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

MIS32-01 Room:304 Time:May 24 09:00-09:15

Miocene to Pliocene osmium isotopic record of Mediterranean sediments: new insights into the Messinian Salinity Crisis

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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.

Keywords: Messinain Salinity Crisis, Os isotopes

Japan Geoscience Union Meeting 2015
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MIS32-02 Room:304 Time:May 24 09:15-09:30

Past 60 kyr changes in the diatoms and glacial sediment supply to the Gulf of Alaska (IODP Exp. 341 Site U1419)

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Integrated Ocean Drilling Program (IODP) Expedition 341 during May to July, 2013 has achieved collecting continuous sediment records in the Gulf of Alaska (GoA) to examine the response of an orogenic system to the establishment of a highly erosive glacial system. Obtained Cenozoic sediments permit to seek their relationship to the circum-North Pacific paleoenvironmental changes at extremely high time-resolution. Together with distal location of drilling sites to the ice-sheet and regional sedimentation process of less influenced by the on-land systems of sedimentation, transportation and supply, ensures execute aforementioned research objectives.

In this presentation, we will present preliminary outlines, including analyses of diatoms, physical properties and foraminiferal oxygen isotopes, using the Holocene sediment samples drilled at the continental shelf (Site U1419). According to off-shore analyses, the estimated sedimentation rate at this site was 200 m/100 kyrs. The fossil diatom assemblages consists not only of several taxa which indicate the paleoceanographic changes but also of coastal and freshwater species and resting spores, which show the influences of continental environments and the nutrient fluctuation in water column. Their abundances with significant fluctuation show the paleoceanographic variation, changes in the development of ice sheets, the sedimentation rate with erosion and supply, and grain size of supplied sediments affecting the volume of pore water, as well as the dissolution of siliceous/calcareous microfossils during 100 ka to the present in the GoA.

Keywords: IODP Exp. 341, Diatom fossils, Paleoenvironmental chang, Glaciation, Gulf of Alaska

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MIS32-03 Room:304 Time:May 24 09:30-09:45

Diatom analysis of IODP Exp.341 Site U1418 in the Gulf of Alaska

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In early summer 2013 (May, 29th-July, 29th), the Integrated Ocean Drilling Program (IODP), Expedition 341, has drilled five sites along the transect from the distal end of the ice edge in southern Alaska until the proximal continental shelf, and the Gulf of Alaska (GOA) (Expedition 341 Scientists 2014; Suto et al., 2014).The geomorphology of the GOA shelf sea floor has been strongly influenced by active tectonics and glacial strata formation overprinted by glacial erosion (Carlson et al., 1982; Elmore et al., 2013). The GOA is rich in in terrigenous sediments and nutrients supplied by fresh water originated by ice cover melting. Until now, studies on sediment samples in the GOA coastal areas, indicate that sedimentation rate was very fast for the last glacial period (Jaeger et al., 2008; Davies et al., 2011).

The core collected from site U1418 revealed that only 1 Ma is reached at the depth of 900 m CCSF-B after the microfossils and paleo magnetism preliminary results (Expedition 341 Scientists 2014). In this study, we propose to report the offshore data obtained during the expedition, supplemented by the data obtained onshore.

Keywords: IODP Exp.341, U1418, Diatom

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MIS32-04 Room:304 Time:May 24 09:45-10:00

Holocene sedimentation in estuaries of the Baltic Sea (Exp. 347)

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The IODP Expedition 347 ”Baltic Sea Paleoenvironment” drilled two sites in the Angermanalven 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 Angermanalven River. One aim of the IODP drilling was to recover a uniquely long varve record from the two sites in Angermanalven 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.

国際深海掘削計画(IODP)のExp.347航海において、Ångermanälven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１８m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。

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MIS32-05 Room:304 Time:May 24 10:00-10:15

Changes in Paleocene ostracodes at IODP Site U1407, off Newfoundland, with special reference to the hyperthermal events

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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).

Keywords: Hyperthermal events, Northwestern Atlantic, taxonomic diversity, Ostracoda, Paleocene

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MIS32-06 Room:304 Time:May 24 10:15-10:30

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

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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.

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

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MIS32-07 Room:304 Time:May 24 10:30-10:45

Introduction to the International Continental Scientific Drilling Program in the Samail Ophiolite, Sultanate of Oman

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The Samail ophiolite in Oman is the largest, best-exposed, and most-studied ophiolite in the world. The Scientific Drilling in the Samail Ophiolite has been approved by the International Continental Drilling Project. In the presentation, we introduce the scientific objectives, geology of the potential sites, and practical and educational perspectives of the proposal. The scientific objectives are as follows: quantify 1) the nature and timing of solid upwelling beneath a spreading ridge using crystal shape and lattice preferred orientation data systematically collected on core from the periphery of a mantle diaper, 2) the nature and structural relationships of melt transport features in the shallow mantle, to evaluate mechanisms that focus transport from a melting region to the ridge, 3) chemical variability deformation structures in the crust-mantle transition zone and plutonic lower crust, to determine the depth of crystallization, the nature of ductile flow, and mechanisms of melt transport to the lower crust through the MOHO, 4) hydrothermal alteration and cooling of the plutonic lower crust using mineral compositions, diffusion profiles, and stable isotopes to determine the importance of hydrothermal convection in heat and mass transfer and 5) investigate processes in the critical dike-gabbro transition via study of cross-cutting igneous relationships, metamorphic mineral assemblages, and geochemical alteration, for igneous and metamorphic processes at oceanic spreading centers. The drillings can also adders 1) mass transfer from subducted sediments into overlying peridotite via petrologic and geochemical studies, with special focus on carbon cycling, and 2) ongoing-subsurface alteration of mantle peridotite, including fluid compositions, hydrology, characterization of fracture and vein spacing, studies of mineral assemblages formed by carbonation, hydration (serpentinization) and oxidation and resulting mass transfer, and characterization of the subsurface microbial biosphere that derives energy from catalysis of low temperature alteration.

Lead proponents are Peter B. Kelemen, Jurg Matter and Damon A. Teagle. Other principal investigators are 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.

Keywords: Oman Ophiolite, Mid-Ocean Ridge, Island Arc, Serpentinization, Carbonation, Subsurface microbial biosphere

Japan Geoscience Union Meeting 2015
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MIS32-08 Room:304 Time:May 24 11:00-11:15

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

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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.

Keywords: Lake Van, Nemrut Volcano, Alkaline lake, lake sediment, tephra, ICDP Paleovan project

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MIS32-09 Room:304 Time:May 24 11:15-11:30

IODP Expedition 351 Izu-Bonin-Mariana Arc Origins: Temporal evolution of arc volcanism inferred from melt inclusions

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International Ocean Discovery Program (IODP) Expedition 351 (June-July 2014) cored 1611-m-long cores composed of 1461-m-long sediments and 150-m-long igneous basement rocks from Site U1438 in the Amami Sankaku Basin (ASB), west of the Kyushu-Palau-Ridge (KPR) which represents a remnant part of the now active Izu-Bonin-Mariana (IBM) arc. Based on lithostratigraphy, the sedimentary section is divided into four units. The uppermost Unit I (160.3-m long) is composed of Neogene hemi-pelagic sediments with interspersed discrete ash layers derived from explosive volcanism probably from the Ryukyu and Kyushu arcs. Unit II (139.4-m long) is composed of late-Oligocene turbidites. Unit III (1046.4 m long) is composed of Oligocene to Eocene coarser-grained turbidites. Unit IV (99.7-m long) is composed of siliceous pelagic sediments interbedded by tuffaceous sandstones.

In order to study the temporal evolution of island arc volcanism at an earlier stage of the IBM arc, we analyzed major and volatile elements (Cl and S) of melt inclusions collected from Unit III (30-40 Ma based on onboard biostratigraphy) using electron probe microanalyzers (EPMAs) installed at JAMSTEC and ANU. Most of the host minerals of melt inclusions are clinopyroxene and plagioclase and the compositions of melt inclusions are diverse, ranging from basalt through rhyolite, and also ranging from low-K to medium-K series. In terms of major elements, low-K series melt inclusions are consistent with the melt compositions reported from forearc region and volcanic front of the IBM arc. Major element composition of medium-K series melt inclusions overlaps with the melt composition reported from the IBM rear-arc, such as volcanoes on the KPR and/or near the ASB. These observation suggests that the turbidites accumulated at the ASB originate not only from the IBM rear arc, but also from the IBM forearc and/or frontal-arc.

Both low-K and medium-K melt inclusions older than ∼35 Ma are basaltic and andesitic melts. Rhyolitic melts suddenly occur at ∼35 Ma and afterward. The number of melt inclusions containing intermediate composition (66-74 wt.% SiO_2) is smaller, suggesting that such intermediate melts represent mixtures of mafic and rhyolitic melts. We infer that the middle crust beneath the arc volcanoes would have been growing and thickening until ∼35 Ma after subduction had been initiated at ∼50 Ma, and that the rhyolitic magmas would have been generated by partial melting of the middle crust at ∼35 Ma and afterward.

Keywords: IODP, IBM arc, Kyushu-Palau ridge, Amami Sankaku Basin, melt inclusion

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MIS32-10 Room:304 Time:May 24 11:30-11:45

IODP Expedition 352 FAB and boninite

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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 Room:304 Time:May 24 11:45-12:00

Advanced Technologies of CHIKYU to Challenge the Deep Earth's Interior

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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.

Keywords: Scientific drilling, Deep water, Deep penetration, NanTroSEIZE, JFAST

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

MIS32-12 Room:304 Time:May 24 12:00-12:15

High paleo-heat flow in Costa-Rica seismogenic zone, off Osa peninsula (CRISP Exp344)

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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.

Keywords: IODP, Seismogenic zone drilling, CostaRica, Heat flow, Vitrinite reflectance

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

MIS32-13 Room:304 Time:May 24 12:15-12:30

Deep Fault Drilling Project, Alpine Fault, New Zealand

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]

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The Alpine Fault is mature (>460 km offset), active (25 mm/yr), and late in its seismic cycle. It ruptured in AD 1717, has a 330 yr return time, and M8 earthquake probability is c. 30% in the next 50 yrs (Berryman et al. 2013). The objective of the Deep Fault Drilling Project (DFDP) is to collect materials, measure ambient conditions, and monitor at depth on the Alpine Fault, to understand earthquake processes and the formation of a continental orogen. Second phase of DFDP was carried out at the Whataroa River.

An open hole with depth of 893.18 m was drilled without coring during the DFDP-2. The drilling revealed the several features of the hanging wall of the Alpine Fault. The thickness of quaternary sediments at the Whataroa River is about 240 m. Cutting samples were collected with interval of 2 m and the microstructural changes within the fault zone were revealed. Geophysical wire-line loggings were carried out. The result of temperature logging indicates that the geothermal gradient in the hanging wall is as high as 100 ℃/km.

Water level, density, viscosity and other properties of mud water were continuously monitored, which are expected to constrain the hydrological property of fault zone.

DFDP-2 unfortunately failed to get the drill-core samples and penetrate the Alpine fault due to several problems during drilling. One of the objectives of DFDP-2 was to reveal fault behavior at depth and core-log integration is essential. However it is impossible to achieve this. The Alpine fault is a unique and scientifically intriguing fault, and it is worth being drilled again at the Whataroa River. A strategy for succeeding at the drilling should be important.

Keywords: Fault Zone Drilling, Alpine Fault

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

MIS32-14 Room:304 Time:May 24 12:30-12:45

Drilling into seismogenic zones of M2.0 - M5.5 earthquakes in deep South African gold mines (DSeis)

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Several fault-zone drilling projects have been carried out around the world (e.g. the Nojima, San Andreas, Chelungpu, Wenchuan, and Alpine faults, Gulf of Corinth, Nankai Trough, Japan Trench, and Costa Rica). Building on these, the 2013 ICDP Science Conference (Mori and Ellsworth, 2013) proposed that in the next decade ICDP focuses on fault drilling topics such as:

- How do earthquakes nucleate and propagate? Why do they stop?
- What controls the frequency and size of earthquakes?
- How does fault permeability and fluid pressure vary during earthquakes?
- How does stress vary during the earthquake cycle?

However, necessary near-field borehole observations have always been difficult where earthquakes nucleate.

Mining-induced earthquakes with magnitudes $\geqq$ 2 take place only a few tens of meters away from active workings in South African (SA) gold mines at depths of up to 3.4 km, where recent work (e.g. Ogasawara et al. 2014) yielded unique results. The largest event recorded around SA mining region, a M5.5 earthquake, took place near Orkney on 5 August 2014, with the upper edge of the activated fault being only some hundred meters below the nearest mine workings (3.0 km depth). This is one of the rare events for which detailed seismological data are available (Figure). We also have some additional sites where M$\simeq$2 hypocenters are located within several tens of meters. So, drilling is possible with a significantly better spatial coverage (including nuclei of ruptures, strong motion sources, asperities, and rupture edges) and a lower risk and at much smaller costs.

In seismogenic zones in a critical state of stress, difficult is to measure 3D absolute stress reliably. However, we have overcome this problem. Better recovery of cores with less stress-induced damage is also feasible. These will allow us the following work:

(1) DIRECT MEASUREMENT of 3D ABSOLUTE STRESS.

(2) INTEGRATED STRESS ANALYSIS of hydro-fracturing and stress damage in boreholes and cores, compared with the 3D absolute stress.

(3) ANALYSIS of AVAILABLE SEISMIC DATA to delineate co- and post-seismic rupture processes, strong motion sources, stress inversion, spatio-temporal variation of stress drop, Coulomb failure stress, b-value, and pore pressure to compare with the results of drilling and measurements.

(4) TESTING of HYOPOTHETICAL M5.5 SOURCE MECHANISMS: the Orkney M5.5 was significantly deeper than the mining horizon with a strike-slip faulting mechanism, being different from nearby mining induced events typically on mining horizons with normal faulting mechanisms. The stress in-situ measured at ˜3km depth just above the M5.5 fault didn′ t account for strike-slip faulting, suggesting the fault was weak or stress abruptly changes somewhere.

(5) INSTALLATION of SENSORS CLOSE to the M5.5 FAULT to monitor seismicity, and spatio-temporal changes in strain, pore pressure, and velocity structure, enabling investigation into background loading, fault-healing, and stress perturbation sources.

Our potential future work reported here was built on the outcome by the researchers from Ritsumeikan, Tokyo, Tohoku, Kyoto, Kagoshima, and Hokkaido universities, AIST, TRIES, NIED, CSIR, Wits University, and Council for Geoscience, and the engineers at gold mines and associated companies (Angogold, Sibanye, Goldfields, GoldOne, First Uranium, Seismogen, OHMS, Groundwork, 3D Geoscience, Akema Boring, Homeseismo, Techno Sugaya), and funded by SATREPS, JSPS (No. 21224012, 21246134), Obs. Res. Prog. Prediction Earthq. Volc. Erupt., Ritsumeikan Univ., Tohoku Univ. COE, SA DST, and SA Research Chairs initiative.

Figure Caption: Main and aftershocks of the Orkney M5.5 (green circles), surface strong motion stations (light blue triangles), strainmeters and stress measurement site at ˜3km depth (a pink square), and a tunnel at 3km depth for potential drilling (white thin rectangle).

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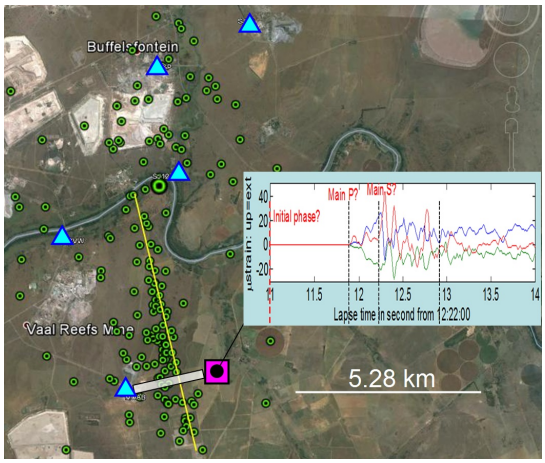
Keywords: Drilling into seismogenic zones, Deep South African gold mines, Physics of earthquakes, Stress and Strength, Comparison with seismological analyses



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

MIS32-15 Room:304 Time:May 24 14:15-14:30

Crush Zone Drilling Project for Development of Fault Activity Evaluation Methods

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Fault activity is often revealed from trench excavating investigations that clarify the cross-cutting relationship and depositional age of overlying sediments. However, in some area, these methods cannot be applied because of the lack of overlying sediments and samples indicating depositional age. In such case, fault activity is evaluated on the basis of identification of depositional age and/or characteristics of the crush zone, however, these fault activity evaluation methods with sufficient resolution have not been established yet. For example, material sampled from surface or near surface outcrops of crush zone indicates sometimes older active age than actual one. Considering this situation, S/NRA started up a crash zone drilling project to improve fault activity evaluation methods.

This project consists of borehole surveys, dating analysis, laboratory tests, and integrated analysis. In borehole surveys we conduct a deep borehole drilling, physical logging, various borehole tests, and structural analysis by use of borehole and borehole core samples through the crush zone of a target fault with known activities to reveal the physical (temperature and pressure) and geological conditions in which the sample with a reliable dating can be acquired. We are implementing the crush zone drilling project in Gomura-Yamada Faults and Nojima Fault. Gomura-Yamada Faults ruptured during the 1927 Kita-Tango Earthquake and Nojima Fault ruptured during the 1995 Hyogo-ken Nanbu Earthquake. In each drilling site, the target depth of drilling is 1,000-2,000m to understand the conditions in which fault activation age estimated from fault gouge is initiated. In dating analysis, we plan to apply luminescent and ESR dating methods to sample from crush zone in the vicinity of the latest active fault plane in the zone. Furthermore, in laboratory tests, rotary-shear high-velocity friction tests using natural fault gouge under water-pressure conditions will be able to estimate frictional behavior of faulting and condition of initiation of fault activation age estimated from fault gouge in our plan. In addition, we will also study how to improve the conventional method of fault activity evaluations based on qualitative characteristics of the crush zone. Combining some results from multi-methods, integrated analysis on fault activity will be performed.

We will principally investigate fault activity research focused on the crush zone and attempt to get practical results within the next few years.

Keywords: Crush Zone Drilling, Fault Activity Evaluation, Nojima Fault, Gomura-Yamada Faults

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

MIS32-16 Room:304 Time:May 24 14:30-14:45

Anisotropic resisitiviy profiles and fault rock microstructures in fault zones

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Structure and frictional characteristic in a fault zone are not homogeneous, and the inhomogeneity should be related to earthquake generation mechanism. However, main features of the inhomogeneity in fault zones are not yet sufficiently understood. I consider it is effective to compare geophysical data, such as seismological and/or physical survey data, and fault rock microstructures and mineral compositions in the fault zone. In this presentation, I report the results of comparisons of two cases of Hatagawa and Atotsugawa fault and suggest the factors affecting the inhomogeneity of fault structure. We compared the anisotropic resistivity profile by laboratory measurements of fault rocks and physical survey across the fault zones with microscopic observations and mineral composition analysis of fault rocks provided by drilling into the fault zone. As a result, the anisotropic resistivity profiles are strongly related to foliation structure of fault rocks. It is suggested that, during earthquake recurrences, foliation fabric is developed and resistivity profile becomes anisotropic progressively, and that, in other words, the anisotropic resistivity profile of fault zone reflect the fault activity history.

Keywords: resisitivity, anisotropy, physical survey, fault zone, microstructure, activity history

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

MIS32-17 Room:304 Time:May 24 14:45-15:00

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

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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.

Keywords: In-Situ Stress, CCS, Taiwan, ASR, Breakout, Hydraulic Fracturing

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

MIS32-18 Room:304 Time:May 24 15:00-15:15

An enhanced geothermal system

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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.

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Keywords: deep and ultra-deep drilling, geothermal energy, petrothermal power plants

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

MIS32-19 Room:304 Time:May 24 15:15-15:30

Preliminary report on logging while drilling conducted at Iheya-North Knoll, Okinawa Trough

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[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 Cruise member: TAKAI, Ken; KUMAGAI, Hidenori; KUBO, Yusuke; SAITO, Saneatsu; NOZAKI, Tatsuo; YAMAMOTO, Hiroyuki (JAMSTEC); YAMASAKI, Toru (AIST/GSJ); KAWACHI, Masanobu (NIES); Moe Kyaw Thu; FUKUSHIMA, Tomohiko; TAKAMI, Hideto; ARAI, Wataru; SINNIGER, Frederic; MASAKI, Yuka; NAKAJIMA, Ryota; MIYAZAKI, Jun’ichi; KAWAGUCCI, Shinsuke; TAKAYA, Yutaro; SARUHASHI, Tomokazu; SUGIHARA, Takamitsu; SANADA, Yoshinori; KIDO, Yukari; NITTA, Suehiro (JAMSTEC); TSUTSUMI, Saki; TOTSUKA, Shuhei (JAMSTEC & Univ. Kyushu)

Keywords: CHIKYU, Okinawa Trough, Iheya-North Knoll, Logging while drilling, SIP

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

MIS32-20 Room:304 Time:May 24 15:30-15:45

Intact preservation of environmental samples by freezing under an alternating magnetic field

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The study of environmental samples requires a preservation system that stabilizes the sample structure, including cells and biomolecules. To address this fundamental issue, we tested the cell alive system (CAS)-freezing technique for subseafloor sediment core samples. In the CAS-freezing technique, an alternating magnetic field is applied during the freezing process to produce vibration of water molecules and achieve a stable, super-cooled liquid phase. Upon further cooling, the temperature decreases further, achieving a uniform freezing of sample with minimal ice crystal formation. In this study, samples were preserved using the CAS and conventional freezing techniques at 4, -20, -80 and -196 (liquid nitrogen)oC. After 6 months of storage, microbial cell counts by conventional freezing significantly decreased (down to 10.7% of initial), whereas that by CAS-freezing resulted in minimal. When *Escherichia coli* cells were tested under the same freezing conditions and storage for 2.5 months, CAS-frozen *E. coli* cells showed higher viability than the other conditions. In addition, an alternating magnetic field does not impact on the direction of remanent magnetization in sediment core samples, although slight partial demagnetization in intensity due to freezing was observed. Consequently, our data indicate that the CAS technique is highly useful for the preservation of environmental samples.

Keywords: Subseafloor sediment, Freezing, Cell Alive System