Cruise report of 2004 seismic reflection surveys in Izu-Ogasawara Arc

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Abstract In order to obtain detailed crustal structures in a typical oceanic island arc system, we have been conducting multi-channel seismic (MCS) reflection survey 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 the cruises. In 2004 fiscal year, we collected a total of 2030.9 km of MCS data: 228.20 km in KR04-10, 384.70 km in KR04-13 and 1417.95 km in KR04-15 cruises. On-board processing results demonstrate clear seismic reflection images of the subducting Pacific plate, forearc tectonic features and backarc basin structures, showing that all of the MCS data collected are of good quality.

Keywords: Izu-Ogasawara arc, Crustal structure, Continental shelf, Seismic reflection

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[1)].

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 splitted 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[2)]. The subduction of the oceanic crust beneath the arc has occurred since Eocene time and the crustal growth has started[3)], and it is reported that the initial oceanic arc does not have the granitic layer[4)]. Macpherson and Hall[5)] 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[6)], 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.[1)] 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[7)], an MCS study[8)] and a microseismicity study[9)]. The new subduction is not inconsistent with the crustal shortening of the northern Izu-Ogasawara arc. Recently, Tamura et al.[10)] 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

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and the 50 m.y. evolution history of the entire Izu-Ogasawara intra-oceanic island arc system, we have been collecting multichannel seismic (MCS) reflection data in this region. Here we report on the MCS surveys that were conducted in 2004 fiscal year.

2. Data acquisition

To achieve the above objectives, we conducted a total of three MCS cruises using *R/V Kairei* of Japan Agency for Marine-Earth Science and Technology (JAMSTEC) in 2004 fiscal year: KR04-10, KR04-13 and KR04-15. During KR04-10 cruise from August 21 to September 2, we collected MCS data of only the east half of line IBr2 (KR0410-2) because of bad sea condition due to typhoons (Figure 1). Line IBr2 (KR0410-2) covers the Izu-Ogasawara Trench and the forearc of the northern Izu-Ogasawara arc, and the line length is 228.2 km. In KR04-13 cruise, we observed MCS data of 384.7 km on line IBr1 (Figure 2), along the present volcanic front of the northern Izu-Ogasawara arc from October 22 to October 29. During KR04-15 survey from December 7 to 28, 1417.95 km of MCS data were collected on the west half of line IBr2 (KR0410-2) and line SPr2 (Figure 3). Line SPr2 started from Kyushu-Palao ridge, went across the Shikoku-basin and the southern Izu-Ogasawara arc, and reached the seaward slope of the Izu-Ogasawara Trench. As a result, a total of 2030.90

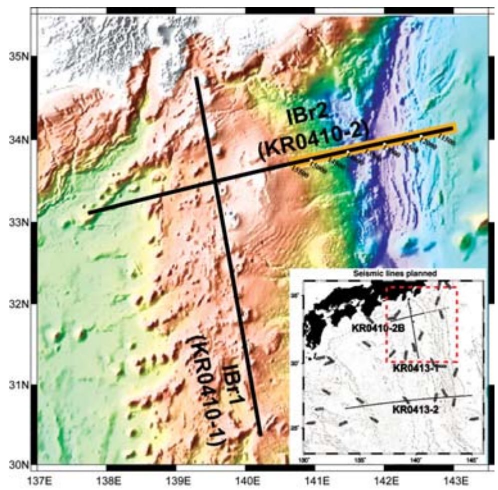


Figure 1: Study area and survey line of KR04-10 cruise. Two crossing lines (black) were planed and only the eastern half of line IBr2 (orange) was observed.

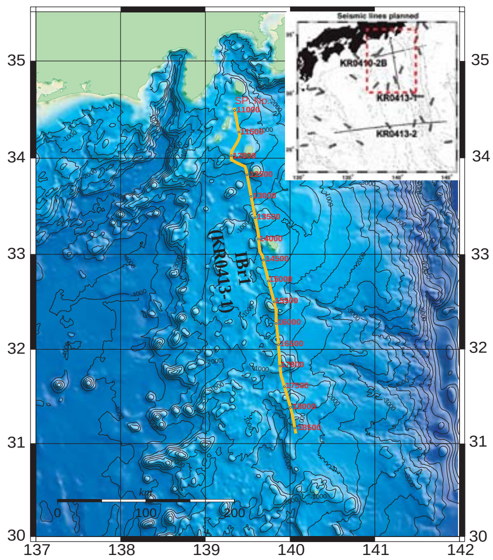


Figure 2: Study area and survey line of KR04-13 cruise.

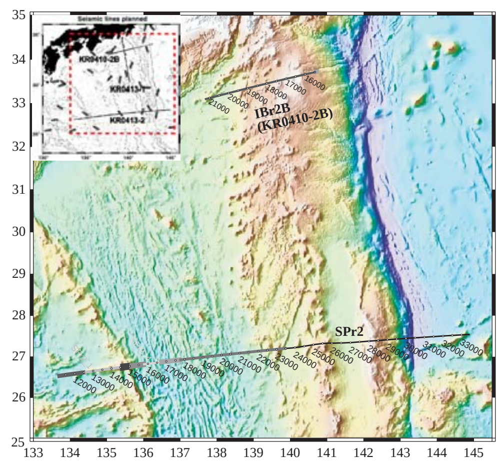


Figure 3: Study area and survey line of KR04-15 cruise.

Table 1: Activity log during KR04-10 leg2 cruise.

Cruise name	Line name	Start position	End position	SP number	Line length
KR04-10	IBr2 (KR0410-2)	34°08’ 50.8”N 143°02’ 28.9”E	33°42’ 25.2”N 140°37’ 51.2”E	11012 - 15575	228.20 km
KR04-13	IBr1 (KR0413-1)	34°31’ 06.5”N 139°20’ 26.4”E	31°06’ 17.8”N 140°04’ 06.9”E	10938 - 18631	384.70 km
KR04-15	IBr2	33°44’ 08.4”N 140°46’ 45.4”E	33°05’ 40.7”N 137°40’ 10.1”E	15293 - 21250	297.85 km
	SPr2	26°31’ 37.7”N 133°39’ 23.1”E	27°32’ 27.2”N 144°53’ 30.3”E	11040 - 33442	1120.15 km
Total line length in 2004 fiscal year					2030.90 km

km of MCS data are successfully collected in 2004 fiscal year. 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 1500 cubic inches (25 liters) each. The standard air pressure was 2000 psi (14 MPa). As shown in the top panel of Figure 4, two strings of sub-arrays were deployed at the port and starboard sides of the vessel. Their width was expanded to 91.1 m by a paravane system and the central position of the array was set 196.4 m behind the ship antenna position.

In 2004 surveys, shooting was stopped or temporarily suspended due to bad weather conditions, air leaks, fishing activity and a telemetry error of streamer cable. As a result, line IBr2 (KR0410-2) was divided into five segments and line SPr2 into eight segments. There was no stop shooting due to mechanical trouble at the observation of line IBr1. The shot logs were summarized in Table 2.

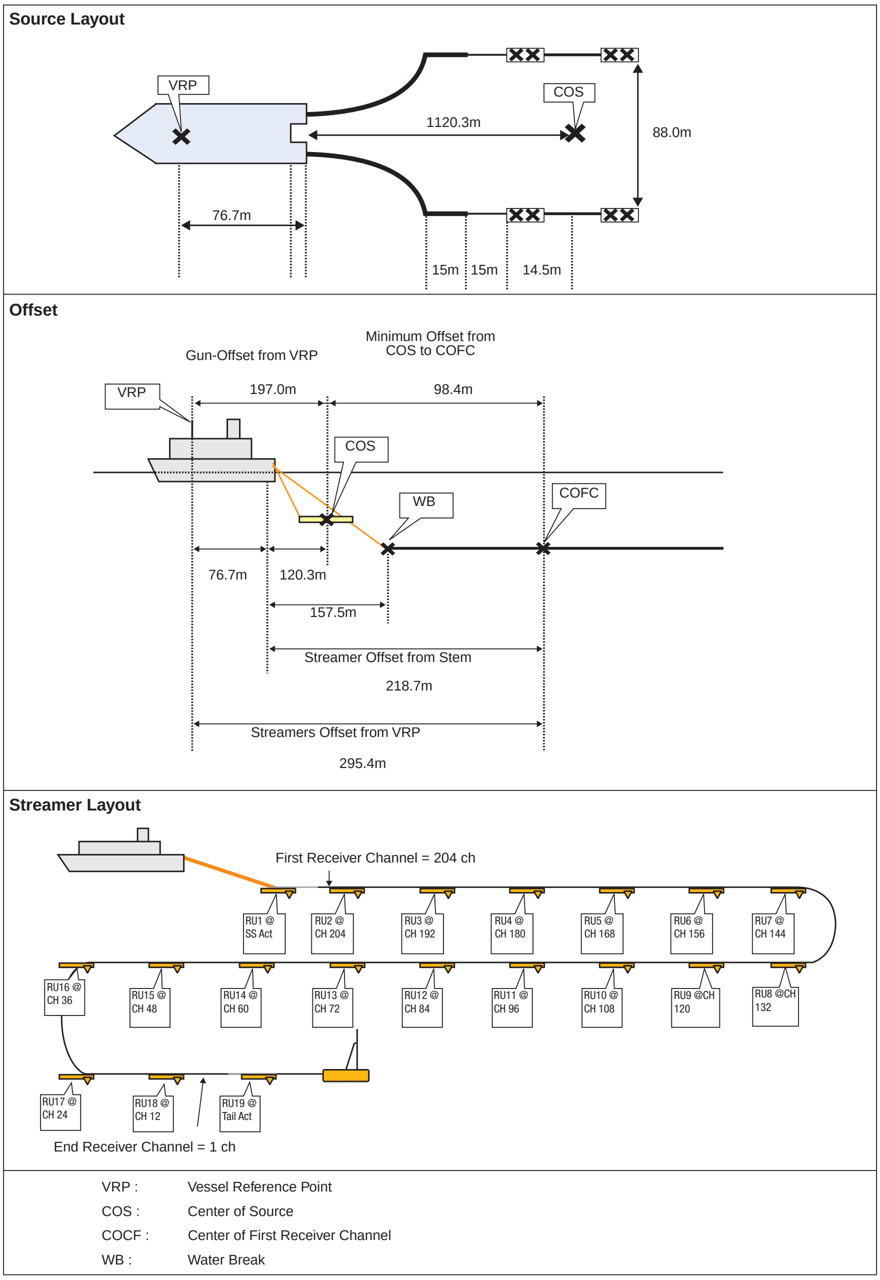


Figure 4: Geometry of airgun system and the hydrophone streamer. Top figure shows the source (airgun system) layout, middle one represents source-receiver offset, and bottom one is streamer cable configuration.

Table 2: Daily report.

KR0410	Date	Time	Remarks
	Aug 21	1000	Departure from JAMSTEC
	Aug 22	0600	Arrived at the easternmost survey area
		0611	XBT
		0706	Adjustment and deployment of investment equipments
		2340	Start KR0410-2 airgun shooting
	Aug 23	0538	Stop shooting due to air leak, Recovery and Repair.
		1300	Restart airgun shooting
		1400	Suspend shooting due to bad weather
	Aug 24		Standby all day due to bad weather
	Aug 25	0657	Re-deployment of equipments
		1510	Restart shooting
	Aug 26	1558	Stop shooting due to typhoons
	Aug 27		Standby
	Aug 28		Standby
	Aug 29	0840	MNBES survey near Chichi-jima for KR04-13 cruise
		1530	Stop MNBES survey due to typhoons
	Aug 30		Standby
	Aug 31		Transit to JAMSTEC
	Sep 1		Transit
	Sep 2	0900	Arrive at JAMSTEC
KR0413	Oct 22		Departure from Atsumi-wan
	Oct 23	0630	Arrived at the northernmost part of the survey area.
			Adjustment and deployment of investment equipments
		1515	Start KR0413-1 shooting from north
	Oct 24		Shooting
	Oct 25		Shooting
	Oct 26	1000	Stop shooting due to typhoon
	Oct 27		Standby
	Oct 28		Transit to JAMSTEC
	Oct 29	0900	Arrive at JAMSTEC
KR0415	Dec 07	0930	Departure from JAMSTEC
	Dec 08	0715	Adjustment and deployment of equipments
		2352	Start KR0410-2 (IBr2B) shooting
	Dec 09	0136	Stop shooting due to air leak, recover and repair
		0924	Restart IBr2B shooting
	Dec 10		Shooting
	Dec 11	0244	Finish IBr2B shooting and recover equipments
		1155	Transit to line SPr2
	Dec 12	1459	Deployment of equipments
	Dec 13	0124	Start SPr2 shooting
		0357	Suspended shooting due to bad weather and recover equipments
	Dec 14		Standby
	Dec 15	0636	Deployment of equipments
		1311	Re-start SPr2 shooting
	Dec 16	0910	Suspend SPr2 shooting to avoid the operation of the fishing boat
		1202	Re-start shooting
		1641	Stop shooting due to air leak, recover and repair
		2059	Re-start SPr2 shooting
	Dec 17	0502	Stop shooting due to air leak, recovery and repair
		1325	Re-start SPr2 shooting
		2014	Suspended shooting due to telemetric error of streamer cable, repair
	Dec 18	0310	Re-start SPr2 shooting
		1255	Suspended shooting because old fishing net was twined around a umbilical cable, remove
		2023	Re-start SPr2 shooting
	Dec 19		Shooting
	Dec 20	1257	Stop shooting due to bad weather
	Dec 21		Standby
	Dec 22		Standby
	Dec 23	0630	Deployment of equipments
		1222	Re-start SPr2 shooting
	Dec 24		Shooting
	Dec 25		Shooting
	Dec 26	0900	Finish SPr2 shooting
		0927	Recovery of all equipments
		1356	Transit to JAMSTEC
	Dec 27		Transit
	Dec 28	0800	Arrival at JAMSTEC

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 75 m long and consists of three receiver groups (channels). The active modules including 24 bit A/D converters are inserted every four active sections and collect seismic data from the four sections. 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. Hydrophone sensors (Benthos Reduce Diameter Array hydrophone) with sensitivity of 20 V/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 15 m below sea surface by the depth controller called Bird (DigiCOURSE System3).

During the observation on Shot Points 11012-11990 of line IBr2 (KR0410-2), seismic records of channels 190-192 contained large noises, we therefore removed these records at data processing. 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 150 ms and water delay to be 0-600 ms depending on water depth. The sampling rate was 4 ms and the record length was 15 s.

The Differential Global Positioning System (DGPS) 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 Figure 5.

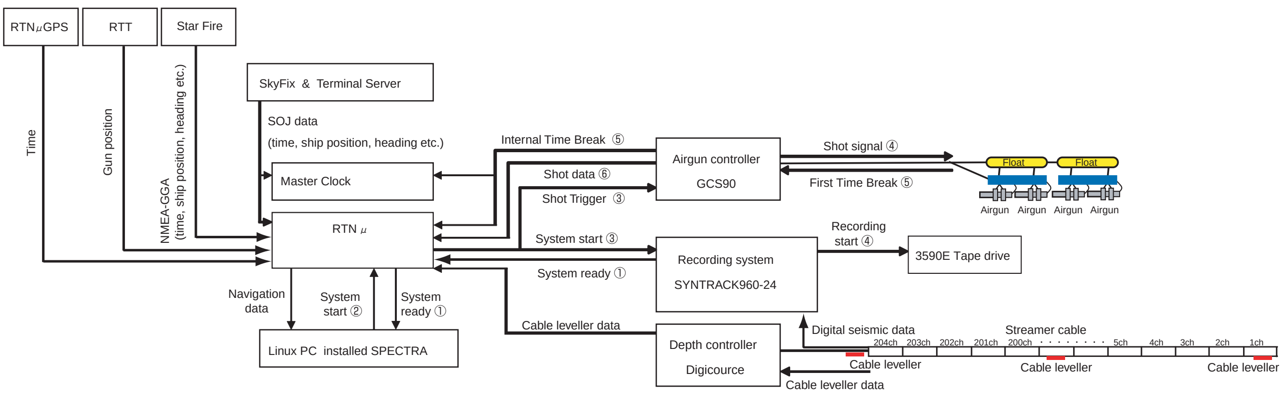


Figure 5: MCS recording system on *R/V Kairei*. Circled numerals show the signal transfer flow in the system.

3. Onboard processing and preliminary interpretation of MCS data

Raw MCS reflection data are processed on board 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 Figure 6, which contains noisy-trace editing, 5-100 Hz band-pass filtering, deconvolution with a 28-ms-length predictive distance and a 250-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 7-10 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.

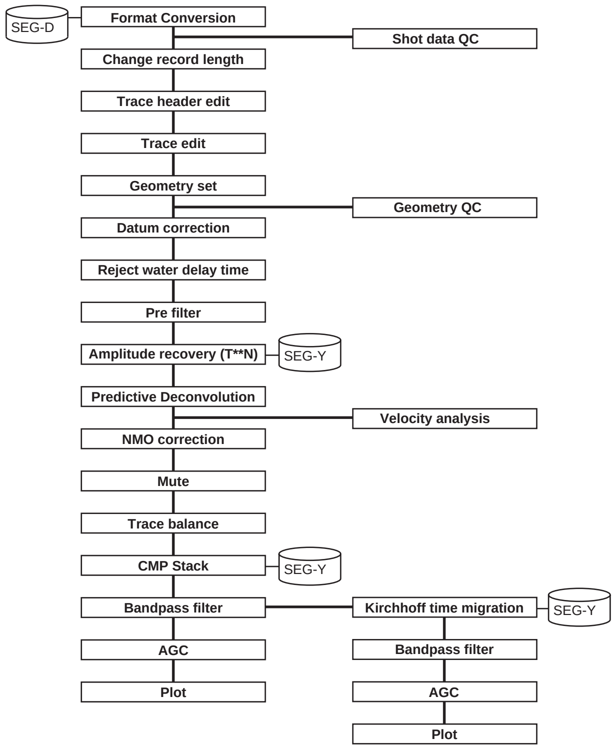


Figure 6: Flow chart of onboard data processing.

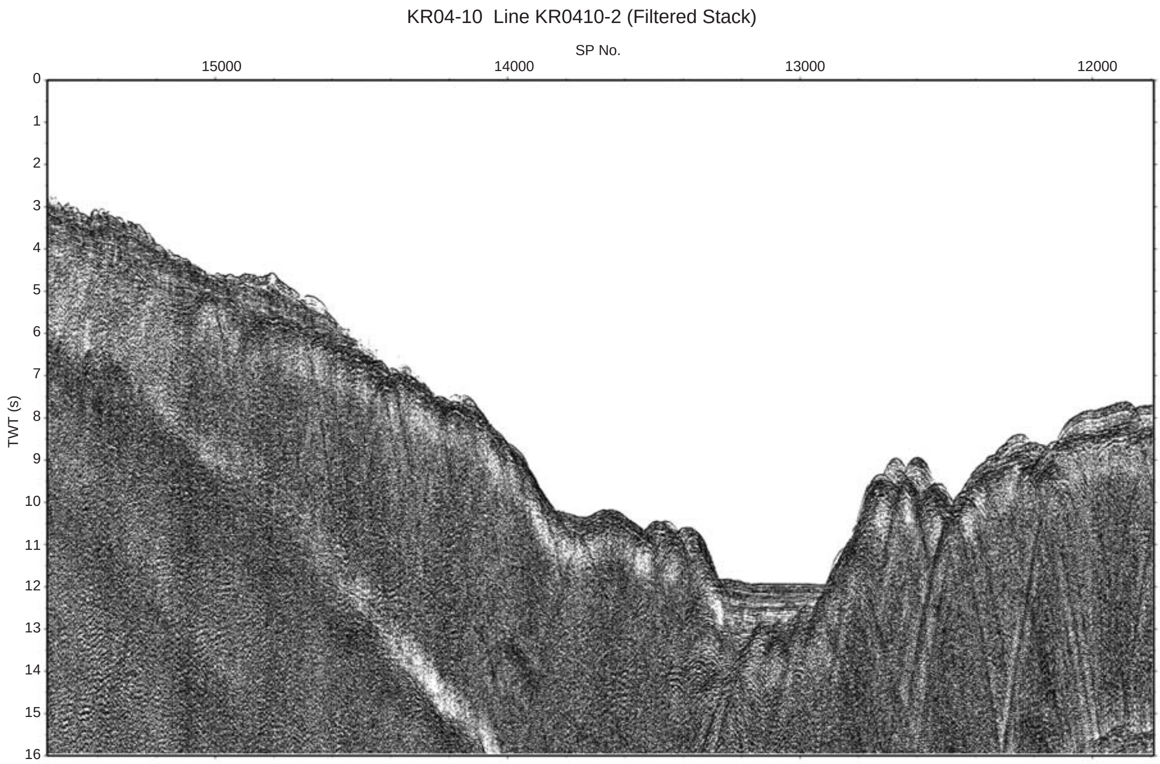


Figure 7: MCS profile of line IBr2 (KR0410-2).

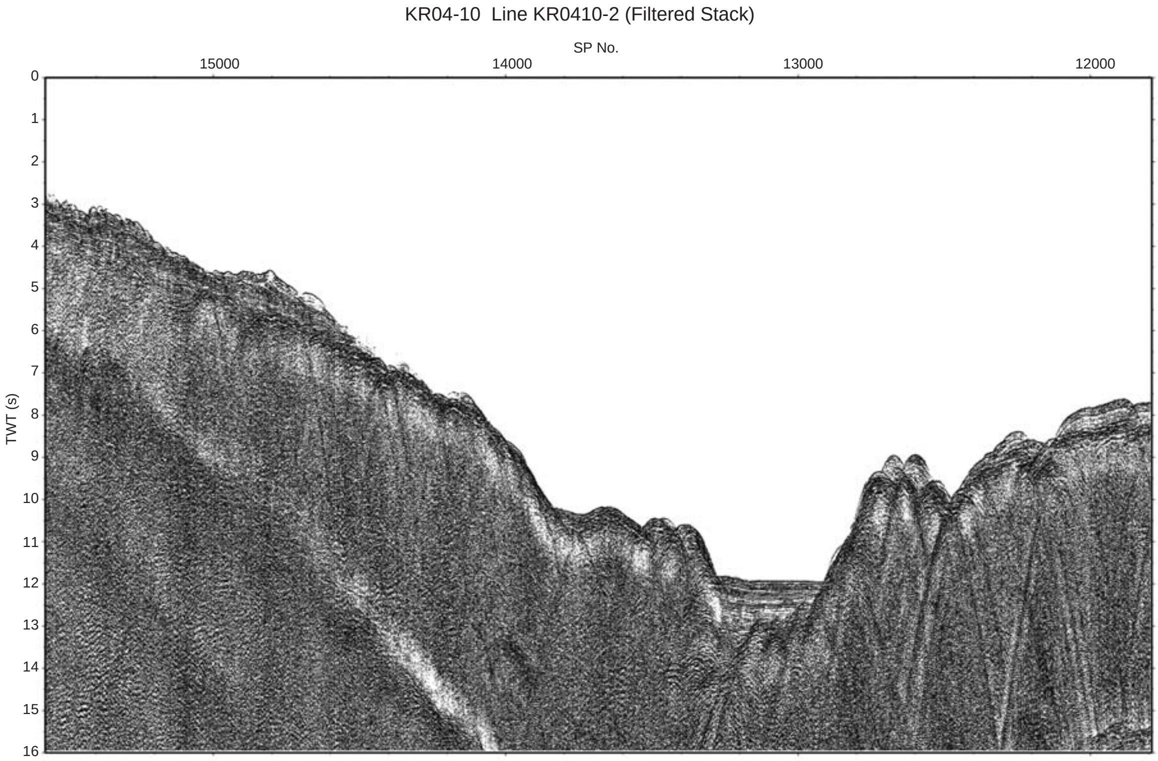


Figure 8: MCS profile of line IBr1 (KR0413-1). The profile is separatedly shown by four panels (a-d).

(a)

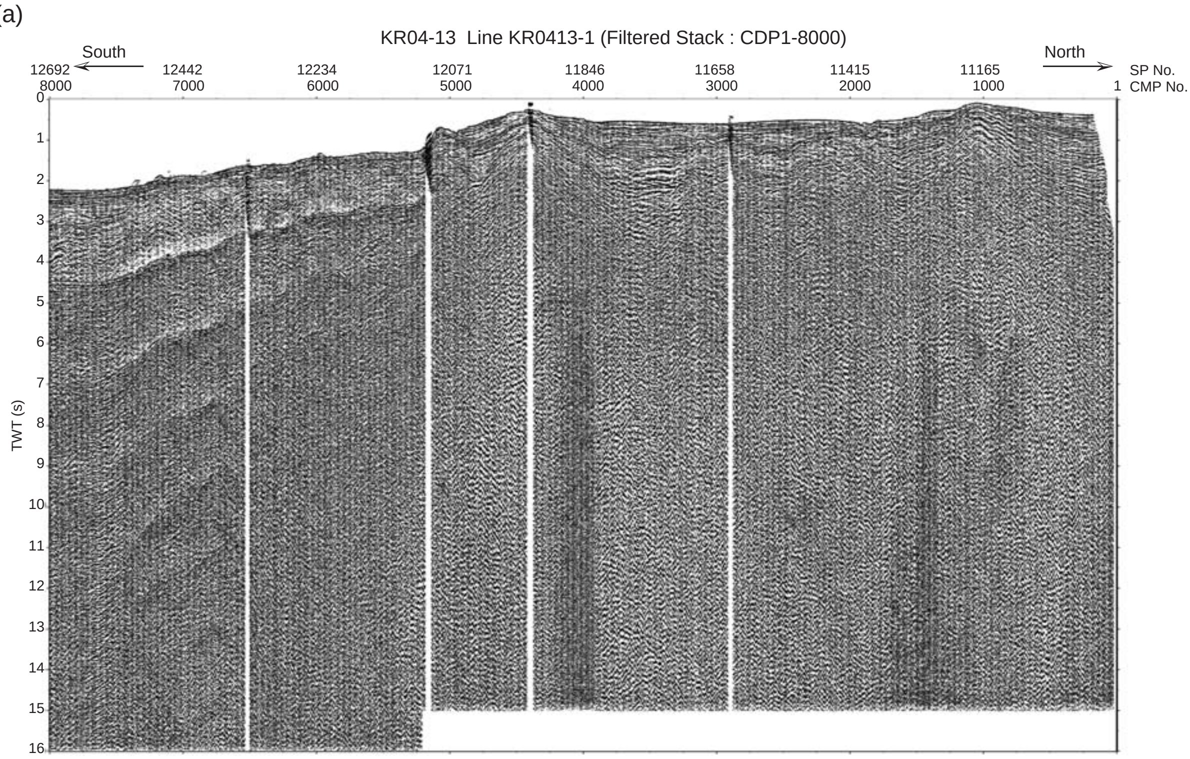


Figure 8: (Continued).

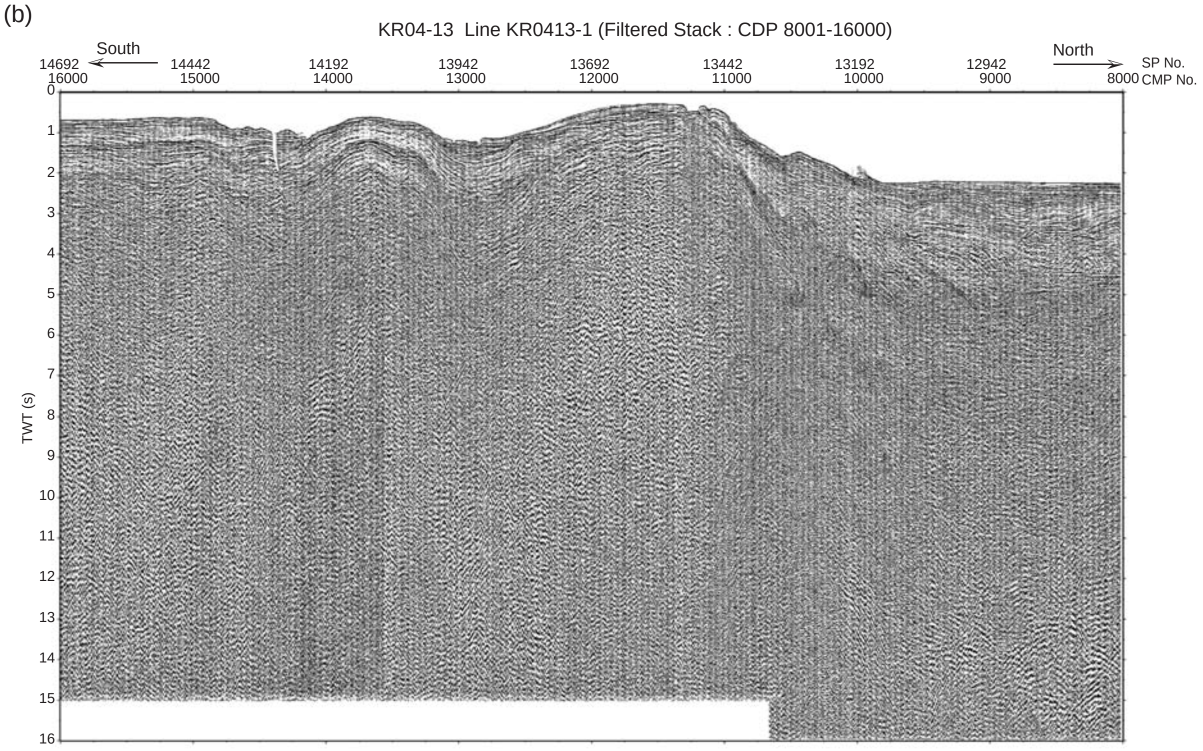
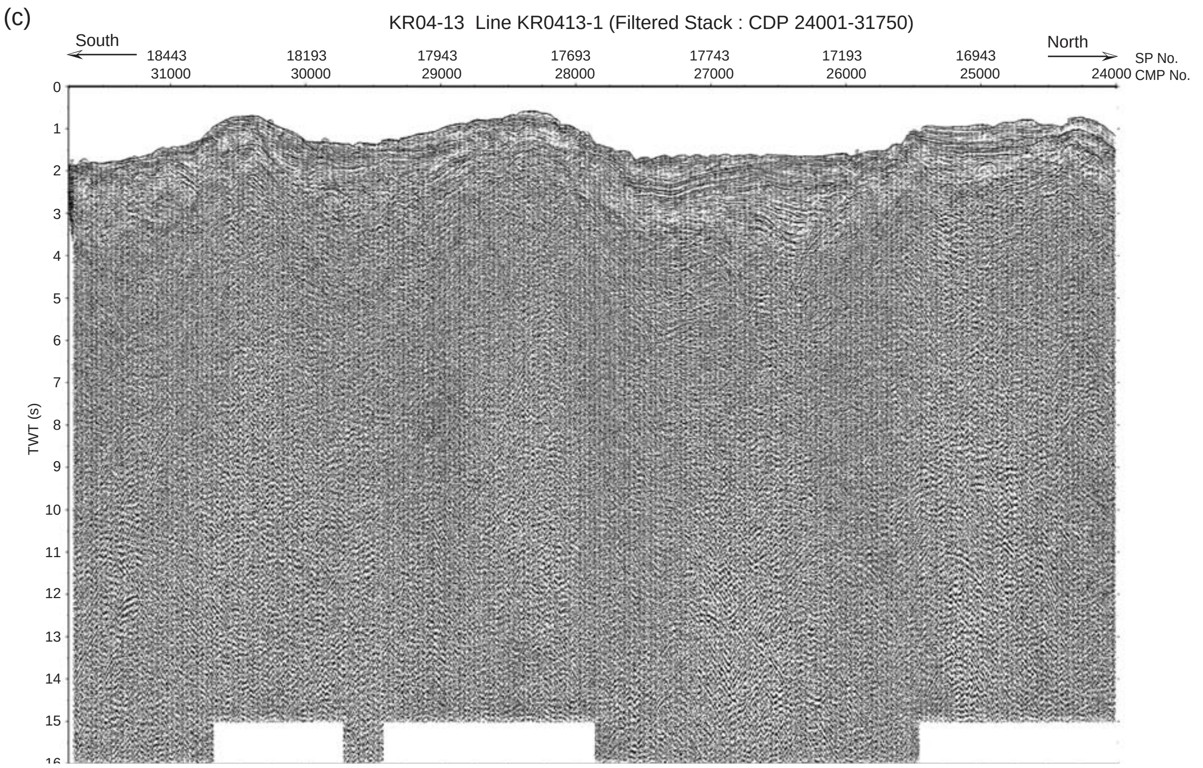


Figure 8: (Continued).



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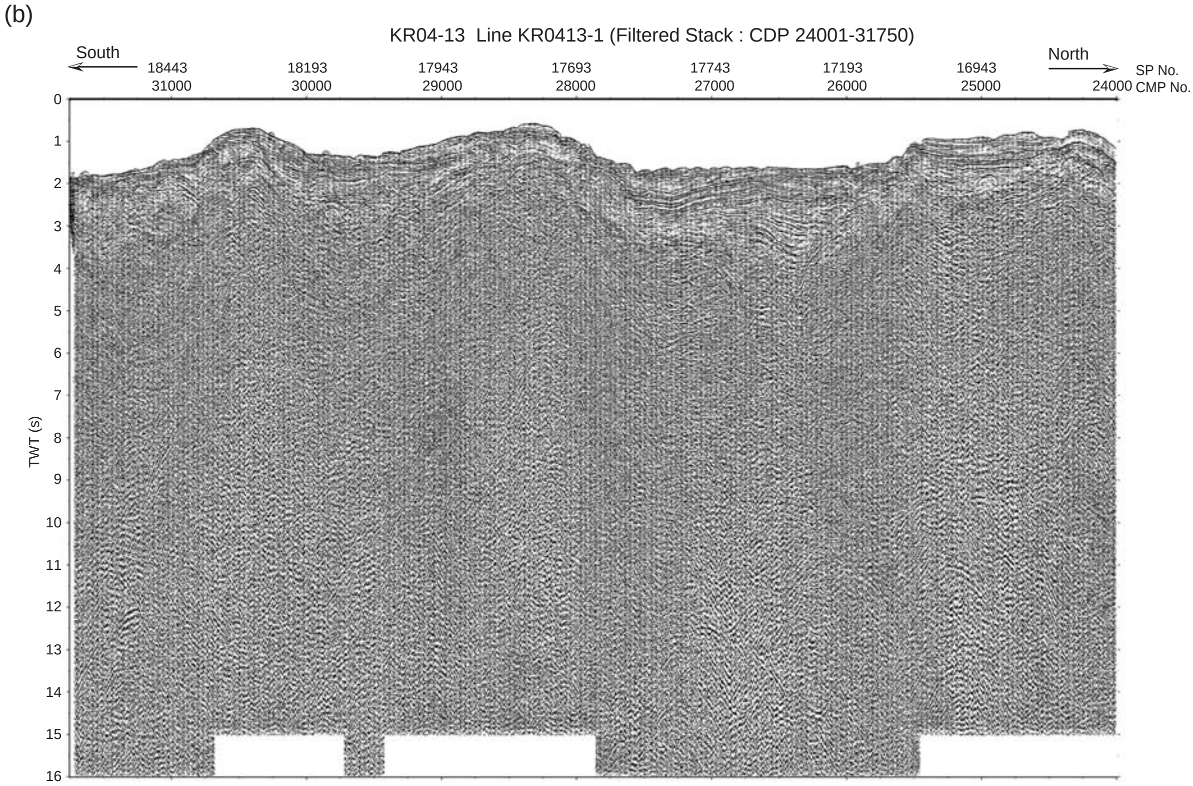

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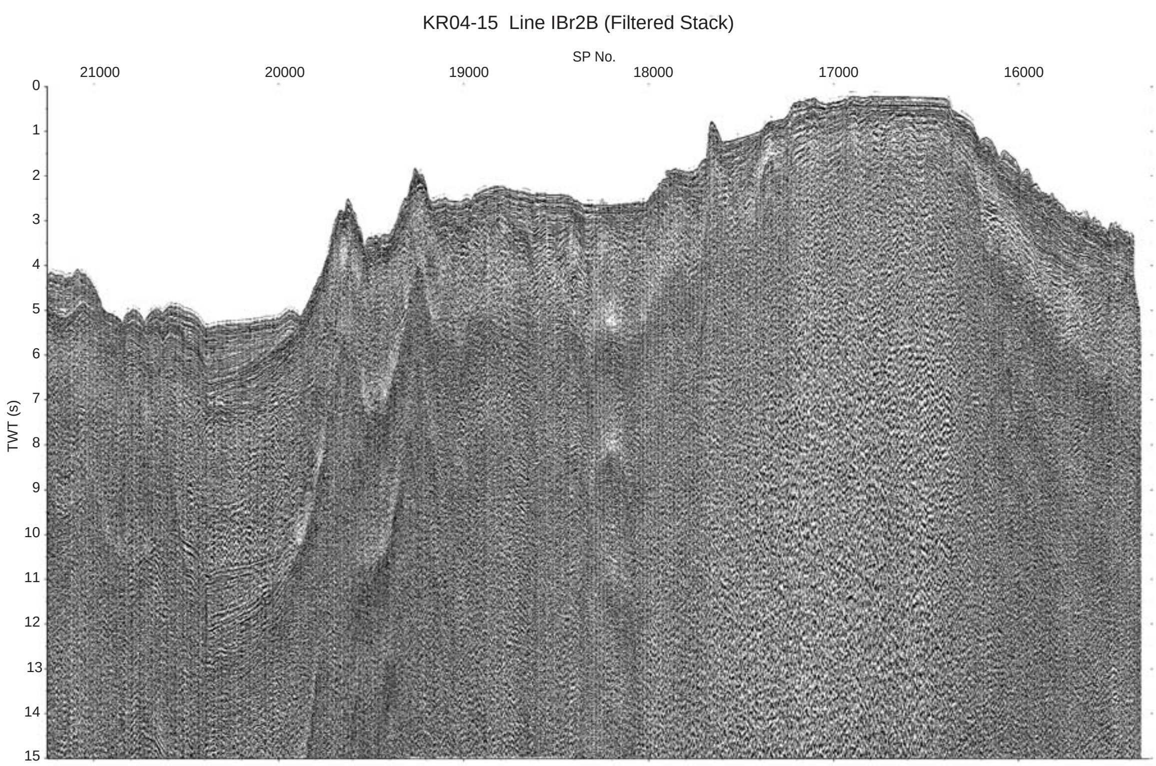

Figure 9: MCS profile of line IBr2B (KR0410-2B).

(a)

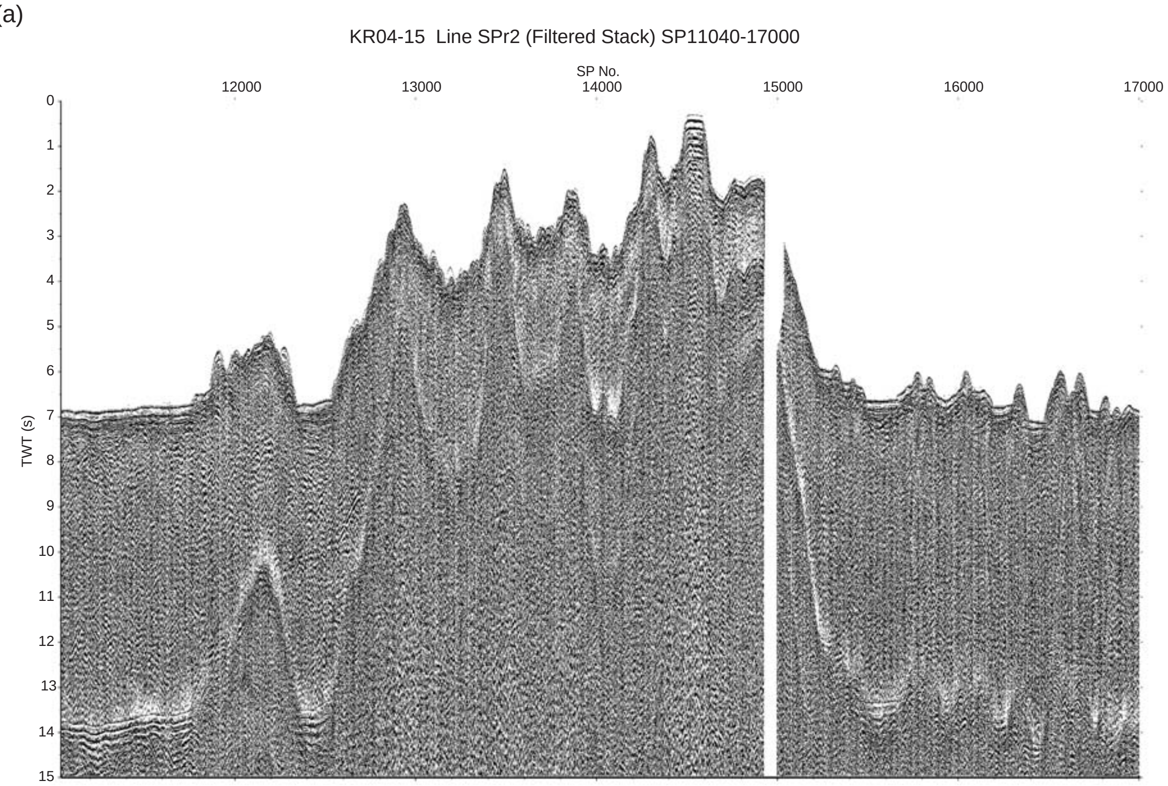

Figure 10: MCS profile of line SPr2. The profile is separatedly shown by four panels (a-d).

(b)

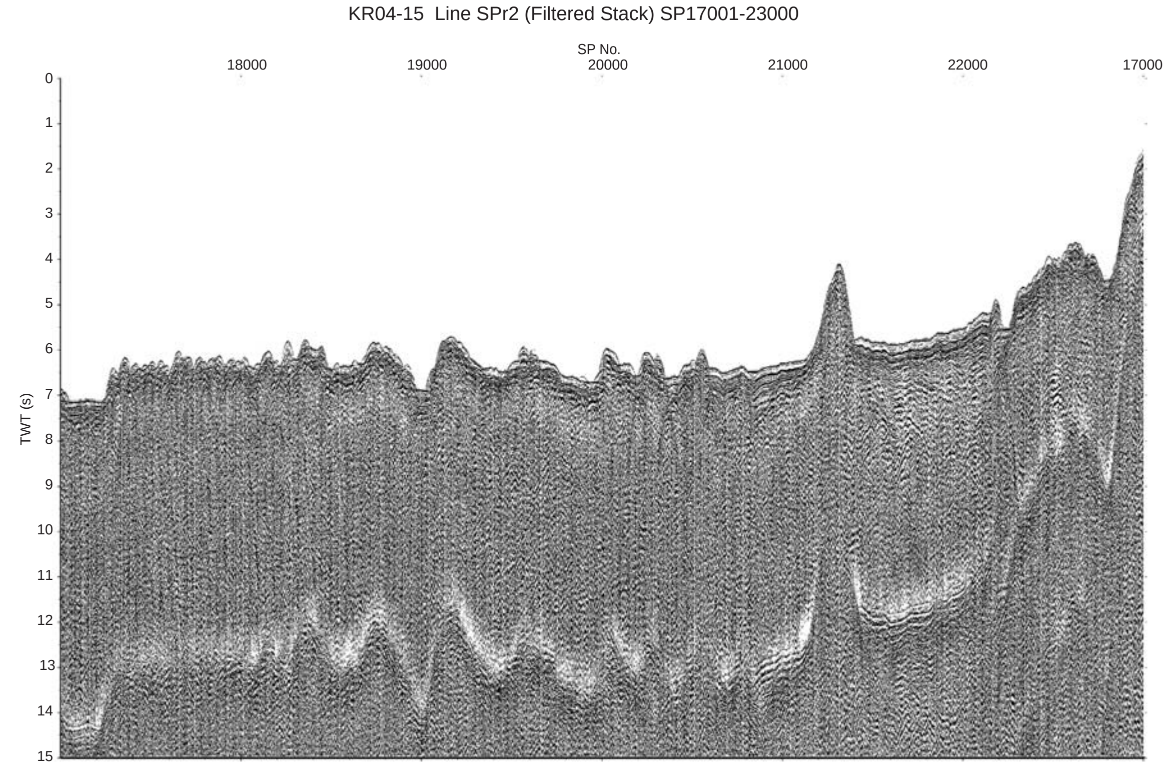

Figure 10: (Continued).

(c)

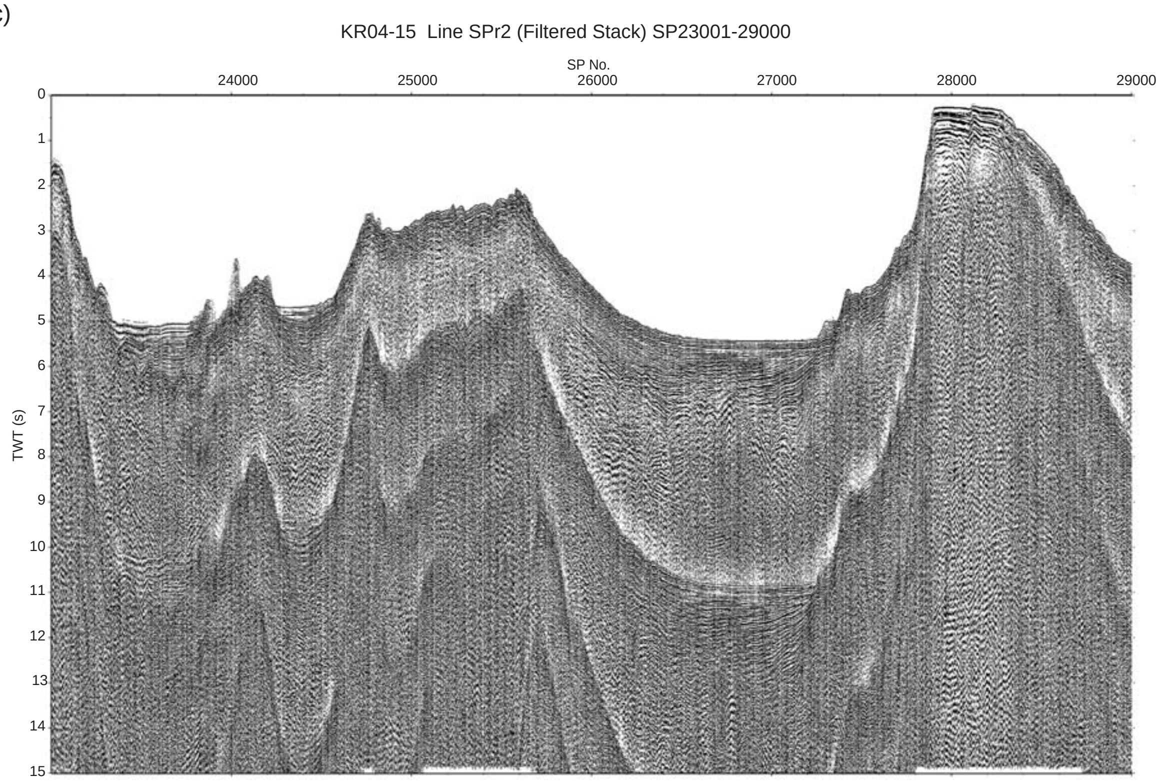

Figure 10: (Continued).

(d)

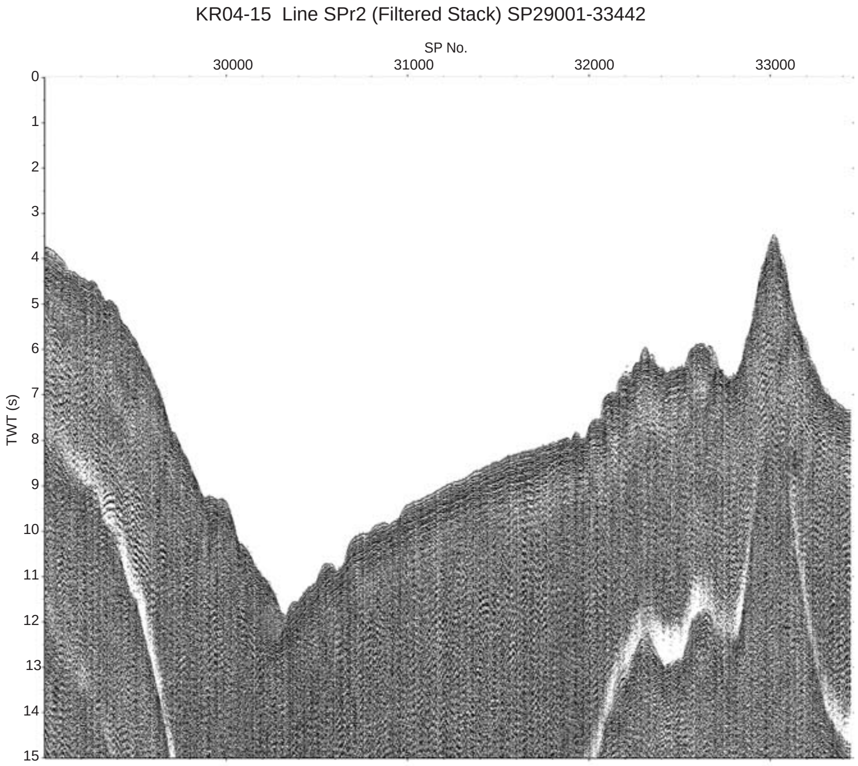

Figure 10: (Continued).

4. Acknowledgement

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