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Multi-channel seismic reflection survey in the northern Izu-Ogasawara island arc – KR07-09 cruise –

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Abstract Multi-channel seismic reflection (MCS) experiments were carried out in KR07-09 cruise to investigate crustal structures and deformations in the northern Izu-Ogasawara island arc, by using the R/V KAIREI of Japan Agency for Marine-Earth Science and Technology (JAMSTEC). Swath bathymetry, geomagnetic, and gravity data are also simultaneously observed during this cruise. Five MCS survey lines (Lines IBr5, IBr9, KT01, KT04, and KT05) with 2001.6km of total line length were obtained in this survey. An airgun array with a total capacity of 12,000 cubic inches (eight airguns with 1,500 cubic inches each) was shot with shot spacing of 50 m, air pressure of 2000 psi, and towing depth of 10 m. These airgun signals are recorded by a 204-channel hydrophone streamer cable with group interval of 25 m. The record length and sampling interval were 18 sec (Lines IBr5 and IBr9) or 15sec (Lines KT01, KT04, and KT05) and 4 msec, respectively. The MCS data has sufficient quality to know the crustal deformation of the arc-backarc transition zone. The preliminary interpretations from the onboard processing result indicated unique features of the basement and sediment in the northern Izu-Ogasawara island arc.

Keywords: Izu-Ogasawara island arc, Crustal structure, Multi-channel seismic reflection

1. Introduction

The Izu-Ogasawara-Mariana island arc (IBM arc) is characterized by a typical intra-oceanic island arc involving trench, arc and backarc basin. The Pacific plate is subducting in direction of northwest beneath the Izu-Ogasawara arc in the Philippine Sea plate (e.g., Seno et al., 1993). The Shikoku basin and the Parece Vela basin, which lies western next to the IBM arc, has a magnetic lineation pattern indicating typical structure oceanic crust (e.g., Okino et al., 1994; Okino et al., 1998). The evolution of the IBM arc had been started in Eocene and the Shikoku basin opening had started in 30 Ma (e.g., Starn et al., 1993; Okino et al., 1994; Okino et al., 1998). During the backarc opening, it is known that the arc volcanism had been inactive in the northern IBM arc (Taylor, 1992). After the backarc opening ceased, the arc volcanism has activated again since Miocene age (e.g., Taylor 1992).

Since the seismic surveys have been carried out in the IBM arc recent, studies of the crustal structure in this field have made remarkable progress. The northern Izu-Ogasawara arc has granitic middle crust with P-wave velocity (Vp) of 6 km/s and relatively thick lower crust according to a wide-angle seismic experiment (Suyehiro et al., 1996). And, the middle crust abruptly diminishes at the arc-backarc transition zone, while high velocity lower crust with 7.0-7.4 km/s can be seen in the thin crust of the eastern margin of the Shikoku basin without the middle crust. In the Mariana arc, very similar crustal structure was clarified by Takahashi et al. (2007). The thick middle crust with P-wave velocity of 6 km/s beneath the arc region, the heterogeneous lower crust including high velocity region beneath the arc-backarc transition zone are common characteristics.

In the Izu-Ogasawara forearc, the production of ODP Leg 125 and 126 serve to us in conducting our study (Taylor et al. 1990a, Taylor et al. 1990b). Taylor (1992) argued rifting and volcanism in the forearc basin and paleo-

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volcanic arc by seismic stratigraphy using ODP data and seismic profiles. His paper suggested that the frontal arc volcanoes create a linear zone of lithospheric weakness that controls the location of arc rifting. Since seismic profiles discussed by Taylor (1992) were single channel seismic data and multi-channel seismic data using short streamer cable, little is known about lower sediment structure and basement structure.

In order to clarify these unknown issues in the IBM arc, multi-channel seismic (MCS) reflection survey is one of best tools. In particular, MCS is strongly useful to discuss seismic stratigraphy of the sedimentary layer and the deformation of the basement, and to image reflectivity within the crust (e.g., Yamashita et al., 2007).

We have been carrying out multi-channel seismic (MCS) reflection survey in the Izu-Ogasawara region since 2002 (e.g., No et al., 2007). This paper reports the primary results of the data acquisition and the onboard data processing on MCS survey in KR07-09 cruise.

2. Data acquisition

In June – July 2007, we conducted an MCS reflection survey in the Izu-Ogasawara arc- backarc system using the R/V KAIREI of Japan Agency for Marine-Earth Science and Technology (JAMSTEC). We obtained MCS data of five survey lines (Lines IBr5, IBr9, KT01, KT04, and KT05) with 2001.6km of total line length (Fig.1).

Line IBr5 started from west foot of the Kinan seamount chain, went across the Koshu seamount, Komahashi Dai-san seamount, Mikawa seamount on the Shikoku Basin, the northern Izu-Ogasawara arc, and reached the Izu-Ogasawara trench with 810.85 km of line length. Line IBr9 started from west foot of the Koza seamount to Izu-Ogasawara trench through the Shikoku basin, the middle Izu-Ogasawara arc, and the northernmost Ogasawara trough, and the line length is 640.5 km. Line KT01 runs through the eastern part of the middle Shikoku basin in direction of N-S, and the line length is 282.95 km. Line KT04 runs in direction of N-S through

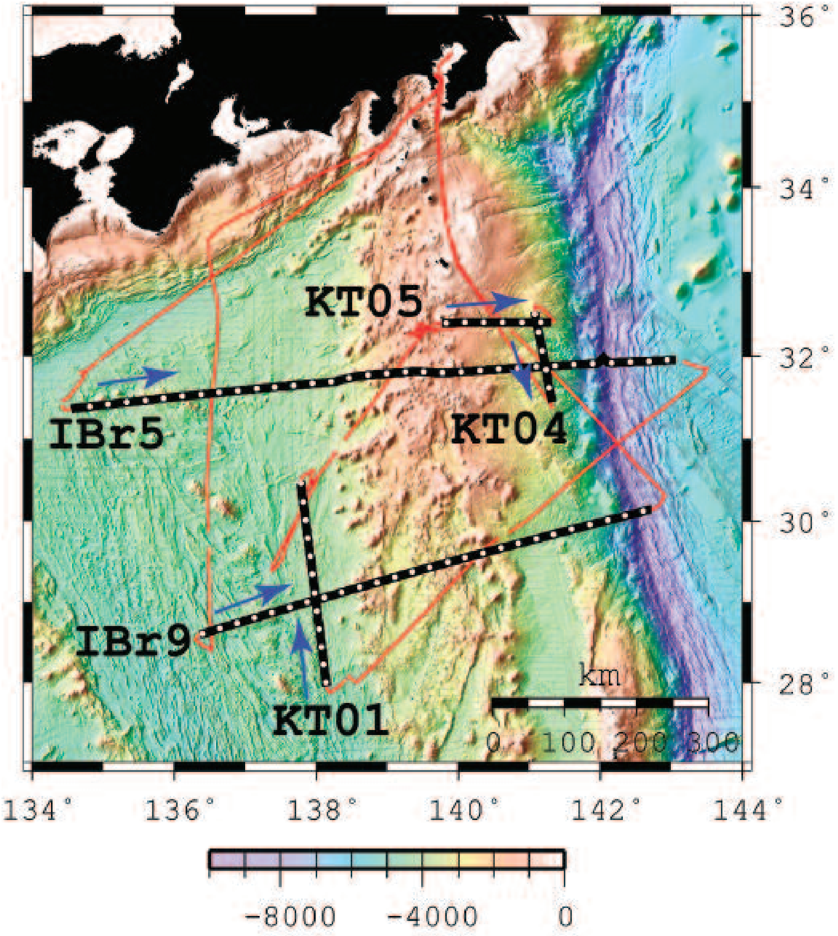


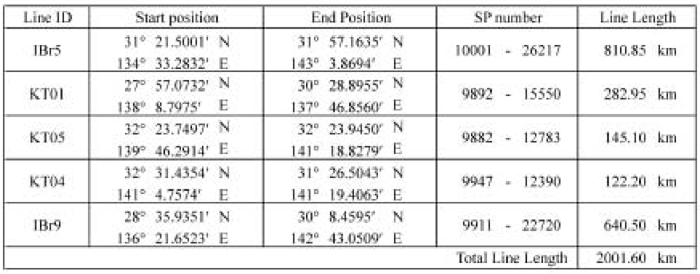
Fig. 1: Location and index map of the survey area. Black lines show MCS lines, Red line shows the ship tracks of R/V KAIREI.

the "Outer-arc high" of the northern part of forearc with 122.2 km of line length. Line KT05 covers the northern part of forearc basin, and the line length is 145.1 km. Survey line information and the shot logs are summarized in Table 1 and Table 2, respectively. In this survey, we carried out not only MCS survey but also geophysical survey (bathymetry, gravity, geomagnetic). Swath bathymetry, gravity, and geomagnetic survey were explored in same MCS lines.

2.1. Source

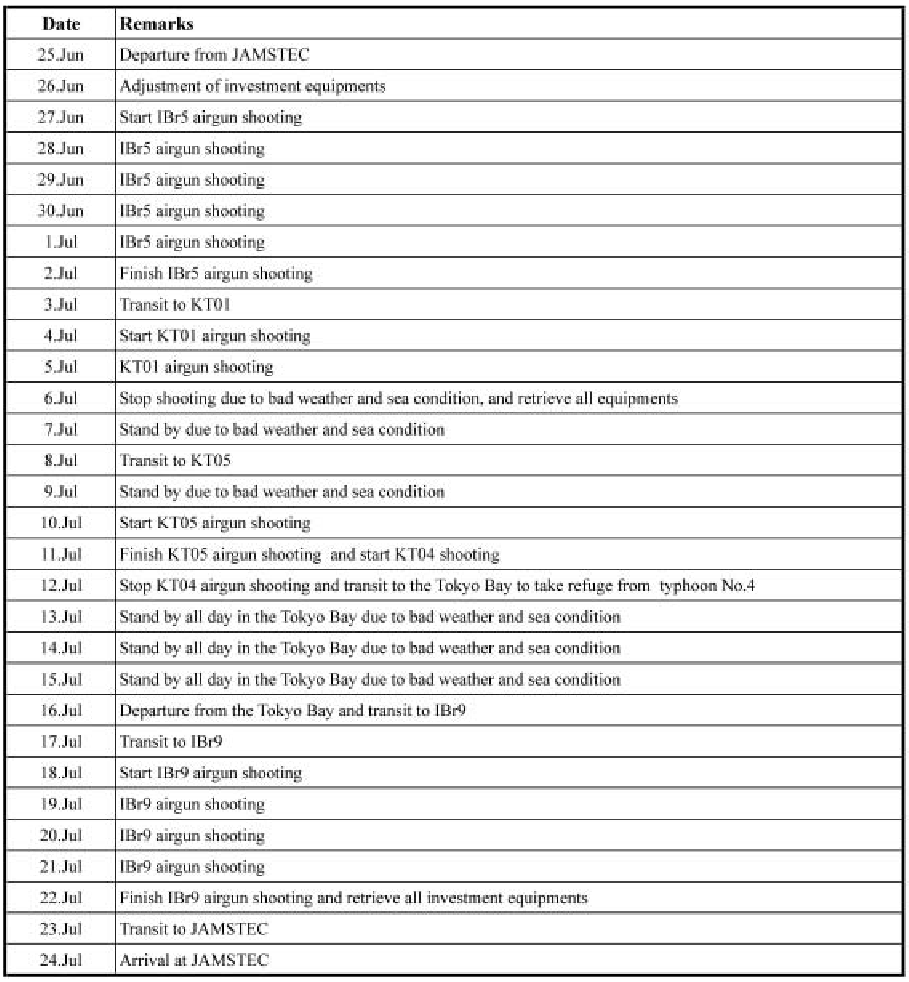
To obtain MCS data of good quality, we shot an airgun array with a spacing of 50 m, which corresponds to 20-30 s in time depending on the vessel speed (average 3.5 knot). The airgun array has total capacity of 12,000 cubic inches (about 200 liters), and consists of eight Bolt long life airguns with 1,500 cubic inches (about 25 liters) each. The standard air pressure was 2,000 psi (about 14 MPa). A depth of the airgun array during the experiment had

Table 1: List of MCS survey lines.



Line ID	Start position	End Position	SP number	Line Length
IBr5	31° 21.5001' N 134° 33.2832' E	31° 57.1635' N 143° 3.8694' E	10001 - 26217	810.85 km
KT01	27° 57.0732' N 138° 8.7975' E	30° 28.8955' N 137° 46.8560' E	9892 - 15550	282.95 km
KT05	32° 23.7497' N 139° 46.2914' E	32° 23.9450' N 141° 18.8279' E	9882 - 12783	145.10 km
KT04	32° 31.4354' N 141° 4.7574' E	31° 26.5043' N 141° 19.4063' E	9947 - 12390	122.20 km
IBr9	28° 35.9351' N 136° 21.6523' E	30° 8.4595' N 142° 43.0509' E	9911 - 22720	640.50 km
			Total Line Length	2001.60 km

Table 2: Activity logs during KR07-09 cruise.



Date	Remarks
25.Jun	Departure from JAMSTEC
26.Jun	Adjustment of investment equipments
27.Jun	Start IBr5 airgun shooting
28.Jun	IBr5 airgun shooting
29.Jun	IBr5 airgun shooting
30.Jun	IBr5 airgun shooting
1.Jul	IBr5 airgun shooting
2.Jul	Finish IBr5 airgun shooting
3.Jul	Transit to KT01
4.Jul	Start KT01 airgun shooting
5.Jul	KT01 airgun shooting
6.Jul	Stop shooting due to bad weather and sea condition, and retrieve all equipments
7.Jul	Stand by due to bad weather and sea condition
8.Jul	Transit to KT05
9.Jul	Stand by due to bad weather and sea condition
10.Jul	Start KT05 airgun shooting
11.Jul	Finish KT05 airgun shooting and start KT04 shooting
12.Jul	Stop KT04 airgun shooting and transit to the Tokyo Bay to take refuge from typhoon No.4
13.Jul	Stand by all day in the Tokyo Bay due to bad weather and sea condition
14.Jul	Stand by all day in the Tokyo Bay due to bad weather and sea condition
15.Jul	Stand by all day in the Tokyo Bay due to bad weather and sea condition
16.Jul	Departure from the Tokyo Bay and transit to IBr9
17.Jul	Transit to IBr9
18.Jul	Start IBr9 airgun shooting
19.Jul	IBr9 airgun shooting
20.Jul	IBr9 airgun shooting
21.Jul	IBr9 airgun shooting
22.Jul	Finish IBr9 airgun shooting and retrieve all investment equipments
23.Jul	Transit to JAMSTEC
24.Jul	Arrival at JAMSTEC

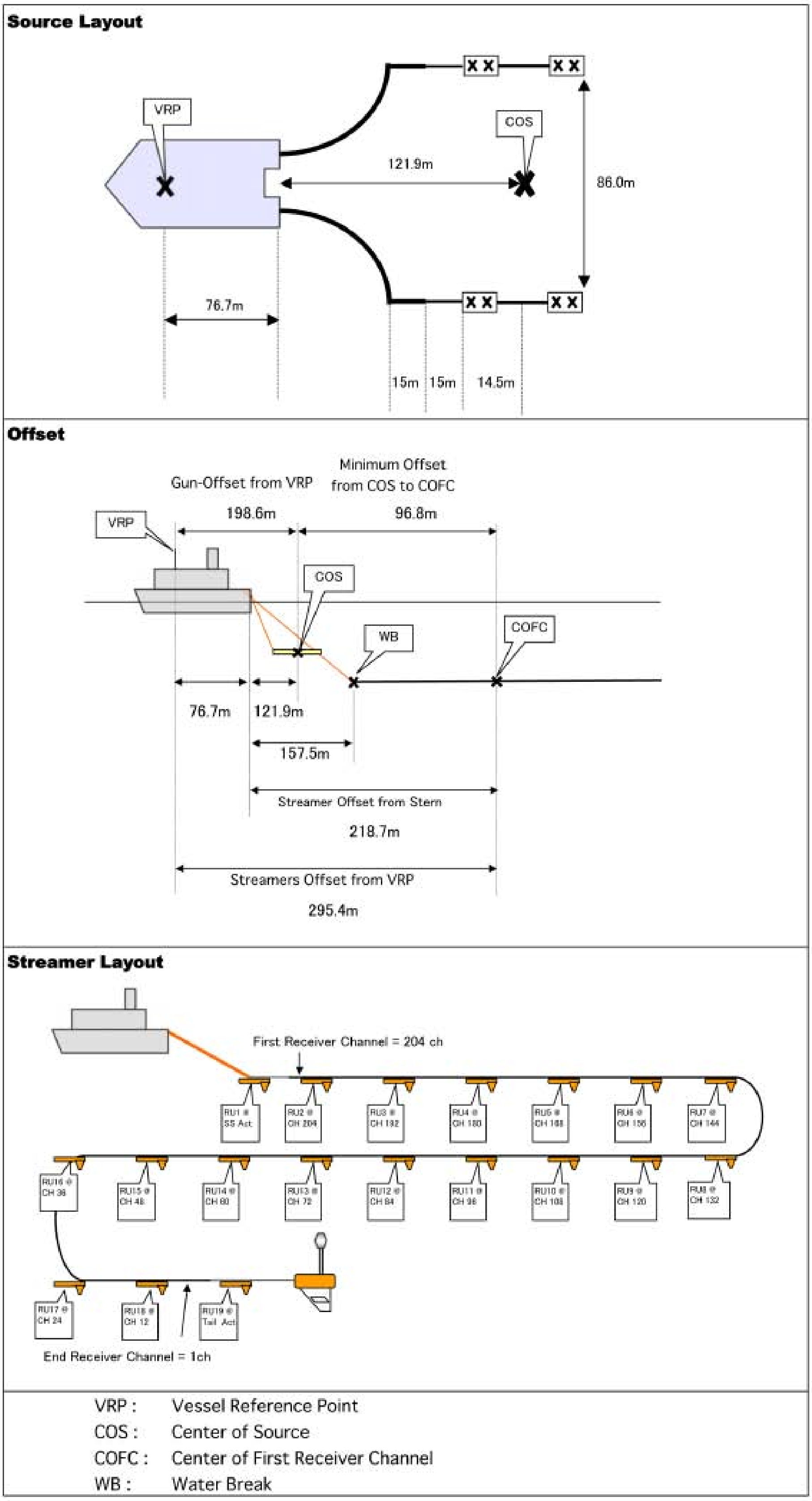


Figure 2: Geometry of airgun system and the streamer cable. Top figure shows the source (airgun system) layout, middle one represents source-receiver offset, and bottom one is streamer cable configuration.

been kept to be 10 m below the sea surface. Fig. 2 shows two strings of sub-arrays deployed at the port and starboard sides of the vessel. Their width was expanded to 86.0 m by a paravane system and the central position of the array was set 198.6 m behind the ship antenna position. The troubles of airgun array system (e.g. air leak) occurred at the observations of line IBr5, IBr9, and KT04. Therefore a number of airguns were seven due to stop air supply to the broken airgun by using the stealth valve.

2.2. Receiver

During the shooting, we towed a 204-channel hydrophone streamer cable (SYNTRAK RDA Streamer System, Sercel Inc.). Hydrophone sensors (Benthos Reduce Diameter Array hydrophone) with sensitivity of 20 V/Bar are used. The signals from 32 sensors in the same group (channel) are stacked before A/D conversion. The streamer cable is composed of 68 active sections, and each active section is 75 m long consisting of three receiver groups (channels). The active modules including 24 bit A/D converters are inserted in every four active sections which collect seismic data. The interval of each group is 25 m. The lengths of total active section and lead-in cable are 5100 m (75 m × 68) and 110 m, respectively. The towing depth of the streamer cable was controlled to be 15 m below sea surface by the depth controller called Bird (I/O DigiCOURSE streamer depth controllers). Large spike noises were frequently recorded in seismic channel 84, 107, and 135 during the observation of IBr5, KT04, and KT05. Therefore, we omitted these noise records in data processing. The streamer cable feathering which occurred due to the ocean current and the direction of survey line influenced the quality of seismic records and the distribution of CMP (Common mid point) fold. Fig.3 shows the direction of the streamer cable feathering on five MCS lines. Large noisy trace owing to the cable feathering were removed from shot gather data.

2.3. Recording and navigation systems

The recording system is “SYNTRAK 960-24 Multiple Streamer Telemetry System” made by Sercel Inc., and collected seismic data onto 3590E tapes with SEG-D 8048

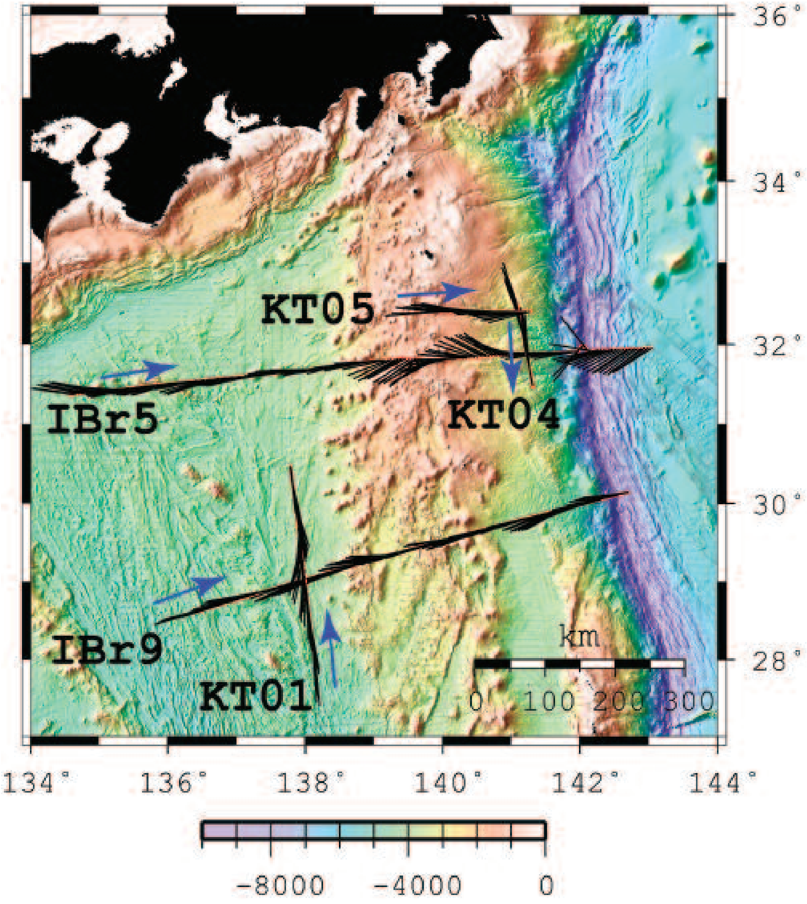


Figure 3: The cable feathering map of the MCS lines. Black lines show the direction of the cable feathering. Red lines show the MCS lines.

Rev.1 format. We set system delay to be 150 msec. The sampling rate was 4 msec and the record length was 18 sec (Lines IBr5 and IBr9) and 15sec (Lines KT01, KT04, and KT05).

The Differential Global Positioning System (DGPS) was used for the positioning. We adopted StarFire system (NAVCOM's DGPS service) as a main positioning system and SkyFix (Fugro's DGPS service) as the backup. The accuracy was 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 2D made by Concept Systems Ltd.. Positioning data collected from StarFire as well as SkyFix were sent to RTNμ (The Real Time Navigation Unit by Concept Systems Ltd.) via a terminal server connected to LAN in the vessel. Shot times and Shot Point (SP) were set on the SPECTRA and then a trigger signal was sent to the recording system and the gun controller (Sercel GCS90), the following paragraph and Fig. 4 were illustrated these flows in details

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. 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. The position data are output to ASCII file with UKOOA P1/90 and UKOOA P2/91 format. 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.4.

The QC (Quality Control) and processing of UKOOA navigation data were done by SeisPos (an offline navigation post-processing and QC software made by FGPS Ltd.).

3. Onboard processing and preliminary interpretation of MCS data

TRaw data (Shot gather data) were processed onboard for the purpose of QC and preliminary interpretation of crustal structures in the study areas. The QC and processing were done by ProMAX 2D (a product of Landmark). The onboard data processing was conducted to preserve relative amplitudes under the conventional processing scheme, as show in Fig. 5, which contains trace header edit, noisy-trace editing, 2D marine geometry set, band-pass filtering (3-125 Hz), datum correction, amplitude compensation by T**2 (T is two way traveltime), predictive deconvolution with 24 ms- length predictive distance and a 250 ms-length operator, velocity analysis with interval of 500 CMP, NMO(Normal Moveout) correction, multiple suppression by radon filter, muting, CMP stacking, band-pass filtering (4-50 Hz) and poststack time migration. According to the QC of seismic data, the percentages of removed traces in each survey lines were

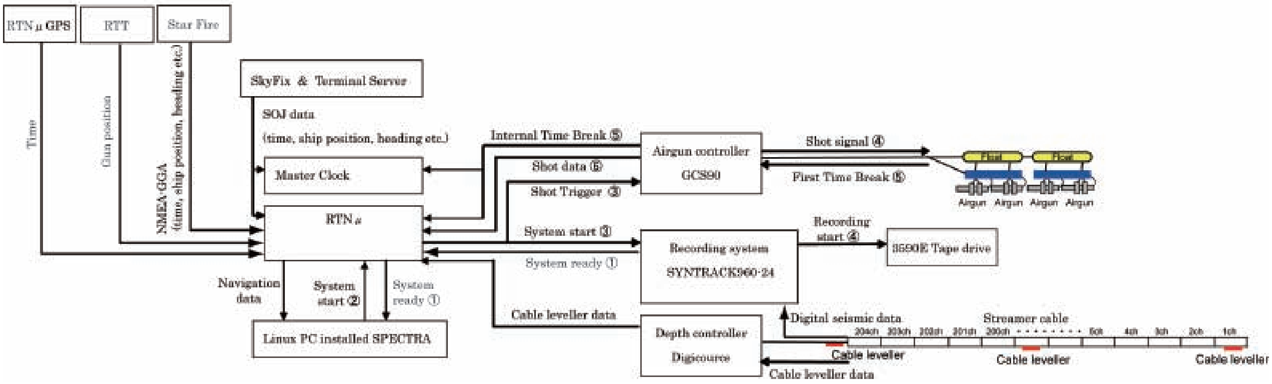


Figure 4: MCS recording system on R/V KAIREI. Circled numerals show the signal transfer flow in the system.

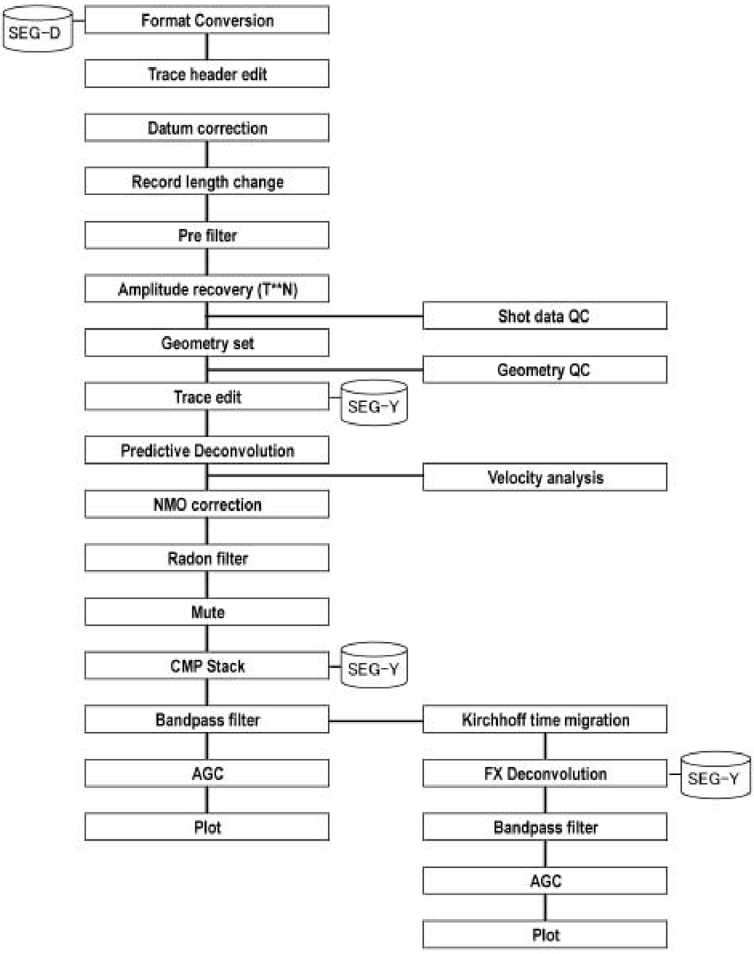


Figure 5: Flow chart of onboard data processing.

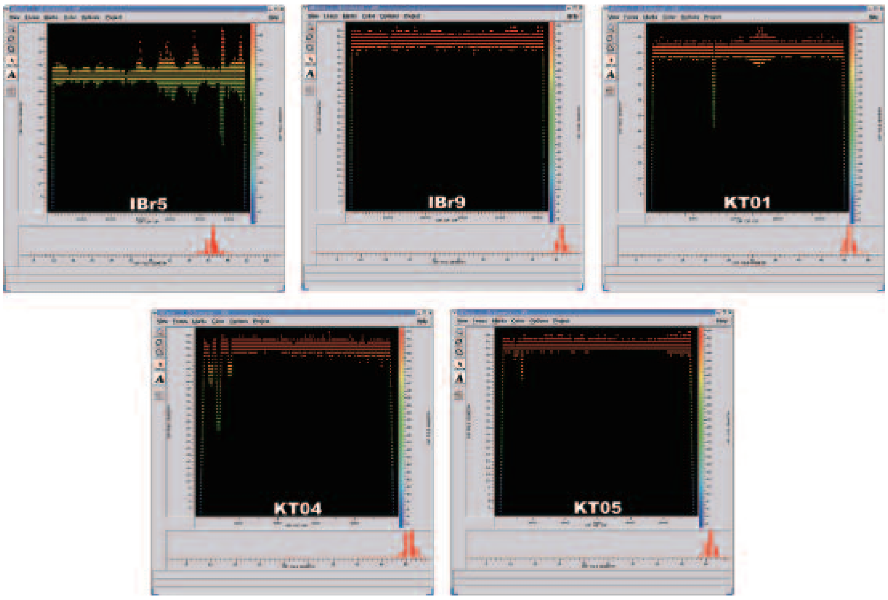


Figure 6: CMP fold after trace edit. Vertical axis shows the number of CMP fold. Horizontal axis shows CMP No. The histogram shows frequency distribution of CMP fold.

0.211% (IBr5), 0.016% (IBr9), 0.019% (KT01), 2.282%(KT04), and 0.226% (KT05). As a result, the number of CMP fold ranges dispersed in the part of removed traces. CMP fold maps of each lines are shown in Fig.6.

Figs. 7 to 11 show MCS profiles (poststack migration section) of each line. Although we will process and interpret in detail for MCS data at the laboratory, the preliminary interpretations from the onboard processing are as follows.

In the Shikoku Basin, the sediment gradually thickens northward and eastward along line IBr5 and KT01 (Fig. 7, Fig. 9). The seismic character in the sediment is changed around SP 18000. The reflectors in the sediment are more coherency in the eastern side than the western part (Fig. 12). The basement of the Shikoku Basin is formed very deformational geometry by the half-graben, the knolls, and so on (Fig. 12). The Arc-Backarc trasition and central rift zone is imaged clear the basement and sediment structure, what is more, we can see normal faults in the basin (Fig. 12).

In Forearc, the sediment is very thick (2s and over) in the forearc basin. The sediment structure in the forearc basin corresponds to the result of ODP Leg125 Site786 and Leg126 Site792 (Taylor et al. 1990a, Taylor et al. 1990b), for example, strong reflectors in Line IBr5 corre-

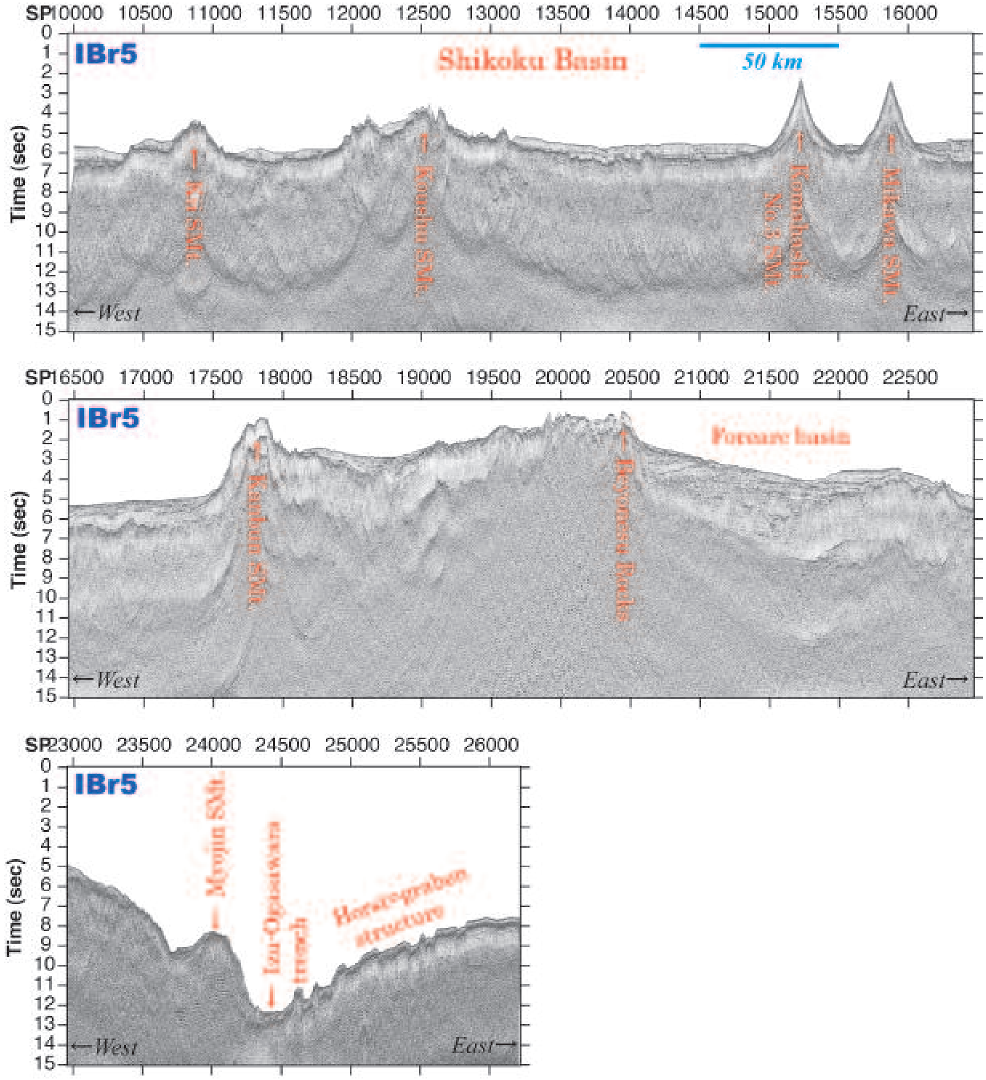


Figure 7: Poststack time migration section of Line IBr5.

spond to units boundaries of Site 792 lithostratigraphy (Fig. 13). Sediments around Aogashima canyon and Myoujin canyon is relatively thin, about 0.3 s, and these canyons seem to be developed by erosion. Beneath the Ogasawara trough, the sedimentary structure in the eastern part is different from that in the western part. The thickness of the sedimentary layer in the western part from SP 19000 of Line IBr9 is maximum 0.5 s. However, the basement suddenly becomes deep about SP 19000 to eastern part, the thickness reaches maximum 3 s or over. This feature suggests that the half-graben in the basement of the trough had been developped.

Around the Izu-Ogasawara trench, the horst-graben structure is imaged on the Pacific Plate, and the reflection from the Moho was intermittently imaged. Morefore, the reflectors of the subducing plate are seen in the forearc (Fig. 14).

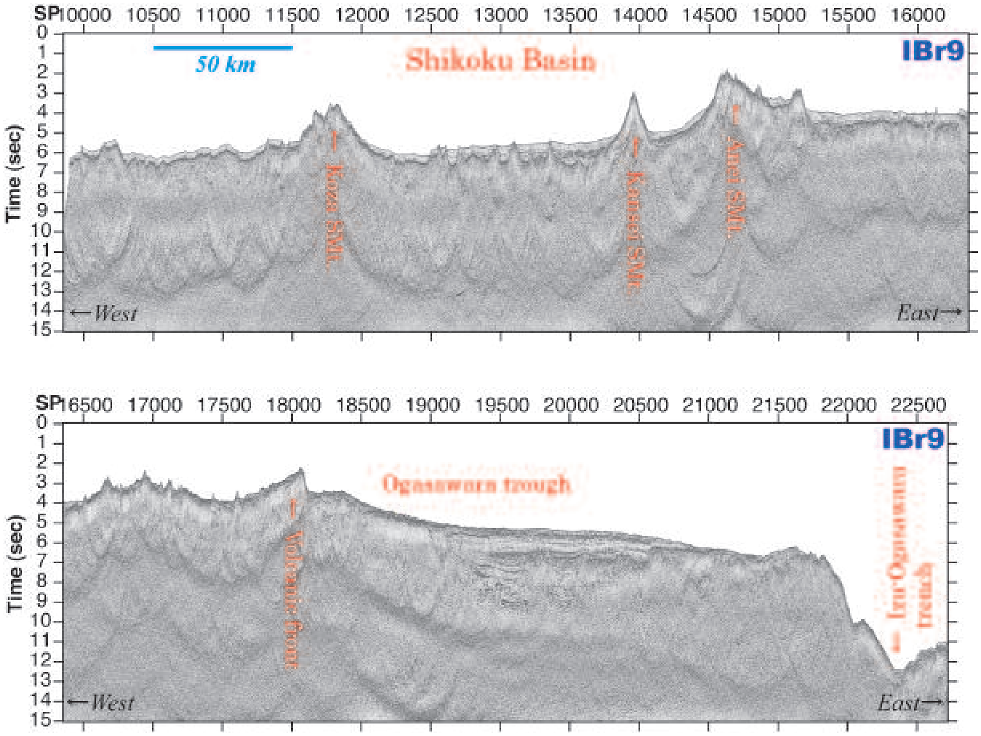


Figure 8: Poststack time migration section of Line IBr9.

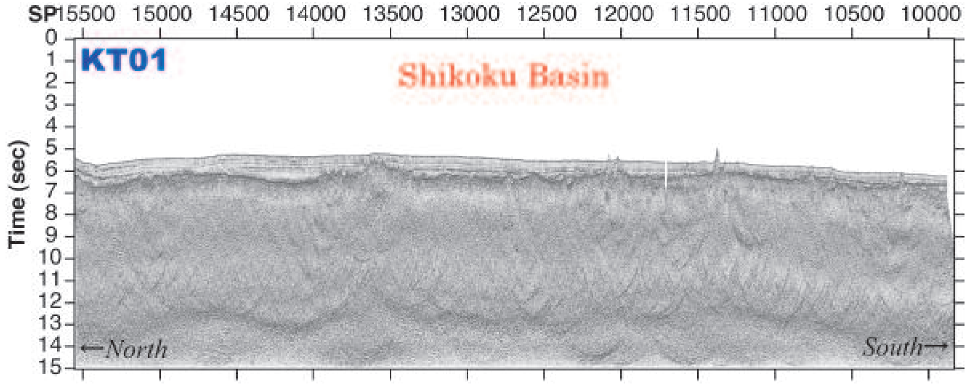


Figure 9: Poststack time migration section of Line KT01.

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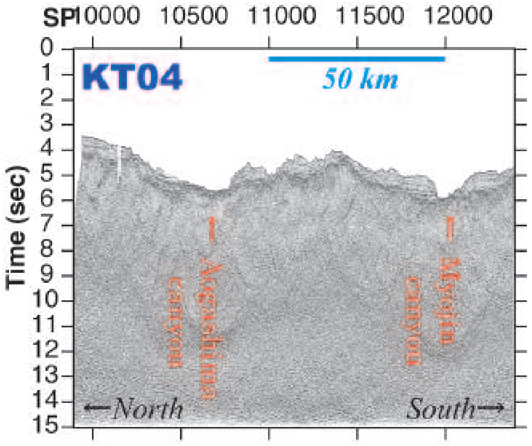

Figure 10: Poststack time migration section of Line KT04.

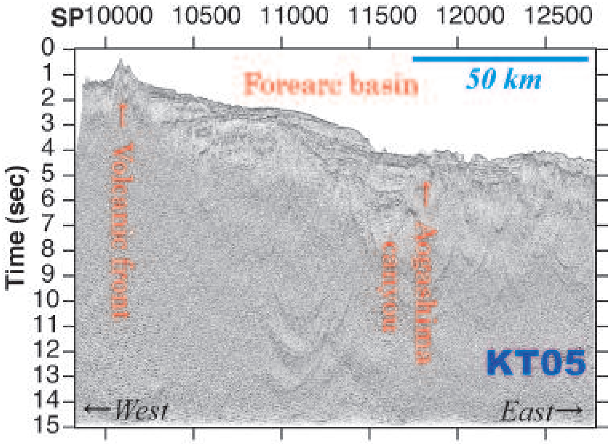

Figure 11: Poststack time migration section of Line KT05.

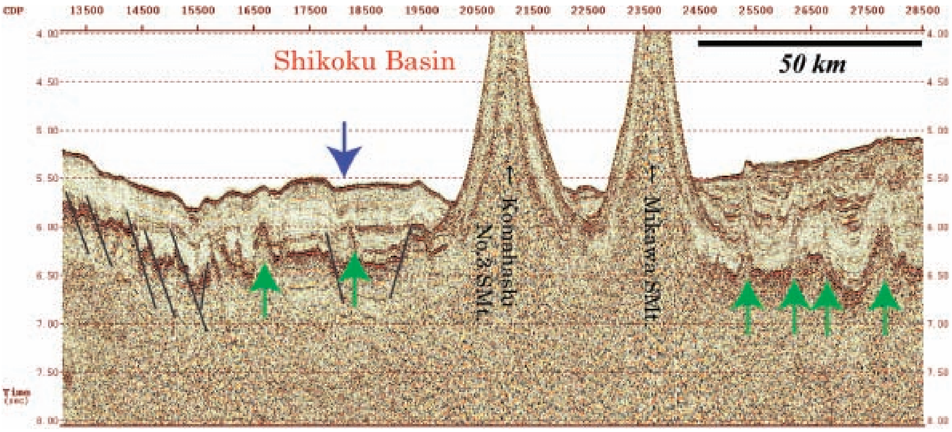

Figure 12: Seismic section of Line IBr5 across the Shikoku basin. Black lines show normal faults. Green arrows show buried knolls. Brue arrow shows the point of changed seismic character in the sediment.

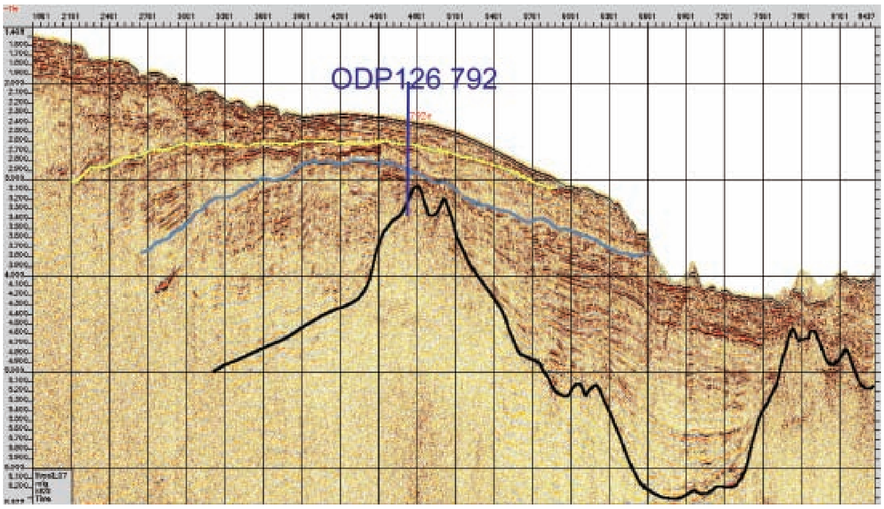

Figure 13: Seismic section of Line KT05 crossing ODP Leg126 Site 792, illustrating the seismic stratigraphy of the forearc basin. Correlation of seismic horizons with drilling results at Site 792 allows the identification of four units.

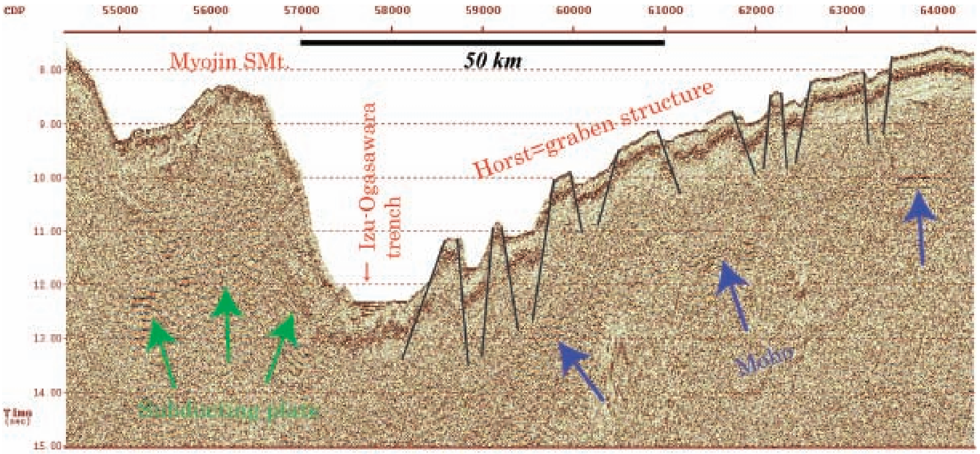

Figure 14: Seismic section of Line IBr5 across Izu-Ogasawara trench.