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R/V MIRAI Cruise Report
MR15-E01 Leg3

Cross-ministerial Strategic Innovation Promotion Program (SIP),
Next-generation technology for ocean resources exploration
(ZIPANG in ocean)

"Site survey for scientific drilling using portable multi-channel seismic reflection survey system"

Around Minami-torishima island
28 March – 18 April 2015

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

Contents

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Acknowledgement

We would like to express our sincere appreciation for the excellent support and assistance by Captain Akutagawa and his officers and crew. We are deeply grateful to marine technicians of Global Ocean Development Inc. and Nippon Marine Enterprise Inc. for their efforts in obtaining MCS data and geophysical data.

1 Cruise Information

Cruise ID: MR15-E01 Leg3

Name of vessel: R/V *MIRAI*

Title of the cruise: Cross-ministerial Strategic Innovation Promotion Program (SIP), Next-generation technology for ocean resources exploration (ZIPANG in ocean), “Site survey for scientific drilling using portable multi-channel seismic reflection survey system”

Chief scientist: Koichi IIJIMA [Japan Agency for Marine-Earth Science and Technology; JAMSTEC]

Representative of the Science Party: Katsuhiko SUZUKI [JAMSTEC]

Cruise period: 28 March – 18 April 2015

Ports of departure / arrival: Chichi-jima / Yokohama

Research area: Around Minami-torishima island

Research area map:

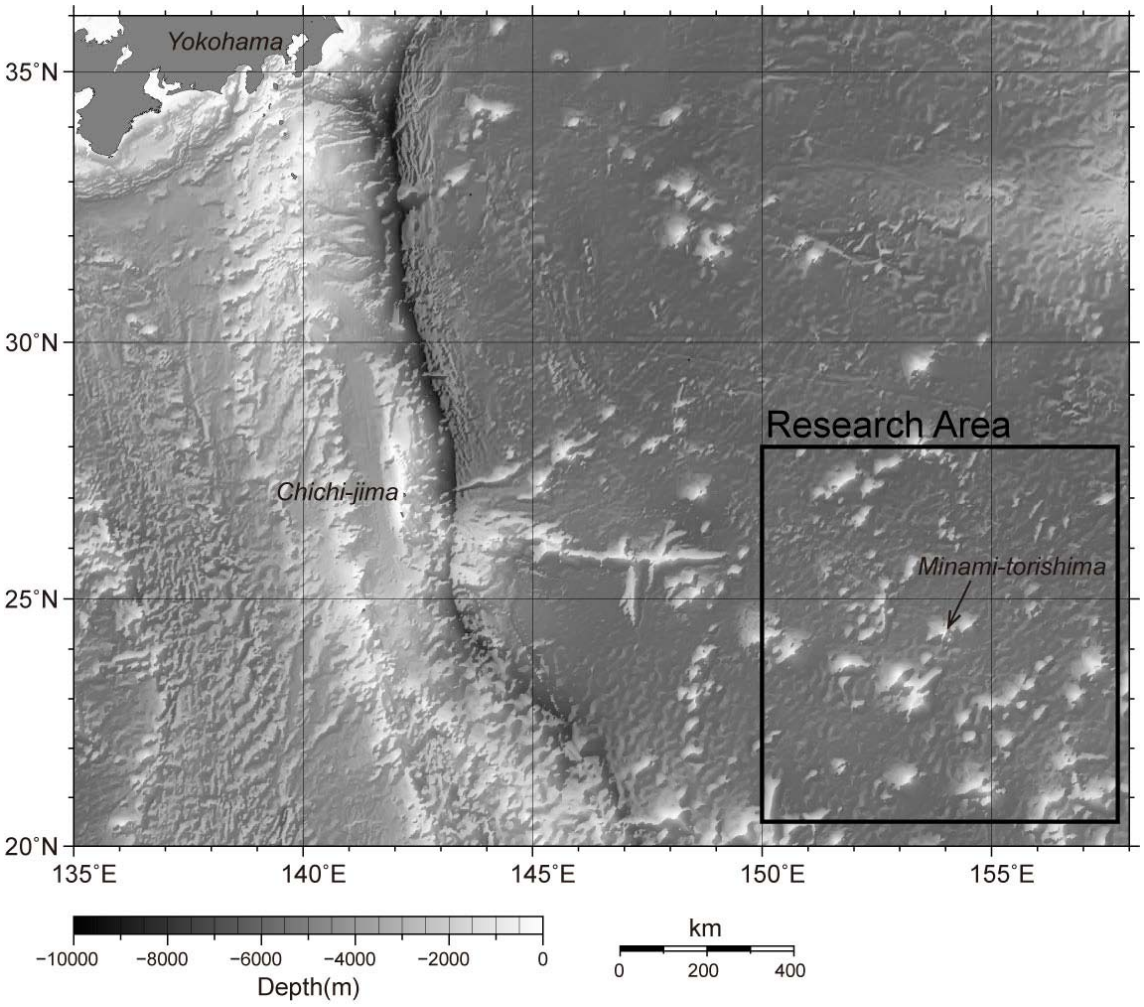

Fig.1. Research area map of cruise MR15-E01 Leg3. Bathymetric image is drawn using ETOPO1 bathymetric data [1].

2 List of participants

2.1 Science party

Katsuhiko SUZUKI [JAMSTEC] * Representative of the science party

Koichi IIJIMA [JAMSTEC]

Yuka MASAKI [JAMSTEC]

Kentaro NAKAMURA [JAMSTEC]

Shiki MACHIDA [JAMSTEC]

Kazuya KITADA [JAMSTEC]

2.2 Onboard scientists

Koichi IIJIMA [JAMSTEC] * Chief scientist

Shiki MACHIDA [JAMSTEC]

Kazuya KITADA [JAMSTEC]

2.3 Marine technicians

Wataru TOKUNAGA [GODI]

Toshio FURUTA [GODI]

Miki MORIOKA [GODI]

Makoto ITO [NME]

Yuki OHWATARI [NME]

Naoto NOGUCHI [NME]

Norio SHIMOMURA [NME]

Akie SUZUKI [NME]

Keita SUZUKI [NME]

Kimiko SERIZAWA [NME]

2.4 Crew members

Captain	Toshihisa AKUTAGAWA
Chief Officer	Takeshi ISOHI
2nd Officer	Nobuo FUKAURA
Junior 2nd Officer	Hirokazu SUGAWARA
3rd Officer	Akihiro NUNOME
Junior 3rd Officer	Satohiro TANAKA
Chief Engineer	Shigeru FUJITA
1st Engineer	Kazuhito IKEDA
2nd Engineer	Jun TAKAHASHI
3rd Engineer	Katsumitsu KODAMA
Radio officer	Ryo KIMURA

Boat Swain	Yosuke KUWABARA
Able Seaman	Tsuyoshi SATO
Able Seaman	Tsuyoshi KADOSAWA
Able Seaman	Shuji KOMATA
Able Seaman	Kaito MURATA
Able Seaman	Masaya TANIGAWA
Sailor	Shohei UEHARA
Sailor	Tomohiro SHIMADA
Sailor	Ryoya CHISHIMA
Sailor	Tetsuya SAKAMOTO
Sailor	Hideyuki OKUBO
No.1 Oiler	Yoshihiro SUGIMOTO
Oiler	Kazumi YAMASHITA
Oiler	Fumito KAIZUKA
Fireman	Kazuya ANDO
Fireman	Shintaro ABE
Fireman	Hiromi IKUTA
Chief Steward	Ryotaro BABA
Steward	Tamotsu UEMURA
Steward	Yukio SHIGE
Steward	Yukio CHIBA
Steward	Toshiyuki ASANO

3 Background and objectives

Deep-sea mud that is extremely enriched in rare-earth elements and yttrium (together called REY-rich mud) around Minami-torishima island was discovered in cruise KR13-02 [2]. Since that, many piston coring, sub-bottom profiling (SBP) and multi-beam echo sounder (MBES) bathymetric survey has been conducted on fundamental objective to investigate the features, distribution and generation of REY-rich mud.

To extend REY-rich mud research onto the global history, however, we have to have drilling cores. In the past cruises, 20 m class piston coring penetration stopped maximum around 13m. On the other hand, past drilling cores near Minami-torishima island, Deep Sea Drilling Program (DSDP) site 198 [3] and Ocean Drilling Program (ODP) site 800 [4], did not recovered enough sediment to investigate REY-rich mud generation. That is, we have never seen deeper part of continuous sediment beneath 13 meters below sea floor (mbsf).

Then we make a simple drilling proposal to recover whole sediment above acoustic basement supposed to be chert or porcelanite according to sub-bottom profiling described in Nakamura et al. (2016) [5]. They distinguished three acoustic facies in the sub-bottom profiling: opaque (O), transparent (T), and layered (L), and they revealed that T-type facies represents REY-rich mud. We selected 3 sites to drill; St.1: T-type, extremely REY-rich mud existing (Fig. 3.1), St.2: L-type, thick layered sediments existing as a reference (Fig. 3.2) and St.3: L-type, also as a reference, thick layered sediments existing (Fig. 3.3). Piston cores and SBP images were already obtained in past cruises.

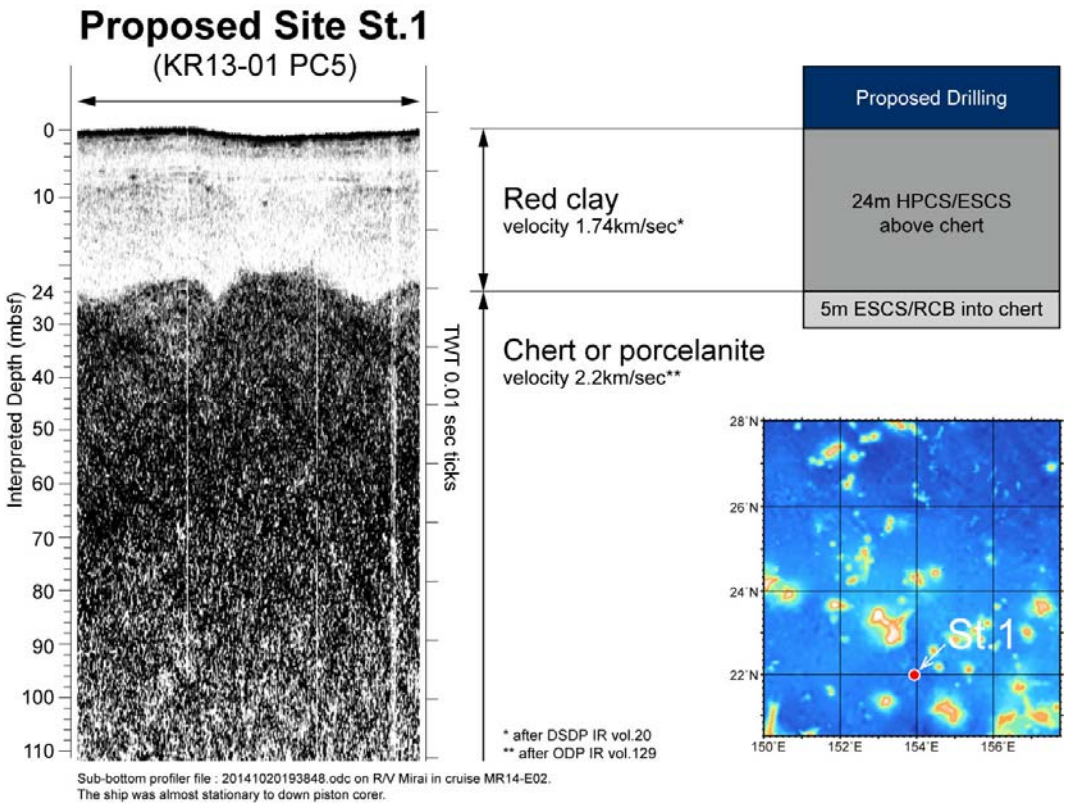

Fig.3.1. Preliminary drilling proposal for extremely REY-rich mud site, St.1. Axis on the left of SBP image

is interpreted (calculated) depth from velocity obtained in DSDP site 198 and ODP site 800 cores.

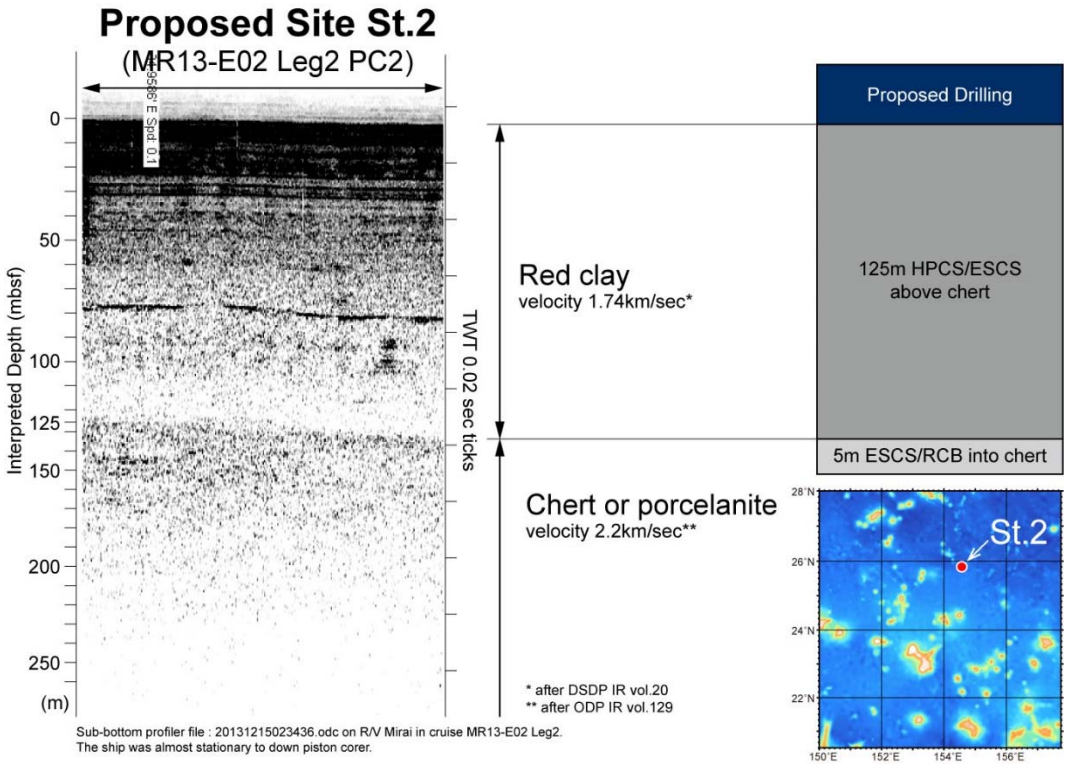

Fig.3.2. Preliminary drilling proposal for thick “layered” site, St.2, as a reference. Axis on the left of SBP image is interpreted (calculated) depth from velocity obtained in DSDP 198 core at this site and ODP site 800 cores.

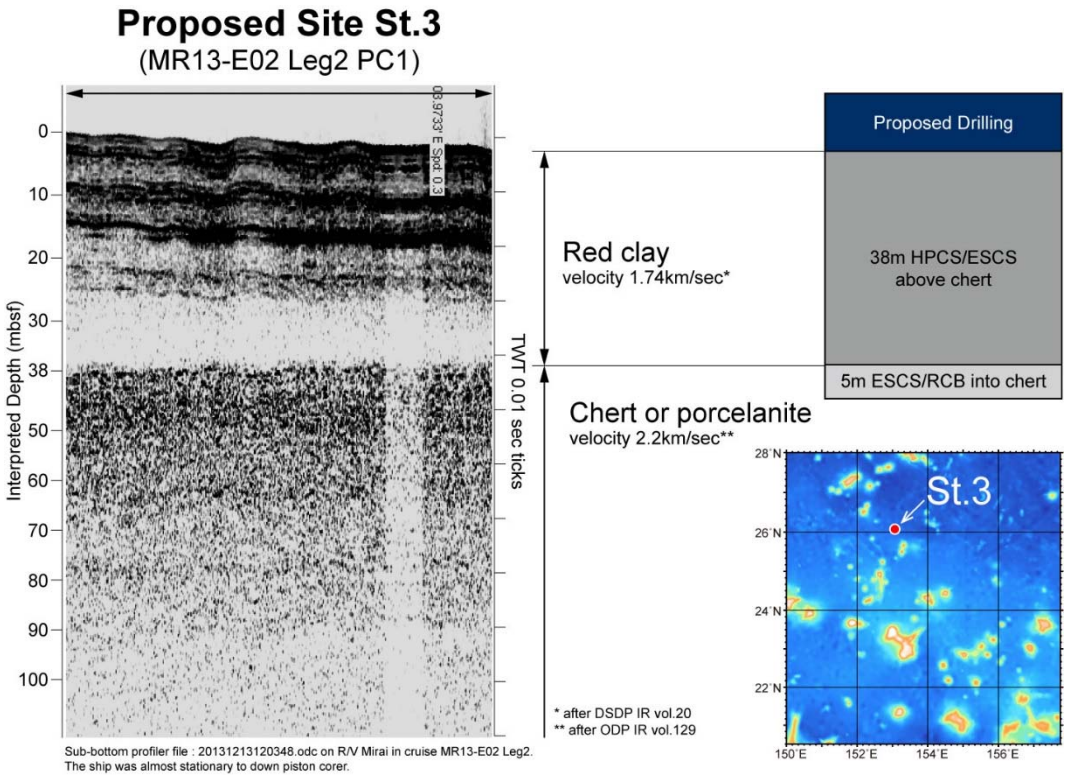

Fig.3.3. Preliminary drilling proposal for thick “layered” site, St.3, for a reference. Axis on the left of SBP image is interpreted (calculated) depth from velocity obtained in DSDP site 198 and ODP site 800 cores.

In this cruise MR15-E01 Leg3, first objective is to investigate multi-channel seismic (MCS) reflection survey for required pre-drilling site survey. We used portable high resolution MCS survey system to reveal structures around 150 mbsf where we need to know in detail. The general description and ability of the system is described in Miura et al. (2013) [6], in comparison with R/V KAIREI system and R/V KAIYO system. MCS lines are coordinated to cross above the sites St.1, 2, 3 and additional St.4 (ODP site 800 / KR13-02 PC3) (Fig.3.4)

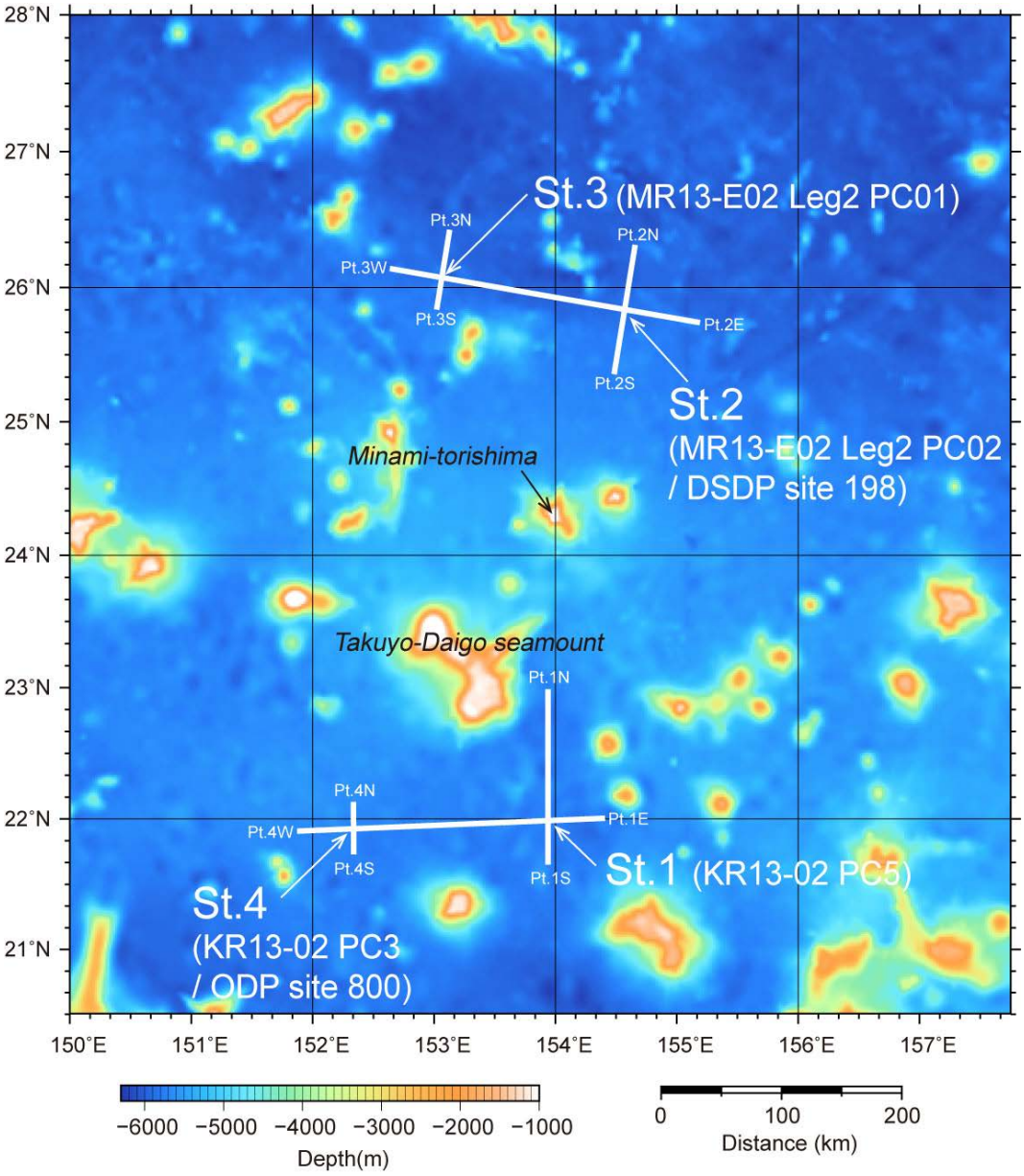

Fig.3.4. Planned MCS survey lines in cruise MR15-E01 Leg3. Background bathymetric image is drawn using ETOPO1 bathymetric data [1].

Second objective is to obtain wide-area bathymetric data around proposed drill site. There were few

data to study topography and MBES reflection intensity except St.1 where we already investigated ~60 nm^2 area around there. Third objective is to investigate SBP in penetration to ~50 mbsf with continuous recording in research area to identify distribution of 3 type of SBP facies.

4 Observation instruments

4.1 High resolution MCS survey

We used portable, high resolution MCS system on R/V *MIRAI*. The layout is shown in Fig.4.1.1.

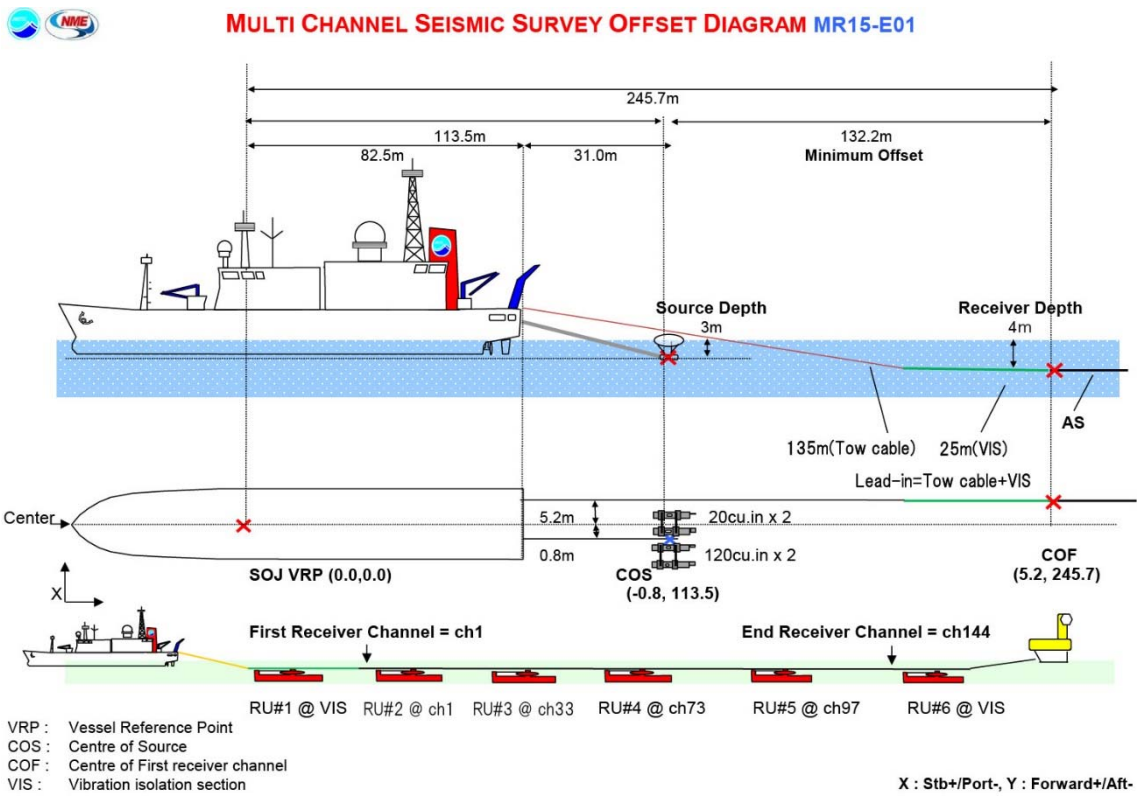

Fig.4.1.1. Towing geometry and offset diagram of MCS survey in cruise MR15-E01 Leg3.

Source

We used BOLT 2800LLX as a source with two 20 cu.in. and two 120 cu.in. (total volume 280 cu.in.) air gun array in 2000 psi air pressure produced by National Compressed Air NCA5-138. Gun depth is 3m and towing length is 31 meters (Fig.4.1.1). Photo 4.1.1 shows the air gun array onboard and towing.

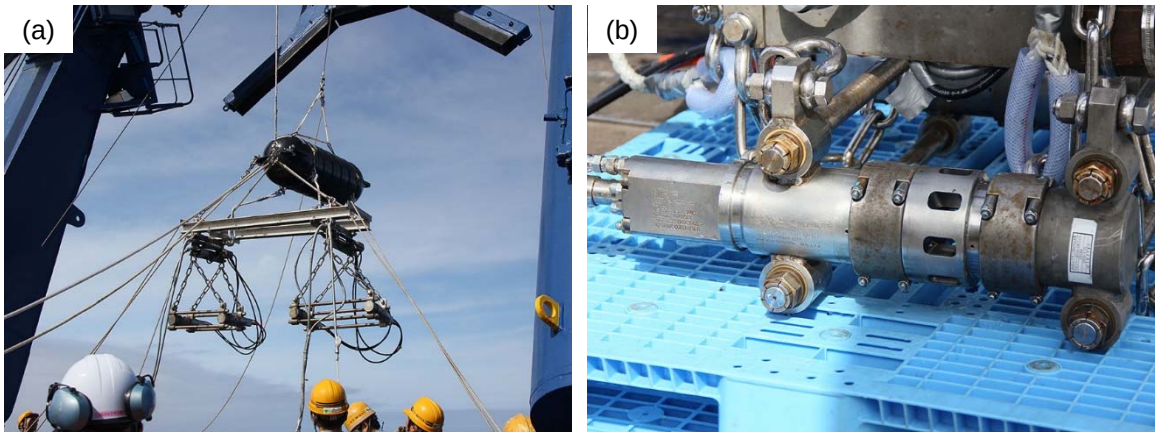

Photo 4.1.1. Photographs of source of MCS survey. (a) whole view of the air-gun array. (b) BOLT 2800LLX air-gun with 20 cu.in gun (looking from starboard side). (c) towing air-gun array.

Receiver

Receiver in this system consist of streamer cable, cable depth compensator “bird”, tail buoy and onboard instruments. We used Geometrics GEOEEL Digital Streamer cable system equipped 144 channels in total of 1,140 m long (Fig.4.1.2). Channel interval is 6.25 m, 8 channels in 1 active section, and 12 channels in hydrophone group. The hydrophone is Geometrics proprietary polymer. Tow leader length is 163.2 m (include front VIS) and cable depth is 4 m (fig.4.1.1). Photo 4.1.2 shows components of receiver.

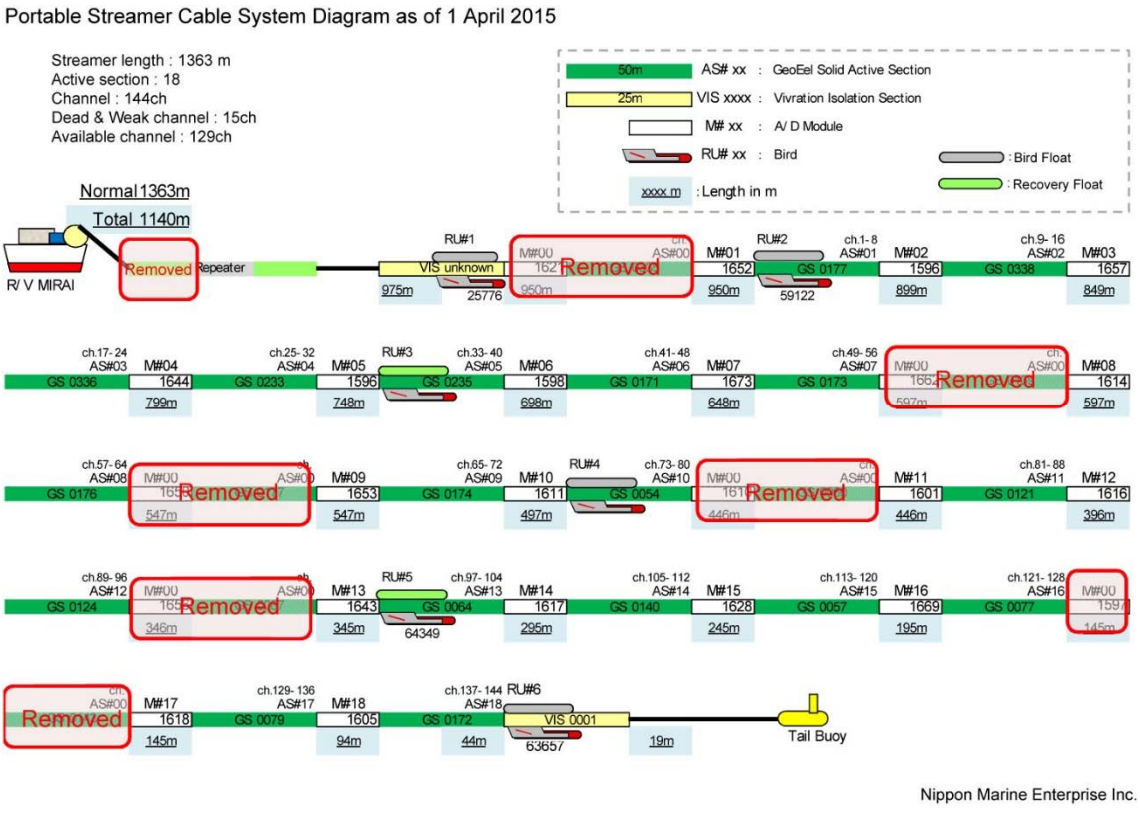

Fig.4.1.2. System diagram of portable streamer cable used in cruise MR15-E01 Leg3 as of 1 April 2015. Some bad sections are already removed which result in reduction of total channel from 192 to 144.

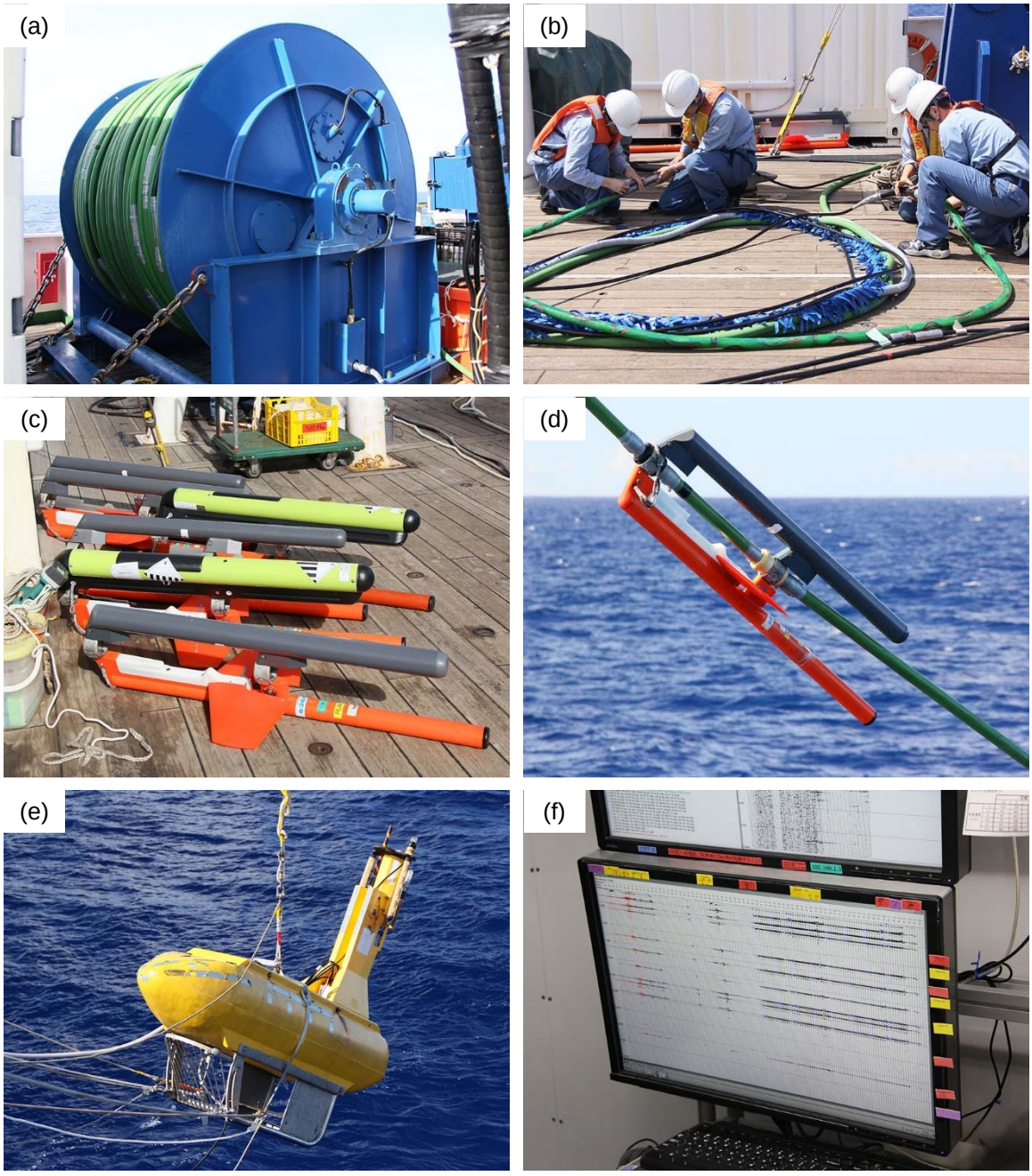

Photo 4.1.2. Photographs of receiver of MCS survey. (a) streamer cable drum. (b) replacing lead-in section. (c) "bird" to control depth of streamer cable. (d) a bird attached to streamer cable. (e) tail buoy towed at end of the cable. (f) monitor window of all channel.

Recording

Recording is carried out using CNT-2 Marine Controller ver.5.715. Sample rate is 1 msec, recording length is 10 sec. (10,000 msec) and system delay is 200 msec. Data is stored as SEG-D 8058 rev.1 4byte 32bit IEEE demultiplexed format. Sercel Triggerfish ver. 1.7.12 for the navigation and SKYFIX XP DGPS is used for primary positioning.

Onboard processing

Onboard data processing is conducted in the conventional processing sequence, which includes trace edit, velocity analysis, common depth point (CDP) stack and automatic gain control (AGC) (Fig.4.1.3).

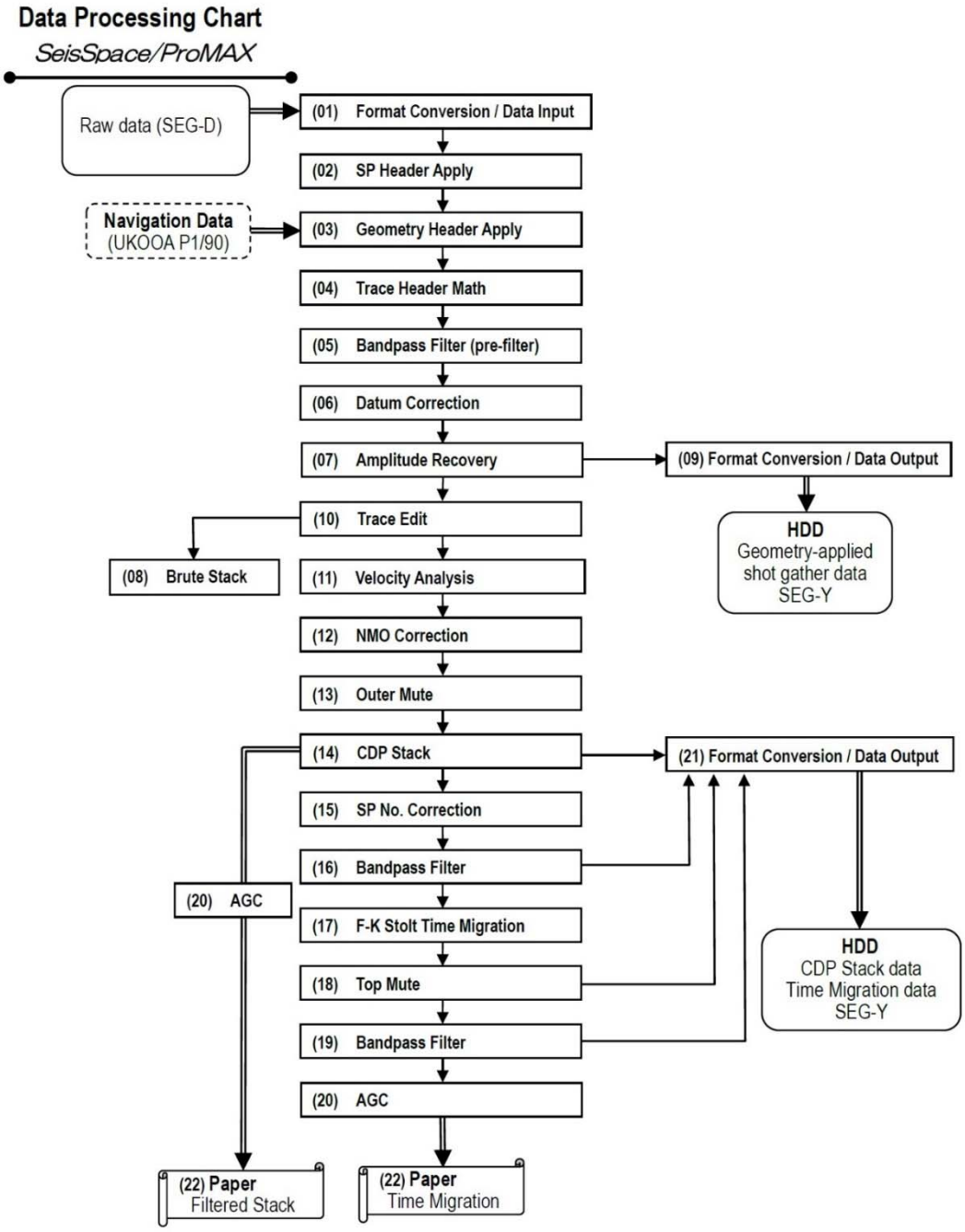

Fig.4.1.3. Schematic chart of onboard data processing.

4.2 Bathymetric survey

MIRAI is equipped with a Multi-beam echo sounder system (MBES) Sea Beam3012 Upgrade Model (L-3 ELAC Nautik GmbH) for bathymetric survey. In this cruise, MBES bathymetric data is obtained throughout the cruise within the research area. Solid lines in Fig.4.2 represent the MBES survey lines that

planned for proposed drilling sites except for St.1.

The specifications of L-3 ELAC Nautik GmbH SeaBeam 3012 Upgrade Model

Operating frequency	12 kHz
Transmit beam width	1.6 deg.
Transmit power	20 kW
Transmit pulse length	2 to 20 msec
Receive beam width	1.8 deg.
Depth range	100m to 11,000 m
Beam spacing	0.5 degree athwart ship
Swath width	150 degree (max) 120 deg. to 4,500 m 100 deg. to 8,000 m 90 deg. to 11,000 m
Depth accuracy	Within < 0.5% of depth or ±1m, whichever is greater, over the entire swath.

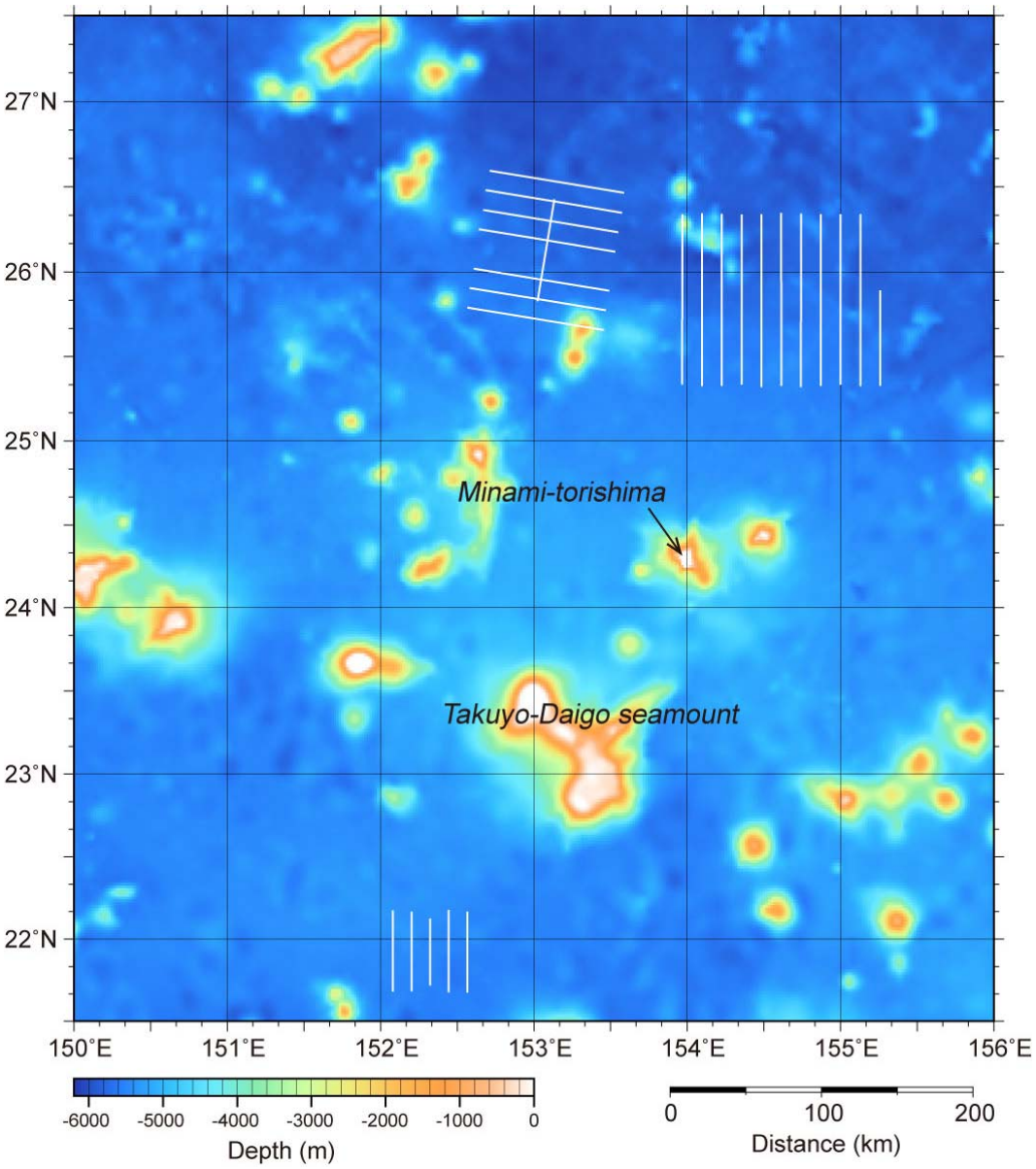

Fig. 4.2. MBES survey lines planned in cruise MR15-E01 Leg3. MBES survey along the MCS lines are also to be carried on. Background bathymetric image is drawn using ETOPO1 bathymetric data [1].

4.3 Geophysical survey

MIRAI is equipped with geophysical instruments such as SBP, gravimeter, cesium magnetometer, onboard three components magnetometer etc. The specifications of these equipment are listed below. In this cruise, SBP data, gravity data and geomagnetic data (cesium and onboard tri-axis) are obtained throughout the cruise within the research area.

The specifications of SyQwest, Inc. BATHY-2010 for SBP

Frequency output	3.5 kHz FM Chirp
Transmit beam width	23 deg.
Transmit pulse length	0.5 to 50 msec
Strata resolution	Up to 8 cm with 300+ Meter of bottom penetration (Bottom type dependent)
Depth resolution	0.1 Meters
Depth accuracy	±10 cm to 100 m, ±0.3% to 6,000 m
Depth accuracy	±0.3% to 6000 m

The specifications of Geometrics Inc. G-882 for cesium marine magnetometer

Recorder	Clovertech Co. G-882 data logger (Ver.1.0.0)
Dynamic operating range	20,000 to 100,000 nT
Absolute accuracy	< ±2 nT throughout range
Cycle rate	0.1 sec
Sensitivity	0.001265 nT at a 0.1 second cycle rate
Sampling rate	1 sec

The specifications of Tierra Tecnica SFG-1214 for onboard triaxial magnetometer

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

The specifications of LaCoste and Romberg S-116 for onboard gravimeter

Measurement range	~12,000 mGal
Drift	3 mGal per month or less
Temperature set point	46 to 55 °C
Resolution	0.01 mGal
Static repeatability	0.05 mGal
Accuracy at sea	1.0 mGal or better
Sampling rate	1 sec

Relative gravity Counter unit [CU] To change gravity [mGal] = (coef1: 0.9946) * [CU]

5 Preliminary results

5.1 Seismic lines

We have surveyed 7 seismic lines, 877.5km long with 35,109 good shots (Table 5.1). Line 4W1E is consisted of 2 lines due to system maintenance. Fig.5.1.1 shows track map of all MCS lines.

Table 5.1. Seismic line list of MR15-E01 Leg3

Line name	Date	Time (UTC)	F.S.P. F.G.S.P. L.G.S.P. L.S.P.	Vessel position		Depth (m)	Number of shot (FGSP to LGSP)	Length (FGSP to LGSP) (km)	Direction (°)	Mode (m)
				Latitude	Longitude					
1S1N_0	4-Apr	08:41:40	969	21_38.65717'N	153_56.34867'E	5,785		87.9	359.643	Distance (25.0m)
	4-Apr	08:50:46	993	21_38.98250'N	153_56.34950'E	5,790	3,515			
	5-Apr	05:00:01	4,507	22_26.59650'N	153_56.36300'E	5,729				
	5-Apr	05:00:01	4,507	22_26.59650'N	153_56.36300'E	5,729	(+1)			
2E3W_0	10-Apr	07:33:13	969	25_44.24850'N	155_11.82583'E	5,920		259.7	279.304	Distance (25.0m)
	10-Apr	07:40:53	995	25_44.31950'N	155_11.44417'E	5,915	10,388			
	12-Apr	09:11:05	11,382	26_08.01350'N	152_38.09083'E	5,907				
	12-Apr	09:11:05	11,382	26_08.01350'N	152_38.09083'E	5,907	(+1)			
2S2N_0	4-Sep	00:35:41	969	25_20.97083'N	154_29.76633'E	5,666		107.8	08.607	Distance (25.0m)
	9-Apr	00:42:04	993	25_21.28950'N	154_29.82550'E	5,655	4,312			
	9-Apr	21:31:54	5,304	26_18.89917'N	154_40.24200'E	5,931				
	9-Apr	21:31:54	5,304	26_18.89917'N	154_40.24200'E	5,931	(+1)			
3S3N_0	12-Apr	22:32:28	969	25_49.62600'N	153_01.40050'E	5,790		66.6	09.285	Distance (25.0m)
	12-Apr	22:40:12	994	25_49.95983'N	153_01.47650'E	5,797	2,664			
	13-Apr	14:56:49	3,657	26_25.54950'N	153_07.94933'E	5,964				
	13-Apr	14:56:49	3,657	26_25.54950'N	153_07.94933'E	5,964	(+1)			
3W3S_0	12-Apr	10:11:13	969	26_06.25233'N	152_38.37683'E	5,880		48.3	131.491	Distance (25.0m)
	12-Apr	10:11:13	969	26_06.25233'N	152_38.37683'E	5,880	1,931			
	12-Apr	21:49:10	2,899	25_48.95717'N	153_00.05983'E	5,734				
	12-Apr	21:49:10	2,899	25_48.95717'N	153_00.05983'E	5,734	(+1)			
4S4N_0	30-Mar	18:26:34	969	21_43.03750'N	152_19.39167'E	5,729		43.8	00.253	Distance (25.0m)
	30-Mar	18:37:50	1,022	21_43.75533'N	152_19.38983'E	5,724	1,752			
	31-Mar	01:48:14	2,773	22_07.48367'N	152_19.37567'E	5,646				
	31-Mar	01:48:14	2,773	22_07.48367'N	152_19.37567'E	5,646	(+1)			
4W1E_0	1-Apr	02:24:20	969	21_54.39433'N	151_51.97100'E	5,656		-	87.566	Distance (25.0m)
	-	-	-	-	-	-	-			
	-	-	-	-	-	-				
	1-Apr	02:43:29	1,012	21_54.40790'N	151_52.59510'E	5,653	(+1)			
4W1E_1	1-Apr	08:38:17	969	21_54.39800'N	151_51.97100'E	5,656		79.0	87.566	Distance (25.0m)
	1-Apr	08:46:06	994	21_54.40883'N	151_52.33417'E	5,661	3,159			
	1-Apr	23:00:10	4,152	21_56.43617'N	152_38.14500'E	5,722				
	1-Apr	23:00:10	4,152	21_56.43617'N	152_38.14500'E	5,722	(+1)			
4W1E_2	2-Apr	07:05:39	4,072	21_56.38167'N	152_36.98533'E	5,725		184.7	87.566	Distance (25.0m)
	2-Apr	07:11:40	4,097	21_56.39633'N	152_37.34683'E	5,724	7,388			
	3-Apr	21:29:26	11,484	22_00.31133'N	154_24.58517'E	5,633				
	3-Apr	21:29:26	11,484	22_00.31133'N	154_24.58517'E	5,633	(+1)			
					Total		35,109	877.5		

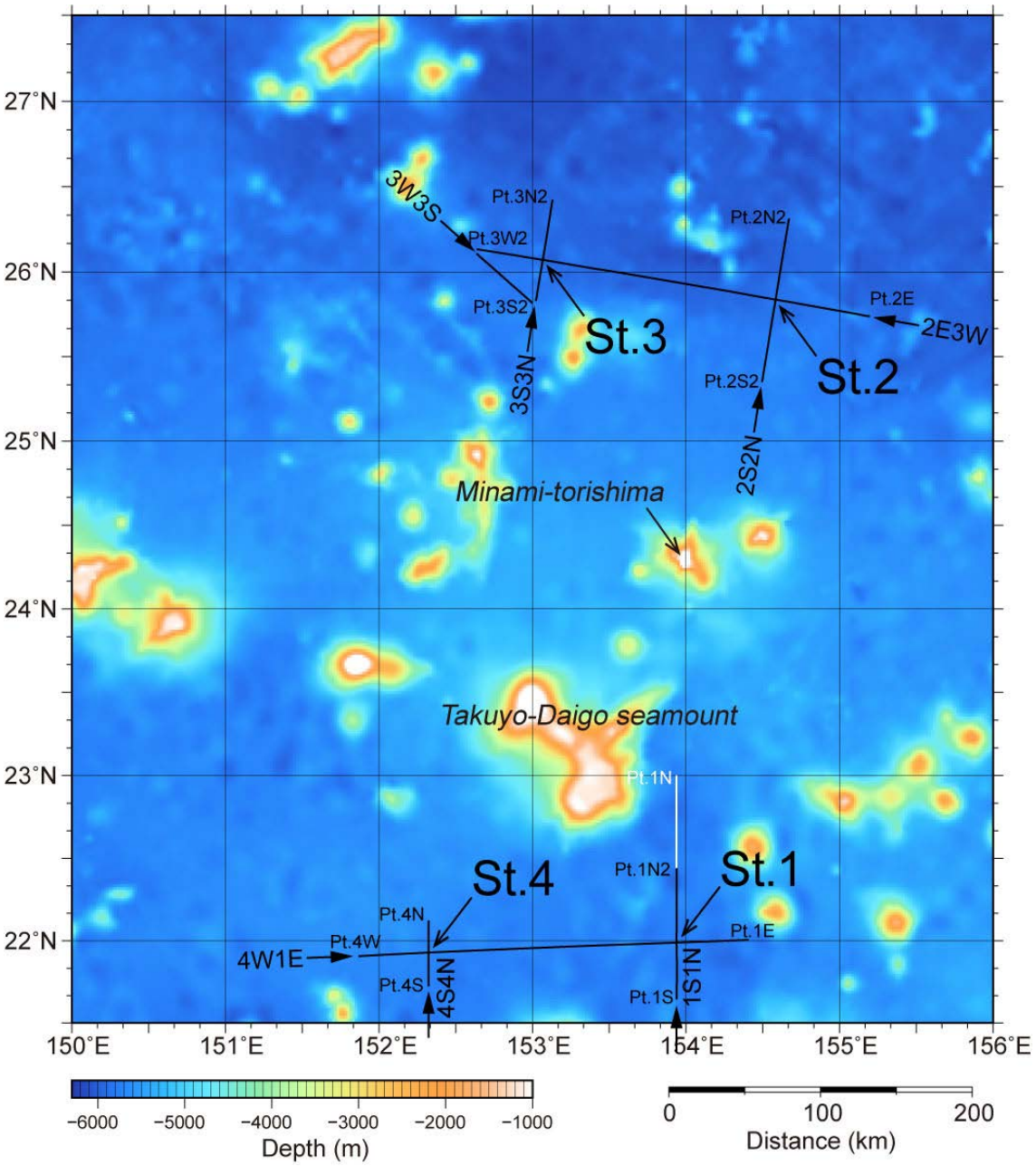

Fig.5.1.1. Track map of all MCS lines in cruise MR15-E01 Leg3. Black lines are investigated and white line is planned but not investigated. Line name is shown with solid arrow which represents vessel direction. Some point numbers are renamed (such as Pt.1N2) from planned shown in Fig.3.4 due to scheduling and small adjustment. Background bathymetric image is drawn using ETOPO1 bathymetric data [1].

Southern part

Fig.5.1.2 shows track lines with CDP number of MCS survey in south part of research area. Cross point of lines 4W1E and 1S1N is St.1 and cross point of lines 4W1E and 4S4N is St.4. Fig.5.1.3, Fig.5.1.4 and Fig.5.1.5 shows an image of time migration profile of line 4S4N, 1S1N and 4W1E respectively.

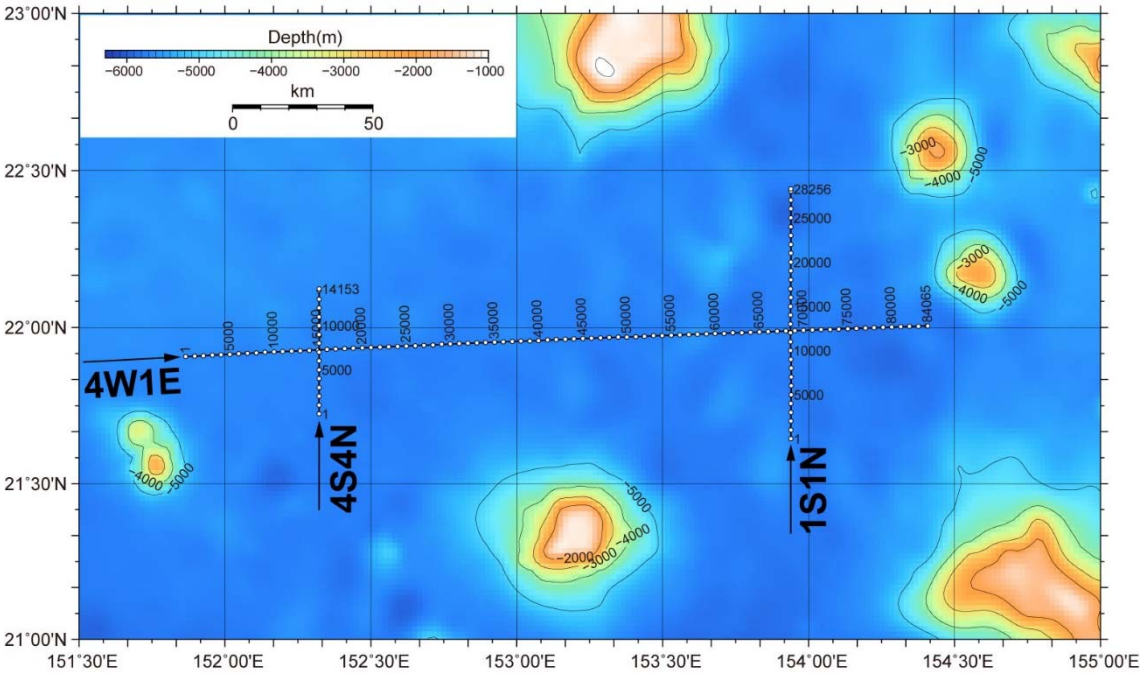

Fig.5.1.2. Track lines with CDP number of MCS survey in south part of research area in cruise MR15-E01 Leg3. Line name is shown with solid arrow which represents vessel direction. Background bathymetric image is drawn using ETOPO1 bathymetric data [1].

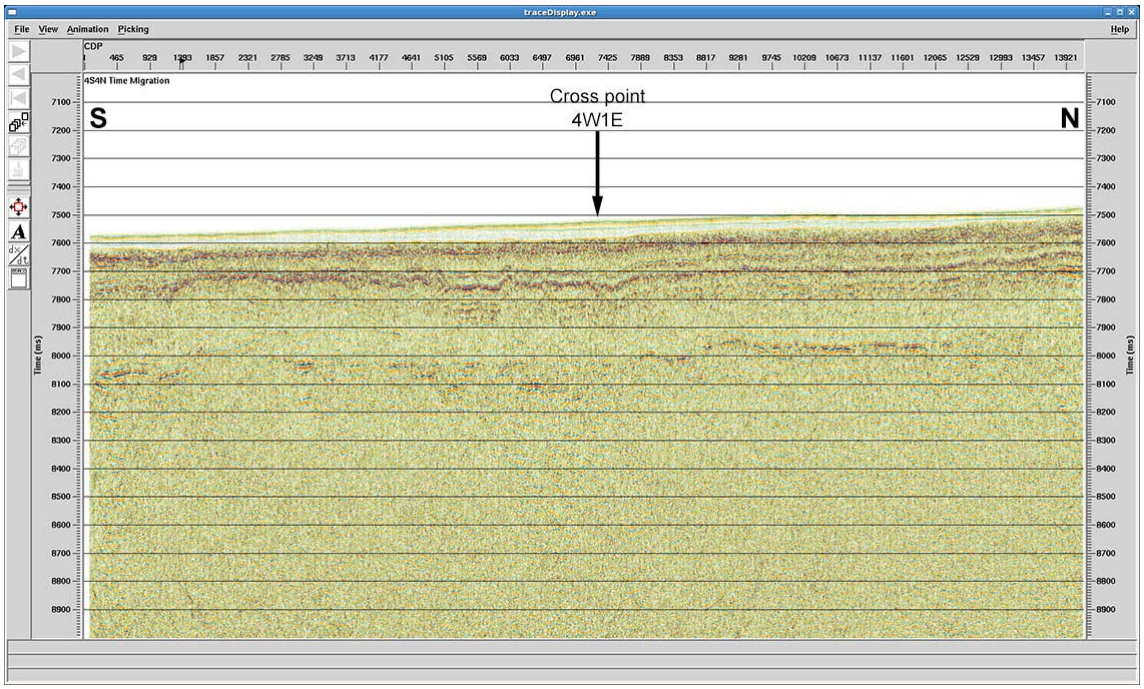

Fig.5.1.3. An image of time migration profile of line 4S4N.

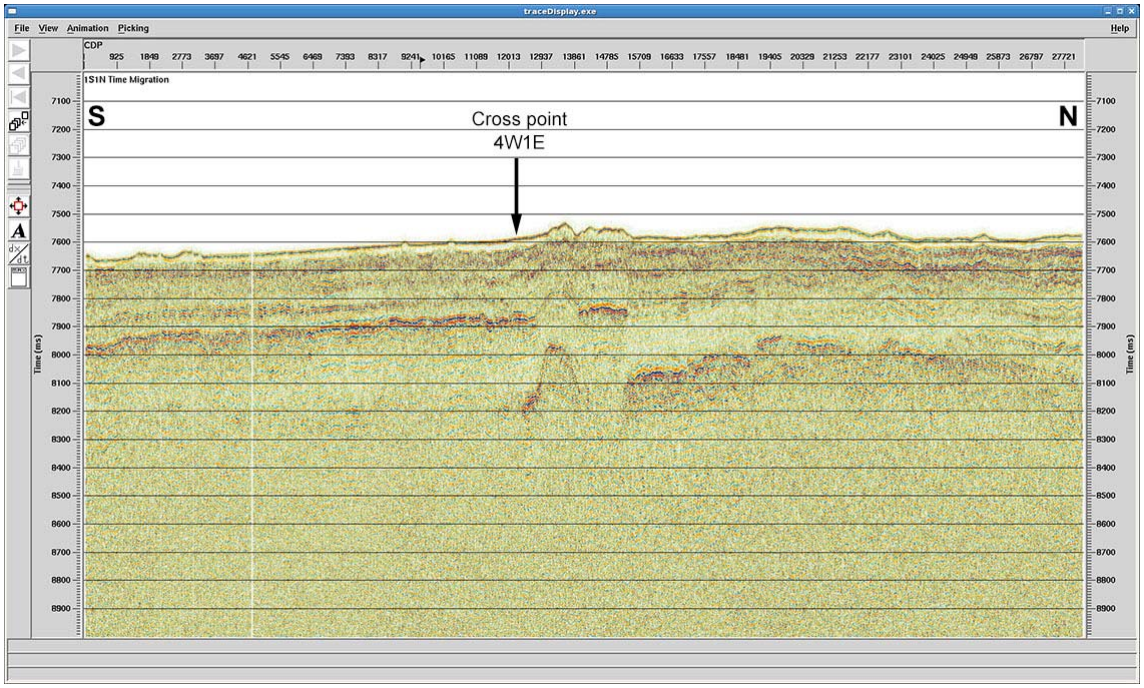

Fig.5.1.4. An image of time migration profile of line 1S1N.

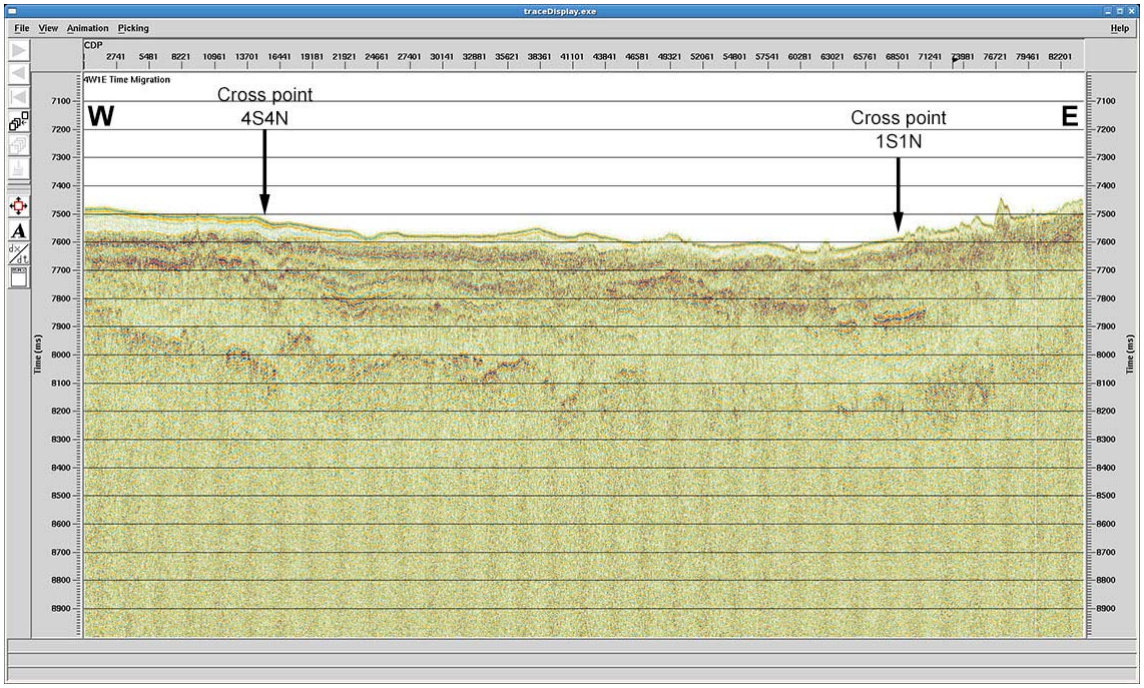

Fig.5.1.5. An image of time migration profile of line 4W1E.

Northern part

Fig.5.1.6 shows track lines with CDP number of MCS survey in north part of research area. Cross point of lines 2E3W and 2S2N is St.2 and cross point of lines 2E3W and 3S3N is St.3. Fig.5.1.7, Fig.5.1.8, Fig.5.1.9 and Fig.5.1.10 shows an image of time migration profile of line 2S2N, 3S3N, 2E3W and 3W3S respectively.

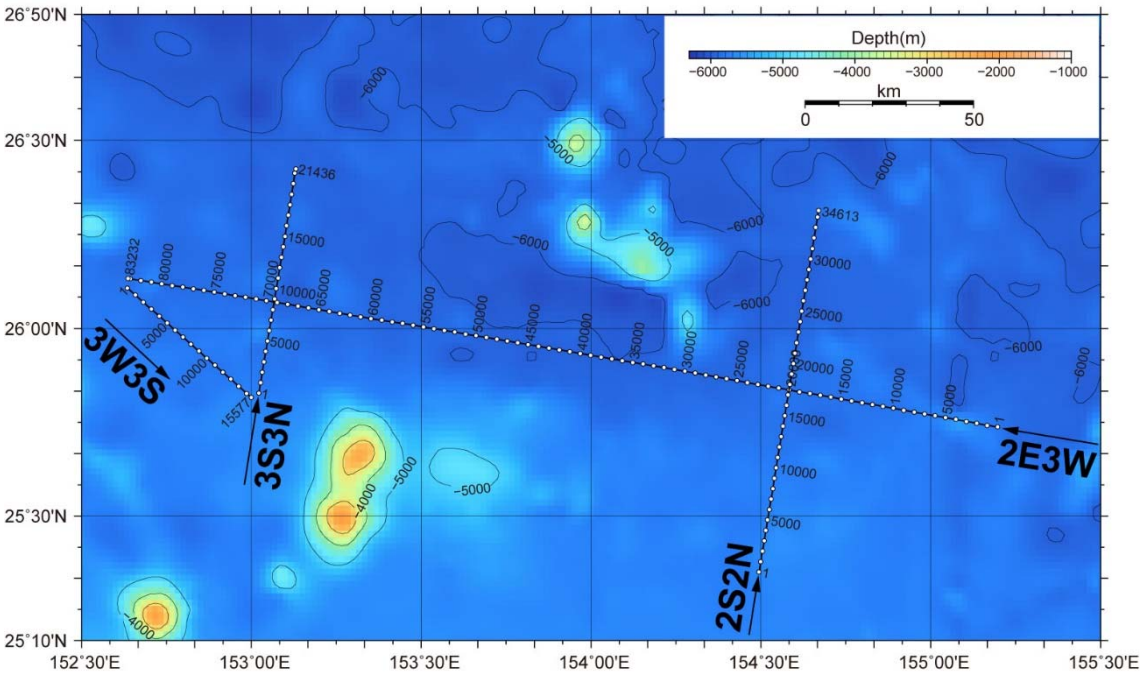

Fig.5.1.6. Track lines with CDP numbers of MCS survey in north part of research area in cruise MR15-E01 Leg3. Line name is shown with solid arrow which represents vessel direction. Background bathymetric image is drawn using ETOPO1 bathymetric data [1].

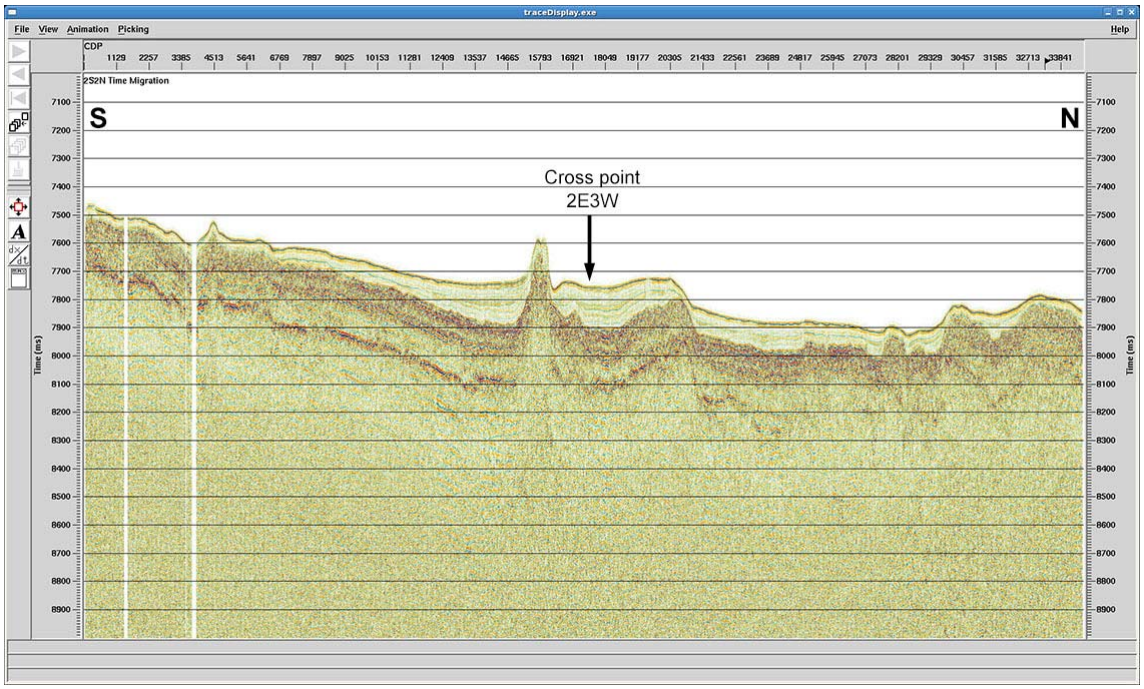

Fig.5.1.7. An image of time migration profile of line 2S2N.

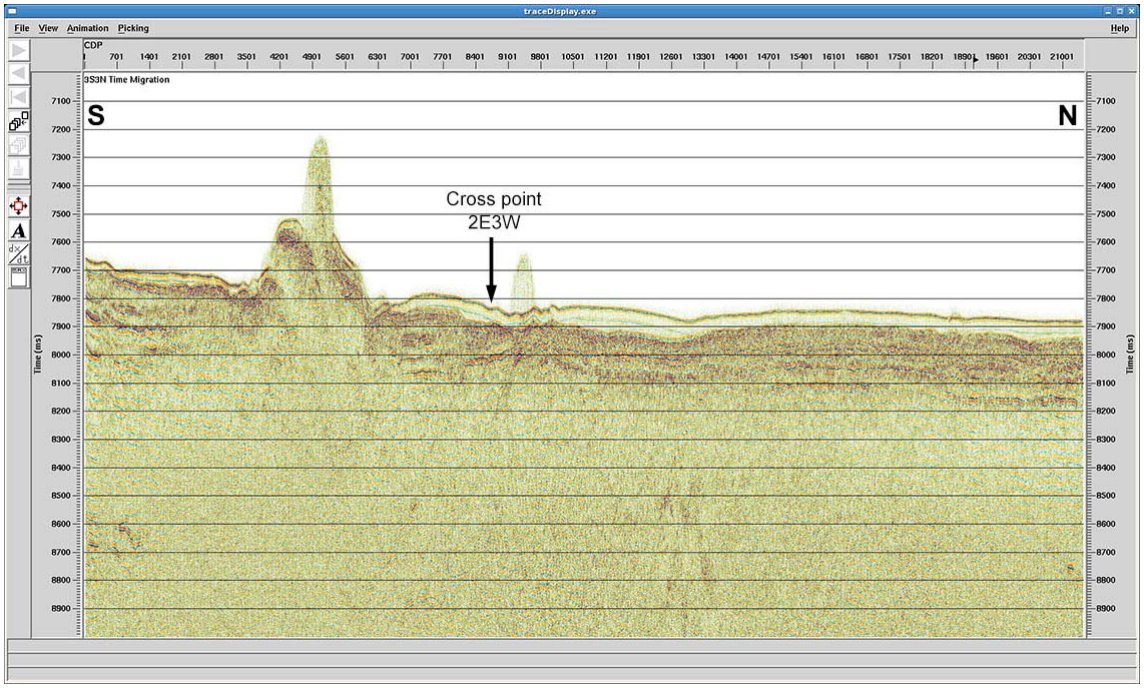

Fig.5.1.8. An image of time migration profile of line 3S3N.

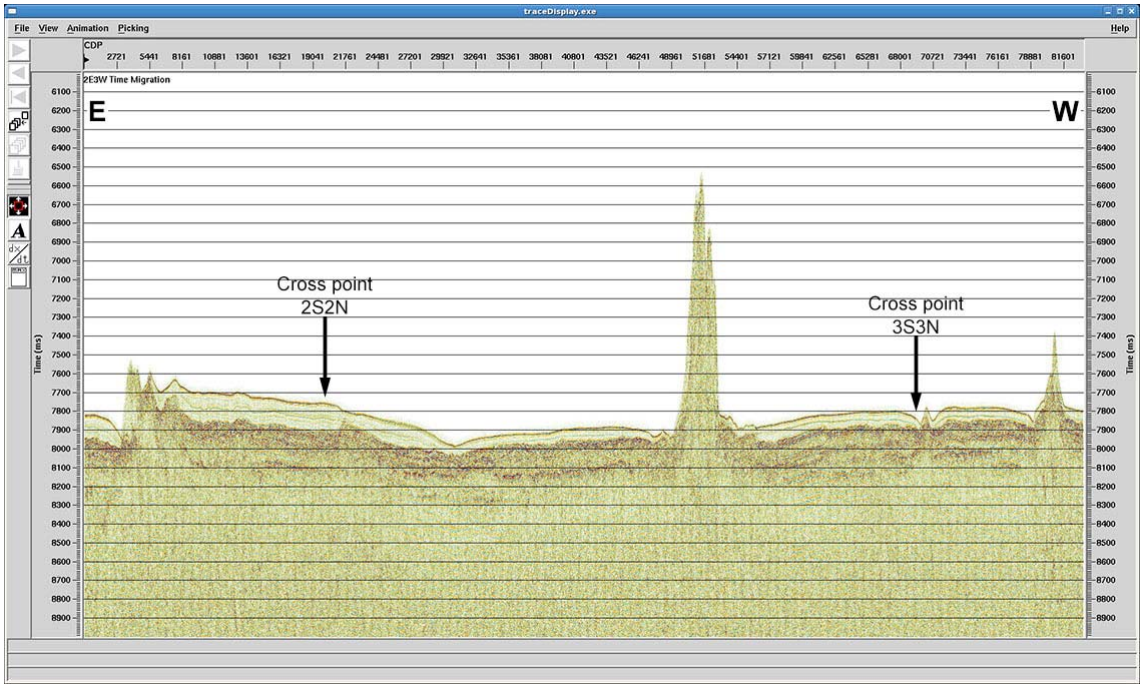

Fig.5.1.9. An image of time migration profile of line 2E3W.

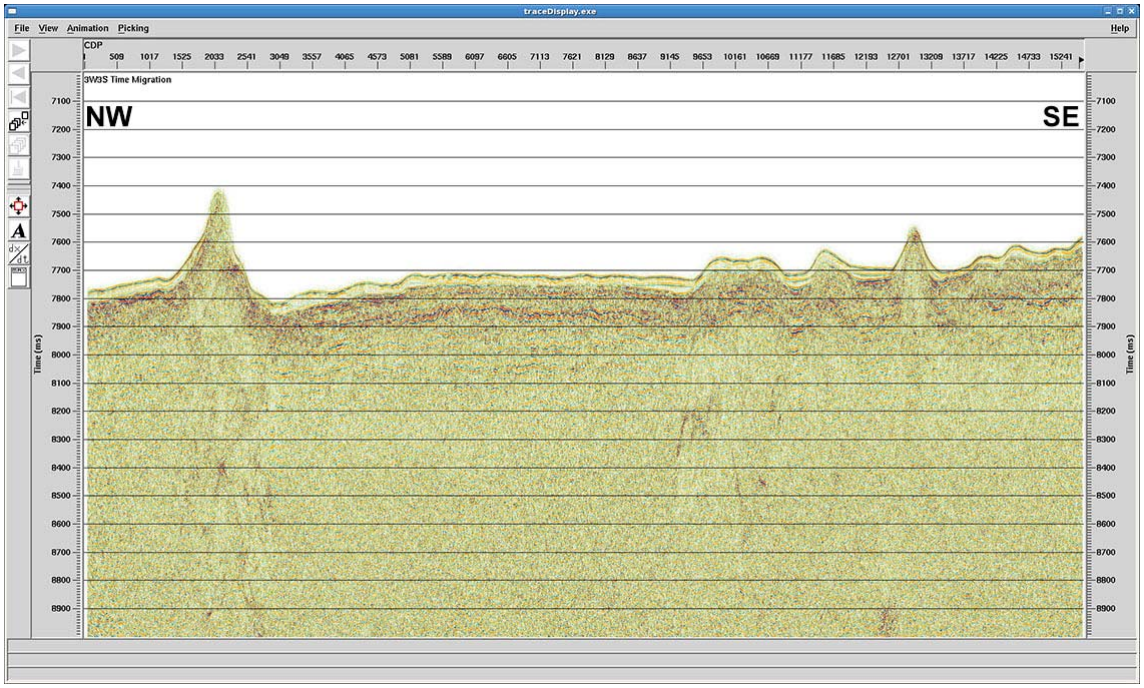

Fig.5.1.10. An image of time migration profile of line 3W3S.

5.2 Bathymetry

Coordinates of all MBES survey line investigated in this cruise is shown in Table 5.2. Fig.5.2 shows bathymetric image integrated from MBES data obtained in this cruise.

Table 5.2 Coordinates of MBES survey line investigated in cruise MR15-E01 Leg3.

Line	Start point				End point			
	Date 2015	Time (UTC)	Latitude	Longitude	Date 2015	Time (UTC)	Latitude	Longitude
4S-4N	30-Mar	18:27	21:43.06N	152:19.39E	31-Mar	1:49	22:07.52N	152:19.38E
M4-1	31-Mar	7:32	22:10.01N	152:33.94E	31-Mar	10:24	21:40.48N	152:33.90E
M4-2	31-Mar	11:05	21:40.60N	152:26.65E	31-Mar	13:58	22:10.64N	152:26.64E
M4-3	31-Mar	15:11	22:10.03N	152:12.13E	31-Mar	18:04	21:40.93N	152:12.10E
M4-4	31-Mar	18:44	21:40.82N	152:04.82E	31-Mar	21:35	22:10.46N	152:04.82E
4W-1E_0	1-Apr	2:24	21:54.39N	151:51.99E	1-Apr	2:47	21:54.40N	151:52.70E
4W-1E_1	1-Apr	8:37	21:54.40N	151:51.92E	1-Apr	23:00	21:56.44N	152:38.17E
4W-1E_2	2-Apr	7:05	21:56.38N	152:37.00E	3-Apr	21:29	22:00.31N	154:24.61E
1S-1N	4-Apr	8:41	21:38.68N	153:56.35E	5-Apr	5:00	22:26.63N	153:56.36E
M2-01	5-Apr	19:53	25:20.15N	153:57.99E	6-Apr	1:38	26:20.29N	153:58.01E
M2-02	6-Apr	2:24	26:20.72N	154:05.72E	6-Apr	8:13	25:19.52N	154:05.77E
M2-03	6-Apr	8:55	25:19.65N	154:13.50E	6-Apr	14:53	26:20.46N	154:13.50E
M2-04	6-Apr	15:34	26:20.31N	154:21.27E	6-Apr	21:30	25-19.66N	154-21.26E
M2-05	6-Apr	22:09	25:19.15N	154:28.98E	7-Apr	4:08	26:20.42N	154:29.01E
M2-06	7-Apr	4:47	26:20.84N	154:36.76E	7-Apr	10:49	25:19.58N	154:36.78E
M2-07	7-Apr	11:29	25:19.21N	154:44.47E	7-Apr	17:28	26:20.52N	154:44.52E
M2-08	7-Apr	18:09	26:20.41N	154:52.24E	8-Apr	0:05	25:19.60N	154:52.26E
M2-09	8-Apr	0:50	25:20.04N	154:59.99E	8-Apr	6:43	26:20.38N	155:00.00E
M2-10	8-Apr	7:23	26:20.40N	155:07.75E	8-Apr	13:21	25:19.56N	155:07.76E
M2-11	8-Apr	14:02	25:19.63N	155:15.48E	8-Apr	17:19	25:53.49N	155:15.53E
2S-2N	9-Apr	0:35	25:21.17N	154:29.77E	9-Apr	21:32	26:18.92N	154:40.25E
2E-3W	10-Apr	7:33	25:44.25N	155:11.82E	12-Apr	9:11	26:08.02N	152:38.07E
3W-3S	12-Apr	10:11	26:06.24N	152:38.39E	12-Apr	21:49	25:48.94N	153:00.08E
3S-3N	12-Apr	22:32	25:49.64N	153:01.40E	13-Apr	14:57	26:25.57N	153:07.95E
M3-1	14-Apr	1:37	26:27.89N	153:35.23E	14-Apr	6:21	26:35.68N	152:42.73E
M3-2	14-Apr	7:01	26:28.83N	152:41.12E	14-Apr	11:47	26:20.88N	153:34.41E
M3-3	14-Apr	12:28	26:14.02N	153:32.93E	14-Apr	17:10	26:21.86N	152:40.21E
M3-4	14-Apr	17:51	26:15.10N	152:38.47E	14-Apr	22:41	26:07.12N	153:31.79E
M3-5	14-Apr	23:59	25:53.34N	153:29.40E	15-Apr	4:44	26:01.16N	152:36.48E
M3-6	15-Apr	5:24	25:54.31N	152:34.88E	15-Apr	10:09	25:46.40N	153:28.13E
M3-7	15-Apr	10:44	25:39.42N	153:27.41E	15-Apr	15:29	25:47.36N	152:33.95E

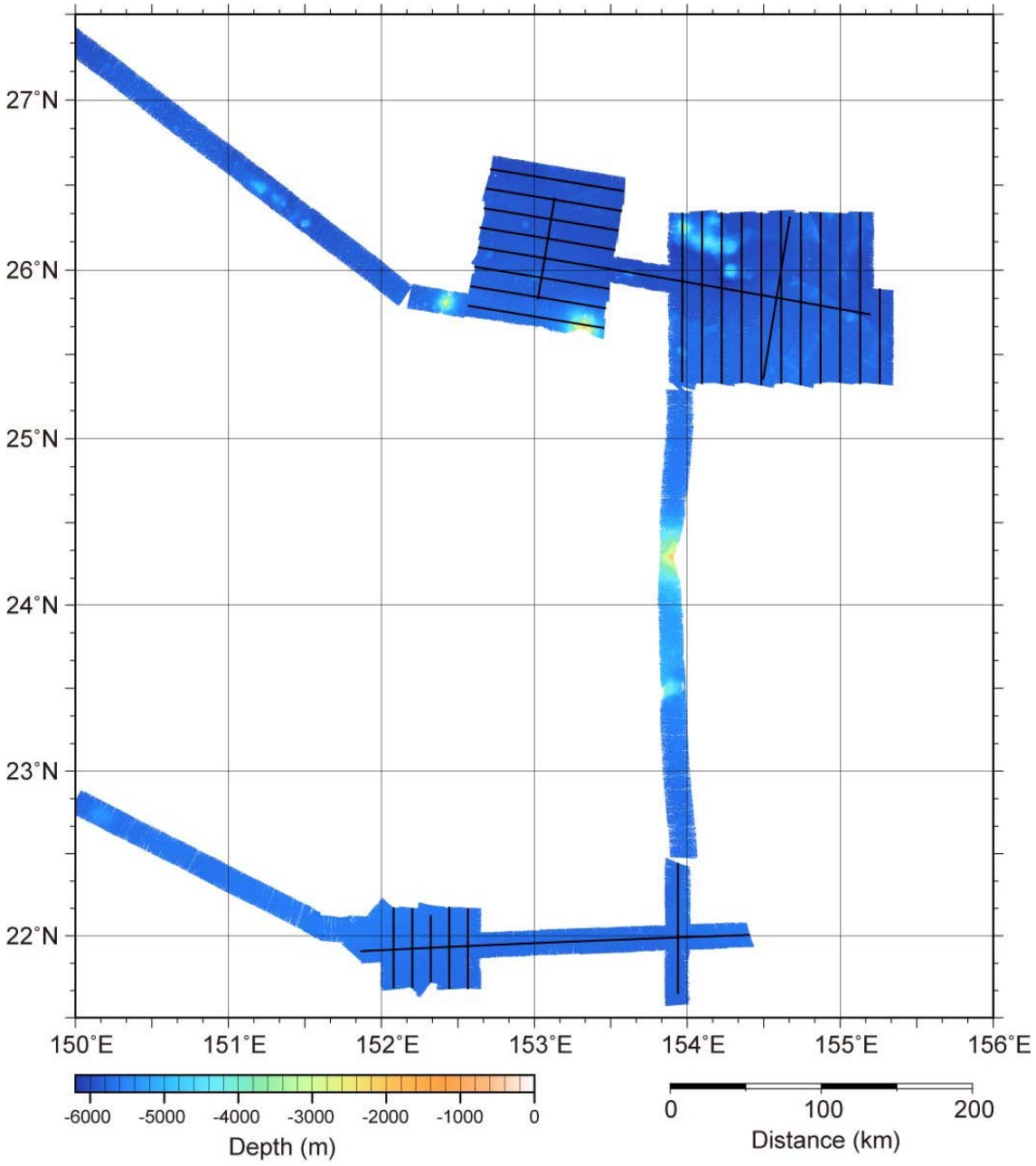

Fig.5.2. Bathymetric image derived from MBES data obtained in cruise MR15-E01 Leg2. Solid lines represent run survey lines, while images without line represent transit.

5.3 Geophysical data

SBP data, gravity data and geomagnetic data (cesium and onboard tri-axis) are successfully obtained throughout the cruise within the research area. Fig.5.3.1 shows an image of SBP obtained along MCS line 4S4N with approximate cross point with line 4W1E, where represents St.4 (ODP site 800 and KR13-02 PC3). Fig.5.3.2 and Fig.5.3.3 shows an image of magnetic anomaly and free-air gravity anomaly respectively, obtained around St.4 along MCS lines and MBES survey lines.

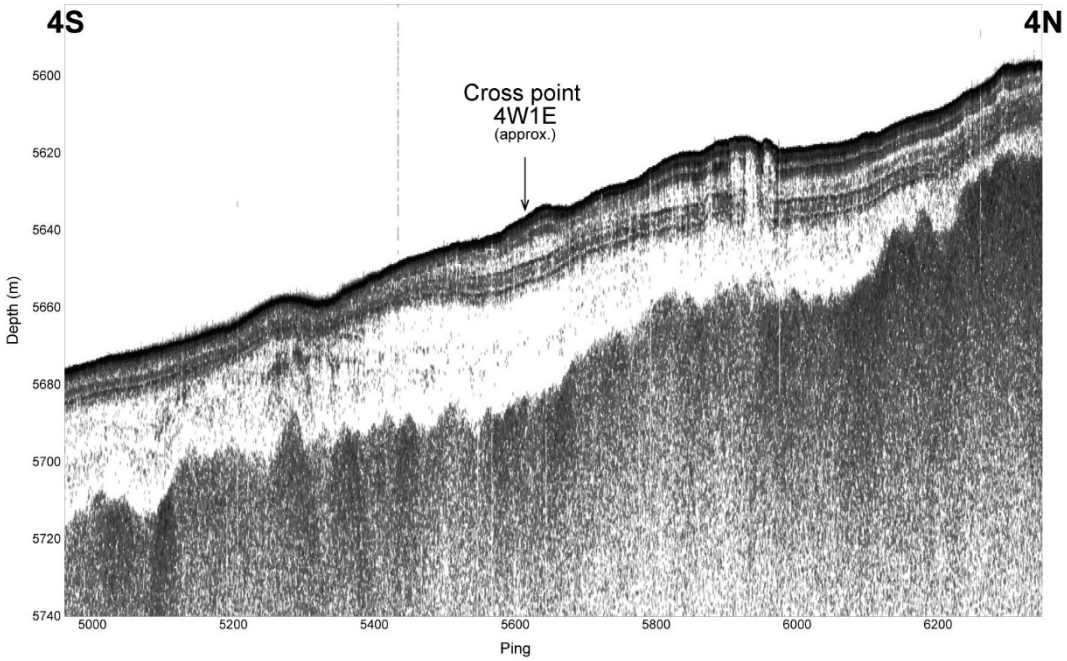

Fig.5.3.1. An example image of SBP obtained in cruise MR15-E01 Leg3 along MCS line 4S4N.

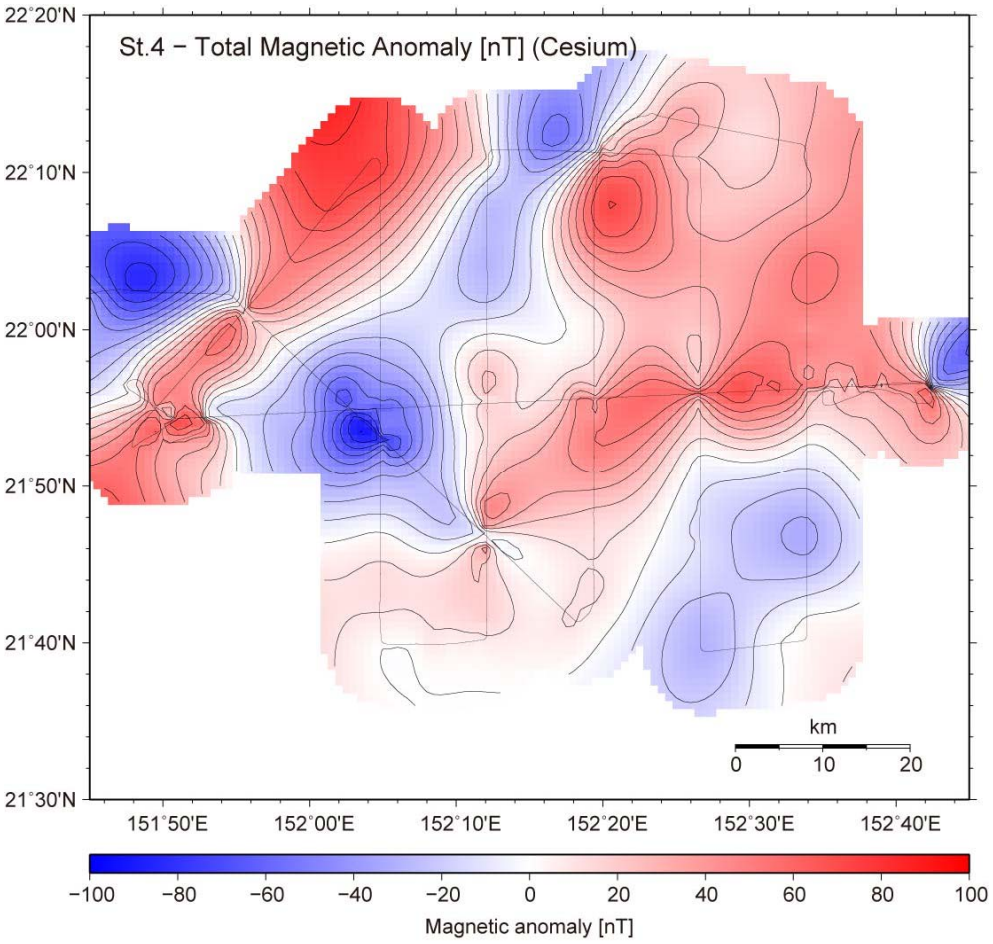

Fig.5.3.2. An example image of magnetic anomaly obtained in cruise MR15-E01 Leg3 at St.4.

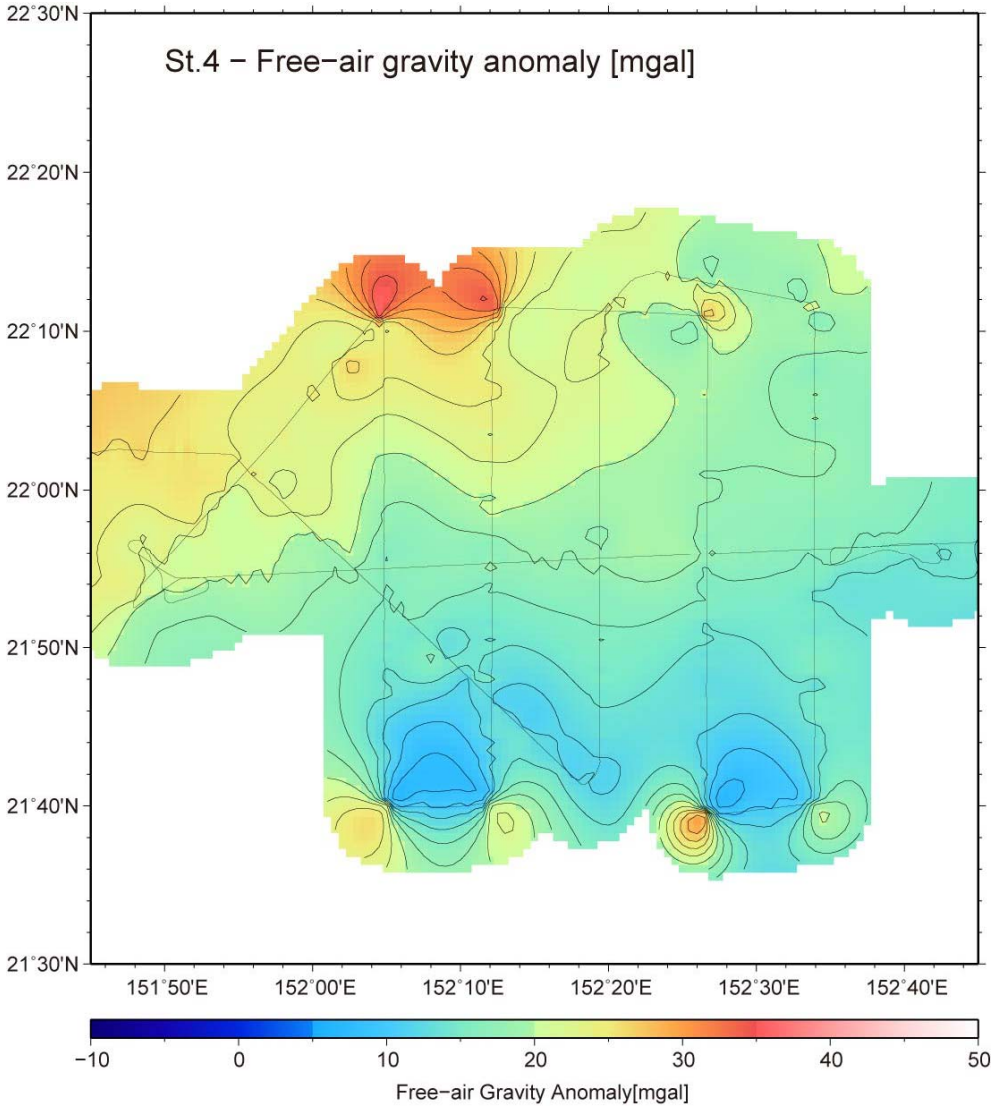

Fig.5.3.3. An example image of free-air gravity anomaly obtained in cruise MR15-E01 Leg3 at St.4.

6 Cruise track and shipboard log

6.1 Cruise track

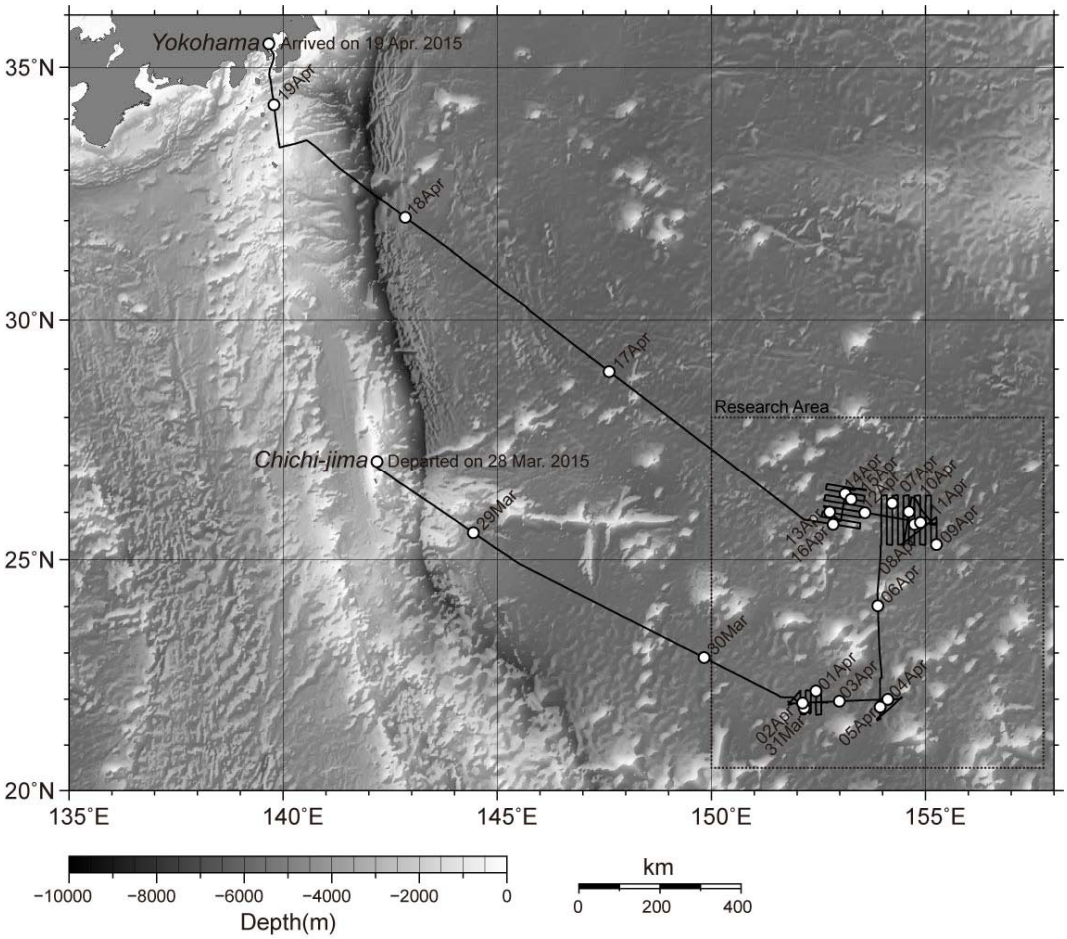

Fig.6.1. Cruise track of R/V *MIRAI* during cruise MR15-E01 Leg3.

6.2 Shipboard log

Date and Local Time	Note	Position/Weather/ Wind/Sea condition
28-Mar-2015	**Sail out, proceeded to research area**	28 Mar. 12:00 (UTC+9h)
12:30	Leg3 members Embarked.	27°05.0'N, 142°11.6'E
12:50	Sail out from Futami port, Chichi-jima, Ogasawara.	Futami port
14:00	Briefing about ship's life and safety	bc (Fine but Cloudy)
16:45	Konpira ceremony.	East-3 (Gentle breeze)
		1 (Calm rippled)
		1 (Low swell Short)
		Visibility: 10'
29-Mar-2015	**Proceeded to research area**	29 Mar. 12:00 (UTC+9h)
09:00	Replace Leg2 and Leg3 instruments on upper deck.	24°06.5'N, 147°14.3'E
15:00	Science meeting.	Southeast of Chichijima
22:00	Time forwarded 1 hour to change UTC +10.	bc (Fine but Cloudy)
		East-5 (Fresh breeze)

		4 (Moderate) 4 (Moderate average) Visibility: 10'
30-Mar-2015	**Tuning of MCS**	30 Mar. 12:00 (UTC+10h)
00:49	Entered to research area.	25°17.8'N, 149°56.5'E
00:56	Released XBT probe. <22°48.826'N, 150°00.709'E>	Southwest of Takuyo-
	Started SBP and gravimeter observation.	daigo seamount
08:55	Released Cesium magnetometer probe.	bc (Fine but Cloudy)
	Started observation.	East-4 (Moderate breeze)
08:56	Started to release MCS streamer cable.	3 (Slight)
10:45	Finished to releasing the streamer cable.	3 (Moderate short)
11:12	Started to MCS system adjustment.	Visibility: 10'
13:06	Started to recover air-gun array.	
13:24	Finished recovering air-gun array.	
14:46	Started to release air-gun array.	
15:00	Finished releasing air-gun array.	
17:15	Finished MCS system adjustment.	
31-Mar-2015	**MCS line 4S4N finished, MBES/SBP survey of St.4**	31 Mar. 12:00 (UTC+10h)
04:28	Started MCS line 4S4N_0 observation.	22°08.2'N, 152°19.4'E
11:49	Finished MCS line 4S4N_0 observation.	Southwest of Takuyo-
13:06	Started to recover MCS system.	daigo seamount
16:12	Finished recovering MCS system.	bc (Fine but Cloudy)
17:30	Started MBES and SBP survey of St.4.	ENE-4 (Moderate breeze)
		3 (Slight)
		3 (Moderate short)
		Visibility: 10'
1-Apr-2015	**MCS line 4W1E_1 started**	1 Apr. 12:00 (UTC+10h)
07:30	Finished MBES survey.	21°54.2'N, 151°51.4'E
09:24	Arrived at west of Pt.4W	Southwest of Takuyo-
09:34	Started to release MCS system.	daigo seamount
11:22	Finished releasing MCS system.	bc (Fine but Cloudy)
12:24	Started MCS line 4W1E_0 observation.	ENE-5 (Fresh breeze)
	Communication error occurred at 2 knots.	4 (Moderate)
12:45	Aborted the observation. No data.	4 (Moderate average)
13:23	Started to recover streamer cable for the maintenance.	Visibility: 10'
	Exchanged stretch section.	
14:02	Finished the maintenance.	
14:15	Started to release streamer cable, tested observation.	
14:52	Finished the test and started to recover streamer cable.	
15:01	Recovered 65 m tow cable and started observation.	
	No noise at 3.5 knot. Changed to another stretch section.	
16:00	Finished the maintenance.	
16:10	Started to release streamer cable, tested observation.	
16:28	Confirmed no noise at 3.5 knot. Head to Pt.4W again.	

18:38	Started MCS line 4W1E_1 observation.	
2-Apr-2015	**Stretch section exchanged, MCS line 4W1E_2 started**	2 Apr. 12:00 (UTC+10h)
09:00	Finished MCS line 4W1E_1 observation.	21°55.3'N, 152°41.0'E
09:05	Started to recover streamer cable for the maintenance.	Southwest of Takuyo-daigo seamount
09:26	Cable of magnetometer was fouled at #3 bird, released. Locked streamer cable at stern, exchanged stretch section on deck.	bc (Fine but Cloudy) East-2 (Light breeze) 2 (Smooth) 2 (Low Swell Long)
10:02	Communication error occurred, exchanged to another stretch section.	Visibility: 10'
10:19	Started to release streamer cable, tested observation.	
10:45	Head back to west of endpoint of line 4W1E.	
12:00	Communication error occurred, recovered the cable. Restored the stretch section to the one used in 4W1E.	
13:02	Started to release streamer cable, tested observation.	
16:00	Head to North.	
16:30	Head to 87.6°	
17:05	Started MCS line 4W1E_2 observation.	
3-Apr-2015	**MCS line 4W1E_2 continued**	3 Apr. 12:00 (UTC+10h) 21°58.6 'N, 153°33.3 'E South of Takuyo-daigo seamount bc (Fine but Cloudy) ENE-5 (Fresh breeze) 4 (Moderate) 4 (Moderate average) Visibility: 10'
4-Apr-2015	**MCS line 4W1E_2 finished, line 1S1N started**	4 Apr. 12:00 (UTC+10h)
07:30	Finished MCS line 4W1E_2 observation.	21°41.3'N, 154°01.9'E
08:02	Started to recover streamer cable and gun for cruising.	South of Minami-torishima island
08:02	Air-gun on deck.	bc (Fine but Cloudy)
09:28	Tail buoy on deck.	NE-5 (Fresh breeze)
09:42	Started to sail to Pt.1S.	4 (Moderate)
12:36	Arrived at Pt.1S.	4 (Moderate average)
12:41	Released XBT probe. <21°35.1953'N,153°53.1489'E>	Visibility: 10'
12:52	Sailed 8 figure turn for magnetometer calibration.	
14:10	Started to release streamer cable, exchanged lead-in section.	
14:21	Released air-gun.	
16:04	Finished releasing the cable.	
18:42	Started MCS line 1S1N_0 observation.	
5-Apr-2015	**MCS line 1S1N finished, proceeded to Pt.2S**	5 Apr. 12:00 (UTC+10h)
15:00	Finished MCS line 1S1N_0 observation.	22°18.7'N, 153°56.3'E
15:11	Started to recover streamer cable and gun for cruising.	South of Minami-torishima

15:34	Air-gun on deck.	island
15:55	Removed #2 section.	bc (Fine but Cloudy)
16:03	Connected #1 and #3 section.	ENE-6 (Strong breeze)
16:06	Communication and IP addressing succeeded.	5 (Rough)
17:00	Tail buoy on deck, started to sail to southeast of St.2.	5 (Heavy Short)
		Visibility: 10'
6-Apr-2015	**MBES/SBP survey of St.2 started**	6 Apr. 12:00 (UTC+10h)
05:34	Released XBT probe. <25°17.7369'N,153°57.0484'E>	22°29.1'N, 153°12.0'E
05:53	Started MBES and SBP survey of St.2.	North of Minami-torishima
		island
		o (Over cast)
		ENE-4 (Moderate breeze)
		4 (Moderate)
		4 (Moderate average)
		Visibility: 10'
7-Apr-2015	**MBES/SBP survey of St.2 continued**	7 Apr. 12:00 (UTC+10h)
		25°58.6'N, 154°29.0'E
		North of Minami-torishima
		island
		c (Cloudy)
		East-4 (Moderate breeze)
		3 (Slight)
		4 (Moderate average)
		Visibility: 10'
8-Apr-2015	**MBES/SBP survey of St.2 continued**	8 Apr. 12:00 (UTC+10h)
		25°31.7'N, 155°00.0'E
		North of Minami-torishima
		island
		bc (Fine but Cloudy)
		East-4 (Moderate breeze)
		3 (Slight)
		3 (Moderate short)
		Visibility: 10'
9-Apr-2015	**MBES/SBP survey finished, MCS line 2S2N started**	9 Apr. 12:00 (UTC+10h)
03:22	MBES and SBP survey finished.	25°24.8'N, 154°30.5'E
07:20	Arrived at Pt.2S.	North of Minami-torishima
08:08	Started to release streamer cable.	island
08:18	Released air-gun.	bc (Fine but Cloudy)
09:30	Finished releasing the cable.	ENE-4 (Moderate breeze)
10:35	Started MCS line 2S2N_0 observation.	3 (Slight)
		3 (Moderate short)
		Visibility: 10'

10-Apr-2015	**MCS line 2S2N finished, line 2E3W started**	10 Apr. 12:00 (UTC+10h)
07:32	Finished MCS line 2S2N_0 observation.	26°05.1'N, 154°53.3'E
09:00	Started to recover streamer cable and gun for cruising.	North of Minami-torishima island
09:24	Air-gun on deck.	
10:23	Tail buoy on deck.	bc (Fine but Cloudy)
10:24	Started to sail to Pt.2E.	East-4 (Moderate breeze)
14:30	Arrived at Pt.2E	3 (Slight)
14:40	Started to release streamer cable.	4 (Moderate average)
15:13	Released air-gun.	Visibility: 10'
16:11	Finished releasing the cable.	
17:33	Started MCS line 2E3W_0 observation.	
11-Apr-2015	**MCS line 2E3W continued**	11 Apr. 12:00 (UTC+10h)
		25°53.5'N, 154°13.9'E
		North of Minami-torishima island
		bc (Fine but Cloudy)
		East-5 (Fresh breeze)
		4 (Moderate)
		4 (Moderate average)
		Visibility: 10'
12-Apr-2015	**MCS line 2E3W finished, line 3W3S started**	12 Apr. 12:00 (UTC+10h)
19:11	Finished MCS line 2E3W_0 observation.	26°05.0'N, 152°59.0'E
20:11	Started MCS line 3W3S_0 observation.	Northwest of Minami-torishima island
		bc (Fine but Cloudy)
		ENE-3 (Gentle breeze)
		3 (Slight)
		3 (Moderate short)
		Visibility: 10'
13-Apr-2015	**MCS line 3W3S finished, line 3S3N started**	13 Apr. 12:00 (UTC+10h)
07:49	Finished MCS line 3W3S_0 observation.	25°58.3'N, 153°02.9'E
08:32	Started MCS line 3S3N_0 observation.	Northwest of Minami-torishima island
		bc (Fine but Cloudy)
		East-4 (Moderate breeze)
		4 (Moderate)
		4 (Moderate average)
		Visibility: 10'
14-Apr-2015	**MCS line 3S3N finished, MBES/SBP survey started**	14 Apr. 12:00 (UTC+10h)
00:57	Finished MCS line 3S3N_0 observation.	26°58.5'N, 153°31.0'E
08:08	Started to recover streamer cable and gun for cruising.	Northwest of Minami-torishima island
08:34	Air-gun on deck.	
09:57	Tail buoy on deck.	bc (Fine but Cloudy)

10:14	Released XBT probe. <26°29.9855'N, 153°24.4073'E>	East-4 (Moderate breeze) 4 (Moderate) 4 (Moderate average) Visibility: 10'
11:37	Started MBES and SBP survey of St.3.	
15-Apr-2015	**MBES/SBP survey of St.3 continued**	15 Apr. 12:00 (UTC+10h) 25°56.7'N, 153°06.8'E Northwest of Minami-torishima island q (Squalls) SE-3 (Gentle breeze) 2 (Smooth) 3 (Moderate short) Visibility: 10'
09:00	Moved Leg2 instruments to upper deck for rigging off.	
16-Apr-2015	**MBES/SBP survey of St.3 finished.**	16 Apr. 12:00 (UTC+10h) 27°05.3'N, 150°21.8'E West of MIT guyot bc (Fine but Cloudy) SSW-5 (Fresh breeze) 4 (Moderate) 4 (Moderate average) Visibility: 10'
03:01	Sailed 8 figure turn for magnetometer calibration.	
13:44	Exited research area, halted all observation.	
15:00	Started to recover Ce magnetometer probe.	
15:30	Recovered Ce magnetometer probe.	
22:00	Time changed backward 1 hour to UTC +9.	
17-Apr-2015	**Proceeded to Yokohama port**	17 Apr. 12:00 (UTC+9h) 30°36.7'N, 145°07.3'E Far east of Torishima o (Over cast) SSW-3 (Gentle breeze) 2 (Smooth) 3 (Moderate short) Visibility: 10'
02:09	Sailed 8 figure turn for magnetometer calibration.	
17:42	Sailed 8 figure turn for magnetometer calibration.	
18-Apr-2015	**Proceeded to Yokohama port**	18 Apr. 12:00 (UTC+9h) 33°20.0'N, 140°54.1'E East of Hachijo-jima bc (Fine but Cloudy) East-3 (Gentle breeze) 2 (Smooth) 3 (Moderate short) Visibility: 10'
14:00	Science meeting for MCS data.	
19-Apr-2015	**Disembarked at Yokohama port**	
08:30	Berthing to Yamashita Pier	
09:00	Disembarked.	

7 Reference

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