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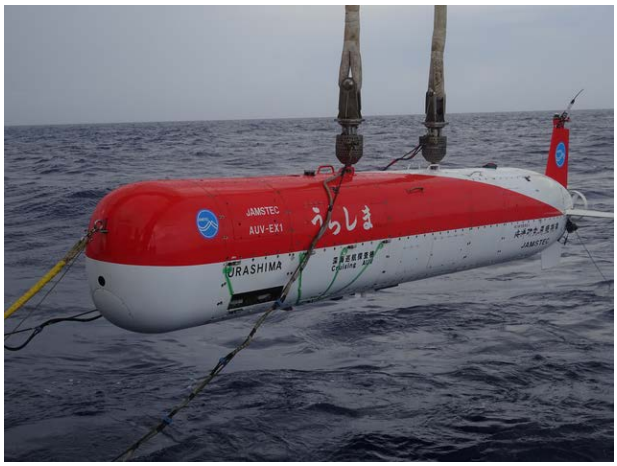
Cruise Report

YK16-10

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

Okinawa trough, South-West Japan



R/V Yokosuka

6 Aug 2016 – 20 Aug 2016

Contents

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.

1.Cruise summary of YK16-10 cruise

Cruise information

Cruise number	YK16-10
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	6 Aug 2016 – 20 Aug 2016
Ports of call	Yokosuka – Naha port
Research Area	Okinawa trough (Fig.1)

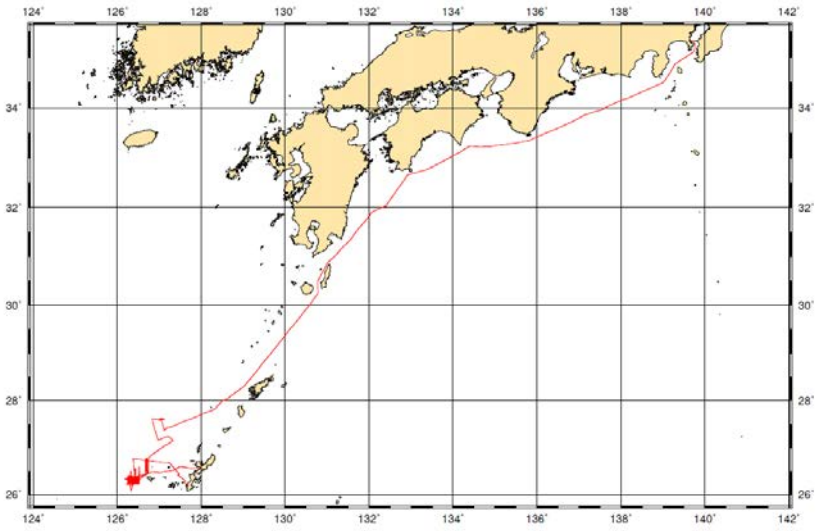


Fig.1 Ship track of this cruise.

Cruise summary

Title of proposal:" Verification of the hydro thermal structure survey using the electro-magnetic geophysical survey technique"

Few exploration techniques were developed to evaluate the thickness of 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. For detailed bathymetric and geophysical data using shipboard instruments, we obtained the bathymetric data, gravity data and magnetic data using shipboard equipment. 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. AUV Urashima and Deep-tow (YKDT) dives carried out at the western Kume Island for the confirmation of our geophysical survey procedure for the hydrothermal deposit. First, we used the AUV Urashima to narrow five candidates, which obtained by the topographic features and some water column anomaly, down to a few detailed survey areas. We carried out the YKDT dives at two candidate areas with the controlled source system. The data acquisition of the SP and resistivity data was successfully. Moreover, we have deployed eight OBEMs to obtain magneto-telluric data using an OBEM for characterization a back-arc basin development

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
Junji Kaneko	Japan Agency for Marine-Earth Science and Technology
Atsushi Oshida	Japan Marine Surveys Association
Masahiro Ohara	Japan Marine Surveys Association
Toshimitsu Goto	Japan Marine Surveys Association
Hidehiro Ishikawa	Japan Marine Surveys Association
Chikara Okada	Japan Marine Surveys Association
Fuyuki Katase	Japan Marine Surveys Association

Marine Technician

Toshimasa Nasu	Nippon Marine Enterprises, LTD.
Hiroyuki Hayashi	Nippon Marine Enterprises, LTD.

AUV URASHIMA operation team

Submersible Op. Manager	Toshiaki Sakurai
1st Submersible Staff	Akihisa Ishikawa
1st Submersible Staff	Fumitaka Saito
2nd Submersible Staff	Takuma Onishi
2nd Submersible Staff	Ryo Saigo
3rd Submersible Staff	Naoto Minamino
3rd Submersible Staff	Hideki Sugiura

R/V YOKOSUKA Officers and Crew

Captain	Shinya Ryono
Chief Officer	Akihisa Tsuji
2nd Officer	Tetsuo Shirayama
3rd Officer	Keiji Itahashi
Jr.3rd Officer	Yuki Ito
Chief Engineer	Minoru Tsukada
1st Engineer	Takashi Ota
2nd Engineer	Yoshinobu Hiratsuka

3rd 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	Ryoto Suzuki
Oiler	Ryo Matsuuchi
Assistant Oiler	Motohiro Kawana
Chief Steward	Sueto Sasaki
Steward	Hideo Fukumura
Steward	Hironobu Hodokuma
Steward	Tsuyoshi Nagatamo
Steward	Yukihide Chikuba
Steward	Yudai Kusunoki

3. Ship Logs

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 condition
2016.8.6	08:00	Scientists onboard.		12:00 (UTC+9h)
	09:00	Let go all shore lines & left YOKOSUKA for Research area(okinawa trough).		OFF IZU-OOSHIMA
	09:03	S/H eng's, then used it & steering var'ly.		North
	10:00-11:00	Carried out Shipboard education & traning for scientist.		32-37.0N,132-52.9E
	11:00-12:00	Cruise meeting(Scientist & URASHIMA team).		Fine but coudy
				East-3 gentle breeze
				3 Sea slight
				1 Low swell sea
				Visibly: 8'
2016.8.7		Left YOKOSUKA for Research area		12:00 (UTC+9h)
	15:15-15:35	Carrid out eight figure runnig		OFF ASHIZURI MISAKI
				SW.
				32-37.0N,132-52.9E
				Fine but coudy
				East-3 gentle breeze
				3 Sea slight
				1 Low swell sea
				Visibly: 8'
2016.8.8	17:00	Arrive at reserch area		12:00 (UTC+9h)
	17:07	Release XBT		OFF TOKUNOSHIMA
				West.
	17:41	Deployed OBEM7		27-59.8N,128-33.6E
	19:10	Deployed OBEM5		Rain
	21:20	Com'ced heave to		ESE-6 Strong breeze
				3 Sea slight

				1 Low swell sea
				Visibly: 6'
2016.8.9	03:30	Finished heave to		12:00 (UTC+9h)
	06:21	Deployed OBEM4		OFF IZENA
	08:15	Deployed OBEM1		27-10.0N,126-59.0E
	10:17	Deployed OBEM2		Fine but coudy
	12:01	Deployed OBEM3		SE-5 Fresh breeze
	13:53	Deployed OBEM6		3 Sea slight
	15:15	Deployed OBEM8		1 Low swell sea
	16:00-17:00	Carried out soot blow running		Visibly: 8'
	18:16	Release XBT (26-47.3566N 126-46.0462E)		
	18:54	Com'ced MBES mapping & SBP survey		
2016.8.10	02:54	Finished MBES mapping & SBP survey		12:00 (UTC+9h)
	02:55	Com'ced proceeding to dive area		OKINAWA TROUGH(ANA SITE North)
	05:00	arrived at dive area ,soon release XBT(26-20.0401N 126-28.6532E)		26-18.7N,126-27.0E
	07:36	Hoisted up URASHIMA		Overcast
	07:44	Launched URASHIMA & started operation Dive262		East-5 Fresh breeze
	16:52	Refloated URASHIMA		3 Sea slight
	17:17	Hoisted up above URASHIMA		1 Low swell sea
	17:25	Recovered URASHIMA & finished above operation		Visibly: 6'
	17:59	Lauched proton magnetometer		
	18:07	Com'ced towing to proton magnetometer		
	18:47	Released XBT (26-13.3180N 126-22.0940E)		
	19:05-19:25	Carrid out eight figure runnig		
	20:27	Com'ced MBES mapping & SBP survey		
2016.8	05:34	Finished MBES mapping & SBP survey		12:00 (UTC+9h)

.11				
	06:00	Finished towing to proton magnetometer		OKINAWA TROUGH
	06:06	Recovered proton magnetometer		26-18.3N,126-23.6E
	07:32	Hoisted up URASHIMA		Fine but coudy
	07:38	Launched URASHIMA & started operation Dive263		SE-4 Moderate breeze
	17:00	Refloated URASHIMA		3 Sea slight
	17:16	Hoisted up above URASHIMA		1 Low swell sea
	17:22	Recovered URASHIMA & finished above operation		Visibly: 8'
	17:57	Lauched proton magnetometer		
	18:05	Com'ced towing to proton magnetometor		
	18:26	Released XBT (26-20.5306N 126-24.2173E)		
	20:21	Com'ced MBES mapping & SBP survey		
2016.8 .12	05:14	Finished MBES mapping & SBP survey		12:00 (UTC+9h)
	05:58	Finished towing to proton magnetometer		OKINAWA TROUGH
	06:06	Recovered proton magnetometer		26-17.1N,126-23.2E
	07:13	Hoisted up URASHIMA		Fine but coudy
	07:20	Launched URASHIMA		East-4 Moderate breeze
	07:21	started operation Dive264		2 Sea Smooth
	16:59	Refloated URASHIMA		1 Low swell sea
	17:18	Hoisted up above URASHIMA		Visibly: 8'
	17:23	Recovered URASHIMA & finished above operation		
	17:55	Lauched proton magnetometer		
	18:03	Com'ced towing to proton magnetometor		
	19:48	Com'ced MBES mapping & SBP survey		
2016.8 .13	05:27	Finished MBES mapping & SBP survey		12:00 (UTC+9h)
	06:00	Finished towing to proton magnetometer		OKINAWA TROUGH
	06:07	Recovered proton magnetometer		26-20.4N,126-25.6E
	08:48	Hoisted up URASHIMA		Cloudy
	08:55	Launched URASHIMA		SE-3 gentle breeze
	08:56	started operation Dive265		3 Sea slight
	16:55	Refloated URASHIMA		1 Low swell sea

	17:43	Hoisted up above URASHIMA		Visibly: 8'
	17:49	Recovered URASHIMA & finished above operation		
	18:21	Lauched proton magnetometer		
	18:30	Com'ced towing to proton magnetometor		
	19:00-19:30	Scientist meeting		
	18:48	Released XBT (26-24.8954N 126-31.7843E)		
	20:34	Com'ced MBES mapping & SBP survey		
2016.8.14	05:20	Finished MBES mapping & SBP survey		12:00 (UTC+9h)
	05:59	Finished towing to proton magnetometer		OKINAWA TROUGH
	06:08	Recovered proton magnetometer		26-18.0N,126-23.3E
	07:15	Hoisted up URASHIMA		Fine but coudy
	07:21	Launched URASHIMA		ENE-4 Moderate breeze
	07:22	started operation Dive266		3 Sea slight
	16:38	Refloated URASHIMA		1 Low swell sea
	16:58	Hoisted up above URASHIMA		Visibly: 8'
	17:05	Recovered URASHIMA & finished above operation		
	17:42	Lauched proton magnetometer		
	17:51	Com'ced towing to proton magnetometor		
	18:05	Com'ced MBES mapping & SBP survey		
	23:56	Finished MBES mapping & SBP survey		
2016.8.15	05:58	Finished towing to proton magnetometer		12:00 (UTC+9h)
	06:04	Recovered proton magnetometer		NAGO-WAN
	07:50	arrived at NAGO-WAN.		26-34.5N,127-58.0E
	13:00-14:30	change equipment(URASHIMA→YKDT)		Fine but coudy
	14:45	Left NAGO-WAN for research area		East-2 Light breeze
	16:28	Lauched proton magnetometer		1 Sea Calm
	18:00-18:30	Scientist meeting		1 Low swell sea
	20:30	Arrived at reseach area		Visibly: 8'

	20:36	Com'ced MBES mapping & SBP survey		
2016.8.16	05:45	Finished MBES mapping & SBP survey		12:00 (UTC+9h)
	06:25	Finished towing to proton magnetometer		OKINAWA TROUGH
	06:33	Recovered proton magnetometer		26-16.9N,126-22.9E
	08:12	Hoisted up YKDT		Fine but coudy
	08:16	Launched YKDT. started operation No.181		SE-3 gentle breeze
	08:26	Com’ced towing YKDT		2 Sea Smooth
	08:51	Finished towing YKDT		1 Low swell sea
	09:17	Hoisted up YKDT. Finished above operation		Visibly: 8'
	09:18	Recovered YKDT		
	09:49	Hoisted up YKDT		
	09:50	Launched YKDT		
	09:56	Hoisted up YKDT		
	09:58	Recovered YKDT		
	11:21	Hoisted up YKDT		
	11:23	Launched YKDT		
	11:31	Hoisted up YKDT		
	11:34	Recovered YKDT		
	11:46	Hoisted up YKDT		
	11:49	Launched YKDT. started operation No.182		
	11:54	Com’ced towing YKDT		
	16:56	Finished towing YKDT		
	17:27	Hoisted up YKDT. Finished avove operation		
	17:29	Recovered YKDT		
	17:40	Lauched proton magnetometer		
	17:49	Com'ced towing to proton magnetometor		
	19:56	Com'ced MBES mapping & SBP survey		
2016.8.17	05:45	Finished MBES mapping & SBP survey		12:00 (UTC+9h)
	06:27	Finished towing to proton magnetometer		OKINAWA TROUGH
	06:36	Recovered proton magnetometer		26-18.4N,126-23.8E
	07:59	Hoisted up YKDT		Fine but coudy

	08:01	Launched YKDT. started operation No.183		SSE-1 Light air
	08:34	Com’ced towing YKDT		1 SeaCalm
	16:21	Finished towing YKDT		1 Low swell sea
	16:54	Hoisted up YKDT. Finished avove operation		Visibly: 8'
	16:56	Recovered YKDT		
	17:06	Lauched proton magnetometer		
	17:15	Com'ced towing to proton magnetometor		
	17:33	Rereased XBT (26-18.0184N 126-19.2649E)		
	19:39	Com'ced MBES mapping & SBP survey		
2016.8.18	05:55	Finished MBES mapping & SBP survey		12:00 (UTC+9h)
	06:25	Finished towing to proton magnetometer		OKINAWA TROUGH
	06:33	Recovered proton magnetometer		26-17.9N,126-24.9E
	08:03	Launched YKDT. started operation No.183		Fine but coudy
	08:08	Com’ced towing YKDT		SE-2 Light breeze
	16:15	Finished towing YKDT		2 Sea Smooth
	16:47	Hoisted up YKDT. Finished avove operation		1 Low swell sea
	16:49	Recovered YKDT		Visibly: 8'
	16:58	Lauched proton magnetometer		
	17:07	Com'ced towing to proton magnetometor		
	19:06	Com'ced MBES mapping & SBP survey		
2016.8.19	05:30	Finished MBES mapping & SBP survey		
	06:26	Finished towing to proton magnetometer		
	06:35	Recovered proton magnetometer		
	07:59	Hoisted up YKDT		
	08:01	Launched YKDT. started operation No.184		
	08:06	Com’ced towing YKDT		
	15:40	Finished towing YKDT		
	16:14	Hoisted up YKDT. Finished avove operation		
	16:17	Recovered YKDT		
	18:37-18:57	Carrid out eight figure runnig		

	23:45	Arrived at Off NAHA		
2016.8 .20	09:00	Sent out 1st shore line, arrived at NAHA-KO, then completed voy.		

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.

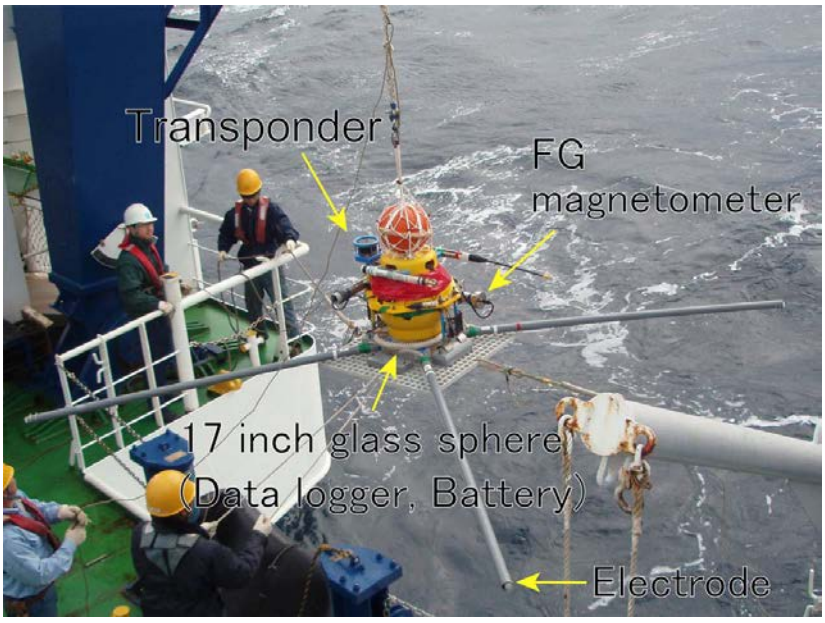


Fig. 4.1.1 OBEM system

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).

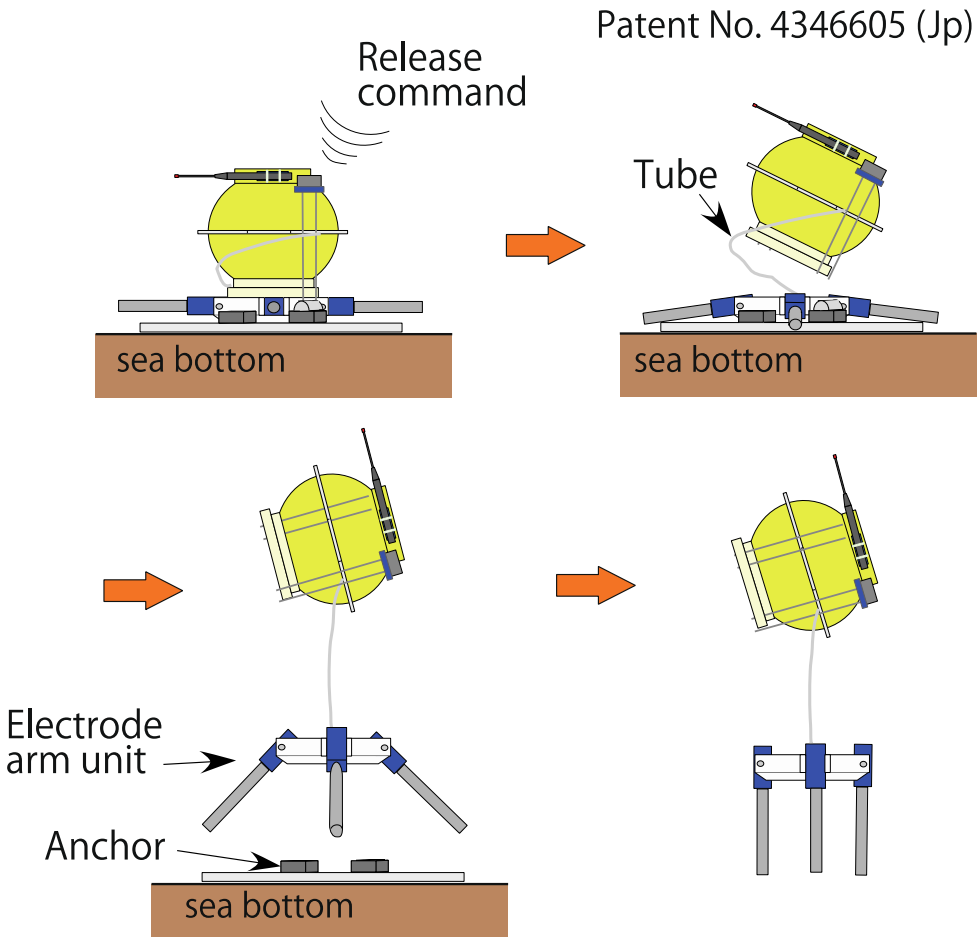


Fig. 4.1.2 Electrode arm-holding mechanism of type A OBEM

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 originally designed for the controlled source survey with over 500 Hz sampling. An electric circuit and battery are involved in one cylinder type aluminum pressure case. In this cruise, we loaded this OBE and electrodes on an AUV Urashima for the self-potential survey to detect some signal of the hydrothermal deposit.

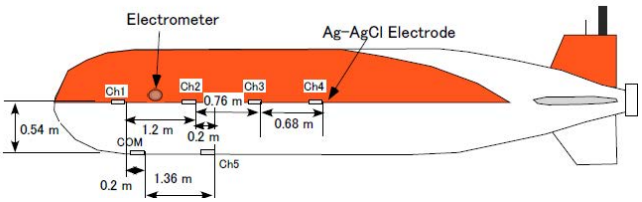


Fig. 4.2.1 Configuration of the electrodes on an AUV Urashima.

4.3 DC resistivity system

On this cruise, we use two type controlled-source systems. One is the original system developed by Kyoto university, called “A-MANTA”. This system was loaded on the deep-tow system. The logger unit can record the data of output power data of a transmitter unit and four electric fields with a 8 Hz sampling rate. Another one is the improved system based on the A-MANTA, called “HF-MANTA”. Both 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 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.

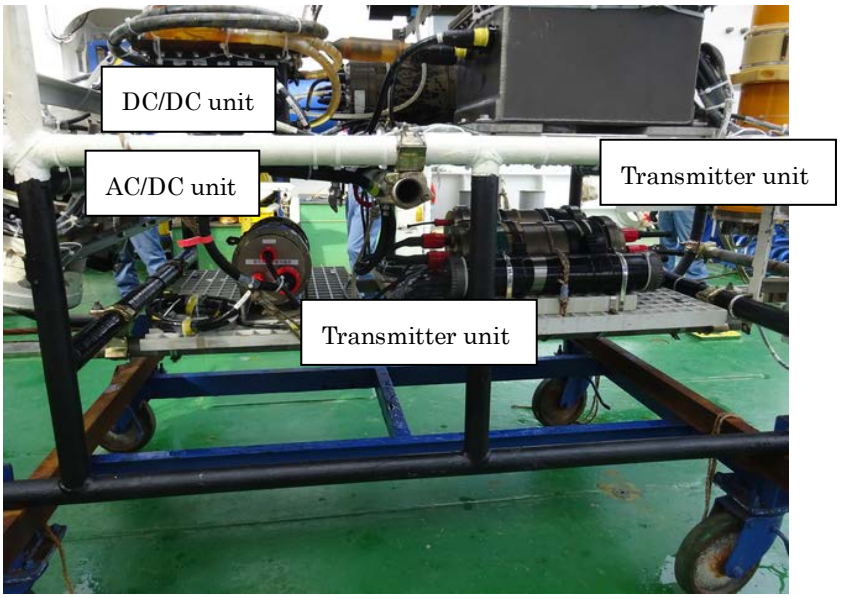


Fig. 4.3.1 Photo of a controlled source survey system on the deep-tow system.

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

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 shipboard equipment (see Appendix). Figure5.1.1 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.

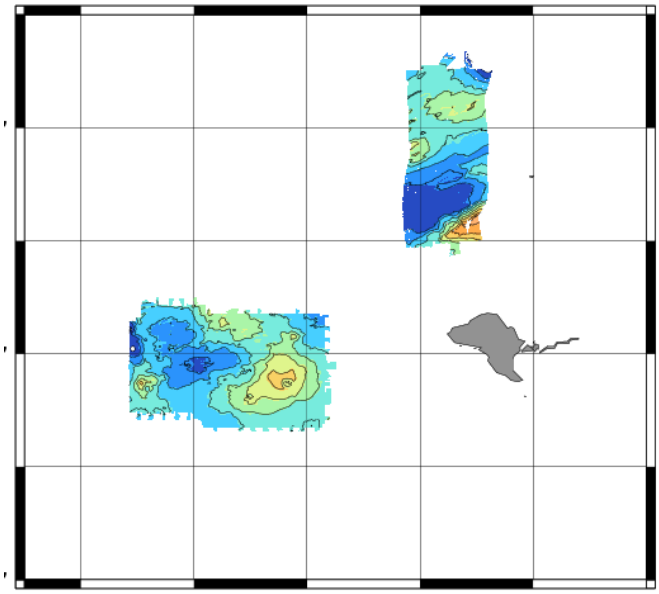


Fig. 5.1.1 Survey area of shipboard data in this cruise.

5.2 Pop-up type OBEM and OBE operations

For characterization a back-arc basin development, we have obtained Magneto-telluric data using an OBEM. In this cruise, OBEMs were launched using an articulated crane for all stations (Fig. 5.2.1), and sunk by their own weights. The operations were quick and smooth. We tracked the OBEMs by acoustic signals and confirmed that all equipment were successfully settled on the seafloor. Then, each position was determined by the SSBL system equipped on the R/V Yokosuka (Fig. 5.2.2, Table 5.2.1). All OBEMs will be recovered in the YK16-12 cruise.

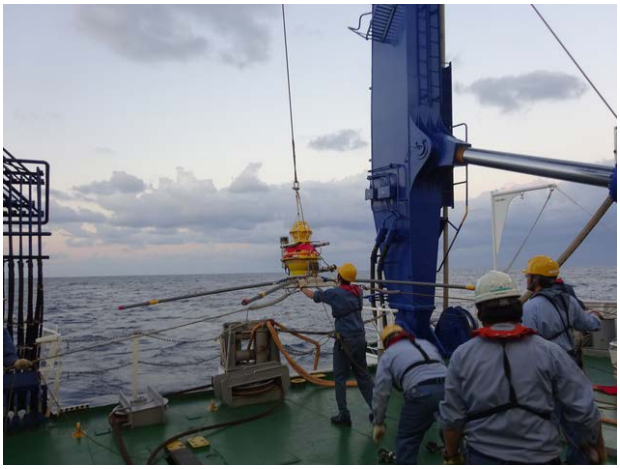


Figure 5.2.1 Photo of the OBEM deployment.

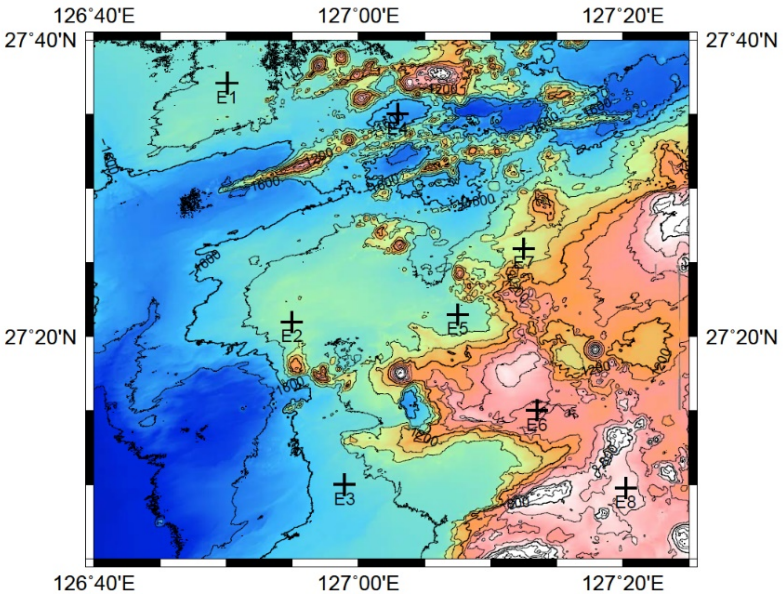


Figure 5.2.2 Site map of deployed OBEMs.

Table 5.2.1 Information of the 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	27-25.8801 N	127-12.5246 E	2016/8/8 18:13	27-25.9354 N	127-12.5184 E	1405.5
JM400	2016/8/8 19:10	27-21.4359 N	127-07.4994 E	2016/8/8 19:40	27-21.5041 N	127-07.5090 E	1480.0
JM103	2016/8/9 6:21	27-34.8583 N	127-02.9289 E	2016/8/9 6:56	27-35.0120 N	127-02.9695 E	1656.1
KYT02	2016/8/9 8:15	27-36.8410 N	126-49.9498 E	2016/8/9 8:44	27-37.1025 N	126-50.0570 E	1485.0
JM108	2016/8/9 10:17	27-20.8668 N	126-54.8991 E	2016/8/9 10:47	27-20.9894 N	126-54.9686 E	1441.5
JM110	2016/8/9 12:01	27-09.8929 N	126-59.0149 E	2016/8/9 12:34	27-09.9869 N	126-58.9787 E	1542.7
JM109	2016/8/9 13:53	27-14.9418 N	127-13.5418 E	2016/8/9 14:14	27-14.9952 N	127-13.5141 E	1007.0
JM402	2016/8/9 15:15	27-09.7362 N	127-20.2443 E	2016/8/9 15:37	27-09.7694 N	127-20.2155 E	840.0

5.3 AUV Urashima and deep-tow dives

Figure 5.3.1 shows all AUV Urashima and Deep-tow (YKDT) dive tracks carried out at the western Kume Island for the confirmation of our geophysical survey procedure for the hydrothermal deposit. First, we used the AUV Urashima to narrow five candidates, which obtained by the topographic features and some water column anomaly, down to a few detailed survey areas. We loaded the controlled source unit on the YKDT, and carried out the YKDT dives at two candidate area. The data acquisition of the SP and resistivity data was successfully.

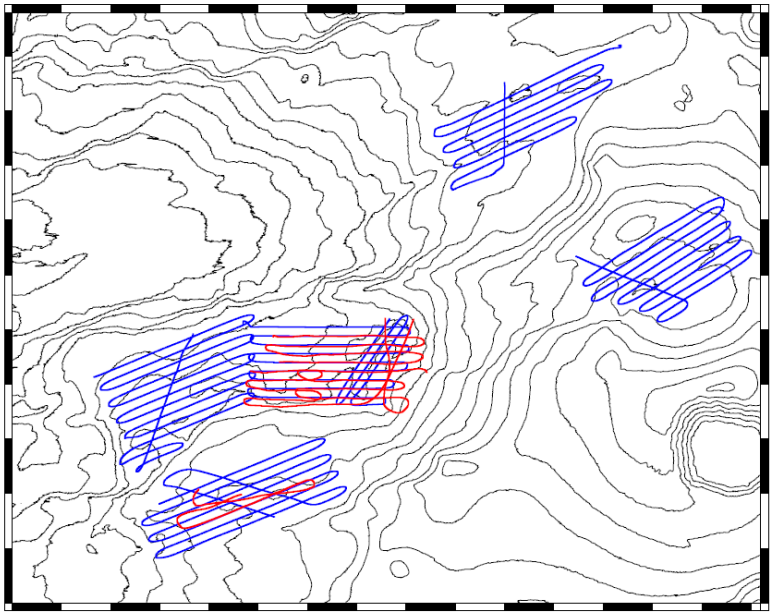


Fig. 5.3.1 AUV Urashima and deep-tow dive tracks at Western Kume Island.

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
Stabilized platform	
Platform pitch(deg.)	±22
Platform roll(deg.)	±25
Platform period(min.)	4 to 4.5
Beam interval(deg.)	1
Control system	
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 G
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 ~ 7 x 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)