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Kairei Cruise Report
KR16-11

Geophysical research on large earthquake by 4D observation using seafloor and borehole observatories off Kumano Nankai Trough

off Kumano Nankai Trough

Sep.14,2016-Sep.22,2016

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

Contents

1. Cruise Information

● KR16-11
● Kairei
● Title of cruise
Geophysical research on large earthquake by 4D observation using seafloor and borehole observatories off Kumano Nankai Trough
● Chief Scientist [Affiliation] Eiichiro Araki [JAMSTEC]
● Cruise period 2016/9/14 - 2016/9/22
● Ports of departure / call / arrival Wakayama port to Yokosuka JAMSTEC pier
● Research area Kumano Nada the Nankai Trough
● Research map
Figure 1. Ship track in KR15-08 cruise (solid black line)

2. Research Proposal and Science Party

● Title of proposal
Geological and Geophysical survey to elucidate mechanism of mega-thrust earthquake and tsunamis 4-D seismic survey using seafloor and subseafloor seismic observatories in the Nankai Trough test field

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Representative of the science party
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Shipboard science party
Shipboard Research Scientists
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Shore based science party
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3. Research/Development Activities

3.1. Background and Objectives

A cabled seismic observation system, named DONET (Dense Ocenfloor Network Systems for Earthquake and Tsunamis) have been in operation since 2011, which includes three-components seismometers deployed on the seafloor in the Nankai Trough area at twenty sites. Borehole observatories were constrcuted as a part of IODP (Integrated Ocean Drilling Program) NantroSEIZE program. Currently, two borehole observatories were installed in holes C0002G and C0010A. These were also connected to the DONET. The borehole observatories have borehole seismometers, including three-component seismometers at the bottom of the borehole with depth of 900 mbsf (C0002G) and 600 mbsf (C0010A). These observatories are distributed above the seismogenic plate boundary of the subducting Philippine Sea plate beneath Japan island arc, where large Tonankai earthquakes occur at 100-150 years intervals, and are mainly constructed for monitoring “passive” earthquake related phenomena, e. g. regional microearthquake, VLF events, seismic tremors, etc. In this area, the occurrence of the next Tonankai

earthquake is anticipated in the near future, therefore it is important not only to monitor seismic events, but also to evaluate stress state of the seismogenic plate interface where the large earthquake may initiate, and the temporal evolution of the stress state. Stress state may be inferred in terms of seismic velocity structure of the media, by such as seismic anisotropy or the velocity itself of the media, which changes through deformation of micro-structure in different condition of the stress state.

In this cruise, we aim to use these observatories as seismic receivers for acquiring "active" seismic signal excited by air gun source to reveal the above mentioned properties in the subduction zone.

The detailed objectives of this cruise are as follows:
-Experimental study on new data acquisition and processing technique, air gun circle-shooting data observed by DONET and IODP C0002G, C0010A three components seismometers, to obtain seismic velocity and anisotropy structure, which should be proxies of stress state beneath the subduction zone.
-Data acquisition for time-lapse survey to obtain time variation of subseafloor structure, including P- and S-wave velocity structure and velocity anisotropy for stress monitoring. This cruise is the forth cruise to obtain time-lapse dataset by the air gun system and DONET and IODP C0002G observatories. The first cruise, KR13-17 with the same seismic source and receivers as this cruise, was conducted on Nov. 2013. The second cruise, KR-15-05 also used the same seismic source, was conducted in March. 2015. The third cruise KR15-08 in June, 2015, was conducted relatively short interval after the KR15-05 cruise. The C0010A borehole observatory was installed in April 2016 and linked to DONET in July 2016. Therefore, this is the first cruise to shoot airgun near the C0010A borehole observatory.

3.2. Observation plan and results.

1) Seismic survey using DONET and C0002G, C0010A borehole seismometers and air gun array system

In this cruise, a tuned air gun array system was towed at 6 m depth and shot along circular and inline survey lines around DONET and C0002G, C0010A observatories. Air gun signals were recorded by seismometers deployed on these observatories. 7 circular (KMA01-R3, KMA04-R3, C0002G-R3, KMD15-R3, KMD13-R3, KMC12-R3, KMC09-R3) and 2 inline (NS1, EW1) survey lines were shot during this cruise. Fig. 1 shows location of these circular and linear shot tracks. Table 1. summarizes detail of the shot tracks such as location, period, number of shot, and ship movement direction in circular shooting.

For circular survey lines, the firing timing of air gun array was controlled by "distance mode" and the lay back parameter was set to zero. The trigger signal was therefore transmitted when R/V KAIREI passed just above each shot point. The positions of air gun array were measured by GPS attached to the gun array, and monitored by the shot point navigation system. To keep the positions of the air gun array being on circular lines, the ship crews and air gun operation team shared the shot point navigation system. Finally, precise ship control was achieved to maintain shot points. The air gun shootings at circular survey lines were started from North end of each survey lines, and were conducted with clockwise direction at every 2.0 degrees. The shooting intervals were 86.5 m. For inline survey lines (NS and EW lines), the shooting interval of 100m was maintained by using the distance mode. Test shooting observations were also conducted before and after the survey.

The seismic wave from the airgun array was received 20 seafloor observatories of DONET-1, and the long-term borehole monitoring system in IODP hole C0002G, C0010A as well as land seismic stations. To correct for the sound velocity structure in seismic and seafloor topography survey, we performed XBT seawater temperature profiling in three locations.

Fig. 3 shows airgun seismic profile obtained for two linear lines (EW1 and NS1) and each nearby seafloor stations (KMA03 and C0002G borehole). These profiles exhibit clear arrivals of refracted waves below the plate interface as well as reflection at the Philippine sea plate interface, although strong multiple reflections in seawater layer overlay in later arrivals. Fig. 4 shows circular airgun shot profiles for seafloor observatories KMA01 and KMA04, shot at 3 km offset from each station. For the case of circular shots in 3 km distance for seafloor observatories, the first motion is acoustic phase in the seawater. The profiles show multiple seafloor reflections with effects from seafloor topography.

2) General geophysical observation

Seafloor topography, shipboard gravity, and sea current data were collected during the cruise.

3.3. Observation Instruments

1) Tuned air gun array system (APG)

A tuned air gun array of 7,800 cubic inch that has 4 sub-arrays (32 units) was used for this survey. The standard air pressure was 2,000 psi (about 14 MPa). During this survey, the air gun array was maintained at a depth of 6 m below the sea surface, which is the same as in the previous cruises KR13-17 and KR15-05, KR15-08. Top and side views of the air gun array are shown in Fig.2.

2) DONET and borehole seismometers used as receivers

Seismometers deployed at DONET and seafloor boreholes at sites C0002G, C0010A were used as receivers for the airgun shooting. DONET three component broadband seismometers, CMG3T manufactured by Guralp systems, were used as receivers with the sampling rate of 5 ms (200 Hz). Seafloor borehole seismometers at holes C0002G and C0010A are three components broadband seismometer, CMG3TBD, and geophones, GS-11D. The sampling interval for these seismometers are 5 ms (200 Hz) and 8 ms (125 Hz), respectively. C0002G observatory also has seafloor seismometer, comprising three component geophone unit with sampling rates of 8 ms (125Hz). All acquired data were collected through DONET seafloor cable network, and data QC was conducted by land support scientists.

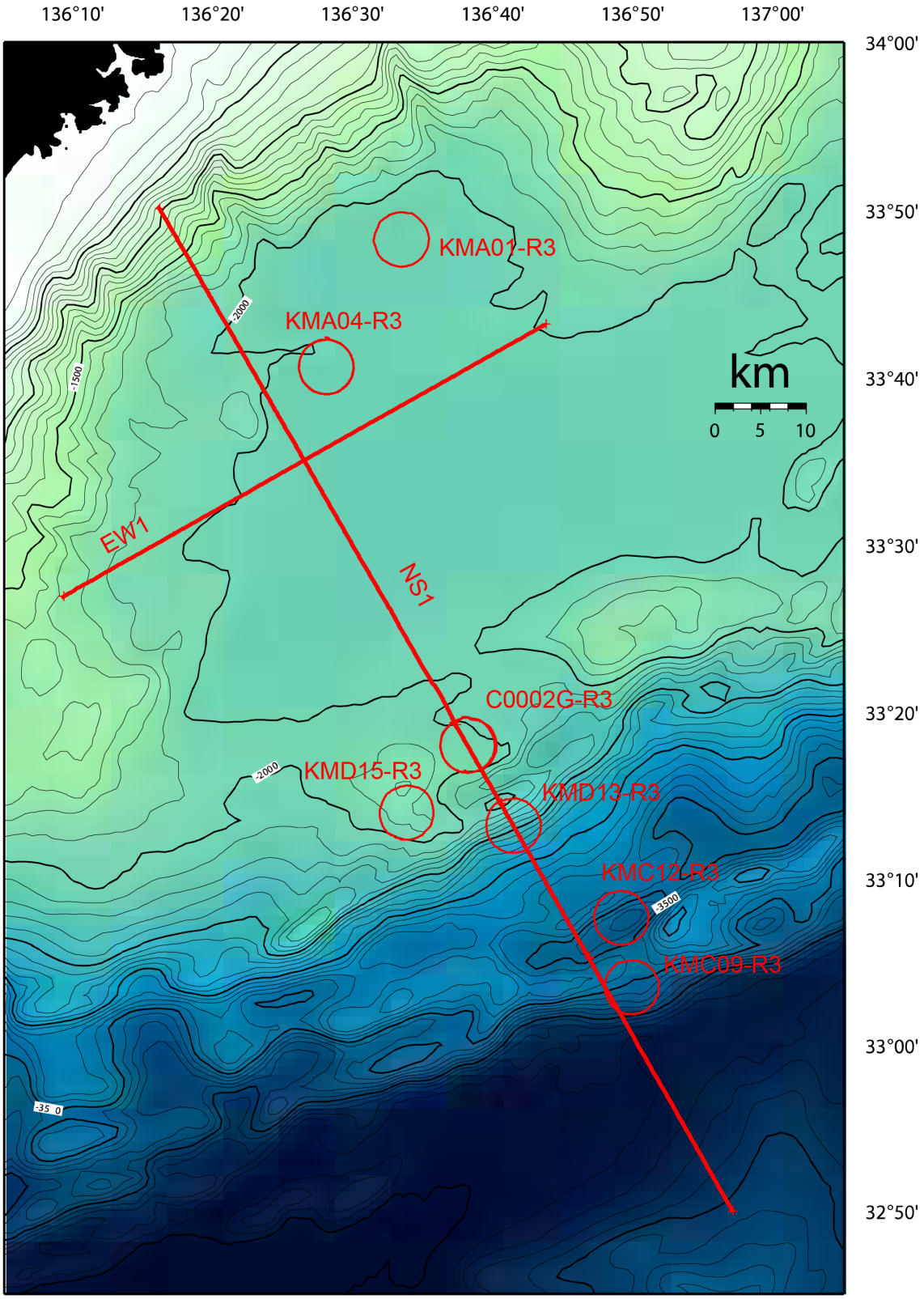

Figure 1. Survey area map of KR16-11. Red line: airgun shot track with line names.

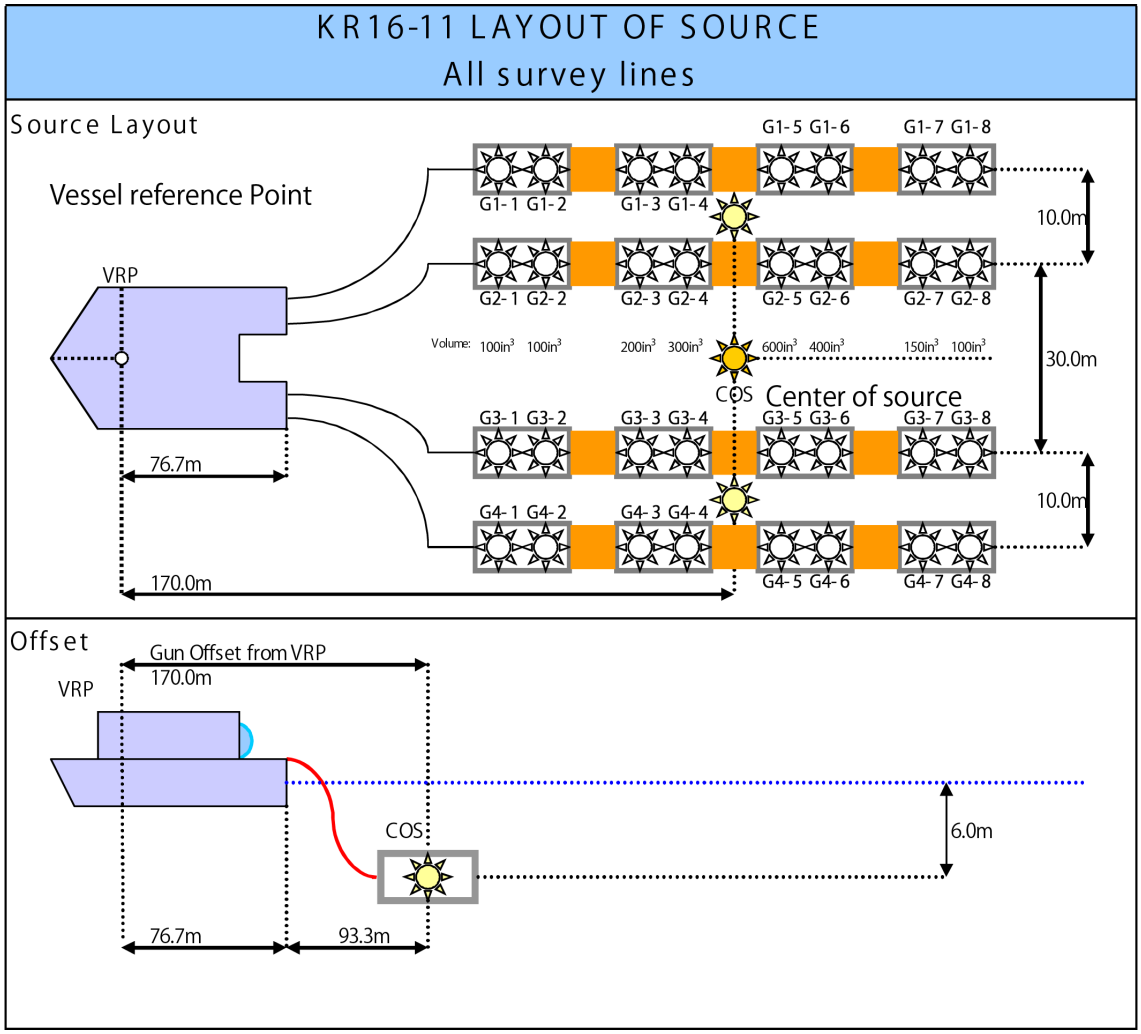

Figure 2. APG tuned airgun system layout in KR16-11 cruise.

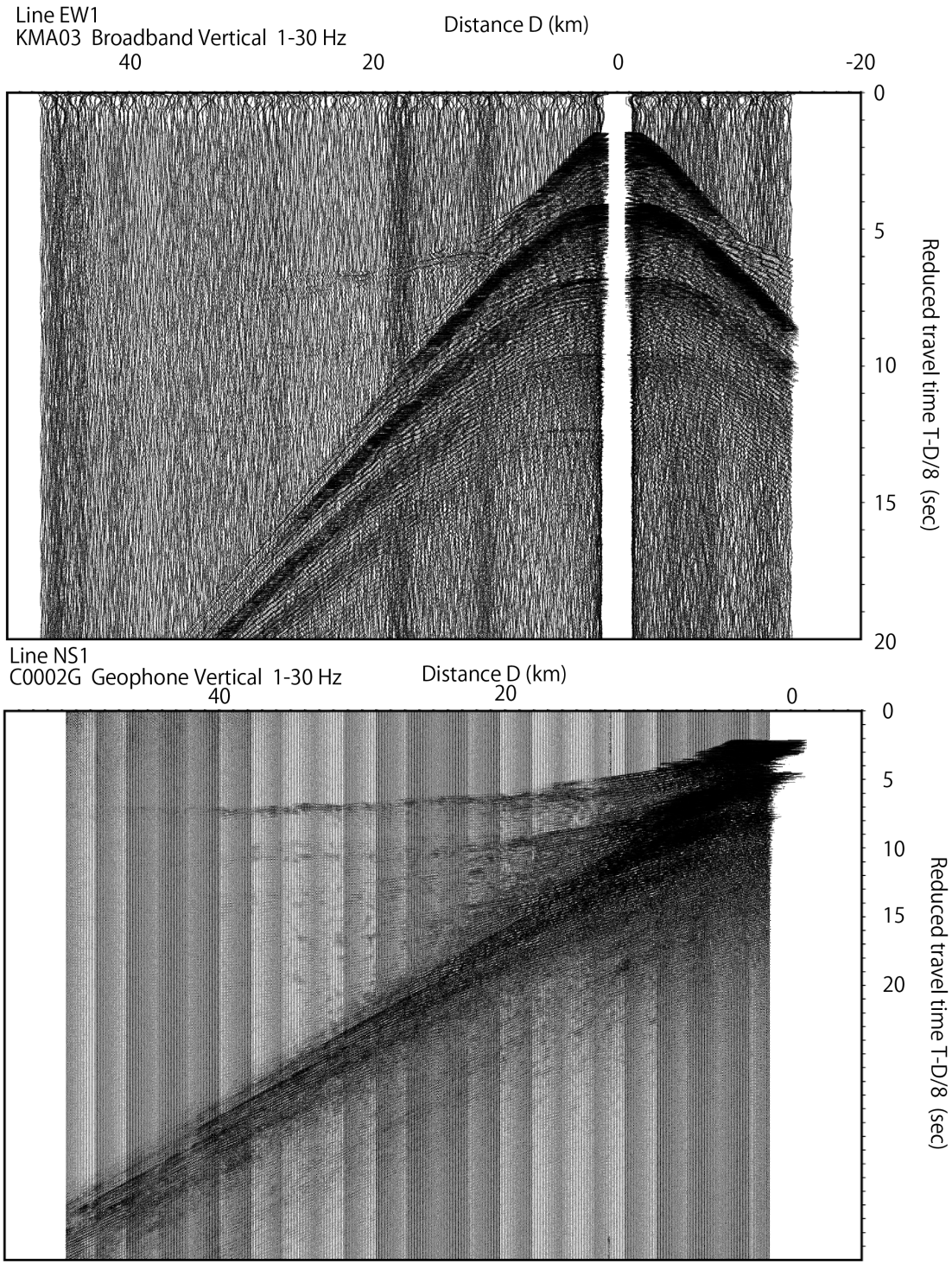

Figure 3. Airgun shot profiles for linear lines. Top: EW1 line received at KMA03 station. Bottom: NS1 line received at C0002G borehole station. Both profiles show vertical component records filtered at 1-30 Hz band. Time is reduced by 8 km/s.

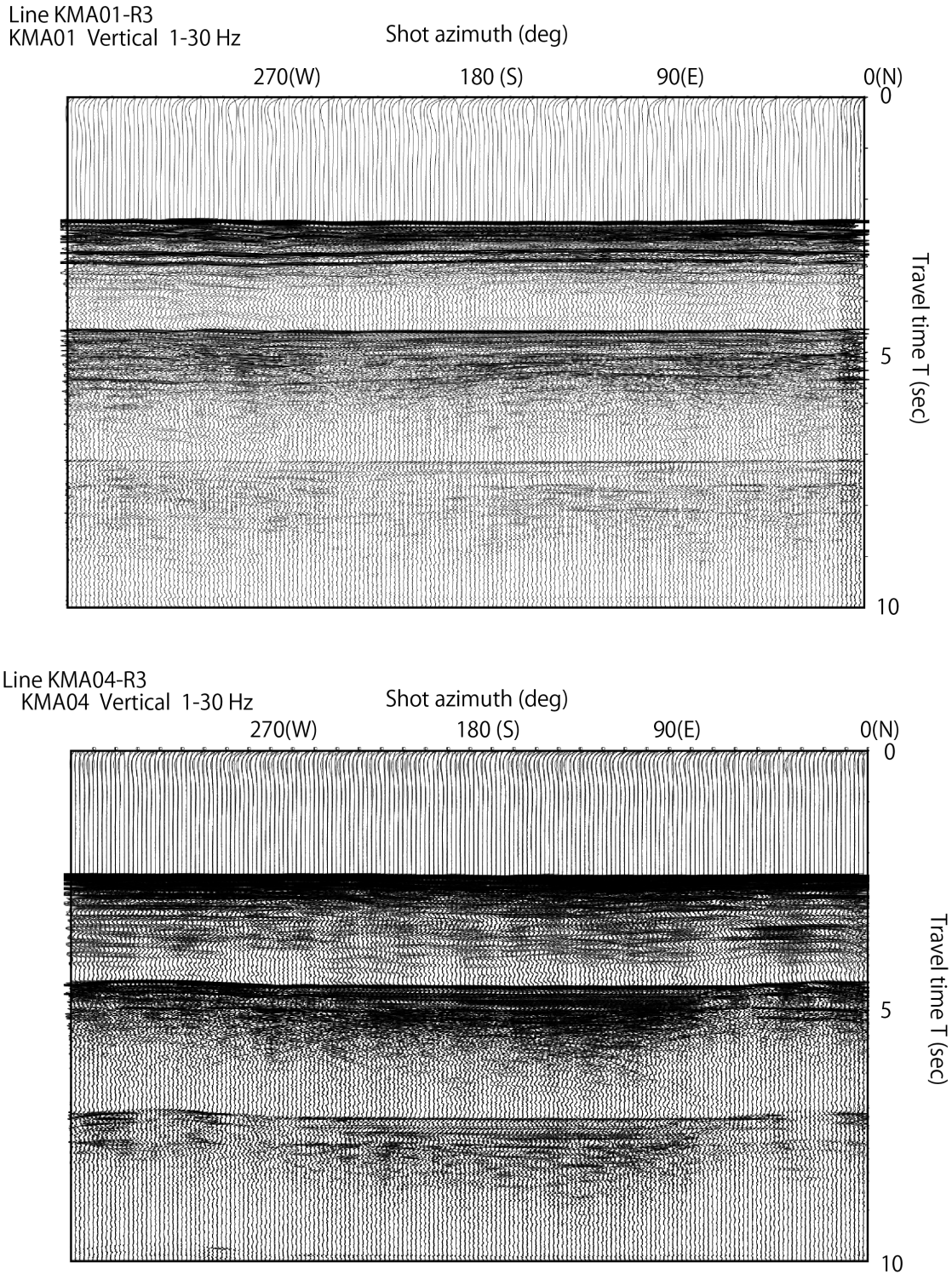

Figure 4. Airgun circular shot profiles. Top: KMA01-R3 line received at KMA01 station. Bottom: KMA04-R3 line received at KMA04 station. Both profiles show vertical component records filtered at 1-30 Hz band.

KR16-11 LINE LIST

NO.	LINE NAME	UKOOA P1/90 P2/91	DATE (UTC)	TIME (UTC)	F.S.P. F.G.S.P. L.G.S.P. L.S.P.	VESSEL POSITION Lat.	VESSEL POSITION Lon.	Depth (m)	NUMBER OF SHOT FGSP - LGSP (SP# Increment)	LENGTH FGSP - LGSP (km)	DIRECTION (°)	Mode (m)
			19/09/2016	02:01:42	1001	32_48.82302'N	136_57.38197'E	3875				
1	160919_wave	160919_wave.0.p190 160919_wave.0.p291	19/09/2016	02:01:42	1001	32_48.82302'N	136_57.38197'E	3875	98	-	-	Cycle (30.0sec)
			19/09/2016	02:50:12	1098	32_47.77752'N	136_57.50947'E	3799				
			19/09/2016	02:50:12	1098	32_47.77752'N	136_57.50947'E	3799	(+1)			
			16/09/2016	21:13:58	301001	33_19.62274'N	136_38.14972'E	2024				
2	C0002G-R3_0	C0002G-R3_0.0.p190 C0002G-R3_0.0.p291	16/09/2016	21:17:34	301003	33_19.60964'N	136_38.28341'E	2028	360	37.3	clockwise	Distance (2°)
			17/09/2016	07:47:53	301362	33_19.67620'N	136_38.21778'E	2026				
			17/09/2016	07:47:53	301362	33_19.67620'N	136_38.21778'E	2026	(+1)			
			15/09/2016	12:33:00	499986	33_26.94077'N	136_09.25469'E	1704				
3	EW1_0	EW1_0.0.p190 EW1_0.0.p291	15/09/2016	12:34:45	499988	33_26.99173'N	136_09.36864'E	1705	613	61.2	59.790	Distance (100.0m)
			15/09/2016	20:27:16	500600	33_43.27581'N	136_43.81667'E	1969				
			15/09/2016	20:27:16	500600	33_43.27581'N	136_43.81667'E	1969	(+1)			
			15/09/2016	23:07:12	11001	33_49.89988'N	136_33.42089'E	2025				
4	KMA01-R3_0	KMA01-R3_0.0.p190 KMA01-R3_0.0.p291	15/09/2016	23:11:02	11006	33_49.88365'N	136_33.75917'E	2024	181	18.7	clockwise	Distance (2°)
			16/09/2016	01:28:39	11186	33_49.87285'N	136_33.75722'E	2023				
			16/09/2016	01:28:39	11186	33_49.87285'N	136_33.75722'E	2023	(+1)			
			16/09/2016	03:29:53	41001	33_42.46043'N	136_28.04576'E	2041				
5	KMA04-R3_0	KMA04-R3_0.0.p190 KMA04-R3_0.0.p291	16/09/2016	03:32:24	41004	33_42.35866'N	136_28.25247'E	2043	540	56.1	clockwise	Distance (2°)
			16/09/2016	10:19:18	41543	33_42.30165'N	136_28.17834'E	2041				
			16/09/2016	10:19:18	41543	33_42.30165'N	136_28.17834'E	2041	(+1)			
			18/09/2016	07:29:38	91001	33_05.13939'N	136_49.87932'E	3427				
6	KMC09-R3_0	KMC09-R3_0.0.p190 KMC09-R3_0.0.p291	18/09/2016	07:34:57	91003	33_05.13724'N	136_50.01436'E	3525	180	18.6	clockwise	Distance (2°)
			18/09/2016	12:52:21	91182	33_05.10933'N	136_49.94558'E	3511				
			18/09/2016	12:52:21	91182	33_05.10933'N	136_49.94558'E	3511	(+1)			
			18/09/2016	15:16:22	121001	33_09.27259'N	136_49.12858'E	3311				
7	KMC12-R3_0	KMC12-R3_0.0.p190 KMC12-R3_0.0.p291	18/09/2016	15:22:06	121004	33_09.28209'N	136_49.33075'E	3322	180	18.6	clockwise	Distance (2°)
			18/09/2016	19:57:38	121183	33_09.28181'N	136_49.26300'E	3314				
			18/09/2016	19:57:38	121183	33_09.28181'N	136_49.26300'E	3314	(+1)			
			17/09/2016	20:58:04	131001	33_14.88317'N	136_41.42129'E	1908				
8	KMD13-R3_0	KMD13-R3_0.0.p190 KMD13-R3_0.0.p291	17/09/2016	21:03:28	131003	33_14.82678'N	136_41.55485'E	1953	180	18.6	clockwise	Distance (2°)
			18/09/2016	03:13:25	131182	33_14.80782'N	136_41.48657'E	1960				
			18/09/2016	03:13:25	131182	33_14.80782'N	136_41.48657'E	1960	(+1)			
			17/09/2016	11:28:51	151001	33_15.60770'N	136_33.78306'E	1775				
9	KMD15-R3_0	KMD15-R3_0.0.p190 KMD15-R3_0.0.p291	17/09/2016	11:35:19	151003	33_15.60637'N	136_33.91770'E	1783	181	18.7	clockwise	Distance (2°)
			17/09/2016	18:02:12	151183	33_15.56321'N	136_33.91511'E	1782				
			17/09/2016	18:02:12	151183	33_15.56321'N	136_33.91511'E	1782	(+1)			
			16/09/2016	13:03:16	401284	33_50.16857'N	136_16.07739'E	929				
10	NS1_0	NS1_0.0.p190 NS1_0.0.p291	16/09/2016	13:05:34	401281	33_50.03335'N	136_16.18573'E	935	658	65.7	149.354	Distance (100.0m)
			16/09/2016	20:39:25	400624	33_19.17605'N	136_37.26866'E	2006				
			16/09/2016	20:39:25	400624	33_19.17605'N	136_37.26866'E	2006	(-1)			
			17/09/2016	19:12:36	400630	33_19.44486'N	136_37.04935'E	2013				
11	NS1_1	NS1_1.0.p190 NS1_1.0.p291	17/09/2016	19:14:50	400627	33_19.30035'N	136_37.13835'E	2011	106	10.5	149.354	Distance (100.0m)
			17/09/2016	20:27:23	400522	33_14.38347'N	136_40.52635'E	1936				
			17/09/2016	20:27:23	400522	33_14.38347'N	136_40.52635'E	1936	(-1)			
			18/09/2016	04:25:59	400527	33_14.63497'N	136_40.40157'E	1945				
12	NS1_2	NS1_2.0.p190 NS1_2.0.p291	18/09/2016	04:28:12	400524	33_14.47138'N	136_40.45037'E	1874	201	20.0	149.354	Distance (100.0m)
			18/09/2016	06:52:37	400324	33_05.07712'N	136_46.83445'E	3619				
			18/09/2016	06:52:37	400324	33_05.07712'N	136_46.83445'E	3619	(-1)			
			18/09/2016	21:38:58	400330	33_05.37853'N	136_46.68403'E	3633				
13	NS1_3	NS1_3.0.p190 NS1_3.0.p291	18/09/2016	21:41:00	400327	33_05.22246'N	136_46.74744'E	3627	327	32.6	149.354	Distance (100.0m)
			19/09/2016	01:26:06	400001	32_49.90278'N	136_57.11520'E	3953				
			19/09/2016	01:26:06	400001	32_49.90278'N	136_57.11520'E	3953	(-1)			
							Total		3805	376.7		

Table 1. Airgun survey line list during KR16-11.

4. Cruise Log

Time is JST.

Sep. 15

0830 Departed Wakayama port.
~16h Arrived near start point of EW1 line
Installed paravane and airgun array.
Test airgun shooting
Airgun shooting
EW1 (21:33-)

Sep. 16

Airgun shooting
EW1 (-5:27)
KMA01-R3 (8:07-10:28)
KMA04-R3 (12:29-19:19)
NS1 (21:03-)

Sep. 17

Airgun shooting

NS1 (-05:39)
C0002G-R3 (6:13-16:47)
KMD15-R3 (20:28-)

Sep. 18
KMD15-R3 (-03:02)
NS1 (the section from near C0002G-R3 04:12-05:27)
KMD13-R3 (05:58- 12:13)
NS1 near KMD13-R3 to near KMC09-R3 (13:25 -15:52)

Sep. 19
KMC12-R3 (0:16-4:57)
NS1 near KMC09-R3 to end point (6:38-10:26)
Test shot
Left survey area

Sep. 20
Arrive at Yokosuka JAMSTEC

● 5. Notice on Using

This cruise report is a preliminary documentation as of the end of cruise.
This report is not necessarily corrected even if there is any inaccurate description (i.e. taxonomic classifications). This report is subject to be revised without notice. Some data on this report may be raw or unprocessed. If you are going to use or refer the data on this report, it is recommended to ask the Chief Scientist for latest status.
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