

IODP Expedition 338 掘削概要

Preliminary results of IODP Expedition 338: Operational aspects

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The Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) is a multi-disciplinary scientific project designed to investigate fault mechanics and seismogenesis along subduction megathrusts through reflection and refraction seismic imaging, direct sampling, in situ measurements, and long-term monitoring in conjunction with laboratory and numerical modeling studies. As part of the NanTroSEIZE program, operations during Integrated Ocean Drilling Program (IODP) Expedition 338 were planned to extend and case riser Hole C0002F located at the southeastern margin of the Kumano forearc basin, begun on Expedition 326 in 2010, from 856 meters below the sea floor (mbsf) to 3600 mbsf.

Riser operations extended the hole to 2005.5 mbsf, collecting a full suite of logging- and measurement-while-drilling (LWD/MWD), mud gas and cutting data. However, due to damage to the riser during unfavorable winds and strong current conditions, riser operations were cancelled. Hole C0002F was suspended at 2005.5 mbsf, but left for re-entry during future riser drilling operations, which will deepen the hole to penetrate the megasplay fault at about 5000 mbsf. Contingency riserless operations included coring at Site C0002 (200-505, 902-940 and 1100.5-1120 mbsf), LWD at Sites C0012 (0-709 mbsf) and C0018 (0-350 mbsf), and LWD and coring at Sites C0021 (0-294 mbsf) and C0022 (0-420 mbsf).

Combined primary riser operations and contingency riserless operations at Site C0002 allowed to sample the upper part of the forearc basin sediments and gas hydrate zone, the basal Kumano Basin-to-accretionary prism unconformity, and the upper portion of the inner wedge with cores, drill cuttings, mud gas sampling, and an extensive suite of LWD logs.

Site C0018 is located within a depocenter for downslope mass transport in a slope basin seaward of the megasplay fault, and was drilled and sampled during Expedition 333 targeting mass-transport deposits (MTDs). Site C0021 is located ~2 km NW of Site C0018 and at a more proximal site for MTDs observed at Site C0018. LWD at Site C0018 provided logging data to characterize the sedimentary section and MTDs, which are correlatable with the previous core and seismic data. LWD and coring at Site C0021 provided data for correlation to Site C0018. Together the sites provided constraints on the lateral variability of MTDs within the basin, which relates to the nature, provenance, and kinematics of the submarine landslides.

Site C0022 is located in the slope basin between previously drilled Sites C0004 and C0008. LWD and coring at this site penetrated through the tip of the megasplay fault, and provided constraints on the activity of this megasplay fault.

Site C0012 is located in the Shikoku Basin on the crest of a prominent basement high (Kashinosaki Knoll) on the subducting Philippine Sea plate, where coring down to 630.5 mbsf had been conducted during Expeditions 322 and 333. LWD operations at this site provided logging data to characterize the sedimentary section and the upper portion of the oceanic crust, which are correlatable with the previous core and seismic data.

Keywords: IODP Expedition 338, C0002, C0012, C0018, C0021, C0022

IODP 第 338 次航海の船上分析に基づいた南海トラフの堆積物の間隙水組成について Porewater chemistry of seafloor sediments based on the onboard analyses Expedition 338 at Nankai Trough

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During IODP Expedition 338, sediments were sampled from Site C0002 at Kumano Basin and Site C0022 on the frontal arc slope of Nankai Trough. At Site C0002, the sediments were obtained from the depths between 200 - 500 mbsf (meters below seafloor), 900 - 940 mbsf, and 1100 - 1120 mbsf. Porewater was analyzed after squeezing using the standard onboard analytical procedures. Porewater from the sediments at 1111 mbsf was extracted using GRIND method after testing the appropriateness of this method. Here, the tested results of GRIND method and porewater chemistry of the Site C0002 are described.

GRIND method was originally developed for the sediments and rocks, for which standard squeezing (standard method, hereafter) did not provide adequate volumes of pore fluid. However, it would also be applicable to extract the porewater from small volume of the sediment samples. 40 g sediment was ground with 5 mL ultrapure water in a ball mill, and the water was squeezed using the standard method. As results, chlorinity was comparable (RD <2%) with that obtained using the standard method, and major ions, Br, sulfate, Na, Mg and Ca, and minor ions, B, Li and Sr are useful if 5-10 % difference of concentration from that obtained using the standard method can be acceptable. Among the major ions, K concentration was always ca. 20 % higher and phosphate ca. 15 % lower than those obtained using the standard method. Most of the minor and trace metal concentrations (Fe, Mn, Si, Ba, V, Cu, Zn, Rb, Mo, Cs, Pb, U) obtained using the GRIND method were much larger than those obtained using the standard squeezing method, probably due to extraction of adsorbed elements onto the sediment particles via desorption in addition to the dissolved components. Thus, the GRIND method cannot be applicable for the minor and trace metals except Li and Sr, of which RD are <10%.

At Site C0002, continuous profiles of porewater chemistry are obtained down to 1050 mbsf combining the results of previous and present expeditions. 10 samples from the above former two intervals were analyzed using both standard squeezing and GRIND methods, and the deepest porewater chemistry was obtained for the sediment at 1111 mbsf only using the GRIND method.

Chlorinity decreased from 550 mM of the porewater from the seafloor sediment to 350 mM down to 400 mbsf, increased to 480 mM down to 800 mbsf, then decreased to 450 mM at 1111 mbsf. The boundary between Units I (upper forearc basin sediment) - II (lower forearc sediment) and II-III (basal (starved) sediment) are 140 and 830 mbsf respectively. The depletion of chlorinity occurs in Unit II due to the contribution of freshwater from gas hydrates. Similar depletion of the concentration in the Unit II are observed for Na, K, Mg, B, Sr, Ba and Rb. Alkalinity, phosphate and ammonium increase in Unit I and decrease in Unit II, suggesting that those are released via decomposition of organic matters and then removed by precipitation (P) and decomposition (ammonium). Br increases in Unit I due to decomposition of biogenic material (probably algae), similar to P and ammonium, while in and below Unit II, it changes in accordance with Cl. Ca and Li increase in Unit II probably due to dissolution of biogenic and/or detrital minerals. In Unit IV (upper accretionary prism), chlorinity alkalinity and Na decreased, while Ca increased with depth in Unit IV. Variations of each element correspond to the lithological units, suggesting that the porewater chemistry is partly controlled by the interaction between porewater and sediments including microbiology of each sediments, which comprise different mineralogy and chemistry.

キーワード: 間隙水, ガスハイドレート, 熊野海盆, グラインドメソッド
Keywords: porewater, gas hydrate, Kumano Basin, GRIND method

JFAST: Drilling to the Plate Boundary to Investigate the Large Slip of the 2011 Tohoku-oki Earthquake

JFAST: Drilling to the Plate Boundary to Investigate the Large Slip of the 2011 Tohoku-oki Earthquake

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The 2011 Tohoku-Oki earthquake produced the largest fault slip ever recorded for an earthquake, up to 50 meters on the shallow portion of the subduction megathrust. This region of the plate boundary was not expected to have large slip during earthquakes, so the huge co-seismic displacements and resultant devastating tsunami were a shocking surprise to the seismological community. In response to the earthquake, the Integrated Ocean Drilling Program (IODP) rapidly planned and carried out Expedition 343 (JFAST) to investigate the rupture mechanisms and physical conditions that produced the large slip. During April/May and July 2012, three boreholes located at a site close to the Japan Trench about 90 km east of earthquake epicenter, successfully reached the plate boundary fault at depths of about 820 meters below seafloor. These boreholes enabled geophysical logging, core sampling and installation of a temperature observatory in the vicinity of the fault zone.

Analyses of core samples obtained from the plate boundary decollement show a narrow zone (less than 5 meters) of highly deformed fabric in a clay layer. The pronounced localization of deformation within this material suggests coseismic weakening during past earthquakes. Estimates of the level of dynamic friction during the recent earthquake are expected from the temperature monitoring that was installed during the expedition. Also, laboratory experiments on the retrieved core samples will give estimates of the frictional properties of the fault rocks. Combining investigations of the physical, chemical, and mechanical properties of the fault zone along with determinations of the local stress state from borehole breakouts, will provide information to help explain the very large slip that occurred during the earthquake.

キーワード: JFAST, Tohoku-oki earthquake, IODP, Sea-floor Drilling, Fault Friction, Japan Trench

Keywords: JFAST, Tohoku-oki earthquake, IODP, Sea-floor Drilling, Fault Friction, Japan Trench

日本海溝前弧域のプレート境界域生命圏 Subseafloor biosphere in plate boundary of Japan Trench forearc

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IODP 第 343 次航海は、2011 年 3 月 11 日に起きた「東北地方太平洋沖地震」における大規模な海底および海底下での変動や巨大津波発生の原因となった断層滑りやそのメカニズムを明らかにすることを目的に実施された。その最重要科学目的は、実際に滑った断層を特定すること、そしてその断層を含むコアサンプルを回収し断層における物理学的特性や地質学的諸性質を解明すること、である。一方で IODP 第 343 次航海にはもう一つ重要な科学目的があった。それは、地震（すなわち断層滑り）に伴う地球化学プロセスによって支えられた地震生命圏の存在を検証し、地震による海底下微生物群集へのインパクトを明らかにすることであった。

掘削同時検層の結果から、東北地方太平洋沖地震時に滑ったと考えられる断層として、海底下 820m 付近のプレート境界、海底下 720m 付近の破砕帯、そして全く目立たない海底下 700m 付近の破砕帯の 3 つの候補が考えられた。地震前後の地震波探査による海底下構造の変化や地質学的な予備分析から、乗船研究者の間では、海底下 820m 付近のプレート境界こそが東北地方太平洋沖地震時の最大滑り断層である可能性が高いと考えられているが、まだその証拠は得られていない。しかし、掘削コアの間隙ガスの分析からは、海底下 700m 付近の破砕帯において水素ガスの極めて劇的な濃度異常が認められ、「断層滑り水素発生」の可能性も考えられる。時間分解能を持った断層滑りの物理・化学的証拠としては、温度か水素ガスしか考えられず、2013 年の温度計測の結果と合わせて断層の特定に決着がつかうかもしれない。

一方、C0019 サイト掘削では、海底下 680-840m に至るプレート境界を貫通するコア試料が得られた。これまでの ODP-IODP の歴史上沈み込み帯プレート境界を貫通した例は、パルパドス海溝、コスタリカ海溝、南海トラフの前弧域だけであり、日本海溝前弧域のプレート境界貫通は 4 例目（サイトとして 5 例目）となる。しかも地球化学的特性だけでなく微生物学的研究が行われるのは初めてである。そのコア試料を用いたガス組成や間隙水化学プロファイルの分析から、全く新しいプレート境界域における地球化学プロセスや微生物活動の兆候が示されつつある。本講演では、その「プレート境界域における熱水循環と海底下生命圏の存在様式」について議論したい。

キーワード: 海底下生命圏, プレート境界, 前弧, 断層すべり, メタン, 水素

Keywords: subseafloor biosphere, plate boundary, forearc, fault slipping, methane, molecular hydrogen

海洋堆積物深部のアミノ酸の生物地球化学的動態：化合物レベル窒素同位体組成とD/L比からの制約

Biogeochemical dynamics of amino acids in deep-subsurface marine sediments

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Amino acids in sediment pore waters are key compounds in metabolic activities of sedimentary microbes and in remineralization of carbon and nitrogen. However little is known about their biogeochemical dynamics (e.g., sources and transformation processes) in deep-subsurface sediments.

As a new approach to constrain the sources of dissolved amino acids in sediment pore waters, this study reports and compares compound-specific d15N and enantiomer ratio (%D) of total hydrolysable amino acids (THAA) in solid phase and dissolved hydrolysable amino acids (DHAA) in pore waters from the same sediment samples. Samples were collected from deep-subsurface sediments (down to 172.9 m below seafloor) at the Sagami Trough (NW Pacific) during D/V Chikyu cruise CK09-03 (Expedition 905: December 2009).

In the sediments deeper than 9 mbsf, average %D values of DHAA were 25.9% in alanine, 24.8% in aspartic acid, 11.3% in serine, and 16.3% in glutamic acid, and average %D changes from THAA were +15.3% in alanine, -0.4% in aspartic acid, -8.1% in serine, and 4.6% in glutamic acid. Compound-specific d15N analysis showed that d15N values of alanine are higher in the DHAA than the THAA and that d15N values of glycine and glutamic acid are similar between the two fractions (d15N-DHAA - d15N-THAA = +5.8 permil, +1.9 permil, -0.3 permil, respectively). These results suggest that the DHAA fractions have different d15N and %D signatures from the THAA fractions, and that hydrolysis of the THAA could not be the sole source of the DHAA. Alternatively, the d15N and %D signatures of DHAA are consistent with the idea that in situ release of proteinaceous materials from sedimentary microbial biomass (such as peptidoglycan of Gram-positive bacteria) is an important source of DHAA. This suggests that recycle of dissolved amino acids by microbes would be an important process during amino-acid degradation and microbial metabolism in the deep-subsurface sediments.

キーワード: 海底下生命圏, 有機物, 窒素同位体, アミノ酸, バクテリア

Keywords: Deep biosphere, Organic matter, Nitrogen isotope, Amino acids, Bacteria

下北八戸沖石炭層生命圏掘削調査 (IODP 第337次研究航海) の概要と展望 Exploration of the Deep Coalbed Biosphere off Shimokita (IODP Expedition 337): Overview and Perspectives

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Among the least characterized Earth systems that can be addressed by scientific ocean drilling are deeply buried hydrocarbon reservoirs in sediments along continental margins. In particular, the role of seafloor microbial ecosystems for the formation and fate of these reservoirs remains poorly understood. The IODP Expedition 337 was the first expedition dedicated to seafloor microbiology that used riser-drilling technology on the drilling research vessel CHIKYU. The drilling site C0020 is located in a forearc basin formed by the subduction of the Pacific Plate off the Shimokita Peninsula at a water depth of 1,180 meters. During Expedition 337, we penetrated a 2.466 meters-deep sedimentary sequence with a series of coal (i.e., lignite) layers at around 2 km below the seafloor. Hole C0020A is currently the deepest hole in the history of scientific ocean drilling. Riser drilling at Site C0020 provided an unprecedented record of dynamically changing depositional environments in the former forearc basin off the Shimokita Peninsula during the late Oligocene and Miocene. This record is comprised of a rich diversity of lithological facies reflecting environments ranging from warm-temperature coastal back-swamps to cool water continental shelf. The use of riser-drilling technology in very deep sediments created both unique opportunities and new challenges the study of seafloor life. Downhole logging operations yielded data of unprecedented quality that provide a comprehensive view of sediment properties and water mobility at Site C0020. Onboard analysis of gas chemistry and isotopic compositions provided the first indication of the existence of a seafloor biosphere in deep coalbed horizons. Expedition 337 also provided a test ground for the use of riser drilling technology to address geobiological and biogeochemical objectives and was therefore a crucial step toward the next phase of deep scientific ocean drilling.

キーワード: 統合国際深海掘削計画第337次研究航海, 地下生命圏, 地下深部炭素循環
Keywords: IODP Expedition 337, Deep Biosphere, Deep Carbon Cycle

下北沖三陸沖堆積盆、IODP C0020 サイトにおけるコアおよびカッタイングスの物理特性

Physical properties of sediment cores and cuttings in Sanrikuoki Basin at Site C0020, IODP Expedition 337

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Physical properties which should be affected by local diagenesis process are very important to evaluate sedimentary formations below the seafloor. A series of physical properties measurements were carried out in laboratory on D/V Chikyu, using core samples and cuttings from a riser drill hole at Site C0020 in northern Sanrikuoki Basin off Shimokita Peninsula. As routine, measurements with multi-sensor core logger were performed, moisture and density (MAD), P-wave velocity and electric resistivity were measured using discrete core samples, and thermal conductivity was measured on half cores. Cuttings recovered by the riser drilling system were also applied to MAD analysis, being separated into four categories: original bulk and sieved size categories of >4.0, 1.0?4.0, and 0.25?1.0 mm. Cubic samples cut off from the cuttings were applied to the P-wave velocity analysis and the electrical impedance analysis. In addition, anelastic strain recovery analysis was made on the vessel using some whole-round cores and vitrinite reflectance analysis was also performed on some coaly samples. As a result of the MAD analysis, porosity of siltstone, sandstone, and shale gradually decreased to the greater depth. Porosity corresponds to lithologic variation. For example, porosity of carbonate-cemented sandstone and siltstone has much lower values than non-cemented sandstone and siltstone. The carbonate-cemented rocks have also higher thermal conductivity than the others, and indicate specific CT values on X-ray computed tomography analysis. The cuttings also show a gradual decrease in porosity but have generally higher values than the core samples. Discrete core samples are likely more representative of in-situ porosity than cuttings. Vitrinite reflectance indicates basically low maturity.

キーワード: 物性, コア, カッタイングス, 石炭, IODP, Expedition 337

Keywords: physical properties, core, cuttings, coal, IODP, Expedition 337

NanoSIMS およびセルソーティングによる南太平洋環流域堆積物試料中の微生物代謝活性解析

Coordination of NanoSIMS and cell sorting to reveal microbial metabolic activity in sediment of the South Pacific Gyre

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The South Pacific Gyre (SPG) is characterized as the most oligotrophic open ocean environment. The sediment is rich in oxygen but poor in energy-sources such as reduced organic matter, and hence harbors very low numbers of microbial cells in relatively shallow (~20 meters below the seafloor) subseafloor sediment (D'Hondt et al., 2009; Kallmeyer et al., 2012). In such an energy-limited sedimentary habitat, only a small size of microbial community persists living functions with extraordinary low oxygen-consumption rate (Roy et al., 2012). However, because of the current technological limitation, deeper habitats of the SPG remain largely unknown.

During IODP Expedition 329, sediment samples recovered from whole sedimentary column down to the sediment-basement interface were successfully recovered, providing an unprecedented opportunity to tackle some technological challenges to clarify if indigenous life is present, and if any, what is the microbiological and biogeochemical characteristics in such extreme environments.

To evaluate small biomass in the SPG sedimentary habitat accurately, we made modification on a cell separation technique. Cell recovery ratio was monitored with an image-based cell enumeration technique (Morono et al., 2009). The control samples were prepared by mixing *E. coli* cells in sterilized sediment. Increasing sediment volume resulted in lower recovery of microbial cells. Cell recovery rates in the SPG sediment samples, which contain small zeolitic mineral grains, were generally lower than those in other oceanographic settings (i.e., organic-rich continental margin sediments). To gain cell recovery rate, we examined multiple density gradient layers. After multiple modifications, we could increase cell recovery rate up to 80-95%. In addition, cell enumeration using flow cytometry showed consistent numbers with microscopy-based cell count.

We then used the above-mentioned technique for deciphering eco-physiology of microbial life in the SPG sediments. During Expedition 329, we have initiated incubation with stable isotope-labeled substrates such as bicarbonate, glucose, amino acids, acetate, and ammonium (Morono et al., 2011) under the (micro-)aerobic condition. One of the critical technological challenges in this project is to harvest low concentrations of sedimentary microbial cells for the single-cell-based microbiological analysis. Using a new cell separation technique and sorting, we successfully sorted enough number of microbial cells in small spots on the membranes (i.e., 10^3 to 10^5 cells per spot). Preliminary results from NanoSIMS analysis showed incorporation of substrates after 1.5-years incubation of microbial cells in subseafloor sediments of the SPG.

キーワード: NanoSIMS, 海底下生命圏, 南太平洋環流域, 安定同位体

Keywords: NanoSIMS, Subseafloor biosphere, South Pacific Gyre, Stable Isotope Probing

貝形虫化石群集解析に基づくニュージーランド沖カンタベリー堆積盆地における鮮新 - 更新世の海水準変動の復元 Plio-Pleistocene sea-level changes in Canterbury Basin, off New Zealand based on fossil ostracode assemblages

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後期鮮新世から前期更新世の詳細な海水準変動を明らかにするため、ニュージーランド沖カンタベリー堆積盆地大陸棚上のIODP(Integrated Ocean Drilling Program)サイトU1353(水深85m), U1354(水深113m), U1351(水深122m)で高時間分解能の貝形虫化石の群集解析を行った。U1353, U1354, U1351の鮮新-更新統からそれぞれ40試料, 80試料, 18試料を選択した。さらに調査地域における近年の貝形虫群集を明らかにするため、陸棚3サイトと陸棚斜面サイト(水深344m)それぞれのコアトップ試料も用いた。少なくとも70属178種の貝形虫種が同定され、その多くが現在もニュージーランド周辺の大陸棚に生息しているものであった(例えばSwanson, 1979)。そのうち、貝形虫化石を40個体以上産出した103試料と、いずれかの試料で3.5%以上の産出割合を占めた78タクサの情報を用いてQモード因子分析を行った。その結果、第6因子までで全分散の69.3%が説明でき、各因子で因子得点の高いタクサの生息域に基づいて各因子の古水深範囲を推定すると次のようになった: 第1因子, 内側-中部陸棚(40-80m); 第2因子, 中部-外側陸棚(80-200m); 第3因子, 中部-外側陸棚(50-180m); 第4因子, 中部-外側陸棚(75-125m); 第5因子, ラグーンもしくはエスチュアリーおよび内側陸棚(0-50m); 第6因子, 外側陸棚(ca. 200m)。Qモード因子分析結果と岩相情報に基づいて、古水深変動が復元できた。少なくともU1353では7回, U1354では14回, U1351では3回の、およそ25-115mの変動幅を持つ海進-海退サイクルが確認された。これらの古水深変動は、サイクルの頻度や信頼性の高い微化石生層序、そして不整合を用いることで、Lisiecki & Raymo (2005)の海洋酸素同位体比曲線と対比することができた。いくつかの高海水準期と低海水準期が酸素同位体ステージM2, G10, G10-7, G6-4, G3, G2, G1, 104, 103, 102, 101, 100, 99, 63, 62, 61, 60, 59, 43, 42, 41そして40と対応していると考えられる。さらに調査地域の堆積盆沈降速度と堆積物供給速度は互いに相殺し合っているため、これらの古水深変動は海水準変動を強く反映している。

キーワード: IODP Exp.317, 貝形虫群集, 鮮新-更新世, ニュージーランド, 海水準変動

Keywords: IODP Exp.317, Ostracode assemblage, Plio-Pleistocene, New Zealand, Sea-level change

IODP Exp.318 U1357A コアへの化合物レベル放射性炭素年代測定の適用 Application of compound-specific radiocarbon dating to IODP Exp.318 U1357A core

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Radiocarbon (¹⁴C) dating of Antarctic margin sediments is difficult, because these sediments generally lack calcareous foraminifera. Moreover, the sediments are subjected to contamination of relict organic matter eroded from the Antarctic continent (e.g. Ohkouchi *et al.*, 2003), leading to older radiocarbon ages of bulk sedimentary organic matter. Compound-specific (CS) ¹⁴C dating targets short-chain (C₁₄, C₁₆ and C₁₈) fatty acids isolated from sediments. These compounds are derived from various organisms, but they are little contained in relict organic matter because the decomposition rate is relatively fast (Ohkouchi *et al.*, 2003). Therefore, CS ¹⁴C dating is unaffected by relict organic matter from Antarctic continent (Ohkouchi and Eglinton, 2008) and can provide accurate age. The aim of this study is establishment of accurate age model of U1357A core using CS ¹⁴C dating. U1357A core (66°24.7991'S, 140°25.5008'E; 1014.9 m water depth; 186.6 m core length) was drilled at Adelie Basin located on the continental shelf off Wilkes Land, Antarctica during Integrated Ocean Drilling Program (IODP) Expedition 318 by D/V JOIDES Resolution (Expedition 318 Scientists, 2011). Lithology of this core is diatom ooze with lamination. We measured CS ¹⁴C ages from 13 samples. Target compound is mainly C_{16:0} fatty acid. In some samples, C_{16:1} fatty acid and cyclopheophorbide a were used for CS ¹⁴C dating. Samples were processed chemically using the protocol of Ohkouchi *et al.* (in review). Purification of target fatty acids uses high performance liquid chromatography - evaporative light scattering detector (HPLC-ELSD) system in JAMSTEC. Purification of CO₂ and graphitization were undertaken by dedicated high vacuum line of University of Tokyo (Yokoyama *et al.*, 2010), and the measurement of ¹⁴C was conducted by Accelerator Mass Spectrometry (AMS) at University of Tokyo (Matsuzaki *et al.*, 2007). ¹⁴C ages were calibrated using CALIB 6.02 and the Marine09 calibration curve (Reimer *et al.*, 2009) with a reservoir age of 1144 +/- 120 years (Hall *et al.*, 2010). We successfully obtained 13 CS ¹⁴C ages. CS ¹⁴C ages showed the deepest samples is last glacial period (21,957 +/- 260 cal. BP) and other samples are Holocene (9,663 +/- 190 cal. BP to modern). This suggests that; i) there is hiatus between 176.65 meters below seafloor (mbsf) and 181.66 mbsf of this core, ii) this core has a continuous record of the past ~10,000 years.

キーワード: 化合物レベル放射性炭素年代測定, 南大洋, アデリー海盆, 完新世, 統合国際深海掘削計画

Keywords: compound-specific radiocarbon dating, Southern Ocean, Adelie Basin, Holocene, IODP

IODP Expeditions 342 ニューファンドランド沖掘削航海の成果速報

The preliminary results on drilling Paleogene drift sediments off Newfoundland, IODP Expedition 342

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In June and July 2012, the R/V JOIDES Resolution for IODP Expedition 342 drilled the seafloor off Newfoundland. This cruise successfully recovered high quality cores from nine sites (U1403 to U1411) across a depth transect ranging from 3022 to 4944 m water depth. The recovered sedimentary sequence consists of carbonate clay to oozes, recording Cretaceous to Miocene climatic and oceanographic events, including the K/Pg boundary, the Paleocene/Eocene thermal maximum, Middle Eocene climatic optimum, and the Eocene-Oligocene transition.

The shipboard biostratigraphy and magnetostratigraphy provide high-quality age models of the sediments. The models are consistent and correlative between the cores. In all the sites, Pleistocene foraminifer ooze caps the Miocene clay and Eocene calcareous ooze. The pre-Pliocene sediments are dated to 102 to 15 Ma. Sedimentation rates indicate rapid accumulation in middle Eocene (47-40 Ma; > 3 cm/k.y.) and in the Oligocene-Miocene sediments (26-22 Ma; >10 cm/k.y.).

The Expedition aims to evaluate changes in the carbonate compensation depth (CCD) through the Eocene hyperthermal events. Shipboard analytical results of the recovered sediments allow us to reconstruct the history of the CCD in the North Atlantic. Carbonate contents in the sediments suggest the CCD was deeper than ~4.5 km depth through the late Cretaceous to the early Eocene and as deep as ~4.5-3.5 km after the early Eocene.

Another main objective of the expedition was to obtain high deposition rate records of the transition from the early Eocene climatic optimum ~50 Ma, through the development of northern hemisphere ice sheets in the Oligocene and Miocene. We recovered expanded records of the middle Eocene that include numerous carbonate accumulation events that are possibly correlative with those in the equatorial Pacific. In the early Oligocene sediments, we found sand-sized lithics, possibly correlating with expansion of ice sheets around Greenland. We also recovered an exceptionally expanded record of the Oligocene/Miocene boundary. Many of the mid-depth sites display well developed lithologic cycles that likely reflect astronomical forcing. Other objectives were to understand overturning of deep-water masses in the North Atlantic and to tune bio- and magneto-stratigraphic events astronomically. We found exceptionally well-preserved calcareous and siliceous microfossils in the sedimentary succession of the cores. The biostratigraphy, magnetostratigraphy, cyclostratigraphy, and geochemistry of the microfossils will provide high-quality data for understanding North Atlantic paleoceanography and calibrating geochronology of the Eocene and Oligocene.

キーワード: IODP Exp 342, 古第三紀, 古海洋, 北大西洋

Keywords: IODP Exp 342, Paleogene, paleoceanography, North Atlantic

前~中期始新世の低緯度放散虫群集 IODP Leg 320 (PEAT I) の成果報告 Early and Middle Eocene radiolarian assemblages in the eastern equatorial Pacific Ocean (IODP Leg 320 Site U1331)

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本研究の目的は、前期始新世から中期始新世における低緯度放散虫の群集解析を行い、海洋表層の古海洋環境を復元することである。研究試料には統合国際深海掘削計画 (IODP) によって掘削された 1500 万年間にわたる堆積物を使用した。掘削地点は東部赤道太平洋の U1331 地点である。本研究で使用する堆積物は、主に放散虫軟泥より成り、中期始新世においては石灰質堆積物が挟在する。これらのコア試料から合計 65 試料を採取し、Sanfilippo et al. (1985) に準じた方法で試料処理を施した後、検鏡用のプレパラートを作成した。水洗には 63 μ m 目の篩を用いた。本研究で用いたコア試料にはほぼ連続的な古地磁気層序が設定されている。本研究で認められた放散虫化石帯・基準面は以下に示す地磁気極性年代尺度に対応させて年代値を計算した：C18n から C19n までは Palike et al. (2006)；C20n から C23n までは Cande and Kent (1995)。

本研究では合計 89 の放散虫基準面を認定した。これらの群集は、太平洋低緯度の標準微化石層序の示準種を含むので、Sanfilippo and Nigrini (1998) によって提唱された化石帯区分を使用することができ、U1331 地点のコアを RP8 から RP16 の 9 化石帯に区分した。本試料から産出した優占種には、温暖種に属する *Stylosphaera coronata coronata*, *Phormocyrtis embolum*, *Dendrospyris didiceros*, *Phormocyrtis cf. proxima*, *Thyrsoyrtis triacantha* が含まれ、さらに寒冷種に属する *Lophocyrtis aspera* group, *Lithocyclia ocellus* group, *Hexacontium* sp. A, *Hexacontium* sp. B, *Thecosphaerella glebulenta*, *Lithelius* sp. A が含まれる。

放散虫群集に基づくと、前期始新世から中期始新世にかけて 2 つの温暖期と 6 つの寒冷期が認められた。これらの寒冷事件は南大洋の底生有孔虫の酸素同位体比から認められた 6 つの寒冷事件と時期的に一致する。海洋表層の生物生産性を示す放散虫生産性とオパール量の増大は、中期始新世の寒冷期と同時期に起こったため、低緯度太平洋の寒冷化と密接に関連していると考えられる。

キーワード: 赤道太平洋, 中期始新世, 放散虫, 統合国際深海掘削計画

Keywords: Equatorial Pacific Ocean, Middle Eocene, Radiolaria, IODP

東部赤道太平洋 IODP Site U1338 における浮遊性有孔虫年代指標種 *Paragloborotalia siakensis* (LeRoy) の分類学的検討とサイズ変化
Taxonomic study of the Miocene species *Paragloborotalia siakensis* at IODP Site U1338 in the Eastern Equatorial Pacific

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Paragloborotalia siakensis (LeRoy) は、その絶滅が Blow (1969) の N.14 帯の上限を定義する重要な年代指標種である。しかし、Bolli and Saunders (1982) は、多数の個体の検討により本種を *Globorotalia mayeri* (Cushman and Ellisor) の新参シノニムとした。Berggren et al. (1995) の年代尺度でもこの観点に立ち、N.14 帯の上限を“*Neogloboquadrina mayeri*”の産出上限として定義している。最近、Zachariasse and Sudijono (2012) は、原記載地のごく近傍で得られた多数の個体および完模式標本について電子顕微鏡による検討を行い、*P. siakensis* は *G. mayeri* と殻表面構造や縫合線の特徴等で区別できることを示した。したがって、従来年代指標種 *P. siakensis* または *G. mayeri* とされてきた種について、その産出の意義を再検討する必要がある。

P. siakensis および *G. mayeri* とされてきた種は、東部赤道太平洋に分布中心をもつとされる（例えば Kennett et al., 1985）。本研究では、東部赤道太平洋で掘削された IODP Site U1338 の試料を用いて *P. siakensis* の分類学的検討を行った。

Site U1338 で *P. siakensis* が多産する 11~15Ma の年代区間から、約 1Ma 間隔で 5 層準を選び、電子顕微鏡写真による検討を行った結果、検討した 382 個体については *P. siakensis* の完模式標本に比較された。一方で、*G. mayeri* の完模式標本に明瞭に比較される個体は認められなかった。縫合線の湾曲度や最終旋回の室数といった形質を数値化して散布図を作成したところ、*P. siakensis* の完模式標本の形態は Site U1338 における形態空間の端部に含まれることが示された。

上記の年代区間から 15 層準を選び、*P. siakensis* の殻サイズ（最大径）を測定して頻度分布を調べた。その結果、アルケノンおよびバルク炭酸塩の酸素同位体比で示された水温低下期（Miller et al. 1991 の南極氷床拡大期 Mi3 および Mi4; Rousselle et al., 2013）で顕著な殻サイズの減少イベント（dwarfing）が認められた。浮遊性有孔虫のいくつかの種群では絶滅直前に環境ストレスによって dwarfing を示すことが知られている（Wade and Olsson, 2009）。本研究による *P. siakensis* の dwarfing は、寒冷化による温度躍層の上昇により *P. siakensis* の生息環境が狭められたことに対応している可能性がある。

キーワード: 浮遊性有孔虫, 統合国際深海掘削計画, 東部赤道太平洋, 生層序, 分類

Keywords: planktonic foraminifera, Integrated Ocean Drilling Program, Eastern Equatorial Pacific, biostratigraphy, taxonomy

Changes in coral assemblages in the Great Barrier Reef since the last glaciation Changes in coral assemblages in the Great Barrier Reef since the last glaciation

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Drilling into submerged reef structures along the shelf edge of the Great Barrier Reef was carried out during IODP Expedition 325 with the purpose of reconstructing sea level and environmental changes since the Last Glacial Maximum (LGM) and analyzing their impact on reef communities and reef growth. A total of 34 boreholes were drilled between 42 and 167 mbsl at 17 sites along four transects at three geographic locations (Hydrographers Passage, Noggin Pass, and Ribbon Reef). Two basic chronostratigraphic units can be recognized: a last glacial to deglacial reef sequence overlying older Pleistocene reefal and non-reefal deposits. The former varies in thickness from ~5.5 m to ~34 m and consists primarily of coralgal boundstone with various proportions of microbialite. In this study we analyze the variations in coral assemblages since the last glaciation. Exp. 325 cores show that diverse corals, including Faviids, *Acropora*, *Montipora*, and *Porites*, were growing during the last glacial period on the shelf edge. Their distribution was limited to the most distal boreholes during the LGM lowstand. The subsequent deglaciation saw the development of a shallow-water coral assemblage dominated by encrusting to massive *Isopora* and branching *Acropora* and *Seriatopora* as sea level rose. The tops of distal boreholes are marked by a shift to deeper assemblages dominated by encrusting *Porites* and *Montipora* reflecting reef drowning and the formation of submerged reef terraces. As sea level kept rising, a shallow-water *Isopora*-dominated assemblage re-established further upslope and formed a barrier reef before drowning in turn.

キーワード: IODP Expedition 325 GBREC, Great Barrier Reef, Corals, Last Glacial Maximum, Reef initiation, Reef demise
Keywords: IODP Expedition 325 GBREC, Great Barrier Reef, Corals, Last Glacial Maximum, Reef initiation, Reef demise

石灰質ナノ化石群集に基づく後期新生代の北西太平洋および東インド洋の古海洋復元

Late Cenozoic paleoceanography in the northwestern Pacific and eastern Indian oceans based on calcareous nannofossils

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北西太平洋および東インド洋で掘削された ODP Hole 1210A, 762B の深海コアを用いて, 石灰質ナノ化石群集変化に基づいた中新世から更新世の古海洋変遷の復元を行った。コッコリス生産量, 下部透光帯種とされる *Discoaster* 属の相対頻度, *Reticulofenestra* 属のコッコリスサイズ分布は良い相関関係を示し, 中新世から更新世の海洋表層の成層化または混合に伴う栄養塩の変化を反映しているとされている。低いコッコリス生産量, *Discoaster* 属の多産, 小型の *Reticulofenestra* 属の多産は, 海洋表層の富栄養化, すなわち浅い温度躍層と栄養塩躍層を示す。逆に, 高いコッコリス生産量, *Discoaster* 属の減少, 大型の *Reticulofenestra* 属の多産は, 海洋表層の貧栄養化, すなわち深い温度躍層と栄養塩躍層を示唆する。この関係に着目して, 東インド洋および北西太平洋の石灰質ナノ化石群集変化を検討した。その結果, 両海域とも 9 から 13 Ma には海洋表層は温暖で貧栄養な水塊が広がっていたが, 9 Ma 以降に富栄養化したことが判明した。しかし, *Reticulofenestra* 属のコッコリスサイズ分布に注目すると, 北西太平洋では 8.1 Ma, 6.5 Ma, 5.0 Ma に段階的な富栄養化があったのに対し, 東インド洋では 8.9 Ma に海洋表層が急激に富栄養化した。よって, 両海域は, 9 Ma 以降富栄養化したものの, その過程と時期は異なることが明らかとなった。

キーワード: 石灰質ナノ化石, 新生代, 富栄養化, コッコリスサイズ

Keywords: Calcareous nannofossil, Cenozoic, Eutrophication, Coccolith size

ルイビル海山列, Canopus 海山から採取されたポストクルーズ試料の古地磁気伏角 (IODP Expedition 330)

Paleoinclinations of post-cruise samples from Canopus Guyot of the Louisville seamount trail (IODP Expedition 330)

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IODP Expedition 330 sampled volcanic basement rocks at five sites on four guyots along the northwestern part (late Cretaceous to early Eocene age) of the 4300-km-long Louisville seamount trail. Shipboard paleomagnetic data were used for the calculation of paleolatitudes of each guyot, and we (Exp. 330 shipboard scientists) concluded that the Louisville hotspot has remained within 3-5° of its present-day latitude of about 51°S between 70 and 50 Ma (Koppers *et al.*, 2012, *Nature Geoscience*, **5**, 911-917). In order to determine more reliable paleolatitude estimates, a number of discrete rock samples were collected for a post-cruise research. In this presentation, we will present the paleolatitude of Canopus Guyot (ca. 74 Ma) that was determined from analysis of post-cruise paleomagnetic data of Site U1372. In our post-cruise study, paleomagnetic measurements and stepwise demagnetizations (alternating-field and thermal methods) were conducted in magnetically shielded rooms, and characteristic remanent magnetization components were used to calculate lava unit-mean paleoinclinations. On the basis of inclination-only statistics of 20 lava unit-means, we obtained a paleolatitude of ca. 45°S for Canopus Guyot, which is statistically indistinguishable from the paleolatitude estimate (ca. 43°S) for this guyot determined from shipboard discrete sample data. The paleolatitude for Canopus is low compared to the present latitude of the hotspot, implying possible southward motion of the Louisville hotspot before 70 Ma.

キーワード: ルイビル海山列, ルイビル・ホットスポット, Canopus 海山, IODP 第 330 次航海, 古緯度, 古地磁気伏角

Keywords: Louisville seamount trail, Louisville hotspot, Canopus Guyot, IODP Expedition 330, paleolatitude, paleomagnetic inclination

IODP Exp. 345 ヘスディーブ海盆深成岩掘削速報 Preliminary report for IODP Expedition 345 Hess Deep Plutonic Crust

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IODP Exp. 345 ヘスディーブ海盆深成岩掘削が、2012年12月13日?2013年2月12日の間に行われたので、船上での観察結果概要を報告する。本航海の主な目的は、海洋地殻形成に関する2つの相対するモデル(ガブロ・グレイシア・モデルとシートシル・モデル)を検証することである。海洋下部地殻の形成過程の違いは、海洋プレートの冷却過程や熱水循環パスに影響することから、海洋プレート進化過程を解明する上で重要である。

本航海では、1サイト、16掘削孔(Holes U1415A-P)で掘削し、7掘削孔からコアが採取された。コア回収率は20%以下と低かったものの、組織や鉱物組成の異なる初生的な深成岩が採取され、海洋プレートの形成・進化を知る上で、重要な試料となるであろう。採取された岩石は多い方から、かんらん石はんれい岩、トロクトライト、はんれい岩、斜方輝石を含むはんれい岩類(ガブロノーライト等)、少量の玄武岩類(含むドレライト)である。これらの岩石コア試料は、オフィオライトの下部地殻セクションや、マフィック貫入岩体にしばしば見られるものと、組織や種類が非常に類似している。

キーワード: IODP Exp. 345, Hess Deep, Oceanic lower crust, Gabbro

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