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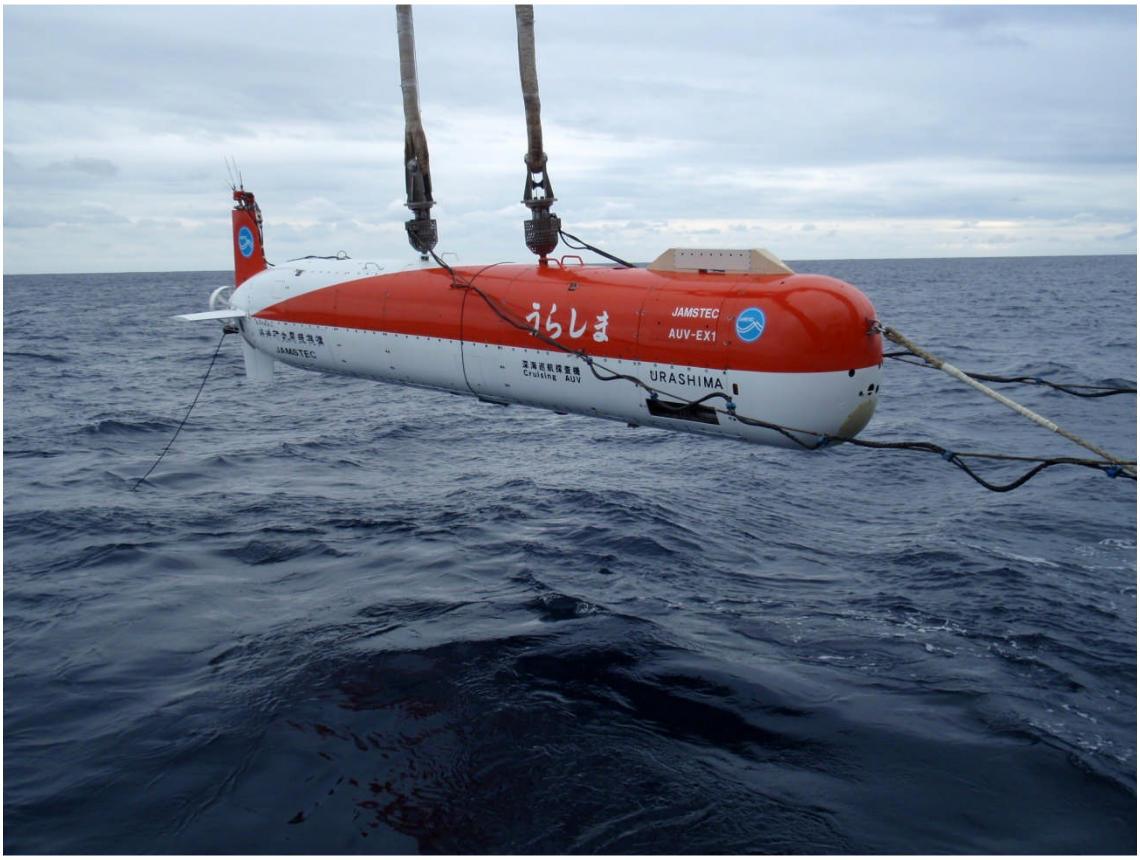
R/V Yokosuka Cruise Report
YK11-11



Izu-Bonin area

(Bayonnaise knoll and the surrounding area)

December 9th – December 19th, 2011

Japan Agency for Marine-Earth Science

and Technology (JAMSTEC)

Contents

1. Cruise Information

Cruise ID:	YK11-11
Name of vessel:	R/V Yokosuka
Title of the cruise:	AUV Urashima Research Dives (Izu-Bonin Area)
Chief scientist:	Tada-nori Goto [Kyoto University]
Cruise period	December 9th - December 19th, 2011
Ports of call	Naha port, Okinawa – JAMSTEC Yokosuka pier
Research area	Izu-Bonin area (Bayonnaise knoll and the surrounding area)
	Water Depth： 600m～1,500m
	Area surrounded by the following LAT/LON.
	31° 30.0'N 139° 30.0'E ,32° 20.0'N 139° 30.0'E
	32° 20.0'N 140° 10.0'E ,31° 30.0'N 140° 10.0'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 AUV Urashima. The main purposes of this cruise are summarized below:

Representative of the Science Party

Theme 1: Tada-nori Goto (Kyoto University)

Theme 2: Tamaki Ura (University of Tokyo)

Title of proposal

Theme 1: Development of AUV-based marine CSEM survey system and the test experiments around a hydrothermal area

Theme 2: Magnetic survey for revealing the subsurface structure of hydrothermal deposits

2. Researchers and Crews

Onboard Scientists

Chief Scientist	TADA-NORI GOTO [Univ. Kyoto]
	KIM KANGSOO [Univ. Tokyo]
	TAKASHI KASAYA [JAMSTEC]
	NOBUHIRO ISEZAKI [Univ. Tokai]
	SHIGEO MATSUDA [CLOVERTECH Inc.]
	NAOTO IMAMURA [Univ. Kyoto]

R/V YOKOSUKA Crews

Captain	SHINYA RYONO
Chief Officer	TATSUO ADACHI
2nd Officer	TOMOYUKI TAKAHASHI
3rd Officer	TSUBASA SHIOJIMA
Chief Engineer	KAZUHIKO KANEDA
1st Engineer	KIMIO MATSUKAWA
2nd Engineer	KENTA IKEGUCHI
3RD Engineer	KOICHI HASHIMOTO
Chief Radio Officer	HIROYASU SAITAKE
2nd Radio Officer	YOHEI YAMAMOTO
3rd Radio Officer	MAI MINAMOTO
Boat Swain	YOSHIKANE ODA
Able Seaman	SHUJI TAKUNO
Able Seaman	NOBUYUKI ICHIKAWA
Able Seaman	MASANORI OHATA
Able Seaman	SAIKAN HIRAI
Sailor	JIRO HANAZAWA
Sailor	YOSHIHIRO OGAWA
No1.Oiler	KAZUAKI NAKAI
Oiler	KEITA FUNAWATARI
Oiler	SOTA MISAGO
Assistant Oiler	TOSHINORI MATSUI
Assistant Oiler	EIJI ARATAKE
Assistant Oiler	KAZUHO MURASE

Chief Steward	TOMIHISA MORITA
Steward	KAZUHIRO HIRAYAMA
Steward	TORU WADA
Steward	MASANAO KUNITA
Steward	NAKAMICHI KANDA

AUV- URASHIMA Operation Team

Operation Manager	TOSHIAKI SAKURAI
1st Submersible Staff	MASANOBU YANAGITANI
1st Submersible Staff	KEITA MATSUMOTO
2nd Submersible Staff	AKIHISA ISHIKAWA
2nd Submersible Staff	TAKUM A ONISHI
3rd Submersible Staff	HITOMI IKEDA

NME Marine Technician

Marine Technician	MORIFUMI TAKAESU
Marine Technician	SATOMI MINAMIZAWA

3. Introduction

3.1 Sumary of cruise

1) Development of AUV-based marine CSEM survey system and the test experiments around a hydrothermal area

Tada-nori Goto

We developed AUV-based controlled-source electromagnetic (CSEM) survey system which can be applied to exploration of seafloor massive sulphide. Our system can be attached to AUV "Urashima" and other various platforms, and allows us to image sub-seafloor resistivity structure with depth of several tens to hundreds meters. In the Bayonnaise knoll, our target in this cruise, Japan Oil, Gas and Metals National Corporation (JOGMEC) found seafloor massive sulphide (SMS) deposits, whose detailed distribution on the seafloor has been reported. In general, the metallic deposits indicate low resistivity. If the seafloor resistivity distribution derived by our survey system is similar to the SMS distribution, we can conclude that the marine CSEM survey with AUV is effective to evaluate spatial distribution and the approximate thickness of SMS.

As a result, we carried out the experiment with one dive of AUV Urashima. We attached the transmitter for artificial electromagnetic singals to the AUV. We also deployed and retrieved the six ocean-bottom electro-magnetometers (OBEM) as receivers. On the basis of preliminary analysis, the electromagnetic field transmitted from the AUV was successfully received by the ocean bottom receivers in and around the hydrothermal area. The data will give us information about the three-dimensional resistivity structure around the SMS.

2) Magnetic survey for revealing the subsurface structure of hydrothermal deposits

Kangsoo Kim

Recent extensive marine surveys on the Izu-Ogasawara island arc and the Okinawa trough have revealed the existence of many Kuroko-type deposits accompanying seafloor hydrothermal activity on the volcanic front and the backarc rift zone. The metal content of hydrothermal sulfide samples from these island arc deposits is characterized by the enrichment of Au, Ag and Zn compared with those from mid-ocean ridges. Understanding of the structure of these deposits and the processes of their formation is necessary not only for our geoscientific interests in these phenomena, but also for their economic importance.

The magnetic field measurement has been considered as one of the means to approach the subsurface structure of hydrothermal deposits. In this cruise, we investigate the Bayonnaise knoll caldera, a silisic caldera on the rift zone of the Izu-Ogasawara island arc, using an Autonomous Underwater Vehicle (AUV) "Urashima" developed by JAMSTEC. Focusing the survey on the known sites of sulfide deposit in the caldera, we aim to reveal the magnetic structure of these areas in relation to the hydrothermal deposit.

3.2 Cruise schedule and operations

Dec. 9 (Fri.)
R/V Yokosuka left the Naha port, Okinawa at 10:00 AM (JST).
PM: transit

Dec. 10 (Sat.)
AM: transit
PM: Instrument Test of AUV Urashima off the Amami Ohshima Island.
We brought the AUV below the sea surface and adjusted the balance weight. Then transmitting of artificial electric current from the CSEM instrument was examined. These tests were successfully done, but the LED light indicating current transmitting did not work. The cause was not LED light but was inferred as low power for LED.

Dec. 11 (Sun.)
Transit to the survey area, the Bayonnaise knoll, Izu-Bonin area.
During the transit, we adjusted the LED light and the problem was fixed.
Six OBEMs were ready for deployment.

Dec. 12 (Mon.)
We arrived at the survey area before noon.
From13:00, deployment of six OBEMs was started. All of them were landed on seafloor in the Beyonnaise caldera. The six OBEMs were settled in a area with diameter of about 0.4 mile.
We also examined the current transmitter of CSEM instrument on AUV Urashima. The AUV was on the deck of vessel, and only the current electrodes were set below the sea surface. The LED light for indicator worked well and the current amplitude was about +/- 30A.
We conducted the multi-beam bathymetry mapping.

Dec. 13(Tue.)
AUV Urashima dived into the Beyonnaise caldera (#140). The AUV could send artificial current signal to the OBEM. Five profiles, with each length of about 0.6 mile, were achieved during this dive. On the profiles, the altitude of AUV was kept with 60-100m, and the cruising speed was about 2 knots. The stable and speedy cruise ability of AUV Urashima allowed a quick survey along the profiles: start of first profile at 9:00 – end of fifth profile at 14:00. The current shooting was done every 30 sec, and total number of shot points was about 200. Then the AUV was safely retrieved. After the retrieval, we checked the data for transmitting signal and confirmed the successful operation with amplitude of +/- 20

to 25 A. This was the first CSEM transmitting experiment using AUV in the world. The side-scan data obtained by AUV was also checked, in which the rough seafloor topography, seems to be chimneys, were confirmed. After the operations, we obtained the sub-bottom profiling data of the sediment layer in the caldera by using R/V Yokosuka.

Dec. 14 (Wed.)
Rough sea state did not allow us the dive of AUV.
Instead, we decided the location of OBEM by using acoustic ranging from the vessel.

Dec. 15 (Thu.)
Dive of AUV Urashima to the Beyonnaise knoll was carried out (#141). We obtained the magnetic anomaly mapping around the knoll. For this experiment, we attached the three-component fluxgate magnetometers and the proton magnetometer. The six-hour cruise with total survey length of about 12 miles was achieved, and the magnetic survey data around the southern side of Beyonnaise caldera, including the Hakurei SMS site, was obtained. Unfortunately, strong water current near the seafloor interrupted the cruise and the whole of planned cruise line was not finished.

Dec. 16 (Fri.)
Due to the high wave condition, we gave up the dive of Urashima and started to recovery the OBEMs. The acoustic release commands were successfully received by OBEMs, and four of them were retrieved safely. Due to the worse weather condition, we stopped the recovery work of OBEMs and left the survey area.

Dec. 17 (Sat.)
Due to the rough sea state, we stayed off the Aogashima Island. We had an onboard scientific seminar. The lecture includes research purposes, introduction of the Aogashima Island, etc.

Dec. 18 (Sat.)
We recovered the remained two OBEMs in the survey area. After the retrieval, we checked the data obtained by OBEMs, and confirmed that they recorded the electromagnetic signals from AUV.
Then, we carried out the dive of AUV Urashima for mapping the magnetic anomalies (#142). After three-hour survey and we retrieved the AUV on the vessel. The all instruments were successfully recovered, and started the transit to JAMSTEC.

Dec. 19 (Mon.)
AM: R/V Yokosuka arrived at the JAMSTEC pier.

3.3. Shipboard Log

日付 Date	時間 Local Time	内容 Note	特記事項 Description	本船位置／気象／海象 Position/Weather/Wind/Sea
09-Dec-11		**Sail out, proceeding to research area**		12/09 12:00 (UTC+9h)
	08:00	boarded		26-21.8'N, 127-35.6'E
	10:00	let go all shore line, left NAHA		West off Okinawa - honto
	13:00	scientific meeting		Overcast
				North-7 (Near gale)
				5 (Sea rough)
				4 (Moderate average)
				Visibly: 8'
10-Dec-11		**Proceeding to research area**		12/10 12:00 (UTC+9h)
	11:00	arrived at AUV-URASHIMA operation test area		28-01.3'N, 129-22.8'E
	13:00	commenced checking over the electlic current cable, which was passed safty level		Southeast off Amami-Oshima
	14:31	launched AUV-URASHIMA		Overcast
	15:35	recovered		North-4 (Moderate breeze)
	16:00	Finished AUV-URASHIMA operation test		3 (Sea slight)
	16:50	commenced proceeding to research area (Bayonnaise)		2 (Low swell long)
	18:00	scientific meeting		Visibly: 10'
11-Dec-11		**Proceeding to research area**		12/11 12:00 (UTC+9h)
	09:00-09:30	practiced fire drill		29-52.8'N, 133-57.1'E
	16:40-17:00	The Kom'pira-san Ceremony, praying for a safe and successful cruise		Southward the cope of Muroto
				Overcast
				NNW-3 (Gentle breeze)
				3 (Sea slight)
				2 (Low swell long)
				Visibly: 10'
12-Dec-11		**Deploy OBEM**		12/12 12:00 (UTC+9h)
	11:20	arrived at Izu Ogasawara research area (Bayonaise)		31-54.5'N, 139-42.5'E
	11:28	released XBT @ 31-51.1890'N, 139-40.0989E		Southward of Aogashima
	13:19	deployed OBEM#1 at 31-57.35'N, 139-44.41'E		Fine but cloudy
	14:11	deployed OBEM#2 at 31-57.28'N, 139-44.41'E		NW-3 (Gentle breeze)
	15:00	deployed OBEM#3 at 31-57.39'N, 139-44.53'E		2 (Sea smooth)
	15:45-16:45	Carried out above OBEM#3 calibration (31-57.462'N, 139-44.4919'E)	depth:810m	1 (Low swell short)
	16:45	deployed OBEM#4 at 31-57.32'N, 139-44.53'E		Visibly: 10'
	17:27	deployed OBEM#5 at 31-57.50'N, 139-44.65'E		
	18:12	deployed OBEM#6 at 31-57.43'N, 139-44.65'E		
	19:05-20:40	Carried out MBES site survey		
13-Dec-11		**AUV-URASHIMA dive 140**		12/13 12:00 (UTC+9h)
	06:00	arrived at dive point		31-57.4'N, 139-44.8'E
	07:23	hoisted up URASHIMA		Southward of Aogashima
	07:30	launched URASHIMA		Fine but cloudy
	07:31	started URASHIMA#140 dive operation		NNW-4 (Moderate breeze)
	08:58	started URASHIMA line survey		3 (Sea slight)
	14:13	finished URASHIMA line survey		2 (Low swell long)
	14:32	refloated URASHIMA		Visibly: 10'
	15:14	hoisted up URASHIMA		
	15:22	recovered		
	16:59-19:59	carried out SBP survey		
	18:00	scientific meeting		
14-Dec-11		**Calibrated OBEM**		12/14 12:00 (UTC+9h)
	06:00	arrived at dive point		31-57.6'N, 139-44.6'E
	09:30	suspended AUV-URASHIMA submergence dueto large swell		Southward of Aogashima
	11:00	commenced calibration for OBEM		Fine but cloudy
		OBEM#1 (31-57.4229'N, 139-44.3875'E)	depth: 820m	NNW-4 (Moderate breeze)
		OBEM#2 (31-57.3560'N, 139-44.4470'E)	depth: 840m	3 (Sea slight)
		OBEM#3 (31-57.4508'N, 139-44.5496'E)	depth: 830m	4 (Moderate average)
		OBEM#4 (31-57.4318'N, 139-44.5120'E)	depth: 830m	Visibly: 12'
		OBEM#5 (31-57.5019'N, 139-44.6448'E)	depth: 820m	
		OBEM#6 (31-57.4230'N, 139-44.6567'E)	depth: 820m	
	14:33	Finished calibration of OBEM		

YK11-11 Shipboard Log
(09. Dec, 2011 - 19. Dec, 2011)

Bayonnaise caldron

日付 Date	時間 Local Time	内容 Note	特記事項 Description	本船位置／気象／海象 Position/Weather/Wind/Sea
15-Dec-11		**AUV-URASHIMA dive 141**		12/15 12:00 (UTC+9h)
	06:00	arrived at dive point		31-57.4'N, 139-44.6'E
	07:33	hoisted up URASHIMA		Southward of Aogashima
	07:39	launched URASHIMA		Cloudy
	08:23	started URASHIMA#141 dive operation		WNW-3 (Gentle breeze)
	09:13	started URASHIMA line survey		2 (Sea smooth)
	15:12	finished URASHIMA line survey		1 (Low swell short)
	15:28	refloated URASHIMA		Visibly: 10'
	15:55	hoisted up URASHIMA		
	16:01	recovered		
	18:00	scientific meeting		
16-Dec-11		**Recovered OBEM**		12/16 12:00 (UTC+9h)
	06:00	arrived at dive point		31-57.3'N, 139-44.8'E
	06:30	suspended AUV-URASHIMA submerdence dueto large swell		Southward of Aogashima
	08:41	recovered OBEM#1		Overcast
	09:45	recovered OBEM#3		West-6 (Strong breeze)
	11:45	recovered OBEM#5		5 (Sea rough)
	13:20	recovered OBEM#4		3 (Moderate short)
				Visibly: 8'
17-Dec-11		**Suspended AUV-URASHIMA dive**		12/17 12:00 (UTC+9h)
	08:00	suspended AUV-URASHIMA submergence dueto large swell		32-18.6'N, 139-41.6'E
	10:00-11:10	on board seminar		Southward of Aogashima
				Cloudy
				NW-6 (Strong breeze)
				5 (Sea rough)
				4 (Moderate average)
				Visibly: 10'
18-Dec-11		**Recovered OBEM/ AUV-URASHIMA dive 142**		12/18 12:00 (UTC+9h)
	06:58	recovered OBEM#5		31-57.5'N, 139-43.4'E
	08:08	recovered OBEM#2		Southward of Aogashima
	08:45	hoisted up URASHIMA		Cloudy
	08:52	launched URASHIMA		WNW-5 (Fresh breeze)
	08:55	started URASHIMA#142 dive operation		4 (Sea moderate)
	09:54	started URASHIMA line survey		3 (Moderate short)
	13:27	finished URASHIMA line survey		Visibly: 10'
	13:47	refloated URASHIMA		
	14:16	hoisted up URASHIMA		
	14:24	recovered		
	15:00	left reserch area for YOKOSUKA		
19-Dec-11		**Arrived at YOKOSUKA**		
	09:00	scientists disembark from YOKOSUKA		
		finished YK11-11 cruise		

4. Research Objectives

4.1. AUV-based marine CSEM survey

The recent growth of world-wide requirement of metals demands advanced explorations for finding metal mine and deposits. Especially, the submarine massive sulfides (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 autonomous underwater vehicle (AUV) as shown in Fig. 4.1.1. In our concept, the AUV-based CSEM survey system consists of two instruments; a transmitter and receivers attached to AUV and seafloor receivers. If the cruising altitude of AUV can be kept with a lower level (< 20m), the former can solely measure the seafloor resistivity with sounding depth of several meters, which is used for the resistivity mapping. However, a high cruising altitude (>20m) will give us little information about the seafloor resistivity. The later seafloor receivers (ocean-bottom electromagnetometers=OBEMs or ocean bottom electrometers=OBEs) give us a larger source-receiver separation, and allow us to obtain the deeper images below the seafloor.

In this cruise, we examine our CSEM system to image the sub-seafloor resistivity structure below the SMS deposits in the Bayonnaise 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 AUV gives us information about SMS.

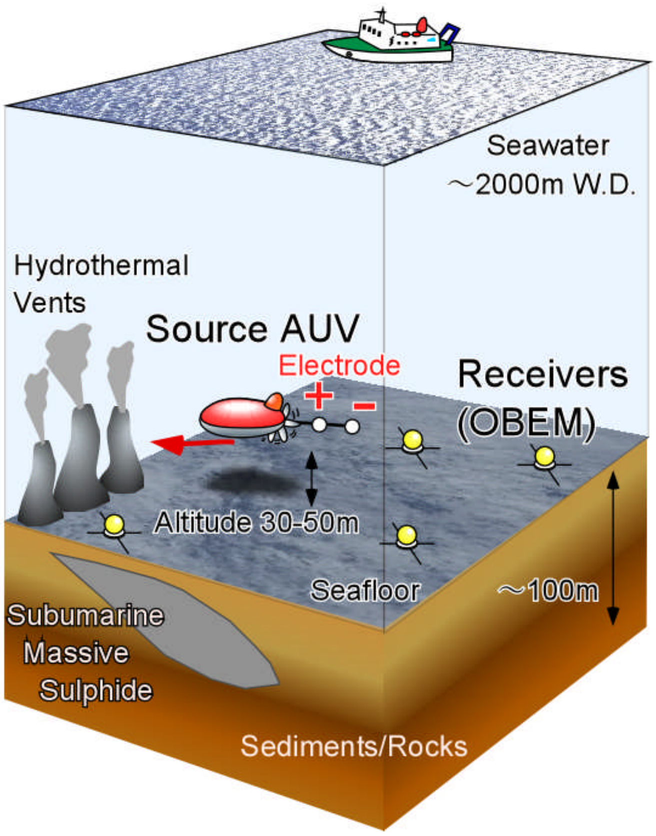


Fig. 4.1.1. Schematic drawing of AUV-based marine CSEM survey.

4.2. 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 Bayonnaise caldera. This is very important to consider the magmatism of Izu-Bonin arc including the Bayonnaise caldera.

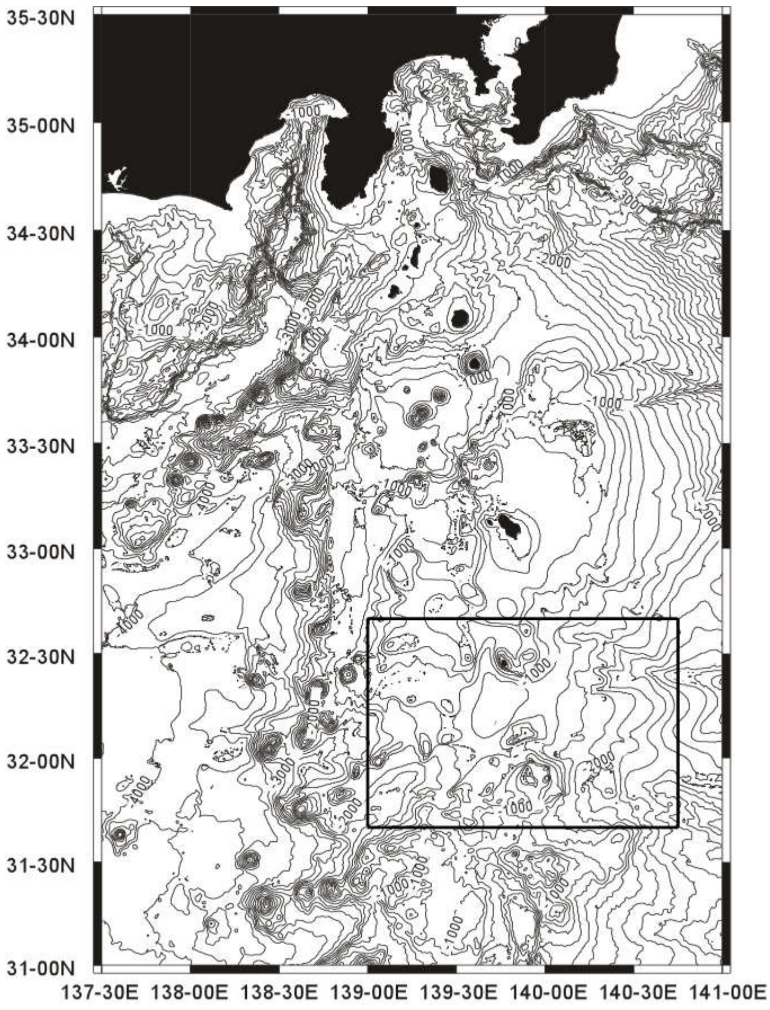


Fig. 4.2.1. Survey Area of YK11-11 cruise

4.3. AUV-based magnetic survey

In the magnetic survey of YK11-11 cruise, we have three targets as follows:

1) The Hakurei sulfide deposit in the Bayonnaise knoll caldera, located in the southeastern margin of the caldera floor. To obtain the magnetic field data at a high resolution, the survey lines was arranged densely (~120 m apart) and the depth of the vehicle was taken as deep as possible (~80 m above the seafloor).

2) The southewestern part of the Bayonnaise knoll caldera, where the deep-sea magnetic survey has not yet been conducted. Revealing the magnetic structure of the whole caldera is expected by compiling the result of the previous reaseah cruises together (by the R/V Natsushima and the R/V Hakurei-maru No.2 in 2008).

3) The Sunrise sulfide deposit in the southeastern Myojin knoll caldera, located in the southeastern margin of the caldera floor. The magnetic feature of the Sunrise deposit is not known yet, as no deep-sea magnetic survey in the caldera has been conducted. Arranging several long survey lines going along the topographic contours we investigate from the southeastern to the southern margin of the caldera floor. Figure 4.3.1 shows 3-D perspective view of the seafloor in the survey site.

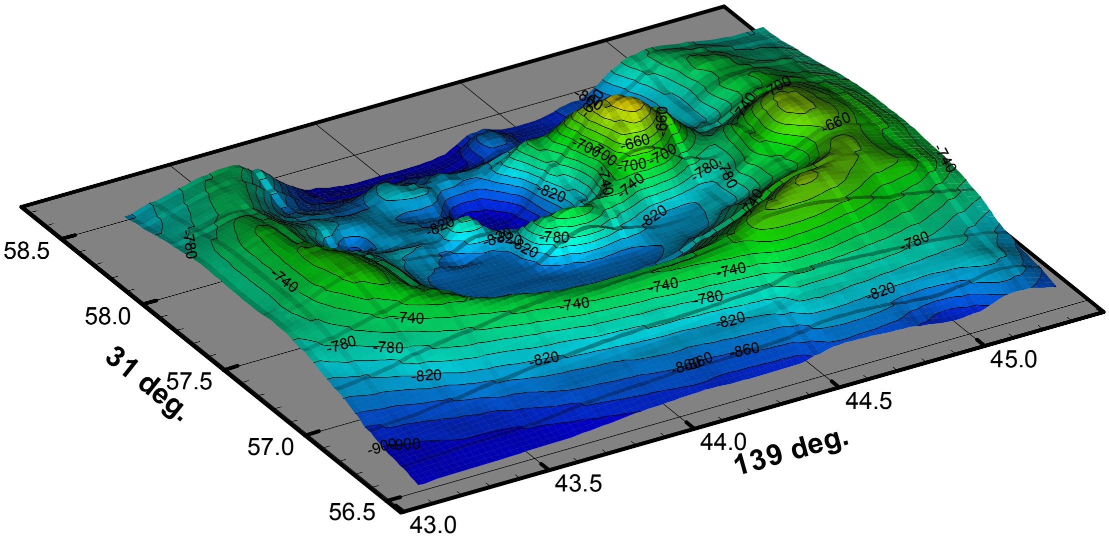


Fig.4.3.1 3-D perspective view of the seafloor in the survey site.

5. Instruments and Operation Methods

5.1 AUV-based marine systems

We developed AUV-based controlled-source electromagnetic (CSEM) survey system which can be applied to exploration of seafloor massive sulfide (Fig.5.1.1-5.1.3). Our system can be attached to AUV, and allows us to image sub-seafloor resistivity structure with depth of several tens to hundreds meters. We deployed six OBEM/OBEs for receivers. The OBEM (Fig.5.1.4) was a self pop-up type, developed in 2005. The acoustic communication allows the positioning of OBEMs on the seafloor and also to release the weight for lifting off toward the sea surface. The sampling rate is 8Hz. The resolutions of magnetic and electric field are 0.01nT and 0.01microV/m, respectively. The Ag-AgCl electrodes are attached at the tip of arm of OBEM, with length of 2m each. For details of OBEM, see the chapter 5.2.

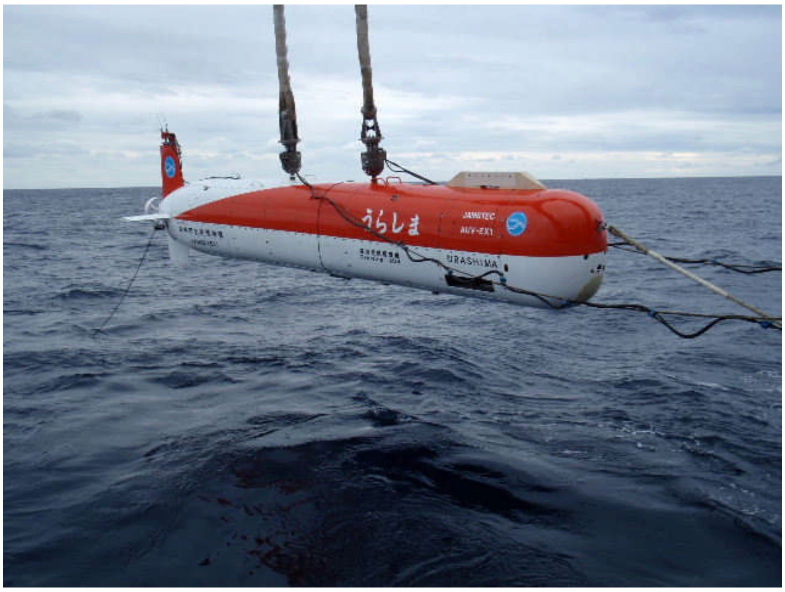


Fig.5.1.1. AUV Urashima (dive#140). Our new CSEM unit was installed in the payload. A source dipole antenna was attached as the tail.

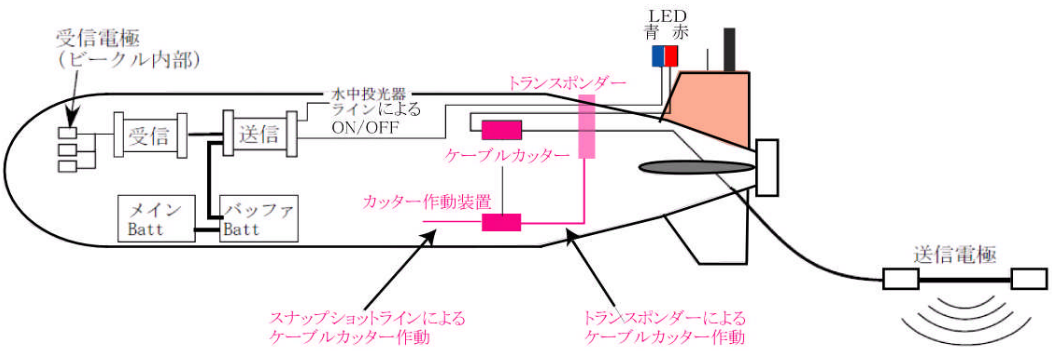


Fig. 5.1.2. Schematic view of AUV Urashima with the CSEM unit.

Fig. 5.1.3.　Photograph of the payload (from starboard side of AUV Urashima).
TX, RX and battery packs were arranged in the payload.

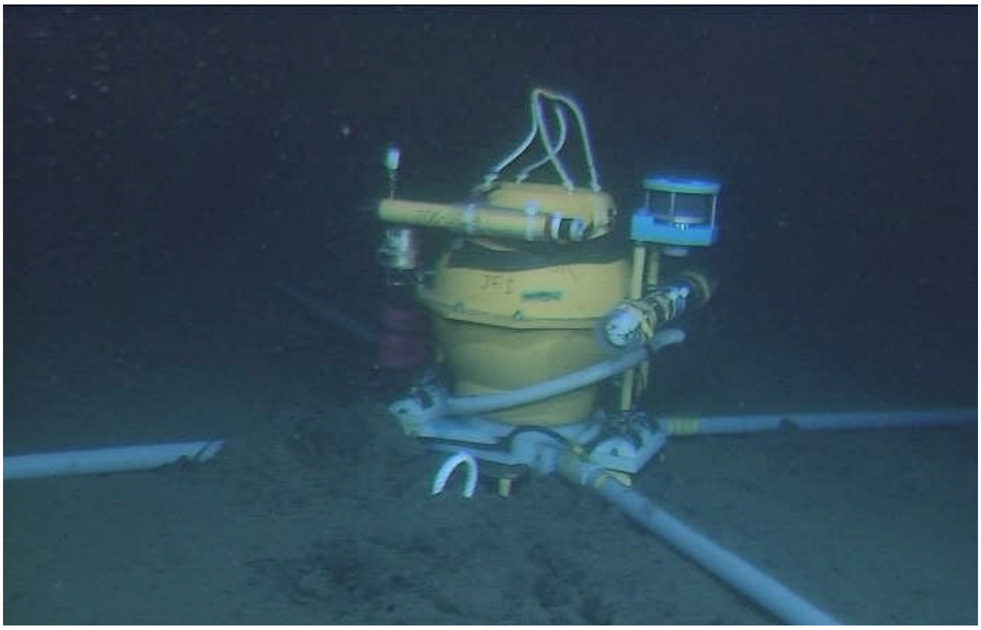


Fig.5.1.4. Ocean bottom electromagnetometer (OBEM).
The photograph was taken in 2005 by ROV Hyper-Dolphine.

5.2 Outline of OBEM systems

In this cruise, we used two type OBEM systems. The OBEM system with a high sampling rate was designed to investigate the crustal and mantle structure (Fig. 5.2.1). 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 5.2.2 shows the schematic diagram of the arm-folding system.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. 5.2.1). The salient characteristic of our system is its arm-folding mechanism, which facilitates and simplifies our onboard operations.For measuring the electric field, we used Ag-AgCl electrode mounted at the toe of each electrode arm.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.

Other type OBEM is designed to deploy around the rough topographic area(Fig.5.2.3). The electriccircuit, tilt meter and small fluxgate magnetometer are installed in analuminumpressure case. Ag-AgCl electrodes mounted at the toe of each short electrode arm are also used for electric field measurement. A common electrode is mounted on the top of buys. An acoustic release system is used same as former OBEM's releaser.

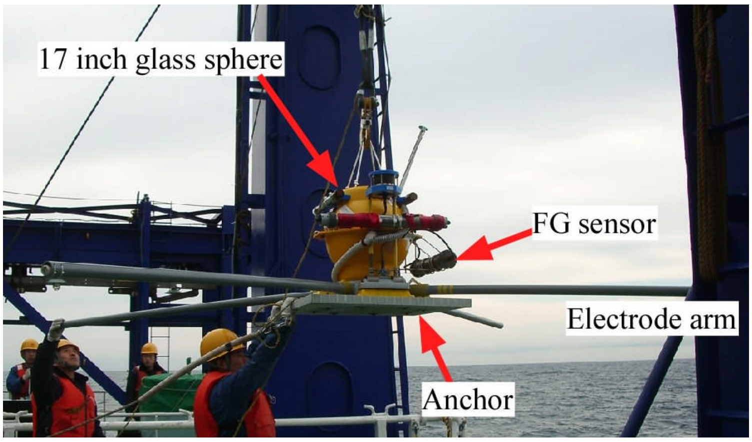


Fig. 5.2.1 Photo of an OBEM with the arm-folding system.

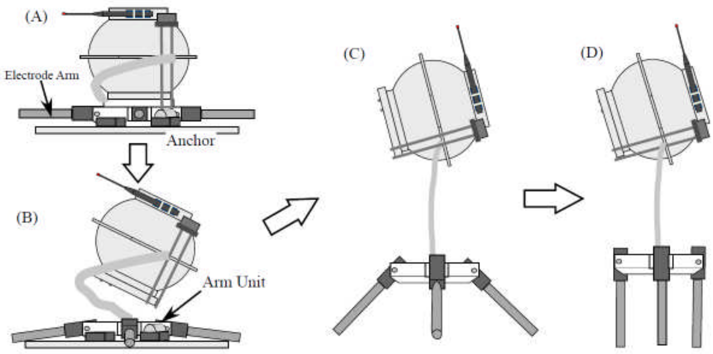


Fig. 5.2.2 Schematic diagram of the arm-folding system. After starting to pop up, the arm unit is picked up as the sphere ascends (Patent number of Japan: 4346605).

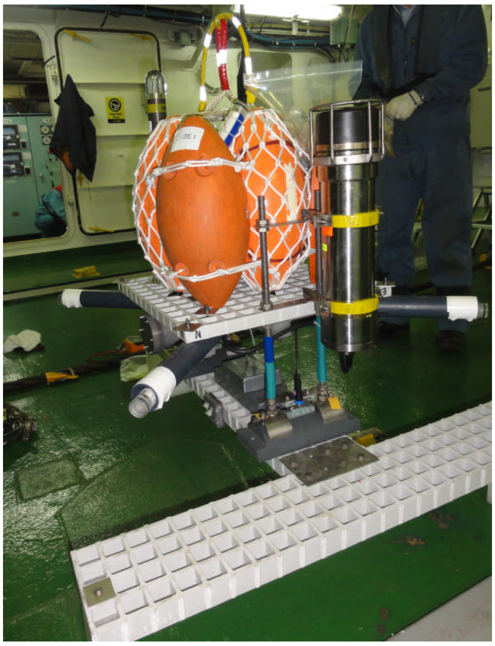


Fig. 5.2.3 Photo of new OBEM system designed to deploy around the rough topographic area.

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.

5.3 AUV-based Magnetic survey system (TakafumiKasaya. JAMSTEC)

The main features of the magnetic survey system are to measure three components and total intensity of the geomagnetic field with high resolution and high sampling rate on an AUV system. The magnetic surveysystem in this cruise consists of one 3-axis flux-gate magnetometer, oneOverhauser magnetometer and a main unit (Fig. 5.3.1). The three component magnetometer measure three components of the geomagnetic field and the overhauser magnetometer does total intensity of the geomagnetic field. The main unit controls the system, communicates data and commands with sensor units and external devices, and records data. Data sampling rate is 10 Hz for all the data except for total intensity of the geomagnetic field (4Hz to 10sec).

The 3-axis flux-gate magnetometer is attached to the inside of the top frame of the payload section of the AUV (Fig. 5.3.2). The Overhauser magnetometer was mounted on the top of the AUV (Fig. 5.3.2). Electric power for the magnetic exploration system was supplied from the AUV. Navigation data of the AUV were recorded in the main unit through a communication port.

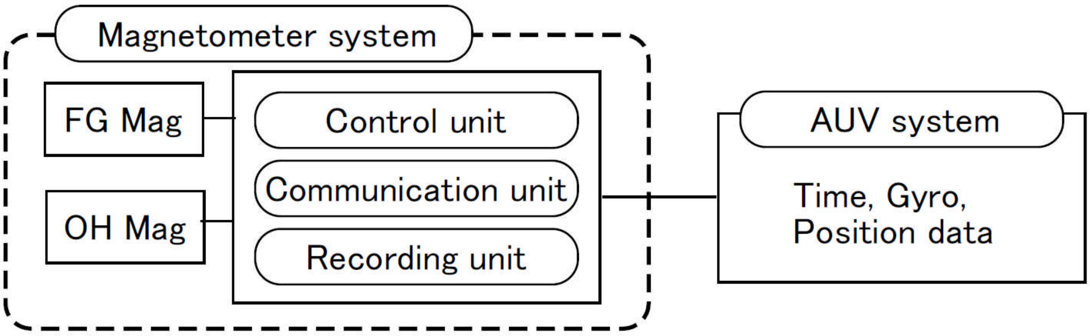


Fig. 5.3.1 Magnetic survey system for AUV exploration

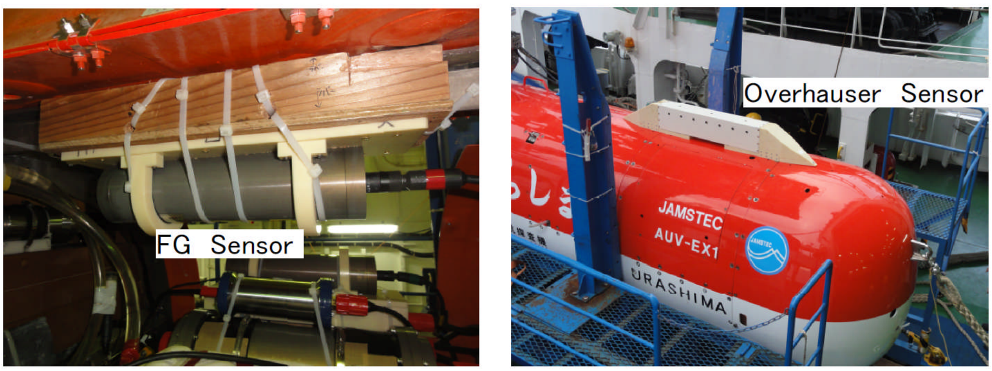


Fig. 5.3.2 Photo of each magnetometer mounted on an AUV Urashima.

6. Preliminary Results

6.1. AUV-based marine CSEM survey

The AUV dive #140 was carried out on Dec. 13, for examination of our new CSEM survey system. The water depth is about 700-800m. Due to the rough weather condition, we achieved only one dive of AUV in this cruise. Although such a limited survey time, we carried out five survey profiles around the OBEMs. Here, we report the preliminary results especially the first look of the observed data.

Figs. 6-1-1 and 6-1-2 indicate the site map and tow profiles with bathymetry. Each profile has a length of about 1000m, and the profile spacing is about 150m. The AUV can swim with altitude of 10-70m along the profiles. The cruising speed of AUV was about 2 knots. The source electrodes (copper wires) were towed behind the AUV, with dipole length of 10m. The direction and inclination of the source dipole were monitored by the magnetometer and tilt-meter attached to the dipole cable. During the cruise on profiles, AUV sent the artificial signal with every 30 second, so that the spacing of source points for CSEM was about 30m. The waveform of source signal was squared one, and the period was about 8 sec.

After the AUV dive (#140), all of OBEMs/OBEs were successfully recovered as described later, and recorded the signal from AUV. Fig. 6-1-3 indicates the received electric and magnetic field by OBEM 4 (Fig.6-1-1). In this case, the maximum amplitude of source current from AUV was about 50A (+/-25A), and the maximum received amplitude was about 0.05mV/m and 3nT, respectively. Especially, the received electric field was clear even if the source-receiver separation was about 500m. This means that the source waves from all of transmitting points will be received by all of six seafloor receivers. In this case, the number of transmitter-receiver combination exceeds to 900 because the number of transmitting points was about 150. It will give us information about the sub-seafloor resistivity structure around the SMS. For example, the forward calculation with assuming the realistic seafloor topography and constant resistivity of seafloor will be effective to discuss the distribution of anomalous resistive bodies below the seafloor. Then the three-dimensional CSEM inversion will give us a three-dimensional resistivity structure.

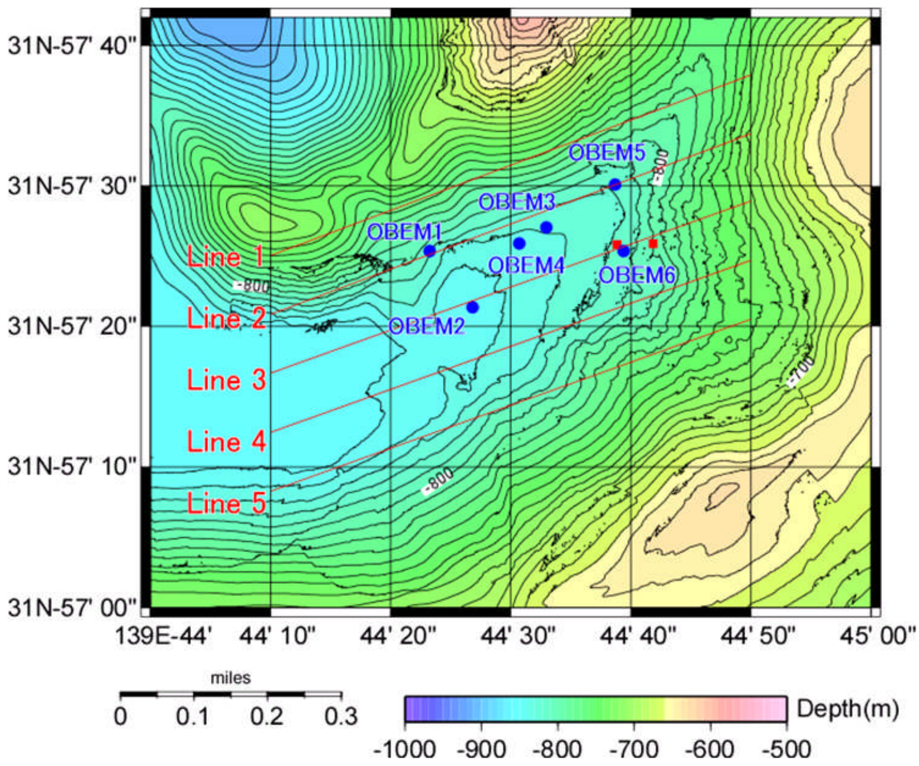


Figure 6-1-1 Site map with tow profiles. Blue circles: landing points of OBEMs . Red lines show the planned survey lines of AUV Urashima. Red square: OBEs at the KR11-02 experiments, roughly indicating the location of the Hakurei ore deposits.

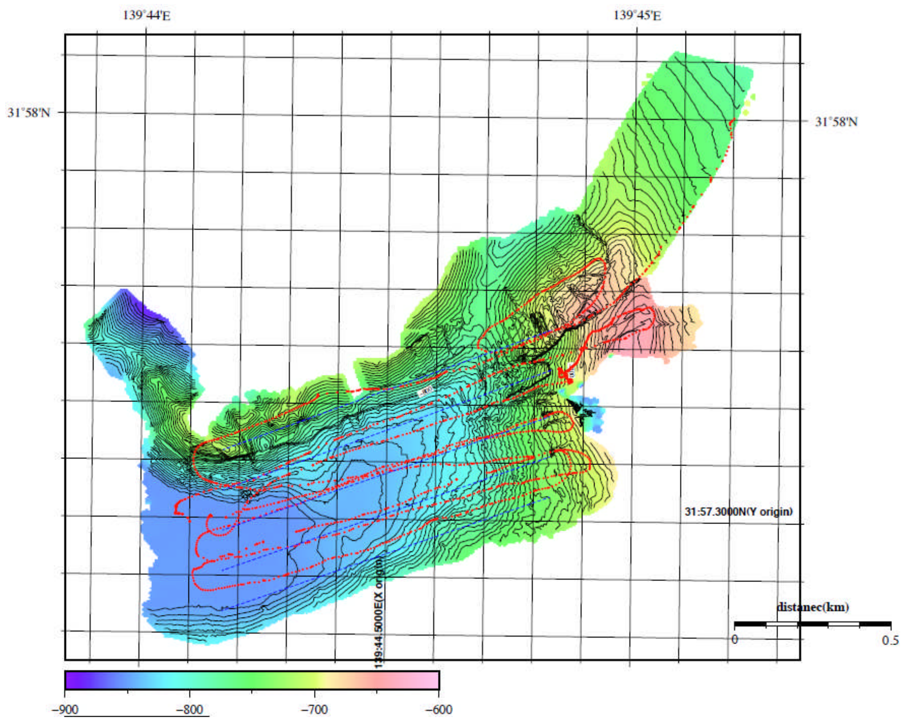


Figure 6-1-2 Actual cruise profile of AUV Urashima at the dive #140.

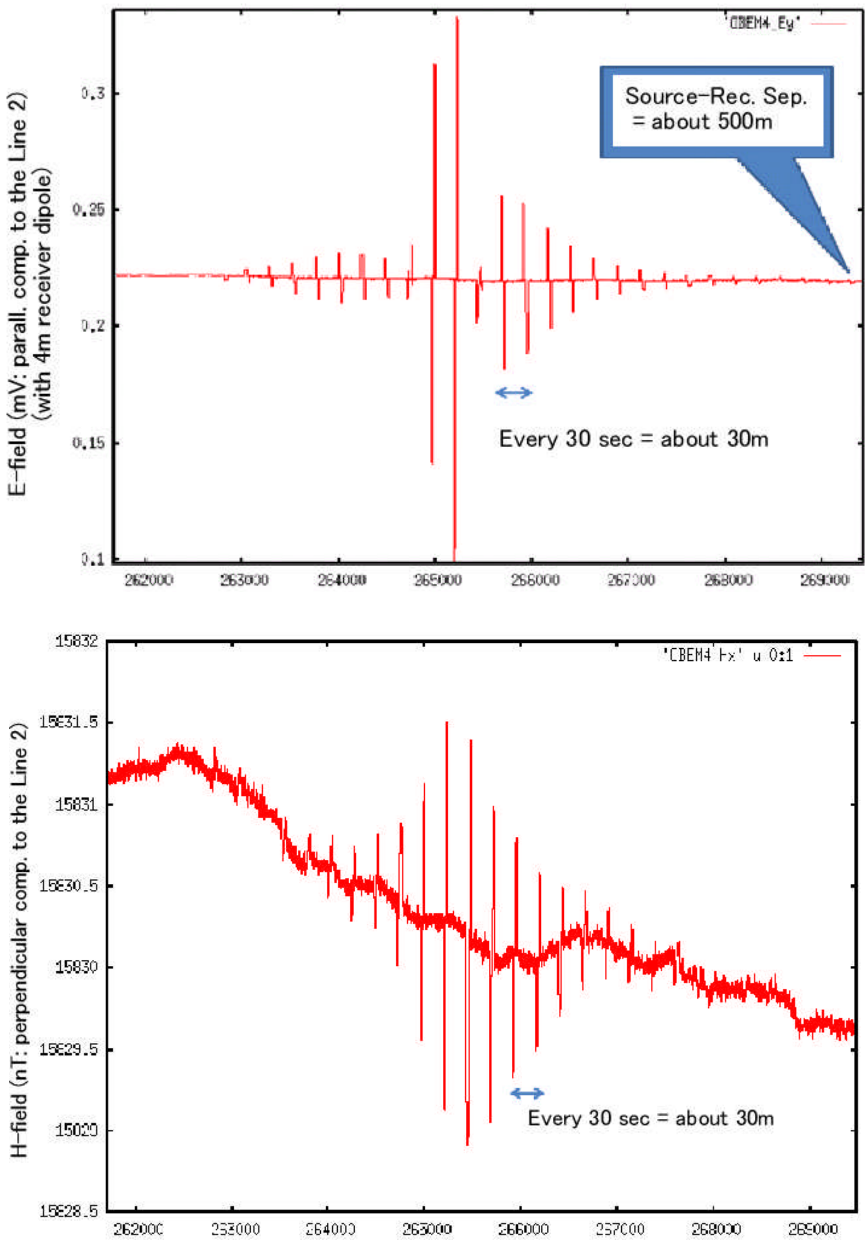


Fig. 6-1-3 Example of received EM data. Top: electric signal. Bottom: magnetic signal. Both are recorded by OBEM 4.

6.2. OBEM deployment and recovery

The OBEMs were launched from deck using A-frame for all stations (OBEM 1~6), and sunk by their own weights. The operations were quick and smooth. We tracked the OBEMs by acoustic signals and confirmed that the OBEMs were successfully settled on the seafloor. Then, the settled positions were determined by measurements of the slant ranges from calibration points using at least three positions surrounding the launched point for each OBEM (Tables 6-2-1 to 6-2-2, Figures 6-1-1 and 6-2-1). All of OBEMs were recovered in this cruise.

OBEM name	Latitude (sea floor)	Longitude (sea floor)	Depth
OBEM1	31°57.4229'N	139°44.3875'E	820m
OBEM2	31°57.3560'N	139°44.4470'E	840m
OBEM3	31°57.4508'N	139°44.5496'E	830m
OBEM4	31°57.4318'N	139°44.5120'E	830m
OBEM5	31°57.5019'N	139°44.6448'E	820m
OBEM6	31°57.4230'N	139°44.6567'E	820m

Table 6-2-1 Information of the OBEMs deployed during this cruise.

Calibration point name	Latitude (sea floor)	Longitude (sea floor)
Cal 1	31°57.27.5'N	139°44.10'E
Cal 2	31°57.35'N	139°44.10'E
Cal 3	31°57.27.5'N	139°44.10'E
Cal 4	31°57.27.5'N	139°44.10'E
Cal 5	31°57.27.5'N	139°44.10'E
Cal 6	31°57.27.5'N	139°44.10'E
Cal 7	31°57.27.5'N	139°44.10'E

Table 6-2-2 Information of the calibration point.

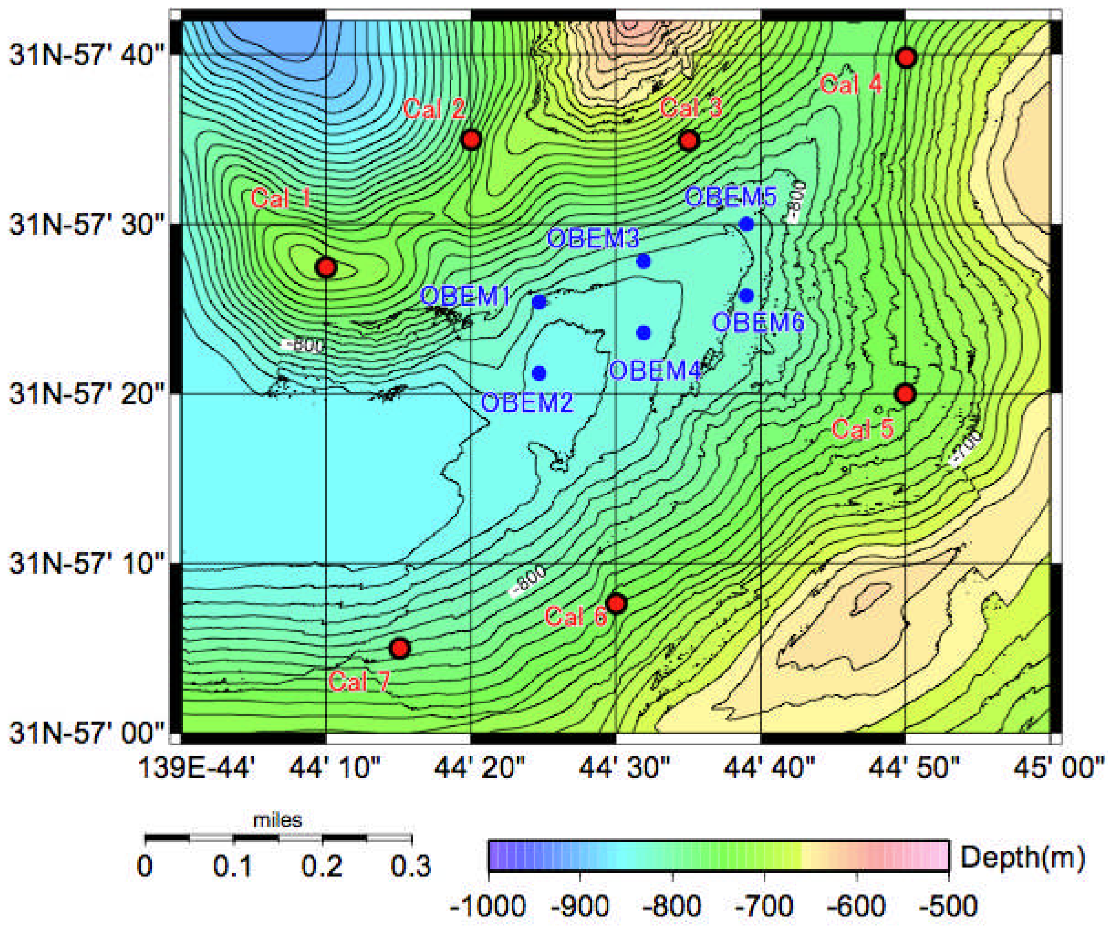


Figure 6-2-1 Information of calibration points (Cal 1~7). The settled positions of OBEMs were determined by measurements of the slant ranges.

6.3. AUV-based magnetic survey

In order to achieve the target of our magnetic survey stated in 4.3, we installed four 3-comp. fluxgate magnetometer and one overhauser magnetometer in the forebody payload space in Urashima (Fig. 6.3.1). As shown in Fig. 6.3.2, keeping its altitude from seafloor between 50 m ~ 150 m, Urashima covered the area of magnetic survey in Bayonnaise knoll caldera, tracking the survey trajectory prepared beforehand. While the planned total distance for survey is 20.65 nm, Urashima completed the survey tracking 12.36 nm long (Fig. 6.3.2).

Fig.6.3.1 FG magnetometer #3 installed in forebody patload space.

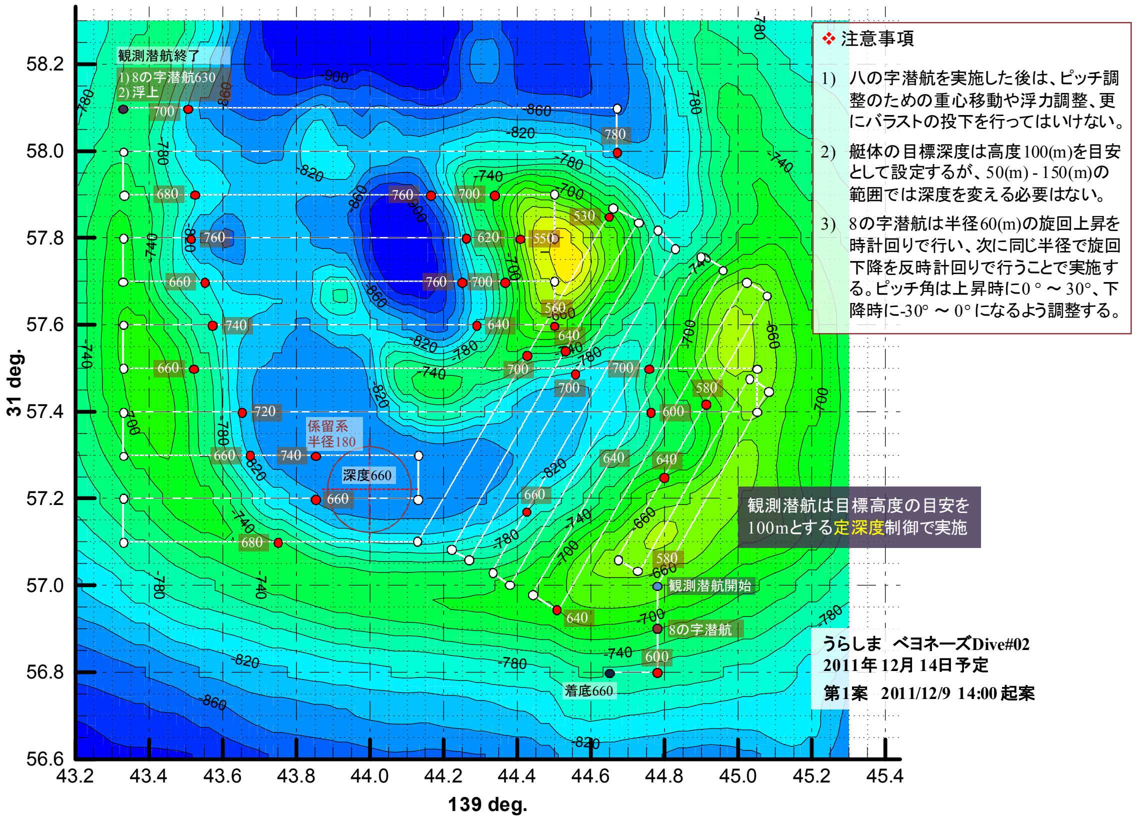


Fig.6.3.2 Planned trajectory for magnetic survey in Bayonnaise knoll caldera by Urashima.

7. Acknowledgements

The researchers thank the captain, crews and technicians of RV Yokosuka and operators of AUV Urashima. This project is supported by the Ministry of Education, Culture, Sports, Science & Technology in Japan.