroshio current, which is estimated to have started to influence the sea surface of site C0011 around 3 Ma due to the plate motion.

Keywords: Nankai Trough, Shikoku Basin, Hemipelagite, Sr-Nd-Pb isotopes, Asian dust

## Structural styles and stress field of the Nankai accretionary prism: insights from geophysical logging

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The stage-1 expeditions in the Nankai Trough area by IODP drilling performed geophysical logging measurements. By analyzing these data-sets, structural geometry and stress fields in both of large and small scales have been identified. This presentation includes recent achievements of such research.

Keywords: IODP, geophysical logging, geologic structure, stress, accretionary prism

## Accretion process of sediments below Kumano basin by analyzing cuttings from IODP Exp.319, the first riser drilling

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The structure, stress condition and rock properties of accreted sediments in the Nankai Trough have been studied by reflection seismology and deep sea drillings. Accretion processes have been suggested by onland geological studies that the sediments are circulated with undergoing lithification and deformation in shallow subduction zone driven by the plate motion. However the process in the modern Nankai Trough has yet to be elucidated. We discuss the accretion process of the Nankai Trough accretionary prism below Kumano basin by clarifying thermal structure and materials by vitrinite measurement and whole rock chemical analyses, respectively, using cuttings samples from IODP The Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) the first scientific riser drilling Expedition 319 at Site C0009. We also introduce the use of the cuttings samples for academic research, which becomes important in the upcoming riser drilling expeditions of NanTroSEIZE and in the future ocean drilling in general.

Cuttings were collected with an interval of every 5 m from 703.9 to 1604 m and cores were recovered from 1509.7 m to 1593.9 m below sea floor (mbsf). Due to poor consolidation of drilled sediments, cuttings samples typically consist of sand and silt floating in a matrix of mixed sedimentary and drilling muds, and solid rock chips were not retrieved above 802.7 mbsf. Visual description based on macro- and micro-scope observation, XRD and XRF analysis, rocks properties and the age of washed cuttings (i.e. grains without mud) were made throughout the hole, which allowed to establish some indexes to estimate lithology. Four lithologic units (Unit I ? IV) were defined at Site C0009 based on compositional and textural variations of cuttings samples, which are believed to closely reflect lithologic changes of drilled sequences, and show good consistency with logging data. Unit IV is believed to be accreted sediment by mainly age and the textural change of sediments. Dissoluble element ratios (Ti/P) and clay content ratios in the samples analyzed by XRF and XRD are different from that in basin sediment, which also might support Unit IV are accreted materials. XRD and XRF analyses on cuttings samples provide useful information to estimate difference of lithology. Comparison of cuttings and cores at corresponding depth indicates compositional and textural differences between the cuttings and core samples, which could reflect mixing of cuttings in drill hole.

Paleop-maximum Temperature (i.e. highest temperature rock experienced) of drilled sediments is estimated by vitrinite reflectance measurement in cuttings and core samples. Vitrinite is common in all units and the results show 0.2 ? 0.3 % in reflectance which are indicative of 50 ? 60 oC when considering sedimentary age. The reflectance (temperature) slightly increases depth-ward. There is no large temperature difference between the units including unconformity, which suggests that the temperature distribution is similar to the past or present geothermal gradient and that the accreted sediments (Unit IV) have not subducted, accordingly. Our attempt further connects to the detailed discussion on ongoing accretion processes when we reach to the greater depth in the planned future expeditions of NanTroSEIZE.

Keywords: Accretionary prism, Vitrinite, Riser drilling, cuttings, NanTroSEIZE



## Outline of the Japan Beyond-Brittle Project (JBBP) for geothermal energy development in ductile zone

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Geothermal energy is one of the most promising solutions for global warming, shortage of energy resources, and national energy security. Utilization of geothermal energy has not been promoted during the last 10 years in Japan because of cost consideration, amount of generated electricity per a power plant, various uncertainties and risks, although Japan has 3rd world largest potential of hydrothermal energy. Engineering approach to artificially create geothermal reservoirs (EGS: engineered geothermal systems) in granitic basement has been highlighted recently because of applicability to many of the sites where permeable fracture system and satisfactory water charge can not be found, and EGS projects are under way in many countries. However, some critical problems have been experimentally identified, such as low recovery rate of injected water, unexpectedly small improvement in permeability, and occurrence of large induced seismicity (Majer et al., 2007).

We understood that such problems in the EGS development can not be evaded because they are highly related to the nature of brittle rock mass, and, hence, propose a new concept of the engineered geothermal development where reservoirs are created in ductile basement (see figure). We expect that power generation using the EGS reservoirs in ductile zone especially in Northeast Japan have advantages, namely: (a) homogeneous rock properties and stress make it simpler to design and control the reservoir, (b) nearly full (100%) recovery of injected water from hydraulically closed reservoir can be achieved, (c) sustainable energy production would be realized by controlling water injection rate, (d) shallower brittle-ductile transition depth in the Northeast Japan (Muraoka and Yano, 1998) can effectively reduce costs for drilling and operational risks, (e) widely distributed ductile zones in relatively shallow depth in the Northeast Japan have potential for a large quantity of power generation, (f) possible common characteristics of the ductile zones brings universal design/development methodology free from the site dependency, and (g) induced/triggered earthquakes with disastrous magnitude do not occur from/around the reservoirs.

Scientific and technological breakthroughs are indispensable to realize the EGS system in ductile zones. Hydraulic stimulation, the most important process to create artificial fracture systems, has been commonly used in geothermal and oil industries, and experimental/theoretical studies have been made to understand physics behind the stimulation. Meanwhile, few investigations on the hydraulic stimulation in the ductile zone have been ever made. Control factors of the human created fracture systems in the ductile zone, including stress, constitutive laws, homogeneity of physical properties, and presence of liquid/gas, should be clearly investigated, and methods for design and modeling of the EGS reservoir should be derived based on the clarified control factors. Monitoring of the reservoir extension is another key issue to be considered. Induced seismicity has been widely used for monitoring in the previous EGS projects, however, considering the depth and temperature of the target and expected magnitude of the seismicity, the seismic monitoring may not have sufficient ability to provide information on the behavior and characteristics of the reservoir. New principles and technology development for the monitoring must be investigated.

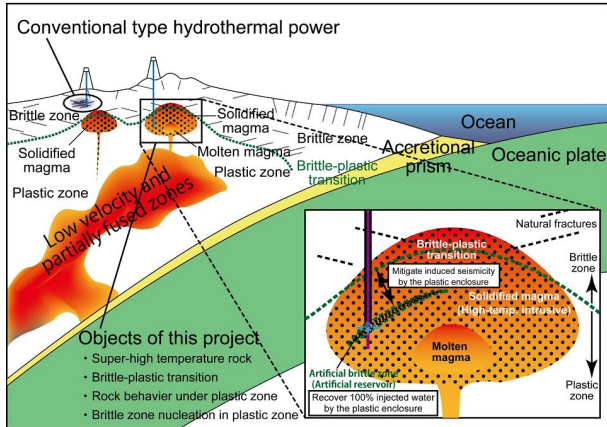
We referred to the development of EGS system in the ductile zone as "Japan Beyond-Brittle Project (JBBP)" and have initiated project preparation. First few years will be spent for scientific investigation and technology development, and deep borehole will be penetrated into ductile zone in Northeast Japan afterwards. We expect that feasibility of the EGS system in the ductile zone can be demonstrated from information from the borehole and multi-level hydraulic stimulation in the brittle-ductile transition zone.

Keywords: EGS, JBBP, Ductile zone, Hydraulic stimulation, Geothermal power generation

MIS27-P07

Room:Convention Hall

Time:May 24 17:15-18:30



## Deep structures and melt-fluid migration in the Hole 1256D Superfast-Spread Crust

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ODP-IODP Hole 1256D drilled through the upper oceanic crust of the Cocos plate formed at the superfast spreading East Pacific Rise ~15 Ma ago (220 mm/yr). This hole penetrated, for a first time in the history of scientific ocean drilling, the upper gabbro layer of an intact oceanic section during IODP Expedition 312. IODP Expedition 335 deepened the hole by ~20 m and recovered cores and cobbles of basalts with granoblastic texture (granoblastic dikes) beneath two bodies of gabbroic rocks (Gabbro 1 and Gabbro 2). Recovered basaltic materials contain cross-cutting relationships between dioritic magmatic veins and hydrothermal veins, and between opx-bearing veins and hydrothermal veins. Here we present the structures in the sheeted dikes and gabbros, and deduce melt-fluid transport system in the deep part of the superfast-spread crust.

The Hole 1256D is located at the boundary between C5Br and C5Bn.2n (15.16 Ma) and inclines ~5 degree from vertical to the west. Results of GPIT logging imply that the upper part of the hole has reversed magnetic polarity, whereas granoblastic dikes and gabbros have normal polarity. Gabbro 1 yielded zircon U-Pb ages of 15.04 +/- 0.18 Ma and 15.06 +/- 0.30 Ma. U-Pb age for Gabbro 2 was 15.20 +/- 0.17 Ma.

Structural orientations measured on the Exp. 312 cores with respect to the conventional IODP reference frame and AMS orientations were reoriented into a geographic reference frame using paleomagnetic data and assuming the magnetic structure obtained by GPIT tool. We also assumed that there was no significant tectonic tilting. Restored Sheeted dikes dip steeply to WSW toward the paleo-EPR axis. Kmax axes of AMS fabric parallel to the dike strike and mostly sub-vertical Kmin axes suggest that the magma transferred horizontally and underwent compaction during solidification. The recovered upper boundary between Gabbro 2 and the granoblastic dikes was irregular, and sub-parallel to the sheeted dike planes. However, textural banding and flow foliation in gabbros tend to dip gently to the east. Diorite veins in granoblastic dikes have irregular boundaries with various orientations and often accompany amphibolite alteration halo. X-ray CT images show inhomogeneous distribution of heavy mineral phases (Fe-oxides?) and light mineral phases (Qz?) in the melt channel implying flow differentiation occurring at hand specimen scale. Opx veins also exhibit irregular shape. Both dioritic and opx veins are cut by amphibole-bearing hydrothermal veins that accompany alteration halos of various width. Dips of amphibole veins exhibit a bimodal distribution: one shallower than ~30 degrees and other steeper than 60 degrees and dipping mostly to SW. S-poles to veins are plotted on a great circle on a stereographic projection about an axis (sigma 2 direction) plunging sub-horizontally to the NW. Brittle fractures also have the same tendency. Restored orientations of structures imply that, since the formation of the sheeted dike complex until formation of the brittle fractures, the crust dominantly underwent extension parallel to the spreading direction. Melt and fluid were likely to transfer subhorizontally through dike planes and through intersections of fracture planes, respectively.

Keywords: oceanic crust, structure, melt migration, paleomagnetism, dating, superfast spreading ridge

## Outline of the GONAF: A deep geophysical observatory at the NAFZ

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We will start drilling under the GONAF (Geophysical Observatory at the North Anatolian Fault) project in 2012, which is partly supported by ICDP.

The North Anatolian Fault Zone (NAFZ) is the most active plate-bounding strike-slip fault in Europe that follows an EW trend offshore through the Sea of Marmara within less than 20 km south of Istanbul. The fault has produced a series of large and devastating earthquakes during the 20th century starting in 1939 in eastern Anatolia and then systematically propagating westwards. The most recent  $M > 7$  earthquakes occurred in 1999 near Izmit and Duzce and temporarily produced accelerated seismic activity along the NAFZ south of the greater Istanbul area below the Sea of Marmara now representing a seismic gap of up to 150 km length. This part of the NAFZ is the only segment that has not been activated in the present series and may have accumulated a slip deficit of up to 4-5 m since the last event in 1766. Recent estimates indicate a 35-70% probability for the occurrence of a  $M > 7$  earthquake close to the population center of Istanbul by 2034. Owing to post-seismic stress redistribution after the 1999 Izmit earthquake the eastern part of the seismic gap along the Princes Islands segment is likely subjected to enhanced stresses.

The principal scientific objective is to study physical processes acting before, during and after the expected  $M > 7$  earthquake along the Princes Islands segment of the NAFZ by monitoring microseismic activity at significantly reduced magnitude detection threshold and improved hypocentral resolution. It is also intended to study wave propagation characteristics of a large earthquake using downhole seismic recordings at two different spots along the expected rupture and potentially close to its initiation point.

GONAF is focused on the installation of a deep borehole seismological observatory. Combining GONAF recordings with existing nearby surface arrays and regional permanent stations will allow to substantially improve monitoring conditions along the entire Princes Islands segment by lowering the magnitude-detection threshold by at least one order of magnitude thus allowing to study the spatial and temporal evolution of microseismic activity prior to the expected Marmara earthquake with unprecedented detail. GONAF will involve two vertical chains of downhole short-period and broadband seismometers allowing to record the entire frequency band of the seismic wavefield close to the fault from two different azimuths. Prior to the long-term installation of the seismological observatory we will use the GONAF boreholes to also measure heat and gas/fluid flow and to determine orientation and magnitude of local stresses for the first time in the entire Marmara region. This will in turn allow to test and calibrate existing stress models.

GONAF will give new insight into physical processes acting prior and potentially also during and after a large ( $M > 7$ ) earthquake at a major transform fault zone during the seismic cycle. Moreover, GONAF is expected to address fundamental questions related to rupture dynamics, temporal changes of material properties and to refine and calibrate ground shaking models and near-real time hazard assessment for the mega-city of Istanbul with its  $> 13$  million inhabitants.

## Paleo-elevation and subsidence of ~145 Ma Shatsky Rise inferred from CO<sub>2</sub> and H<sub>2</sub>O in fresh volcanic glasses

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Shatsky Rise is a large Mesozoic oceanic plateau located in the northwest Pacific. It consists of three massifs, Tamu, Ori and Shirshov Massifs, which formed along the trace of a mid-ocean ridge triple junction. Because of this setting, Shatsky Rise is uniquely suited to testing plume head versus ridge-controlled hypotheses of oceanic plateau genesis. We estimated paleo-eruption depths of Shatsky Rise massifs based on dissolved CO<sub>2</sub> and H<sub>2</sub>O of volcanic glasses and core descriptions that were cored from five drilling sites of Integrated Ocean Drilling Program (IODP) Expedition 324. The elevation of Shatsky Rise is estimated to be 2500-3500 m above the surrounding seafloor, which is consistent with a mantle plume formation if the average crustal thickness and density of Shatsky Rise are 21 km and 2.9-3.0 g/cm<sup>3</sup>, respectively. Short-term subsidence, which may be due to rapid isostatic adjustment of volcanic load, was detected from the downhole depth estimate profile of one drill site. Post-emplacment subsidence of Shatsky Rise was estimated to be ~3000m, which can be explained by thermal subsidence models. A slight increase of total subsidence was observed from the center of Tamu Massif (~2700m) toward Ori Massif (~3400m), implying existence of large buoyant mass, perhaps a refractory mantle root or prolonged magmatic crustal growth beneath the rise center.

This research was supported by IODP After Cruise Research Program, JAMSTEC.

Keywords: Shatsky Rise, volcanic glass, water, CO<sub>2</sub>, subsidence, elevation

## 3-dimensional imaging service of X ray CT scan data obtained from deep-sea core sample

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Recently, X-ray CT scanning on cored sediment sample has been frequently performing in several institutes before splitting the core sample to research internal structure of the sediment. These scanned data produces 3-dimensional graphic on screen after processing the data using rendering software. Researcher can cut the graphic freely and to see inner structures of sediment sample without physical destruction as like actual discrete sampling from split half of a core section. Additionally, the visualized graphic can be easily reconstructed again using original data and that is great advantage on visual sampling for many scientists in future. Integrated Ocean Drilling Program (IODP) has added the X-ray CT scanning of the core section to standard measurement on board D/V Chikyu in order to record digital archive of core samples and to search geological structures before splitting.

Scanned data are stored into special file of which format is DICOM (Digital Image and Communication in Medicine) with several information of scanning, setting and inventory of sample. DICOM format has been developed along to innovation of medical scanners such as X-ray CT and MRI to accommodate patient information and scan settings. The characteristic format of DICOM produces and helps quick and easy scanning in a hospital, however, the format lost general compatibility among different model of scanners instead of individual settings of each patient and equipment. Generally, researcher uses a software, DICOM viewer, to handle the file on personal computer so that purchasing personally control assembly of a scanner is not realistic. Drawing 3-dimensional graphic requires high speed processing unit and big size of memory, although the viewer software makes it possible to create easily visualized image from DICOM files. Another problem is that a file size of a core section of which standard length is 150cm becomes to be huge, from ten to hundred MB, although it depends on scanning resolution. Consequently, total size of scanned files at a coring hole will be from hundreds MB to a few TB. Therefore, contriving adequate plan to download files based on several measurement results is required to save time to research files and resources of personal hardware.

Can't we create more suitable, quick and easy method to handle huge number of the digital archives of core samples scanned in each expedition and/or coring? Researcher's burdens to create 3-dimensional graphic of samples such as time and cost will be resolved, if brand-new drawing technique is released. We study the innovative-drawing method of DICOM file for geology by developing a new algorithm of high-spec GPU to calculate 3-dimensional information ordered from user. In this method, user sends request information of rotation and/or cut through special browser on PC, then, GPU creates 3-dimensional image from a DICOM file and sends back a JPEG file of a snapshot of the image to user. The communication speed on network to create a 3-dimensional graphic will be fast and quick, and quality of a snapshot of the image on screen is expected to be almost same as a DICOM viewer. We also aim to research a method to access the DICOM files via handy tablet PC and smart phone for an interactive-imaging service of geological core samples everywhere.

Keywords: core sample, X-ray CT image, 3-dimensional graphic, virtual core, DICOM format, cloud

## Volcaniclastic facies associations of Tamu Massif, Shatsky rise

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Shatsky Rise, a large oceanic plateau in the northwest Pacific, was formed during the Late Jurassic and Early Cretaceous at a rapidly spreading triple junction. Formation style of Shatsky Rise was poorly understood and sedimentary processes of volcaniclastics were not clarified.

Integrated Ocean Drilling Program (IODP) Expedition 324 cored five sites from Shatsky Rise, with one site (U1346) on the summit of Shirshov Massif and two sites each on Ori (Sites U1349 and U1350) and Tamu (Sites U1347 and U1348) massifs. Cores from Site U1348 are a thick sequence (~120 m) of volcaniclastic sediments topped with shallow-water carbonaceous sandstones. The volcaniclastic rocks from Site U1348 are generally highly altered, but a single interval containing fresh glass shards. We have examined sedimentary processes of the Tamu Massif based on facies analysis.

Shipboard Scientists have suggested that the thick sequence of volcaniclastic sediments is composed of four stratigraphic units, from Unit III to VI (Sager et al., 2010; Proc. IODP vol. 324). Our detailed facies analysis subdivided the Site U1348 section into six units. The clasts in Units III to VI are almost entirely composed of volcanogenic material, and are predominantly composed of various sized altered glass fragments and partly composed of carbonaceous sandstones. The sedimentary features of Units III to VI are inclined layers and foreset beds, mainly composed of parallel stratified altered vitric glass. Graded bedding (normal and reversed) and laminations are present throughout the section. We classified volcaniclastic rock of the section into 9 facies associations as a result of facies analysis.

The 9 facies are (1)-(3) three types of resedimented hyaloclastites (mainly mass flows), (4) in-situ hyaloclastite, (5) mixed facies of resedimented hyaloclastites / in-situ hyaloclastite, (6) low-density turbidites, (7) high-density turbidites, (8) grain flow deposits, and (9) mixed facies of carbonate clasts / epiclastics. The hyaloclastite are primary volcaniclastics, and turbidites and grain flow deposits are mostly epiclastics. Mixed facies of carbonate clasts / epiclastics is subdivided into 2 types.

The presence of hyaloclastite and turbidites, and no evidence of shallow marine sedimentary structures (e.g. wave ripples) indicate deposition of the volcaniclastic sediments in submarine environments at depths below wave base. The inclined layers may have been deposited as part of the "slope apron" of a volcano. The gradual observed increase of dip with increasing depth in the core, implies decrease slope dip upward through time, possibly related to the progradation of a volcano slope apron.

This research was supported by IODP After Cruise Research Program, JAMSTEC.

Keywords: Shatsky Rise, Tamu massif, facies analysis, submarine volcano, sediment gravity flow, hyaloclastite

## Paleoposition of Intertropical Convergence Zone in the east Pacific inferred from glacial-interglacial magnetic changes

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Magnetic properties are increasingly used for paleoclimatic and paleoceanographic studies. Utilizing recently developed proxies, an environmental magnetic study was conducted on the uppermost 12 m sediments of IODP Site U1337 in the eastern equatorial Pacific. This interval is above the Fe-redox boundary, and covers the last ~800 kyr. The site is located near the present southern boundary of the Intertropical Convergence Zone (ITCZ), and thus expected to be sensitive to variations of its position. Ratio of anhysteretic remanent magnetization susceptibility to saturation isothermal remanent magnetization (kARM/SIRM), first-order reversal curve diagrams, and IRM acquisition curves indicate that the magnetic mineral assemblage consists of dominant biogenic component and minor terrigenous component. Two groups, the biogenic soft (BS) and hard (BH), are identified for the biogenic component, which probably correspond to different magnetofossil morphology. The BH component, probably carried by elongated magnetofossils, increases in sediments of glacial periods, which are probably in less oxic conditions due to increased ocean productivity. This demonstrates that magnetofossil morphology, which can be discriminated by rock-magnetic technique, is a sensitive indicator of slight oxic-suboxic environmental fluctuations in sediments. Temporal variations of the terrigenous component, most likely transported as eolian dust, were estimated from kARM/SIRM ratio and S-ratio; significant glacial-interglacial variations occurred at Marine Isotope Stage (MIS) 10 and before, but not after. In addition, coeval upcore increases in sedimentation rates and the BH component were observed, suggesting increased productivity. These observations may indicate that the position of ITCZ was southward than today at ~250 ka and before.

Keywords: environmental magnetism, ITCZ, eolian dust, biogenic magnetite, IODP, east Pacific



## Relative geomagnetic paleointensity estimation from the IODP Site U1331 and U1332 sediments for Eocene and Oligocene

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Integrated Ocean Drilling Program (IODP) Expeditions 320 and 321 recovered sediment cores from equatorial Pacific. Cores taken from Sites U1331 and U1332 covered Eocene and Oligocene (Expedition 320/321 Scientists, 2010). Although many efforts have been made to reveal relative geomagnetic paleointensity variations in geologic time, those prior to ca. 3 m.y. have been not yet reported except a few studies.

This study concentrates on paleomagnetic and rock magnetic measurements on the Site U1331 and U1332 sediment cores. The measurements include stepwise alternating field demagnetization of the natural remanent magnetization (NRM), the anhysteretic remanent magnetization (ARM) and the isothermal remanent magnetization (IRM). The magnetostratigraphy constructed from the NRM data show that the sedimentary section extends from 29.166 to 41.358 Ma for U1331 (10-90 mcd), and from 23.030 to 41.358 Ma for U1332 (20-125 mcd).

Intensity variation of ARM and IRM is within about a factor of six throughout the core. Ratio of ARM to IRM (ARM/IRM), that is index parameter for degree of magnetostatic interactions and/or proxy of magnetic grain size, differs between Eocene and Oligocene. These suggest that we should divide the cores into Eocene and Oligocene intervals in order to try relative paleointensity (RPI) estimation. RPI estimates have been done by using ARM and IRM as normalizers for NRM. RPIs by ARM and IRM generally show consistent variations. However, several experimental results imply that RPI by IRM may be more preferable. We will report the RPI estimates from the U1331 and U1332 cores and compare these estimates.

## Variations in higher plant terpenoid compositions in the eastern equatorial Pacific sediments over the last 30 Ma

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We analyze terrestrial plant-derived biomarkers (higher plant terpenoids; HPTs) in sediments recovered during the IODP Expeditions 320/321, the Pacific Equatorial Age Transect (PEAT), to reconstruct variations in terrestrial input in the eastern equatorial Pacific Ocean, as well as to evaluate transport systems of terrigenous matter from land to ocean. Terrestrial plant-derived organic molecules in these pelagic areas are considered to be mainly transported through atmosphere by aeolian system. The HPTs such as sesqui-, di- and triterpenoid are major constituents of plant resin, cuticle and supportive tissues. These groups possess different taxonomic origin (i.e. gymnosperms and angiosperms), so that their compositions in the PEAT sediments could be recorded climatic system such as wind strength and direction, and atmospheric circulation, and moreover, the environmental information in the hinterland of continental area(s).

In this study, we perform organic solvent extraction from freeze-dried sediment samples, and separate the extract to four fractions by using silica gel column chromatography. Each separated fractions are analyzed by gas chromatography / mass spectrometer (GC/MS). Because of extremely low concentration and frequent coelution for the HPTs, we quantify by selected ion monitoring (SIM) chromatogram with the representative ions of the compounds.

We could identify the HPTs such as cadalene (sesquiterpenoid), abietane type diterpenoids and oleanane type triterpenoids. The total concentrations of HPTs were 0.03-7.90 ng/g and increased over the last 10 Ma. Paleo-latitudinal distributions of the ratios of the Ole/(DT+Ole) ratio, which is oleanoids to the sum of the oleanoids and diterpenoids, show the highest values near the equator (1°S to 3°N). Oleanoids are relatively abundant only in 0°N to 2°S until the middle Miocene, while the northernmost latitudinal samples are predominated by gymnosperm-derived diterpenoids. Oleanoid-dominant samples appear in northern latitude (0°N to 3°N) during the late Miocene and Pleistocene sediment samples. The result agreed with the general trends of higher plant wax-derived n-alkane ratios ( $C_{31}/(C_{29} + C_{31})$ ), in which the lowest values were observed near the equator, presumably associated with zonal transport of higher plant wax from the tropical South America. The oleanoids mainly originate from angiosperm wax, and therefore, the transport mechanism may be the same as n-alkanes. The rainforest is major vegetation in The tropical South America is characterized by the major cover of rainforest which vegetation is predominated by the angiosperms. Atmospheric transport via aeolian dust from the semiarid and arid region of the central East Asia and North America can also contribute in significant portion of n-alkanes and HPTs in the eastern equatorial Pacific Ocean. The HPTs transported from such arid and/or cool hinterlands might be more abundant in diterpenoids, compared to that from tropical South America. In the study area, the intertropical convergence zone (ITCZ) behaves as a barrier to southward transport of dust from the Asia with its high rainfall, resulting higher deposition of aeolian dust in the latitude. The a little northward areas from the suggested zonal transport shows higher concentrations of HPTs and low Ole/(DT+Ole) ratio. Hence the latitudinal positions of the paleo-ITCZ may correspond to this area.

It is suggested that the latitudinal shift of locations that HPT concentrations and compositions are associated with the change in atmospheric circulation in study area, and that the ITCZ located southward during the early to middle Miocene.

Keywords: Pacific Equatorial Age Transect (PEAT), Intertropical Convergence Zone, aeolian transport, Higher Plant Terpenoid

## The radiolarian biostratigraphy in east equatorial Pacific Ocean (IODP Exp. 321 Site U1338)

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The radiolarian biostratigraphy has been already performed on 119 core catchers and core (mostly two per core) on shipboard. We examined 172 additional material (mostly four per core) collected for establishing the higher resolution biostratigraphy of radiolarians.

A total of 291 samples were collected from Hole U1338A. The sampling interval was about 1.5 to 3.0 m. The samples were processed with hydrochloric acid and hydrogen peroxide, and washed through the 63 micro meter sieve. The residues were dried and mounted on the slide glass with Canada balsam. Total of 500-1000 individuals were observed at each sample.

The radiolarian assemblages of Site U1338 show good to moderate preservation except in the lowermost portion (lower Miocene). Tropical radiolarian biostratigraphy was used for establishing the radiolarian zones of Site U1338. The radiolarian stratigraphy spans the interval from the uppermost part of Zone RN16-17 (late Pleistocene) to uppermost part of RN3 (early Miocene). Fifty eight radiolarian biostratigraphic datum events have been recognized in Site U1338. The biostratigraphy of radiolarians generally agree with the shipboard biostratigraphic data of other microfossils: nannofossil, foraminifera and diatom except for some small inconsistencies.

Keywords: Radiolaria, Biostratigraphy, east equatorial Pacific Ocean

## deep-sea benthic foraminiferal assemblage in the eastern equatorial Pacific since the latest middle Miocene

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Our research objective is to study the influences of the climatic and oceanographic changes on deep-sea benthic foraminifera from the middle Miocene to Pleistocene. The mid-Miocene climatic optimum was followed by rapid global cooling, when Antarctic ice sheets expanded. In the middle Miocene to Pliocene, there are paleoceanographic events, such as "carbonate crash" (12-9 Ma) and "biogenic bloom" (6.7-4.5 Ma). These events are strongly influenced by ocean circulation changes. Such oceanographic changes enhanced the evolution of marine organisms.

Samples used in this study were collected in the eastern equatorial Pacific (Hole U1338B, IODP expedition 321), and studied interval is 12 to 0 Ma.

The relative abundance of high-productivity taxa increased at ca. 7-5 Ma, corresponding to high TOC interval (biogenic bloom). Long-term trend of benthic foraminiferal assemblage revealed that major faunal changes occurred at around 6-5.5 Ma and 2 Ma. The former period is the Messinian to the Pliocene transition period, and the relative abundance of *Cibicides mundulus* decreased and the relative abundance of *Epistominella exigua* increased. *Cibicides mundulus* and *Nonion affine* increased after the latter period. *Epistominella exigua* is good indicator of the influence of seasonal surface primary production. On the other hand, *Cibicides mundulus* prefers a low organic content substrate related to NADW (north Atlantic deep water). Thus, these foraminiferal changes are associated with the global oceanographic changes related to these factors.

Keywords: benthic foraminifera, paleoceanography, Miocene, Pliocene, equatorial Pacific, IODP Expedition 321

## Mid- Late Miocene marine Os isotopic fluctuation and burial fluxes of Re, Os and Ir into deep-sea deposits

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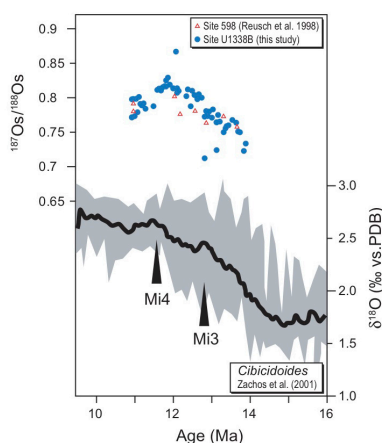
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Temporal variations in <sup>187</sup>Os/<sup>188</sup>Os and burial fluxes of Re, Os and Ir into deep-sea deposits were studied using late to middle Miocene nanofossil ooze from IODP Exp. 321 (PEAT II; Pacific Equatorial Age Transect II) from the time interval investigated ranges from 14 Ma to 11 Ma with sampling resolution of about 40 kyr.

Marine Os isotopic ratio (<sup>187</sup>Os/<sup>188</sup>Os ratio) increases monotonically from 14 Ma to 11.8 Ma, reaches a local maximum at 11.8 Ma, and decreases continuously to 11 Ma. This broad peak around 11.8 Ma was not apparent in previous low-resolution data (Reusch et al., 1998). The causes of change of Os isotopic trend at 11.8 Ma are still uncertain. Based on the similarity of trends between oxygen-carbon isotopes from benthic foraminifera (Zachos et al., 2001) and marine Os isotopes (Fig.), some relationship with global climatic changes is expected.

Burial fluxes of Re, Os and Ir range 0.04 - 36 ng/cm<sup>2</sup>/kyr, 60 - 330 pg/cm<sup>2</sup>/kyr and 18 - 28 pg/cm<sup>2</sup>/kyr, respectively. Burial fluxes of Os and Ir are within the range of the published data from Quaternary pelagic calcareous oozes (Burton et al., 2010; Cave et al., 2003; Dalai and Ravizza, 2006, 2010; Kyte et al., 1993). On the other hand, studied values of Re burial fluxes are out of the range of Quaternary pelagic calcareous oozes (Burton et al., 2010). Especially, Re burial fluxes at the two horizons of 12.1 Ma and 11 Ma are over 15 pg/cm<sup>2</sup>/kyr. Re is sensitive tracer for moderately reducing conditions when oxygen is present in bottom waters but rapidly consumed from interstitial waters (Morford et al., 2005). It was suggested that accumulation flux of organic carbon increased suddenly at 12.1 Ma and 11 Ma around the eastern Equatorial Pacific.

Keywords: Os, Miocene, Paleoceanography, IODP, PEAT



## Fluctuations of stable carbon isotope ratio in organic matter - example from the IODP Site U1352 offshore Canterbury -

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IODP Expedition 317 drilled three sites on the continental shelf and one site on the slope of the offshore Canterbury, on the eastern margin of the South Island of New Zealand, for understanding the relative importance of global sea level versus local tectonic and sedimentary processes in controlling continental margin sedimentary cycles. Samples using this study are collected from Site U1352 located on the upper continental slope and this site was suitable for providing age control for the studies. Its water depths is 344m, and core recovery was nearly 100% above 550m depth from the sea floor.

Global climate changes have been studied on the basis of the oxygen isotope and stable carbon isotope records derived from marine foraminifers. However, in the southern hemisphere ocean, stable carbon isotope ratios of marine organic matters are considered to depend on latitude change, and temperature of surface seawater (Rau et al. ,1982).

This study aims to examine whether stable carbon isotope ratios derived from marine organic matter can correspond to Marine Isotope Stage (MIS), namely compare stable carbon isotope fluctuations derived from marine organic matters with oxygen isotope curve derived from marine foraminifers.

The measurement intervals are ~10,000 years durations based on the rates of deposition.

Spikes of stable carbon isotope ratios coincide with these of oxygen isotope and stable carbon isotope of foraminifers. Based on our isotope data together with nannofossil datums, we identify most of the marine isotope stages since MIS 63 (1.76 Ma).

Keywords: stable carbon isotope ratio, marine organic matter, Marine Isotope Stage

## Paleoenvironments of the Plio-Pleistocene strata in Canterbury Basin based on fossil ostracode assemblages

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Integrated Ocean Drilling Program (IODP) Expedition 317 was devoted to understanding the relative importance of global sea-level (eustasy) versus local tectonic and sedimentary processes in controlling continental margin sedimentary cycles. Drilling in the Canterbury Basin, off the South Island of New Zealand, takes advantage of Plio-Pleistocene samples, which preserves a high-frequency (0.1-0.5 m.y.) record of depositional cyclicity. The Pliocene and Pleistocene periods are characterized by cyclic sea-level changes induced by glacial and inter-glacial climatic shifts. Numerous investigations found cyclic sea-level changes caused by glacio-eustasy from the Plio-Pleistocene sequences. However, it is little known vertical and temporal changes of the paleodepth corresponding to glacial and interglacial cycles through long-term periods of the Plio-Pleistocene. The object of this study is to reveal Plio-Pleistocene sea-level changes and their vertical and temporal distributions on the continental shelf of Canterbury Basin. We used the samples which were collected in sites U1354 (water depth 113.4 m) and U1353 (water depth 84.7 m) on the continental shelf. Samples less than 20 cc were freeze-dried and washed through a 63 micrometer opening sieve. The residues were dried and then divided into aliquot parts containing around 200 specimens using a sample splitter. As a result, 116 fossil ostracode species belonging to 48 genera and 136 species belonging to 57 genera were identified from 81 samples of U1354 and from 40 samples of U1353, respectively. Q-mode factor analysis was proceeded by using total 81 samples of U1354 and 29 samples of U1353. The vertical changes of varimax factor loadings indicate that at least thirteen and eight transgressive-regressive cycles were recorded in sediments of U1354 (3.3 to 0.5 Ma) and U1353 (3.7 to 1.5 Ma), respectively. Total seventeen transgressive-regressive cycles were recognized between 3.7 to 0.5 Ma due to comparison of both cores based on the biostratigraphy. The amplitude of paleodepth changes and the cycles of about 40,000 year reveal that some cycles were induced by glacio-eustasy. In addition, four high stand periods could be compared with MIS G7, G1, 61, and 59.

## Response of reef-building corals to post-glacial sea level rise: IODP Expedition 325

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Major objectives of the Integrated Ocean Drilling Program (IODP) Expedition 325 (GBREC: Great Barrier Reef Environmental Changes) include reconstructing histories of sea-level change, sea surface temperature variation and reef growth since the Last Glacial Maximum (LGM), and analyzing the responses of reef-building corals to post-glacial sea level rise. Submerged reef structures were drilled along four transects in three localities (Hydrographers Passage, Noggin Pass, and Ribbon Reefs) on the shelf edge seaward of the modern Great Barrier Reef. A total of 34 boreholes were cored at 17 sites ranging in depth from 42 to 167 meters below present sea level.

Seven coral assemblages are identified based on coral taxonomy and morphologies. Their paleoenvironments are inferred by comparison with modern coral communities of the Great Barrier Reef and range from shallow wave-exposed to deep low-energy reef habitats. The initial post-glacial coral assemblage is dominated by shallow-water massive-submassive-branching *Isopora* associated with branching *Acropora* and *Seriatopora*. The deeper assemblages consist mainly of encrusting to submassive *Montipora* and encrusting *Agariciidae*. Horizontal changes in coral assemblages along transects, from proximal to distal cores, probably reflect the changing reef geomorphology and hydrodynamic regime during sea level rise. Vertical changes within a core reflect an increase in water depth followed by a drowning of the coral community and the formation of the submerged reef tops. As sea level rose, shallow reef assemblages re-established further upslope and accumulated several meters of reef structure before drowning in turn.

Keywords: IODP Expedition 325 GBREC, Great Barrier Reef, corals, last deglaciation, sea level rise, paleoenvironmental changes



## Large benthic foraminiferal assemblages from shelf slope cores of the Great Barrier Reef: IODP EXP. 325

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The Integrated Ocean Drilling Program (IODP) Expedition 325 was conducted in 2010 on tectonically stable continental shelf slopes of the Great Barrier Reef (GBR) to understand sea-level changes, paleoceanographic changes and the history of coral-reef developments since the Last Glacial Maximum. A total of 34 boreholes in four transects were cored in depths ranging from 42 to 167 meters below sea level. Large benthic foraminifera are unique tools to reconstruct the past environmental histories (e.g., Fujita et al., 2010) for reef systems including paleo-water depths, and hence we aim to employ this method for GBR samples to reconstruct sea-level changes and reef development processes. Unconsolidated sediment samples from cores taken in three transects (HYD\_01C, HYD\_02A and NOG\_01B) were used for grain-size and foraminiferal analyses, and multivariate analyses of foraminiferal assemblages were performed. *Operculina* spp. was common in a gravel fraction; it was particularly abundant in muddy sediments in the lower part of cores from deep shelf slopes. A total of 25 taxa of large benthic foraminifera were identified in a coarse sand fraction. Four foraminiferal assemblages (A, B, C, and D) were delineated by Q-mode cluster analysis and they correspond to distinct sedimentary environments; namely back reefs (assemblage A), fore-reef slopes with either high energy (assemblage B) or low energy condition (assemblage C), and deep shelf slopes (assemblage D). The assemblage A which is dominated by *Baculogypsina* sp. and *Calcarina* spp. would be a key to reconstruct past sea levels. The current study is indicative of the potential for reconstructions of paleo-sea-levels using large benthic foraminiferal assemblages.

## Mid-late Pleistocene tephrostratigraphy of C9001C and C9002A/B cores off Shimokita, Tohoku Japan

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We report the tephrostratigraphy in the core C9001C and C9002A/B corrected by RV CHIKYU off Shimokita Peninsula. The recovery of sediment at Hole C9002A is 0 - 26.2 mbsf, Hole C9002B is 23.3 -70.8 mbsf and Hole C9001C is 0 - 365 mbsf, respectively. The upper part of sediment of the Hole C9001C, 0 -158 mbsf, was correlated to the core C9002A/B by two widespread tephra, Spfa-1 and Aso-4, completely (Aoike et al., 2010). Domitsu et al.(2010) integrated the age model based on the oxygen isotopic stratigraphy of foraminiferal fossils and tephrochronology, microbiostratigraphy, and magnetostratigraphy and mentioned to the core C9001C covered mid-late Pleistocene and the bottom age of the core C 9001C was the base of the Brunhes Chron. In this study, we observed sediment cores, and described tephra deposits in detail. Some of them are overlooked at the initial core description.

Tephra deposits are fine ash layer to pumice layers, the sand layer which heavy minerals concentrated, and bright layer and spots which suggested that fine volcanic glass shards fall out. We corrected eleven samples from the core C9002A, twenty samples from the core C9002B, and thirty-six samples from the core C9001C. Tephra samples were dissolved in water and washed by ultrasonic cleaner. After decantation, the upper water was discarded and deposited samples were dry up. All samples are sieved by 63 micrometer, 125 micrometer, 250 micrometer and observed by stereomicroscopy. When the need arises, major-element chemistry of volcanic glass shards determined by EPMA, and refractive indices of volcanic glass shards and heavy minerals were measured.

In the core C9002B, Spfa-1 at 30m and Aso-4 at 53m have already reported by Aoike et al.(2010). Tephra layer at 52.8m is correlated to tephra provided from Kuttara volcano based on the major element chemistry of volcanic glass shards. Tephra at 52.8m just above Aso-4 at 53 m should be correlated to Kt-6 or Kt-7. In the core C9001C, Two tephra bed provided from Osore volcano and Shiobara-Otawara tephra provided from Shibara caldera in north Kanto district were detected. Suzuki et al. (2012, JpGU) discuss about these correlations in detail.

Chronology of Shiobara-Otawara tephra and two tephra from Osore volcano were discussed with widespread tephra in Kanto-Kinki districts, and stratigraphy of marine terraces in Shimokita Peninsula. In this report, we cast whether there is no room for reconsideration about the boundary of MIS8/7 settled by Domitsu et al.(2010), or not.

Keywords: Chikyu, Shimokita Peninsula, tephrochronology, Kuttara volcano, Osorezan-Tanabu tephra, Shiobara-Otawara tephra

## Preliminary results of paleoceanographic study of IODP Expedition 334

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The East equatorial Pacific marginal sea off Costa Rica is one of the most important region to understand latitudinal shift of Intertropical Convergence Zone (ITCZ) and ventilation changes in intermediate waters of south or north origin during the Quaternary. We successfully obtained excellent sediment core samples from the upper slope and continental shelf off Costa Rica during Integrated Ocean Drilling Program (IODP) Expedition 334 (Costa Rica Seismogenesis Project; CRISP) of the D/V Joides Resolution. In these cores, we selected cores U1378B and U1379C as reasonable cores for our Quaternary paleoceanographic study. Now we are analyzing benthic foraminiferal assemblages, organic carbon contents, and Corg/N ratio from these cores. Moreover, we will analyze foraminiferal oxygen isotope ratio and carbonate content in core U1378B to construct the isotope stratigraphy and reconstruct intermediate water ventilation changes related with glacial- interglacial climate shift. The preliminary results of biostratigraphic ages obtained from core U1378B indicate high sediment accumulation rate of about 283-296 m/my in the upper 34-35m. The result is based on the extinction horizon (120 kyr) of planktonic foraminifera *Globigerinoides ruber* (pink specimens). Thus, the sedimentary horizon would correspond to the peak last interglacial event of marine isotope stage 5. We will report on preliminary results of paleoceanographic analyses in these cores. We thank IODP cruise staff for their kind support during the CRISP cruise.

## Logging data from gas hydrate production well

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For the 2nd onshore production test of gas hydrate at Mallik 2L-38, lots of pre-studies had been done in order to ensure the identification of the gas hydrate by logging measurements with various principles. The logging data at gas hydrate interval where is interbedded sand and shale at Mallik (Dallimore and Collett, 1997) can be consistent with the behavior of the ones at Japanese deep sea field. Since this resemblance of lithology will not be affected by the condition as permafrost at Mallik, the behavior of log data at gas hydrate interval will help to optimize the logging program and to predict the measurements for Japanese gas hydrate projects.

Gas hydrate bearing formation is usually represented as higher resistivity and velocity interval (e.g. Sager et al., 2000), and there are not so much reports about the other conventional logs. But these conventional logs can be also used for the interpretation of gas hydrate. For example, gas hydrate in pore spaces makes the neutron porosity be overestimated than the one of formation filled with water. On the other hand, nuclear magnetic resonance porosity regards the volume of gas hydrate as matrix. Therefore the separation of two porosity curves can show the range of gas hydrate distribution. Although it is not so difficult to find the gas hydrate interval in the ideal condition as above, the other conventional logs like gamma-ray density are also essential because we have to consider about the effects of clay and so on, practically.

To use the logging results for research, it is necessary to understand the uncertainties of data. Logging data is affected by the movement of acquisition device, deviation, borehole size, drilling mud and its invasion, lithology, relative dips, formation fluid type and salinity, temperature, pressure and everything. Loggings are based on various acquisition principles, and are affected by the environmental factors caused by acquisition principles. In the other word, the environmental factors caused by acquisition principles enable to measure the arbitrary information. Therefore the lack of environmental corrections and principle specific processing will be the critical issues of data quality. After all processing, we can start to interpret the tool and parameter limitations. If there are still some gaps between the measurements of laboratory and the ones of field, the quality of logging and cores, the limitation of acquisition principles, the limitation of processing and the resolution of measurements should be considered.

Thank to the cooperation of MH21 consortium, this study was carried out. The logging data were acquired in 2nd onshore production test of gas hydrate at Mallik 2L-38 carried out mainly by the Minister of Natural Resources Canada and Japan Oil, Gas and Metals National Corporation (JOGMEC) in 2007 and 2008 winter. And the processed results obtained under "Additional petrophysical analysis for 2nd onshore production test" committed by JOGMEC were partially referred.

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Keywords: hydrate, logging, interpretation, Mallik

## Petrological and geochemical analysis of basalts in forearc & subducting slab offshore Costa Rica, IODP Exp. 334, CRISP

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The Costa Rica Seismogenesis Project (CRISP) is designed to understand the processes that control nucleation and seismic rupture of large earthquakes at erosional subduction zones. Integrated Ocean Drilling Program (IODP) Expedition 334 penetrated the slope sediments of the overriding Caribbean plate at Sites U1378 and 1380, the entire sequence of the slope sediments and the upper part of the acoustically defined basement at Site U1379, and sediments and oceanic crust of the incoming Cocos plate at Site U1381. In order to constrain the tectonic setting of the drill site and fluid rock interaction within the basaltic crust, which is a potential fluid source for the seismogenic zone, basalts were petrologically and geochemically analyzed. Basalt clasts from poorly sorted matrix-supported breccia were recovered at the top of the acoustically defined basement at Site U1379. Some of the clasts contain prehnite and pumpellyite, indicating prehnite-pumpellyite facies metamorphic conditions, similar to the Osa melange onshore Costa Rica. At Site U1381, sequences of pillow basalts are intercalated with calcareous mudstone as part of the oceanic crust. The pillow basalts are characterized by plagioclase and pyroxene phenocrysts with microcrystalline to fine-grained groundmass with variable extent of alteration. The basalts were cut by numerous veins mostly consisting of calcite. Groundmass alteration is especially evident along veins, fractures and vesicles, associated with clay minerals and pyrites. Based on our data, the origin of the basalt clasts in the forearc basement, and fluid-basalt interaction in the subducting oceanic crust will be discussed.

Keywords: IODP Expedition 334, Costarica Seismogenesis Project, CRISP, basalt, fluid, oceanic crust

## Geological structures controlling hydrothermal circulation system in the eastern flank of the Juan de Fuca Ridge

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Hydrothermal fluid in the ridge flank influences physical state and evolution of the crust and mantle. Global advective heat loss from ridge flanks is more than 3 times as large as that at the axis, and the ridge-flank mass flux is at least 10 times as large. To reveal hydrothermal fluid system in the ridge flank, intensive drilling operations (ODP Leg 168, IODP Exp. 301 and 327) were conducted in the eastern flank of the Juan de Fuca Ridge (Fisher et al. 2011). Before these drilling campaigns, we believed a largely 2D view of the dominant fluid-circulation pathways across the ridge flank. However, in the eastern flank of the Juan de Fuca ridge, the hydrothermal flow occurs largely parallel to the ridge (Hutnak et al., 2006). The basement outcrops could be fluid entry and exit points to and from the crust.

Drill string packer experiments in upper basement indicate a layered crustal structure with permeabilities of  $10^{-12}$  to  $10^{-11}$  m<sup>2</sup> (Becker and Fisher, 2008). Additional hydrogeologic analyses completed using the formation pressure response to the long-term flow of cold bottom seawater into basement at Site U1301 in the 13 months after drilling, as observed at Site 1027 (2.4 km away) (Fisher et al., 2008). The large-scale cross-hole tests indicate lower crustal permeability than smaller-scale single-hole tests. This result was unexpected because larger scale testing tends to give greater permeability values. The difference between these permeabilities may be reconciled by azimuthal anisotropy in basement hydrogeologic properties.

In this study, we extracted 3D structures of crust surface and faults distribution from seismic profiles in order to reveal geological structures controlling hydrological properties in the ridge flank. Three seismic surveys acquired over 100 seismic lines in the eastern flank of the Juan de Fuca ridge (e.g., Nedimovic et al., 2008). Although these seismic surveys were two-dimensional, the densely-distributed survey lines enable us to extract 3D subseafloor structures around the drill sites. By interpolating the horizons extracted on each profile, we constructed 3D geometry of the crust surface and fault planes. By considering anisotropic characteristics in the interpolation process, we clearly obtained geometry of crust surface. The detailed fault distribution as well as basement geometry can explain the permeability anisotropy observed by the hydrological experiments (Fisher et al., 2008).

When we compare the drilling results and seismic profiles, we can roughly distinguish the fractured zone vs. massive zone within oceanic crust on seismic profile; the lithology boundary seems to be consistent with the seismic characteristics (e.g., quality factor). From logging (e.g. borehole image) data, furthermore, the preferred fracture orientation can be estimated as ridge-parallel direction. By integrating seismic-logging-core data, we evaluate the permeability anisotropy as well as its scale-dependence.

Keywords: IODP Exp 327, Seismic reflection analysis, Eastern flank of Juan de Fuca plate, downhole logging

## Environmental reconstruction in the Southwestern Pacific by fossil corals obtained from IODP Exp. 325

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Sea-level during the Last Glacial Maximum (LGM) has been observed as much as ca. 130 m below its present value for sites remote from former ice sheet (far-field sites). Regions far from areas of previous glaciation are sensitive to glacial meltwater influx and have therefore provided useful constraints on the temporal variation and magnitude of this influx from the LGM to the present day. Fossil coral records contain evidence of a dramatic sea level rise in excess 20 m within the last deglaciation, termed meltwater pulse 1A (mwp-1A). Although this event would have had a significant effect on global climate, the relationship between mwp-1A and the climate system remains a subject of debate. In addition, climatic variations such as seasonality and/or an El Nino/Southern Oscillation (ENSO) variation during Holocene and the LGM have been still open to question, especially in tropical to sub-tropical regions. IODP Great Barrier Reef Environmental Changes Expedition (Exp. 325) collected coral samples which covered around the LGM to the early Holocene. In this study, geochemical tracers, such as  $\delta^{18}\text{O}$ , Sr/Ca and Mg/Ca, contained in skeletons of fossil corals were analyzed and we will discuss past marine environments in the Southwestern Pacific reconstructed by fossil corals.

Keywords: IODP, Great Barrier Reef, coral, climate change