doi : 10.17596/0002947

R/V KAIREI Cruise Report

KR13-04

Ocean bottom geodetic and thermal observation in the coseismic area of the 2011 Tohoku-Oki earthquake

Feb.11–21, 2013

Japan Agency for Marine-Earth Science and Technology

(JAMSTEC)

●Contents

1. Objectives and cruise summary

(1) Objective

Three science projects have been conducted on R/V KAIREI to identify and understand the factor that controlled the tremendous slip exceeding 50 m in this trench during the 2011 Tohoku-Oki Earthquake. Understanding this aspect is important because the slip near the trench is strongly related to the generation of the huge tsunami that stuck the coast of northeastern Japan. Key observations needed to determine the physical properties, such as friction and pore pressure on a plate interface, controlling the coseismic slip near the trench are the post-seismic deformation after the main shock, fluid distributions around the huge slip area, and the thermal conditions at the plate interface. The three proposals that the cruise focused on are as follows: (a) a study of plate coupling at a shallow subduction zone based on ocean bottom geodesy and fluid flow observations; (b) fluid detection using the electro-magnetic survey method and chemical anomaly; and (c) retrieval of temperature loggers from the borehole drilled by the Japan Trench Fast Drilling Project (JFAST).

(a) Plate coupling at a shallow subduction zone based on ocean bottom geodesy and fluid flow observations (S12-06)

Two types of instruments—acoustic distance meters (ADMs) and an ocean bottom pressure recorder (OBPR), which was installed on the wellhead of the JFAST drilling site—have been prepared to determine the plate coupling or plate convergence rate at the shallow subduction zone during the post-seismic period of the 2011 Tohoku-Oki earthquake. The convergence rate of a subducting plate to the overriding plate is a key piece of information necessary for understanding the subduction system. Currently, little information is available about the convergence rate, in particular, in the vicinity of the Japan Trench. This can be attributed to the extreme sea floor depth of more than 7000 m. To observe the convergence rate across the trench axis, we are developing the ADM system. This system can be used to determine the distance between a pair of ADMs on the basis of the travel times of acoustic waves. An OBPR is a powerful instrument that can measure vertical deformation. We have installed an OBPR on the wellhead of the JFAST drilling site, because the wellhead is potentially useful as semipermanent stable benchmark on the seafloor. During KR13-04, we tried to install these instruments and test their performance.

(b) Fluid detection using the electromagnetic survey method and chemical anomaly (S12-66)

Electrical resistivity is a very sensitive parameter for water. Therefore, we have conducted a survey using ocean bottom electro-magnetometers (OBEMs) located around the subduction zone to investigate the relationship between fluid and earthquake occurrence.

In this cruise, we carried out OBEM recovery operation at five sites to obtain the resistivity structures at these sites. All the OBEMs were recovered. We also planned a recovery dive for the long-term OBE system and heat flow probe (SAHF) near the cold seep area. However, we could not carry out this planed dive because of bad weather conditions.

(c) Retrieval of the temperature loggers from the borehole drilled by the Japan Trench Fast Drilling Project (JFAST) (S12-70)

JFAST primarily aims to understand the physical mechanisms and dynamics of large slip earthquakes (Chester et al., 2012). The site for a JFAST expedition would be chosen such that the borehole would penetrate the large-slip plate boundary fault involved in the 2011 Tohoku-Oki Earthquake. One of the objectives of JFAST is to estimate the frictional heat and stress within and around the fault zone by measuring temperatures across the fault. During the JFAST expeditions (Integrated Ocean Drilling Program [IODP] Expedition 343 from April to May 2012 and IODP Expedition 343T in July 2012), five holes were drilled using the D/V Chikyu. Three holes penetrated the plate boundary. In Hole C0019D, the miniature temperature logger (MTL) autonomous observatory was installed. The wellhead is installed on the seafloor close to the Japan Trench at a depth of about 6900 m. The ROV KAIKO 7000 II was scheduled to retrieve the MTL observatory on the KR13-04 cruise.

During Dives 592 and 593 of the KR13-04 cruise, we could not locate the C0019D site. The search for the wellheads was conducted with reference to the location determined during Dive 579 of the KR12-16 cruise, when the wellheads were located. In Dive 592 of the KR13-04 cruise, the vehicle could not approach the area because of inappropriate positioning of the KAIKO launcher and vehicle and KAIREI, while in Dive 593, an area of 500 m × 300 m was extensively searched but the wellheads were not found.

(2) Cruise number/ship name

KR13-04/　R/V KAIREI

(3) Title of the cruise

Ocean bottom geodetic and thermal observation in the coseismic area of the 2011 Tohoku-Oki earthquake

(4) Period of the cruise

February 11, 2013–Feb 21, 2013

(5) Port calls

Yokosuka–Shiogama

(6) Research area

The landward slope of the Japan Trench, Off Miyagi, Northeastern Japan

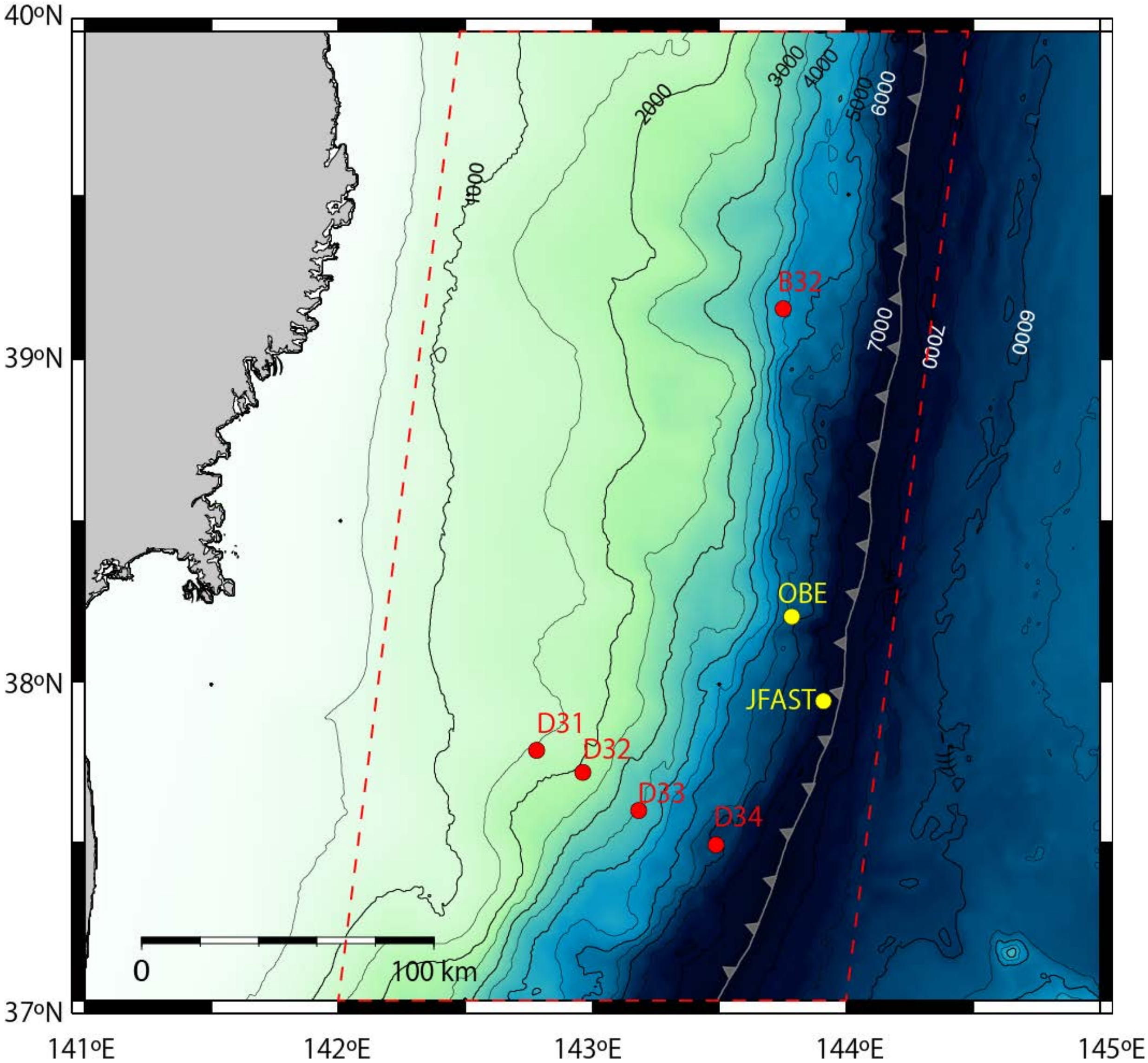


Fig 1.1: The preliminary research area. The yellow circles indicate the dive points. The red circles indicate OBEM stations operated by JAMSTEC.

(7) Dive list (Dive numbers, Observers, Dive points, Keywords for the dives)
7K#0592, Yasuyuki KANO, Landward slope of the Japan Trench, JFAST
7K#0593, Yasuyuki KANO, Landward slope of the Japan Trench, JFAST

(8) The track line chart of the vessel.

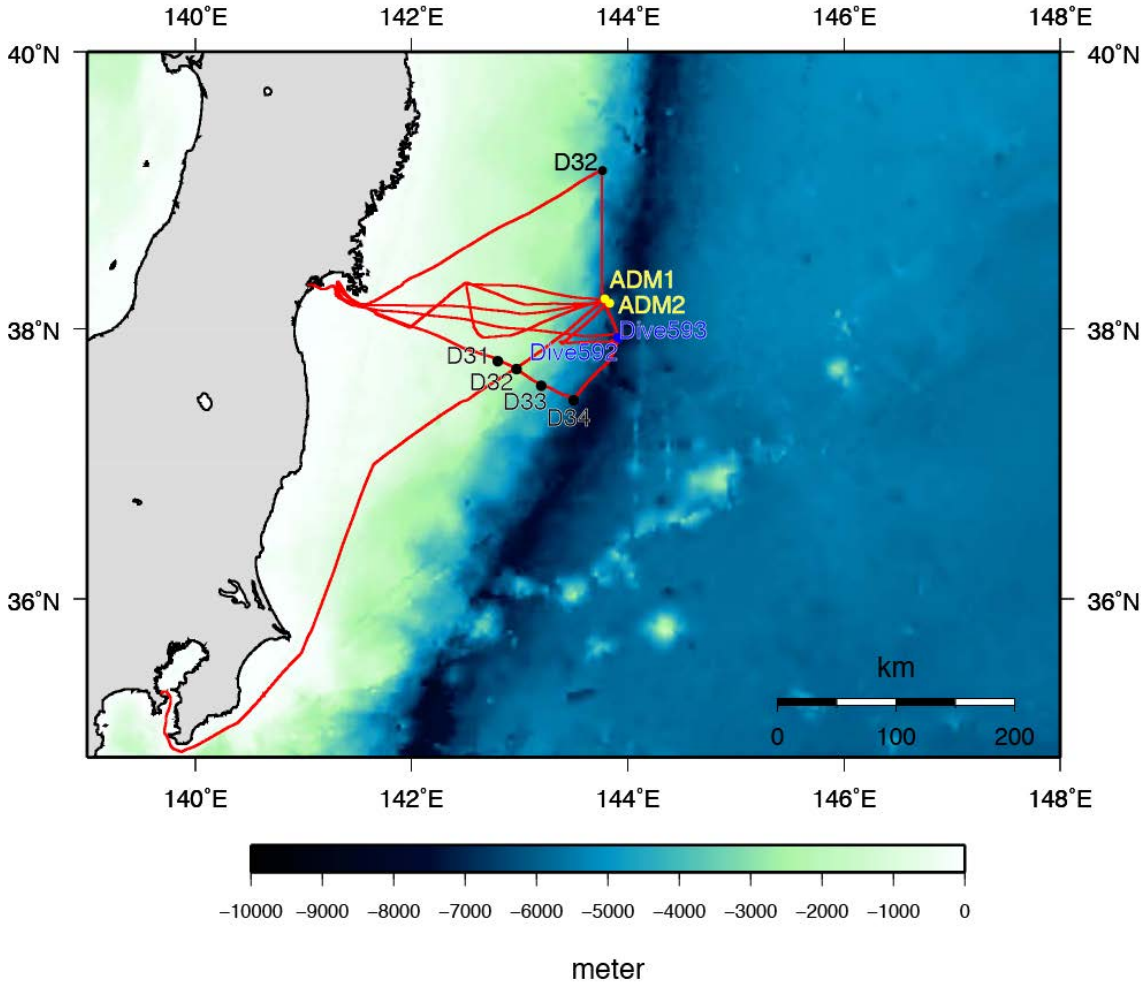


Fig. 1.2: The cruise track (red), dive points (blue), deployed and recovered instruments (yellow), and recovered instruments (black).

2. List of Participants

Chief Scientist

YOSHIHIRO ITO	Tohoku University

Onboard Scientists

YUKIHITO OSADA	Tohoku University
SHUICHI SUZUKI	Tohoku University
TATSUYA KUBOTA	Tohoku University
KAZUYA HASEGAWA	Tohoku University
TAKAFUMI KASAYA	JAMSTEC
HIROSHI ICHIHARA	JAMSTEC
MASANORI KYO	JAMSTEC
YASUHIRO NANBA	JAMSTEC
LIN WEIREN	JAMSTEC
YASUYUKI KANO	Kyoto University
JIM MORI	Kyoto University
TAKESHI TSUJI	Kyushu University
PATRICK MICHAEL FULTON	University of California Santa Cruz
HIDETOSHI OKANO	Power House

Marine Technician

HIROAKI MURAKI	Marine Works JAPAN
SATOMI MINAMIZAWA	Nippon Marine Enterprises, LTD.

ROV KAIKO 7000II operation team

Operation Manager	ATSUMORI MIURA
2nd ROV Operator	KIYOSHI TAKISHITA
2nd ROV Operator	TOMOE KONDO
2nd ROV Operator	TETSUYA ISHIZUKA
2nd ROV Operator	ATSUSHI TAKENOUCHI
2nd ROV Operator	SEIJI SHIGETAKE
3rd ROV Operator	RYU ASAI
3rd ROV Operator	TAKUMA GOTO

R/V KAIREI Officers and Crew

Captain	MASAYOSHI ISHIWATA
Chief Officer	HIROAKI MASUJIMA
1st Officer	HIROYUKI KATO
2nd Officer	MOTOI KATSUMATA
3rd Officer	YUKI DEGURA
Chief Engineer	TADASHI ABE
1st Engineer	KAZUNORI NOGUCHI
2nd Engineer	TAKAHIRO MORI
3rd Engineer	KOTA KATAOKA
Chief Electronics Operator	TOKINORI NASU
2nd Electronics Operator	MICHIYASU KATAGIRI
3rd Electronics Operator	TAKAYUKI MABARA
Boat Swain	TADAHIKO TOGUCHI
Able Seaman	YASUO KONNO
Able Seaman	YUKI YOSHINO
Able Seaman	HIROAKI MURASE
Sailor	SHUN ABE
Sailor	SHUN MIURA
Sailor	YASUNOBU KAWABE
Sailor	SHINYA KOJIMA
No.1 Oiler	HIROYUKI OISHI
Oiler	KAZUO SATO
Oiler	SHINYA SUGI
Oiler	MASANORI UEDA
Assistant Oiler	SHOTARO SUMITOMO
Chief Steward	TERUYUKI YOSHIKAWA
Steward	YOSHINOBU HASATANI
Steward	TORU WADA
Steward	KIYOTAKA KOSUJI
Steward	KANA YUASA

3. Shipboard log

Date	Local Time	Note	Description	Position/Weather/Wind/Sea condition
11-Feb-13		**Sail out, proceeding to research area**		02/11 12:00 (UTC+9h)
	14:00	boarded		
	15:00	let go all shore line, left YOKOSUKA-SHIN-KO	for OFF SANRIKU	
	16:00-16:50	carried out onboard education & training for scientists		
12-Feb-13		**Deploy ADM1 and ADM2**		02/12 12:00 (UTC+9h)
	09:00-09:30	briefing with KAIKO7000II team		38-04.0N,142-34.0E
	12:45	arrived at research area (OFF SANRIKU)		OFF SANRIKU
	12:49	released XBT @ 38-11.1178'N, 143-44.1460'E		Fine but cloudy
	13:18-13:51	carried out MBES site survey		NW-4 (Moderate breeze)
	14:14	deployed Acostic Distance Meter(ADM)2		3 (Sea slight)
	15:41-16:37	carried out caribration ADM2		2 (Low swell log)
	17:02	deployed ADM1		Visibly: 8'
	18:30-19:45	carried out caribration ADM1		
	20:00	commenced proceeding to		

		off ISHINOMAKI due to rough sea		
13-Feb-13				02/13 12:00 (UTC+9h)
	07:00	let go starb'd anchor @ off ISHINOMAKI		38-21.0N,141-19.0E
	13:00-14:20	scientific seminar		ISHINOMAKI Bay
				Snow
				NNW-6 (Strong breeze)
				3 (Sea slight)
				1 (Low swell short)
				Visibly: 4'
14-Feb-13		**Recover OBEM @ B32**		02/14 12:00 (UTC+9h)
	07:00	hove up starb'd anchor, and proceeding to research area (B32)		38-37.0N,142-32.3E
	16:30	arrived at research area (B32)		OFF SANRIKU
	18:57	recovered OBEM(B32), and then proceeded to ADM1		Cloudy
	22:30	arrived at ADM1 point		WSW-4 (Moderate breeze)
	22:54-23:09	carrided out calibration (ADM1 and OBE)		3 (Sea slight)
				4 (Moderate average)
				Visibly: 8'
15-Feb-13		**ROV KAIKO7000II dive 592**		02/15 12:00 (UTC+9h)
	06:21	hoisted up KAIKO 7000II		37-56.5N,143-54.8E

	07:32	hoisted up KAIKO 7000II		OFF SANRIKU
	07:37	launched KAIKO 7000II, and started 7K#592 dive operation		Rain
	13:08	landed at sea bottom	Depth = 6925m	NE-5 (Fresh breeze)
	13:40	left bottom	Depth = 6965m	3 (Sea slight)
	17:20	hoisted up KAIKO 7000II		4 (Moderate average)
	17:30	recovered KAIKO 7000II		Visibly: 8'
	18:15	proceeded to off ISHINOMAKI due to rough sea		
16-Feb-13				02/16 12:00 (UTC+9h)
	07:00	Let go port anchor @ off ISHINOMAKI		38-20.8N,141-19.1E
	13:00-15:30	scientific seminar		ISHINOMAKI Bay
				Overcast
				NW-7 (Near gale)
				3 (Sea slight)
				1 (Low swell short)
				Visibly: 8'
17-Feb-13		**Recover OBEM**		02/17 12:00 (UTC+9h)
	07:00	hove up port anchor, and proceeding to research area (D31)		37-47.3N,142-46.0E
	12:05	arrived at research area (D31)		OFF SANRIKU
	13:23	recovered OBEM (D31)		Fine but cloudy
	15:31	recovered OBEM (D32)		West-5 (Fresh breeze)
	18:10	recovered OBEM (D33)		3 (Sea slight)

				2 (Low swell log)
				Visibly: 8'
18-Feb-13		**Recover OBEM and ROV KAIKO7000II dive 593**		02/18 12:00 (UTC+9h)
	01:25	recovered OBEM (D34)		37-56.2N,143-54.8E
	05:00	arrived at dive point		OFF SANRIKU
	07:54	hoisted up KAIKO 7000II		Overcast
	08:00	launched KAIKO 7000II, and started 7K#593 dive operation		SE-2 (Light breeze)
	11:47	landed at sea bottom	Depth = 6912m	2 (Sea calm)
	18:29	left bottom	Depth = 6949m	3 (Moderate short)
	21:29	hoisted up KAIKO 7000II		Visibly: 8'
	21:38	recovered KAIKO 7000II		
	22:29-22:50	carried out figure eight turning		
19-Feb-13		**Recover ADM**		02/19 12:00 (UTC+9h)
	07:09	recovered ADM2		38-03.0N,143-12.2E
	09:14	recovered ADM1		OFF SANRIKU
	09:30	suspended 7K dive operation due to rough sea		Overcast
	15:00	commenced heave to at SANRIKU coast		WNW-6 (Strong breeze)
				4 (Sea moderate)
				4 (Moderate average)
				Visibly: 8'

20-Feb-13		**Proceeding to SHIOGAMA-KO**		02/20 12:00 (UTC+9h)
	00:30	finished heave to and shifted to dive point		38-10.0N, 142-23.2E
	07:00	canceled dive due to rough sea and then proceeded to SHIOGAMA-KO		OFF SANRIKU
	16:15	let go starb'd anchor at off SHIOGAMA		Fine but cloudy
				WNW-5 (Fresh breeze)
				3 (Sea slight)
				2 (Low swell log)
				Visibly: 8'
21-Feb-13		**Arrived at SHIOGAMA-KO**		02/21 12:00 (UTC+9h)
	07:00	hove up port anchor, and proceeding to SHIOGAMA-KO		
	09:00	arrived at SHIOGAMA-KO		
	10:00	disembarked from KAIREI		
		finished KR13-04 cruise		

4. KAIKO 7000II Dive

4.1 Instruments at JFAST site

Fig.4.1.1 shows a schematic diagram of the observatory system installed during the IODP Expedition 343T at the JFAST site, Hole C0019D. An 8.5" open hole was drilled to a total depth of about 850 m below the seafloor (mbsf). The hole penetrated two fault zones. The MTL autonomous observatory was loaded in a 4.5" tubing, which was then placed in the 8.5" hole.

The MTL observatory system consists of a sinker bar, 8 ropes, 55 MTL sensors, 3 weak links, an MTL hanger, and an ROV hook ring. In Fig. 4.1.3.1, these sensors are represented by several symbols. There are two types of temperature sensors—"Temperature-1" and "Temperature-2"—and the total number of these sensors is 45. In addition, 10 sensors are employed to measure pressure for determining depth. The wet weight of the MTL observatory is about 80 kg. Because it is possible that the faults are still slipping, three weak links were employed to avoid the losing the entire system within the hole during retrieval.

The measured data are being stored in the sensors and the MTL observatory system was to be recovered during this cruise. As shown in the upper right part of Fig.4.1.1, the upper end of the 20" casing and a running tool connector are located on the seafloor. The MTL observatory has an ROV hook ring at its upper most end, and it can be retrieved by hooking onto and pulling up this ring.

To evaluate the tension in the rope from KAIKO after hooking the MTL string, we deployed a loadcell on the payload KAIKO. The rope can be cut off for KAIKO's safety if the load becomes extremely large because of problems with the MTL string.

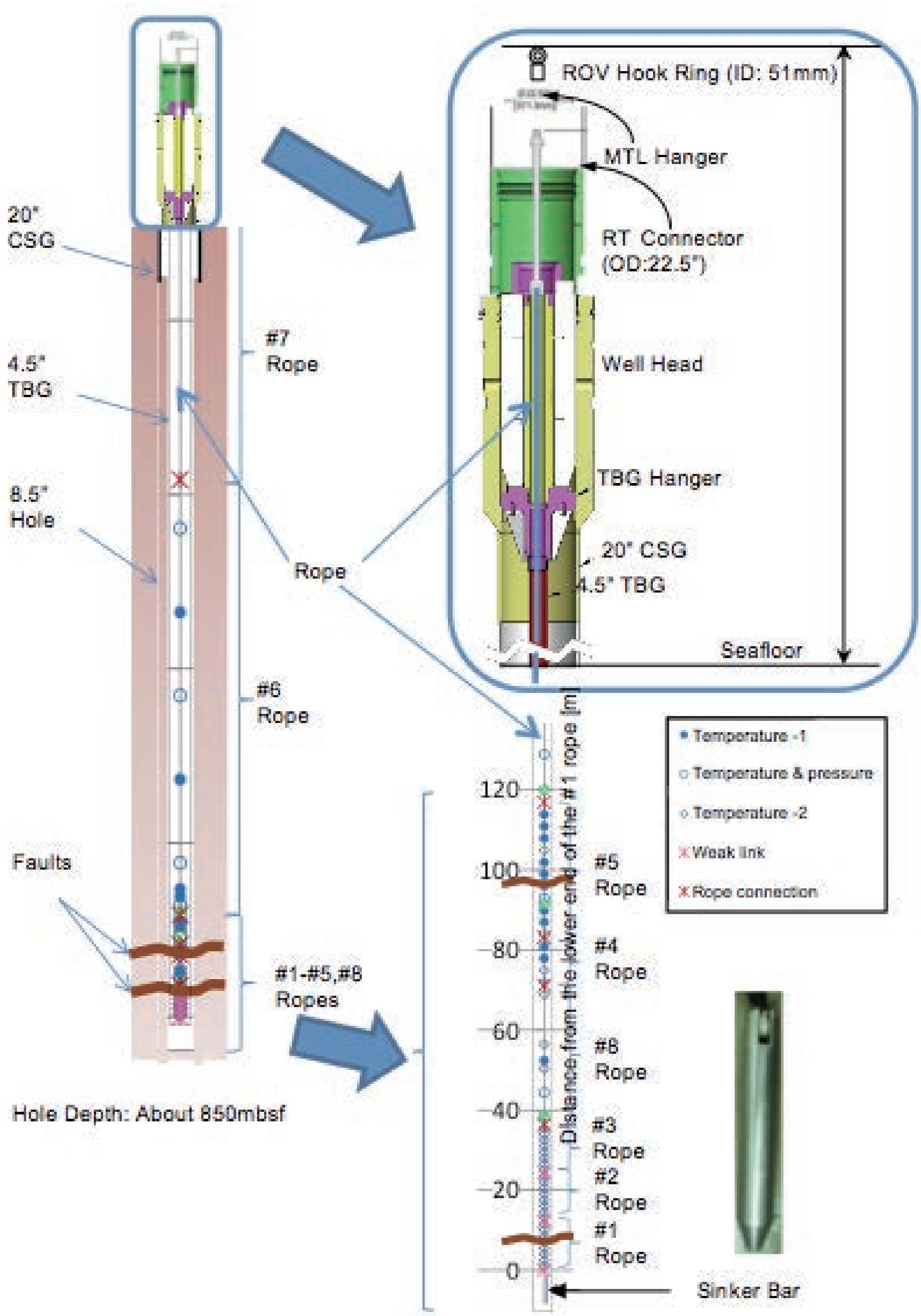


Fig. 4.1.1: A schematic diagram of the MTL observatory installed during Expedition 343T at the JFAST site. Abbreviations: CSG, Casing; TBG, Tubing; MTL, Miniature Temperature Logger; RT, Running Tool; and mbsf, meters below the seafloor.

4.2 Dive summary

4.2.1 Dive 592

The retrieval of MTL observatory was attempted during Dive 592. A strong dragging force on the KAIKO vehicle restricted the mobility of the launcher and prevented a close approach to the JFAST site. This dragging force was a result of the inappropriate positioning of the KAIKO launcher and vehicle along with the mother ship KAIREI. Rough sea conditions may have also contributed to the inappropriate positioning. The dragging force caused apparent motion of the vehicle similar to the motion observed when a strong current is encountered at the sea floor.

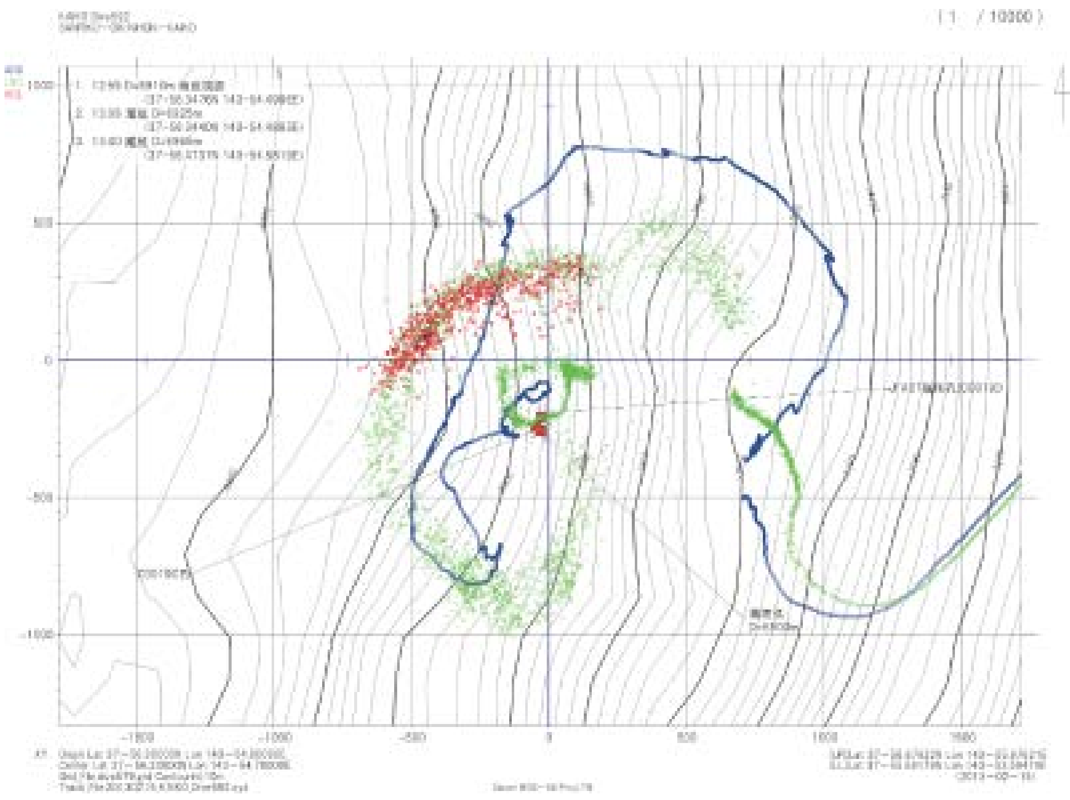


Figure 4.2.1.1. A map showing tracks of R/V KAIREI (blue), ROV KAIKO launcher (green), and the vehicle (red).

4.2.2 Dive 593

In Dive 593, a 500 m × 300 m area was searched to find the JFAST site; however, the wellhead could not be found. Although an Obstacle Avoidance Sonar (OAS) received several signals, which were thought to correspond to the possible location of the wellhead, they all were, in fact, reflections from topography, such as mounds and cliffs The range of OAS covers an area with a radius of about 500-m centered at Hole C0019D. The wellhead is 4-m high, and the seafloor undulations around the site may have prevented finding the wellhead using the signals received by the OAS. Another possibility is that the wellhead was tilted or was buried by landslides caused by a large aftershock. However, although some fresh cracks were observed on the sea floor, no signs of a landslide were observed.

It may be difficult to find the wellhead in future dives. To find the wellhead, we need: (1) a detailed survey of local topography by KAIKO, which helps to determine KAIKO's location on the sea floor; (2) to search after confirming the location so as to systematically cover the entire area with a fixed reference location, such as an ROV homer. It will be preferable to conduct separate dives for searching and retrieval operations. Several dives are necessary to carry out the procedure above. To safely retrieve the MTL observatory, the hooking procedure and load cell system also need to be revisited.

The visibility on the sea floor was 10–20 m, which is worse than that experienced during Dive 579 in October 2012. The turbidity was less, but similar to that observed after the 2011 Tohoku earthquake.

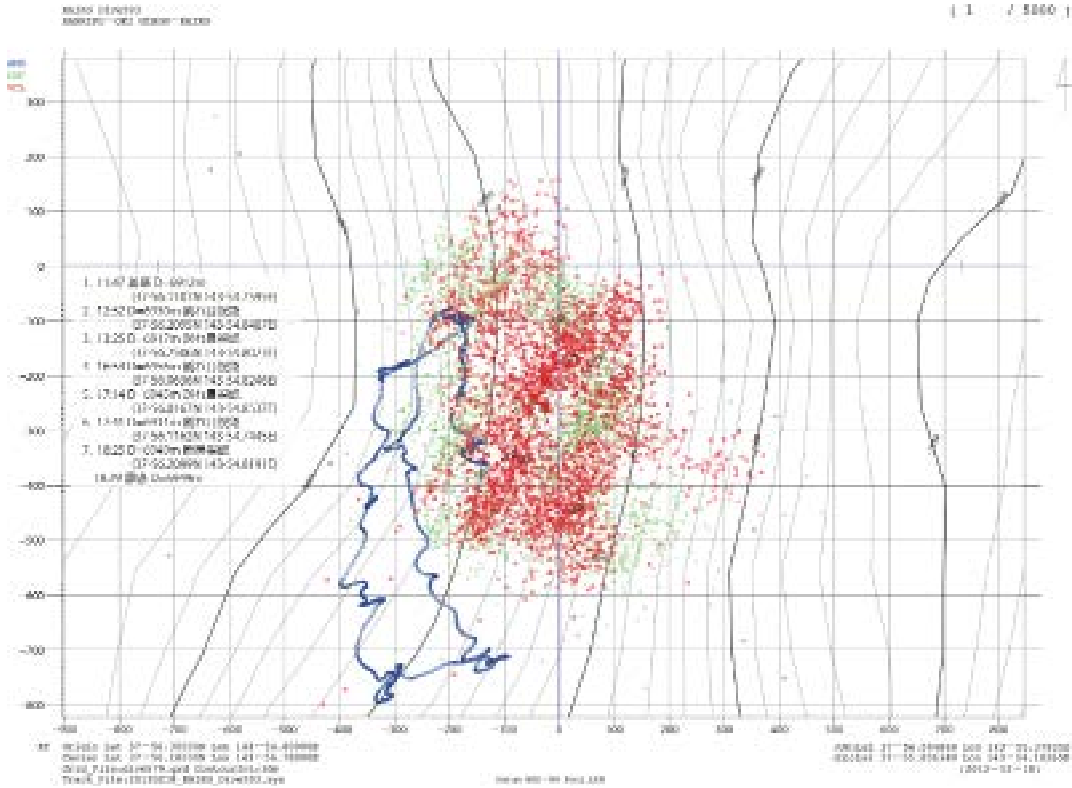


Figure 4.2.2.1. A map showing tracks of R/V KAIREI (blue), ROV KAIKO launcher (green), and the vehicle (red).

5. Shipboard data (Gravity and 3-axis magnetic data)

Gravity and 3-axis magnetic data were measured continuously throughout the entire cruise. The gravity meter on board R/V KAIREI is the Air-Sea Gravity System II (LaCoste & Romberg Corporation, USA). These data were reduced to 1-min interval data by the host computer. Detailed information is provided in Table 5.1.

A shipboard three-component magnetometer (STCM: Isezaki, 1986) was used for measuring the geomagnetic field during the cruise. The STCM (SFG-1212, TIERRA TECNICA) is a 3-axis flux-gate magnetometer installed on the Nav. deck above the bridge. The specifications of the STCM are listed in Table 5.2. To obtain information on the ship's attitude and direction (roll, pitch, and heading), a gyro system was installed on board. These data were collected at a sampling rate of 8 Hz during the cruise.

The STCM data contain information on the effects of the ship's magnetic field, for which corrections should be made in order to derive the accurate geomagnetic field. In general, an 8-shaped navigation was made for calibrating the ship's magnetic effect, taking into account the magnetic susceptibility of the ship and the permanent magnetic moment of the ship's body (Isezaki, 1986). The 8-shaped navigation was conducted from 18:19 to 18:38 on July 26 as shown in Table 5.3.

Table 5.1: Specifications of the Air-Sea Gravity System

The Specifications of Gravity Meter	
Measurement Range (mGal)	12,000
Drift	3 mGal per month or less
Stabilized Platform	
Platform Pitch (dig.)	±22
Platform Roll (deg.)	±25
Platform Period (min.)	4–4.5
Beam Interval (deg.)	1
Control system	
Recording Rate (Hz)	1
Serial Output	RS-232
System Performance	
Resolution (mGal)	0.01

Static Repeatability (mGal)	0.05
50,000 mGal Horizontal Acceleration (mGal)	0.25
100,000 mGal Horizontal Acceleration (mGal)	0.50
100,000 mGal Vertical Acceleration (mGal)	0.25
Dimension (cm)	71×56×84
Weight (kg)	Meter:86, UPS:30

Table 5.2: Specifications of the three-component magnetometer.

The Specifications of 3 axes Fluxgate Magnetometer	
System	Ring core Fluxgate
Number of Components	Directly 3 axes
Cable Length (m)	50
Sensor Dimension (mm)	ϕ280×130H
Measurement Range (nT)	±100,000
Resolution (nT)	1

Table 5.3: Information on the 8-shape navigation calibration of the STCM.

Information on the 8-shape navigation			
MM/DD	TIME (JST)	Locations	
2/18	22:29–22:50	37° 51.4′	143° 49.5′

6. ADM deployment and retrieval

6.1 ADM System

The 2011 Tohoku-Oki Earthquake ruptured the interplate boundary off the eastern shore of Honshu, generating a devastating tsunami that swept the coastal area along northeastern Japan. The seafloor geodesy yielded important results showing that the large slip was located near the Japan Trench and suggesting the heterogeneity of the coseismic slip distribution in the plate interface. The maximum displacement region for an interplate earthquake is mainly located in the offshore region. Therefore, it is important to monitor both postseismic displacement and the stress accumulation process using seafloor geodesy. Further, if we can observe the postseismic displacement near the Japan Trench, we can better understand the coupling condition of the plate boundary. A seafloor acoustic ranging system is available for the direct observation of horizontal displacement on seafloor. The system is designed to measure distances of up to 1–2 km with a precision of less than 1 cm. We plan to use such systems to make time-series distance measurements across the faults to detect and quantify seafloor crustal movements. However, this system cannot be used to study the area in the vicinity of the axis of Japan Trench because it cannot be applied in a deep-sea area. Therefore, we needed to modify this system so that it can be employed to study the axis of the Japan Trench. The design concept behind the system was to enable them to be installed at any location (Fig. 6.1.1). The electronics and battery of this system are housed in a 17” diameter glass sphere that is depth-rated to 9000 m. The sphere is equipped an acoustic transducer, a temperature sensor (RBR ltd), and an attitude sensor. The system is set on a 3-m monopod anchor with a universal joint, allowing the PXP to sway slightly with bottom currents and thus enabling its deployment on slopes; the attitude sensor can be used to correct the effects caused by this sway.

6.2 Operation marks

We carried out the experiment using a seafloor acoustic ranging system between Feb. 12 and 19, 2013. We deployed two acoustic distance-meters (ADMs) on Feb. 12 (Fig. 6.2.1). We estimated 72 m/min as the rate of sinking for an ADM. After deployment of two ADMs, we calibrated their positions. We collected slant ranges on three points within a 1-mile radius in terms of horizontal distance from the deployment point. The difference from the point of deployment and the calibrated point is about 540 m in the direction of EN on ADM1 (Fig. 6.2.2), and 400 m in the direction of EN (Fig. 6.2.3). We checked the acoustic ranging on the ship. On Feb. 19, 2013, we recovered the ADMs. We estimated 54 m/min as the rate of float.

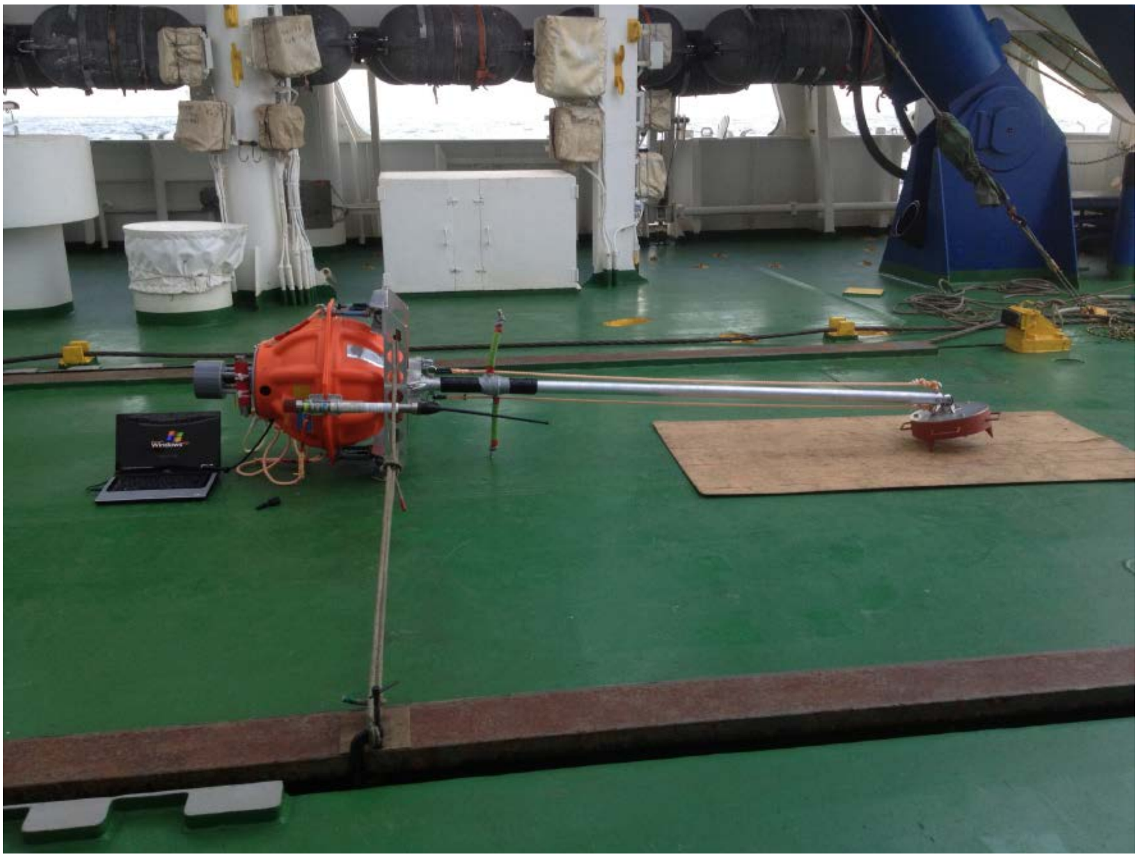


Fig. 6.1.1:　A photograph of an acoustic distance-meter.

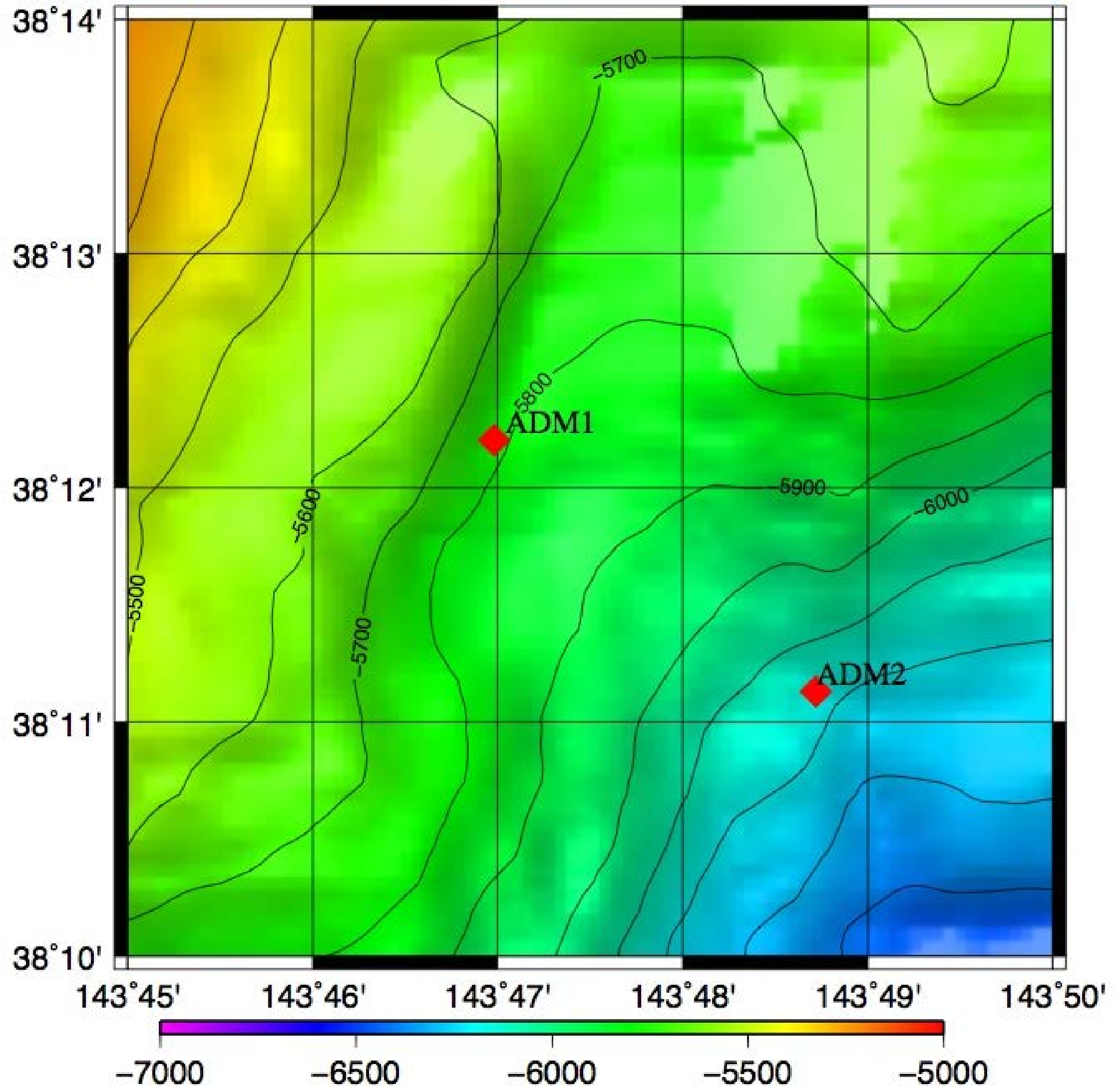


Fig. 6.2.1: A map showing the location of the seafloor acoustic ranging system, which was deployed in this cruise, at the Japan Trench. ADM1 is a slave PXP. ADM2 is the master PXP.

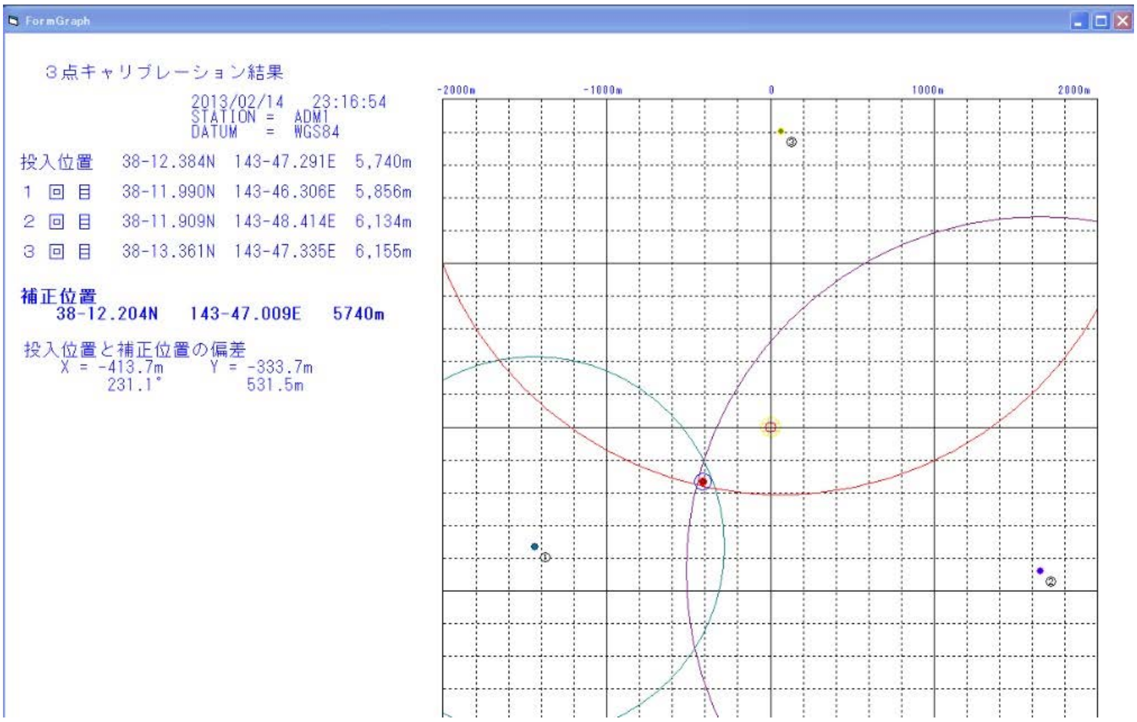


Fig. 6.2.2: Results for the location of ADM1.

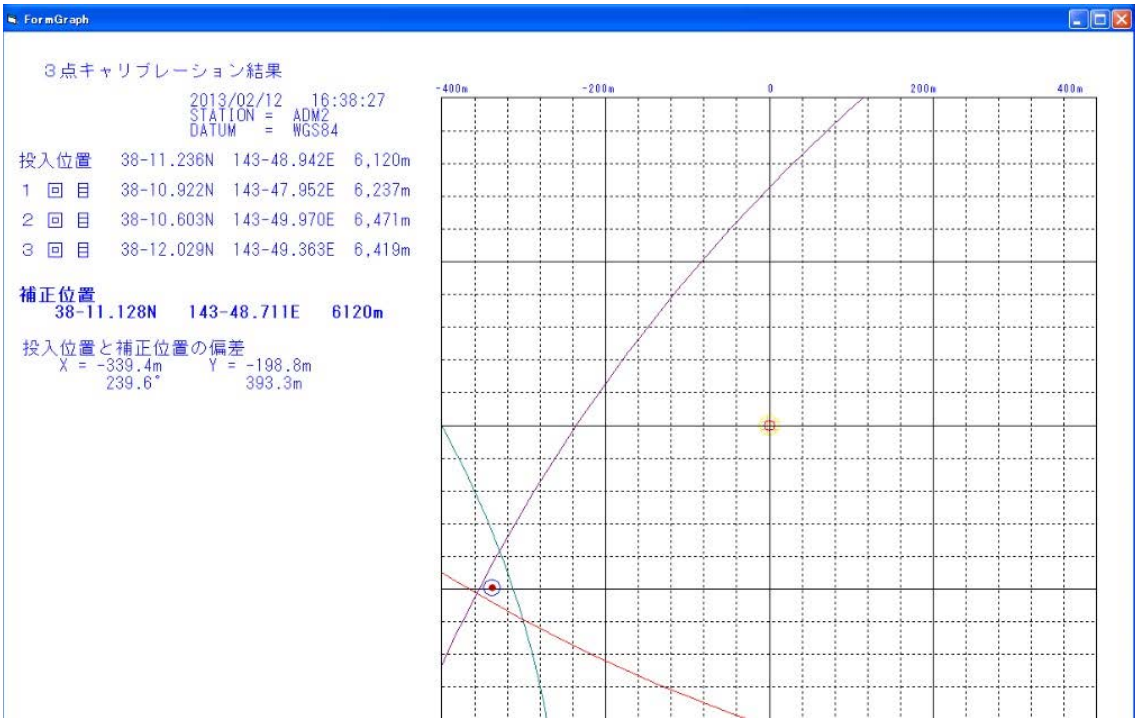


Fig. 6.2.3: Results for the location of ADM2

7. OBEM retrieval

7.1 OBEM system

The OBEM system can measure time variations in three components of magnetic field, horizontal electric field, the instrumental tilts, and temperature. It mainly consists of one 17" glass sphere, a sensor unit in an aluminum/titanium pressure housing, and an electrode arm unit with an arm-holding mechanism (Fig. 7-1-1). The glass sphere houses the 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 the electric field, four voltage differences between the electrodes on the tip of the pipes and the ground electrode are measured. The electrodes were monitored for their self-potentials in a laboratory prior to the seafloor observations, and pairs whose coherence was 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 KAIREI's SSBL system, and it is easy for us to determine its position in the sea or on the seafloor. Concepts important in the development of the OBEM system are miniaturization, a high sampling rate, easy assembly and recovery operations, and low construction and operation costs. The arm-holding mechanism, whose electrode arm is folded when an OBEM is surfacing, enables a recovery operation even by a small ship that is not equipped with an A frame (Kasaya et al., 2006; Kasaya and Goto, 2009).

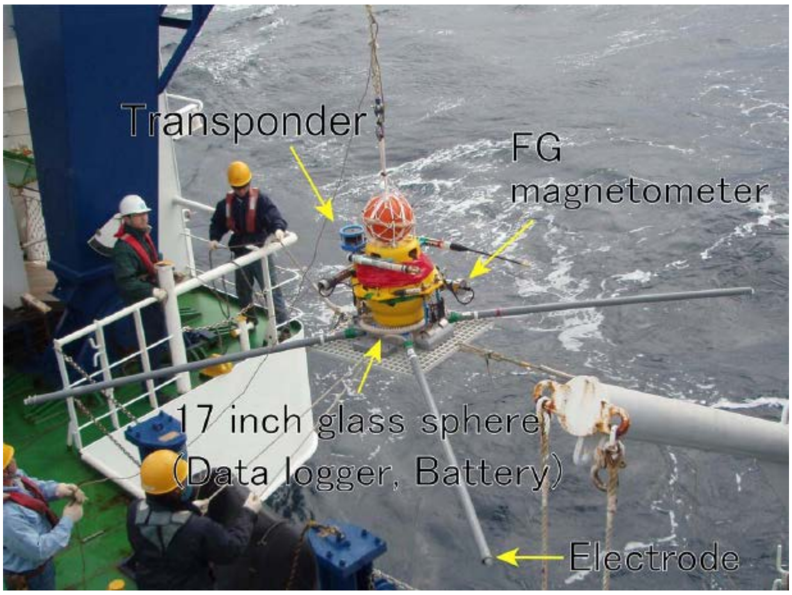


Fig. 7.1.1:　An OBEM system

7.2 Operation remarks

We retrieved five OBEMs at the sites B32, D31, D32, D33, and D34 (Fig. 7-2-1). These OBEMs were deployed during the KR12-15 and KR12-16 cruises. We transmitted the acoustic weight-release signal from the SSBL system equipped by R/V KAIREI. The OBEMs in the sites B32, D31, D32, and D33 started to ascend in the usual releasing time (15–19 min, Table 7.2.1). However, the OBEM settled in the site D34 only ascended 200 min after the release command was transmitted. For the following reasons, we concluded that sediment covered this OBEM, thus impeding its ascent: 1) a large earthquake occurred a few tens of kilometers east of the site D34 on December 7, 2012 (Fig. 7.2.1); 2) a large amount of mud was deposited on the OBEM; 3) this situation was reported in the Japan Trench after the 2011 Tohoku-oki earthquake (see the Cruse report of KR12-15).

The ascent rates of the OBEMs were about 40 m/min according to the SSBL system. The OBEMs were found with the ship looking and using a radio beacon signal soon after the OBEM's surfacing. The OBEMs were hooked and lifted onto the deck from the starboard. The OBEMs conditions were checked after we removed the arm-unit, sensor unit and transponder (Fig. 7.2.2). Then the glass-spheres were opened to collect the data. High-quality time series were successfully recorded in most OBEMs. The clock of each data logger was compared with the laptop PC synchronized by using an NTP server unit connected to GPS (Table 7.2.1).

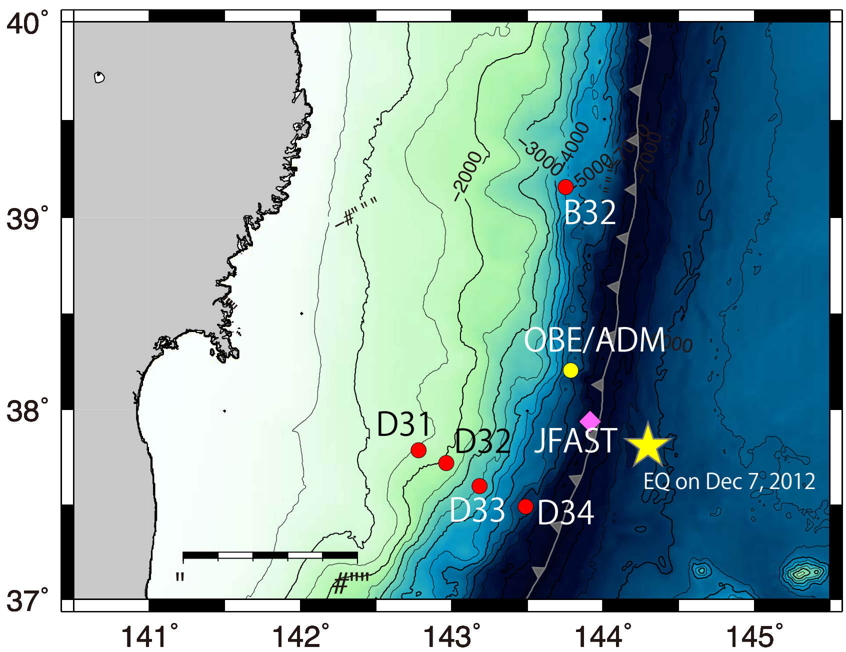


Fig. 7.2.1: Recovered OBEM locations in the cruise KR13-04.

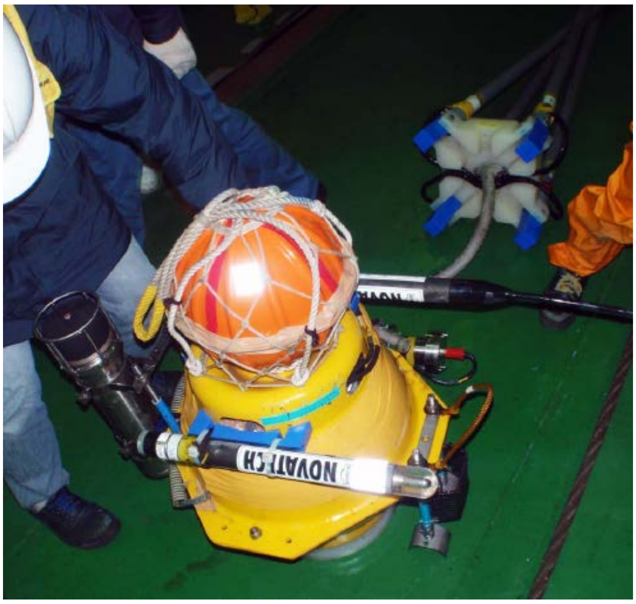


Fig. 7.2.2: A recovered OBEM (JM102, site D34)

Table 7.2.1: Recovery information

Site ID	OBEM ID	Releasing duration (min)	Ascent rate (m/min)	On deck time (JST)	Clock set time (JST)	Clock compared time (JST)	Time diff. (sec)
B32	JM105	18	43.1	13/2/14 18:53	12/10/9 16:42:29	13/2/19 15:51:00	15.446
D31	TIT02	19	39.1	13/2/17 13:23	12/10/13 5:42:36	13/2/19 17:35:31	11.648
D32	JM101	17	42.4	13/2/17 15:31	12/10/13 7:39:24	13/2/19 16:36:55	13.960
D33	TIT01	15	44.4	13/2/17 18:10	12/10/18 9:52:06	13/2/19 15:48:11	14.447
D34	JM102	(200)	37.3	13/2/18 1:25	12/10/8 17:25:14	13/2/18 1:36:46	11.925

7.3 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.

8. Notice regarding the use of this cruise report

Notice on using: Insert the following notice to users regarding the data and samples obtained.

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

This report may not be corrected even if changes in 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 from this report, please consult the Chief Scientist for the latest information.

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

Appendix

A.1 R/V KAIREI

The deep sea research vessel "KAIREI" is designed to survey deep sea floor and sub-seafloor structures of arc-trench-backarc systems, ridge systems and basic oceanic crustal structure. R/V KAIREI is the exclusive mother vessel for "KAIKO 7000 II".

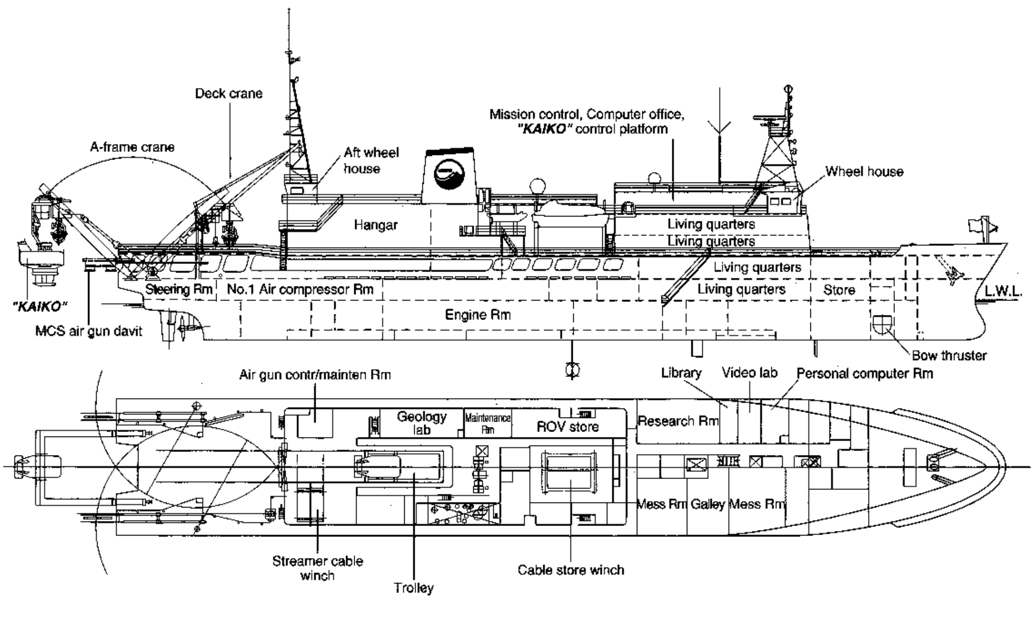
In addition, R/V KAIREI is equipped with various kinds of geophysical equipment; a multi narrow beam echo sounder and a sub bottom profiler (Sea Beam 2112.004, Sea Beam Instruments, Inc.), a gravity meter (Marine Gravity meter System type KSS 31, BODENSEEWERK PERKIN-ELMER), a three axis magnetometer (Type SFG-1212, Tera Technica Inc.), and a proton magnetometer (Type PM-217, Kawasaki Geological Engineering Co., Ltd.). The specifications of R/V KAIREI are listed below.

The general specifications of R/V KAIREI

Nationality	JAPAN
Owner	JAMSTEC
Operator	Nippon Marine Enterprises, Ltd
Length overall	106.0 m
Beam overall	16.0 m
Draft	4.5 m
Gross tonnage	4,517 tons
Maximum speed	16.7 knots
Main propulsion system Diesel engines	2,206kW x 2
Main propulsion method	Controllable pitch propeller x 2

Complement

Crew / Submersible operation staff	38 persons
Researchers	22 persons
	Total 60 persons



A.2 KAIKO 7000 II System

The 7,000m-class ROV "***KAIKO 7000 II***" system has been developed for use in deep-sea research that has not been possible by existing manned submersible for reason of ocean depths or sea floor topographies.

The specifications of Launcher

Dimensions	5.2m (Length) x 2.6m (Wide) x 3.2m (Hight with fin)	
Weight	5.8 tons in air / 3.5 tons in water	
Tow speed	MAX 1.5 knots	
Operating depth	MAX 11000m	
Equipment		
Side Scan Sonar (SSS)		Frequency ：42kHz, 38kHz Range ：1000m in each side
Sub Bottom Profiler (SBP)		Parametric method Frequency ：60kHz (Primary wave) 2.5, 3.5, 5.0kHz (Secondary) Pulse level ：235dB
CTD, Gyro compass, Obstacle avoidance sonar, Acoustic positioning system, Monitoring camera, Pitch / roll sensor,		

The specifications of Vehicle

Dimensions	3.0m (Length) x 2.0m (Wide) x 2.1m (Hight)
Weight	4.0 tons in air / 0.0 tons in water
Speed	0 – 0.5 knots
Propulsion	4 horizontal thrusters / 6 vertical thrusters
Operating depth	MAX 7000m
Equipment	
CTD, Gyro compass, Obstacle avoidance sonar, HDTV camera x2, Color TV camera x2 (with Pan &Tilt), Digital still camera, manipulators x2, Sample basket (Payload:100kg in air, 50kg in water)	