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オスミウム同位体記録から見る中新世～鮮新世の地中海の姿とメッシニアン塩分危機
Miocene to Pliocene osmium isotopic record of Mediterranean sediments: new insights into the Messinian Salinity Crisis

黒田 潤一郎 [1*] ; Jimenez-Espejo Francisco[1] ; 野崎 達生 [1] ; 吉村 寿紘 [1] ; 大河内 直彦 [1]
KURODA, Junichiro[1*] ; JIMENEZ-ESPEJO, Francisco[1] ; NOZAKI, Tatsuo[1] ; YOSHIMURA, Toshihiro[1] ; OHKOUCHI, Naohiko[1]

[1] 独立行政法人海洋研究開発機構
[1]JAMSTEC

In the late Miocene the Mediterranean Sea experienced a salinity crisis and formation of thick sequences of evaporites precipitated across the basin (Messinian salinity crisis). In this presentation we briefly review the Messinian salinity crisis, and report Os isotopic ratio from drilled cores in the Mediterranean to investigate hydrological evolution in the Mediterranean Sea. Pliocene sediments at all sites show Os isotopic ratios close to that of the coeval ocean water. This indicates that the Mediterranean was connected to the North Atlantic. Evaporitic sediments deposited during the late Miocene however, have lower isotopic ratios than coeval ocean water values. Os isotopic ratios of the pre-evaporite sediments in the western Mediterranean are almost identical to that of the coeval ocean water. In contrast, equivalent sediments from the Florence Rise have significantly lower isotopic values. The offset of Mediterranean evaporite Os isotopic ratios is attributed to limited exchange with the North Atlantic during the Messinian Salinity Crisis. The source of unradiogenic Os is likely to be weathering of ultramafic rocks (ophiolites) cropping out in the Mediterranean's drainage basins. Our Os isotopic record, that suggests limited exchange of seawater between the North Atlantic and Mediterranean Sea, is consistent with the previous Sr isotopic records. The offset in the Os ratio on the eastern Mediterranean Sea is attributed either to limited water exchange between eastern and western Mediterranean, or to local effects associated with exhumation of ophiolites around the eastern Mediterranean Sea. In the presentation, we also introduce a drilling project entitled 'Uncovering a salt giant', that is proposed by an international scientific community.

キーワード: メッシニアン塩分危機, オスミウム同位体
Keywords: Messinain Salinity Crisis, Os isotopes

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アラスカ湾陸棚縁辺部（IODP Exp. 341 Site U1419）の過去6万年間の珪藻化石と氷床堆積物供給変遷
Past 60 kyr changes in the diatoms and glacial sediment supply to the Gulf of Alaska (IODP Exp. 341 Site U1419)

須藤 斎[1*] ; 福村 朱美[2] ; 今野 進[3] ; 朝日 博史[4] ; Mix A.C.[5] ; Davies-Walczak M.[5] ; IODP Exp. 341 Scientists[6]
SUTO, Itsuki[1*] ; FUKUMURA, Akemi[2] ; KONNO, Susumu[3] ; ASAHI, Hirofumi[4] ; MIX, A.c.[5] ; DAVIES-WALCZAK, M.[5] ; IODP, Exp. 341 scientists[6]

[1] 名大・環境学・地球環境科学, [2] 北大・院・理学, [3] 九大・院・理学, [4] 韓国極地研究所, [5] オレゴン大学, [6]IODP Exp. 341 Scientists
[1]Graduate School of Environmental Studies, Nagoya Univ., [2]Graduate School of Science, Hokkaido Univ., [3]Faculty of Sciences, Kyushu Univ., [4]Korea Polar Res. Inst., S. Korea, [5]Coll. Earth Ocean Atmos. Sci., Oregon State Univ., USA, [6]IODP Exp. 341 Scientists

2013 年 5 月末～7 月末に IODP 第 341 次掘削航海が，アラスカ湾沿岸部に分布する後期新生代の高解像度堆積物記録を用いて造山運動や氷河消長と北太平洋気候変動の関連性を解明するために実施された．本掘削海域は，氷床分布域に極めて近いが，陸域の堆積・運搬・供給システムにほとんど影響を受けずに氷床や氷河に削剥された陸上物質が沿岸域に供給されるため，氷床の消長と海洋堆積環境の関係を知るのに最適な場所である．

本発表では，陸棚縁辺部（Site U1419）で掘削された更新世堆積物中に含まれる珪藻化石分析と物性分析，有孔虫化石による酸素同位体比変動解析結果の概要を発表する．本掘削点は，船上データから約 10 万年で 200 m の堆積速度が見積もられている．珪藻化石群集には，海洋環境変動を示す種群だけでなく，沿岸～陸域に生息する種群や栄養塩変動を指標する休眠胞子等も含まれ，それらの産出量は大きな変動を示している．これらの変動は，古海洋環境変動，陸上氷床発達やそれに伴う削剥・供給量と堆積速度の変動，供給物質の粒度に影響を受ける間隙水量の変動，さらに，それに伴う珪藻化石の溶解など様々な要因を示している可能性がある．

キーワード: IODP Exp. 341, 珪藻化石, 古環境変動, 氷河作用, アラスカ湾
Keywords: IODP Exp. 341, Diatom fossils, Paleoenvironmental chang, Glaciation, Gulf of Alaska

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IODP341 次航海アラスカ湾 U1418 コア堆積物中の珪藻化石分析
Diatom analysis of IODP Exp.341 Site U1418 in the Gulf of Alaska

今野 進[1*] ; 菅 聖一郎[1] ; 岡崎 裕典[1] ; 朝日 博史[2] ; 福村 朱美[3] ; 松崎 賢史[4] ; 須藤 斎[5]
KONNO, Susumu[1*] ; SUGA, Sei-ichiro[1] ; OKAZAKI, Yusuke[1] ; ASAHI, Hirofumi[2] ; FUKUMURA, Akemi[3] ; MATSUZAKI, Kenji M.[4] ; SUTO, Itsuki[5]

[1] 九州大学大学院　理学研究院, [2] 韓国極地研究所, [3] 北海道大学, [4] 産業技術総合研究所地質調査総合センター, [5] 名古屋大学大学院環境学研究科
[1]Graduate School of Sciences, Kyushu University, [2]Korea Polar Research Institute, [3]Hokkaido university, [4]Geological Survey of Japan, AIST, [5]Graduate School of Environmental Studies, Nagoya University

アラスカ南方陸棚から外洋域において、2013 年 5 月末から 7 月末にかけて IODP 第 341 次航海が実施された（Expedition 341 Scientists, 2014；須藤ほか，2014）。掘削海域であるアラスカ湾周辺域はプレートの沈み込み帯にあり、活発な造山運動や北米氷床の存在で良く知られている地域である。海底地形は造山活動や氷河作用によって大きな影響を受けており（Carlson et al., 1982; Elmore et al., 2013）、多量の陸上堆積物や、陸水や融氷水を起源とする淡水などにより栄養塩が供給されている。そのため、珪質・炭酸塩殻を持つ植物・動物プランクトンが多く生息し、アラスカ湾の豊かな生態系を支えている。これまでアラスカ湾沿岸域におけるピストンコアで得られた海底堆積物試料を用いた研究は、研究対象域における堆積速度が極めて速かったため、最終氷期以降のものに留まっていた（Jaeger et al., 2008；Davies et al., 2011）。
本研究で使用する U1418 コアは船上の微化石及び古地磁気データから約 1 Ma まで堆積している事が明らかになっており、珪藻化石分析を始めている。本発表では、U1418 コアの船上データと下船後に分析したデータを報告する。

キーワード: IODP341 次航海, U1418, 珪藻
Keywords: IODP Exp.341, U1418, Diatom

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完新世におけるバルト海の河口域堆積物を用いた古環境復元（Exp. 347）
Holocene sedimentation in estuaries of the Baltic Sea (Exp. 347)

オブラクタ スティーブン[1*] ; Kotilainen A.T.[2] ; Hyttinen O.[3] ; Andren T.[4] ; Ryabchuk D.[5] ; Snowball I.[6] ; Yokoyama Y.[7] ; Exp. 347 Science Party[8]
OBROCHTA, Stephen[1*] ; KOTILAINEN, A.t.[2] ; HYTTINEN, O.[3] ; ANDREN, T.[4] ; RYABCHUK, D.[5] ; SNOWBALL, I.[6] ; YOKOYAMA, Y.[7] ; EXP. 347, Science party[8]

[1] 秋田大学国際資源学部, [2]Geological Survey of Finland (GTK), [3]University of Helsinki, Department of Geosciences and Geography, [4]Sodertorn University, School of Natural Sciences, [5]A.P. Karpinsky Russian Research Geological Institute (VSEGEI), [6]Uppsala University, Department of Earth Sciences - Natural Resources and Sustainable Development, [7] 東京大学大気海洋研究, [8]International Ocean Discovery Program (IODP)
[1]Akita University Faculty of International Resource Science, [2]Geological Survey of Finland (GTK), [3]University of Helsinki, Department of Geosciences and Geography, [4]Sodertorn University, School of Natural Sciences, [5]A.P. Karpinsky Russian Research Geological Institute (VSEGEI), [6]Uppsala University, Department of Earth Sciences - Natural Resources and Sustainable Development, [7]University of Tokyo Atmosphere and Ocean Research Institute, [8]International Ocean Discovery Program (IODP)

国際深海掘削計画 (IODP) の Exp.347 航海において、Angermanalven 河口の２カ所のサイトで掘削が行われた。１万年前にスカンジナビア氷床の退氷がおきたとされるサイト M0061 と M0062 は、年縞がよく保存されているという特徴がある。これまで、現生の年縞の形成過程について研究した先行研究によると、AD1907?AD1977 に形成された平均年縞幅と河川流量の相関が高いということが分かっている。そこで本研究のサイト M0061 と M0062 では、より長い堆積シーケンスから年縞幅などを用いて過去の河川流量を復元し、古環境を復元することが目的である。

この発表では、M0062 の予察的な結果を紹介する。サイト M0062 では 36 メートルの堆積シーケンスを確認し、２つの岩相単位に分けられることがわかった。より下位の Unit2（17.09-35.9　mbsf）は、淘汰の良い砂層からなっており、氷河性の河川堆積物であることが岩相から明らかとなった。また、上位の Unit 1 (0-17.09 mbsf) では、氷河性の年縞堆積物から氷河性の河川堆積物、更に氷河性の汽水および海洋堆積物へと遷移する様子が捉えられている。これまでに最上部１８ m については、粒度分析および元素分析を 0.3-0.5m おきに行った。また最上部の 26m については、1cm の間隔で XRF スキャナによる元素分析を行った。さらに特定の部位については 1mm 間隔での高分解能の分析を行っている。

本講演ではこれまでの取得データを紹介するとともに、バルト海沿岸における最終退氷期および完新世の古環境復元について、得られつつある知見について発表する予定である。

The IODP Expedition 347 “Baltic Sea Paleoenvironment” drilled two sites in the Ångermanälven River estuary. Sites M0061 and M0062 are located in an area that was deglaciated ca. 10 ka ago. It has long been known that varves continue to form in this estuary and previous work has shown that a correlation exists between maximum daily discharge and mean varve thickness at least AD 1901-1971 in the Ångermanälven River. One aim of the IODP drilling was to recover a uniquely long varve record from the two sites in Ångermanälven and study varve thickness and sediment geochemistry, potentially yielding estimations on past changes in discharge and sedimentation processes in the estuary.

In this presentation, we show the preliminary results from site M0062. The core recovery was ~ 36 m and the sediment sequence was divided into two lithological units. Unit 2 (17.09-35.9 mbsf) consists of well-sorted sand, deposited by a (glacio)fluvial system. Unit 1 (0-17.09 mbsf) contains a transition from clastic varves typical of a glaciolacustrine environment to couplets characteristic of a glaciomarine, or brackish environment. The uppermost 18 metres were analysed for grain-size and elemental geochemistry every 0.3-0.5 m. The uppermost 26 m were scanned by XRF at 1-cm resolution, and select intervals at 1-mm resolution.

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ニューファンドランド沖 IODP Site U1407 での暁新世の貝形虫群集の変化
Changes in Paleocene ostracodes at IODP Site U1407, off Newfoundland, with special reference to the hyperthermal events

山口 龍彦 [1*] ; 松井 浩紀 [2] ; 西 弘嗣 [2]
YAMAGUCHI, Tatsuhiko[1*] ; MATSUI, Hiroki[2] ; NISHI, Hiroshi[2]

[1] 高知大学, [2] 東北大学, [3] 東北大学
[1]Kochi University, [2]Tohoku University, [3]Tohoku University

During the Paleogene greenhouse period, a series of global warming events called the hyperthermal events occurred. The events may be driven by the orbital forcing of carbon cycling alike the Oligocene and Miocene climates (Kirtland Turner et al., 2014, Nat. Geosci., 7, 748-751). A primary objective of IODP Expedition 342 is to answer questions about the rate and magnitude of ecosystem changes during the greenhouse period with the hyperthermal events. Exp 342 drilled off Newfoundland and obtained successive cores of the Paleogene sediments that formed in high sedimentation rates (Exp 342 Scientists, 2012, IODP Prel. Rep., 342, 1-263).

We study benthic ostracodes from the Paleocene cores (146-218 mcd) at Site U1407 to understand changes in ostracode faunas during the Paleocene hyperthermal events such as the Latest Danian Event (LDE; 61.8 Ma) and the Mid-Paleocene Biotic Event (MPBE; 59.2 Ma). The core sediments are calcareous nannofossil ooze with radiolarians. They show light greenish grey to radish brown in color. The carbonate content ranges from 54 to 92%. The sediment color reflects the carbonate content. Using the calcareous nannofossil biostratigraphy, the sediments were dated to 66.3-57.4 Ma. The sedimentation rates were estimated as 1.3 to 2.4 cm/kyr. We obtained 3353 ostracode specimens from 226 samples and identified 37 species.

The ostracode faunas are composed mainly of *Krithe crassicaudata, Krithe dolichodeira, Krithe pernoides*, *Cytherella* sp., and *Neonesidea* sp. Species richness and abundance range from one to twelve and from one to 75, respectively. We binned samples in the interval of 100 kyrs and calculated expected species richness at 30 specimens, *E(S30)*, and equitability, *Eq*., of 50 binned samples, following Hurlbert (1971, Ecology, 52, 577-586) and Buzas and Gibson (1969, Science, 163, 72-75). *E(S30)* values fluctuate between 5.4 and 10.5, whereas *Eq.* values amplify between 0.62 and 0.91. During the LDE, both *E(S30)* and *Eq*. dropped off, indicating stressful condition (e.g., Graham et al., 2009, Ecol. Indic., 9, 866-877). During the MPBE, *E(S30)* decreased, but *Eq.* did not drop. The LDE switched seafloors into stressful condition for benthic communities alike the Paleocene-Eocene Thermal Maximum (Webb et al., 2009, Geology, 37, 783-786).

キーワード: 温暖化イベント, 北西大西洋, 種多様性, 貝形虫, 暁新世
Keywords: Hyperthermal events, Northwestern Atlantic, taxonomic diversity, Ostracoda, Paleocene

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Probing the Tectonic Evolution of the South China Sea: International Ocean Discovery Program Expedition 349

Probing the Tectonic Evolution of the South China Sea: International Ocean Discovery Program Expedition 349

TEJADA, Maria luisa[1*] ; LI, Chun-feng[2] ; LIN, Jian[3] ; KULHANEK, Denise[4] ; WILLIAMS, Trevor[5] ; BAO, Rui[6] ; BRIAIS, Anne[7] ; CHEN, Yifeng[8] ; CLIFT, Peter[9] ; COLWELL, Frederick[10] ; DADD, Kelsie[11] ; DING, Weiwei[12] ; HERNANDEZ-ALMEIDA, Ivan[13] ; HUANG, Xiao-long[8] ; HYUN, Sangmin[14] ; JIANG, Tao[15] ; KOPPERS, Anthony[10] ; LI, Qianyu[2] ; LIU, Chuanlian[2] ; LIU, Qingsong[16] ; LIU, Zhifei[2] ; NAGAI, Renata[17] ; PELEO-ALAMPAY, Alyssa[18] ; SU, Xin[19] ; SUN, Zhen[20] ; TRINH, Hai son[21] ; YEH, Yi-ching[22] ; ZHANG, Chuanlun[2] ; ZHANG, Fan[3] ; ZHANG, Guo-liang[23] ; ZHAO, Xixi[2]
TEJADA, Maria luisa[1*] ; LI, Chun-feng[2] ; LIN, Jian[3] ; KULHANEK, Denise[4] ; WILLIAMS, Trevor[5] ; BAO, Rui[6] ; BRIAIS, Anne[7] ; CHEN, Yifeng[8] ; CLIFT, Peter[9] ; COLWELL, Frederick[10] ; DADD, Kelsie[11] ; DING, Weiwei[12] ; HERNANDEZ-ALMEIDA, Ivan[13] ; HUANG, Xiao-long[8] ; HYUN, Sangmin[14] ; JIANG, Tao[15] ; KOPPERS, Anthony[10] ; LI, Qianyu[2] ; LIU, Chuanlian[2] ; LIU, Qingsong[16] ; LIU, Zhifei[2] ; NAGAI, Renata[17] ; PELEO-ALAMPAY, Alyssa[18] ; SU, Xin[19] ; SUN, Zhen[20] ; TRINH, Hai son[21] ; YEH, Yi-ching[22] ; ZHANG, Chuanlun[2] ; ZHANG, Fan[3] ; ZHANG, Guo-liang[23] ; ZHAO, Xixi[2]

[1]Department of Solid Earth Geochemistry, Japan Agency for Marine-Earth Science and Technology, Japan, [2]State Key Laboratory of Marine Geology, Tongji University, China, [3]Woods Hole Oceanographic Institution, USA, [4]IODP, Texas A&M University, USA, [5]Lamont-Doherty Earth Observatory of Columbia University, USA, [6]Geologisches Institut, Swiss Federal Institute of Technology, Switzerland, [7]Centre National de la Reserche Scientifique, University of Toulouse, France, [8]Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, China, [9]Department of Geology and Geophysics, Louisiana State University, USA, [10]College of Earth, Ocean and Atmospheric Sciences, Oregon State University, USA, [11]Department of Earth and Planetary Sciences, Macquarie University, Australia, [12]Second Institute of Oceanography, State Oceanic Administration, China, [13]Institute of Geography/Oeschger Centre for Climate Change Research, Univ. of Bern, Switzerlandl, [14]Korea Institute of Ocean Science and Technology, Republic of Korea, [15]Faculty of Earth Resources, China University of Geosciences, China, [16]State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, CAS, China, [17]Department of Physical, Chemical and Geological Oceanography, Universidade de Sao Paulo, Brazil, [18]National Institute of Geological Sciences, Univ. of the Philippines, Philippines, [19]School of Marine Geosciences, China University of Geosciences, China, [20]South China Sea Institute of Oceanology, Chinese Academy of Sciences, China, [21]Department of Science and Technology, Min. of Natural Resources and Environment, Vietnam, [22]Taiwan Ocean Research Institute, Taiwan, Republic of China, [23]Key Laboratory of Marine Geology and Environment, Institute of Oceanology, CAS, China
[1]Department of Solid Earth Geochemistry, Japan Agency for Marine-Earth Science and Technology, Japan, [2]State Key Laboratory of Marine Geology, Tongji University, China, [3]Woods Hole Oceanographic Institution, USA, [4]IODP, Texas A&M University, USA, [5]Lamont-Doherty Earth Observatory of Columbia University, USA, [6]Geologisches Institut, Swiss Federal Institute of Technology, Switzerland, [7]Centre National de la Reserche Scientifique, University of Toulouse, France, [8]Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, China, [9]Department of Geology and Geophysics, Louisiana State University, USA, [10]College of Earth, Ocean and Atmospheric Sciences, Oregon State University, USA, [11]Department of Earth and Planetary Sciences, Macquarie University, Australia, [12]Second Institute of Oceanography, State Oceanic Administration, China, [13]Institute of Geography/Oeschger Centre for Climate Change Research, Univ. of Bern, Switzerlandl, [14]Korea Institute of Ocean Science and Technology, Republic of Korea, [15]Faculty of Earth Resources, China University of Geosciences, China, [16]State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, CAS, China, [17]Department of Physical, Chemical and Geological Oceanography, Universidade de Sao Paulo, Brazil, [18]National Institute of Geological Sciences, Univ. of the Philippines, Philippines, [19]School of Marine Geosciences, China University of Geosciences, China, [20]South China Sea Institute of Oceanology, Chinese Academy of Sciences, China, [21]Department of Science and Technology, Min. of Natural Resources and Environment, Vietnam, [22]Taiwan Ocean Research Institute, Taiwan, Republic of China, [23]Key Laboratory of Marine Geology and Environment, Institute of Oceanology, CAS, China

Expedition 349, South China Sea (SCS) Tectonics, was the first voyage of the *JOIDES Resolution* under the new International Ocean Discovery Program. The objectives of this expedition were to: 1) determine the timing, mechanisms, and sequence of the opening and closing of different subbasins of the SCS by coring and directly dating the oceanic crust; 2) investigate the tectonic history of the SCS by conducting biostratigraphic and magnetostratigraphic investigations on the sedimentary sequences

to help constrain the timing and sequence of geologic events and the sedimentary responses to tectonic evolution of the basin; 3) measure the geochemical composition, magnetization, and physical properties of the oceanic crust and seamount volcanic products to understand crustal accretion and deep mantle processes associated with the tectonic development of the basin; and 4) test the different proposed driving mechanisms that led to continental breakup and seafloor spreading. To attain these objectives, we cored near the ocean-continent boundary (U1432 and U1435) inferred to be underlain by the oldest oceanic crust, and near the fossil spreading centers in the East Subbasin (U1431) and the Southwest Subbasin (U1433 and U1434) where the youngest crust formed. The main scientific outcomes of Expedition 349 include 1) in-situ SCS oceanic crust was recovered for the first time, providing critical control on the timing of termination of spreading in the SCS; 2) the cessation age of spreading in both the East and Southwest Subbasins are similar (~16 Ma), based on shipboard biostratigraphy from reddish-brown clays overlying and within the oceanic crust at Sites U1431 and U1433; and 3) determination of the nature of the structural high at Site U1435, where a sharp, possibly rift-related unconformity was recovered, providing indirect evidence for the onset of seafloor spreading at ~33 Ma. In addition, 4) the nature of post-spreading seamount volcanism will be examined from the volcaniclastic sediments recovered at Sites U1431 and U1434; and 5) the past environmental, climatic, and oceanographic conditions related to the tectonic evolution of the SCS will be gleaned from studies of the 1524 m of sedimentary deposits recovered from all sites.

キーワード: South China Sea, tectonic evolution, seafloor spreading, International Ocean Discovery Program, Expedition 349, oceanic crust drilling
Keywords: South China Sea, tectonic evolution, seafloor spreading, International Ocean Discovery Program, Expedition 349, oceanic crust drilling

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オマーン・オフィオライト国際陸上科学掘削計画紹介
Introduction to the International Continental Scientific Drilling Program in the Samail Ophiolite, Sultanate of Oman

敬礼人 笛太[2] ; 森下 知晃[1*]
KELEMEN, Peter[2] ; MORISHITA, Tomoaki[1*]

[1] 金沢大学, [2] ラモントードハティ地球観測所
[1]Kanazawa University, [2]Lamont-Doherty Earth Observatory

オマーン王国に露出するサマイル・オフィオライトは世界最大で，堆積物から上部マントルに相当するかんらん岩体までの保存状態・露出が良く，世界で最も研究されている白亜紀に形成されたオフィオライトである。そのため，海洋プレートの形成プロセスに加え，地表条件での現在進行中の低温変成・変質プロセスを解明するための貴重な天然の実験室であるといえる。現在，このサマイル・オフィオライト南部における国際陸上科学掘削計画が採択され，実行に向けて動き始めている。日本からは，荒井章司，道林克禎，宮下純夫，高澤栄一，海野進の各氏が主要共同研究者として名を連ねている。本陸上掘削による科学目標を次に示す。海洋底海嶺軸下のプロセスに関連したの科学目標は，１）マントル上昇は能動的なのか受動的なのか　２）マントル中でのメルトの発生と移動，３）地殻?マントル境界でのメルトの集積，４）海嶺軸近傍での熱水循環による熱水変成・変質作用と下部地殻の形成との関係，５），貫入岩?はんれい岩境界での火成・変成作用である。また，オフィオライトの基底部の変成岩が，オフィオライトが衝上する際に形成されたと解釈されていることから, 変成岩とオフィオライト基底部との関係は，プレート沈み込み直上のマントルウエッジ環境相当と考えらえる。そのため，沈み込む堆積物相当層から上盤のかんらん岩への元素供給に関する情報を得ることも科学目標の一つである。さらに，現在進行中のマントル起源かんらん岩で起きている炭酸塩岩化，蛇紋岩化，水文学の解明と，これらに関係した地下生命圏の解明も目指す。発表では，オマーン・オフィオライト陸上掘削の科学目標に加え，現地の様子や実行的な計画，掘削に付随する教育目標などについて紹介する。

申請書のリードプロポーネントは Peter B. Kelemen, Jurg M. Matter, Damon A. Teagle の３名。他の主要な共同研究者は、Raeid Abed, Ali Al Rajhi, Shoji Arai, Wolfgang Bach, Kier Becker, Francoise Boudier, Georges Ceuleneer, Laurence Coogan, Kathyrn Gillis, Marguerite Godard, Steve Goldstein, Philippe Gouze, Greg Hirth, Albrecht Hofmann, Benoit Ildefonse, Bjorn Jamtveit, Frieder Klein, Jurgen Koepke, Charles Langmuir, Chris MacLeod, Craig Manning, Katsu Michibayashi, Jay Miller, Sumio Miyashita, Sobhi Nasir, Adolphe Nicolas, Matthew Schrenk, Barbara Sherwood-Lollar, Everett Shock, Satish Singh, Rob Sohn, Martin Stute, Eiichi Takazawa, Alexis Templeton, Susumu Umino, Jessica Warren である。

キーワード: オマーンオフィオライト, 中央海嶺, 島弧, 蛇紋岩化, 炭酸塩岩化, 地下生命圏
Keywords: Oman Ophiolite, Mid-Ocean Ridge, Island Arc, Serpentinization, Carbonation, Subsurface microbial biosphere

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MIS32-08 会場:304 時間:5 月 24 日 11:00-11:15

The volcanic, geodynamic and climatic evolution of alkaline Lake Van, eastern Anatolia (ICDP Paleovan Drilling project)

The volcanic, geodynamic and climatic evolution of alkaline Lake Van, eastern Anatolia (ICDP Paleovan Drilling project)

隅田 まり [1*] ; シュミンケ ハンス-ウルリッヒ [1] ; Paleovan Scientific Team[1]
SUMITA, Mari[1*] ; SCHMINCKE, Hans-U lrich[1] ; Paleovan Scientific Team[1]

[1]GEOMAR 海洋科学センター (キール)
[1]GEOMAR Helmholtz Centre for Ocean Reasearch

Alkaline Lake Van and adjacent active stratovolcanoes Nemrut and Suphan represent a coupled system that evolved over ca. 570 000 years. We present a preliminary synthesis of chronological, chemical, mineralogical, volcanological and sedimentological data obtained on ca. 170 of a total of ca. 450-500 tephra layers drilled at Site 2 of the ICDP Paleovan drilling project (2010). We compare these with the chemistry, mineralogy and volcanology of the ca. 570 ka onshore record of Nemrut Volcano adjacent to, and underlying, western Lake Van.

Nemrut explosive activity extends from ca. 570 ka to historic in age onshore and from ca. 580 ka to Holocene in the core. Most individual tephra layers are slightly peralkaline trachytes, larger volumes of rhyolitic tephras having been erupted at intervals of 30-40 ka. Fallout deposits dominate while the larger rhyolite eruptions are generally associated with ignimbrites onshore, thick massive tephra deposits drilled being interpreted as syn-ignimbrite turbidites. We infer stages of caldera collapse to be associated with large-volume rhyolitic eruptions.

Eruptive rates at Nemrut volcano apparently increased (onshore and core evidence) at ca. 200 ka. Tephras from adjacent subalkalic Suphan volcano dominate the felsic tephras drilled prior to about 200 ka. Nemrut volcanic explosive activity appears to have been roughly periodic while that of Suphan was more episodic and seems to have strongly waned during the past 200 ka with external forcing (seismic, hydroclastic) having been characteristic forcing mechanisms, the Nemrut magma system having been open throughout its recorded lifetime.

Basaltic tephras are most common in the lower ca. 100 m of the core and appear to represent dominantly subaqueous eruptions. The dominantly high-Al composition suggests parent magma to subalkalic Suphan system. A huge subaqueous to subaerial basaltic eruption at ca. 80 ka is represented onshore by large Incekaya tephra cone and widespread fallout onshore and throughout western Lake Van. It is the most widespread and voluminous seismic marker bed and represents one of largest basaltic explosive eruption globally with a volume of >1 km^3 (DRE).

We estimate about 30 % of the cored tephra layers to be reworked by various mechanisms. Wind-transported tephras appear most common and mostly associated with dry climate intervals. They range from nearly pure to mixed tephras containing a large proportion of xenocrysts and nonvolcanic and organic particles. We define thick fallout deposits consisting of fine-grained basal tephra and variously rounded pumice lapilli at the top as pumice raft deposits reflecting prolonged abrasion in pumice rafts covering the lake surface. Most significant are poorly sorted reworked tephra deposits containg abundant organic debris (plants, shell fragments), many also containing gypsum crystals and are interpreted as recording extended periods of low lake levels. Core intervals with abundant reworked tephra layers appear to correlate with seismically defined low lake level periods.

The initial fundamental precise stratigraphic and temporal correlation of the upper part of cores from sites 1 and 2, as well as with the onshore tephra record was based on several fallout tephra layers defined by chemical composition, highly concordant ^{40}Ar/^{39}Ar ages and nature of the tephra deposit.

There is a tentative correlation of higher eruption frequency with warm climate periods both within the cores and on land suggesting magma generation/eruption control via lithosphere loading.

キーワード: Van 湖, Nmerut 火山, アルカリ湖, 湖成堆積物, テフラ, ICDP Paleovan プロジェクト
Keywords: Lake Van, Nemrut Volcano, Alkaline lake, lake sediment, tephra, ICDP Paleovan project

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MIS32-09 会場:304 時間:5 月 24 日 11:15-11:30

国際深海掘削科学計画第 351 次研究航海で得られたメルト包有物から探る伊豆ー小笠原ーマリアナ弧の火成活動の時間発展
IODP Expedition 351 Izu-Bonin-Mariana Arc Origins: Temporal evolution of arc volcanism inferred from melt inclusions

浜田 盛久 [1*] ; ブランドル フィリップ [2]
HAMADA, Morihisa[1*] ; BRANDL, Philipp[2]

[1] 独立行政法人海洋研究開発機構, [2] オーストラリア国立大学地球科学研究所
[1]Japan Agency for Marine-Earth Science and Technology, [2]Research School of Earth Sciences, The Australian National University

国際深海掘削科学計画第 351 次研究航海（2014 年 6〜7 月に実施）では，伊豆―小笠原―マリアナ（IBM）弧の古島弧である九州パラオ海嶺の西側に位置する奄美三角海盆海域の U1438 地点の掘削が行われた．回収された 1611 m のコアのうち，上位 1461 mは堆積物であり，下位 150 mは基盤の海洋地殻である．岩石学的記載に基づき，堆積物は 4 つのユニットに区分される．最上位のユニット I（厚さ 160.3 m）は, おそらく琉球弧や九州弧の爆発的火山活動に由来すると考えられる火山灰の層を幾重にも挟む新生代の半遠洋性堆積物から成る．ユニット II（厚さ 139.4 m）は漸新世後期のタービダイトから，ユニット III（厚さ 1046.4 m）は漸新世から始新世にかけてのより粗粒なタービダイトから成る．ユニット IV（厚さ 99.7 m）は，凝灰岩質の砂岩に挟まれた珪長質の遠洋性堆積物から成る．

初期の IBM 弧の火成活動の時間発展を調べるため，私たちはユニット III（船上で決定された生層序年代は 30-40 Ma）から採取したメルト包有物の主要元素および揮発性元素（Cl および S）を、海洋研究開発機構およびオーストラリア国立大学に設置されている電子線プローブマイクロアナライザー（EPMA）を用いて分析した．メルト包有物は単斜輝石または斜長石に包有されており，メルト包有物の化学組成は玄武岩から流紋岩まで，また低 K_2O 系列から中 K_2O 系列まで幅広く多様である．主要元素で比較する限りにおいて，低 K_2O 系列のメルト包有物の組成は，IBM 弧の前弧域あるいは火山フロントから報告されている液（メルト）の組成と一致している．中 K_2O 系列のメルト包有物の組成は，九州パラオ海嶺や奄美三角海盆海域付近の火山といった IBM 弧の背弧域の火山から報告されている液（メルト）の組成と一致する．これらの観察事実より，奄美三角海盆海域に堆積したタービダイトには IBM 弧の背弧域に由来するものばかりではなく，前弧域あるいは火山フロントに由来するものも含まれることが示唆される．

約 3500 万年前よりも古い低 K_2O 系列と中 K_2O 系列のメルト包有物は，玄武岩 ～ 安山岩質である．流紋岩質のメルトは約 3500 万年前以降に突如として出現する．中間的な化学組成（66-74 wt.% SiO_2）のメルト包有物は比較的少ないことから，それらのメルトが苦鉄質メルトと珪長質メルトとの混合物である可能性を示唆する．私たちは，約 5000 万年前にプレートの沈み込みが開始されて以降約 3500 万年前までの間に島弧火山直下の中部地殻は成長を続けて厚くなり，約 3500 万年前以降，中部地殻が部分融解して流紋岩質マグマが形成されたと考える．

キーワード: 国際深海科学掘削計画, 伊豆―小笠原―マリアナ弧, 九州パラオ海嶺, 奄美三角海盆, メルト包有物
Keywords: IODP, IBM arc, Kyushu-Palau ridge, Amami Sankaku Basin, melt inclusion

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MIS32-10 会場:304 時間:5 月 24 日 11:30-11:45

IODP Expedition 352 前弧玄武岩とボニナイトの掘削成功
IODP Expedition 352 FAB and boninite

栁山 徹也[2*] ; 道林 克禎[1] ; Python Marie[3] ; 清水 健二[4] ; IODP EXP352 乗船研究者一同[5]
SAKUYAMA, Tetsuya[2*] ; MICHIBAYASHI, Katsuyoshi[1] ; PYTHON, Marie[3] ; SHIMIZU, Kenji[4] ;
IODP EXP352, Shipboard scientists[5]

[1] 静岡大学・理・地球科学, [2] 大阪市立大学, [3] 北海道大学, [4] 海洋研究開発機構, [5] 国際深海科学掘削計画
[1]Institute of Geosciences, Shizuoka University, [2]Osaka City University, [3]Hokkaido University, [4]JAMSTEC, [5]IODP

The Izu-Bonin-Mariana (IBM) system consists of oceanic crustal related to convergence between the Philippine Sea Plate and the Pacific Plate. International Ocean Discovery Program (IODP) Expedition 352 has drilled through the entire volcanic sequence of the Bonin fore arc (1) to obtain a high-fidelity record of magmatic evolution during subduction initiation and early arc development, (2) to test the hypothesis that fore-arc lies beneath boninite and understand chemical gradients within these units and across the transition, (3) to use drilling results to understand how mantle melting processes evolve during and after subduction initiation, and (4) to test the hypothesis that the fore-arc lithosphere created during subduction initiation is the birthplace of suprasubduction zone (SSZ) ophiolites (Expedition 352 Preliminary Report, 2015). During Expedition 352, 1.22 km of igneous basement and 0.46 km of overlying sediment were cored, including fore-arc basalts (FAB) and boninite related to seafloor spreading and earliest arc development. We present preliminary results obtained during Expedition 352, focusing on physical and chemical properties of igneous rocks.
Keywords: IODP, Expedition, Forearc, IBM, FAB, boninite

Japan Geoscience Union Meeting 2015
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MIS32-11 会場:304 時間:5 月 24 日 11:45-12:00

地球内部へ挑戦する「ちきゅう」の最先端技術
Advanced Technologies of CHIKYU to Challenge the Deep Earth's Interior

許 正憲 [1*]
KYO, Masanori[1*]

[1](独) 海洋研究開発機構
[1]Japan Agency for Marine-Earth Science and Technology

JAMSTEC developed the deep sea scientific drilling vessel *Chikyu* to drill the sea floor, recover core samples, and analyze these on board to obtain important scientific information targeted by International Ocean Discovery Program (IODP, in previous, Integrated Ocean Drilling Program), which includes the studies of deep biosphere, environmental change, and solid earth dynamics. *Chikyu* was delivered to JAMSTEC in July 2005 and the shakedown, training, System Integration Tests (SITs) were initiated shortly thereafter. Then, JAMSTEC started the scientific drilling operation for IODP beginning in September 2007. *Chikyu* already conducted such major scientific projects as 1) Nankai Trough Seisomogenic Zone Experiment (NanTroSEIZE), 2) Deep Hot Biosphere, 3) Japan Trench Fast Drilling (JFAST), 4) Deep Coalbed Biosphere off Shimokita, and so on. Any of these expeditions could satisfyingly contribute to understanding of the earth system. However, in order to successfully achieve these brilliant scientific results, we challenges many technical difficulties related to strong current, high wave, rough sea, deep water, deep penetration, which have not been experienced even in the oil industries nor the previous ocean drilling programs.

For example, the NanTroSEIZE C0002 deep riser hole site is located in a water depth of approximately 2,000 m and persistently experiences the Kuroshio Current, which is a strong/deep current with mean surface currents of 3.5 knots, and a 1-yr extreme current of approximately 7.0 knots. When drill pipe is placed in a strong current, an alternating Karman vortex forms on the downstream side. Vibration occurs when two of these vortices alternately pull at one another, known as VIV, which potentially cause serious damage on riser pipe, drill pipe, and the instruments attached along. The NanTroSEIZE site also experiences intense typhoons during the summer and autumn. Thus all operational phases should need to be analyzed thoroughly for high currents and potential typhoons; evacuation criteria are developed for each operational condition. Considering the major operational concerns, we developed the VIV reduction countermeasures for riser/drill pipe, real-time riser VIV monitoring system to estimate the fatigue, to successfully conduct riser drilling operation and riserless borehole observatory deployment at the NanTroSEIZE sites.

To realize the JFAST operation which was a challenging drilling program (water Depth: 6,897.5 m, penetration depth: 854.81 mbsf), thorough investigation of the strength of drill pipe was conducted, and operation criteria was determined based on the strength evaluation by considering such combined forces as the drill pipe weight in water, dynamic load caused by heaving motion, over pull force caused by hole condition, and bending force caused by ship motion and current.

As the other developments, we are developing the Turbine Driven Coring System (TDCS) to improve core quality and recovery especially for hard rock, the new material riser pipe such as the Carbon Fiber Reinforced Plastic (CFRP), the precise dynamic analysis for deep water drill pipes, the Long Term Borehole Monitoring System (LTBMS) for riser hole and so on.

IODP will start afresh in the new era from 2013 to implement the Mohole project which is long-cherished dream for scientific drilling communities. *Chikyu* continues to evolve furthermore toward this great challenge of unexplored scientific mission.

キーワード: 科学掘削, 大水深, 大深度, NanTroSEIZE, JFAST
Keywords: Scientific drilling, Deep water, Deep penetration, NanTroSEIZE, JFAST

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MIS32-12 会場:304 時間:5 月 24 日 12:00-12:15

CRISP コスタリカ地震発生帯における高い古地殻熱流量
High paleo-heat flow in Costa-Rica seismogenic zone, off Osa peninsula (CRISP Exp344)

坂口 有人[1*] ; 山下 純平[3]
SAKAGUCHI, Arito[1*] ; YAMASHITA, Junpei[3]

[1] 山口大学大学院・理工学研究科, [2] 海洋研究開発機構, [3] 山口大学・理学部・地球圏システム科学科
[1]Graduate School of Science and Engineering, Yamaguchi University, [2]JAMSTEC, [3]Dept.Geosphere Sciences, Fac. Sciences, Yamaguchi University

Seismogenic depth of the plate subduction large earthquake may depend on thermal condition of the plate boundary (Hyndman et al., 1990). Thermal condition is one of important data to drill the seismogenic zone. Two types of plate subduction zones of the accretion and erosive are developed in the world, and the Costa-Rica subduction zone is one of the typical erosive margin. The Cocos ridge originated from the Galapagos hotspot subducts in the southern part of the Costa-Rica and uplifts the seismogenic zone to drillable depth for CHIKYU riser drilling system. The IODP Exp.344 drilled and took the core samples at the upper plate wedge of the Costa-Rica margin (Harris et al., 2013). The site U1380 and U1413 penetrated upper pate rock above the seismogenic zone. We estimated paleo-heat flow in these sites using the technique of the vitrinite reflectance.

In the results, 11 and 13 samples of the vitrinite reflectance are obtained at site U1380 (500-800 mbsf) and U1413 (0-600 mbsf) respectively. The value of the vitrinite reflectance increases with depth from 0.15 to 0.60 %. The average increase rate of 0.51 %/km at site U1380 and 0.53 %/km at site U1413 correspond to the heat flow of 115-123 mW/m2. This heat flow is two times higher than the present heat flow of 44.2-56.2 mW/m2 obtained from borehole temperature measurement (Harris et al., 2013). Pore-fluid chemistry found fluid seepage from deep level within middle slope sediment (Harris et al., 2013). Such fluid flow from deep portion can transfer heat and possibly have caused high thermal-event.

キーワード: IODP, 地震発生帯掘削, コスタリカ, 地殻熱流量, ビトリナイト反射率
Keywords: IODP, Seismogenic zone drilling, CostaRica, Heat flow, Vitrinite reflectance

Japan Geoscience Union Meeting 2015
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MIS32-13 会場:304 時間:5 月 24 日 12:15-12:30

アルパイン断層掘削報告
Deep Fault Drilling Project, Alpine Fault, New Zealand

重松 紀生[1*] ; 岡田 知己[3] ; 加藤 尚希[2] ; 米谷 優佑[4] ; 森 宏[1] ; 西川 治[5] ; 吉田 圭佑[6] ; 高木 涼太[7] ; 林 為人[8] ; 松本 則夫[1] ; 東郷 徹宏[1]
SHIGEMATSU, Norio[1*] ; OKADA, Tomomi[3] ; KATO, Naoki[2] ; KOMETANI, Yusuke[4] ; MORI, Hiroshi[1] ; NISHIKAWA, Osamu[5] ; YOSHIDA, Keisuke[6] ; TAKAGI, Ryota[7] ; LIN, Weiren[8] ; MATSUMOTO, Norio[1] ; TOGO, Tetsuhiro[1]

[1] 産業技術総合研究所 活断層・火山研究部門, [2] 東北大学大学院理学研究科附属地震・噴火予知研究観測センター, [3] 大阪大学大学院, [4] 山口大学, [5] 秋田大学工学資源学研究科, [6] 防災科学技術研究所, [7] 東京大学地震研究所, [8] 海洋研究開発機構
[1]Institute of Earthquake and Volcano Geology, AIST, [2]Tohoku University, [3]Graduate School of Science, Osaka University, [4]Yamaguchi University, [5]Graduate School of Engineering and Resource Sciences, Akita University, [6]National research institute for earth science and disaster prevention, [7]ERI, The University of Tokyo, [8]JAMSTEC

国際陸上科学掘削計画（ICDP）の一環として、ニュージーランド南島西海岸のアルパイン断層掘削する DFDP-2 (Alpine Fault, Deep Fault Drilling Project-2) が 2014 年に行われた．残念ながら，事故により断層の貫通も，ボーリングコアの取得もできなかった．

アルパイン断層はニュージーランド南島西海岸に位置する北東-南東走向南東傾斜の断層で，東側の太平洋プレートと西側のオーストラリアプレートの境界をなす．中央部における平均変位速度は，右横ずれ成分が 30 m/千年弱，逆断層成分が 10 m/千年弱と大きな値を示す．最新活動は 1717 年に記録があり，平均活動間隔は 330 年で M8 クラスの大地震を発生させている．最新の地震発生から 298 年経過し地震後経過率が 0.9 と高く，近い将来に地震を起こす可能性が高い．そのため，掘削時に大規模地震を誘発する可能性が懸念され，掘削サイト周囲に地震観測網を設置し，リアルタイムで地震の監視を行った．幸い，掘削期間中に重大な地震は発生しなかった．

アルパイン断層は地震後経過率が高い点，上盤側の隆起速度が速く地質学的に見て比較的新しい断層深部の情報が得られうる点が特徴である．DFDP-2 は，深度 1000 m 付近で断層を貫通させ，さらに深度 1300 m 付近まで掘削することを目指し，ファタロア川で掘削が行われた．

DFDP-2 の掘削は Phase 1，Phase 2A － C，Phase 3 までの工程が考えられていた．Phase 1 はケーシング挿入しながらの第四紀層掘削，Phase 2A は着岩後の 8.5”ビットによるノンコア掘削，Phase 2B はアルパイン断層上盤のコアリング掘削，Phase 2C はアルパイン断層下盤のコアリング掘削，Phase 3 は埋め戻しと観測機器の設置である．Phase 2A と Phase 2B の切り替えは，カッティングス観察によりマイロナイト帯に入ったかを確認することによる．これは断層に近づくにつれプロトマイロナイト→マイロナイト→カタクレーサイト→断層ガウジと変化するからである．また Phase 2A の最終段階では，孔の崩壊を防ぐため，ケーシングと呼ばれる鉄管を挿入しその回りをセメントで固める計画になっていた．

Phase 2A では掘削深度 893.18 m まで掘削した．しかし Phase 2A の最終段階で，ケーシングの破断により掘削孔をセメントで埋めてしまい，掘削を断念せざるをえない状況になった．この他にも掘削中には多数のトラブルが発生した．

掘削の結果，アルパイン断層上盤側の厚さ 240 m の堆積物の層序が明らかになった．また各種物理検層の結果も得られ，非火山地帯の 1 km に満たない坑井で孔底温度が 100 ℃を超えるほど地温勾配が高いことがわかった．カッティングスは 2 m 間隔で採取し，6 m 間隔で薄片を製作し微細構造観察を行い，掘削孔内での岩相変化が明らかになった．さらに掘削中は泥水の密度，粘性を連続測定しており，断層上盤の水理特性に制約を与えることが期待される．

DFDP-2 での当初目標は達成できなかった．しかしアルパイン断層は，掘削研究の対象としての価値が高い断層であり，2016 年以降に再掘削を目指している．このためには DFDP-2 掘削の技術的課題等を十分検討する必要があると思われる．

キーワード: 断層掘削, アルパイン断層
Keywords: Fault Zone Drilling, Alpine Fault

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(May 24th - 28th at Makuhari, Chiba, Japan)

MIS32-14 会場:304 時間:5 月 24 日 12:30-12:45

大深度南アフリカ金鉱山の M2-M5.5 震源域の科学掘削計画
Drilling into seismogenic zones of M2.0 - M5.5 earthquakes in deep South African gold mines (DSeis)

小笠原 宏[1*] ; 矢部 康男[2] ; 伊藤 高敏[2] ; ファンアスウェヘン ヘリ[3] ; チホビチ アルトゥール[4] ; ダーハイム レイモンド[5] ; 関連会議 参加者[6]
OGASAWARA, Hiroshi[1*] ; YABE, Yasuo[2] ; ITO, Takatoshi[2] ; VAN ASWEGEN, Gerrie[3] ; CICHOWICZ, Artur[4] ; DURRHEIM, Raymond[5] ; PARTICIPANTS, Related meeting[6]

[1] 立命館大学, [2] 東北大学, [3] 鉱山地震研究所、南アフリカ, [4]Council for Geoscience, South Africa, [5]CSIR / Witwatersrand Univ., South Africa, [6]J-DESC SATREPS WS と関連会議の参加者
[1]Ritsumeikan Univ., [2]Tohoku Univ., [3]Inst. Mine Seismology, South Africa, [4]Council for Geoscience, South Africa, [5]CSIR / Witwatersrand Univ., South Africa, [6]Participants of J-DESC SATREPS WS and related meetings

野島、San Andreas、集集地震、四川地震、Alpine などの断層、Gulf of Corinth、南海トラフ、日本海溝、Costa Rica など、断層ドリリングが世界各地で行われ、2013 年 ICDP 科学会議では、これらの大きな成果を鑑みてもなお次の 10 年には以下のトピックに集中すべきだと提言している（Mori and Ellsworth 2013）：
－どう破壊核が形成され破壊が伝播するのか？　なぜ破壊が止まるのか？
－何が地震の頻度と規模を決めるのか？
－地震時に断層の透水性や流体圧がどう変化するのか？
－地震再来周期の間に、応力の大きさと向きがどう変わるのか？
これらの地震学の重要な問題の議論は、震源から遠い観測のデータでは困難であり、ドリリングによる至近距離の観測データでしかできない。しかし、地震核形成深度まで地震発生帯をドリリングすることは容易ではない。

金の採掘が最深で地表下 3.4km に達する南アフリカ（南ア）の金鉱山は、年に数回の頻度で M2 かそれ以上の地震が採掘現場から数十m以内で発生するため、地震活動域に容易に直接アクセスできる世界でも非常に限られた場所である。古くは、McGarr et al. (1975) や Gay and Ortlepp (1979) などの先駆的研究があり、最近でもユニークな地震発生場の至近距離観測結果が得られている（e.g. Ogasawara et al. 2002, 2009, and 2014; Nakatani et al. 2008）. その様な中、南アの金採掘地域における過去最大の M5.5 の地震が Orkney 市近郊で 2014 年 8 日 5 日に発生した（以下 M5.5 Orkney 地震）。この震源断層の上端は、付近の金鉱山の最深部（地表下約 3km）のわずか数百m下であり、地下の坑内 Geophone やひずみ計や地表の強震記録など、かつてない多くのデータが SATREPS などの取り組みによって得られた。このようなまれにしか得られないデータで詳しい地震解析を行い、地震発生帯での直接観測を比較して地震発生帯の物理学を議論するために、この震源をできるだけ早くドリリングする計画を議論するための ICDP workshop を我々は提案した。我々はまた、M2 の震源に数十mで到達できるドリリング候補地も見つけており、規模依存性を議論できるデータも得たいと考えている。この様なドリリングは、従来の他の自然地震のドリリング計画よりも地震発生帯の有意に広い範囲 (震源核、強震源、滑り量が大きい地点、断層端) をカバーすることができ、ドリリング・リスクやコストは小さくて済む可能性がある。

応力が臨界状態の地震発生帯では、３次元絶対応力の空間分布の直接測定は一般に困難であり、現場への往復に時間がかかる南ア金鉱山でも確実に十分な数の測定ができる技術・経験・体制がなかった。しかし、我々はこの困難を克服した。改善された数値応力モデリングに基づき、高応力によるボアホールやコアのダメージが小さくて済むドリリング方向を見つけ、より高い成功率で３次元絶対応力を測定できることを実証した。コアの回収率も高い。この成果を踏まえ以下の取り組みを行いたい：
（１）地震発生帯における３次元絶対応力分布の直接測定。
（２）水圧破砕や他のボアホールやコアのダメージから応力を推定する方法との総合解釈や比較。
（３）地震データ解析から得られる、地震時および地震後の破壊プロセス、強震発生過程、応力逆解析、応力降下量や b 値、間隙水圧の空間分布などと、孔やコアのロギングや測定で得られる地質・物性・間隙水圧や応力分布との比較。
（４）M5.5 Orkney 地震の謎の解明：通常の鉱山誘発地震は正断層型で鉱山採掘深度で発生するのに対し、M5.5 Orkney 地震は横ずれ型で採掘域よりも有意に深い地点で発生した。M5.5 の断層直上の地下約 3km の実測応力は、横ずれ型の地震発生を説明できなかった。
（５）ドリリング後に、地震後の地震活動、間隙水圧、歪などを連続観測し、バックグラウンド載荷速度や断層載荷源、断層強度回復過程などを議論。

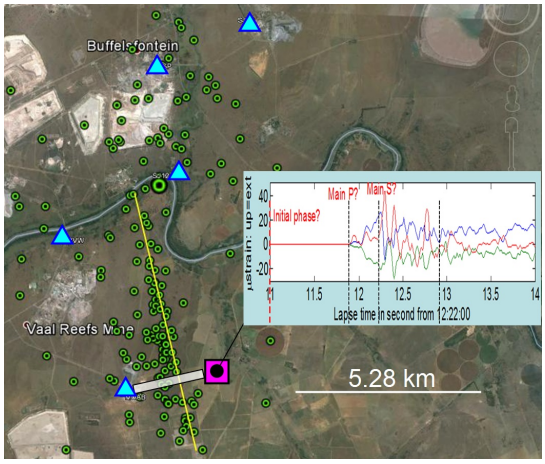
本連合大会では、南ア金鉱山での採掘と誘発地震、および、SATREPS 計画のインパクトや、M5.5Orkney 地震の破壊過程の予備解析の結果も報告されるので、参考にされたい。

MIS32-14 会場:304 時間:5 月 24 日 12:30-12:45

今回紹介する計画は、立命大、東大、東北大、鹿児島大、北大、産総研、東濃地震科学研、CSIR, Wits 大、Council for Geoscience の研究者、および、鉱山や関連会社（Anglogold Ashanti, Sibanye, Goldfields, GoldOne, First Uranium, Seismogen, OHMS, Groundwork, 3D 地科学研究所, 明間ボーリング, ホームサイスモメータ, テクノ菅谷）の技術者達による成果に基づく。研究資金は JST-JICA SATREPS、科研費（No. 21224012, 21246134）、地震・火山噴火予知のための観測研究計画、立命館大学、東北大 21 世紀 COE プログラム、南ア科技省、Research Chair initiative などによる。

図の説明：M5.5 の本震と余震（緑丸）、地表強震計（水色三角）、地下約 3km のひずみ計と応力測定地点（桃四角）およびドリリングが可能と思われる地下 3km の坑道（白細四角）。

キーワード: 地震発生場へのドリリング, 大深度南アフリカ金鉱山, 地震発生の物理, 応力と強度, 地震解析との比較
Keywords: Drilling into seismogenic zones, Deep South African gold mines, Physics of earthquakes, Stress and Strength, Comparison with seismological analyses



Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

MIS32-15 会場:304 時間:5 月 24 日 14:15-14:30

断層の活動性評価手法を構築するための破砕帯掘削プロジェクトの概要
Crush Zone Drilling Project for Development of Fault Activity Evaluation Methods

宮脇 昌弘[1*] ; 内田 淳一[1]
MIYAWAKI, Masahiro[1*] ; UCHIDA, Jun-ichi[1]

[1] 原子力規制庁技術基盤グループ
[1]Regulatory Standard and Research Department, Secretariat of Nuclear Regulation Authority (S/NRA/R)

断層の活動性はトレンチ調査等により断層上部を被覆する地層の切断関係や地層の年代から特定すること（いわゆる上載地層法）が多い。しかし、地域によっては地層の欠如や年代試料が採取できないなどの理由により、このような方法が適用できないことがある。この場合、破砕帯を用いた年代測定や破砕帯の性状に基づいた活動性の評価を行うこともあるが、十分に精度の高い評価手法が確立しているわけではない。例えば、地表付近の露頭で採取した破砕帯の年代測定値は、実際よりも古い時代に活動した年代値を示すこともある。この現状に鑑み、原子力規制庁では上載地層法の適用が困難な場合における断層の活動性評価手法を整備することを目的として破砕帯掘削プロジェクトに着手した。

本プロジェクトは「ボーリング調査」、「年代分析」、「室内試験」、「総合評価」の 4 つの視点から総合的に実施される。ボーリング調査では、活動時期が分かっている断層を対象として破砕帯を貫く大深度のボーリング掘削や物理検層、孔内試験、各種地質構造解析等を行い、信頼できる年代試料が採取できる温度圧力条件や地質条件などを検証する。掘削候補地点としては、現在、郷村・山田断層や野島断層等で実施することを検討している。郷村・山田断層は 1927 年の北丹後地震、野島断層は 1995 年の兵庫県南部地震で活動した断層である。各地点において、年代のリセット条件等を把握するために深度 1,000m-2,000 mのボーリングを掘削する予定である。年代分析では採取した破砕帯試料を用いた最新活動面付近でのルミネッセンス年代や ESR 年代等の年代測定を行う。さらに、室内試験では採取した断層ガウジを用いた水圧環境下での高速せん断摩擦試験も行い、断層の摩擦特性や年代のリセット条件の特定についても実施する予定である。これらと合わせて、従来から行われてきた破砕帯の性状に基づいた活動性評価手法の高度化についても検討する。これらの複数の手法から得られた結果を比較・検証し、断層の活動性に関する総合解釈を行う。

今後数年程度を目途に、断層の活動性評価に係る重点的な調査を実施し、評価精度の向上を図る。

キーワード: 破砕帯掘削, 断層の活動性評価, 野島断層, 郷村・山田断層
Keywords: Crush Zone Drilling, Fault Activity Evaluation, Nojima Fault, Gomura-Yamada Faults

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断層帯比抵抗分布の異方性と断層岩微細構造
Anisotropic resisitiviy profiles and fault rock microstructures in fault zones

小村 健太朗 [1*]
OMURA, Kentaro[1*]

[1](独) 防災科学技術研究所
[1]Nat'l Res Inst Earth Sci Disast Prev

内陸活断層では，断層面の構造や摩擦特性は一様ではなく不均質になり，それが地震発生に関与しているはずである．しかし，その断層面の不均質性の本体については，まだわからないことが多く，地震観測や物理探査などの結果と断層を構成する断層岩の微細組織や鉱物組成との比較から，不均質の要因が探求されている．本発表では，不均質のひとつとして断層帯比抵抗分布の異方性に着目し，断層ドリリングによって採取された地下断層岩の微細構造観察との比較から，畑川断層と跡津川断層を例として，比抵抗異方性の要因を考察した．畑川断層では，路頭で採取された断層岩試料について，常温常圧下で 3 次元 3 方向の比抵抗を実測し，断層岩試料の微細構造観察と比較した．同じく，跡津川断層では，断層帯を横断する複数の測線における物理探査による比抵抗分布と断層ドリリングによる断層岩コアの微細構造観察を比較した．その結果，比抵抗異方性には，断層岩の面構造の発達，層状ケイ酸塩鉱物（粘土鉱物）の面状分布が重要な要因と考えられた．つまり，地震が繰り返すなかで，断層帯の面構造が発達し，次第に比抵抗分布が異方的になると考えられる．そのため，断層帯の比抵抗異方性の分布や強さは，その場所の過去の断層活動の履歴と相関が深いと予想される．

キーワード: 比抵抗, 異方性, 物理探査, 断層帯, 微細組織, 活動履歴
Keywords: resisitivity, anisotropy, physical survey, fault zone, microstructure, activity history

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Assessment of In-Situ Stress from Deep Borehole in the Middle Coastal Plain and Its Implications for Taiwan CCS Project

Assessment of In-Situ Stress from Deep Borehole in the Middle Coastal Plain and Its Implications for Taiwan CCS Project

YEH, En-chao[1*] ; LI, Wei-cheng[1] ; CHIANG, Tung-chin[1] ; WU, Feng-yi[1] ; CHENG, Chuan-li[1] ; LIN, Weiren[2] ; WANG, Tai-tien[3] ; YU, Chi-wen[4] ; CHIAO, Chung-hui[5] ; YANG, Ming-wei[6]
YEH, En-chao[1*] ; LI, Wei-cheng[1] ; CHIANG, Tung-chin[1] ; WU, Feng-yi[1] ; CHENG, Chuan-li[1] ; LIN, Weiren[2] ; WANG, Tai-tien[3] ; YU, Chi-wen[4] ; CHIAO, Chung-hui[5] ; YANG, Ming-wei[6]

[1]Department of Earth Sciences, National Taiwan Normal University, Taipei, Taiwan, ROC, [2]Kochi Institute for Core Sample Research, Japan Agency Marine-Earth Science and Technology, Japan, [3]Institute of Mineral Resources Engineering, National Taipei University of Technology, Taipei, Taiwan, [4]Sinotech Engineering Consultants, Inc., Taipei 114, Taiwan, ROC, [5]Taiwan Power Company, Taipei 100, Taiwan, ROC, [6]Taiwan Power Research Institute, Taipei 238, Taiwan, ROC
[1]Department of Earth Sciences, National Taiwan Normal University, Taipei, Taiwan, ROC, [2]Kochi Institute for Core Sample Research, Japan Agency Marine-Earth Science and Technology, Japan, [3]Institute of Mineral Resources Engineering, National Taipei University of Technology, Taipei, Taiwan, [4]Sinotech Engineering Consultants, Inc., Taipei 114, Taiwan, ROC, [5]Taiwan Power Company, Taipei 100, Taiwan, ROC, [6]Taiwan Power Research Institute, Taipei 238, Taiwan, ROC

Global warming have been becoming an important issues around the world. One of efficient ways to reduce the global warming and decrease CO2 in the atmosphere is to sequestrate the supercritical CO2 into the underground structures or formations. To evaluate the risk of CO2 leakage, the knowledge of in-situ stress state and integrity and rock strength of cover formation is essential. Besides, the assessment of in-situ stress state is significant for drilling-casing plan. Furthermore, understanding the relationship between fracture and in-situ stress is one of key information to evaluate the potential of fracture seal/conduit and fracture reactivity for such underground projects.

Formations under the Coastal Plain in Taiwan have been evaluated as saline-water formations with gently east-dipping and no distinct fractures endured by regional tectonics of obliquely arc-continental collision with N35W compression. The formation is characterized as a suitable place for carbon sequestration. In this study, we will integrate the comprehensive results of different in-situ stress determinations such as anelastic strain recovery (ASR), diameter core deformation analysis (DCDA), borehore breakout, hydraulic fracturing from a 3000m borehole of carbon sequestration testing site and further evaluate the seal feasibility in terms of rock mechanics and tectonic implication in the context of stress state.

Results of 30 ASR experiments between the depth of 1500m and 3000m showed the consistent normal faulting stress regime. Stress gradient of vertical stress, horizontal maximum stress and horizontal minimum stress with depth is estimated as 22, 20, and 18MPa/km, respectively. The distribution of borehole breakout is not completely throughout all of interval in 1500-3000m. The mean orientation of breakout is about 175deg and mean width of breakout is 84 deg. Based on rock mechanic data, maximum injection pressure of carbon sequestration can be estimated. Furthermore, although it is normal faulting stress regime consistent with core observations and borehole image logging, the horizontal maximum stress of 85deg inferred from breakout suggested that this place has been affected by the compression of oblique collision. The comparison of stress magnitudes estimated from ASR, DCDA, breakout and hydraulic fracturing cab further verified current results.

キーワード: In-Situ Stress, CCS, Taiwan, ASR, Breakout, Hydraulic Fracturing
Keywords: In-Situ Stress, CCS, Taiwan, ASR, Breakout, Hydraulic Fracturing

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An enhanced geothermal system
An enhanced geothermal system

DMITRIEV, Alexei[1*] ; KURYANOV, Roman[2]
DMITRIEV, Alexei[1*] ; KURYANOV, Roman[2]

[1]Institute of Space Science, National Central University, Jungli City, Taiwan, [2]Private Job
[1]Institute of Space Science, National Central University, Jungli City, Taiwan, [2]Private Job

We introduce a new technology of heat extraction from the deep crustal rocks known as an enhanced geothermal system (EGS). EGS is based on an innovative way to drill deep and ultra-deep (6-12 km) geothermal wells with a speed of up to 30 meters per hour, with a diameter of 250 mm to 500 mm at a temperature in the bottom of the well up to 400C. This allows building environmentally friendly petrothermal power plants and heat sources. EGS are built in a number of regions in Russia from the European part to Siberia and Far East. The pilot scientific and experimental petrothermal power plant is characterized by rated capacity of 24 MW with an annual power generation of 187,4 millions KWh and heat supply of 905 thousand Gcal/year. The estimated technical & economical parameters of the petrothermal power plant are the following (all costs are in 2010 year prices):

- construction period - 6-10 months ;
- cost of electricity produced - 0,01 USD/kWh;
- cost of heat produced - 1,30 USD/Gcal;
- total investment in the power plant - 44 million USD;
- lifetime - 40 years;
- average payback period - 2 years.

Contact person for further information: Roman M. Kuryanov, e-mail: roman.taiwan@gmail.com

キーワード: deep and ultra-deep drilling, geothermal energy, petrothermal power plants
Keywords: deep and ultra-deep drilling, geothermal energy, petrothermal power plants

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沖縄トラフ熱水活動域で実施された掘削同時検層の概要
Preliminary report on logging while drilling conducted at Iheya-North Knoll, Okinawa Trough

斎藤 実篤[1*] ; 真田 佳典[1] ; MOE KYAW[1] ; 木戸 ゆかり[1] ; 濱田 洋平[1] ; 熊谷 英憲[1] ; 高井 研[1] ; 鈴木 勝彦[1] ; CK14-04 乗船者一同[1]
SAITO, Saneatsu[1*] ; SANADA, Yoshinori[1] ; MOE, Kyaw[1] ; KIDO, Yukari[1] ; HAMADA, Yohei[1] ; KUMAGAI, Hidenori[1] ; TAKAI, Ken[1] ; SUZUKI, Katsuhiko[1] ; CK14-04, Cruise member[1]

[1] 海洋研究開発機構
[1]JAMSTEC

In July 2014, a scientific drilling expedition, CK14-04/Expedition 907 was conducted at an active hydrothermal field on the Iheya-North Knoll by D/V Chikyu as a part of “Next-generation Technology for Ocean Resources Survey” of the Cross-ministerial Strategic Innovation Promotion Program (SIP). During the expedition logging while drilling (LWD) was deployed to constrain the area of the fluid reservoir beneath seafloor followed by three coring holes down to 150 meter below the seafloor (mbsf). The LWD system is composed of arcVISION for resistivity and natural gamma ray measurement and TeleScope for real-time transmission of drilling parameters and arcVISION data. Both tools also measure annular pressure and temperature at two different depths. To protect the LWD tools from the anticipated high temperature of hydrothermal fluids, exceeding 300 ℃, a continuous pumping system (Non Stop Driller) was applied to maintain fluid circulation continuously even during pipe connection.

Five sites (C9011-C9015) at the Iheya-North Original Site and one site (C9016) at Aki Site were drilled with LWD. At C9012 and C9016, the arcVISION detected temperature anomaly up to 84 ℃ at 234 mbsf and up to 39 ℃ at 80 mbsf, respectively. The temperature quickly increases at that depth and it would reflect the existence of high-temperature heat source along borehole. Due to the continuous fluid circulation during drilling, the measured temperature does not indicate in-situ temperature, but it reflects the heat disturbed by the cold circulated water instead.

High quality resistivity and natural gamma ray data were acquired at six sites. The log curves at Site C9016 show characteristic response; the natural gamma ray log exhibits extremely high radiation (>500 gAPI) at 7-13 and 23-31 mbsf (Zone A). In the underlying interval of 31-40 mbsf, the resistivity log exhibits extremely low value (<0.2 ohm-m) (Zone B). Then the resistivity log exhibits higher value (˜10 ohm-m) and the natural gamma ray log shows very low radiation (<50 gAPI) at the interval of 41-48 mbsf (Zone C). The log characteristics in Zone A, B, and C can be interpreted as a series of K-rich alteration zone, sulfide zone, and low-K hard (silicified) sediments, respectively. The LWD-based lithological interpretation was confirmed by the following core description. Zones A and B can be correlated to altered clay zone and sulfide zone including sphalerite, galena, chalcopyrite, and pyrite. Our results show that LWD is a powerful tool for the scientific investigation of submarine hydrothermal deposits and LWD survey enhances the successful recovery of sulfide samples.

*CK14-04 航海乗船者　高井研・熊谷英憲・久保雄介・斎藤実篤・野崎達生・山本啓之（海洋研究開発機構），山崎徹（産業技術総合研究所），河地正伸 (国立環境研究所)、Moe Kyaw Thu・福島朋彦・髙見英人・荒井渉・Frederic Sinniger・正木裕香・中嶋亮太・宮崎淳一・川口慎介・高谷雄太郎・猿橋具和・杉原孝充・真田佳典・木戸ゆかり・新田末広 (海洋研究開発機構)、堤彩紀・戸塚修平 (海洋研究開発機構／九州大学)

キーワード: ちきゅう, 沖縄トラフ, 北伊平屋海丘, 掘削同時検層, SIP
Keywords: CHIKYU, Okinawa Trough, Iheya-North Knoll, Logging while drilling, SIP

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掘削コア試料の高品質、長期間保管を可能とする磁場振動型凍結とその評価
Intact preservation of environmental samples by freezing under an alternating magnetic field

諸野 祐樹[1*] ; 寺田 武志[3] ; 山本 裕二[5] ; 肖 楠[1] ; 廣瀬 丈洋[1] ; 菅野 正也[4] ; 大和田 哲男[4]
MORONO, Yuki[1*] ; TERADA, Takeshi[3] ; YAMAMOTO, Yuhji[5] ; XIAO, Nan[1] ; HIROSE, Takehiro[1] ; SUGENO, Masaya[4] ; OHWADA, Norio[4]

[1] 海洋研究開発機構 高知コア研究所, [2] 海洋研究開発機構 海底資源研究開発センター, [3] マリン・ワーク・ジャパン, [4] 高知大学海洋コア総合研究センター, [5] 株式会社アビー
[1]Kochi Institute for Core Sample Research, JAMSTEC, [2]Research and Development Center for Submarine Resources, JAMSTEC, [3]Marine Works Japan Ltd., [4]Center for Advanced Marine Core Research, Kochi University, [5]ABI Co. Ltd.

掘削コア試料を含む環境試料を用いた研究を実施する際、最も基礎的かつ重要なことは、試料の物理、化学、生物的な特性を保持した状態で陸上研究施設へ移動し、かつ保存することである。特に掘削試料を用いた生命研究を実施する場合には、船上環境において十分な汚染対策や分子生物学的な実験を行うことは非常に困難であることから、下船後の研究手法に応じた複数の保存法、又は一部の構造的特性が破壊されてしまう凍結保存が実施されてきた。本研究では、上記問題点を解決するため、交流磁場環境で試料を凍結する Cell Alive System (CAS) を用いた海底下堆積物試料の凍結を実施し、その評価を行った。地球深部掘削船「ちきゅう」試験航海 CK09-03 などによって得られた海底下堆積物試料から同一層準を分割して作成したサブサンプルについて、CAS および-20、-80、-196 ℃（液体窒素）で凍結し、未凍結冷蔵試料と共に 6 ヶ月間保管を行った。保管後の試料について微生物細胞を計数したところ、通常の凍結では細胞数が最大 90%程度減少したのに対し、CAS 凍結試料では初期の細胞数に近い細胞が維持されていた。さらに、CAS 凍結によって堆積物試料が保持している残留磁化の強度はやや減少するもの の、方位は影響を受けないことが明らかとなった。次に、培養を行った大腸菌細胞について同様の凍結を行い、2.5 ヵ月後にコロニー形成で生存率の評価を行ったところ、CAS 凍結が最も高い生存率を示した。本研究の結果により、CAS 凍結は生命研究だけでなく、様々な研究を目的とした環境試料の各種特性を保持したまま長期間の保管を可能とする有用なツールであることが示された。

キーワード: 海底堆積物, 掘削コア試料, 凍結, CAS
Keywords: Subseafloor sediment, Freezing, Cell Alive System

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アラスカ沖における第四期放散虫生層序 (IODP Exp.341 Site U1417)
Quaternary radiolarians biostratigraphy in the Alaska margin (IODP Exp.341 Site U1417)

松崎 賢史 [1*] ; 朝日 博史 [2] ; 福村 朱美 [3] ; 今野 進 [4] ; 須藤 斎 [5]
MATSUZAKI, Kenji M.[1*] ; ASAHI, Hirofumi[2] ; FUKUMURA, Akemi[3] ; KONNO, Susumu[4] ; SUTO, Itsuki[5]

[1] 産業技術総合研究所　地質情報研究部門, [2] 韓国極地研究所, [3] 北海道大学大学院 理学院 自然史科学専攻, [4] 九州大学 大学院理学研究院 地球惑星科学部門, [5] 名古屋大学環境学研究科
[1]Geological Survey of Japan, AIST, [2]Korea Polar Research Institute, [3]Hokkaido University Graduate School of Science, [4]Kyushu University Graduate School of Science, [5]Nagoya University Graduate School of Environmental Studies

The Gulf of Alaska is marked by the St. Elias orogen largely influenced by the ice-sheet expansion over the past 10 Myr. In this context, the Integrated Ocean Drilling Program (IODP) Expedition 341 drilled several sites in southern Gulf of Alaska in order to determine the linkage between the tectonic uplift, erosion by ice sheet and climate changes since Miocene. Concerning the paleontological aspect of the collected cores, siliceous microfossils were not abundant. Cores collected from Site U1417 present the highest abundance in siliceous microfossils. Indeed, in Site U1417, siliceous microfossils present moderate abundance for the upper 200 meters CCSF-B, which correspond to the Pleistocene. This interval is composed of dark gray mud with several interbeds of diatomaceous oozes. For deeper intervals, siliceous microfossils abundances were low, with numerous barren intervals.

Therefore, in this study, samples from the upper 200 m CCSF-B of Site U1417 were analyzed in order to establish the depth-age model based on shipboard diatom/radiolarian biostratigraphy and paleomagnetic polarity stratigraphy for enables further paleoceanographic studies. Indeed, several radiolarian datum events such as the last occurrences (LOs) of *Stylatractus universus*, *Lychnocanoma sakaii* and *Amphimelissa setosa* appear to be important for chronostratigraphic use. Particularly, temporal distribution of *Amphimelissa setosa* is highly interesting because the LO records at the MIS 4/ 5 boundary (77 ka) in the North Pacific, while this species is still extant in the Arctic Ocean, Norwegian Sea, or in the Labrador Sea. In this study, we could establish the LOs of *Sphaeropyle robusta* (1,500 ka, 161.9 m CCSFB at the median depth), *Eucyrtidium matuyamaii* (1,250 ka, 143.3 m), *Stylatractus universus* (450 ka, 74.9 m), *Axoprunum acquilonium* (350 ka, 61.5 m) and *Amphimelissa setosa* (77 ka, 25.0 m), and acme of *Lychnocanoma sakaii* (61 ka, 18.81 m). On the other hand, the FO of *Amphimelissa setosa* could be established for the first time in the northeastern Pacific between the LO of *Eucyrtidium matuyamaii* and the base of Jaramillo magnetic normal polarity epoch (1,072 ka).

キーワード: 第四期, 放散虫, 生層序
Keywords: Quaternary, Radiolarians, Biostratigraphy

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Last glacial to deglacial biotic changes on the Great Barrier Reef from offshore boreholes

Last glacial to deglacial biotic changes on the Great Barrier Reef from offshore boreholes

HUMBLET, Marc[1*] ; WEBSTER, Jody M.[2] ; BRAGA, Juan carlos[3] ; IRYU, Yasufumi[4] ; POTTS, Don C.[5] ; YOKOYAMA, Yusuke[6] ; ESAT, Tezer M.[7] ; FALLON, Stewart[8] ; THOMPSON, William G.[9] ; THOMAS, Alexander L.[10]
HUMBLET, Marc[1*] ; WEBSTER, Jody M.[2] ; BRAGA, Juan carlos[3] ; IRYU, Yasufumi[4] ; POTTS, Don C.[5] ; YOKOYAMA, Yusuke[6] ; ESAT, Tezer M.[7] ; FALLON, Stewart[8] ; THOMPSON, William G.[9] ; THOMAS, Alexander L.[10]

[1]Dep. of Earth and Planetary Sc., Nagoya Univ., [2]Geocoastal Research Group, Univ. of Sydney, [3]Dep. de Estrat. y Paleont., Univ. de Granada, [4]Inst. of Geol. and Paleont., Tohoku Univ., [5]Dep. of Ecol. & Evol. Bio., Univ. of California, [6]AORI, Univ. of Tokyo, [7]ANSTO, Inst. for Env. Res., Australia, [8]Res. Sch. of Earth Sc., Austral. Nation. Univ., [9]Lamont-Doherty Earth Observatory, USA, [10]School of GeoSciences, Univ. of Edinburgh
[1]Dep. of Earth and Planetary Sc., Nagoya Univ., [2]Geocoastal Research Group, Univ. of Sydney, [3]Dep. de Estrat. y Paleont., Univ. de Granada, [4]Inst. of Geol. and Paleont., Tohoku Univ., [5]Dep. of Ecol. & Evol. Bio., Univ. of California, [6]AORI, Univ. of Tokyo, [7]ANSTO, Inst. for Env. Res., Australia, [8]Res. Sch. of Earth Sc., Austral. Nation. Univ., [9]Lamont-Doherty Earth Observatory, USA, [10]School of GeoSciences, Univ. of Edinburgh

IODP Expedition 325 drilled 34 boreholes into submerged reef structures along the shelf edge of the Great Barrier Reef (GBR). The 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). The last glacial to deglacial reef sequence (˜8 ka to ˜27 ka) varies in thickness from ˜5.5 m to ˜34 m and consists primarily of coralgal boundstone with various proportions of microbialite. We use a detailed chronostratigraphic scheme based on numerous C14 and U-Th ages to discuss the evolution of the coralgal communities since the last glaciation. Exp. 325 cores show that different phases of sea level change promoted different shallow reef-building coral species at the study sites. The onset of the deglacial (16-19 ka) is characterized by a peak abundance of *Seriatopora* and *Tubipora* whereas the following rapid sea level rise (<16 ka) is marked by the dominance of massive *Isopora* and *Acropora* with medium- to robust-size branches. The shift in composition of coral communities around 16 ka coincides with the flooding of a pre-LGM MIS2 reef terrace, an event which had a major influence on reef growth and reef composition. We discuss the impact of this event on coralgal communities in the GBR and its significance for Quaternary reef evolution in general.

キーワード: IODP Expedition 325, Great Barrier Reef, Coralgal assemblages, Sea level changes, Glacial, Deglacial
Keywords: IODP Expedition 325, Great Barrier Reef, Coralgal assemblages, Sea level changes, Glacial, Deglacial

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IODP 第 350 次航海伊豆背弧掘削で得られた火山岩化学組成の予察的結果
Geochemical variation of Izu rear-arc volcanic rocks at drill Site U1437: Preliminary results from IODP Expedition 350

佐藤 智紀 [1*] ; 田村 芳彦 [1] ; 宮崎 隆 [1] ; Gill James B.[2] ; Hamelin Cedric[3] ; 仙田 量子 [1] ;
Vaglarov Bogdan S.[1] ; 原口 悟 [1] ; 常 青 [1] ; 木村 純一 [1] ; IODP 第 350 次航海 乗船研究者 [4]
SATO, Tomoki[1*] ; TAMURA, Yoshihiko[1] ; MIYAZAKI, Takashi[1] ; GILL, James B.[2] ; HAMELIN, Cedric[3] ;
SENDA, Ryoko[1] ; VAGLAROV, Bogdan S.[1] ; HARAGUCHI, Satoru[1] ; CHANG, Qing[1] ; KIMURA, Jun-ichi[1] ;
IODP EXPEDITION 350, Scientists[4]

[1] 独立行政法人海洋研究開発機構, [2]Earth and Planetary Sciences, University of California, Santa Cruz, [3]Centre for Geobiology, University of Bergen, [4] 国際深海科学掘削計画
[1]Japan Agency for Marine-Earth Science and Technology, [2]Earth and Planetary Sciences, University of California, Santa Cruz, [3]Centre for Geobiology, University of Bergen, [4]International Ocean Discovery Program

The Izu-Bonin-Mariana (IBM) arc is a good place to understand oceanic arc evolution. Crustal composition of the Izu segment of the arc differs beneath the arc-front and rear-arc (e.g. in terms of K, LREEs) (e.g. Hochstaedter et al., 2001; Ishizuka et al., 2003; Tamura et al., 2007). However, the magmatic history of the Izu rear-arc has not been well studied because Oligocene and Eocene Izu rear-arc lavas and volcaniclastics produced before the opening of the Shikoku basin have not been recovered by dredging or ROV sampling. Site U1437, drilled during IODP Expedition 350, is the first drill site in the Izu rear-arc and aimed to recover a record of volcanism in the rear arc from the present day to the Paleogene. This study will present preliminary major element (measured by X-ray fluorescence, XRF), trace element (measured by XRF and inductively coupled plasma-mass spectrometry, ICP-MS) and isotope ratios such as Sr, Nd, Pb and Hf (measured by ICP-MS and thermal ionization mass spectrometry, TIMS) to examine the geochemical signature of the recovered material and whether it can be related to the present day rear-arc or arc-front.

Site U1437 is located in a basin between the Manji and Enpo rear-arc seamount chains, about 90 km west of Myojinsho volcano on the Izu arc-front. Drilling reached 1806.5 meters below seafloor (mbsf), and the recovered rocks were divided into seven lithostratigraphic units and one igneous unit (a rhyolite intrusion). Lithostratigraphic Units I to V (0-9 Ma) dominantly consist of tuffaceous mud/mudstone. Below 1320 mbsf, Units VI and VII (older than 9 Ma) are composed chiefly of volcaniclastic layers, including coarser (>2 cm) volcanic clasts that are possibly derived from more proximal sources (Tamura et al., 2015).

Initially we have analyzed the major and trace element compositions of the volcanic clasts from Units VI and VII. Those show a wide range of compositions, from basalt to rhyolite, but are mainly intermediate (average SiO_2 = 54.1 wt%). The K_2O contents of the basalt to andesite clasts within the volcaniclastics are <0.9 wt%, with the exception of one clast, and their Zr/Y are <3.2 (average = 2.4), with the exception of two clasts. These characteristics are within the range of both the present day Izu arc-front and rear-arc. The present rear-arc type lavas are strongly enriched in LREEs, whereas the arc-front type are depleted. However, the chondrite normalized REE patterns of the clasts are flat (La/Yb ∼ 1.0) or show slight depletions in LREEs relative to HREEs, so it is not clear if these proximal clasts are similar to the current arc-front or rear-arc. The deepest clasts that have been analyzed (from 1797.26 and 1798.57 mbsf) are basaltic andesites and have relatively high Zr/Y (3.5 and 4.1, respectively), similar to the present day rear-arc. However, their K_2O contents (0.89 and 0.35 wt%, respectively) and flat REE patterns are not.

The wide range of clast compositions make it difficult to distinguish whether the clasts from the deeper part of Site U1437 are derived from the present day Izu arc-front or rear-arc and whether or not this geochemical distinction existed when this material was erupted on the basis of major and trace elements alone. Analyses from additional samples and the isotope compositions of the clasts may be more diagnostic.

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海底掘削試料中のクロミタイトに記録されている高温変成作用について
High temperature metamorphism recorded on chromitite samples in drilling cores from ocean floor

阿部 なつ江 [1*] ; 針金 由美子 [2]
ABE, Natsue[1*] ; HARIGANE, Yumiko[2]

[1] 独立行政法人海洋研究開発機構海洋掘削科学研究開発センター, [2] 産業技術総合研究所地質情報研究部門
[1]R&D Ocean Drilling Science, JAMSTEC, [2]Institute of Geology and Geoinformation, AIST

ODP、IODP における海洋地殻および蛇紋岩掘削では、下部地殻下部?モホ遷移帯に相当すると思われるはんれい岩や蛇紋岩化かんらん岩、さらにはポディフォーム型クロミタイトなどが採取されている（ODP Leg 209, IODP Exps. 304/305, 345）。それらの試料の一部は、著しく変質しており、変はんれい岩や蛇紋岩になっている。一見、非変質と思われる高温角閃石や、クロムスピネルなども、詳細に観察すると、緑色岩相?角閃岩相相当の高温変成作用を受けて（Alt et al., 2003; Abe, 2011 など）。とくに、低温で変質に比較的強いと考えられているクロムスピネルの高温変成作用中の変化については、オフィオライトやコマチアイト試料についての研究例はあるが、海底試料においては少なく、近年の海洋科学掘削の大きな成果の一つであろう。

本発表では、ODP Leg 209 および IODP Exp. 345 の成果を踏まえ、低速拡大および高速拡大プレートにおいて、下部地殻?最上部マントル付近の深さまで熱水が循環していた可能性を検討したい。

キーワード: クロミタイト, IODP Exp. 345, 高温変成, モホ遷移帯, 海洋地殻, ODP Leg 209
Keywords: chromitite, IODP Exp. 345, high temperature metamorphism, Moho transition zone, oceanic crust, ODP Leg 209

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ハードロック掘削での泥水検層とその意義
Mud logging in hard rock drilling

杉原 孝充 [1*] ; モーキョー スー [2] ; 青池 寛 [1]
SUGIHARA, Takamitsu[1*] ; MOE KYAW, Thu[2] ; AOIKE, Kan[1]

[1] 海洋研究開発機構　地球深部探査センター, [2] 海洋研究開発機構　海洋掘削科学研究開発センター
[1]CDEX/JAMSTEC, [2]ODS/JAMSTEC

Mud logging in a riser drilling operation has been powerful tool in the scientific drilling. Since fast and safe drilling are minimum requirements in the deep drilling operation, it is generally difficult that continuous coring is carried out to obtain geological sample (rocks and fluid). Therefore, cuttings survey and mud gas monitoring in mud logging are essentially important in the riser drilling for scientific research. Some hard rock drilling operations by using the Chikyu have been planned (e.g., IBM, MoHole). Since continuous coring in the hard rock drilling is technically more difficult as compared with the drilling for sedimentary rocks and slow rate of penetration results in consuming much of operation time, the cuttings survey is a unique approach for lithological characterization in the hard rock drilling. In addition, fluid sampling from hard rock core is also difficult, even if core sample is obtained. Thus, the mud logging is especially important for the hard rock drilling, not only minimizing operation time but also maximizing scientific result. In this presentation, we will introduce current technology of advanced mud logging and discuss on potential of the mud logging for the hard rock drilling.

キーワード: 泥水検層, 大深部掘削, ハードロック掘削, ライザー掘削, マッドガスモニタリング, カッティングス
Keywords: Mud logging, Deep drilling, Hard rock drilling, Riser drilling, Mud gas monitoring, Cuttings

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IODP Expedition 344 コスタリカ沖の堆積物物性と間隙水圧
Distribution of physical properties and pore pressure of sediments off Costa Rica: IODP Expedition 344

佐伯 綾香 [1*] ; 橋本 善孝 [1]
SAIKI, Ayakia[1*] ; HASHIMO, Yoshitaka[1]

[1] 高知大学
[1]Kochi University

Evolution of physical properties in subduction zone is a key to understand lithification processes, location of decollement, stress distribution. In this study, we examined the physical properties of sediments using on-board data and laboratory experimental data on sediments obtained off Costa Rica margin to understand the distribution of compaction states.

Target sites are in the Integrate Ocean Drilling Program (IODP) Expedition 344 off Costa Rica, including reference sites (U1381 and U1414), frontal prism site (U1412), mid-slope site (U1380) and upper-slope site (U1413).

Laboratory experiments for velocity and porosity measurements were conducted with variation of effective pressure.

Porosity ranges from about 80% to about 53% during experiments. P-wave velocity ranges from about 1.4 to about 1.7 km/s. S-wave velocity ranges from about 0.75 to 0.93 km/s. Vp/Vs ranges from about 1.73 to 2.04. bulk modulus ranges 1.7 to 2.7. shear modulus ranges from about 0.8 to 1.4. Vp-porosity relationships from on-board data and from laboratory experiments are comparable nicely. This comparable trend in Vp-porosity relationship suggests that the relationship between porosity and effective pressure can be applied to most of sediments.

The porosity-effective pressure curves under isotropic condition were converted to the curves under uniaxial condition (Teeuw, 1971). Using the normal consolidation curves under isotropic and uniaxial stress conditions, we converted the on-board porosity to effective pressure and fluid pressure.

In balk modulus-shear modulus graph, bulk modulus is not seen much change, but shear modulus there are variations.

For U1381 Unit I, hydrostatic fluid pressure was estimated as expected as a reference site.

For U1414 in another reference site, hydrostatic pressure was observed in Unit I, but lower fluid pressure than hydrostatic pressure was estimated in the upper part of Unit II. Below that, the pore pressure returned along hydrostatic pressure. This boundary can be weakened by higher fluid pressure below the boundary, suggesting that this boundary is likely a precursor of decollement.

For Unit 1412 in frontal prism, pore fluid pressure is lower than hydrostatic pressure, suggesting that they have lower porosity possibly caused by tectonic stress.

For 1380 in mid-slope andU1413 in upper slope, very low fluid pressure is observed. Because there is almost no age difference at the boundary, the extremely low porosity can be caused by rapid sedimentation and erosion on the seafloor or tectonic stress enhanced-dehydration.

キーワード: 掘削, コスタリカ, 海底堆積物, 物性, 間隙水圧
Keywords: Drilling, IODP, Costa Rica, Expedition 344, Physical properties

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南海付加体，巨大分岐断層浅部コア試料に認められる変形構造：IODP Exp. 338 解析結果

Structures characterizing the megasplay fault across shallow slope sediments of the Nankai accretionary prism

大橋 聖和 [1*] ; Olivier Fabbri[2] ; 山口 飛鳥 [3]
OOHASHI, Kiyokazu[1*] ; OLIVIER, Fabbri[2] ; YAMAGUCHI, Asuka[3]

[1] 山口大学大学院理工学研究科, [2]University of Franche-Comte, Besancon, France, [3] 東京大学大気海洋研究所
[1]Graduate School of Science and Engineering, Yamaguchi University, [2]University of Franche-Comte, Besancon, France, [3]Atomosphere and Ocean Research Institute, The University of Tokyo

LWD measurements at Hole C0022A and coring at Hole C0022B during IODP Expedition 338 confirm the early suggestion from seismic reflection imaging that a branch of the mega-splay fault crosses shallow slope sediments and may thus get close to the sea bottom. At C0022A, the evidence include (1) the presence of moderately to steeply dipping fractures between 86.6 and 105.5 mbsf and (2) the presence of a low-resistivity zone at the same interval, with a particularly low resistivity interval at 100-101 mbsf. At C0022B, the evidence include (1) three age reversals recognized between 76.48 and 84.48 mbsf, between 132.38 and 142.70 mbsf, and between 142.70 and 148.46 mbsf, (2) a bedding disturbed interval from 73.49 to 143.82 mbsf, (3) poor core recovery in the interval of 94.5-99.5 mbsf, suggesting highly fractured or disturbed material, and (4) the presence of three intervals of clay characterized by a composite planar fabric (338-C0022B-10T-5, 49-51 cm, 10T-CC, 19-20 cm, and 11H-1, 18-19 cm). By comparison with the nearby 3D seismic reflection image, the C0022A low-resistivity image at 100-101 mbsf could correspond to the megasplay fault core zone where displacement is supposed to be the largest. The sudden drop in core recovery at this interval indicates that coring at Site C0022 likely missed the megasplay fault core zone. Conversely, coring likely sampled secondary fault zones characterizing the damage zone of the megasplay fault branch at Site C0022. Post-cruise investigations aim at examining all structures and microstructures associated with this supposed damage zone.

Based on CT scan images, seven intervals were selected from Core 10T (three from section 5, one from core catcher) and from Core 11T (three intervals). For each interval, a slab was cut, dried, epoxied and polished before being analysed by XRF scanner for compositional mapping. Polished thin sections were made from the most deformed-looking parts of the slabs.

XRF scanning analysis brings two main results: At least three gently dipping planar surfaces outlined by iron sulphide (most likely pyrite) cross the cores. It is not clear whether these surfaces are faults or not but, in one case (11T-1, 72-83 cm), the surface separates clays with different Ca contents, suggesting some offset. The presence of iron sulphide along the surfaces may be related to fluid flow having allowed recrystallization of this mineral species. Shipboard observation revealed three intervals characterized by weakly marked planar fabrics. Two of these intervals (338-C0022B-10T-5, 49-51 cm and 11H-1, 18-19 cm) are characterized by a depletion in Ca and Sr and an enrichment in K with respect to the surrounding sediments.

Lastly, preliminary optical microscope observation indicates that some incipient non-coaxial shear deformation (asymmetrical sand lenses and composite planar fabric) affected the intervals with planar fabrics. Put together, these results indicate that deformation so far recognized in C0022B cores is weak to moderate. This is not an unexpected result given (1) the young age of the sediments and (2) the fact that samples likely come from the damage zone a few meters and not from the core zone.

[Acknowledgements]
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MIS32-P08 会場:コンベンションホール 時間:5 月 24 日 18:15-19:30

IODP 第 338 次および第 348 次航海で採取された堆積物コアの有機地球化学的研究
Distribution and evolution of organic matters in deep seafloor sediments collected during IODP Exp.338 and 348

淵田 茂司 [1*] ; 益田 晴恵 [1] ; 岡崎 香生里 [1] ; 黒川 将貴 [2]
FUCHIDA, Shigeshi[1*] ; MASUDA, Harue[1] ; OKAZAKI, Kaori[1] ; KUROKAWA, Syoki[2]

[1] 大阪市立大学大学院理学研究科, [2] 石油資源開発株式会社
[1]Department of Geoscience, Osaka City University, [2]Japan Petroleum Exploration Co., Ltd. (JAPEX)

Seafloor sediments are important as a significant reservoir of organic matter, especially organic carbon and nitrogen. Sedimentary organic matters are mainly supplied through a photosynthetic process of phytoplankton biomass and other metabolisms of zooplankton and maturated during diagenesis (Lee *et al*., 1988). Proteins, peptides, and amino acid monomers are the main components and account for 30 – 40% of the total nitrogen and 10 – 15% of the total organic carbon content of seafloor sediments (Burdige and Martens, 1988). Some studies revealed the distribution and concentration of organic matters including hydrolyzable amino acids in shallow seafloor area (e.g., Cowie and Hedges, 1992; Kawahata and Ishizuka, 1993). The recent Integrated Ocean Drilling Program (IODP) Nankai Trough Seismogenic Zone Experiment (NanTro SEIZE) Expedition 338 and 348 at Site C0002 drilled and cored successfully up to 3059 mbsf. In this study, concentrations of hydrolyzable amino acids and maturation stage of organic matters in the sediments collected during the expeditions were determined in order to evaluate the distribution and evolution of sedimentary organic matters during diagenesis in deep seafloor.

Sediment core samples collected at Site C0002 (202.1 – 2216.9 mbsf), C0021 (3.7 – 186.4 mbsf), and C0022 (1.2 – 411.4 mbsf) were dried and powdered manually with an agate mortar on shore. The type and maturity of sedimentary organic matters were determined using Rock – Eval pyrolysis method at Japan Petroleum Exploration CO., LTD.

A part of the sediments were hydrolyzed to extract the amino acids from the hydrolyzable peptides and proteins. 1.0 g of the dried sediment was reacted with 6 N HCl at 110 ℃ for 22 h. The amount of total hydrolyzable amino acids (THAA) in the treated sample solutions were measured by high performance liquid chromatograph using postcolumn ortho-phthalaldehyde derivation.

The concentrations of THAA in the core collected at Site C0002 vary between 819.9 – 177.1 nmol/g, and Gly was the most abundant amino acid followed by Asp, Ser, Ala, Val, and Phe. At Site C0021 and C0022, the concentrations of THAA were 4679.2 and 6729.7 nmol/g at surface, respectively, and decreased drastically with depth. The THAA carbons account for $<$1% of total organic carbon and nitrogen, indicating that most of the biogenic organic matters would be changed into kerogens.

The amounts of hydrocarbons generated through thermal cracking of non-volatile sedimentary organic matter (S_2) were 1.2 – 0.15 mg/g. The low S_2 values and TOC (1.2 – 0.3 %) indicate that most of kerogen in the cores is categorized as type III. The temperatures at which the maximum release of hydrocarbons from thermal cracking of kerogen occurs during pyrolysis (T_{max}) were 379 – 416 ℃ at the shallow area (1.2 – 91.7 mbsf), increased gradually with depth, and reached to 439 ℃ at 2216.9 mbsf. Rock – Eval data indicate that the maturation of kerogens could be progressed with depth in seafloor sediment.

キーワード: ロックエバル, ケロジェン, アミノ酸
Keywords: Rock Eval, Kerogen, Amino Acids

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IODP 第 348 次航海で得られたカッティングス中の炭質物ビトリナイト反射率
Vitrinite reflectance of carbonaceous materials in cuttings retrieved during the IODP Expedition 348

福地 里菜[1*] ; 山口 飛鳥[1] ; 山本 由弦[2] ; 芦 寿一郎[1]
FUKUCHI, Rina[1*] ; YAMAGUCHI, Asuka[1] ; YAMAMOTO, Yuzuru[2] ; ASHI, Juichiro[1]

[1] 東京大学大気海洋研究所, [2] 海洋研究開発機構
[1]Atmosphere and Ocean Research Institute, The University of Tokyo, [2]Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

Integrated Ocean Drilling Program (IODP) Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) Expedition 348 took place from 13 September 2013 to 29 January 2014. During the Exp. 348, cuttings, core samples, mud gas, and logging data were collected from Holes C0002N and C0002P down to 3058.5 mbsf. Four lithologic units were identified at Site C0002 based on geological and geochemical characteristics of core and cuttings samples: Unit II (475-512.5 mbsf in Hole C0002M), Unit III (875.5-975.5 mbsf in Hole C0002N), Unit IV (975.5-1665.5 mbsf in Hole C0002N), and Unit V (1665.5-2325.5 mbsf in Hole C0002N, and 1965.5-3058.5 mbsf in Hole C0002P)(Tobin et al., 2015).

To evaluate whole thermal structure of the Site C0002, we performed vitrinite reflectance analysis for cuttings samples collected every 100 m of Holes C0002N and C0002P. Vitrinite reflectance (R_o) is an indicator to estimate maximum paleotemperature, which has been widely applied to reveal tectonic evolution of on-land accretionary complex (e.g. Underwood et al., 1992; Sakaguchi, 1996; Ohomori et al., 1997) and thermal anomalies along fault slip zones reflecting frictional heating due to seismic slip (e.g. Sakaguchi et al., 2007; Sakaguchi et al., 2011). This is the first study that applied vitrinite analyses systematically to the entire modern accretionary prisms.

In this presentation, we report preliminary results of vitrinite reflectance analysis. R_o values are 0.15 to 0.20 in Unit III (forearc basin strata), 0.20 to 0.27 in Unit IV (accretionary prism strata), and 0.20 to 0.45 in Unit V (hemipelagic sediment). In general, R_o values tend to be gradually and continuously increasing with depth. Estimated paleotemperatures of Unit IV and V are approximately 40 ℃ and 90 ℃, respectively, which are consistent with estimated modern temperatures (Sugihara et al., 2014).

キーワード: ビトリナイト反射率, 炭質物, 最高被熱温度, 付加体
Keywords: vitrinite reflectance, carbonaceous matter, paleotemperature, accretionary prism

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MIS32-P10 会場:コンベンションホール 時間:5 月 24 日 18:15-19:30

統合国際深海掘削計画第 337 次研究航海の非弾性ひずみ回復（ASR）測定結果
Preliminary results of anelastic strain recovery (ASR) measurements during IODP Expedition 337

林 為人[1*] ; 谷川 亘[1] ; 山本 裕二[2] ; 森田 澄人[3] ; 山田 泰広[4] ; 稲垣 史生[1]
LIN, Weiren[1*] ; TANIKAWA, Wataru[1] ; YAMAMOTO, Yuhji[2] ; MORITA, Sumito[3] ; YAMADA, Yasuhiro[4] ; INAGAKI, Fumio[1]

[1] 海洋研究開発機構　高知コア研究所, [2] 高知大学, [3] 産業技術総合研究所, [4] 海洋研究開発機構　掘削科学センター
[1]Kochi/JAMSTEC, [2]Kochi University, [3]GSJ/AIST, [4]ODS/JAMSTEC

IODP (Integrated Ocean Drilling Program) による下北八戸沖石炭層生命圏掘削（第 337 次研究航海、Exp337）は、青森県八戸市の沖合約 80km、水深 1,180m の地点（C0020）において「ちきゅう」によるライザー掘削を行い、当時の海洋科学掘削史上の最深記録となる海底下深度 2,466 mまで到達した。海底下深度 1,276.5m～2,466m の範囲において、コア試料の採取を行った。本研究は、当該掘削のコア試料を用いて、地層の三次元応力情報を得る目的で、コア試料の非弾性ひずみ回復（Anelastic strain recovery、ASR と略称）を「ちきゅう」船上で測定した。

コア試料が地下で負荷していた応力が掘削により解放された場合、岩石の弾性ひずみは瞬間的に解放され、その解放のプロセスは測定することができない。しかし、非弾性ひずみは徐々に回復するので、コア試料が船上に上がってからでも、その一部を測定することが可能である。このコア試料の非弾性ひずみテンソルと解放された応力テンソルとの関連性を利用した応力測定法は、非弾性ひずみ回復法（ASR 法）といい、IODP Exp315 と Exp316 においては海洋科学掘削の分野において初めて成功に適用された（Byrne et al., 2009; GRL, Vol.36, L23310）。

Exp337 においては、海底下深度 1,370～2,448m の範囲から計 7 つのコア試料を採取して、6 つのコア試料について良質な非弾性ひずみ回復の時間連続変化データを得ることができた。海底下深度 2,448m から採取されたコア試料の ASR 測定は、海洋科学掘削計画では最深の適用例である。本研究では ASR の測定方法として、Byrne et al. (2009) と同様な方法・装置・実験手順で行った。また、非弾性ひずみ回復測定後のコア試料を用いて、古地磁気測定によるコアの定方位を行なった。その結果、浅部の 5 試料で測定した応力状態は、基本的に正断層型、すなわち、最大主応力の方向はほぼ鉛直方向であった。最深（2,448 mbsf）のコア試料の非弾性ひずみ回復から得られた最大主応力は、約 30° の傾斜ではあるが、概ね逆断層型の応力状態を呈した。一方、水平面内の二次応力状態でみれば、すべての深度の最大水平主応力の方向は、東南東-西北西から東北東-西南西までの範囲に分布しており、平均的に東西方向であった。

謝辞：本研究で使用したコア試料は IODP の提供によるものである。また、船上での実施については Exp337 Scientists, 「ちきゅう」の掘削オペレーションチーム、ラボのテクニシャーンの協力を得たので、ここに深謝の意を申し上げる。

キーワード: 応力, 非弾性ひずみ回復法, IODP, Exp 337
Keywords: Stress, ASR, IODP, Exp 337

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Stress State in the Tip of Ilan Plan and Its Applications for Taiwan Geothermal Plan

Stress State in the Tip of Ilan Plan and Its Applications for Taiwan Geothermal Plan

WU, Fang-yih[1*] ; YEH, En-chao[1] ; KAO, Tsu-en[1] ; SHIU, Chi-shun[1] ; LIN, Weiren[2] ; WANG, Tai-tien[3] ; HUNG, Jih-hao[4] ; SONG, Sheng-rong[5]
WU, Fang-yih[1*] ; YEH, En-chao[1] ; KAO, Tsu-en[1] ; SHIU, Chi-shun[1] ; LIN, Weiren[2] ; WANG, Tai-tien[3] ; HUNG, Jih-hao[4] ; SONG, Sheng-rong[5]

[1]Department of Earth Sciences, National Taiwan Normal University, Taipei, Taiwan, [2]Kochi Institute for Core Sample Research, Japan Agency for Marine-Earth Science and Technology, [3]Institute of Mineral Resources Engineering, National Taipei University of Technology, Taipei, Taiwan, [4]Department of Earth Sciences, National Central University, Jhongli, Taiwan, [5]Department of Geosciences, National Taiwan University, Taipei, Taiwan
[1]Department of Earth Sciences, National Taiwan Normal University, Taipei, Taiwan, [2]Kochi Institute for Core Sample Research, Japan Agency for Marine-Earth Science and Technology, [3]Institute of Mineral Resources Engineering, National Taipei University of Technology, Taipei, Taiwan, [4]Department of Earth Sciences, National Central University, Jhongli, Taiwan, [5]Department of Geosciences, National Taiwan University, Taipei, Taiwan

Understanding the relationship between in-situ stress and fluid-conduits is one of the most important keys for developing the enhanced geothermal system. At the same time, understanding this relationship also provide insights into evaluating the well locations and drilling direction.

The Ilan Plain of northeastern Taiwan is located between the Hsuehshan Range and Backbone Range and is influenced by the compression of mountain building between the Eurasian and Philippine Sea Plates and the back-arc extension of Okinawa Trough simultaneously. As a result, the 3D stress field is complicated and the attitude and spatial distribution of fluid conduits is not clear. To develop the technology of the enhanced geothermal system, this study focused on the evaluation of in-situ stress state on multiple scales.

Stress inversion of regional focal mechanism suggests that the stress state varies dramatically in the region and it is strike-slip faulting stress regime with NNE-SSW compression in the tip of Ilan Plain. The paleostress inversion results from the southern foothills show that the stress pattern of strike-slip faulting and normal faulting regime took place repeatedly and horizontal minimum stress orientation switched between N-S and W-E orientation. Analysis of anelastic strain recovery experiments on the retrieved cores of 720-920m indicates that a strike-slip faulting stress regime with NNW compression and NEE tension. Several hydraulic fracturing tests were conducted in the interval of 750-765m. The shut-in pressure is determined as 13.57MPa and reopening pressure is estimated as 12.66MPa. Diameter Core Deformation Analysis and rock mechanics experiments are also conducted. Integration of different stress assessments and rock strength data will provide insights to understanding the reasonable 3D in-situ stress in the tip of Ilan plain and further help the development of enhanced geothermal system.

キーワード: in-situ stress, enhanced geothermal system, Taiwan, Ilan Plain, hydraulic fracturing, ASR
Keywords: in-situ stress, enhanced geothermal system, Taiwan, Ilan Plain, hydraulic fracturing, ASR

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新型 XRF コアスキャナーの性能と海洋コア研究への応用
Introduction of a new XRF core scanner and application of marine core science

村山 雅史[1*] ; 松崎 琢也[1] ; 入野 智久[2] ; 多田 隆治[3]
MURAYAMA, Masafumi[1*] ; MATSUZAKI, Takuya[1] ; IRINO, Tomohisa[2] ; TADA, Ryuji[3]

[1] 高知大学海洋コア総合研究センター, [2] 北海道大学大学院地球環境科学研究院, [3] 東京大学大学院理学系研究科地球惑星科学専攻
[1]Center for Advanced Marine Core Research, Kochi University, [2]Faculty of Environmental Earth Science, Hokkaido University, [3]Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo

2014 年，高知大学海洋コア総合研究センターでは増設建て屋が完成し， 同 8 月に新型 XRF コアスキャナー（COX 社製）が導入された． 従来機器に比べ，微小領域の元素マッピングが可能になり， 高分解能，高解像度でコア試料が連続測定できる．機器の特徴として，以下が挙げられる．

1）測定幅が小さい（200 μ m × 8mm）ため，微少な堆積構造（ラミナやバーブなど）の元素分布を連続的に非破壊で，高解像度の測定が可能である．

2）従来の機器に比べ管電流が高く，検出器の感度が高いため， 1 測点あたりに要する測定時間が短くても，十分な強度が得られる．

3）XRF 測定と同時に，X 線透過画像，カラーイメージが撮影でき，かつ，3 つのデータを統合して解析が可能である．

今後の海洋コア研究への応用が期待される．

キーワード: XRF コアスキャナー, ITRAX, 海洋コア
Keywords: XRF core scanner, ITRAX, marine core science