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KAIYO Cruise Report

KY11-02 (Leg1)

Growth Process and Environment for Deposition of Ferromanganese Crusts at the Ryusei Seamount, Kyushu-Palau Ridge

January 31-February 8, 2011

Japan Agency for Marine-Earth Science and Technology

(JAMSTEC)

1 . Cruise Information

The research vessel KAIYO left the Yamashita Berth, Yokohama on January 31, 2011 for a joint exploration of ferromanganese crusts over the Ryusei Seamount, a member of the Kyushu-Palau Ridge seamounts, located about 200 nautical miles away from the Daito Islands. The title of the Cruise KY11-02 (Leg 1) is "Growth Process and Environment of Ferromanganese crusts at the Ryusei Seamount, Kyushu-Palau Ridge." Shipboard scientist group consists of 10 scientists and students from four universities, Kochi Uni., Univ. Tokyo, Hiroshima Univ., Tokyo Univ. of Pharmacy & Life Sciences. Important cruise date is as below.

Jan. 31 9am KAIYO left Yokohama
Feb.2 Topography survey over the dive lines
Feb. 3 ROV dive HD#1243 at the Ryusei Seamount
Feb. 4 ROV dive HD#1244 at the Ryusei Seamount
Feb. 6 4pm Arive at Naha Port
Feb. 8 9am scientists left ship

2. Participants List

The cruise, KAIYO KY11-02 Leg1 was successfully conducted by the science team, crew members, and ROV staff with two dives of Hyper Dolphin at the seamount during the scheduled period.

2.1 Scientist Party

Akira Usui , Kochi University, geologist, Chief Scientist
Blair Thornton, physical engineer, Underwater Technology Research Center of the University of Tokyo, Vice Chief Scientist
Adrian Bodenmann, graduate student, Underwater Technology Research Center of the University of Tokyo
Ayaka Tokumaru, graduate student, University of Tokyo
Shingo Kato, microbiologist, Tokyo University of pharmacy and Life Science
Shota Nitahara, graduate student, Tokyo University of pharmacy and Life Science
Aya Sakaguchi, geochemist, Hiroshima University
Toshiki Sugiyama, graduate student, Hiroshima University
Hisaaki Sato, graduate student, Kochi University
Keisuke Nishi, undergraduate student, Kochi University
Shusuke Machida, technical engineer, Nippon Marine Enterprises Co., Ltd.

2.2 Crew Member

Shinya Ryouno, Captain
Takafumi Aoki, Chief Officer
Shintaro Hashimoto, 2nd Officer
Hidehiko Konno, 3rd Officer
Hiroyoshi Kikkawa, Chief Engineer
Kazuhiko Kaneda, 1st Engineer
Kenzo Kato, 2nd Engineer
Takaatsu Imoto, 3rd Engineer
Satoshi Watase, Chief Radio Operator
Hidehiro Ito, 2nd Radio Operator
Yuka Moriwaki, 3rd Radio Operator
Yasuyoshi Kyuki, Boat Swain
Yoshiaki Kawamura, Able Seaman
Kuniharu Kadoguchi, Able Seaman
Hideo Isobe, Able Seaman
Saikan Hirai, Able Seaman
Jiro Hanazawa, Sailor
Shun Abe, Sailor
Kozo Miura, No.1 Oiler
Toshikazu Ikeda, Oiler
Takeshi Watanabe, Assistant Oiler
Daiki Igarashi, Assistant Oiler
Ryo Matsuuchi, Assistant Oiler
Yasunori Kawai, Assistant Oiler
Ryuei Takemura, Chief Steward
Yoshio Okada, Steward
Kana Yuasa, Steward
Shigeto Ariyama, Steward
Yoshie Hidaka, Steward

2.3 HyperDolphin Operation Team

Yoshio Oono, Operation Manager
Kazuki Iijima , ROV Operator
Katsushi Chiba, ROV Operator
Yudai Sskakibara, ROV Operator
Shigeru Kikuya, ROV Operator
Atsushi Takenouchi, ROV Operator
Ryou Saigou, ROV Operator

3. On-site observation and sampling

We dove with ROV *HyperDolphin 3000* along two lines on the slope of the Ryusei Seamount, the Kyushu-Palau Ridge as part of “exploration of ferromanganese crusts in the NW Pacific Ocean.” Five sub-programs are as below.

3.1 Growth processes and metal concentration into hydrogenetic ferromanganese crusts: A case study at the Ryusei seamount.

Akira Usui(Kochi University) and KY11-02 Leg 1 Scientific Party

Objective: Ocean hydrogenetic ferromanganese crusts are potential archives of paleoceanographic and geological environments and events as well as potential future mineral resources. However, the oceanographic or geological parameters controlling their elemental diversity have not determined with combined geochemical, mineralogical, physical and microbiological characterization on areal small-scale or microscopical scale. We attempt to figure out the parameters related to the variations of chemical and physical characteristic of ferromanganese crusts in space and time. For this purpose, the key technique is a delicate sampling method that should provide us undisturbed ferromanganese crusts and on-site measurement. This cruise is a part of our program to characterize geological occurrences ferromanganese crusts from two typical areas (MinamiTorishima Island area and OkinoTorishima Island area) over the northwestern Pacific Ocean. We plan to describe on microscopical scale geochemical, mineralogical, structural properties with reliable time scales, as we did at the Takuyo-Daigo seamount during the earlier cruise NT09-02.

Method and samples: We tried to collect samples without damage or break of samples, after continuous measurement of C-T-D-pH-DO during lowering and uplifting of the vehicle as well as on the track on the bottom. In-situ samples were taken for geochmisty, mineralogy, microbiology, and physical engineering study on the ferromanganese crusts. At each station, with approximately 200m water-depth intervals, more than 1-20 kg samples were taken, and then slice and carefully kept wet cool in a refrigerator after packing in air-tight plastic bags. To avoid chemical biological damage, air-tight, wet and cool conditions are requisites for analysis samples.

Results: We mapped the occurrence of the hydrogenetic ferromanganese crusts (including nodules) during two dives along a total 2.5 km track within water depths between 2200 to 950 meters on the southwestern slope of the seamount. Total 29 ferromanganese samples (178 kg in wet total) were taken at 19 stops. The thickness of ferromanganese crusts ranges from less than 1 mm to 95 mm in maximum, whereas 19 samples were apparent crusts over substantial rock outcrops not a rolling stone or nodules. The apparent rock outcrops that occur more than 60% on the total track were fully coverage with ferromanganese crusts with more than 60 mm average thickness.

The overall occurrence of the crusts were much more than we expected, where the maximum thickness occur around the water depth range between 1500 and 1050 m. The samples were variable in thickness and in water depth. DO varies from 2.7(2200m) to 1.2 mL/L(1000m) . The apparent sediment cover is generally very thin mostly less than 20 cm, but very rarely greater than 50 cm. As a result, the areal distribution and thickness range of ferromanganese crusts in the upper slope of the seamount were much more than we expected.

Future plan: The sliced samples (2 cm thickness) are scheduled to be analyzed for the items below in collaboration within the shipboard scientists for the first priority. The samples and topics of analysis will be shared and informed to each other among the party to avoid overlapping and secure priority of all members.

We will first select specific key samples from several sites on the track, and following analysis will be made mostly on the same slice or columns after discussion and negotiation.

-Bulk chemical analysis using ICP/AES and ICP/MS for about 2-3 meter intervals.
-Powder X-ray diffraction analysis for the above aliquots
-Microscopic observation on polished and thin sections for the same columns
-SEM&EDS
-EPMA/WDS
-XANES, EXAFS
-Spring-8 for trace metals
-Isotopes
-PGE
-Dating (radiochemical, paleomagnetic, paleontological)

In order to extend the range of depth environments, we should collect more samples in the adjacent areas out of the depth range, for examples, shallower than 1000m or deeper than 3000 m. On the other hand, micro-analysis including LA/ICP-MS, SIMS, TEM observation and analysis will be considered to specify chemical and mineralogical form of useful elements and fractionation..

3.2 Chemical speciation in ferromanganese crusts for paleoceanic reconstruction

Aya Sakaguchi and Toshiki Sugiyama (Hiroshima Univ.)

Objectives: Discussion on the paleoceanic environment was made from concentrations of elements without considering the incorporation mechanism of elements into the crust. Recently, these ferromanganese crusts can be sampled without any disturbing of small scale sampling area by using hyper-dolphin (remotely operated vehicle) system. In this study, we attempted to get information on speciation and enrichment mechanism of elements to serve as an aid to reconstruct the paleoceanic environment using the samples obtained from Ryusei seamount collected in this research cruise with hyper-dolphin equipped with live video camera and manipulators.

Methods and material: The sample description of ferromanganese crusts are presented elsewhere.

Bottom waters were also collected with Niskin water sampler for preliminary analysis.

Immediately after sampling, pH, temp and Alkalinity were measured. The results are shown in the Table below.

#1243

Time	Latitude	Longitude	Depth (m)	pH	Temperature (°C)	Alkalinity (meq/l)
10:14	25°31.7454N	135°33.5696E	2079	7.71	16.1	2.29
15:46	25°32.3066N	135°34.2271E	1608	7.73	10.8	2.20

#1244

Time	Latitude	Longitude	Depth (m)	pH	Temperature (°C)	Alkalinity (meq/l)
09:34	25°32.3518N	135°34.2992E	1553	7.68	13.5	2.29
13:55	25°32.5580N	135°34.6869E	1100	7.63	9.8	2.42

Future plan: The surface layers of these ferromanganese crusts will be analysed with ICP-MS, ICP-AES to get the information on the profile of elements through the sea mount. Some of them will be analysed with XANES and EXAFS at SPring-8 and/or PF (KEK) for some elements which have typical concentration profile. The mineral composition will be also analysed with XRD, XANES and EXAFS. Considering speciation of elements in seawater and ferromanganese crusts, the concentration mechanisms of elements will be discussed.

3.3 **Geochemical and Mineralogical Characterization**

Ayaka Tokumaru (Dept. Earth & Planetary Sciences, Univ. Tokyo)

Objective: The Ryusei Seamount is known as one of those seamounts, at least partly covered with ferromanganese crusts, by the past dredge survey. In this cruise, we use Hyper Dolphin to get samples from known depths. It is important to understand the features of ferromanganese crusts. In the previous survey with Hyper Dolphin (NT09-02 Leg.2, NT10-11) at the #5 Takuyo Seamount, we got many samples and took clear and oblique images of the seafloor, which enabled us to examine depth variation is its occurrence, thickness, mineralogy, chemistry. Analyzing chemical composition, the amounts of trace elements in the crusts are controlled by the MnO_2 or Fe_2O_3 content. Another interesting feature is the ratios at the surface of the samples show strong correlation with the DO (dissolved oxygen) content at their depths.

Future plan: For further research, the samples should be collected by care not to hurt its surface. Its depth data and seafloor inspection are important to know its occurrence. We expect the Ryusei Seamount to be a representative ferromanganese crust seamount in Kyusyu-Palau Ridge, as well as the #5 Takuyo Seamount in Markas-Weik Seamounts. Ferromanganese crusts is an excellent recorder of the environmental change of the ocean. The slow but steady accumulation rate (2-7 mm per million years) of Mn-crust for up to 50-60Ma makes it an excellent recorder of the environmental change of the ocean. However, calibrating their age based on the empirical growth rate models using Co concentrations have large uncertainties. A new method for dating these crusts by measuring their osmium (Os) isotope record and matching it to the well-known marine Os isotope evolution makes it possible to know the certain date.

It is well known that the PGE (platinum group elements) are enriched by a factor of about 10^5 to10^7 compared to their concentrations in seawater. There are great controversies about its occurrence, whether it is incorporation as fine-grained particles or adsorption of the elements from the seawater. Among the six PGE, Pt and Rh are well concentrated compared to the other four elements. New data about this difference may be a key to figure out the occurrence.

3.4 **Generation of 3-dimensional reconstructions and acoustic characterization of ferromanganese crust deposits at the Ryusei seamount**

Blair Thornton, Adrian Bodenmann (Institute of Industrial Science, The University of Tokyo)

Objective: The engineering group is working towards the development of a remote manganese crust survey system that consists of an acoustic probe designed to measure the thickness of manganese crusts, and a mapping device that can generate 3-dimensional colour reconstructions of the seafloor. It is proposed that these systems can be mounted on a mobile underwater platform, such as an autonomous underwater vehicle (AUV) or remotely operated vehicle (ROV), to continuously map crust thickness from low altitudes at depths of up to 3000m. The proposed system was deployed during NT10-11 at #5 Takuyo seamount using the ROV HyperDolphin, and acoustic measurements of manganese crust thickness were successfully performed for the first time. Although it has been demonstrated that for the topology and types of substrate dominant in the surveyed area of #5 Takuyo seamount, continuous acoustic measurement of manganese crust thickness is possible, it is still not yet known if the technique can be generalized to other manganese crust deposit sites. The main factors that influence the application of this approach to survey, are thought to be the topology of the seafloor, which may constrain low altitude operation of the platforms used, and the acoustic properties of the crusts and their substrate, which determine the strength of the acoustic signals used for thickness measurement. As a first step towards generalization, our group performed both mapping and sampling at Ryusei seamount to determine the feasibility of performing *in situ* acoustic thickness measurements in this area.

Instruments and methods: A mapping device was mounted on HyperDolphin in order to create 3-dimensional colour reconstructions of the seafloor. This data can be used to extract accurate statistical information concerning the distribution and topology of manganese deposits, as well as forms a basis to visualize the data recorded by the other payload sensors, i.e. an acoustic probe (not deployed during this cruise) and the C-T-DO sensor measurements, as a form of underwater GIS. The system consists of a sheet laser, camera and LED array, which were mounted on a jig at the aft of HyperDolphin, as shown in Figure 1 below.

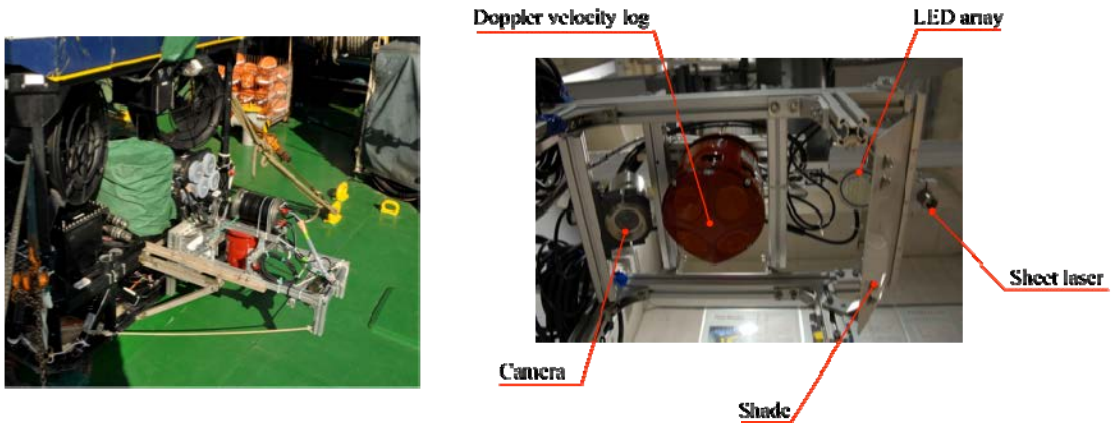

Fig. 1. SeaXerocks mapping device mounted on HyperDolphin during KY11-02

The sheet laser projects a green laser line onto the seafloor perpendicular to the direction of motion of the vehicle. The projected images are captured by a colour camera mounted with a translational and angular offset with respect to the laser. As the vehicle moves forwards, the projected laser line scans the shape of seafloor, and based on triangulation of the laser

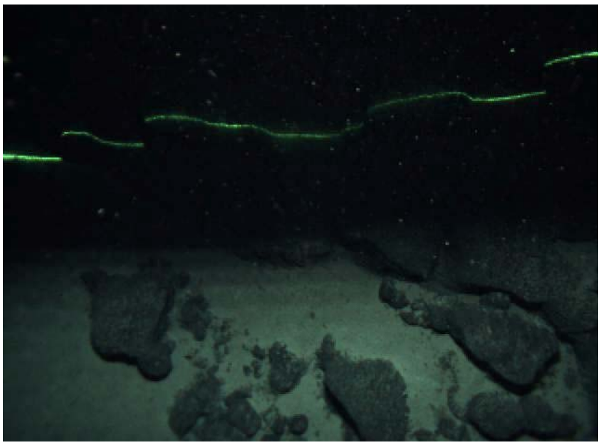

Fig. 2. Image captured during HPD#1244. The upper portion of the image is used to generate bathymetry whil information e the lower part of the image is illuminated and contains colour

projections recorded by the camera can be used to generate a detailed 3-dimensional bathymetry of the seafloor assuming that the vehicle's position and pose at the time of measurement are known. A LED array is used to illuminate the lower portion of the image captured by the camera to obtain colour information. Figure 2 shows an example shows an example of an image obtained during HPD#1244. The shade prevents light from being cast into the upper region of the image, where the laser line is projected in order to make detection of the laser line more robust. This setup allows for efficient scanning of the seafloor since the upper portion of the image is at an angle with respect to the laser, which is necessary for triangulation of bathymetry, but unsuitable for imaging, and the lower portion of the image looks almost straight down onto the seafloor, making it suitable for imaging, but unsuitable for triangulation, since the projections of the pixels in this region are almost parallel to the laser. Vehicle position information is obtained using a Doppler velocity log (DVL) equipped with an attitude heading reference system (AHRS) mounted on the vehicle. This information is used together with depth data to resolve the vehicle position and pose. The DVL measures the vehicle's surge, sway and heave velocity while the AHRS uses a 3-axis magnetic compass, 3-axis gyro and 3-axis accelerometers to determine the vehicle's heading, roll and pitch rates and angles. This information is passed through a Kalman filter and combined with the measurement of the depth sensor, forming an inertial navigation system (INS) to determine the robots 3-dimensional position in the inertial coordinate system (*x*, *y*, *z*, *roll*, *pitch*, *yaw*).

During the cruise, a green 532nm 50mW sheet laser with an opening angle of 64° in water, was used to scan the seafloor. A digital camera with a resolution of 640×480 was used to record images at 30fps. During this cruise, the system was setup to operate at 1~2.5m off the seafloor, with the camera set at an angle of 20° to the vertical with a baseline of 800mm, giving horizontal and vertical resolutions of 2.6mm and 3.8mm respectively at an altitude of 1m. The resolution of the system in the direction of travel depends on the velocity of the platform, where the scanning phases of this cruise were performed at 20 to 30 cm/s, translating to longitudinal resolutions of 6 to 10mm. Figure 3 shows an example of a short area of seafloor scanned during HPD1244.

Acoustic properties

The acoustic properties of the samples directly related to the measurement of crust thickness, namely the acoustic propagation velocity, impedance and attenuation in the crusts and the impedance of the substrate rock, will be determined in the laboratory. Since Ryusei seamount is a relatively young (c15~25Ma), marginal seamount located on the Phillipine sea plate, it is expected that there will be significant contrast in the substrate geology when compared to #5 Takuyo

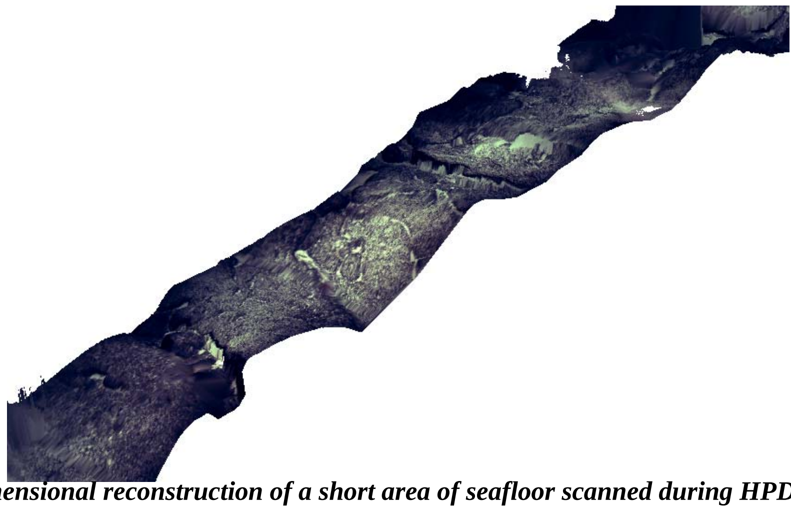

Fig. 3. A 3-dimensional reconstruction of a short area of seafloor scanned during HPD#1244.

seamount, an older (c100Ma) oceanic flat top seamount located on the Pacific plate, where our previous surveys took place. It is intended the acoustic properties of the crusts and the substrate rocks of these two seamount can be used as a basis for more generalized discussions concerning the feasibility of acoustic measurement of crust thickness for different substrate rock types. The following samples obtained during this cruise will be used for acoustic assessment.

Future work

The seafloor bathymetry and acoustic properties measured from data and samples obtained during this cruise will help our group assess the generality of remote acoustic survey of manganese crust thickness. The seamount was found to have steep slopes of up to 20°, with a wide variety of crust deposit topologies. The small scale topology was found to be favorable for low altitude operation using the ROV and it will be possible to generate several, high resolution reconstructions of the seafloor. However, since the mapping device was mounted at the rear of HyperDolphin, there were a number of regions where the vehicle agitated sediments on the seafloor and no mapping data could be obtained. Furthermore, due to the sharp gradient of the seafloor, there were several regions when the mapping device was out of range. A simple solution to this problem would be to mount the mapping device at the front of HyperDolphin, which is closer to the seafloor when surveying steep slopes, and is also less prone to agitation since the thrusters are located near the centre of mass of the vehicle. With regard to acoustic measurement, although analysis of samples' acoustic properties has not yet been performed, it is recommended that a pan-tilt mechanism be introduced in order to optimize the angle of incidence of the acoustic signal when performing surveys on steep slopes, and to compensate for changes in the vehicle's pitch that occur as the number of samples increases.

During the cruise, sampling of the crust deposits was found to be time consuming and difficult, and it would be helpful to develop tools to enable more efficient sampling. From our previous surveys (NT09-02 Leg2, NT10-11), it has been found that the most efficient way to extract crusts directly from rocky outcrops, is to make incision near the edge of a crust overhang using a cutting instrument, such as a rotary saw, and the use a crowbar to apply leverage and break off the crust together with its substrate. However, a number of difficulties concerning the operation of these tools have been identified and an improved rotary saw and crow bar are being developed at the IIS University of Tokyo the address these issues. It is hoped that these tools will help overcome some of the difficulties encountered previously and will allow for more efficient sampling during future cruises.

3.5 **Characterization of microbial communities**

Shingo Kato (Tokyo Univ. Pharmacy & Life Sciences)

Objective : Microbes are abundant and diverse on outcrop rocks on the seafloor. These microbes potentially play a role in mineralization and dissolution of elements at the boundary of the ocean and earth crust. The geologically aged outcrops are commonly covered with ferromanganese oxides. Previously, we showed the presence of abundant and diverse microbes on the ferromanganese-coating rocks (called hereafter as Mn crusts and Mn nodules) of the Takuyo-Daigo Seamount. However, the commonalty and function of the microbial communities on oceanic Mn crusts and Mn nodules are still unclear. Our purpose of this cruise is to collect oceanic ferromanganese nodules in the Ryusei Seamount for microbiological analysis, in addition to surrounding sediments and seawater as references.

Materials and Methods

The rock samples collected by *Hyper-Dolphin* were divided into at least three parts, i.e., upper (seawater side), middle and bottom (basement rock side) portions, using a clean hammer. Large subsamples were stored in airtight condition at –80ºC for molecular microbiological analysis. Cells attached with small subsamples were fixed in plastic tubes with filtered seawater containing formalin (final 3.7% v/v) at 4ºC untile microscopic observation. Small subsamples were also stored in glass vials filled with N_2 at 4ºC for cultivation.

Approximately 50 ml subsamples of the sediments collected using a push-core sampler were stored in plastic tubes at –80ºC for molecular biological and geochemical analysis. The sediments were also divided into at least three parts as Mn nodules. Cells within subsamples were fixed in plastic tubes with filtered seawater containing formalin (final 3.7% v/v) at 4ºC overnight, and then stored at –80ºC for microscopic analysis. Subsamples were also stored in glass vials filled with N_2 at 4ºC for cultivation.

One litter of the seawater samples collected using NISKIN bottles were filtrated with 0.2-μm-pore-size membrane filters and then the filters were stored in plastic tubes at –80ºC for molecular biological analysis. Cells in the seawater samples were fixed to add formalin (final 3.7% v/v) and stored in plastic tubes at 4ºC overnight, and then stored at –80ºC for microscopic analysis.

For cultivation on board, the rock, sediment samples were suspended with filtered seawater. The suspensions as inocula and the collected seawater were plated on solid and liquid media. The media were incubated at room temperature or 4ºC.

Future plan: Our goals of the present study are: 1) to show the abundance, phylogenetic diversity and composition of microbial communities on and within Mn nodules in the Ryusei Seamount by culture-independent molecular methods, 2) to reveal the local variety of the microbial communities on the surface of the Mn nodules that are exposed to overlying seawater or underlying sediments, 3) to reveal the uniqueness of the microbial communities on the Mn nodules as compared with those of the surrounding sediments and seawater, 4) to assess the commonalty of the microbial communities on the Mn nodules as compared with the previous results from the Takuyo-Daigo Seamount, and 5) to characterize physiology of microbes living there by culture-dependent methods. Cell densities in the samples will be determined by microscopic observation and quantitative PCR. Phylogenetic diversity and composition of the microbes in the samples will be determined by DNA/RNA analysis targeting 16S rRNA and 16S rRNA genes. Comparative analysis among samples will be performed using several bioinformatics tools based on the gene sequences determined. Metabolic functions of the microbes in the samples will be determined by DNA/RNA analysis targeting functional genes and their mRNA, which are related to carbon fixation, sulfide oxidization, manganese oxidation, ammonia and nitrite oxidation and nitrate and sulfate reduction, and by culture-dependent characterization.

****COMMENTS from STUDENTS on board.**

It was my third cruise with Hyper Dolphin, and the first time to board KAIYO. Fortunately, we were able to conduct all of the two dives. Hyper Dolphin team members worked hard for us and communicated frequently with us, which enabled us to get valuable samples. Another impressive event was a tour of inside KAIYO. The ship crew kindly gave us a exciting ship tour at laboratories, thruster room and wheel operating room. Each crew at the room gave us a nice lecture about their system of the ship. It was my first time to make such an interesting tour. I'm happy about the success of this cruise. I appreciate all the KAIYO crew and Hyper Dolphin team members that supported us.

Ayaka Tokumaru (grad student at Univ. Tokyo)

I have studied by using the Fe-Mn crust samples which were obtained with Hyper-Dolphin from an earlier cruise. However, I have never seen how the instrument works. I'm glad to see the real one and real samples in this cruise. I didn't know that many people work together to get Fe-Mn crust samples before coming to this cruise. I appreciate all people in this cruise. Fortunately, my first cruise was very enjoyable, and I had a precious experience. I'm inspired to study about Fe-Mn crusts in return for your kindness.
Toshiki Sugiyama (grad student at Hiroshima Univ.)

I was on board KAIYO during KY 11-02 Leg1. And we research ferromanganese nodules and crusts at the Ryusei Seamount using Hyper-Dolphin. In the previous method, such as dredge, we scratch on seafloor, so we could not know the source of ferromanganese nodules and crusts. However, Hyper-Dolphin can take a sample without contamination and destruction that is suitable to investigate microbial community. We all thank ALL scientific party and crews of Hyper-Dolphin and KAIYO.
Shota Nitahara (grad student at Tokyo Univ. Pharmacy and Life Science)

I thank crew and staff for providing us with nice study space, many delicious meals, and equipments. I could study and live a full life in Kaiyo. Our samplings and investigations ware great successes. I was able to spend splendid time. If there is the next opportunity, I want to go on board. Thanks to Hyperdolphin operation team and Kaiyo crew members!!
Hisaaki Sato （grad student at Kochi Univ.）

I was able to spend a substantial study and life in the ship at this voyage. I once participated in a Tanseimaru cruise when we used rock dredge. I was very interested in the highest study with a ROV HyperDolphin for this time. Thank you for Kaiyo's crews and ROV operation team.
Keisuke Nishi (undergrad student at Kochi Univ.)

4. Other Research Information
See the track map of the KAIYO (Fig. 4), track map of "HyperDolphin for two dives" (Fig. 5), and an example of occurrences of ferromanganese crusts at the slope of the Ryusei seamounts (Fig. 6).
Other details will be open in symposiums and papers.

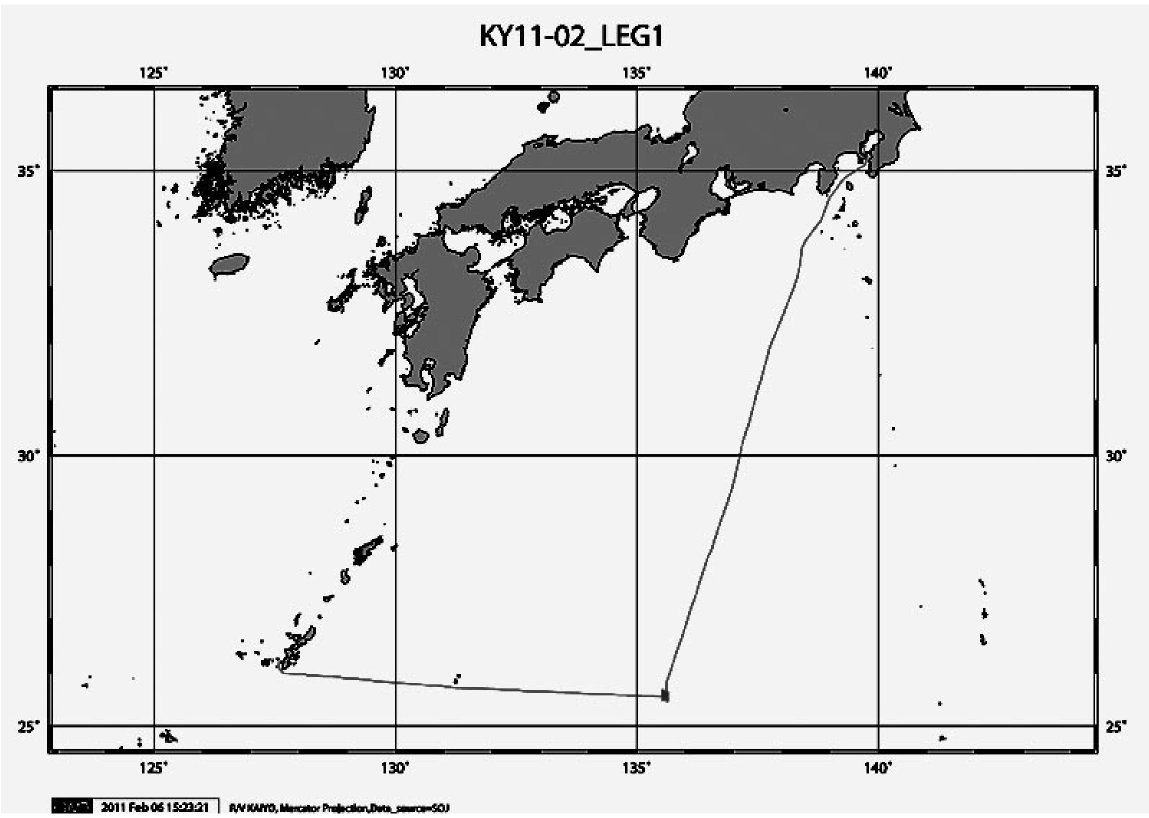

Fig. 4. Ship track of the cruise KY11-02.

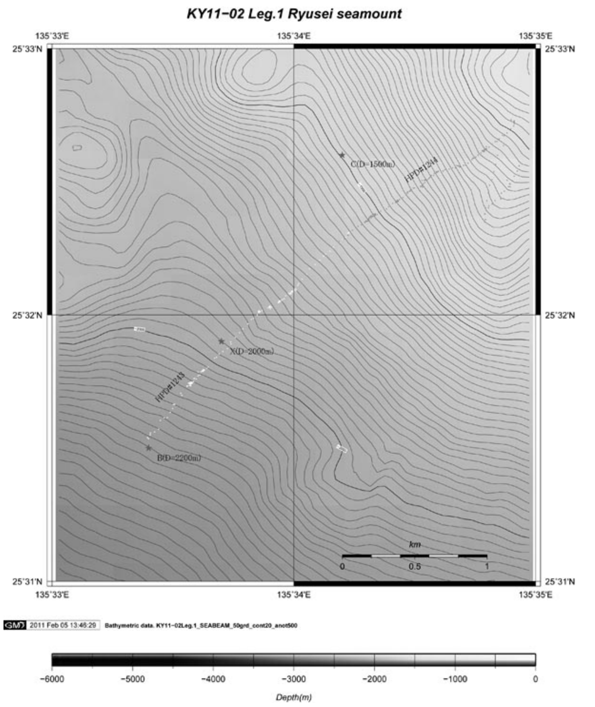

Fig. 5. Track of Dives HPD#1243 and #1244 on the southwestern slope of the Ryusei seamount.

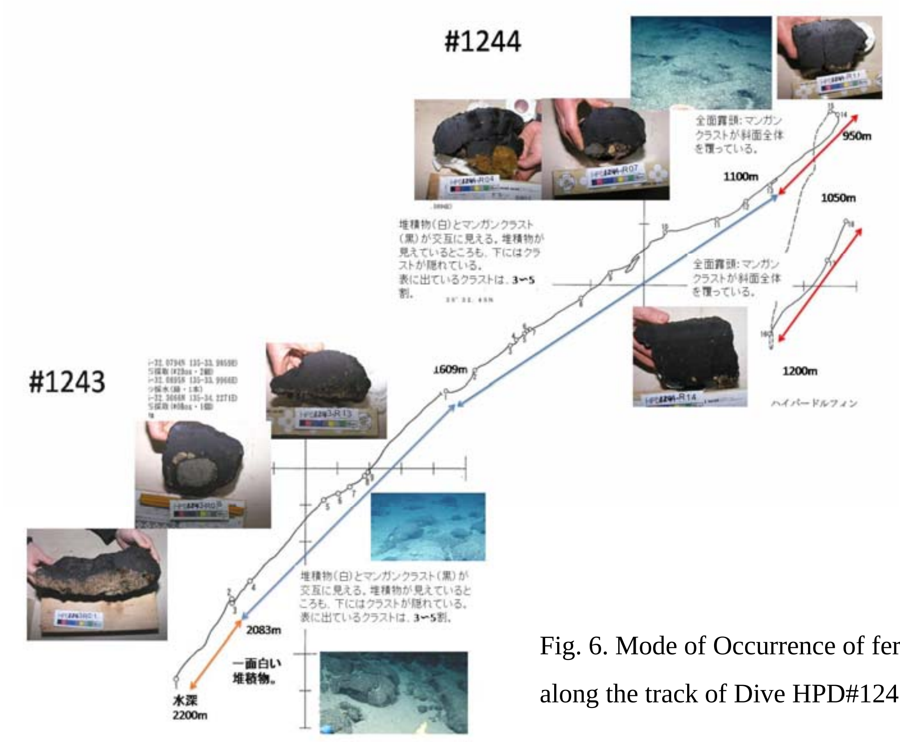

Fig. 6. Mode of Occurrence of ferromanganese crusts along the track of Dive HPD#1243.

5. Notice on Using

Notice on using: Insert the following notice to users regarding the data and samples obtained.