



Cruise Report

YK16-12

Okinawa trough, South-West Japan



R/V Yokosuka

8 Sep 2016 – 22 Sep 2016

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Acknowledgements

We would like to thank Captain Mr. Ryono and all ship crew of R/V Yokosuka for their safe cruise. We are grateful to Shinkai 6500 operation team and marine technicians of NME for their operation. We are pleased to MARITEC/JAMSTEC staff for their supports during our cruise.

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

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

Cruise information

Cruise number	YK16-12
Name of the cruise	R/V YOKOSUKA
Chief scientist	Takafumi Kasaya (JAMSTEC)
Representative of the Science Party	Eiichi Kikawa (JAMSTEC)
Title of the cruise	

Verification of the hydro thermal structure survey using the
electro-magnetic geophysical survey technique

Cruise period	8 Sep 2016 – 22 Sep 2016
Ports of call	Naha port – Kagoshima port
Research Area	Okinawa trough (Fig.1)

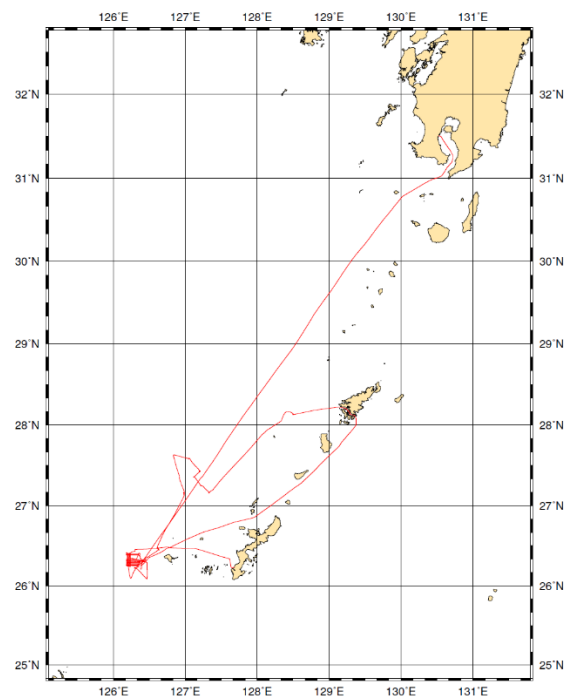


Fig.1 Ship track of this cruise.

Cruise summary

” Verification of the hydro thermal structure survey using the electro-magnetic geophysical survey technique”

Few exploration techniques were developed to evaluate the thickness of the submarine massive sulfides (SMS) and to find the buried SMS. It is also very important for the study of the origin and formation of SMS to detect the subsurface hydrothermal circulation system and characterization a back-arc basin development .

The purpose of this cruise is the confirmation of our geophysical survey procedure for the hydrothermal deposit. For this achievement, we carried out various observation around the western Kume Island in the central part of Okinawa Trough. In this cruise, we carried out two Shinkai 6500 dives and deep-towed MDCR dive around the target area of the hydrothermal deposit. Before these dives, we deployed OBEs for the receiver of the artificial electrical source. Two mobile-type OBEs were also set up in Shinkai dives around a large mound. The data acquisition of the SP and resistivity data was successfully. Moreover, we obtained the bathymetric data, gravity data and magnetic data using shipboard equipment for detailed bathymetric and geophysical data using shipboard instruments. Acoustic intensity data in a water column of the MBES were also obtained through these observations for detecting distributions of the plume like structure in a water column.

This study was supported by the Cross-ministerial Strategic Innovation Promotion Program “Next-generation technology for ocean resources exploration” launched by the Council for Science, Technology and Innovation (CSTI) and managed by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC).

2. List of Participants

Scientists

Takafumi Kasaya	Japan Agency for Marine-Earth Science and Technology
Hisanori Iwamoto	Japan Agency for Marine-Earth Science and Technology
Kazuya Kitada	Japan Agency for Marine-Earth Science and Technology
Tadanori Goto	Japan Agency for Marine-Earth Science and Technology
Yuka Masaki	Japan Agency for Marine-Earth Science and Technology
Keiichi Ishizu	Japan Agency for Marine-Earth Science and Technology
Yusuke Oota	Japan Agency for Marine-Earth Science and Technology
Hisatoshi Koji	Japan Agency for Marine-Earth Science and Technology
Yutaka Kanai	Japan Marine Surveys Association
Minoru Takahashi	Japan Marine Surveys Association
Takuya Mii	Japan Marine Surveys Association
Chikara Okada	Japan Marine Surveys Association

Marine Technician

Satomi Minamizawa	Nippon Marine Enterprises, LTD.
Toshimasa Nasu	Nippon Marine Enterprises, LTD.

SHINKAI6500 operation team

Submersible Op. Manager	Toshiaki Sakurai
Deputy Submersible Op. Manager	Kazuhiro Chiba
1st Submersible Staff	Tetsuya Komuku
1st Submersible Staff	Mitsuhiro Ueki
1st Submersible Staff	Keita Matsumoto
1st Submersible Staff	Akihisa Ishikawa
2 nd Submersible Staff	Hirofumi Ueki
2 nd Submersible Staff	Yousuke Chida
2 nd Submersible Staff	Keigo Suzuki
2 nd Submersible Staff	Ryo Saigo
2 nd Submersible Staff	Takuma Onishi
3 rd Submersible Staff	Yoshikazu Kuramoto

R/V YOKOSUKA Officers and Crew

Captain	Shinya Ryono
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Chief Officer	Tatsuo Adachi
2 nd Officer	Shozo Fujii
3 rd Officer	Yuki Ito
Chief Engineer	Minoru Tsukada
1 st Engineer	Takashi Ota
Jr. 1 st Engineer	Shinichi Ikuta
2 nd Engineer	Yoshinobu Hiratsuka
3 rd Engineer	Kazuki Ono
Chief Electronic Operator	Hiroyasu Saitake
2nd Electronic Operator	Toshihiko Yuasa
3rd Electronic Operator	Ryuji Onikubo
BoatSwain	Kazuo Abe
Quarter Master	Yasuo Konno
Quarter Master	Kaname Hirosaki
Quarter Master	Yukito Ishii
Quarter Master	Yamato Sekine
Sailor	Kyohei Murai
Sailor	Tomoki Asakuni
No.1 Oiler	Junji Mori
Oiler	Tatsuomi Chino
Oiler	Ryota Suzuki
Oiler	Ryo Matsuuchi
Assistant Oiler	Motohiro Kawano
Chief Steward	Sueto Sasaki
Steward	Hironobu Hodokuma
Steward	Tsuyoshi Nagatomo
Steward	Masanao Kunita
Steward	Koki Shinohara
Steward	Yudai Kusunoki

3. Ship Logs

2016/9/8 OKINAWA NAHA Port (26-14.2N,127-40.8E)

Weather: Rain / Wind direction: SW/ Wind force: 4/ Wave scale: 2 /
Swell scale: 0 / Visibility: 6 miles (12:00 JST)

11:00	onboard
14:30-15:00	Carried out education and training for scientists
16:00	let go all shore line, left NAHA, proceeded to research area
16:58	Launched proton magnetometer
17:08	Com'ced towing to proton magnetometer
22:00	Arrived at research area
22:03	Released XBT @ 26-26.8669N, 126-18.1402E
22:46	Com'ced MBES mapping survey

2016/9/9 Off WEST KUMEJIMA (26-18.4N,126-24.4E)

Weather: Overcast / Wind direction: North/ Wind force: 3 /Wave scale:2 /
Swell scale: 1 / Visibility: 8 miles (12:00 JST)

04:40	Finished MBES mapping and SBP survey
06:08	Finished towing to proton magnetometer
06:16	Recovered proton magnetometer
06:54	Launched OBE1
08:07	Suspended to deploy OBE operation due to machine trouble
08:37	Recovered OBE1
09:30-10:03	Deployed OBE1
11:05-11:40	Deployed OBE2
12:53-13:37	Deployed OBE3
14:28-15:07	Deployed OBE5
16:25-16:59	Deployed OBE4
17:45	Released XBT @ 26-18.7845N, 126-25.3224E
18:07	Launched proton magnetometer
18:16	Com'ced towing to proton magnetometer
18:37	Com'ced MBES site survey
18:52	Finished MBES site survey
20:57	Com'ced MBES mapping and SBP survey

2016/9/10 Off WEST KUMEJIMA (26-18.4N,126-24.5E)

Weather: Overcast / Wind direction: ENE / Wind force: 4/ Wave scale: 3 /

Swell scale: 1 / Visibility: 8 miles (12:00 JST)

05:51	Finished MBES mapping and SBP survey
06:30	Finished towing to magnetometer
06:38	Recovered proton magnetometer
09:48	Hoisted up "SHINKAI 6500"
09:54	Launched "SHINKAI 6500"
10:02	"SHINKAI 6500" dove and started her operation #1471
11:00	"SHINKAI 6500" landed on the sea bottom(Depth = 1,420m)
16:25	"SHINKAI 6500" left the sea bottom(Depth = 1,379m)
17:03	Refloated "SHINKAI 6500"
17:18	Hoisted up "SHINKAI 6500"
17:26	Recovered "SHINKAI 6500" and finished above operation
18:16	Launched proton magnetometer
18:26	Com'ced towing to proton magnetometer
20:08	released XBT @ 26-13.0271N, 126-18.9562E
20:16-20:38	Carried out eight figure running survey
21:03	Com'ced MBES mapping survey and SBP survey

2016/9/11 Off WEST KUMEJIMA (26-18.4N,126-24.9E)

Weather: Overcast / Wind direction: ENE / Wind force: 3 / Wave scale: 2 /

Swell scale: 1 / Visibility: 8 miles (12:00 JST)

05:50	Finished MBES mapping and SBP survey
06:30	Finished towing to magnetometer
06:38	Recovered proton magnetometer
09:53	Hoisted up "SHINKAI 6500"
10:01	Launched "SHINKAI 6500"
10:08	"SHINKAI 6500" dove and started her operation #1472
10:58	"SHINKAI 6500" landed on the sea bottom(Depth = 1,430m)
16:25	"SHINKAI 6500" left the sea bottom(Depth = 1,351m)
17:00	Refloated "SHINKAI 6500"
17:16	Hoisted up "SHINKAI 6500"
17:25	Recovered "SHINKAI 6500" and finished above operation
18:11	Launched proton magnetometer
18:21	Com'ced towing to proton magnetometer
19:31	Com'ced MBES mapping survey and SBP survey

2016/9/12 Off WEST KUMEJIMA (26-18.4N,126-25.3E)

Weather: Fine but cloudy / Wind direction: NNW / Wind force: 1/ Wave scale: 1 /
Swell scale: 1 / Visibility: 8 miles (12:00 JST)

04:15	Finished MBES mapping and SBP survey
06:35	Finished towing to magnetometer
06:46	Recovered proton magnetometer
08:44	Hoisted up MEMSYS
08:47	Launched deep MEMSYS and started her operation
09:57	Com'ced towing MEMSYS
16:16	Finished towing MEMSYS
17:22	Hoisted up MEMSYS and finished above operation
17:32	Recovered MEMSYS
18:00	Left kumejima western site for Iheya northern site

2016/9/13 Off North-South IHEYAJIMA (27-35.6N,127-00.5E)

Weather: Fine but cloudy / Wind direction: ENE / Wind force: 2/ Wave scale: 2 /
Swell scale: 1 / Visibility: 8 miles (12:00 JST)

04:00	arrived at research area (Iheya northern site)
06:49	Recovered OBEM3
08:50	Recovered OBEM2
11:12	Recovered OBEM1
13:27	Recovered OBEM4
15:26	Recovered OBEM7
17:06	Recovered OBEM5
18:43	Recovered OBEM6
20:14	Recovered OBEM8
20:30	Com'ced proceeding to off KONIYA

2016/9/14 Off KONIYA (28-08.1N,129-17.1E)

Weather: Fine but cloudy / Wind direction: ESE / Wind force: 4/ Wave scale: 1 /
Swell scale: 0 / Visibility: 8 miles (12:00 JST)

02:57-03:17	Carried out eight figure running
07:50	Let go port anchor
09:06	One scientist onboarded by traffic boat

13:00-14:10 Carried out education and training for all crew

2016/9/15 Off KONIYA (28-08.1N,129-17.1E)

Weather: Fine but cloudy / Wind direction: ENE / Wind force: 3/ Wave scale: 1 /
Swell scale: 0 / Visibility: 8 mile (12:00 JST)

2016/9/16 Off KONIYA (28-08.1N,129-17.1E)

Weather: Fine but cloudy / Wind direction: ESE / Wind force: 4/ Wave scale: 1 /
Swell scale: 0 / Visibility: 8 miles (12:00 JST)

2016/9/17 Off KONIYA (28-08.1N,129-17.1E)

Weather: Fine but cloudy / Wind direction: SSE / Wind force: 4/ Wave scale: 1 /
Swell scale: 0 / Visibility: 8 miles (12:00 JST)

2016/9/18 Off KONIYA (28-08.1N,129-17.1E)

Weather: Fine but cloudy / Wind direction: SSE / Wind force: 5/ Wave scale: 1 /
Swell scale: 0 / Visibility: 8 miles (12:00 JST)

13:10 6 scientists disembarked then let go traffic boat

2016/9/19 Off KONIYA (28-08.1N,129-17.1E)

Weather: Rain / Wind direction: SSW / Wind force: 5/ Wave scale: 2 /
Swell scale: 0 / Visibility: 8 miles (12:00 JST)

2016/9/20 Off KONIYA (28-08.1N,129-17.1E)

Weather: Cloudy / Wind direction: West / Wind force: 4 / Wave scale: 1 /
Swell scale: 0 / Visibility: 8 miles (12:00 JST)

14:06 Proceeded to research area

2016/9/21 Off WEST KUMEJIMA (26-18.5N,126-24.7E)

Weather: Fine but cloudy / Wind direction: NE / Wind force: 4 / Wave scale: 3 /
Swell scale: 3 / Visibility: 8 miles (12:00 JST)

05:00	Arrived at research area
07:59	Recovered OBE1
08:59	Recovered OBE2
09:56	Recovered OBE3
11:05	Recovered OBE5
11:58	Recovered OBE4
12:00	Left research area for KAGOSHIMA

2016/9/22 Arrive at KAGOSHIMA

15:00	arrived at KAGOSHIMA
15:30	disembarked YOKOSUKA
	finished YK16-12 cruise

Wind Scale

0	Calm	0~0.2m/s
1	Light air	0.3~1.5m/s
2	Light breeze	1.6~3.3m/s
3	gentle breeze	3.4~5.4m/s
4	Moderate breeze	5.5~7.9m/s
5	Fresh breeze	8.0~10.7m/s
6	Strong breeze	10.8~13.8m/s

Wave scale

0	Calm (Glassy)	0.0m
1	Calm (Rippled)	0~1/10m
2	Smooth (Wavelet)	1/10~1/2m
3	Slight	1/2~1 1/4m
4	Moderate	1 1/4~2 1/2m

SWELL SCALE

0	No Swell	
1	Low Swell Short or Average	< 2m
2	Low Swell Long	< 2m
3	Moderate Short	2m~4m

4. Instruments

4.1 Ocean bottom electro-magnetometer (OBEM)

The OBEM system can measure time variations of three components of magnetic field, two components of horizontal electric field, the instrumental tilts, and temperature. It mainly consists of one 17-inch glass sphere, sensor unit in aluminium/titanium pressure housing and electrode arm unit with arm holding mechanism (Fig. 4.1.1). The glass sphere involves data logger and a lithium battery pack. The sensor unit has a high-accuracy fluxgate magnetometer, tiltmeter and thermometer. The electrodes are Ag-AgCl equilibrium type made by Clover Tech. For electric field, four voltage differences between the electrodes on the tip of the pipes and the ground electrode are measured. The electrodes were monitored their self-potentials in laboratory in advance of the seafloor observation and pairs that the coherence is high enough were selected, in order to reduce the noise due to the voltage drift of electrodes themselves. A transponder unit, radio beacon and a flashlight are also mounted on the OBEM. The acoustic system can communicate with the SSBL system and it is easy for us to detect its position in the sea or on the seafloor. There are a transponder unit mounted on the OBEM system. This transponder unit, of which the acoustic and the pressure case units are combined, has a 2-year battery life.

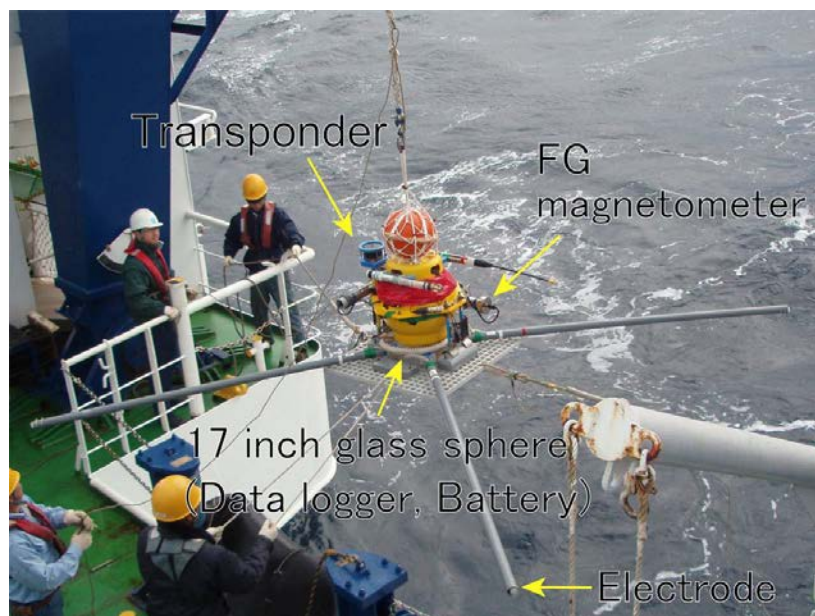


Fig. 4.1.1 OBEM system

Concepts of the type the OBEM system are miniaturization, a high sampling rate, easy assembly and recovery operations, and low costs of construction and operation. The arm holding mechanism, which electrode arm is folded when OBEM is in surfacing (Fig. 4.1.2), enable recovery operation even by the small ship that do not equip A frame ([Kasaya et al., 2006](#); [Kasaya and Goto, 2009](#)).

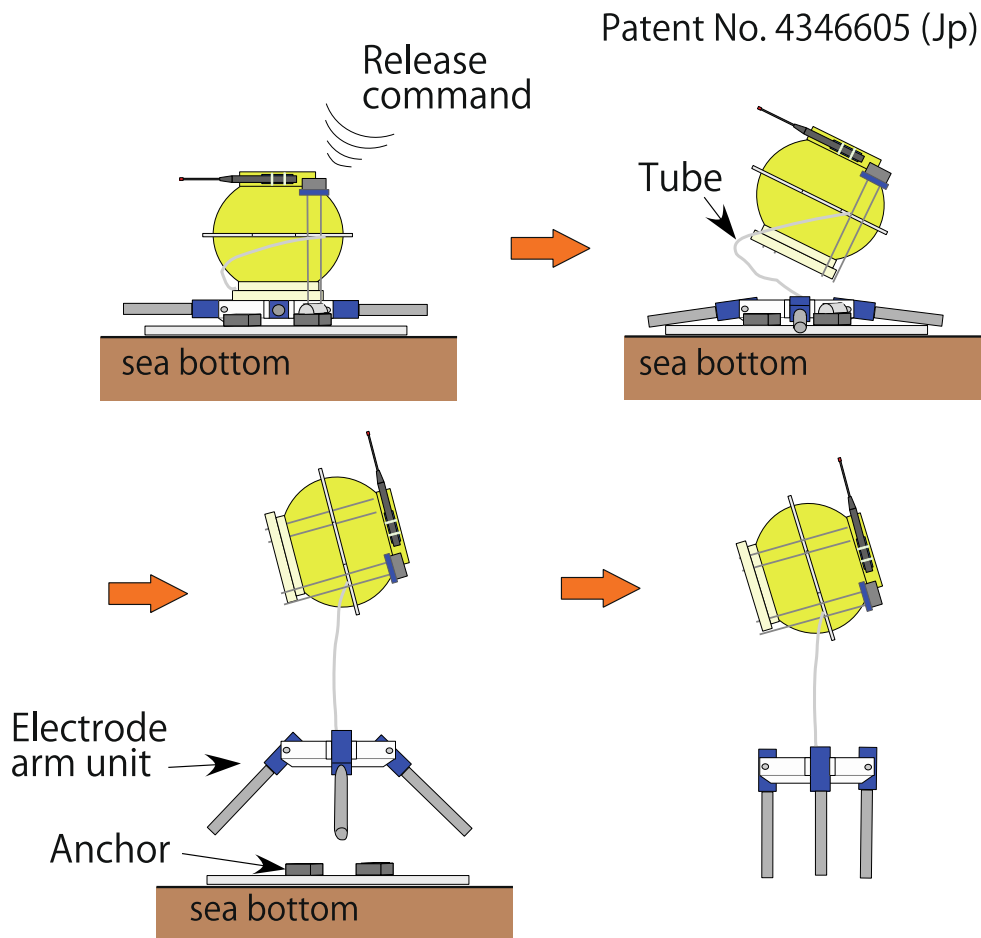


Fig. 4.1.2 Electrode arm-holding mechanism of type A OBEM

References

- Kasaya, T., T. Goto, and R. Takagi, Marine electromagnetic observation technique and its development –For crustal structure survey-, *BUTSURI-TANSA*, **59**, 585-594 (in Japanese with English abstract), 2006.
- Kasaya, T., and T. Goto, A small OBEM and OBE system with an arm folding mechanism, *Exploration Geophysics*, **40**, 41-48, 2009.

4.2 Ocean bottom electrometer (OBE)

The OBE system is designed for the controlled source survey with over 20 Hz sampling. An electric circuit and battery are involved in one cylinder type aluminum pressure case (Fig. 4.2.1). These OBEs were used for two observation style. One is a pop-up type with a 17-inch glass float an acoustic transponder and arm folding system (Fig. 4.2.1). Another is a mobile type with short electrode arms (Fig. 4.2.2), and two mobile OBEs were set up by the HOV Shinkai 6500.

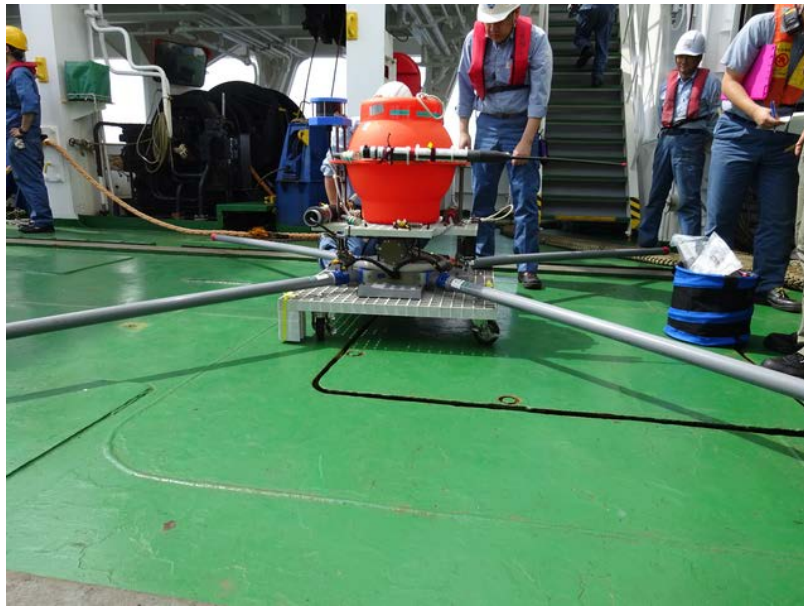


Fig. 4.2.2 Photo of a pop up type OBE system

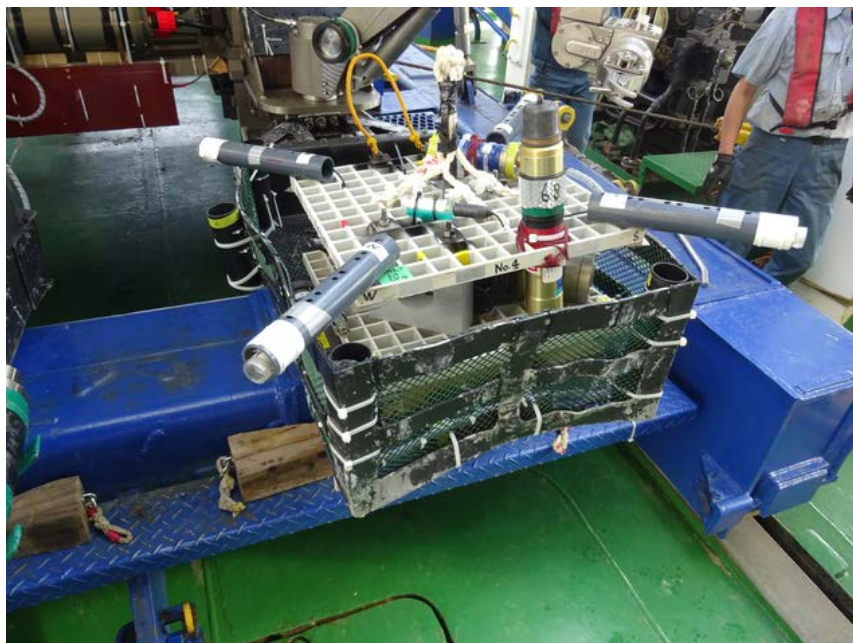


Fig. 4.2.3 Photo of a mobile type OBE system

4.3 DC resistivity system

On this cruise, we use two type controlled-source systems. This system consists of a transmitter unit and a main unit with a data logger, which recorded a transmitting signal and received signal. In the case of deep-tow, the AC 100 V supplied from the deep-tow transfers to DC 48 V, and it is input to a transmitter unit. The DC 100V power supplied to this system from the battery of the Shinkai 6500 in the operation using the Shinkai 6500. The logger unit can record data of output power data of a transmitter unit and four electric fields with a 50 Hz sampling rate. The maximum output power of both transmitter is about 1.2 kW with maximum voltage of 48V peak-to-peak and current of 50A.

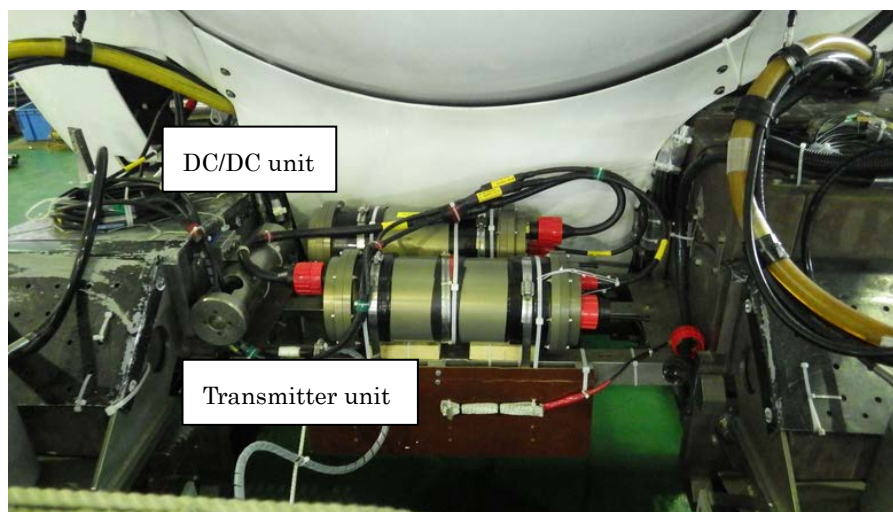


Fig. 4.3.1 Photo of a controlled source survey system on the Shinkai 6500.

Table 4.3.1 Specification of a control source survey system

Power unit

Max Input Voltage: 120 V

Max Output Current: 50 A

Circuit type: IGBT

Transmit channel: 4 ch

Main unit

Control unit

Max Measurement Current Range: 50 A

Max Measurement Voltage Range: 200V

A/D converter: 24 bit

Recording Media: SDHC

Sampling rate: 500 Hz

Logger unit

Measurement channels: 5 CH

Measurement Voltage Range: ± 100 mV

A/D converter: 24 bit

Recording Media: SDHC

Sampling rate: 500 Hz

4.4 Controlled source deep-tow system

On this cruise, we examined new deep towed DC resistivity surveys (Fig. 4.4.1). This system consists of a transmitter unit and a main unit with a data logger, which recorded a transmitting signal and received signal. The AC 1200 V is supplied from the optical-electric cable to a transformer on the deep tow, and a transformer converts it to AC 100 V. Although the maximum output power capacity of this transmitter on the design is 10 kW, the electric energy that can be used for this cruise is about 3kW because of the limitation of the which cable. A data logger can record data such as transmit voltage, transmit current and CTD with 1k Hz sampling rate. Onboard computer can monitor the all data including an altimeter and an monitoring camera, control various setting of the deep tow (Fig.4.4.2).



Fig. 4.4.1 Photo of a controlled source deep tow system.

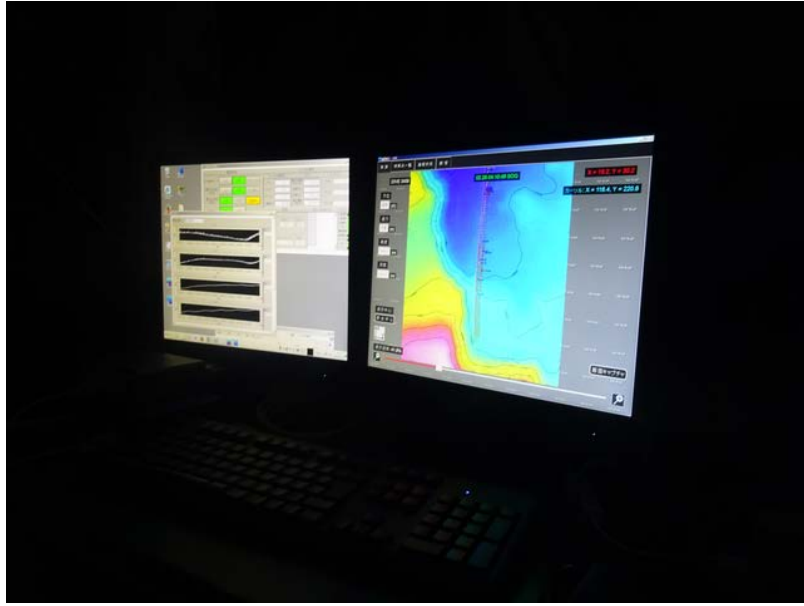


Fig. 4.4.2 Onboard monitoring system.

5. Operation report

5.1 Shipboard data

For detailed bathymetric and geophysical data using shipboard instruments around the western Kume Island in the central part of Okinawa Trough, we obtained the bathymetric data, gravity data and magnetic data using a shipboard equipment (see Appendix). Figure 5.1.1 shows the preliminary bathymetry map. In this cruise, these data were collected with about 5 knots ship speed. Acoustic intensity data in a water column of the MBES were also obtained through these observations for detecting distributions of the plume like structure in a water column.

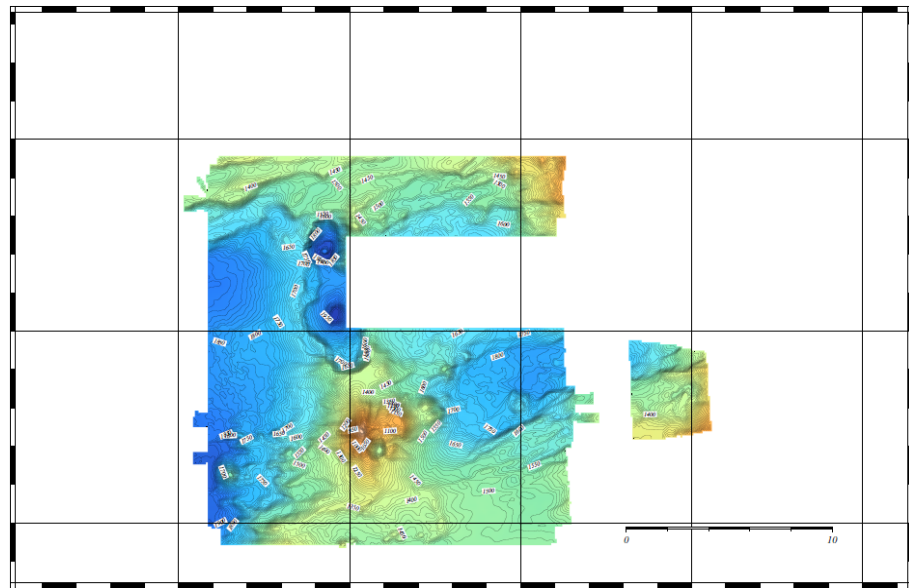


Fig. 5.1.1 Survey tracks of MBES survey.

5.2 Pop-up type OBEM and OBE operations

For characterization a back-arc basin development, we have obtained Magnetotelluric data using an OBEM. In this cruise, we made a recovery operation of OBEMs set up in the YK16-10 cruise. Table 5.2.1 shows a list of recovered OBEMs set up in the YK15-06 cruise. We tracked the OBEM's positions by SSBL system of R/V Yokosuka while they were ascending after sending acoustic release command. The ascent rate was approximately 40 m/min. We found with the ship looking, radio beacon and flasher. We could recover every six units successfully. After finishing recovery operation, the time difference between the OBEM's clock and the laptop pc synchronized by NTP server were measured. We could obtain enough quality EM data including some geomagnetic signals.

As the receiver of the DC resistivity surveys and CSEM surveys, six OBEs were deployed on the northern survey line of Fig. 5.3.1. The operations were quick and smooth. We tracked OBEs by acoustic signals and confirmed that all instruments were successfully settled on the seafloor. Then, each position was determined by the SSBL system equipped on the R/V Yokosuka. All OBEs were recovered successfully in this cruise.

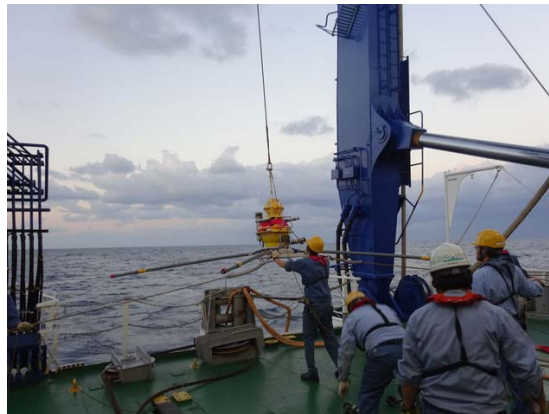


Figure 5.2.1 Photo of the OBEM deployment.

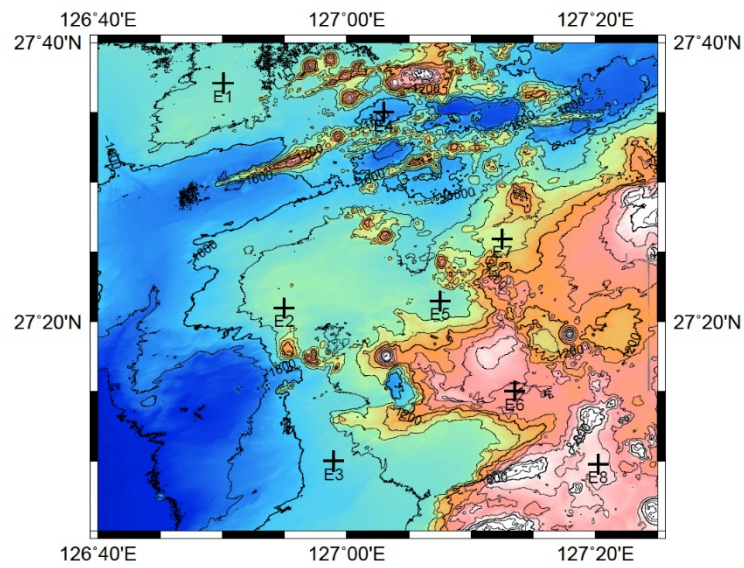


Figure 5.2.2 Site map of recovered OBEMs.

Table 5.2.1 Information of the recovered OBEMs.

OBEM ID	Deployed time (JST)	Deployed Latitude	Deployed Longitude	Calibrated time (JST)	Landed Latitude	Landed Longitude	Depth (acoustic vertical)
JM401	2016/8/8 17:41	27- 25.8801N	127- 12.5246E	2016/8/8 18:13	27- 25.9354N	127- 12.5184E	1405.5
JM400	2016/8/8 19:10	27- 21.4359N	127- 07.4994E	2016/8/8 19:40	27- 21.5041N	127- 07.5090E	1480.0
JM103	2016/8/9 6:21	27- 34.8583N	127- 02.9289E	2016/8/9 6:56	27- 35.0120N	127- 02.9695E	1656.1
KYT0 2	2016/8/9 8:15	27- 36.8410N	126- 49.9498E	2016/8/9 8:44	27- 37.1025N	126- 50.0570E	1485.0
JM108	2016/8/9 10:17	27- 20.8668N	126- 54.8991E	2016/8/9 10:47	27- 20.9894N	126- 54.9686E	1441.5
JM110	2016/8/9 12:01	27- 09.8929N	126- 59.0149E	2016/8/9 12:34	27- 09.9869N	126- 58.9787E	1542.7
JM109	2016/8/9 13:53	27- 14.9418N	127- 13.5418E	2016/8/9 14:14	27- 14.9952N	127- 13.5141E	1007.0
JM402	2016/8/9 15:15	27- 09.7362N	127- 20.2443E	2016/8/9 15:37	27- 09.7694N	127- 20.2155E	840.0

5.3 Shinkai 6500 and deep-tow dives

In this cruises, two “Shinkai 6500” dives and a deep-tow dive were carried out for the detailed survey of the hydrothermal deposit. Two “Shinkai 6500” dive were carried out for the controlled source EM survey at the western Kume Island site. Our controlled-source unit was loaded on “Shinkai 6500” (Fig.4.3.1). Two mobile OBE (Fig. 4.2.3) was set up near the large mound of this site shown in the central area of Fig. 5.3.1. In these operation, output current was controlled with 20-25 A. Figure 5.3.1 shows deep-tow dive tracks carried out at the western Kume Island site. We loaded the controlled source unit on the deep-tow system, and carried out on the 2 survey lines (Fig. 5.3.1).

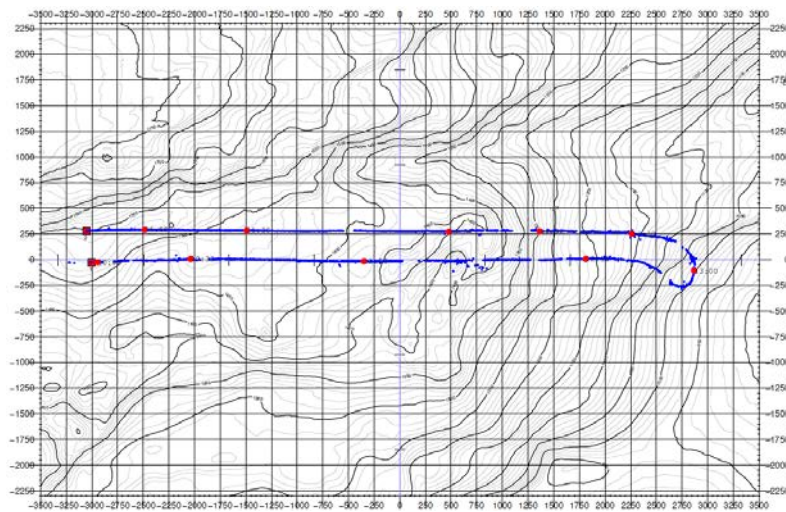


Fig. 5.3.1 Dive tracks of the MDCR deep-tow at western Kume Island site.

Appendix

Research Vessel YOKOSUKA

R/V YOKOSUKA is designed serve as the mother vessel for SHINKAI 6500 and Autonomous Underwater Vehicle (AUV) URASHIMA. It has silent engine, an advanced acoustic navigation systems and an underwater telephone for its state of the art operations. There are 5 laboratories on Yokosuka, No.1-No.4 laboratories and No.1 Study room. No.1 Lab. has dry space. The permanent installations are an video editing system, a PC and a printer. No.2 Lab. has semi-dry and wet space. There are two freezers (-40 & -80 deg.C), a incubator, a Milli-Q, and a fumigation chamber at dry one, and wet one has a rock saw. No.3 Lab. has dry space with storage. No.4 Lab. has semi-dry and wet space. No.1 Study room has dry space, there are a gravity meter, a data acquisition system of gravity meter, a 3 axis fluxgate magnet meter and also a proton magnet meter, a work station for data processing, and a A0 size plotter.

The general specifications of R/V YOKOSUKA

Length overall	105.2 m
Beam overall	16.0 m
Depth	7.3 m
Draft	4.5 m
Gross tonnage	4,439 tons
Service speed	16knot
Main propulsion system Diesel engines	2,206kW x 2
Main propulsion method	Controllable pitch propeller x 2

Complement

Crew	28 persons
Submersible operation staff	8 persons
Researchers	6 persons
Total 52 persons	

R/V YOKOSUKA MBES / magnetometers / gravity meter

YOKOSUKA is equipped with various kinds of underway geophysical equipment, a multi narrow beam echo sounder (EM122, Kongsberg Maritime, Inc.), a gravity meter (Type S-63, LaCoste & Romberg Gravity Meters Inc.), a portable gravity meter (Type CG-5, SCINTREX Limited), a ship borne 3 axis magnet meter (Type SFG-1212, Tierra Technica Inc.), and a proton magnet meter (Type STC 10, Kawasaki Geological Engineering Co., Ltd.). The specifications of these instruments are listed below.

The specifications of EM122

Measurement depth (m)	20 ~ 11,000
Measurement frequency (kHz)	12
Measurement method	cross fan beam style
Beam numbers	288
Mesurement point	432
Pulse lengths	2/5/15msec CW(~2000m) 100msec FM(2000m~)
Beam width (deg.)	2
Beam interval (deg.)	2
Swath width (deg.)	150 (Max)
Sampling rate (msec.)	0.33
Roll (deg.)	±15
Pitch (deg.)	±10
Yaw (deg.)	±10

The specifications of Gravity meter

Measurement range (m Gal)	12,000
Drift	3mGal per month or less
<u>Stabilized platform</u>	
Platform pitch(deg.)	±22
Platform roll(deg.)	±25
Platform period(min.)	4 to 4.5
Beam interval(deg.)	1
<u>Control system</u>	
Recording rate(Hz)	1
Serial out put	RS-232

System performance

Resolution (mGal)	0.01
Static repeatability (mGal)	0.05
50,000m Gal horizontal acceleration (mGal)	0.25
100,000m Gal horizontal acceleration (mGal)	0.50
100,000m Gal vertical acceleration (mGal)	0.25
Dimension (cm)	71×56×84
Weight (kg)	Meter:86, UPS:30

The specifications of Portable Gravity meter

Sensor Type:	Fused Quartz using electrostatic nulling
Reading Resolution:	1 microGal
Standard Field Repeatability:	<5 microGal
Operating Range:	8,000 mGal without resetting
Residual Long-Term Drift:	Less than 0.02 mGal/day (static)
Automatic Tilt Compensation:	±200 arc sec
Tares:	Typically less than 5 microGals for shocks up to 20

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Automated Corrections:	Tide, Instrument Tilt, Temperature, Drift, Near Terrain, Noisy Sample, Seismic, Noise Filter
Operating Temperature:	-40°C to +45°C (-40°F to 113°F)
Ambient Temperature Coefficient:	0.2 microGal/°C (typical)
Pressure Coefficient:	0.15 microGal/kPa (typical)
Magnetic Field Coefficient:	1 microGal/Gauss (typical)
Memory:	Flash Technology (data security)
Dimensions (cm) :	30 cm (H) x 22 cm x 21 cm (12" (H) x 8.5" x 8")
Weight (including batteries):	8 kg (17.5 lbs)
Battery Capacity:	2 x 6.6 Ah (11.1 V) rechargeable Lithium-Ion Smart Batteries. Full day operation in normal survey conditions with two fully charged batteries
Power Consumption:	4.5 W at +25°C (77°F)
Standard System:	CG-5 Console, Tripod base, 2 rechargeable batteries, Battery Charger 110/240 V, External Power Supply 110/240 V, RS-232 and USB Cables, Carrying Bag, Data dump and utilities software, Operating Manual (CD), Transit Case

The specifications of 3 axis magnet meter

System	ring core fluxgate
Number of component directly	3 axes
Cable length (m)	50
Sensor dimension (mm)	φ280×130H
Measurement range (nT)	±100,000
Resolution (nT)	1

The specifications of Proton magnet meter

Measurement range (nT)	$3 \sim 7 \times 10^{*4}$
Resolution (nT)	0.01
Sampling rate	10sec, 20sec, 1min, manual, external
Time of applying field(sec.)	3 to 10
Sensor dimension (mm)	φ200×1050
Weight (kg)	28.6(in the air), 6.2(in the sea)