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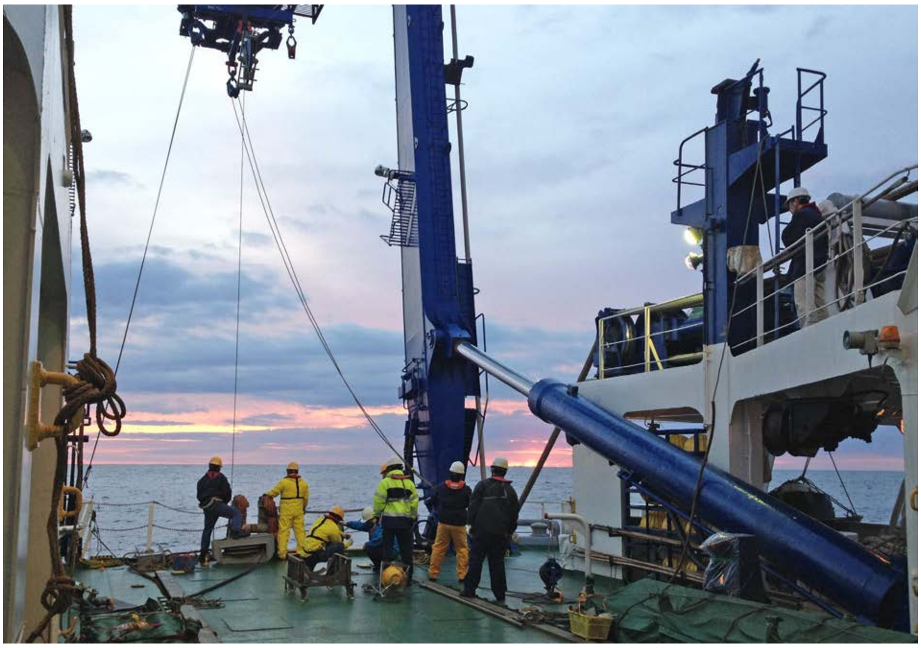
YOKOSUKA Cruise Report

YK14-21

Studies of fracturing and pore fluid circulation in the oceanic crust subducting along the Japan Trench through heat flow and electromagnetic surveys



Japan Trench off Sanriku

December 15, 2014 – December 24, 2014

Japan Agency for Marine-Earth Science and Technology
(JAMSTEC)

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1. Cruise Information

Cruise number:

YK14-21

Ship name:

R/V YOKOSUKA

Title of the cruise:

2014 Deep Sea Research

Studies of fracturing and pore fluid circulation in the oceanic crust subducting along the Japan Trench through heat flow and electromagnetic surveys

Title of proposal:

S14-27

Studies of fracturing and pore fluid circulation in the oceanic crust subducting along the Japan Trench through heat flow and electromagnetic surveys

Cruise period:

December 15, 2014 – December 24, 2014

Port call:

2014	Dec. 15	Dept. from Tokyo (Harumi)
	Dec. 24	Arriv. at Sendai (Shiogama)

Research area:

Japan Trench area off Sanriku

Research map:

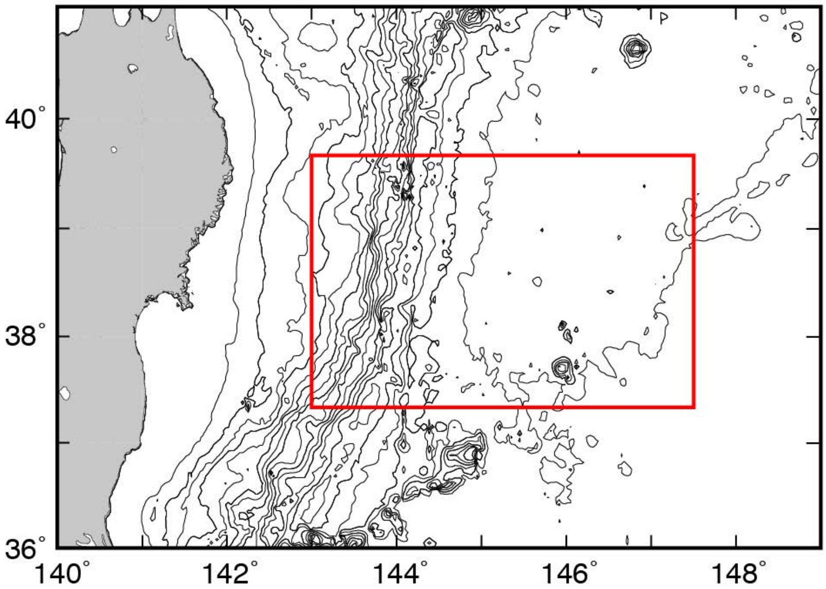

Figure 1-1. Proposed research area of YK14-21 cruise.

Ship track and observation points are shown in 3.2.3.

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3. Observation

3.1. Introduction

The temperature structure of the subducting oceanic plate, generally determined by the seafloor age, is one of the most important factors controlling the subsurface thermal structure of subduction zones. The Pacific plate subducting along the Japan Trench is very old, over 130 m.y., and thus supposed to be cold. Heat flow values measured on the seaward slope of the Japan Trench along a parallel of 38°45’N were, however, significantly higher than that expected from the seafloor age (Yamano et al., 2008). It indicates that the temperature structure of the incoming Pacific plate may be anomalous, which has an influence on the temperature distribution along the subduction plate interface. Aiming to investigate the extent and cause of the high heat flow anomaly, we conducted heat flow measurements along three E-W lines across the Japan Trench at latitudes of about 38 to 40°N (lines A, B, and C in Fig. 3.1-1). The obtained data, combined with the existing data, revealed the following features of heat flow distribution on the seaward side of the Japan Trench (Fig. 3.1-1; Yamano et al., 2014).

1) On the seaward trench slope and trench outer rise along the three lines, heat flow is anomalously high, higher than 70 mW/m^2, at many stations, while values normal for the seafloor age (about 50 mW/m^2) are observed at some stations. No anomalously low values were obtained. It suggests that high heat flow anomaly seaward of the Japan Trench extends at least over the northern half of the trench.

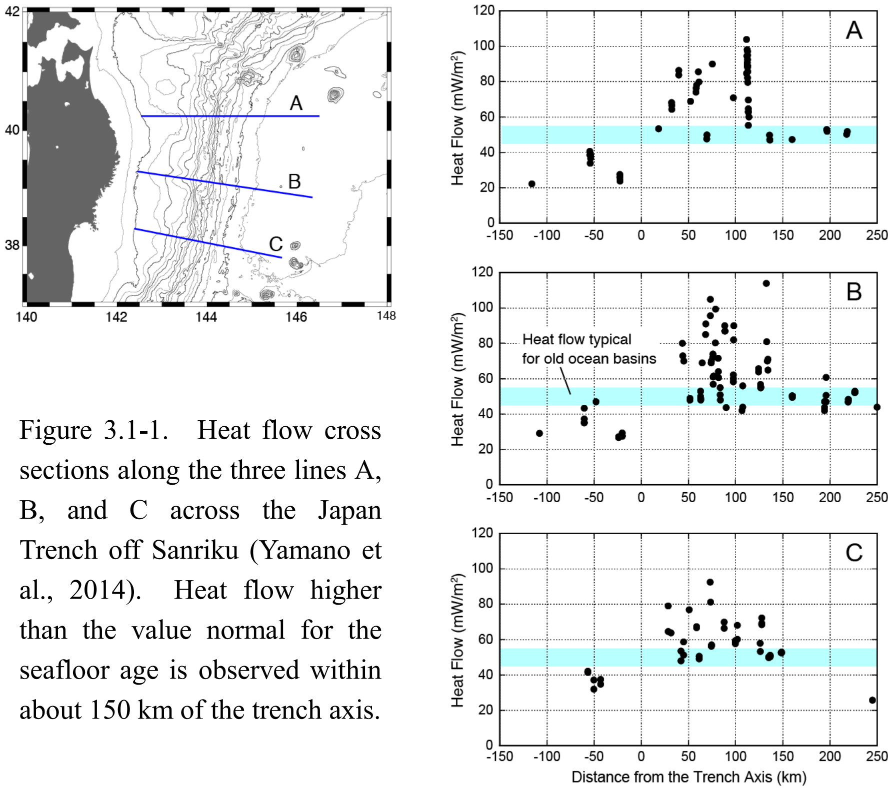

Figure 3.1-1. Heat flow cross sections along the three lines A, B, and C across the Japan Trench off Sanriku (Yamano et al., 2014). Heat flow higher than the value normal for the seafloor age is observed within about 150 km of the trench axis.

2) Significantly high heat flow (over 70 mW/m^2) was observed within about 150 km of the trench axis. The limited extent indicates that the anomaly is closely related to deformation of the Pacific plate associated with subduction.

A possible cause of the heat flow anomaly is heat transport by pore fluid flow along normal faults developed on the seaward trench slope (e.g., Tsuru et al., 2000). Prominent normal faults are, however, distributed within about 80 km of the trench axis (Nakanishi et al., 2011), while the high heat flow zone extends further seaward. Magma intrusion due to petit-spot volcanism (a peculiar type of intra-plate volcanism around the outer rise of the Japan Trench; e.g., Hirano et al., 2006) may have provided some heat. But it cannot be a major source of the observed extensive heat flow anomaly because petit-spot volcanoes are rather sparsely distributed and petrological study showed that the total amount of melt produced in the mantle is small.

Seismic reflection and refraction surveys seaward of the Japan and Kuril trenches revealed that significant change in the seismic velocity structure of the oceanic crust occurs in the incoming Pacific plate (Fujie et al., 2013a, 2013b): the compressional and shear wave velocities (Vp and Vs) decrease and the Vp/Vs ratio increases. The thickness of the anomalous velocity layer appears to increase toward the trench axis, which is more obvious off the Kuril Trench. Such changes in the seismic velocities probably represent increase in water content as a result of fracturing of the oceanic crust due to bending of the plate (Fujie et al., 2013a). Seismic surveys conducted along a line parallel to the Japan Trench about 100 km seaward of the trench showed that the velocity structure also varies in the north-south direction. It indicates that the density of fractures and the amount of water in the oceanic crust may vary along the trench as well.

The seismic velocity changes are found within 150 to 200 km of the trench axis, both off the Kuril Trench and off the Japan Trench, which appears to correspond with the extent of the high heat flow anomaly off the Japan Trench. Based on the correlation between the heat flow distribution and the seismic velocity structure, Kawada et al. (2014) proposed that the high heat flow observed seaward of the Japan Trench may be attributed to the following processes in the incoming Pacific plate (Fig. 3.1-2).

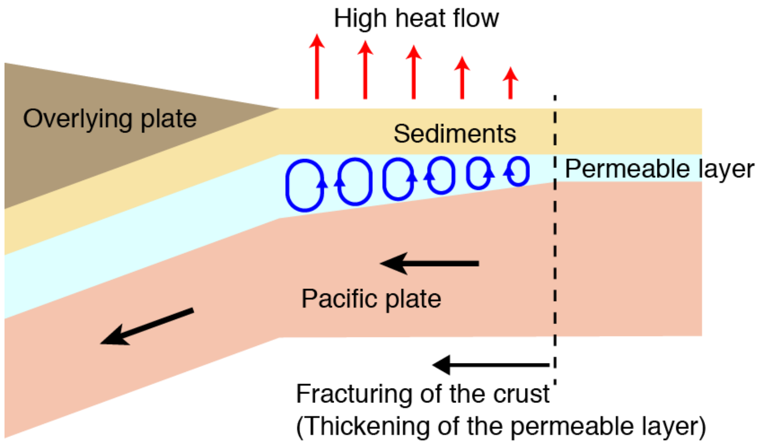

Figure 3.1-2. Hydrothermal heat mining model (Kawada et al., 2014). The permeable layer in the upper oceanic crust thickens toward the trench.

Bending of the Pacific plate associated with subduction yields fractures in the oceanic crust, increasing the permeability of the crust. Development of fractures toward the trench leads to thickening of the permeable layer, which enhances vertical heat transport by pore fluid circulation from deeper part of the crust and raises the surface heat flow. This hydrothermal heat mining model (Kawada et al., 2014) can be tested through more detailed heat flow measurements and electromagnetic surveys to reveal the electrical resistivity structure which reflects the distribution and connectivity of pore fluid.

3.2. Summary of the Cruise

3.2.1. Research items

(1) Heat flow measurement (HF)

Measurement of temperature profiles in surface sediment with an ordinary deep-sea heat flow probe for determination of terrestrial heat flow.

(2) Sediment core sampling (HFPC)

Sampling of surface sediments with a piston corer and heat flow measurement at the same site using small temperature recorders mounted on the core barrel.

(3) Bathymetry and subbottom profiling surveys

Bathymetry mapping with a multi narrow beam system and surface sediment structure survey with a subbottom profiler.

3.2.2. Cruise schedule and operations

Date	Events, Operations
Dec. 15	Leave Tokyo (Harumi) Transit to Ishinomaki Bay
Dec. 16	Take refuge from rough sea (Ishinomaki Bay)
Dec. 17	Take refuge from rough sea (Ishinomaki Bay)
Dec. 18	Take refuge from rough sea (Ishinomaki Bay)
Dec. 19	Transit to the survey area
Dec. 20	Arrive in the survey area Bathymetry and subbottom profiling surveys Heat flow measurement (HF01)
Dec. 21	Take refuge from rough sea (Ishinomaki Bay)
Dec. 22	Bathymetry and subbottom profiling surveys Piston core sampling with heat flow measurement (HFPC01)
Dec. 23	Take refuge from rough sea (Ishinomaki Bay)
Dec. 24	Arrive at Sendai (Shiogama)

Detailed cruise log is given in 7.1.

3.2.3. Ship track and observation points

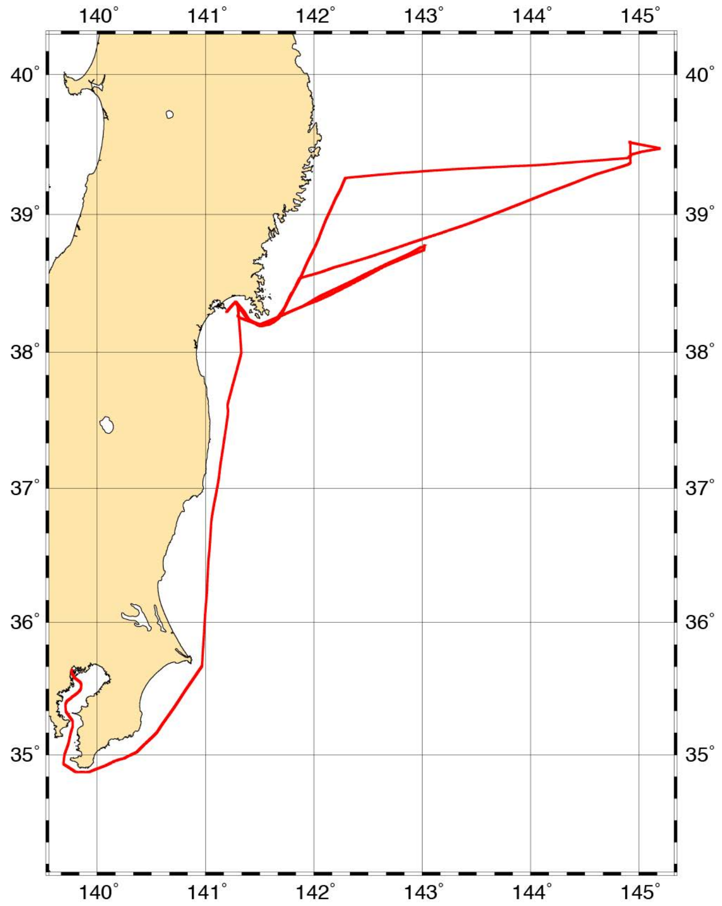

Figure 3.2-1. Ship track of YK14-21 cruise.

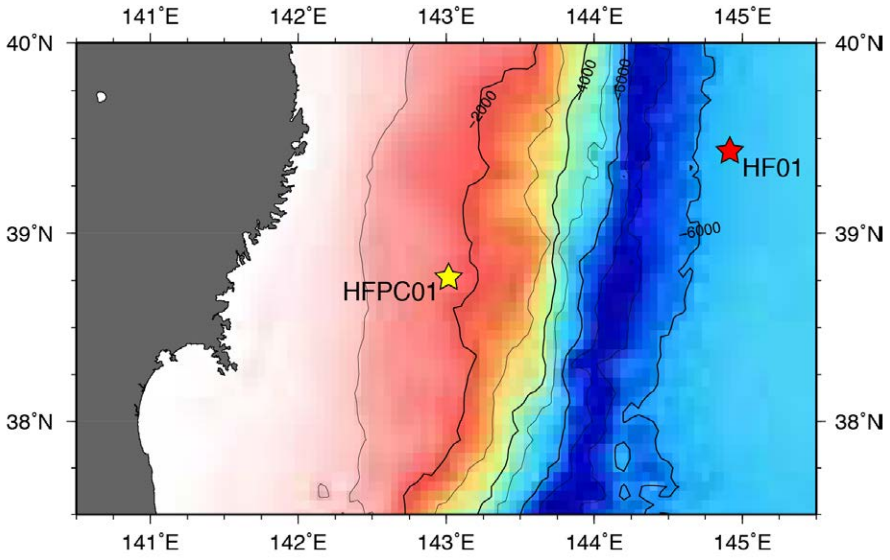

Figure 3.2-2. Measurement and sampling stations on YK14-21 cruise.

3.3. Research Objectives

We conduct heat flow and electromagnetic surveys on the Pacific plate seaward of the Japan Trench to test the hydrothermal heat mining model (Kawada et al., 2014; Fig. 3.1-2). Heat flow measurements are made mainly along the line B in Fig. 3.1-1, along which the seismic velocity structure was obtained (Fujie et al., 2013b). The observed heat flow distribution should be compared with the heat flow calculated assuming trenchward thickening of the permeable layer in the oceanic crust estimated from the velocity structure. Electromagnetic surveys are made using the controlled-source electromagnetic (CSEM) method as well as the passive magnetotelluric method so that we can image the electrical resistivity structure of the oceanic crust and the uppermost mantle. The obtained resistivity structure would allow us to delineate the spatial variation of the porosity and permeability of the crust and improve the hydrothermal heat mining model if necessary.

Based on the results of these studies, we will be able to reveal how fractures and pore fluid circulation develop seaward of the trench and how water penetrates into the upper part of the incoming plate. Our final goal is evaluation of the influence of these processes on the thermal structure and water distribution around the plate interface, the seismogenic zone of large thrust earthquakes.

Specific objectives of this research cruise

On this cruise, YK14-21, we investigate detailed heat flow distribution on the seaward trench slope and the outer rise of the Japan Trench around 39°N, mainly in the following four areas.

1) Within 50 km of the trench axis

There are few existing heat flow data between 0 and 50 km from the trench axis (Fig. 3.1-1). Average heat flow in this area would be indispensable for test and improvement of the hydrothermal heat mining model.

2) Between 150 and 250 km from the trench axis

Heat flow data in this area would show the transition from normal values for the seafloor age to the anomalous high heat flow zone, which can be compared with the seismic velocity structure.

3) Between 60 and 80 km from the trench axis

We conducted dense heat flow measurements along the line B in this area on KS-14-17 cruise of the R/V SHINSEI-MARU and found prominent sawtooth-like variation at a scale of several kilometers. For investigation of the origin of such small-scale anomaly, we need to know heat flow variation in the direction perpendicular to the line B.

4) CSEM survey sites

On KY14-10 cruise of the R/V KAIYO, we conducted CSEM surveys at two sites about 50 km north of the line B. Heat flow data at these sites can be combined with the electrical resistivity structure imaged through analysis of the CSEM survey data.

In addition to the above four areas, we may make measurements on the landward slope of the trench aiming to constrain thermal models of the interplate seismogenic zone taking account of influence of the hydrothermal heat mining process.

3.4. Instruments and Operation Methods

3.4.1. Deep-sea heat flow probe

Heat flow is obtained as the product of the geothermal gradient and the thermal conductivity. We measured the geothermal gradient by penetrating an ordinary deep-sea heat flow probe or a heat flow piston coring system (HFPC, cf. 3.4.2) into seafloor sediments.

[Specification of tools]

The deep-sea heat flow probe (Fig. 3.4-1) weighs about 800 kg and has a 3.0 m-long lance, along which seven compact temperature recorders (Miniaturized Temperature Data Logger, ANTARES Datensysteme GmbH; Fig. 3.4-2) are mounted in an outrigger fashion (Ewing type). A heat flow data logger (Kaiyo Denshi Co., DHF-650) placed inside the weight head (cf. Fig. 3.4-3) was used for recording the tilt and the depth of the probe. Tilt and depth data were sent to the surface with acoustic pulses so that we can monitor the status of the probe on the ship.

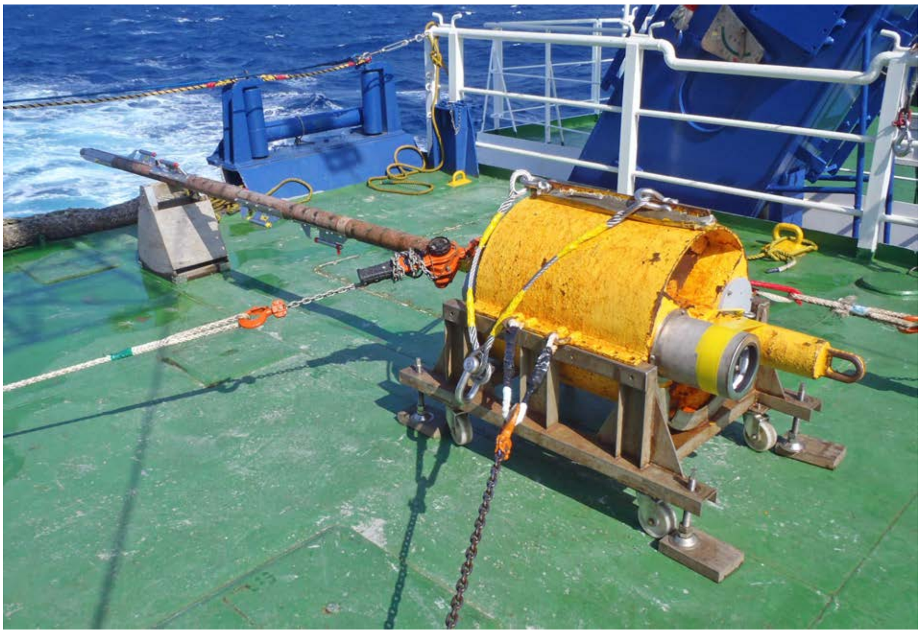

Figure 3.4-1. Deep-sea heat flow probe.

Figure 3.4-2. ANTARES Miniaturized Temperature Data Logger (MTL).

Specifications of the heat flow data logger and the ANTARES Miniaturized Temperature Data Logger (MTL) are summarized below:

Heat Flow Data Logger DHF-650 (Kaiyo Denshi Co.)
Pressure case: titanium alloy
Case length: 725 mm
Maximum diameter: 145 mm
Pressure rating: 7000 m water depth
Tilt: two-axis, 0 to ±45°
Data-cycle interval: 30 sec

Miniaturized Temperature Data Logger (ANTARES Datensysteme GmbH)
Pressure case: stainless steel
Case length: 160 mm
Diameter: 15 mm
Pressure rating: 6000 m water depth
Number of temperature channel: 1
Temperature resolution: 1.2 mK at 20°C, 0.75 mK at 1°C
Sample rate: variable from 1 sec to 255 min.

[Operations]

A 15-m long nylon rope was inserted between the heat flow probe and the winch wire rope in order not to kink the wire rope during probe penetrations. An acoustic transponder and a pinger were attached about 60 m above the probe for precise determination of the position of the probe and the distance from the seafloor (Fig. 3.4-3).

Multi-penetration heat-flow measurement operations were conducted following the procedures described below.

1. Measure water temperature about 30 m above the seafloor for calibration of the temperature recorders.
2. Lower the probe at a speed of about 1 m/sec until it penetrates into the sediment.
3. Measure temperatures in the sediment for about 15 min. Monitor the wire tension and pay out the wire when necessary to keep the probe stable.
4. Pull out the probe.
5. Move to the next station keeping the probe about 100 m above the seafloor.
6. Repeat penetrations.

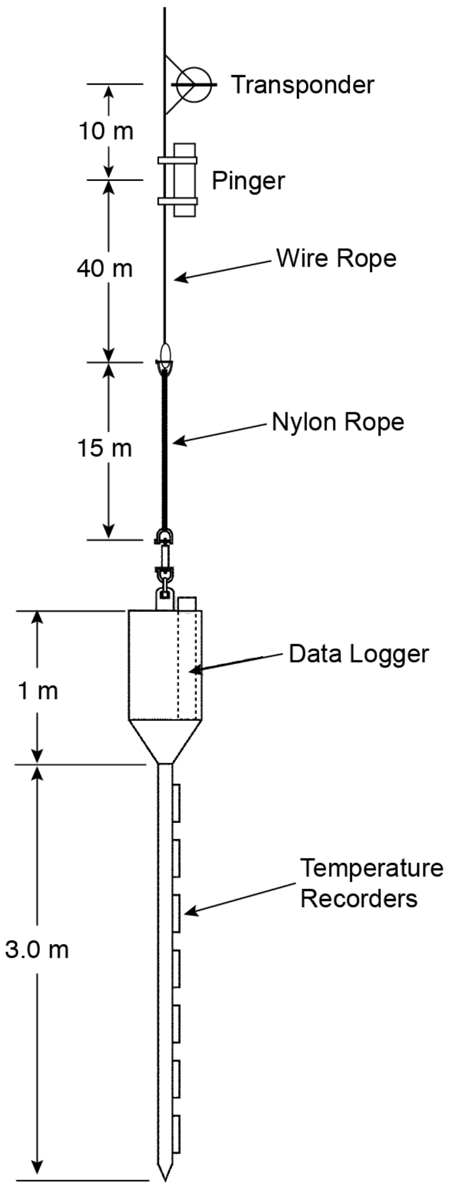

Figure 3.4-3. Configuration of the heat flow measurement system using a deep-sea probe.

3.4.2. Heat flow piston coring system

[Specification of tools]

During this cruise, sediment core samples were taken with the heat flow piston coring system (HFPC) (Fig. 3.4-4). This coring system is used for combined operation of measuring heat flow and recovering sediments. The HFPC consists of body (800 kg in weight), 4-m long stainless steel barrel with liner tube, a balance and a 74-mm diameter long type pilot corer. The general outline of the system is shown in Fig. 3.4-5.

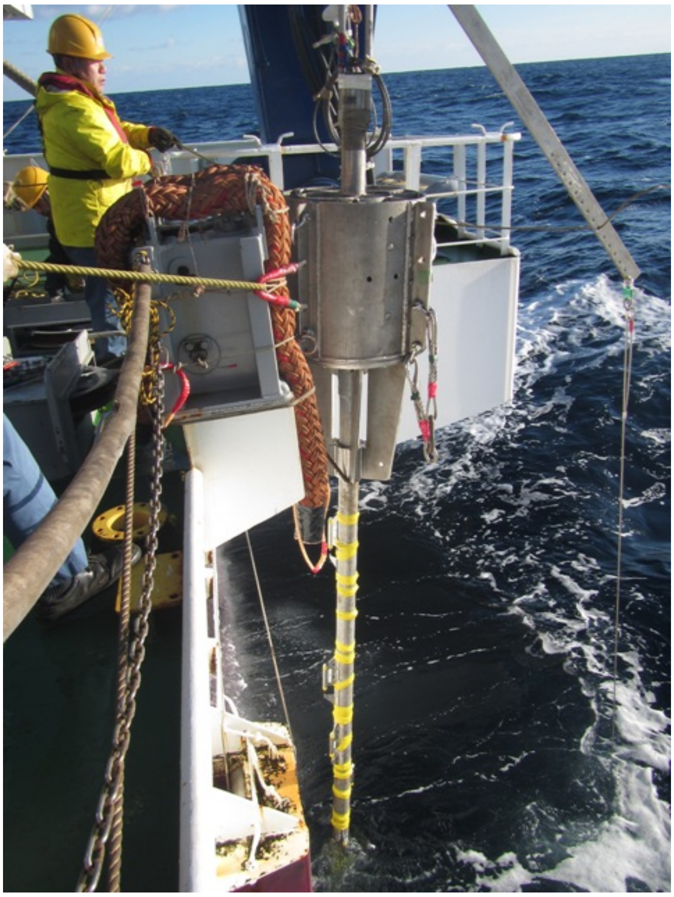

Figure 3.4-4. Heat flow piston coring system (HFPC) with compact temperature data loggers (MTLs).

A stainless steel barrel is attached to a piston core head. On this cruise, eight ANTARES MTLs (cf. 3.4.1) were mounted helically on the outside of barrel, between the base of the weight stand and the core catcher bit. A transponder is also mounted on the winch wire to obtain the depth and position of this equipment.

Nylon rope was placed between the balance and winch wire for additional wire out and/or increased tension after hitting sea bottom. Because the system must be kept in the sediment for 15 minutes to obtain stable temperature, additional wire out is necessary for avoiding pulling the barrel out of the sea floor by either heaving or drifting of the ship during the measurement.

[Preparation for piston coring]

After the barrel is attached to the head (weight stand), the main wire is connected, through the barrel, to the piston at the bottom of the barrel. The core catcher and bit are then attached. The balance is connected to the end of the main wire. The entire assemblage is carried under the A-frame using a cart and is lifted over the edge of the deck by the winch, A-frame and capstan winches. The pilot corer and its wire are then connected to the balance. The system is then lowered through the water to the sea floor.

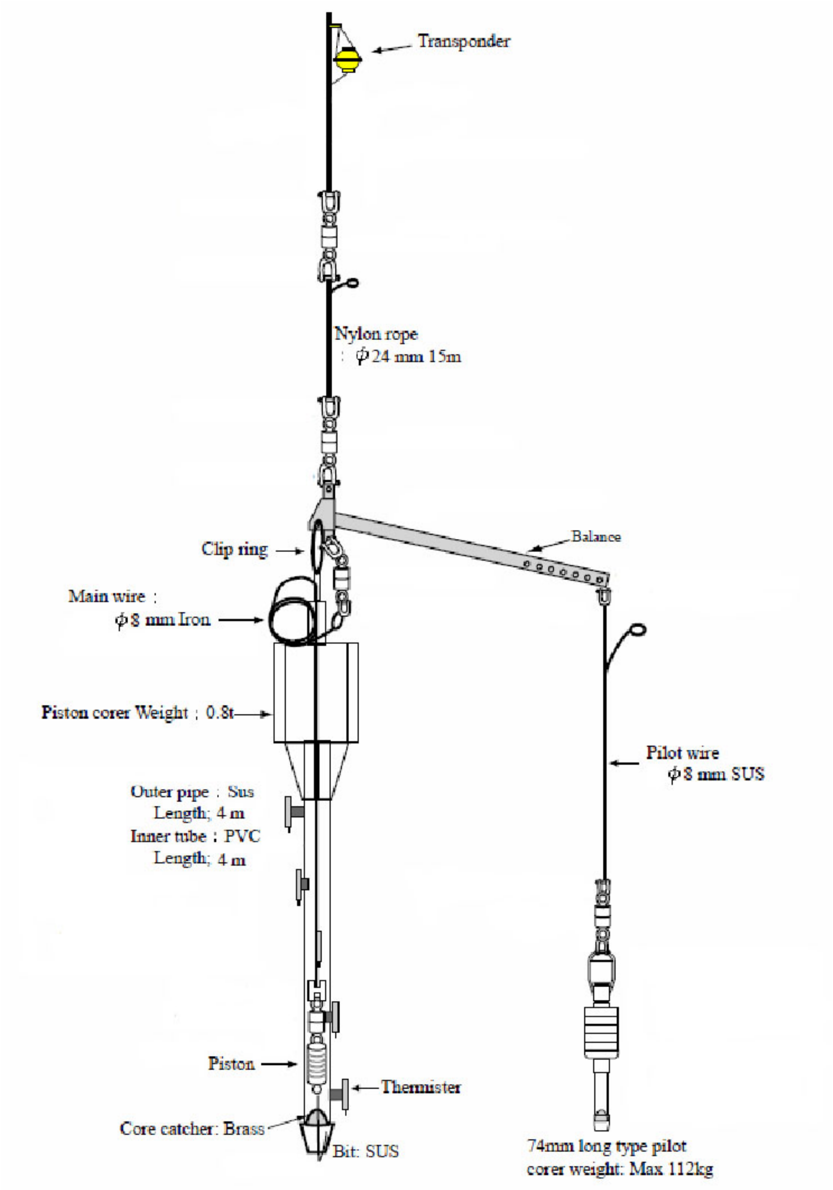

Figure 3.4-5. Configuration of the heat flow piston coring system (HFPC).

[Winch Operations]

The wire out speed is within 50 m/min. The HFPC is stopped at the depth about 80 m above the sea floor, then it is suspended for 10 minutes. After that, the wire is run in 20 m/min. After the recognition of bottom hit, add about 5 m to wire out, stop and keep the position for 15 minutes. And then, rewinding of the wire is started at a slow speed, until HFPC leaves the sea floor. After we can recognize absolutely that the piston corer is above the sea floor, the wire speed is increased within 50 m/min. The HFPC comes back on the deck, core sample is detached from the body.

3.4.3. Measurement on core samples

[Thermal property]

Thermal properties (thermal conductivity, heat capacity, and thermal diffusivity) of earth materials are important parameters for calculating heat flow, modeling the thermal structure and transport of heat and fluid under the ground. During YK14-21 cruise, we used two instruments for thermal property measurement. One is Model QTM-500 (Kyoto Electronics Manufacturing Co., Japan; Fig. 3.4-6), which measures thermal conductivity of sediment with a half space box-type probe (Sass et al., 1984). Measurements with this instrument were made on split core samples. The other is KD2 Pro Thermal Properties Analyzer (Decagon Devices, Inc., USA) with a single needle probe sensor (KS-1 probe) (Von Herzen and Maxwell, 1959) or a dual needle probe sensor (SH-1 probe) (Bristow et al., 1994; Fig. 3.4-7). On this cruise, we inserted dual needle probes into split core samples and measured thermal conductivity, heat capacity, and thermal diffusivity simultaneously.

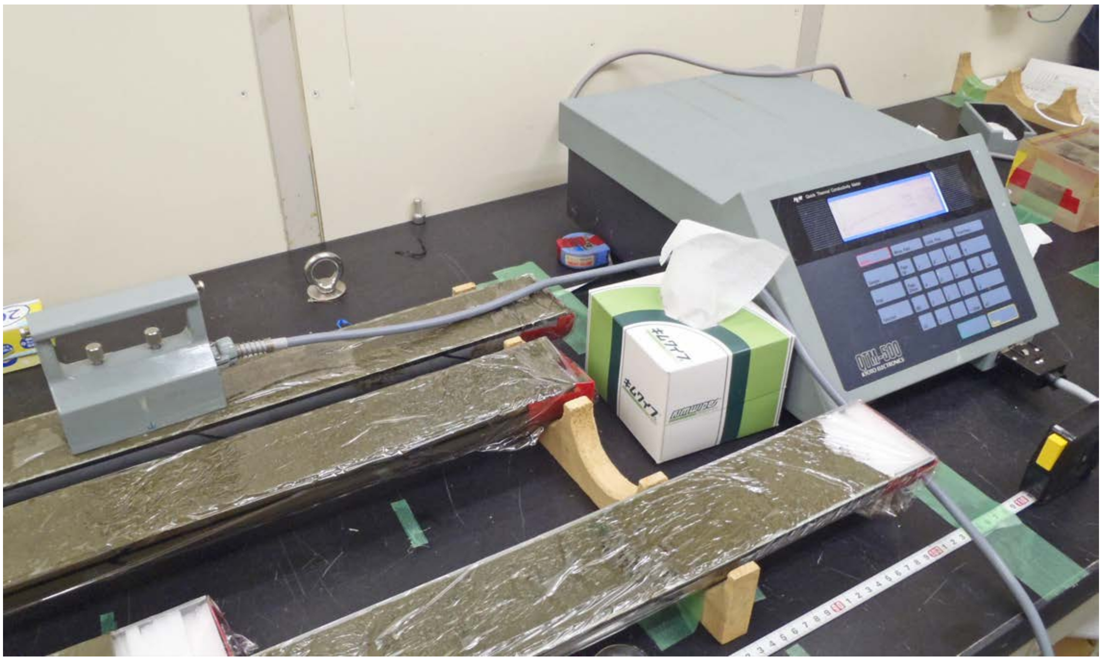

Figure 3.4-6. Thermal conductivity measurement with QTM-500.

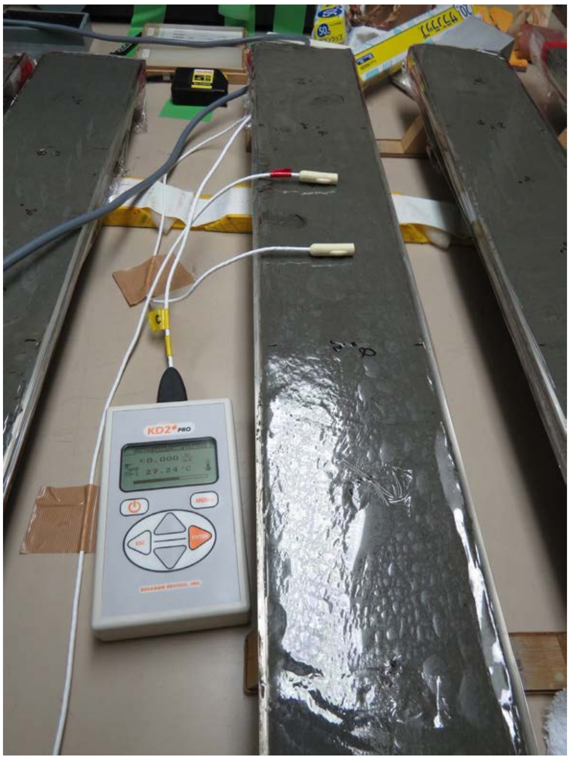

Figure 3.4-7. Thermal conductivity, heat capacity and thermal diffusivity measurement with dual probes of KD2 Pro Thermal Properties Analyzer.

3.5. Preliminary Results

3.5.1. Heat flow measurement

We could conduct heat flow measurements and piston coring within limited times on December 20 and 22 only, because the sea condition was too rough on the other days.

Heat flow measurements (Fig. 3.5-1) were carried out at one site with the deep-sea heat flow probe and at one site with the HFPC (Table 3.5-1; Fig. 3.2-2). At HF01, the deep-sea heat flow probe was penetrated twice for examining local variability of heat flow. The coordinates of the stations listed in Table 3.5-1 are the positions of the acoustic transponder attached above the probe or the HFPC determined with the SSBL system of the ship. The water depth in the table is the depth right below the ship determined with the multi-narrow beam echo sounder and may be slightly different from the depth at the station.

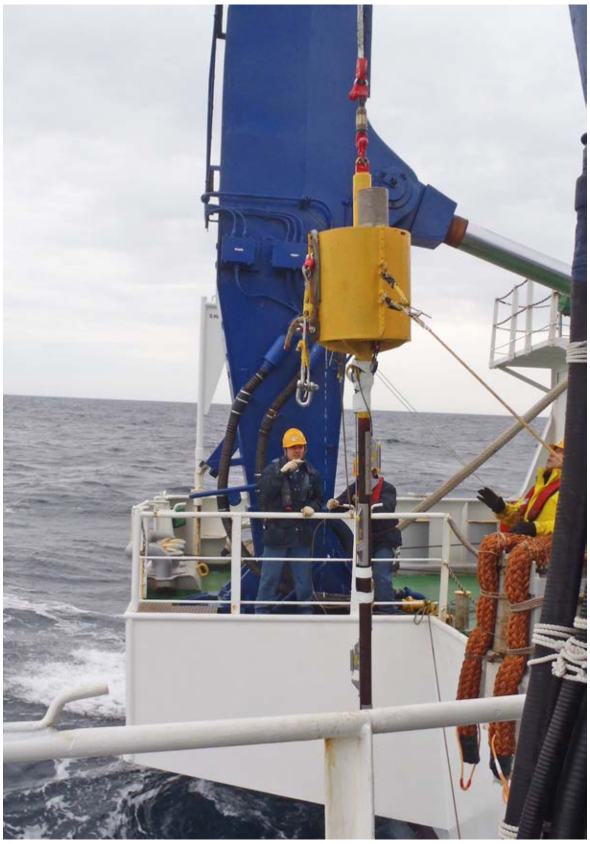

Figure 3.5-1. Heat flow measurement operation.

HF01 is located on the uppermost part of the outer slope of the Japan Trench, about 55 km from the trench axis, where the seafloor topography obviously shows horst and graben structures. At this site, CSEM surveys were conducted on KY14-10 cruise of the R/V KAIYO and magnetotelluric measurements with an OBEM were also made for two months. We could successfully penetrate the probe at HF01A and B at an interval of about 400 m.

HFPC01 is located on the landward side of the Japan Trench. All the eight temperature sensors penetrated into sediments and provided temperature data of good quality. The obtained temperature profile was, however, significantly disturbed by temporal variations in bottom water temperature, as expected from rather shallow water depth of this site (cf. Yamano et al., 2014).

Table 3.5-1. Results of heat flow measurements

	Date	Station	Latitude (N)	Longitude (E)	Depth (m)	N
Deep-sea heat flow probe						
	Dec. 20	HF01A	39°25.80'	144°55.12'	5635	5
		B	39°25.68'	144°55.33'	5635	6
HFPC						
	Dec. 22	HFPC01	38°46.00'	143°01.02'	1555	8

N: number of temperature sensors used to obtain temperature profile in sediment.

3.5.2. Core samples

One piston core sample was collected in the Japan Trench area off Sanriku using a 4-m-piston-corer system operated by Marine Works Japan Co. Ltd. (3.4.2). The piston corer system has a 74-mm long type pilot corer. Eight temperature recorders for heat flow measurements were attached on the core barrel of the piston corer. We call this system a heat-flow piston corer (hereafter HFPC). Sample name of piston core is YK14-21 HFPC01 in this description, and the formal sample name in the Kochi Core Center is YK14-21 PC01. Sample name of pilot core is YK14-21 HFPL01 in this description, and the formal sample name in the Kochi Core Center is YK14-21 PL01.

Piston core and pilot core samples were processed as follows;

1) Cut piston core into sections.
2) Split all cores into Working and Archive halves.
3) Archive half: take photographs, describe sedimentary structures by naked eyes. Only HFPC01: describe sedimentary structures by smear slides.
4) Working half: measure thermal properties using a half-space probe and needle probes.
5) Pack cores into plastic cases (D-tubes) for storage, then transport to the Kochi Core Center.

The recovered core sample is described in detail below.

[HFPC01]

HFPC01 was taken on the seafloor at 38°46.00’N and 143°01.02’E (Fig. 3.5-2). The water depth was 1555 m. The longitude and latitude of the coring site are average values of a data set of the acoustic transponder during the coring operation. The water depth at the coring site is an average value of the depth below the ship determined with the multi-narrow beam echo sounder.

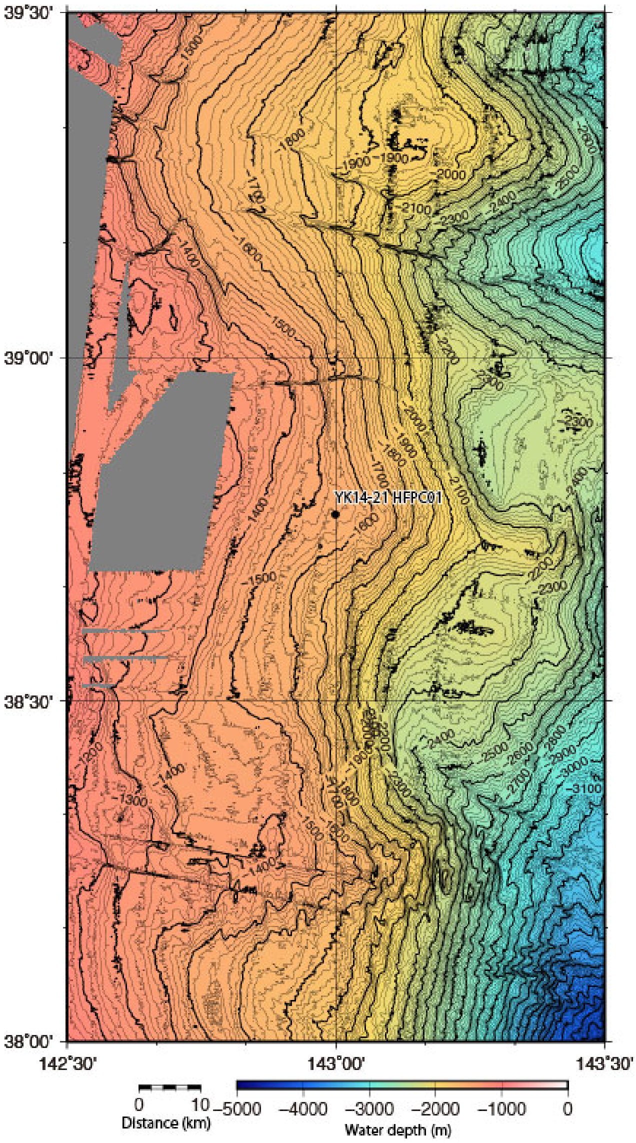

Figure 3.5-2. Coring site.

The recovered core sample is 175.5 cm long (including CC). The piston core was divided into two sections being Section 1 at 0-69.5 cm (69.5 cm long) and Section 2 at 69.5.0-164.5 (95.0 cm long). We have a core catcher sample of 11 cm long (at 164.5-175.5 cm). The pilot core is 64 cm long. The sediments of the pilot core are mostly same as those of Section 1. The sample of the core catcher is same as the lower part of Section 2.

We describe the sediment cores of Sections 1 and 2 as follows (see Fig. 3.5-3).

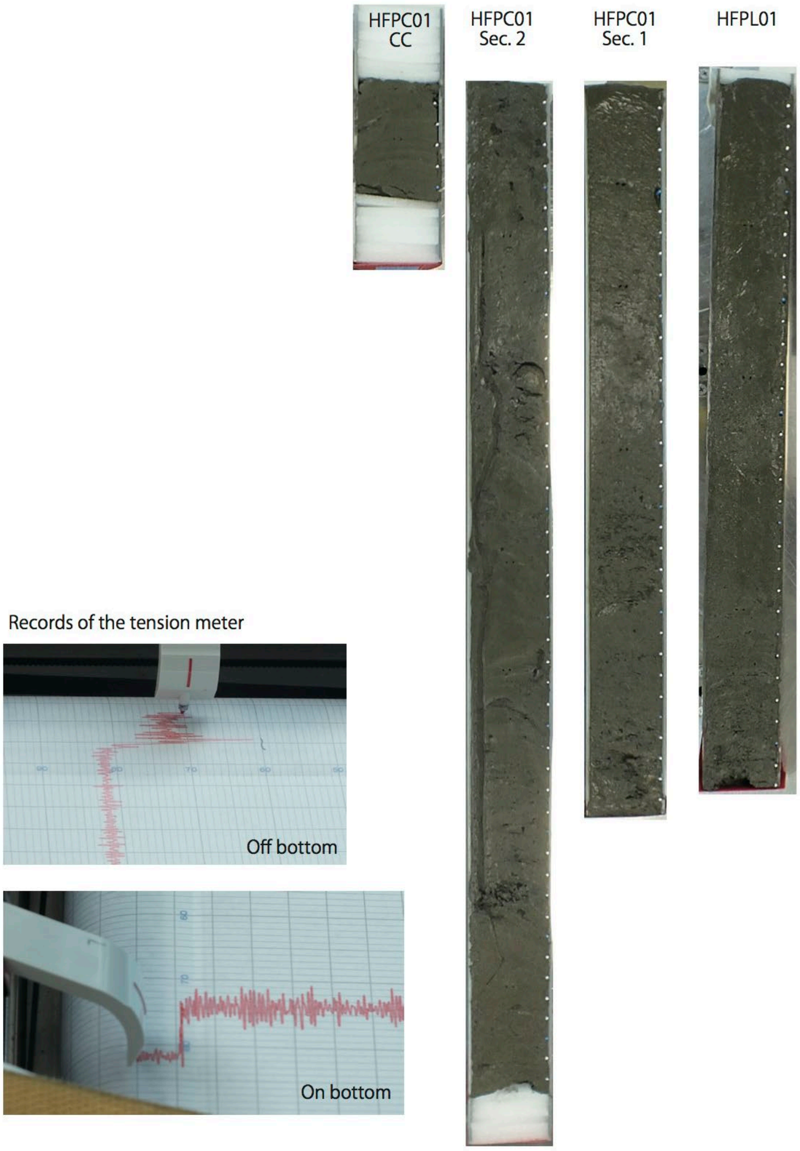

Figure 3.5-3. Core photographs and records of the tension meter.

[Section 1]

The section is predominantly olive black (7.5GY3/2) bioturbated silty clay with volcanic ash. Clasts of about 4 mm are seen at 10 cm, ones of 5 mm are seen at 44, 48 and 49 cm. Foraminifers are disseminated at 50 and 57 cm.

[Section 2]

The section is predominantly olive black (7.5GY3/2) bioturbated silty clay with volcanic ash. Sediment color slightly changes from olive black to black at 0-24 cm, to very dark reddish brown (5YR2/4) at 24 cm, to dark bluish gray (5B 3/1) at 75 cm. Clasts of 1-8 mm are seen at 3-6, 16-18 26-31, 54, 67, 70 and 74-77 cm. White particles (probably foraminifers) of < 1 mm are seen at 86-88 cm. Strong bioturbation is seen at 15-23 and 39-45 cm.

3.5.3. Thermal property measurement

Thermal conductivities of sediments were measured with QTM-500 at 11 locations on HFPC01 split core samples (8 on main core samples and 3 on pilot core sample). With dual probes of KD2 Pro Thermal Properties Analyzer, three thermal properties (thermal conductivity, thermal diffusivity and heat capacity) of sediments were measured at 13 locations (10 on main core samples and 3 on pilot core sample), 11 of them are the same locations as those of the QTM-500 measurements.

3.5.4. Bathymetry and subbottom profiling surveys

Multi beam echo sounding and subbottom profiling surveys were conducted along three lines in small areas around HF01 and HFPC01 (7.2). The data obtained around HF01 will be used for analysis of electromagnetic survey data (CSEM survey on KY14-10 cruise and magnetotelluric measurements with an OBEM).

4. Notice on Using

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

This report may not be corrected even if changes on contents (i.e. taxonomic classifications) may be found after its publication. This report may also be changed without notice. Data on this cruise report may be raw or unprocessed. If you are going to use or refer to the data written on this report, please ask the Chief Scientist for latest information.

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

5. Acknowledgements

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7. Appendices

7.1. Cruise Log

Date	Local Time	Description	Position/Weather/Wind/Sea condition
15-Dec-14	08:50	scientists onboard	12/15 12:00 (JST)
	10:00	departure from Harumi, Tokyo	35-22.8N,139-42.8E
	10:30-11:00	scientists meeting	blue sky
	13:00-13:25	lecture for shipboard life and safety	ESE-2 (light breeze)
			1 (calm)
			0 (No swell)
			Visibilitly: 8'
16-Dec-14	06:30	go for Ishinomaki bay	12/16 12:00 (JST)
	9:35	let go anchor at Ishinomaki bay	38-22.1N,141-16.5E
			rain
			NNW-3 (gentle breeze)
			1 (calm)
			1(Low swell sea)
			Visibilitly: 1'
17-Dec-14		Ishinomaki-bay	12/17 12:00 (JST)
			38-22.1N,141-16.5E
			snow
			WNW-6 (strong breeze)
			3 (sea slight)
			1 (Low swell sea)
			Visibilitly: 5'
18-Dec-14		Ishinomaki-bay	12/18 12:00 (JST)
	13:30-14:05	onboard seminar	38-22.1N,141-16.5E
	14:10-14:40	scientists meeting	fine but cloudy
			NW-6 (strong breeze)
			3 (sea slight)
			1 (Low swell sea)
			Visibilitly: 8'
19-Dec-14	11:15	heave anchor, go for research area	12/19 12:00 (JST)
			38-17.6N,141-20.2E
			fine but cloudy
			NW-4 (moderate breeze)
			2 (sea smooth)
			1 (Low swell sea)
			Visibilitly: 8'
20-Dec-14	01:00	arrived at research area	12/20 12:00 (JST)
	1:01	released XBT	39-25.8N,144-55.2E
	01:24-04:10	MBES and SBP survey	overcast
	06:25-13:39	heatflow survey	SSE-4 (moderate breeze)
	14:00	go for Ishinomaki bay	3 (sea slight)
			4 (Moderate average)
			Visibilitly: 8'
21-Dec-14	08:30	arrived at Ishinomaki bay, let go anchor	12/21 12:00 (JST)
	10:00-10:30	scientists meeting	38-22.1N,141-16.5E
	16:10	heave anchor	fine but cloudy
			WNW-7 (near gale)
			3 (sea slight)
			2 (Low swell long)
			Visibilitly: 8'

Date	Local Time	Description	Position/Weather/Wind/Sea condition
22-Dec-14	00:00	go for research area	12/22 12:00 (JST)
	6:00	arrived at research area	38-41.7N,142-49.4E
	08:24-10:57	HFPC survey	fine but cloudy
	18:00	arrived at Ishinomaki bay, let go anchor	WNW-7 (near gale)
			4 (sea moderate)
			4 (Moderate average)
			Visibilitly: 8'
23-Dec-14		Ishinomaki bay	41223 12:00 (JST)
	15:00-15:20	scientists meeting	38-22.0N,141-16.7E
			fine but cloudy
			NW-6 (fresh breeze)
			3 (sea slight)
			1 (Low swell sea)
			Visibilitly: 8'
24-Apr-14	09:00	arrived at Shiogama, Miyagi	12/24 12:00 (JST)
	11:30	scientists left ship	Shiogama

7.2. Survey Lines

Line Name	Source	Start				End			
		Date	Time (UTC)	Latitude	Longitude	Date	Time (UTC)	Latitude	Longitude
Line HF01-1	MBES, SBP	12/19	16:24	39°23.0'N	144°55.2'E	12/19	17:26	39°31.0'N	144°55.2'E
Line HF01-2	MBES, SBP	12/19	17:35	39°31.0'N	144°55.2'E	12/19	19:10	39°28.6'N	145°11.2'E
Line HFPC01	MBES, SBP	12/21	21:07	38°45.5'N	143°01.0'E	12/21	21:16	38°46.5'N	143°01.0'E

MBES: Multi-beam echo sounder
SBP: Subbottom profiler

7.3. R/V YOKOSUKA Crew

Captain	TAKAFUMI AOKI
Chief Officer	HIROYUKI KATO
2nd Officer	TOMOYUKI TAKAHASHI
3rd Officer	YUSUKE ISHI
Chief Engineer	KIYONORI KAJINISHI
1st Engineer	DAISUKE GIBU
2nd Engineer	KATSUTO YAMAGUCHI
3rd Engineer	KAZUKI ONO
Chief Electronic Operator	TAKEHITO HATTORI
2nd Electronic Operator	TAKATOMO SHIROZUME
3rd Electronic Operator	RYOSUKE KOMATSU
Boatswain	KOZO YATOGO
Quarter Master	KAZUMI OGASAWARA
Quarter Master	YUKI YOSHINO
Quarter Master	NAOKI IWASAKI
Sailor	KAZUHO IKEDA
Sailor	RYOMA TAMURA
Sailor	YUTA MOTOOKA
No.1 Oiler	KAZUAKI NAKAI
Oiler	KAZUO SATO
Oiler	KOTA AIZAWA
Assistant Oiler	SHOTA SHIMOHATA
Assistant Oiler	ATSUMU HARA
Chief Steward	TERUYUKI YOSHIKAWA
Steward	YOSHIO OKADA
Steward	KATSUYUKI OMIYA
Steward	KENTO OKAZAKI