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On Board Cruise Report

YOKOSUKA Cruise: YK10-15

Southern Mariana Trough

10-17/November/2010

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

Contents

1. Purpose

We recover ocean bottom electro-magnetometers (OBEMs) and ocean bottom seismometers (OBSs), which were used to observe magnetic and electric field variations and to conduct seismic observation at the ocean bottom across the Southern Mariana Trough back-arc spreading system. Observation started after the deployment of OBEMs and OBSs during another Yokosuka cruise (YK10-10) in this August. We also conduct seismic survey to investigate seismic velocity structure using 9 OBSs, an air-gun, and a single channel hydrophone streamer. Further, we conduct surface geophysical survey after the instruments recovery. The Southern Mariana Trough back-arc spreading system shows asymmetry spreading, and has high relief at spreading axes, which infers abundant melt supply. Furthermore, three hydrothermal vents that extrude different water contents, exists within 5 km near the spreading axis. The observed data will be analyzed to derive upper mantle structure, crustal structure, hypocenter distribution, and tectonic history, which will provide important constraint on following four main points to understand the back-arc spreading system; 1) imaging melt delivery to the spreading axis and off axis seamount including volcanic arc, 2) production and character of the crust, 3) relationship between melt supply and crustal formation, and 4) pathway and heat source for hydrothermal circulation with related to its formation.

2. Participants

2-1.Onboard Scientists

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Sailor	Syun Miura
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Oiler	Yuki Nakahara
Oiler	Yoshinori Kawai
Oiler	Yuji Higashikawa
Chief Steward	Takeshi Miyauchi
Steward	Mizuki Nakano
Steward	Kazuyoshi Sonoda
Steward	Hiroki Fukuda
Steward	Yukihide Chikuba

3. Cruise Information

3-1. Basic Information

Cruise ID: YK10-15

Name of vessel: YOKOSUKA

Title of the cruise: Southern Mariana Trough back-arc spreading system with three different hydrothermal activities, Part 2

Title of the proposal: Southern Mariana Trough back-arc spreading system with three different hydrothermal activities

Cruise period: 10-17/November/2010

Ports of call: Palau - Guam

3-2. Research area

Our research area is the Southern Mariana Trough back-arc spreading system at 13°N (Figure 3-2-1). The ship tracks of the cruise are shown in Figure 3-2-2.

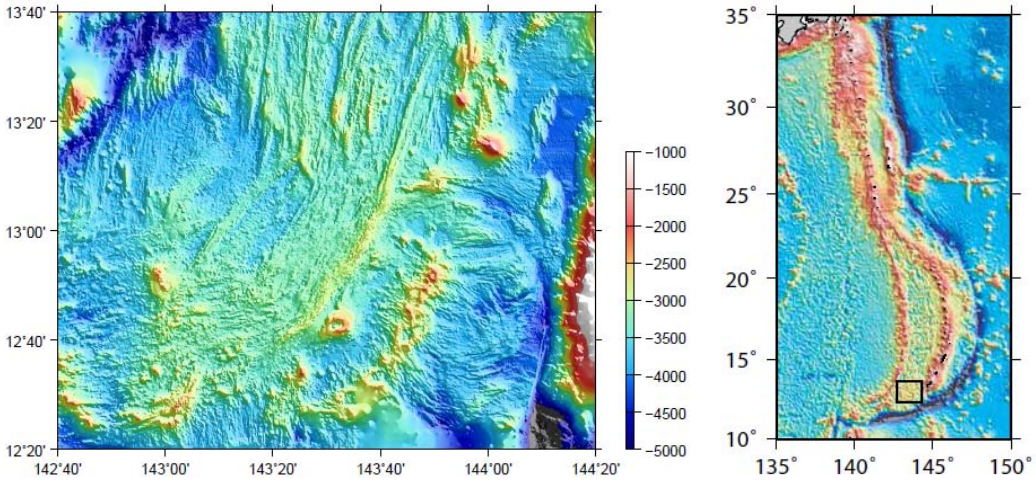
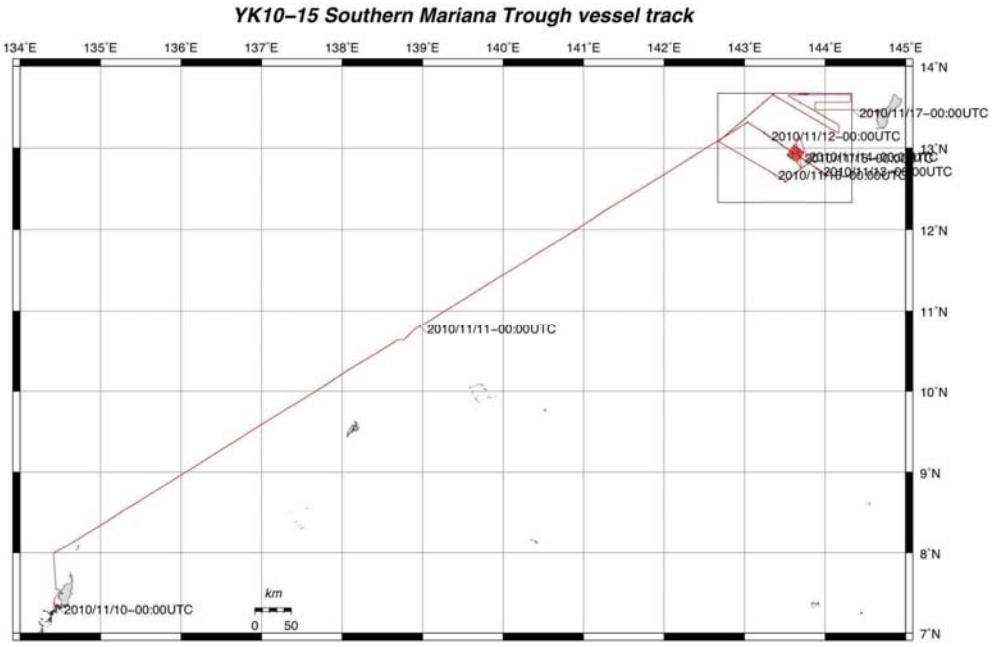


Figure 3-2-1. Bathymetry map of area surveyed (left) and its location shown by square in the right figure.



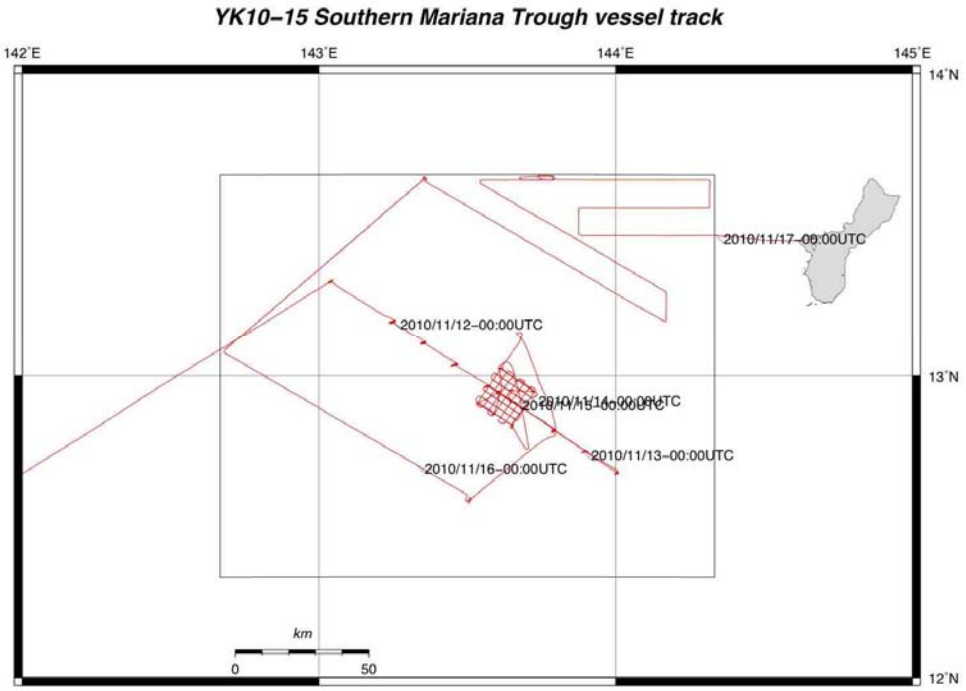


Figure 3-2-2. Ship tracks of the cruise

3-3. Ship Log

YK10-15 Shipboard Log
(10.Nov, 2010 - 18.Nov, 2010)

Southern Mariana Trough

Date	Local Time	Note	Description	Position/Weather/ Wind/Sea condition
10 Nov, 2010		**Sail out and Transit**		11/10 12:00 (UTC+9h)
	09:30-09:42	immigration		07-40.0N, 134-26.3E
	10:00	sail out from port of KOROR, Palau		Cloudy
	11:27	pilot left her		South-2 (Light breeze)
	13:30-14:00	onboard education and safety training	chief officer, 1st ratio	1 (Sea rippled calm)
	14:00	scientists meeting		1 (Low swell short)
				Visibly: 8'
11 Nov, 2010		**Transit**		11/11 12:00 (UTC+10h)
	10:00-11:00	practiced search of unauthorized visitor	shipboard drill	11-04.0N, 139-22.3E
				Fine but cloudy
				SE-4 (Moderate breeze)
				2 (Sea smooth)
				1 (Low swell short)
				Visibly: 8'
12 Nov, 2010		**Recovery operation**		11/12 12:00 (UTC+10h)
	04:00	arrived at research area		13-10.8N, 143-15.2E
	07:00	recovered EM1		Fine but cloudy
	10:23	recovered S1		ENE-6 (Strong breeze)
	12:59	recovered EM2		3 (Sea slight)
	16:50	recovered EM3		2 (Low swell long)
	18:57	recovered S3		Visibly: 7'
	20:21	recovered EM4		
	23:24	recovered EM5		

YK10-15 Shipboard Log
(10.Nov, 2010 - 18.Nov, 2010)

Southern Mariana Trough

Date	Local Time	Note	Description	Position/Weather/ Wind/Sea condition
13 Nov, 2010		**Recovery operation**		11/13 12:00 (UTC+10h)
	01:59	recovered EM6		12-49.3N, 143-47.8E
	06:52	recovered EM11		Fine but cloudy
	08:59	recovered S10		ENE-5 (Fresh breeze)
	10:24	recovered EM10		4 (Sea moderate)
	12:25	recovered S9		3 (Moderate short)
	12:39-14:23	sent out release command to EM9	but no response	Visibly: 8'
	15:57	released XBT sensor (12-49.0363N, 143-47.3251E)	Depth: 1830m	
	17:56	launched airgun		
	18:11	deployed streamer cable		
	19:40	commenced SCS survey		
14 Nov, 2010		**SCS survey**		11/14 12:00 (UTC+10h)
				12-50.2N, 143-39.0E
				Fine but cloudy
				East-6 (Strong breeze)
				4 (Sea moderate)
				3 (Moderate short)
				Visibly: 8'
15 Nov, 2010		**Recovery operation**		11/15 12:00 (UTC+10h)
	02:40	finished SCS survey		12-55.5N, 143-38.2E
	02:55	recovered streamer cable		Fine but cloudy
	03:03	recovered airgun		ENE-4 (Moderate breeze)
	06:34	recovered S17		3 (Sea slight)
	08:34	recovered S8		2 (Low swell long)
	09:35	recovered EM8		Visibly: 8'
	11:13	recovered S7		
	12:33	recovered EM7		
	14:09	recovered S16		
	16:10	recovered S14		
	18:02	recovered S13		
	19:56	recovered S12		
	20:31-21:35	sent out call command to S5	but no response	
16 Nov, 2010		**Recovery operation and MBES survey**		11/16 12:00 (UTC+10h)
	00:04	recovered S15		12-52.5N, 142-53.5E
	01:48	recovered S16		Fine but cloudy
	02:29-03:22	carried out communication of S5	but no response	NE-6 (Strong breeze)
	04:31-07:00	sent out release command to EM9	but no response	4 (Sea moderate)
	07:07	commenced towing proton magnetometer		3 (Moderate short)
	08:45-09:04	carried out figure eight circle running		Visibly: 8'
	09:14	commenced MBES mapping survey		
	16:47-17:04	carried out figure eight circle running		
17 Nov, 2010		**Transit**		11/17 12:00 (UTC+10h)
	09:58	finished MBES mapping survey		13-26.9N, 144-35.2E
	10:11	recovered proton magnetometer		Overcast
	13:10	arrived at APRA port, GUAM		NE-6 (Strong breeze)
				4 (Sea moderate)
		YK10-15 cruise completion		2 (Low swell long)
				Visibly: 6'

4. Instruments

4-1. OBEM (ocean bottom electro-magnetometer)

The OBEMs (Photo 4-1) measure three components of magnetic field variation, three components of electric field variation, two components of instrument tilt, and temperature. Each OBEM has two pressure resistant cases (two pressure resistant glass spheres, or one pressure resistant glass sphere and one pressure resistant titanium cylinder case), which contains fluxgate type magnetometers, voltmeters, tilt meters, the transponder unit and battery packs (lithium batteries or alkaline batteries). They have pipes for attaching five Filloux-type silver-silver chloride electrodes (Filloux, 1987). The OBEM sensors are divided into two types. One type has a sensor made by Bartington Instruments Ltd. with using data logger made by Clover-tech Corp. (9 OBEMs). The other type is made by Tierra Tecnica Corp. (2 OBEMs). All data are recorded internally on flash cards. The OBEM's also have radio beacon and flashing light for recovery.

Data sampling of OBEM was carried out 16 times (3.2 seconds) per one minute with Bartington Instruments Ltd.'s sensors, and once per one minute with Tierra Tecnica Corp.'s sensor. The clock of the OBEM was set to the GPS clock before the deployment, and it was compared to the GPS clock after the recovery. The time difference is shown in Table 5-1-2a. The starting time of measurement was set to 9:00 (UTC) on 22th August, and record files made by each OBEM ensure that the measurement started at this time.

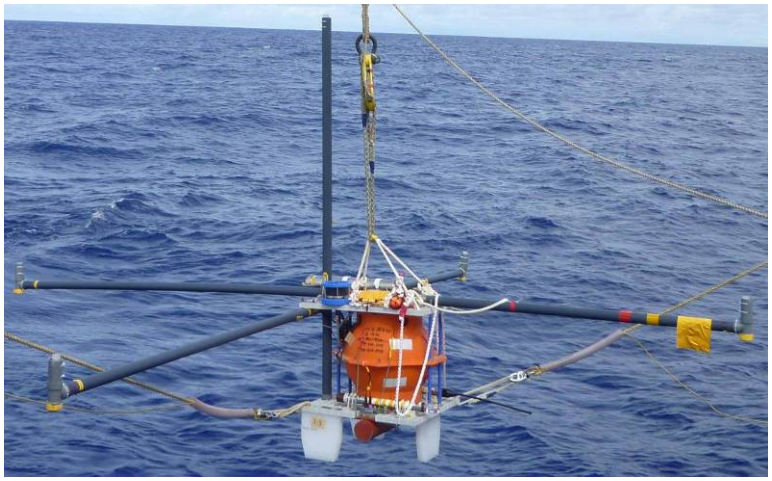


Photo 4-1a. BC1 type OBEM. BC2 type shows similar feature to BC1 type.

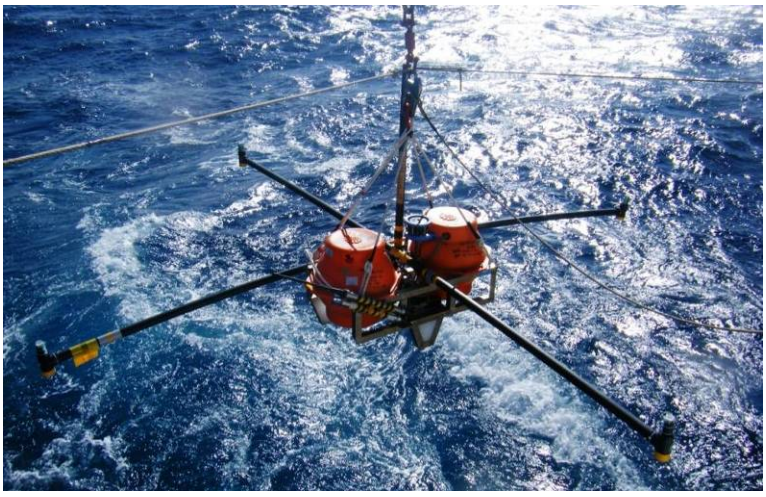


Photo 4-1b. T type OBEM

4-2. OBS (ocean bottom seismometers)

We used three types of digital OBSs, LTOBS_ERI, STOBS_ERI, and STOBS_Chiba (Photo 4-2). LTOBS_ERI was used a 50cm titanium sphere and equipped with a three-component 1 Hz natural frequency velocity seismometers, a 24-bit analogue-to-digital (A/D) converter, and two hard disks for storage of seismic waveform data. The data-sampling rate was 200 Hz. The data were stored after removing the lower 4 bits. STOBS_ERI was used a 40cm glass sphere and equipped with a three-component 4.5Hz velocity seismometers, a 24-bit A/D converter, and two hard disks. The data-sampling rate was 200 Hz. The data were stored after removing the lower 4 bits. STOBS_Chiba was used 40cm glass sphere and equipped with three-component 4.5Hz velocity seismometers, a 24-bit A/D converter, and a 20GB hard disks. The data-sampling rate was 125 Hz. Two of STOBS_Chiba have a depth sensor (sampling rate is 30s), and one has a hydrophone (sampling rate is 125Hz).

Photo 4-2a. LTOBS_ERI type OBS

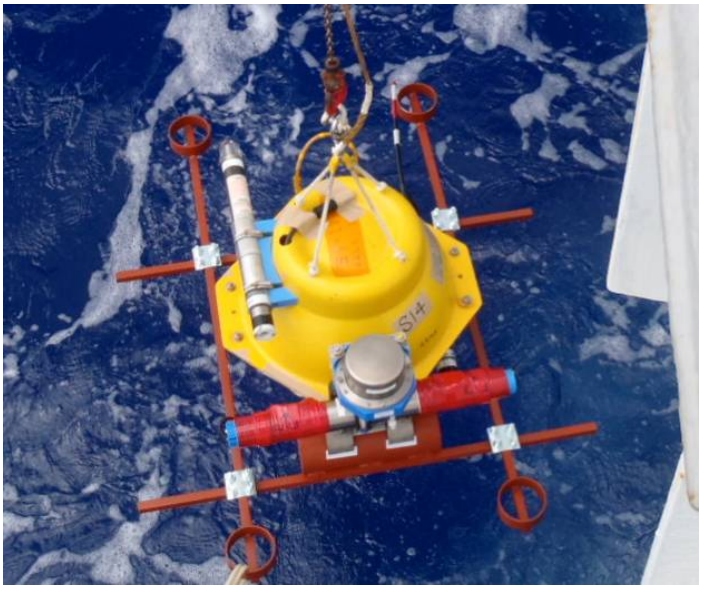


Photo 4-2b. STOBS_ERI type OBS

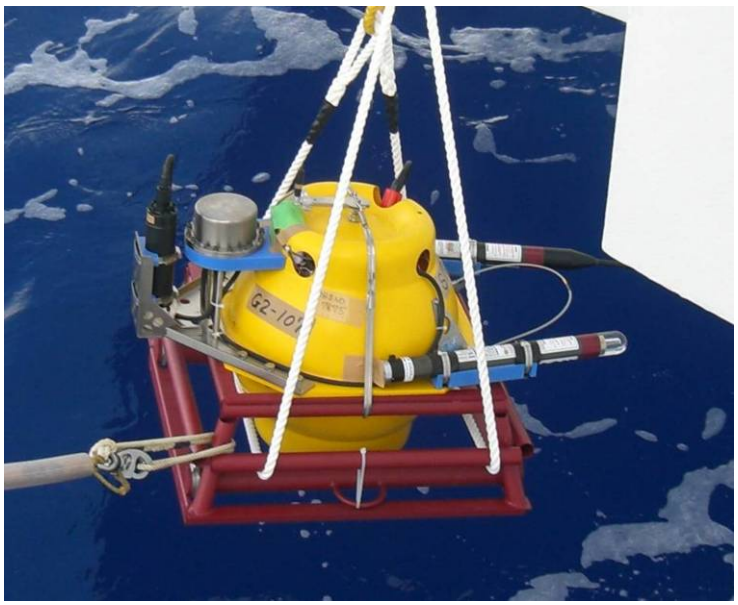


Photo 4-2c. STOBS_Chiba type OBS

5. Preliminary Results

5-1. OBEM and OBS recovery

We conducted recoveries of 11 OBEMs and 15 OBSs at 21 sites across the Southern Mariana Trough back arc spreading center. Site locations are given in Figure 5-1-1 and Table 5-1-1, and the instrument information at each site is given in Tables 5-1-2. Sites spacing was approximately 4 km in the vicinity of the spreading center, but the spacing was coarser at the both ends (15-30km). Positioning of the each instrument on the ocean floor was performed during R/V Yokosuka YK10-10 cruise in August 2010.

10 OBEMs and 14 OBSs were successfully recovered (Tables 5-1-3), and one OBEM and one OBS were abandoned because there was no response to the acoustic ‘call’ or ‘release’ commands. In most cases, acoustic contact was first established, and then a release command was sent; continuous ranging in the first 1 minute (STOBS_Chiba type OBS) or 17 minutes (the others) established the time at which the burn wire corroded sufficiently for the ballast weight to drop and the instrument began to ascend. Instruments were tracked to the surface by using a combination of slant ranges and the ship position along with the starting position and measured ascent rates to calculate the position. By tracking the instruments closely we were able to accurately predict their surface times and positions and quickly find them with the ship. In many cases, radio beacon signal was used to establish the exact time at which the instrument surfaced as it came out of the water. Instruments were recovered using a platform on the starboard side of the ship. The instruments were hooked by the crew and lifted by a chain hoist and crane onto the platform where the instrument was broken down and moved inboard. Recoveries for all the OBEMs and the LTOBS_ERI type OBSs were through the hero platform on the starboard side of the ship. This operation after an instrument at the surface was quick and took at most 20 minutes to complete.

The two instruments lost were at site EM9 and S5 where the instruments did not respond to acoustic signals. Despite waiting and searching after the predicted surface arrival time (assuming receipts of the release commands), no sign of the instrument was observed and they were abandoned as lost.

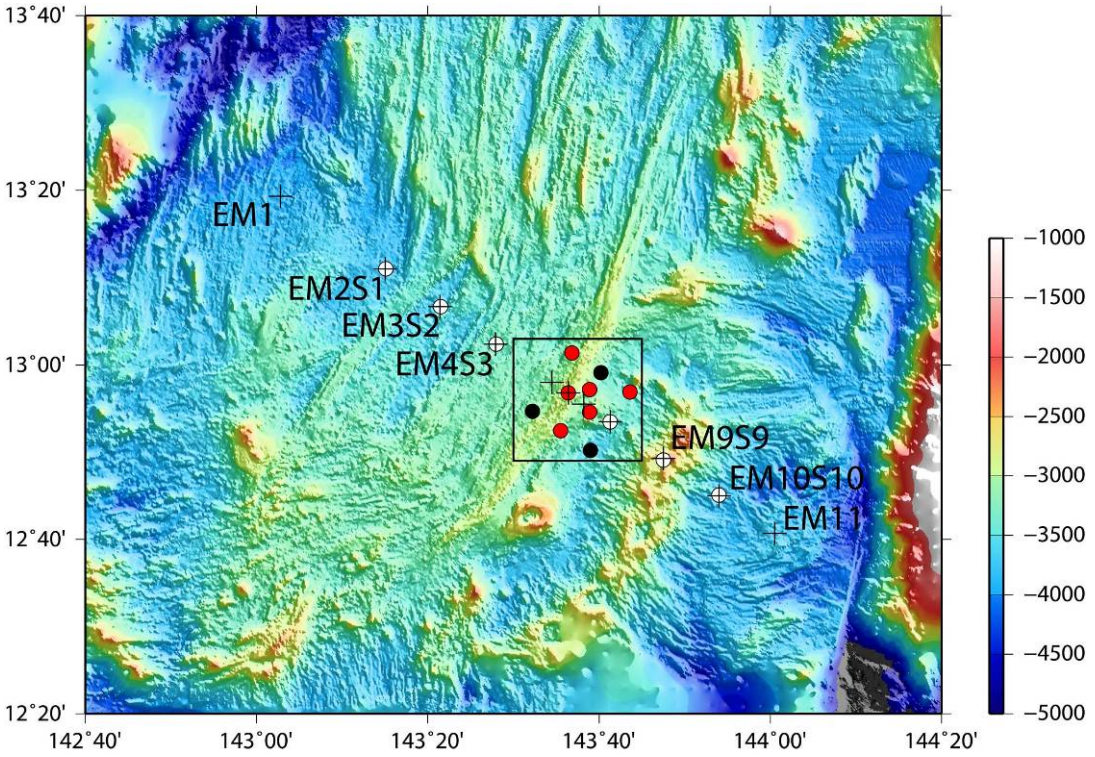


Figure 5-1-1a. Location map of OBEM (crosses) and OBS (circles). Colors of circles show different types of OBSs (white, red, and black correspond to LTOBS_ERI, STOBS_ERI, and STOBS_Chiba types of OBSs, respectively). Location of Figure 1b is shown by square.

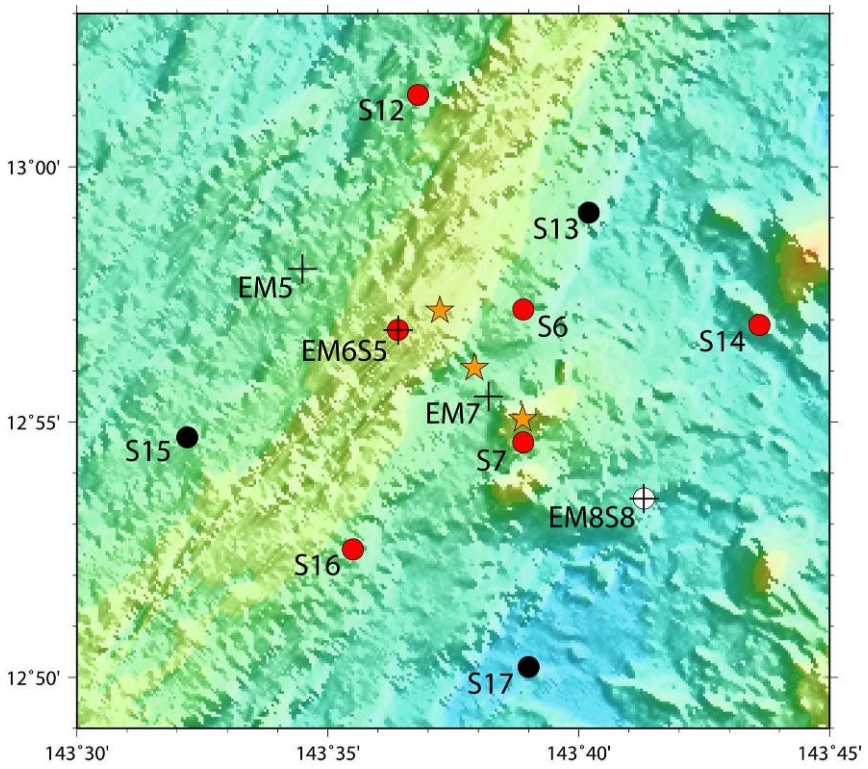


Figure 5-1-1b. Location map of OBEM and OBS near the spreading center. Symbols are the same as Figure 1a. Three hydrothermal fields that extrude different water contents are also shown by orange stars.

Site		Deployment Location					Estimated Location				
		Latitude (N)		Longitude (E)		Depth (m)	Latitude (N)		Longitude (E)		Depth (m)
		Deg.	Min.	Deg.	Min.		Deg.	Min.	Deg.	Min.	
EM1	EM1	13	19.25	143	02.81	3924	13	19.25	143	02.80	3924
EM2S1	S1	13	10.99	143	15.03	3746	13	11.00	143	15.06	3746
	EM2	13	10.92	143	15.02	3746	13	10.92	143	15.09	3750
EM3S2	S2	13	06.72	143	21.45	3550	13	06.72	143	21.49	3550
	EM3	13	06.69	143	21.49	3550	13	06.69	143	21.56	3567
EM4S3	S3	13	02.39	143	27.92	3268	13	02.37	143	27.96	3268
	EM4	13	02.37	143	27.99	3255	13	02.37	143	28.05	3254
EM5S4	EM5	12	58.04	143	34.50	3091	12	58.00	143	34.53	3086
EM6S5	S5	12	56.81	143	36.34	2865	12	56.80	143	36.39	2866
	EM6	12	56.82	143	36.37	2867	12	56.74	143	36.41	2868
S6	S6	12	57.20	143	38.87	3074	12	57.19	143	38.92	3075
S7	S7	12	54.59	143	38.87	2984	12	54.59	143	38.92	2985
EM7	EM7	12	55.52	143	38.23	3113	12	55.43	143	38.18	3123
EM8S8	S8	12	53.52	143	41.31	3315	12	53.46	143	41.27	3315
	EM8	12	53.57	143	41.29	3291	12	53.47	143	41.21	3316
EM9S9	S9	12	49.10	143	47.54	2585	12	49.13	143	47.51	2585
	EM9	12	49.13	143	47.57	2581	no data for estimation				
EM10S10	S10	12	45.00	143	54.02	3684	12	45.05	143	54.01	3685
	EM10	12	44.99	143	53.98	3676	12	45.09	143	53.96	3685
EM11S11	EM11	12	40.71	144	00.51	3766	12	40.82	144	00.47	3750
S12	S12	13	01.39	143	36.81	3073	13	01.38	143	36.75	3073
S13	S13	12	59.12	143	40.23	3135	12	59.06	143	40.16	3135
S14	S14	12	56.85	143	43.66	3161	12	56.85	143	43.60	3164
S15	S15	12	54.75	143	32.11	3104	12	54.69	143	32.19	3103
S16	S16	12	52.47	143	35.55	3084	12	52.48	143	35.45	3084
S17	S17	12	50.18	143	39.01	3542	12	50.19	143	39.01	3541

Table 5-1-1. Location of OBEM and OBS. The location of instruments were estimated using slant ranges between the transponder of the instrument and that of the ship at different three locations around the site.

Site	Type	No.(frame / pressure case)	S/N (data logger / sensor)	Clock Information (second)
EM1	BC1	K2010-001 / 107 - K2010-001	18 / 1675	-30
EM2	BC1	K2010-002 / 104 - K2010-003	17 / 1598	-38
EM3	BC1	K2010-003 / 101 - K2010-004	16 / 1729	-15
EM4	BC2	K2010-008 / 108 – KN2010-001	22 / 1924	-25
EM5	T	KN2007-002 / 5	KB1-OBEM	+14

EM6	BC1	K2010-005 / 106 – K2010-005	20 / 1725	-13
EM7	BC1	K2010-007 / 105 - K2010-006	19 / 1728	-53
EM8	T	KN2007-001 / 11	NIPR2-OBEM	+4
EM9	BC1	K2010-004 / 102 - K2010-002	15 / 1726	none
EM10	BC2	K2010-009 / 109 - KN2010-002	23 / 1925	-29
EM11	BC1	K2010-006 / 103 - K2010-007	21 / 1727	-54

Notes:
BC1: Sensor made by Bartington Instruments Ltd. with using data logger made by Clover-tech Corp. and all of these are packed in on a pressure case (Photo 1a).
BC2: Sensor made by Bartington Instruments Ltd. with using data logger made by Clover-tech Corp. and the sensor are packed in an independent pressure case.
T: Sensor and data logger made by Tierra Tecnica Corp. (Photo 1b).
Clock Information: Clock (OBEM)-Clock (reference, GPS). +: gain, -: delay

Table 5-1-2a. Instrument information on OBEM at each site.

Site	Type	OBS No.
S1	LTOBS_ERI	724
S2	LTOBS_ERI	722
S3	LTOBS_ERI	729
S5	STOBS_ERI	ERI-5B
S6	STOBS_ERI	ERI-5F
S7	STOBS_ERI	ERI-5C
S8	LTOBS_ERI	662
S9	LTOBS_ERI	744
S10	LTOBS_ERI	752
S12	STOBS_ERI	ERI-5D
S13	STOBS_Chiba	7876
S14	STOBS_ERI	ERI-5E
S15	STOBS_Chiba	7882
S16	STOBS_ERI	ERI-5A
S17	STOBS_Chiba	7875

Table 5-1-2b. Instrument information on OBS at each site.

Site	Type	Depth (m)	Date(UTC)	Send release command	Lift off confirmed	On Surface confirmed	On deck
EM1	BC1	3924	2010/11/11	18:18	18:36	20:43	21:00
EM2	BC1	3746	2010/11/12	0:31	0:47	2:47	2:59
EM3	BC1	3550	2010/11/12	4:24	-	-	6:50
EM4	BC2	3255	2010/11/12	8:17	-	10:10	10:21
EM5	T	3091	2010/11/12	11:27	-	13:12	13:24

EM6	BC1	2867	2010/11/12	14:01	14:17	15:48	15:59
EM7	BC1	3113	2010/11/15	0:26	-	2:20	2:33
EM8	T	3291	2010/11/14	21:44	22:00	23:25	23:35
EM9	BC1	2581	-	-	-	-	-
EM10	BC2	3676	2010/11/12-13	22:08	-	0:14	0:24
EM11	BC1	3766	2010/11/12	18:27	-	20:41	20:52

Table 5-1-3a. Timetable for OBEM recovery at each site

Site	Type	Depth (m)	Date(UTC)	Send release command	Lift off confirmed	On Surface confirmed	On deck
S1	LTOBS_ERI	3746	2010/11/11-12	23:11	23:26	0:16	0:25
S2	LTOBS_ERI	3550	2010/11/12	3:59	4:17	5:04	5:11
S3	LTOBS_ERI	3268	2010/11/12	7:54	−	8:48	8:58
S5	STOBS_ERI	2865	−	−	−	−	−
S6	STOBS_ERI	3074	2010/11/15	3:03	3:18	4:05	4:10
S7	STOBS_ERI	2984	2010/11/15	0:03	0:19	1:07	1:14
S8	LTOBS_ERI	3315	2010/11/14	21:18	21:40	22:25	22:34
S9	LTOBS_ERI	2585	2010/11/13	1:35	1:44	2:18	2:25
S10	LTOBS_ERI	3684	2010/11/12	21:49	22:02	22:51	22:59
S12	STOBS_ERI	3073	2010/11/15	8:38	8:57	9:45	9:57
S13	STOBS_Chiba	3135	2010/11/15	6:46	−	7:55	8:02
S14	STOBS_ERI	3161	2010/11/15	4:47	5:10	6:03	6:09
S15	STOBS_Chiba	3104	2010/11/15	12:55	12:56	13:55	14:04
S16	STOBS_ERI	3084	2010/11/15	14:40	−	15:39	15:49
S17	STOBS_Chiba	3542	2010/11/14	19:16	19:17	20:25	20:34

Table 5-1-3b. Timetable for OBS recovery at each site

5-2. Seismic Reflection and Refraction Survey

We conducted a seismic reflection and refraction survey at the hydrothermal area (Figure 5-2-1 and Table 5-2-1). Line A's were NE-SW direction parallel to the spreading center, line B's were NW-SE perpendicular to the spreading center. Line length was 15 km each, and line interval was 2.5 km. The air gun was GI gun with 355 cu. in. (5.5 l), air pressure was 13.5 Mpa, and the shot interval was 40 s, spaced ca. 97 m. We fired 2519 shots along the profiles. Table 5-2-1 shows locations and times of start and end points of each line. Nine OBS's recorded seismic refraction data. Seismic reflection data were obtained using a hydrophone streamer. The hydrophone streamer was a single channel combined 48 hydrophone signals, and the data were recorded with recording length of 16 s and sampling rate of 1000 Hz for each shot.

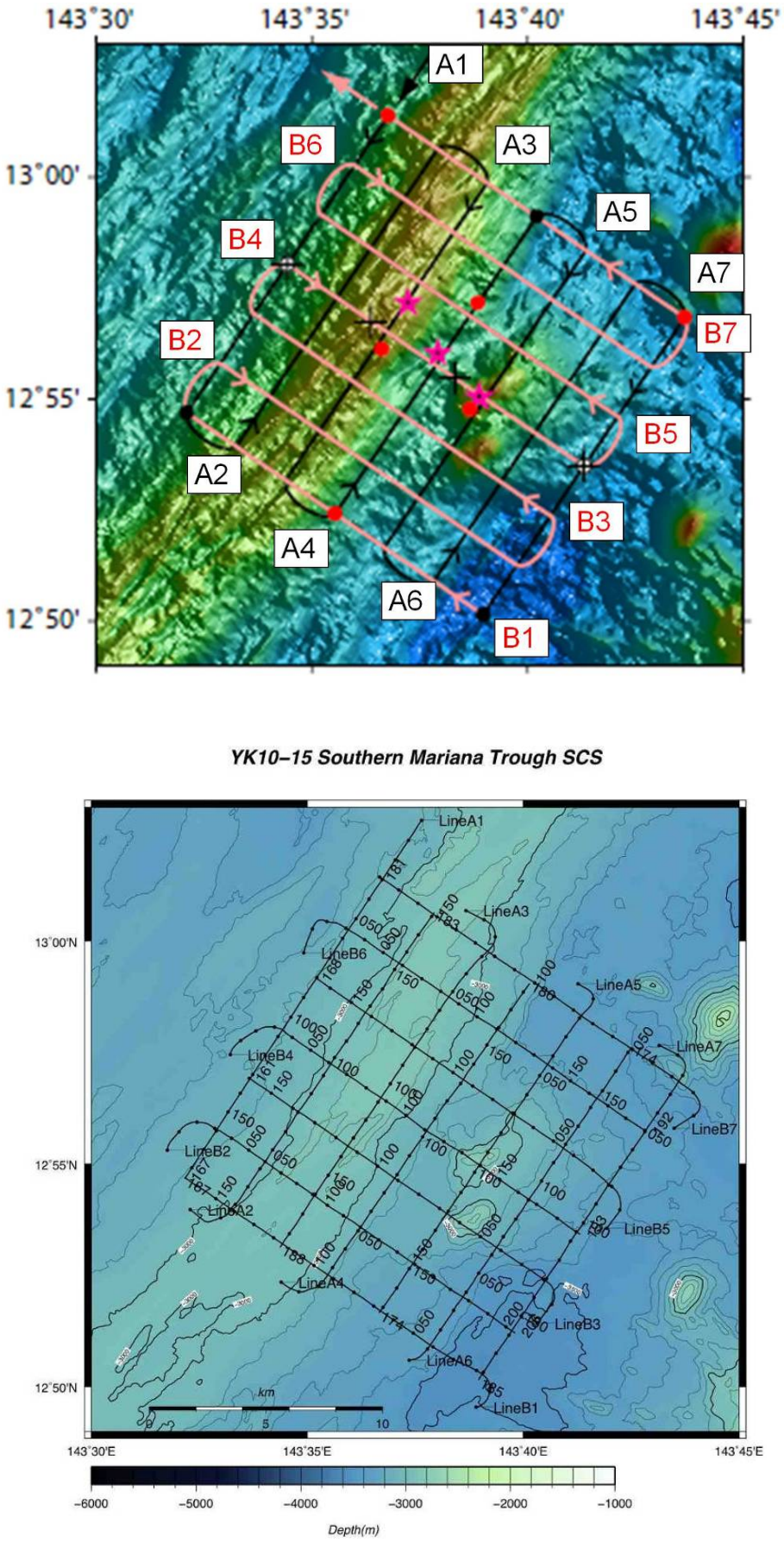


Figure 5-2-1. Location map of seismic reflection and refraction survey line (top) and numbers in the bottom figure denote air-gun shot numbers of each survey line.

Survey line	Start Location and Time (UTC)						End Location and Time (UTC)					
	Longitude (E)		Latitude (N)		Date	Time	Longitude (E)		Latitude (N)		Date	Time
	Deg.	Min.	Deg.	Min.			Deg.	Min.	Deg.	Min.		
A1	143	36.75	13	01.39	11/13	9:58	143	32.13	12	54.59	11/13	11:44
A2	143	33.24	12	53.99	11/13	12:13	143	38	13	00.71	11/13	14:05
A3	143	39.20	12	59.79	11/13	14:35	143	34.32	12	53.05	11/13	16:23
A4	143	35.46	12	52.48	11/13	16:52	143	40.2	12	59.12	11/13	18:39
A5	143	41.35	12	58.33	11/13	19:09	143	36.62	12	51.58	11/13	20:53
A6	143	37.84	12	50.92	11/13	21:27	143	42.58	12	57.68	11/13	23:16
A7	143	43.63	12	56.88	11/13	23:41	143	38.93	12	50.08	11/14	1:49
B1	143	39.01	12	50.25	11/14	1:50	143	32.1	12	54.75	11/14	3:31
B2	143	32.90	12	55.78	11/14	4:00	143	39.89	12	51.17	11/14	5:57
B3	143	40.53	12	52.38	11/14	6:18	143	33.58	12	56.97	11/14	7:53
B4	143	34.40	12	58.04	11/14	8:25	143	41.4	12	53.38	11/14	10:11
B5	143	42.07	12	54.48	11/14	10:34	143	35.11	12	59.23	11/14	12:13
B6	143	35.22	13	00.43	11/14	12:30	143	42.93	12	55.68	11/14	14:29
B7	143	43.62	12	56.84	11/14	14:56	143	36.6	13	01.49	11/14	16:40

Table 5-2-1. Information on seismic reflection and refraction survey line.

5-3. Surface Geophysical Survey

We conducted a surface geophysical survey to collect multi-narrow beam bathymetry, magnetic field, and gravity field data. The ship tracks of the survey area are shown in Figure 5-3-1. Multi-narrow beam bathymetric data were obtained using a SeaBeam 2112 (Swath width 150°; 150 beams with its width and interval of 2°and 1°, respectively), which also provides a backscatter image that will be processed after the cruise. We could cover total 340 miles in the survey area. An XBT was done at 5:57 on November 13 (UTC). The DGPS (differential global positioning system) was used to derive the ship's location. Magnetic field data were collected with two instruments: a shipboard three component magnetometer (STCM: Isezaki, 1986) that can measure the vector geomagnetic field using deck-mounted fluxgate magnetometers and gyros, and a ship-towed proton precession magnetometer that can measure the intensity of the geomagnetic field. The STCM data contain the effects of the ship's magnetic field that must be corrected in order to derive the real geomagnetic field. Twelve constants related to the ship's permanent and induced magnetic field will be estimated using data from "Figure 8 turns". "Figure 8 turns" is made by steering the ship in a tight circle, both clockwise and counter clockwise. During the cruise, "Figure 8 turns" were conducted two times and it is listed in Table 5-3-1. Gravity field data were obtained from a shipboard gravimeter (Model S-63, Lacoste & Romberg). The gravity field data at Palau, Guam, and Yokosuka ports measured with a portable gravimeter will be used to correct the instrument drift.

No.	Date	Time(UT)	Latitude	Longitude
1	15/Nov.	22:45-23:04	12°35.4’N	143°30.5’E
2	16/Nov.	06:47-07:04	12°39.3’N	143°21.4’E

Table 5-3-1. List of “Figure 8 turns”

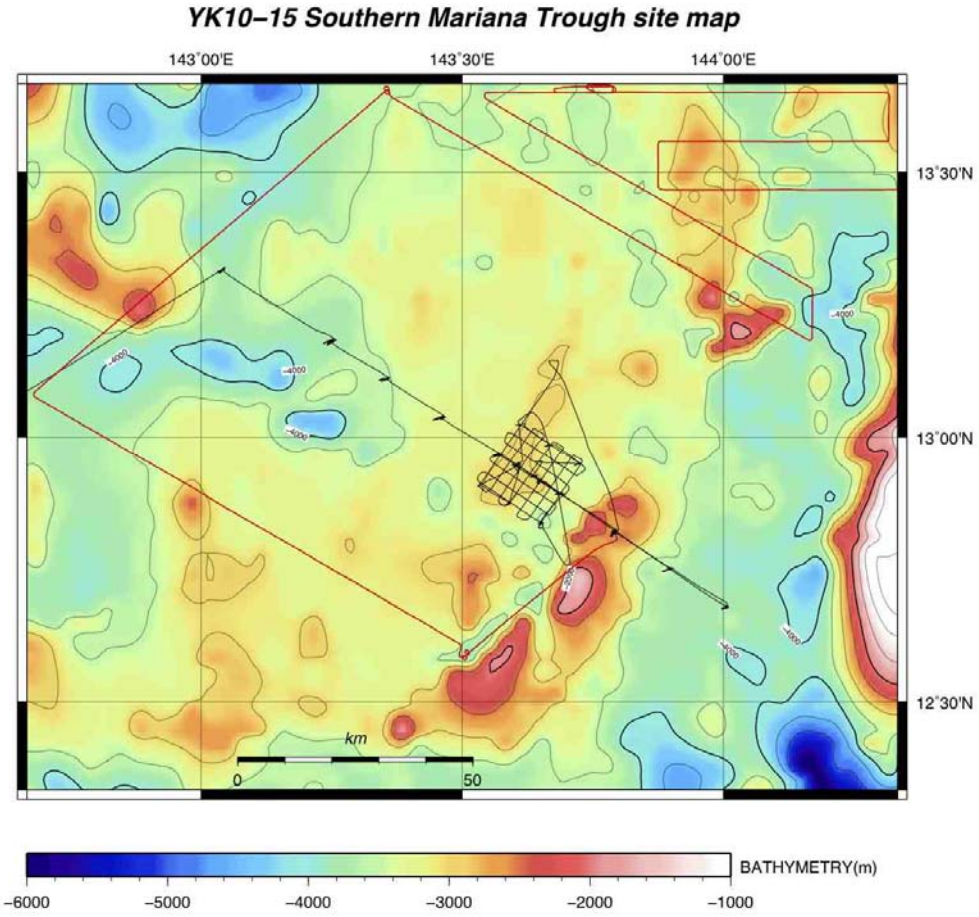


Figure 5-3-1. Ship tracks (red and black lines) of the cruise in the survey area and red lines shows ship tracks for the surface geophysical survey

6. Summary

We successfully recovered 10 OBEMs and 14 OBSs across the Southern Mariana Trough back-arc spreading system. Observation started after the deployment of OBEMs and OBS during another Yokosuka cruise (YK10-10) in this August; the measurement of magnetic and electric field variations by OBEMs and seismic observation by OBSs at the ocean bottom. We also conduct seismic survey to investigate seismic velocity structure using 9 OBSs, an air-gun, and a single channel hydrophone streamer. Further, we conducted surface geophysical survey to collect multi-narrow beam bathymetry, magnetic field, and gravity field data after the instruments recovery, which cover total 340 miles in the survey area. These observed data will be used to provide geophysical constraint on geodynamics of the Southern Mariana Trough back-arc spreading system with three different hydrothermal activities.

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