doi : 10.17596/0002755

R/V KAIREI Cruise Report
KR16-01 Leg1

Cross-ministerial Strategic Innovation Promotion Program (SIP),
Next-generation technology for ocean resources exploration
(ZIPANG in ocean)

KAIKO dives;
"Research on formation process and mechanism of Cobalt-rich ferromanganese crusts covering over seamounts in the northwestern Pacific - deployment of current direction and velocity meter and ROV research dives -"

Takuyo-Daigo Seamount
Jan. 9 - 19, 2016

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

Contents

Notice on using

This cruise report is a preliminary documentation as of the end of the cruise.

Except sections that author(s) is shown, all manuscripts are described by KI and MK.

This report may not be corrected even if changes on contents (i.e. taxonomic classifications) may be found after its publication. This report may also be changed without notice. Data on this cruise report may be raw or unprocessed. If you are going to use or refer to the data written on this report, please ask the Chief Scientist for latest information.

Users of data or results on this cruise report are requested to submit their results to the Data Management Group of JAMSTEC.

1 Cruise Information

Cruise ID: KR16-01 Leg1

Name of vessel: R/V KAIREI

Title of the cruise: Cross-ministerial Strategic Innovation Promotion Program (SIP), Next-generation technology for ocean resources exploration (ZIPANG in ocean), KAIKO dives; "Research on formation process and mechanism of Cobalt-rich ferromanganese crusts covering over seamounts in the northwestern Pacific - deployment of current direction and velocity meter and ROV research dives -"

Title of proposal: Research on formation process and mechanism of Cobalt-rich ferromanganese crusts covering over seamounts in the northwestern Pacific - deployment of current direction and velocity meter and ROV research dives -

Chief scientist: Koichi IIJIMA [Japan Agency for Marine-Earth Science and Technology; JAMSTEC]

Representative of the Science Party: Katsuhiko SUZUKI [JAMSTEC]

Cruise period: 9 Jan. - 19 Jan. 2016

Ports of departure / arrival: Yokosuka / Takuyo-daigo seamount (followed by Leg2 cruise)

Research area: Takuyo-daigo seamount

Research area map:

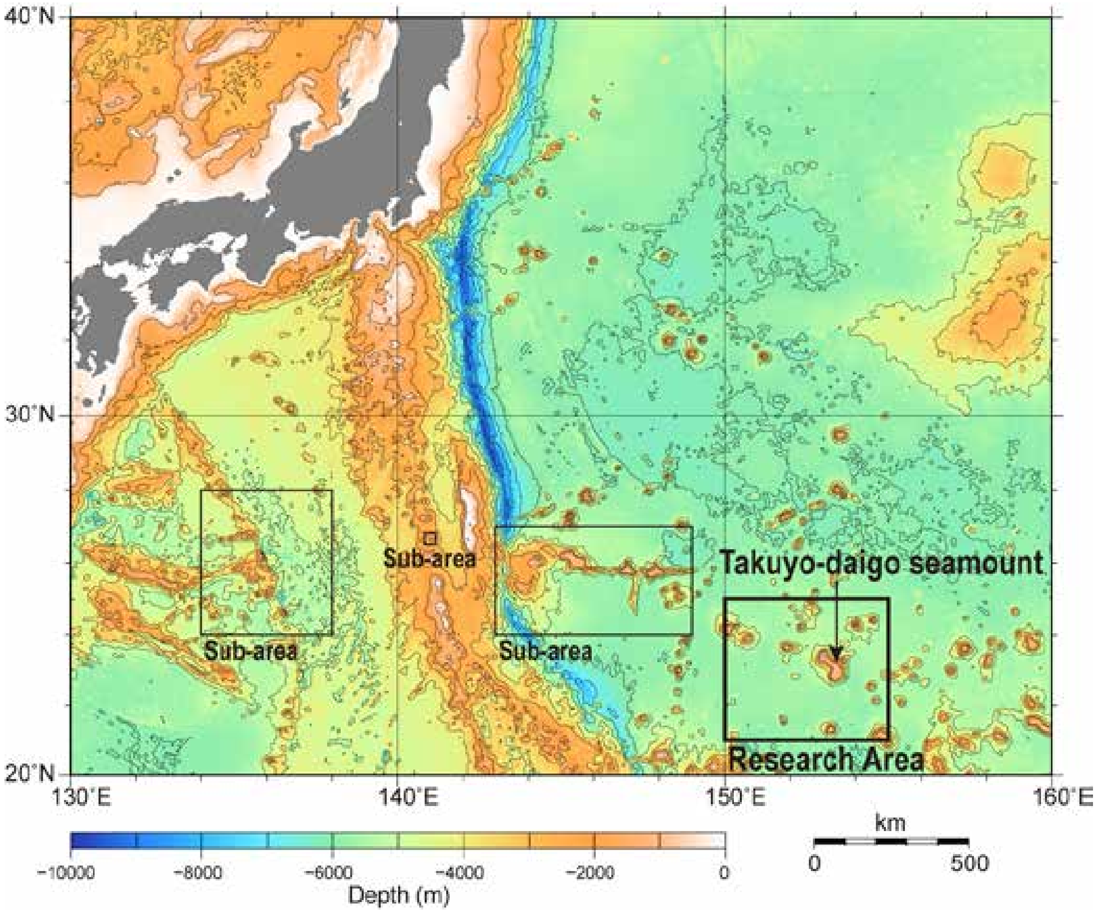


Fig.1.1. Research area map of cruise KR16-01 Leg1.

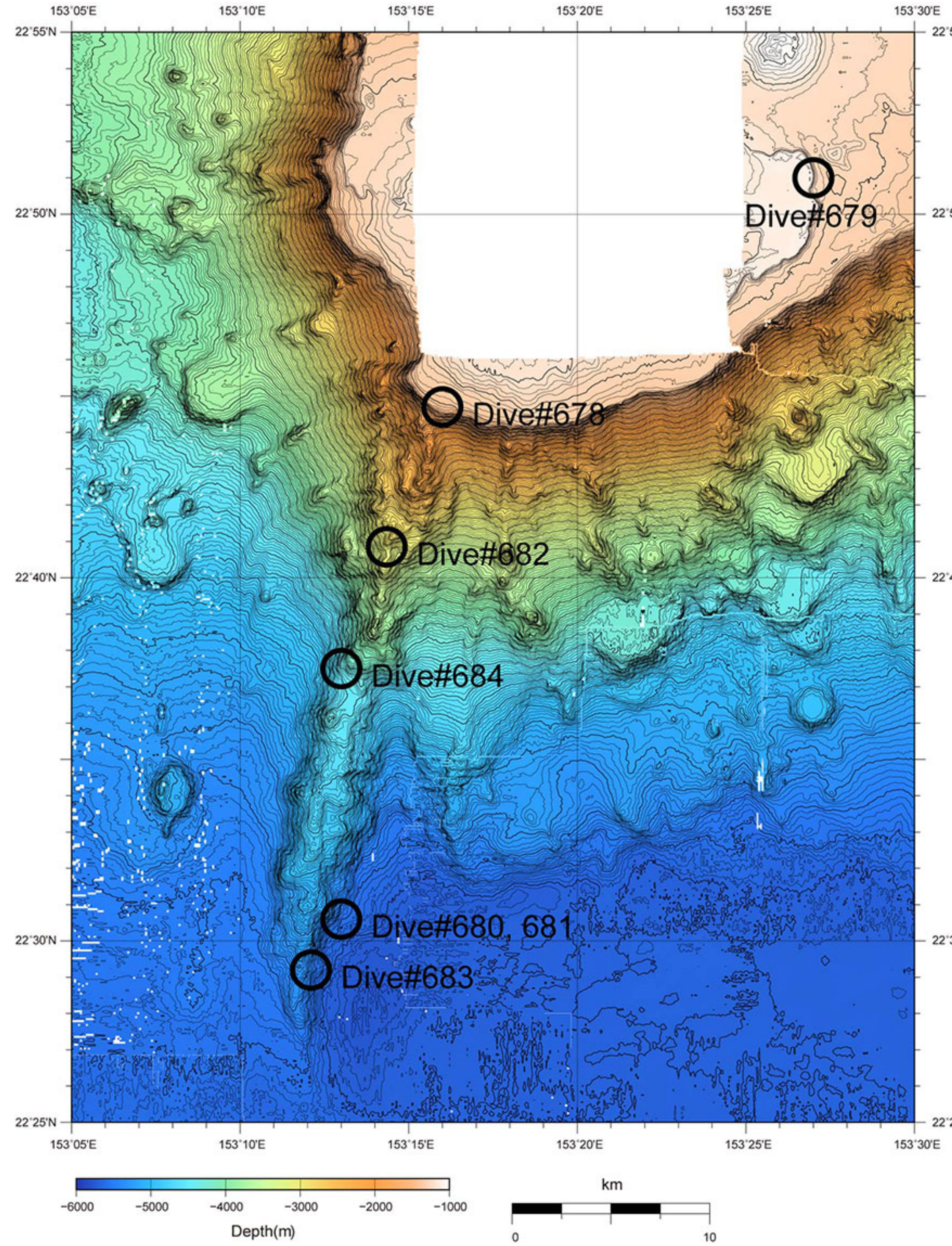


Fig.1.2. Dive area (open circles on southern long ridge and eastern flat plateau) map of Takuyo-daigo seamount in cruise KR16-01 Leg1. Bathymetric data is combined which are previously obtained in cruises KR15-E01 and YK15-15.

2 List of participants

2.1 Science party

<u>Leg 1 members</u>

Koichi IIJMA [JAMSTEC]

Teruhiko KASHIWABARA [JAMSTEC]

Shingo KATO [JAMSTEC]

HIROSHI AMAKAWA [JAMSTEC]

Sakiko KIKUCHI [JAMSTEC]

Hirofumi YAMAMOTO [JAMSTEC]

Akira USUI [Kochi University]

Keisuke NICHI [Kochi University]

Eri SHIMIZU [Kochi University]

Soichiro UESUGI [University of Tokyo]

Hiroki TAKAHASHI [Ibaraki University]

<u>Leg 2 members</u>

Blair THORNTON [Institute of Industrial Science (IIS), the University of Tokyo]

Yuya NISHIDA [Kyushu Institute of Technology University]

Kazunoni NAGANO [IIS, the University of Tokyo]

Umesh NEETTIYATH [IIS, the University of Tokyo]

Yuji OYABU [Dominant Plus One]

Hiroki YANASE [Arc Geo Support Co., LTD]

Kaito MIKAMI [Arc Geo Support Co., LTD]

Tetsu KOIKE [Kaiyo Engineering Co., LTD]

2.2 Onboard scientists

<u>Leg 1 members</u>

Koichi IIJMA [JAMSTEC]

Teruhiko KASHIWABARA [JAMSTEC]

Shingo KATO [JAMSTEC]

HIROSHI AMAKAWA [JAMSTEC]

Sakiko KIKUCHI [JAMSTEC]

Hirofumi YAMAMOTO [JAMSTEC]

Akira USUI [Kochi University]

Keisuke NICHI [Kochi University]

Eri SHIMIZU [Kochi University]

Soichiro UESUGI [University of Tokyo]

Hiroki TAKAHASHI [Ibaraki University]

Leg 2 members

Blair THORNTON [Institute of Industrial Science (IIS), the University of Tokyo]

Yuya NISHIDA [Kyushu Institute of Technology University]

Kazunoni NAGANO [IIS, the University of Tokyo]

Umesh NEETTIYATH [IIS, the University of Tokyo]

Yuji OYABU [Dominant Plus One]

Hiroki YANASE [Arc Geo Support Co., LTD]

Kaito MIKAMI [Arc Geo Support Co., LTD]

Tetsu KOIKE [Kaiyo Engineering Co., LTD]

2.3 Marine technicians

Mitsuteru KUNO	Nippon Marine Einterprises, Ink.
Keisuke MATSUMOTO	Marine Works Japan. Ltd

2.4 KAIKO operation team

Homare WAKAMATSU	Operation Manager
Junya NIIKURA	2nd ROV Operator
Kiyoshi TAKISHITA	2nd ROV Operator
Tetsuya ISHITSUKA	2nd ROV Operator
Seiji SHIGETAKE	2nd ROV Operator
Shota IHARA	2nd ROV Operator
Takuma GOTO	3rd ROV Operator

2.5 Crew members

Eiko UKEKURA	Captain
Takaaki SHISHIKURA	Chief Officer
Takeshi MURAMATSU	2nd Officer
Satoru YOSHIDA	3rd Officer
Tadashi ABE	Chief Engineer
Shinichi IKUTA	1st Engineer
Naohito TADOOKA	2nd Engineer
Katsuto YAMAGUCHI	3rd Engineer
Fukuo SUDA	Chief Electronics Operator
Yuka MORIWAKI	2nd Electronics Operator
Emi SAWAYANAGI	3rd Electronics Operator
Kazuo ABE	Boat Swain
Yukito ISHII	Able Seaman
Nao ISHIZUKA	Able Seaman

Hideaki NAKATA	Able Seaman
Yuta MOTOOKA	Sailor
Yusaku KANADA	Sailor
Toshiya SAGA	Sailor
Masanori UEDA	No.1 Oiler
Kazuo SATO	Oiler
Masaki TANAKA	Oiler
Keiya TANIGUCHI	Oiler
Atsumu HARA	Assistant Oiler
Tatsunari ONOUE	Chief Steward
Toru MURAKAMI	Steward
Masanao KUNITA	Steward
Yoshie HIDAKA	Steward
Koki SHINOHARA	Steward

3 Background and objectives

Ferromanganese crust, mainly consist of iron and manganese oxides as covering basement rocks of basalt or limestone, draw attention as a seafloor metal resource containing minor- and noble metals. We have investigated for these years Takuyo-daigo seamount as a model seamount, at shallower than 3,000 m, well organized rock sampling or measurement of thickness of crusts were carried out.

In this cruise, we use heavy-duty remotely operated vehicle (ROV) KAIKO Mk-IV which can operate at more than 5,000 m. Depend on the ability of KAIKO, the first objective is to observe and sampling of crusts at depth below 4,000 m that previous cruise KR15-E01 could not accomplished. The second objective is to deploy electromagnetic current meter, in-situ chemical adsorption and incubation system at depths ranging from 5,000 m to 1,000 m, to observe physical oceanographic situation of crusts and to understand formation process and mechanisms of them, in a natural state.

4 Instrumentation and methods

4.1 Electromagnetic current meter

We decided to observe bottom currents above ferromanganese crusts of Takuyo-daigo seamount to know how much, and what direction of currents are flowing at the present geological, geographical and oceanological setting. Through many observation of ferromanganese crusts using ROVs, nodules and sediments covered on seamounts are there, we had recognized that occurrence of them has something regularity between small-scale topography and their location. Especially for ferromanganese nodules on sediments (foraminifer sand), their occurrence seemed to be controlled by a bottom current; such as stream-like spatial high density distribution on sediments, accumulated small area behind a big boulder, or occurrence along ferromanganese crusts.

There are some types of current profiler exists, though the most typical choice is acoustic doppler current profiler (ADCP), we used an electromagnetic current meter (Fig.4.1.1). Our objective of this observation is to measure current near surface of crusts, so that ADCP which must have a blank range is not suitable for this purpose. Additionally, compact size and light weight are preferred on account of handling and weight limitation of payload in ROV. Then we choose JFE Advantech AEMD-USB electromagnetic current meter for our observation (see general specification listed below).

Fig.4.1.1. JFE Advantech AEMD-USB electromagnetic current meter, ϕ 8.5 cm, height 42.1 cm. A biaxial electromagnetic field-induced sensor is installed at the top (painted by black rubber)

General specifications of JFE Advantech AEMD-USB

	Current speed	Current direction	Water temp.	Depth	Inclination
Sensor type	biaxial electromagnetic field-induced	Hall effect	Thermistor	Semiconductor	Biaxial
Range	0 ~ ±100 cm/sec.	0 ~ 360°	-3 ~ 45°C	0 ~ 60 MPa	0 ~ ±30°
Resolution	0.02 cm/sec.	0.01°	0.001°C	0.002 MPa	0.01°
Precision	±1 cm/sec.	±2°	±0.02°C	±0.3 %FS	±1°

Sampling interval	0.1 ~ 600 sec.
Burst time	1 ~ 1,440 min.
Maximum sample	18,000
Power supply	4 CR-V3 Li-ion battery
Memory type	miniSD card
Connection type	USB 2.0
Material	Ti-6Al-4V
Dimension	ϕ 8.5 cm x Height 42.1 cm
Weight	4.1 kg (Air) / 2.4 kg (Water)
Depth rating	6,000m

The observation term may continue as long as depending on battery capacity which energy consumption is widely changeable according to measurement property. On the other hand, a cruise for the retrieval will be carried out on 10 months after this cruise. Hence the observation duration must be over 10 months and the measurement property must be considered a balance between battery resource and efficient sampling number (measurement number, bigger is low deviation), sampling interval (shorter is energy consumable) and the burst interval (shorter is highly energy consumable). At last we programmed the property as shown in Table 4.1. We could not know the sampling number 20 is sufficient for deep-sea current observation, however, this number is the largest on 30 minutes interval observation for more than 10 months duration. Also, 30 minutes is sufficient interval for observation of tidal fluctuation.

Table 4.1. Measurement property for the electromagnetic current meter.

Sampling number	20
Sampling interval	1.00 sec.
Burst interval	30 min.

To deploy the electromagnetic current meter on the seafloor of seamount, might be inclined, we made a frame equipped with a gimbal structure (Fig.4.1.2). Even if the deployed site is inclined, the gimbal frame compensate its body on horizontally balanced position using its gravity center at lower spot (X-axis up to 30°, Y-axis up to 20°). As a result, the electromagnetic sensor is positioned at about 57 cm above the seafloor.

The main frame is consist of titanium to avoid rapid corrosion and deterioration in seawater, without any anode alloy. Although the material is same as main body of electromagnetic current meter, insulation is guaranteed at polyoxymethylene binding parts connecting the main body to the gimbal frame. Thanks to its chemical stability, the main frame is useful as stay tube to fix chemical adsorption experimental pars (Fig.4.1.3). We put them on the frame in all the three electromagnetic current meter deployment, and one frame is used only for the experimentation.

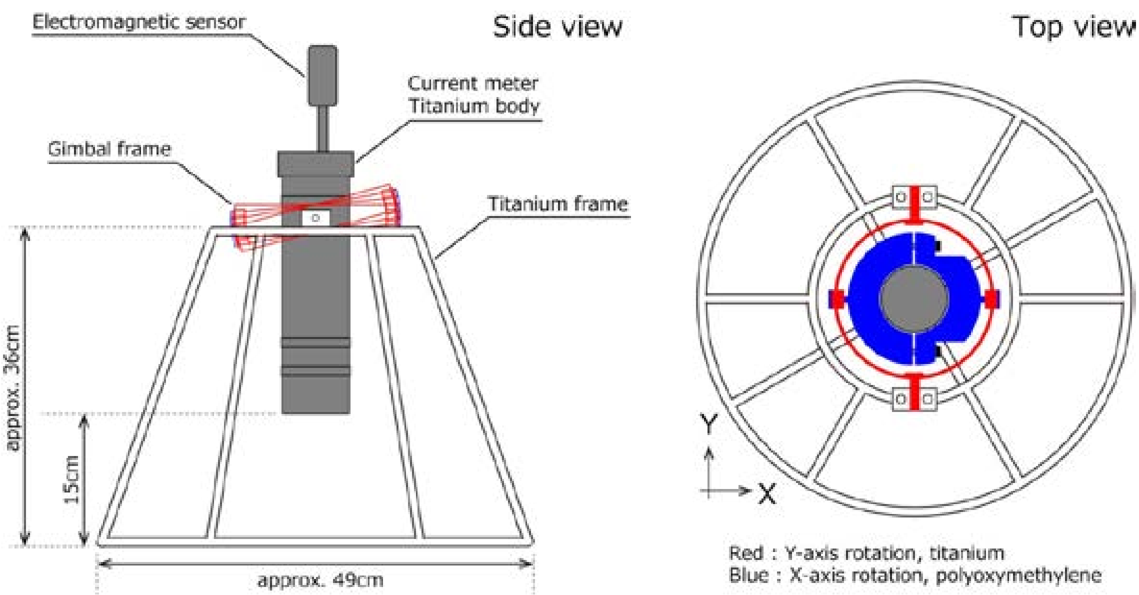


Fig.4.1.2. A frame for the electromagnetic current meter with gimbal structure.

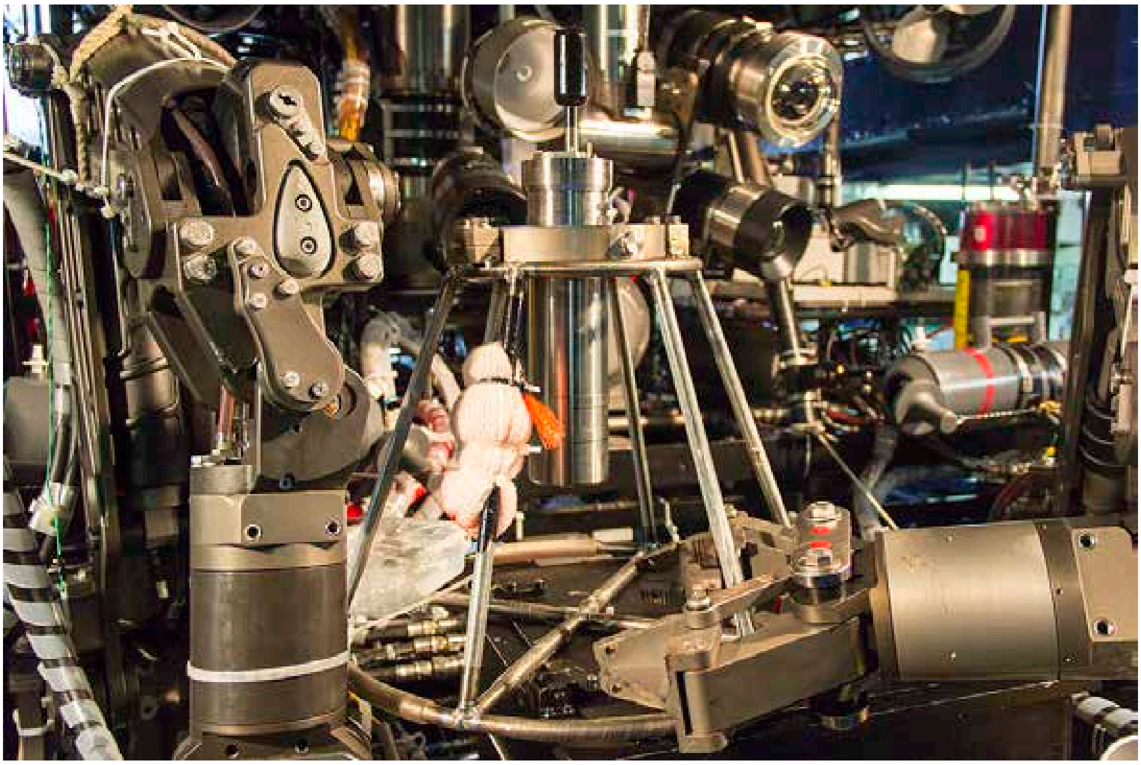


Fig.4.1.3. An electromagnetic current meter and a frame is assembled with chemical adsorption parts. White squashy material covered with orange-colored net is wool for covering MnO_2 interfused fiber (see section 6.2). Photographed during pre-dive check of dive #679 on 13 Jan. 2016.

4.2 *in situ* chemical adsorption and incubation experimentation system

For *in situ* chemical adsorption and incubation experimentation, we made a cell to contain many kind of materials to be chemically adsorbed and incubated with membrane filter caps (Fig.4.2 (a)). The seawater pass through the membrane filters. Then the cells are hanged on aluminum frame using thin plastic rope (Fig.4.2 (b)). The system should be isolatedly exposed to "*in situ*" deep seawater, which means the system must not touched surface and water column seawater. Thus we made an aluminum tight box to keep the system in full of fresh water equipped with hose connector at the bottom and air vent with filter at the top, called "Biobox" (Fig.4.2 (c)). The air vent plays a role for pressure compensation between inside and outside the box during descending vehicle in water column. At least, inflow of seawater to the box is microbiologically cleaned by a 0.2 µm-pore-size membrane filter. Finally the system is immersed in fresh water in the box (Fig.4.2 (d)) and is brought to the seafloor. The system deployed on the seafloor will be retrieved in next cruise in Takuyo-daigo seamount (10 months later) or later.

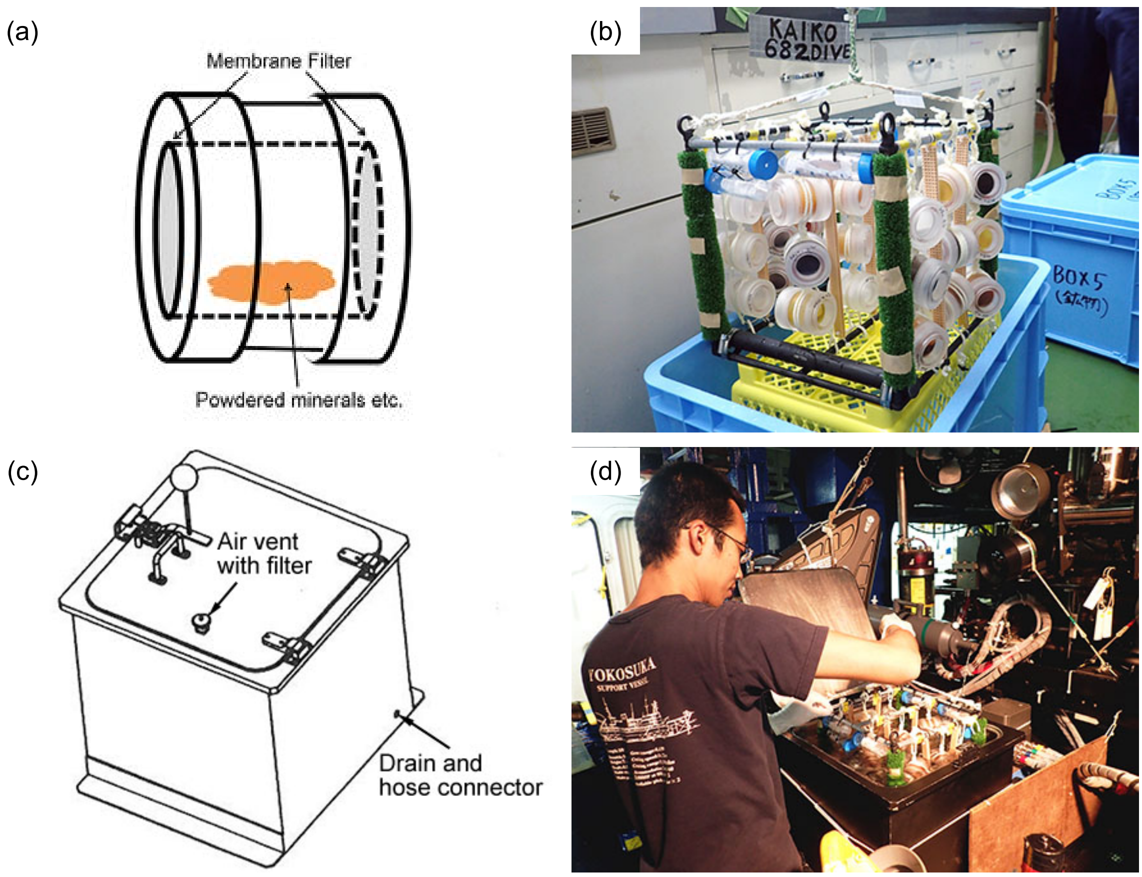


Fig.4.2. (a) A cell of *in situ* chemical adsorption and incubation experimentation. (b) *in situ* experimentation system. (c) "Biobox" equipped with hose connector and air vent. (d) The system is immersed into fresh water.

4.3 Water and sediment sampling

Two large Niskin bottles are used for water sampling (General Oceanics Inc. GO-101005ROV, 5 litters each, see Fig.4.3.1). They are installed at back of manipulator arms of both port side and starboard side of the vehicle. The trigger is executable with pulling a color wire by manipulators, settled in front of payload box as seen in Fig.4.3.2 and Fig.5.1 (Ns and Np).

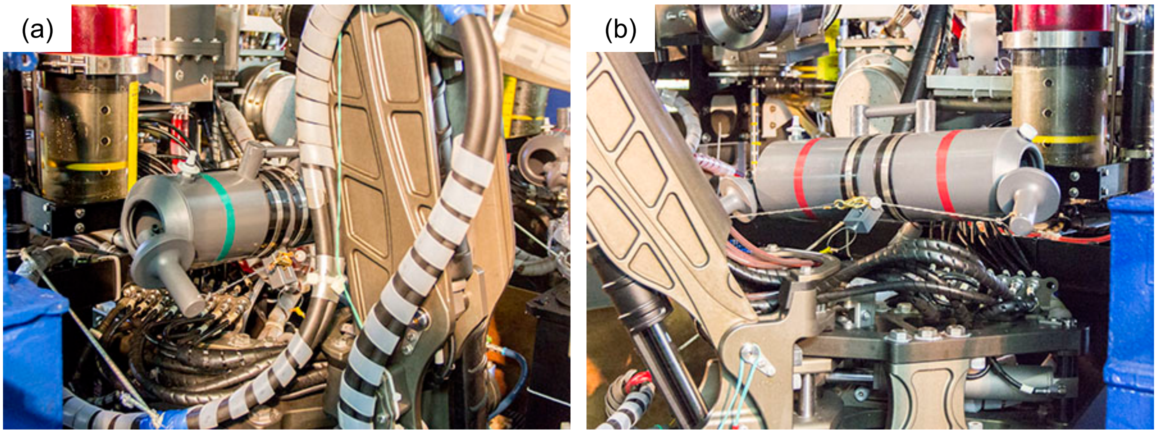


Fig.4.3.1. (a) Niskin bottle with green label installed at back of manipulator arm of starboard side. (b) Niskin bottle with red label installed at back of manipulator arm of port side. Trigger pin with circled wire, connected to color wire Np, is seen at the center of the bottle.

A H-type push corer is used for sediment sampling (Fig. 4.3.2). We used normal 40 cm long core tube and valve is slightly tightened to keep coarse grains inside the tube, though it is quite difficult to retrieve a “sand” core. If the bottom is sand, we will use this corer as a scoop to shovel seafloor surface sediments, and the sand is recovered in the casing to bring them up to the ship.

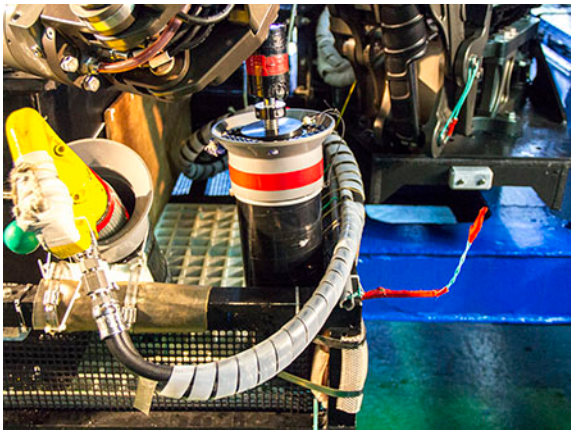


Fig.4.3.2. H-type push corer installed in its own casing, placed at front end of port side of the payload box. Hydraulic hammering chisel is seen in left of the photograph, and triggering color wire (green wire with red vinyl tape) is shown just beside the push corer.

4.4 Rock sampling

A hydraulic rotary cutter (Fig.4.4 (a)), a hydraulic hammering chisel (Fig.4.3.2), a handy chisel (Fig.5.1) and also two manipulators are used for rock sampling. The effectivity of these hydraulic tools are demonstrated through past ROV Hyper-Dolphin dives, however, hydraulic system of KAIKO is absolutely different from that of Hyper-Dolphin. To adopt these tools to the system of KAIKO, we made a pressure valve unit with compensator (Fig.4.4 (b)). Supply pressure, flow rate, back pressure of both rotary cutter and hammering chisel is adjusted and confirmed before the dives, especially for hammering chisel that is sensitive for the back pressure.

For microbiological samples of ferromanganese crust, nodules and rocks, after the *in situ* chemical adsorption and incubation experimentation system is deployed, are retrieved in the Biobox and the door is locked. Water pressure change while vehicle ascending is compensated through vent with membrane filter, as same as descending, which enable the samples to isolate microbiologically from large microbes in water column and surface seawater.

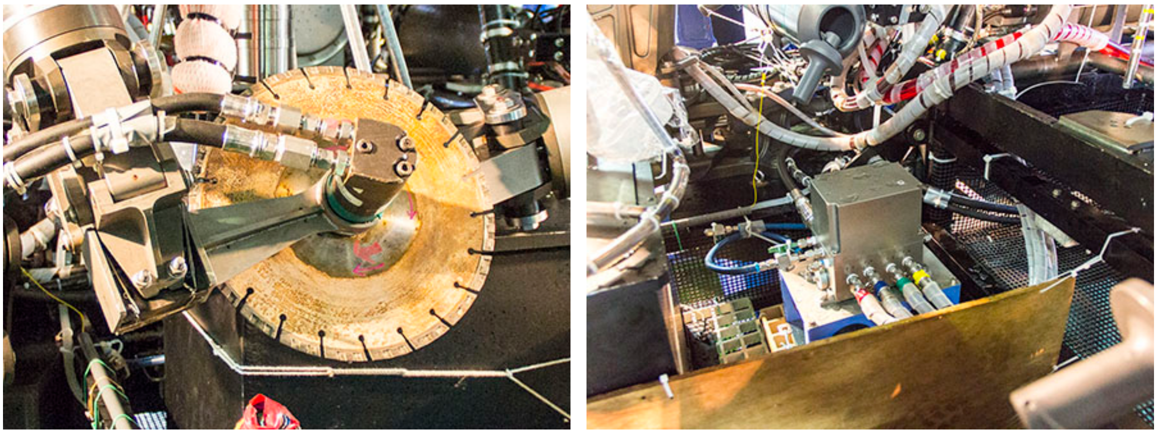


Fig.4.4. (a) Hydraulic rotary cutter placed at right hand of the manipulator (starboard side of the vehicle). (b) A hydraulic valve system connected between the vehicle's hydraulic system and payload hydraulic tools.

4.5 Geophysical survey

Research Vessel KAIREI

Deep sea research vessel "KAIREI" is the exclusive mother ship for the 7,000m class ROV KAIKO Mk-IV which entered service in 2015. In addition, KAIREI is equipped with geophysical instruments such as a 444 channel seismic profiler. The major instruments installed in KAIREI are a Multi-beam echo sounder (MBES) bathymetric mapping system (Sea Beam3012), integrated sub-bottom profiler (SBP), gravimeter, proton magnetometer, onboard three components magnetometer, and various kinds of sampling devices such as piston corer, dredge, etc. There are several onboard laboratories for data recording, data and sample analysis such as; research room, mission control & computer room, wet laboratory (chemistry and biology), dry laboratory (geophysics), gravimeter room, KAIKO operation's center, rocks and sediment laboratory, library, video room and personal computer room. The ship also has an aft wheel house which overlooks the entire aft operations deck for the operation of the ship, winches, A-frame and cranes during station work such as dredge hauls, piston coring and sampling, launch and recovery operations.

General specifications of R/V KAIREI

Length overall	106.0 m
Beam overall	16.0 m
Depth	7.3 m
Draft	4.5 m
Gross tonnage	4,517 tons
Service speed	16.7 knot
Main propulsion system	Diesel engines 2,206kW x 2
Main propulsion method	Controllable pitch propeller x 2
Complement	
Crew	29 persons
Submersible operation staff	9 persons
Researchers	22 persons

In this cruise, MBES bathymetric data, SBP data, gravity data and geomagnetic data (onboard tri-axis) are obtained during transit, maintenance days and night time after on-deck of KAIKO. In Fig.4.5, foreground colored area shows previously obtained MBES data area by R/V "KAIREI" cruise KR15-E01 and support vessel "YOKOSUKA" cruise YK15-15. We try to get the data of absent areas on flat plateau and northeastern big ridge in this cruise.

The specifications of L-3 ELAC Nautik GmbH SeaBeam 3012 for MBES

Operating frequency	12 kHz
Min. depth	50m below transducers
Max. depth	11,000 m (full ocean depth)
Number of beams	301 equi-distance
Accuracy	<1 % of water Depth (Average Across Swath)
Side scan	12-Bit Resolution to maximum 2000 pixels
Average footprint resolution	2° x 1.6°
Max. vessel speed	6 knots (100 % Coverage @ 140° swath)
	12 knots (100 % Coverage @ 120° swath)
Environmental limits for compensation	
Roll	±10°
Pitch	±7°
Yaw	±5°

The specifications of SyQwest, Inc. BATHY-2010 for SBP

Depth ranges	10, 20, 40, 80, 150, 300, 500, 750, 1000, 2000, 5000, 12000 meters
Strata resolution	Up to 6 cm with 200 Meter of bottom penetration (Bottom type dependent)
Depth resolution	0.1 Meters
Depth accuracy	±0.3% to 6000 m
Frequency output	3.5 KHz

The specifications of BODENSEEWERK PERKIN-ELMER KSS31 for onboard gravimeter

Measurement range	~10,000 mGal
Drift	3 mGal per month or less
Resolution	1 mGal

The specifications of Tierra Tecnica SFG-1214 for onboard triaxial magnetometer

System	ring core fluxgate
Number of component directly	3 axes
Sensor dimension	φ280×130H mm
Measurement range	±100,000 nT
Resolution	1 nT

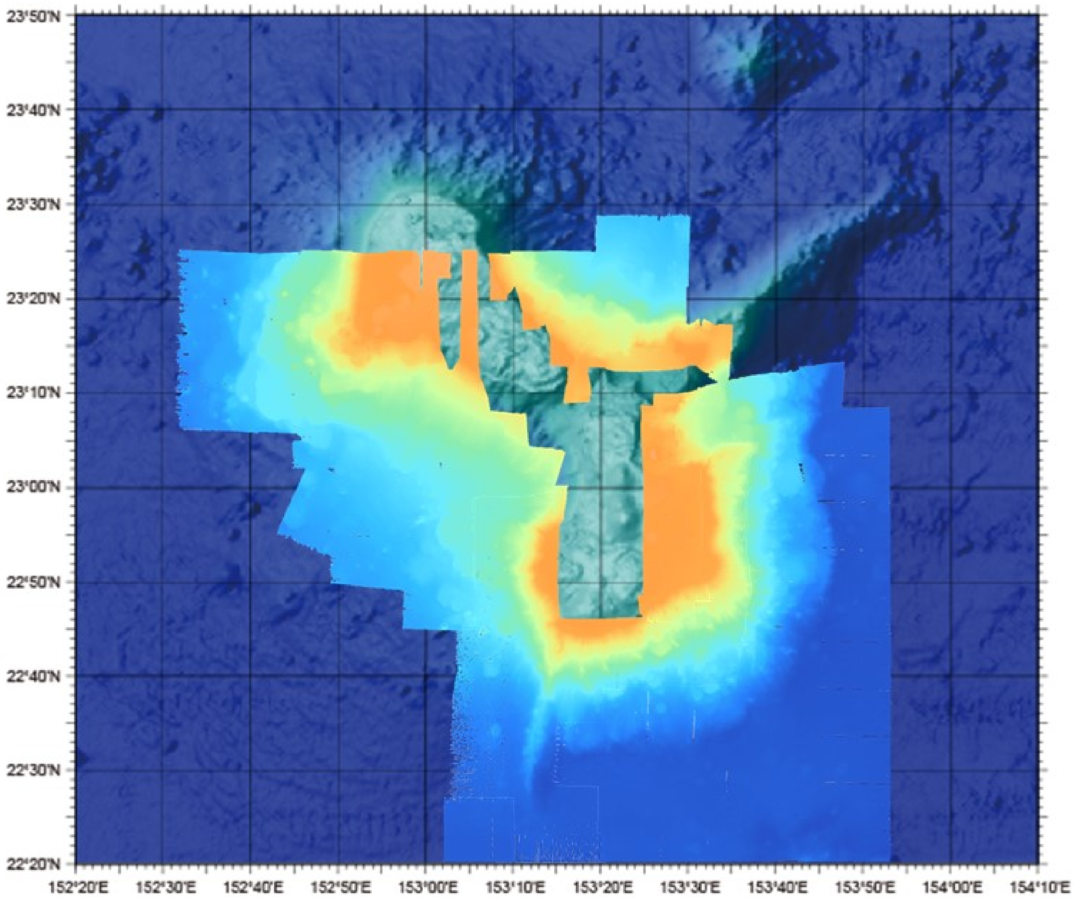


Fig.4.5. MBES survey covered area (foreground colored area) in Takuyo-daigo seamount obtained by previous KR15-E01 and YK15-15 cruises. The background bathymetric image is captured from Marine Cadastre, Japan Coast Guard and ESRI, Japan (http://www.kaiyoudaichou.go.jp/).

5 KAIKO operation

5.1 General description of KAIKO

ROV Hyper-Dolphin is used for our research dives for ferromanganese crust through these years, however, in 2014, R/V Natsushima, a main mother ship for Hyper-Dolphin, is decommissioned. After that, ROV operation is basically changed to use KAIKO system. The most obvious difference between Hyper-Dolphin and KAIKO, are launching system, maximum depth and power. New vehicle “Mk-IV” is designed for heavy duty work in deep seafloor so that especially the manipulators have absolutely strong power. This power enable us to grasp and pull ferromanganese crusts which are firmly fixed onto basement rocks.

<u>General specifications of ROV KAIKO comparison with ROV Hyper-Dolphin</u>

		KAIKO	Hyper-Dolphin
Launcher	Length, wide, height	5.2 m, 2.6 m, 3.2 m	No launcher
	Weight	5.8 t (Air) / 3.5 t (Water)	
	Depth range	~11,000 m	
Vehicle	Length, wide, height	3.6 m, 2.1 m, 2.6 m	3.0 m, 2.0 m, 2.6 m
	Weight	6 t (Air) / 10 kgf (Water)	4.3 t
	Depth range	~7,000 m	~4,500m
	Tether cable length	200m	No tether system
	Payload limit	300 kg (Air) / 200 kg (Water)	300 kg (Air) / 100 kg (Water)
	Lift up power	250 kg (Water, max. outreach)	70kg (Water, max. outreach)
	Grasp power	500 kg (Water)	450kg (Water)

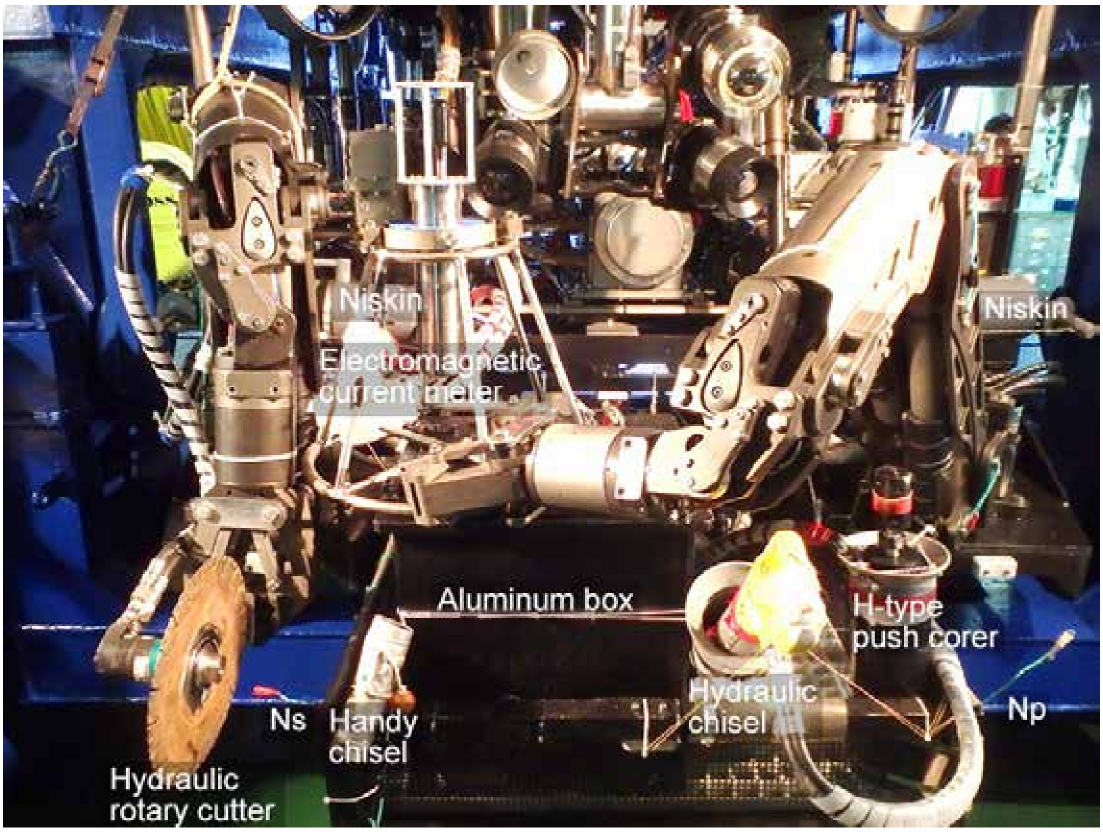


Fig.5.1. Payloads for dive #679 on 13 Jan. 2016.

Positioning of the vehicle is determined using super short baseline (SSBL) between the launcher. Transmitted acoustic signal from the vehicle is received by launcher, and the absolute position is calculated from relative position from the launcher (within 200 m regulated by tether cable length) based on position of the launcher determined by SSBL between the ship. The vehicle has internal navigation system (INS) and doppler velocity log (DVL), which provide highly precise positioning information, while position update is depending on SSBL positioning. In this cruise we did not use INS information due to its instability. However, precision of SSBL positioning vary depend on water depth and sea state, especially for deeper dive (~5,500m). Therefore we calculate 3-minutes moving average of coordinates (longitude and latitude) provided by SSBL for our use. For revisit to the outcrop in the future, we deployed Sonardyne type 7835 mini transponder on the seafloor, for ROV homer target relocation system installed on the vehicle. Its depth rating is up to 11,000m, and battery has more than 4 years long life.

KAIKO has many cameras for visual observation, there are two pairs of high-definition camera and NTSC camera, and one digital still camera. Conductivity, temperature and depth (CTD) meter and dissolved oxygen (DO) meter, depth meter are also installed. These general specification are listed below.

General specifications of cameras

	No.1 & No.2 HDTV camera	No.1 & No.2 TV camera	Digital still camera
Type	SONY FCBH11	SONY FCBIX11A	OLYMPUS E-PL6
Image device	1/3-type CMOS	1/4-type Exview HAD CCD	4/3-tye Live MOS
Effective pixels	2,000,000	380,000	16,050,000
Signal	HD: 1080/59.94i etc.	NTSC	-

The specifications of SeaBird Electronics SBE49 FastCAT CTD meter

	Conductivity (S/m)	Temperature (°C)	Depth
Measurement range	0 to 9	-5 to +35	0 to 20/100/350/1000/2000/3500/7000 dBar
Initial accuracy	0.0003	0.002	0.1 % full scale
Stability(/Monthly)	0.0003	0.0002	0.004 % full scale
Resolution	0.00005 (In the case of seawater)	0.0001	0.002 % full scale

The specifications of JFE Advantech RINKO II DO meter

	Dissolved oxygen (%)	Temperature (°C)
Measurement range	0 to 200	-3 to +45
Precision	±2%	±0.02°C

The specifications of Paroscientific 8B7000-2 depth meter

Measurement range	0 to 7,000 m
Accuracy	±0.01%
Resolution	1×10^{-8}

5.2 Dive results

5.2.1 Dive #678

KAIKO dive #678 is carried out on 12 January 2016 to go to unique canopy-like ferromanganese crust existing around 1,430m at southern tip of flat plateau (Fig.1.2). This is one of a revisit site where visited on 30 June 2013 in Hyper-Dolphin dive #1544. The canopy continues alongside contour, the altitude from sand basement varies dozens to a hundred cm (Fig.5.2.1 (a)). A simple chemical adsorption and incubation system is deployed on the canopy (Fig.5.2.1 (b)), which is not carried in the Biobox (traveled through sea surface water to the bottom). Foraminifer sand (ooze) is collected by H-type push corer, as used as a scoop (Fig.5.2.1 (c)). At this site, the bottom current is slightly flowing that stirred up sands and clays are immediately run away. The manipulator is very useful and powerful tools for direct sampling of platy ferromanganese crust (Fig.5.2.2 (d)). We will be realized that the strong power is helpful for rock sampling as dives through carried out. In this dive, hydraulic tools are examined, they worked, and however, it is not powerful as seen as before using on ROV Hyper-Dolphin.

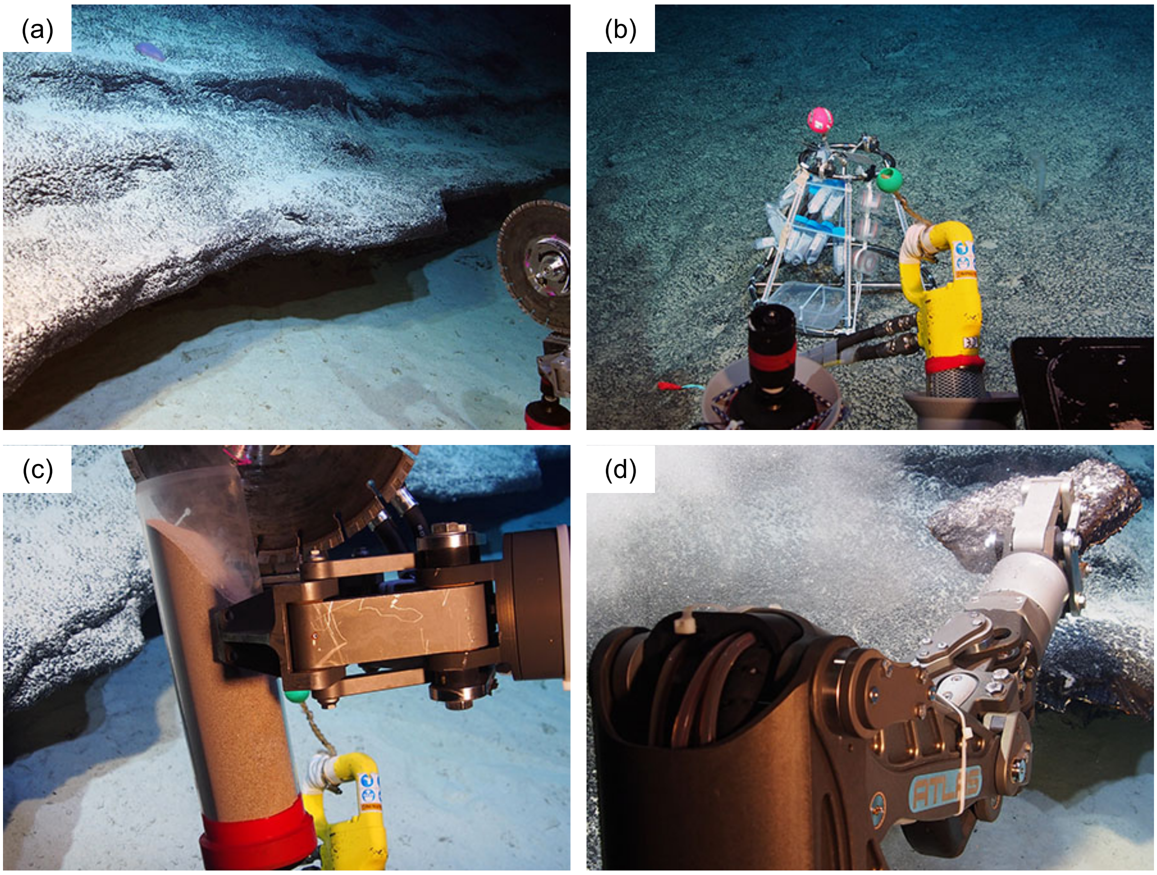


Fig.5.2.1.1. Images taken during KAIKO dive #678 on 12 January 2016. (a) A canopy-like structure. (b) A simple chemical adsorption and incubation system on the canopy. (c) Sediment sampling by H-type push corer. (d) Direct crust sampling using the manipulator.

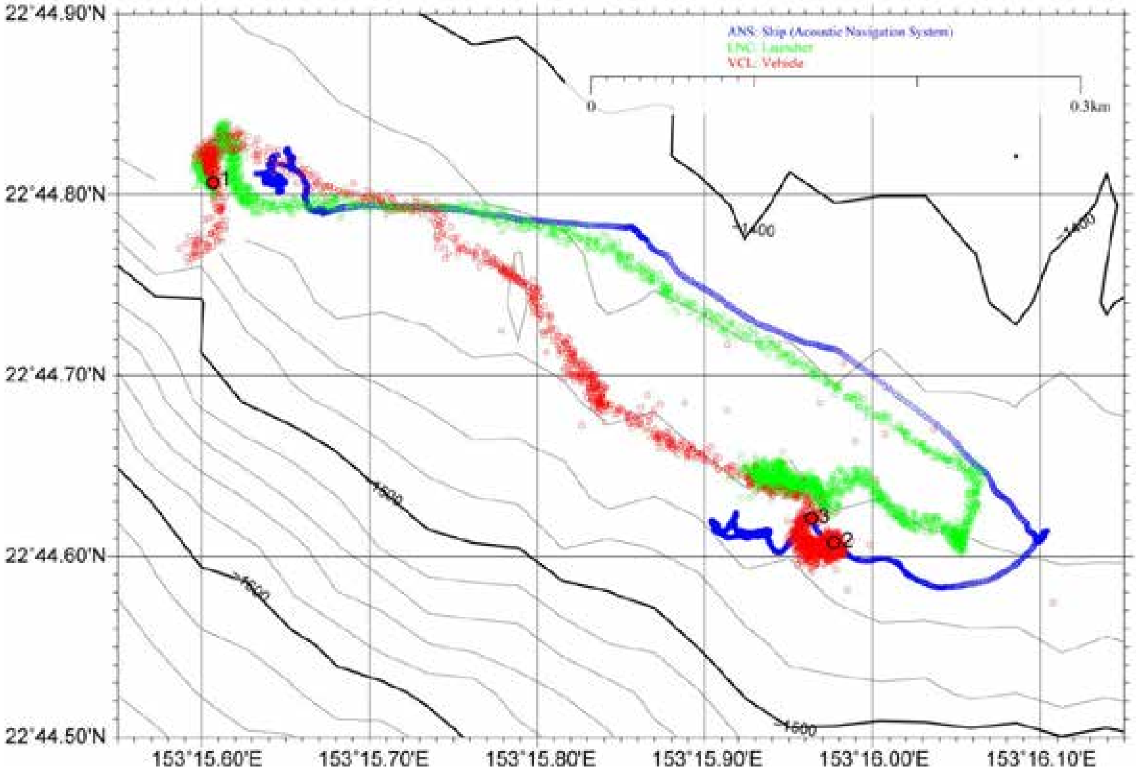


Fig.5.2.1.2. Cruise track of dive #678 on 12 Jan. 2016 obtained by acoustic navigation system using SSBL. Red circles represent the vehicle, green circles represent the launcher and blue circles represent ship track respectively. Error data is not eliminated.

Table.5.2.1. Dive log of #678 on 12 Jan. 2016. Event # correspond to numbers shown in Fig.5.2.1.2.

Event #	Time[*]	Latitude[*2]	Longitude[*2]	Vehicle Depth (m) [*3]	Description
1	10:11	-	-	-	Vehicle landed and check transponder
	11:25	22°44.765'N	153°15.591'E	1,456	Transponder works, start to move
2	13:02	22°44.605'N	153°15.956'E	1,425	Vehicle elevated to around 20 m above the seafloor and water sampling by Niskin bottle (red label)
	13:05	22°44.607'N	153°15.960'E	1,426	Vehicle landed on pavement crust
	13:09				Deployed an *in situ* experimentation system
	13:16	22°44.603'N	153°15.971'E	1,432	Vehicle moved shortly and landed in front of canopy-like outcrop
	13:37				Sediment sampling by H-type push corer
	13:57				R1a rock sample retrieved and put into the Biobox
	14:05				R1b rock sample retrieved
	14:21				Started hydraulic rotary cutter sawing
	14:31				Terminated hydraulic rotary cutter sawing
	14:35				R2 rock sample retrieved
	14:46				R3 rock sample retrieved
	14:54				Started hydraulic chisel hammering
	15:01				Terminated hydraulic chisel hammering
	15:01	22°44.608'N	153°15.972'E	1,432	Vehicle left bottom
3	15:09	22°44.621'N	153°15.964'E	1,378	Vehicle elevated to around 50 m above the

seafloor and water sampling by Niskin bottle (green label)

* Time is UTC+10 (local ship time). *2 Latitude, longitude are result of 3-minutes moving average to reduce positioning error of SSBL, except event #3 (the vehicle is ascending for docking to the launcher). *3 Depth derived from depth meter of the vehicle.

5.2.2 Dive #679

Dive #679 is carried out on 13 January 2016 to go to a flat plateau in around 1,150 m (Fig.1.2), to investigate chemical and oceanological characteristics near beneath the oxygen minimum zone (OMZ) of seamount (c.f. Fig.5.2.8). This site is also one of revisit after Hyper-Dolphin dive #1145 on 2 July 2010. We deployed an electromagnetic current meter (Fig.5.2.2.1 (a)), in situ experimentation system (Fig.5.2.2.1 (b)) and a marker onto pavement-like ferromanganese crust. There are small cliffs, few meters height, where rock samplings are carried out (Fig.5.2.2.1 (c)). Also hydraulic rotary cutter and hydraulic hammering chisel is used for sampling but the time runs out and left the bottom. Though it works well, the power is not sufficient to break the crust.

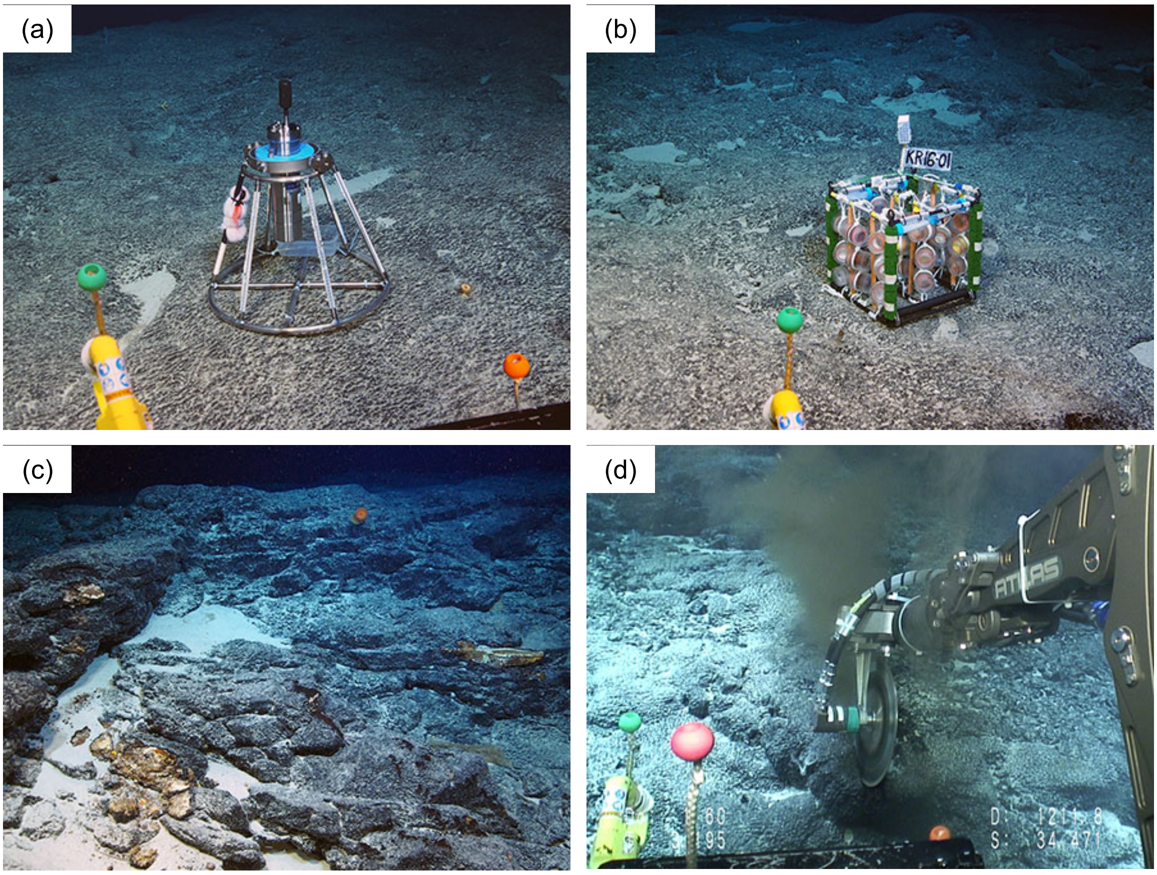


Fig.5.2.2.1. Images taken during KAIKO dive #679 on 13 January 2016. (a) Deployed electromagnetic current meter assembled in gimbal frame. (b) *in situ* chemical adsorption and incubation experiment system is also deployed. (c) Small cliff showing a cross section of basement rocks where we tried to take samples. (d) Hydraulic rotary cutter is cutting ferromanganese crust (dark grey smokes).

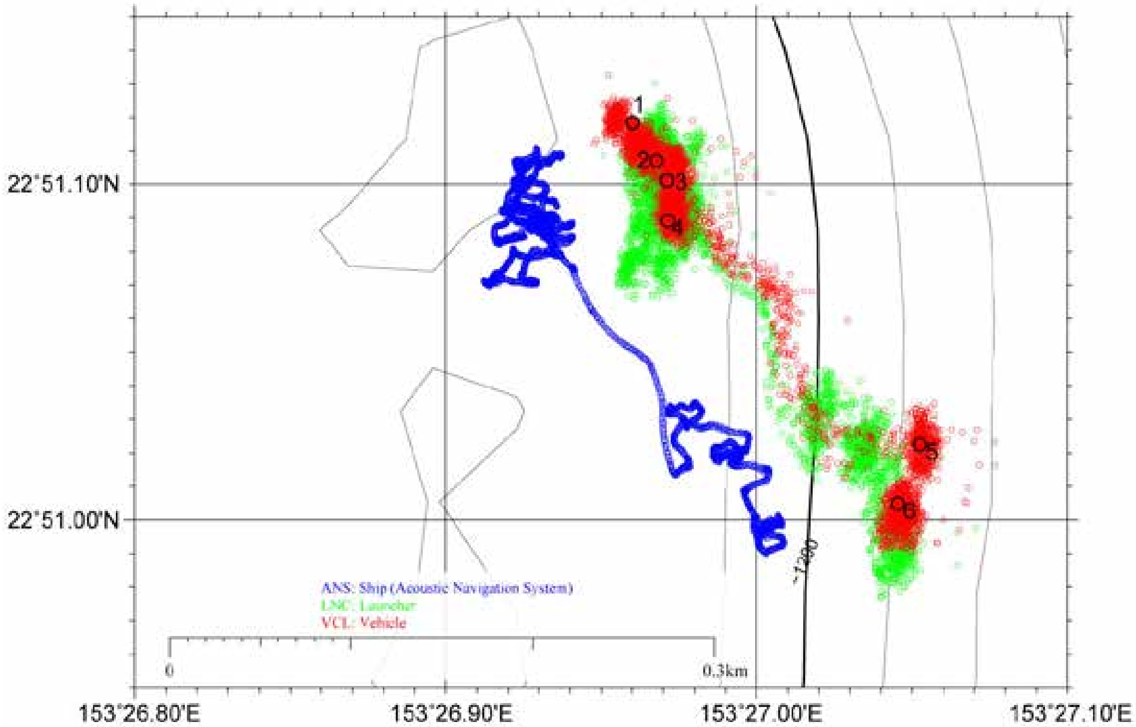


Fig.5.2.2.2. Cruise track of dive #679 on 13 Jan. 2016 obtained by acoustic navigation system using SSBL. Red circles represent the vehicle, green circles represent the launcher and blue circles represent ship track respectively. Error data is not eliminated.

Table.5.2.2. Dive log of #679 on 13 Jan. 2016. Event # correspond to numbers shown in Fig.5.2.2.2.

Event #	Time*	Latitude*2	Longitude*2	Vehicle Depth (m) *3	Description
1	9:58	22°51.122'N	153°26.957'E	1,152	Vehicle landed
	10:23	22°51.110'N	153°26.961'E	1,150	Water sampling by Niskin bottle (green label)
2	10:59	22°51.111'N	153°26.965'E	1,151	Deployed electromagnetic current meter
	11:06				Deployed a marker
	11:25				Deployed an *in situ* experimentation system
3	12:01	22°51.104'N	153°26.973'E	1,154	R1 rock sample retrieved and put into the Biobox
	12:27				Sediment sampling by H-type push corer
4	12:59	22°51.090'N	153°26.974'E	1,153	R2 rock sample retrieved
	13:08				R3 rock sample retrieved
5	14:17	22°51.023'N	153°27.006'E	1,214	R4 rock sample retrieved
6	14:30	22°51.003'N	153°27.006'E	1,216	Started hydraulic rotary cutter sawing
	14:41				Terminated hydraulic rotary cutter sawing
	14:45				Started hydraulic chisel hammering
	15:05				Terminated hydraulic chisel hammering
	15:16				Vehicle left bottom

* Time is UTC+10 (local ship time). *2 Latitude, longitude are result of 3-minutes moving average to reduce positioning error of SSBL. *3 Depth derived from depth meter of the vehicle.

5.2.3 Dive #680

Dive #680 is carried out on 14 January 2016 to go to a deepest part of southern long ridge of Takuyo-daigo seamount at the depth around 5,500 m (Fig.1.2), to investigate existence of ferromanganese crust and its chemical, microbiological and oceanological characteristics.

The bottom of landed site is clay with bimodal and moderately sorted, semi-angular pebbles and cobbles (Fig.5.2.3.1 (a)). We took a sediment sample near this site. Along cruising to the ridge, there are fluctuation of dispersal density of pebbles/cobbles. High dispersal density band (dozens of cm width) is recognized with another high density line of cobbles as shown in Fig.5.2.3.1 (b). On the other hand, some clay dunes and cleavages are observed in dense area of stones as shown in Fig.5.2.3.1 (c). However, boulder size stones are not recognized through the cruising at the base of seamount. Finally, we arrived at an absolute boundary of cliff of the ridge and base, there are not densely covered with stones (Fig.5.2.3.1 (d)).

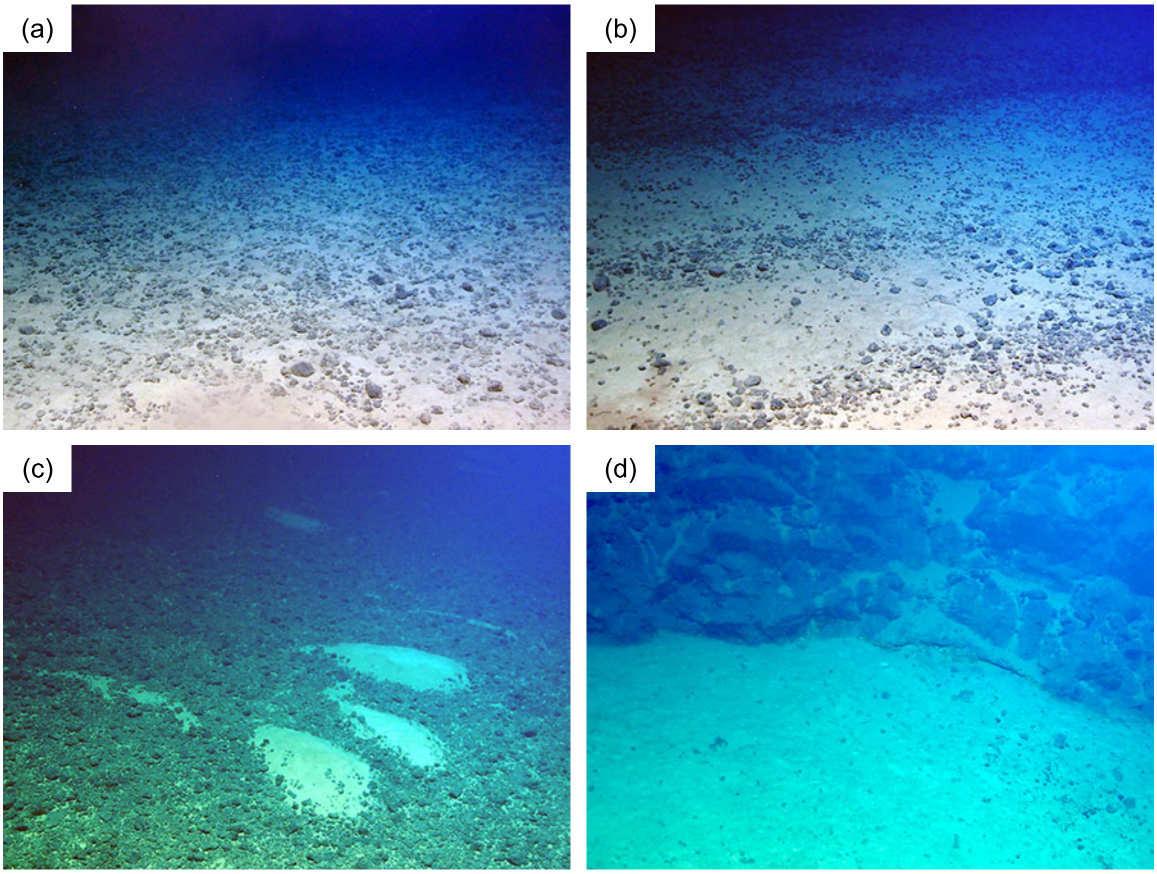
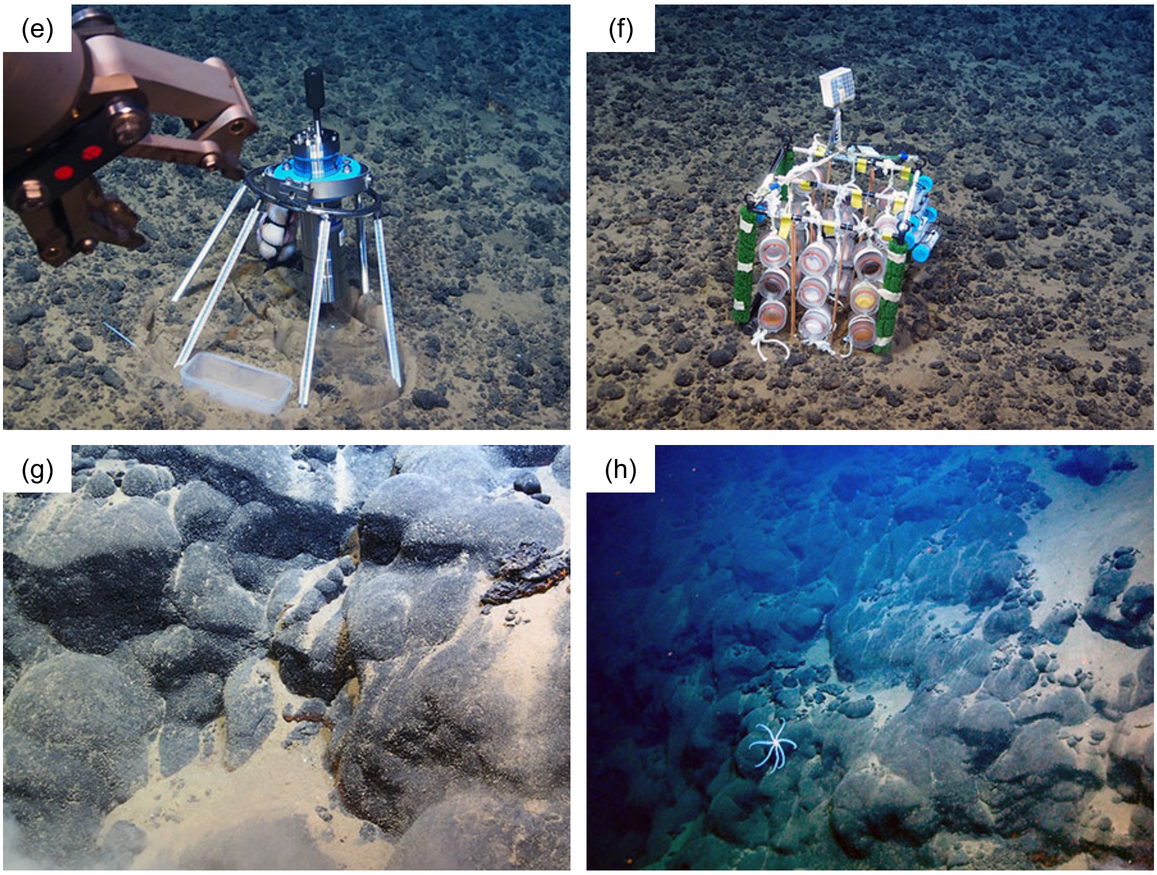


Fig.5.2.3.1. Images taken during KAIKO dive #680 on 14 January 2016. (a) Landed site, event #1 in Fig.5.2.3.2. (b) "Streams" of stones on clay bottom. (c) Clay dunes and cleavages in dense area. (d) Absolute boundary of cliff and base of the ridge.

We deployed an electromagnetic current meter (Fig.5.2.3.1 (e)), *in situ* experimentation system (Fig.5.2.3.1 (f)) and a mini transponder for ROV homer onto near boundary of cliff and base, where bimodal and moderately sorted, semi-angular pebbles and cobbles are densely dispersed on clay. The site is inclined but the gimbal frame definitely acts to keep the current meter horizontal. As shown in Fig.5.2.3.1 (g) and (h), ferromanganese crust is absolutely exist in this deep area of seamount. The surface is relatively smooth and it seems to grow mostly upward rather than all directions. Small stones looks like ferromanganese nodule are not free but firmly fixed onto basement or adjacent crusts. Ferromanganese crust grown at steep cliff looks like a pillow-shape (Fig.5.2.3.1 (h)). This outcrop is too difficult to take samples of crusts, then we moved up to shallower area. Before leaving bottom, we observed densely dispersed semi-angular pebbles and cobbles on a terrace (Fig.5.2.3.1 (i)) similar to the site where the current meter and *in situ* experimentation system are deployed. Also, linear structure of no-stones (clay exposed) are recognized at inclined plane (Fig.5.2.3.1 (j)).



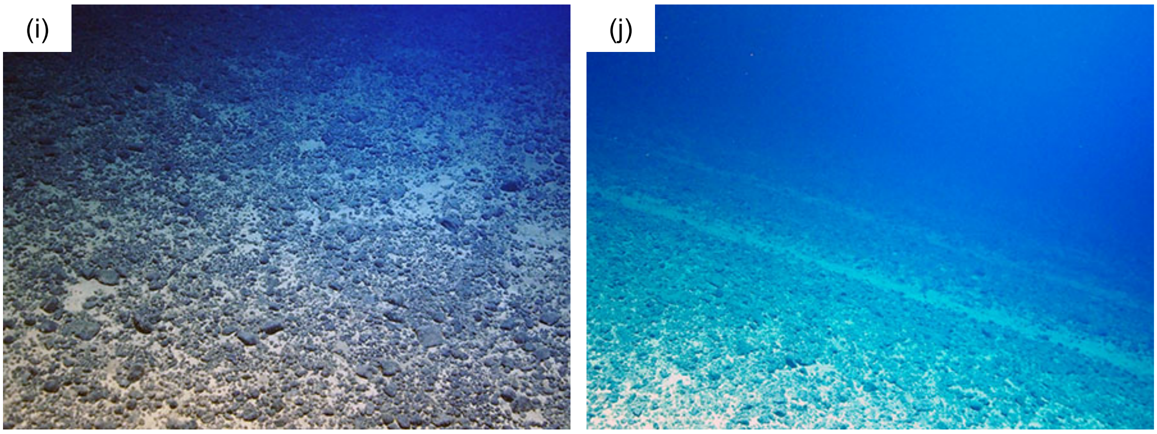


Fig.5.2.3.1 *continued*. (e) Deployed electromagnetic current meter on inclined plane (f) *in situ* chemical adsorption and incubation experiment system is also deployed. (g) Ferromanganese crust and fixed nodules. (g) Pillow-like crusts covers steep cliff. (i) Pebbles and cobbles are densely dispersed. (j) No-stones, clay exposed linear structure.

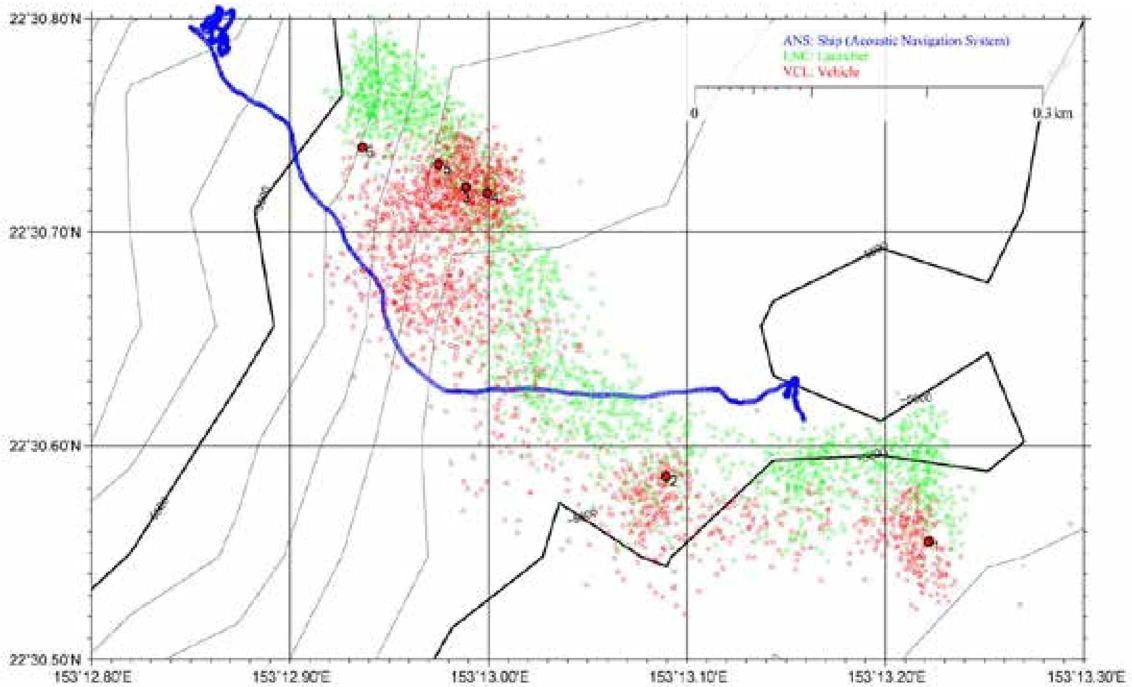


Fig.5.2.3.2. Cruise track of dive #680 on 14 Jan. 2016 obtained by acoustic navigation system using SSBL. Red circles represent the vehicle, green circles represent the launcher and blue circles represent ship track respectively. Error data is not eliminated. Note SSBL positioning varies widely worse unable to track.

Table.5.2.3. Dive log of #680 on 14 Jan. 2016. Event # correspond to numbers shown in Fig.5.2.3.2.

Event #	Time*	Latitude*2	Longitude*2	Vehicle Depth (m) *3	Description
1	10:57	22°30.555'N	153°13.219'E	5,582	Water sampling by Niskin bottle (green label)
	10:58	22°30.555'N	153°13.216'E	5,588	Vehicle landed
2	11:31	22°30.569'N	153°13.090'E	5,577	Sediment sampling by H-type push corer
3	12:26	22°30.719'N	153°12.989'E	5,531	Deployed electromagnetic current meter

	12:29	22°30.717’N	153°12.989’E	5,531	Deployed a marker
4	12:36	22°30.710’N	153°12.999’E	5,533	Deployed an *in situ* experimentation system
5	12:53	22°30.722’N	153°12.983’E	5,518	R1, R2 rock samples retrieved and put into the Biobox
	13:05	22°30.727’N	153°12.978’E	5,518	Deployed ROV homer mini transponder (ID=13)
6	13:16	22°30.731’N	153°12.937’E	5,475	Vehicle left bottom

* Time is UTC+10 (local ship time). *2 Latitude, longitude are result of 3-minutes moving average to reduce positioning error of SSBL. *3 Depth derived from depth meter of the vehicle.

5.2.4 Dive #681

Dive #681 is carried out on 15 January 2016 to revisit to same site of dive #680, to retrieve crust samples of ~5,500 m depth. The revisit is smoothly completed owing to ROV homer and the mini transponder (Fig.5.2.4.1 (a) and (b)). It is quite difficult to take samples from steep cliff because there are very few platy structure to grasp by manipulator (Fig.5.2.4.1 (c)). We have had to take a lot of time using only hydraulic tools to try to take samples from a cliff (Fig.5.2.4.1 (d)), however, we unfortunately abandoned using the tools due to spill out of hydraulic oil. Then we went to another slope to find some rocks to be able to grab (Fig.5.2.4.1 (e) and (f)). At last, we retrieved four rock samples in this dive.

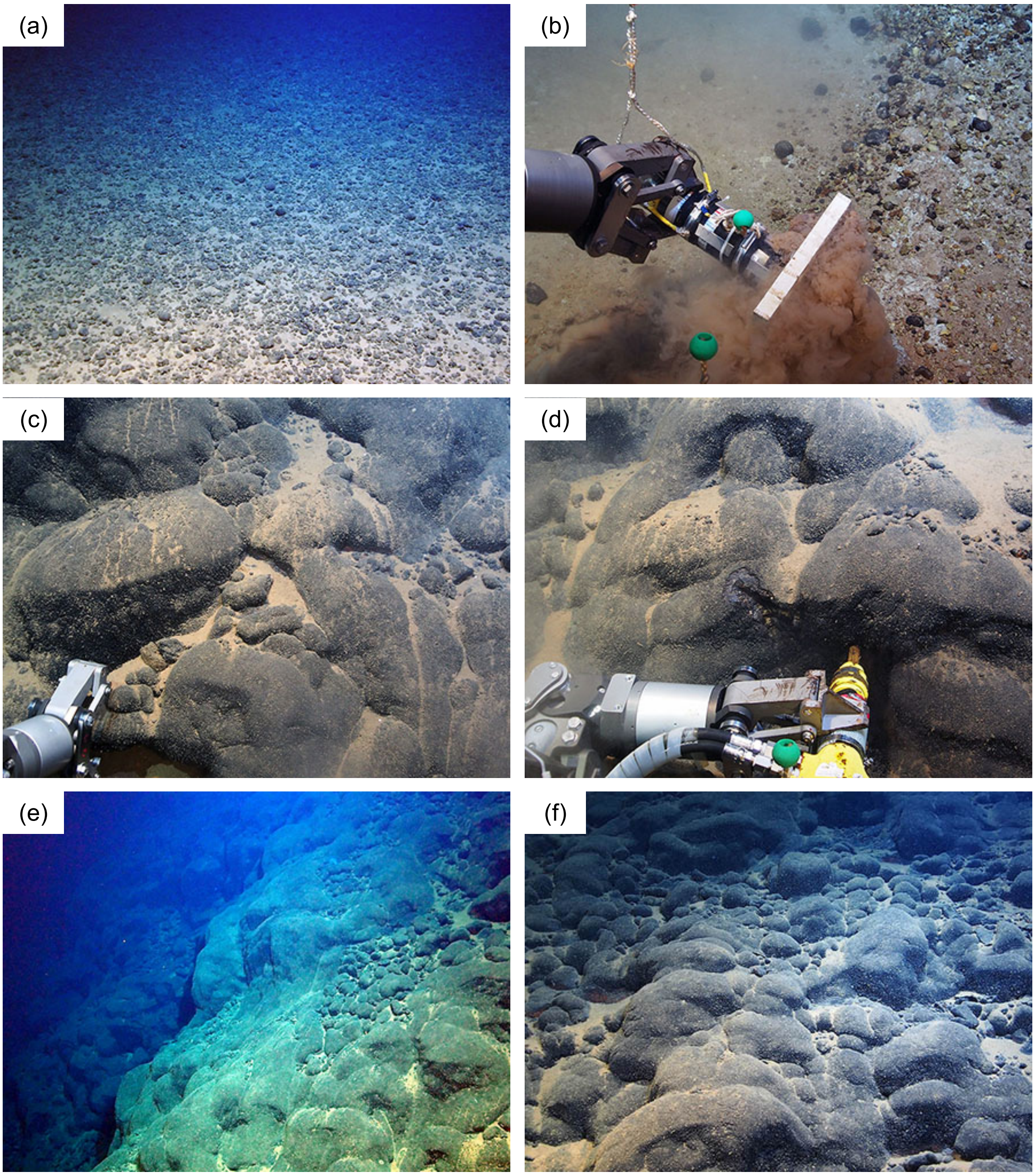


Fig.5.2.4.1. Images taken during KAIKO dive #681 on 15 January 2016. (a) Landed site, event #1 in Fig.5.2.4.2. (b) Mini transponder for ROV homer. Round nodules are seen. (c) Ferromanganese crust covering on steep cliff. (d) Hydraulic hammering chisel. (e) Steep cliff just above the boundary between base and ridge is continued along contour line. (f) A typical view of ferromanganese crusts at event #5 site in Fig.5.2.4.2.

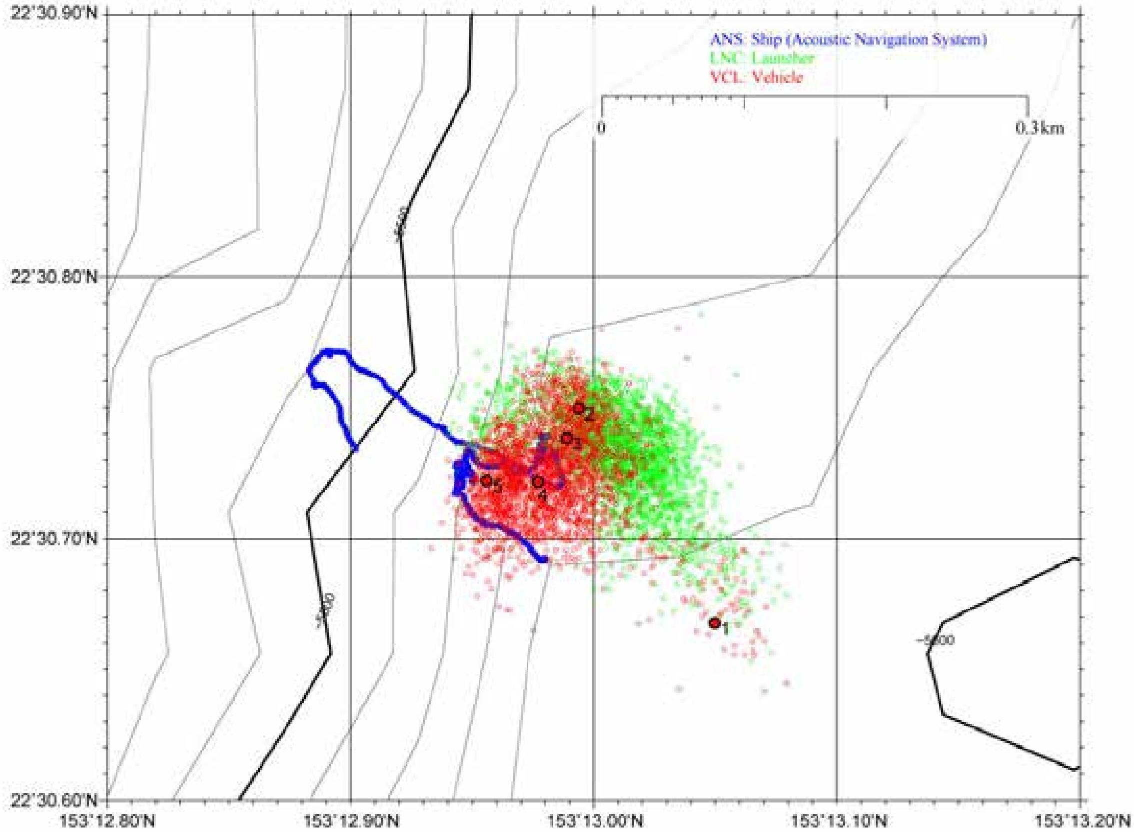


Fig.5.2.4.2. Cruise track of dive #681 on 15 Jan. 2016 obtained by acoustic navigation system using SSBL. Red circles represent the vehicle, green circles represent the launcher and blue circles represent ship track respectively. Error data is not eliminated. SSBL positioning is also unable to track as worse as dive #680.

Table.5.2.4. Dive log of #681 on 15 Jan. 2016. Event # correspond to numbers shown in Fig.5.2.4.2.

Event #	Time*	Latitude*2	Longitude*2	Vehicle Depth (m) *3	Description
1	10:35	22°30.671'N	153°13.054'E	5,554	Vehicle landed
2	10:57	22°30.747'N	153°12.997'E	5,518	Retrieved ROV homer mini transponder (ID=13)
	11:07				Deployed ROV homer mini transponder (ID=14)
3	11:44	22°30.735'N	153°13.003'E	5,520	R1 & R2 rock samples retrieved
4	12:04	22°30.715'N	153°12.986'E	5,519	Started hydraulic chisel hammering
	12:26				Terminated hydraulic chisel hammering
5	13:16	22°30.725'N	153°12.965'E	5,493	Rock sampling started
	13:31	22°30.714'N	153°12.959'E	5,492	R3A, R3B & R4 rock samples retrieved
	13:31				Vehicle left bottom

* Time is UTC+10 (local ship time). *2 Latitude, longitude are result of 3-minutes moving average to reduce positioning error of SSBL. *3 Depth derived from depth meter of the vehicle.

5.2.5 Dive #682

Dive #682 is carried out on 16 January 2016 to visit to around 3,000m water depth, to deploy electromagnetic current meter and *in situ* experimentation system, where one of a typical ferromanganese crust is covered the slope of seamount.

Landed site was bumpy and angular to sub-angular rocks are covered, so that we moved to find more typical crust area. Soon we found fine location to deploy the set of current meter and *in situ* experimentation system where is a several meters wide scree between widely spreading pavement-like crusts (Fig.5.2.5.1 (a) and (b)). The slope angle of pavement-like crust area may over 20° which unable the frames to be settled and have a risk to be upset and lost, therefore, the scree is the best ground for the deployments. After the *in situ* experimentation system is deployed, rock samples for microbiology is sampled and retrieved in the Biobox (Fig.5.2.5.1 (c)). Although the sampling tool is only the manipulators due to the hydraulic tools are failed in last dive, they work effectively for sampling owing to its grasp and heft power (Fig.5.2.4.1 (d)).

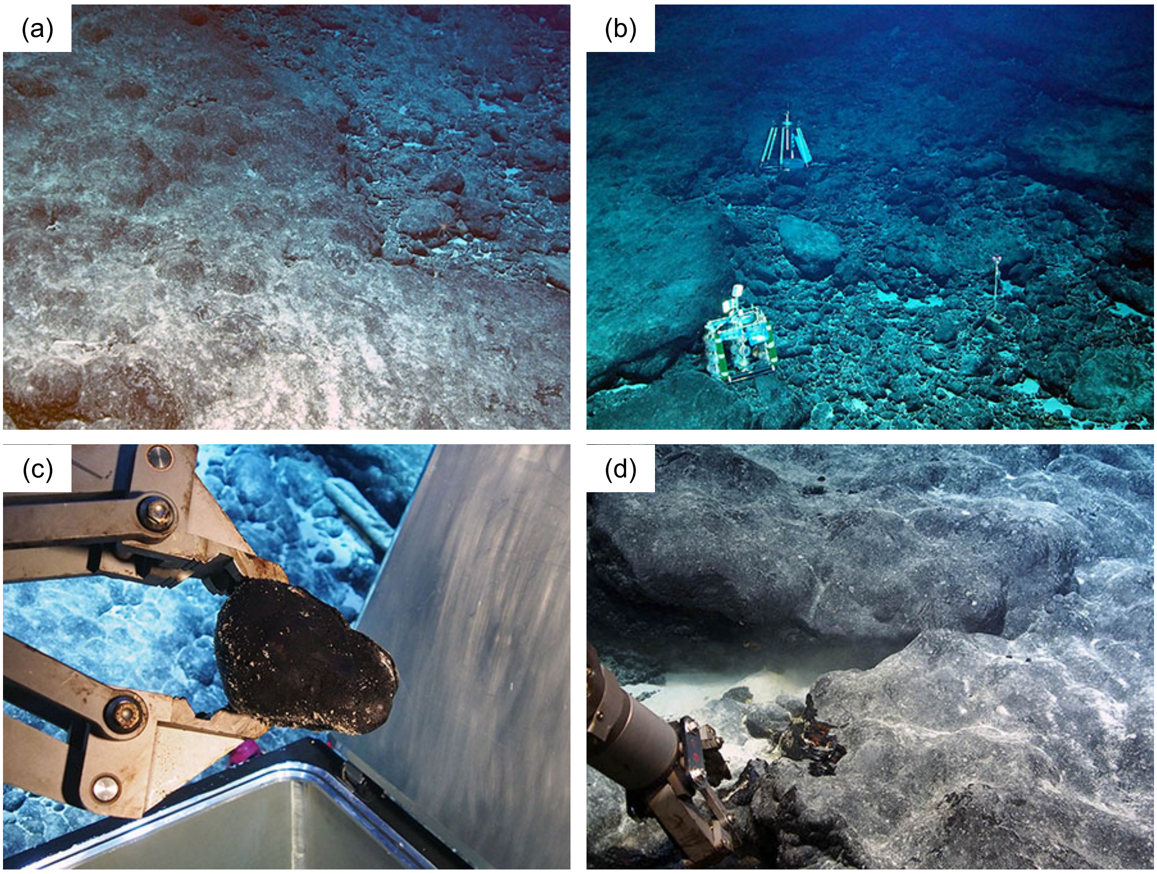


Fig.5.2.5.1. Images taken during KAIKO dive #682 on 16 January 2016. (a) A boundary between pavement-like crust and scree. (b) Electromagnetic current meter (back), *in situ* experimentation system (front left) and a marker (right) are deployed at scree. (c) Rock sample for microbiology is retrieved in Biobox. (d) Manipulator grasps ferromanganese crust.

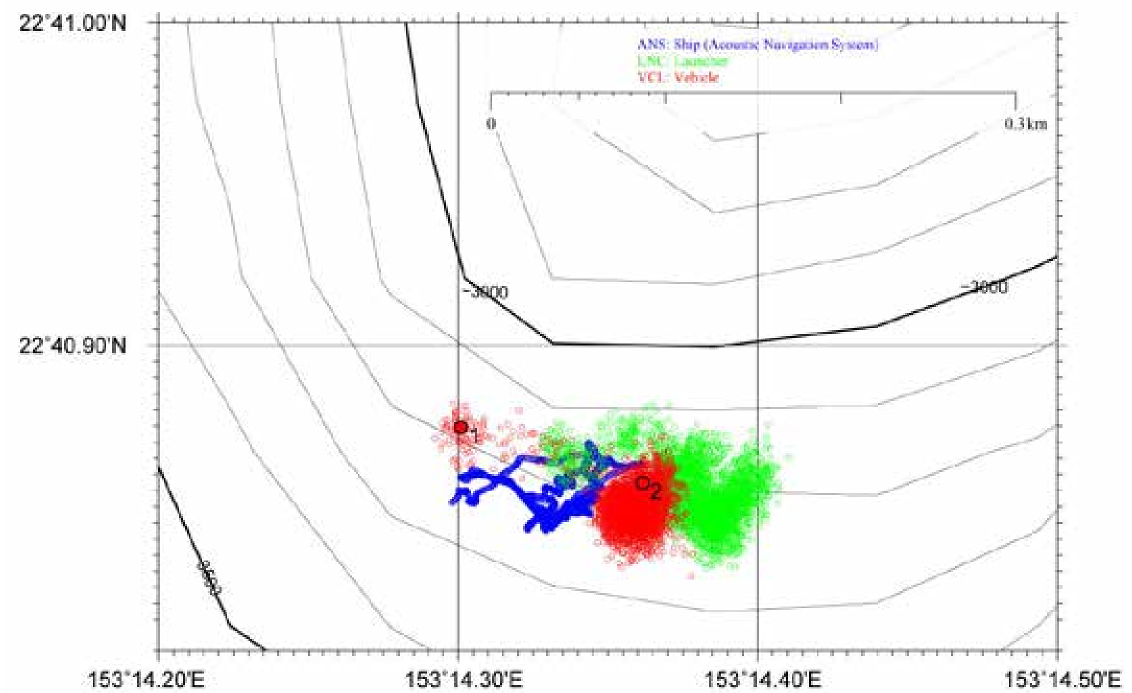


Fig.5.2.5.2. Cruise track of dive #682 on 16 Jan. 2016 obtained by acoustic navigation system using SSBL. Red circles represent the vehicle, green circles represent the launcher and blue circles represent ship track respectively. Error data is not eliminated.

Table.5.2.5. Dive log of #682 on 16 Jan. 2016. Event # correspond to numbers shown in Fig.5.2.5.2.

Event #	Time*	Latitude*2	Longitude*2	Vehicle Depth (m) *3	Description
1	10:47	22°40.871'N	153°14.303'E	2,988	Vehicle landed
2	11:06	22°40.860'N	153°14.366'E	2,986	Deployed electromagnetic current meter
	11:08	22°40.858'N	153°14.363'E	2,986	Water sampling by Niskin bottle (red label)
	11:12	22°40.852'N	153°14.363'E	2,987	Deployed a marker
	11:22				Deployed an *in situ* experimentation system
	12:03				R1, R2 & R3 rock samples retrieved and put into the aluminum box
	13:16	22°40.849'N	153°14.352'E	2,989	R4 & R5 rock samples retrieved
	14:32	22°40.845'N	153°14.363'E	2,991	R6 rock sample retrieved
	14:32				Vehicle left bottom

* Time is UTC+10 (local ship time). *2 Latitude, longitude are result of 3-minutes moving average to reduce positioning error of SSBL. *3 Depth derived from depth meter of the vehicle.

5.2.6 Dive #683

Dive #683 is carried out on 18 January 2016 to go to deepest part of southern long ridge of Takuyo-daigo seamount again at the depth around 5,400 m, a different area of dives #680 and #681 (Fig.1.2), to retrieve another deep water crust samples. The angle of this area shows rather low than the area of previous two dives, expects that more easy for rock sampling.

The landed site is a scree where any size of rounded cobbles and boulders are dispersed looks like a channel or stream (Fig.5.2.6.1 (a)). As moved to shallower depth, pillow-like crusts are recognized (Fig.5.2.6.1 (b) and (c)). The scree and pillow-like crusts are alternatively present. Some stones may fixed onto platy crusts covered and hidden beneath clay (Fig.5.2.6.1 (d)). A notable fact is that basement rock is not so hard which means rocks are easy to be crashed by manipulator's hand, then grasping power should be saved to hold them. At last, we retrieved nine rock samples through this dive.

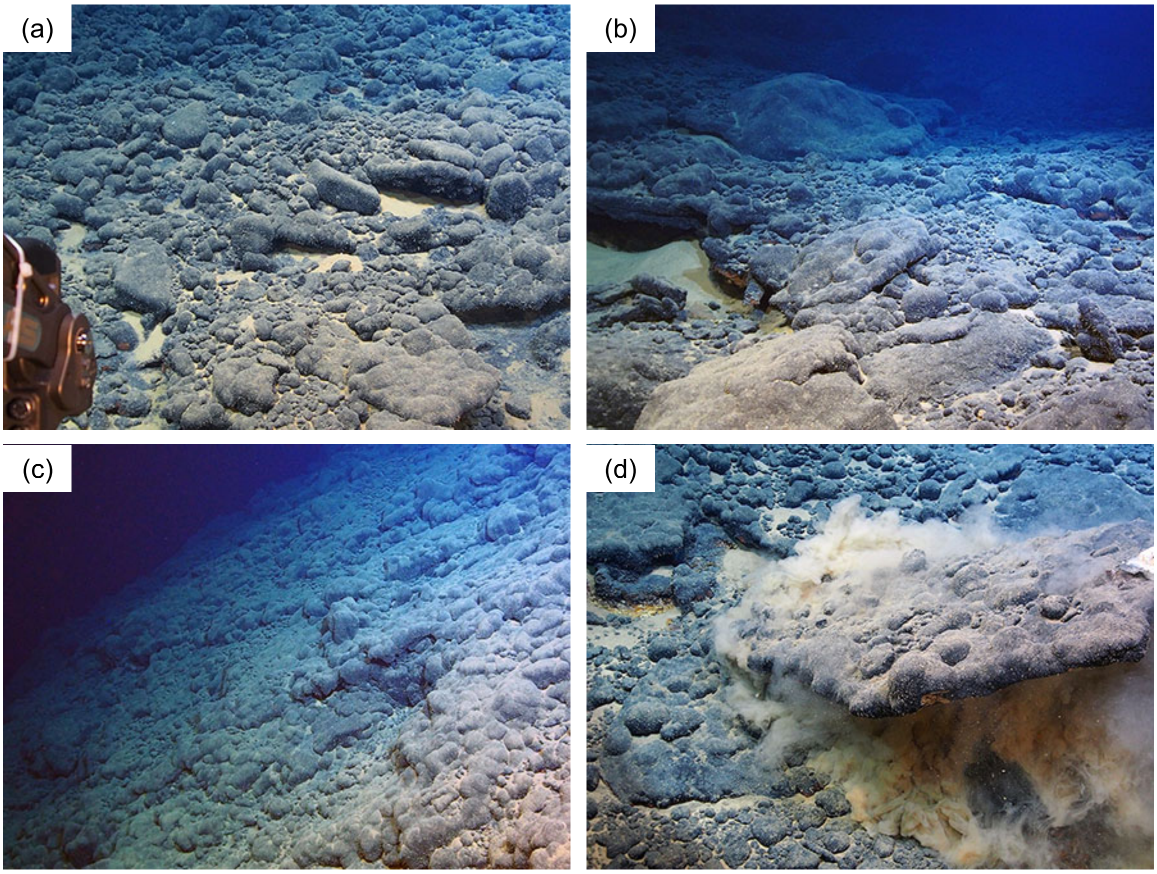


Fig.5.2.6.1. Images taken during KAIKO dive #683 on 18 January 2016. (a) Landed site is a scree with a lot of cobbles and boulders. (b) A mixture of pillow-like crusts and scree. (c) Steep cliff with fully covered with pillow-like crusts. (d) A connected platy sample of crust and round stones.

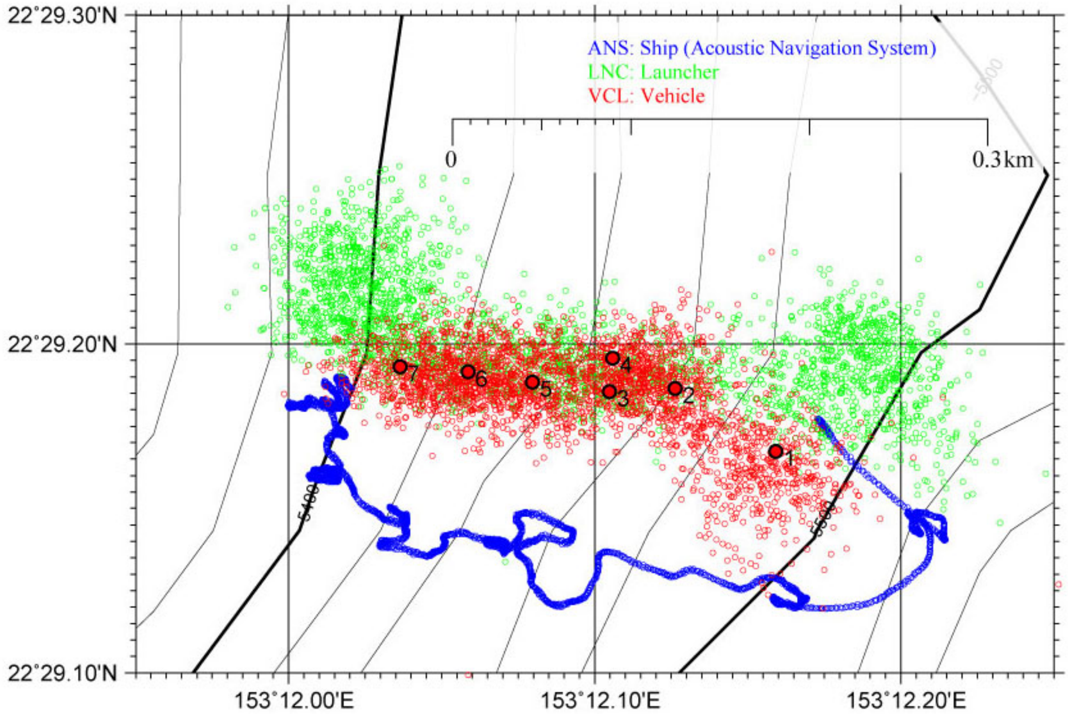


Fig.5.2.6.2. Cruise track of dive #683 on 18 Jan. 2016 obtained by acoustic navigation system using SSBL. Red circles represent the vehicle, green circles represent the launcher and blue circles represent ship track respectively. Error data is not eliminated. SSBL positioning is better than dives #680 and #681.

Table.5.2.6. Dive log of #683 on 18 Jan. 2016. Event # correspond to numbers shown in Fig.5.2.6.2.

Event #	Time*	Latitude*2	Longitude*2	Vehicle Depth (m) *3	Description
1	10:26	22°29.172'N	153°12.166'E	5,443	Vehicle landed
	10:38	22°29.168'N	153°12.161'E	5,442	R1 & R2 rock samples retrieved
2	11:01	22°29.187'N	153°12.126'E	5,423	R3 rock sample retrieved
3	11:30	22°29.194'N	153°12.110'E	5,443	Observation of an outcrop
4	11:47	22°29.196'N	153°12.112'E	5,404	R4 rock sample retrieved
5	12:12	22°29.186'N	153°12.079'E	5,385	R5 rock sample retrieved
	12:19	22°29.187'N	153°12.078'E	5,385	R6 rock sample retrieved
6	12:39	22°29.192'N	153°12.070'E	5,373	R7 rock sample retrieved
	12:57	22°29.187'N	153°12.047'E	5,373	R8 rock sample retrieved
7	13:08	22°29.187'N	153°12.04'E	5,356	R9 rock sample retrieved
	13:29	22°29.189'N	153°12.054'E	5,356	Vehicle left bottom

* Time is UTC+10 (local ship time). *2 Latitude, longitude are result of 3-minutes moving average to reduce positioning error of SSBL. *3 Depth derived from depth meter of the vehicle.

5.2.7 Dive #684

Dive #684 is carried out on 19 January 2016 to go to unexplored depth of ~4,500 m in southern long ridge of Takuyo-daigo seamount (Fig.1.2), to deploy a simple *in situ* experimentation system and to retrieve new crust samples at this depth.

After deployed a simple *in situ* experimentation system onto slightly low angle slope (Fig.5.2.7.1 (a)), we immediately started to search for sampling. It seems the thickness of crust may thin according to the fresh cross section (Fig.5.2.7.1 (b)) and observation of pavement-like crusts (Fig.5.2.7.1 (c)) which are not obese nor asphalt-like. Nevertheless, we took six rock samples from this level of depth. Also, we took a sediment sample at a terrace fully covered with bimodal well-sorted pebbles (Fig.5.2.7.1 (d)) and deployed a buried-type adsorption system (Fig.5.2.7.1 (e)). We found a unique crustacean during sampling (Fig.5.2.7.1 (f)).

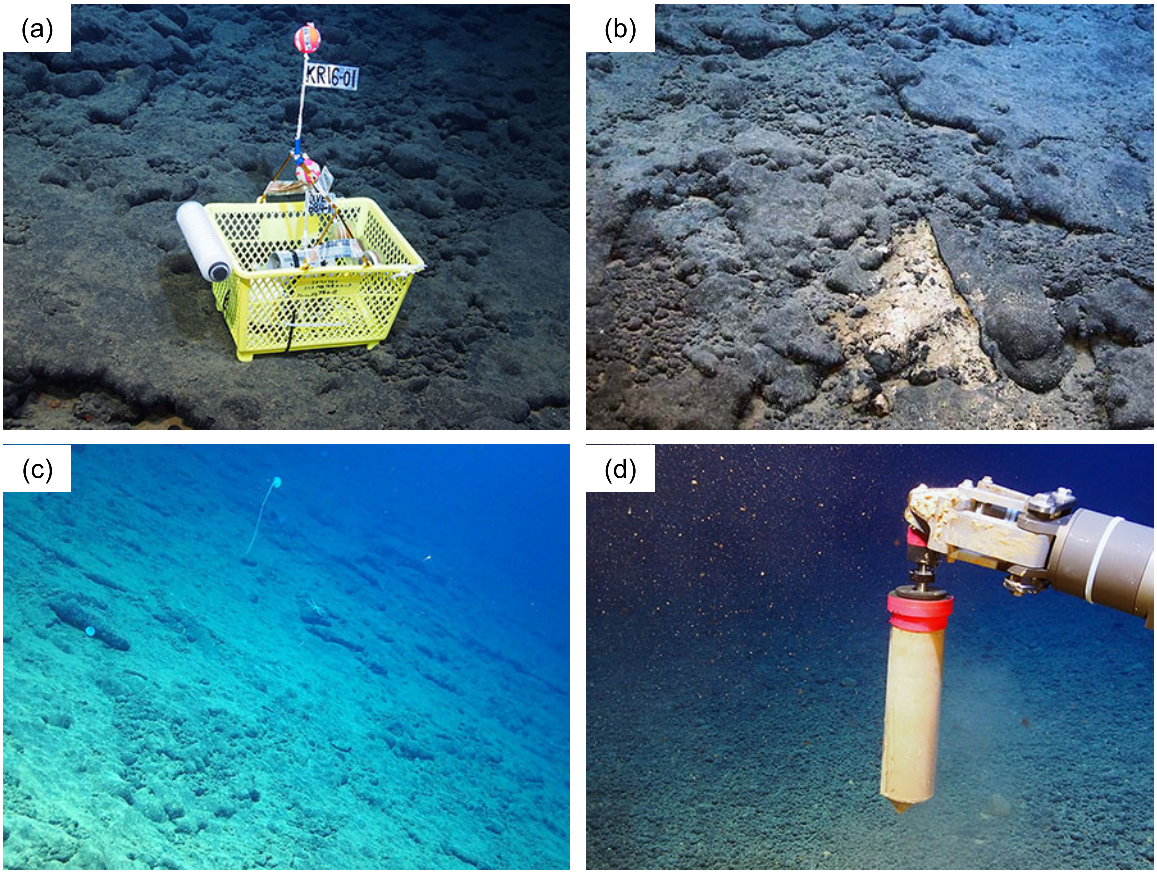


Fig.5.2.7.1. Images taken during KAIKO dive #684 on 19 January 2016. (a) A simple in situ experimentation system. (b)Thin crust is seen from fresh cross section made after sampling. (c) Steep cliff covered with crusts but there are no obese nor asphalt-like crust. (d) A clay sediment is retrieved using push corer at a terrace where is fully covered with well-sorted pebbles.

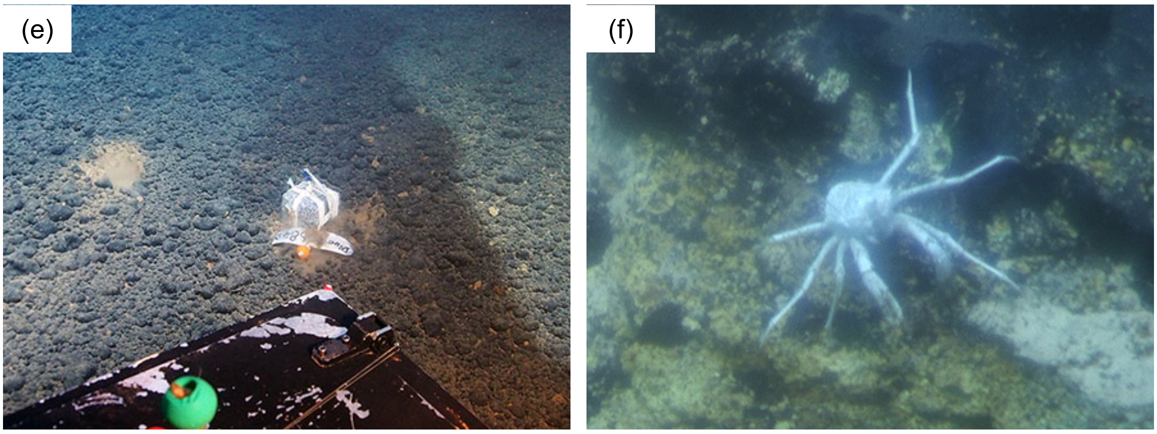


Fig.5.2.7.1 *continued*. (e) A buried-type adsorption system (center) and a remained hole of push corer (left). (f) A unique crustacean is observed.

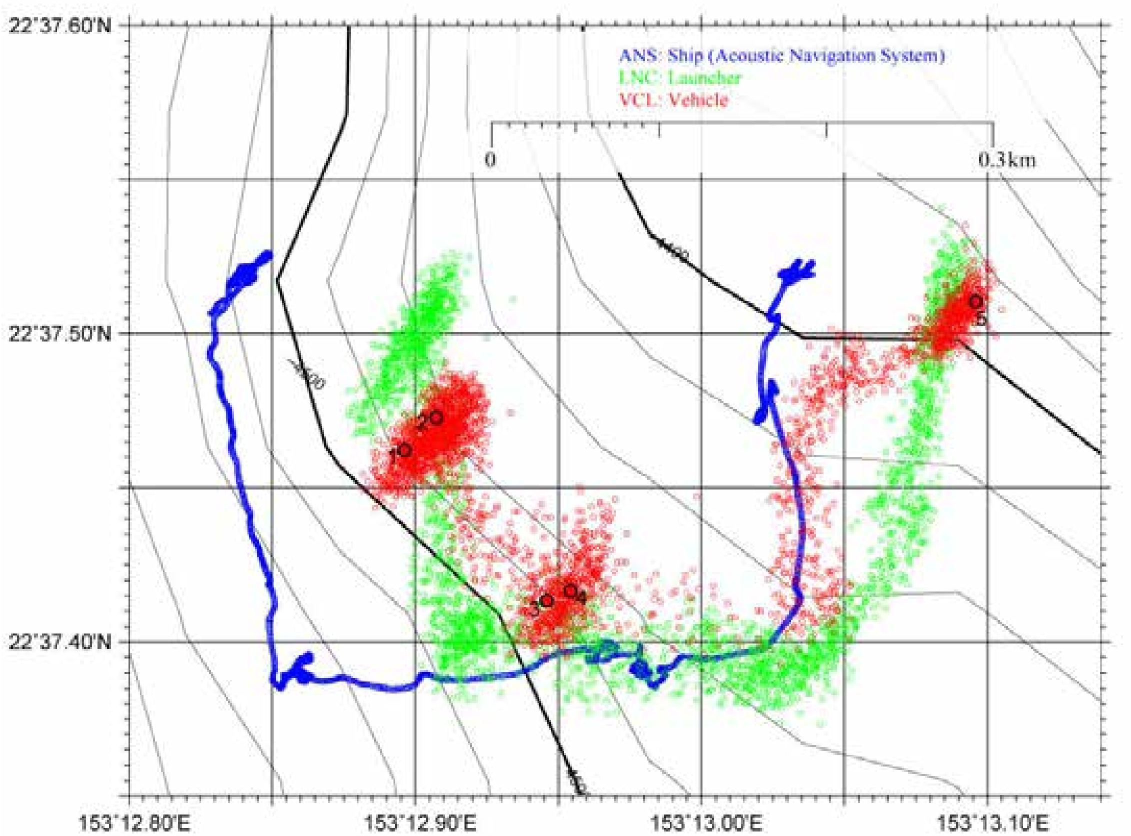


Fig.5.2.7.2. Cruise track of dive #684 on 19 Jan. 2016 obtained by acoustic navigation system using SSBL. Red circles represent the vehicle, green circles represent the launcher and blue circles represent ship track respectively. Error data is not eliminated.

Table.5.2.7. Dive log of #684 on 19 Jan. 2016. Event # correspond to numbers shown in Fig.5.2.7.2.

Event #	Time[*]	Latitude[*2]	Longitude[*2]	Vehicle Depth (m)[*3]	Description
1	10:09	22°37.461’N	153°12.897’E	4,482	Vehicle landed
	10:18	22°37.455’N	153°12.893’E	4,478	Water sampling by Niskin bottle (green label)

	10:29	22°37.461'N	153°12.902'E	4,478	Deployed a simple *in situ* experimentation system
2	10:50	22°37.474'N	153°12.916'E	4,479	R1 rock sample retrieve and put into the aluminum box
	11:11	22°37.476'N	153°12.908'E	4,479	R2 & R3 rock sample retrieved
	11:28	22°37.467'N	153°12.910'E	4,476	R4 rock sample retrieved
3	12:04	22°37.408'N	153°12.942'E	4,441	R5 rock sample retrieved
4	12:16	22°37.415'N	153°12.953'E	4,430	R7 rock sample retrieved (no R6 sample)
	12:27	22°37.407'N	153°12.949'E	4,430	Observation of a crustacean
5	13:27	22°37.510'N	153°13.091'E	4,374	Sediment sampling by H-type push corer
	13:36	22°37.507'N	153°13.093'E	4,374	Deployed buried-type adsorption system
	13:41	22°37.515'N	153°13.093'E	4,372	Vehicle left bottom

* Time is UTC+10 (local ship time). *2 Latitude, longitude are result of 3-minutes moving average to reduce positioning error of SSBL. *3 Depth derived from depth meter of the vehicle.

5.2.8 Notice on DO data

Y. Amakawa and K. Iijima

There are some inconsistency in dissolved oxygen (DO) data obtained DO meter installed on the vehicle, between data while descending and ascending in all seven dives (Fig.5.2.8). The DO data while ascending tend to present lower value than descending in comparison at same water depth.

The DO data obtained in dives #680 and #681 shows obviously abnormal value during ascending. In dive #680, the data from ascending shows parallel trend lower than that of descending around 0.5 to 1.2 ml/l. In dive #681, the value indicated on controlling board in the operation room shows already abnormal at the beginning of ascending but we recognized the measurement was still ongoing because the feasible value is recorded on logging tool. However, the value in the log became abnormal in half way through ascending and finally the data cannot be recorded.

Although there are same differences in dives #679, #682 ~ #684, it is not so broad difference in comparison to dives #680 and #681. There are some common features on the appearance in relation to water depth. In dives #679, #682 ~ #684, discrepancy occur beneath 500 m and above 900 m water depth. The data looks consistent at water depth range of 1,000 to 2,000 m. In dive #683, a dissimilarity occurs again below 3,000 m.

In summary, excepting the phenomenon in shallower than 1,000 m, significant inconsistency between acquired data while vehicle's descending and ascending is recognized in dives to 5,000 m water depths. Therefore, DO data of dives to this depth level should be dealt with severe look-over.

Finally, user of this data should pay attention to the unit of DO, ml/L. Unfortunately, a series of pressure and temperature data is not expressly output, so that the state of ml/L remains obscure.

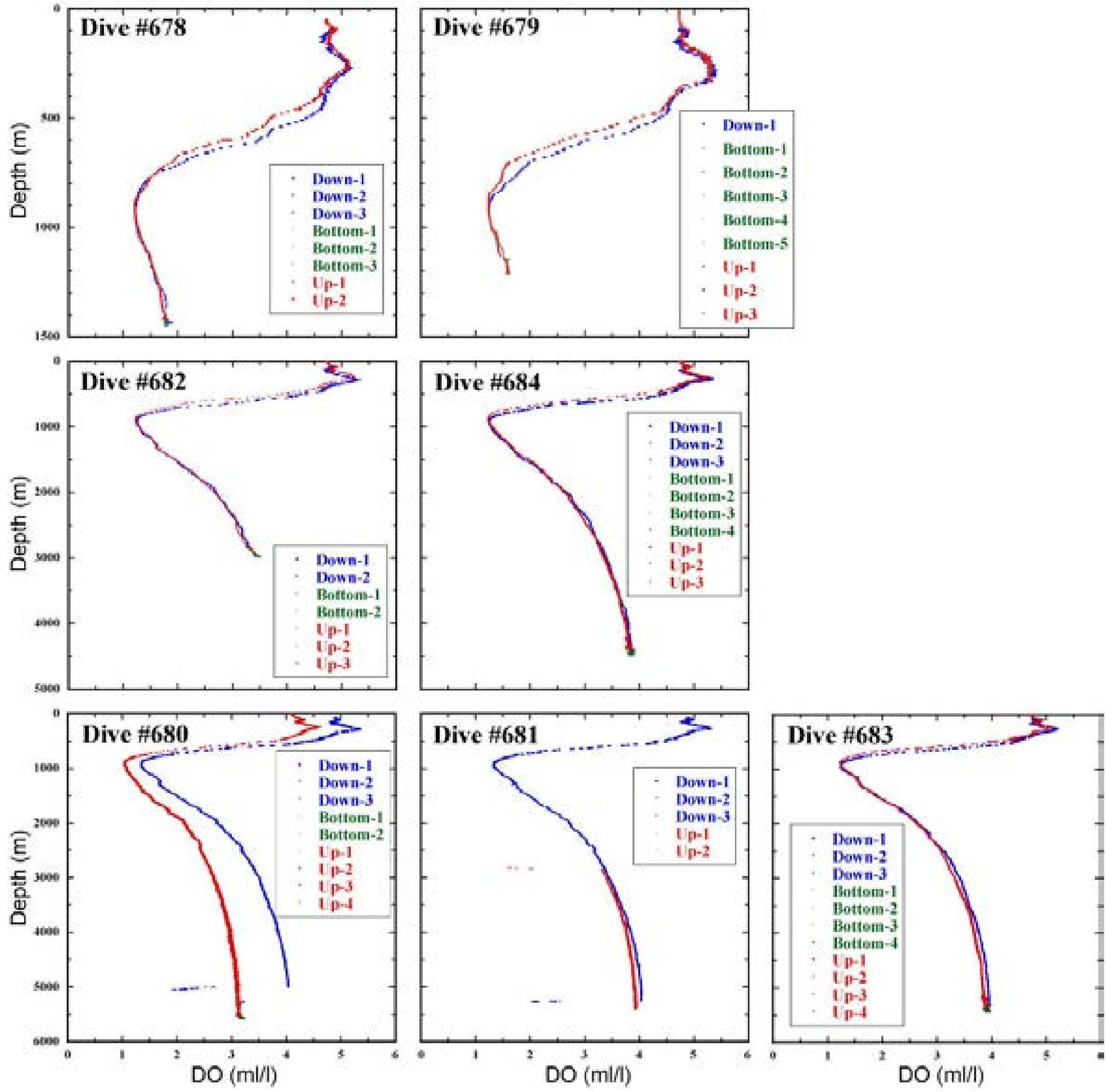


Fig.5.2.8. Cross plots of dissolved oxygen (ml/l) and water depth (m) obtained by DO meter installed on the vehicle. Blue plots represents acquired data during descending, green plots represents the data during at bottom, and red plots represents the data during ascending respectively. Data from beneath 5,000 m during descending in dive #680 and from above 2,800 m during ascending in dive #681 are not accurately collected.

6 Preliminary results

6.1 Deployment of the electromagnetic current meter

We successfully deployed three electromagnetic current meter coupled with some chemical absorption experimentation unit at different depth of 1,151 m, 2,986 m and 5,531 m (Table 6.1). The gimbal frame to compensate horizontal position of the current meter is absolutely worked at inclined grounds. The observation is started in the morning of deployed date. These current meters will be retrieved in next cruise in Takuyo-daigo seamount (10 months later).

Table.6.1. Sites of deployment of electromagnetic current meter in this cruise.

Dive #	Date	Time*	Latitude*2	Longitude*2	Depth (m) *3	Deployed bottom
679	13 Jan. 2016	10:59	22°51.111'N	153°26.965'E	1,151	On flat pavement crust, ~150 m beneath the OMZ.
680	14 Jan. 2016	12:26	22°30.719'N	153°12.989'E	5,531	On sediment, few meters far from cliff of crust.
682	16 Jan. 2016	11:06	22°40.860'N	153°14.366'E	2,986	On cobbles and boulders in scree, adjacent to pavement crust

* Time is UTC+10 (local ship time). *2 Latitude, longitude are result of 3-minutes moving average to reduce positioning error of SSBL. *3 Depth derived from depth meter of the vehicle.

6.2 Deployment of the *in situ* experimentation system

***in situ* adsorption and incubation experiments using Fe/Mn (oxyhydr)oxides on the deep seafloor**

T. Kashiwabara, S. Kikuchi, S. Kato, Y. Amakawa, and K. Iijima (JAMSTEC)

Marine ferromanganese crusts are hydrogenetic metal deposits considered as potential mineral resources as well as archives of paleoceanographic environments. However, mechanisms of their formation on the deep-sea seafloor and the enrichment of trace elements from seawater are still unresolved. The purpose of our project in this cruse is to understand chemical/biological reactions at the seawater/ferromanganese oxide interface responsible for incorporation of trace elements by using in situ adsorption and incubation experimental systems. The system consists of acrylic cells entrapping various minerals and the frame hanging them in the flow of ambient seawater (Fig.6.2 (a)). In contrast to natural samples which are the mixtures of polygenetic minerals produced through geological timescale, this system allows us to examine ongoing reactions on each surface of constituent minerals of ferromanganese oxides with modern seawater.

In this cruse, we have successfully set up the systems on slopes of three different water depths (Table 6.2). These depths offer different chemical/oceanographic conditions relative to OMZ and Carbonate Compensation Depth (CCD), which should be reflected in chemical composition of ferromanganese crusts. We also have placed electromagnetic current direction and velocity profiler near the systems to estimate the total volume of seawater, and so the amount of specific elements, passed by them (Fig.6.2 (b)). In the next cruise, we are planning to collect these systems to investigate (i) reactions on each constituent mineral under different water depth, and (ii) whether they can explain the enrichment of elements into natural ferromanganese crusts or not.

MnO_2 fiber

Y. Amakawa (JAMSTEC)

To concentrate trace elements in seawater, we deployed a manganese oxide (MnO_2) fiber in three depths at Takuyo-Daigo seamount.

The MnO_2 fiber was prepared by impinging MnO_2 to a knitting wool. Then, the MnO_2 fiber was wrapped by a polyester wool and put into a plastic net. The wrapped MnO_2 fiber was finally set to a frame for electromagnetic current meter, which was deployed at Takuyo-daigo seamount (Fig.4.1.3 and Fig.6.2 (b)).

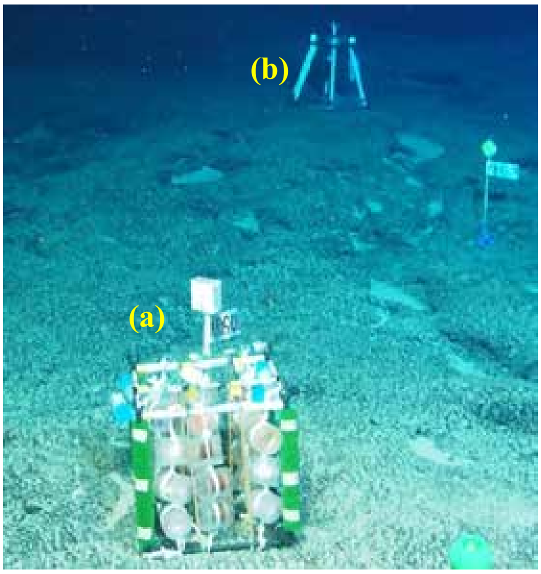


Fig.6.2. (a) *in situ* adsorption and incubation experimental system with (b) electromagnetic current direction and velocity profiler.

Table 6.2 Location for in situ adsorption and incubation experiments

Dive #	Depth (m)	Latitude	Longitude	DO(mg/L)
679	1151.0	22:51.106N	153:26.967E	1.6
682	2987.5	22:40.852N	153:14.36E	3.4
680	5533.1	22:30.71N	153:12.999E	3.13

6.3 Microbiology

Shingo KATO

Background

Our previous studies have shown that microbes are rich and phylogenetically diverse on Mn crusts at the Takuyo-Daigo Seamount (Nitahara et al., 2011; Kato et al., in preparation). However, it is still unclear whether and how they contribute to the formation of Mn crusts. To this end, in this cruise, we collect Mn crusts for DNA/RNA analyses, microscopy and cultivation, and also collect surrounding sediments and seawater as references. Furthermore, to reveal what microbes are initially attached to basement rocks and whether and how the microbes contribute to trigger the formation of Mn crusts, we put a newly developed in situ colonization device on the seafloor, which will be recovered after 10 months or later. The microbiological analyses/experiments will provide novel insights into mechanism of formation of Mn crusts.

Sampling

Seven samples of Mn crusts were collected at water depths of 1,153 m, 1,425 m, 2,987 m, 4,479 m, 5,373 m, and 5,518 m (Table 6.3). To bring Mn crust samples from the seafloor or carry in situ colonization devices to the seafloor without microbial contaminations from surface seawater, we used a sealable "Biobox" made of aluminum with a 0.2-um-pore-size membrane filter unit to balance internal pressure. The collected Mn crusts were trapped in the Biobox on the seafloor. We collected sediments using a push-core sampler and bottom seawater using Niskin bottle samplers (6 L) equipped with the ROV around the sampling points of the Mn crusts as references.

Sample preparation for microbiology

Microbes in the seawater (approx. 6 L) were collected on 0.2 µm-pore-size membrane filters by filtration. The Mn crusts were crashed into small pieces by a sterile hammer and chisel in a clean booth. Some pieces were stored at -80ºC for DNA analysis or for RNA analysis with RNA later. For cultivation, some pieces were stored in glass bottles with N2 gas at 4ºC. The other pieces of the samples were fixed with formalin (final 3.7%) or glutaraldehyde (final 2%) at 4ºC overnight, washed with filtered seawater three times, and stored in PBS : ethanol (50:50) solution at 4ºC for microscopy.

Table 6.3. List of the collected samples for microbiological analyses

Dive #	Date	Time (LTC)	Latitude (N)	Longitude (E)	Depth (m)	ID	Type
#678	2016.1.12	13:02	22:44.606N	153:15.956E	1426	W1	Seawater
		13:36	22:44.603N	153:15.971E	1432	C1	Sediment
		13:52	22:44.606N	153:15.978E	1432	R1	Mn crust
		15:09	22:44.623N	153:15.962E	1385	W2	Seawater
#679	2016.1.13	10:23	22:51.110N	153:26.961E	1150	W1	Seawater
		12:01	22:51.104N	153:26.973E	1154	R1	Mn crust
		12:26	22:51.100N	153:26.973E	1154	C1	Sediment
#680	2016.1.14	10:57	22:30.555N	153:13.219E	5582	W1	Seawater
		11:31	22:30.570N	153:13.089E	5577	C1	Sediment
		12:53	22:30.722N	153:12.983E	5517	R2	Mn crust
#682	2016.1.16	11:08	22:40.857N	153:14.363E	2986	W1	Seawater
		11:51	22:40.853N	153:14.364E	2988	R2	Mn crust
		11:59	22:40.853N	153:14.361E	2987	R3	Mn crust
#683	2016.1.18	12:38	22:29.192N	153:12.069E	5373	R7	Mn crust
#684	2016.1.19	10:18	22:37.454N	153:12.892E	4479	W1	Seawater
		10:48	22:37.474N	153:12.915E	4480	R1	Mn crust
		13:25	22:37.509N	153:13.089E	4374	C1	Sediment

6.4 Seafloor observation and rock samples — Akira USUI

Seafloor observation and sampling of ferromanganese crusts and rocks

Ocean hydrogenetic ferromanganese crusts are potential archives of paleoceanographic and geological environments and modern precipitates controlled by geochemical, physical and possibly microbiological conditions of the sea water and at the sea bottom, as well as potential future mineral resources. In this study, in cooperation with multi-institutional and inter disciplinary collaboration, we attempt to understand the oceanographic or geological parameters which control their elemental and mineralogical diversity. The ROV mapping and sampling proved the most delicate, accurate, and effective method for on-site geological study and geochemical analysis. We attempt to figure out the parameters related to the variations of chemical and physical characteristics of ferromanganese crusts in space and time. This cruise is a part of our joint program to compare the geological occurrences of ferromanganese crusts from two typical model areas (Minami-torishima island area, the Pacific and Okino-torishima Island area, the Philippine Sea) over the northwestern Pacific Ocean.

During the Leg 1, Cruise KR16-01, we dove with ROV KAIKO Mk-IV seven times (Dives #678 through #684) at the southern ends of the Takuyo-daigo seamount, where we observed and sampled the ferromanganese crusts over the rock outcrop in the slopes.

During the seven dives on a survey track at depths between approximately 1,150 to 5,600 m water depths, we tried to take intact, undisturbed, and in-situ samples of ferromanganese crusts together with the associated substrates or nuclei, which serve as chemical, mineralogical, and structural analyses. The major purposes of the cruise are to characterize the mode of occurrence of hydrogenetic ferromanganese crusts along the deeper and lower half of the slope on this seamount, take large enough samples for compositional characteristics of surface modern precipitates and thick enough samples for characterization of secular variation since 20 million years, or older ages. All samples obtained in this cruise are listed in Table 6.4.

<u>Dive #678 (1,445 ~ 1,453 m WD)</u>

During the dive #678, at the southern edge of a flat continuous horizontal table top, on the shoulder of the seamount, between water depths 1,445m and 1,453m. The average gradient is about 5 degree or less, and whole of the survey line was almost covered with knobby thick ferromanganese crusts. Most of platy crusts over phosphatize limestone are broken into pieces with 80-90 mm ferromanganese oxide layers. We settled a microbiology trap and sorption trap onto the crusts. We took two bottles of seawater, one push core and three rock samples along the contour of 1,430 m.

The maximum 90 mm thick ferromanganese crust covering mostly wave-cut rudist reef or lagoon sediments with very thinly cover of foraminifer ooze.

<u>Dive #679 (1,150 ~ 1,215 m WD)</u>

During the dive #679, on the slope across a N-S extending long escarpment with 100-meter gap, around the center of the float top of the seamount, at the water depths 1,150 m and 1,215 m. The average gradient of the scarp is about 20 degree, and whole of the scarp is covered with crusts or angular boulders which are covered with several centimeter in maximum 70 mm. Most of platy crusts or boulder nodules are associated with phosphatizes calcareous. We settled a microbiology trap and sorption trap onto the crusts. We took one bottle of seawater, one push core and four rock samples along the track over the heights of the scarp.

Dive #680 (5,518~ 5,587 m WD)

During the dive #680, at the southernmost foot of steep cliff of the characteristic N-S extending ridge southern edge, at about water depths 5,518m and 5,587m. The gradient of the sleep cliff is about 40 degree or more in part, and whole of the knobby rock outcrop is covered with ferromanganese crusts. We tried to take the crust samples with rotary cutter and chisel but unsuccessful by any means. By contrast, the foot of the cliff was covered with buff-brown clayey sediments with Mn-coated black pebbles (small Manganese nodules). We took two drop stones buried within the sediments, which proved fragments of thick (60 mm in max.) platy ferromanganese crusts. This drop stones reminded us of finding better ferromanganese crust cover at the shallower part of the cliff. We settled a microbiology trap, a sorption trap, and a current meter on the sediments at the foot. We took one bottle of seawater, one push core and two rock samples.

Dive #681 (5,557~ 5,593 m WD)

During the dive #681 (almost the same place as #680), at the southernmost foot of steep cliff of the ridge, we tried to take samples of typical ferromanganese crust cover from the real rock outcrop at about water depths 5,557m and 5,593m. We tried to remove the knob or plates from the complicated rocky outcrop in vain. We tried chisel and cutter but unsuccessful to take samples, but took drop stones or boulders covered with 10-30 mm ferromanganese oxide layers. The substrates or nucleus are composed of highly altered volcanic rocks, almost buff-brown clayey rock.

Dive #682 (2,990 m WD)

During the dive #682, at the slope of the ridge of the characteristic N-S extending ridge, at about water depth 3,000m. This point is the deepest point of ROV Hyper-Dolphin dive #953 in R/V Natsushima cruise NT09-02 Leg2. The gradient of the sleep cliff is about 20 degree, and the knobby rock outcrop is covered with ferromanganese crusts or fragments of crusts. We collected several drop stones and one bottle of seawater. We settled a microbiology trap, a sorption trap, and a current meter over the ferromanganese crusts. The substrate and nucleus are mostly highly altered basalt fragments but rarely calcareous conglomerate. The thickness is 10-20 mm for nodules, and 70 mm for the crust over the out crop in maximum.

Dive #683 (5,442 ~ 5,355 m WD)

During the dive #683 at the southernmost part of the N-S trending ridge, we challenged to take ferromanganese crust samples from the real outcrop at about a water depth 5,500m. We expected to remove the crusts associated with underlain soft and fragile substrate, and successfully recovered several ferromanganese crusts from the cliff with about 20 degree gradient. We collected nine rock samples fully covered with black ferromanganese oxide; mostly drop stones with average 20 mm ferromanganese crusts and in maximum 60 mm thick ferromanganese crust. The substrates are mostly slump deposits, which include angular highly-altered volcanic rock, 10-mm thick covered manganese nodules, and thinly or scarcely covered volcanic rocks. The matrix is stiff brown-clay sediments. This complicated structure indicates frequent mass movement from the shallower depth which cause debris flow or slump deposits.

Dive #684 (4,481 ~ 4371 m WD)

During the dive #684 at the middle part of the N-S trending ridge, we tried to take ferromanganese crust samples from the outcrop at about a water depth 4,500-4,400 m. We expected to remove the crusts associated with underlain soft and fragile substrate again, but unsuccessfully recovered thick ferromanganese crusts. We collected seven rock samples fully covered with black ferromanganese oxide; mostly drop stones with average 10-20 mm ferromanganese crusts and in maximum 25 mm thick ferromanganese crust. The substrates are mostly slump deposits, which include angular highly-altered volcanic rock, 10-mm thick covered manganese nodules, and thinly or scarcely covered volcanic rocks. The matrix is stiff brown-clay sediments. This complicated structure indicates frequent mass movement which caused debris flow or slump deposits.

Table 6.4. Rock sample list obtained in this cruise. ID "Bio" samples are same listed in table 6.3.

Dive #	Date	Time	Latitude	Longitude	Depth (m)	ID	Dimension (WDH, cm)	Weight (kg)
678	12 Jan. 2016	14:00	22°44.606'N	153°15.979'E	1,432	R01A Bio	37x14x9	2.6
		14:00	22°44.606'N	153°15.979'E	1,432	R01B	37x14x9	2.6
		14:35	22°44.604'N	153°15.974'E	1,432	R02	38x20x8	8.4
		14:42	22°44.605'N	153°15.974'E	1,432	R03	36x15x9	3.8
679	13 Jan. 2016	11:58	22°51.104'N	153°26.973'E	1,154	R01 Bio	27x13x13	4.6
		12:56	22°51.088'N	153°26.973'E	1,152	R02	29x17x14	5.6
		13:06	22°51.092'N	153°26.972'E	1,153	R03	38x10x8	2.6
		14:01	22°51.025'N	153°27.051'E	1,214	R04	52x42x23	39.0
680	14 Jan. 2016	12;54	22°30.722'N	153°12.985'E	5,518	R01 Bio	16x18x7	2.0
		12:54	22°30.722'N	153°12.985'E	5,518	R02 Bio	14x11x12	1.4
681	15 Jan. 2016	11:30	22°30.733'N	153°12.990'E	5,520	R01	10x9x6	0.5
		11:43	22°30.735'N	153°13.003'E	5,520	R02	14x11x9	1.0
		13:14	22°30.720'N	153°12.966'E	5,494	R03A	12x5.5x5	0.2
		13:17	22°30.727'N	153°12.963'E	5,493	R03B	10x6x6	0.3
		13:30	22°30.715'N	153°12.957'E	5,492	R04	14x14x9	0.8
682	16 Jan. 2016	11:46	22°40.851'N	153°14.367'E	2,988	R01	12x7x8	0.3
		11:51	22°40.854'N	153°14.365'E	2,988	R02 Bio	13x12x9	1.0
		11:59	22°40.854'N	153°14.361'E	2,988	R03 Bio	9x8x6	0.3
		13:08	22°40.85'N	153°14.352'E	2,989	R04	21x16x12	3.4
		13:16	22°40.849'N	153°14.352'E	2,989	R05	12x11x9	0.8
		14:32	22°40.845'N	153°14.363'E	2,991	R06	15x11x10	2.2
683	18 Jan. 2016	10:37	22°29.168'N	153°12.161'E	5,442	R01	46x27x11	7.4
		10:38	22°29.168'N	153°12.164'E	5,442	R02	27x27x11	4.8
		11:00	22°29.186'N	153°12.131'E	5,423	R03	44x38x10	9.0
		11:46	22°29.199'N	153°12.115'E	5,404	R04	25x20x13	5.2
		12;12	22°29.186'N	153°12.079'E	5,385	R05	45x16x8	2.8
		12:18	22°29.187'N	153°12.078'E	5,385	R06	28x22x9	3.6
		12:38	22°29.189'N	153°12.067'E	5,373	R07	51x29x16	16.6
		12:56	22°29.185'N	153°12.051'E	5,375	R08	45x33x17	12.2
		13:11	22°29.191'N	153°12.051'E	5,356	R09	28x18x9	3.0
684	19 Jan. 2016	10:48	22°37.474'N	153°12.914'E	4,480	R01 Bio	26x13x8	1.4
		11:11	22°37.476'N	153°12.908'E	4,479	R02	19x14x8	1.2
		11:11	22°37.476'N	153°12.908'E	4,479	R03	15x10x7	0.4

11:27	22°37.465'N	153°12.909'E	4,476	R04	70x42x12	16.2
12:03	22°37.41'N	153°12.942'E	4,441	R05	43x37x16	10.3
12:16	22°37.413'N	153°12.952'E	4,430	R07	36x28x9	5.0

6.5 Geophysical survey

Geophysical survey was successfully carried out. SBP, gravimeter and magnetometer data are processing so only MBES result is shown in Fig.6.5.1 and Fig.6.5.2.

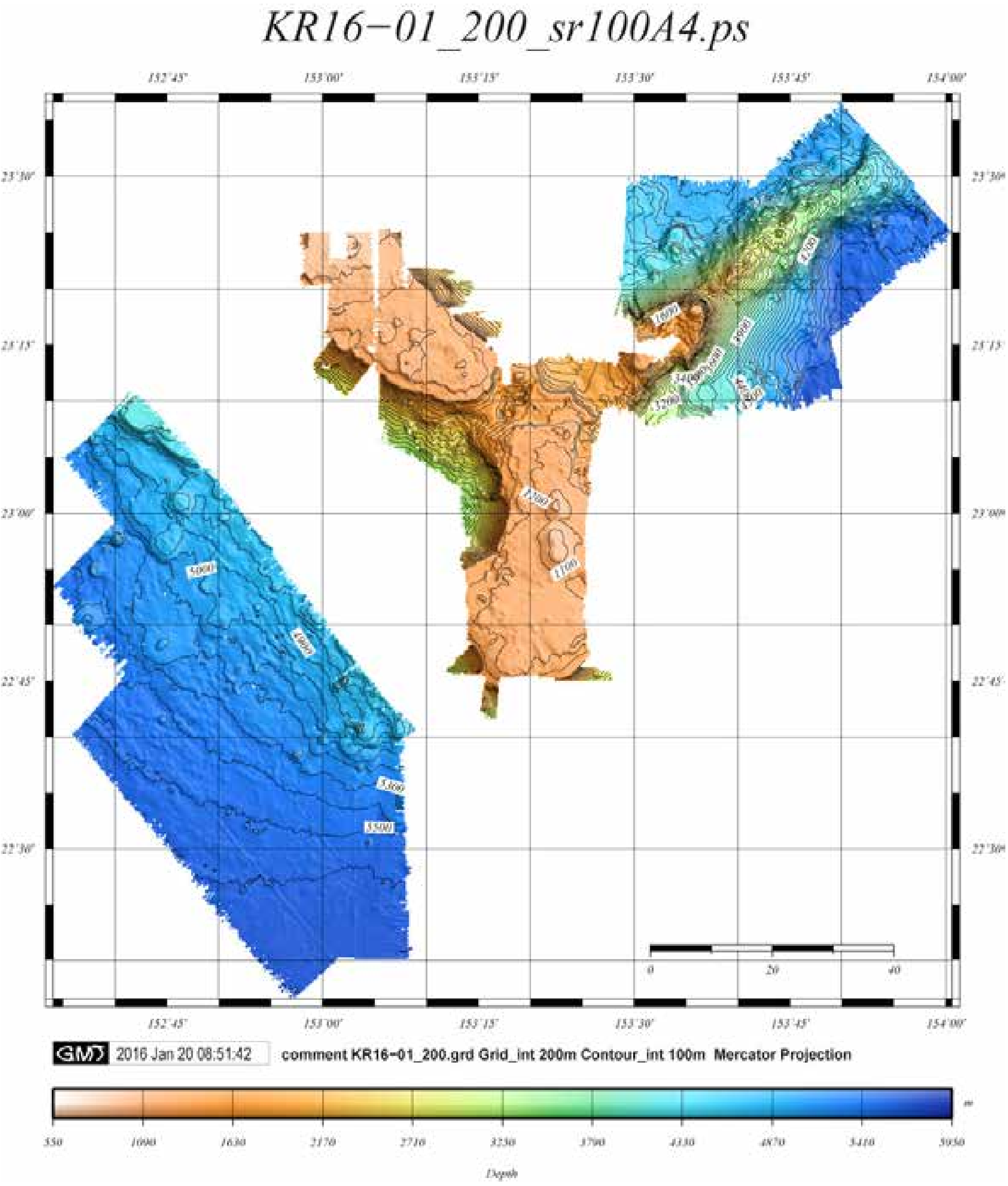


Fig.6.5.1. Bathymetric image of Takuyo-daigo seamount obtained in this cruise.

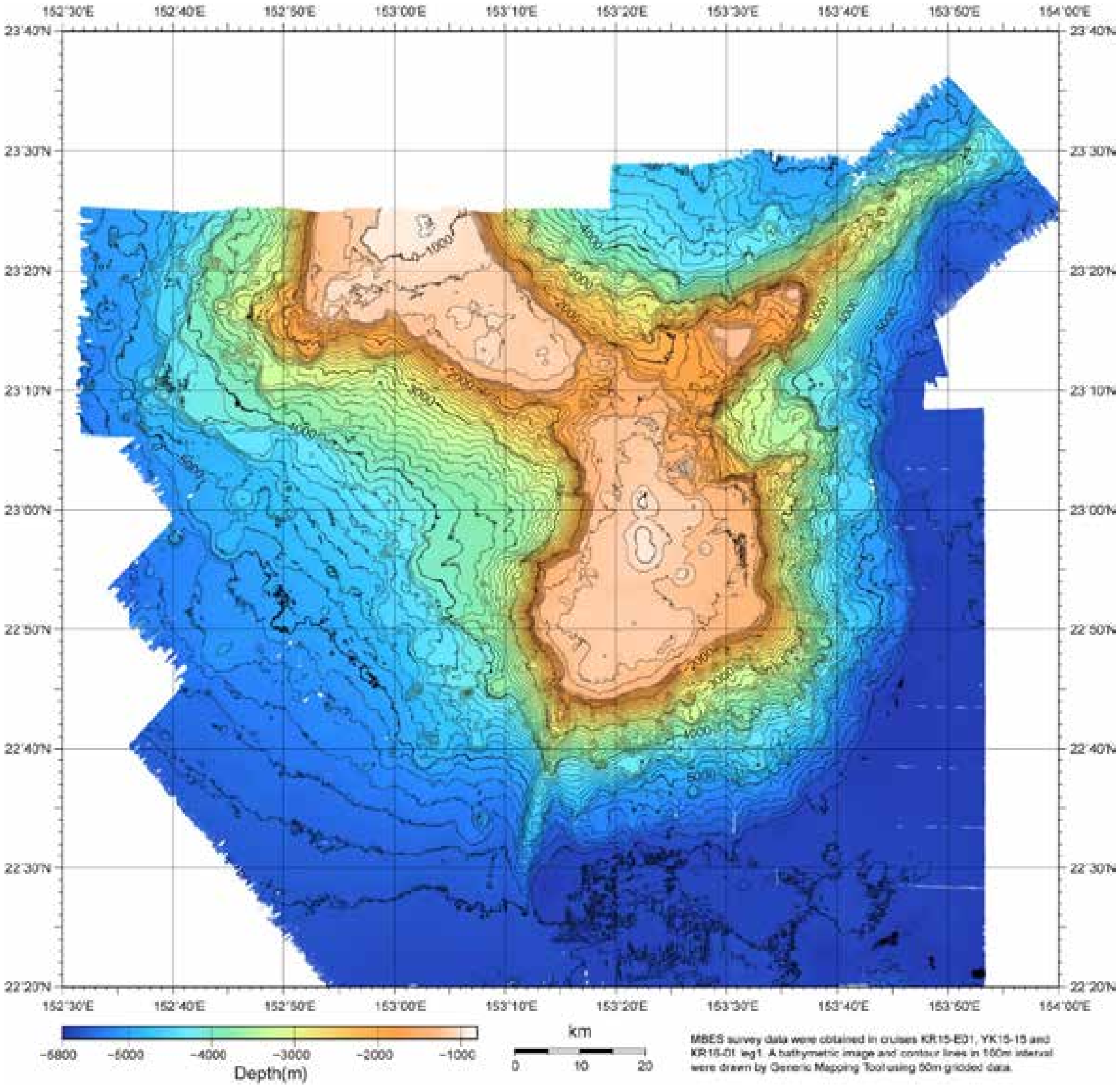


Fig.6.5.2 Bathymetric image of Takuyo-daigo seamount using MBES survey data obtained by previous KR15-E01, YK15-15 and this KR16-01 Leg1 cruises (cf. Fig.4.5).

7 Cruise track and shipboard log

7.1 Cruise track

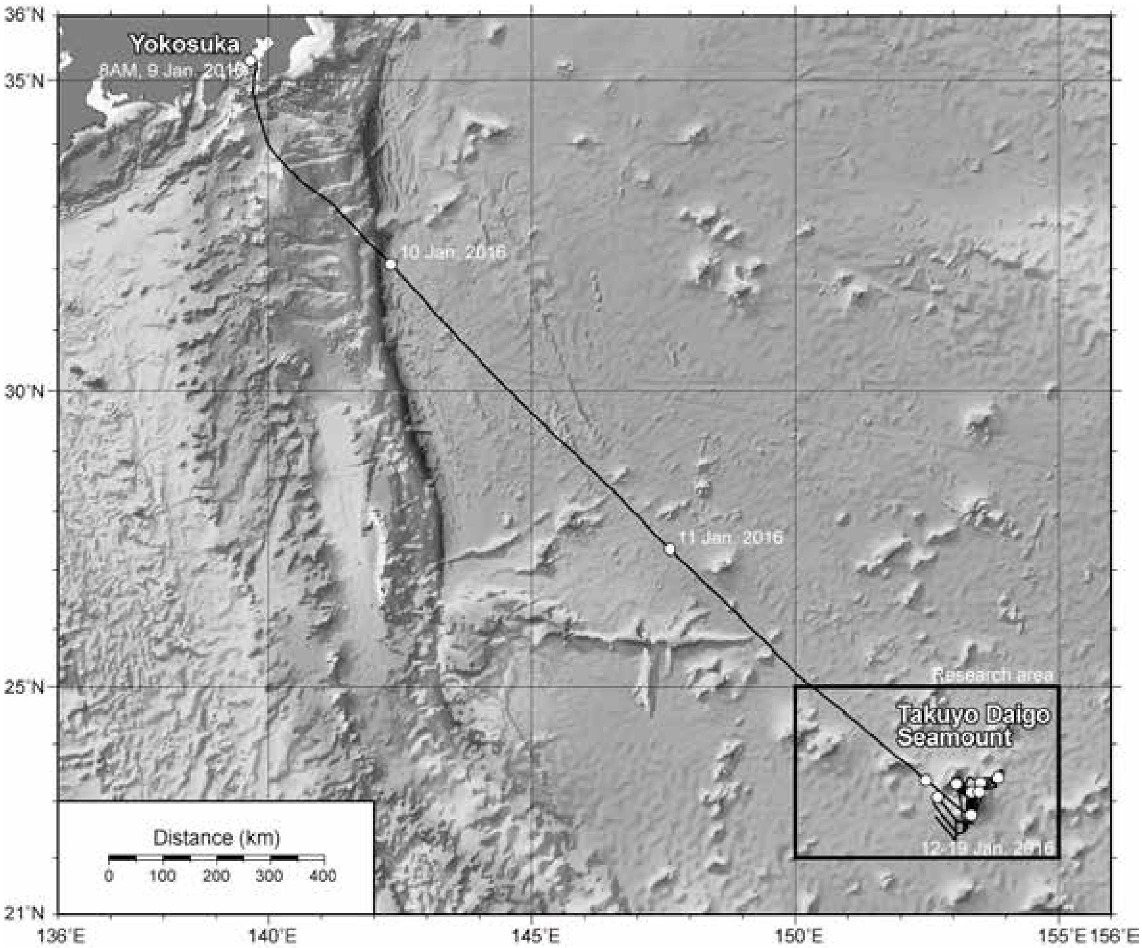


Fig.7.1 Cruise track of KR16-01 Leg1 from departure to the end of Leg1 (midnight of 19 Jan. 2016)

7.2 Shipboard log

Date and Local Time	Note	Position/Weather/ Wind/Sea condition
09-Jan-16	**Sail out, proceeding to research area**	1/9 12:00 (UTC+9h)
08:00	Sail out from Yokosuka.	25-58.5'N, 128-11.0'E
9:00-9:45	Briefing about ship's life and safety	Eastward of Nijima
10:00	Scientist meeting.	bc (Fine but Cloudy)
13:00	Briefing about KAIKO operation	NE-3 (Gentle breeze)
16:40	Konpira ceremony.	2 (Smooth)
		1 (Low swell Short)
		Visibility: 8'
10-Jan-16	**Proceeding to research area**	1/10 12:00 (UTC+9h)
13:00	Safety exercise for scientist.	29-42.3'N, 144-55.5'E
14:00	Meeting about BOSS-A with crew and operation team.	Northeast of Chichi-jima

15:00	Meeting about KAIKO dive#678 with operation team.	bc (Fine but Cloudy)
18:00	Scientist meeting.	WNW-5(Fresh breeze)
		3 (Slight)
		1 (Low swell Short)
		Visibility: 8'
11-Jan-16	**Proceeding to research area**	1/11 12:00 (UTC+10h)
09:00	Meeting about BOSS-A operation with crew.	25-17.8'N, 149-56.5'E
15:00	Scientist meeting.	West of Minami-torishima
18:00	Scientist meeting.	c (Cloudy)
		North-4 (Moderate breeze)
		2 (Smooth)
		1 (Low swell Short)
		Visibility: 8'
12-Jan-16	**KAIKO Dive678**	1/12 12:00 (UTC+10h)
05:00	Arrived at research area.	22-44.8'N, 153-15.7'E
05:24	Released XBT <22-46.1383'N, 153-17.9960'E>	Takuyo-Daigo Seamount
5:46 - 5:56	MBES survey.	bc (Fine but Cloudy)
08:35	Hoisted up KAIKO.	SE-3(Gentle breeze)
10:11	Vehicle landed. <vehicle depth = 1,431m>	3 (Slight)
15:01	Vehicle left the bottom. <vehicle depth=1,431m>	1 (Low swell Short)
16:28	Recovered KAIKO & finished the operation.	Visibility: 8'
19:22	Released XBT <23-15.7990'N, 153-32.8120'E>	
19:42	Started MBES survey.	
13-Jan-16	**KAIKO Dive679**	1/13 12:00 (UTC+10h)
02:33	Finished MBES survey.	22-51.1'N, 153-26.9'E
08:30	Hoisted up KAIKO.	Takuyo-Daigo Seamount
09:57	Vehicle landed. <vehicle depth = 1,152m>	bc (Fine but Cloudy)
15:15	Vehicle left the bottom. <vehicle depth = 1,215m>	SW-5(Fresh breeze)
16:33	Recovered KAIKO & finished the operation.	3 (Slight)
18:31	Started MBES survey.	1 (Low swell Short)
		Visibility: 8'
14-Jan-16	**KAIKO Dive680**	1/14 12:00 (UTC+10h)
03:08	Finished MBES survey.	22-30.7'N, 153-12.9'E
07:39	Hoisted up KAIKO.	Takuyo-Daigo Seamount
10:58	Vehicle landed <vehicle depth = 5,587m>	c (Cloudy)
13:16	Vehicle left the bottom. <vehicle depth = 5,476m>	SSW-4(Moderate breeze)
16:10	Recovered KAIKO & finished the operation.	3 (Slight)
18:44	Started MBES survey.	2 (Low Swell Long)
		Visibility: 8'
15-Jan-16	**KAIKO Dive681**	1/15 12:00 (UTC+10h)

04:08	Finished MBES survey.	22-30.7'N, 153-12.9'E
08:33	Hoisted up KAIKO.	Takuyo-Daigo Seamount
10:35	Vehicle landed. <vehicle depth = 5,557m>	bc (Fine but Cloudy)
13:31	Vehicle left the bottom. <vehicle depth = 5,492m>	South-3(Gentle breeze)
16:21	Recovered KAIKO & finished the operation.	2 (Smooth)
18:09	Started MBES survey.	2 (Low Swell Long)
		Visibility: 8'

16-Jan-16	**KAIKO Dive682**	1/16 12:00 (UTC+10h)
03:05	Finished MBES survey.	22-40.9'N, 153-14.3'E
08:36	Hoisted up KAIKO.	Takuyo-Daigo Seamount
10:47	Vehicle landed. <vehicle depth = 2,990m>	bc (Fine but Cloudy)
14:32	Vehicle left the bottom. <vehicle depth = 2,990m>	SW-4(Moderate breeze)
16:47	Recovered KAIKO & finished the operation.	3 (Slight)
18:59	Started MBES survey.	1 (Low swell Short)
		Visibility: 8'

17-Jan-16	**MBES survey**	1/17 12:00 (UTC+10h)
02:40	Finished MBES survey.	22-41.7'N, 153-17.0'E
	Today's dive is aborted.	Takuyo-Daigo Seamount
11:50	Started MBES survey.	bc (Fine but Cloudy)
		SW-4(Moderate breeze)
		3 (Slight)
		1 (Low swell Short)
		Visibility: 8'

18-Jan-16	**KAIKO Dive683**	1/18 12:00 (UTC+10h)
02:49	Finished MBES survey.	22-29.1'N, 153-12.0'E
07:28	Hoisted up KAIKO.	Takuyo-Daigo Seamount
10:26	Vehicle landed. <vehicle depth = 5,442m>	c (Cloudy)
13:28	Vehicle left the bottom. <vehicle depth = 5,355m>	SE-5(Fresh breeze)
16:15	Recovered KAIKO & finished the operation.	3 (Slight)
17:38	Started MBES survey.	1 (Low swell Short)
		Visibility: 8'

19-Jan-16	**KAIKO Dive684**	1/19 12:00 (UTC+10h)
04:49	Finished MBES survey.	22-37.4'N, 153-12.9'E
07:28	Hoisted up KAIKO.	Takuyo-Daigo Seamount
10:09	Vehicle landed. <vehicle depth = 4,481m>	bc (Fine but Cloudy)
13:41	Vehicle left the bottom. <vehicle depth = 4,371m>	SSW-5(Fresh breeze)
16:15	Recovered KAIKO & finished the operation.	3 (Slight)
17:31	Started MBES survey.	1 (Low swell Short)
23:59	Terminated KR16-01 Leg1.	Visibility: 8'

8 Acknowledgement

Here we express our sincere appreciation for the excellent support and assistance by Captain Ukekura and his crew, and the operation manager of KAIKO, Wakamatsu, and his ROV team throughout the cruise.