Cruise Report of KY03-06 Cruise

Leg. 1 :

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Leg. 2 :

Narumi Takahashi (DSRD, Jamstec)

Aki Itoh (IFREE, Jamstec)

Leg 1 : June 9, 2003 (Yokosuka) ~ June 26, 2003 (Saipan)

Leg 2 : June 27, 2003 (Saipan) ~ July 16, 2003 (Yokosuka)

US and JP LTOBS on R/V Kaiyo.

Overview of This Project

An island-arc system has become to be explained as a subduction factory from the petrologic point of view, recently. There is, however, an unsolved question concerning the mechanical source for the volcanic-arc system and the evolution of the back arc basin. Because we have not enough information on the deep arc structure, such as the mantle wedge, beneath the arc crust until top of the subducting oceanic plate, due to limited coverage by land observatories.

In order to obtain the deep arc structure, we plan to make a long term seismic array observation using ocean bottom seismometers (OBS) and a controlled source active crustal structure survey by an airgun–OBS system. These OBSs will be brought by scientists from USA and Japan.

Seismological studies we will carry out in the Mariana arc will be expected to provide most fundamental information for the structure of the mantle wedge, which will be a key to solve the question above. US institutions are also conducting seismological/geological studies for understanding the evolution of the Mariana arc as a NSF program (*). A part of our Mariana cruise is planned as one of the main part of the NSF program.

(*) US-JAPAN COLLABORATIVE RESEARCH: MULTI-SCALE SEISMIC IMAGING OF THE MARIANA SUBDUCTION FACTORY

Principal Investigators: B. Taylor, G. Moore, A. Goodliffe, P. Fryer (SOEST, U. Hawaii), D. Wiens, G. Smith (Washington U., St. Louis), S. Klemperer (Stanford U.), J. Hildebrand (SIO, UCSD), K. Suyehiro, S. Kodaira, A. Taira (JAMSTEC), H. Shiobara (ERI, U. Tokyo), N. Seama (Kobe U.)

Cruise Report of Leg 1, KY03-06 cruise

Hajime Shiobara (IFREE, Jamstec / ERI, University of Tokyo)
Hiroko Sugioka (IFREE, Jamstec)
Douglas Wiens (Washington University)

1. Introduction

We carried out a large deep seismic experiment in the middle Mariana area by R/V Kaiyo of Japan Marine Science and Technology Center (JAMSTEC) in June and July, 2003 as a part of the MARGINS program (US-JAPAN COLLABORATIVE RESEARCH: MULTI-SCALE SEISMIC IMAGING OF THE MARIANA SUBDUCTION FACTORY). The aim of this leg is a deployment of fifty-eight long term ocean bottom seismometers (LTOBSs), those owned by USA and Japan, for crustal and mantle structure modeling by using passive and active seismic observations for about one year. The passive component of this Mariana SUBFAC experiment will use earthquake sources and a one year deployment of OBSs and land seismic stations to better image the upper mantle beneath the Mariana arc and backarc regions.

Principal objectives of the passive experiment include:

- **imaging the 3-D seismic velocity and attenuation structure of the Mariana mantle wedge.** These 3-D images will then be used to map temperature, hydration, and partial melting conditions below the backarc spreading center and the active volcanic arc to constrain processes of melt production.
- **determining the large-scale pattern of flow in the mantle wedge by mapping seismic anisotropy.** Upper mantle seismic anisotropy is thought to result from mineral preferred orientations caused by mantle flow. The pattern of mantle flow will be used to constrain dynamic models of flow and partial melting in subduction zones.
- **determining the precise location and velocity structure of subducting oceanic crust,** which will place constraints on the depth of various dehydration reactions and the basalt-eclogite transformation.
- **identifying possible seismicity associated with serpentinite diapers.** This seismicity may outline fluid conduit systems associated with the serpentinite seamounts and thus provide constraints on the source of fluids.
- **determining the configuration of intermediate depth seismicity and the possible existence of an intermediate depth double seismic zone**. This will allow exploration of possible relationships between slab seismicity and island arc volcanism, and provide further evidence on the mechanism producing intermediate depth earthquakes.
- **determining the updip and downdip limits of the Mariana seismogenic zone.** These results

will allow better understanding of the cause of aseismic subduction in the Mariana islands and its possible relationship to factors such as convergence rate, incoming plate thermal structure, and mineralogy.

2. Experiment

The deployment of 58 LTOBSs was performed around the middle Mariana area by R/V Kaiyo (Figure 1). She departed from port of Yokosuka on June 9 and arrived at port of Saipan on June 26, and during the leg 1, 21 short period OBSs for the leg 2 were also deployed (Table 1). The ship track is shown in Figure 2.

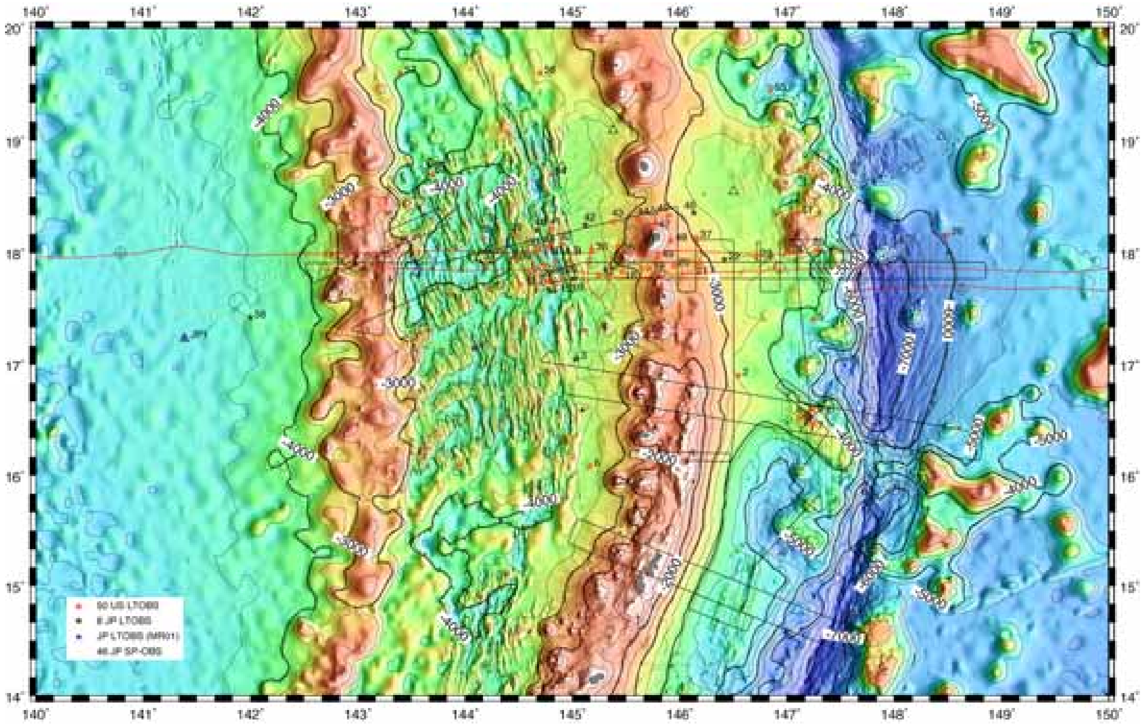


Figure 1. Map of the experimental area. Stars show USA and Japanese LTOBS locations, except fo JP1 which was deployed in 2001 and tried to be recovered in cruises, KY03-01 and KY03-06. Yellow dots indicate 46 SP-OBSs for the crustal structure survey during the leg 2. Topography data is a combined one from several swath surveys and predicted water depth. Lines are ship tracks by R/V Ewing in 2002 for the MCS survey of this project.

Date	Activities	Remarks
6/9	Departure form Port of Yokosuka (15:00)	
10	Transit	
11	Transit	
12	Transit	
13	Arriving the area and deployment for site57, 53, 38	Two OBSs at #38 for test data

14	Deployment of site39, 34, 33, 38, 30, 32, 31, 41, 40, 54	Recovery of two OBSs and deploy one at #38
15	Deployment of site56, 52, 42, 43, 44, 47	
16	Deployment of site45, 48, 37, 46, 55	
17	Deployment of site26, 25, 51, 24, 23, 5	
18	Deployment of site9, 7, 8, 2, 22, 21, 20	
19	Deployment of site49, 19, 50, 36, 18, 35, 17, 6	
20	Deployment of site3, 16, 29, 31, 28, 15, 14, 27, 13	Recovery and deploy OBS at #31 for data check
21	Deployment of site12, 4, 1 10, 11	
22	Retry recovery of JP1 and deployment of site58	JP1 (MR01) deployed in 2001
23	SP-OBS deployment	#1 – #9
24	SP-OBS deployment	#10 – #18
25	SP-OBS deployment and transit to Saipan	#19 – #21
26	Arriving at port of Saipan (15:00)	

Table 1. Schedule of the leg 1, LT-OBS deployment. Local time is used here.

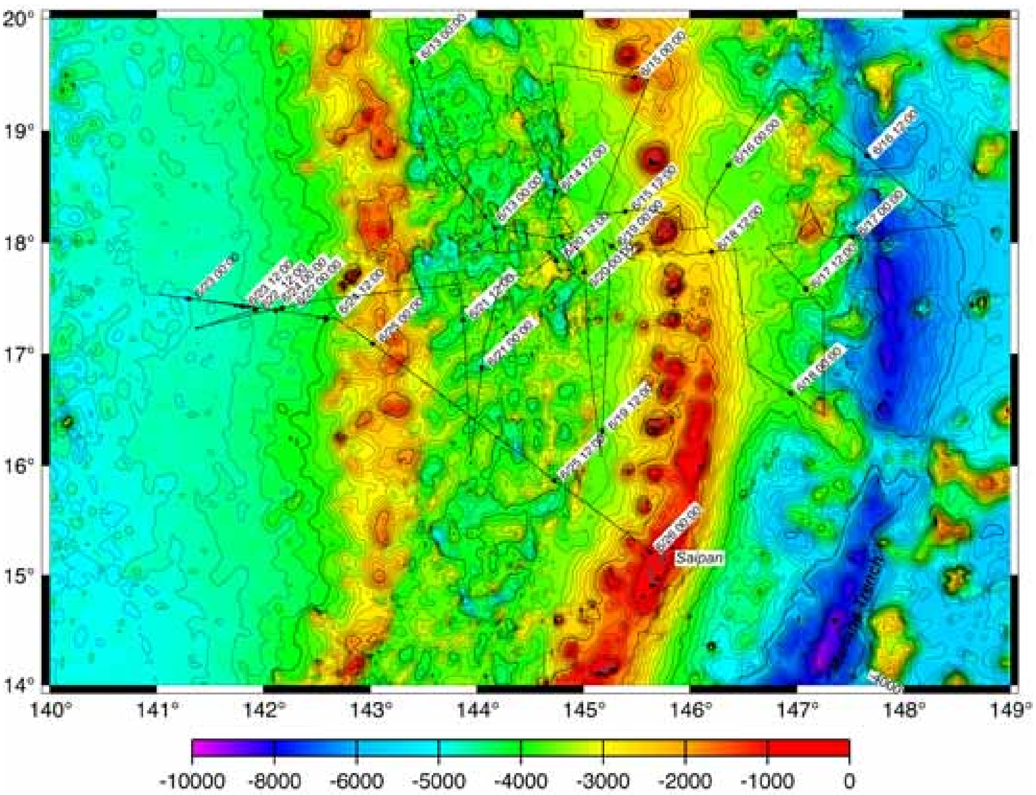


Figure 2. Track lines of R/V Kaiyo during Leg 1 with UTC time.

Topography of each OBS site was surveyed just before the arrival by using the SeaBeam system. The detailed information of each LTOBS, the drop position, water depth, time, type and the start time of recording, is shown in Table 2. US LTOBSs deployed along airgun shooting profiles during the leg 2 are programmed to change the sampling rate into slow after the shooting.

site	Lat.	Lon.	location note	depth	type	deploy date	start date
1	16.0999	143.9492	southern backarc	3613	new	6/21 04:47	6.26.2007 00:40
2	16.8998	146.5501	forearc - SP line	3492	new	6/18 12:50	6.22.2007 00:40
3	17.0512	145.0434	backarc - SP line	3815	ERI	6/19 19:45	6.21.2007 00:00
4	17.1479	144.0923	backarc - SP line	4338	ERI	6/20 21:24	6.22.2007 01:00
5	17.3999	147.2490	forearc	4421	new	6/17 13:50	6.21.2007 00:40
6	16.0834	145.1657	near Anatahan	3608	new	6/19 13:34	6.24.2007 00:40
7	16.4604	147.2519	Celestial - South	3224	new	6/17 20:49	6.21.2007 00:40
8	16.5206	147.1191	Celestial - West	3541	old	6/17 22:16	6.22.2007 01:00
9	16.6002	147.2499	Celestial - North	3334	old	6/17 19:08	6.22.2007 01:00
10	17.5614	143.1964	W. Mariana ridge -line	2418	new	6/21 18:23	6.24.2007 00:55
11	17.6304	143.8576	western backarc - line	3889	new	6/21 14:07	6.24.2007 00:50
12	17.6787	144.2322	western backarc - line	3948	new	6/20 17:16	6.24.2007 01:00
13	17.7172	144.5174	western backarc - line	3132	new	6/20 14:52	6.24.2007 00:40
14	17.7450	144.7803	SW ridge - line	3671	old	6/20 11:07	6.24.2007 01:00
15	17.7677	144.9094	south ridge axis - line	4152	new	6/20 09:05	6.23.2007 00:40
16	17.7748	145.0206	SE ridge -line	3489	ERI	6/20 00:36	6.21.2007 05:00
17	17.8033	145.2489	eastern backarc - line	3595	new	6/19 02:47	6.23.2007 00:40
18	17.8309	145.4667	eastern backarc - line	3244	new	6/18 22:17	6.22.2007 00:40
19	17.8577	145.7169	arc - line	2882	old	6/18 16:32	6.23.2007 01:00
20	17.8849	145.9510	arc - line	2702	new	6/18 13:55	6.23.2007 00:40
21	17.9114	146.1851	forearc - line	2602	new	6/18 12:18	6.22.2007 00:40
22	17.9381	146.4201	forearc - line	3434	ERI	6/18 10:00	6.19.2007 12:00
23	17.9659	146.7163	forearc - line	3491	old	6/17 08:39	6.21.2007 01:00
24	18.0036	147.0056	forearc - line	3270	old	6/17 06:33	6.21.2007 01:00
25	18.0333	147.2825	trench - line	3723	new	6/17 01:24	6.20.2007 00:40
26	18.1624	148.4979	outer rise - line	5923	new	6/16 18:38	6.19.2007 00:40
27	17.8880	144.7443	west ridge	3883	new	6/20 12:33	6.24.2007 00:40
28	17.9158	144.8412	ridge axis	4624	old	6/20 08:13	6.24.2007 01:00
29	17.9229	144.9672	east ridge	3740	new	6/20 02:09	6.23.2007 00:40
30	18.0402	144.6900	west ridge	3685	new	6/14 04:03	6.17.2007 00:40
31A	18.0586	144.7900	ridge axis	4381	new	6/14 05:20	6.17.2007 00:40
31B	18.0605	144.7835	ridge axis	4386	new	6/20 06:30	6.24.2007 00:40
32	18.0809	144.9098	east ridge	3565	old	6/14 06:32	6.17.2007 01:00
33	17.9072	144.1998	western backarc	3847	old	6/13 19:20	6.17.2007 01:00
34	17.9404	144.4809	western backarc	3880	new	6/13 16:55	6.17.2007 00:40
35	18.0261	145.1856	eastern backarc	3688	new	6/19 00:47	6.23.2007 01:00
36	18.0529	145.4317	eastern backarc	3176	old	6/18 20:25	6.23.2007 01:00
37	18.1345	146.1582	forearc	3034	new	6/15 19:46	6.19.2007 00:40
38	18.1297	144.1725	western backarc-test	4154	new	6/14 00:00	6.17.2007 00:40
39	18.1630	144.4542	western backarc	3993	old	6/13 15:04	6.17.2007 01:00
40	18.2054	144.6759	northern ridge	3698	ERI	6/14 10:00	6.16.2007 01:00
41	18.2147	144.8160	northern ridge	3204	new	6/14 08:35	6.17.2007 00:40
42	18.2491	145.1240	eastern backarc	3742	ERI	6/15 09:06	6.16.2007 12:00
43	18.2762	145.3824	eastern backarc	3338	new	6/15 11:35	6.19.2007 00:40
44	18.3027	145.6191	arc	2585	old	6/15 13:23	6.19.2007 01:00
45	18.3311	145.9002	arc	2669	new	6/15 16:03	6.19.2007 00:40
46	18.3579	146.1370	forearc	3393	ERI	6/15 21:29	6.17.2007 00:00

47	18.2501	145.7693	Pagan - north	1898	old	6/15 14;45	6.19.2007 01:00
48	18.1085	145.9230	Pagan - east	2247	old	6/15 17:56	6.19.2007 01:00
49	17.9595	145.7990	Pagan - south	2287	old	6/18 15:25	6.23.2007 01:00
50	18.0984	145.6161	Pagan - west	2339	new	6/18 18:45	6.22.2007 00:40
51	18.3497	147.1013	Big Blue seamount	2757	new	6/17 03:59	6.20.2007 00:40
52	19.4504	145.6001	arc - north	2475	new	6/15 00:45	6.18.2007 00:40
53	18.7006	143.6993	western backarc	3656	new	6/13 07:04	6.17.2007 00:40
54	18.7009	144.8001	eastern backarc	4139	new	6/14 13:25	6.18.2007 00:40
55	19.4498	146.8497	northern forearc	4735	new	6/16 05:22	6.19.2007 00:40
56	19.5994	144.6991	northern backarc	3570	new	6/14 19:15	6.18.2007 00:40
57	19.5999	143.4003	northern backarc	4070	new	6/12 23:01	6.17.2007 00:40
58	17.4198	141.9995	Philippine Basin	4512	ERI	6/22 12:32	6.23.2007 05:00

Table 2. LT-OBS deployment position, depth and time (in UTC). Type of old, new and ERI indicates US-LTOBS (Webb/SIO), US-LTOBS (Webb/LDEO) and JP-LTOBS (ERI, Univ. Tokyo), respectively.

2.1. USA LTOBS

35 of the newer model US-LTOBSs (Webb/Lamont) were deployed from the R/V Kaiyo. This instrument is designed to provide good broadband three component seismic data (0.005 – 60 Hz) during very long deployments (up to one year) for experiments utilizing earthquakes as sources to study structure of the upper mantle and oceanic crust. The recording system and one of the acoustic releases are contained in a 8.5" OD x 36" cylindrical pressure case housed beneath glass flotation spheres within a mostly polyethylene instrument structure. An additional acoustic release is contained in a separate pressure case mounted higher on the instrument. The seismic sensors are housed within a 17" glass pressure housing carried to the seafloor at the end of the arm shown. The sensor package is released from the arm after the instrument reaches the seafloor.

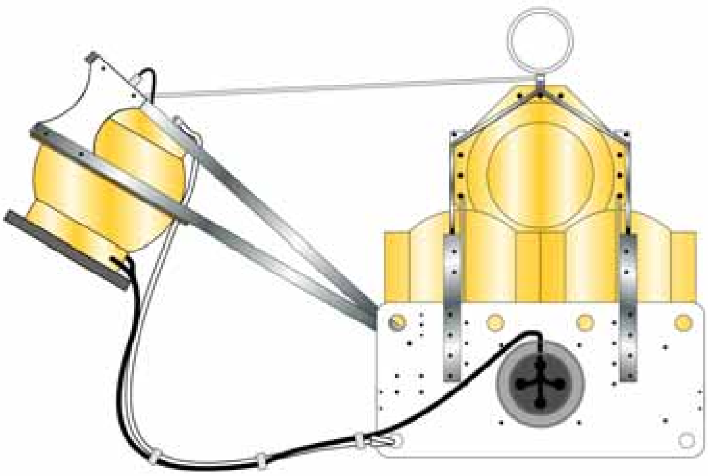


Figure 3. Illustration of the US-LTOBS (older model).

Technical Specifications – New model US-LTOBS (Webb/Lamont, Photo 1):

Seismometer: Mark Products L-4, three component 1 Hz geophones coupled to very low noise chopping amplifiers within motor-driven leveling gimbals. The useful bandwidth of the sensors is from about 0.005 to 60 Hz. Gimbals will level to a precision of better than 0.2° from any orientation. Instrument response is flat to acceleration from 0.015 Hz to 30 Hz.

Pressure Sensor: Three of the new model OBSs were deployed with new dual band hydrophones, which have a useful bandwidth from about 0.001 to 60 Hz. Recovery of two systems showed that this system adversely affected the seismograph signal. Five additional systems were then deployed with a single band differential pressure gauge (DPG) sensors. Power systems for the pressure sensors are separate from the seismographs/recording packages.

Digitizer: 24-bit nominal. Gain and bandwidth switching under software control can also be employed to extend dynamic range of the seismometer.

Clock: Qtech clock. Drift rate on the order of 0.5 ms/day, correctable to about 30 ms over the course of a one year experiment.

Release: Dual Edge-tech acoustic transponder releases with burn wires. One transponder is located in the main instrument pressure case, and the other in a separate pressure case mounted higher on the instrument.

Weight: Approx. 250/160 kg with/without anchor.

Older model US-LTOBS (Webb/SIO, Photo 2)

In addition, 15 of the older model Webb OBSs were deployed from the R/V Kaiyo. These systems used identical L-4 seismographs and sensor packages to the newer instruments. 13 of these OBSs also employed hydrophone sensors. The recorders on these systems employed older 16-bit digitizers and SeaScan clocks. The clocks have a drift rate of order 0.5 ms/day.

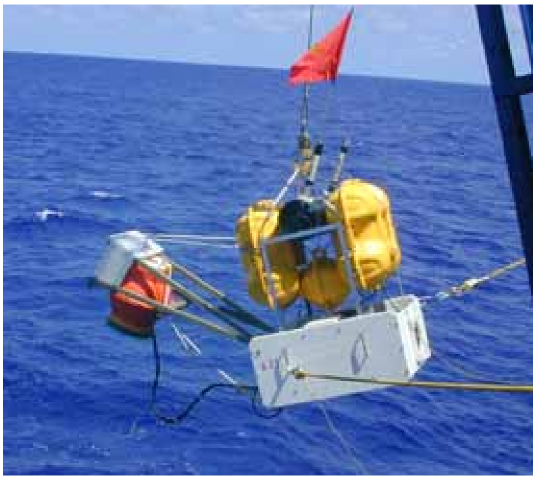


Photo 1. US-LTOBS (newer).

Photo 2. US-LTOBS (older).

2.2. Japanese LTOBS

The Japanese LTOBS is designed as a free-fall deployment and a self pop-up recovery type OBS (Photo 3), which has been developed more than 15 years by our OBS group. But, there are some differences in components to achieve the long term and tele-seismic observation. They are, a titanium pressure case with a diameter of 50cm instead of a 17 inch glass sphere for more capacity and buoyancy, and a semi broad band sensor with the pass band of 30s ~ 30Hz instead of a 4.5Hz geophone. This sensor is modified to reduce the unnecessary weight and volume from the original design, and it is controlled the power supply by an additional CPU including a tiltmeter and a compass unit. The longest observation period is about one year due to the limit of the battery weight, but the Real Time Clock can be survive about one year after the main power supply is exhausted. Principal specifications are as following;

Outside:

Size and weight 1m x 1m x 0.7m (W x D x H), 140kg (deployment) / 90kg (recovery)

Pressure case Titanium sphere (D=50cm, Buoyancy=35kg, Russian)

Releasing mechanism Forced electric corrosion of two thin Ti plates (t=0.5mm)

Recovery control Acoustic transponder system with recorder communication facility

Recovery aids Radio beacon (43.528MHz) and Xenon flasher with light switch

Inside:

Sensor PMD WB2023LP 3 comp. sensor with original control unit (incl. tiltmeter and compass)

Analog unit Gain: 8dB, LPF: 50Hz (4th-order Butterworth)

A/D 24bit (0~5V), 200Hz sampling, continuous recording with a compression

Data media Two 2.5inch 30GB IEEE1394 HDDs

RTC +/-0.005ppm, backuped by four DD size lithium cells (3.6V, 120Ah)

Power supply DD size lithium cells, Sensor: 12 (10.8V, 120Ah), Recorder:33 (10.8V, 330Ah)

Photo 3. Japanese LTOBS.

3. Data from Site31

One US LTOBS at site31 was recovered after 6 days long observation for a possible noise check. Although it was a short period, there were some events found in the recorded data. In Figure 4, a example record for the event at Kamchatka is indicated. The event parameter in the PDE is as followings;

Time: 2003/06/16 22:08:01.61, Lon.: 55.49°N, Lat.: 159.94°E, Depth: 173km, Mw: 6.90.

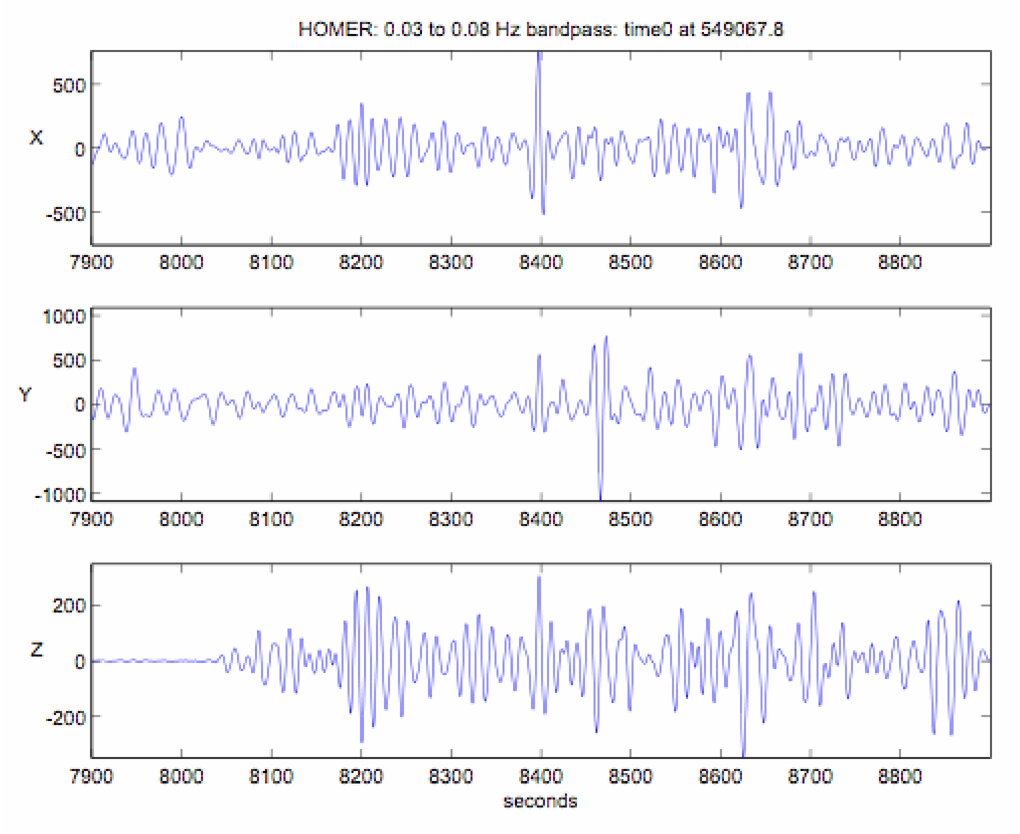


Figure 4. A record at site31 (US LTOBS) for the event at Kamchatka.

4. Participants

<u>Scientists</u>

Hajime SHIOBARA[1]	Chief scientist
Hiroko SUGIOKA[1]	Assistant chief scientist
Douglas WIENS[4]	Professor (Chief of US team)
James CONDER[4]	PD Researcher
Allan SAUTER[5]	Instrument specialist
Patrick JONKE[3]	Lead Engineer
Bern MCKEIRAN[3]	Technician

Eric Phillips[3]	Technician
Marine Technicians	
Makoto ITO[2]	Chief technician
Shinichi HOSOYA[2]	Technician
Masato SUGANO[2]	Technician
Yuki OHWATARI[2]	Technician
Crew	
Sadao ISHIDA[2]	Captain
Toshinobu MIYATA[2]	Chief officer
Isao MAEDA[2]	2nd officer
Toshiyo OHHARA[2]	3rd officer
Kenta OHYA[2]	3rd officer
Tatsuo JITOZONO[2]	Chief engineer
Minoru TSUKADA[2]	1st engineer
Yoshinobu HIRATSUKA[2]	2nd engineer
Naoyuki TAKAHARA[2]	3rd engineer
Hideyuki AKAMA[2]	Chief radio officer
Kenji TAKAKUSU[2]	2nd radio officer
Hiroshi ITO[2]	3rd radio officer
Kingo NAKAMURA[2]	Boat’swain
Mikio ISHINOMORI[2]	Able seaman
Kozo YATOHGO[2]	Able seaman
Takao KUBOTA[2]	Able seaman
Shuichi YAMAMOTO[2]	Able seaman
Yuki YOSHINO[2]	Able seaman
Shozo FUJII[2]	Able seaman
Masaru MURAO[2]	No.1 oiler
Takeshi FUKUHARA[2]	Oiler
Masaki SHIINO[2]	Oiler
Hiroyuki OHISHI[2]	Oiler
Yuichi ISHII[2]	Oiler
Kaoru TAKASHIMA[2]	Chief steward
Kyoichi HIRAYAMA[2]	Steward
Koji KIRITA[2]	Steward
Hideo FUKUMURA[2]	Steward
Kazunori NAGANO[2]	Steward

1: Japan Marine Science and Technology Center
2: Nippon Marine Enterprise, Ltd.
3: Lamont-Doherty Earth Obs.
4: Washington University
5: Scripps Institute of Ocean.

Acknowledgments

We are grateful to Captain and ship crews of R/V Kaiyo and marine technicians of Nippon Marine Enterprise Ltd. for much supports during cruise. And, we also thank to Narumi Takahashi, Shuichi Kodaira, Yoshio Fukao, Toshihiko Kanazawa, Masanao Shinohara and Kiyoshi Suyehiro giving us encouraging words.

Cruise Report of Leg 2, KY03-06 cruise

Narumi Takahashi (Japan Marine Science and Technology Center)
Aki Ito (Japan Marine Science and Technology Center)

1. Introduction

We carried out a large deep seismic experiment in the middle Mariana area by R/V Kaiyo of Japan Marine Science and Technology Center (JAMSTEC) in June and July, 2003 as a part of the MARGINS program (US-JAPAN COLLABORATIVE RESEARCH: MULTI-SCALE SEISMIC IMAGING OF THE MARIANA SUBDUCTION FACTORY).

Activities of this leg are wide-angle refraction/reflection seismic experiment using the short term Ocean Bottom Seismographs (OBSs) and the airgun shooting for long term OBSs deployed during leg 1 of this cruise. At previous KY03-01 cruise, we performed the similar seismic experiments using the OBSs and airguns to clarify the structural variation across the entire Mariana arc – backarc system, however, the airgun shooting was not able to complete due to typhoon attack and the bad weather/sea status. To make up for the above, the wide-angle refraction/reflection seismic experiments were carried out right on the western part of a main seismic line of the KY03-01 cruise. At later half of this leg, we had carried out the airgun shooting for about five days to understand 3-D image of the Mariana arc and the trough area.

2. Experiment

A seismic experiment using 46 Ocean Bottom Seismographs (OBSs) and an airgun array was performed around the middle Mariana area by R/V Kaiyo (Figure 1). The R/V Kaiyo departed from port of Saipan at June 28 and arrived at JAMSTEC at July 16. The ship track is shown in Figure 2.

We could not complete airgun shooting during previous KY03-01 cruise and it was limited to only eastern half because of the bad weather and sea status due to strong wind from Siberian high pressure and the typhoon attack to experimental area. Therefore, the airgun shooting was performed again on the western half of the main line to obtain the complete velocity profile from the forearc region to the backarc, Parece Vela Basin. The specifications of this seismic experiment were almost same to those of KY03-01 cruise except used OBS number.

We also shoot the airgun array over the long term OBSs deployed at leg 1 from Jul. 6 to 11. The main target of this shooting is to clarify the velocity variation of the upper mantle beneath the Mariana trough. The sampling rate of the long term OBSs was changed to 100 Hz to record the airgun signals.

During the airgun shooting, we towed a 12-channel hydrophone streamer to understand the shallow structural nature. The actual activities is shown in Table 1. The specific contents of the airgun shooting, OBSs and Multichannel Seismics (MCS) are described below.

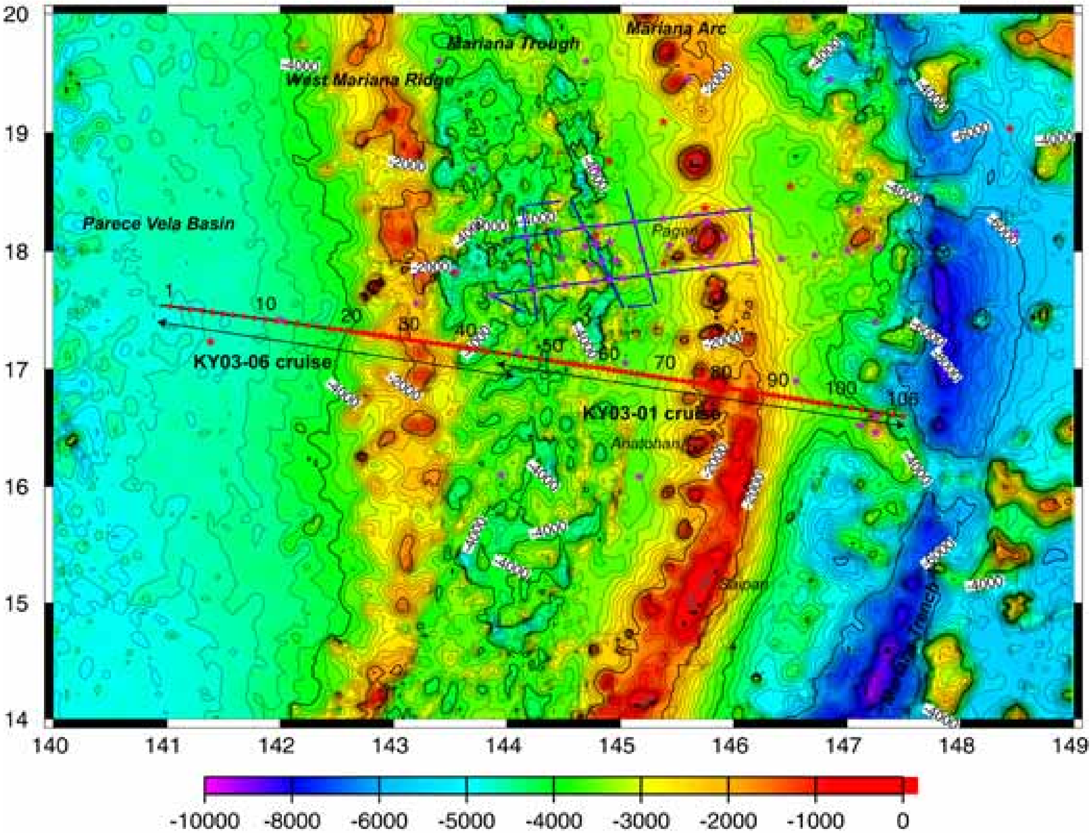


Figure 1. Map of the experimental area. Red circles show the OBS locations for two cruises, KY03-01 and KY03-06. In this cruise, 46 OBSs of western part on the main line were deployed. Black and blue lines indicate the seismic lines for short term OBSs and long term OBSs, respectively. Red and purple stars indicate long term OBSs retrieved during KY03-01 cruise and deployed during KY03-06, respectively. Two double arrows indicate the areas of airgun shooting during KY03-01 and KY03-06 cruises.

date	activities	remarks
6/28	Departure form Port of Saipan (8:00)	
29	Arriving at Site#22 and starting OBS deployment (3:45)	Site#22 -> Site#46
30	Finish of OBS deployment at Site#46, starting airgun array deployment (4:00) and starting airgun shooting (6:58)	Shooting on MR101c
7/1	Airgun shooting (ESE->WNW)	Shooting on MR101c
2	Finish of airgun shooting (4:30), retrieval of airgun array and starting OBS retrieval (6:00)	OBS#1 -> OBS#35 for OBS retrieval
3	OBS retrieval	
4	OBS retrieval	

5	OBS retrieval	OBS#46 -> OBS#36 for OBS retrieval and retry to retrieve OBS #20
6	OBS retrieval, transit to long term OBSs array area, starting airgun array and starting airgun shooting (10:52)	Retry to retrieve OBS#19 Shooting on L3
7	Airgun shooting	Shooting on L3, L2 and L1
8	Airgun shooting	Shooting on L1
9	Airgun shooting	Shooting on L1, T1B and L4
10	Airgun shooting	Shooting on L4, T2B, L5 and T3B
11	Finish airgun shooting (16:00), retrieval of airgun array and transit to JAMSTEC (17:30)	Shooting on T3B and T6
12	Transit	
13	Transit	
14	Transit	
15	Transit	
16	Arriving at JAMSTEC (7:30)	

Table 1. Schedule of seismic experiments. Local time (+10h for UTC) is used here.

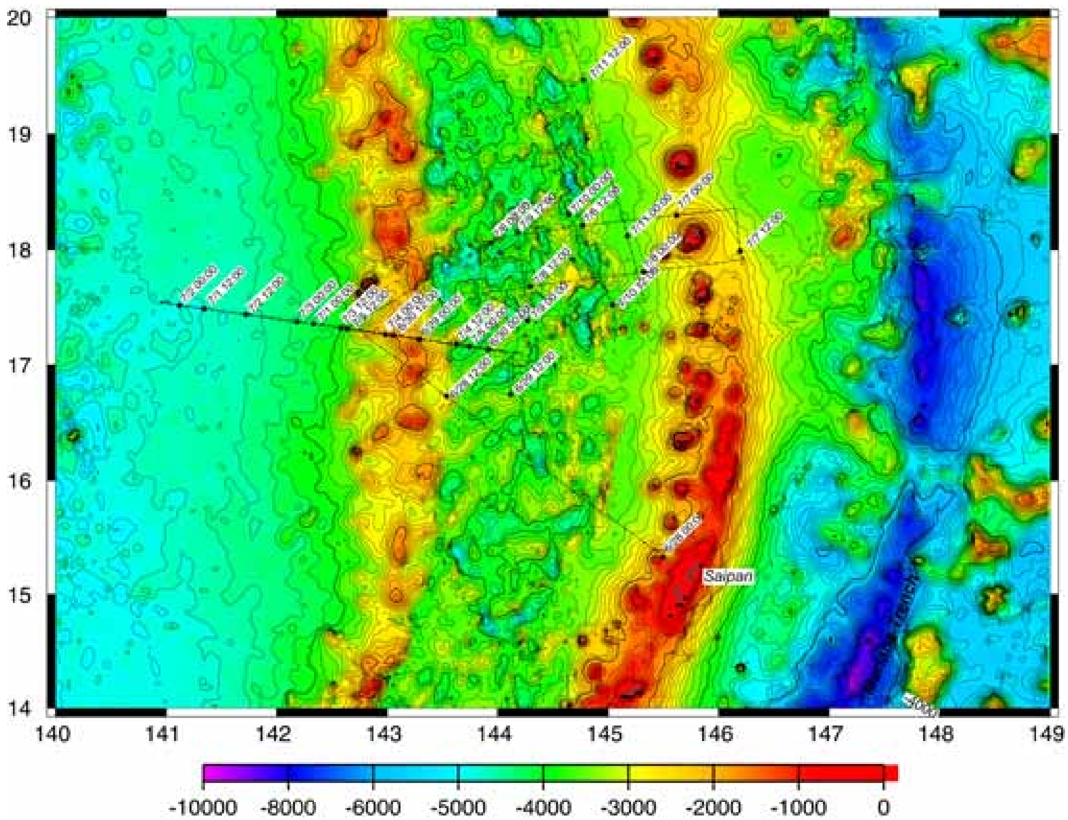


Figure 2. Track line of R/V Kaiyo during Leg 2 with UTC time.

2.1. Airgun shooting

The length of the original seismic line planned at previous KY03-01 cruise was 700 km long from the forearc region just on the serpentinite seamount to the Parece Vela basin (Figure 1).

However, the shooting area of the previous cruise was limited to the eastern part from the forearc region to the western Mariana trough, which corresponds to OBS#45 site. Then, we performed the airgun shooting again in this cruise at the western half of the original line from the western Mariana trough to the Parece Vela basin, between OBS#1 and OBS#47 (Figure 3). The airgun array of R/V "Kaiyo" had been shot from Jun. 30 to Jul. 2 along the line named MR101c.

We shot the airgun array over long term OBSs deployed around the Pagan Island and the Mariana trough during a late half of this leg (Figure 3). These seismic lines consist of two lines across the trough axis (L1 and L3), three lines parallel to the axis (L2, L4, L5 and L6) and three transit lines (T1B, T2B and T3B). The Lines L1 of 248.5 km long and L3 of 227.5 km long run from western part of the Mariana trough to the forearc through the trough axis and near the Pagan island. Line L2 of 49.9 km long is on the forearc region and very near to other seismic line carried out by Kerr et al. (2002). Line L4 of 107.1 km long is in western part of the Mariana trough and Line L5 of 113.2 km long is just on the trough axis. According to preliminary results by Takahashi et al. (2003), the crustal thickness beneath Lines L4 and L5 is about 5-6 km. Line L6 of 108.8 km long is in the transition area between the trough and the arc and has smooth sea floor topography. Line T1B of 48.9 km long, T2B of 46.2 km long and T3B of 31.1 km long are transit lines.

The specifications related to the airgun were right same to those of KY03-01 cruise. The airgun array with total capacity of 12,000 cubic inches consists of eight airguns with 1500 cubic inches capacity each. The air pressure sent to chamber was 2000 psi. The shot interval was 200 m (about 70-100 sec depending on the ship speed) to reduce noise by previous shot The geometry of the seismic experiment is shown in Figure 4. The two floats with two airguns each were deployed from port and starboard sides, respectively. The airgun array's size is 34.56 m length x 21.3 m width. Airgun's position was located 139.6 m behind the ship position (distances from ship antenna to tail of ship, and from tail of ship to center of the airgun array, are 29.4 m and 110.2 m, respectively). During the shooting for the long term OBSs, the airgun array was located behind 118.9 m from tail of the ship to reduce the possible damage for the ship body by long period vibration. It took 1–2 hours to deploy and retrieve whole airgun array.

The airgun was shot according to orders from the navigation system using differential GPS (see section 2.3). We adopted a nearest reference station, Manila. However, the Manila station became unstable during the airgun shooting from Jul.9 and we could not sometimes receive the signals. Then, we changed the reference station from Manila to Sapporo. The estimated error by the change of the reference station was about 10 m.

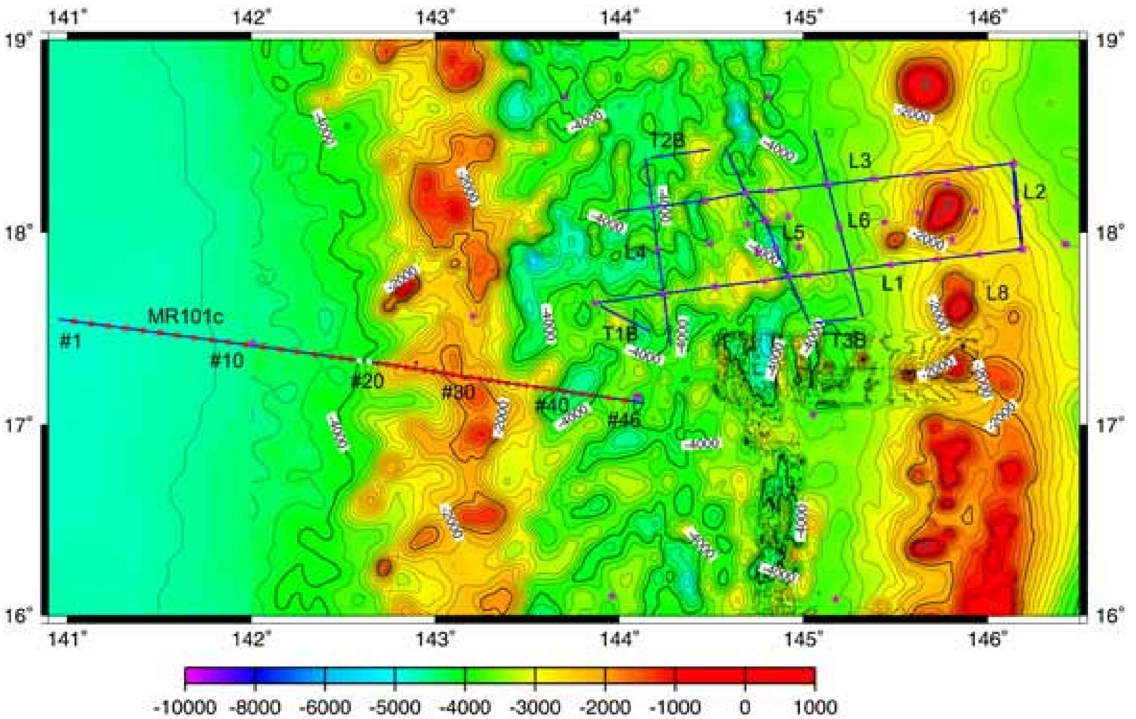


Figure 3. Map showing seismic line. Red circles show locations of the short term OBS available of this cruise. Black and blue lines indicate the seismic lines for short term OBSs and long term OBSs, respectively. Purple stars indicate long term OBS locations.

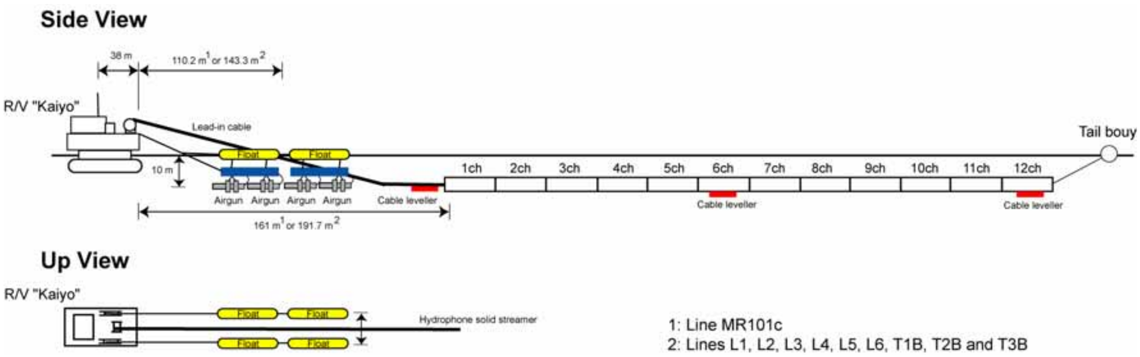


Figure 4. Geometry of seismic experiment.

2.2. Ocean Bottom Seismographs

We deployed 46 OBSs of JAMSTEC on the same position of seismic line used in previous KY03-01 cruise (Figure 1). The interval of each OBS is 5.4 km for the strong crustal variation or 10 km for the relative homogeneous area. These intervals were decided by 2-D ray tracing using expected velocity model referring to that of Izu-Ogasawara arc (Suyehiro et al., 1996; Takahashi et al., 1998). The locations of OBSs were right same to those of KY03-01 cruise (See cruise report of KY03-01 cruise for the topography).

The specifications of OBSs were also right same to those of KY03-01 cruise. The OBSs were equipped with a hydrophone sensor and three-component geophones (vertical and two horizontal components perpendicular each other) using gimbal-leveling mechanisms; natural frequency of the geophones was 4.5 Hz. The digital recorder with a 16-bit A/D converter can store data on digital audiotape or a hard disk sampling continuously for 17 days with original format (Shinohara et al., 1993). The power for the recorder system of OBS is supplied by rechargeable lithium-ion. Above geophone sensors with gimbal-leveling mechanism, batteries and a recorder system are installed in 15 inches glass sphere by Benthos, Inc. The glass sphere is stored in the yellow hard hat. A sketch for the OBS is shown in Figure 5. To check air pressure status inside a glass sphere, an air pressure sensor is also attached to inside wall of the glass sphere directly. The sensitivities of a geophone and a hydrophone sensor are shown in Table 2. To enable easy OBS retrieval after arriving at sea surface, all OBSs are attached to a flush light and a beacon with coded signal.

An OBS is deployed by free fall and retrieved by melting releaser composed of stainless steel plates connecting an OBS with a weight after a transponder system receives acoustic signal sent from a vessel (Table 3). This acoustic communication between the OBS and the vessel was performed using transducers installed on the vessel. During OBS deployment, we monitored depth of OBS until 500 m below sea level, because leak to the transponder seems to occur at shallower depth than 500 m empirically. And, inferred position of OBS at sea bottom is estimated by the vessel’s positioning system. The accuracy of the positioning seems to be less than 100 m. Despite of we deployed 46 OBSs, we recovered 44 OBSs. Two OBSs were not retrieved due to troubles of a transponder and/or a releaser system, because one OBS had no response for signals from the vessel and the other was not taken off sea bottom despite of clear response. It took 11-40 minutes for separating from the sea bottom and the time seems to depend on the situation of the sea bottom. The speed of popup was about 60 m/minute.

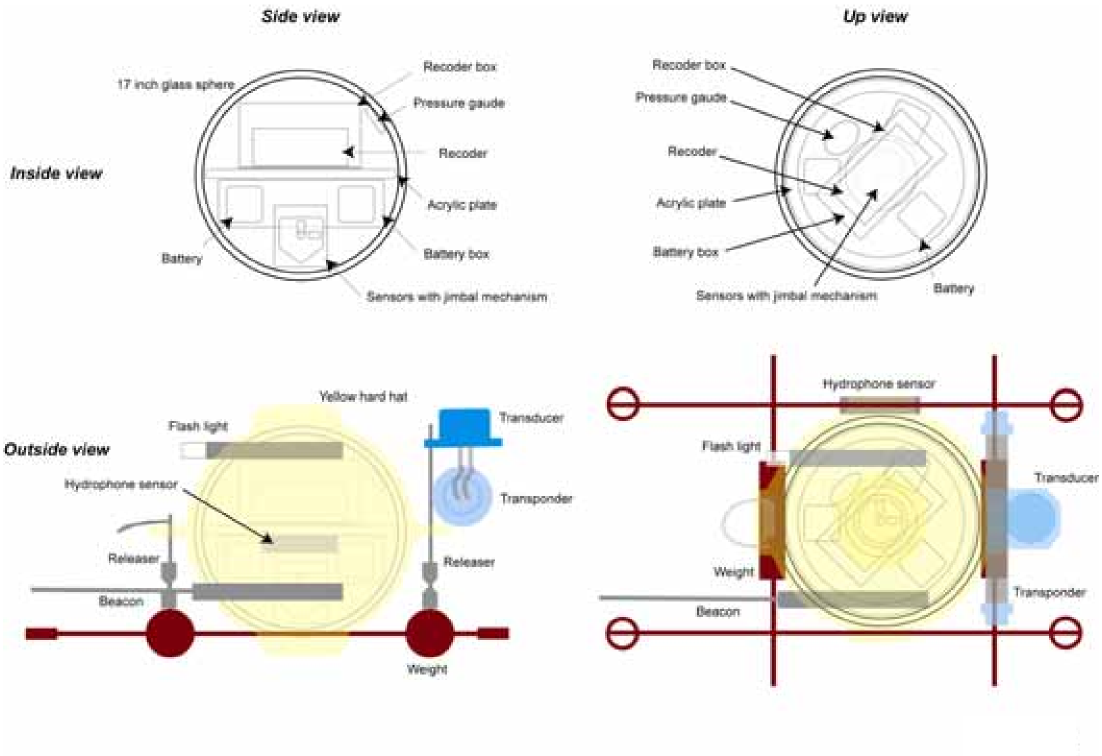


Figure 5. Sketch of Japanese OBS instrument.

Sensor type	Sensor name	Maker	Sensitivity	Frequency
Geophone (three components)	L-28LB.H.V	Mark Products	0.69 V/in/sec	4.5Hz (natural freq.)
Hydrophone	AQ-18	Benthos, inc.	-169 dB	1Hz - 12kHz
Hydrophone	HTI-99DY	HIGH TECH, inc	-165dB	2Hz - 20kHz

Table 2. Sensitivities of geophone and hydrophone sensors

(a)

Site	Deployment time (local)		Deployment position		Depth (m)	Retrieval time (local)		Retrieval position	
1	6/23	6:48	17-32.0679	141-01.6542	4774	7/2	7:42	17-32.0185	141-01.6971
2	6/23	8:55	17-31.3588	141-07.2696	4833	7/2	10:00	17-31.4442	141-07.1597
3	6/23	8:58	17-30.6160	141-12.8679	4742	7/2	11:52	17-30.6928	141-12.8033
4	6/23	10:03	17-29.8835	141-18.4630	4758	7/2	13:01	17-29.9005	141-18.4490
5	6/23	11:06	17-29.1634	141-24.0632	4729	7/2	16:04	17-29.1715	141-23.9075
6	6/23	12:16	17-28.4422	141-29.6662	4715	7/2	17:45	17-28.4849	141-29.4544
7	6/23	13:31	17-27.7096	141-35.2567	4696	7/2	19:37	17-27.7860	141-34.9759
8	6/23	14:40	17-26.9747	141-40.8681	4699	7/2	21:27	17-26.9658	141-40.6604
9	6/23	15:50	17-26.2347	141-46.4769	4664	7/2	23:20	17-26.1670	141-46.2225
10	6/24	6:41	17-25.4826	141-52.0804	4591	7/3	2:32	17-25.4103	[illegible]
11	6/24	7:55	17-24.7343	141-57.6710	4526	7/3	5:05	17-24.3851	
12	6/24	9:07	17-23.9846	142-03.2753	4485	7/3	7:20	17-23.8828	142-03.0725
13	6/24	10:20	17-23.2454	142-08.8880	4401	7/3	9:30	17-23.1569	142-08.6478
14	6/24	11:29	17-22.4923	142-14.4898	4341	7/3	11:41	17-22.5069	142-14.3249
15	6/24	12:37	17-21.7390	142-20.0924	4181	7/3	13:56	17-21.8782	142-20.0642
16	6/24	13:43	17-20.9818	142-25.6929	4174	7/3	16:06	17-21.0587	142-25.6962
17	6/24	14:19	17-20.5812	142-28.7161	4124	7/3	17:45	17-20.6386	142-28.6695
18	6/24	14:56	17-20.1718	142-31.7290	4093	7/3	19:18	17-20.2763	142-31.6942

19	6/25	6:33	17-19.7433	142-34.7459	4077	not retrieval			
20	6/25	7:13	17-19.3531	142-37.7493	3882	not retrieval			
21	6/25	7:49	17-18.9337	142-40.8014	3539	7/4	2:39	17-19.0226	142-40.9381
22	6/29	3:49	17-18.5173	142-43.8142	3405	7/4	3:57	17-18.5544	142-43.9094
23	6/29	4:23	17-18.1048	142-46.8439	3240	7/4	5:26	17-18.1325	142-46.8118
24	6/29	4:57	17-17.7061	142-49.8563	2642	7/4	6:45	17-17.7044	142-49.9212
25	6/29	5:31	17-17.2864	142-52.8834	2473	7/4	8:02	17-17.3455	142-52.8811
26	6/29	6:04	17-16.8628	142-55.8992	2680	7/4	9:03	17-16.9328	142-55.8629
27	6/29	6:37	17-16.4607	142-58.9137	2769	7/4	10:24	17-16.6007	142-58.9613
28	6/29	7:09	17-16.0307	143-01.9392	1881	7/4	12:21	17-16.1322	143-02.0532
29	6/29	7:42	17-15.6174	143-04.9543	1843	7/4	13:27	17-15.7437	143-05.0768
30	6/29	8:15	17-15.1756	143-07.9737	2037	7/4	14:28	17-15.2562	143-08.1053
31	6/29	8:47	17-14.7501	143-10.9892	1901	7/4	15:35	17-14.7931	143-11.1301
32	6/29	9:21	17-14.3314	143-13.9993	1931	7/4	16:51	17-14.3983	143-14.1067
33	6/29	9:56	17-13.9259	143-17.0109	1999	7/4	17:50	17-13.9202	143-17.0354
34	6/29	10:31	17-13.4967	143-20.0369	2564	7/4	19:07	17-13.4893	143-20.0285
35	6/29	11:06	17-13.0711	143-23.0615	2643	7/4	20:23	17-13.0747	143-23.0329
36	6/29	11:41	17-12.6535	143-26.0765	2438	7/5	17:54	17-12.6316	143-26.1702
37	6/29	12:18	17-12.2327	143-29.0977	2448	7/5	16:45	17-12.2415	143-29.2064
38	6/29	12:55	17-11.8005	143-32.1189	2673	7/5	15:30	17-11.7905	143-32.1922
39	6/29	13:33	17-11.3701	143-35.1338	3145	7/5	14:23	17-11.3142	143-35.1484
40	6/29	14:09	17-10.9318	143-38.1560	3833	7/5	13:09	17-10.9006	143-38.1497
41	6/29	14:47	17-10.4961	143-41.1841	4240	7/5	11:48	17-10.3635	143-41.1054
42	6/29	15:25	17-10.0789	143-44.1904	4230	7/5	10:14	17-09.9541	143-44.0136
43	6/29	16:02	17-09.6570	143-47.1911	4109	7/5	8:34	17-09.3919	143-46.9528
44	6/29	16:39	17-09.2372	145-50.2100	4232	7/5	6:58	17-09.0183	143-50.0378
45	6/29	17:50	17-08.4375	143-55.7961	3764	7/5	4:14	17-08.3377	143-55.6408
46	6/29	18:58	17-07.6282	144-01.3798	3518	7/5	2:09	17-07.5437	144-01.2904

(b)

Site	Estimated position at sea bottom		Estimated depth (m)	Hydrophone Type	RecorderType	Remarks
1	17-31.9866	141-01.8950	4797	BENTHOS	HDD	
2	17-31.3588	141-07.2696	4833	BENTHOS	DAT	*
3	17-30.6160	141-12.8679	4742	BENTHOS	HDD	*
4	17-29.8835	141-18.4630	4758	BENTHOS	DAT	*
5	17-29.1634	141-24.0632	4729	BENTHOS	DAT	*
6	17-28.4422	141-29.6662	4715	BENTHOS	DAT	*
7	17-27.7096	141-35.2567	4696	BENTHOS	HDD	*
8	17-26.9747	141-40.8681	4699	BENTHOS	DAT	*
9	17-26.2347	141-46.4769	4664	BENTHOS	DAT	*
10	17-25.4826	141-52.0804	4591	BENTHOS	DAT	*
11	17-24.7343	141-57.6710	4526	BENTHOS	DAT	*
12	17-23.9846	142-03.2753	4485	HIGH TECH	DAT	*
13	17-23.2528	142-08.9017	4391	BENTHOS	DAT	*
14	17-22.4923	142-14.4898	4341	BENTHOS	DAT	*
15	17-21.7390	142-20.0924	4181	BENTHOS	DAT	*
16	17-20.9818	142-25.6929	4174	BENTHOS	DAT	*
17	17-20.6607	142-28.7180	4133	BENTHOS	DAT	*
18	17-20.1718	142-31.7290	4093	BENTHOS	DAT	
19	no response			BENTHOS	DAT	Not retrieval
20	17-19.3986	142-37.8137	3883	BENTHOS	DAT	Not retrieval
21	17-18.9337	142-40.8014	3539	BENTHOS	DAT	*
22	17-18.5173	142-43.8142	3405	HIGH TECH	HDD	*
23	17-18.1464	142-46.7574	3322	BENTHOS	DAT	
24	17-17.7191	142-49.9534	2590	BENTHOS	DAT	
25	17-17.3222	142-52.8676	2451	BENTHOS	DAT	
26	17-16.8628	142-55.8992	2680	BENTHOS	DAT	*
27	17-16.5420	142-58.9513	2842	BENTHOS	HDD	
28	17-16.0689	143-01.6237	1924	HIGH TECH	DAT	
29	17-15.6174	143-04.9543	1843	HIGH TECH	HDD	*
30	17-15.1756	143-07.9737	2037	BENTHOS	DAT	*
31	17-14.7602	143-11.0366	1901	BENTHOS	DAT	

32	17-14.3784	143-14.0670	1917	BENTHOS	DAT	
33	17-13.9910	143-17.0504	1951	BENTHOS	HDD	
34	17-13.5336	143-20.1159	2581	BENTHOS	HDD	
35	17-13.0527	143-23.1473	2606	BENTHOS	DAT	
36	17-12.7421	143-26.0427	2430	BENTHOS	DAT	
37	17-12.2327	143-29.0977	2448	BENTHOS	DAT	*
38	17-11.8005	143-32.1189	2673	BENTHOS	HDD	*
39	17-11.3701	143-35.1338	3145	BENTHOS	DAT	*
40	17-10.9318	143-38.1560	3833	BENTHOS	DAT	*
41	17-09.9780	143-43.1205	4246	BENTHOS	DAT	
42	17-10.0789	143-44.1904	4230	BENTHOS	DAT	*
43	17-09.6006	143-47.0963	4093	BENTHOS	DAT	
44	17-09.1938	143-50.1559	4232	BENTHOS	DAT	
45	17-08.4104	143-55.7183	3764	BENTHOS	HDD	
46	17-07.5863	144-01.3490	3539	BENTHOS	DAT	

Table 3. OBS information. (a) Activity log of the OBS deployment and retrieval. (b) OBS information of estimated position at sea bottom, attached hydrophone type (Benthos or High Tech) and the recorder type. DAT and HDD mean the media to record signals, which is 4mm tape and hard disk, respectively. Asterisks indicate that the locations are the deployment ones.

2.3. Multichannel hydrophone streamer

During airgun shooting, we towed a 12-channel hydrophone streamer to know the distribution of sediments with low P-wave velocity. The hydrophne streamer cable is solid type made by Sercel. The interval of each channel was 25m. Hydrophone sensors (TYPE Bruel & Kjaer Free-field 1/2 Microphone) with sensitivity of -25.9dB re1V/Pa (50.4mV/Pa) were used and these analog signals form five sensors in same channel were stacked before A/D conversion. The A/D conversion kit was attached in the recording system, the StrataVisor NX Marine made by Geometrics Inc, digitized data was recorded on 3490E tapes with SEG-D format and converted to SEG-Y format. Recording delay was none and system delay was 50 msec. The sampling rate was 4-msec and the record length was 12 sec. The shot number was distributed from eastern end of the line and the first number was 1001. The recording log is shown in Table 4.

The flow chart of this seismic experiment was shown in Figure 6. Navigation data collected by the ship’s navigation system was sent to the RTNμ and the master clock via the terminal server connecting the LAN of the ship and this MCS system. The navigation data has GGA and SOJ format, and includes much information used for ship operation, time, ship position, ship speed, ship heading, weather information, sea status information and so on. The RTNμ obtains time signals of GPS from original antenna and the signals are used for the confirmation of navigation data sent from the ship’s system. Then, the navigation data is sent to the Sun workstation installed SPECTRA software and monitored on the display. Timing of the system start and ways to set shot number and so on are set in the SPECTRA software. The system start signal from the SPECTRA was sent to the gun controller, GCS90 and the recording system, StrataVisor NX Marine, as trigger signal via the RTNμ. The gun controller sends back the internal time break signal to the master clock and RTNμ just after getting trigger signals, the shot signal is sent to eight airguns, and the recording system starts to record digitized seismic data from a hydrophone streamer. The first break signal is sent to the gun controller from the airguns at same timing with the shot., then the gun controller sends the shot data to RTNμ.

KY0306 MCS Research SEG-Y Data list						
LINE NAME	File No.	Shot point No.	FF/LF	Time (UTC)	Location	REMARKS
MR101c	1	-	FF			Noise record
	2	995		Jun. 29 20:58:25	17°06'45.345"N 144°07'39.578"E	First shot point
	1711	2704		Jul. 1 17:04:52	17°32'42.909"N 140°56'37.842"E	Last shot point
	1712	-	LF			Noise record
	Files 1-3 are lost.					
L3	1	-	FF			Noise record
	2	991		Jul. 6 00:51:59	18°06'21.277"N 145°58'52.572"E	First shot point
	1155	2144		Jul. 7 07:18:00	18°21'32.270"N 146°08'40.480"E	Last shot point
	1156	-	LF			Noise record
L2	1	-	FF			Noise record
	2	1024		Jul. 7 7:56:00	18°18'59.583"N 146°08'29.075"E	First shot point
	208	1230		Jul. 7 12:31:44	17°56'46.798"N 146°10'53.381"E	Last shot point
	209	-	LF			Noise record
L1	1	-	FF			Noise record
	2	999		Jul. 7 13:10:23	17°54'46.973"N 146°11'19.314"E	First shot point
	1252	2249		Jul. 8 16:49:54	17°37'45.657"N 143°51'00.882"E	Last shot point
	1253	-	LF			Noise record
T1B	1	-	FF			Noise record
	2	1020		Jul. 8 17:47:30	17°36'52.250"N 143°53'21.635"E	First shot point
	164	1182		Jul. 8 22:02:46	17°28'46.891"N 144°09'36.791"E	Last shot point
	165	-	LF			Noise record
L4	1	-	FF			Noise record
	2	991		Jul. 9 00:21:54	17°24'31.121"N 144°16'05.017"E	First shot point
	549	1538		Jul. 9 15:20:15	18°23'18.295"N 144°07'55.513"E	Last shot point
	550	-	LF			Noise record
T2B	1	-	FF			Noise record
	2	1016		Jul. 9 15:52:21	18°23'07.912"N 144°09'41.056"E	First shot point
	175	1189		Jul. 9 20:29:50	18°25'49.676"N 144°29'07.702"E	Last shot point
	176	-	LF			Noise record
L5	1	-	FF			Noise record
	2	1001		Jul. 9 22:04:19	18°26'30.378"N 144°34'00.731"E	First shot point
	570	1569		Jul. 10 12:05:30	17°31'07.646N 145°01'40.680"E	Last shot point
	571	-	LF			Noise record
T3B	1	-	FF			Noise record
	2	1021		Jul. 10 12:38:42	17°31'42.788"N 145°03'44.957"E	First shot point
	118	1137		Jul. 10 15:25:47	17°32'59.133"N 145°16'47.535"E	Last shot point
	119	-	LF			Noise record
L6	1	-	FF			Noise record
	2	1004		Jul 10 16:09:07	17°33'30.809"N 145°18'55.162"E	First shot point
	557	1559		Jul. 11 06:00:59	18_31'43.761"N 145°03'00.807"E	Last shot point
	558	-	LF			Noise record
			FF : First File			
			LF : Last File			

Table 4. Airgun shooting log.

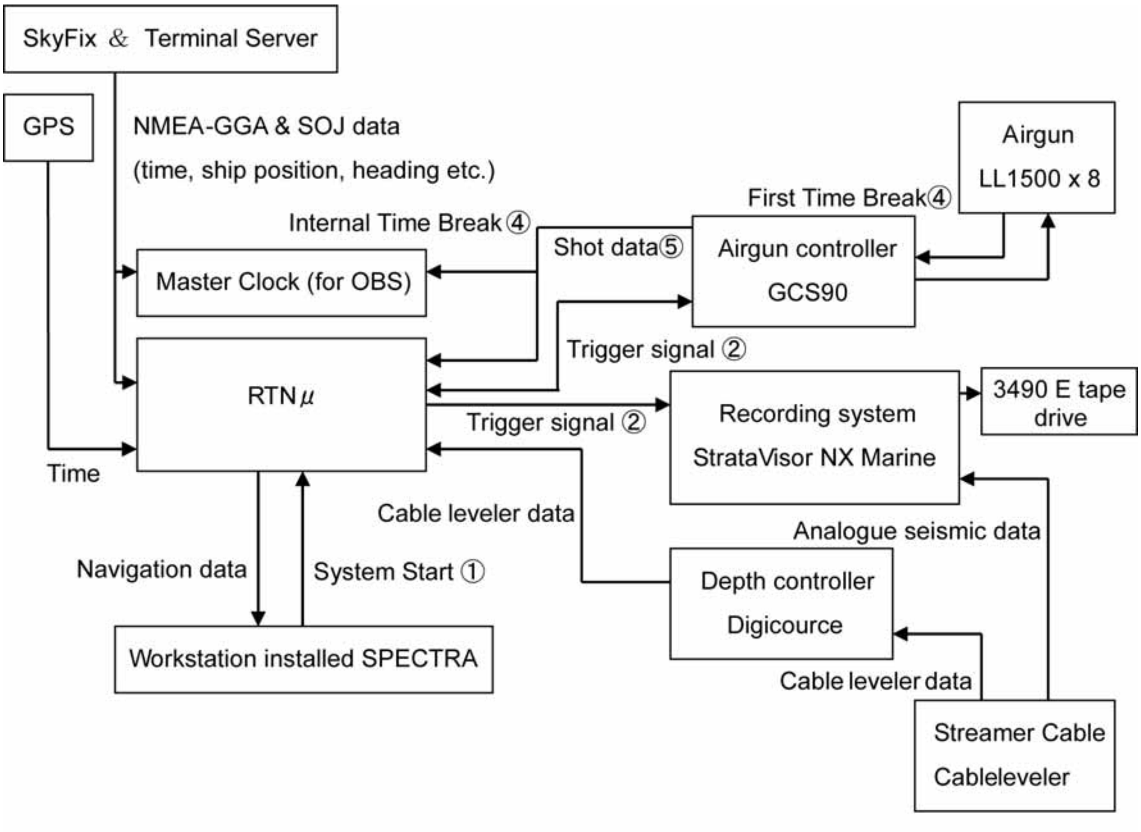


Figure 6. Flow chart for the MCS recording system. Circled numerals show the timing flow of this seismic system.

3. Data

In this chapter, we introduce examples of the seismic data, OBS and MCS. Each four components of OBS#1 on the Parece Vela basin, OBS#30 on the West Mariana ridge and OBS#46 on the Mariana trough and the MCS data are described below subsection.

3.1. OBS

We retrieved all OBSs data except two OBSs with recovery system. All OBSs started the recording from 18:00, Jun. 29 (UTC), and the timing was after the deployment.

We indicate record sections of OBS#1 (Figure 7), OBS#30 (Figure 8) and OBS#46 (Figure 9) as temporal examples. We can identify the airgun signals until about 200-250 km from the OBS and trace first phases over 150-km distance due to good quality of vertical records. Horizontal records also show good quality despite of poorer S/N ratio than the vertical, and we can see after phases until about 100 km from the OBS. Vertical record sections of OBS#1 and OBS#46 has apparent velocity of about 8 km/s at far offset from 10 km and 20 km, respectively. On the other hand, vertical section of OBS#30 has apparent velocity of about 6 km/s at offset of about 10-60 km.

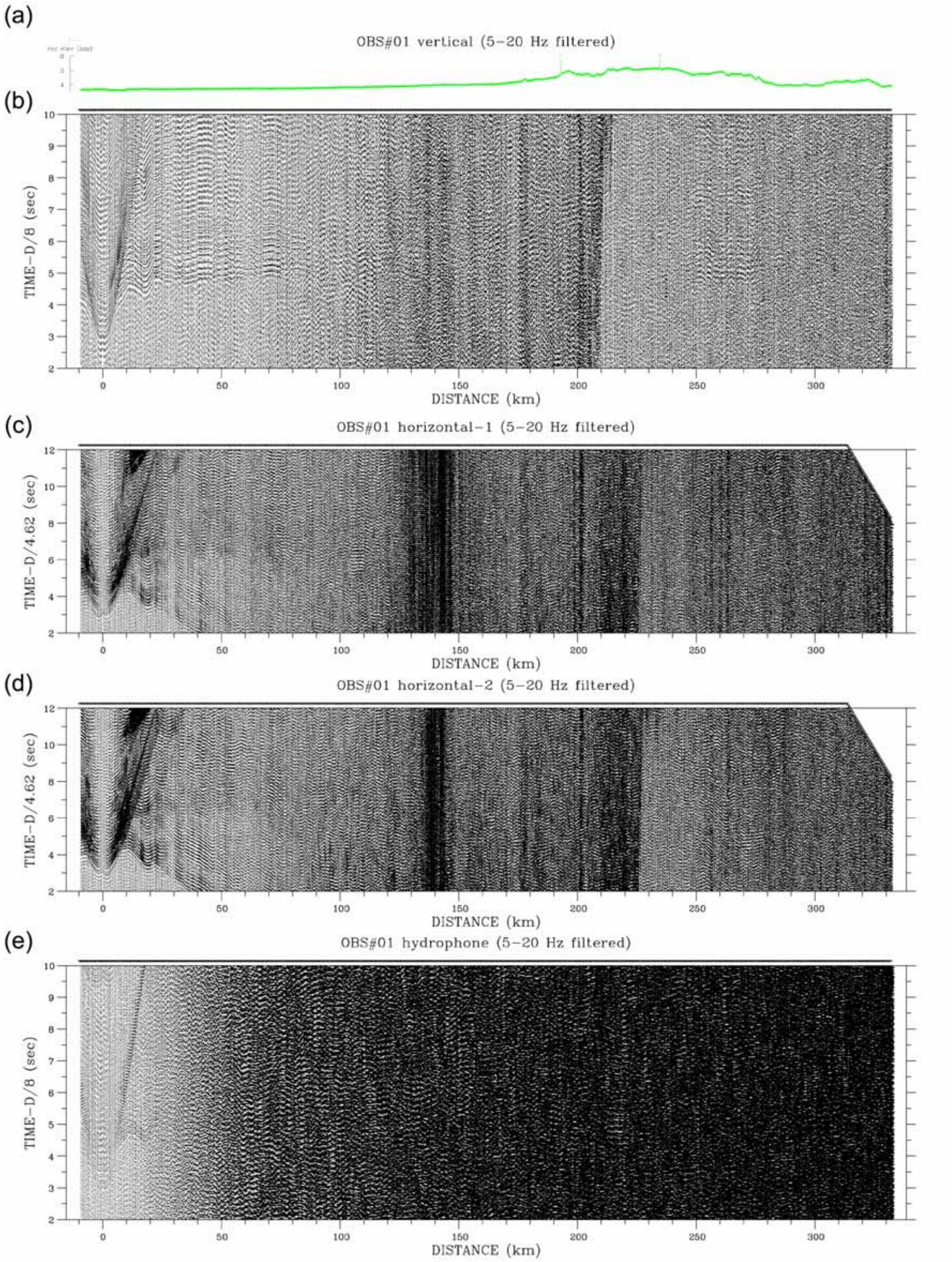


Figure 7. Record section of OBS#1. (a) Sea floor topography (b) Vertical section. All traces are filtered by 5-20 Hz. Horizontal and vertical axes are distance from the OBS (km) and reduced traveltime (sec). (c) Horizontal-1 section. (d) Horizontal-2 section. (e) Hydrophone section.

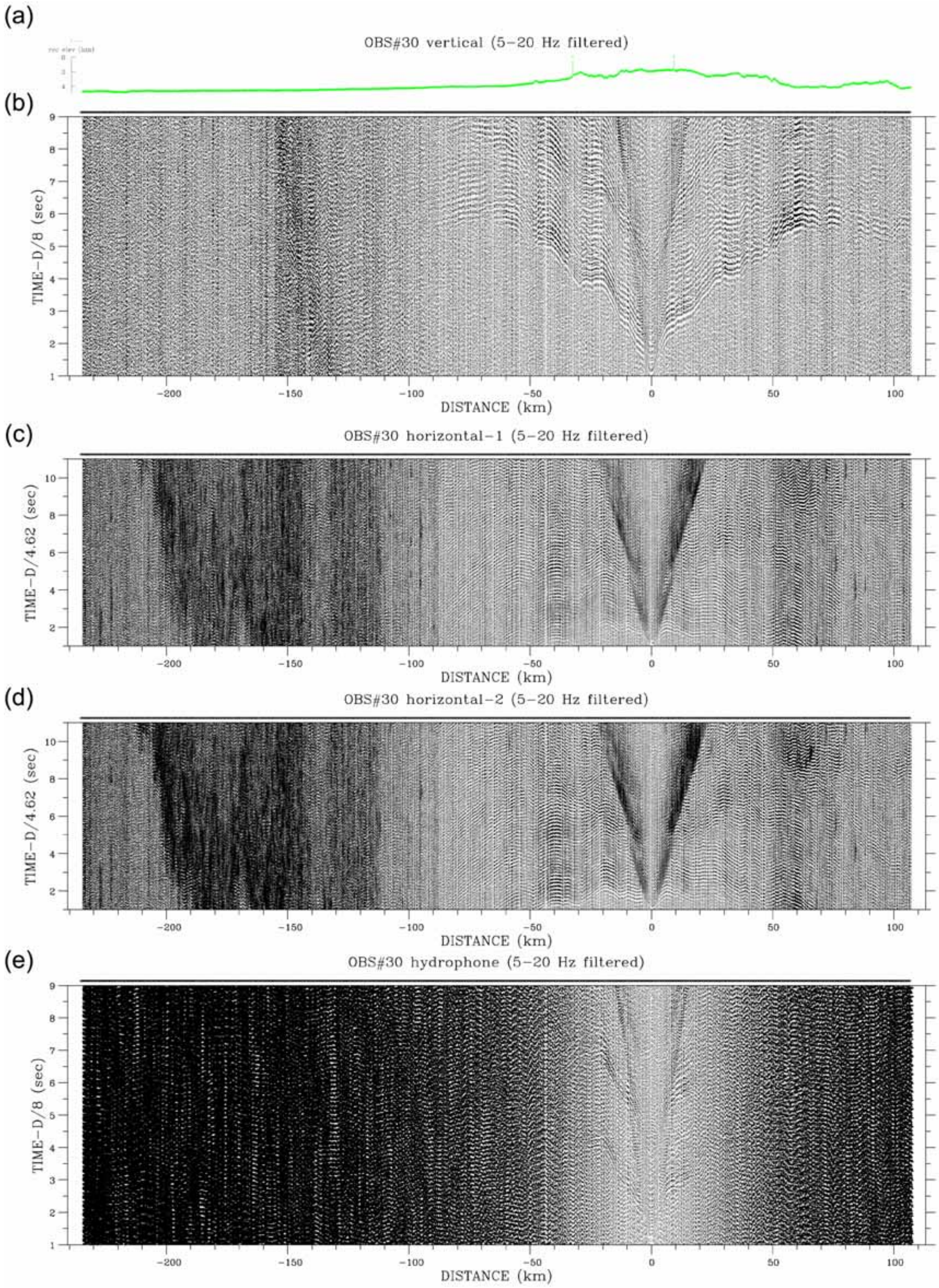


Figure 8. Record section of OBS#30. (a) Sea floor topography (b) Vertical section. All traces are filtered by 5-20 Hz. Horizontal and vertical axes are distance from the OBS (km) and reduced traveltime (sec). (c) Horizontal-1 section. (d) Horizontal-2 section. (e) Hydrophone section.

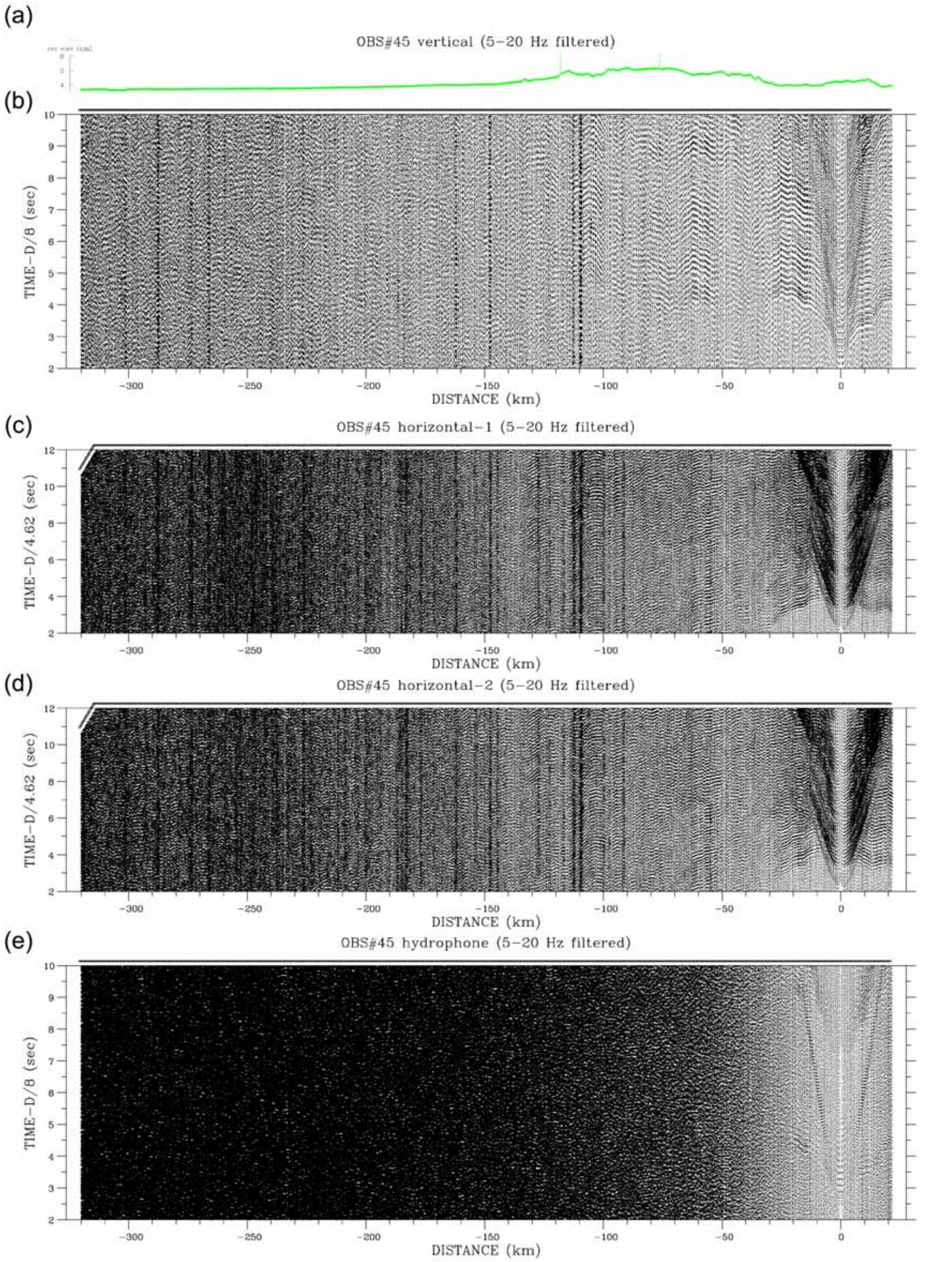
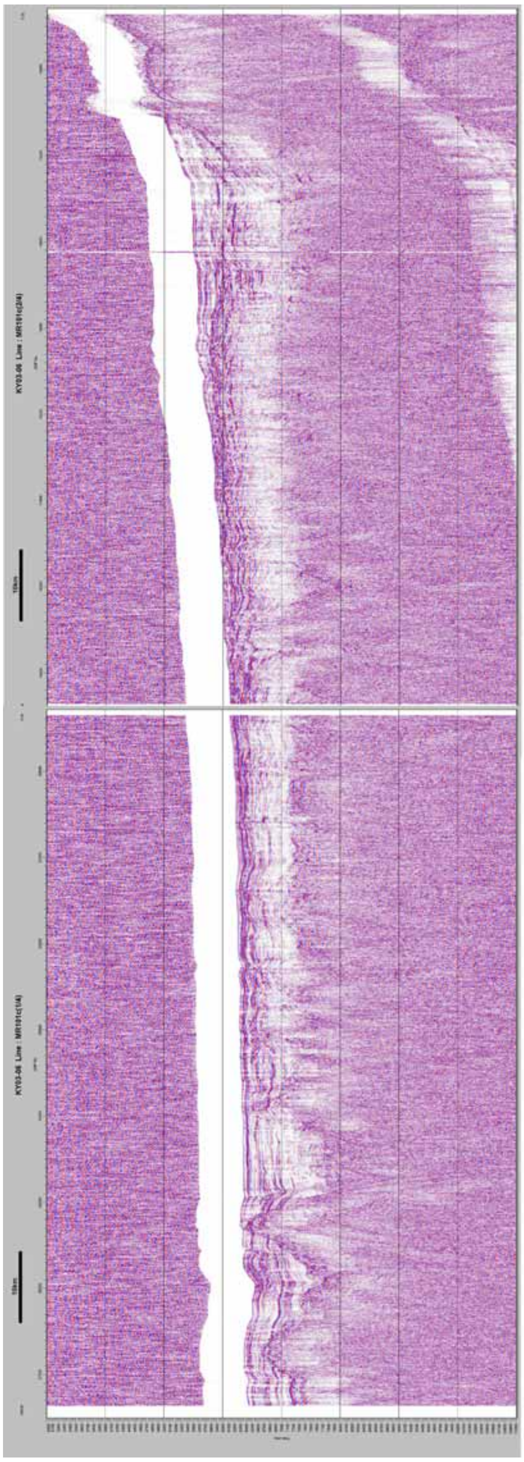


Figure 9. Record section of OBS#45. (a) Sea floor topography (b) Vertical section. All traces are filtered by 5-20 Hz. Horizontal and vertical axes are distance from the OBS (km) and reduced traveltime (sec). (c) Horizontal-1 section. (d) Horizontal-2 section. (e) Hydrophone section.

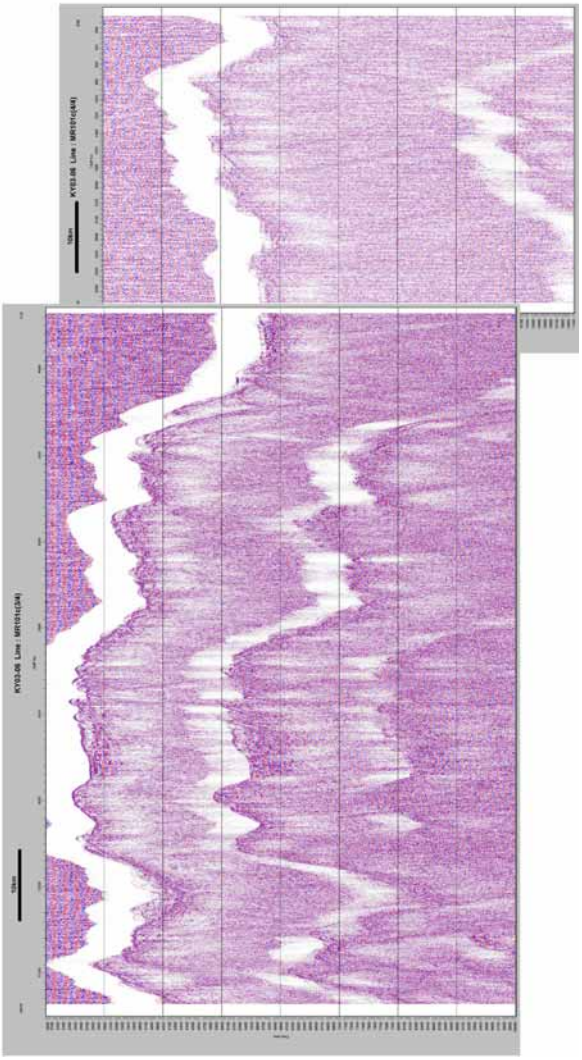
3.2. MCS

The reflection data recorded by 12-channel hydrophone streamer has also enough quality to pick the acoustic basement except 7-ch and sometimes 10-ch. We processed the reflection data using the Seismic Processing Workshop (SPW) of Parallel Geoscience Corporation during the cruise. The applied flows were the NMO correction with water velocity of 1500 m/s, sorting by CDPs, the bandpass filter of 8-45 Hz and the auto gain control. Because of the channel interval of 25m and the shot interval of 200 m, the fold number was less than 1. Therefore, the stacking was not included in this processing.

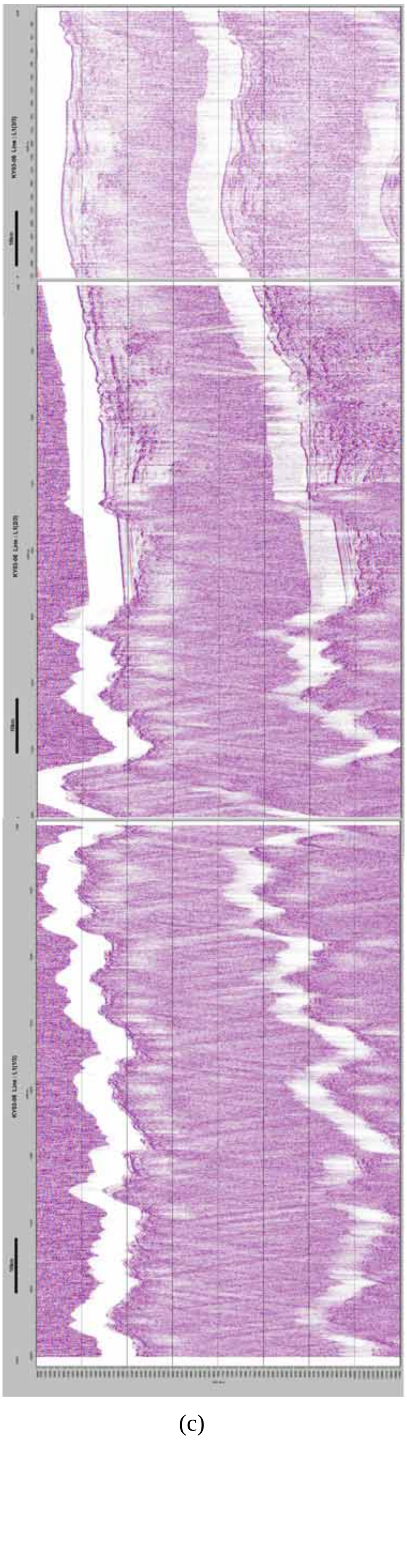
We showed all processed reflection profiles using above flows (Figure 10). The remarkable characteristic is the oceanic Moho beneath the Parece Vera basin along Line MR101c. The Moho can be identified at about 9 sec and we can see the crustal thinning at CMP 23000-25000 (Figure 10a). Such crustal thinning was identified near the Kinan escapement of the Shikoku basin (Park et al., 2002). This may bring the important information to understand the tectonics of this arc. Line L5 indicates some disconnected interfaces with a little strong amplitude at about 0.5 sec below sea floor. Such interfaces may seem to be at boundaries of trough segments (Figure 10f).



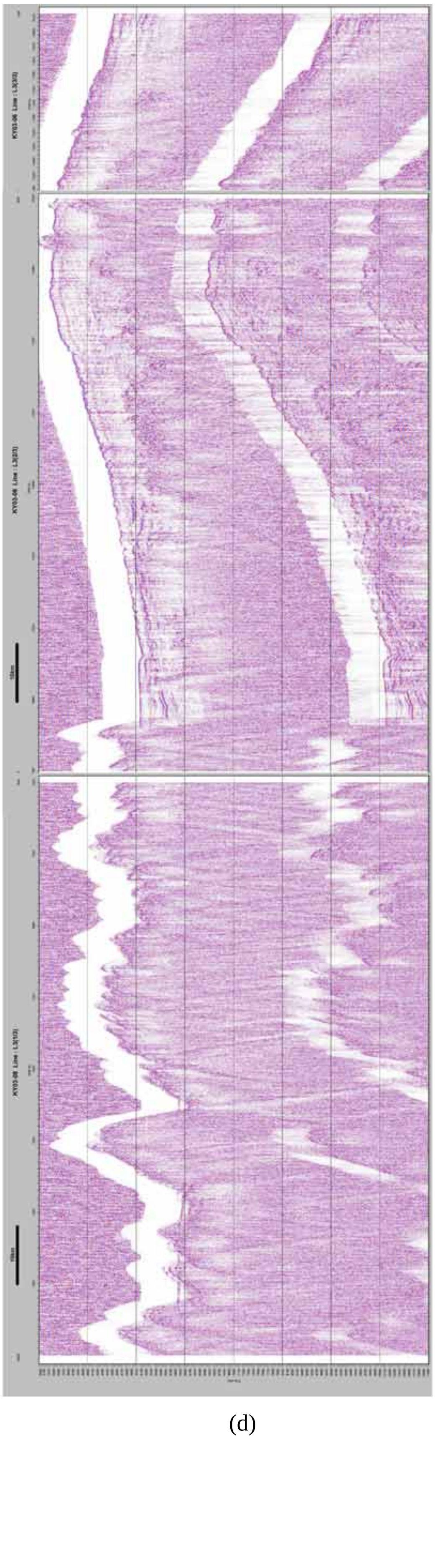
(a)



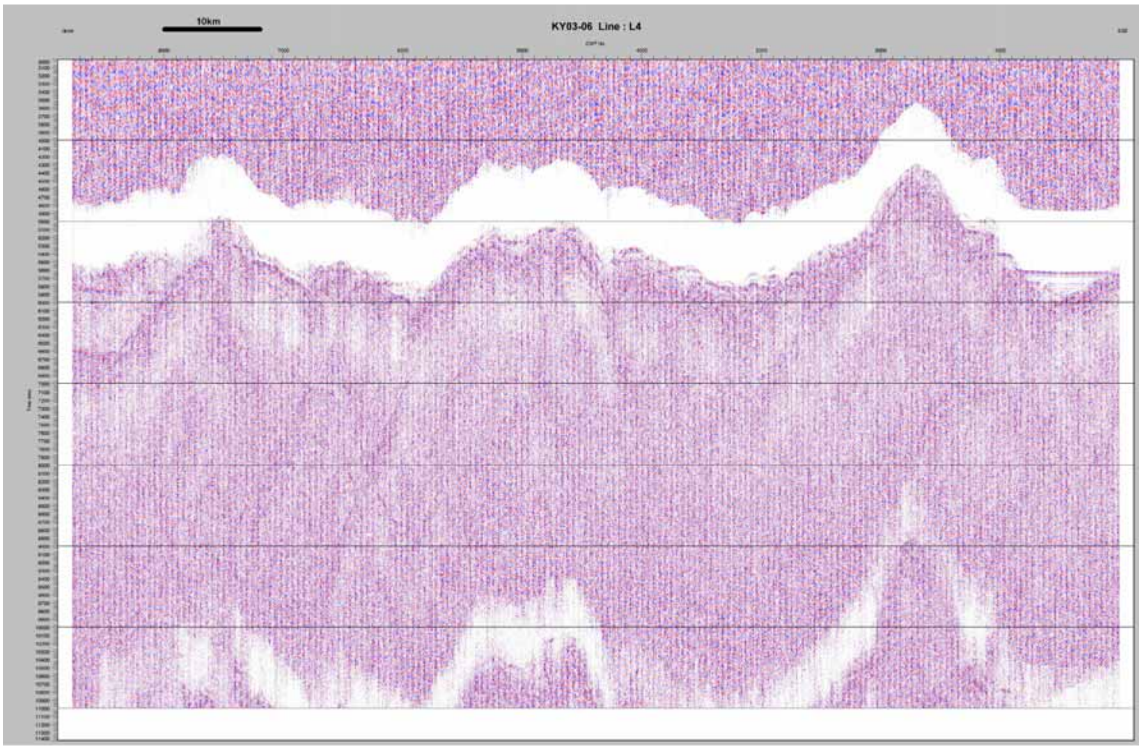
(b)



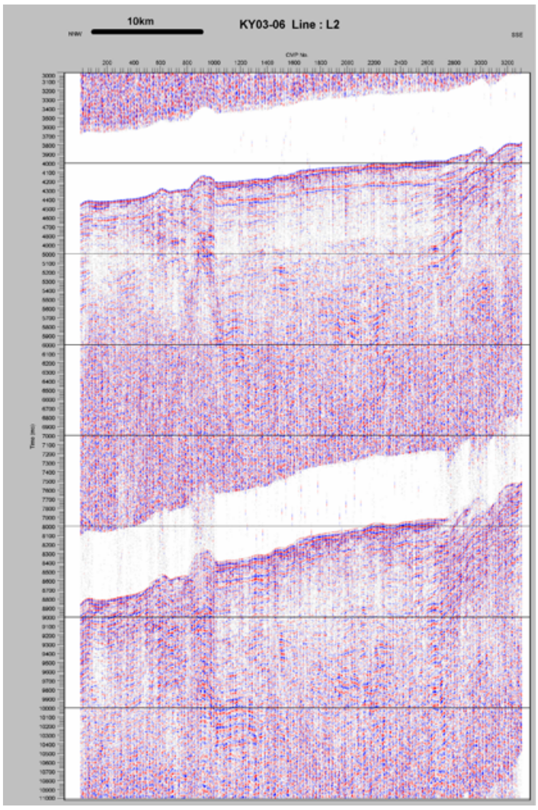
(c)



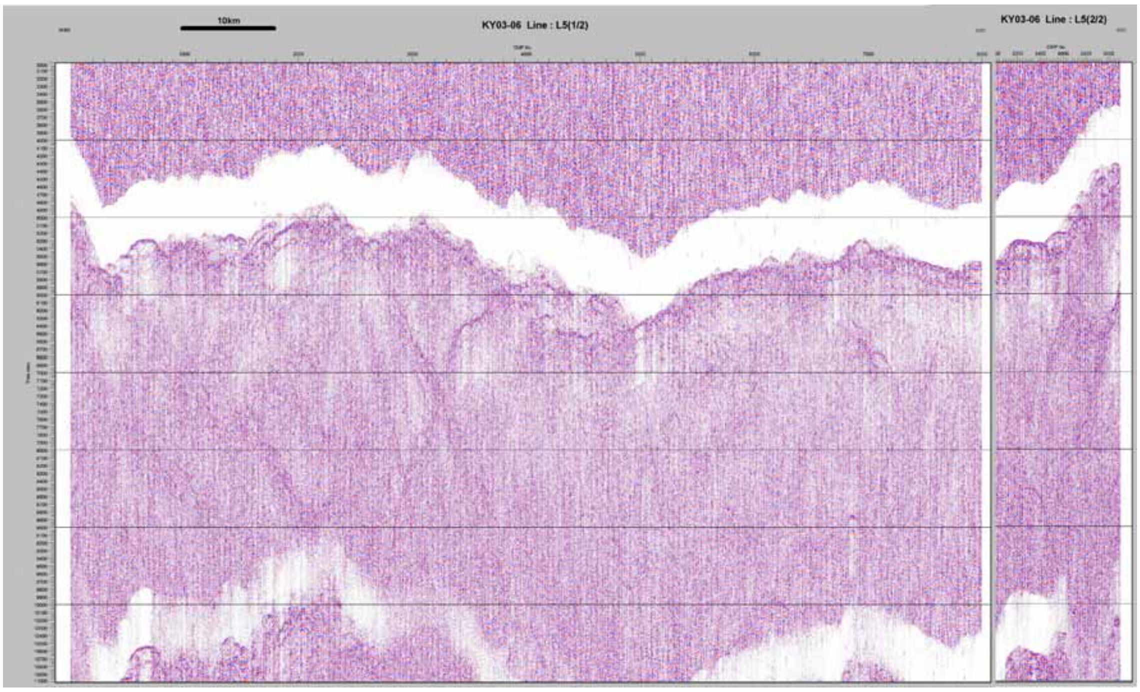
(d)



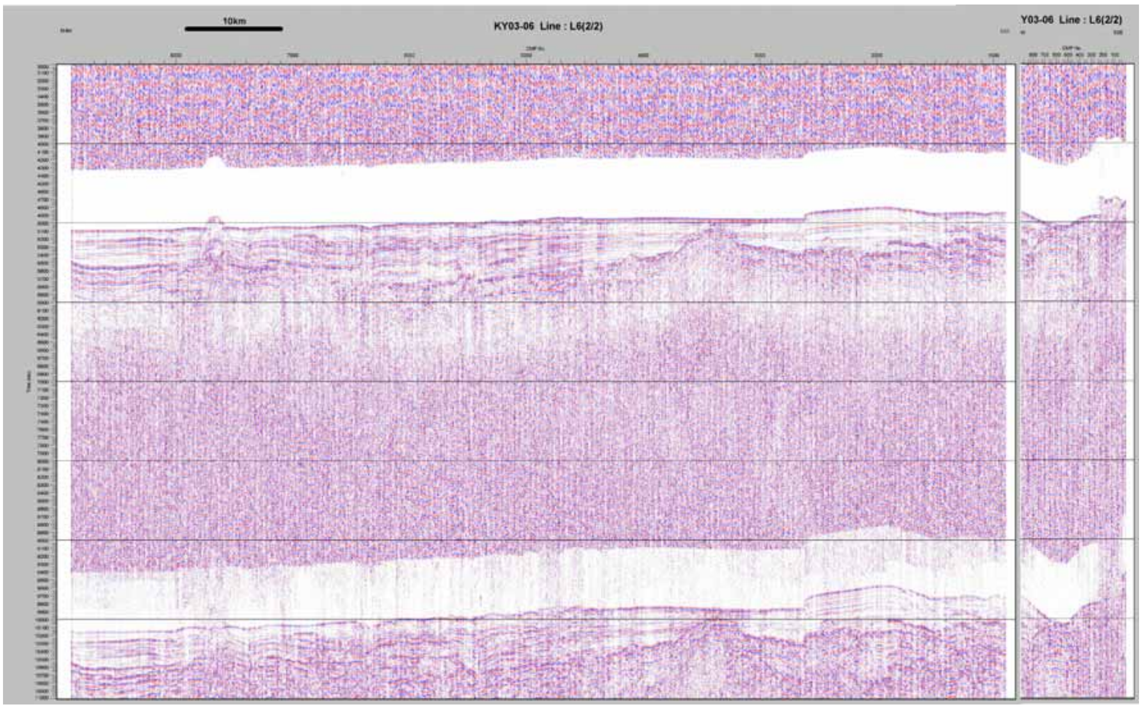
(e)



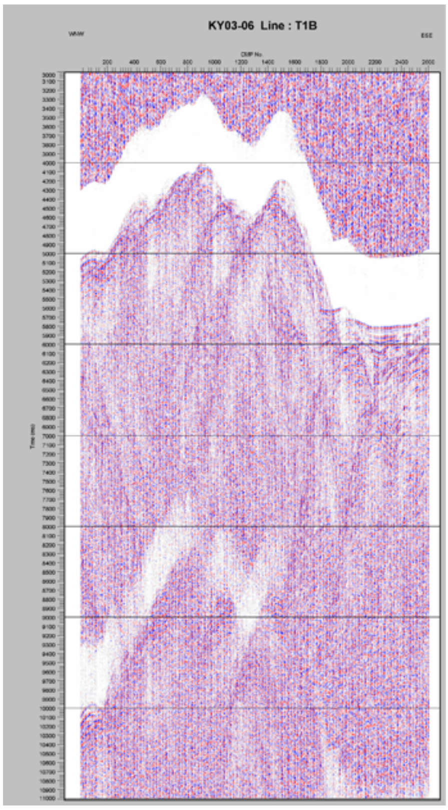
(f)


10km
KY03-06 Line : L5(1/2)
KY03-06 Line : L5(2/2)

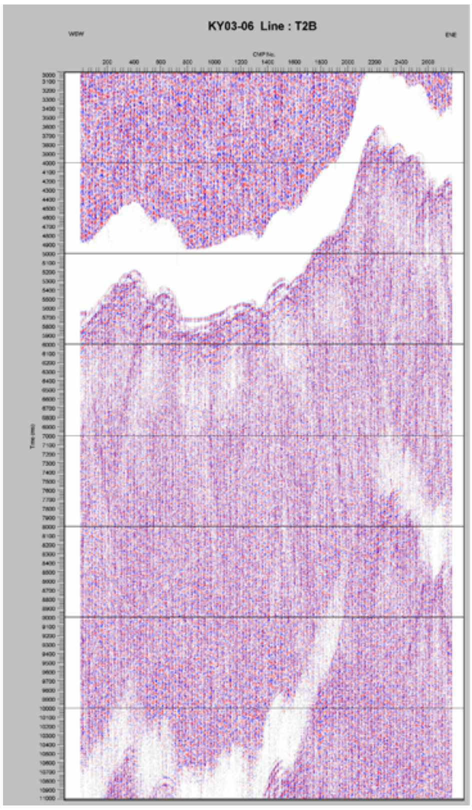
(g)


10km
KY03-06 Line : L6(2/2)
Y03-06 Line : L6(2/2)

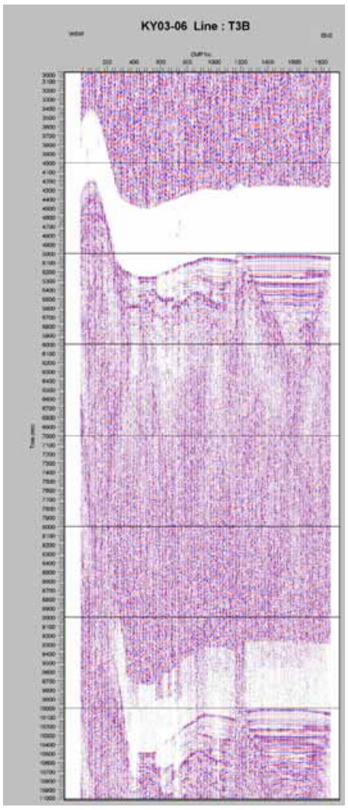
(h)



(h)



(i)



(j)

Figure 10. Reflection profiles. Horizontal and vertical axes indicate CMP number and traveltimes. (a) MR101c (b) L1 (c) L3 (d) L2 (e) L4 (f) L5 (g) L6 (h) T1B (i) T2B (j) T3B.

4. Participants

Scientists

Narumi TAKAHASHI[1]	Chief scientist
Aki ITO[1]	Assistant chief scientist

Marine Technicians

Makoto ITO[2]	Chief technician
Shinichi HOSOYA[2]	Technician
Ken SHIMIZU[2]	Technician
Masato SUGANO[2]	Technician
Ikumasa TERADA[2]	Technician
Hidenori SHIBATA[3]	Technician
Keigo SUZUKI[3]	Technician
Yuki OHWATARI[2]	Technician
Masaki MINAMIZAWA[2]	Technician

Crew

Sadao ISHIDA[2]	Captain
Toshinobu MIYATA[2]	Chief officer
Isao MAEDA[2]	2nd officer
Toshiyo OHHARA[2]	3rd officer
Kenta OHYA[2]	3rd officer
Tatsuo JITOZONO[2]	Chief engineer
Minoru TSUKADA[2]	1st engineer
Yoshinobu HIRATSUKA[2]	2nd engineer
Naoyuki TAKAHARA[2]	3rd engineer
Hideyuki AKAMA[2]	Chief radio officer
Kenji TAKAKUSU[2]	2nd radio officer
Hiroshi ITO[2]	3rd radio officer
Kingo NAKAMURA[2]	Boat'swain
Mikio ISHINOMORI[2]	Able seaman
Kozo YATOHGO[2]	Able seaman
Takao KUBOTA[2]	Able seaman
Shuichi YAMAMOTO[2]	Able seaman
Yuki YOSHINO[2]	Able seaman
Shozo FUJII[2]	Able seaman
Masaru MURAO[2]	No.1 oiler

Takeshi FUKUHARA[2]	Oiler
Masaki SHIINO[2]	Oiler
Hiroyuki OHISHI[2]	Oiler
Yuichi ISHII[2]	Oiler
Kaoru TAKASHIMA[2]	Chief steward
Kyoichi HIRAYAMA[2]	Steward
Koji KIRITA[2]	Steward
Hideo FUKUMURA[2]	Steward
Kazunori NAGANO[2]	Steward

1: Japan Marine Science and Technology Center

2: Nippon Marine Enterprise, Ltd.

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