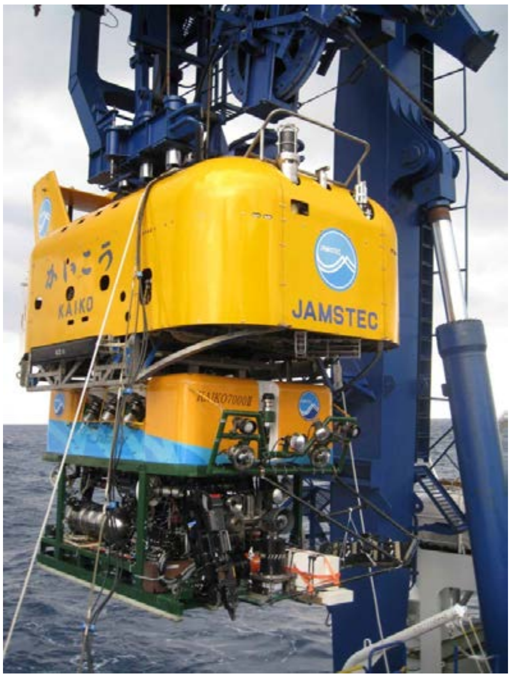
doi : 10.17596/0003112

R/V Kairei Cruise Report
KR11-02



Izu-Bonin area

(Bayonnaise knoll and the surrounding area)

January 25th – February 2nd, 2011, 2011

Japan Agency for Marine-Earth Science

and Technology (JAMSTEC)

Contents

1. Cruise Information

Cruise ID:	KR11-02
Name of vessel:	R/V Kairei
Title of the cruise:	ROV Kaiko 7000II Research Dives (Izu-Bonin Area)
Chief scientist:	Tada-nori Goto [JAMSTEC]
Cruise period	January 25th – February 2nd, 2011.
Ports of call	JAMSTEC Yokosuka pier – JAMSTEC Yokosuka pier
Research area	Izu-Bonin area (Bayonnaise knoll and the surrounding area) Water Depth：500m～3,200m Area surrounded by the following LAT/LON. 31deg. 40.0min.N 139deg. 00.0min.E , 31° 40.0'N 140deg. 45.0min.E 32deg. 40.0min.N 140deg. 45.0min.E , 32° 40.0'N 139deg. 00.0min.E

Purpose:

On the basis of project by MEXT, “Program of development of fundamental tools for advancing the availability of marine resources”, we conducted the research dive of ROV Kaiko 7000II. The main purposes of this cruise are summarized below:

Representative of the Science Party

Theme 1:	Keizo Sayanagi (Tokai University)
Theme 2:	Akira Asada (Graduate School of Frontier Sciences, University of Tokyo)

Title of proposal

Theme 1:	Trial of ROV-based marine DC resistivity survey at the seafloor massive sulphide.
Theme 2:	Offshore test of synthetic aperture interferometry and multi-beam bathymetry sounding system in the area with seafloor massive sulphide.

2. Researchers and Crews

Onboard Researchers

後藤　忠徳	海洋研究開発機構	Tada-nori Goto	JAMSTEC
笠谷　貴史	海洋研究開発機構	Takafumi Kasaya	JAMSTEC
澤　隆雄	海洋研究開発機構	Takao Sawa	JAMSTEC
佐柳　敬造	東海大学	Keizo Sayanagi	Tokai Univ.
原田　誠	東海大学	Makoto Harada	Tokai Univ.
浅田　昭	東京大学生産技術研究所	Akira Asada	Univ. Tokyo
望月　将志	東京大学生産技術研究所	Masashi Mochizuki	Univ. Tokyo
松田　滋夫	クローバテック株式会社	Shigeo Matsuda	Clover Tech
高橋　英晴	(株)エス・イー・エイ	Hideharu Takahashi	SEA
岡崎　淳一	(株)エス・イー・エイ	Junichi Okazaki	SEA
坂本　公夫	(株)リンク	Kimio Sakamoto	LINK
今村　尚人	京都大学	Naoto Imamura	Kyoto Univ.
河合　真	早稲田大学	Makoto Kawai	Waseda Univ.
真行寺　泰輔	早稲田大学	Taisuke Shingyoji	Waseda Univ.

R/V Kairei Crew

職　名	氏　名	Position	NAME
船　長	鮫島　耕児	Captain	SAMESHIMA KOJI
一航士	足立　龍生	Chief Officer	ADACHI TATSUO
二航士	大原登志世	2nd Officer	OHARA TOSHIYO
三航士	浅地　寛人	3rd Officer	ASAJI KANTO
機関長	柴田 裕之	Chief Engineer	SHIBATA HIROYUKI
一機士	船江　幸司	1st Engineer	FUNAE KOJI
二機士	儀武　大輔	2nd Engineer	GIBU DAISUKE
三機士	山口　雄治	3rd Engineer	YAMAGUCHI KATSUTO
次三機士	大津賀吉広	Jr.3rd Engineer	OTSUGA YOSHIHIRO
電子長	井上　翼一	Chief Electronics Operator	INOUE YOICHI
二電士	山本　洋平	2nd Electronics Operator	YAMAMOTO YOHEI
三電士	幡　三沙都	3rd Electronics Operator	HATA MISATO
甲板長	安部　正市	Boat Swain	ABE SHOICHI
甲板手	渡口　忠彦	Able Seaman	TOGUCHI TADAHIKO
甲板手	大端　正則	Able Seaman	OHATA MASANORI
甲板手	石井　幸人	Able Seaman	ISHII YUKITO
甲板手	村田　海人	Able Seaman	MURATA KAITO
甲板員	中田　秀明	Sailor	NAKATA HIDEAKI
甲板員	窪田　朋晃	Sailor	KUBOTA TOMOAKI
操機長	北野　　勝	No.1 Oiler	KITANO MASARU
操機手	船渡　啓太	Oiler	FUNAWATARI KEITA
操機手	藤原　正幸	Oiler	FUJIWARA MASAYUKI
機関員	佐藤　　諒	Assistant Oiler	SATO RYO
機関員	唐田　一孝	Assistant Oiler	KARATA KAZUTAKA
司厨長	芳川　輝幸	Chief Steward	YOSHIKAWA TERUYUKI
司厨手	大場　寛幸	Steward	OBA HIROYUKI
司厨手	三上理香子	Steward	MIKAMI RIKAKO
司厨手	久保田秀樹	Steward	KUBOTA HIDEKI
司厨員	木下　春風	Steward	KINOSHITA HARUKA

ROV Kaiko Operators

職　名	氏　名	Position	NAME
運航長	南部　喜信	Operation Manager	NAMBU YOSHINOBU
一等潜技士	三浦　豊司	1st ROV Operator	MIURA ATSUMORI
一等潜技士	植木　光弘	1st ROV Operator	UEKI MITSUHIRO
二等潜技士	瀧下　　清	2nd ROV Operator	TAKISHITA KIYOSHI
二等潜技士	若松　　誉	2nd ROV Operator	WAKAMATSU HOMARE
二等潜技士	瀬底　秀樹	2nd ROV Operator	SEZOKO HIDEKI
三等潜技士	浅井　　隆	3rd ROV Operator	ASAI RYU
三等潜技士	井原　章太	3rd ROV Operator	IHARA SHOTA

3. Introduction

3.1 Summary of cruise

1) Trial of ROV-based marine DC resistivity survey at the seafloor massive sulphide

We developed marine DC resistivity survey system which can be applied to exploration of seafloor massive sulphide. Our system can be attached to ROV Kaiko 7000 II, and allows us to image sub-seafloor resistivity structure with depth of several to hundred meters. In the Bayonnaise knoll, our target in this cruise, Japan Oil, Gas and Metals National Corporation (JOGMEC) found seafloor massive sulphide deposits, whose detailed distribution on the seafloor has been reported. In general, the metallic deposits indicate low resistivity and/or high chargeability. If the seafloor resistivity distribution derived by our survey system shows a similarity to seafloor geological feature reported by JOGMEC, we can conclude that the marine DC resistivity survey is effective to evaluate spatial distribution of seafloor massive sulphide. In addition, if we obtain the deeper resistivity structure, our geophysical information is valuable for evaluation of total amount of metal deposits in this area.

Although the sea condition was rough, we fortunately carried out the experiment with one dive of ROV Kaiko 7000II. We obtained the real field data in and around the hydrothermal area, and carried out the mapping of seafloor resistivity. On the basis of preliminary analysis, the resistivity distribution has a correlation with the seafloor geological feature. In addition, we recorded the electric field generated by artificial electric current from ROV with large source-receiver distance of several tens meters. The data will allow us to obtain deeper resistivity structure. Finally, we retrieved the ocean-bottom electro-magnetometers (OBEM), deployed at the previous cruise, named YK10-12 (December, 2010).

2) Offshore test of synthetic aperture interferometry and multi-beam bathymetry sounding system in the area with seafloor massive sulphide.

We have been developing measurement systems of high-accuracy positioning and high-resolution bathymetry on the seafloor toward future developments of submarine resources. Performance evaluation test of the newly-developed sonar system based on techniques of interferometry and synthetic aperture for high-resolution bathymetric survey was conducted in the KR11-02 cruise. Hakurei site on Bayonnaise knoll was selected as a target for bathymetric survey.

Five 200m-long NS-oriented survey lines were set just on Hakurei site. ROV KAIKO7000II equipped with new sonar system followed the survey lines as slow as possible. KAIKO7000II kept her altitude 50m at the first trial, and 30m at the last trial, respectively. The bathymetric survey system continued to ping measuring pulse every 0.5 s during KAIKO7000II cruised. Sufficient amount of the data to evaluate the performance of new sonar system were collected.

3.2. Cruise schedule and operations

Tada-nori Goto

(Based on the daily research report to the JAMSTEC headquarter)

Jan. 25 (Tue.)

Departure at 15:00 JST from JAMSTEC pier.

Toward the Bayonnaise knoll, Izu-Bonin back-arc rift, off Japan.

Jan. 26 (Wed.)

Dive # 498: ROV Kaiko 7KII dived with the interferometry and multi-beam acoustic system developed by Univ. Tokyo. The Kaiko vehicle kept the altitude from the seafloor with 50m (or 30m) and measured the micro-topography. Five N-S profiles with length of 200m (with 50m separation each other) were conducted just above the hydrothermal area in the Bayonnaise knoll caldera. The data was stored successfully, and the quality will be checked. The forward-looking sonar of the Kaiko vehicle roughly imaged the rock masses with about 1-2m diameter, inferred as hydrothermal chimneys. The interferometry and multi-beam acoustic system will reveal such a distribution of chimneys with high precision images.

Jan. 27 (Thu.)

Due to the rough weather condition, R/V Kairei stayed off the Hachijo island for avoiding strong wind and swell. We prepared the ROV-based marine DC resistivity survey system (named "Remior") and stand-alone electric signal receiver (named "CUBE") for the payload instrument of Kaiko 7KII.

The date of acoustic survey, obtained on Jan. 26, was successfully recorded in the HDD of instruments. The vehicle positioning using the gyroscope and DVL was started onboard. Additional data analysis will be tried.

Jan. 28 (Fri.)

From early morning (05:50 JST), we started to retrieve OBEMs, which were deployed in Dec., 2010 (at YK10-17 cruise). Six OBEMs were deployed at the cruise. Location of self pop-up OBEM was tracked using SSBL in real-time. Four of OBEMs were safely retrieved. However, one OBEM, which could be on sea surface, was not recovered on the board. The acoustic transponder attached to the OBEM was alive, and we decided the seafloor position of unrecovered OBEM.

On board of R/V Kairei, we prepared the ROV-based marine DC resistivity survey system. All instruments (Remior and CUBE) were loaded to ROV Kaiko 7KII. The onboard instruments test was successfully.

Jan. 29 (Sat.)
From 06:00 JST, one OBEM was retrieved and on the deck at 07:00 JST. Then ROV Kaiko 7KII dive was started.
Dive # 499: We tested new instruments for marine DC resistivity survey. A transmitter and receivers, attached to the ROV, recorded seafloor resistivity at the Bayonnaise knoll caldera. The amplitude of current was 5-10A. The ROV was landed on the seafloor or moved near the seafloor at the measurements. Simultaneously, two CUBEs, stand-alone electric signal receivers, were set on the seafloor. Two CUBEs are separated with distance of 70m, which allow us to image deeper resistivity structure to a depth of 100m. At 15:07, ROV Kaiko 7KII left from the seafloor and recovered onboard. As a result, the received electric field near the seafloor was larger than one at the middle depth of sea. It implies the more resistive seafloor than seawater and the successive works of new instruments, although the system did not fully work at previous cruises; KR08-10 and KR09-16. The received field at the center of hydrothermal area indicates slight attenuation, which indicate more conductive feature. Further quantitative data analysis allows us more detailed discussion.

Jan. 30 (Sun.)
We stayed off Hachijo Island for avoiding the rough weather condition. We cleaned up the recoverd OBEMs. We also opened the glass spheres of OBEMs and picked up the memory cards.

Jan. 31 (Mon.)
We stayed off Hachijo Island for avoiding the rough weather condition.
Departure at 19:00JST to the survey area, the Bayonnaise knoll caldera.

Feb. 1 (Tue.)
Due to the rough weather condition, we gave up the diving of ROV.
Departure to the JAMSTEC pier.

Feb. 2 (Wed.)
Arrive off the JAMSTEC pier. We left R/V Kairei at 08:00 JST.
Research cruise was terminated safely and succesufully.

4. Research Objectives

4.1 New bathymetric survey system based on techniques of interferometry and synthetic aperture

Akira Asada (IIS, Univ. of Tokyo)
Masashi Mochizuki (IIS, Univ. of Tokyo)

Utilizations of Autonomous underwater vehicle (AUV) and Remotely operated vehicle (ROV) are absolutely necessary when we explore and develop submarine resources. Development of submarine resource begins with a bathymetric survey based on AUV or ROV. Accuracy of the bathymetric survey has a decisive influence on assessment of reserve resource and development planning. Efficiency is another important factor when we conduct bathymetric survey based on AUV or ROV. The method to measure wide area even in single dive is required when we explore vast expanse of seafloor.

We have launched a three-year project to develop new bathymetric survey system supported by MEXT. This bathymetric survey system will have the specifications listed below.

- ・Depth rating : 3,000m
- ・Platform: AUV or ROV
- ・Bathymetric resolution: 5cm
- ・Swath width: 0 to 90 degree (Full swath)
- ・Coverage: 400m swath (Platform cruise at 50m altitude)
- ・Positioning accuracy: 5cm

Combination of multibeam echo sounder technology and newly developed sonar based on techniques of interferometry and synthetic aperture (Interferometric SAS) realizes a seamless full-swath bathymetric survey system.

We use KAIKO7000II to conduct a performance evaluation test of the interferometric SAS system of new bathymetric survey system.

4.2. ROV-based marine DC resistivity survey

Tada-nori Goto (JAMSTEC), Takafumi Kasaya (JAMSTEC)
Takao Sawa (JAMSTEC), Keizo Sayanagi (Tokai Univ.)
Makoto Harada (Tokai Univ.), Shigeo Matsuda (Clover Tech)
Naoto Imamura (Kyoto Univ.), Makoto Kawai (Waseda Univ.)
Taisuke Shingyoji (Waseda Univ.)

The recent growth of world-wide requirement of metals demands advanced explorations for finding metal mine and deposits. Especially, the submarine massive sulphides (SMS) have attracted mining companies because of its compactness with high grades. However, few exploration techniques were developed to evaluate the thickness of SMS and to find the buried SMS.

One of the great problems is the rough seafloor feature near the hydrothermal area, which restricts the ways for marine controlled-source electromagnetic (CSEM) survey. Recently, the deep-towed CSEM technique is used for imaging the shallower structure below the seafloor for detection of methane hydrate etc. (e.g., Schwalenberg et al., 2005). However, the deep- towed CSEM survey requires a long towed cable for source and receiver electrodes. The rough topography does not allow the towing just on the seafloor. The high altitude of towed cable gives us a chance of towing but the obtained data mainly reflect the seawater layer below the cable, so that the resolution to the sub-seafloor structure is decreased.

Here, we propose a new EM exploration technique with a Remotely Operated Vehicle (ROV) as shown in Fig. 4.2.1. In our concept, the ROV-based DC resistivity survey system consists of two instruments; on-line transmitter and receivers attached to ROV and off-line receivers. Although the former can measure the seafloor resistivity with sounding depth of several meters due to the short source-receiver separation, the real-time observation with ROV is quite helpful for mapping the in-situ resistivity combined with the seafloor camera image and rock samples by the ROV's manipulators. The later seafloor receivers (ocean-bottom electromagnetometers=OBEMs or ocean bottom electrometers=OBEs) can be simultaneously used for keeping far source-receiver distances to obtain the deeper images.

In this cruise, we test our newly developed system to image the sub-seafloor resistivity structure below the SMS deposits in the Bayonnaise knoll caldera. As reported in Tanahashi et al. (2006), JOGMEC had conducted surveys targeting for SMS and found a huge hydrothermal sulfide deposit, named as the "Hakurei ore deposit" in the Bayonnaise knoll caldera. It was the first discovery of Kuroko-type ore deposit in the Izu-Bonin back-arc rift. The water depth is about 700-800m. There are many inactive sulfide chimneys at the central area, which mainly consist of sphalerite associated with chalcopyrite, galena, pyrite and barite. On the basis of comparison between the resistivity distribution obtained in this cruise and the seafloor geological settings around the Hakurei ore deposits, we can discuss how effectively new marine EM sounding techniques with ROV gives us information about SMS.

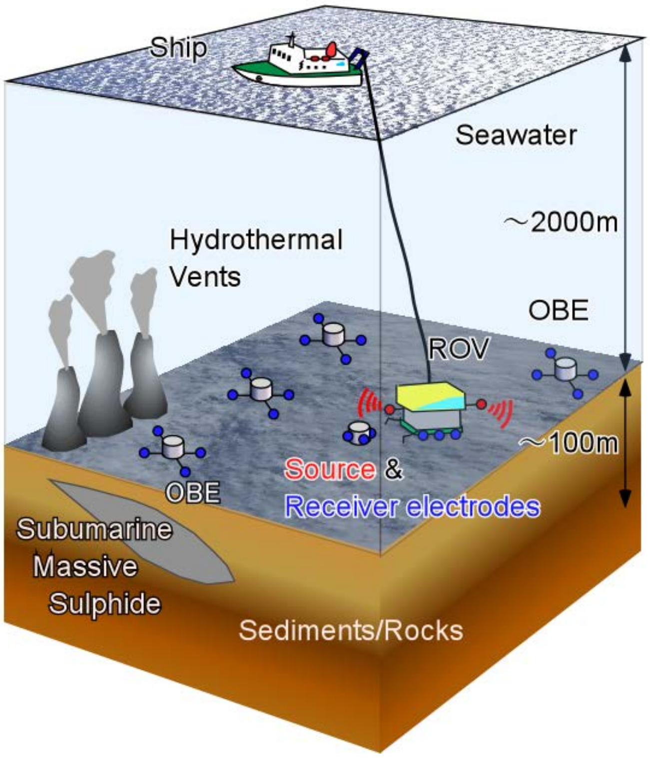
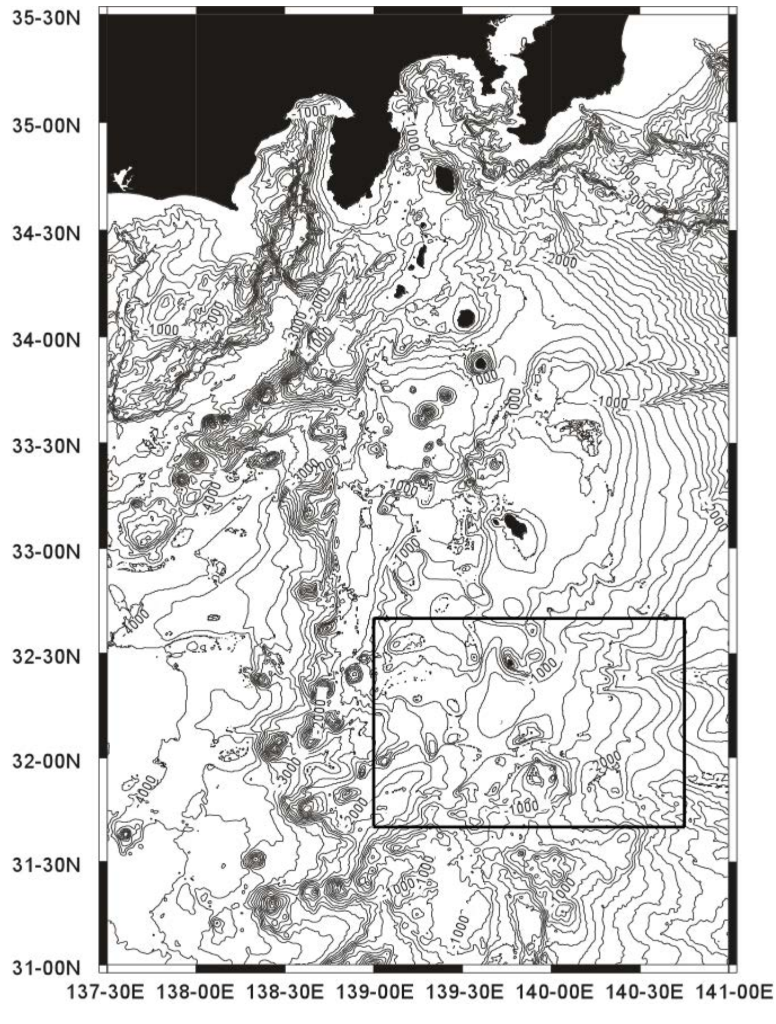


Fig. 4.2.1. Schematic drawing of ROV-based marine DC resistivity survey.

4.3. OBEM recovery

Electrical resistivity structure provides useful information of crust and mantle. For the hydrothermal deposit survey, resistivity data also play very important role. Objective of this survey using a seafloor electromagnetic observation is to reveal the regional structure around the Beyonnaise caldera. This is very important to consider the magmatism of Izu-Bonin arc including the Beyonnaise caldera.



Survey Area of KR11-02 cruise

5. Instruments and Operation Methods

5.1 New bathymetric survey system with techniques of interferometry and synthetic aperture

Akira Asada (IIS, Univ. of Tokyo)
Masashi Mochizuki (IIS, Univ. of Tokyo)

5.1.1 Instrumentation

New bathymetric survey system employs techniques of interferometry and synthetic aperture to achieve seafloor mapping with cm-level resolution.

The system consists of a control unit, a sonar unit, a motion sensor and a Doppler velocity log (DVL). The control unit generates precise timing pulse and then synchronizes acoustic transmissions of the sonar unit and the DVL. Timing errors of acoustic transmissions are controlled within 1 μs.

The projector of the sonar unit was designed so that it has ideal beam pattern for applying interferometry and synthetic aperture techniques, that is, perfectly monopole-type beam pattern without side-lobes in vertical direction. The operational frequency of the projector is around 100kHz.

The receiver of the sonar unit is a hydrophone array. The hydrophone array characterizes this bathymetric survey system. They form five lines. Each line is 1.2 m length and eight hydrophone elements are embedded in it. Five lines of hydrophone sub array are arranged in triangular shape to employ interferometry technique. The hydrophone array consists of totally forty hydrophones.

A motion sensor and a DVL are needed to acquire precise positioning of the system. MiniRLG2 (CDL, UK) is employed into the system as motion sensor. MiniRLG2 measures pitch and roll with 0.028 degrees rms and heading with ±0.028 degrees secant latitude. WHN300 (Teledyne RD Instruments, USA) is selected as DVL of the system. WHN300 provides ±0.3cm/s precision measurements at altitude of 1 – 200 m.

5.1.2 Installation of the bathymetric survey system to KAIKO7000II

Total weight of the bathymetric survey system exceeded allowance of payload weight, and 1.2 m-long hydrophone array of the system was possible interruption in smooth launch operation of KAIKO7000II. We needed to take measure to them.

Before the installation of the bathymetric survey system, the left manipulator and the sample basket of KAIKO7000II were dismounted in order to increase the allowance of payload weight and to make room for the installation of the system. The hydrophone array was installed at the position where the left manipulator was so that it could align with left side of the KAIKO7000II body (Fig.5.1.2-1). The motion sensor and the DVL were mounted (Fig.5.1.2-2), through the use of the supporting frame for the sample basket, on KAIKO7000II.

Auxiliary battery unit was prepared only for this experiment (Fig.5.1.2-3). This battery unit kept supplying power to the motion sensor after it was calibrated with time and position from GPS system until power would be supplied through KAIKO7000II.

All the system including the battery unit was installed on the front part of KAIKO7000II, and KAIKO7000II would be inevitably front-heavy and ill-balanced. So then, floating buoyant material was attached to the front part of KAIKO7000II to keep postural stabilization (Fig.5.1.2-2).

Fig5.1.2-1 Appearance of the hydrophone array of the bathymetric survey system. The length of the hydrophone array is 1.2m and forty hydrophone elements are embedded in it.

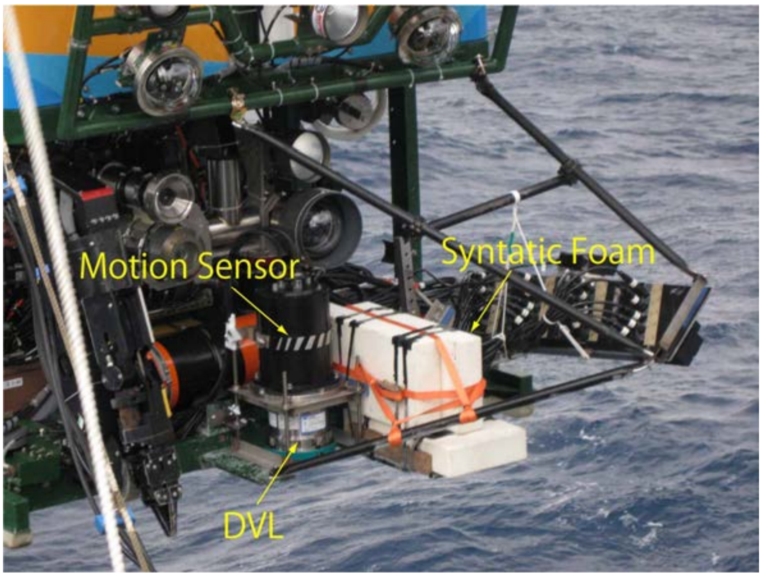


Fig.5.1.2-2 The motion sensor and the DVL were mounted using the supporting frame for KAIKO7000II's basket. In order to keep body balance of KAIKO7000II, floating buoyant material was installed.

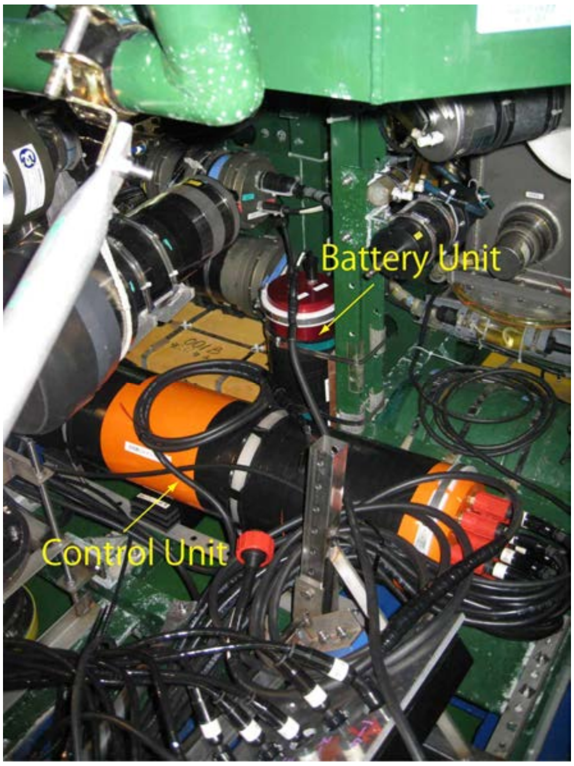


Fig.5.1.2-3 Cylinders of auxiliary battery unit and control unit were installed near center of vehicle's body balance in order not to disrupt the body balance.

5.1.3 Experiment (KAIKO 7000II dive#498)

The target of the dive #498 was Hakurei site on Bayonnaise caldera. Five 200m-long NS-oriented survey lines were set just on Hakurei site. They were located parallel each other. Intervals among them are 50m.

KAIKO7000II (Fig.5.1.3-1) followed the survey lines twice as slow as possible. Her average cruising speed was something around 0.2-0.3knt. KAIKO7000II kept her altitude 50m at the first trial, and 30m at the last trial, respectively. The bathymetric survey system continued to ping measuring pulse every 0.5 s during KAIKO7000II cruised. Backscattered signals were received by the hydrophone array, sampled at 1 MHz and then stored on memories of the control unit of the system.

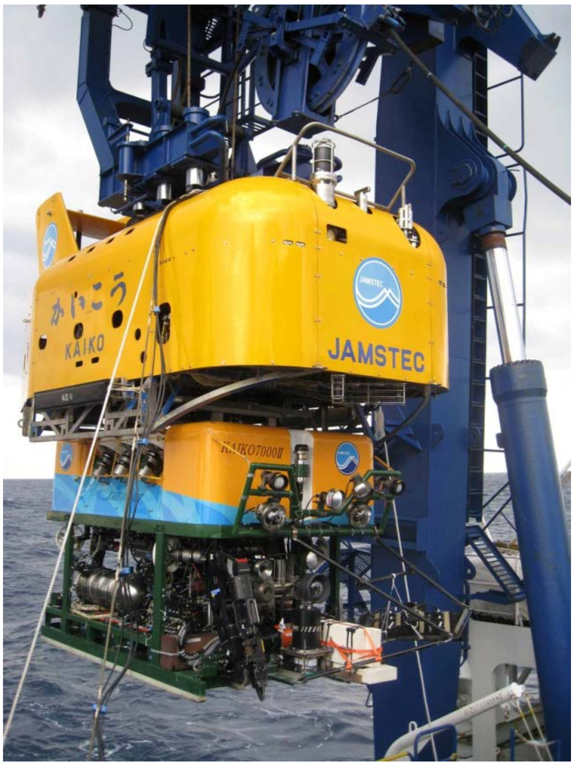


Fig.5.1.3-1 ROV KAIKO7000II equipped with the bathymetric survey system.

5.2 ROV-based marine DC resistivity survey

In this cruise, we used a new marine DC resistivity survey system operated by the ROV "Kaiko 7000II". The schematic explanation of the operation and system are shown in Fig.5.2.1 and Fig.5.2.2, respectively. The details of the system will be explained with the following photos (Fig.5.2.4). A package of a transmitter and receivers attached to the ROV frame is called as REMIOR (REsistivity Measuring Instruments for Ocean floor Resources). During dive#499, the transmitter on the Kaiko vehicle sends the artificially controlled electric current (with squared waves) using 3.9 m-dipole (Fig.5.2.3, Fig.5.2.4 (c)-(d)). We set two CUBEs (Compact Underwater Box-shaped Electrometer, Figs.5.2.4 and 5.2.6) on the seafloor (Fig.5.2.7), which were used as receiver of electric signals, with using the ROV before experiment. Since the seawater conductivity is measurable with the CTD sensor attached to the Kaiko vehicle, we can obtain the electrical conductivity distribution below the seafloor. Also, the electrical potential field generated by artificial current can be measured by the ROV itself using seven electrodes attached to the frame of the ROV (Fig.5.2.3, Fig.5.2.4 (e)-(f)). Those short-range receivers can be used for imaging the shallow sediments or rocks just below the seafloor.

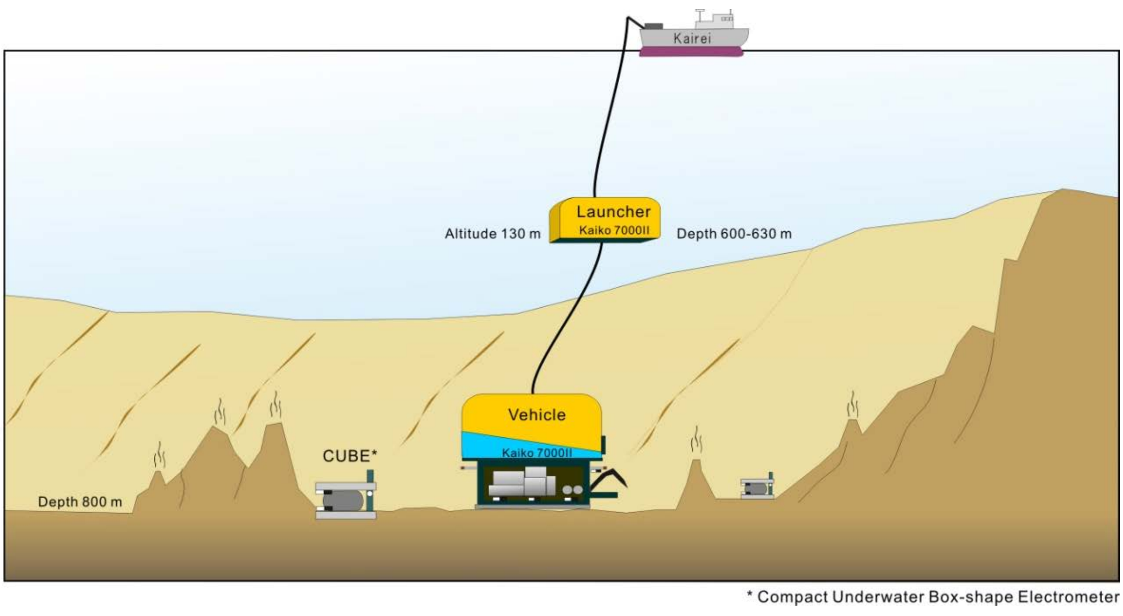


Fig.5.2.1 Concept of the electrical exploration with using Kaiko 7000II

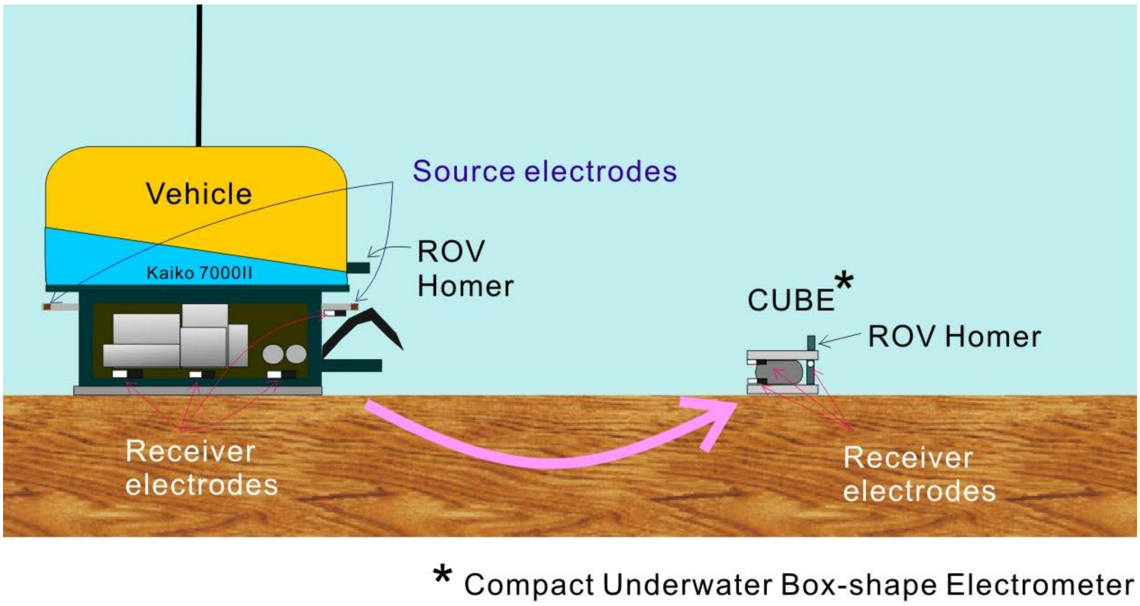


Fig.5.2.2 Detailed description of concept of the Kaiko electrical exploration

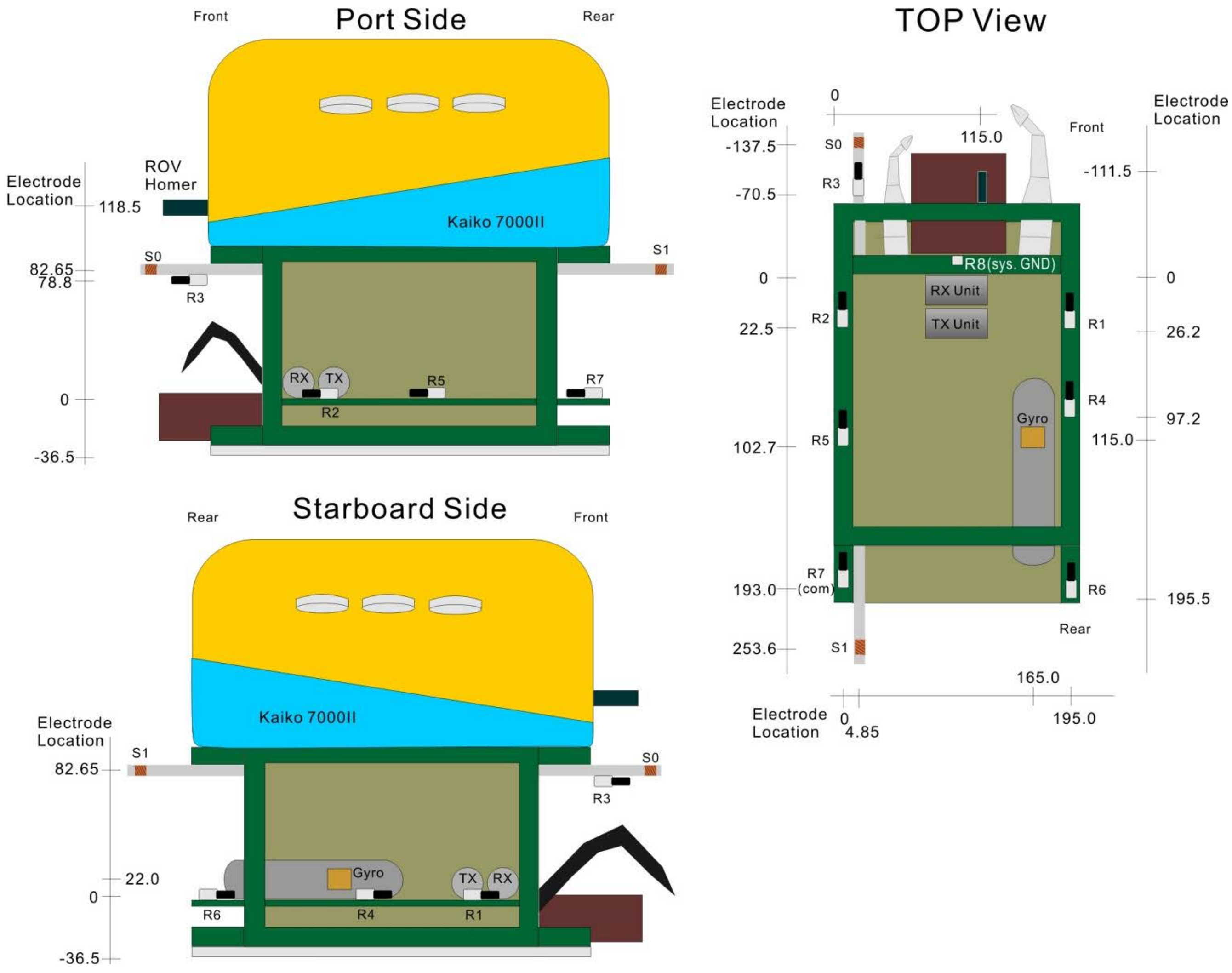
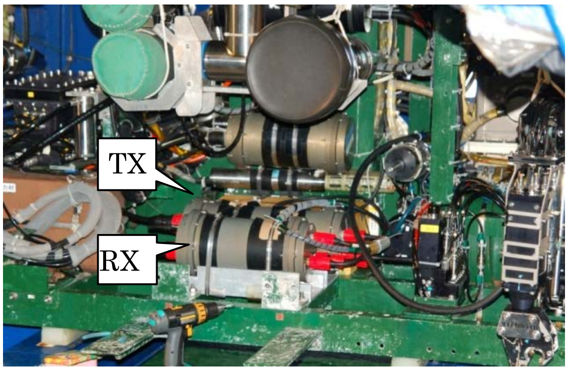


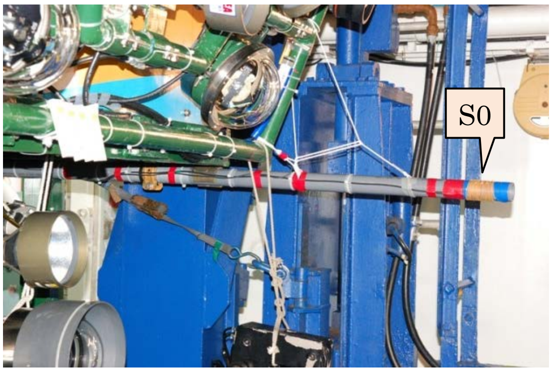
Fig.5.2.3 Configuration of transmitter and receiver electrodes installed on the Kaiko 7000II vehicle (unit=cm). S0 and S1 are the transmitter electrodes. Numbers from R1 to R7 mean the receiver electrodes. R8 means the GND for the electrical exploration system (REMIOR).

(a)

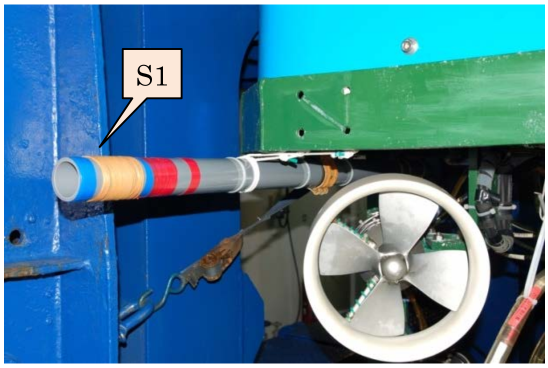


(b)

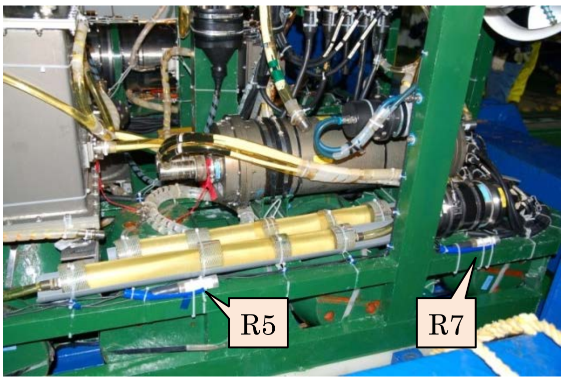
(c)



(d)



(e)



(f)

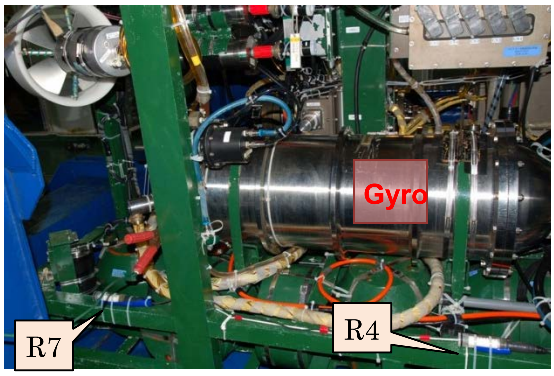


Fig.5.2.4 Photos of the Kaiko electrical exploration system. (a) TX unit (transmitter) and RX unit (SP receiver),(b) Front view of the sample basket with two CUBUs, (c) Transmitter electrode S0, (d) Transmitter electrode S1, (e) Receiver electrodes (Ag-AgCl_2) R5 and R7 in the port side, and (f) Receiver electrodes R4 and R6 in the starboard side.

(a) (b)

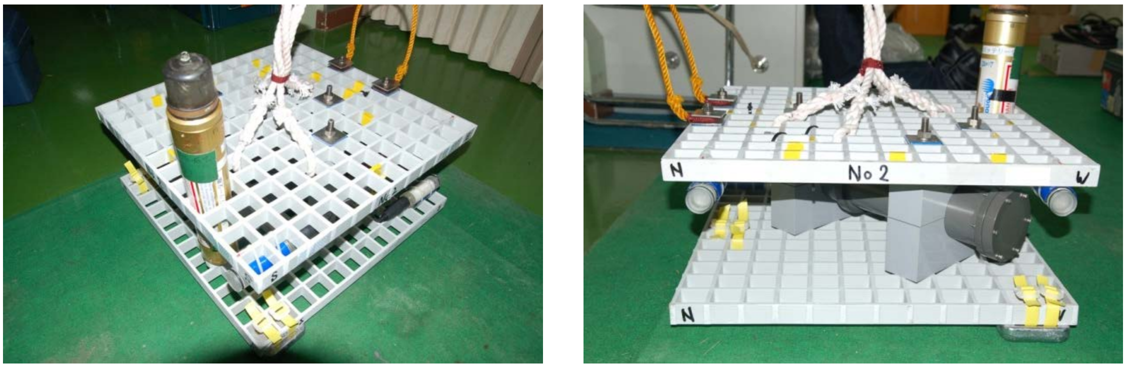


Fig.5.2.5 Photo of the “CUBE” (Compact Underwater Box-shape Electrometer). (a) Top view and (b) Side view.

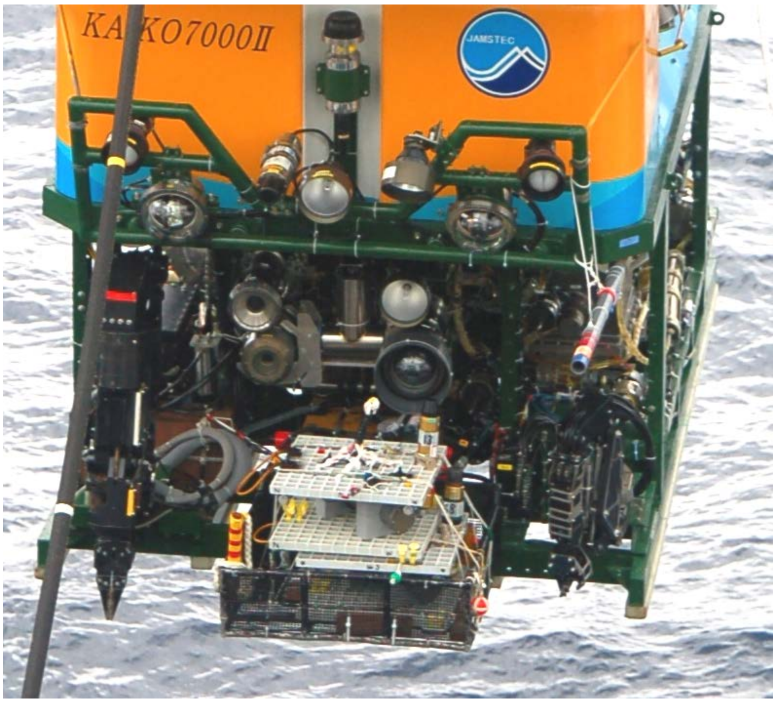


Fig.5.2.6 Front view of the Kaiko vehicle before dive #499. Two CUBEs are set in the basket.

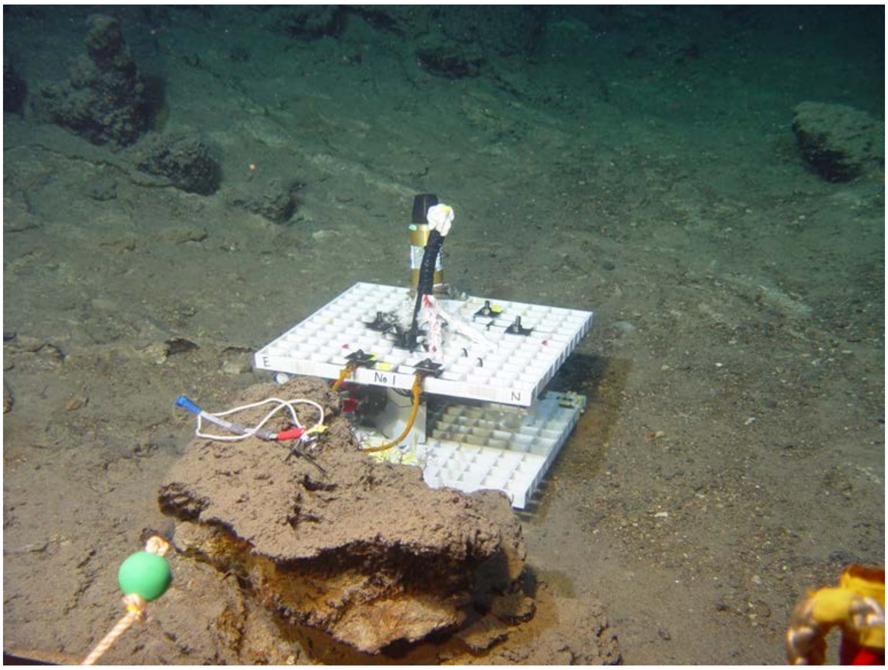


Fig.5.2.7 Photo of the CUBE (site 1) set in the inside of hydrothermal area (depth 800m).

5.3 OBEM system

The OBEM system with a high sampling rate was designed to investigate the crustal and mantle structure (Fig. 5.3.1). It has a folding-arm system to facilitate assembly and recovery operations (Kasaya et al., 2006; Kasaya and Goto, 2009). Concepts of our developed OBEM and OBE system are miniaturization, a high sampling rate, easy assembly and recovery operations, and low costs of construction and operation. Figure 5.3.2 shows the schematic diagram of the arm-folding system. For measuring the electric field, we used Ag-AgCl electrode mounted at the toe of each electrode arm.

Electric circuit used for each system is contained in the pressure glass spheres. The fluxgate magnetometer of the OBEM system is mounted outside the glass sphere (Fig. 5.3.1). The salient characteristic of our system is its arm-folding mechanism, which facilitates and simplifies our onboard operations. We used an acoustic release system that had been already used by JAMSTEC for Ocean Bottom Seismography (OBS).

Clock synchronization before deployment and calibration after recovery are important. This OBEM system can synchronize to the laptop PC using USB communication. To synchronize the laptop PC to GPS clock, we developed the NTP server unit.

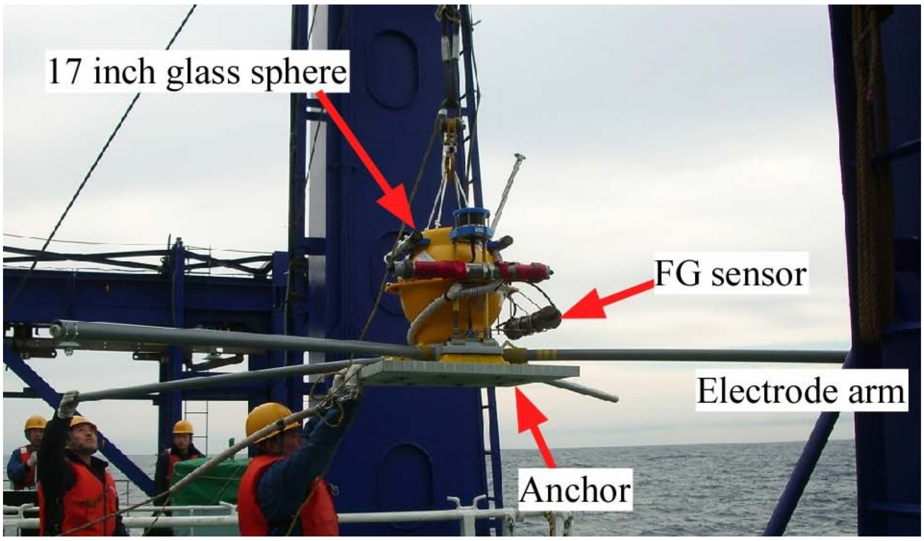


Fig. 5.3.1 Photo of a small OBEM system.

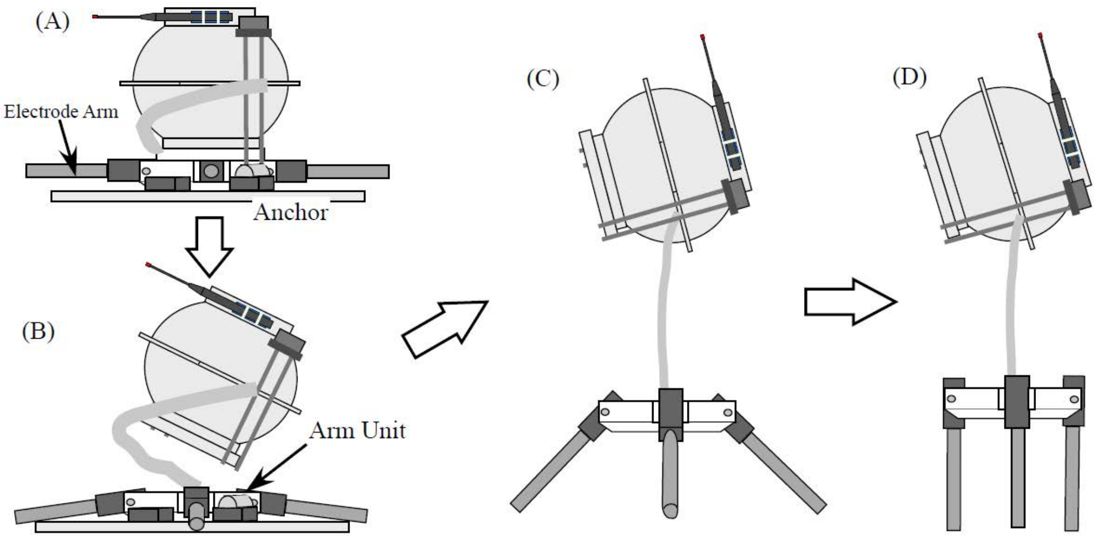


Fig. 5.3.2 Schematic diagram of the arm-folding system. After starting to pop up, the arm unit is picked up as the sphere ascends (Patent number of Japan: 4346605).

References

Kasaya, T., T. Goto, and R. Takagi (2006), Marine electromagnetic observation technique and its development –For crustal structure survey-, *BUTSURI-TANSA, 59*, 585-594 (in Japanese with English abstract).

Kasaya, T. and T. Goto (2009), A small OBEM and OBE system with an arm folding mechanism , *Exploration Geophysics*, *40*, 41-48.

6. Preliminary Results

6.1 New bathymetric survey system based on techniques of interferometry and synthetic aperture

Akira Asada (IIS, Univ. of Tokyo)
Masashi Mochizuki (IIS, Univ. of Tokyo)

During dive #498, totally 43,987 pings had been shot for bathymetric survey. Total amount of stored data received by forty hydrophones reached 85GB. They are sufficient for us to evaluate performance of the interferometric SAS system. We are dedicated to analyzing the data now.

Fig. 6.1-1 shows track line of KAIKO7000II estimated from the data of the motion sensor and the DVL of the bathymetric survey system. SSBL positioning system had worked unsteady during the dive #498. Not good sea condition brought heavily usage of the thrusters of R/V KAIREI. And then, noise made by thrusters seemed to get in the way of SSBL positioning. The motion sensor and the DVL on occasion of seafloor activity are clearly beneficial.

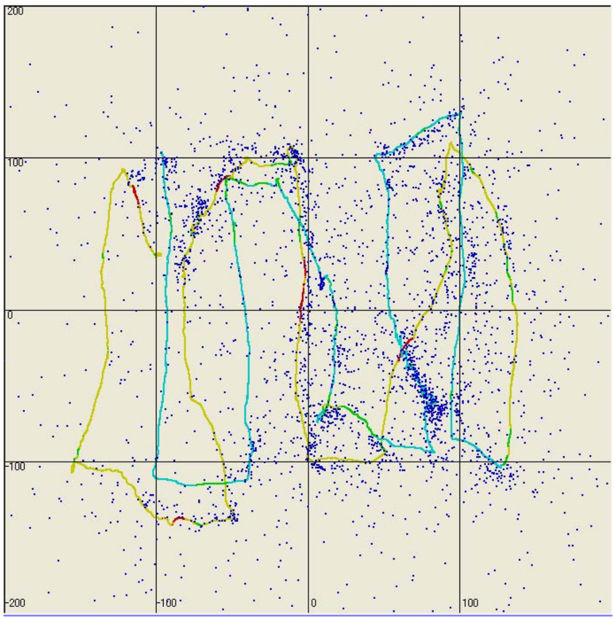


Fig.6.1-1 Track line of KAIKO7000II at the dive #498. Blue dot indicates the position deduced from SSBL positioning. Lines are track lines of KAIKO7000II estimated from the data of the motion sensor and the DVL of the bathymetric survey system. Light blue line shows the track line of the first trial. KAIKO7000II kept her altitude 50m. Yellow line shows the track line of the last trial. KAIKO7000II kept her altitude 30m.

6.2 Preliminary Results of ROV-based marine DC resistivity survey

Tada-nori Goto (JAMSTEC), Takafumi Kasaya (JAMSTEC)
Takao Sawa (JAMSTEC), Keizo Sayanagi (Tokai Univ.)
Makoto Harada (Tokai Univ.), Shigeo Matsuda (Clover Tech)
Naoto Imamura (Kyoto Univ.), Makoto Kawai (Waseda Univ.)
Taisuke Shingyoji (Waseda Univ.)

At the dive #499, two survey lines are suggested as shown in Fig. 6.2.1. Along Line 1, two CUBEs were arranged on the seafloor, which were brought by ROV. Then, we carried out DC resistivity survey as follows:

1) Western half of line 1 (from west to east),
2) Eastern half of line 1 (from east to west)
3) Line2 (from west to east)
4) Line1 (from west to east: second run)

For the operation 1-3, the ROV Kaiko 7KII landed on the seafloor for stationary observation during several minutes. Then, the artificial current was sent to both receivers attach to the ROV and CUBEs on the seafloor. We obtained discrete measurements of seafloor resistivity. For the operation 4, the second run along line1, the ROV swam at low altitude (1-3m) and continuous speed of 1-2 knots. The continuous resistivity observation along line 1 was conducted at the last run.

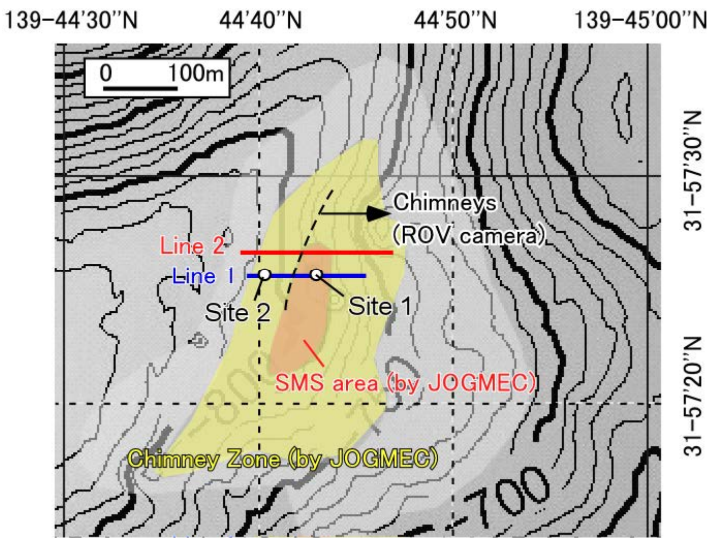


Fig. 6.2.1. Location of survey lines (1 and 2) and two CUBEs (sites 1 and 2). Colored area indicates the geological districts based on the report by JOGMEC (2010). Active chimneys confimed by camera observation of ROV Kaiko 7KII in this cruise is also added.

Our measuring system, Remior (Resistivity Measuring Instruments for Ocean floor Resources), stably send artificial electric current (5-10 A) using the transmitter and received electric field with receiver electrodes (Ag-AgCl) attached to the ROV frame. A typical example of wave form is shown in Fig. 6.2.2. The polarity of source current is switched every 6.25 seconds (ON->zero->OFF->zero). Clear correlation between wave forms of source current and received electric field is recognized in Fig. 6.2.2. It indicates that the current noise from ROV is small enough to estimate apparent resistivity on the seafloor precisely. Note the wave form at the turning-on / turning-off. Although the source wave form suddenly changes from zero to some levels, the received electric field could not catch up with it. This feature was not observed when the ROV is settled in the middle of seawater (surrounded by seawater and far from the seafloor). We interpret that the less similarity between wave forms comes from the induced polarization (IP) effect, often observed around the ore deposits on land. We will calculate chargeability of rock / sediments which is available for discussion of the amount of metallic materials below the seafloor.

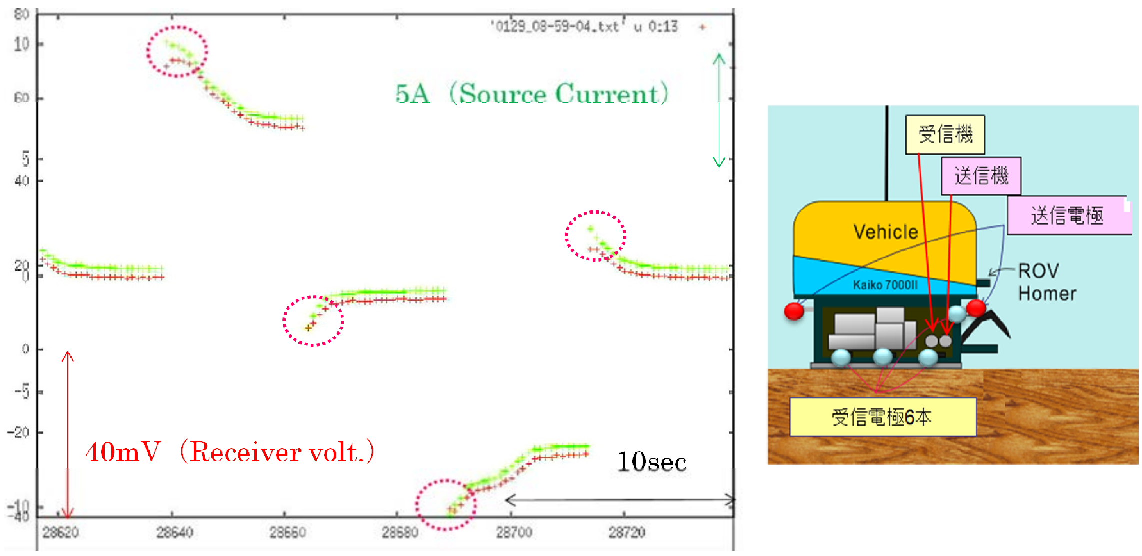


Fig. 6.2.2. Typical example of wave forms. Green: source current sent from source electrode (red circles in right cartoon). Red: received electrical voltage using receiver electrodes (blue circles in right carton).

Ratio between source and received amplitude, reflecting the seafloor resistivity, is simply recognized in the received field because the source amplitude is almost constant. In other word, longer time series of received electric field roughly shows variation of seafloor resistivity. Fig. 6.2.3 indicates the wave form of source and received field. Each peak indicates the signal at each landing points of ROV (i.e., horizontal compressed wave form of Fig.6.2.2). At the beginning, the source amplitude is almost same between the sections “A” and “B” in Fig. 6.2.2. However, the amplitude of received electric field shows great difference between two sections. At “A”, the ROV was still far from the seafloor and surrounded by seawater. On the other hand, at “B”, the ROV was landed on the seafloor. The seafloor should be resistive than the seawater, and the observed difference between “A” and “B” is reasonable. We conclude that our new system can detect the seafloor resistive properly.

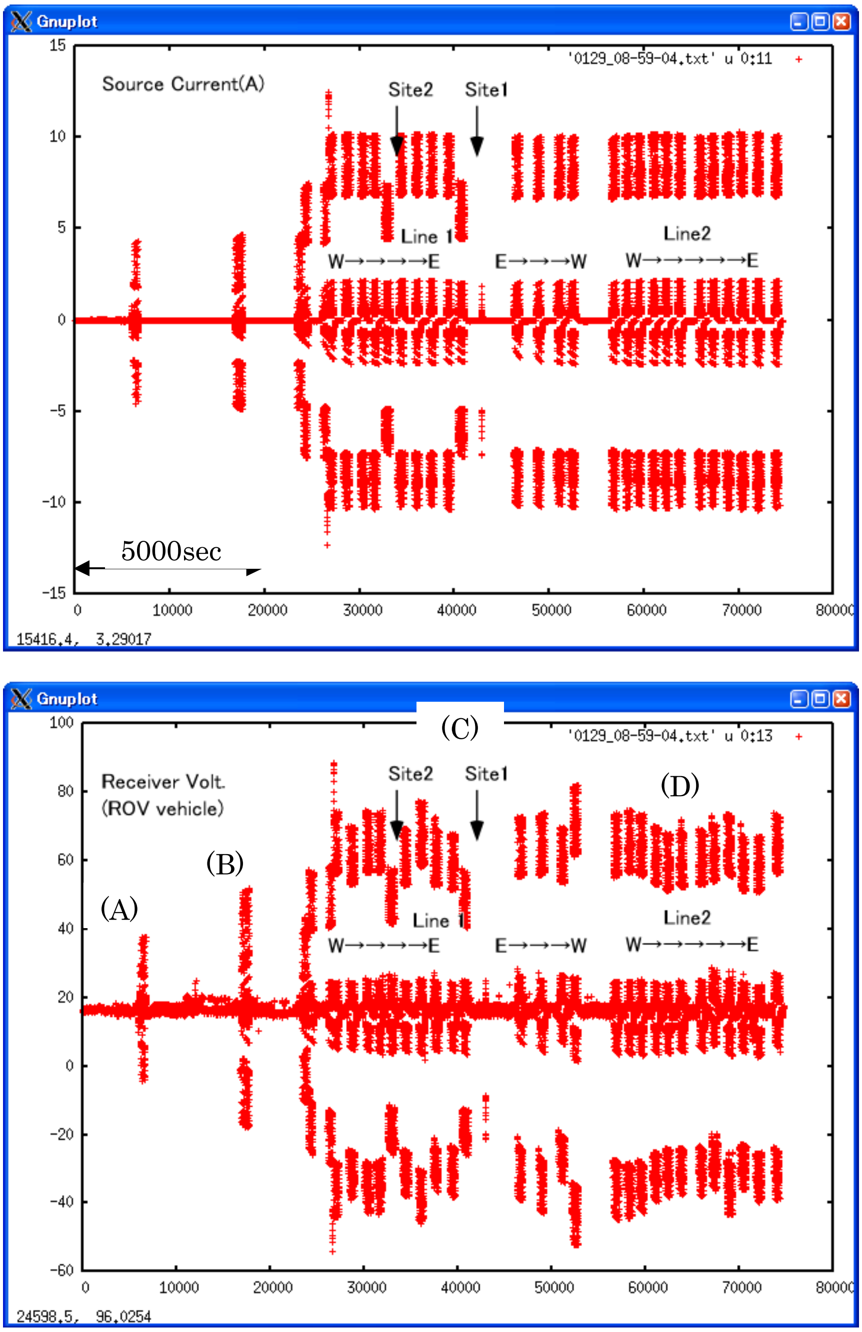


Fig. 6.2.3. Raw time-series of source current and received electric field.

Along the lines 1 and 2, we found the amplitude variation of received electric field. It should reflect the resistivity variation of seafloor. Especially, the amplitudes around Site 1 and at the center of line 2 (sections "C" and "D" in Fig. 6.2.3) are relatively low. These areas are included in the SMS zone (Fig. 6.2.1). Therefore, roughly to say, the seafloor resistivity in the SMS area seems to be relatively lower than one in the surrounding area. Note that the amplitude close to Site 2 is also low. It implies a low resistive spot in the chimney zone (Fig. 6.2.1). We infer more complicated distribution of conductive materials near the seafloor than the geological features reported by JOGMEC. Further data analysis will give us a quantitative distribution of seafloor resistivity and degree of the IP effect

At the operation 4, we tested the continuous mapping of seafloor resistivity. Although the quantitative analysis was not done, the qualitative distribution of apparent resistivity is obtained, which indicates similar trend obtained by stationary observation at the operations 1-3. We conclude that the continuous resistivity measurements with swimming ROV at a low altitude are effective for mapping seafloor resistivity. We also found that obtained resistivity at high altitude (>5m) is similar to seawater resistivity, and conclude that such a high altitude condition gives us less information of seafloor. In other words, our system called as Remior has a penetration depth of about 5m from seafloor.

Two CUBES, the seafloor receivers, successfully recorded the signal from ROV. The maximum separation distance between source ROV and CUBE was about 70m. The data example is shown in Fig. 6.2.4. It allows us to image deeper resistivity structure in this area. We could deploy and recover two CUBEs with only one ROV diving. Further diving allows us a much number of seafloor receivers (e.g. 10 or more) for higher spatial resolutions. We confirmed that our small seafloor receiver scan be handled by ROV easily.

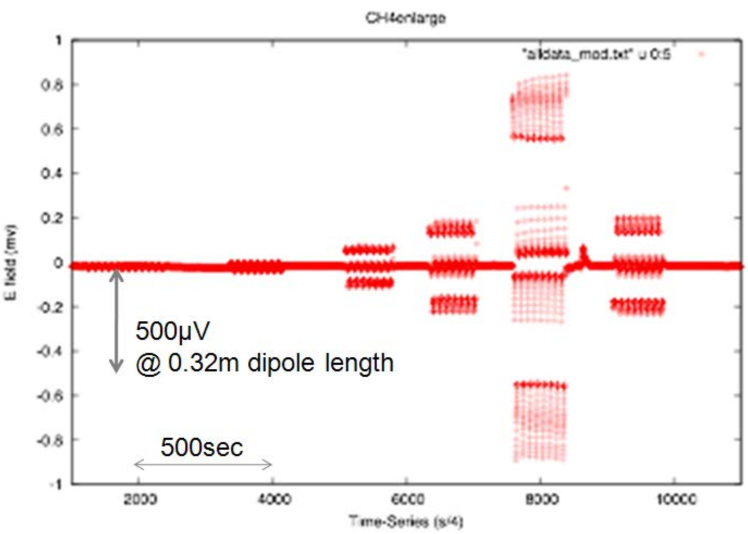


Fig.6.2.4. Example of received time series by CUBE.

6.3. OBEM recovery

We tracked the OBEM's positions by SSBL system of R/V KAIREI because the communication frequency of our acoustic system matched ship's SSBL system. They started ascending with about 15 minutes after sending the acoustic release signal. We also could track the OBEM position while they were ascending. In this cruise, we successfully recovered five OBEMs in this cruise. It is easy to find the surfaced OBEM easily because the precise surface time by SSBL system.

All recovered OBEMs recorded data with 8Hz sampling rate. After finishing recovery operation, the time difference between the OBEM's clock and the laptop pc synchronized by NTP server unit was measured. Their clock compare results are shown in Table 6.3.1. We could obtain enough quality EM data over 40 days including some geomagnetic signals.

Site ID	Recovery data (JST)	Clock set time (JST)	Clock compare time (JST)	Time difference (sec)
Site 1	2011/1/28	2010/12/16 16:35:57	2011/1/28 18:42:46	+3.881 sec
Site 3	2011/1/29	2010/12/11 16:53:55	2011/1/29 07:27:14	+2.92 sec
Site 4	2011/1/28	2010/12/10 14:46:47	2011/1/28 12:03:13	+5.774 sec
Site 5	2011/1/28	2010/12/13 17:52:39	2011/1/28 10:09:31	+5.378 sec
Site 6	2011/1/28	2010/12/17 15:55:35	2011/1/28 10:04:03	+4.076 sec

Table 6.3.1 Clock information of each OBEM.

7. Notice on Using

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

8. Acknowledgement

The onboard scientific party thanks the captain, crews and technicians of RV Kairei and operators of ROV Kaiko 7KII. Officers and researchers in JAMSTC greatly helped our cruise, especially, Dr. Noriko Tada, Dr. Masa Kinoshita and Mr. Ken Yatsu. Dr. Akira Saito and Ms. Keiko Nakayama supported student's works in this cruise.