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Multi-channel seismic reflection experiments in Izu-Ogasawara arc -2005 cruises-

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Abstract Multi-channel seismic (MCS) reflection experiments were carried out in 2005 to investigate a typical oceanic island arc system by obtained crustal structures in the Izu-Ogasawara region, by using R/V Kairei of Japan Agency for Marine-Earth Science and Technology (JAMSTEC). Swath-bathymetry, geomagnetic and gravity data are simultaneously observed during these cruises. In 2005, we collected a total of 3720km of MCS data: 1739.65km in KR05-06 and 1980.35km in KR05-16 cruises. The clear seismic reflection profiles of the subducting Pacific plate, forearc tectonic features and backarc basin structures, for the investigation of the crustal growth, showing that all of the MCS data collected are of good quality by onboard processing.

Keywords: Izu-Ogasawara arc, Crustal structure, Seismic reflections, MCS

1. Introduction

Oceanic island arc is one of the best fields to study a process of crustal growth, because the tectonics of oceanic island arc is simpler than that of continental island arc. The oceanic arc grew with subduction of an oceanic crust beneath another oceanic crust with simple structure, while the continental arc was separated from the continental margin with complex structure. The arc-arc collision is one of the important elements to understand the nature of the crustal growth but still poorly understood. The collision between the northern Izu-Ogasawara arc and the Honshu arc affects until 300 km south, and the effects are presented as a crustal shortening and a crustal thickening (Aoike et al., 2001).

The Izu-Ogasawara island arc occupies almost a northern half of the Izu-Ogasawara-Mariana arc, which extends 2500 km south from Tokyo and is one of the largest convergent margins on the earth. This Izu-Ogasawara island arc is characterized by a typical intra-oceanic island arc involving trench, arc and backarc basin, i.e., the Izu-Ogasawara trench, the Izu-Ogasawara arc and the backarc Shikoku basin. The Pacific plate is subducting in the northwest direction, beneath the Izu-Ogasawara arc that belongs to the Philippine Sea plate. The Shikoku basin, which lies to the west of the Izu-Ogasawara arc, has a magnetic lineation pattern indicating typical structure oceanic crust. The evolution of the Izu-Ogasawara arc was started in Eocene (˜50 Ma). By late Oligocene (˜25 Ma), the Shikoku basin had begun to spread, causing the proto Izu-Ogasawara arc to be split into two parts. One is the Kyushu-Palau ridge, and the other is the Izu-Ogasawara arc.

The Izu-Ogasawara arc has granitic middle crust with P-wave velocity (Vp) of 6 km/s and relatively thick lower crust, and a total thickness of the whole crust is about 20 km (Suyehiro et al., 1996). The subduction of the oceanic crust beneath the arc has occurred since Eocene time and the crustal growth has started (Karig et al., 1975), and it is reported that the initial oceanic arc does not have the granitic layer (Tatsumi et al., 2003). Macpherson and Hall (2001) suggested that there was initial plume activity with basalt-type magmatism and that the granitic crust was generated at almost the same time with a high heat flow stage in the evolution history of the arc. After the Shikoku and the Parece Vela basins were spread in about 30-15 Ma (Okino et al., 1998), new volcanism has started near the current arc position and the oceanic island arc has been growing.

Concerning the above crustal growth by arc-arc interaction and subsequent crustal thickening and shortening, Aoike et al. (2001) suggested that a basement high called the Shinkurose in the northern Izu-Ogasawara arc had been developed by the crustal thickening. And the new subduction of the Philippine Sea Plate at the southern foot of the Zenisu ridge has been reported by a wide-angle refraction study (Nakanishi et al., 1999), an MCS study (Takahashi et al., 2002) and a microseismic-

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ity study (Shiobara et al., 1996). The new subduction is not inconsistent with the crustal shortening of the northern Izu-Ogasawara arc. Recently, Tamura et al. (2002) proposed the hot finger thesis, which shows finger-like high temperature regions within the mantle wedge and causes the spatial heterogeneity of the volcanoes along the arc. The heterogeneous volcanic activity would form a variety of crustal structure along the arc.

In order to figure out the present detailed structure and the 50 m.y. evolution history of the entire Izu-Ogasawara intra-oceanic island arc system, we have been collecting multi-channel seismic (MCS) reflection data in this region. This paper reports the primary results of the MCS experiments that were conducted in 2005 cruises.

2. Data acquisition

Continually in previous experiment (Tsuru et al., 2005), we conducted two MCS cruises using R/V Kairei of Japan Agency for Marine-Earth Science and Technology (JAMSTEC) in 2005: KR05-06 and KR05-16 (Fig.1). During KR05-06 cruise from May 26 to June 20, we obtained three MCS profiles (IBr3, IBr6, and IBr13) with 1739.65km of total line length (red lines of Fig.1). There are many troubles such as air leak in this cruise. Line IBr3 is along the southern part of Izu-Ogasawara arc, and the line length is 847.5km. Line IBr6 covers the Shikoku basin and the middle Izu-Ogasawara arc, and the line length is 593.5km. Line IBr13 which crosses the Parece Vela basin, the joint section between the Izu-Ogasawara arc and the Mariana

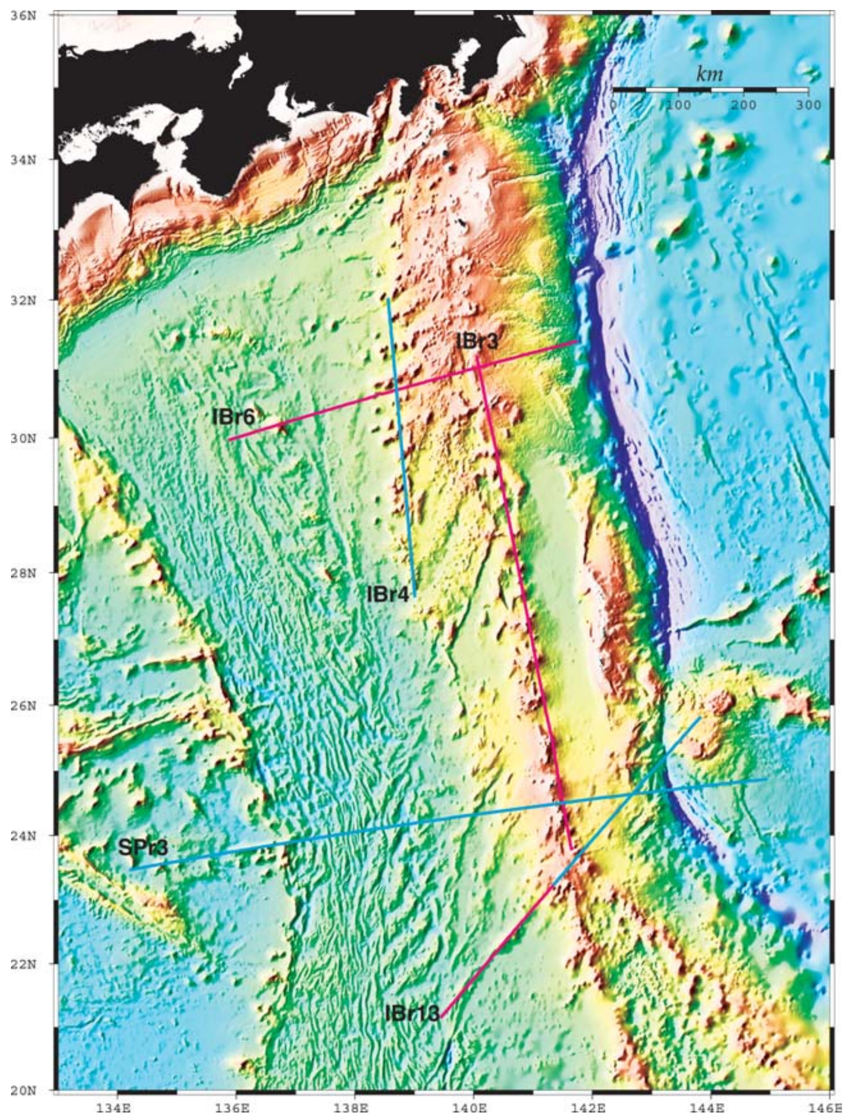

Figure 1: Study area and survey line of 2005 cruise. Red and blue lines show survey lines of KR05-06 cruise and KR05-16 cruise, respectively.

arc, and the Mariana trench and reaches the Ogasawara Plateau is observed only in the western half part of planed line (319.0km) in this cruise. During KR05-16 cruise from November 11 to December 5, 1980.35km of MCS data were collected on the east half of line IBr13, line SPr3, and IBr4 (blue lines of Fig.1). Line SPr3 started from east foot of the Oki-Daito ridge, went across the Kyushu-Palau ridge, the Shikoku-basin and the southernmost Izu-Ogasawara arc, and reached the south foot of the Ogasawara Plateau. The total line length is 1113.35km. This line was observed separately for two parts: SPr3 and SPr3R. Line IBr4 is along the Nisi-Sitito ridge, and line length is 487km. As a result, a total of 3742.35km of MCS data are successfully collected in 2005. Survey line information is summarized in Table 1.

2.1 Source

To obtain MCS data of good quality, shooting was made by a shot spacing of 50 m, which corresponds to 20-30 s in shooting time interval depending on the vessel speed. We used an airgun array with total capacity of 12,000 cubic inches (200 liters), which consists of eight Bolt long life airguns with 1,500 cubic inches (25 liters) each. The standard air pressure was 2000 psi (14 MPa). Fig.2 shows two strings of sub-arrays were deployed at the port and starboard sides of the vessel. Their width was expanded to 88.0 m by a paravane system and the central position of the array was set 197.0 m behind the ship antenna position.

In 2005 cruise, shooting was stopped or temporarily suspended due to bad weather conditions, air leaks and streamer troubles. As a result, line IBr3 was divided into eight segments, line IBr6 into three segments, line IBr13 into six segments, and line SPr3 and SPr3R into three segments each. There was no stop shooting at the observation of line IBr4. The shot logs were summarized in Table.2.

2.2 Receiver

During the shooting, we towed a 204-channel hydrophone streamer cable made by Sercel Inc. and received seismic reflection data from the subsurface by the cable. The streamer cable is composed of 68 active sections, and each active section is 75m long and consists of three receiver groups (channels). The active modules including 24bit A/D converters are inserted every four active sections and collect seismic data from the four sections. The interval of each group is 25m. The lengths of total active section and lead-in cable are 5100m (75m × 68) and 110m, respectively. Hydrophone sensors (Benthos Reduce Diameter Array hydrophone) with sensitivity of 20V/Bar are used and the signals from 32 sensors in the same group (channel) are stacked before A/D conversion. The towing depth of streamer cable was controlled to be 15m below sea surface by the depth controller called Bird (DigiCOURSE System3).

During the observation on line IBr3, IBr13, and IBr4, seismic records of some channels contained large noises, we therefore removed these records at data processing; channel 105 at line IBr3, channel 47, 105, and 168 at line IBr13, and channel 120 and 144 at line IBr4. There were no noisy records in the other lines.

2.3 Recording and navigation systems

The recording system is the SYNTRAK960-24, which was made by Sercel Inc., and outputs seismic data onto 3590E tapes with SEG-D 8048 format. We set system delay to be 150ms and water delay to be 0-6000ms depending on water depth. The sampling rate was 4ms and the record length was 18s.

The Differential Global Positioning System (DGPS)

Table 1:Survey line list.

Cruise ID	Line ID	Start position	End Position	SP number	Line Length
KR05-06	IBr3	31°11'45.298"N 140°02'57.824"E	23°46'43.722"N 141°38'50.595"E	18426 - 35164	847.50 km
	IBr6	29°57'54.367"N 135°51'42.368"E	31°24'36.508"N 141°45'29.735"E	10890 - 22633	593.50 km
	IBr13	21°08'50.007"N 139°26'35.475"E	23°19'10.548"N 141°25'27.525"E	11027 - 17338	319.00 km
KR05-16	IBr13	23°13'59.975"N 141°20'38.340"E	25°49'42.555"N 143°49'37.709"E	17086 - 24726	382.00 km
	SPr3	23°28'15.339"N 134°12'58.439"E	24°06'04.510"N 138°20'17.483"E	10675 - 19192	427.85 km
	SPr3R	24°52'12.685"N 144°56'58.478"E	24°05'15.900"N 138°14'27.048"E	10104 - 23814	685.50 km
	IBr4	27°39'21.157"N 139°00'23.724"E	32°01'52.392"N 138°33'24.179"E	9851 - 19590	487.00 km
Total line length in 2005 fiscal year					3742.35 km

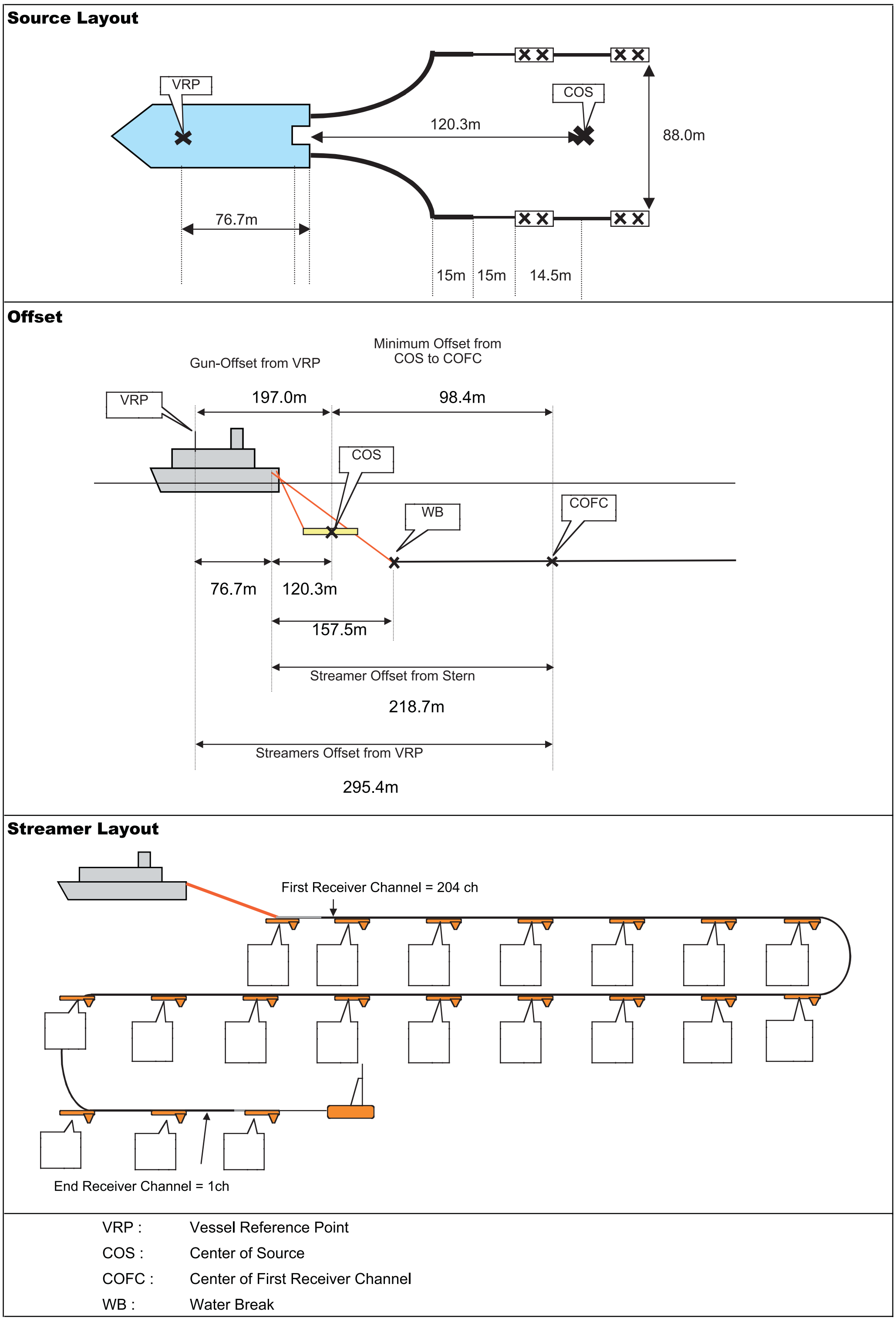

Figure 2: Geometry of airgun system and the hydrophone streamer. Top figure shows the source (airgun system) layout, middle one represents source-receiver offset, and bottom one is streamer cable configuration.

Table 2:Activity log during 2005 MCS cruises.

Cruise ID	Date	Remarks
KR05-06	26-May	Departure from Yokosuka
	27-May	Starting IBr3 airgun shooting
	28-May	IBr3 airgun shooting
	29-May	IBr3 airgun shooting
	30-May	IBr3 airgun shooting
	31-May	IBr3 airgun shooting
	1-Jun	IBr3 airgun shooting
	2-Jun	IBr3 airgun shooting
	3-Jun	IBr3 airgun shooting
	4-Jun	Weather stand by
	5-Jun	Weather stand by
	6-Jun	Weather stand by
	7-Jun	Weather stand by
	8-Jun	Starting IBr13 airgun shooting
	9-Jun	IBr13 airgun shooting
	10-Jun	IBr13 airgun shooting
	11-Jun	IBr13 airgun shooting and transit to Omaezaki
	12-Jun	Transit to Omaezaki
	13-Jun	Arrival and supply of spare parts at Omaezaki. Transit to the start point of IBr6
	14-Jun	Starting IBr6 airgun shooting
	15-Jun	IBr6 airgun shooting and weather stand by
	16-Jun	Weather stand by and IBr6 airgun shooting
	17-Jun	IBr6 airgun shooting
	18-Jun	IBr6 airgun shooting
	19-Jun	IBr6 airgun shooting and transit to JAMSTEC
	20-Jun	Transit and arrival at JAMSTEC
KR05-16	11-Nov	Departure from Apra port, Guam
	12-Nov	Transit to western part of survey line SPr3
	13-Nov	Adjustment of investment equipments and Start SPr3 airgun shooting
	14-Nov	Suspended SPr3 airgun shooting due to air leak and recovery and repair airgun Restart SPr3 airgun shooting
	15-Nov	Suspended SPr3 airgun shooting due to air leak and recovery and repair airgun
	16-Nov	Restart SPr3 airgun shooting Suspended SPr3 due to bad weather and sea condition and Transit to IBr16
	17-Nov	Maintenance of air gun and Transit to survey line IBr16
	18-Nov	Stand by due to approach the low pressure and transit to survey line IBr13
	19-Nov	Maintenance of air gun and Start IBr13 airgun shooting
	20-Nov	Suspended IBr13 airgun shooting due to air leak and recovery and repair airgun Restart IBr13 airgun shooting
	21-Nov	Suspended IBr13 airgun shooting due to cutting off the streamer cable Recovery the cut streamer cable
	22-Nov	Recovery the streamer cable for normal direction
	23-Nov	Suspended investment equipment dut to air leak, and recovery airgun Restart IBr13 airgun shooting
	24-Nov	Finish IBr13 airgun shooting, and transit to survey line SPr3R
	25-Nov	Start SPr3R airgun shooting
	26-Nov	SPr3R airgun shooting all day
	27-Nov	Suspended SPr3R airgun shooting due to air leak and recovery and repair airgun Restart SPr3R airgun shooting
	28-Nov	Suspended SPr3R airgun shooting due to air leak and recovery and repair airgun Restart SPr3R airgun shooting
	29-Nov	Finish SPr3 airgun shooting and transit to survey line IBr4
	30-Nov	Start IBr4 airgun shooting
	1-Dec	IBr4 airgun shooting all day
	2-Dec	IBr4 airgun shooting all day
	3-Dec	Finish IBr4 airgun shooting and transit to JAMSTEC
	4-Dec	Transit to JAMSTEC
	5-Dec	Arrival at JAMSTEC

was used for the positioning. We adopted StarFire system as a main positioning system and SkyFix as a backup. The accuracy is reported to be about 0.4 m in StarFire and 5 m in SkyFix. As navigation software for seismic data acquisition, we used the SPECTRA made by Concept Inc. Positioning data collected from StarFire as well as SkyFix were sent to RTNμ (a network interface made by Concept Inc.) via a terminal server connected to LAN in the vessel. The RTNμ obtains time signals of DGPS (StarFire) from the original antenna. Then, the navigation data is sent to the PC Linux machine, on which the SPECTRA was installed and displayed. Shot times and Shot Point (SP) are set on the SPECTRA and then a trigger signal is sent to the recording system and the gun controller (GCS90), as follows.

First, a system-start-signal generated from the SPECTRA is sent to the recording system via the RTNμ, and soon after, the recording system send back a reply signal to the SPECTRA when the system is ready for recording. Second, the SPECTRA sends a trigger signal to the gun controller and the recording system sends a data-acquisition-start-signal to the streamer cable. The gun controller sends back an internal-time-break-signal to the RTNμ and recording system, and also sends trigger-signals to the eight airguns as shooting orders just after receiving the trigger signal from the SPECTRA. At the same timing with shot, the gun controller starts to gather both position data of the airgun sub-arrays from the airgun positioning system (RGPS) and first breaks of near-field shot records from monitor hydrophones nearby guns. Then seismic data are transmitted from the active modules to the recording system and position data of the streamer are sent from the depth controllers (so-called birds). After that, the position data of both the airgun and streamer cable are stored into the SPECTRA via the RTNμ and are also sent to the recording system. Finally, the seismic data are output to a tape drive and recorded on 3590E tapes. The recording system and gun controller are connected via RTNμ as shown by Fig.3.

3. Onboard processing and preliminary interpretation of MCS data

Raw MCS reflection data are processed onboard for the purpose of quality control and preliminary interpretation of tectonic structures in the study areas. The onboard data processing was conducted preserving relative amplitudes under the conventional processing scheme, as show in Fig.4, which contains noisy-trace editing, 5-100 Hz band-pass filtering, deconvolution with a 28-ms-length (IBr4, SPr3, SPr3R) and a 32-ms-length (IBr3 and IBr13) predictive distance and a 300-ms-length operator, amplitude compensation by T**2 (T is two way traveltime), velocity analysis, multiple suppression by radon transform, muting, CDP stacking and post-stack time migration.

Resulting MCS profiles are shown in Figures.5-11 and clearly exhibit sedimentary covers on the acoustic basement, which evidenced that all of the raw data observed has good enough quality to interpret sedimentary structures and then meets the primary requirement. Secondary requirements, for instance interpretation of deep crustal structures, will be achieved by the results of data processing at the laboratory, however such work is beyond the scope of this report.

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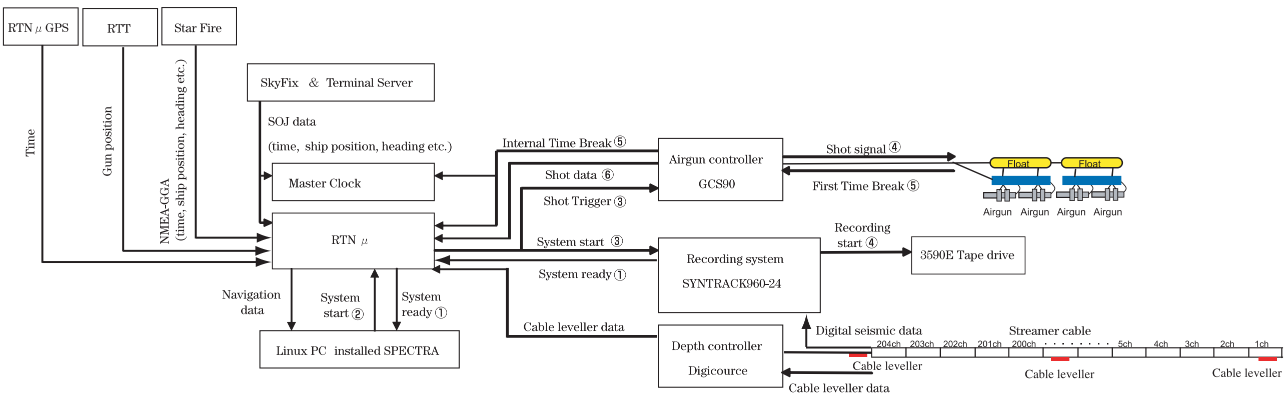
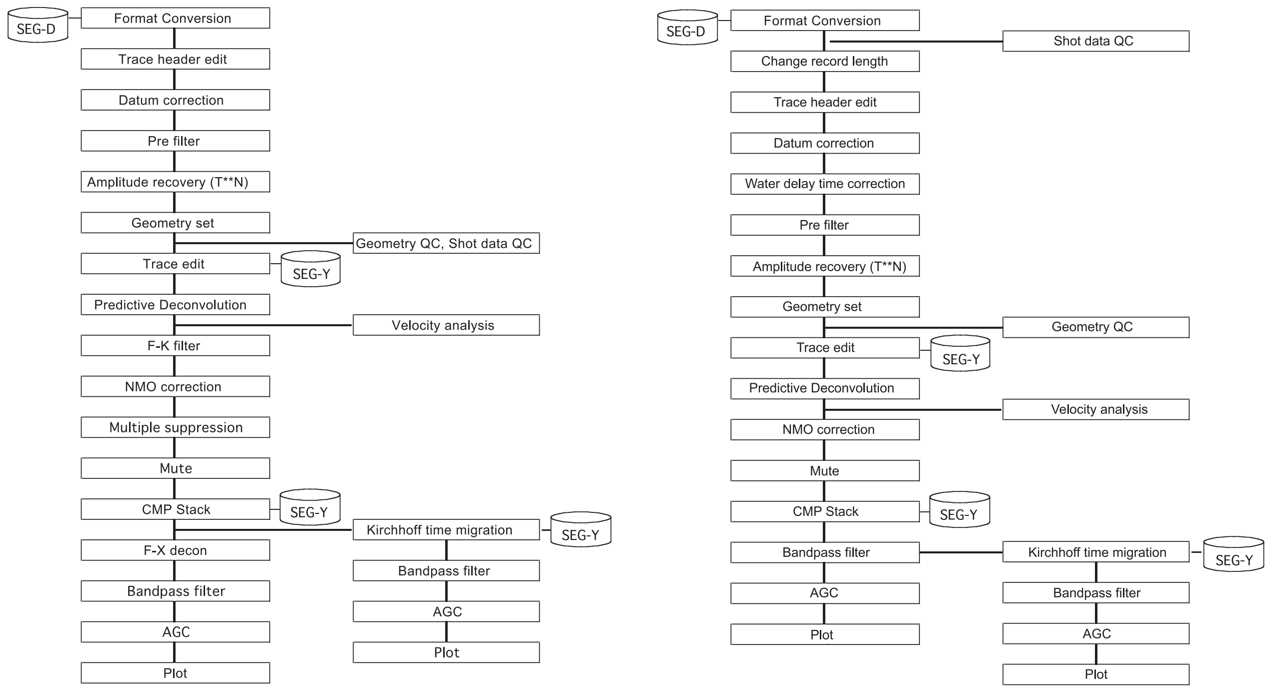


Figure 3: MCS recording system on R/V Kairei. Circled numerals show the signal transfer flow in the system.



(a) (b)

Figure 4: Flow chart of onboard data processing. (a) KR05-06 flow (b) KR05-16 flow

R/V Kairei. We are grateful to Drs. N. Takahashi, Y. Kaiho, S., Kodaira, S. Miura and T. Sato for their planning advise in these cruises.

References

1) Aoike, K., Soh, F., Tokuyama, H., and Taira, A., Tectonics of Izu collision zone and crustal materials circulation (in Japanese), Monthly Chikyu Extra, 32, 180-190 (2001).
2) Suyehiro, K., N. Takahashi, Y. Ariie, Y. Yokoi, R. Hino, M. Shinohara, T. Kanazawa, N. Hirata, H. Tokuyama, and A. Taira, Continental crust, crustal underplating, and low-Q upper mantle beneath an oceanic island arc, Science, 272, 390-392,(1996).
3) Karig, D. E. and G. F. Moore, Tectonic complexities in the Bonin arc system, Tectonophysics, 27, 97-118 (1975).
4) Tatsumi, Y., Kogiso, T., The subduction factory: its role in the evolution of the Earth’s crust and mantle, Geological Society of London, Special Publication, 219, 55-80 (2003).
5) Macpherson, C. G. and R. Hall, Tectonic setting of Eocene boninite magmatism in the Izu-Bonin-Mariana forearc, Earth Planet. Sci. Lett., 186, 215-230 (2001).
6) Okino, K., S. Kasuga and Y. Ohara, A new scenario of the Parace Vela basin genesis, Mar. Geophys. Res., 20, 21-40 (1998).
7) Nakanishi, A., Miura, S., Park, J.-O., Higashikata, T., Kaneda, Y., Kono,Y., Takahashi, N., Kinoshita, H., Crustal Structure Around the Eastern Nankai Trough From OBS Profiles -Results of the KAIREI Cruise KR98-06, Proceedings of workshop on Recurrence of Great Interplate Earthquakes and its Mechanism,pp. 127-133, (1999).
8) Takahashi, N., Amano, H., Hirata, K., Kinoshita, H., Lallemant, S., Tokuyama, H., Yamamoto, F., Taira, A., and Suyehiro, K., Faults configuration around the eastern Nankai trough deduced by multichannel seismic profiling, Marine Geology, 187, 1/2, 31-46 (2002).
9) Shiobara, H., A. Nakanishi, S. Kodaira, R. Hino, T. Kanazawa, and H. Shimamura, Seismicity and crustal structure around the eastern Nankai Trough by ocean bottom seismographic observation (abstract), Eos Trans. AGU, 77(46), Fall Meet. Suppl., F704 (1996)
10) Tamura, Y., Y. Tatsumi, D. Zhao, Y. Kido, and H. Shukuno, Hot fingers in the mantle wedge: new insights into magma genesis in subduction zones, Earth Planet. Sci. Lett. 197, 105-116 (2002).
11) Tsuru, T., J.-O. Park, T. No, K. Takizawa and Y. Kaneda: Cruise report of 2004 seismic reflection surveys in Izu-Ogasawara Arc, JAMSTEC Rep. Res. Dev. 2, 1-12 (2005).

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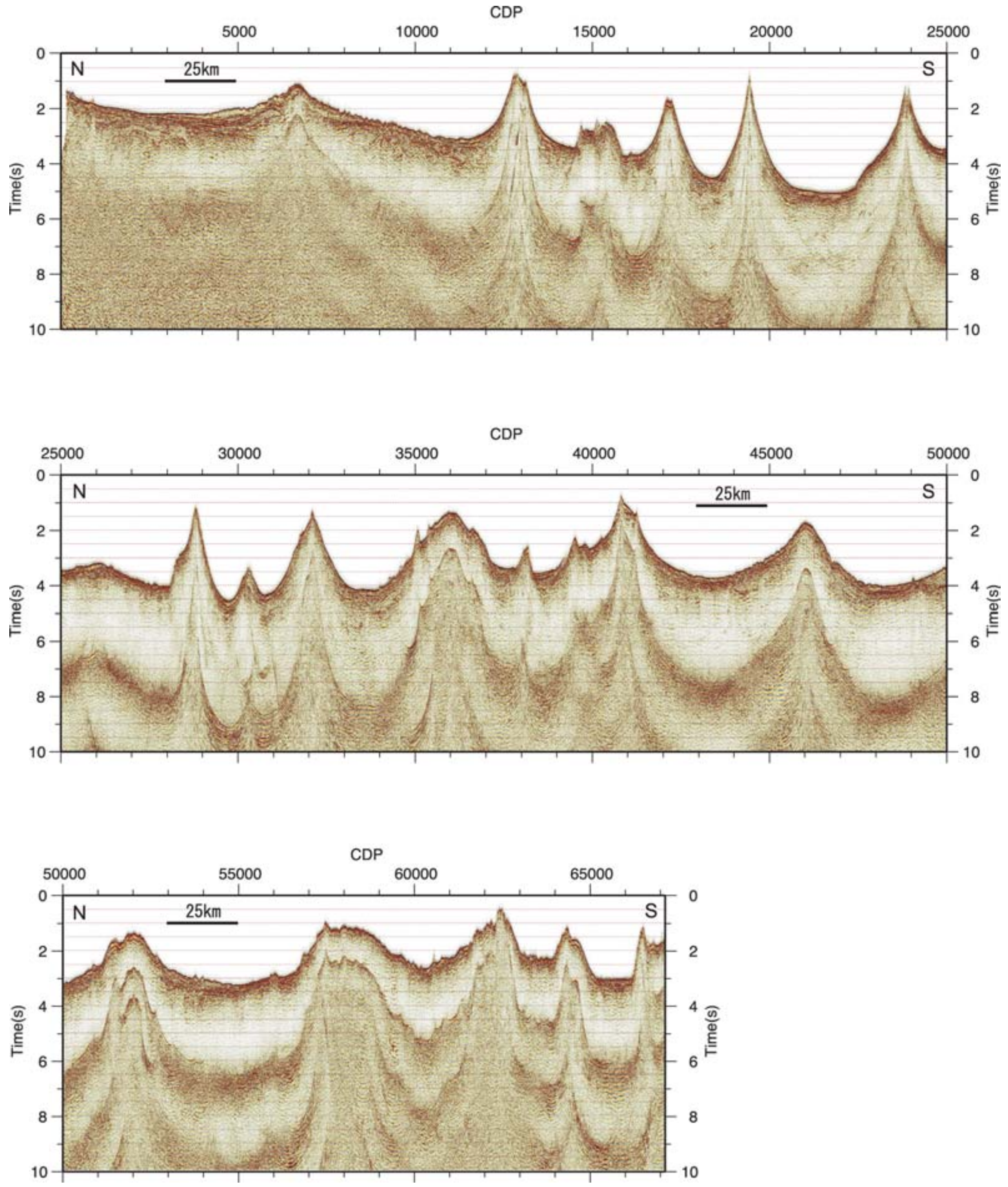

Figure 5: MCS profile of line IBr3. The profile is separately shown by three panels (a-c).

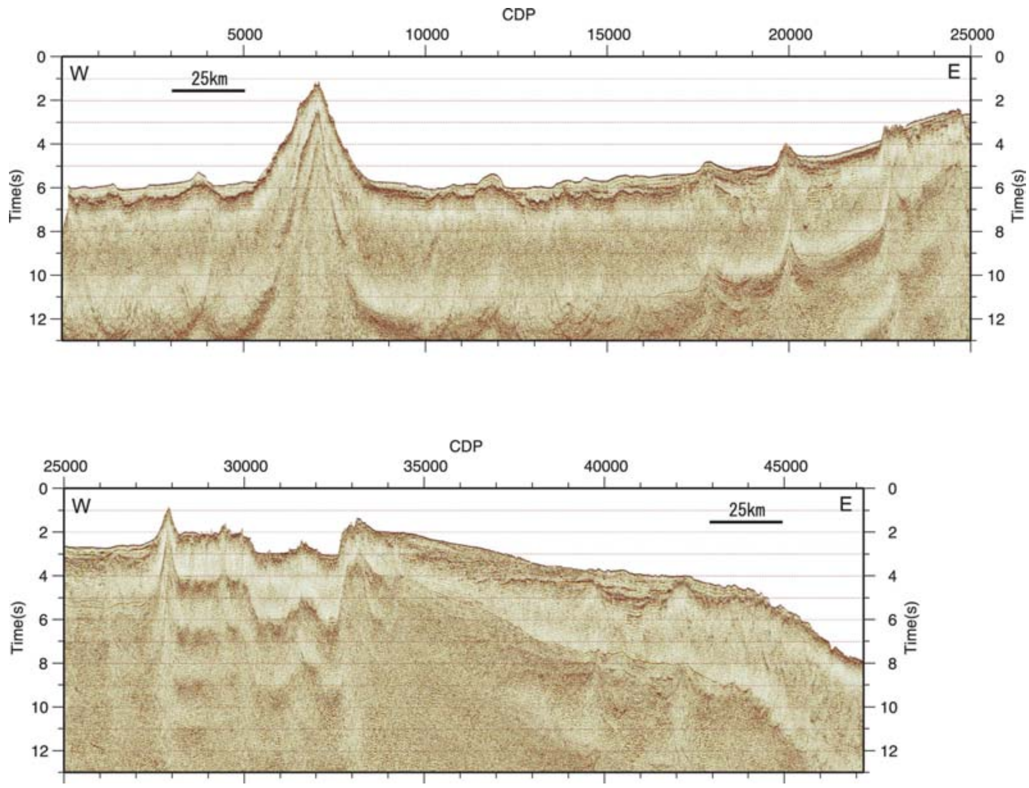

Figure 6: MCS profile of line IBr6. The profile is separately shown by two panels (a-b).

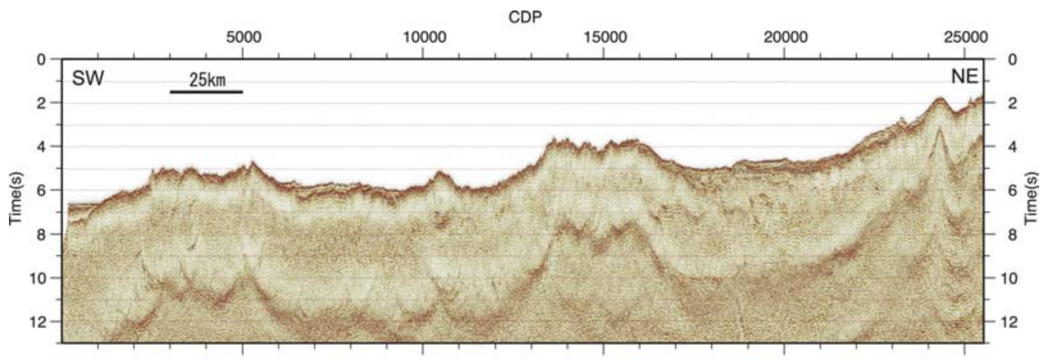

Figure 7: MCS profile of line IBr13 of the KR05-06 cruise.

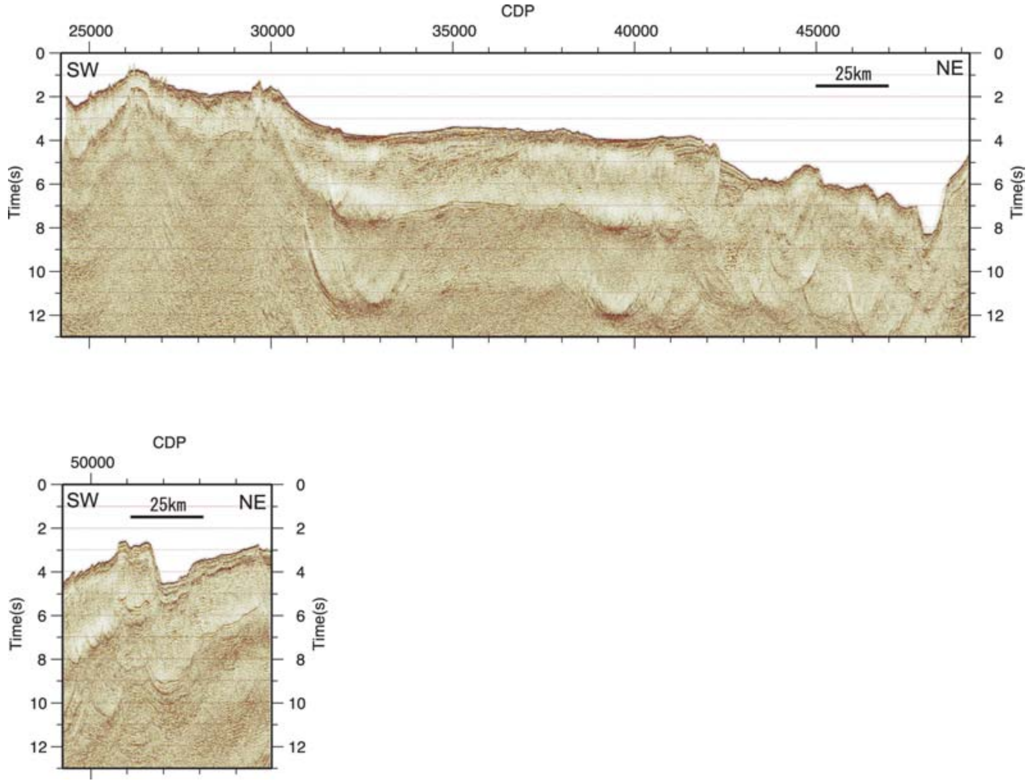

Figure 8: MCS profile of line IBr13 of the KR05-16 cruise. The profile is separately shown by two panels (a-b).

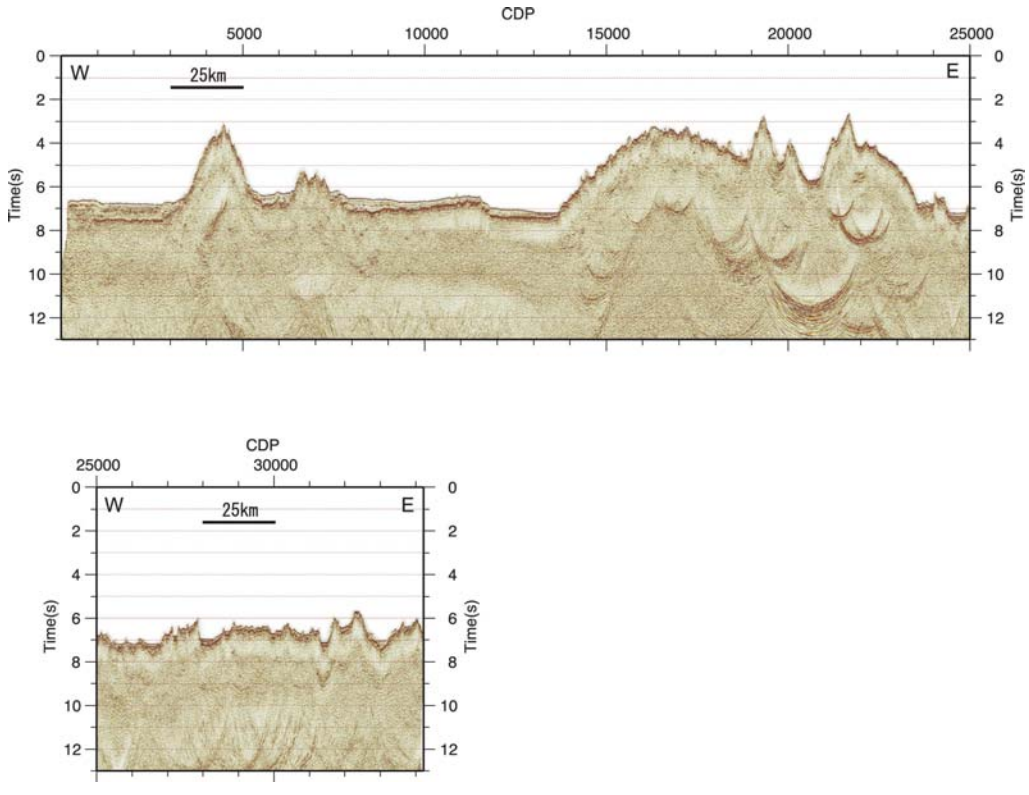

Figure 9: MCS profile of line SPr3. The profile is separately shown by two panels (a-b).

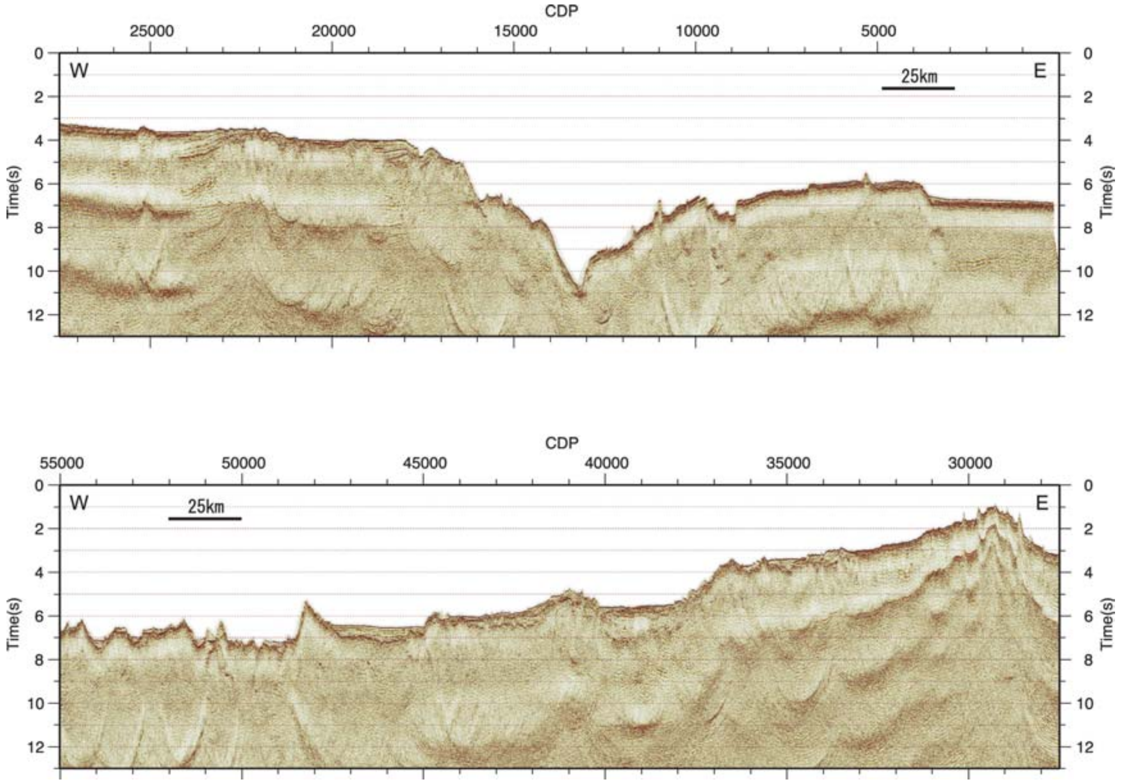

Figure 10: MCS profile of line SPr3R. The profile is separately shown by two panels (a-b).

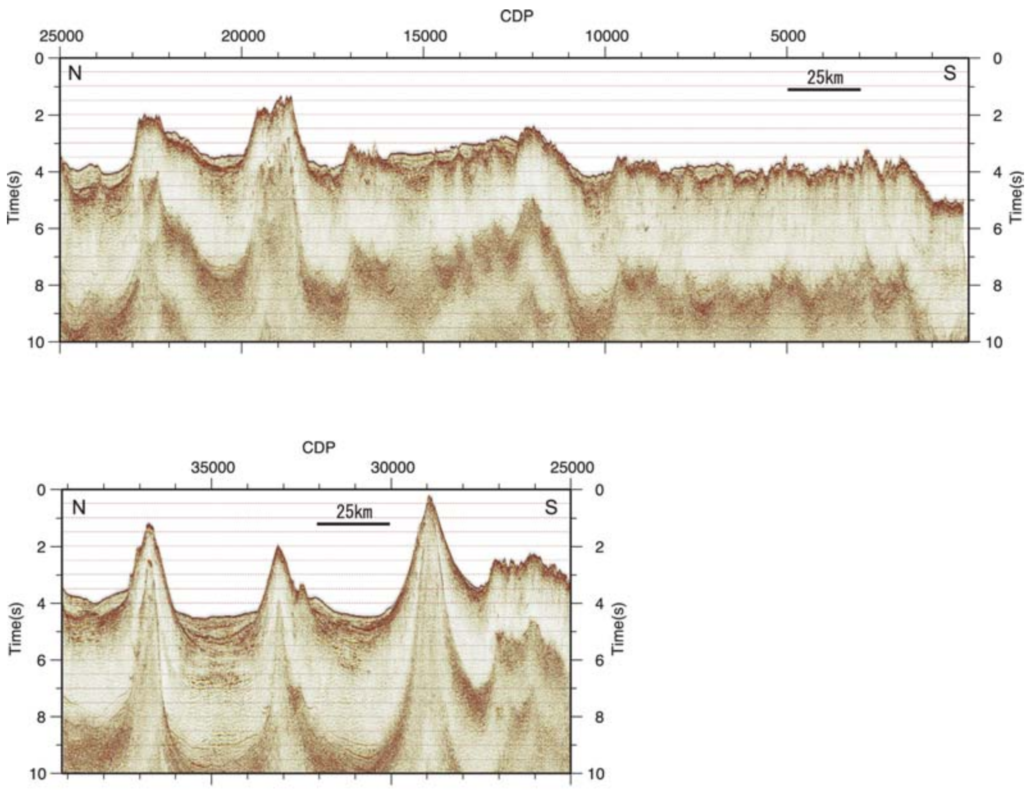

Figure 11: MCS profile of line IBr4. The profile is separately shown by two panels (a-b).