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JAMSTEC 独立行政法人
海洋研究開発機構
JAPAN AGENCY FOR MARINE-EARTH SCIENCE AND TECHNOLOGY

NATSUSHIMA Cruise Report

NT13-25

Irabu Knoll

Okinawa Trough, Japan

Dec. 4, 2013 – Dec. 11, 2013

Chief Scientist: Teruo Fujii

(Institute of Industrial Science, University of Tokyo)

in collaboration with:

Kyushu University and Kochi University

&

Japan Agency for Marine-Earth Science and Technology
(JAMSTEC)

Preface

This report describes preliminary information on the data taken during NT13-25 cruise by R/V Natsushima with ROV HyperDolphin from Dec.4 to 11, 2013.

NT13-25 cruise was conducted based on the proposal KS13-06 titled “Optimization of a method to search for novel hydrothermal activity using a set of chemical sensors, and its implementation” (representative: Teruo Fujii / University of Tokyo) and KS13-09 titled “3D image mapping of deep sea hydrothermal field using an AUV” (representative: Toshihiro Maki / University of Tokyo).

As for KS13-06, the purpose of the cruise is to examine the feasibility of a new method to search for hydrothermal activity in deep-sea environment using a set of chemical sensors including pH, ORP, H₂S sensors and ATP analysis system, which are all mounted on the ROV. As for KS13-09, the purpose of the cruise is to examine the feasibility of a new method to obtain 3D image of hydrothermal vent field based on a seafloor station and an autonomous probe (AUV).

In this cruise, the research works described in the following has been conducted mostly focusing on the hydrothermal activity in the Irabu Knoll. The extensive exploration over the area of the Irabu Knoll has been conducted by the ROV. During two dives (#1604 and #1605) in total by ROV, CTD profiler, turbidity, pH, ORP, and H₂S sensor (TANSAKUN), and a prototype of *in situ* measurement system (IISA-ATP2) were deployed into the deep-sea environment. As a result of survey operations, biogeochemical anomalies were successfully detected around the East and the West seamounts. Visible signs and biogeochemical indications of the hydrothermal activity were detected on the South seamount. Although the detailed analyses are needed to validate the data, a plenty of useful information to further improve the systems could be collected.

As for the AUV deployment, the experimental seafloor station was installed on the seafloor near the hydrothermal mounds by the dive #1606. Then three test dives of the AUV Tri-TON 2 were conducted near the station. The station was finally recovered by the dive #1607. Although the detailed analyses are needed to validate the data, a plenty of useful information to further improve the systems was collected.

Finally, I would like to thank all the members of the HyperDolphin operation team (Chief: Yoshinari Ohno), and the crewmembers of R/V Natsushima (Captain: Hitoshi Tanaka) for their dedicated efforts to make this cruise so successful.

December 2013

Teruo Fujii (NT13-25 Chief Scientist)

Notice on Using:

This cruise report is a preliminary documentation as of the end of the cruise. It may not be corrected even if changes on content (i.e. taxonomic classifications) are found after publication. It may also be changed without notice. Data on the cruise report may be raw or not processed. Please ask the PI for the latest information before using. Users of data or results of this cruise are requested to submit their results to Data Integration and Analysis Group (DIAG), JAMSTEC.

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1. Cruise Information

(1) Cruise number/ship name: NT13-25 R/V Natsushima, ROV HyperDolphin (HPD)

(2) Title of the cruise: FY2013 Deep Sea Survey by ROV HyperDolphin in Nansei Islands

(3) Proposal number/Title of the proposal:

KS13-06 “Optimization of a method to search for novel hydrothermal activity using a set of chemical sensors, and its implementation” (representative: Teruo Fujii / University of Tokyo)

KS13-09 titled “3D image mapping of deep sea hydrothermal field using an AUV” (representative: Toshihiro Maki / University of Tokyo)

(4) Period of the cruise: 8 days from December 4 to 11, 2013

(5) Port calls: dep. Naha, ret. Naha

(6) Research area: Irabu Knoll (Fig.1.1)

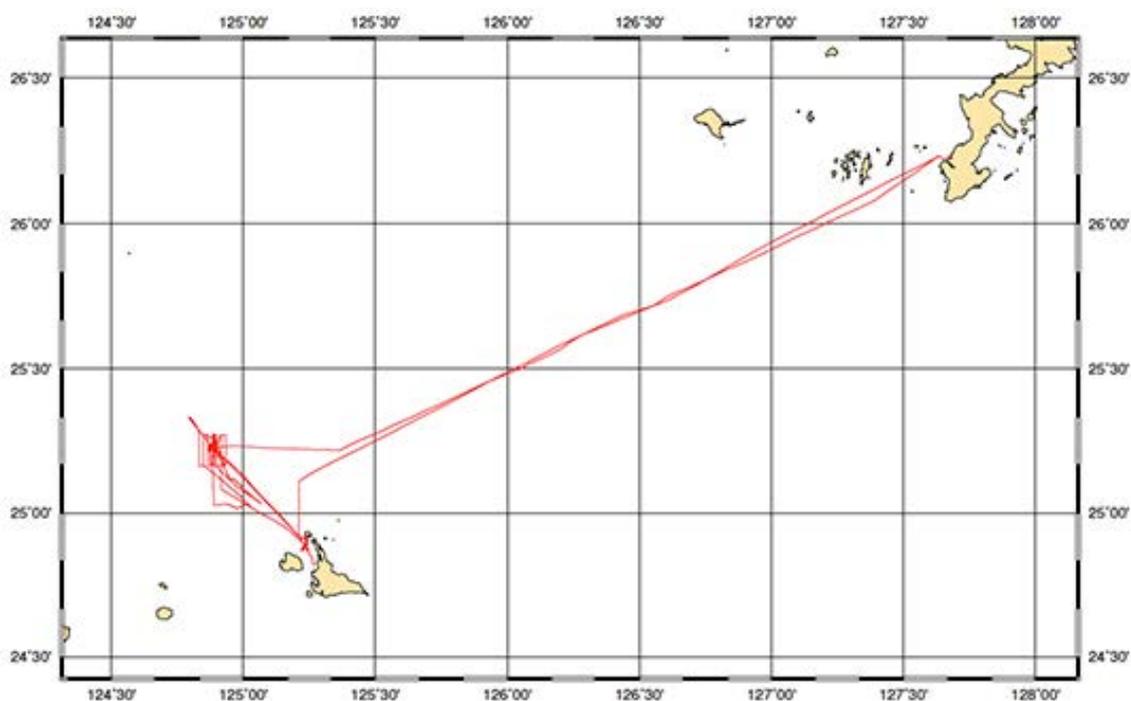


Fig.1.1 Ship track of R/V Natsushima during NT13-25 cruise

2. Research Maps

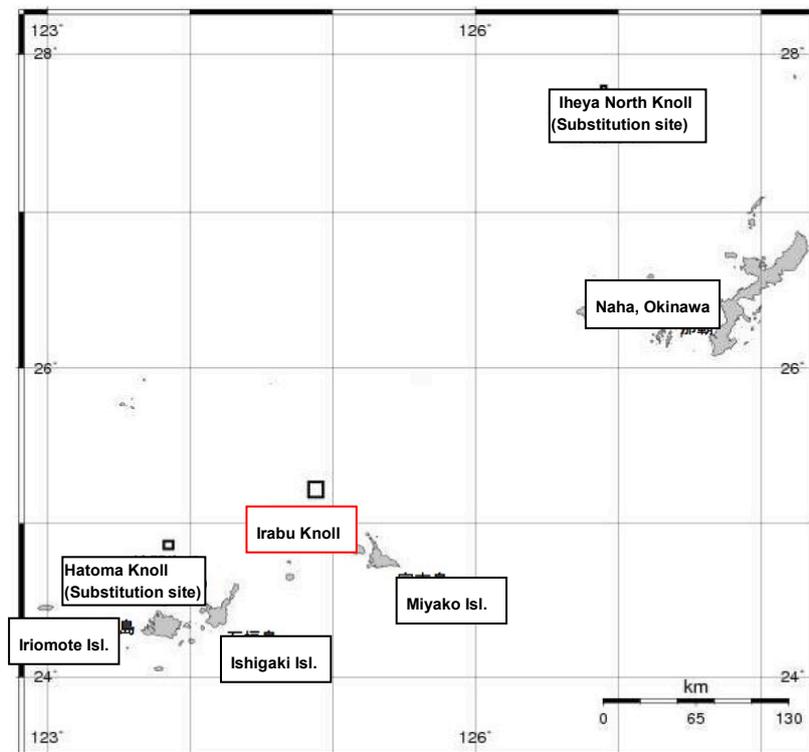


Fig. 2.1 Location of research area (The Irbabu Knoll in the Okinawa Trough)

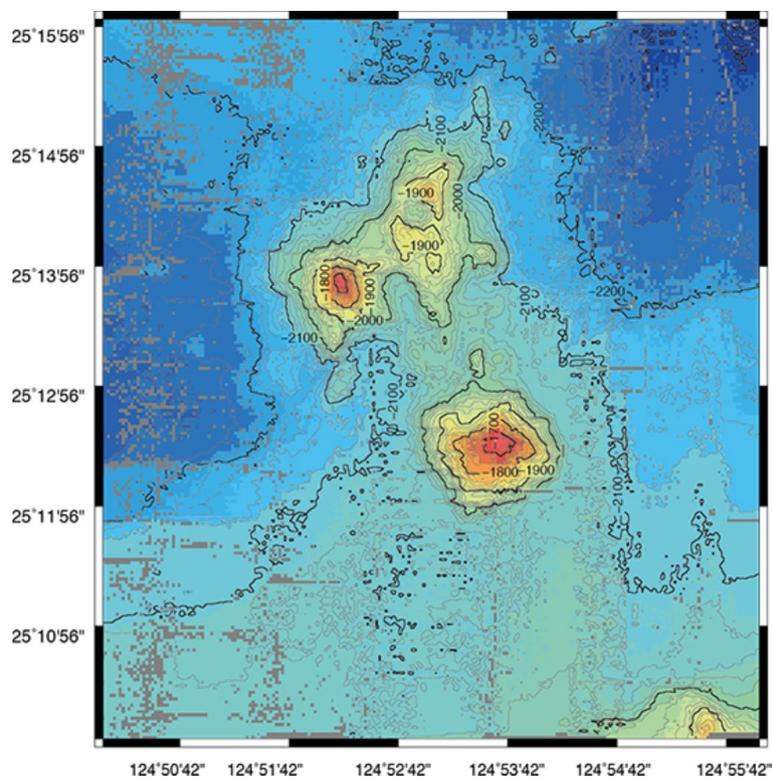


Fig. 2.2 Bathymetry map of the Irbabu Knoll area

3. Researchers

(1) Chief Scientists:

Teruo Fujii [IIS, University of Tokyo]

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Teruo Fujii [IIS, University of Tokyo]

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Kei Okamura [Kochi University]

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4.1 Searching Hydrothermal Activity by Chemical Sensors

4.1.1 Introduction

In the Okinawa Trough area, a variety of hydrothermal sites such as the Minami-Ensei Knoll, the Iheya Ridge, the Izena Cauldron, the Hatoma Knoll, and the Dai-Yon Yonaguni Knoll have been discovered and studied. These sites have been recognized as promised candidates of novel natural resources containing rare metals. Moreover, novel hydrothermal sites have been discovered in succession. One of the purposes of this cruise is optimization of a method to search for novel hydrothermal activity using a set of chemical sensors. Biogeochemical sensors, *in situ* analyzers, and a variety of sampling apparatuses were deployed using ROV HPD in the Irabu Knoll. In 2000 (YK00-06 Leg 2), two hydrothermal sites were discovered on the East and the West seamount in the Irabu Knoll area and its distribution were studied in detail during NT11-17 and YK12-05 scientific cruise. On the other hand, the South seamount had not been studied well. We utilized a set of chemical sensors and analyzers to discover novel hydrothermal sites on the previously untrodden South seamount.

4.1.2 Chemical Sensors and *in situ* Analysis Systems

4.1.2.1 CTDT profiler

A real-time monitoring of conductivity, temperature, depth and turbidity using CTDT profiler (Fig. 4.1.2.1.1) was carried out during dive #1604 and #1605.

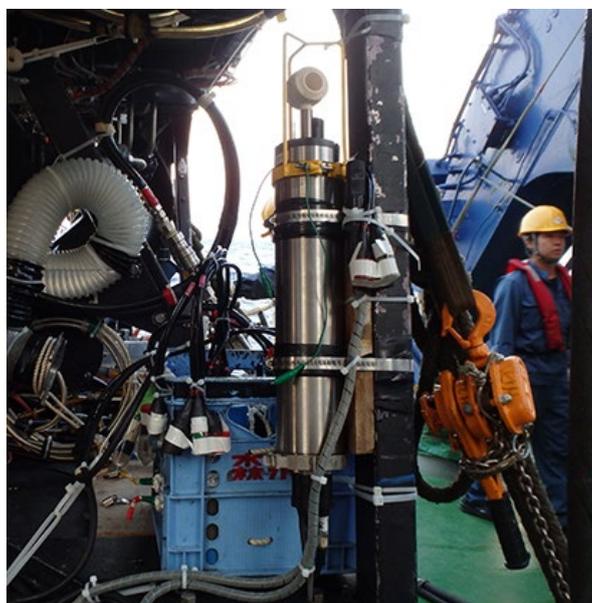


Fig. 4.1.2.1.1 CTDT profiler (Kyushu Univ.)

4.1.2.2 ISFET pH/pCO₂ and ORP sensor

Real-time monitoring and offline measurement of pH/pCO₂ (partial pressure of CO₂) using ISFET based chemical sensors ORP (oxidation-reduction potential) measurements using potentiometric sensors (Fig. 4.1.2.1.2) were also conducted in all dives except for dive #1606. The pH/pCO₂ sensor used a non-glass type pH electrode, ion-sensitive field-effect transistor (ISFET), and the ORP sensor employed Pt wire as a working electrode. These sensors applied a chloride ion selective electrode (Cl-ISE) as the reference electrode. In the pCO₂ sensor, both the ISFET-pH electrode and the Cl-ISE of the pH sensor are sealed in a unit with a gas permeable membrane (Teflon AF™) whose inside is filled with inner electrolyte solution with 1.5 % of NaCl. The pH sensor can detect pCO₂ change as inner solution pH change caused by permeation of carbon dioxide gas species through the membrane.

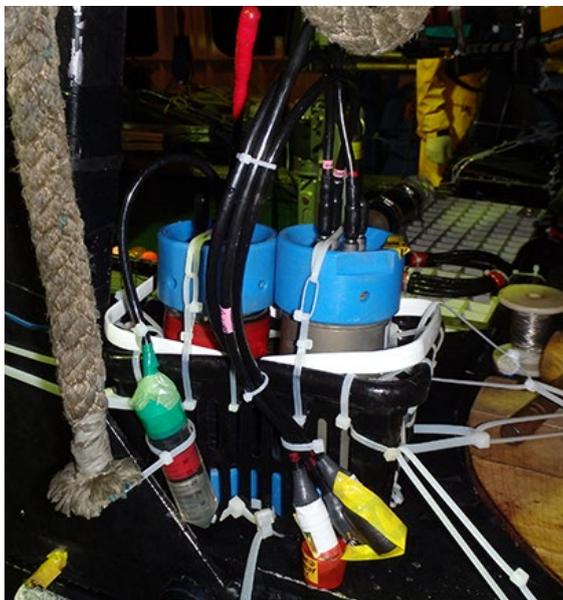


Fig. 4.1.2.1.2 ISFET pH/pCO₂ sensor and potentiometric ORP sensor
(Kyushu Univ., Univ. of Tokyo, and JAMSTEC)

4.1.2.3 pH/ORP and H₂S sensor (TANSAKUN)

In situ H₂S quantitative determination and ORP profiling was conducted using an electrochemical sensor “TANSAKUN” (Fig. 4.1.2.3.1) mounted on HPD for all dives except for dive #1606. H₂S was measured by a linear-sweep voltammetry using an Ag electrode. H₂S in surrounding water was concentrated on the Ag-electrode on TANSAKUN at -0.3 V v.s. an Ag/AgCl electrode for 10 seconds. Then, the concentrated H₂S was released by sweeping the voltage down to -1.3 V v.s. the Ag/AgCl electrode for 1 second. The electric current during the removal stage is correlated with the concentration of H₂S. H₂S concentration was calculated from the electric currents. The electric currents and the calculated H₂S concentration data were stored in a data logger inside a pressure housing.

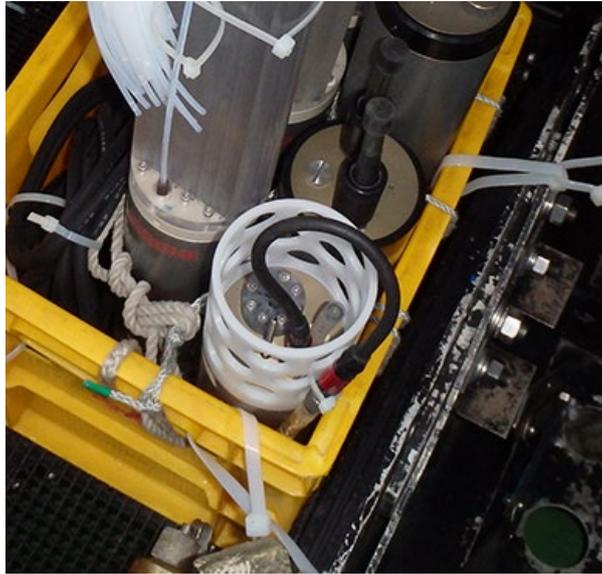


Fig. 4.1.2.3.1 TANSAKUN (Kochi Univ.)

4.1.2.4 *In situ* ATP analyzer (IISA-ATP2)

ATP (adenosine triphosphate) concentration, widely accepted proxy of biomass, in seawater was measured using a prototype of IISA (Integrated *In Situ* Analyzer) -ATP2. Total (microbial and dissolved) ATP in seawater is quantified by applying a modified luciferin-luciferase assay. A functionally integrated and highly miniaturized continuous flow analysis apparatus was realized by using a microfluidic device and a micro-pumping unit. Bioluminescent intensity measured by a PMT (photomultiplier tube) enclosed in a pressure tight housing is proportional to ATP concentration. The bioluminescent intensity is monitored in real-time onboard.



Fig. 4.1.2.4.1 IISA-ATP2 (Univ. of Tokyo, JAMSTEC)

4.1.3 Sample Collection and Onboard Processing

4.1.3.1 Syringe water samplers

Water samples were collected by using 4 of 8 syringe water samplers (Tokyo Univ., Fig. 4.1.3.1.1). Collected water samples were immediately transferred to clean plastic tubes aseptically after each dive. Portions of samples were used for total ATP content measurement assay. A luciferin-luciferase based ATP quantitative determination reagent kit (ChekLite™ HS Kit (Kikkoman, Japan)) and desktop bioluminescence intensity measurement apparatus (Luminescencer, ATTO Co., Japan) was used for the assay. The ChekLite™ HS kit and Luminescencer were used as shown in instruction manual. All bioluminescence measurements were performed 3 times to obtain average values.

The remaining 4 syringe water samplers were operated with membrane filters (25 mm ϕ , 0.22 μm nucleopore filter, Millipore, USA) on their water inlet. Collected filters and filtrates were stored in $-20\text{ }^{\circ}\text{C}$ for post cruise analysis using an AFM (Atomic Force Microscope) to visualize organic and/or inorganic particulate matters in seawater samples.

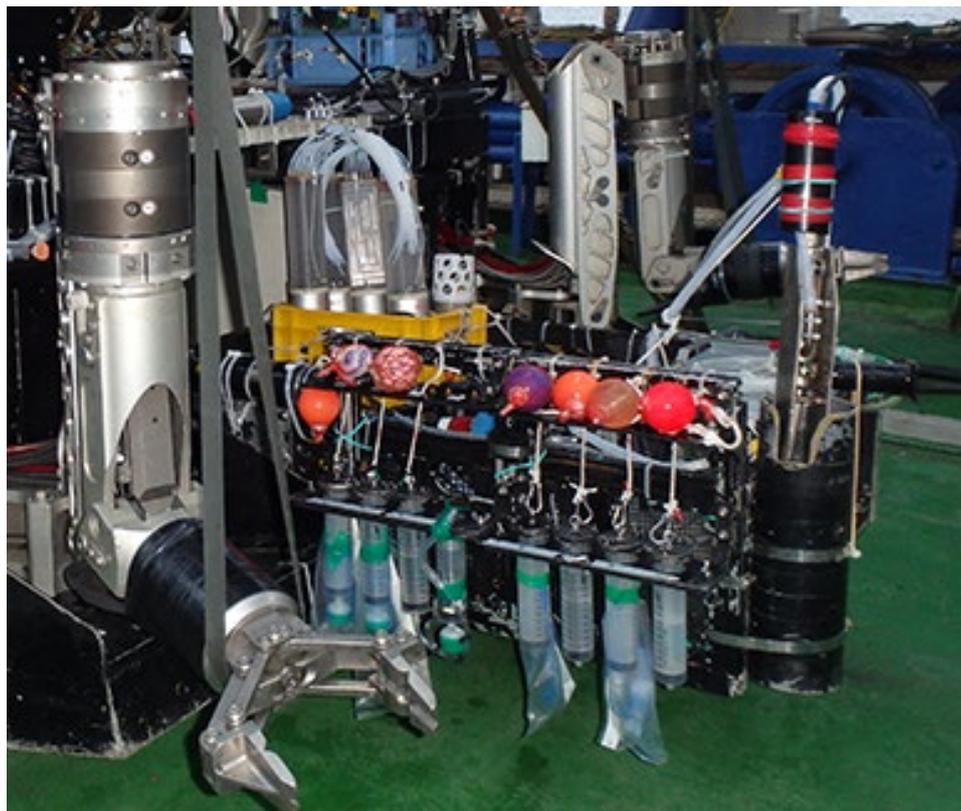


Fig. 4.1.3.1.1 Syringe water samplers (Univ. of Tokyo)

4.1.3.2 “ANEMONE” multi-water-sampling system

Highly spatiotemporally resolved water sampling was performed using a multi-water-sampling system “ANEMONE” (Fig. 4.1.3.2.1). The system can collect 24 water samples with sole unit. Small portions of seawater sample (10 ml) are stored in a cylindrical plastic chamber by replacing pure water by the sample. Sampling interval and replacing volume (defined by pumping time) can be set prior to each dive. All of the operation is autonomous and the system can be activated by applying external trigger signals. During this cruise, up to 4 units were operated in serial to collect 96 of water samples. Sampling interval was set to 5 min.

Collected samples were transferred to clean glass bottles and stored in 4 °C until onboard analysis. Salinity, pH, and total dissolved inorganic carbon were measured using desktop apparatuses onboard. The residual samples were used for the density and nutrient (silicate, phosphate, ammonium, nitrate) analysis in Kochi University.

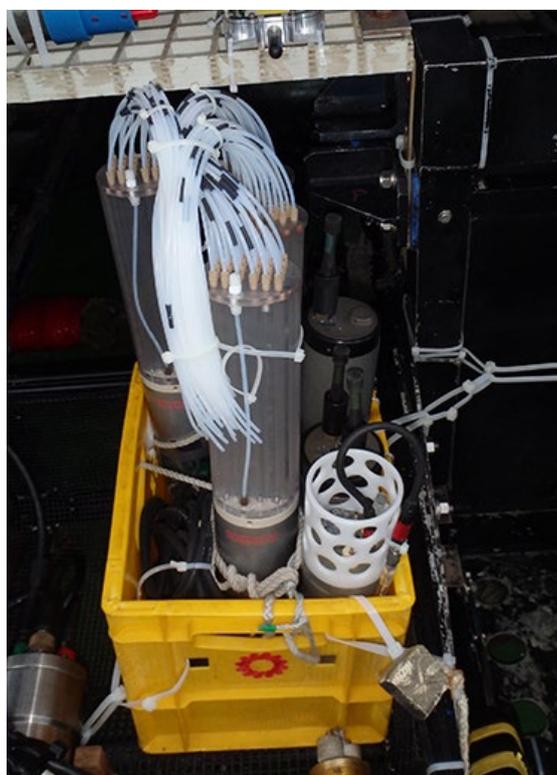


Fig. 4.1.3.2.1 ANEMONE water sampler (Kochi Univ.)

4.1.3.3 Hydrothermal fluid sampler

Water sampler powered by an impeller pump with an RTD temperature sensor is used for hydrothermal fluid sampling and temperature measurements (Fig. 4.1.3.3.1). Water sampling can be triggered onboard and temperature of sampled water can be monitored in real-time. The sample is stored in a Tygon tube as a sample reservoir. During this cruise, the sampler was operated with a valve apparatus to collect two samples for one dive. The valve was handled with a manipulator of HPD.

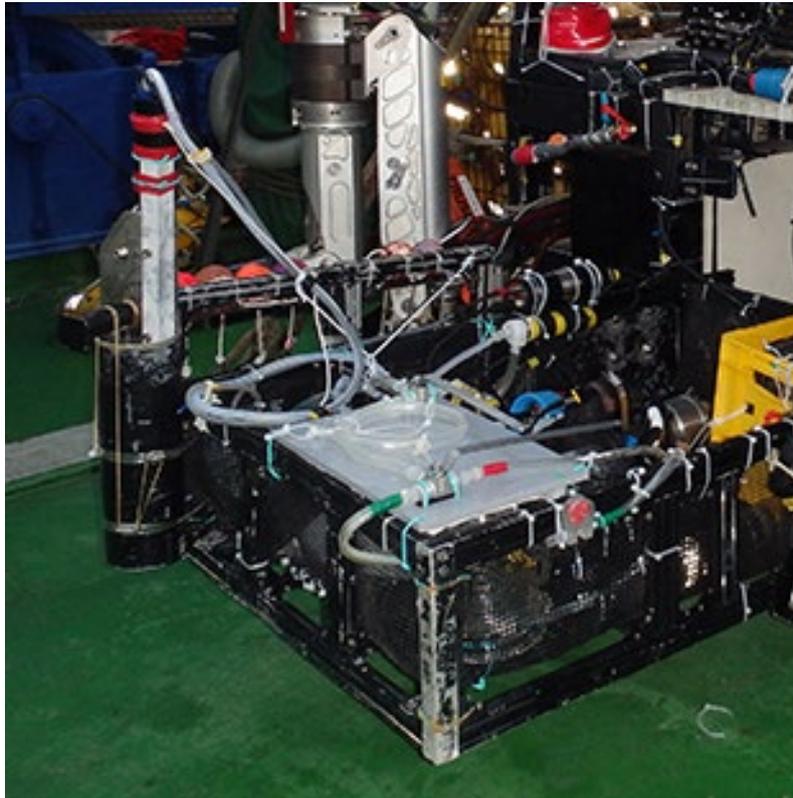


Fig. 4.1.3.2.1 Hydrothermal fluid sampler (Kochi Univ.)

4.1.4 Preliminary Results in the Irabu Knoll

4.1.4.1 Chemical sensors

The set of chemical sensors and *in situ* analyzer were mainly operated during dive #1604, 1605 and 1607. For dive #1606, ISFET pH/pCO₂/ORP sensors were operated. When HPD approached to the known hydrothermal sites at the West and the East seamount, apparent anomalies caused by hydrothermal fluid were successfully detected for all of the sensor and the analyzer.

ISFET pH sensor and temperature sensor mounted on the seafloor station were functioned during more than 20 hrs of deployment and successfully recovered with the station. For some of the sensors, vertical profiles were also obtained by keeping the sensor activated from the beginning to the end of each dive. Preliminary result of biogeochemical sensing during dive #1604 is shown in Fig. 4.1.4.1.1.

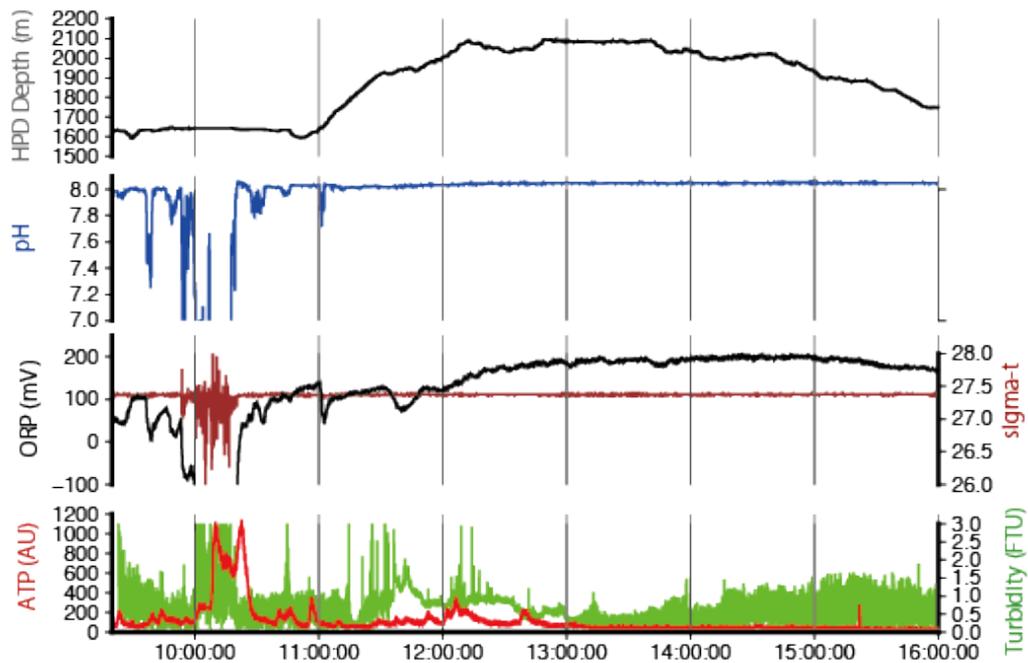


Fig. 4.1.4.1.1 Preliminary result of biogeochemical sensing during dive #1604

4.1.4.2 Sample collection and onboard analysis

Water samples were successfully collected using the syringe water samples for the dive #1604, 1605 and 1607. Collected samples were immediately processed for ATP contents analysis and all of the measurements were succeeded. Hydrothermal fluids contained apparently higher ATP compare to the seawater collected from the surrounding area. Seawater sample were also taken at middle layer of the water column (650 – 700 m.) and one of the samples was taken at the surface. The surface sample showed higher ATP concentration than the other samples presumably because of existence of photosynthetic planktons and related microbial communities.

Water samples collected by ANEMONE water sampler were immediately processed for pH, dissolved inorganic carbon, and salinity measurements. The measured results were agreed with the *in situ* values obtained by using sensors.

4.1.4.3 Hydrothermal site survey

When HPD moved to the West seamount to the South seamount, apparent anomalies on turbidity and ATP concentration were detected. Though HPD approached to the seafloor immediately after the anomaly detection, source of the anomaly was not recognized. As a result of novel hydrothermal site survey on the South seamount, weak signals from chemical sensors were detected. Part of seafloor on the South seamount was covered with white mats (presumably bacteria mat or hydrothermal precipitates, Fig. 4.1.4.3.1). Some of the rocks on the seafloor were pigmented in black-brown and accompanied by a benthic sessile ecosystem (Fig. 4.1.4.3.2). However hydrothermal site with visible fluid venting was not discovered.

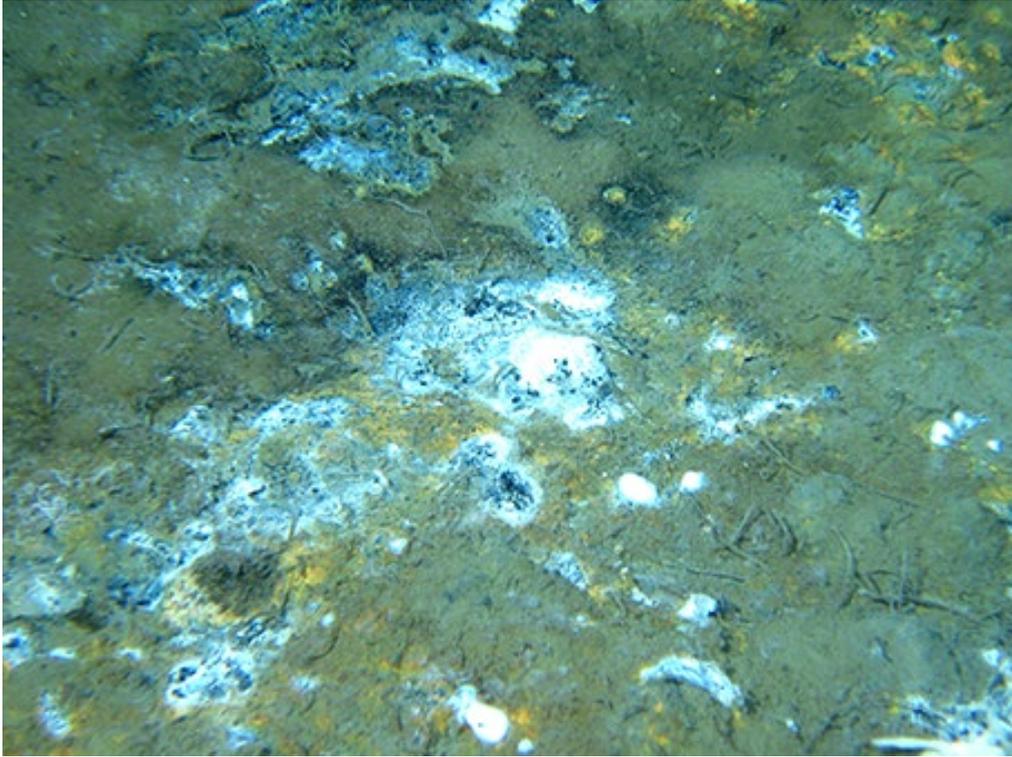


Fig. 4.1.4.3.1 Seafloor with white bacterial mat or precipitates on the South seamount

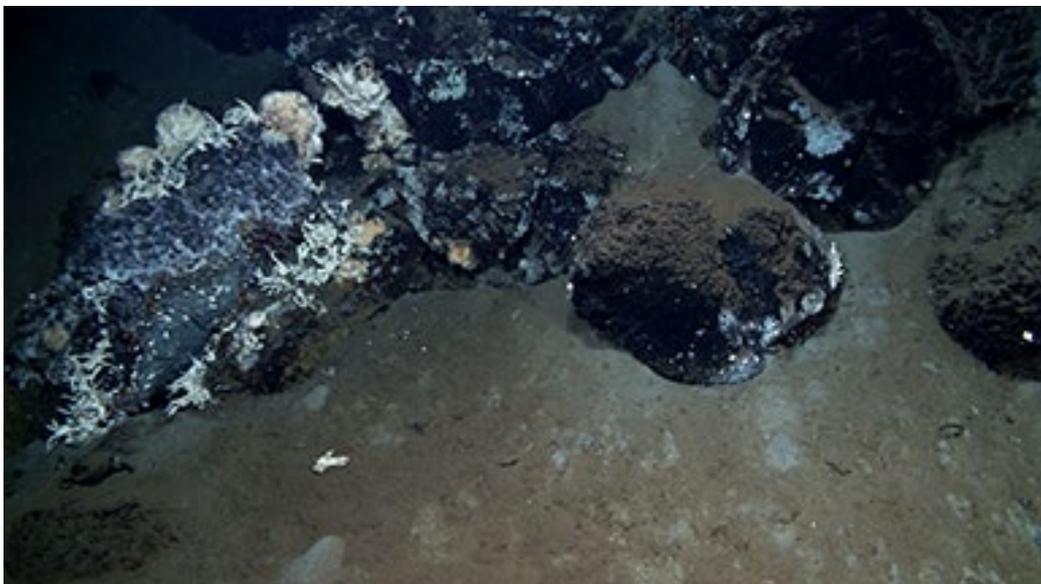


Fig. 4.1.4.3.2 Rocks with black-brown pigmentation and a benthic sessile ecosystem

4.1.4.4 Post-cruise Analysis

Filter samples collected using the syringe water samples were stored in -20 °C immediately after the recovery. The samples were transported to the laboratory and the surface was analyzed using an AFM. Preliminary result implies that particles suspended in seawater were successfully captured *in situ*. Further investigation on the particles is under going.

4.2 AUV Experiments

4.2.1 Introduction

We are developing an autonomous platform system consisting of a seafloor station and a hovering-capable autonomous underwater vehicle (AUV) in order to visualize hydrothermal vent fields. The station serves as a position reference for the AUV. To stand horizontally on a slope, the station has extendable three legs. The station is equipped with a depth sensor, AHRS (Attitude and Heading Reference System) and an ALOC (Acoustic Localization and Communication device, which is an SBL-based acoustic positioning and communication system). The AUV uses a DVL (Doppler Velocity Log), a FOG (Fiber Optic Gyro), and an ALOC to stochastically estimate its position and orientation, based on a seafloor station. The AUV takes seafloor images every second. The AUV uses flash every 10 seconds to obtain an illuminated color image. The remaining images are taken with a sheet laser to obtain bathymetric information.

4.2.2 Methods

During this cruise, the experimental seafloor station (Fig.4.2.2.1) was installed by HPD on the seafloor near the hydrothermal mounds at the dive #1606. After the installation, the station automatically stretched its legs at the specified time to keep its attitude horizontal. After that, three test dives of the AUV Tri-TON 2 (Fig.4.2.2.2) were conducted near the station. The station was finally recovered by HPD at the dive #1607.



Fig. 4.2.2.1 Experimental seafloor station

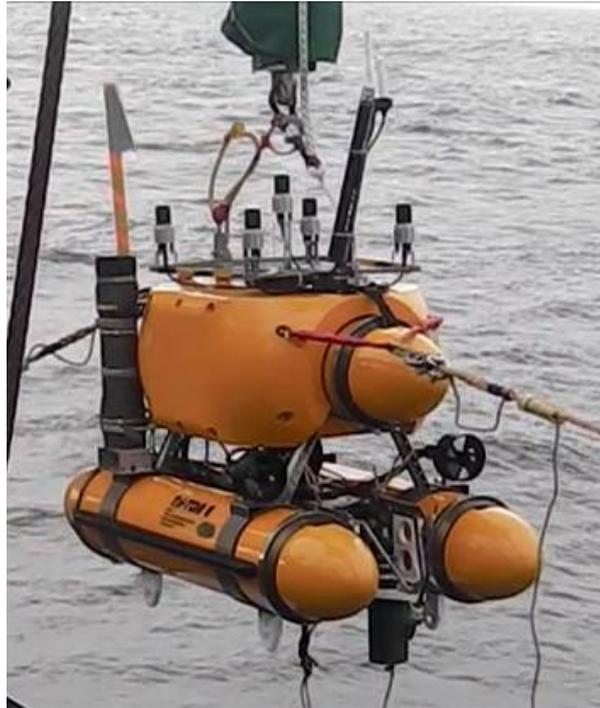


Fig. 4.2.2.2 AUV Tri-TON 2

4.2.3 Results and discussions

Fig. 4.2.3.1 shows time series of the attitude of the station. The station began to stretch its legs at 17:00. Here, θ , ϕ , and ψ represent roll, pitch, and yaw angle of the station, respectively. The yaw angle is the relative value with reference to the heading at $t=0$ [sec] in the Figure. After the station stretched its legs, the roll angle converged in less than 1 degree. Yaw angle was also stabilized. Although the pitch angle was not converged, the basic performance of the method was verified.

The AUV succeeded in the observation of the seafloor. Fig. 4.2.3.2 shows the estimated trajectory of the AUV at the dive 3 on 8th December. In Fig. 4.2.3.2, the blue line and black points show that the trajectory of the AUV and measured terrain, respectively. Fig. 4.2.3.3 and Fig. 4.2.3.4 are example of the seafloor photos taken by the AUV during the dive. Although the detailed analyses are needed to validate the data, a plenty of useful information to further improve the systems was collected.

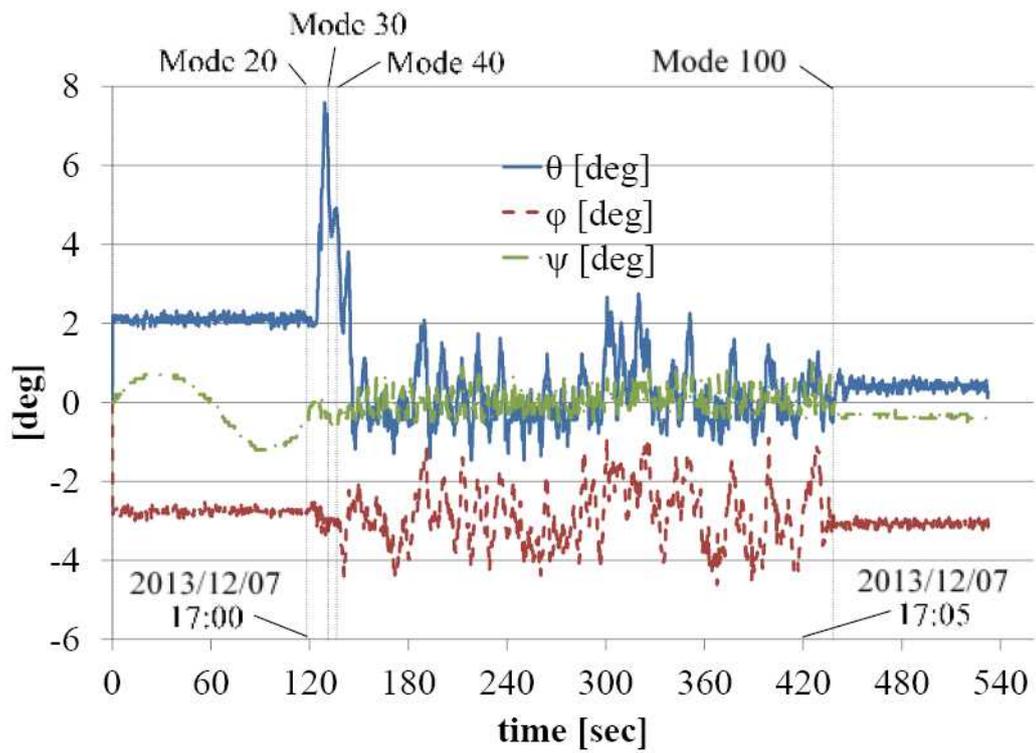


Fig. 4.2.3.1 Attitude of the station

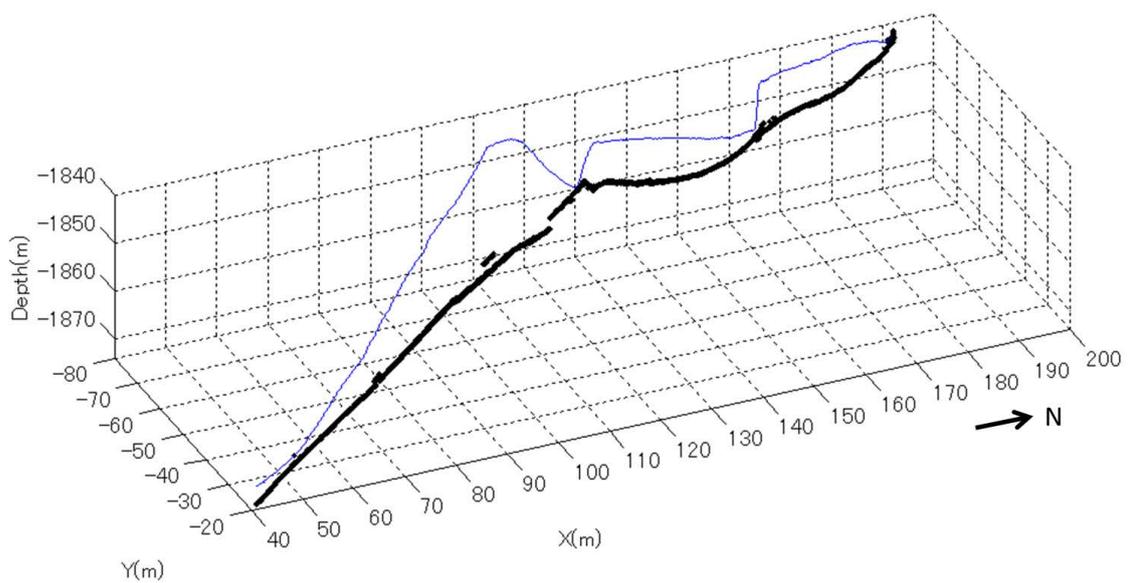


Fig. 4.2.3.2 Trajectory of Tri-TON 2 (Dive 3)

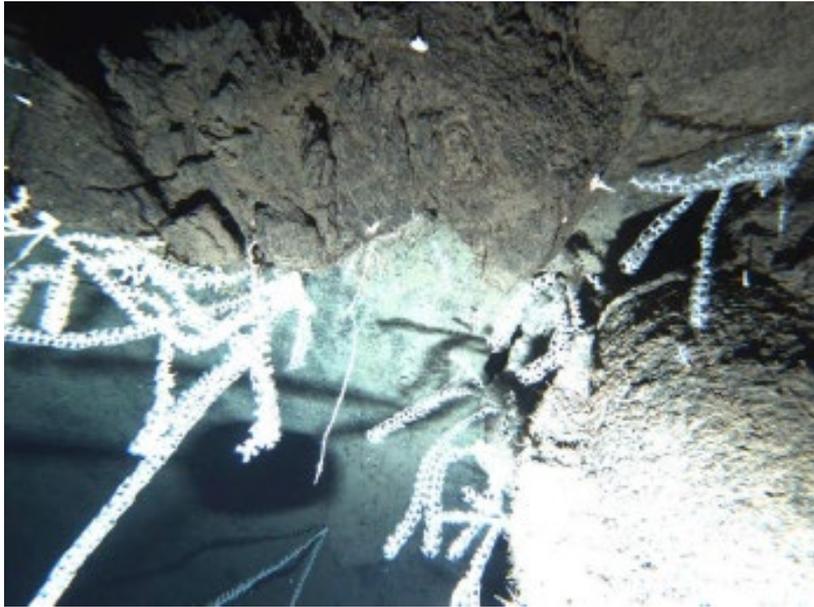


Fig. 4.2.3.3 Seafloor image taken by Tri-TON 2 (Downward looking camera)



Fig. 4.2.3.4 Seafloor image taken by Tri-TON 2 (Forward looking camera)

5. Summaries and Proposal for the Future Plans

Through this cruise, feasibility of *in situ* chemical sensors and analyzers were successfully demonstrated. State-of-art water samplers provided us the spatiotemporally resolved water sampling capability. The data from the *in situ* sensors and analyzers were fully utilized for hydrothermal activity survey and detailed analysis in real environment. Improvement of the reliability and stability of the sensors and analyzers should be continuously conducted. Development of standalone type sensors is also one of the important issues to realize an advanced survey operations utilizing AUVs such as Tri-TON2.

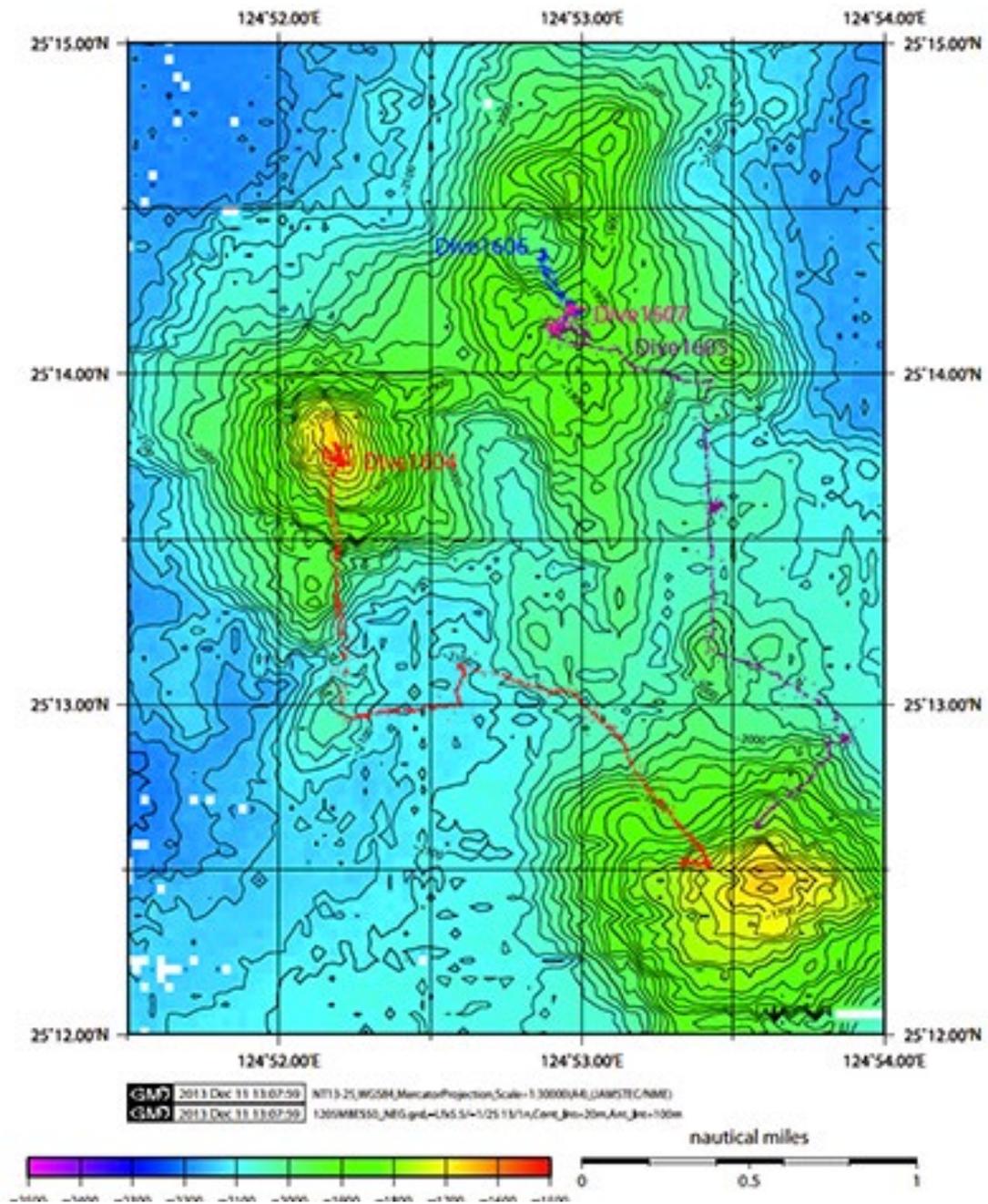
6. Acknowledgement

I would like to thank all the members of the ROV HyperDolphin operation team (Chief: Yoshio Ohno), and the crewmembers of R/V Natsushima (Captain: Hitoshi Tanaka) for their dedicated efforts to make this cruise so successful. I also would like to thank Ms. Satomi Minamizawa (Nippon Marine Enterprises, LTD) for her helpful assistance on all scientific activities onboard.

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7. Appendix

7.1 Dive Information and Photos



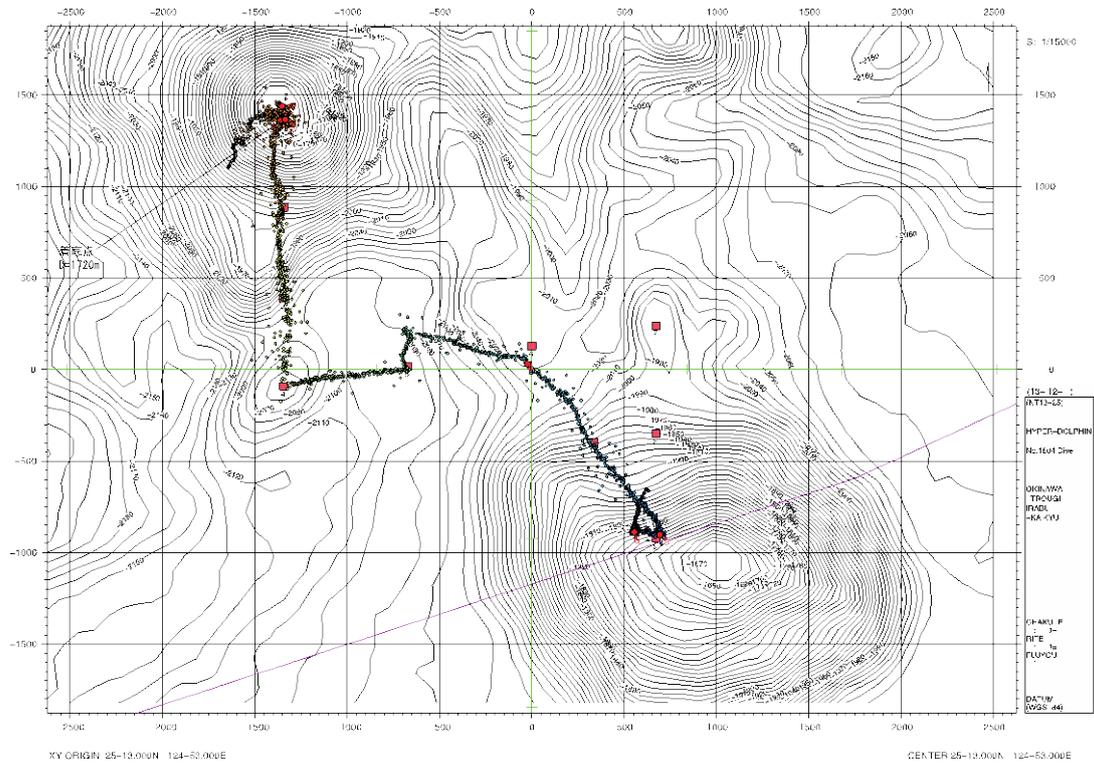
HPD tracks for all of dives during NT13-25 cruise

7.1.1 Dive #1604

Payload: CTD, pH, ORP, TANSAKUN, IISA-ATP2, ANEMONE, Hydrothermal fluid sampler, Syringe water samplers

Mission: Sensor evaluation, Hydrothermal site survey, Sampling (water)

Dive track:



Photos:



HPD payload for dive #1604



MASAKO2 marker



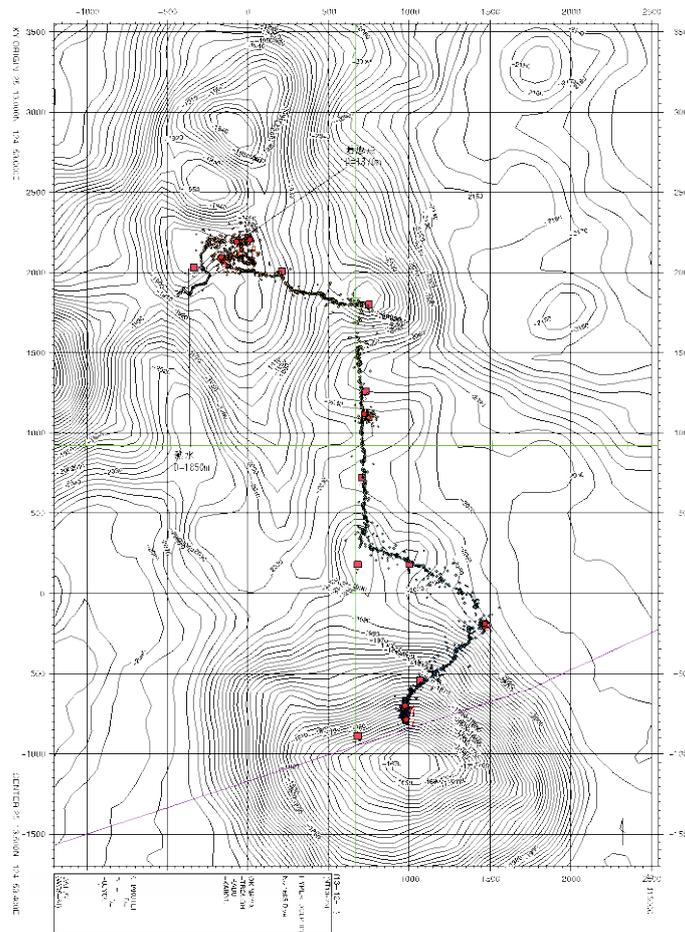
6K marker

7.1.2 Dive #1605

Payload: CTD, pH, ORP, TANSAKUN, IISA-ATP2, ANEMONE, Hydrothermal fluid sampler, Syringe water samplers

Mission: Sensor evaluation, Hydrothermal site survey, Sampling (water)

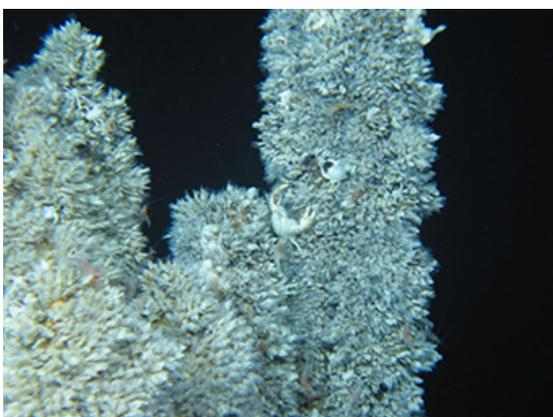
Dive track:



Photos:



HPD payload for dive #1605



Chimneys covered with dense biota



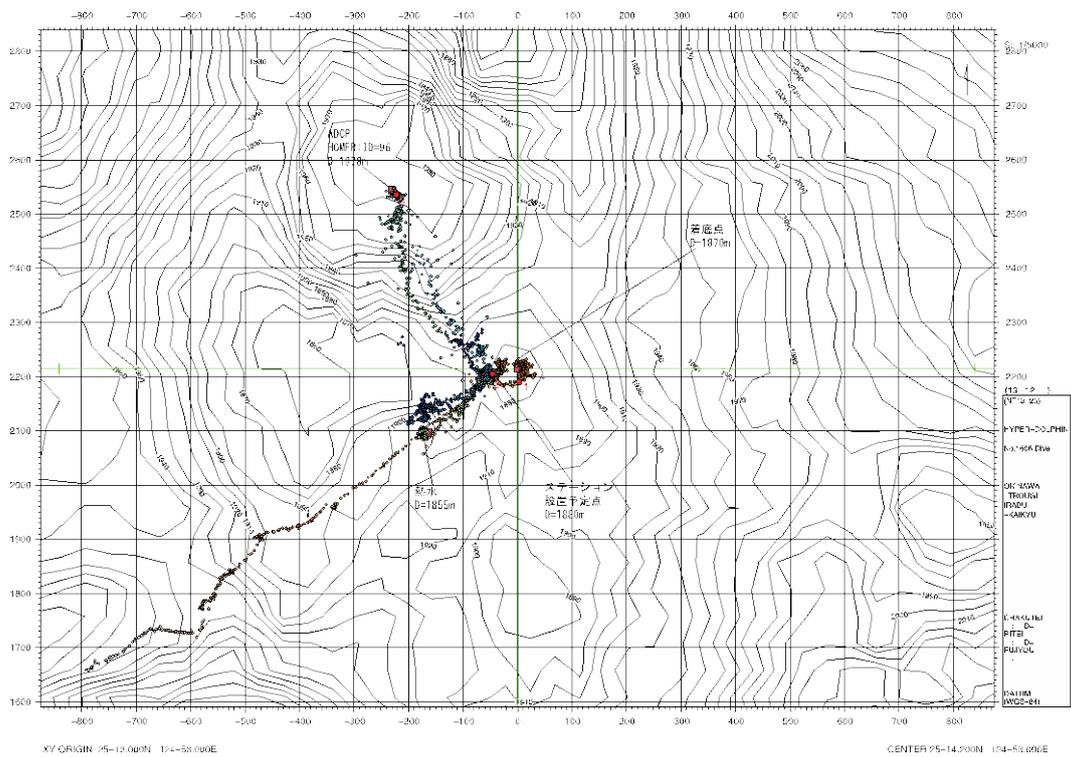
Outcrop on the slope of a small mound

7.1.3 Dive #1606

Payload: Seafloor station and peripherals

Mission: Seafloor station deployment, ADCP recovery

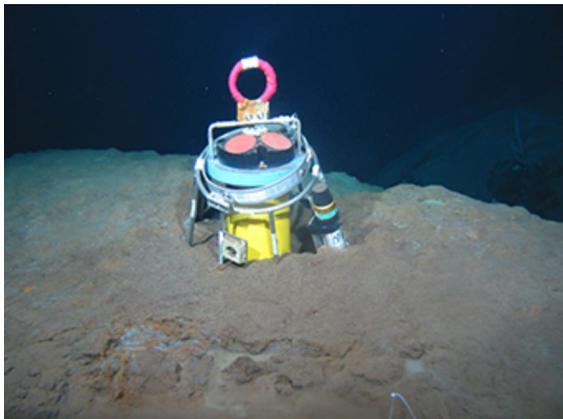
Dive track:



Photos:



Seafloor station mounted on HPD



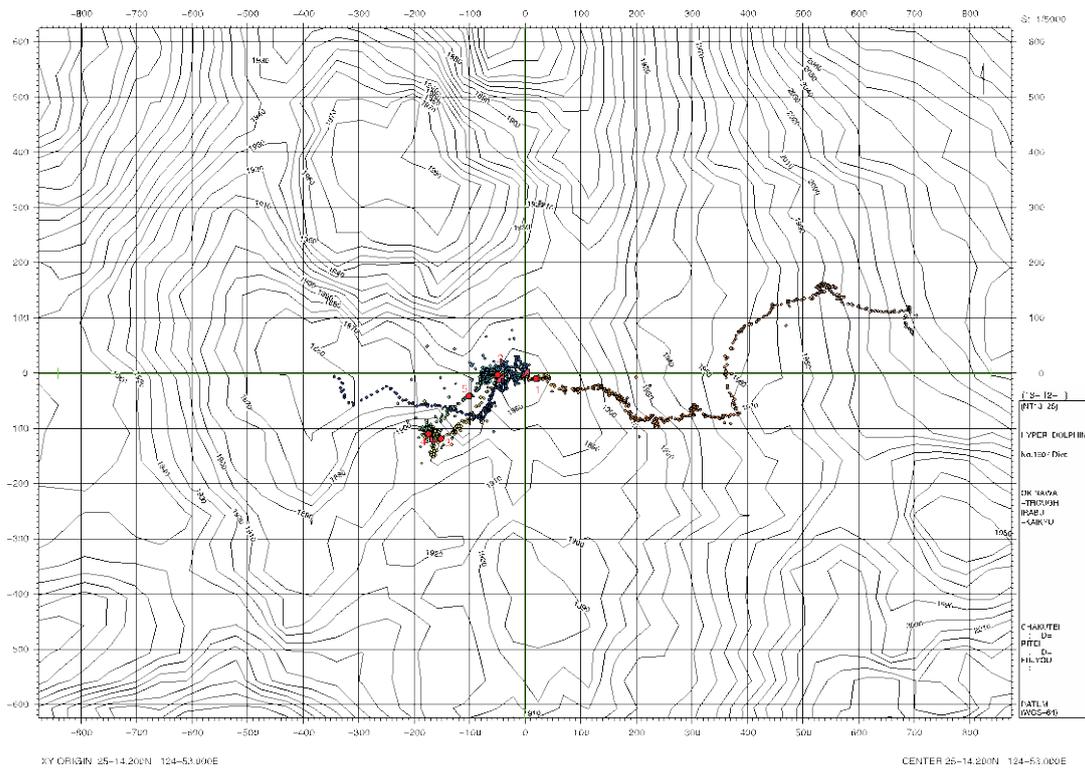
ADCP deployed more than 2 years

7.1.4 Dive #1607

Payload: pH, ORP, TANSAKUN, Syringe water samplers

Mission: Seafloor station recovery, hydrothermal site observation

Dive track:



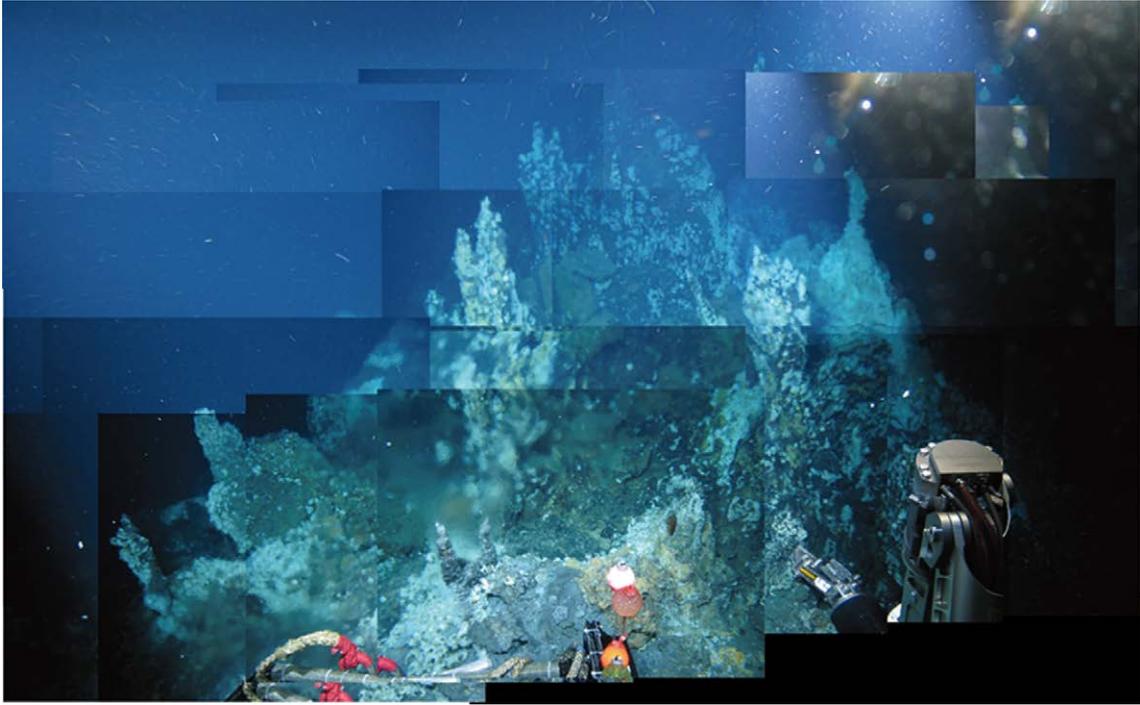
Photos:



HPD payload for dive #1607



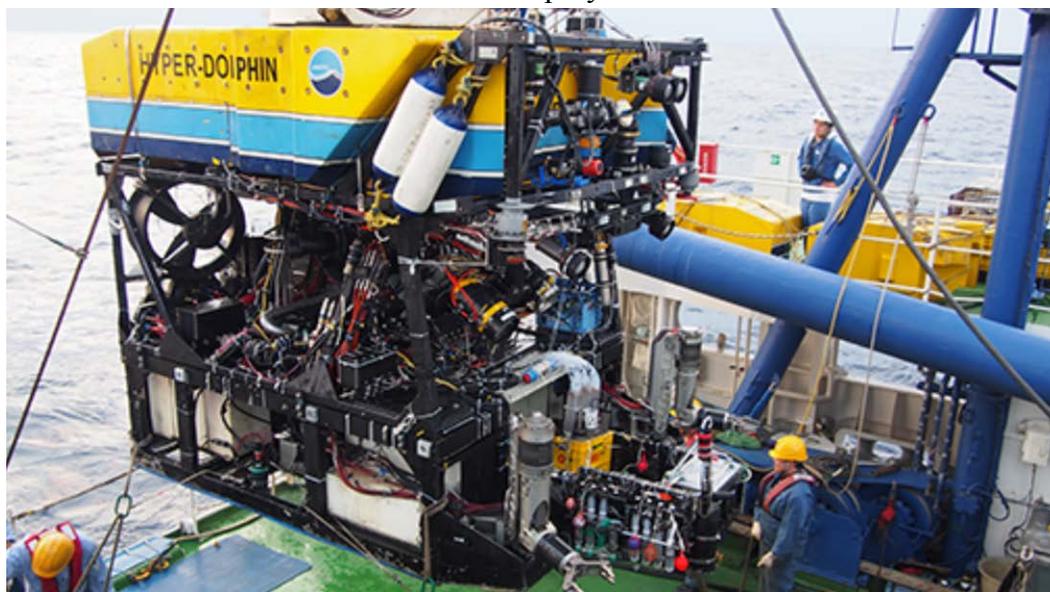
Chimneys emitting clear fluid



Landscape view of the hydrothermal site on the West seamount

7.2 Cruise Photos

ROV deployment



Onboard scientists in HPD control room



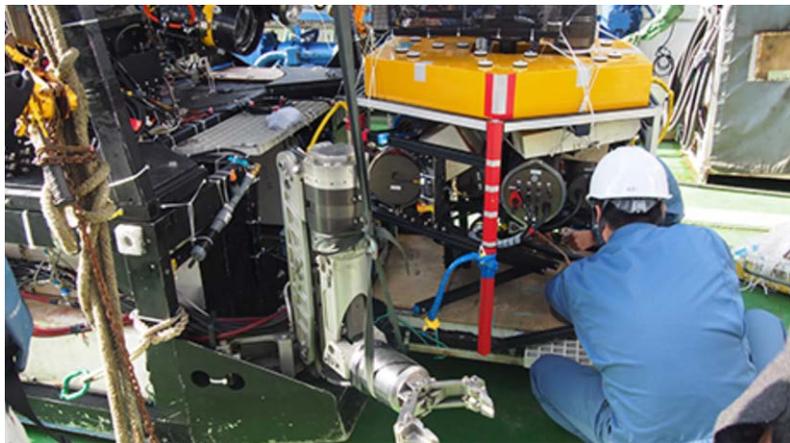
Discussion at the No.2 laboraloty



Some scientists left Natsushima at Miyako Island



Seafloor station assembly



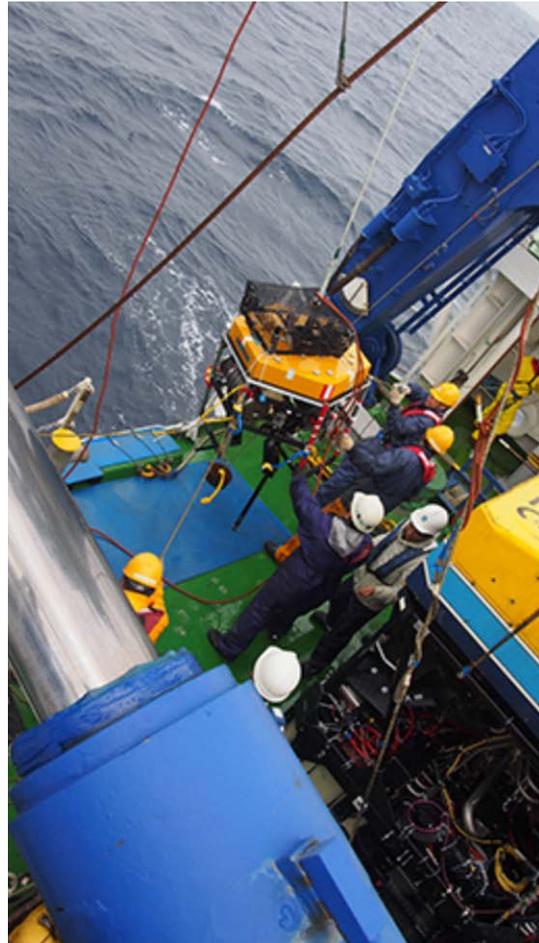
Mounting the Seafloor station on HPD



AUV maintenance before deployment



AUV deployment from the deck



Seafloor station recovery on the deck