DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2012/120

Seismic Acquisition Report – LOMROG III in 2012

Acquisition of reflection and refraction seismic data during Oden's Lomonosov Ridge off Greenland (LOMROG III) cruise in 2012

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Contents

Summary

The LOMROG III cruise in 2012 was organized as a joint Danish-Swedish cruise where the Continental Shelf Project of the Kingdom of Denmark financed 80% of the cost of the cruise. The cruise started on July 31 in Longyearbyen, Svalbard, where it also ended on September 14. The primary objective of the Danish part of LOMROG III was to collect bathymetric, seismic and gravimetric data along the Eurasian flanks of the Lomonosov Ridge and in the Amundsen Basin in order to supplement the data acquired during the previous two LOMROG cruises. The LOMROG I to III cruise were organized to document an Extended Continental Shelf beyond 200 nautical miles according to Article 76 in UNCLOS in the area north of Greenland. The Swedish part of the cruise, consisting of three science projects, was organized by the Swedish Polar Research Secretariat.

During the cruise a total of 498 km seismic reflection data were collected and 63 sonobuoys were deployed, hereof 59 successful deployments. Based on the operative experiences gained during LOMROG II, the seismic lines were acquired by *Oden* breaking a 20-25 nautical mile long lead along the pre-planned line, going back along the same lead to make it wider, and finally to acquire the seismic data while passing through the lead a third time. Due to severe ice-conditions data acquisition had to be terminated twice despite a lead had been prepared.

LOMROG III was the last cruise of the Continental Shelf Project of the Kingdom of Denmark to the area north of Greenland and therefore represents the end of a very successful cooperation between The Geological Survey of Denmark and Greenland (GEUS) and the Swedish Polar Research Secretariat. It is hoped that the experience gained during the three LOMROG cruise and the EAGER cruise can be useful for future cruises of *Oden* to the Arctic Ocean.

On August 22, 2012 at 21:43 (UTC) Oden reached the North Pole - the 7th time Oden reached the North Pole and the 4th time on its own (Photo: Björn Eriksson).

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1. Introduction

By *Christian Marcussen, Geological Survey of Denmark and Greenland (GEUS)*

The area north of Greenland is one of three potential areas off Greenland for extension of the continental shelf beyond 200 nautical miles according to the United Nations Convention on the Law of the Sea (UNCLOS), article 76 (Marcussen et al. 2004, Marcussen & Heinesen 2010). The technical data needed for a submission to the Commission on the Limits of the Continental Shelf (CLCS) include geodetic, bathymetric, geophysical and geological data. Acquisition of the necessary data poses substantial logistical problems due to the ice conditions in the area north of Greenland.

Data acquisition in the area north of Greenland started in 2006 with the Danish-Canadian LORITA expedition (Jackson & Dahl-Jensen 2010), during which seismic refraction data from the shelf area north of Greenland and Ellesmere Island to the Lomonosov Ridge were collected. In spring of 2009, bathymetric and gravimetric data were collected from the sea ice in cooperation with Canada, using helicopters in an area north of Greenland covering the southern part of the Lomonosov Ridge. Furthermore, aero-geophysical data were acquired on either side of the Lomonosov Ridge. The LOMROG I cruise with *Oden* and *50 let Pobedy* collected bathymetric and seismic data in 2007 (Jakobsson et al. 2008). The LOMROG II cruise in 2009 cruise continued the work of LOMROG I (Marcussen et al. 2011). More information is available on www.a76.dk.

The LOMROG III cruise was organized in cooperation with the Swedish Polar Research Secretariat. The costs were split between Denmark (80%) and Sweden (20%). The main objectives of the LOMROG III cruise were:

UNCLOS related:

- Acquisition of bathymetric data on flank of the Lomonosov Ridge facing the Amundsen Basin supported by CTD casts from both Oden and the sea ice and supplemented by single beam spot soundings using Oden's helicopter.
- Acquisition of seismic data in the Amundsen basin and on the Lomonosov Ridge
- Acquisition of gravity data along Oden's track
- Dredging along the flank of the Lomonosov Ridge facing the Amundsen Basin

Add-on science:

- Swedish research projects:
  - Sediment Coring
  - Plankton Ecology
  - Microbial Communities
- Research projects from Denmark:
  - Oceanography
  - Ice-algae
  - Bioactive Gram-positive Spore-forming Arctic Bacteria
  - Sea Ice Temperature

A detailed description of the various projects is given in the LOMROG III cruise report (Marcussen et al. 2012). The LOMROG III cruise started on July 31 in Longyearbyen, Svalbard, where it also ended on September 14.

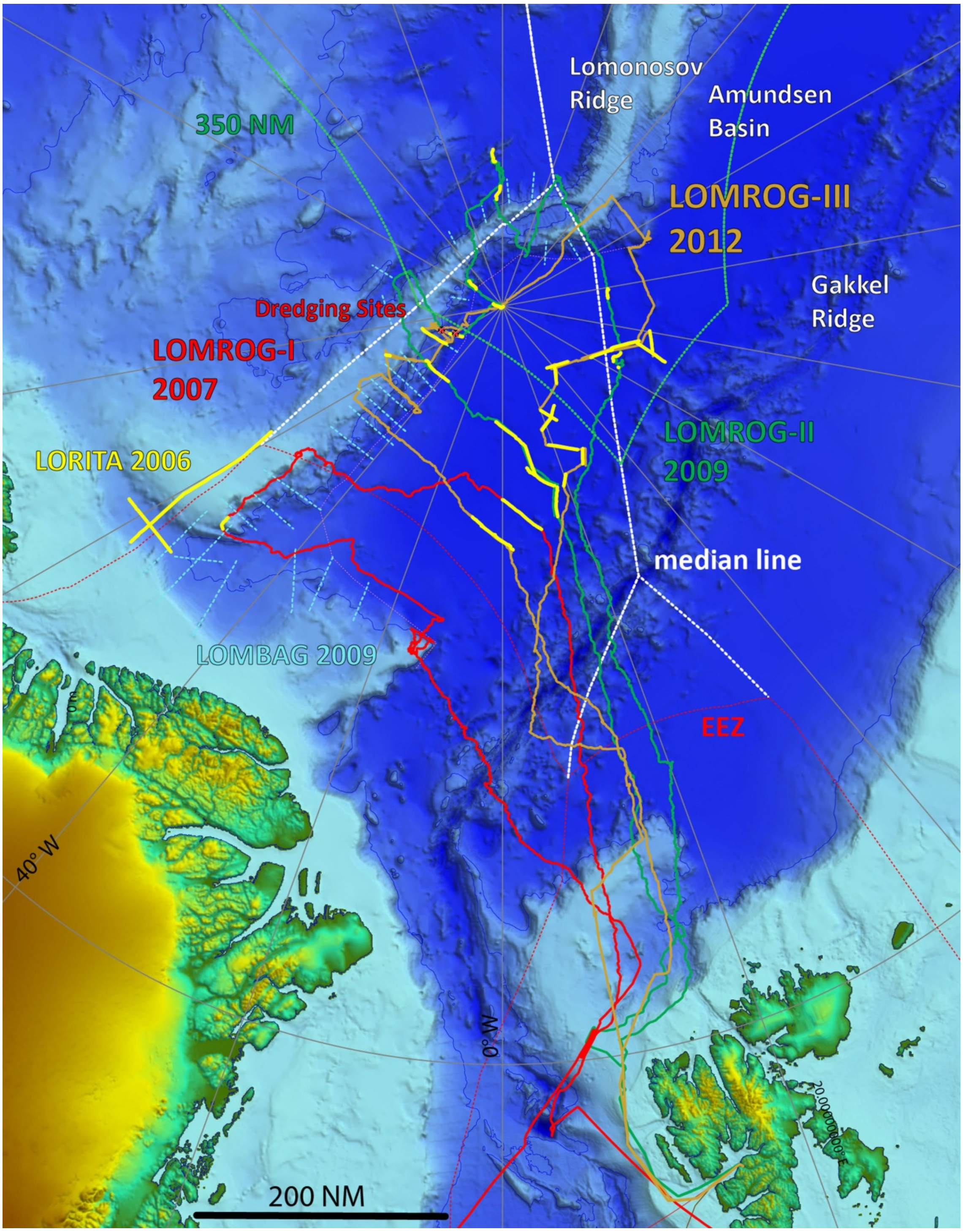

Figure 1. *LOMROG III ship track (orange) and Denmark's Article 76 field work north of Greenland from 2006 to 2012. Yellow line: LORITA seismic refraction lines (2006); green line – LOMROG I ship track (2007); red line – LOMROG II ship track (2009), light blue lines – bathymetric profiles acquired by helicopter during spring of 2009 and during LOMROG II (2009) & III (2012); yellow lines – seismic lines acquired during LOMROG I and II (2007 and 2009); red crosses – dredging sites; white stippled lines – unofficial median lines.*

Weather and Ice Conditions

Oden left Longyearbyen on July 31 in fair weather with a temperature at about 6ºC. The second day, when *Oden* reached the ice edge, temperatures dropped and in the evening it was near the freezing point.

During most of the expedition temperatures stayed between plus 0.5ºC and minus 2.0ºC. The highest temperature was about plus 1.5ºC and the lowest minus 8ºC, during the night between September 10 and 11.

The weather has generally not stopped helicopter operations, though it has been necessary to adjust plans at times, due to marginal conditions. Only on a few occasions helicopter operations were delayed or cancelled due to poor visibility, icing conditions or strong winds.

Synoptic weather observations were made at 06, 12 and 18 UTC and were sent via email to the Swedish Meteorological and Hydrological Institute, SMHI, and then further to the global meteorological community. Fog has been reported in 25 % of these observations and the figure for a cloud base lower than 300 meters is as high as 68 %.

The precipitation during the first 2-3 weeks of the expedition was mostly rain or drizzle. Later snowfall or freezing rain dominated since it was colder. About 15 % of the observations report precipitation.

We have had some days - or mostly nights - with sunny weather, mainly during the second week of the expedition.

On August 19 winds were at 14-16 m/s for several hours due to an unusually deep low pressure system passing through the Arctic area. Due to the strong winds the sea ice drifted with a considerable speed which had to be taken into account when planning the seismic data acquisition, since a broken lead could close quite fast depending on its direction relative to the drift direction.

On 26 August 2012 the Arctic sea ice reached its lowest areal extent of 4.1 million km^2 ever recorded since systematic satellite measurements began in 1978 with the SMMR instrument on the American NIMBUS-7 satellite. At the time of writing (12 September 2012) the total ice extent of 3.6 million km^2 is near its absolute minimum for the season and a record low during the satellite era. However, the area north of Greenland and near the North Pole along the *Oden* cruise track on LOMROG III are expected to be where the ice will disappear last due to global warming.

Nevertheless, the ice conditions along the cruise track were in general lighter than what could be expected when comparing to climatology: There were only small concentrations of multiyear ice near 87.5ºN; 45ºW and average ice thickness of first- and second year ice was not larger than 2 m. When navigating in areas with multiyear ice the snow and daylight conditions were favourable for visual identification of ice types.

References:

Jackson, H.R., Dahl-Jensen, T. & the LORITA working group 2010: Sedimentary and crustal structure from the Ellesmere Island and Greenland continental shelves onto the Lomonosov Ridge, Arctic Ocean. Geophysical Journal International **182**, 11-35.

Jakobsson, M., Marcussen, C. & LOMROG Scientific Party 2008: Lomonosov Ridge off Greenland 2007 (LOMROG) – cruise report. Special Publication Geological Survey of Denmark and Greenland, Copenhagen, Denmark, 122 pp.

Marcussen, C., Christiansen, F.G., Dahl-Jensen, T., Heinesen, M., Lomholt, S., Møller, J.J. and Sørensen, K. 2004: Exploring for extended continental shelf claims off Greenland and the Faroe Islands – geological perspectives. Geological Survey of Denmark and Greenland Bulletin **4**, 61–64.

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Marcussen, C. & LOMROG III Scientific Party 2012: Lomonosov Ridge off Greenland (LOMROG III) – Cruise Report. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2012/119**, 220 pp.

2. Seismic Reflection Survey

By *Thomas Varming*[1], *Per Trinhammer*[2], *Simon Ejlertsen*[2], *Lars Rödel*[3], *Marie Lykke Rasmussen*[2,3], *Sofie Ugelvig*[2,3], *Trine Kvist-Lassen*[2,3] *and Christian Marcussen*[3]; [1]*Bureau of Minerals and Petroleum* [2]*Department of Earth Sciences, University of Aarhus* [3]*Geological Survey of Denmark and Greenland (GEUS)*

Seismic reflection data were collected with an acquisition system, which consisted of standard seismic equipment modified for data acquisition under extreme ice conditions as expected during the LOMROG expeditions in the Arctic Ocean.

The most important elements of the seismic equipment are a digital streamer and recording system produced by Geometrics and the seismic source - a so-called linear gun cluster - produced by Sercel.

The setup of the entire system used during LOMROG III included the same main components as the previous two LOMROG cruises, but with a few important changes implemented from the experiences gained from the LOMROG I and II cruises in 2007 and 2009 respectively (Marcussen et al. 2008 & Lykke-Andersen et al. 2010).

In the following a brief overview of the seismic reflection equipment used onboard *Oden* on the LOMROG III expedition 2012 is given. Further details are given in Appendix I.

2.1 Seismic Source

The seismic source consisted of one 1040 cu. in. linear airgun cluster, each consisting of two Sercel 520 cu. in. G-guns (Figure 2). The volume of the airgun cluster has been increased considerably compared to the two previous LOMROG cruise (From 605 cu. in. to 1040 cu. in.) in order to increase penetration of the seismic reflection signal and the range of the seismic refraction signal.

The firing interval was 14 seconds and the firing pressure was 180 bar, The pressurized air was produced by two Hamworthy 185E_MK2 70mm Series Air Compressors and two Bauer K23 High Pressure Compressor units. A trigger pulse generated by NaviPac was sent to the gun trigger unit, Macha TGS-8 (Figure 2) which synchronized and triggered the guns.

A time-break signal was sent to the TGS-8 trigger unit from each G-gun for synchronization of the guns.

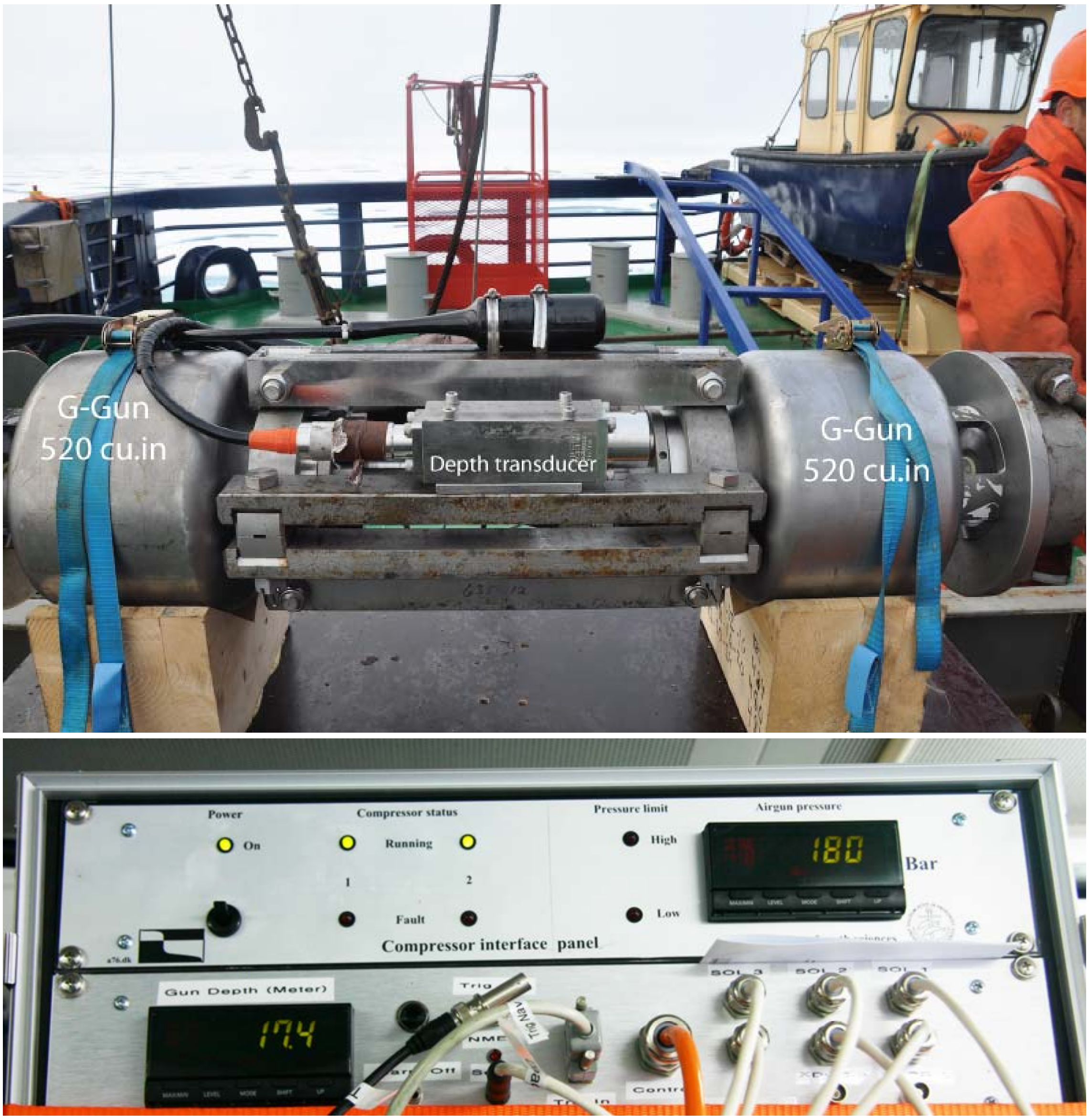

Figure 2. *Sercel 1040 cu.in. linear airgun cluster (top). (Bottom) TGS-8 gun trigger unit (cables right side of lower panel), gun depth monitor (left side of lower panel). Compressor monitor and air gun pressure (upper panel).*

A hydrophone was placed in the middle of the two G-guns (Figure 2). The signals from the hydrophone were recorded by the TGS-8 trigger unit for near-field data. The near-field data is stored in a SEG-Y format on the hard disk on the TGS-8. In spited that the TGS-8 is based on MS-DOS 5.0 system and the only external drive is a 3.5” floppy disk, the data was retrieved by taking the hard disk out and read to a USB media after the end of the entire survey.

In addition, a depth transducer was mounted on the gun cluster in order to monitor the tow depth of the array. The transducer values were updated every 1 s and displayed. The gun depth data were sent via RS 232 to NaviPac and stored in the log files.

The Macha TGS-8 was controlled from a dedicated computer running the gun control software program. Within the software program, various settings and displays were used to monitor the gun array behaviour (Figure 3).

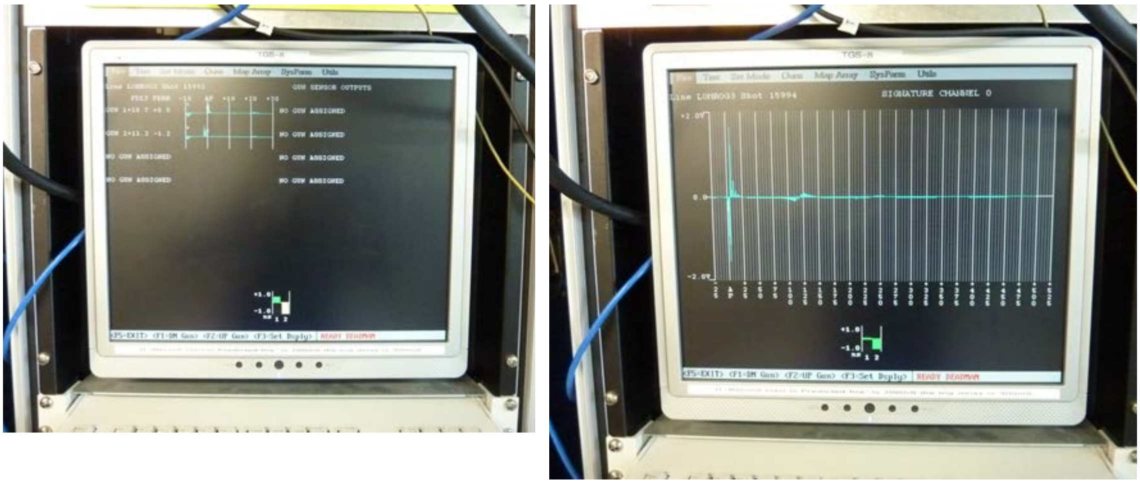

Figure 3. *The Macha TGS-8 software running on its own dedicated computer. Display showing the timing of the two air guns in the array (left) and on the right the display showing the nearfield pulse from the air gun array.*

2.2 Streamer

The streamer was a digital Geometrics GeoEel streamer (Figures 4, 9 & 10) with four 50 m long live sections (total active length 200 m) and one 50 m long stretch section. The live sections contained in total 32 hydrophone groups each composed of 8 Benthos GeoPoint hydrophones. Group separation was 6.25 m and hydrophone separation 0.78 m. Power supply unit (SPSU) to the streamer and all data communication from the streamer took place through the umbilical cable. In the front end of each live section was an A/D module; in the front of the stretch section was a repeater module for transmitting the signals through the lead-in cable of the streamer.

Each live section had a depth transducer installed in one end. The streamer was configured with depth transducers in the front ends of sections 1-3 and at the tail end of section 4 or at the front end of all live sections. Appendix IV (Configuration of the Geometrics GeoEel streamer) gives further details on the configuration of the depth transducers for each line.

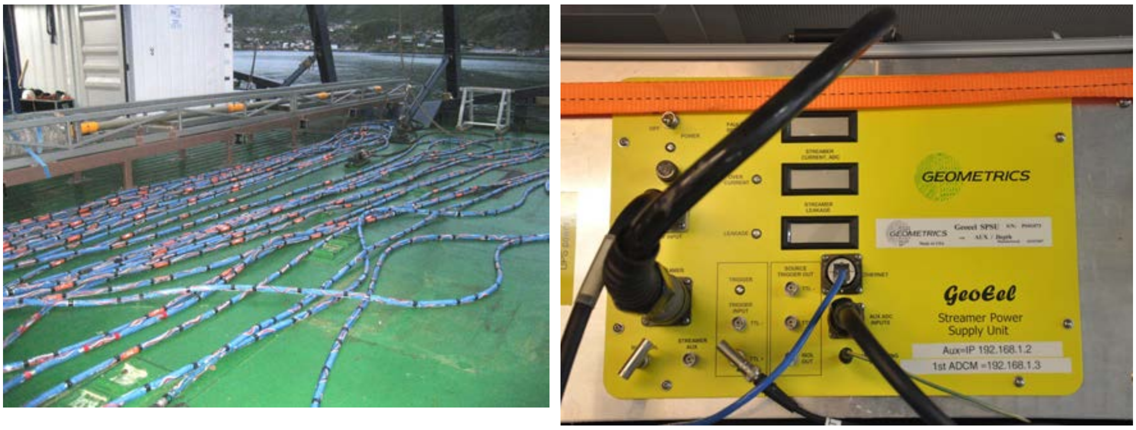

Figure 4. *Geometrics GeoEel streamer on deck (left) - for streamer on winch see Figs. 9 and 11. Geometrics GeoEel streamer power supply unit SPSU (right).*

2.3 Recording System

Data were recorded in SEG-D format (8058 revision 1) on a PC running Geometrics GeoEel controller software CNT-2. The controller was connected to the streamer power supply unit (SPSU) (Figure 4) via Ethernet and receiving the digitized signals from the streamer as well as auxiliary channels 1-8. On auxiliary channels 1, 2, 3 and 4 data from the sonobuoy radio receivers were recorded and on auxiliary channel 8 the PPS pulse from the GPS. The PPS pulse has a reduction of a factor 10 to avoid cross talk. Data were recorded simultaneously on LTO-2 tapes with a capacity of 200 GB, a RAID 250 GB hard disk and a USB 320 GB hard disk.

Note: During the recording of seismic line 10 it was noted that the computer system had difficulties with writing to the USB hard disk and that some of the files written to the USB hard disk were corrupted and the simultaneous writing on all three disks was putting a lot of stress on the computer system. It was therefore decided not to write to the USB hard disk and only use it as a backup on the remaining seismic lines.

The navigation software NaviPac (see below) sent an event trigger every 14 s and a string to COM port 1 on the CNT-2 PC. The string contained time, event number, position (x, y for the gun cluster), gun depth and the string was transferred to the SEG-D external header on tape and hard disks. The data string is also stored in a log file on the CNT-2 PC with the filename:

Lomrog3.0000x.Nav.txt.

The seismic controller provided the following display facilities during survey:

- A shot gather window (Figure 5) where various display settings could be changed as appropriate.
- A single channel window (Figure 5).
- A brute stack window (Figure 5).

- A noise window showing noise values in µbar from all 32 channels as a "snapshot" calculated between shots. Additionally the noise can be displayed as S/N ratio in dB.
- A trigger window showing the time interval between shots and the energy of a specified hydrophone (in this set-up channel 1).
- A streamer depth window displaying the depth from each depth transducer module.

Figure 5. *Seismic controller display facilities: noise window, trigger window and log window (left) and shot gather window, brute stack window and a streamer depth window (right).*

During the survey the CNT-2 software generated a log file named:

Lomrog3_linenumber.log

with the following format:

- First line is read from the serial input from the NaviPac software described below (not all numbers are readable in the log file, but all data are stored in the SEG-D header and in a log file called Lomrog3.linenumber.Nav.txt). The format of the string is: time HH:MM:SS:sss (UTC), event no, X pos, Y pos (UPS, WGS 84, LC 1040 gun array position), Gun depth<CR> <LF>.
- Second line is file no., exact CNT-2 trigger time, size in Kb and reel number.

Furthermore, data from the streamer depth transducers were stored in a text file. These files were named:

Lomrog3.linenumber.Depth.txt

An example of a depth file from the streamer depth transducers is shown in Figure 6 below.

```
File: 101, Depths: 5004: 83.49m 5015: 134.53m 5016: 186.67m 5010: 237.86m
File: 102, Depths: 5004: 81.47m 5015: 132.01m 5016: 185.23m 5010: 236.22m
File: 103, Depths: 5004: 78.03m 5015: 132.01m 5016: 182.21m 5010: 233.28m
File: 104, Depths: 5004: 72.44m 5015: 128.02m 5016: 177.71m 5010: 227.91m
File: 105, Depths: 5004: 72.44m 5015: 121.53m 5016: 171.02m 5010: 220.49m
File: 106, Depths: 5004: 65.32m 5015: 113.76m 5016: 162.13m 5010: 211.03m
File: 107, Depths: 5004: 57.05m 5015: 102.80m 5016: 150.26m 5010: 211.03m
File: 108, Depths: 5004: 48.03m 5015: 88.40m 5016: 134.28m 5010: 197.96m
File: 109, Depths: 5004: 39.20m 5015: 71.69m 5016: 134.28m 5010: 180.94m
File: 110, Depths: 5004: 32.00m 5015: 55.23m 5016: 114.80m 5010: 160.57m
File: 111, Depths: 5004: 26.00m 5015: 41.28m 5016: 91.50m 5010: 134.15m
File: 112, Depths: 5004: 21.48m 5015: 41.28m 5016: 67.95m 5010: 106.58m
File: 113, Depths: 5004: 19.15m 5015: 32.46m 5016: 49.67m 5010: 79.40m
File: 114, Depths: 5004: 19.15m 5015: 26.04m 5016: 38.46m 5010: 58.07m
File: 115, Depths: 5004: 18.00m 5015: 22.73m 5016: 30.77m 5010: 45.11m
File: 116, Depths: 5004: 17.83m 5015: 21.13m 5016: 26.49m 5010: 45.11m
File: 117, Depths: 5004: 18.21m 5015: 20.24m 5016: 24.44m 5010: 36.51m
File: 118, Depths: 5004: 18.53m 5015: 20.24m 5016: 24.44m 5010: 31.20m
File: 119, Depths: 5004: 19.05m 5015: 20.12m 5016: 22.76m 5010: 28.55m
File: 120, Depths: 5004: 19.36m 5015: 20.12m 5016: 22.32m 5010: 26.30m
File: 121, Depths: 5004: 19.35m 5015: 20.51m 5016: 21.76m 5010: 25.23m
File: 122, Depths: 5004: 19.35m 5015: 20.70m 5016: 21.81m 5010: 24.25m
File: 123, Depths: 5004: 18.14m 5015: 20.47m 5016: 21.79m 5010: 24.00m
File: 124, Depths: 5004: 17.48m 5015: 19.29m 5016: 21.56m 5010: 24.00m
File: 125, Depths: 5004: 17.77m 5015: 18.82m 5016: 20.36m 5010: 23.67m
File: 126, Depths: 5004: 18.14m 5015: 19.15m 5016: 20.56m 5010: 23.73m
File: 127, Depths: 5004: 18.23m 5015: 19.34m 5016: 20.56m 5010: 22.53m
File: 128, Depths: 5004: 17.73m 5015: 19.34m 5016: 20.57m 5010: 22.50m
File: 129, Depths: 5004: 17.78m 5015: 19.21m 5016: 20.41m 5010: 22.60m
File: 130, Depths: 5004: 18.25m 5015: 18.93m 5016: 20.31m 5010: 22.37m
File: 131, Depths: 5004: 18.25m 5015: 19.06m 5016: 20.05m 5010: 22.29m
File: 132, Depths: 5004: 17.95m 5015: 19.13m 5016: 19.88m 5010: 22.04m
File: 133, Depths: 5004: 17.40m 5015: 18.86m 5016: 19.86m 5010: 22.04m
File: 134, Depths: 5004: 17.24m 5015: 18.52m 5016: 19.75m 5010: 21.63m
File: 135, Depths: 5004: 17.89m 5015: 18.64m 5016: 19.75m 5010: 21.56m
File: 136, Depths: 5004: 18.52m 5015: 18.64m 5016: 19.71m 5010: 21.56m
File: 137, Depths: 5004: 19.20m 5015: 19.27m 5016: 19.69m 5010: 21.73m
File: 138, Depths: 5004: 19.20m 5015: 19.77m 5016: 20.29m 5010: 21.67m
File: 139, Depths: 5004: 19.65m 5015: 20.38m 5016: 20.72m 5010: 21.67m
File: 140, Depths: 5004: 20.30m 5015: 20.96m 5016: 21.39m 5010: 22.08m
File: 141, Depths: 5004: 20.60m 5015: 21.55m 5016: 21.39m 5010: 22.71m
File: 142, Depths: 5004: 20.17m 5015: 21.79m 5016: 21.95m 5010: 23.09m
File: 143, Depths: 5004: 20.17m 5015: 21.55m 5016: 22.47m 5010: 23.80m
File: 144, Depths: 5004: 19.48m 5015: 21.55m 5016: 22.88m 5010: 24.39m
File: 145, Depths: 5004: 18.50m 5015: 21.27m 5016: 22.68m 5010: 24.85m
File: 146, Depths: 5004: 17.52m 5015: 20.50m 5016: 22.31m 5010: 24.72m
File: 147, Depths: 5004: 17.52m 5015: 19.60m 5016: 21.54m 5010: 24.32m
File: 148, Depths: 5004: 17.14m 5015: 18.78m 5016: 20.71m 5010: 24.32m
File: 149, Depths: 5004: 17.56m 5015: 18.56m 5016: 20.71m 5010: 23.75m
File: 150, Depths: 5004: 18.67m 5015: 19.38m 5016: 20.29m 5010: 23.10m
```

Figure 6. *Example of a depth file generated by the CNT-2 software from the input data from the depth transducers in the streamer live sections.*

2.4 Navigation and Positioning System

A separate Thales DG16 GPS was used for positioning of the seismic reflection equipment together with the navigation and data logging software NaviPac from EIVA A/S. The GPS has a built-in beacon and WAAS receivers for differential corrections. However, the survey area in the Arctic Ocean was outside the coverage area of both systems and the GPS was used without differential corrections. NaviPac received antenna coordinates from the GPS.

Note: The water depth below the transducer from the centre beam of the ships Kongsberg EM 120 multibeam system was initially planned to be input into NaviPac, but this function did not work during the whole cruise, since the multibeam system had not been setup for this function after its annual service by Kongsberg prior to the start of the survey.

The network connection supplying the Furuno ship gyro to NaviPac often proved unreliable and it was therefore necessary to supply the NaviPac system with a secondary gyro calculated from the Thales DG16 GPS system.

The NaviPac system provided the trigger signal for the TGS-8 and an event trigger and data string for the CNT-2 controller. The shooting interval was 14 sec. To reduce the signal from the last shot the feature of adding a noise of +/- 1 sec to the trigger interval was used. Run lines (survey lines) were generated in the so-called Helmsman's display part of NaviPac and the survey is controlled from this display (Figure 7). The option of distributing runline data to a Helmsman's display on the bridge running in slave mode was not used.

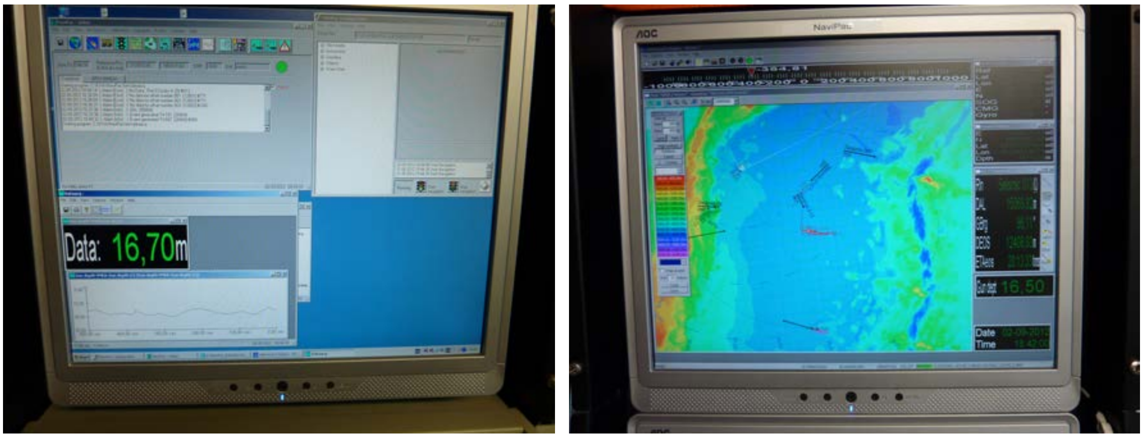

Figure 7. *NaviPac setup window (left) and NaviPac Helmsman's display for survey control (right).*

2.5 Container and Equipment Setup on *Oden*

Several containers were used for the seismic reflection operation. The winch container with the three winches for the umbilical, streamer and sheave wire, respectively, was placed on the central part of the aft deck (Figure 8). On the starboard side, two compressor containers (the two containers stacked on top of each other), a gun workshop as well as streamer container and storage containers were placed (Figure 9).

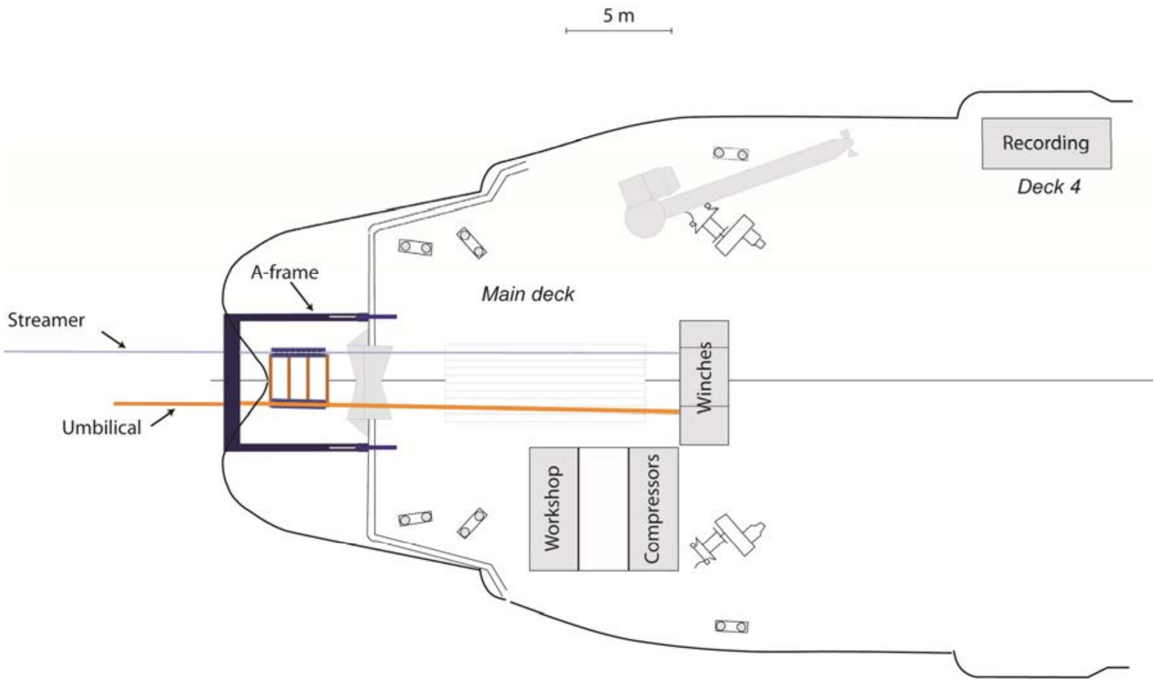

Figure 8. *Plan view showing location of main equipment components on aft deck and deck 4.*

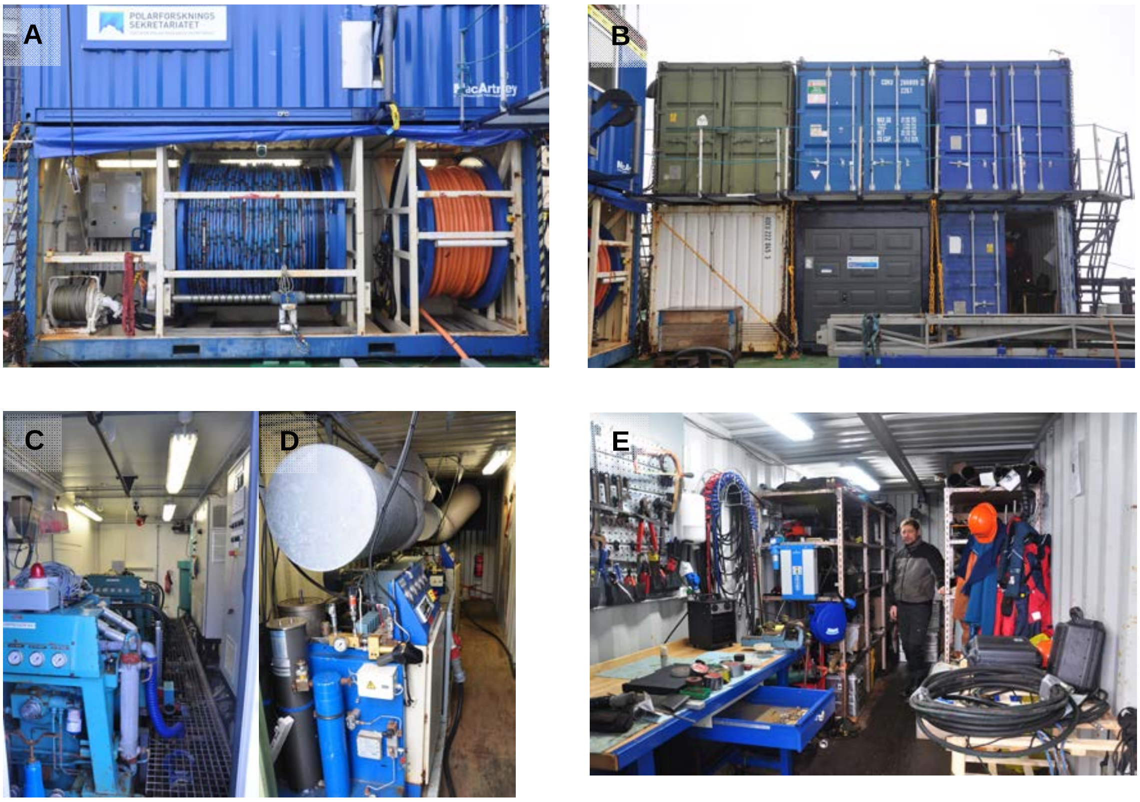

Figure 9. *Containers on aft deck: (A) winch container; (B) compressor containers (white and green), storage containers (blue) in the upper layer and workshop container (blue) in the lower layer to the right; interior of compressor container: (C) Hamworthy and (D) Bauer compressors; (E) interior of workshop container.*

Cables were connecting the umbilical winch and the recording container placed on the port aft side of deck 4 (Figure 10 & 19). The recording container houses the navigation software (NaviPac) and multichannel acquisition system (Geometrics CNT-2, SPSU, TGS-8, Winradio).

Figure 10. *Recording container on deck 4 (left) and interior of the container (right).*

2.6 References

Marcussen, C., Vangkilde-Pedersen, T., Lykke-Andersen, H., Trinhammer, P., Funck, T., Dahl-Jensen, T. & Forsberg, R. 2008: Seismic Acquisition Report – LOMROG 2007, Danmarks og Grønlands Geologiske Undersøgelse Rapport 2008/77, 82 pp + 4 appendices + 1 CD.

Lykke-Andersen, H., Funck, T., Hopper, J.R., Trinhammer, P., Marcussen, C., Gunvald, A.K. & Jørgensen, E.V. 2010: Seismic Acquisition Report - LOMROG II in 2009, Danmarks og Grønlands Geologiske Undersøgelse Rapport 2010/53, 73 pp + 5 appendices + 1 CD.

3. Seismic Reflection Equipment for Data Acquisition in Ice

By *Thomas Varming*[1], *Per Trinhammer*[2], *Simon Ejlertsen*[2], *Lars Rödel*[3], *Marie Lykke Rasmussen*[2,3], *Sofie Ugelvig*[2,3], *Trine Kvist-Lassen*[2,3] *and Christian Marcussen*[3]; [1]*Bureau of Minerals and Petroleum* [2]*Department of Earth Sciences, University of Aarhus* [3]*Geological Survey of Denmark and Greenland (GEUS)*

3.1 General Considerations

The strategy and procedures for handling of air guns and streamer as practiced on LOMROG III 2012 were based on the experience gained by other workers on previous seismic cruises in the Arctic Ocean supplemented by experiences obtained during the LOMROG I cruise in 2007 and the LOMROG II cruise in 2009.

The three prime concerns were: 1) to minimize the risk for ice-induced physical damage of the equipment towed in the water behind the icebreaker; 2) to reduce the risk for elevated noise levels by having the streamer forced up into the turbulent propeller wash and 3) to find an acceptable replacement for vulnerable active streamer-depth controllers (“birds”).

It was found that the most reasonable way to achieve these goals was to:

1. Build the towing system for source and streamer as compact and robust as possible, and for the sake of avoiding entanglements, using a minimum of cables, wires and chains;
2. Increase the tow depth to relatively calm waters below the most energetic part of the propeller wash, and since this depth was unknown, to construct the tow system to allow for large flexibility in towing depth;
3. Install passive depth transducers at the source and in the streamer with a spacing suitable for obtaining depths sufficiently reliable to secure high-quality stacked sections.

3.2 Equipment and Procedure for Handling Source and Streamer

The key element in the handling system is the umbilical. It is a heavy duty cable (breaking strength 50 tons) constructed to serve both the air guns (hoses for compressed air, triggering cables, cables for near field hydrophones and depth transducer) and the streamer (data communications with the A/D modules and the hydrophones, cables to depth transducers, power cables). The umbilical sits on a hydraulic winch (right side in Figure 11).

Figure 11. *Winch container.*

The sea-end of the umbilical is terminated in a robust stainless steel head with all cable and hose terminals placed on the plane lower surface of the head and protected in a cone of steel sleeves and rods (Figure 12). The streamer is connected to the umbilical head via a 3.5 m jumper cable contained in a robust, steel reinforced rubber hose. A similar but less wide rubber hose protects the air hoses and electrical connections to the air guns.

Figure 12. *The sea end of the umbilical hanging in the A-frame (left) and close-up photo of the umbilical head (right).*

The launching of air guns and streamer takes place in a concerted procedure composed of the following sequence of steps:

1) *Oden* parks it's stern against the ice and reduces its propeller wash as much as possible, just enough to prevent the vessel from moving backwards. The propeller wash from *Oden* created a 30-100 m long ice free zone behind the ship.

2) The umbilical in the umbilical sheave and the air gun cluster is lifted in the A-frame (Figure 13) by the wire winch (left hand side in the winch container as seen on Figure 11), and lowered to the aft deck next to the platform for docking of sheaves for streamer and umbilical (Figure 14).

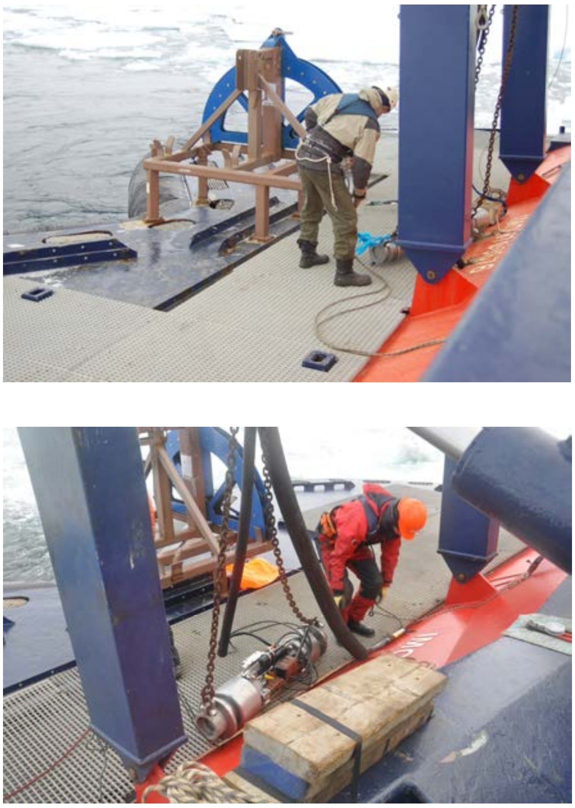

Figure 13. *Umbilical and air guns lifted in the umbilical sheave.*

Figure 14. *Air gun array on aft deck. Streamer sheave in the background (port side).*

3) The deployment of the streamer begins by unrolling the streamer from the winch (middle section Figure 11) and bringing the tail end to the streamer sheave. On its way to the sheave, it is guided by six four-sided roller ports along the rail mounted on the aft deck and used for handling the piston/gravity coring systems (Figure 15). From this point the streamer is deployed into the water. In order to reduce the risk for collision between streamer and unpredictable ice floes three measures were taken to make the streamer sink steeply:

   a. The propeller wash was reduced and the streamer sinks.

   b. 2-3 kg of lead was fastened to the streamer close to the tail end. When the frontend connector of the streamer reaches the sheave the streamer is temporarily fixed by means of a short rope to the deck (Figure 16) and the connector is opened and the streamer end is connected with the jumper cable (Figure 16). For this expedition, a new set of connection jumpers (Figure 17) have been developed, making the fastening of the streamer to the jumper cable easier for the people working on the tail fan of *Oden*.

c. A drag anchor and a weight of 5 kg (Figure 16) were attached to the end of the streamer. Once *Oden* speeds up to approximately 1 knot, the drag of the anchor exceeds the breakage strength of the strings and the anchor and weight sinks to the bottom, while the streamer raises itself in the water column.

Figure 15. *Streamer running through roller ports towards the sheave.*

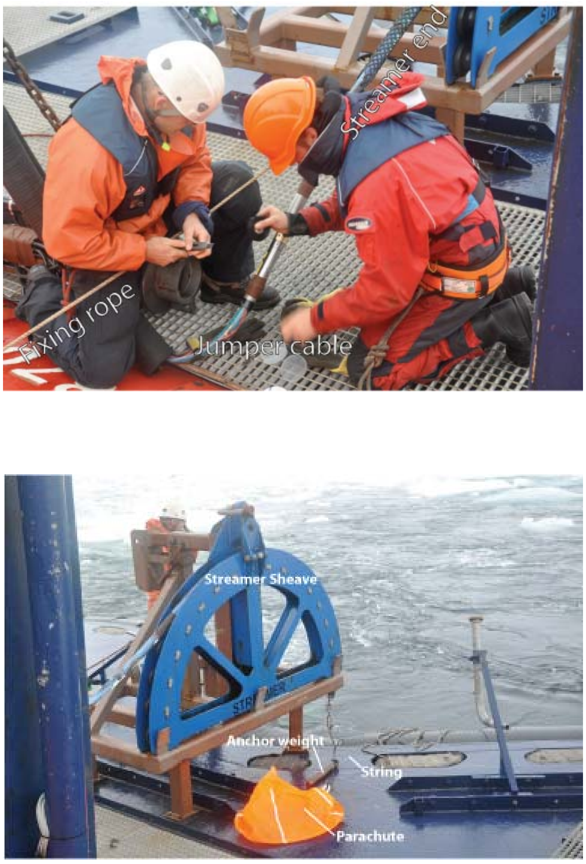

Figure 16. *Above, the front end of the streamer connected to the jumper cable. Below, the drag anchor attached to the tail end of the streamer.*

Figure 17. *Photos of the new connection jumpers. On the left photo is the jumper cable side; while on the right photo is the streamer cable side. These new connectors make it easier to connect the jumper cable and the streamer section for the people working at the tail fan of Oden.*

4) The umbilical with the air guns and the streamer is now lifted in the sheave and at the same time the A-frame is turned outwards to establish free passage for the umbilical with air guns and streamer to be brought in the final position with the 30-m mark on the umbilical at the level of the deck (Figure 18).

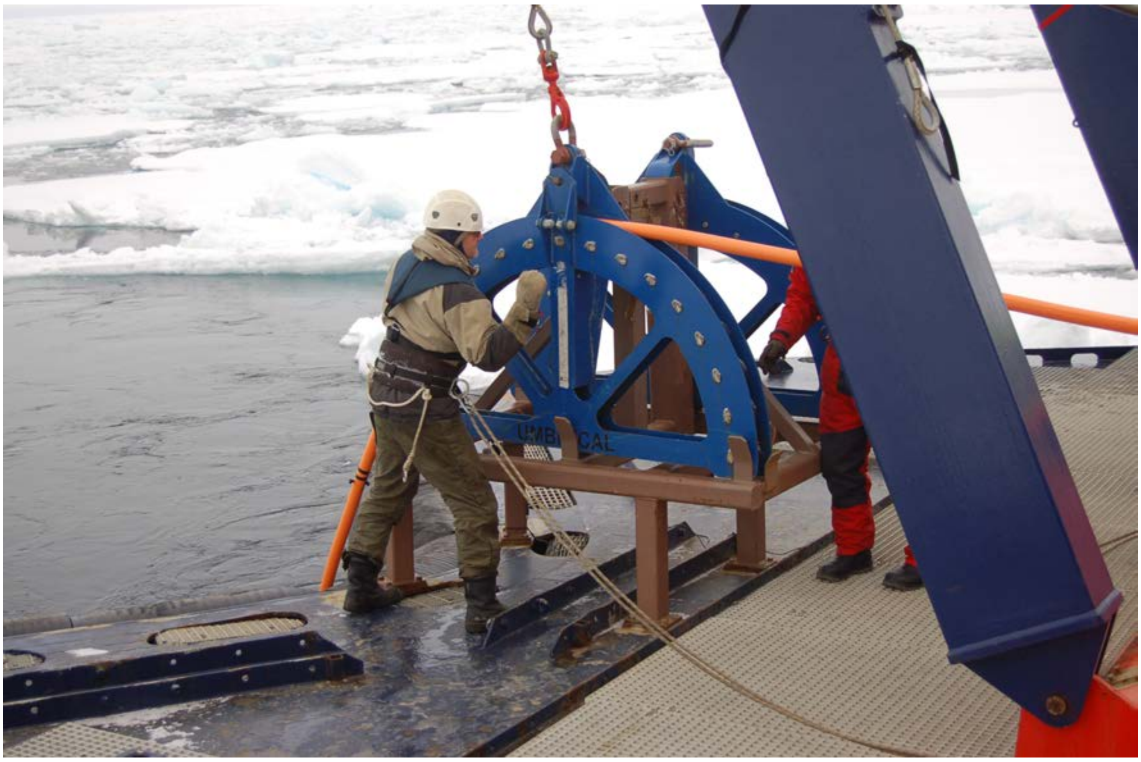

Figure 18. *Umbilical sheave locked and air gun and streamer fully deployed.*

The sketch in Figure 19 illustrates the complete system when the ship has reached speed of 3 to 5 knots and collection of data is ongoing and Figure 20 shows a photo from the aft deck during acquisition of seismic data.

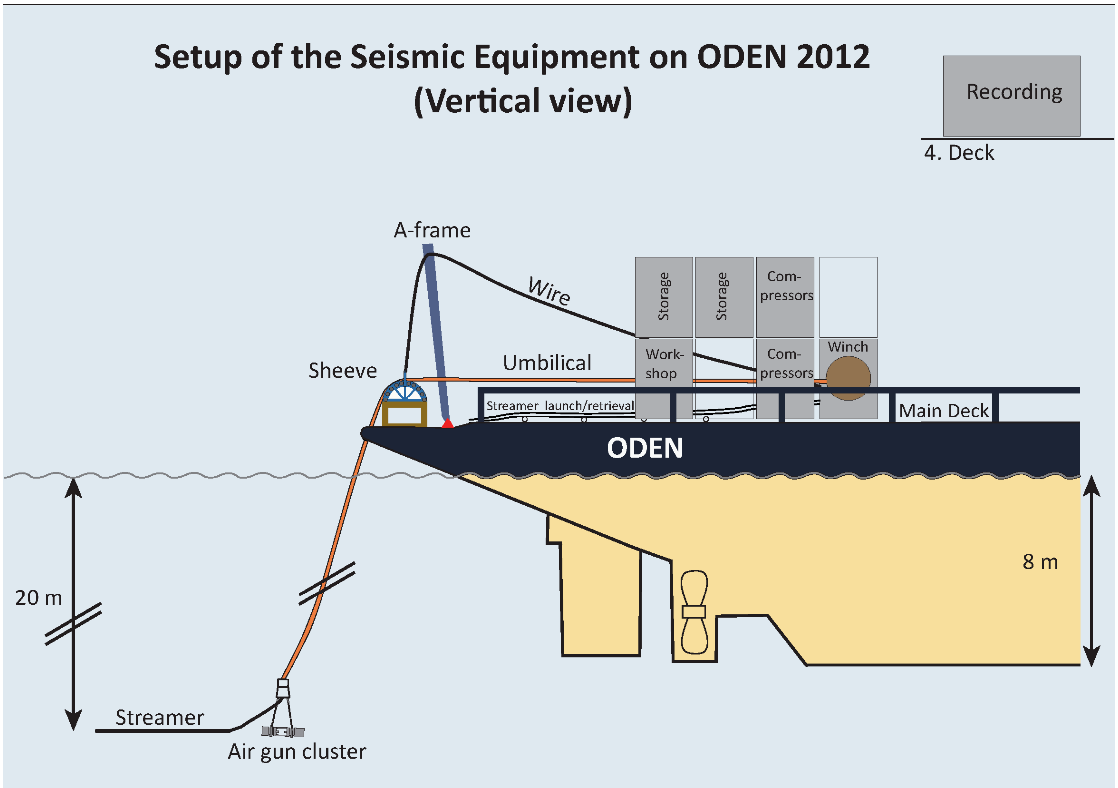

Figure 19. *Vertical view of the setup during data acquisition. The text in the grey rectangles (containers) indicates the function they have in the seismic setup.*

Figure 20. *Photo from the aft deck during seismic data acquisition with the seismic equipment deployed.*

A video showing the handling of the seismic equipment during LOMROG III made by Jack Schilling is included as Enclosure 2 on the enclosed DVD.

3.3 Depth Monitoring System

The system for monitoring the depth of guns and streamer sections was the same as used on the LOMROG II 2009 cruise, which was improved from the LOMROG I cruise in 2007 in order to allow for recording of the depth status for all elements for each shot. In addition, the depth range has been extended to cover all possible depths for guns and streamer sections.

A depth transducer with a depth range of 0-60 m is mounted directly on the steel frame of the gun cluster (Figure 2). Depth transducers with a range down to 300 m are mounted in one end of each active seismic section.

From the Geometrics GeoEel controller, the time interval the system would request depth information from the depth transducers is set. Throughout the whole survey the depth was read every 2 seconds, one streamer section at a time, meaning that the full streamer would be updated every 8 seconds.

3.4 Gun and Streamer Behavior

Gun depth data were collected and stored together with navigation data in the NaviPac log files. As an example of gun and streamer behavior *Oden*'s speed and depth of gun and streamer were extracted for line 13 as shown in Figure 21 below.

The depth transducers in the streamer were placed in two configurations either at the front end of sections 1-3 and in the rear end of section 4 or with all depth transducers placed at the front of each section (see Appendix 4 for further details). Thus, the distances between the guns and the respective depth transducers were: 50, 100, 150, 200 or 250 m.

Just before the start of data acquisition the umbilical head was deployed to a depth of 30 m below deck. The orientation of the umbilical, and the streamer below, was approximately vertical (cf. streamer depths along the vertical axis at the start of the line (Figure 21C).

The air guns are at a depth of approximately 30 m below sea level at start of line but depth decreases gradually with increasing speed of the ship as shown in Figure 21A. Also shown is the behavior of all sections and the air gun as a function of *Oden*'s speed over ground (Figure 21A). The streamer quickly adjust itself to a more horizontal position and reaches the same depth as the air guns with a vessel speed of about 1.5-2 m/s (3-4 knots).

This relatively stable and near horizontal configuration is largely maintained for speeds between approximately 1.5-2 m/s (3-4 knots) with depth reading for the different streamer sections between 20 m at the front end to about 25 m at the tail end.

Variations in Oden's speed along a seismic line are mimicked in the streamer depths with an increasing delay from front to tail end and with the largest depth deviations in the rear half of the streamer. It is noted that even relatively large (50 %) and also relatively short lived (few minutes) variations in the ships speed only have moderate effects on especially the front half of the streamer (Figure 21B).

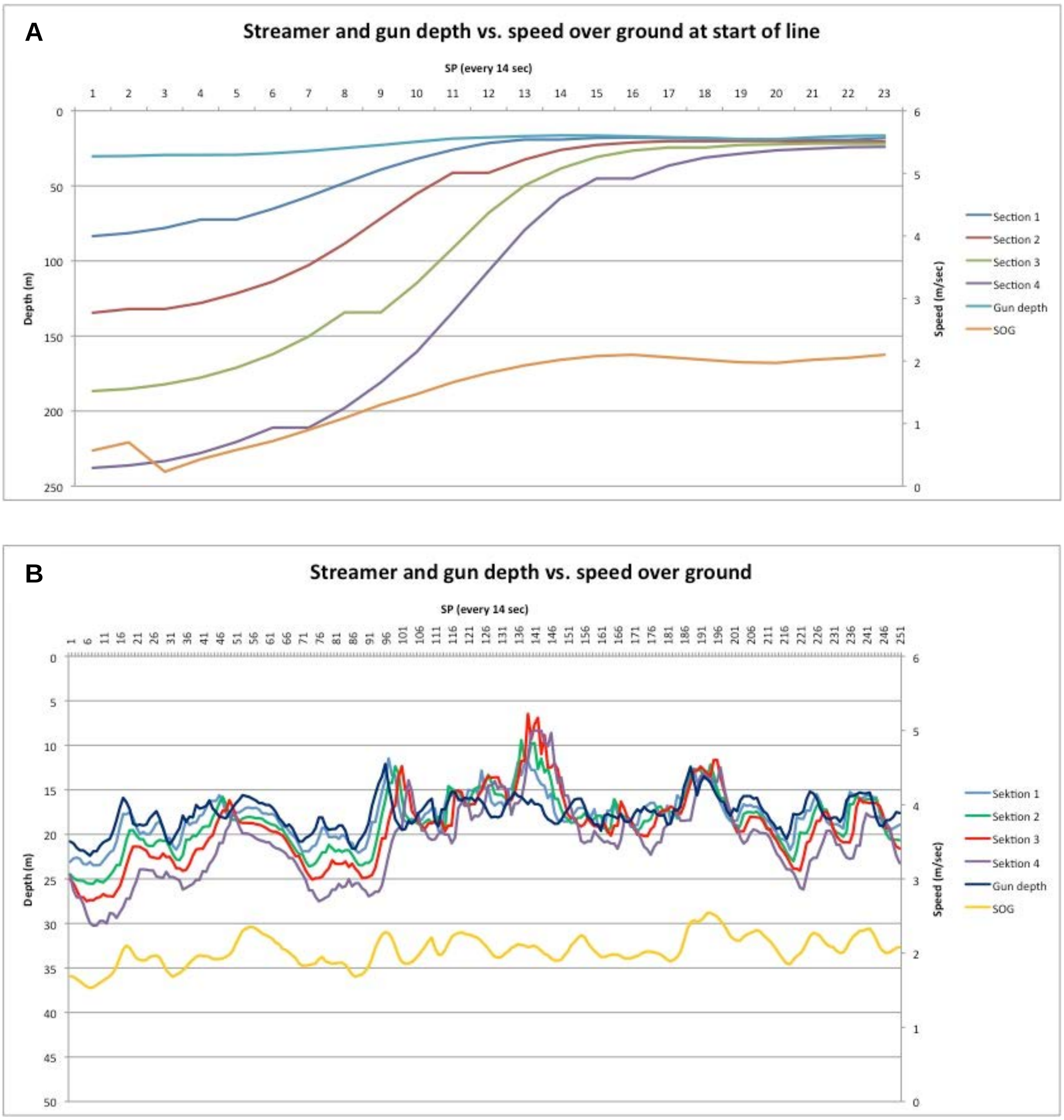

Figure 21. *Streamer and gun behaviour as a function of the vessel speed over ground. A) Display of the first 23 shots of line 13 where Oden is gradually building up speed. Note how the gun and the first streamer section are at the same depth at a vessel speed of app. 1.5 - 2 m/sec (3 - 4 knots). B) Streamer and gun depth for line 13 over a longer time interval emphasising how the depth of streamer and gun is mimicking the vessel speed. Note that depth of the front end and the tail of the streamer are within 5 m of each other. C) Depth of the streamer for shots 101, 110, 113 and 121. Note that after 20 shots the depths of the streamer sections are within 6 m from the front end to the tail end.*

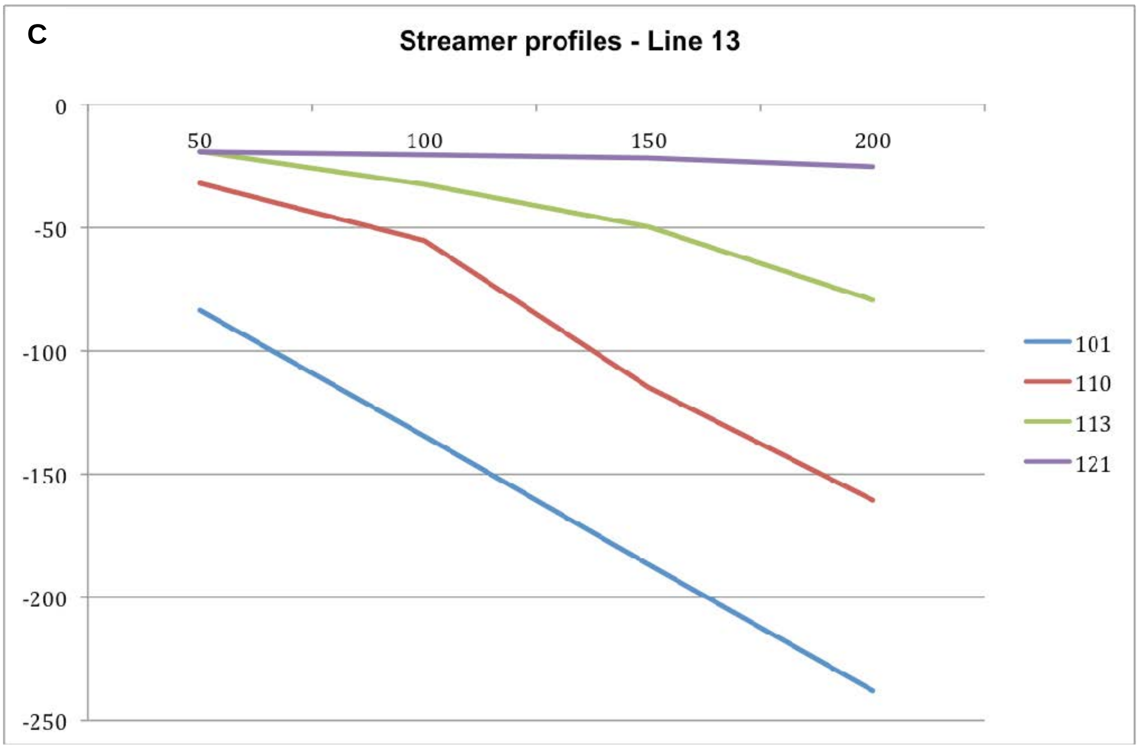

Figure 21 (cont.). *Streamer and gun behaviour as a function of the vessel speed over ground. A) Display of the first 23 shots of line 13 where Oden is gradually building up speed. Note how the gun and the first streamer section are at the same depth at a vessel speed of app. 1.5 - 2 m/sec (3 - 4 knots). B) Streamer and gun depth for line 13 over a longer time interval emphasising how the depth of streamer and gun is mimicking the vessel speed. Note that depth of the front end and the tail of the streamer are within 5 m of each other. C) Depth of the streamer for shots 101, 110, 113 and 121. Note that after 20 shots the depths of the streamer sections are within 6 m from the front end to the tail end.*

4. Seismic Reflection Acquisition Parameters

By *Thomas Varming*[1], *Per Trinhammer*[2], *Simon Ejlertsen*[2], *Lars Rödel*[3], *Marie Lykke Rasmussen*[2,3], *Sofie Ugelvig*[2,3], *Trine Kvist-Lassen*[2,3] *and Christian Marcussen*[3]; [1]*Bureau of Minerals and Petroleum* [2]*Department of Earth Sciences, University of Aarhus* [3]*Geological Survey of Denmark and Greenland (GEUS)*

For each survey line, a marine survey sheet with acquisition parameters and equipment serial numbers etc. was completed (see Appendix III). The acquisition parameters are summarized in Table 1 below:

Source	2 Sercel G guns
Chamber volume	1040 cu. in. (2*520 cu. in.)
Gun pressure	180 bar (2600 psi)
Mechanical delay	Automatically adjusted to 0 ms
Nominal tow depth	20 m
Streamer	Geometrics GeoEel
Length of tow cable	30 m
Length of stretch section	53 m
No. of active sections	4
Length of active sections	200 m
No. of groups in each section	8
Total no. of groups	32
Group interval	6.25 m
No. of hydrophones in each group	8
Depth sensor	In each section
Nominal tow depth	20 m
Acquisition system	Geometrics GeoEel controller
Sample rate	1 ms
Low-cut filter	Out
High-cut filter	Anti-alias (405 Hz)
Gain setting	0 dB
No. of recording channels	32
No. of auxiliary channels	8
Shot interval	14 s (with jitter[1] of ± 1 sec)
Record length	12 s

Table 1. *Summary of acquisition parameters*

[1] For details on the jitter see Section 7.2.2 in Vangkilde-Pedersen et al. 2011

4.1 References

Vangkilde-Pedersen, T., Funck, T., Hopper, J.R., Karkov, K., Mauritzen, E.K., Rasmussen, J.A., Hermann, T., Gossler, J., Trinhammer, P. & Marcussen, C. 2011: Seismic Acquisition Report – EAGER in 2011, Danmarks og Grønlands Geologiske Undersøgelse Rapport 2011/108, 85 pp + 5 appendices + 1 CD.

5. Seismic Reflection Acquisition Geometry and Positioning

By *Thomas Varming[1], Per Trinhammer[2], Simon Ejlertsen[2], Lars Rödel[3], Marie Lykke Rasmussen[2,3], Sofie Ugelvig[2,3], Trine Kvist-Lassen[2,3] and Christian Marcussen[3]; [1]Bureau of Minerals and Petroleum [2]Department of Earth Sciences, University of Aarhus [3]Geological Survey of Denmark and Greenland (GEUS)*

Oden is equipped with GPS and other navigational systems used for navigation. A separate GPS system was used for seismic reflection data acquisition with the navigation software NaviPac for logging and calculation of positions as well as logging of external data from the vessels Furuno gyro compass and the Kongsberg EM120 multi beam echo sounder. In addition, NaviPac generated the trigger signal for the seismic acquisition system.

5.1 Definition of Offset Points

In NaviPac a number of offset points were defined referring to the reference point of the vessel. The reference point is the midpoint of the vessel in the longitudinal and transverse direction in the horizontal plane and at the waterline in the vertical plane. A survey of the vessel was carried out in April 2007 by Metria and Sjökarteenheten at Landskrona Varvet in Landskrona, Sweden, using a total station and a theodolite. A local metric coordinate system was established and the x, y, and z coordinates of the reference point defined as 0,0,0. The x-axis is defined across ship and positive in the starboard direction, the y-axis is defined along ship and positive in the forward direction, while the z-axis is vertical with positive upwards. Coordinates in this local coordinate system were now established for a number of fixed points and installations onboard *Oden*. Two drawings showing the measured points and a list of local coordinates are shown in Appendix II.

A separate antenna was mounted for the GPS system used by the seismic acquisition system. The local coordinates of the antenna (point 2 in Appendix II) were defined measuring the distance in the x, y and z directions, respectively, to point 6 on the vessel reference point (point 1 in Appendix II). Similarly, the local coordinates of the tow point (point 3 in Appendix II) of the umbilical - towing the airguns and streamer - were defined. The vessel reference point, the GPS antenna and the umbilical tow point were all defined in NaviPac using their positions in the local coordinate system.

Additional offset points in NaviPac were the airgun midpoint and the first hydrophone of the first hydrophone group (channel 1) on the streamer (point 4 and 5 in Appendix II). The local coordinates of these two points were defined measuring the length of the tow cable and the combined length of the jumper cable and the stretch section of the streamer assuming a tow depth of 20 m. The length of the tow cable was 30 m and with a height of the tow point of 4.65 m and a tow depth of 20 m the resulting length of the tow cable along the y-axis was 17.1 m using Pythagoras' theorem. The airgun cluster was mounted in chains under the end of the tow cable and the length of the array is ca. 1.5 m. It is assumed that the position of the airgun array is at the end of the tow cable and hence the airgun midpoint was defined to have a layback of 17.85 m (17.1 + 1.5/2) relative to the tow point. The combined length of the jumper cable and stretch section up to channel 1 on the streamer was 53 m and, hence, the 1st hydrophone of channel 1 was defined to have an offset of 52.25 m (53 m – 1.5/2 m) relative to the airgun midpoint or 70.1 m relative to the tow point. The airgun midpoint and channel 1 were entered into NaviPac as offset points with coordinates relative to the tow point.

Drawings showing the location and coordinates of the offset points used and defined in NaviPac are attached as Appendix II and the offset coordinates are given in Table 2 below.

Offset point	**X (m)**	**Y (m)**	**Z (m)**
Vessel reference point	0.0	0.0	0.0
GPS antenna	-11.25	13.40	25.30
Umbilical tow point	0.0	-53.5	4.65
Airgun midpoint	0.0	-17.85	-20.00
Streamer channel 1	0.0	-70.1	-20.00

Table 2. *Offset point coordinates*

5.2 Geodetic Reference System

The geodetic datum for all positions recorded or calculated (except offset for coordinates in the local vessel coordinate system) during the survey was WGS84 and no datum shift has been applied to the data. Hence all latitude and longitude coordinates are in WGS84 datum. NaviPac used the Universal Polar Stereographic projection (UPS) and all x and y coordinates are given in UPS projection and WGS84 datum with -25° E as reference meridian. All coordinates processed in NaviPac, were transformed to the UPS projection, meaning that all logged geographical coordinates were transformed to UPS and back to latitude and longitude. Details are given in Table 3.

Geodetic datum	**WGS84**
Ellipsoid	*WGS84*
Semi-major axis (a)	6378137
Inverse flattening (1/f)	298.257223563
Eccentricity sq. (e^2)	0.081819190843
Projection	*Universal Polar Stereographic (UPS)*
Scale factor at pole	0.994
Latitude of true scale	81° 07' 00''N
Longitude from pole (reference longitude)	-25° 00' 00''E
False northing	2.000.000 m
False easting	2.000.000 m

Table 3. *Geodetic reference system*

5.3 Navigation, Positioning and Trigger Generation

Runlines (the desired survey lines) were distributed to the bridge as waypoint coordinates and the vessel was navigated using its own navigation system. Because of the ice-conditions, large deviations from the distributed survey line were expected. A *NaviPac* Helmsman's display was not set up on the bridge to aid navigation. This was because the actual track of the vessel is often controlled by the local ice situation.

NaviPac received an updated GPS-antenna position and vessel gyro course every second and calculated real-time positions for the defined offset points. Positions for the vessel reference point and the umbilical tow point were calculated using the raw GPS-positions of the antenna, the local offset point coordinates and the gyro course of the vessel.

Note: *The network connection supplying the vessel gyro proved very unstable and often it was necessary to use a calculated gyro from the dedicated seismic reflection GPS system. This meant that NaviPac would initially use the vessel gyro as its primary gyro, but if the network connection was lost, NaviPac would automatically switch to the calculated gyro as secondary gyro.*

Positions for the airgun midpoint and streamer channel 1 were calculated with reference to the position of the tow point using the drag method. Using the drag method the position of the offset point is calculated by projecting the travelled distance along the sailed route of the drag point, here being the tow point.

NaviPac was also used to generate the trigger signal for the seismic system. It was decided to shoot with constant time intervals. The interval 14 s was chosen as the minimum when a recording length of 12 s was needed to secure penetration to basement.

Shooting on distance would be the alternative option, but this was discarded mainly due to the fact that the ships speed in the ice - according to experience - is difficult to control. Substantial variations can be expected and too high speed would lead to generation of a trigger pulse before termination of the recording of the previous shot. Furthermore; at low speed the extended time between consecutive shots may cause compressors to have series of unwanted stop/start sequences as the pressure passes the pre-set maximum allowed pressure.

5.4 NaviPac Log Files

In NaviPac three log files are generated during the survey. These are named yyyymmdd_hhmmss_Z.npd with Z being C, G or S for the custom, general or survey file format, respectively. Year, month and date are specified by yyyy, mm and dd, respectively. The hhmmss is start time of the line.

The custom file contains for every shot:

- Time
- Event
- LC1040 gun (position for airgun midpoint) in UPS projection

- Gun depth (m)
- Gyro
- Filtered vessel pos
- SMG (Speed Made Good in m/s).

The general file and survey file also contains the above data plus other navigation data, such as projections, offset points (in UPS projection and latitude/longitude) and GPS raw data. Furthermore, the survey file is formatted so it can be imported directly into the post processing software “NaviEdit”.

Note: The water depth from the centre beam of the multibeam system was initially planned to be added to the NaviPac log files, but this never worked during the whole cruise. Kongsberg had been requested to setup the multibeam system to be able to supply this information, but it had not been setup properly after annual service undertaken by Kongsberg prior to the cruise.

6. Seismic Reflection Data Acquisition

By *Thomas Varming*[1], *Per Trinhammer*[2], *Simon Ejlertsen*[2], *Lars Rödel*[3], *Marie Lykke Rasmussen*[2,3], *Sofie Ugelvig*[2,3], *Trine Kvist-Lassen*[2,3] *and Christian Marcussen*[3]; [1]*Bureau of Minerals and Petroleum* [2]*Department of Earth Sciences, University of Aarhus* [3]*Geological Survey of Denmark and Greenland (GEUS)*

6.1 Staffing

The seismic reflection operations were carried out by nine members of the scientific crew on-board *Oden* as listed in Table 4.

Name	Affiliation	Function
Per Trinhammer	GEUS, Aarhus University	Chief Technician
Simon Ejlertsen	GEUS, Aarhus University	Technician
Lars Georg Rödel	GEUS	Technician, gun and compressor
John R. Hopper	GEUS	Processing Geophysicist
Trine Kvist-Lassen	GEUS, Aarhus University	Watch keeper and deck hand
Marie Lykke Rasmussen	GEUS, Aarhus University	Watch keeper and deck hand
Sofie Ugelvig	GEUS, Aarhus University	Watch keeper and deck hand
Jack Schilling	GEUS, NIOZ	Marine Technician
Thomas Varming	GEUS, Bureau of Minerals and Petroleum	Geophysicist

Table 4. *Staffing of the seismic reflection group.*

6.2 Acquisition Performance

From the operative experiences gained during LOMROG II, the seismic lines were acquired by Oden breaking a 20-25 nautical mile long lead or track along the pre-planned line, going back along the same lead to make it wider, and finally to acquire the seismic data while passing through the lead a third time. Some of the obvious advantages of this technique are that data can most likely be acquired along pre-planned lines since ice conditions can be evaluated during the first pass and changing ice conditions can be evaluated during the second pass. However, ice drift during preparation of the lead can cause the track to move considerably away from the pre-planned line before data acquisition commences. Data quality is better since Oden does not need full engine power on the third pass and can keep a more steady speed. In addition, the risk of losing or damaging the seismic equipment is reduced considerably. However, data acquisition is more time consuming when employing this method.

Through the collection of the seismic lines 1-17, the acquisition system generally had a satisfactory performance. A few technical problems during acquisition occurred, but all were easily and quickly repaired. A total of 497.5 km of seismic data were acquired during

LOMROG III. Due to severe ice-conditions data acquisition had to be terminated twice on the Lomonosov Ridge despite a lead had been prepared.

After having experienced some problems with the airguns not properly closing their air chambers when emerged in the water, resulting in ice forming inside the airgun chamber a procedure of firing the airguns twice at low pressure of 120 bar at 20 m of water immediately after submerging the airguns into the water proved a very efficient method to avoid this problem.

One incidence occurred where a large piece of ice hit the airgun and the front end of the streamer, resulting in damaging the cabling of the airgun array and the jumper connection to the streamer (Figure 20). The damage was however easily repaired within a couple of hours.

Figure 20. *Pictures of the airgun array after the encounter with a large piece of ice. A chunk of the ice is still visible on the left side of the airgun array; also notice the clean cut of the cable.*

The acquisition of line 2 terminated early because of high current readings on the Geometrics SPSU unit and general higher leakage values than previously on line 1 and 1A. It was therefore decided to change the whole streamer section before starting on line 3. Details on the configuration of the streamer for each line can be found in Appendix IV.

There were some problems with writing to the USB hard disk during data acquisition, and it was decided only to use it as a data backup after having acquired a line. The problems were typically timing issues and the problem resides in the computer system not being able to access and write to the USB hard disk fast enough. This induced time delays in the writing of the SEG-D files, incomplete or wrong information stored in the files written to the USB hard disk and occasionally in the system not being able to write the whole file before the next file had to be written. The procedure of writing directly to the USB hard disk was not used on lines after line 10.

After the end of the survey, all lines were written to tape 100 as a secondary external backup along with the USB hard disk backup. The full list can be found in appendix III.

After having problems with the Geometrics SPSU on line 4, it was decided to change it to a backup. After inspection of the defect SPSU, it was noted that the problem was within the AUX board on the unit. The SPSU was not in use through the remaining of the survey.

A line overview log was maintained during the survey. The log sheets are attached in Appendix III.

In Tables 5 and 6 a summary of the key characteristics of the lines is given. Table 5 is based on the line overview logs and Table 6 is based on the records of gun depths and ships speed with additional information from the line overview logs. Table 7 lists the record inventory and the log files from both NaviPac and Geometrics associated with each line.

Line	Record Length (s)	Duration (hours)	No of shots	Shots per hour
LOMROG3-01	12	01:06	283	257
LOMROG3-01A	12	03:42	953	257
LOMROG3-02	12	03:32	899	257
LOMROG3-03	12	00:04	7	257
LOMROG3-04	12	02:40	687	257
LOMROG3-05	12	00:11	47	257
LOMROG3-05A	12	00:23	99	257
LOMROG3-05B	12	00:21	89	257
LOMROG3-06	12	00:06	20	257
LOMROG3-06C	12	00:01	3	257
LOMROG3-06D	12	05:53	1513	257
LOMROG3-07	12	06:46	1739	257
LOMROG3-08	12	04:47	1232	257
LOMROG3-09	12	06:01	1546	257
LOMROG3-10	12	03:42	955	257
LOMROG3-10A	12	00:26	116	257
LOMROG3-10B	12	Not acquired	0	257
LOMROG3-10C	12	Not acquired	0	257
LOMROG3-10D	12	00:30	170	257
LOMROG3-11	12	00:07	26	257
LOMROG3-11B	12	04:14	1093	257
LOMROG3-12	12	03:08	804	257
LOMROG3-13	12	03:43	960	257
LOMROG3-14	12	05:32	1417	257
LOMROG3-15	12	05:38	1449	257
LOMROG3-16	12	02:54	745	257
LOMROG3-17	12	02:20	599	257

Table 5. *Summary of line overview log*

Line ID	Number of times Oden stuck in ice	Umbilical caught by ice No of incidents		Gear on ice No of incidents
		Gun <5m	Gun 5-10 m	
LOMROG3-01				
LOMROG3-01A				
LOMROG3-02				
LOMROG3-03				
LOMROG3-04				
LOMROG3-05				
LOMROG3-05A	1*			
LOMROG3-05B		1		
LOMROG3-06				
LOMROG3-06C				
LOMROG3-06D				
LOMROG3-07				
LOMROG3-08				
LOMROG3-09		1		
LOMROG3-10		1		
LOMROG3-10A				
LOMROG3-10D	1*			
LOMROG3-11				
LOMROG3-11B		3	1	1
LOMROG3-12				
LOMROG3-13		1		
LOMROG3-14		1	2	
LOMROG3-15			1	
LOMROG3-16	1*	2	1	
LOMROG3-17				

* The survey was terminated after *Oden* being stuck in the ice

Table 6. *Overview of notable ice problems*

An inventory log of files recorded in SEG-D format on tapes is found in Appendix III.

Table 7. *Record inventory*

Line	First Record	Last Record	NaviPac log files*	Tape	Geometrics log files
LOMROG3-01	101.sgd	406.sgd	20120806_124111_C.npd	100	LOMROG 3.line 1 LOMROG 3.line 1.depth LOMROG 3.line 1.nav
LOMROG3-01A	409.sgd	1362.sgd	20120806_144823_C.npd	101	LOMROG3.1a LOMROG3.1a.depth LOMROG3.1a.nav
LOMROG3-02	101.sgd	1000.sgd	20120807_083550_C.npd	102	LOMROG3.2 LOMROG3.2.depth LOMROG3.2.nav
LOMROG3-04	101.sgd	788.sgd	20120807_213451_C.npd	103	LOMROG3.4 LOMROG3.4.depth LOMROG3.4.nav
LOMROG3-05	101.sgd	148.sgd	20120817_083457_C.npd	104	LOMROG3.0005 LOMROG3.0005.depth LOMROG3.0005.nav
LOMROG3-05A	149.sgd	248.sgd	20120817_122001_C.npd	105	LOMROG3.0005a LOMROG3.0005.depth LOMROG3.0005.nav
LOMROG3-05B	249.sgd	338.sgd	20120817_143727_C.npd	106	LOMROG3.0005b LOMROG3.0005b.depth LOMROG3.0005b.nav
LOMROG3-06D	101.sgd	1613.sgd	20120821_121422_C.npd	107	LOMROG3.0006d LOMROG3.0006d.depth LOMROG3.0006d.nav
LOMROG3-07	101.sgd	1839.sgd	20120828_070325_C.npd	108	LOMROG3.0007 LOMROG3.0007.depth LOMROG.0007.nav
LOMROG3-08	101.sgd	1332.sgd	20120829_030120_C.npd	109	LOMROG3.0008 LOMROG3.0008.depth LOMROG3.0008.nav
LOMROG3-09	101.sgd	1646.sgd	20120830_035226_C.npd	110	LOMROG3.0009 LOMROG3.0009.depth LOMROG3.0009.nav
LOMROG3-10	101.sgd	1056.sgd	20120830_230525_C.npd	111	LOMROG3.0010 LOMROG3.0010.depth LOMROG3.0010.nav
LOMROG3-10A	101.sgd	216.sgd	20120831_025852_C.npd	112	LOMROG3.0010a LOMROG3.0010a.depth LOMROG3.0010a.nav
LOMROG3-10D	101.sgd	270.sgd	20120831_072849_C.npd	113	LOMROG3.0010d LOMROG3.0010d.depth LOMROG3.0010d.nav
LOMROG3-11	1.sgd	29.sgd	20120901_062618_C.npd	114	LOMROG3.0011 LOMROG3.0011.depth LOMROG3.0011.nav

LOMROG3-11B	101.sgd	1193.sgd	20120901_074041_C.npd	115	LOMROG3.0011b LOMROG3.0011b.depth LOMROG3.0011b.nav
LOMROG3-12	101.sgd	904.sgd	20120901_220753_C.npd	116	LOMROG3.0012 LOMROG3.0012.depth LOMROG3.0012.nav
LOMROG3-13	101.sgd	1060.sgd	20120902_163736_C.npd	117	LOMROG3.0013 LOMROG3.0013.depth LOMROG3.0013.nav
LOMROG3-14	101.sgd	1517.sdg	20120903_101622_C.npd 20120903_101844_C.npd	118	LOMROG3.0014 LOMROG3.0014.depth LOMROG3.0014.nav
LOMROG3-15	101.sgd	1549.sgd	20120904_074253_C.npd	114	LOMROG3.0015 LOMROG3.0015.depth LOMROG3.0015.nav
LOMROG3-16	1001.sgd	1745.sgd	20120905_010017_C.npd	105	LOMROG3.0016 LOMROG.0016.depth LOMROG3.0016.nav
LOMROG3-17	1001.sgd	1599.sgd	20120905_151506_C.npd	104	LOMROG3.0017 LOMROG3.0017.depth LOMROG3.0017.nav

* Path to NaviPac files: Lomrog3_files/NaviPac_Logs/YYMMDD/YYMMDD_hhmmss_C.npd

In total the seismic equipment was actively acquiring data for 68 hours, while the total number of hours of downtime was 17 hours, making up 20 % of the total number hours. Table 8 shows the production and downtime per line. The numbers are extracted from the line overview logs.

Line Number	**Acq time (hrs)**	**Down time (hrs)**
1, 1A	04:48	01:01
2	03:32	
3, 4	02:44	00:05
5, 5a & 5b	00:55	05:28
6, 6c & 6d	06:00	04:54
7	06:46	
8	04:47	
9	06:01	
10, 10A, 10B, 10C & 10D	04:38	04:05
11 & 11B	04:21	01:07
12	03:08	
13	03:43	
14	05:32	00:02
15	05:38	
16	02:54	
17	02:20	
Total	67:47	16:54

Table 8. *Production time for each line versus downtime.*

7. Shipboard Seismic Processing

By *John R. Hopper Geological, Survey of Denmark and Greenland (GEUS)*

7.1 Summary

Processing the seismic reflection data collected during LOMROG III follows the procedures developed during LOMROG II in 2009 (Hopper & Marcussen, 2010) and EAGER in 2011 (Vangkilde-Pedersen et al., 2011). The computer setup and details are identical to EAGER except that the Linux Centos 4.7 virtual machine was ported from Parallels to VMWare Fusion. The scripts and processing flows from the previous cruises were used with only small modifications. See Appendix C of the LOMROG II processing report for the key scripts (Hopper and Marcussen, 2010). The basic processing was done in ProMAX 2003.19.1.

In the LOMROG II processing report it was mentioned that some of the techniques recommended in Jokat et al. (1995) should be tried on the LOMROG data sets. Jokat et al. noted that a key problem with processing data collected in the Arctic is that noise, in particular noise from ice hitting the equipment, is especially difficult to eliminate. They addressed this by using a median stack. Median stacking suppresses noise by giving less weight to outlier amplitudes associated with random bursts of energy. To work effectively, the mid-point bin size should be sufficiently large to ensure good data fold and sampling statistics.

The natural bin size for a streamer with 6.25 m group interval is 3.125 m. The average data fold for the LOMROG and EAGER cruises is around 4 with this bin size (shooting interval of 25-30 m and 32 active channels). During LOMROG II and EAGER, tests on increasing the bin size to give higher fold had only minimal impact on the imaging quality using simple averaging for producing the stack. In part, this is because trace mixing and combining CDP's for plotting and display has the net effect of increasing the fold to the same as would be achieved with a 12.5 or 25 meter bin. Because the results of this could be quite different for median stacking, some tests were run on this cruise by assigning geometry with 12.5 and 25 meter bins. The data were stacked with both median and mean methods and no significant difference between the stacks was found. Therefore the median stacking method was not used and the binning and processing flow here follows that of the previous cruises.

For all seismic reflection lines on this cruise, the ice adapted towing arrangement was used. The seismic source consisted of two 520 cu. in. G-Guns, roughly double the volume used in 2009. The larger array easily penetrated to basement in all areas surveyed. In some cases, reflections below basement may be indicated. Depth transducers were initially placed at the near end of each section. Prior to shooting Line 4, the depth transducer of the far section was moved to the far end of the streamer. During Line 10 acquisition, the streamer developed leakage problems and was replaced with the spare sections. During this change, depth transducers were again placed at the beginning of each section (beginning with Line 10D). Shots were fired on randomised time and auxiliary channels were used to record the sonobuoys. Basic acquisition parameters are summarised in Table 9.

Shot interval	14 ± 1 s (~ 30 m)
Group interval	6.25 m
Number of channels	32
Distance source to near channel	53.1 m
Cable target depth	20 m
Sample rate	1 msec
Record length	12000 msec
Filter high cut	500 Hz/24dB/oct
Filter low cut	0 Hz/0 dB/oct
Seismic source	2 x 520 cu.in. G-guns
Source target depth	20 m
Gun pressure	180 bar
Trigger delay	0 msec

Table 9. *Basic acquisition parameters*

7.2 Processing Sequence

The basic processing sequence, described more completely below, is as follows:

1. SEG-D read with trace dc bias removal;
2. Bandpass filter;
3. User defined spectral shaping filter;
4. Spike and noise burst editing;
5. Shot gather f-k filter and resample to 2 ms.;
6. Geometry assignment, including gun and cable statics;
7. Trace equalization;
8. Velocity Analysis (Lines 5 and 6 only);
9. Trace mixing on shot gathers;
10. Midpoint sort and stack;
11. Final geometry and amplitude recovery;
12. Post-stack constant velocity migrations;
13. Seafloor mute;
14. SEG-Y output;
15. grd conversion and plot.

7.2.1 SEG-D read with trace dc bias removal

Though not strictly necessary, a dc bias removal was applied as a standard procedure reading the data into ProMAX. In 2009, some early test lines had a dc bias in the recording and this was added as a standard precaution when importing data into ProMAX.

7.2.2 Bandpass filter

There was no low cut filter applied by the acquisition system and the data show high amplitude, low frequency noise. A minimum phase, butterworth bandpass was applied in the frequency domain using 1% additive noise and a low cut of 8-Hz with a slope of 24 dB/octave and a high cut of 450-Hz with a slope of 120 db/octave.

7.2.3 User defined spectral shaping filter

As in LOMROG II in 2009, the deep towing depth compromises the frequency content of the seismic source. The spectral shaping filter we used on that data proved useful on this data as well. The filter serves to suppress, without eliminating, the low frequencies and results in an overall sharper, less ringy image. See Hopper and Marcussen (2010) for filter details and examples.

7.2.4 Spike and noise burst editing

Noise bursts, likely the result of ice hitting the streamer, are common. These are difficult to eliminate completely. However, the worst can be identified and suppressed with a noise burst filter that is tripped with a fairly low threshold. The threshold to trip the filter was set at 2 with a minimum noise block length of 10 ms. Edited zones were not in-filled.

7.2.5 f-k filter

The ship's motion while breaking ice results in strong linear noise in the shot gathers that can be removed with an f-k filter. The key to the f-k filter is to ensure that it is applied prior to any statics, which will alter the slope and destroy the simple linear nature of the noise. Thus, this step must be applied on shot gathers before loading the geometry. The combination of short streamer, small offsets, and deep water means that the apparent velocity of any real reflection event should be very high. Primary reflection energy should be essentially horizontal in the shot gathers. Thus, it is possible to use a fairly steep slope in the fan filter cutoffs without affecting primary reflections. We used a low cut frequency cut of 5 Hz, a high cut of 500 Hz, and the fan is defined by a pie slice from 500 m/s to 4000 m/s, with all energy in between rejected (Hopper & Marcussen 2010, Figure 7). This eliminated most of the linear noise in the records. In testing the velocity slopes, it was clear that the higher frequencies in the linear noise were spatially aliased. The aliasing is also readily apparent in the f-k spectrum (Hopper & Marcussen 2010, Figure 7) Allowing the fan to wrap past Nyquist proved to be worthwhile to help eliminate the linear noise. The wrap around had the further benefit of eliminating all energy in the spectrum above 250 Hz, so we resampled the data to 2 ms at this stage.

7.2.6 Geometry assignment

Seismic lines in the arctic are defined by ice conditions rather than desired starting and stopping points. The lines shot are never straight in ice. With a long streamer, a crooked line binning procedure would be required. With a short streamer, however, this is not necessary. A simple 2D geometry is sufficient. To assign mid-point bins, we assume a simple 2D sail line azimuth calculated as the shot-to-shot distance along track. The X-coordinate increases as the running sum of the shot-to-shot distance and the Y-coordinate is 0. The CDP X-coordinate as then exported to an ascii file so that an actual geographic location for each mid-point can be determined from the navigation files.

During geometry assignment, the gun and cable statics were applied. As noted in the previous reports, the 2D marine geometry spread sheet does not provide a tool to import cable depths unless the entire geometry database is imported as a single UKOOA file. Only the final Trace QC spread sheet provides access to the receiver depth column. Although this column can be manually edited, no import tool has been implemented to read them from a file. Thus, we assigned geometry in several stages. Cable depths were calculated by assigning the depth recorded by the transducers to the nearest channel and linearly interpolating the rest. For lines 1, 2, and 10D-17, the depth transducer was placed on the near end of the last steamer section, so the depth of the tail end of the streamer is unknown. The last 8 channels were assigned the depth recorded by the last transducer.

The depth of each channel calculated this way was placed in an ascii file for importing into ProMAX. A processing flow was run that read the raw data, followed by an "inline geometry load", an "ascii to trace header" to read the cable depth for each shot and channel into the trace headers, and then saved to a temporary ProMAX data set. The temporary data set was then read back in followed by a "trace header to database transfer" to insert the cable depths into the geometry database. At this point, the Trace QC spread sheet was used to verify that the receiver depths were imported correctly. Finally, the noise filtered dataset generated by the previous flows was read in with an "inline geometry load" with gun and cable statics applied. Correction to sea level assumed a velocity of 1480 m/s.

Inspection of shot gathers along Line 4 after assigning geometry indicated problems with the static corrections applied. Roughly 3/4 of the shots showed a 4-10 msec delay in the far channels (last streamer section). Occasionally, the third section also showed a recording delay. A list of shots with these problems was generated by visually inspecting the arrivals on every shot, and the geometry was re-assigned with an additional static correction applied to account for this.

During the downtime in between shooting Lines 4 and 5, it was discovered that the Geometrics power supply unit had a faulty auxiliary channel board. The spare power supply unit was installed and the problem disappeared. It is assumed that the faulty board was generating spurious information that resulted in incorrect triggering of data recording.

7.2.7 Trace equalization

The noise level varied significantly between traces. To balance amplitudes, a trace equalization was applied on the shot gathers. After some experimentation with different assumed amplitude gates, a gate in the water column between the direct arrivals and seafloor reflection was chosen, which effectively uses the random noise for equalizing. This had the effect of reducing the significance of noisy traces, without eliminating them entirely.

7.2.8 Velocity Analysis (Lines 5 and 6 only)

In the Amundsen Basin, there is only 3 ms of moveout for the seafloor reflection along a 300 m streamer. For higher velocity events, the moveout is essentially zero. Other uncertainties, for example cable depths, result in significantly larger misplacement of reflections. For this reason, moveout corrections were ignored, both for trace mixing, and for stack in data collected in deep water. For all lines shot in deep water, moveout corrections and velocity analysis were ignored.

For Lines 5 and 6, which were in water as shallow as 1.8 s two way travel time, moveout could not be ignored. Because of the short streamer length, semblance is meaningless for all practical purposes, however.

For Line 5, which showed little structural variation, a simple 4 layer velocity function was assumed. At 5 control points along the line, the seafloor, the basement, and two prominent horizons were picked. RMS velocities of 1480, 1525, 1680, and 2200 m/s were assigned to these horizons for stacking.

Line 6 showed significant seafloor topography and required more densely sampled control points. ProMAX's standard 2D velocity analysis tools were used to pick velocity functions spaced every 250 CDP's along the line. Picks were made to first flatten the seafloor arrival, and deeper picks were made on prominent reflections ensuring that the selected RMS velocities were "reasonable", generally not exceeding 2500 m/s. No more than 3 additional velocity picks below seafloor were made and the interval velocity below the last knee was set to 6000 m/s.

7.2.9 Trace mixing on shot gathers

To further enhance coherent signal over noise, a 1-2-3-2-1 trace mix was applied on the shot gathers. For Lines 5 and 6, a moveout correction was applied prior to mixing.

7.2.10 Stack

For stacking, traces were sorted into 3.125 m bins. The nominal fold is 3-4 with a 30 meter shot spacing. For plotting and interpretation, it is better to increase the fold by combining CDP's, although this was not done for the plots shown in the appendix. Shooting on time with a highly variable ship speed, the data fold also varies considerably. In general for this survey, the data fold is from 3-4 for 3.125 m bins. Appendix C includes data-fold by line.

7.2.11 Final geometry and amplitude recovery

No processing up to this stage depended critically on amplitude recovery. Except for the trace equalization, amplitudes were not a major concern in the processing sequence. For the post-stack migrations however, better amplitude balancing is desirable. This stage of the processing also involved picking the seafloor, both for amplitude recovery and for later muting. Water depths and travel times from the multibeam data were imported into the trace headers, and the ProMAX trace header WB_TIME was filled with correct values. We were then able to apply a db/sec amplitude correction tied to the water bottom. In addition, because of the simplifying assumptions we made to assign geometry, the geographic X and Y coordinates are not yet in the ProMAX database. These were imported at this stage. The projection used for the LOMROG cruises minimizes distortion in the middle of the survey area, but is a non-standard polar projection. The projected coordinates were placed in separate trace headers called ACTUAL_X and ACTUAL_Y. In addition, the positions were re-projected into IBCAO polar stereographic coordinates, which is supported by Petrel as a predefined projection. These were imported into the database and trace headers called IBCAO_X and IBCAO_Y. The receiver and source coordinates were left alone.

7.2.12 Post stack migration

At this point, we do not have sufficient velocity information to justify more than constant velocity migration. Experience shows that a simple constant velocity migration with a velocity slightly less than water velocity can clean up a significant amount of the diffractive energy in the unmigrated stacks. Although only a partial migration, the resulting images are nevertheless superior. Migration was applied using Stolt's method with a stretch factor 1 and a constant velocity of 1400 m/s. While most of the lines have fairly clean stacks, some residual noise problems remain. Therefore, we migrated the data twice for the shipboard plots. The first migration only uses the db/sec amplitude correction prior to migration, and for the second, an AGC was used to suppress remaining high amplitude noise. A 500 ms AGC window was used.

7.2.13 Seafloor mute

Seafloor mutes were picked on the unmigrated sections, and in cases with significant seafloor topography, on the migrated sections. This was so that the water column could be zeroed for the SEG-Y outputs. This was requested by the sonobuoy team.

7.2.14 SEG-Y output

The shipboard stack and the two migrations were output to SEG-Y. The EBCDIC header contains basic information about the files. The SEGY revision 1 standard reserves bytes 181 and 185 for stacked trace coordinates. The IBCAO X and Y coordinates with no scaling were placed in these locations during SEG-Y output. Bytes 73-80 contain the X and Y coordinate used for processing (X = distance along track, Y = 0) and bytes 81-88 contain receiver coordinates. These have no direct meaning for stacked data. Note that ProMAX calculates a coordinate scalar based on these values in the database upon writing the SEGY file and places it in bytes 71-72. It is not possible to know in advance what this scalar value will be. This scalar should not be used on the IBCAO X and Y coordinates in bytes 181-188 (in violation of the rev. 1 standard).

7.2.15 GRD conversion and plot

The cruise report plots were produced by using SioSEIS to convert the SEG-Y files to GMT compatible netcdf gridded data files. The data plotted are plotted as black and white variable area plots with grdimage. We did not spend much time adjusting clipping parameters. However, the grdimage command line is included for reference on each plot.

7.3 Extra Processing Notes by Line

These notes contain additional information specific to each line. Note that during acquisition, some lines contain data in multiple logs and directories with letters appended to the line number. How these were dealt with in processing is summarised here as well.

Line 1: This profile was shot in two pieces. After approximately the first 250-300 shots, leakage on the streamer became a problem and the equipment was brought on board for repair. An hour later the line was continued as Line 1A. The log and SEG-D files from Lines 1 and 1A were combined and the data processed as a single line with a ~1.5 km gap.

Line 2: The depth transducers for sections 2 and 4 were not functioning for approximately the first 300 shots. The line was terminated due to the ship getting stuck in ice. Some leakage and current problems are noted in the acquisition logs, but these did not affect processing.

Line 3: Note that there is no processed Line 3. During redeployment after terminating Line 2, some of the leakage issues were investigated. After several attempts to get the streamer deployed and several false starts where we cycled through several letters, (line 3A, 3B, etc.), it was decided to swap out the streamer for spare sections and restart with Line 4 after the streamer repair.

Line 4: As noted earlier, the depth transducer for the last section was moved to the end of the streamer beginning with this line. The depth transducers for sections 1 and 2 did not function properly for the first half of the line. A majority of the shots for Line 4 show a delay in the recording of the last section (554 out of 688 shots). A 6 msec static shift on these traces was necessary to correct for this. The shots were identified manually and the additional static shift applied after loading geometry. In addition, 3 shots showed delays on both sections 3 and 4. Corrections for these shots varied from 6 to 10 msec and in two cases were different for the two sections. A technician from Geometrics suggested that this could be caused by excessive noise generating false recording triggers. Per investigated this further and determined that one of the auxiliary boards on the Geometrics power supply unit was faulty. The backup power supply was installed and no further timing problems were noticed for the remainder of the cruise.

Line 5: Line 5 is very short and was terminated because of problems with ice. Ice conditions resulted in several starts and stops where equipment had to be brought on board and thus consists of several pieces, Line 5, 5A, and 5B. The data and logs were combined and processed as a single line with gaps. Because of the shallow water, moveout corrections were necessary. See additional notes in the processing sequence section.

Line 6: There were several attempts to deploy the equipment to come online for Line 6. Line 6 consists of 21 shots, 6A and 6B none, and 6C only 3 shots. Processed Line 6 consists only of recorded Line 6D. Line 6 was also in shallow water. See additional notes in the processing sequence section regarding moveout corrections.

Lines 7, 8 and 9: Acquisition of these lines went smoothly and there are no additional processing notes. During processing of Line 7, the spectral shaping filter was looked at to investigate if it could be further optimized for the larger guns in use for this cruise. It was found that only small improvements could be made and there was effectively no difference in the final stacked sections using "better" filters. Many filters produced during testing resulted in poorer imaging. Thus, the original filter was kept throughout all processing. During these tests, it was noted that there is frequently noise with a strong power spike at 67 Hz. It is not clear where this comes from and is found in many, but not all shots. Tests on eliminating this spike showed little difference in the final stacked images and was therefore ignored.

Line 10: Line 10 proved very problematic and consists of several lines. It was necessary to bring the streamer on board several times. Note that the final processed line consists of a combination of lines 10, 10A, and 10D. No shots were fired while attempting to shoot Lines 10B and 10C. Prior to shooting each line, the FFID was reset to 101. For processing with unique FFID's, 2000 was added to Line 10A and 3000 was added to Line 10D when importing to ProMAX. The streamer was replaced prior to 10D and the depth transducer for the last section was moved to the front of the section. In the acquisition logs it is noted that problems with the depth transducers were common while shooting Line 10, but plots of the cable behaviour seems fairly typical for difficult ice conditions (See Appendix B). However, they are clearly not working by the end of the line (the final 40-50 shots). They do not appear to be functioning correctly for Line 10A as well. A final issue for processing was that the difficult ice conditions meant that Oden was frequently running on 4 engines and the noise level is quite high on the near channels. Shots were inspected and the noisiest traces were killed manually prior to trace equalization.

Line 11. There were several attempts to deploy the equipment to come online for Line 11. Line 11 consists of 29 shots, and 11A none. Processed Line 11 consists only of recorded Line 11B. The navigation string for FFID 134 was not received from NaviPac. The shot contains good data, so the shot position was interpolated and added to the navigation log manually. The shot time is lost, however. Oden frequently required 4 engines and manual trace editing was done to eliminate the noisiest traces.

Lines 12 to 17. Acquisition for the final lines went quite smoothly. The noise level on the near channels was quite high on several lines when Oden required 4 engines. On Lines 14, 16, and 17, manual trace editing was done to eliminate the worst traces.

7.4 References

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8. Sonobuoy Operation

By Thomas Funck, Geological Survey of Denmark and Greenland (GEUS)

8.1 Technical Description

8.1.1 Seismic Source and Receivers

During the seismic reflection data acquisition of the LOMROG III expedition, a Geometrics streamer with a maximum active length of 200 m was used for recording. The streamer consisted of four 50-m long sections with eight channels each. The seismic operation in generally two to three-meter-thick ice prohibited the use of longer streamers as evidenced by severe damage to the equipment during the first field season in the Arctic (LOMROG I in 2007). In the deep Arctic basins it is impossible to gain any velocity information from the sediments by such a short streamer. However, sediment velocities are important for the documentation of the sediment thickness of the extended continental shelf, if the 1-%-sediment-thickness formula (Gardiner line) is to be applied. To record seismic signals at larger offsets and thereby obtain velocity information, sonobuoys were deployed during the seismic reflection data acquisition.

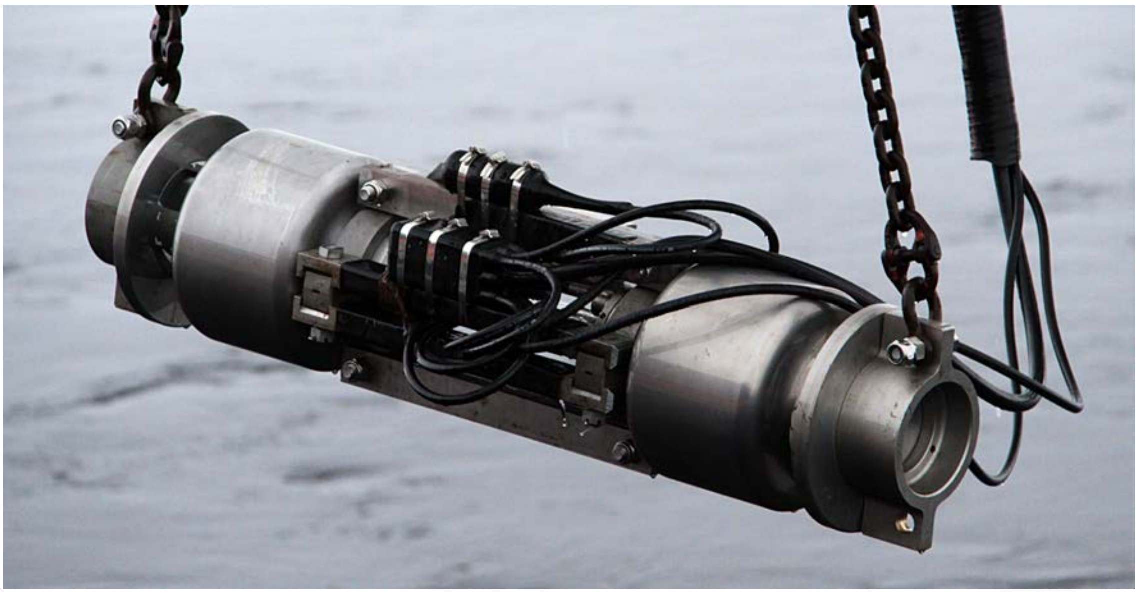

Figure 22. *1040 cu. in. G-gun array used for the seismic experiment.*

The sonobuoys recorded the shots from the seismic reflection experiment with a nominal shot interval of 14 s. The seismic source was an airgun array consisting of two G guns with a volume of 520 cu. in. each (Figure 22). The total volume of the array was 1040 cu. in. (17.0 L); the nominal air pressure was 3000 psi (200 bar). The nominal towing depth of the gun system was 20 m but changed according to the speed of the vessel and when the streamer/gun system was caught by sea ice. However, the gun depth was monitored and was written to the navigation file on the NaviPac computer in the seismic registration container on the fourth deck.

Figure 23. *Sonobuoy type AN/SSQ-53D(3) from ULTRA Electronics. The left part of the image shows the sonobuoy in the hermetically sealed buoy launch container. In the centre, the buoy is shown after removal of the storage container. The right part of the picture provides a view on the sonobuoy with the top cap (lanyard) removed, where the parachute is stored. The buoy is deployed in this state.*

The sonobuoys were deployed from the afterdeck of *Oden* or by helicopter. A total of 71 sonobuoys of the type AN/SSQ-53D(3) from ULTRA Electronics were available for the experiment (Figure 23, see also Appendix V-F). The buoys were not the standard version but modified by ULTRA to meet the requirements of seismic work (lower frequencies). Given the good track record of the deployment procedure developed during the second part of the LOMROG II expedition, the same method was applied here. A 10-m-long rope was attached to the parachute of the buoy. The buoy was then deployed from the far end of the afterdeck on port side, holding the rope until the buoy expanded itself. The parachute and the rope were then pulled back on board. For the helicopter deployment, a safe landing place on a larger ice floe was chosen with access to open water. Also here, the buoy was attached to a rope to prevent currents from moving the buoy below the ice prior to activation.

For the reception of the radio signals transmitted from the sonobuoys, two antennas were used. A Moonraker MD HB-G3/HS antenna (Appendix V-G) was mounted on top of the bridge on the port side (Figure 24) at a height of 29.9 m above sea level. This antenna was used during previous expeditions. In addition, a new Yagi antenna was installed based on the experience that the Geological Survey of Canada received stronger signals with their Yagi antenna when compared with the Moonraker dipole antenna. To increase the signal strength even further, two Yagi R2-10L (145-165 MHz) antennas (Appendix V-H) were stacked on top of each other (Figure 24). The lower and upper antennas were 27.1 and 28.7 m above sea level, respectively.

The signal from the antennas was fed to four Winradios in the registration container on the fourth deck. The Moonraker dipole antenna was connected to a notch filter to eliminate the ship's AIS frequencies (161.975 and 162.025 MHz); while the signal from the Yagi antenna was not filtered. There were two radios of the older type Winradio WR-2902e (see Appendix V-D) and two of the newer type Winradio WR-G39WSB (Figure 25). All radios were controlled by software installed on a PC running Windows XP (Figure 25). With exception of lines 2 and 4, the signal of the Moonraker dipole antenna was recorded by Winradios 2 through 4, while radio 1 received the input from the Yagi antenna (Table 10). On seismic lines 2 and 4, all radios were connected to the dipole antenna (Table 11).

Antenna	Win-radio	Winradio control: Software / Receiver	Channel on Taurus seismometer	Auxiliary channel	SEGD channel
Yagi	1	WR-2902e / Receiver 1	1	1	33
Dipole	2	WR-2902e / Receiver 2	2	2	34
Dipole	3	WR-G39WSB / Receiver 2	3	3	35
Dipole	4	WR-G39WSB / Receiver 1	Not recorded	4	36

Table 10. Antenna, *recording and software control of the four Winradios for lines 1 and 5 through 17.*

Antenna	Win-radio	Winradio control: Software / Receiver	Channel on Taurus seismometer	Auxiliary channel	SEGD channel
Dipole	1	WR-2902e / Receiver 1	1	1	33
Dipole	2	WR-2902e / Receiver 2	2	2	34
Dipole	3	WR-G39WSB / Receiver 2	3	3	35
Dipole	4	WR-G39WSB / Receiver 1	Not recorded	4	36

Table 11. Antenna, *recording and software control of the four Winradios for lines 2 and 4.*

The output of the Winradios was split (Figure 27) to be recorded both on the Geometrics recording system and on a Taurus digital seismometer manufactured by Nanometrics (Figure 26). Tables 1 and 2 specify on which channels the individual Winradios were recorded on the Geometrics and Taurus system. The auxiliary channels correspond to channels 33 through 36 in the raw SEGD files of the Geometrics recording system (using four active streamer segments with a total of 32 channels). Signals on the Geometrics system were recorded with a record length of 12 s at a sampling rate of 1 ms. To allow for a sufficient recording length at larger shot-receiver distances, the sonobuoy data were also recorded continuously on a Taurus seismometer (manufactured by Nanometrics, Figure 26, see Appendix V-E). One Taurus recorders was available onboard (serial number 1574 owned by GEUS). The seismometer can record a maximum of three channels, which is why Winradio 4 was not recorded on the Taurus (Tables 10 and 11). The sampling rate was set to the lowest value (2 ms corresponding to 500 Hz).

During the LOMROG III expedition, the Taurus seismometer was powered by an adapter that provided a voltage of 12.3 V. To avoid severe 50-Hz noise on the recorder, the seismometer was grounded (Figure 28). Not using the grounding results in data spikes as noticed during the LOMROG II expedition in 2009.

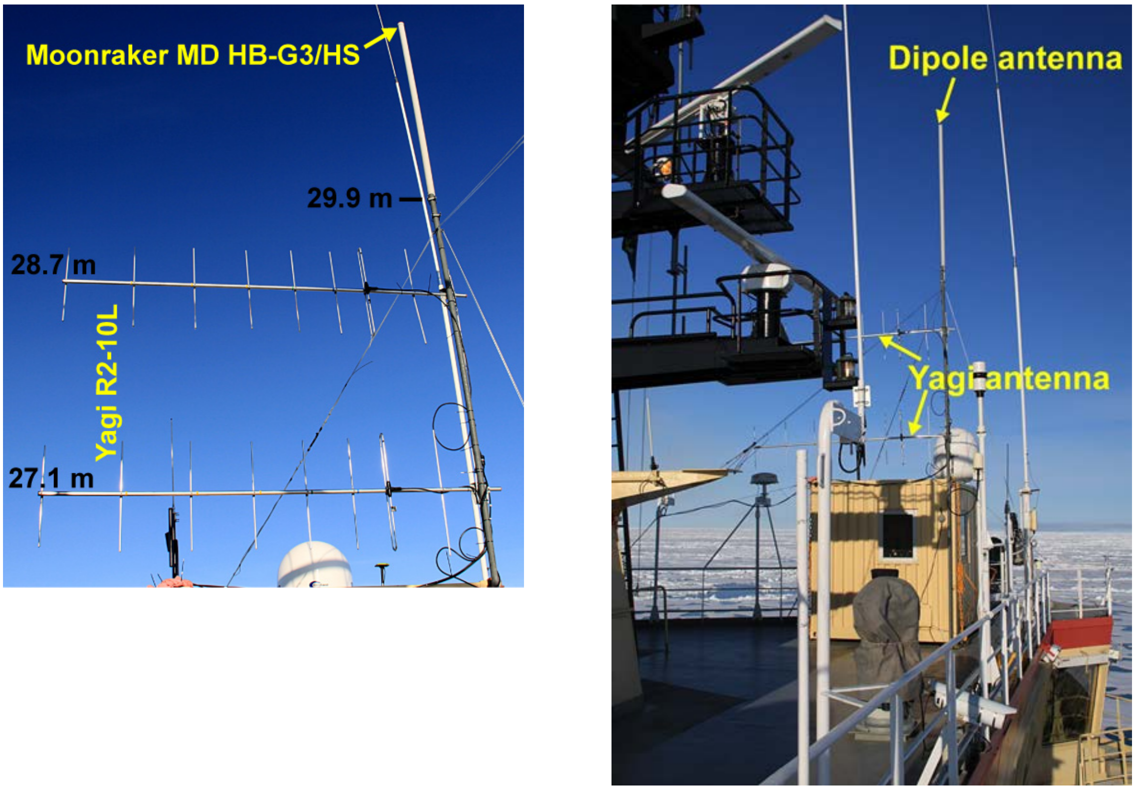

Figure 24. *Dipole antenna MD HB-G3/HS and Yagi antenna R2-10L mounted on top of the bridge of Oden on the port side. Numbers on the left indicate the antenna heights above sea level.*

Figure 25. *Sonobuoy receiving system. The two older Winradios (type WR-2902e; black boxes) are controlled by Winradio software (upper left window on computer display). The two newer Winradios (type WR-G39WSB; green boxes) were controlled by the Winradio software in the lower right window on the computer display.*

Figure 26. *Taurus seismometer in the recording container on the fourth deck of Oden.*

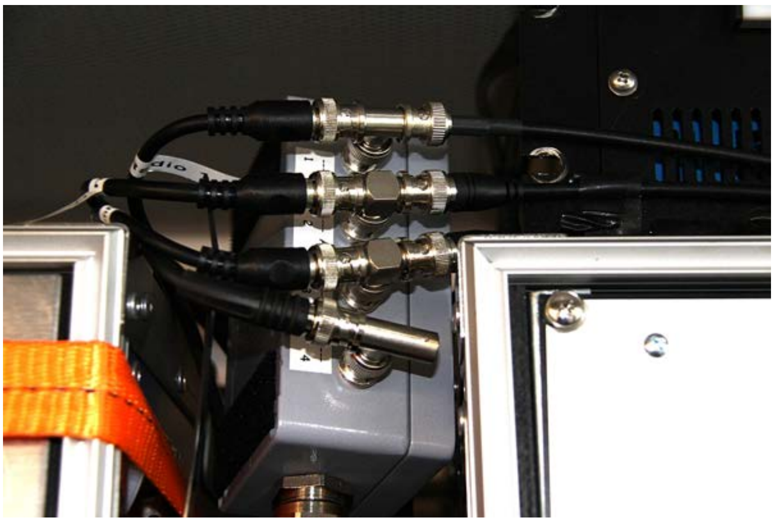

Figure 27. *The output signal of the Winradio was split to go to the auxiliary channels (1 through 4) on the Geometrics recording system and to the Taurus seismometer (cables to the right). Note: The fourth Winradio is not recorded on the Taurus.*

Figure 28. *Connectors at the Taurus seismometer (left). The green-yellow cable at the far left connects to the ground plug (Earth Binding Post) of the GeoEel streamer power supply unit (right).*

8.1.2 Container and Laboratory Setup

Several laboratory and storage spaces were used for the sonobuoy and seismometer operation. On the port side of deck 4, the seismic registration container was located. Here the navigation software (NaviPac) and multichannel registration software (Geometrics) were installed. Also the four Winradios for the sonobuoy reception were in this container, in addition to the Taurus recorder for which a GPS antenna cable was run to the outside through a cable-funnel in the container. The GPS antenna was mounted on top of the container (aft end starboard corner of the container). A laboratory container (Figure 29) on the ship's front on the fourth deck (midships) was used for data processing and analysis, using a MAC Book Pro 13 inch (operating system Mac OS 10.7.4, 2.8 GHz Intel Core i7 processor, 8 GB 1333 MHz DDR3 memory) with an external 19 inch monitor. In addition, a laptop computer (Hewlett Packard Elite Book, operating system Windows XP, Intel Core Duo2 CPU P8400 processor at 2.66 GHz, 3 GB memory) was used for programming the seismometer and for data download. Both computers were connected to the ship's network via Ethernet cable through a router in the container. Sonobuoys were stored in a container on the afterdeck (second container level on starboard side). For immediate access to the buoys, a rack in the workshop container (afterdeck, lower container level on starboard side) was used for the storage of 12 sonobuoys.

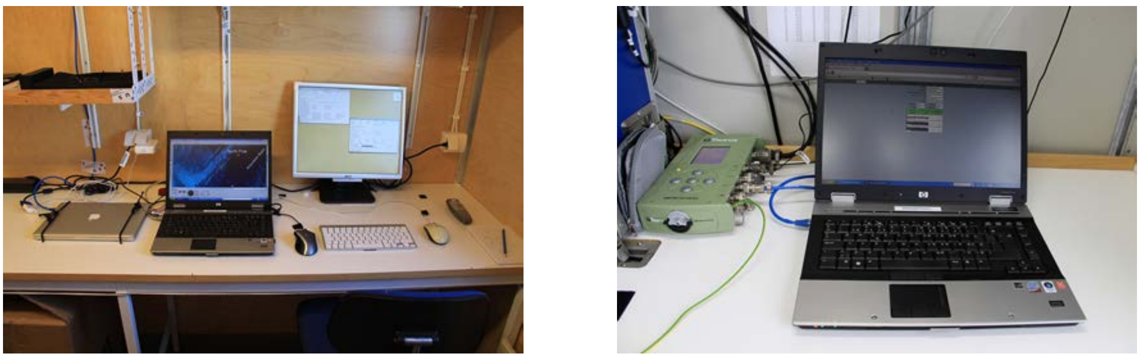

Figure 29. *Setup of the laboratory container on the fourth deck used for data processing and analysis (left). Data download from the Taurus seismometer in the seismic registration container on the fourth deck (right).*

8.2 Line Locations and Operation

During the LOMROG III expedition, the same acquisition technique was used that was successfully developed during the second part of the LOMROG II expedition in 2009. *Oden* would first break the ice along a track (between 9 and 25 nm long), then the ship would return along this track to widen and improve the path. First then, during the third passage of the track, the line would be shot. This also offered the possibility to deploy sonobuoys during the second run along the track. That way, a reversed ray coverage could be achieved. Additional deployments by helicopter ahead of the ship where also possible because the buoys could just be deployed along the track or close to the track. Locations in open leads and ponds close to the track (<200 m) were preferred as chances were higher that *Oden* could pass the buoys without destroying them. The helicopter would land on the ice (Figure 31) and then the buoys were deployed with a rope attached to them until the float bag would inflate. With either method, deployment during the preparation of the track or by helicopter, data could be collected on either side of the sonobuoy which increased the amount of useful data. However, the disadvantage of deploying buoys ahead of the ship was the uncertainty if *Oden* would get to the sonobuoy before the end of the life time of the buoy (8 hours). In addition, it is not always possible to pass the buoys that were deployed into the track without destroying them (e.g., buoy 2-7).

To bypass these two problems as much as possible, the deployment procedure was adjusted starting with line 6. The first sonobuoy was not deployed before the reflection seismic system (compressor, streamer, Geometrics software) was working properly. Such problems had a tendency to occur at the beginning of a line. By waiting a couple of minutes with the sonobuoy deployment, one ensures the maximum benefit of the eight-hour lifetime of the buoy. Once the first buoy was deployed from the afterdeck (Figure 30), the helicopter was loaded with three pre-programmed sonobuoys (plus one spare) to be deployed close to the track ahead of the ship. After a suitable lead or pond was identified, the helicopter would land on the ice and two people deployed the buoy. One person did the actual deployment with a rope attached to the parachute of the buoy (see below), while the other person would take the position and time of the deployment using a handheld GPS receiver. Using two persons for the deployment was also a safety measure as one had to stand very close to the edge of the ice. Starting with line 11, it became increasingly difficult to find open water as temperatures decreased. However, it was still possible to break a hole through the thin ice (Figure 32) using the buoy as a tool.

To decrease the failure rate during sonobuoy deployment, a new technique was introduced during the LOMROG II cruise that was also employed on this expedition. Here a 10-m-long rope was attached to the parachute of the buoy. The deployer kept the rope in the hand and this caused the buoy to stay at the water surface close to the ship where there is least impact by ice (Figure 30). Once the seawater battery activates, the parachute detaches from the remainder of the buoy. Using this technique, a surfacing of the buoy beneath the ice can be avoided. A later destruction by ice is of course still a possibility. For this deployment technique, it is best to lower the speed to a minimum to reduce the drag on the sonobuoys as much as possible. It is also best to avoid thick ice for the deployment because *Oden* needs more power to get through these sections, which increases the strength of the propeller wash. In essence, the higher the drag by the propeller wash, the longer it takes for the sonobuoy to activate. This is because the buoy starts to almost surf on the water, which delays the entrance of water into the buoy that activates the seawater battery. At a speed of 3 knots, the streamer can still maintain its depth, while the drag by the propeller is acceptable. In any case, depending on the drag, the activation of the buoy can take several minutes and sometimes it became difficult to hold the rope that was attached to the buoy.

The objective of the cruise was to identify areas in Amundsen Basin that potentially can be used for the application of the sediment thickness formula in a submission to the Commission on the Limits of the Continental Shelf (CLCS). For this purpose, gravity inversion was carried out prior to the cruise to get an idea about the sediment thickness in the basin. Based on this inversion, lines were strategically placed in areas where thicker sediments were indicated such as in fracture zones or other basement lows. Starting with line 7, the ship's gravity data were used to determine good locations for the sonobuoys. As the objective of the seismic program was to find thick sediments and to determine the velocities within the entire sedimentary column, it was essential to deploy the buoys in the thickest portion of the sediments. Without any additional information, it is unpredictable where these sediments are. Even the online brute stack is only of limited help because it does not show the sediments and basement depth ahead of the ship. The gravity data were processed after the first icebreaking pass of the ship. Since the water depth in Amundsen Basin is almost constant around 4350 m, any changes in the gravity most likely reflect variations in the sediment thickness. For the three helicopter deployments on each line, these gravity lows were the prime target. However, it was still tried to deploy one buoy close to the end of the line to maintain maximum reversed ray coverage. A location map of the seismic lines is shown in Figure 33. Detailed maps can be found in Appendix V-B.

Table 12. *Sonobuoy deployments. Water depths are with reference to sea level (including the transducer depth of 8.3 m).*

Sono-buoy	MCS line	Depth setting	Ope-rating life	Trans-mission channel	Recorded by Winradio	Deployment date (Julian Day)	Time of deployment (UTC)	Longitude	Latitude	Water depth (m)	Comments
1-1	1	D1=30 m	8 h	48	4	06 AUG 2012 (JD 219)	08:12:53	0.24497°W	86.88970°N	4278	Deployed from afterdeck during preparation of path, ship passed 16.00 UTC
1-2	1	D1=30 m	8 h	67	1 & 2	06 AUG 2012 (JD 219)	11:58:30	2.52995° E	86.76624°N	4278	Afterdeck deployment. Radio 1: Yagi antenna Radio 2: Dipole antenna
1-3	1	D1=30 m	8 h	87	3	06 AUG 2012 (JD 219)	13:22:58	2.02353°W	86.96602°N	4273	Helicopter deployment, ship passed 18.09 UTC
1-4	1	D1=30 m	8 h	58	4	06 AUG 2012 (JD 219)	16:47:32	0.38062°W	86.90141°N	4284	Destroyed during deployment from afterdeck
1-5	1	D1=30 m	8 h	43	4	06 AUG 2012 (JD 219)	16:56:44	0.52535°W	86.90680°N	4279	Afterdeck deployment
2-6	2	D1=30 m	8 h	48	4	07 AUG 2012 (JD 220)	05:10:51	5.92300°W	87.10333°N	4277	Deployed from afterdeck during preparation of path
2-7	2	D1=30 m	8 h	58	3	07 AUG 2012 (JD 220)	06:53:16	3.67733°W	87.03132°N	4284	Deployed from afterdeck during preparation of path. Hydrophone detached from antenna when Oden passed buoy at 10:12 UTC
2-8	2	D1=30 m	8 h	67	2	07 AUG 2012 (JD 220)	08:34:30	1.82010°W	86.97334°N	4273	Afterdeck deployment
2-9	2	D1=30 m	8 h	87	1	07 AUG 2012 (JD 220)	09:21:33	6.57307°W	87.12267°N	4281	Helicopter deployment
2-10	2	D1=30 m	8 h	77	3	07 AUG 2012 (JD 220)	10:43:50	4.03235°W	87.03533°N	4277	Afterdeck deployment
4-11	4	D1=30 m	8 h	63	1 & 2	07 AUG 2012 (JD 220)	21:43:32	5.32647°W	87.08694°N	4280	Afterdeck deployment
5-12	5	D1=30 m	8 h	87	2	17 AUG 2012 (JD 230)	06:13:44	64.76392°W	88.40743°N	1351	Afterdeck deployment, destroyed by ice 200 m behind the ship
5-13	5	D1=30 m	8 h	58	1 / 2	17 AUG 2012 (JD 230)	08:35:05	67.24690°W	88.32742°N	1564	Afterdeck deployment. Recording changed from ch1 to ch2 at 11:18 UTC
5-14	5	D1=30 m	8 h	83	1	17 AUG 2012 (JD 230)	12:28:19	66.83015°W	88.34510°N	1554	Afterdeck deployment
6-15	6	D1=30 m	8 h	58	1	21 AUG 2012 (JD 234)	12:21:01	56.68833°W	89.09770°N	2346	Afterdeck deployment
6-16	6	D1=30 m	8 h	87	2	21 AUG 2012 (JD 234)	12:59:39	64.34873°W	89.04182°N	2717	Helicopter deployment, ship passed 14.31 UTC
6-17	6	D1=30 m	8 h	48	3	21 AUG 2012 (JD 234)	13:09:14	69.05805°W	88.99123°N	2801	Helicopter deployment, ship passed 16.06 UTC
6-18	6	D1=30 m	8 h	67	4	21 AUG 2012 (JD 234)	13:22:54	73.51857°W	88.94077°N	1305	Helicopter deployment; radio signals received but hydrophone detached by ice after deployment
7-19	7	D1=30 m	8 h	58	1	28 AUG 2012 (JD 241)	07:11:24	74.63002°E	88.15260°N	4383	Afterdeck deployment
7-20	7	D1=30 m	8 h	87	4	28 AUG 2012 (JD 241)	07:49:13	73.35217°E	88.02552°N	4382	Helicopter deployment, ship passed 09.17 UTC
7-21	7	D1=30 m	8 h	48	2	28 AUG 2012 (JD 241)	08:01:58	72.65180°E	87.94975°N	4381	Helicopter deployment, ship passed 10.24 UTC

Table 12. *Continued.*

7-22	7	D1=30 m	8 h	67	3	28 AUG 2012 (JD 241)	08:12:03	71.89927°E	87.86591°N	4383	Helicopter deployment, ship passed 11.39 UTC
8-23	8	D1=30 m	8 h	58	1	29 AUG 2012 (JD 241)	03:06:05	72.56678°E	87.91987°N	4388	Afterdeck deployment
8-24	8	D1=30 m	8 h	87	4	29 AUG 2012 (JD 241)	03:40:43	75.72588°E	87.96152°N	4385	Helicopter deployment, ship passed 05.11 UTC
8-25	8	D1=30 m	8 h	48	2	29 AUG 2012 (JD 241)	03:48:55	77.15633°E	87.98025°N	4381	Helicopter deployment, ship passed 06.01 UTC
8-26	8	D1=30 m	8 h	67	3	29 AUG 2012 (JD 241)	04:00:46	79.99447°E	88.01403°N	4384	Helicopter deployment, ship passed 07.46 UTC
9-27	9	D1=30 m	8 h	58	1	30 AUG 2012 (JD 242)	04:09:32	75.44827°E	88.15182°N	4381	Afterdeck deployment
9-28	9	D1=30 m	8 h	87	4	30 AUG 2012 (JD 242)	04:40:01	73.68455°E	88.25048°N	4384	Helicopter deployment, ship passed 05.55 UTC
9-29	9	D1=30 m	8 h	48	2	30 AUG 2012 (JD 242)	04:51:14	71.59889°E	88.34247°N	4380	Helicopter deployment, ship passed 07.34 UTC
9-30	9	D1=30 m	8 h	67	3	30 AUG 2012 (JD 242)	05:02:54	69.61134°E	88.42455°N	4379	Helicopter deployment, ship passed 09.09 UTC
10-31	10	D1=30 m	8 h	58	1	30 AUG 2012 (JD 242)	23:09:31	68.26223°E	88.44060°N	4374	Stopped working after 40 shots
10-32	10	D1=30 m	8 h	87	4	30 AUG 2012 (JD 242)	23:41:17	65.60217°E	88.52284°N	4379	Helicopter deployment, ship passed 00.49 UTC
10-33	10	D1=30 m	8 h	48	2	30 AUG 2012 (JD 242)	23:53:05	62.38515°E	88.60495°N	4371	Helicopter deployment, ship passed 02.36 UTC
10-34	10	D1=30 m	8 h	67	3	31 AUG 2012 (JD 243)	00:05:35	58.07375°E	88.70070°N	4370	Helicopter deployment, ship did not pass buoy
10-35	10	D1=30 m	8 h	22	1	31 AUG 2012 (JD 243)	07:37:48	60.39228°E	88.63496°N	4371	Destroyed by ice shortly after deployment
11-36	11	D1=30 m	8 h	58	1	01 SEPT 2012 (JD 244)	07:45:02	49.33335°E	88.87000°N	4363	Afterdeck deployment
11-37	11	D1=30 m	8 h	87	4	01 SEPT 2012 (JD 244)	08:11:35	45.01259°E	88.91493°N	4358	Helicopter deployment, ship passed 09.14 UTC
11-38	11	D1=30 m	8 h	48	2	01 SEPT 2012 (JD 244)	08:19:00	41.85100°E	88.93760°N	4356	Helicopter deployment, ship passed 10.14 UTC
11-39	11	D1=30 m	8 h	67	3	01 SEPT 2012 (JD 244)	08:29:52	36.95673°E	88.97285°N	4352	Helicopter deployment, ship passed 11.45 UTC
12-40	12	D1=30 m	8 h	58	1	01 SEPT 2012 (JD 244)	22:10:45	40.31232°E	88.93617°N	4357	Afterdeck deployment
12-41	12	D1=30 m	8 h	87	4	01 SEPT 2012 (JD 244)	22:39:18	37.83383°E	88.85687°N	4366	Helicopter deployment, ship passed 23.32 UTC
12-42	12	D1=30 m	8 h	48	2	01 SEPT 2012 (JD 244)	22:48:02	36.10295°E	88.79630°N	4364	Helicopter deployment, ship passed 00.30 UTC
12-43	12	D1=30 m	8 h	67	3	01 SEPT 2012 (JD 244)	22:58:32	34.92062°E	88.75459°N	4365	Helicopter deployment
13-44	13	D1=30 m	8 h	58	1	02 SEPT 2012 (JD 245)	16:41:28	20.26178°E	88.52590°N	4370	Afterdeck deployment
13-45	13	D1=30 m	8 h	87	4	02 SEPT 2012 (JD 245)	17:10:29	22.54938°E	88.44405°N	4369	Helicopter deployment, ship passed 18.17 UTC
13-46	13	D1=30 m	8 h	48	2	02 SEPT 2012 (JD 245)	17:16:33	23.64110°E	88.40047°N	4372	Helicopter deployment, ship passed 19.03 UTC
13-47	13	D1=30 m	8 h	67	3	02 SEPT 2012 (JD 245)	17:24:50	25.41553°E	88.32987°N	4369	Helicopter deployment, shooting stopped ca. 25 m before buoy was reached
14-48	14	D1=30 m	8 h	58	1	03 SEPT 2012 (JD 246)	10:18:12	27.42882°E	88.51728°N	4375	Afterdeck deployment
14-49	14	D1=30 m	8 h	87	4	03 SEPT 2012 (JD 246)	10:51:40	23.27432°E	88.39056°N	4379	Helicopter deployment, ship passed 12.52 UTC
14-50	14	D1=30 m	8 h	48	2	03 SEPT 2012 (JD 246)	11:01:21	20.15270°E	88.34299°N	4377	Helicopter deployment,

Table 12. *Continued.*

										ship passed 14.21 UTC
14-51	14	D1=30 m	8 h	67	3	03 SEPT 2012 (JD 246)	11:12:12	17.44533°E	88.28973°N	4375	Helicopter deployment, ship passed 15.40 UTC
15-52	15	D1=30 m	8 h	58	1	04 SEPT 2012 (JD 247)	07:41:45	18.34792°E	88.06587°N	4375	Afterdeck deployment
15-53	15	D1=30 m	8 h	87	4	04 SEPT 2012 (JD 247)	08:09:17	21.07648°E	88.01675°N	4371	Helicopter deployment, ship passed 09.15 UTC
15-54	15	D1=30 m	8 h	48	2	04 SEPT 2012 (JD 247)	08:21:03	23.66690°E	87.95450°N	4378	Helicopter deployment, ship passed 10.52 UTC
15-55	15	D1=30 m	8 h	67	3	04 SEPT 2012 (JD 247)	08:32:40	26.75980°E	87.87355°N	4382	Helicopter deployment, ship passed 12.52 UTC
16-56	16	D1=30 m	8 h	58	1	05 SEPT 2012 (JD 248)	00:59:15	29.39800°E	87.83833°N	4380	Afterdeck deployment
16-57	16	D1=30 m	8 h	87	4	05 SEPT 2012 (JD 248)	01:31:04	28.13203°E	87.74813°N	4381	Helicopter deployment, ship passed 02.29 UTC
16-58	16	D1=30 m	8 h	48	2	05 SEPT 2012 (JD 248)	01:38:15	27.80062°E	87.70887°N	4383	Helicopter deployment, ship passed 03.05 UTC
16-59	16	D1=30 m	8 h	67	3	05 SEPT 2012 (JD 248)	01:46:00	27.05377°E	87.63287°N	4380	Helicopter deployment, line was abandoned before buoy was reached
17-60	17	D1=30 m	8 h	58	1	05 SEPT 2012 (JD 248)	15:13:10	20.56492°E	87.62797°N	4371	Afterdeck deployment
17-61	17	D1=30 m	8 h	87	4	05 SEPT 2012 (JD 248)	15:29:53	19.85842°E	87.56892°N	4371	Helicopter deployment, ship passed 16.12 UTC
17-62	17	D1=30 m	8 h	48	2	05 SEPT 2012 (JD 248)	15:36:55	19.50965°E	87.53830°N	4372	Helicopter deployment, ship passed 16.44 UTC
17-63	17	D1=30 m	8 h	67	3	05 SEPT 2012 (JD 248)	15:43:57	18.91710°E	87.49213°N	4372	Helicopter deployment, ship passed 17.32 UTC

Figure 30. *Sonobuoy deployment from the afterdeck of Oden. The parachute (not shown) of the sonobuoy is attached to a rope during the deployment. Photo: Marie Lykke Rasmussen.*

Figure 31. *Deployment of a sonobuoy close to the prepared track for the seismic line. The helicopter is used for transportation and for finding suitable open water. A rope is attached to the parachute of the sonobuoy.*

Figure 32. *Sonobuoy that was deployed in a refrozen open water pond. The weight of the sonobuoy was sufficient to create the hole in the ice.*

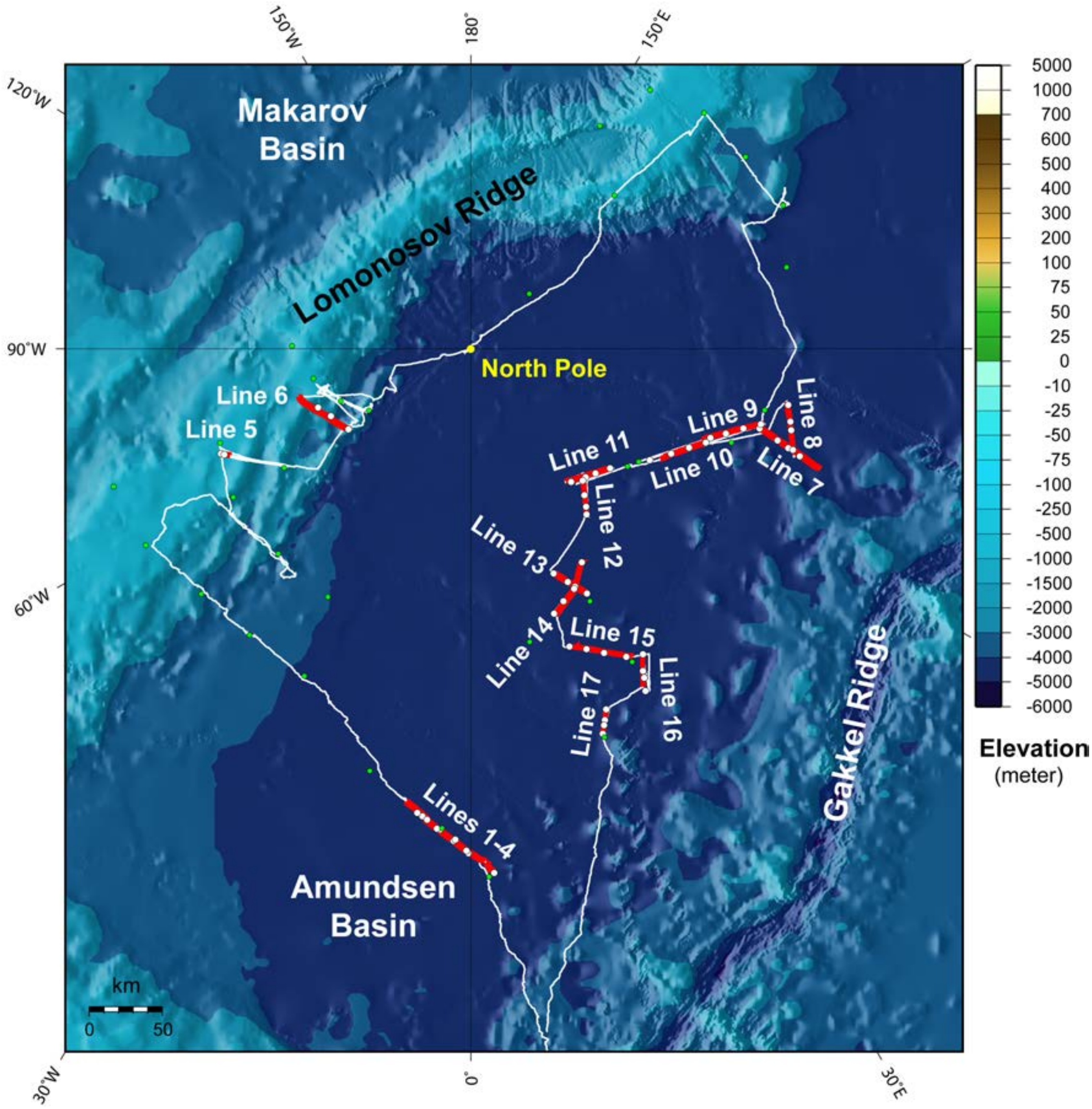

Figure 33. *Bathymetric map (IBCAO 3.0, Jakobsson et al. 2012) with the location of the LOMROG III (2012) seismic reflection lines (red lines). The ship track is marked as white line. White circles indicate the deployment positions of functional sonobuoys. Green circles show the location of CTD measurements. Detailed location maps for individual lines are shown in Appendix V-B.*

8.3 Data Retrieval and Processing

8.3.1 Navigation

Shot times and positions were stored in ASCII format on the NaviPac navigation computer; file names are *Lomrog3.[line#].Nav.txt*. The shot times in that file include the shot delay of

300 ms, which is composed of a user-selectable delay (200 ms) and an additional fixed delay of 100 ms. Comparison with the PPS pulse written to auxiliary channel 8 indicates that the shot time written to the navigation file is accurate within ±10 ms. Automatic picking of the time of the first PPS pulse on each seismic trace has similar uncertainties (this was done during the LOMROG I in 2007 expedition when the shot time was not written to the navigation file). Hence, no attempt was made to analyze the time of the PPS pulse to decrease the uncertainty of the NaviPac shot time.

Positions in the navigation file are corrected for the offset between the gun array and the GPS antenna. Positions are given as x and y values (Easting and Northing in meters) in the Universal Polar Stereographic (UPS) projection with the following projection parameters:

- Reference longitude: 25° W
- Standard parallel: 81° 07' N
- Reference ellipsoid: WGS 84
- False Northing: 2.000.000 m (corresponding to the y value at the North Pole)
- False Easting: 2.000.000 m (corresponding to the x value at the North Pole)

The UPS coordinates were transformed to geographical coordinates (longitude and latitude) employing the process *mapproject* in the Generic Mapping Tools (GMT) software.

During the LOMROG III cruise, the water depth was not written into the navigation files. Instead, grids from the onboard multibeam system were provided by the hydrographers, from which the water depths at the shot positions were extracted. Since there were gaps in these grids, many water depths had to be determined by interpolation to the neighbouring grid points or by extrapolation to the closest constrained grid node. Some sonobuoys were deployed outside the coverage of the grid and water depths from the IBCAO 3.0 grid (Jakobsson *et al*. 2012) had to be extracted. The calculation of the water depths was done as part of the seismic reflection data processing.

Deployment positions and times of the sonobuoys (Table 12) were obtained from a handheld GPS unit (GARMIN GPSmap 60CSx). The position was taken at the time of the activation of the buoy (inflation of the float bag and detachment of the parachute). These waypoints were subsequently downloaded to the PC in the laboratory container.

8.3.2 Data Retrieval

For each line and each auxiliary channel (channels 1 through 4 and channel 8 with the PPS pulse) a SEGY file was compiled from the raw SEGD files written by the Geometrics software. This conversion was done by John R. Hopper using ProMAX software. These files were stored as *Line[line#]chan[channel#].segy*, e.g. *Line1_chan34.segy*. Note that the channel number is increased by 32 to reflect the number of active streamer channels.

Data from the Taurus instruments were downloaded to a PC using the Ethernet interface of the recorders, which allow access with a web-browser. Data were downloaded in MiniSEED format. There are other selectable formats (e.g., ASCII), but MiniSEED is by far the fastest (download in ASCII format can take hours instead of minutes for MiniSEED). Filenames are

Winradio_taurus_[*Taurus serial number*]_[*year*][*month*][*day*]_[*time in hhmmss*].seed

for example *Winradio_taurus_1574_20120806_123900.seed*

8.3.3 Data Processing

The raw SEGY files from the Geometrics system contain all shots along a line. In a first step, the shots that each sonobuoy recorded were extracted into raw SEGY files for each buoy. For the Taurus recordings, the data were converted from MiniSEED to ASCII format using the program *mseed2ascii* (free software under the GNU General Public License). Using UNIX scripts and FORTRAN programs, the appropriate time windows were extracted using the shot times given in the navigation file. Shot positions, receiver position (=sonobuoy deployment position), gun depth, shot time, and offset were subsequently written into the header. The offset was calculated from the shot and receiver positions, no drift corrections were applied initially. These SEGY files are located in the directory *segy/raw* and are named *sono[sonobuoy number][aux/taurus][channel 1/2/3/4].sgy* (e.g. sono4-11taurus1.sgy). Data recorded on the Geometrics system are named *aux(1/2/3/4)* with the number indicating the auxiliary channel; file names with *taurus(1/2/3)* identify the recording channel of the Taurus system. The record length is 12 s for the data from the MCS recording system, for the files created from the Taurus records, windows with a length of 30 s were extracted. Static corrections were applied for both the variable gun depth and the fixed depth of the hydrophone on the sonobuoys (30 m), using sea level as reference. The surface water velocity obtained from a CTD measurement close by was used to calculate the static corrections (CTD S02 for lines 1 through 4, CTD S04 for line 5, CTD H14 for line 6, CTD S06 for lines 7 through 12, CTD H25 for lines 13 and 14, CTD H27 for lines 15 through 17). Velocity-depth curves obtained from the CTD measurements are shown in Appendix V-C.

While the sonobuoys transmitted signals back to the ship, they were drifting in the ice and the water. Since the sonobuoys are not equipped with a GPS or other navigation systems, their exact position is unknown. However, from the arrival time of the direct water wave, the distance between the shot and sonobuoy can be calculated. For this purpose, travel times for all direct arrivals were picked by means of the program *zplot* (written by Collin Zelt). After that, one-dimensional raytracing modelling was carried out using a self-written program to calculate the travel times of the direct wave for a given CTD profile. Figure 34 shows the velocity-depth function obtained from CTD measurement S02. The results from the raytracing modelling are displayed in Figure 35. The direct wave was picked every 5^{th} to 10^{th} trace to avoid jitter that is introduced by the pick uncertainty when every trace is picked. Between these picks, a linear interpolation was carried out. Sometimes, the direct wave could not be identified at large offsets. Then the drift correction was obtained by extrapolation. The new drift-corrected offsets were then written into the SEGY headers (in addition to the shot and receiver water depths) and the SEGY files are stored in the directory *segy/final* using the same file nomenclature as for the raw SEGY files. For the offsets, negative values were used when the shots were fired to the west of the sonobuoys while positive values indicate shots to the east of the buoys.

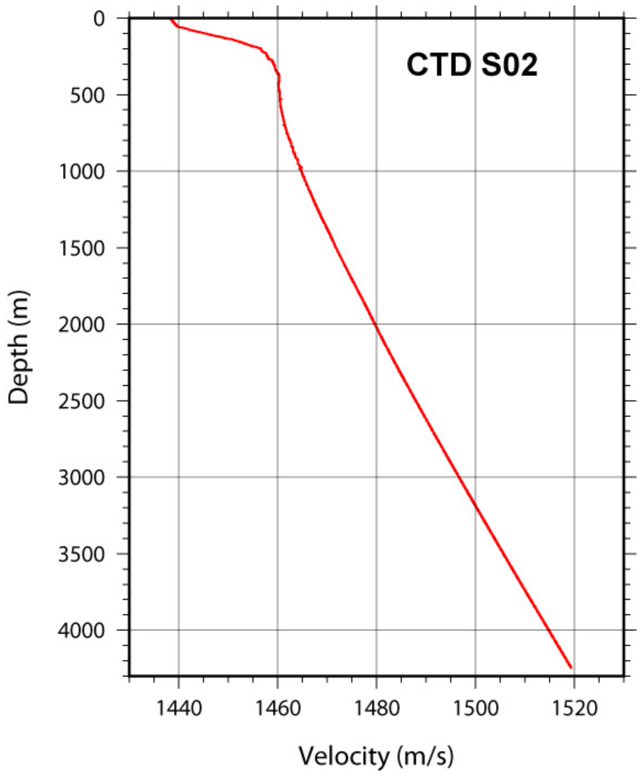

Figure 34. *Velocity-depth function obtained from CTD measurement S02. The complete set of CTD measurements relevant to the seismic data are shown in Appendix C.*

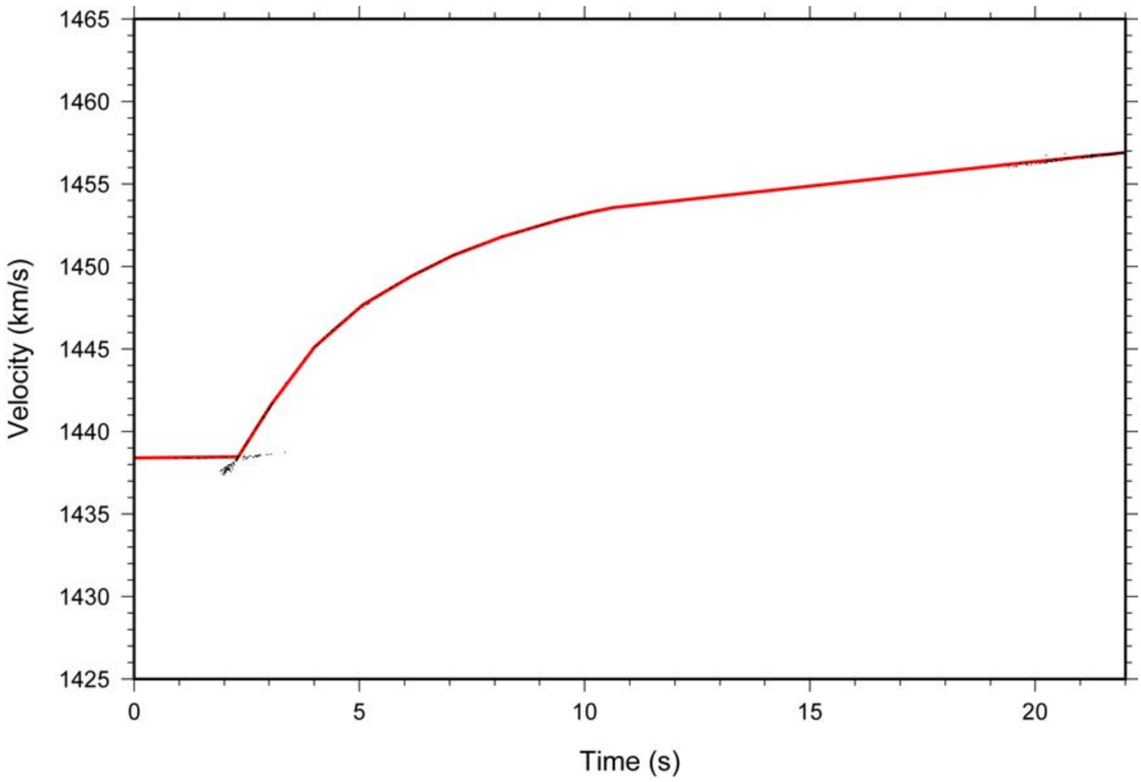

Figure 35. *Average water velocity (offset divided by travel time) as a function of travel time of the direct wave obtained from one-dimensional ray tracing using the velocity function shown in Figure 34 (CTD S02). A complete set of all these curves relevant to the seismic data can be found in Appendix V-C.*

The calculation of the correct offset between the shot and the sonobuoy allows for some estimate of the drift rate of the sonobuoy. However, the drift is composed of two components, one along the line and one perpendicular to the line. The component along the line can be quantified by the difference between the theoretical offset using the deployment position of the buoy and the recalculated shot-receiver distance determined from the direct water wave.

Sonobuoy	Time between deployment and passage (s)	Total drift (m)	Direction of drift	Drift velocity (km/h)
1-1	28065	4285	113°	0.55
1-3	17184	2072	118°	0.43
2-7	12364	1167	158°	0.34
6-16	5516	1602	176°	1.05
6-17	10657	2798	172°	0.95
7-20	5323	158	53°	0.11
7-21	8586	333	71°	0.14
7-22	12466	450	80°	0.13
8-24	5485	807	52°	0.53
8-25	7955	1057	54°	0.48
8-26	13523	1831	56°	0.49
9-28	4272	759	121°	0.64
9-29	9817	670	74°	0.25
9-30	14842	761	75°	0.19
10-32	4100	205	201°	0.18
10-33	9819	476	196°	0.18
11-37	3748	759	329°	0.73
11-38	6928	1412	328°	0.73
11-39	11755	2445	324°	0.75
12-41	3206	226	22°	0.25
12-42	6129	379	38°	0.22
13-45	4049	47	247°	0.04
13-46	6442	61	331°	0.03
13-47	10586	233	301°	0.08
14-49	3623	590	142°	0.59
14-50	12016	1183	131°	0.35
14-51	16090	1573	125°	0.35
15-53	3970	376	36°	0.34
15-54	9060	652	48°	0.26
15-55	15589	819	54°	0.19
16-57	3494	495	289°	0.51
16-58	5205	793	287°	0.55
17-61	2582	138	276°	0.19
17-62	4047	272	271°	0.24
17-63	6487	429	265°	0.24

Table 13. *Drift of sonobuoys calculated from the time and position of the deployment (during ice breaking or by helicopter) and of the passage during airgun shooting.*

The drift component perpendicular to the line cannot be determined that way. However, the ice-drift can be derived from comparing the three tracks of the ship along the seismic line (two during the preparation of the track and one during shooting). An easy way of quantifying the ice drift comes from sonobuoys that were deployed ahead of the ship and that remain at a fixed position within an ice floe. Once the ship passes the buoy during the shooting, the drift (amount and direction) can be determined from the deployment and passage position. A summary of the drift of these sonobuoys is given in Table 13. During periods with strong winds, the drift of the buoys can be as much as 1000 m/h (buoy 6-16). At other times, the drift is almost negligible (30 m/h for buoy 13-46).

Plots of the sonobuoy data are shown in Appendix V-A. The record sections are plotted versus offset (drift corrected). Data were debiased, followed by deconvolution and a band pass filter (5 to 40 Hz). Travel times are reduced with a reduction velocity of 6.8 km/s. Record sections are displayed with true amplitudes.

8.4 Summary and Recommendations

8.4.1 Comparison between Yagi and dipole antenna

To test the new Yagi antenna, the signals of sonobuoy 1-2 were received by the Yagi antenna on Winradio 1, while the dipole antenna was connected to Winradio 2. Record sections are displayed in Figure 36 and clearly show that the Yagi antenna is an improvement when compared with the dipole antenna. With the Yagi antenna, high-amplitude refractions can be correlated up to offsets of 22 km, weaker refractions even out to 34 km. In contrast, high-amplitude refractions disappear around 16 km offset when received

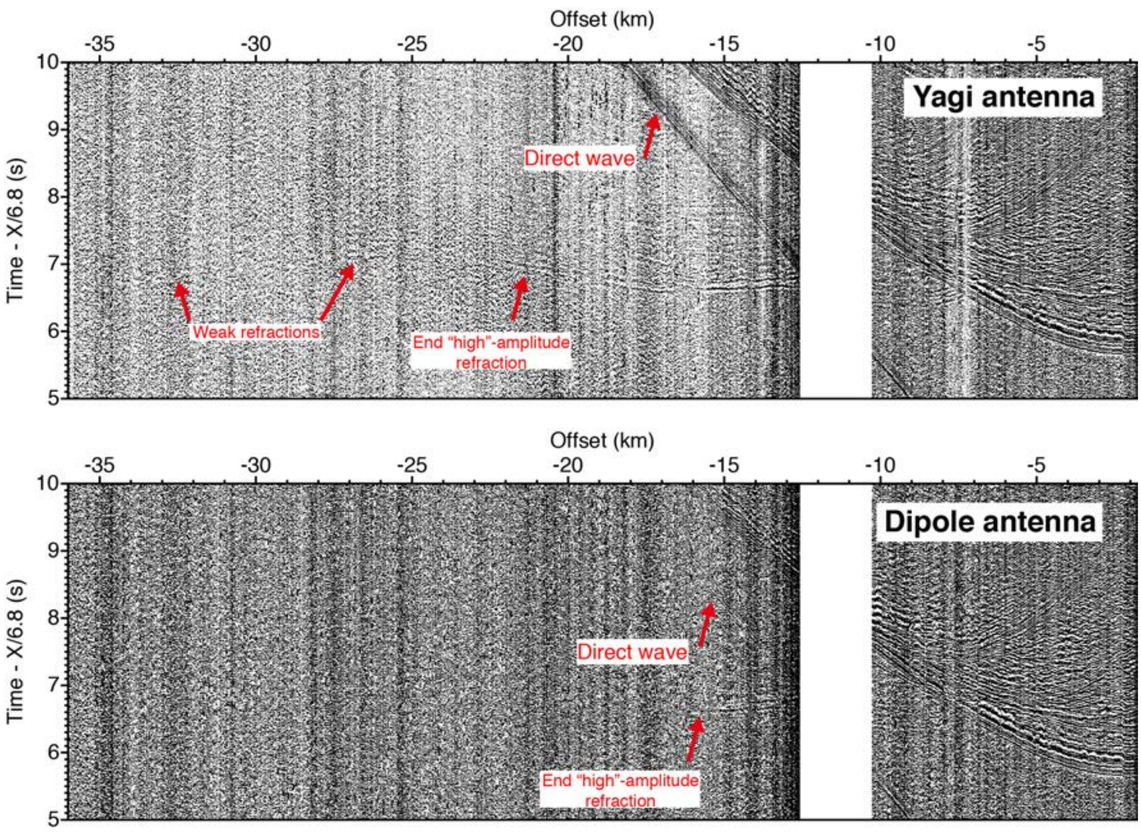

Figure 36. *Comparison of the Yagi (top) and dipole (bottom) antenna for the signals transmitted by sonobuoy 1-2 on Line 1. The records are displayed with a reduction velocity of 6.8 km/s. Processing includes debias, deconvolution, bandpass filter (5-40 Hz) and scaling by true amplitude.*

with the dipole antenna and no weaker refractions can be recognized. In general, the signal-to-noise ratio is better with the Yagi antenna. This is true for both near and far offset. For example, the direct water wave is much more prominent with the Yagi antenna, whereas it is more difficult to detect with the dipole antenna, in particular at larger offsets.

It should also be noticed that the Yagi antenna was mounted lower than the dipole antenna, which would mean that the theoretical line of sight is less for the Yagi antenna. The only drawback for the Yagi antenna is its directivity. There is a substantial gain loss of the antenna when the ship turns more than 10-20 degrees away from the direction of the buoy (see Appendix V-H).

8.4.2 Recommendations

The use of the Yagi antenna resulted in greatly improved record sections (see above). However, due to the directivity of the Yagi antenna (see Appendix V-H), sonobuoys have to be behind the ship for their signals to be received. In Arctic ice, the ship often has to change course to find a suitable path through the ice. Hence, the buoy can easily get out of the 10 to 20 degree pattern of the antenna, where the signal strength is a maximum. Preparation of the track prior to the shooting helps to avoid severe course changes and minimizes variations in the signal strength.

The deployment of sonobuoys ahead of the ship (either during the preparation of the track or by helicopter) improves the amount of data collected by each buoy. In addition, the results of the velocity modelling become more accurate as reversed ray paths provide better constraints on the sub seafloor geometry. During LOMROG III, buoys ahead of the ship could only be monitored with the less sensitive dipole antenna. In order to achieve a similar data quality for buoys that are ahead of the ship, the installation of a second Yagi antenna directed to the front would be necessary. This would also require a switch or other device that would allow changing the antenna that is connected to the Winradio. Once the ship passes the buoy, the forward looking antenna has to be changed to the backward looking antenna.

Winradio 2 was generally used to monitor the sonobuoys transmitting on channel 48 (142.000 MHz). On many record sections, noise spikes were observed which resemble the pulses from the AIS system. The reason for these pulses is unclear, as a notch filter was used on Winradio 2 to eliminate interference with the two known AIS frequencies of 161.975 and 162.025 Hz. This interference may require some further investigations.

In general, four Winradios are an adequate number of receivers to record the sonobuoys. However, with the improved radio range by the Yagi antenna and the newly refined and very efficient helicopter deployment technique, there is some scientific benefit in increasing the number of Winradios. Six available radios would ensure more flexibility to target prime areas of interest. The two older Winradios (radio 1 and 2) should also be replaced with the newer USB type radios (radio 3 and 4) as they are more reliable and have a better performance. This may also help to reduce the number of problems with the computer running the Winradio software. Several reboots of the computer were necessary during the expedition, fortunately not during the data acquisition.

At present, the setup of the system allows only to monitor three of the four Winradios on the Taurus seismometer. This is related to the maximum number of channels that the one available Taurus can record. With four radios and the present length of the lines (not more than 20 to 25 nm), this is not a serious problem if the buoy that is not recorded by the Taurus is located close to the centre of the line. However, with the increased radio range by the Yagi antenna and potentially more Winradios, an additional Taurus would improve the data quality. Without a Taurus recording, drift corrections cannot be carried out for far offset shots (>18 km during LOMROG III with 12 s record length).

8.4.3 Summary

The sonobuoy operation and data quality could be improved when compared with the two previous LOMROG expeditions. This is related to

- a larger airgun source resulting in a better penetration of the seismic energy into the sediments and the crust;
- the availability of a Yagi antenna that can receive radio signals at larger distances when compared to the dipole antenna;
- the increased number of helicopter deployments, which resulted in more reversed seismic data, a generally better signal-to-noise ratio when compared to ship deployments, and a larger reliability with hardly any failures during deployment;
- making use of the gravity data during the preparation of the track to optimize the sonobuoy deployment positions by targeting gravity lows with potentially thick sediments.

A total of 63 sonobuoys were deployed during the LOMROG III expedition. 38 buoys were deployed by helicopter (Figure 31) and only one of those did not function (sonobuoy 6-18). Here the buoy deployed properly but the wind moved it into a narrow (~0.5 m wide) channel with sharp protruding ice edges beneath the surface. As the buoy was still transmitting the carrier upon arrival of the ship, the sharp ice has probably cut the wire to the hydrophone.

The remaining 25 buoys were deployed from the afterdeck of Oden (Figure 30), three of them during the preparation of the track for the seismic line. Three of the buoys were destroyed by ice during or shortly after deployment. For another two buoys, no signals were received for offsets >1.2 km (sonobuoy 10-31) or > 3.5 km (buoy 11-36). It is unclear what happened to these buoys. Either they were destroyed by the ice or thick blocks of ice moved in front of these buoys and blocked the radio signals. In any case, data from these two buoys cannot be used for a velocity analysis. With that, the success rate for afterdeck deployments is 80 % (20 buoys out of 25 with useful data). This compares with a rate of 97 % for the helicopter deployments. The total success rate for all deployments is 90 %. With almost 500 km of seismic reflection data, this translates into an average spacing of 8.7 km between successful sonobuoy deployment positions.

The overall quality of the data is excellent and will allow for high-resolution definition of the velocities within the sedimentary column employing semblance analysis or more sophisticated two-dimensional ray tracing. In addition, many records show crustal refractions and sometimes even reflections from the Moho discontinuity. Since the setup of most lines was similar to classic wide-angle seismic reflection/refraction experiments (all buoys were essentially deployed along the line within an hour after the start of the shooting), there is the potential for a proper analysis of the crustal velocity structure beneath the Amundsen Basin and also at the flank of the Lomonosov Ridge.

8.5 References

Jakobsson, M., Mayer, L., Coakley, B., Dowdeswell. J.A., Forbes, S., Fridman, B., Hodnesdal, H., Noomets, R., Pedersen, R., Rebesco, M., Schenke, H.W., Zarayskaya, Y., Accetella, D., Armstrong, A., Anderson, R.M., Bienhoff, P., Camerlenghi, A., Chruch, I., Edwards, M., Gardner, J.V., Hall, J.K., Hell, B., Hestvik, O., Kristoffersen, Y., Marcussen, C., Mohammad, R., Mosher, D., Nghiem, S.V., Pedrosa, M.T., Travaglini, P.G. & Wetherall, P. 2012: The International Bathymetric Chart of the Arctic Ocean (IBCAO) Version 3. Geophysical Research Letters **39**, LI2609, doi:10.1029/2012GL052219.

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9. Acknowledgement

The successful data acquisition of LOMROG III was due to the excellent cooperation between all members of the crew of *Oden*, the helicopter crew and the science party.

Funding for the cruise was provided by the Continental Shelf Project of the Kingdom of Denmark and the Swedish Polar Research Secretariat.

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10. Appendices and Enclosures

10.1 Appendices

Appendix I: Seismic equipment setup and specifications

- A Seismic equipment setup
- B GeoEel Digital Marine Streamer
- C Geopoint hydrophone (hydrophone in streamer)
- D Winch system: main data
- E Air gun signature and spectrum @ 20 m
- F Marine sources from Sercel
- G Cold weather operation for airguns
- H NaviPac: Integrated Navigation Software
- I Thales DG16 GPS receiver
- J Hamworthy compressor

Appendix II: Definitions of offset points

Appendix III: Marine Survey – General Information, Line Overview logs and Tape Inventory Log

Appendix IV: Configuration of the Geometrics GeoEel streamer

Appendix V: Sonobuoy appendices

- A Record sections of all sonobuoys (recorded on the seismic reflection acquisition system)
- B Location maps for all seismic lines
- C CTD measurements used for offset calculations
- D Technical specifications sonobuoy receiver WR-2902e
- E Technical specifications Taurus seismometer from Nanometrics
- F Technical specifications sonobuoy AN/SSQ-53D(3) from ULTRA Electronics
- G Technical specifications VHF antenna MD G3
- H Technical specifications of Yagi antenna R2-10L

10.2 Enclosures as digital files on enclosed DVD

Enclosure 1: PDF version of this report
Enclosure 2: Video by Jack Schilling: *Seismic Survey on icebreaker Oden 2012*
Enclosure 3: PDF version of the LOMROG III Cruise report
Enclosure 4: Navigation data as ASCII files

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Appendix I: Seismic equipment setup and specifications

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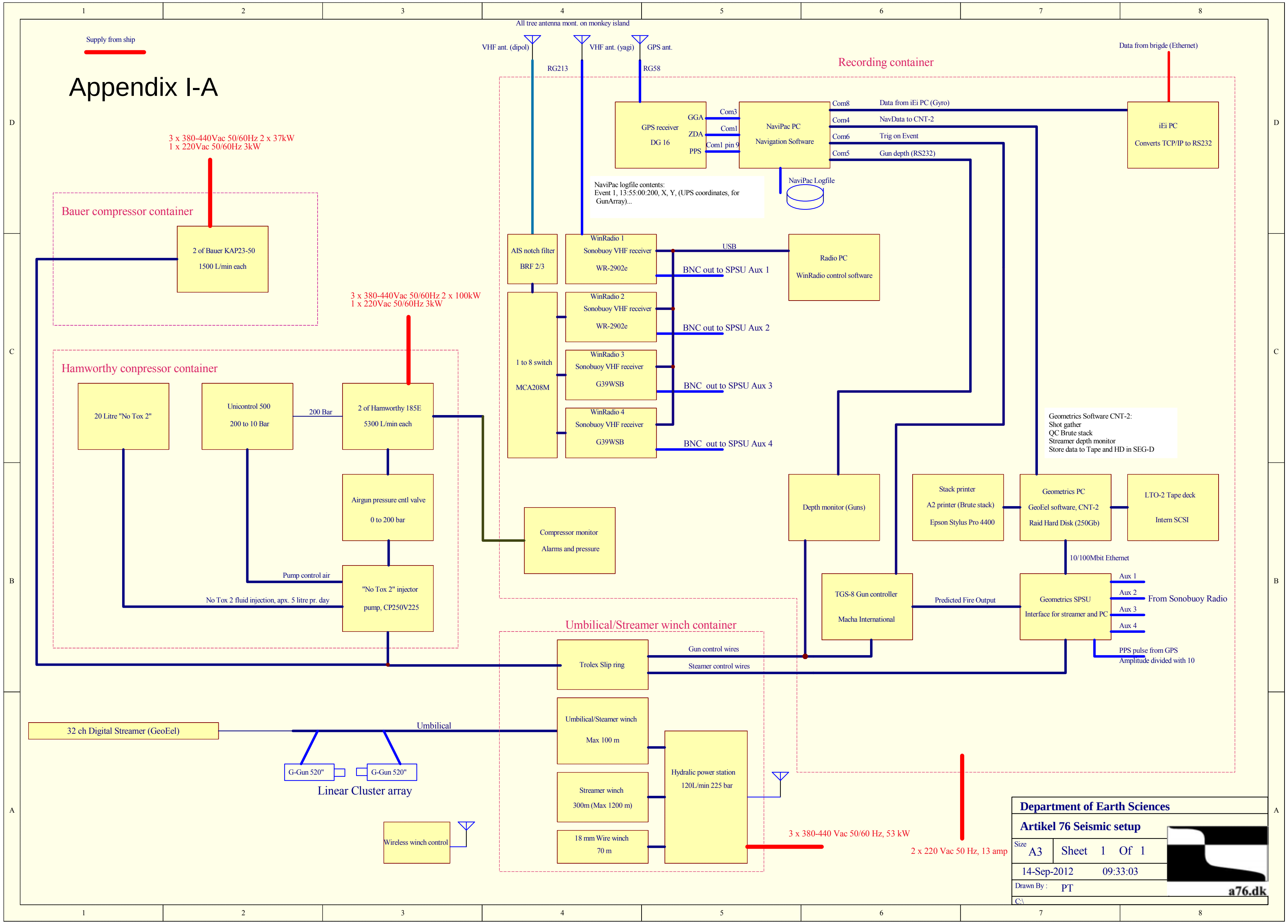
Appendix I-A


Supply from ship
All tree antenna mont. on monkey island
VHF ant. (dipol)
VHF ant. (yagi)
GPS ant.
RG213
RG58
Recording container
Data from brigde (Ethernet)
3 x 380-440Vac 50/60Hz 2 x 37kW
1 x 220Vac 50/60Hz 3kW
GPS receiver
DG 16
GGA
ZDA
PPS
Com3
Com1
Com1 pin 9
NaviPac PC
Navigation Software
Com8
Com4
Com6
Com5
Data from iEi PC (Gyro)
NavData to CNT-2
Trig on Event
Gun depth (RS232)
iEi PC
Converts TCP/IP to RS232
NaviPac logfile contents:
Event 1, 13:55:00:200, X, Y, (UPS coordinates, for GunArray)...
NaviPac Logfile
Bauer compressor container
2 of Bauer KAP23-50
1500 L/min each
AIS notch filter
BRF 2/3
WinRadio 1
Sonobuoy VHF receiver
WR-2902e
USB
BNC out to SPSU Aux 1
Radio PC
WinRadio control software
3 x 380-440Vac 50/60Hz 2 x 100kW
1 x 220Vac 50/60Hz 3kW
WinRadio 2
Sonobuoy VHF receiver
WR-2902e
BNC out to SPSU Aux 2
1 to 8 switch
MCA208M
WinRadio 3
Sonobuoy VHF receiver
G39WSB
BNC out to SPSU Aux 3
Hamworthy conpressor container
20 Litre "No Tox 2"
Unicontrol 500
200 to 10 Bar
200 Bar
2 of Hamworthy 185E
5300 L/min each
WinRadio 4
Sonobuoy VHF receiver
G39WSB
BNC out to SPSU Aux 4
Geometrics Software CNT-2:
Shot gather
QC Brute stack
Streamer depth monitor
Store data to Tape and HD in SEG-D
Airgun pressure cntl valve
0 to 200 bar
Compressor monitor
Alarms and pressure
Depth monitor (Guns)
Stack printer
A2 printer (Brute stack)
Epson Stylus Pro 4400
Geometrics PC
GeoEel software, CNT-2
Raid Hard Disk (250Gb)
LTO-2 Tape deck
Intern SCSI
10/100Mbit Ethernet
Pump control air
"No Tox 2" injector
pump, CP250V225
No Tox 2 fluid injection, apx. 5 litre pr. day
TGS-8 Gun controller
Macha International
Predicted Fire Output
Geometrics SPSU
Interface for streamer and PC
Aux 1
Aux 2
Aux 3
Aux 4
From Sonobuoy Radio
Umbilical/Streamer winch container
Trolex Slip ring
Gun control wires
Steamer control wires
PPS pulse from GPS
Amplitude divided with 10
32 ch Digital Streamer (GeoEel)
Umbilical
Umbilical/Streamer winch
Max 100 m
G-Gun 520"
G-Gun 520"
Linear Cluster array
Hydralic power station
120L/min 225 bar
Streamer winch
300m (Max 1200 m)
Wireless winch control
18 mm Wire winch
70 m
3 x 380-440 Vac 50/60 Hz, 53 kW
2 x 220 Vac 50 Hz, 13 amp
Department of Earth Sciences
Artikel 76 Seismic setup
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Appendix I-B:

GeoEel Digital Marine Streamer

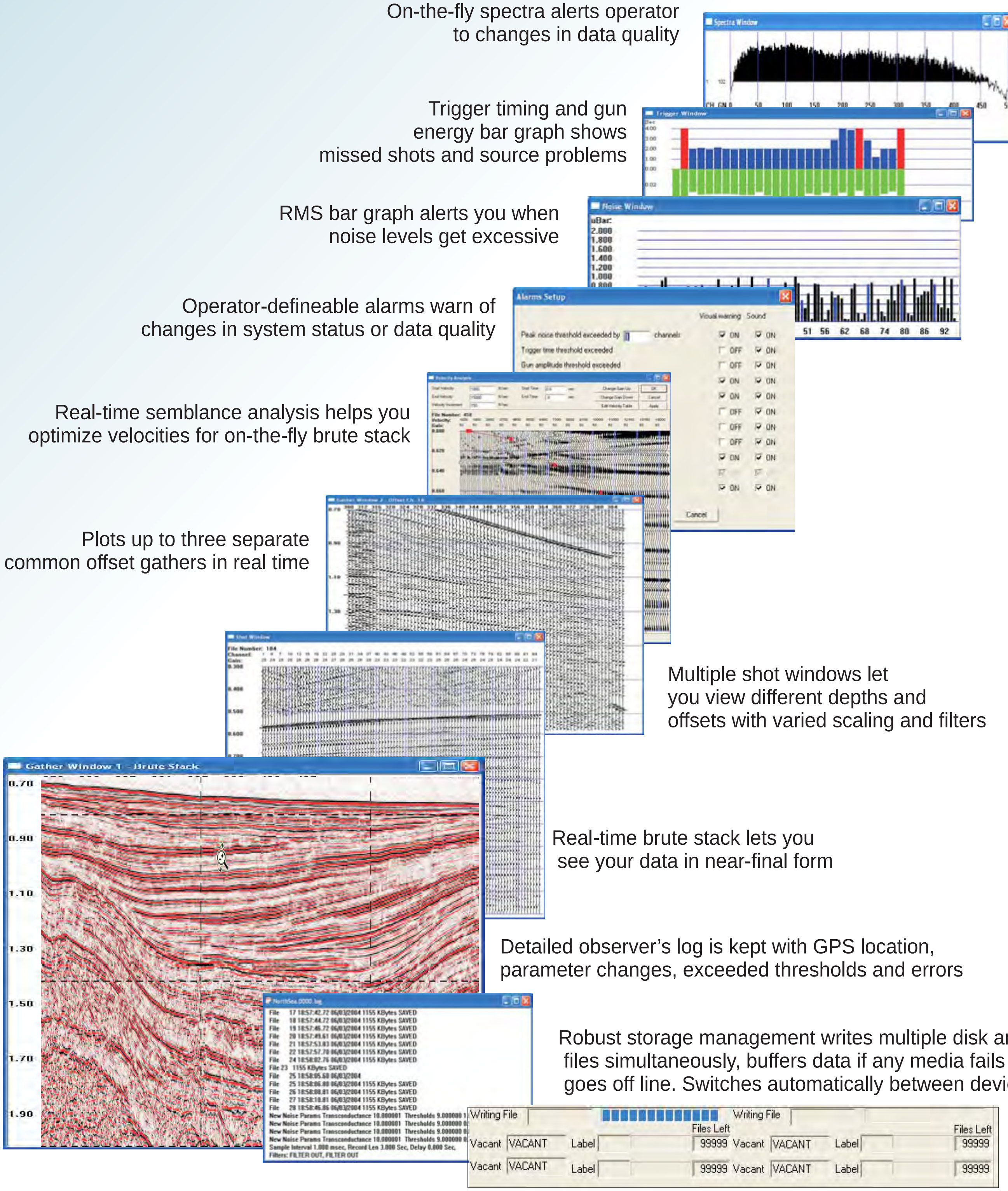
- **Light and Easy to Handle: 40.3 mm diameter, up to 240 channels in 8 channel sections**
- **Environmentally friendly and non-flamable: filled with inert silicone oil, ships by air.**
- **Wide bandwidth means more applications: 1/16 to 4 ms for petroleum, engineering or sub-bottom profiling**
- **Digital sections means better quality data, less time deploying and troubleshooting**
- **No costly controller required: uses any PC and industry standard Ethernet**
- **Low-noise design yields under 4 microbar noise**
- **A/D electronics also available packaged in an instrument enclosure for use with analog streamers**
- **Complete built-in testing of streamer and internal electronics**

The GeoEel digital towed hydrophone streamer is the first narrow-diameter array with the performance of larger systems. With a diameter of only 40.3 mm, the GeoEel is easy to deploy, easy to transport and can be shipped by air. Separate 8 channel modules coupled with unique slim active section design yield noise levels under 4 mBar are largely immune from the electronic interference, leakage and ground loops that plague the installation of analog streamers.

The GeoEel is filled with inert silicone oil which makes it environmentally safe and no-flamable. Thick 1/8 inch abrasion resistant polyurethane makes the streamer extremely rugged but still flexible enough to deploy by hand or mount on small boats. And the GeoEel is easy to repair - no fragile fiber optics to break or go bad.

The GeoEel communicates via fast Ethernet to Geometrics CNT-1 controller, running field-proven software that is used on over 40 installations. And the GeoEel is designed by Geometrics, known for over 35 years as an industry leader in rugged, reliable and well supported instrumentation.

Robust, proven software is easy to operate and provides many quality control tools.



On-the-fly spectra alerts operator to changes in data quality

Trigger timing and gun energy bar graph shows missed shots and source problems

RMS bar graph alerts you when noise levels get excessive

Operator-defineable alarms warn of changes in system status or data quality

Real-time semblance analysis helps you optimize velocities for on-the-fly brute stack

Plots up to three separate common offset gathers in real time

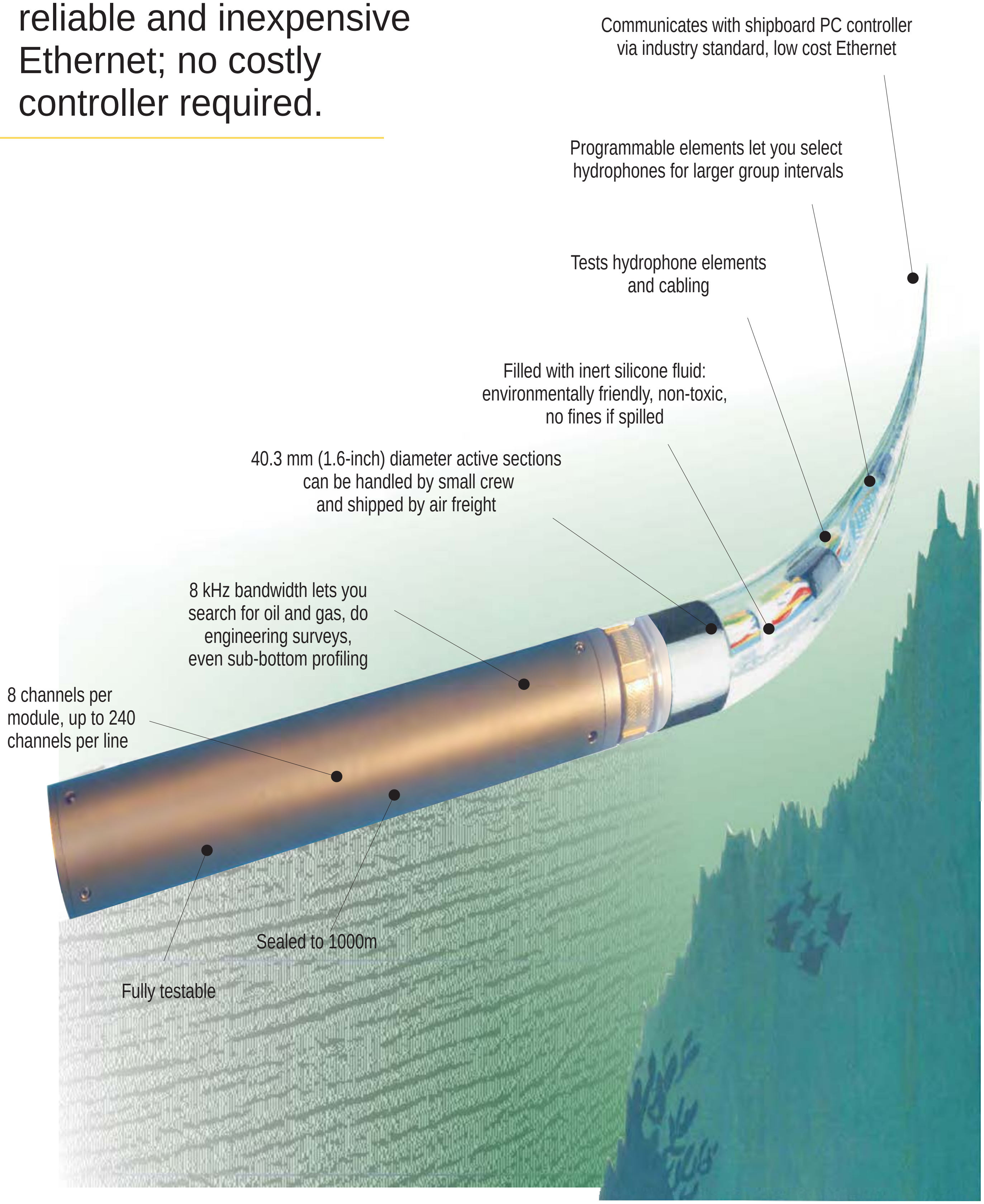
Multiple shot windows let you view different depths and offsets with varied scaling and filters

Real-time brute stack lets you see your data in near-final form

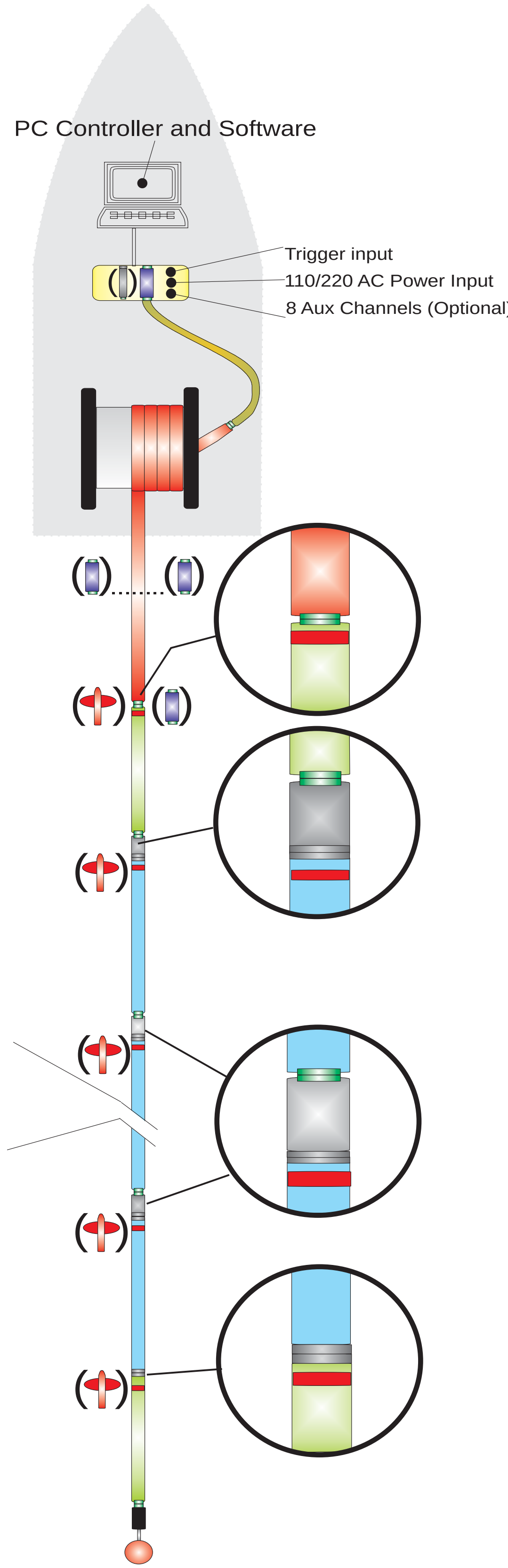
Detailed observer's log is kept with GPS location, parameter changes, exceeded thresholds and errors

Robust storage management writes multiple disk and tape files simultaneously, buffers data if any media fails or goes off line. Switches automatically between devices

In-water A/D modules communicate via reliable and inexpensive Ethernet; no costly controller required.



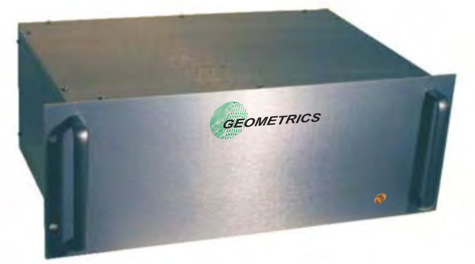
Flexible configuration is easily expandable.



Components:

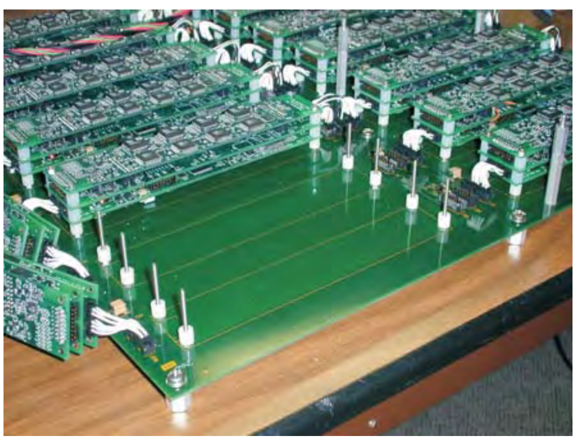
- Streamer Power Supply Unit (SPSU)
- Deck Cable
- Tow Cable
- Repeater Module
- Stretch Section
- A/D Digitizer Module
- Bird
- 8-channel Active Section
- Digital Connector Pair
- Analog/Digital Combo Connector Pair
- Bird Coil
- Tail Swivel
- Tail Buoy
- ( ) Optional

GeoEel Analog Streamer ‘Convertible’ Configuration



Are your analog sections still functional? Need a new on-board seismic recorder but don’t want to buy old technology?

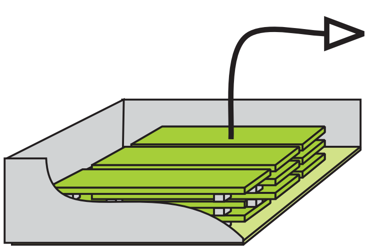
Still have a stock of analog sections with lots of life left in them? Not sure that it is time to make the move to a fully digital system? GeoEel digital electronics can be packaged in a rugged ‘convertible’ rack chassis with up to 120 channels plus 8 aux channels. Each rack mount chassis is controlled by its own Ethernet connection, ensuring fast cycle time and low dead time. The software and hardware functionality is identical to the full in-water digital configuration. Interface modules like charge-coupled amplifiers may be available for your system. Please contact the factory to discuss compatibility.



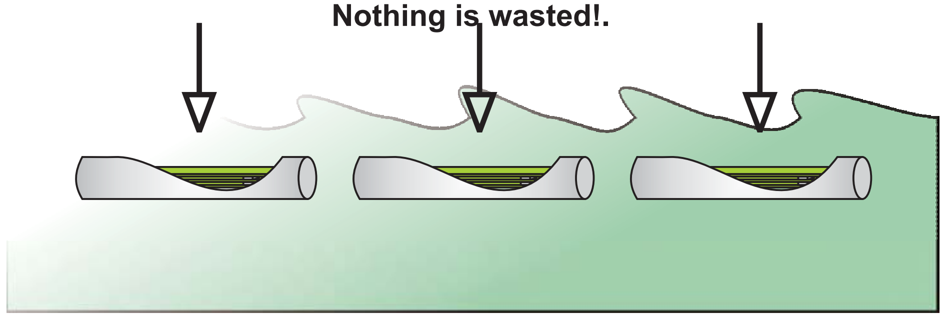
When you are ready to retire your analog system, the electronics can be reassembled in GeoEel waterproof canisters, ready to attach to your new digital hydrophone sections to make a complete, modern digital marine seismic system - at about ½ the price.

The GeoEel convertible is even fast enough to record continuously and synchonize to GPS, ideal for monitoring or multiple source configurations.

Use the GeoEel ‘Convertible’ with your existing analog streamer



When its time to replace your old analog sections, the GeoEel boards are redeployed in the waterproof canisters used in the in-water digital streamer Nothing is wasted!.



Specifications:

A/D Converter Modules

Number of channels per active section: 8
Sample Rates: 1/16 ms, 1/8 ms, 1/4 ms, 1/2 ms, 1 ms, 2 ms, 4 ms
Bandwidth: 5 Hz to 8 kHz
Programmable Gain: 0 dB, 6 dB, 18 dB, 30 dB, 42 dB
Maximum Input Range: ±2.25V
Resolution: 24 bits including sign
Dynamic Range: 120dB Typical @ 1ms, 70dB typical @ 1/16 ms
QC Tests: Leakage and capacitance of hydrophone elements, pulse, oscillator, timing.
Power Consumption: Approximately 100 mA at 48 VDC
Calibration Oscillator: 10 Hz to 2 kHz, 1 µV to 100 mV AC RMS
Dimensions: 44 mm diameter x 33 cm long (1.75" by 11"). 19.28" unbendable length when attached to active sections.
Weight: 900 grams (2.0 lbs)
Packaging Material: Titanium body
Connectors: Waterproof high density stainless steel, 41 pin digital and analog, 19 pin digital

Hydrophone Array

Active Section:
Number of Channels: 8 per section
Number of Sections: Array dependent, 12 for 96 channels
Hydrophones per group: User option, 16 typical at 12.5m
Hydrophone Type: Benthos RDA Geopoint, or Aq2000
Jacket Material: Clear polyurethane, 70 Duro, 3.18mm (1/8 inch) wall thickness
Outer Diameter: 40.3 mm (1.6 inches)
Ballast Fluid: Inert, non-polluting silicon oil, 100 cSt
Weight: ~135 kg (300 lbs) / 8 channels @12.5 meter group
Break Strength: over 2200 kg (5000 lbs), Vectran strain members
Maximum Tow Speed: ~8 knots recording, ~10 knots steaming, depending on configuration and sea state
Minimum Bend Radius: 75 cm (30 inches)
Compass/Bird Coil: IO Model 587, mounted at start of section

Stretch Section:
Length: 10, 25 or 50 meters standard
Outer Diameter: 40.3 mm (1.6 inches)
Compass/Bird Coil: I/O Model 587, mounted at start of section
Jacket Material: Clear polyurethane, 70 Duro, 3.18mm (1/8 inch) wall thickness
Ballast Fluid: Inert, non-polluting silicone oil, 100 cSt
Weight: ~ 67 Kg for 50 meter section
Break strength: over 2200 kg (5000 lbs), Vectran strain members

Tow Cable

Electrical conductors: 10 twisted pair shielded
Weight: Dependent on length, ~ 25 kg (55 lbs) for 50 meters
Strain member: Kevlar
Break strength over 2200 kg (5000 lbs)
Diameter: 20 mm

Streamer Power Supply Unit (SPSU):

Power Requirements: 115/230 VAC, 3/1.5 Amp max, 50/60 Hz
Voltage to Streamer: 36- 72 VDC
I/O Communications: 100Base TX Fast Ethernet, IEEE 802.3 compliant
Trigger Requirements: Isolated Input, Positive or Negative TTL, software selectable
Testing:
Cable leakage and resistance
Ethernet for faults and collisions
Optional Auxiliary Inputs: 8 analog channels with 24-bit resolution
Ethernet Connection: RJ-45
Trigger Connection: BNC

PC Based Controller System:

PC- based running Geometrics CNT-1 software. Multiple shot and gather windows, bar graph noise displays, windows for shot timing, gun energy, brute stack, tape status, spectral analysis. Sure-save software protects against data loss even with total storage device failure. Files automatically kept in sequential order. Auto-switching between storage device, dual tape writing. Supports multiple printers. Full log kept of all parameter changes. Integrates navigation, gun, bird parameters into SEG-D, SEG-Y or SEG-2 header.

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Appendix I-C:

Geopoint hydrophone (hydrophone in streamer)

GEOPOINT
HYDROPHONE

THE GEOPOINT HYDROPHONE represents the next generation of digital streamer hydrophones for the 21st century. With Total Harmonic Distortion levels of <-70 dB over a range of 0-250 Hz @ 1 millibar, an operating depth to 200 meters with zero sensitivity hysteresis, and a hermetic seal, the GeoPoint will allow you to take greater advantage of the latest 24 bit array electronics.

PERFORMANCE HIGHLIGHTS

- **Hermetic enclosure of PZT ceramic element**
- **Waterproof**
- **Small diameter**
- **Very low total harmonic distortion**
- **0.5 dB change in sensitivity with depths to 75 meters**

BENTHOS

SPECIFICATIONS

PHYSICAL

Materials: Tin plated, brass exterior shell. Glass to metal hermetic seal. Sensor element is lead zirconate titanate piezoelectric ceramic.

Weight in Air: 25 grams (.9 oz.).

Size: 1.69 cm dia. X 5.1 cm long (.66 in. dia. X 2 in. long).

Displacement: 11 cc (.67 in.^{3}) typical.

Temperature:

Operating: -10°C to 40°C (14°F to 104°F).

Storage: -50°C to 70°C (-58°F to 158°F).

ELECTRICAL

Leads: Two 26 AWG stranded conductors, PVC insulation, red and blue, 15 cm length.

Connector: None.

Polarity: A positive increase in acoustic pressure generates a positive voltage on the blue conductor.

Capacitance:[2] 16.0 nF ± 10% at 20°C and 1 kHz.

Resistance: 500 Mohm minimum across leads or to sea water at 20°C and 100% relative humidity, 50 VDC.

Dissipation: 0.02 typical.

Connection: Each customer is responsible for making a water-proof/pressure-proof seal to the red/blue wires to maintain the water-proof integrity of the GeoPoint Hydrophone.

PERFORMANCE

Sensitivity @ 10 Hz and 20 psi:

Free-field voltage:[2] -194 dB ± 1.5 dB re 1 V/µPa (20 V/Bar ± 3.5V).

Free-field charge:[2] -169.9 dB ± 2.0 dB re 1 nC/µPA (319.9 nC/Bar).

Sensitivity change:

vs. frequency: ± .5 dB from 1 Hz to 1000 Hz.

vs. depth: 0.5 dB (nominal) change to 75 meters. Zero hysteresis to 200 meters.

vs. temperature: < .03 dB per 1°C change.

Acceleration sensitivity: Output is < 1.0 mV/g due to acceleration in any of the three major axes at 20 Hz.

Distortion: < -70 dB THD using 67 Hz @ 1 millibar over a bandwidth of 250 Hz @ 20 PSI.

Mechanical resonance: 2.5 kHz (in water) typical.

Depth:

Max. operating: 200 meters (656 feet).

Max. survival:[3] 300 meters (984 feet).

The GeoPoint Hydrophone is completely waterproof.

1 Every hydrophone is tested for sensitivity, capacitance and insulation resistance at Benthos, Inc. to ensure the highest quality product.

2 Tolerances on electrical parameters are for reference only, and tighter tolerances are available upon request to meet specific requirements.

3 Exposure beyond maximum operating depths may cause permanent damage to the hydrophone.

ISO 9001 Certified

BENTHOS

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Specifications subject to change without notice (8/98).

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Appendix I-D:

Winch system - main data

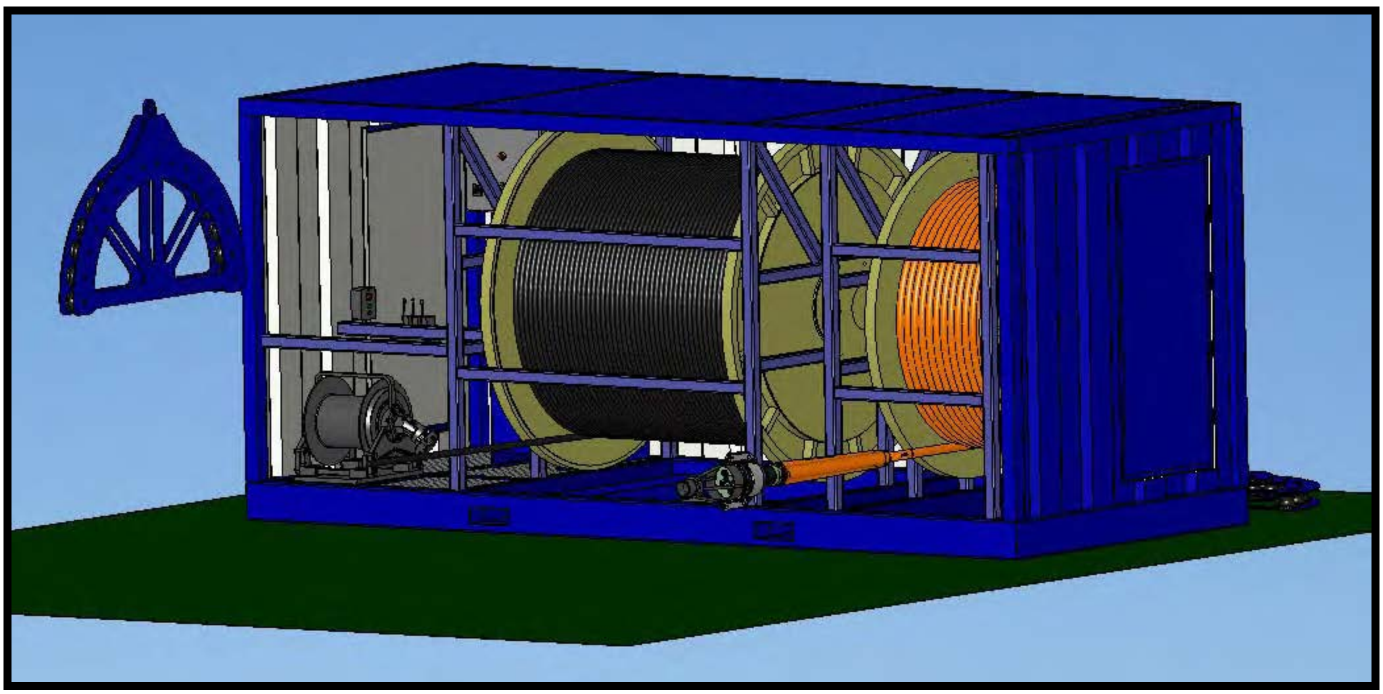
Main data

Scope of work is the design and manufacturing of Airgun termination including cable. See general arrangement drawing below.

A seismic system containerised into a 20ft container, with three off winches:

- 100 meter AGU (Air Gun Umbilical),
- 1200 meter of streamer. (streamer cable is not part of the scope)
- 70 meter of 18mm steel wire.

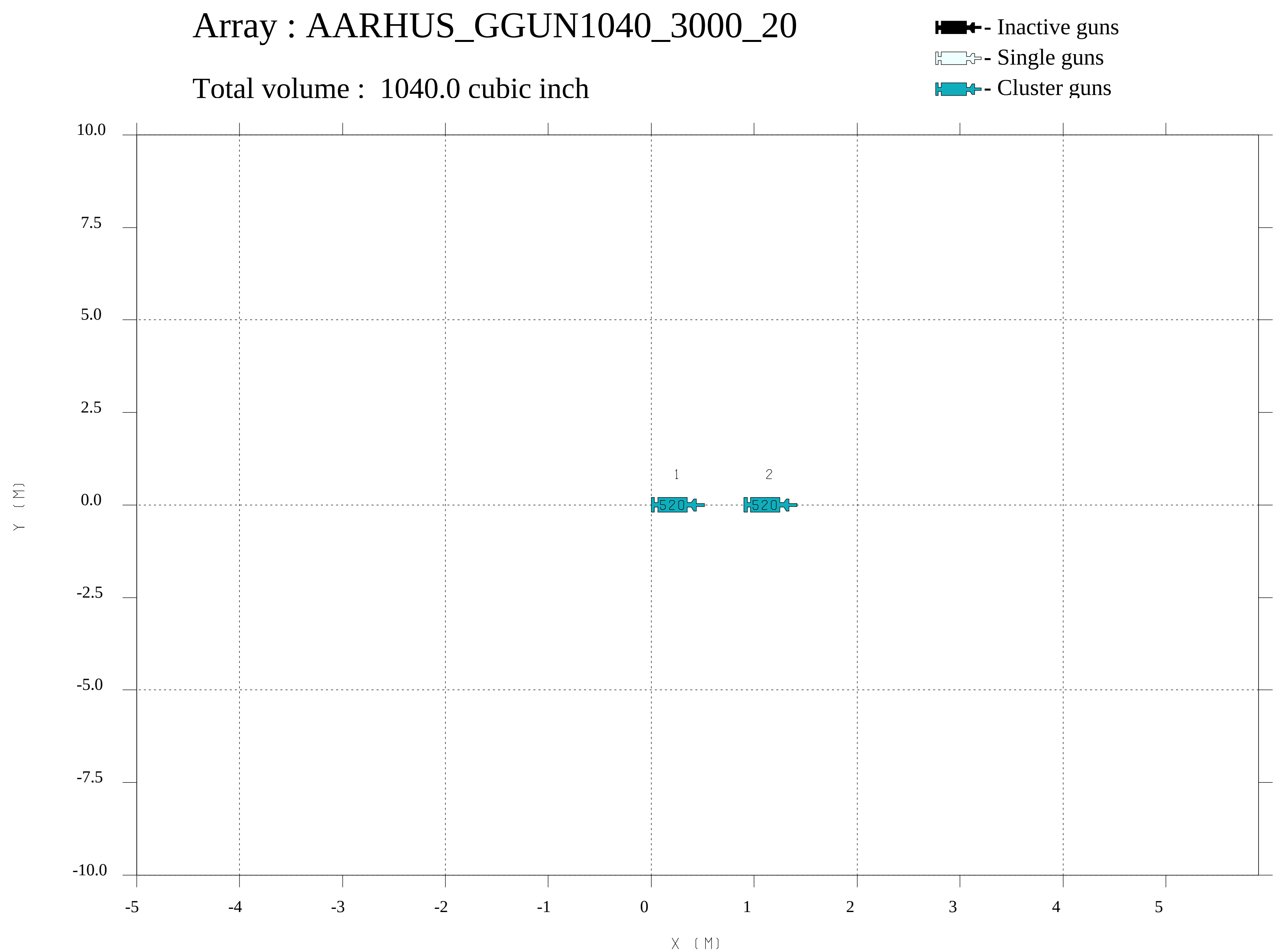
The system is designed for work in polar areas and hence the system is specifically optimized for ice impact in the water column during marine seismic activity.
System delivery includes the AGU cable, with terminations and interface for a durable air gun and streamer mechanical solution. The scope of supply also includes sheaves wheel for mounting in connection with the vessel A-Frame.



The Container is to be installed on the back deck of a vessel (e.g. Oden) and support the load of other equipment on top of the container. The winches are operated from the winch, via a sheave block mounted in connection with the vessel A-frame, over the stern of the vessel.

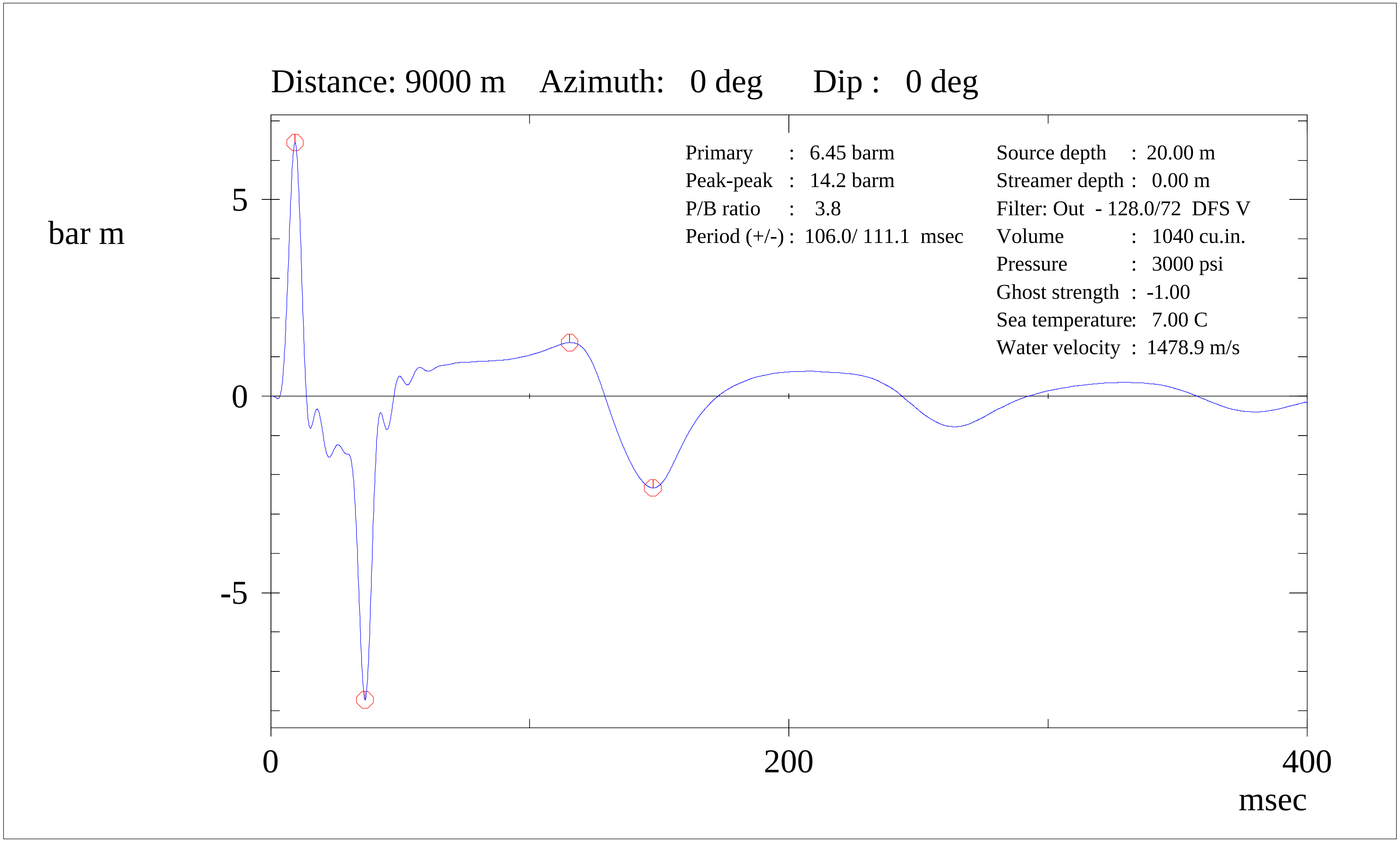
Appendix I-E

Air gun signature and spectrum @ 20 m

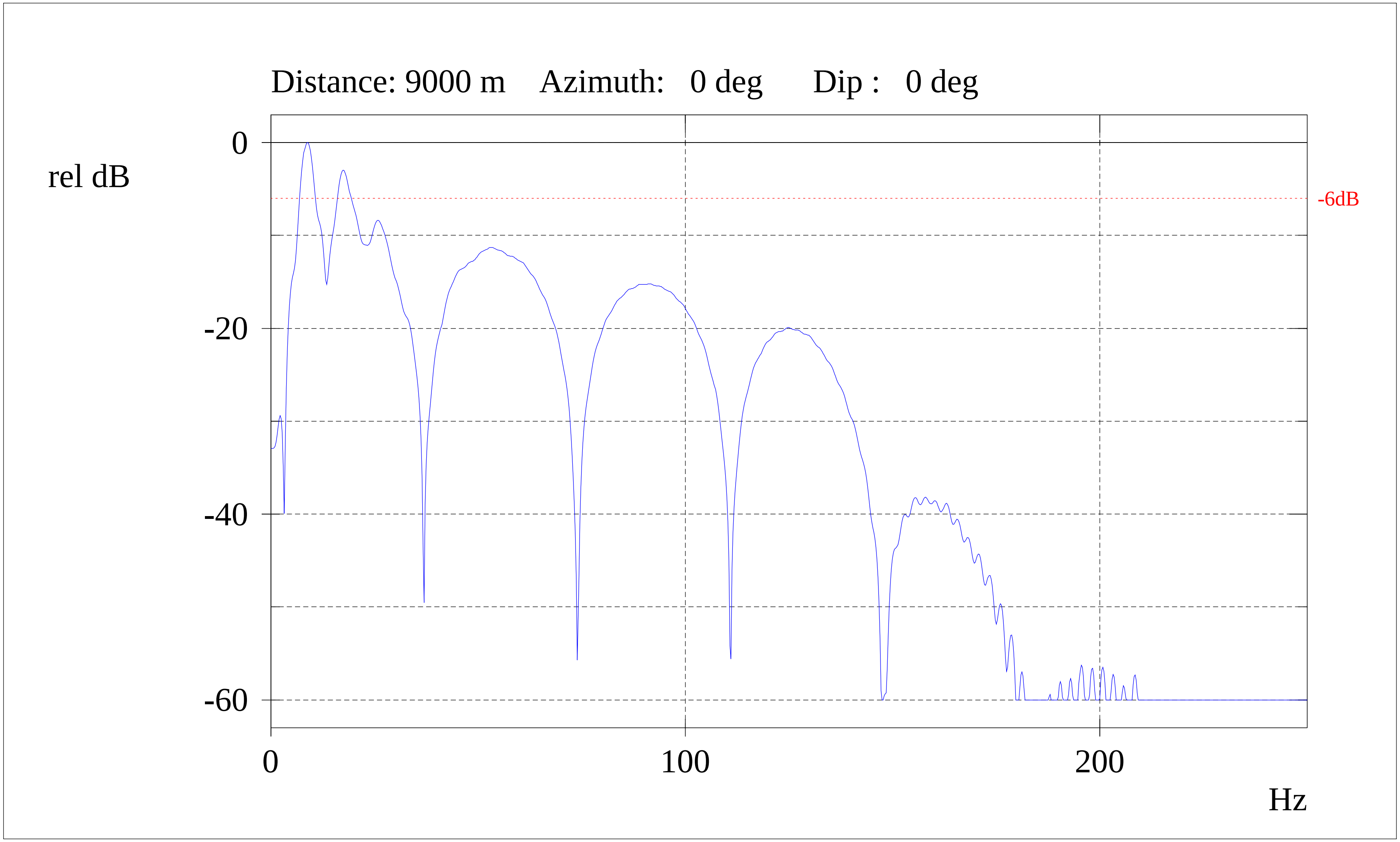


Array : AARHUS_GGUN1040_3000_20
Total volume : 1040.0 cubic inch
- Inactive guns
- Single guns
- Cluster guns
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
Y (M)
-5
-4
-3
-2
-1
0
1
2
3
4
5
X (M)
1
2
520
520

Farfield signature : AARHUS_GGUN1040_3000_20



Amplitude spectrum of farfield signature : AARHUS_GGUN1040_3000_20



Appendix I-F:

Marine sources from Sercel

Marine Sources

Sound science.
Reliable results.

Ahead of the Curve℠

Ahead of the Curve

Index

Marine sources

Sercel offers a wide range of powerful, reliable and compact sources to cover the entire range of surveys in any environment.

Our product line includes three separate families of guns allow the users to tune the source to their needs.

These widely used marine seismic sources were developed in the research and testing facilities of Sodera and Seismic Systems Inc., both well-known players in the marine seismic source industry with more than 30 years of design and manufacturing expertise.

Both companies - and their products - are now part of the Sercel organization. We’re proud to offer our customers the latest in air and Watergun technology.

THE G. GUN

The G. GUN is easy-to-use and reliable, proven in applications all over the globe. Its compact size, strong performance and easy adaptability make it perfect for marine seismic acquisitions, crustal studies and VSP surveys.

Special features include:

- Wide range of volumes. Each gun can easily change from 25 in^3 to 150 in^3 by means of inexpensive plastic inserts called "Volume Reducers," then from 150 in^3 to 520 in^3 by changing the external body, thus retaining the same simple mechanism for the entire range.
- More power from a single gun. The G. GUN is designed to operate continuously at up to 3,000 psi (210 bars).
- High degree of repeatability. Over years of field use, the main pulse has proven steady within ± 0.30 ms.
- Inexpensive and easy to maintain.
- Safer to handle. The G. GUN can be deployed and retrieved without any air pressure.

Two main remarks can be made about the above unique features:

- The same G. GUN mechanism can be used to build any array. Since only one kind of spare has to be stored, maintenance of the array is highly simplified.
- When the air pressure is increased from 2,000 to 3,000 psi for the same gun volume, the peak-to-peak output increases by 27% while the low frequency content of the spectrum is boosted by more than 6 dB.

Higher pressure can be used to increase the array output without changing the array configuration or increasing the number of guns.

The GI GUN

Sercel developed the GI GUN to reduce or suppress the bubble oscillations of a single air gun.

When the bubble created by the air gun reaches its maximum volume, air is injected. Depending on the characteristics of the injection, the buble oscillations can be reshaped and reduced, or totally suppressed.

A GI GUN comprises:

- One Generator to generate the acoustic pulse;
- and one Injector to reduce / suppress the bubble oscillations created by the Generator.

The volume of the Generator can be easily changed from 25 in^3 to 250 in^3, and the Injector from 25 in^3 to 105 in^3.

Working pressure is up to 3,000 psi (210 bars).

The GI GUN is used in a wide range of applications. For example:

- One single unit - hazard surveys and high-resolution surveys.
- Small arrays of 1 to 6 GI GUN - shallow water and transition zones, arctic and antarctic surveys.
- Large arrays of 14 to 20 GI GUN - conventional and 3D deep seismic surveys.
- VSP and walkaway VSP.

The GI GUN arrays are also used:

- To generate shear waves in marine surveys;
- and for crustal studies (Monobulle Technique).

The Watergun

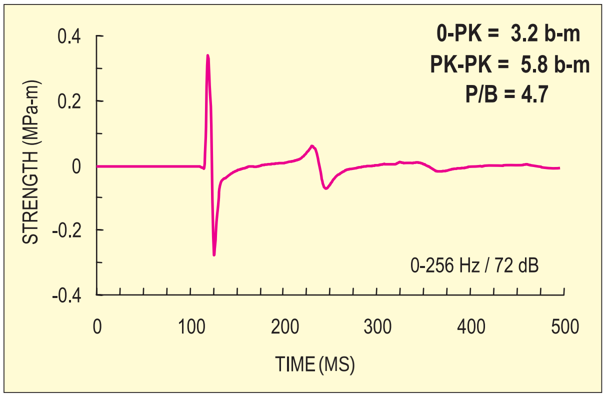
The S15 Watergun is capable of delivering a high-frequency, bubble-free acoustic pulse perfectly suitable for very high resolution applications. Compressed air is used to propel a water jet, which creates a vacuum cavity. When the vacuum cavity implodes from the surrounding hydrostatic pressure, it emits a strong bubble-free, high-frequency signal.

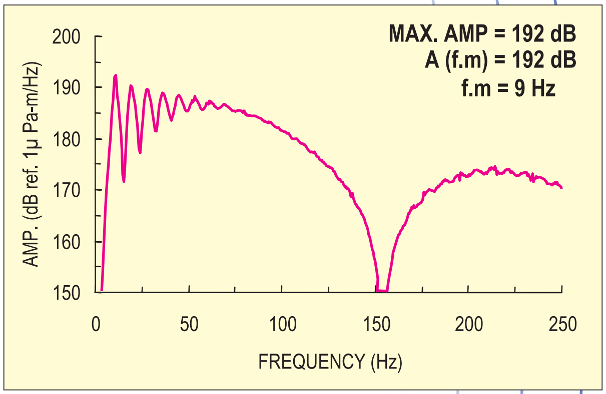
G. GUN 250

Just by changing the gun casing, any G. GUN can be easily retrofitted to 250 in^3. Therefore, the same simple mechanism can be used on all G. GUN from 25 in^3 up to 250 in^3, retaining its one-of-a-kind, field-proven repeatability and reliability.

Both the peak-to-peak output and the low frequency content of the spectrum of a given air gun array, can be increased without changing the general configuration of the array or its handling / towing arrangement.

FAR FIELD SIGNATURE AND SPECTRUM





1 * G. GUN 250 in^3
Pressure = 2,000 psi
Depth = 5.0 m

Specifications

Physical G. GUN 250

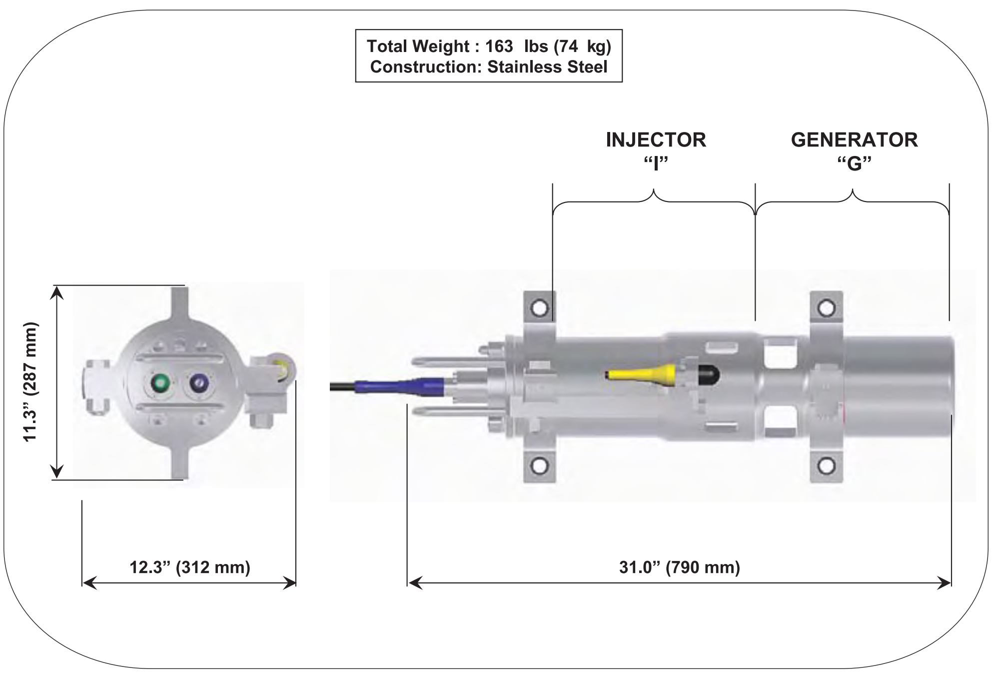
- Weight : 65 kg (143 lbs.)
- Length : 597 mm (23.5 in.)
- Width : 292 mm (11.5 in.)
- Diameter : 287 mm (11.3 in.)

GI GUN

The GI GUN is a pneumatic seismic source, made up of two independent air guns within the same casing, used to control and reduce bubble oscillations. The first air gun is called the Generator, as it generates the primary pulse and creates the bubbles. The second one is called the Injector, as it injects air inside the bubble.

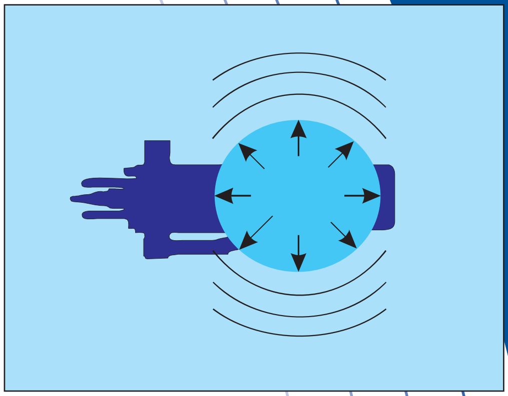
Each gun has its own reservoir, its own shuttle, its own set of exhaust ports, and its own solenoid valve.

A common hydrophone provides both the time break and the shape of the near field signal. This gun phone is located inside the bubble and responds to the actual air blast of the GI GUN, without being affected by the neighboring guns.

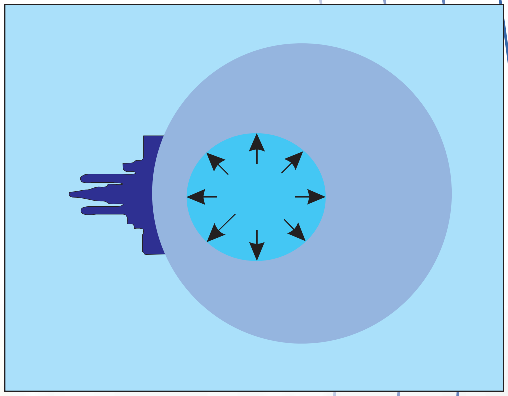


HOW IT WORKS

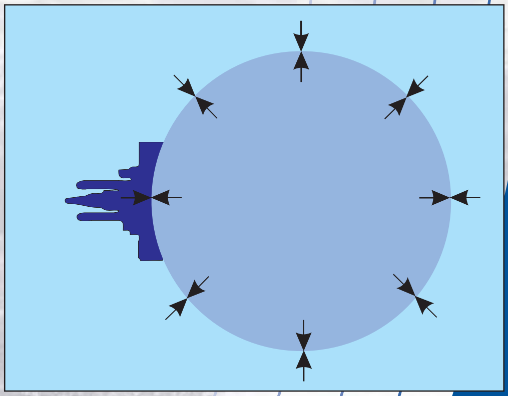
Phase 1 :
The Generator ("g") is fired. The blast of compressed air produces the primary pulse and the bubble starts to expand.



Phase 2 :
When the bubble approaches its maximum size, it encompasses the Injector ports, and its internal pressure is far below the outside hydrostatic pressure. At this time, the Injector ("I") is fired, injecting air directly inside the bubble. Due to the quasi-static state of the bubble, the timing of the Injector is not critical.



Phase 3 :
The volume of air released by the Injector increases the internal pressure of the bubble, and prevents its violent collapse. The oscillations of the bubble and the resulting secondary pressure pulses are reduced and re-shaped.



The signature of a single GI GUN can be shaped virtually at will by adjusting:

- The volume of the Generator from 25 to 250 in^3. This is achieved by means of plastic volume reducers for volumes ranging from 25 to 105 in^3, and by changing the reservoir for volumes 150 and 250 in^3.
- The volume of the Injector from 25 to 105 in^3. This is achieved by means of plastic volume reducers.
- The time when the injection starts. This adjustment is conveniently done at the instrument room.
- The duration of the injection by means of exhaust ports reducers.

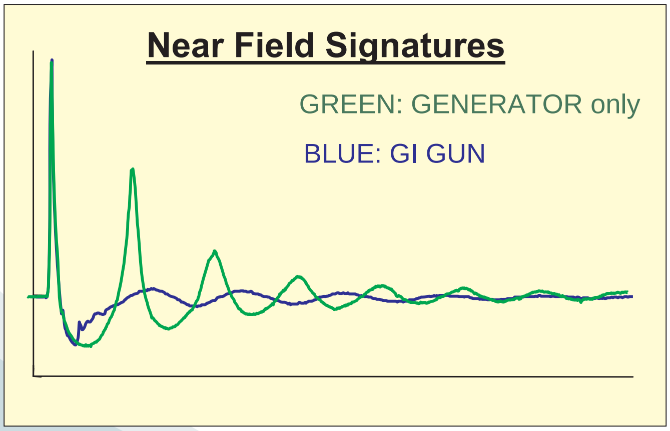
The figures below show how the near field signature and spectrum of the Generator alone (green line) is re-shaped by an optimally tuned injection (blue line). This type of setting is called "true GI mode" and results in an almost total bubble suppression of the bubble oscillation.

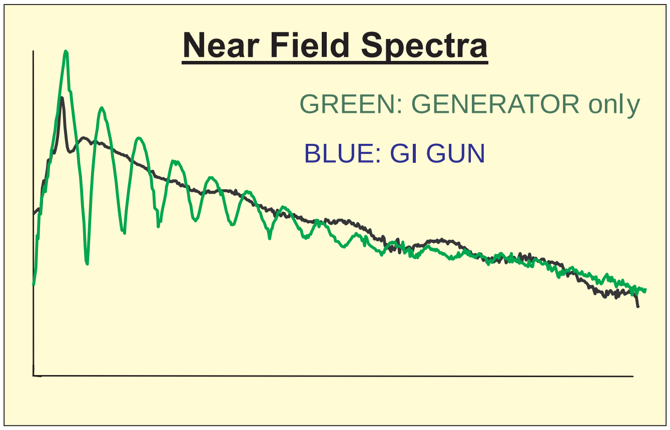
VERSATILITY

While the G. GUN is totally interchangeable with existing air guns in an air gun array, it can also transform easily into a GI GUN.

The shuttle assembly is the same on the G. GUN as on the GI GUN. Overall, the G. GUN and the GI GUN share 90 percent of their components. For instance, starting from two G. GUN, it is possible to build one GI GUN within minutes. The GI kit needed to transform the two G. GUN into one GI GUN includes only six parts specific to the GI GUN.

Near Field signatures and spectra comparison
(Green line : Generator alone - Blue line : true GI mode)





The graphs below illustrate the Far Field signatures generated by two different GI GUN configurations using the same volume of air (150 in^3), compared to the signature of an air gun of the same volume.

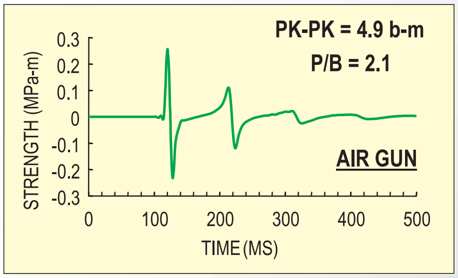
Left (a) : Typical signature of an air gun with a volume of 150 in^3. The peak-to-peak output is maximum, but the primary-to-bubble ratio is poor.

Middle (b) : Signature generated by a single GI GUN where the Generator and the Injector have the same volume (75 in^3), and the firing of the Injector has been delayed from the firing of the Generator by approximately half the period of the Generator fired alone. This configuration is called: "HARMONIC MODE." Compared to the air gun, the peak-to-peak output has been reduced by 24 percent, but the primary-to-bubble ratio has been multiplied by four.

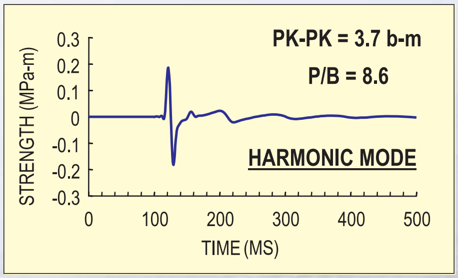
Right (c) : Signature generated by a single GI GUN used in the "true GI mode." The Generator has a volume of 45 in^3 and the Injector has a volume of 105 in^3. Here too, the firing of the Injector has been delayed by about half the time of the Generator fired alone.

Compared to the air gun, the peak-to-peak output has been reduced by 40 percent, but the primary-to-bubble ratio has been multiplied by nearly seven, thus reaching almost 14 with one single gun.

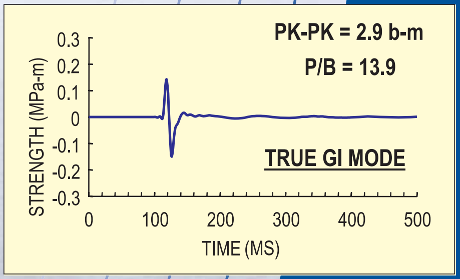
a) AIR GUN
Volume = 150 in^3



b) GI GUN "HARMONIC MODE"
Generator = 75 in^3
Injector = 75 in^3 - Delayed



c) GI GUN "TRUE GI MODE"
Generator = 45 in^3
Injector = 105 in^3 - Delayed



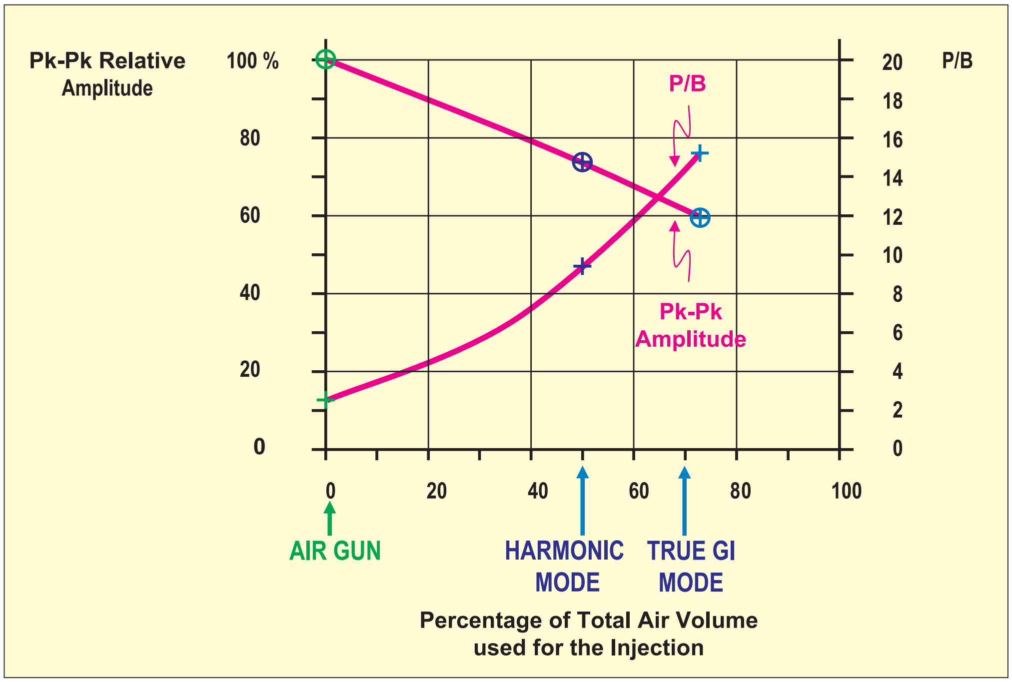
FAR FIELD SIGNATURE COMPARISON WITH SAME TOTAL VOLUME (150 in^3)
Pressure = 2,000 psi - Depth = 6.0 m - Filtered DFS 0 -256 Hz 72 dB/o

The following figure, demonstrates the variations of both the peak-to-peak output and the primary-to-bubble ratio when the percentage of the total volume used for the injection increases (the total volume being constant - 150 in^3).

The peak-to-peak amplitude is plotted as a percentage of its maximum value, when all the air is used in the Generator and no injection is made (air gun). The results given in the previous pages are plotted on the curve.

Again, the results have been obtained using a single GI GUN, and demonstrate the great flexibility (versatility) of the GI GUN, allowing the user to select the characteristics of the signature without having to change the source.

Variations of peak-to-peak
relative amplitude and P/B ratio versus
the percentage of total volume used for the injection



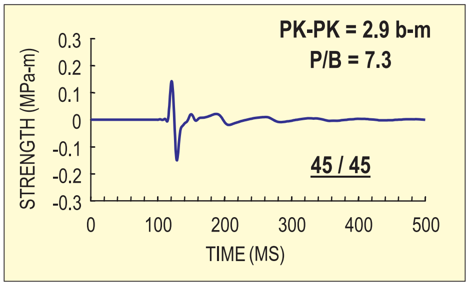
When the Injector has about the same volume as the Generator, the oscillation of the bubble created:

- is re-shaped into a smooth quasi-harmonic oscillation;
- its amplitude is reduced, and the primary-to-bubble increases between seven and 10 or more.

Below are three different harmonic mode far field signatures from a single GI GUN using three different volumes: 90 in³, 150 in³ and 210 in³.

GI GUN HARMONIC MODE - 3 BASIC VOLUMES

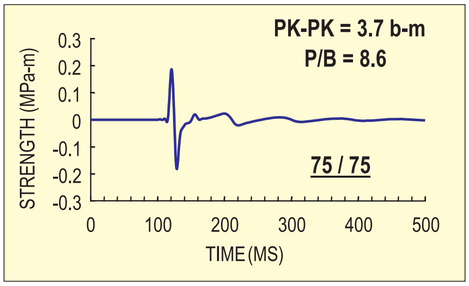
Pressure = 2,000 psi - Depth = 6.0 m - Filtered DFS 0-256 Hz 72 dB/o



GI GUN 90 **in³**

G = 45 **in³**

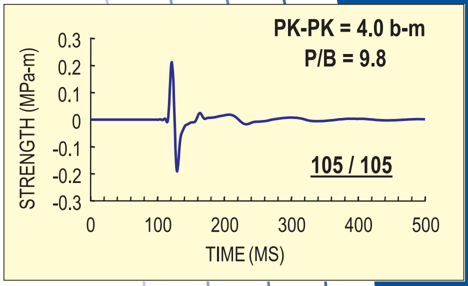
I = 45 **in³** - Delayed



GI GUN 150 **in³**

G = 75 **in³**

I = 75 **in³** - Delayed



GI GUN 210 **in³**

G = 105 **in³**

I = 105 **in³** - Delayed

The signature of a single GI GUN in harmonic mode is similar to the signature generated by a two air gun cluster, so that two independent and identical GI GUN compare favorably with a two air gun cluster of the same total volume.

For instance, a two air gun cluster with a total volume of 300 in³ (2 * 150 in³) gives an output peak-to-peak (DFS 0-128 Hz) = 6.9 bar-meter and a primary-to-bubble ratio of 7.7. While two independent GI GUN in harmonic mode, 150 in³ each, give an output peak-to-peak (DFS 0-128 Hz) = 7.4 bar-meter and a primary-to-bubble ratio of 8.6.

But, unlike the air gun cluster, the signature produced by the two GI GUN, is not sensitive to its separation or actual firing depths, so that in operation, the signature stability is far better.

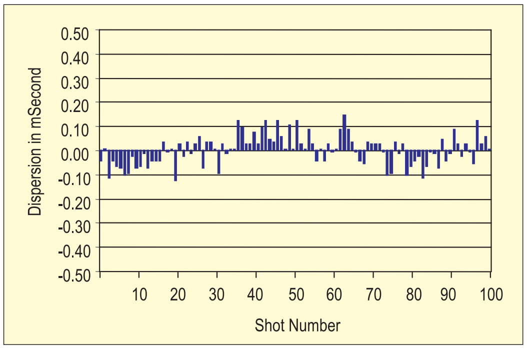
In addition, the smooth harmonic oscillation allows a sub-array of just two GI GUN with different volumes, so that the primaries add up. And, the final oscillation is further reduced by destructive interference and therefore, the primary-to-bubble ratio can reach a value of 14 with only two guns. This can be seen when adding the signature of one GI GUN 90 in³ (left) with the signature of one GI GUN 210 in³ (right). This leads to a two GI GUN 300 in³ sub-array that will be described next, and that could be the building block for larger, more powerful arrays.

REPEATABILITY

The figure below shows the timing dispersion of 100 consecutive shots emitted by the Generator of the GI GUN with a volume of 45 in^3, recorded through a near field hydrophone located one meter below the gun.

- The dispersion of ± 0.14 ms has been confirmed in operation involving a large number of guns

- Repeatability on Generator 45 in^3 of GI GUN - 100 SHOTS



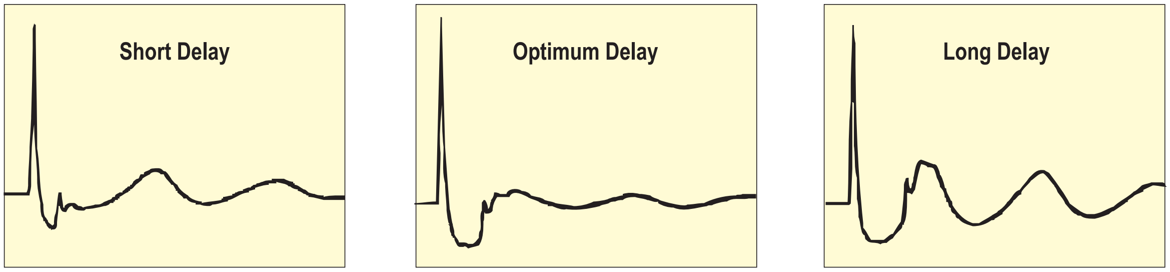
SIGNATURE QC

A time break hydrophone mounted on the GI GUN and located inside the bubble (as soon as the Generator has been fired), displays the signature of the GI GUN without being influenced by the neighboring gun.

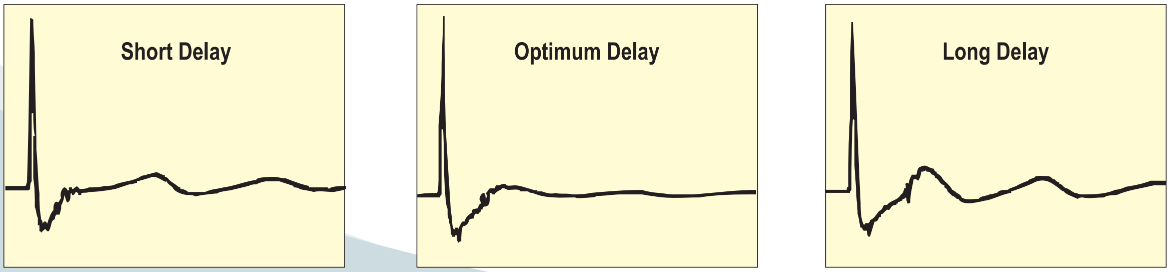
The graphs below compare the signals given by a near field hydrophone (top) with the signals given by the time break hydrophone (TB) located inside the bubble (bottom), for three different delays between the Generator and the Injector.

As illustrated, the shapes of the signals given by both hydrophones are similar and the optimized tuning of the gun can be achieved using the time break signal, which can be used also for the signature QC emitted by each individual gun at every shot.

Near Field Hydrophone



Time Break Hydrophone



Specifications

Physical GI GUN 210

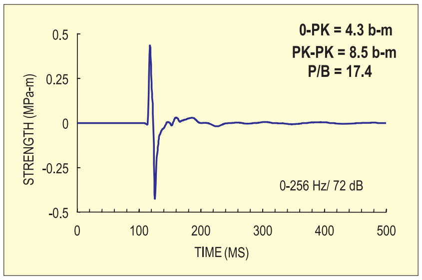
- Weight : 74 kg (163 lbs.)
- Length : 790 mm (31.0 in.)
- Width : 312 mm (12.3 in.)

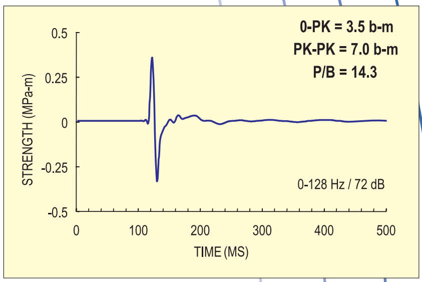
FAR FIELD SIGNATURE AND SPECTRUM

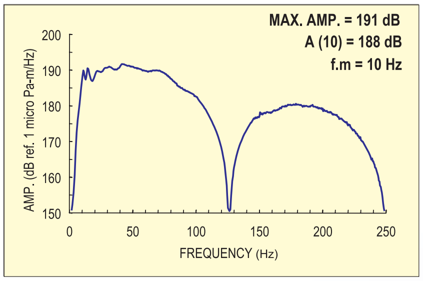
2 * GI GUN 300 in^3 Sub-Array

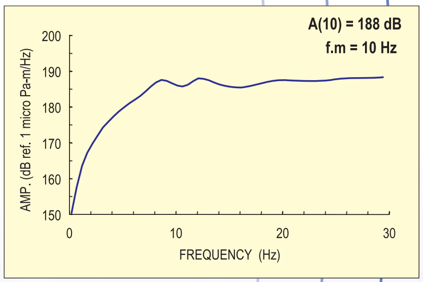
(G45 / I45) + (G105 / I105)

Pressure = 2,000 psi; Depth = 6.0 m







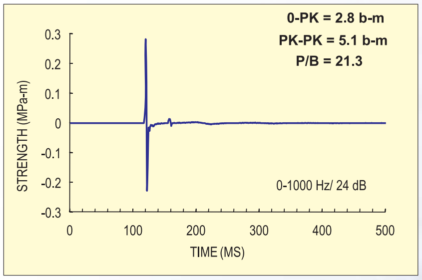


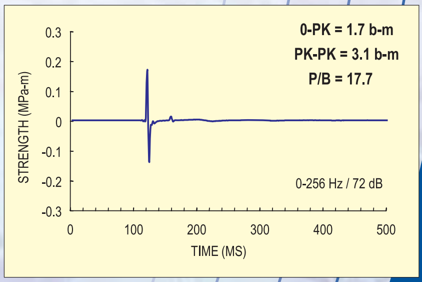
FAR FIELD SIGNATURE AND SPECTRUM

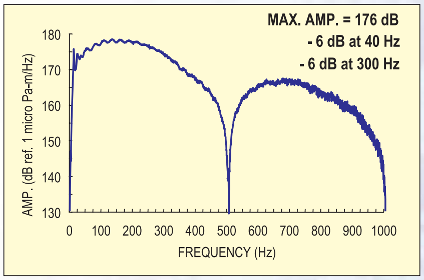
1 * GI GUN / 90 in^3 High Frequency

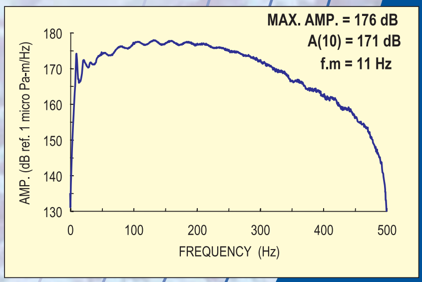
(G45 / I45)

Pressure = 2,000 psi; Depth = 1.5 mm









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www.sercel.com

Ahead of the Curve[SM]

Appendix I-G:

Cold weather operation (Sercel - LC605 gun)

7. - COLD WEATHER OPERATION

When working under freezing conditions, we strongly advise to inject an antifreeze liquid into the compressed air.

We recommend air de-icant "NO TOX 2" from **TANNER SYSTEMS *.**

The quantity of liquid to be injected depends upon numerous parameters.

Previous operations lead to the average of :

- 4 in^3 / hour per 100 SCFM

or

- 40 cm^3 / hour per 100 Nm^3/h

*** TANNER SYSTEMS INC**.
1660 East HIGHWAY 23
ST CLOUD MN 56304 - (U.S.A.)
Tel : 612 252 6454
Fax : 612 252 3001

EXAMPLE OF PUMP :

- **SIGMA CHEMICAL INJECTION PUMP 32 CP 30.**

From :
SIGMA ENTERPRISES INC.
1681 South BROADWAY
CARROLTON TEXAS 75006 - (U.S.A.)
Tel : 214 446 8250
Fax : 214 446 8642

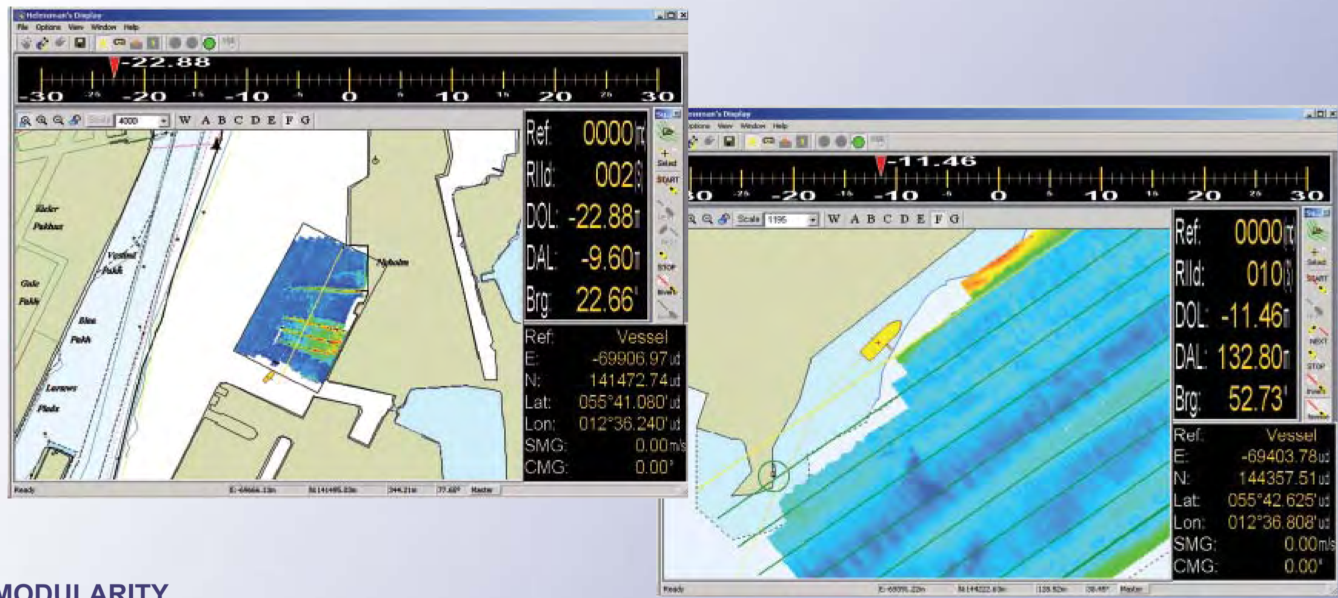
Appendix I-H:

NaviPac - Integrated Navigation Software

NaviPac

Integrated Navigation Software

APPLICATIONS
The NaviPac software utilises integrated navigation and data acquisition software suited for all marine navigation and survey applications.



MODULARITY
NaviPac provides complete modularity through use of the multi tasking, multi threading and networking capabilities of the Windows 2000/XP operating system. The software is highly exible and user con gurable and the user interface adhere to the Microsoft Interface Guidelines making it very intuitive and easy to operate.

NAVIGATION SET-UP
The NaviPac set-up module provides easy selection of geodetic parameters, navigation systems, devices, offsets and port settings.

DEVICE I/O DRIVERS
A vast number of eld-tested device I/O drivers are provided as standard and generic I/O drivers allow user de nition of device I/O drivers. Data is interfaced via RS232, LAN/WLAN or via digital I/O interface. Device I/O drivers for multibeam echosounders, multibeam side scan backscatters, pipe- trackers, scanning and pro ling sonars, etc. are provided in the NaviScan software.

TIME SYNCHRONIZATION
Time stamping of sensor data, incoming as well as outgoing, can be done in two ways, either by the internal computer clock or by the PPS output available from most GPS receivers. Using the PPS output data are synchronized relative to the GPS/UTC time frame resulting in an accuracy of a few milliseconds.

DISTRIBUTED TIMETAGGING
Using the special designed TimeBox NaviPac (and NaviScan) utilises distributed time tagging based on one or more Linux based RT collection boxes that handles interfaces and deliver timed data to any LAN connected clients.

SURVEY PLANNING
Survey planning is done by de ning the survey area and the survey lines. A variety of methods for creation of survey lines is provided, e.g. by click-and-drag (of mouse/trackball), input of survey line coordinates, offset (parallel) survey lines, cross lines, circles, arcs, barge-lines, star patterns etc. Survey lines can easily be adapted to t a de ned survey area. Creation of templates allows input of other data formats.

DISPLAYS
The Navigation Display graphically presents the real-time absolute and relative positions of selected survey objects and cartographic features. The Helmsman Display provides off-track and along-track information, planned and actual x locations, in a fully con gurable graphic format. Total scenario management is available through the use of job and project les.

ELECTRONIC CHARTS

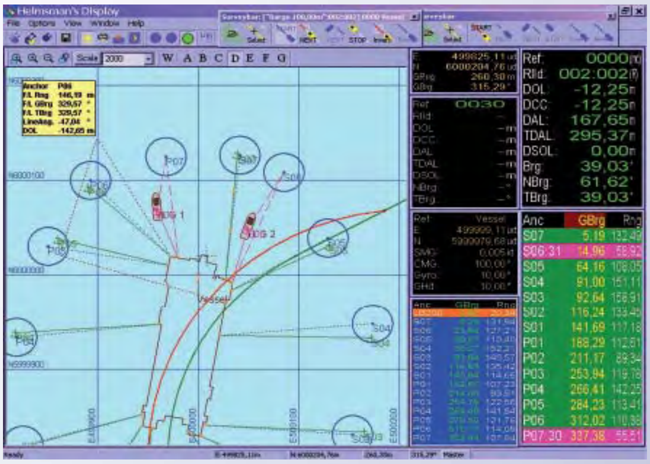
Vessel positions, survey lines (on DXF, DWG and ASCII formats) and objects may be displayed superimposed on C-Map or S57 based electronic chart displays. Coverage of depth information from singlebeam and/or multibeam echosounder as well as DTM's generated on-the-fly can be presented on the Navigation Display through interface with the NaviScan software.

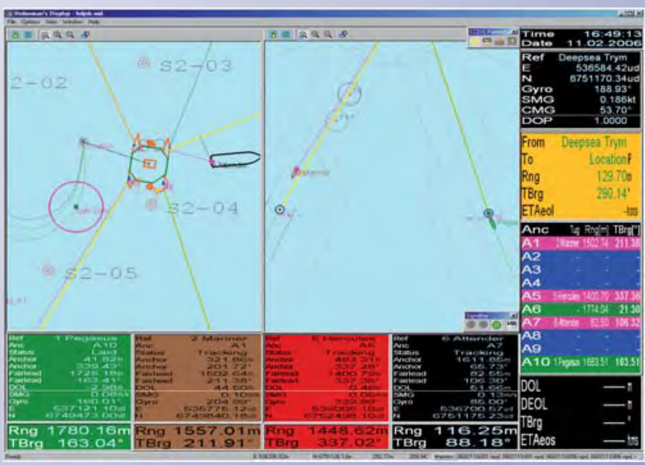
DATA HANDLING

NaviPac provides a systemised way of managing and storing survey data. Records are saved to a project directory allowing you to set up new surveys or to quickly switch to an existing survey. During data logging records can be limited in time or file size defined by the user.

CLIENT/SERVER SYSTEM

NaviPac builds on a client/server solution, which allows execution of all software modules (including a/o Helmsman's display, LogData and several graphical QC displays) on any Personal Computer on the network.





WINDOWS DISPLAYS

Full system flexibility allows designing and configuration of surveys and preferred display settings and layouts. An unlimited number of displays can be opened, one of each type or several of the same type. Displays can be freely distributed to monitors working as slaves or to intelligent workstations for individual windows set-up and interactive use.

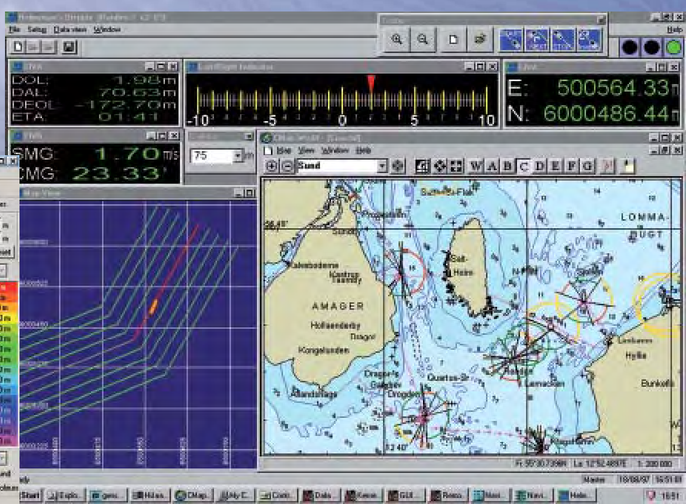
NAVIPAC LITE

Provides an affordable entry-level software package for on-line navigation. NaviPac Lite features same functionality as the NaviPac full version, except that the Lite version is limited in the numbers of device I/O drivers. Additional device I/O drivers can be added for gradual update to a partial or full version of the NaviPac software.

OPTIONAL MODULES

Optional software modules are available for NaviPac comprising a/o:

- Barge/Tug Management System(TMS)
- Rig Moves and Rig Crawl
- Cable and Flexible Pipe Lay
- Template Tracking



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Appendix I-I:

Thales DG16 GPS receiver

DG16 and DG14 Receivers

THE STANDARD IN ADVANCED HIGH-PRECISION OEM GPS TECHNOLOGY

Single Board Solution

The DG16™ from Thales is a low cost, new generation, sub-meter GPS+Beacon+SBAS receiver. DG16 is the perfect single board solution for high-end integration. It incorporates free of charge signals from Satellite Based Augmentation Systems (SBAS), such as WAAS, EGNOS & MSAS, and an embedded beacon receiver to provide sub-meter differential positioning.

The DG16 is a 16-channel receiver with 12 GPS L1 code and carrier channels, two SBAS channels and two DGPS beacon channels. The two SBAS channels can be configured as two additional GPS channels offering a total of 14 GPS channels. DG16 can provide up to 20 Hz precise three-dimensional position and raw data for real-time guidance and navigation. DG16 also incorporates our Integrated Differential Optimization™ techniques for using multiple sources of corrections and can output SBAS ranging, ephemeris and differential corrections as well as beacon corrections through the serial port. While DG16 offers three standard RS232 ports, it is capable of single port operation; one serial port can do it all. In additon, DG16 comes standard with User Defined Messages (UDM) software, a feature that enables the user to create custom messages.

DG16 has better signal tracking and offers Edge™ and Strobe Correlator™ technologies for multipath mitigation and better accuracy in shady environment. DG16 incorporates Receiver Autonomous Integrity Monitoring (RAIM) that allows the receiver to detect and correct errors in the satellite signals. In addition, the DG16 features Horizontal Protection Level (HPL) output for aviation applications such as Automatic Dependent Surveillance Broadcast (ADS-B) stations. DG16 consumes less power than its predecessor G12™ and can be programmed for low power/sleep mode operation. It also features improved in-band and out-of-band interference rejection capabilities. For best performance, DG16 can be configured to use a Kalman filter with adaptive dynamic mode or user can select dynamic modes such as walking, ship, aircraft, etc. to match the operating conditions.

DG14 Receiver

The DG14™ from Thales is a 14-Channel receiver with 12 GPS L1 Code and carrier channels and 2 SBAS channels. While the DG14 is identical to the DG16 in performance, it does not have an on-board beacon receiver. All Other features are common to both DG16 and DG14 receivers. The DG14 receiver is also available with altitude and speed limits removed (International Traffic in Arms Regulations apply) for High Dynamics and Missile Applications (HDMA).

Compatibility

DG16 and DG14 from Thales are backward compatible with G12 in both hardware and software. They both have the same RF connector and the same 30-pin connector location and pin-out as the G12. They also use the same standard Thales serial interface, allowing for easy and smooth upgrades.

DG16 and DG14 Receivers

Multipath Mitigation

Multipath is the single largest cause of differential GPS position errors. The Strobe Correlator (patent pending) is a digital signal processing technique implemented in the hardware and software of the DG16 and DG14 receivers that removes multipath errors almost entirely for reflected signals with delays of 37 m or more. This represents the best DGPS multipath mitigation available today in GPS receivers — and it is available standard with the DG16 and DG14. This means improved accuracy and greater reliability.

Evaluation Software

Evaluate™ software is available with the DG16 and provides visual displays of satellite information (e.g., SNR), receiver position and velocity as well as data logging and analysis. It also allows direct communication with the receiver. Compatible with all of our receivers, the software runs on Windows® version 3.x Windows 95/98, NT, 2000, and XP platforms.

TECHNICAL SPECIFICATIONS

Real-Time Position Accuracy[1]

Autonomous
- CEP: 3.0 m (9.843 ft)
- 95%: 5.0 m (16.4 ft)

Differential[2]

Local Base Station
- CEP: 40 cm (1.31 ft)
- 95%: 90 cm (2.95 ft)

Beacon
- CEP: 70 cm (2.30 ft)
- 95%: 1.6 m (5.25 ft)

SBAS
- CEP: 1.0 m (3.28 ft)
- 95%: 3.0 m (9.84 ft)

Velocity Accuracy[1] (knots)

0.1 (95%)

Time To First Fix[1]

Re-acquisition	3 sec
Hot start	11 sec
Warm start	35 sec
Cold start	90 sec

DG16/DG14 Features

- 14 Channels
  12 GPS code and carrier
  2 SBAS (WAAS/EGNOS/MSAS)
- Standard NMEA-0183 V3.0 output
- Selectable position and raw data rates up to 20Hz
- Position latency output
- Raw data output (code and carrier)

- 1 PPS (5V TTL)
  Precision: 200 ns (stand-alone)
  50 ns (differential)
- Edge and Strobe Correlator
- Differential base and remote RTCM V2.3, message types 1,2,3,6,9,16, 18, 19
- 20 g tracking capability
- Kalman filter
- Event marker
- Session programming
- Integrated Differential Optimization
- Multi-base Differential with WADGPS (optional)
- Low power sleep mode
- Wide array of coordinate transformation options
- 3 bi-directional RS-232 serial ports, up to 115,000 bps
- External LED drivers
- On-board 2 Channel Beacon Receiver (DG16 Only)
- User Defined Messages (UDM)
- Receiver Autonomous Integrity Monitoring (RAIM)
- Horizontal Protection Level (HPL) Output
- Speed (max)[2]: 514 m/sec (1,000 knots)
- Altitude (max)[2]: 18287 m (60,000 feet)

Environmental & Physical

- Operating Temp: –30°C to +70°C
  (-22°F to 158°F)
- Storage Temp: –40°C to +85°C
  (-40°F to 185°F)
- Power Consumption: 1.2 W (GPS only)
  1.6 W (GPS + Beacon)
  0.3 W (antenna)
- Input Voltage: 5 VDC ±5%
  100 mV p-p ripple
- Size: 108 mm x 57 mm
  (4.25 in x 2.25 in)
- Connector: 30 pins
- Weight: 65.35 gr (2.3 ounces)
- Vibration:
  – MILSPEC 810E / Category 10
  "Minimum Integrity Test - General"
- Shock: ±40 g Operational
  ±75 g Non-Operational
- Acceleration: 20 G
- Humidity: 95% non-condensing

Other Configurations

DG16 and DG14 receivers are also available in a compact rugged sensor housing.

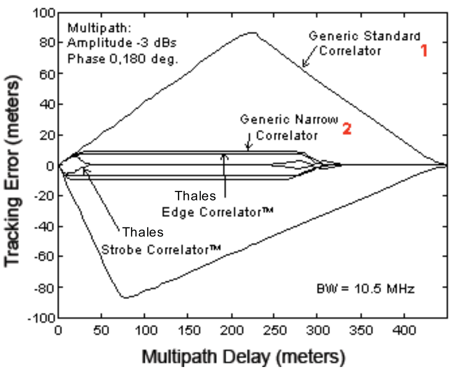
DG16 Development Kit

The DG16 Development Kit includes a DG16 GPS receiver, GPS+Beacon antenna, power supply, cables, manuals and the Thales Evaluate™ and Mission Planning™ Software. The kit is loaded with all the firmware options available.

Multipath Error Envelopes

1. Generic Standard Correlator Spacing, 1 chip
2. Generic Narrow Correlator Spacing, 0.1 chip

This figure shows the errors induced by a multi-path signal half the strength of the direct signal.



The horizontal axis of the plot show the multi-path delay, this is the extra distance that the reflected signal travels compared to the direct signal. The vertical axis shows the induced range error caused by a multipath signal with the indicated delay.

From this plot you can see that typical narrow correlator performance and Edge Correlator performance is similar, while Strobe Correlator performance is much better, almost totally cancelling any multipath with a delay of more than 37 m.

[1] Accuracy and TTFF specifications based on tests conducted in Santa Clara and Moscow. Tests at different locations under different conditions may produce different results. Beacon tests based on 40 km baseline. Position accuracy may degrade with longer baselines.

Position accuracy specifications are for horizontal positioning. Vertical error is typically <2 times horizontal error.

[2] Altitude and Speed limitless versions are available in HDMA configuration under validated export license.

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THALES

Thales Navigation follows a policy of continuous product improvement; specifications and descriptions are thus subject to change without notice. Please contact Thales Navigation for the latest product information.

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Appendix I-J:

Hamworthy compressor

TECHNICAL SPECIFICATION

Hamworthy Containerised Model 2 x 185E MK2 in 20^{FT} ISO Container

Hamworthy 70mm Series Air Compressor 4TH190W70 (185E MK 2)

Quantity: 2 off (each compressor comprises the following fittings/features)

Description: Each compressor will be a four-stage twin-crank, single acting, horizontal reciprocating compressor with three bearing crankshaft

Service: Continuous/Seismic survey

Capacity: 300 M3/hr **(**177 CFM) FAD each. **Total package capacity is 600 M3/hr FAD.**

Shaft KW:	86.8	**RPM:**	1500 nominal
Pressure:	207 Bar (3000 psi) G	**Lubrication:**	Pressurised Oil (Dry Sump)
Cooling:	FW/SW Heat Exchanger	**Unloading:**	Hand/Automatic
Ambient Temp:	0-45°C	**Control Supply:**	110V/1Ph/50Hz

Salt Water Supply : 218 L/Min per compressor @ maximum temperature of 32^{o} C & a maximum pressure of 7 bar

---

Prime Mover: Squirrel Cage Induction Motor

Frame: 280

Power: KW	98	**Supply:**	380/440-3-50/60
Speed: RPM	1480		

Type Starting: Star Delta
Enlosure: IP55
Mounting: Horizontal Foot (B3)
Insulation: Class F
Temperature Rise: Class B
Fittings: Thermistors, Anti Condensation Heaters(220 v) Blank Gland Plate

TECHNICAL SPECIFICATION

Hamworthy Containerised Model 2 x 185E MK2 in 20^{FT} ISO Container

Baseplate and Drive

The compressors will be arranged for direct drive from the electric motor via a flexible coupling. The drive and motor will be mounted on a fabricated steel baseplate complete with a fully guarded flywheel with aperture for barring over compressor.

Instrumentation

- Compressor mounted instrument panel incorporating:
- Air pressure gauge for each stage, glycerine filled
- Oil pressure gauge, glycerine filled

  System temperature indicator mounted on anti vibration mounts with digital display and selectable inputs from:-

  Air inlet and outlet of each stage
- FW inlet and outlet to compressor
- SW inlet and outlet to heat exchanger

Protection And Safety Devices

- Air pressure safety valve on each stage
- Oil pressure relief valve
- Cooling water jacket safety valve
- High air temperature fusible plug on final stage outlet only
- Low lubricating oil pressure switch
- High air pressure limit switch [set 5% above working pressure]
- High water temperature switch
- Cooling water flow switch & indicator complete with kick guard
- Low water level in FW make up tank
- High air temperature switch

Coolers, Separators And Drainage

- Integral interstage coolers
- Integral aftercooler
- Integral oil moisture separators on 2nd stage, 3rd and 4th stages
- Manual unloader and moisture drain system
- Automatic unloader and moisture drain system, operated by solenoid valves

  Liquid piped to an integral condensate manifold.

  Solenoid unloader valves SV2
  SV5

Air inlet

- Air suction filter and silencer

Water Cooling System

- Separate FW circulating pump fitted with pressure gauge
- Sea water/fresh water heat exchanger (218 L/min sea water @ 32 ^{0} C max) per compressor
- Thermostatic by pass valve
- Plastic F.W. make up/expansion tank
- Bleed pipe to assist in commissioning
- All fresh water and sea water pipework to be run in PVC suitable for the working pressures

TECHNICAL SPECIFICATION

Hamworthy Containerised Model 2 x 185E MK2 in 20^{FT} ISO Container

Lubrication

- Integral gear type lubricating oil pump
- Full flow cartridge type oil filter
- Oil sight gauge
- Oil tank (access to inspection hatch be improved to ease cleaning)
- Oil cooler (mounted in such a way that it can be easily drained)
- Crankcase breather with condensate filtration and drainage system.

Ancillary Items

- Final air delivery non return valve (IMF/Thompson Valves type)
- System air pressure control switch fixed differential type
- Set of anti vibration mounts with transportation locking bolts
- 2nd 3rd and 4th stage compressor air pipework to be lagged with insulated jackets

The following items are common for both compressors with total quantities as listed.

Drain Silencer and Demister Assembly [Bentley Filters Ltd]

One type DMSC [15-101/2] oil demister and silencer assembly.

Air Receivers

Four off 50 litre air receivers necked at one end in accordance with BS EN 1964 – 1: 2000.
Maximum WP = 207 bar, test pressure = 300 bar. Inspected and certified.

Adjustable Final Air Pressure Control Valve with System Pressure Gauge

To control final air pressure between 100 and 207 bar g. Excess air to be discharged via a silencer. **2 off 4-20 mA pressure transducers for customer use. One mounted on air receiv ers, one on gun manifold.** 6 off HP air delivery bosses with pressure gauges, shut off valves and dump to atmosphere via a silencer.

Air Pressure Safety Valve

Seetru type loaded air pressure safety valve, set so as to adequately protect the air discharge pipework switch and fittings against accidental over pressure. Valve capable of passing full capacity of 2 off 4TH190W70 compressors when running at 1500 rpm

Contract Documentation

General Arrangement Drawing of Compressor
General Arrangement Drawing of Container Layout
General Arrangement Drawing of Electical Components
Connection Wiring Diagram
Electrical Diagram of Electrical Components.
P & I D of Container Installation
3 Copies of the Compressor Instruction Book
Works Test Certificate for Compressor Unit and System Operation
Hydraulic Test Certificates for Pressurised Parts Including Pressure Vessels and Flexible Connections

TECHNICAL SPECIFICATION

Hamworthy Containerised Model 2 x 185E MK2 in 20^{FT} ISO Container

Local Starter/Control Equipment

Quantity:	**Two off independent panels with two separate power cables**
Power Supply:	380/440-3-50/60
Control Circuit:	110 V
Enclosure:	Sheet steel IP55 with hinged door and removable gland plate
Dimensions:	TBC
Cable Entry:	Power in - Top Power out - Bottom Control & monitoring – Bottom
Anti-Condensation Heaters:	220/1/50 Enclosure & Motor (External Supply)
To start Motor:	98kw
F.L.C.:	185 Amps
Type of Starting:	Star Delta with internal frequency inverter to provide constant compressor speed (1500rpm) with either a 50 or 60Hz supply.

General:

The compressor and control panel is to be installed within a container. The local control panel is to be wall mounted and supplied with resilient mounts.

The compressor is to be operated at the 'Local' control panel. The remote panel is to provide alarm, annuniation and emergency stop facilities only. A separate emergency stop panel is also provided.

Safety interlocks and cut outs to operate in 'Manual' and 'Auto' modes

Description of Operation

The control panel will be provided with a mode selector/start selector for the compressor giving a choice of manual or automatic operation.

Hand Operation – Compressor

Select 'manual' mode and the compressor will start unloaded. After approximately 15 seconds the unloader solenoid valve will operate, putting the compressor on load. In this mode, the air pressure control switch is inoperative, the build-up of pressure in the air receivers being under the control of the operator. When the desired pressure is reached, the compressor can be stopped by selecting the 'OFF' button on the control panel. The compressor unloads and continues to run for a period of approximately 5 minutes to purge the compressor before stopping. The period is controlled by a time delay fitted in the panel which is adjustable over a range of 5-10 minutes.

In hand operation the compressor may run continually and the pressure is controlled by the mechanical control valve fitted to the compressor discharge pipework. Excess air is discharged to atmosphere via a silencer.

TECHNICAL SPECIFICATION

Hamworthy Containerised Model 2 x 185E MK2 in 20^{FT} ISO Container

Automatic Start/Stop Operation

Select 'AUTO' mode on control panel. If the air pressure is below the minimum pressure switch setting the compressor will start. If not, the compressor will start automatically when this limit is reached. The compressor starts unloaded, as in 'manual' mode.

When the air receiver pressure reaches the upper limit setting, the compressor unloads and continues to run for a set period of approximately 5 minutes before stopping. This period is adjustable and is controlled by the time delay relay fitted in the panel as above. In the event of the receiver pressure dropping to the minimum pressure setting during this period the compressor is running unloaded, the compressor immediately reverts to the loaded condition. If however, the receiver pressure has not dropped then the compressor will stop in the unloaded condition, having been purged for the set period of time.

Emergency Stopping

In an emergency, either the local control panel mounted, remote monitoring panel mounted or remote emergency stop push button may be pressed. This will stop the compressor instantly in 'manual' or 'auto' control. To re-start the compressor, reset the emergency stop push button and then press the reset push button. Select 'manual' or 'auto' as appropriate to re-start the compressor.

Cooling Water Pump

The cooling water pump is controlled by a Manual/Off/Auto selector switch. In manual the pump starts and runs continuously until 'Off' is selected. In 'Auto' the pump starts and runs with the compressor motor and stops after a run on period of 5 minutes adjustable 0-10 minutes in the control panel.

Ventilation Fan

The 3.5 kW ventilation fan is controlled by a Manual/Off/Auto selector switch. In manual the fan starts and runs continuously until 'Off' is selected. In 'Auto' the fan starts and runs with the compressor motor and stops after a run on period of 5 minutes adjustable 0-10 minutes in the control panel.

Warning Alarm and Shutdown

Volt free terminals are provided for customer's remote alarm.

Compressor Protection

Under fault conditions of:

- high air pressure
- high water temperature
- high air temperature
- no cooling water flow
- low lubricating oil pressure
- Low fresh water make up level

The compressor will stop and lock out. This will be indicated by a fault lamp.

A time delay will be incorporated to override the following circuits on start-up. [approximately 5-10 seconds]

- low lubricating oil pressure switch
- high water temperature switch
- high air temperature switch
- water flow switch

TECHNICAL SPECIFICATION

Hamworthy Containerised Model 2 x 185E MK2 in 20^{FT} ISO Container

Motor Protection

The thermal overload device shall be electronic with ambient temperature compensation and will shut down the motor and lockout providing single phase and overcurrent protection. Thermistor protection relay will provide motor over temperature protection. These will be indicated by fault lamps on the controller.

Fault Resetting

The panel fault lamps are extinguished by pressing the reset/start push button.

In the 'manual' mode of control this will prepare the compressor for re-starting as described under 'manual operation'.

In the 'auto' mode of control, the compressor will start automatically under the control of the air pressure switch.

Automatic Timed Drainage

A time delay is incorporated to operate the automatic unloader and moisture drain system valves V2 & V5 every 5 minutes for a period of 2 seconds. Both times are adjustable 2-25 minutes and 1-10 seconds respectively

The local control panel will include the following features:

- Interlocked load break isolator
- Inherent under voltage release
- Phase rotation correct lamp(indication only)
- Thermistor over temperature protection relay
- Ammeter & current transformers
- Emergency stop pushbutton and facility for 3 remote emergency stops
- Hours run meter
- Motor ACH selector, controls and indicator lamp
- Auto/Off/Manual selector switch
- Start/Reset push button
- Stop push button
- Cooling water 1.5 kW DOL starter with cct protection, O/load protection and single phase protection
- Cooling water Auto/Off/Manual selector switch
- 3.5 kW Ventilation Fan DOL starter with sct protection, O/load protection and single phase protection
- Vent fan Auto/Off/Manual selector switch
- Power available lamp
- Compressor Motor running lamp
- Compressor motor fault lamp
- Cooling water pump motor running lamp
- Cooling water pump motor fault lamp
- Ventilation fan running lamp
- High air pressure lamp
- No cooling water flow lamp
- Low lubricating oil pressure lamp
- High air temperature lamp
- High cooling water temperature lamp
- Low cooling water level lamp
- Lamp test facility
- 110/1/50 strobe/audible alarm supply
- Mute push button

TECHNICAL SPECIFICATION

Hamworthy Containerised Model 2 x 185E MK2 in 20^{FT} ISO Container

The following points are monitored:

1. Air pressure control switch (NC/open on rising pressure)
2. High water temperature switch (NC/open on rising temperature)
3. Fresh water flow switch (NO/ close on water flow)
4. Compressor low lub oil pressure switch (NO/close on rising pressure)
5. High air temperature switch (NC/open on rising temperature)
6. High air pressure switch (NC/open on rising pressure)
7. Motor O/load (NC open on o/load)
8. Motor over temperature
9. Cooling water pump O/load (NC/open on o/load)
10. Cooling water make up level (NC/open on falling level

TECHNICAL SPECIFICATION

Hamworthy Containerised Model 2 x 185E MK2 in 20^FT ISO Container

<u>20^FT ISO Container</u>

<u>General</u>

All welded steel construction and designed to meet the latest requirements of Lloyds Register of Shipping Certificate Scheme. CSC plating.

<u>Dimensions</u>

External:	Length	20'-0"
	Width	8'-0" [2438mm]
	Height	8'-6" [2590mm]

<u>Description</u>

<u>Externally</u>

<u>Side panels</u> will be in sheet steel. One side panel will include a watertight removable section *complete with lifting handles* to provide additional access for compressor maintenance purposes and suitably positioned logos**.** All removable sections are to be fastened to the container frame with SS bolts in threaded SS inserts. Removable roof sections above air receivers.

Entrance end panel will include the service transit plates and recessed drain connections comprising the following: SW in and out, 6 off HP air outlet bosses, condensate drain and personnel access door.

The container will be force ventilated by an internally mounted 3.5 kW ventilation fan [380/440-3-50/60hz] discharging through a weather louvre. The air inlet comprises a full width low level louvre with internal duct/baffle to minimise water ingress.

Floor will be structured to support the compressor equipment, and finished with a raised open bar (galvanised) walkway. Water drainage points will be incorporated within the floor structure.

<u>Lifting points/holding down fixtures</u> will be rigidly attached to all corners of containers.

The exterior is to be shot blasted and to be painted with one coat zinc-rich primer, followed by white two-pack epoxy. All fastenings and furniture to be stainless steel.

<u>INTERNALLY</u>

The sides and roof panels will be fabricated from mild steel and painted with one coat of primer followed by two coats of white enamel on the walls and roof and two coats of grey deck paint on the floor.

The container will be fitted with a lighting system comprising of anti vibration mounted fluorescent luminaries with a watertight switch fitted by the door (one will have emergency back up), Watertight 220-1-50 socket fitted at one end. Lighting, power and motor anti condensation heaters to be fed by a separate 220-1-50 intruder circuit. One light is to be positioned above the compressor control panel.

All HP air pipework and fittings to be in SS. FW & SW in plastic.

Internal space heaters (220-1-50) to be fitted with appropriate safety covers to maintain an internal temperature of +5^{0}C with an external temperature of -10^{0}C.

There will be suitable lifting eyes placed above each compressor cylinder.

TECHNICAL SPECIFICATION

Hamworthy Containerised Model 2 x 185E MK2 in 20^{FT} ISO Container

The structure of the container will be designed to support and fix the following items of equipment.

<u>4TH190W70</u>

2 No - seismic air compressor with electric motor and heat exchanger and water circulating pump
4 No – air bottles
1 No – condensate blowdown system filter
All ancillary items
2 No – compressor starter control box
1 No – internal and external emergency stop with klaxon and visual indicator for compressor fault

Appendix II: Definitions of offset points

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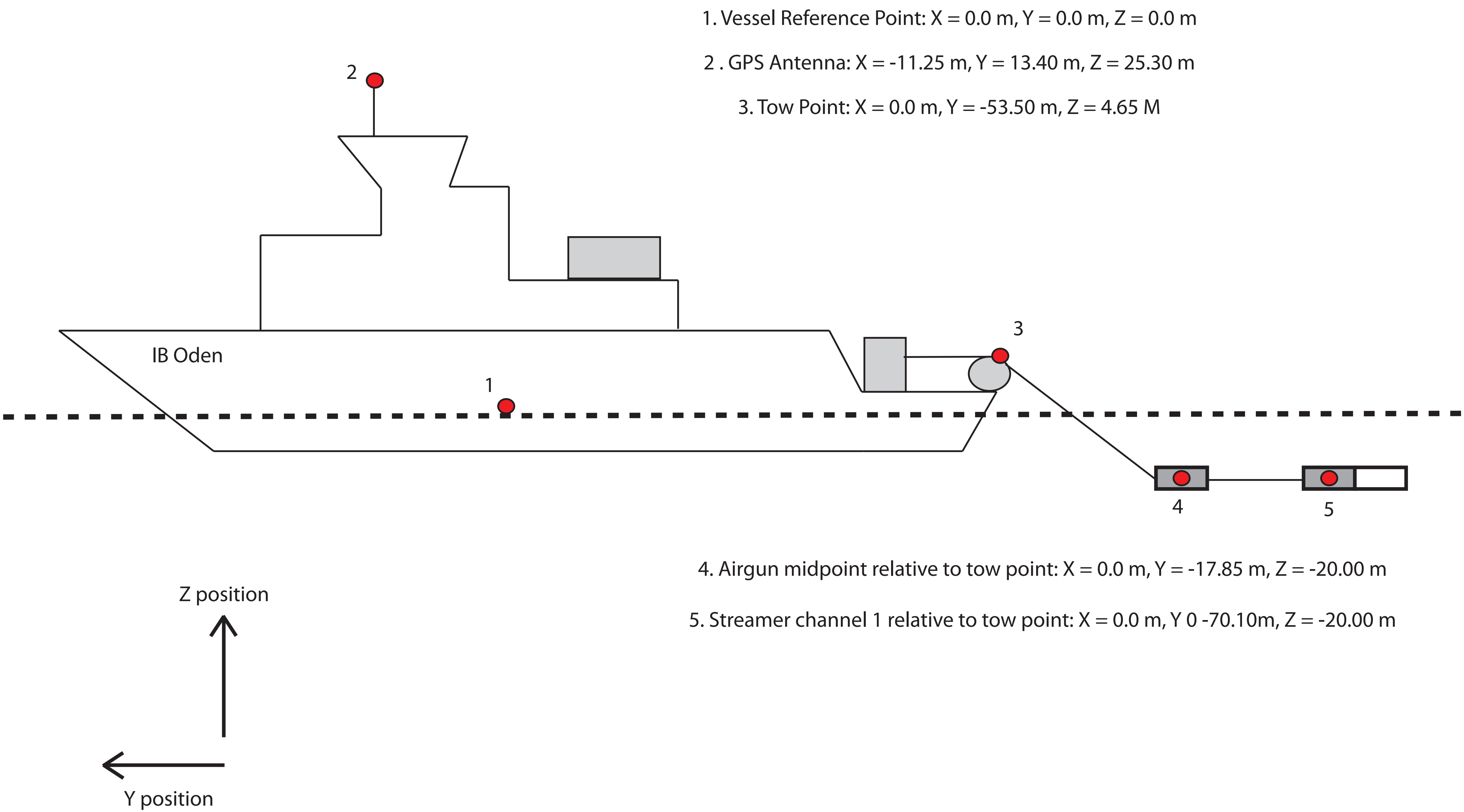
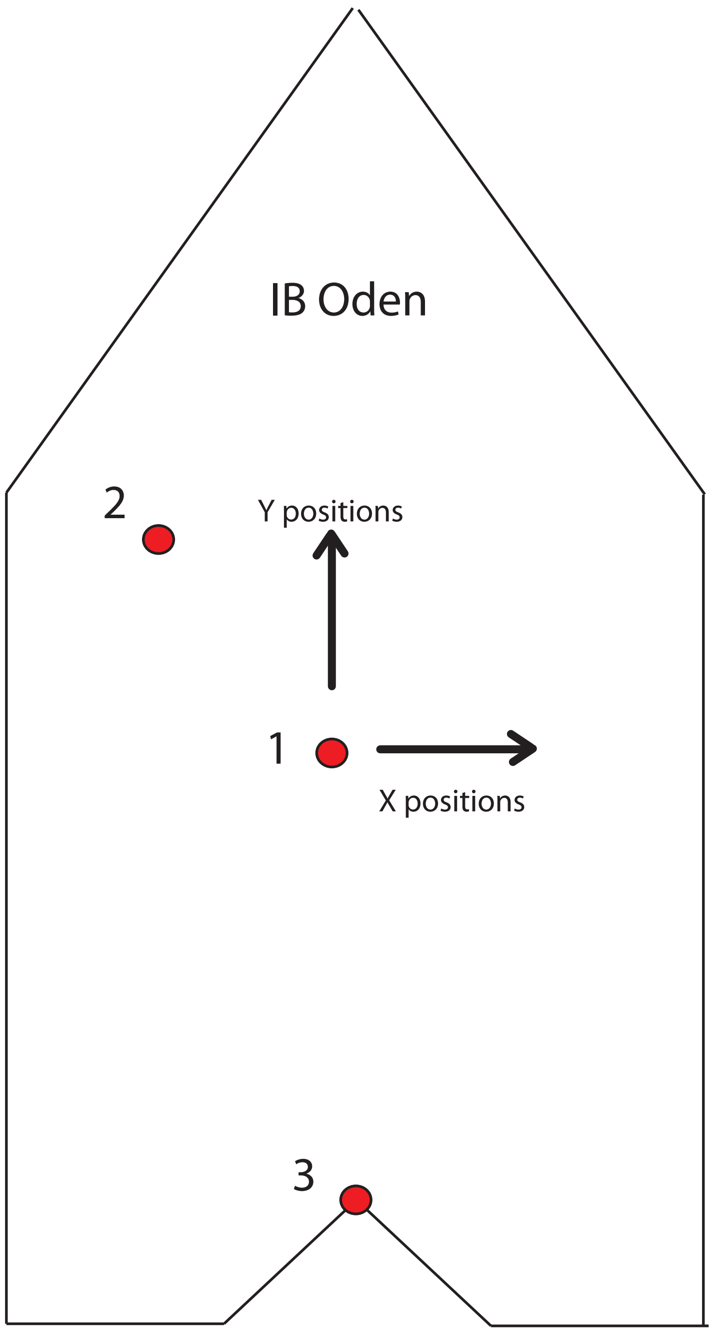

1. Vessel Reference Point: X = 0.0 m, Y = 0.0 m, Z = 0.0 m
2 . GPS Antenna: X = -11.25 m, Y = 13.40 m, Z = 25.30 m
3. Tow Point: X = 0.0 m, Y = -53.50 m, Z = 4.65 M
2
3
IB Oden
1
4
5
4. Airgun midpoint relative to tow point: X = 0.0 m, Y = -17.85 m, Z = -20.00 m
Z position
5. Streamer channel 1 relative to tow point: X = 0.0 m, Y 0 -70.10m, Z = -20.00 m
Y position



1. Vessel ref. point: X = 0.0 m, Y = 0.0 m, Z = 0.0 m
2. GPS Antenna: X = -11.25 m, Y = 13.40 m, Z = 25.30 m
3. Tow Point: X = 0.0, Y = -53.50 m, Z = 4.65m

Appendix III: Marine Survey – General Information, Line Overview logs and Tape Inventory Log

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Date:	06-08-2012	Marine Survey - General Information	Line: 1	LOMROG III_1

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro	
X (m)	-11,25	X (m)	0,00	X (m)	2,15
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00
Towpoint ship		**Airgun midpoint relative to towpoint**		**1st hydroph of Ch 1 relative to towpoint**	
X (m)	0,00	X (m)	0,00	X (m)	0,00
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00

	10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
		30	RP1083	53	50	50	50	50		
Serial no. depth transducer (front of section)					5004	5015	5016	5010		
Serial no. A/D converter (front of section)					1477	1497	1143	1146		

Navigation:

Software:	NaviPac
Projection:	UPS North
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Scale at Origin	0,994	False easting (m):	2000000
		False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. two Sercel G gun
Serial no. G-Gun:	4696
Volume G (cu.inch):	520
Serial no. G-Gun:	46913
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (xx mS)**
Pressure (bar):	180
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	0
Sample Rate (ms):	1
Record Length (ms):	12000
No of recording chs:	32
No of auxilliary chs:	8
Software version	5.43
SPSU Serial No	PS1071

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	83
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	S1101
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	RP1083
Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint

Streamer depth scanned every 2 sec, one by one - means 8 sec in total

Date:	06-08-2012	Marine Survey - General Information	Line:1A	LOMROG III_1A

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro	
X (m)	-11,25	X (m)	0,00	X (m)	2,15
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00

Towpoint ship		Airgun midpoint relative to towpoint		1st hydroph of Ch 1 relative to towpoint	
X (m)	0,00	X (m)	0,00	X (m)	0,00
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00

	10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
		30	RP1083	53	50	50	50	50		
Serial no. depth transducer (front of section)					5004	5015	5016	5010		
Serial no. A/D converter (front of section)					1477	1497	1143	1146		

Navigation:

Software:	NaviPac
Projection:	UPS North
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Scale at Origin	0,994	False easting (m):	2000000
		False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. two Sercel G gun
Serial no. G-Gun:	4696
Volume G (cu.inch):	520
Serial no. G-Gun:	46913
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (xx mS)**
Pressure (bar):	180
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	0
Sample Rate (ms):	1
Record Length (ms):	12000
No of recording chs:	32
No of auxilliary chs:	8
Software version	5.43
SPSU Serial No	PS1071

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	83
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	S1101
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	RP1083
Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint

Streamer depth scanned every 2 sec, one by one - means 8 sec in total

Jumper between umbilical and streamer removed on this line

Date:	07-08-2012	Marine Survey - General Information	Line: 2	LOMROG III_2

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro	
X (m)	-11,25	X (m)	0,00	X (m)	2,15
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00
Towpoint ship		Airgun midpoint relative to towpoint		1st hydroph of Ch 1 relative to towpoint	
X (m)	0,00	X (m)	0,00	X (m)	0,00
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00

10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
	30	RP1105	53	50	50	50	50		
Serial no. depth transducer (front of section)				5004	5015	5016	5010		
Serial no. A/D converter (front of section)				1477	1497	1143	1146		

Navigation:	
Software:	NaviPac
Projection:	UPS North
Datum:	WGS84

Transformation parameters:			
Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Scale at Origin	0,994	False easting (m):	2000000
		False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. two Sercel G gun
Serial no. G-Gun:	4696
Volume G (cu.inch):	520
Serial no. G-Gun:	46913
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (xx mS)**
Pressure (bar):	180
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	0
Sample Rate (ms):	1
Record Length (ms):	12000
No of recording chs:	32
No of auxilliary chs:	8
Software version	5.43
SPSU Serial No	PS1071

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	83
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	S1101
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	RP1105
Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint

Streamer depth scanned every 2 sec, one by one - means 8 sec in total

Date:	07-08-2012	**Marine Survey - General Information**	**Line: 3** LOMROG III_3

Cruise:	LOMROG III	**Ship:**	IB Oden	**Location:**	Arctic

GPS antenna		Refpoint ship		Gyro	
X (m)	-11,25	X (m)	0,00	X (m)	2,15
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00
Towpoint ship		**Airgun midpoint relative to towpoint**		**1st hydroph of Ch 1 relative to towpoint**	
X (m)	0,00	X (m)	0,00	X (m)	0,00
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00

	10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
		30	RP1105	53	50	50	50	50		
Serial no. depth transducer***					5022	5021	5008	5018		
Serial no. A/D converter (front of section)					NA	1675	1674	1481		

Navigation:

Software:	NaviPac
Projection:	UPS North
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Scale at Origin	0,994	False easting (m):	2000000
		False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. two Sercel G gun
Serial no. G-Gun:	4696
Volume G (cu.inch):	520
Serial no. G-Gun:	46913
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (xx mS)**
Pressure (bar):	180
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	0
Sample Rate (ms):	1
Record Length (ms):	12000
No of recording chs:	32
No of auxilliary chs:	8
Software version	5.43
SPSU Serial No	PS1071

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	83
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	S1100
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	RP1105
Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint

Streamer depth scanned every 2 sec, one by one - means 8 sec in total

***(front of section in the first 3 sections and at tail end on the last section)

Date:	07-08-2012	Marine Survey - General Information	Line: 4	LOMROG III_4

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro	
X (m)	-11,25	X (m)	0,00	X (m)	2,15
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00
Towpoint ship		**Airgun midpoint relative to towpoint**		**1st hydroph of Ch 1 relative to towpoint**	
X (m)	0,00	X (m)	0,00	X (m)	0,00
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00

10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
	30	RP1105	53	50	50	50	50		
Serial no. depth transducer***				5022	5021	5008	5009		
Serial no. A/D converter (front of section)				NA	1675	1674	1481		

Navigation:	
Software:	NaviPac
Projection:	UPS North
Datum:	WGS84

Transformation parameters:			
Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Scale at Origin	0,994	False easting (m):	2000000
		False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. two Sercel G gun
Serial no. G-Gun:	4696
Volume G (cu.inch):	520
Serial no. G-Gun:	46913
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (xx mS)**
Pressure (bar):	180
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	0
Sample Rate (ms):	1
Record Length (ms):	12000
No of recording chs:	32
No of auxilliary chs:	8
Software version	5.43
SPSU Serial No	PS1071

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	83
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	S1100
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	RP1105
Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint

Streamer depth scanned every 2 sec, one by one - means 8 sec in total

***(front of section in the first 3 sections and at tail end on the last section)

Date:	17-08-2012	Marine Survey - General Information	Line: 5	LOMROG III_5

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro		10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
X (m)	-11,25	X (m)	0,00	X (m)	2,15		30	RP1105	53	50	50	50	50		
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00										
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00	Serial no. depth transducer***				5022	5021	5008	5009		
Towpoint ship		Airgun midpoint relative to towpoint		1st hydroph of Ch 1 relative to towpoint		Serial no. A/D converter (front of section)				NA	1675	1184	1481		

Towpoint ship		Airgun midpoint relative to towpoint		1st hydroph of Ch 1 relative to towpoint		Navigation:		Transformation parameters:			
X (m)	0,00	X (m)	0,00	X (m)	0,00	Software:	NaviPac	Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10	Projection:	UPS North	Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00	Datum:	WGS84	Scale at Origin	0,994	False easting (m):	2000000
										False northing (m):	2000000

Seismic Energy Source:		Seismic Instruments:		Streamer:	
Type:	Cluster w. two Sercel G gun	Type:	Geometrics GeoEel contoller	Type:	Geometrics GeoEel
Serial no. G-Gun:	4696	Lowcut filter (Hz):	out	Length of tow section (m):	83
Volume G (cu.inch):	520	Lowcut filt. (dB/Oct):	out	Length of live section (m):	200
Serial no. G-Gun:	46913****	Highcut filter (Hz):	anti-alias	No. of live sections:	4
Volume G (cu.inch):	520	Highcut filt. (dB/Oct):	anti-alias	No. of channels:	32
Serial no. G-Gun:		Gain Setting (dB):	0	No. of channels/live section:	8
Volume G (cu.inch):		Sample Rate (ms):	1	channel interval (m):	6,25
Serial no. G-Gun:		Record Length (ms):	12000	No. of hydrophones/channel:	8
Volume G (cu.inch):		No of recording chs:	32	Serial no. Vibration section:	S1100
Delay:	**Autoadjusted (xx mS)**	No of auxilliary chs:	8	Serial no. 10 Mb repeater:	? (inside slipring)
Pressure (bar):	180	Software version	5.43	Serial no. 100 Mb repeater:	RP1105
Planned depth (m):	20	SPSU Serial No	PS1073	Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint

Streamer depth scanned every 2 sec, one by one - means 8 sec in total

***(front of section in the first 3 sections and at tail end on the last section)

****changed to 46918 for line 5A

Date:	17-08-2012	Marine Survey - General Information	Line: 5A	LOMROG III_5A

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro	
X (m)	-11,25	X (m)	0,00	X (m)	2,15
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00
Towpoint ship		**Airgun midpoint relative to towpoint**		**1st hydroph of Ch 1 relative to towpoint**	
X (m)	0,00	X (m)	0,00	X (m)	0,00
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00

	10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
		30	RP1105	53	50	50	50	50		
Serial no. depth transducer***					5022	5021	5008	5009		
Serial no. A/D converter (front of section)					NA	1675	1184	1481		

Navigation:

Software:	NaviPac
Projection:	UPS North
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Scale at Origin	0,994	False easting (m):	2000000
		False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. two Sercel G gun
Serial no. G-Gun:	4696
Volume G (cu.inch):	520
Serial no. G-Gun:	46918
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (xx mS)**
Pressure (bar):	180
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	0
Sample Rate (ms):	1
Record Length (ms):	12000
No of recording chs:	32
No of auxilliary chs:	8
Software version	5.43
SPSU Serial No	PS1073

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	83
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	S1100
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	RP1105
Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint

Streamer depth scanned every 2 sec, one by one - means 8 sec in total

***(front of section in the first 3 sections and at tail end on the last section)

Date:	17-08-2012	Marine Survey - General Information	Line: 5B	LOMROG III_5B

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro	
X (m)	-11,25	X (m)	0,00	X (m)	2,15
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00
Towpoint ship		**Airgun midpoint relative to towpoint**		**1st hydroph of Ch 1 relative to towpoint**	
X (m)	0,00	X (m)	0,00	X (m)	0,00
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00

10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
	30	RP1105	53	50	50	50	50		
Serial no. depth transducer***				5022	5021	5008	5009		
Serial no. A/D converter (front of section)				NA	1675	1184	1481		

Navigation:

Software:	NaviPac
Projection:	UPS North
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Scale at Origin	0,994	False easting (m):	2000000
		False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. two Sercel G gun
Serial no. G-Gun:	4696
Volume G (cu.inch):	520
Serial no. G-Gun:	46918
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (xx mS)**
Pressure (bar):	180
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	0
Sample Rate (ms):	1
Record Length (ms):	12000
No of recording chs:	32
No of auxilliary chs:	8
Software version	5.43
SPSU Serial No	PS1073

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	83
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	S1100
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	RP1105
Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
***(front of section in the first 3 sections and at tail end on the last section)

Date:	21-08-2012	Marine Survey - General Information	Line: 6	LOMROG III_6

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro	
X (m)	-11,25	X (m)	0,00	X (m)	2,15
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00
Towpoint ship		Airgun midpoint relative to towpoint		1st hydroph of Ch 1 relative to towpoint	
X (m)	0,00	X (m)	0,00	X (m)	0,00
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00

	10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
		30	RP1080	53	50	50	50	50		
Serial no. depth transducer***					5022	5021	5008	5009		
Serial no. A/D converter (front of section)					NA	1675	1184	1481		

Navigation:

Software:	NaviPac
Projection:	UPS North
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Scale at Origin	0,994	False easting (m):	2000000
		False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. two Sercel G gun
Serial no. G-Gun:	4696
Volume G (cu.inch):	520
Serial no. G-Gun:	46918
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (xx mS)**
Pressure (bar):	180
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	0
Sample Rate (ms):	1
Record Length (ms):	12000
No of recording chs:	32
No of auxilliary chs:	8
Software version	5.43
SPSU Serial No	PS1073

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	83
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	S1100
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	RP1080
Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint

Streamer depth scanned every 2 sec, one by one - means 8 sec in total

***(front of section in the first 3 sections and at tail end on the last section)

Date:	21-08-2012	Marine Survey - General Information	Line: 6d	LOMROG III_6

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro	
X (m)	-11,25	X (m)	0,00	X (m)	2,15
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00
Towpoint ship		Airgun midpoint relative to towpoint		1st hydroph of Ch 1 relative to towpoint	
X (m)	0,00	X (m)	0,00	X (m)	0,00
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00

	10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
		30	RP1080	53	50	50	50	50		
Serial no. depth transducer***					5022	5021	5008	5009		
Serial no. A/D converter (front of section)					1480	1675	1184	1481		

Navigation:	
Software:	NaviPac
Projection:	UPS North
Datum:	WGS84

Transformation parameters:			
Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Scale at Origin	0,994	False easting (m):	2000000
		False northing (m):	2000000

Seismic Energy Source:	
Type:	Cluster w. two Sercel G gun
Serial no. G-Gun:	4696
Volume G (cu.inch):	520
Serial no. G-Gun:	46918
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (xx mS)**
Pressure (bar):	180
Planned depth (m):	20

Seismic Instruments:	
Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	0
Sample Rate (ms):	1
Record Length (ms):	12000
No of recording chs:	32
No of auxilliary chs:	8
Software version	5.43
SPSU Serial No	PS1073

Streamer:	
Type:	Geometrics GeoEel
Length of tow section (m):	83
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	S1098
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	RP1080
Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint

Streamer depth scanned every 2 sec, one by one - means 8 sec in total

***(front of section in the first 3 sections and at tail end on the last section)

Date:	28-08-2012	Marine Survey - General Information	Line: 7	LOMROG III_7

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro		10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
X (m)	-11,25	X (m)	0,00	X (m)	2,15		30	RP1080	53	50	50	50	50		
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00										
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00	Serial no. depth transducer***				5022	5021	5008	5009		
Towpoint ship		Airgun midpoint relative to towpoint		1st hydroph of Ch 1 relative to towpoint		Serial no. A/D converter (front of section)				1480	1675	1184	1481		

Towpoint ship		Airgun midpoint relative to towpoint		1st hydroph of Ch 1 relative to towpoint		Navigation:		Transformation parameters:			
X (m)	0,00	X (m)	0,00	X (m)	0,00	Software:	NaviPac	Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10	Projection:	UPS North	Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00	Datum:	WGS84	Scale at Origin	0,994	False easting (m):	2000000
										False northing (m):	2000000

Seismic Energy Source:		Seismic Instruments:		Streamer:	
Type:	Cluster w. two Sercel G gun	Type:	Geometrics GeoEel contoller	Type:	Geometrics GeoEel
Serial no. G-Gun:	4696	Lowcut filter (Hz):	out	Length of tow section (m):	83
Volume G (cu.inch):	520	Lowcut filt. (dB/Oct):	out	Length of live section (m):	200
Serial no. G-Gun:	46918	Highcut filter (Hz):	anti-alias	No. of live sections:	4
Volume G (cu.inch):	520	Highcut filt. (dB/Oct):	anti-alias	No. of channels:	32
Serial no. G-Gun:		Gain Setting (dB):	0	No. of channels/live section:	8
Volume G (cu.inch):		Sample Rate (ms):	1	channel interval (m):	6,25
Serial no. G-Gun:		Record Length (ms):	12000	No. of hydrophones/channel:	8
Volume G (cu.inch):		No of recording chs:	32	Serial no. Vibration section:	S1098
Delay:	**Autoadjusted (xx mS)**	No of auxilliary chs:	8	Serial no. 10 Mb repeater:	? (inside slipring)
Pressure (bar):	180	Software version	5.43	Serial no. 100 Mb repeater:	RP1080
Planned depth (m):	20	SPSU Serial No	PS1073	Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint

Streamer depth scanned every 2 sec, one by one - means 8 sec in total

***(front of section in the first 3 sections and at tail end on the last section)

Date:	29-08-2012	Marine Survey - General Information	Line: 8	LOMROG III_8

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro	
X (m)	-11,25	X (m)	0,00	X (m)	2,15
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00
Towpoint ship		**Airgun midpoint relative to towpoint**		**1st hydroph of Ch 1 relative to towpoint**	
X (m)	0,00	X (m)	0,00	X (m)	0,00
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00

10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
	30	RP1080	53	50	50	50	50		
Serial no. depth transducer***				5022	5021	5008	5009		
Serial no. A/D converter (front of section)				1480	1675	1184	1481		

Navigation:	
Software:	NaviPac
Projection:	UPS North
Datum:	WGS84

Transformation parameters:			
Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Scale at Origin	0,994	False easting (m):	2000000
		False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. two Sercel G gun
Serial no. G-Gun:	4696
Volume G (cu.inch):	520
Serial no. G-Gun:	46918
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (xx mS)**
Pressure (bar):	180
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	0
Sample Rate (ms):	1
Record Length (ms):	12000
No of recording chs:	32
No of auxilliary chs:	8
Software version	5.43
SPSU Serial No	PS1073

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	83
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	S1098
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	RP1080
Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
***(front of section in the first 3 sections and at tail end on the last section)

Date:	30-08-2012	Marine Survey - General Information	Line: 9	LOMROG III_9

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro	
X (m)	-11,25	X (m)	0,00	X (m)	2,15
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00
Towpoint ship		**Airgun midpoint relative to towpoint**		**1st hydroph of Ch 1 relative to towpoint**	
X (m)	0,00	X (m)	0,00	X (m)	0,00
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00

	10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
		30	RP1105	53	50	50	50	50		
Serial no. depth transducer***					5022	5021	5008	5009		
Serial no. A/D converter (front of section)					1480	1675	1184	1481		

Navigation:

Software:	NaviPac
Projection:	UPS North
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Scale at Origin	0,994	False easting (m):	2000000
		False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. two Sercel G gun
Serial no. G-Gun:	4696
Volume G (cu.inch):	520
Serial no. G-Gun:	46918
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (xx mS)**
Pressure (bar):	180
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	0
Sample Rate (ms):	1
Record Length (ms):	12000
No of recording chs:	32
No of auxilliary chs:	8
Software version	5.43
SPSU Serial No	PS1073

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	83
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	S1098
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	RP1105
Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint

Streamer depth scanned every 2 sec, one by one - means 8 sec in total

***(front of section in the first 3 sections and at tail end on the last section)

Date:	31-08-2012	Marine Survey - General Information	Line: 10	LOMROG III_10

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro	
X (m)	-11,25	X (m)	0,00	X (m)	2,15
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00
Towpoint ship		**Airgun midpoint relative to towpoint**		**1st hydroph of Ch 1 relative to towpoint**	
X (m)	0,00	X (m)	0,00	X (m)	0,00
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00

	10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
		30	RP1105	53	50	50	50	50		
Serial no. depth transducer***					5022	5021	5008	5009		
Serial no. A/D converter (front of section)					1480	1675	1184	1481		

Navigation:

Software:	NaviPac
Projection:	UPS North
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Scale at Origin	0,994	False easting (m):	2000000
		False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. two Sercel G gun
Serial no. G-Gun:	4696
Volume G (cu.inch):	520
Serial no. G-Gun:	46918
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (xx mS)**
Pressure (bar):	180
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	0
Sample Rate (ms):	1
Record Length (ms):	12000
No of recording chs:	32
No of auxilliary chs:	8
Software version	5.43
SPSU Serial No	PS1073

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	83
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	S1098
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	RP1105
Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint

Streamer depth scanned every 2 sec, one by one - means 8 sec in total

***(front of section in the first 3 sections and at tail end on the last section)

Date:	31-08-2012	Marine Survey - General Information	Line: 10D	LOMROG III_10D

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro		10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
X (m)	-11,25	X (m)	0,00	X (m)	2,15		30	RP1105	53	50	50	50	50		
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00										
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00	Serial no. depth transducer***				5004	5015	5016	5010		
Towpoint ship		Airgun midpoint relative to towpoint		1st hydroph of Ch 1 relative to towpoint		Serial no. A/D converter (front of section)				1477	1497	1143	1146		
						Navigation:				Transformation parameters:					
X (m)	0,00	X (m)	0,00	X (m)	0,00	Software:	NaviPac			Semimajor axis (m):		6378137	Longitude at Origin		-25° 0' 0.0"
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10	Projection:	UPS North			Inverse flattening:		298,257224	Latitude at Orgin		81° 07' 0.0"
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00	Datum:	WGS84			Scale at Origin		0,994	False easting (m):		2000000
													False northing (m):		2000000

Seismic Energy Source:		Seismic Instruments:		Streamer:	
Type:	Cluster w. two Sercel G gun	Type:	Geometrics GeoEel contoller	Type:	Geometrics GeoEel
Serial no. G-Gun:	4696	Lowcut filter (Hz):	out	Length of tow section (m):	83
Volume G (cu.inch):	520	Lowcut filt. (dB/Oct):	out	Length of live section (m):	200
Serial no. G-Gun:	46918	Highcut filter (Hz):	anti-alias	No. of live sections:	4
Volume G (cu.inch):	520	Highcut filt. (dB/Oct):	anti-alias	No. of channels:	32
Serial no. G-Gun:		Gain Setting (dB):	0	No. of channels/live section:	8
Volume G (cu.inch):		Sample Rate (ms):	1	channel interval (m):	6,25
Serial no. G-Gun:		Record Length (ms):	12000	No. of hydrophones/channel:	8
Volume G (cu.inch):		No of recording chs:	32	Serial no. Vibration section:	S1098
Delay:	**Autoadjusted (xx mS)**	No of auxilliary chs:	8	Serial no. 10 Mb repeater:	? (inside slipring)
Pressure (bar):	180	Software version	5.43	Serial no. 100 Mb repeater:	RP1105
Planned depth (m):	20	SPSU Serial No	PS1073	Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint

Streamer depth scanned every 2 sec, one by one - means 8 sec in total

***(front of section)

Date:	01-09-2012	Marine Survey - General Information	Line: 11	LOMROG III_11

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro	
X (m)	-11,25	X (m)	0,00	X (m)	2,15
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00
Towpoint ship		Airgun midpoint relative to towpoint		1st hydroph of Ch 1 relative to towpoint	
X (m)	0,00	X (m)	0,00	X (m)	0,00
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00

10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
	30	RP1105	53	50	50	50	50		
Serial no. depth transducer***				5004	5015	5016	5010		
Serial no. A/D converter (front of section)				1477	1497	1143	1146		

Navigation:

Software:	NaviPac
Projection:	UPS North
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Scale at Origin	0,994	False easting (m):	2000000
		False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. two Sercel G gun
Serial no. G-Gun:	4696
Volume G (cu.inch):	520
Serial no. G-Gun:	46918
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (xx mS)**
Pressure (bar):	180
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	0
Sample Rate (ms):	1
Record Length (ms):	12000
No of recording chs:	32
No of auxilliary chs:	8
Software version	5.43
SPSU Serial No	PS1073

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	83
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	S1098
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	RP1105
Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint

Streamer depth scanned every 2 sec, one by one - means 8 sec in total

***(front of section)

Date:	01-09-2012	Marine Survey - General Information	Line: 11B	LOMROG III_11B

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro	
X (m)	-11,25	X (m)	0,00	X (m)	2,15
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00
Towpoint ship		**Airgun midpoint relative to towpoint**		**1st hydroph of Ch 1 relative to towpoint**	
X (m)	0,00	X (m)	0,00	X (m)	0,00
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00

	10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
		30	RP1105	53	50	50	50	50		
Serial no. depth transducer***					5004	5015	5016	5010		
Serial no. A/D converter (front of section)					1477	1497	1143	1146		

Navigation:

Software:	NaviPac
Projection:	UPS North
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Scale at Origin	0,994	False easting (m):	2000000
		False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. two Sercel G gun
Serial no. G-Gun:	4696
Volume G (cu.inch):	520
Serial no. G-Gun:	46914
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (xx mS)**
Pressure (bar):	180
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	0
Sample Rate (ms):	1
Record Length (ms):	12000
No of recording chs:	32
No of auxilliary chs:	8
Software version	5.43
SPSU Serial No	PS1073

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	83
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	S1098
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	RP1105
Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint

Streamer depth scanned every 2 sec, one by one - means 8 sec in total

***(front of section)

Date:	01-09-2012	Marine Survey - General Information	Line: 12	LOMROG III_12

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro	
X (m)	-11,25	X (m)	0,00	X (m)	2,15
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00
Towpoint ship		**Airgun midpoint relative to towpoint**		**1st hydroph of Ch 1 relative to towpoint**	
X (m)	0,00	X (m)	0,00	X (m)	0,00
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00

	10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
		30	RP1105	53	50	50	50	50		
Serial no. depth transducer***					5004	5015	5016	5010		
Serial no. A/D converter (front of section)					1477	1497	1143	1146		

Navigation:

Software:	NaviPac
Projection:	UPS North
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Scale at Origin	0,994	False easting (m):	2000000
		False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. two Sercel G gun
Serial no. G-Gun:	4696
Volume G (cu.inch):	520
Serial no. G-Gun:	46914
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (xx mS)**
Pressure (bar):	180
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	0
Sample Rate (ms):	1
Record Length (ms):	12000
No of recording chs:	32
No of auxilliary chs:	8
Software version	5.43
SPSU Serial No	PS1073

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	83
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	S1098
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	RP1105
Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint

Streamer depth scanned every 2 sec, one by one - means 8 sec in total

***(front of section)

Date:	02-09-2012	Marine Survey - General Information	Line: 13	LOMROG III_13

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro	
X (m)	-11,25	X (m)	0,00	X (m)	2,15
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00
Towpoint ship		**Airgun midpoint relative to towpoint**		**1st hydroph of Ch 1 relative to towpoint**	
X (m)	0,00	X (m)	0,00	X (m)	0,00
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00

	10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
		30	RP1105	53	50	50	50	50		
Serial no. depth transducer***					5004	5015	5016	5010		
Serial no. A/D converter (front of section)					1477	1497	1143	1146		

Navigation:	
Software:	NaviPac
Projection:	UPS North
Datum:	WGS84

Transformation parameters:			
Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Scale at Origin	0,994	False easting (m):	2000000
		False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. two Sercel G gun
Serial no. G-Gun:	4696
Volume G (cu.inch):	520
Serial no. G-Gun:	46914
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (xx mS)**
Pressure (bar):	180
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	0
Sample Rate (ms):	1
Record Length (ms):	12000
No of recording chs:	32
No of auxilliary chs:	8
Software version	5.43
SPSU Serial No	PS1073

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	83
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	S1098
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	RP1105
Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint

Streamer depth scanned every 2 sec, one by one - means 8 sec in total

***(front of section)

Date:	03-09-2012	Marine Survey - General Information	Line: 14	LOMROG III_14

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro	
X (m)	-11,25	X (m)	0,00	X (m)	2,15
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00
Towpoint ship		**Airgun midpoint relative to towpoint**		**1st hydroph of Ch 1 relative to towpoint**	
X (m)	0,00	X (m)	0,00	X (m)	0,00
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00

	10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
		30	RP1105	53	50	50	50	50		
Serial no. depth transducer***					5004	5015	5016	5010		
Serial no. A/D converter (front of section)					1477	1497	1143	1146		

Navigation:

Software:	NaviPac
Projection:	UPS North
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Scale at Origin	0,994	False easting (m):	2000000
		False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. two Sercel G gun
Serial no. G-Gun:	4696
Volume G (cu.inch):	520
Serial no. G-Gun:	46914
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (xx mS)**
Pressure (bar):	180
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	0
Sample Rate (ms):	1
Record Length (ms):	12000
No of recording chs:	32
No of auxilliary chs:	8
Software version	5.43
SPSU Serial No	PS1073

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	83
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	S1098
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	RP1105
Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
***(front of section)

Marine Survey - General Information

Date:	03-09-2012	**Line: 15**	LOMROG III_15

Cruise:	LOMROG III	**Ship:**	IB Oden	**Location:**	Arctic

GPS antenna		Refpoint ship		Gyro	
X (m)	-11,25	X (m)	0,00	X (m)	2,15
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00
Towpoint ship		**Airgun midpoint relative to towpoint**		**1st hydroph of Ch 1 relative to towpoint**	
X (m)	0,00	X (m)	0,00	X (m)	0,00
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00

	10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
		30	RP1105	53	50	50	50	50		
Serial no. depth transducer***					5004	5015	5016	5010		
Serial no. A/D converter (front of section)					1477	1497	1143	1146		

Navigation:

Software:	NaviPac
Projection:	UPS North
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Scale at Origin	0,994	False easting (m):	2000000
		False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. two Sercel G gun
Serial no. G-Gun:	4696
Volume G (cu.inch):	520
Serial no. G-Gun:	46914
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (xx mS)**
Pressure (bar):	180
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	0
Sample Rate (ms):	1
Record Length (ms):	12000
No of recording chs:	32
No of auxilliary chs:	8
Software version	5.43
SPSU Serial No	PS1073

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	83
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	S1098
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	RP1105
Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint

Streamer depth scanned every 2 sec, one by one - means 8 sec in total

***(front of section)

Date:	05-09-2012	Marine Survey - General Information	Line: 16	LOMROG III_16

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro	
X (m)	-11,25	X (m)	0,00	X (m)	2,15
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00
Towpoint ship		Airgun midpoint relative to towpoint		1st hydroph of Ch 1 relative to towpoint	
X (m)	0,00	X (m)	0,00	X (m)	0,00
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00

	10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
		30	RP1105	53	50	50	50	50		
Serial no. depth transducer***					5004	5015	5016	5010		
Serial no. A/D converter (front of section)					1477	1497	1143	1146		

Navigation:	
Software:	NaviPac
Projection:	UPS North
Datum:	WGS84

Transformation parameters:			
Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Scale at Origin	0,994	False easting (m):	2000000
		False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. two Sercel G gun
Serial no. G-Gun:	4696
Volume G (cu.inch):	520
Serial no. G-Gun:	46914
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (xx mS)**
Pressure (bar):	180
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	0
Sample Rate (ms):	1
Record Length (ms):	12000
No of recording chs:	32
No of auxilliary chs:	8
Software version	5.43
SPSU Serial No	PS1073

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	83
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	S1098
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	RP1105
Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint

Streamer depth scanned every 2 sec, one by one - means 8 sec in total

***(front of section)

Date:	05-09-2012	Marine Survey - General Information	Line: 17	LOMROG III_17

Cruise:	LOMROG III	Ship:	IB Oden	Location:	Arctic

GPS antenna		Refpoint ship		Gyro		10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
X (m)	-11,25	X (m)	0,00	X (m)	2,15		30	RP1105	53	50	50	50	50		
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00										
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00	Serial no. depth transducer***				5004	5015	5016	5010		
Towpoint ship		Airgun midpoint relative to towpoint		1st hydroph of Ch 1 relative to towpoint		Serial no. A/D converter (front of section)				1477	1497	1143	1146		
X (m)	0,00	X (m)	0,00	X (m)	0,00										
Y (m)	-53,25	Y (m)	-17,85	Y (m)	-70,10										
Z (m)	4,65	Z (m)	-20,00	Z (m)	-20,00										

Navigation:

Software:	NaviPac
Projection:	UPS North
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378137	Longitude at Origin	-25° 0' 0.0"
Inverse flattening:	298,257224	Latitude at Orgin	81° 07' 0.0"
Scale at Origin	0,994	False easting (m):	2000000
		False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. two Sercel G gun
Serial no. G-Gun:	4696
Volume G (cu.inch):	520
Serial no. G-Gun:	46914
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (xx mS)**
Pressure (bar):	180
Planned depth (m):	20

Seismic Instruments:

Type:	Geometrics GeoEel contoller
Lowcut filter (Hz):	out
Lowcut filt. (dB/Oct):	out
Highcut filter (Hz):	anti-alias
Highcut filt. (dB/Oct):	anti-alias
Gain Setting (dB):	0
Sample Rate (ms):	1
Record Length (ms):	12000
No of recording chs:	32
No of auxilliary chs:	8
Software version	5.43
SPSU Serial No	PS1073

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	83
Length of live section (m):	200
No. of live sections:	4
No. of channels:	32
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	S1098
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	RP1105
Planned depth (m):	20

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint

Streamer depth scanned every 2 sec, one by one - means 8 sec in total

***(front of section)

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Cruise: LOMROG 3			**Ship:** IB Oden			**Location:** Arctic Ocean				**Page:** 1	
Line ID	**Date** d-m-y	**SOL/EOL**	**H:M UTC**	**Start/End** Latitude N	Longitude E/W(-)	**Remarks gun/streamer depths**	**Data storage** LTO-2	USB HDD	HDD	Navigation	**Navipac**
1	06-08-2012	123	12:41	° ′	° ′	SOL, Gun depth transducer not showing prober depth	100	F:\lomrog 3\line1	E:\lomrog 3\lin1	20120806 _124111_ C	123
		230	13:06	° ′	° ′	Gun transducer appear to be up and running and giving a correct depth, streamer appears to behave well					230
		246	13:09	° ′	° ′	Gun transducer depth shows the set 20 m					246
		313		° ′	° ′	Geometrics Leakage jumps to 50 but comes down again					
		400	13:46	° ′	° ′	Leakage jumping rapidly					
		406	13:47	° ′	° ′	EOL, Line terminated due to streamer leakage					407
1A	06-08-2012	409	14:48	° ′	° ′	SOL, gun and streamer towed deep, jumpers between umbilical and streamer removed prior to line start	101	F:\lomrog 3\1a	E:\lomrog 3\1a	20120806 _144823_ C	409
		487	15:06	° ′	° ′	gun and streamer at correct depth and speed increased					487
			15:26	° ′	° ′	High noise levels on front section from ships propeller					
		1174	17:47	° ′	° ′	High noise level due to engine noise					
		1193	17:51	° ′	° ′	Noise level reduced due to less stress on ship engines					
		1275	18:10	° ′	° ′	No navigation from Navipac, no gyro					
		1294	18:14	° ′	° ′	Navigation from NaviPac up again					

		1307	18:18		°		′		°		′	Leakage jumping to 20-60					
		1321			°		′		°		′	Leakage coming down to 10 and stays there					
		1362	18:30		°		′		°		′	EOL, streamer showing high leakage values after last shot					1363
					°		′		°		′						
					°		′		°		′						

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Cruise:	LOMROG 3	Ship:	IB Oden	Location:	Arctic Ocean	Page:	1/

Line ID	Date d-m-y	SOL/EOL	H:M UTC	Start/End Latitude N	Start/End Longitude E/W(-)	Remarks gun/streamer depths	Data storage LTO-2	Data storage USB HDD	Data storage HDD	Data storage Navigation	Navipac
2	07-08-2012	101	08:38	° ´	° ´	SOL, low pressure on guns or	102	F:\lomrog 3\2	E:\lomrog3	20120807 _083550_ C	1365
		107	08:40	° ´	° ´	Trigger threshold exceeded					
		108	08:41	° ´	° ´	Trigger threshold exceeded					
		113	08:43	° ´	° ´	Both guns firing					
		207	09:06	° ´	° ´	Leakage alarm					
		264	09:19	° ´	° ´	Leakage alarm, keeping high values 300-400, turbulent conditions from the ice					
		280	09:23	° ´	° ´	Leakage alarm, keeping high values 300-400, turbulent conditions from the ice					
		290	09:25	° ´	° ´	Leakage alarm, keeping high values 500-600, turbulent conditions from the ice					
		312	09:30	° ´	° ´	General leakage level is lowering from SP 290					
		318	09:32	° ´	° ´	Leakage alarm, leakage level is rising 600-700					
		340	09:37	° ´	° ´	Depth sensors on two first sections appear not to be updated					
		346	09:38	° ´	° ´	Leakage maintains a high leakage level of 1000					
		354	09:40	° ´	° ´	Leakage level reached its maximum and stays there					

		374	09:45		°		´		°		´	Second depth sensor is updating, only first depth sensor not updating					
		401	09:51		°		´		°		´	First depth sensor manualy updated and comes in with updated depth and continues to update, streamer behaves well in the water, gun pressure around 190 bar					
		434	09:59		°		´		°		´	Gun pressure slightly raised to 194 bar, max leakage level maintained since SP 354					
		459	10:05		°		´		°		´	Gun pressure around 189-190 bar					
		543	10:24		°		´		°		´	Gun at 12.2 m, but coming down again					
		590	10:35		°		´		°		´	Speed dropped and gun drops to 27,2 m, due to ice conditions					
		614	10:41		°		´		°		´	Gun drops to 26,4 m due to slow ship speed due to sonobuoy deployment					
		627	10:44		°		´		°		´	Sonobuoy deployed and vessel speed increases and gun and streamer comes up					
		712	11:03		°		´		°		´	Little noise due to ice					
		754	11:13		°		´		°		´	Noisy data due to ice conditions and ship noise, streamer was carried shallow but comes down again					

		770	11:17		°		´		°		´	Streamer is now down at the right depth and data looks better					
		800	11:24		°		´		°		´	Vessel hits ice and induces noise in data					
		809	11:26		°		´		°		´	Noisy data due to ice conditions and ship noise					
		819	11:28		°		´		°		´	Leakage drops to 030, has been at its max since shot 354					
		865	11:39		°		´		°		´	Leakage values raised to 700 800					
		869	11:40		°		´		°		´	Leakage alarm, but drops to 400-500					
		884	11:43		°		´		°		´	Leakage alarm, but drops to 200-300					
		892	11:45		°		´		°		´	Leakage alarm, value shows max value and stays there					
		917	11:51		°		´		°		´	Leakage alarm, the value fluctuates					
		978	12:05		°		´		°		´	Noise on the near channels, very slow vessel speed less than 1 knt, gun deep and streamer deep					
		1000	12:10		°		´		°		´	EOL, no shooting from gun due to no vessel speed, heavy ice. Over current alarm, deadman to gun pulled. Stop acquisition					2297

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Cruise: LOMROG 3 **Ship:** IB Oden **Location:** Arctic Ocean **Page:** 1

Line ID	Date d-m-y	SOL/EOL	H:M UTC	Start/End Latitude N	Start/End Longitude E/W(-)	Remarks gun/streamer depths	Data storage LTO-2	Data storage USB HDD	Data storage HDD	Data storage Navigation	Navipac
3	07-08-2012	101	21:25	° ′	° ′	SOL, Offset changed to 17,85 m in NaviPac at the start of the survey, changed depth transducers and streamer sections, stretch section and AD converteres, problem with repeater section spotted during deployment of streamer and repeater changed.	103	F:\lomrog3\3	E:\lomrog3\3	20120807_212337_C	101
	07-08-2012	107	21:29	° ′	° ′	EOL, line terminated due to software problems with Geometrics controller.					125
				° ′	° ′						
				° ′	° ′						
				° ′	° ′						
				° ′	° ′						
				° ′	° ′						

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Cruise: LOMROG 3	Ship: IB Oden			Location: Arctic Ocean						Page: 1

Line ID	Date d-m-y	SOL/EOL	H:M UTC	Start/End Latitude N	Start/End Longitude E/W(-)	Remarks gun/streamer depths	Data storage LTO-2	Data storage USB HDD	Data storage HDD	Data storage Navigation	Navipac
4	07-08-2012	101	21:34	° ′	° ′	SOL	103	F:\lomrog 3\4	E:\lomrog 3\4	20120807 _213451_ C	127
		143		° ′	° ′	Ship noise on the next few shots					
		308		° ′	° ′	Gun is not within the 1 ms sync, but comes back in the next shots					
		405	22:46	° ′	° ′	Depth sensors on the two first sections doesn't seem to update					
		449	22:56	° ′	° ′	Depth sensors on the two firrst sections now updating					
	08-08-2012	788	00:15	° ′	° ′	EOL, last ten shots noisy due to ship noise from breaking the ice in front of ship					815
				° ′	° ′						
				° ′	° ′						

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Cruise: LOMROG 3 **Ship:** IB Oden **Location:** Arctic Ocean **Page:** 1

Line ID	Date d-m-y	SOL/EOL	H:M UTC	Start/End Latitude N	Start/End Longitude E/W(-)	Remarks gun/streamer depths	Data storage LTO-2	Data storage USB HDD	Data storage HDD	Data storage Navigation	Navipac
5	17-08-2012	101	08:35	° ′	° ′	SOL, low pressure on gun - only one gun firing	104	F:\lomrog 3\0005	E:\lomrog 3\0005	20120817 _083457_ C	106
		148	08:46	° ′	° ′	EOL - second gun never coming up. Survey stopped.Gun and streamer pulled up.Gun tested, not working and changed					154
				° ′	° ′						
5a	17-08-2012	149	12:20	° ′	° ′	SOL	105	F:\lomrog 3\0005a	E:\lomrog 3\0005a	20120817 _122001_ C	157
		248	12:43	° ′	° ′	EOL, survey stopped due to heavy ice - Oden can't move forward					256
				° ′	° ′						
				° ′	° ′						
5b	17-08-2012	249	14:37	° ′	° ′	SOL	106	F:\lomrog 3\0005b	E:\lomrog 3\0005b	20120817 _143727_ C	258
		338	14:58	° ′	° ′	EOL,survey stopped due to losing gun and leakage - encounter with ice.					348
				° ′	° ′						

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Cruise: LOMROG 3 **Ship:** IB Oden **Location:** Arctic Ocean **Page:** 1

Line ID	Date d-m-y	SOL/EOL	H:M UTC	Start/End Latitude N	Start/End Longitude E/W(-)	Remarks gun/streamer depths	Data storage LTO-2	Data storage USB HDD	Data storage HDD	Data storage Navigation	Navipac
6	21-08-2012	101	07:14	° ´	° ´	SOL	107	F:\lomrog 3\0006	E:\lomrog 3\0006	20120821 _071420_ C	101
		121	07:20	° ´	° ´	EOL, leakage alarm gone					125
				° ´	° ´						
6c	21-08-2012	101	08:26	° ´	° ´	SOL					150
		103	08:26	° ´	° ´	EOL, leakage alarm gone	107	F:\lomrog 3\0006b	E:\lomrog 3\0006b	_082528_ C	156
				° ´	° ´						
6d	21-08-2012	101	12:14	° ´	° ´	Strecth section changed from S1100 to S1098 and 1st ADR changed to 1142, lekage, ADR changed to 1480	107	F:\lomrog 3\0006d	E:\lomrog 3\0006d	20120821 _121422_ C	175
		403	13:25	° ´	° ´	Ship noise increasing, difficult ice, pressure on air gun slowly decreasing to 175 bar					
		442	13:34	° ´	° ´	Pressure on guns increasing to 185-190 bar					
		655	14:23	° ´	° ´	Pressure going down to 176 bar					
		678	14:29	° ´	° ´	Pressure up again 190 bar after LGR has checked Bauer					
		1090	16:05	° ´	° ´	Pressure going dowm to 177 bar					
		1121	16:12	° ´	° ´	Pressure up again 193 bar after SE has checked Bauer					
		1613	18:07	° ´	° ´	EOL					1687

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Cruise: LOMROG 3	Ship: IB Oden	Location: Arctic Ocean	Page: 1/

Line ID	Date d-m-y	SOL/EOL	H:M UTC	Start/End Latitude N	Start/End Longitude E/W(-)	Remarks gun/streamer depths	Data storage LTO-2	Data storage USB HDD	Data storage HDD	Data storage Navigation	Navipac
7	28-08-2012	101	07:03	° ´	° ´	Shot 158 missed due to brute stack setup	108	F:\\lomrog3\0007	E:\\lomrog3\0007	20120828_070325_	101
				° ´	° ´	Shot 392 trigger alarm exceeded					
		1839	13:49	° ´	° ´						1840
				° ´	° ´						

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Cruise: LOMROG 3 | **Ship:** IB Oden | **Location:** Arctic Ocean | **Page:** 1/

Line ID	**Date** d-m-y	**SOL/EOL**	**H:M UTC**	**Start/End** Latitude N	Longitude E/W(-)	**Remarks gun/streamer depths**	**Data storage** LTO-2	USB HDD	HDD	Navigation	**Navipac**
8	29-08-2012	101	03:01	° ´	° ´		109	F:\\lomrog3\0008	E:\\lomrog3\0008	20120829_030120_C	101
		271		° ´	° ´	Gun 6714 file number = SP 271					
		291	03:46	° ´	° ´	Pressure down, compressor down, pressure down to 125 bar					
		381	04:07	° ´	° ´	Pressure coming up					
		404	04:12	° ´	° ´	Pressure up to 188 bar					
		835	05:52	° ´	° ´	Leakage is rising to 100-300					
		1332	07:48	° ´	° ´						1333
				° ´	° ´						

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Cruise: LOMROG 3 | **Ship:** IB Oden | **Location:** Arctic Ocean | **Page:** 1

Line ID	Date d-m-y	SOL/EOL	H:M UTC	Start/End Latitude N		Start/End Longitude E/W(-)		Remarks gun/streamer depths	Data storage LTO-2	USB HDD	HDD	Navigation	Navipac
9	30-08-2012	101	03:52	°	´	°	´	First 30 shots with low gun pressure due to one compressor not working	110	F:\\lomrog3\0009	E:\\lomrog3\0009	20120830_035226_C	103
		289	04:37	°	´	°	´	Gun surfacing SP 289-291					
		553	05:39	°	´	°	´	SP 553 = 8230 in gun shot					
				°	´	°	´	8255 (gun 2 >2 ms out of sync) and 8256 sync ok. Check SEGY file					
		1646	09:53	°	´	°	´	EOL					1648
				°	´	°	´						

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Cruise: LOMROG 3 **Ship:** IB Oden **Location:** Arctic Ocean **Page:** 1

Line ID	Date d-m-y	SOL/EOL	H:M UTC	Start/End Latitude N	Start/End Longitude E/W(-)	Remarks gun/streamer depths	Data storage LTO-2	Data storage USB HDD	Data storage HDD	Data storage Navigation	Navipac
10	30-08-2012	101	23:05	° ´	° ´	SOL, Shot no 9324 on TGS-8, starting with a high leakage value	111	F:\\lomrog3\0010	E:\\lomrog3\0010	20120830_230525_C	101
		240		° ´	° ´	Gun out of water 240 - 242					
		527		° ´	° ´	Depth transducers up and running after having been gone for 20 shots					
		587		° ´	° ´	Depth transducers not stabile for the last 3 shots					
		604		° ´	° ´	Depth transducers are unstable					
		623		° ´	° ´	Very noisy data, rough ice conditions					
		644		° ´	° ´	Depth transducers unstable					
		669		° ´	° ´	High leakage and trancducers not working, trying to get them started again but no success					
		950		° ´	° ´	Transducers stuck, trying to get them started again					
		965		° ´	° ´	Transducers up and running					
		998		° ´	° ´	Transducers stuck, trying to get them started again, no luck					
		1004		° ´	° ´	Visual on sonobouy					

		1055	02:47		°		´		°		´	EOL, line terminated early due to PC and SPSU problems. Restart of PC and line continued as 10a					1052
					°		´		°		´						
10A	31-08-2012	101	02:59		°		´		°		´	SOL, Shot no 9324 on TGS-8, starting with a high leakage value	112	F:\\lomrog3\0010a	E:\\lomrog3\0010a	20120831_025852_C	1055
		216	03:25		°		´		°		´	EOL, line terminated early due to PC and SPSU problems. Streamer and gun pulled out of water					1168
10B		101			°		´		°		´	This line number skipped due to compressor problem, no shots fired					
10C		101			°		´		°		´	This line number skipped due to CNT-2 problem, no shots fired					
					°		´		°		´						
10D	31-08-2012	101	07:28		°		´		°		´	SOL	113	NO USB	E:\\lomrog3\0010d	20120831_072849_C	101
		270	08:08		°		´		°		´	EOL, Oden stuck in ice					272
					°		´		°		´						
					°		´		°		´						

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Cruise: LOMROG 3 | **Ship:** IB Oden | **Location:** Arctic Ocean | **Page:** 1

Line ID	Date d-m-y	SOL/EOL	H:M UTC	Start/End Latitude N	Start/End Longitude E/W(-)	Remarks gun/streamer depths	Data storage LTO-2	Data storage USB HDD	Data storage HDD	Data storage Navigation	Navipac
11	01-09-2012	1	06:27	° ´	° ´	SOL, only one gun working trying to get it to fire	114	No USB	E:\\lomrog3\0011	20120901_062618_	104
		26	06:34	° ´	° ´	EOL no success with gun, terminating line					138
				° ´	° ´						
11B	01-09-2012	101	07:41	° ´	° ´	SOL	115	NO USB	E:\\lomrog3\0011B	20120901_074041_C	140
		191		° ´	° ´	ice under gun and streamer, gun lifted on shots 191 to 195					
		226		° ´	° ´	heavy ice ahead					
		389		° ´	° ´	gun carried up by ice, streamer on the ice					
		912		° ´	° ´	gun at around 2m					
		1066		° ´	° ´	gun at around 6 m					
		1193	11:55	° ´	° ´	EOL					1233
				° ´	° ´						
				° ´	° ´						

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Cruise: LOMROG 3 | **Ship:** IB Oden | **Location:** Arctic Ocean | **Page:** 1

Line ID	Date d-m-y	SOL/EOL	H:M UTC	Start/End Latitude N				Start/End Longitude E/W(-)				Remarks gun/streamer depths	Data storage LTO-2	Data storage USB HDD	Data storage HDD	Data storage Navigation	Navipac
12	01-09-2012	101	22:07		°		´		°		´	SOL, shot 14664 on TGS-8	116	No USB	E:\\lomrog	220753_C	101
		260			°		´		°		´	Leakage rising, but data looks fine					
		329			°		´		°		´	Leakage alarm, but data looks fine					
		904	01:15		°		´		°		´	EOL					904
					°		´		°		´						

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Cruise: LOMROG 3	Ship: IB Oden	Location: Arctic Ocean	Page: 1

Line ID	Date d-m-y	SOL/EOL	H:M UTC	Start/End Latitude N				Start/End Longitude E/W(-)				Remarks gun/streamer depths	Data storage LTO-2	USB HDD	HDD	Navigation	Navipac
13	02-09-2012	101	16:38		°		′		°		′	SOL	117	No USB	E:\\lomrog3\0013	20120902_163736_C	101
		119			°		′		°		′	Shot no 15488 on TGS-8					
		550			°		′		°		′	Leakage alarm					
		592			°		′		°		′	Leakage alarm					
		610			°		′		°		′	Gun out of water and streamer towed shallow for the next 10 shots					
		959										Shot no 16328 on TGS-8					
		969			°		′		°		′	Leakage alarm					
		1060	20:21		°		′		°		′	EOL					1062
					°		′		°		′						
					°		′		°		′	Jumper #2 replaced with jumper #3 after EOL and streamer onboard					
					°		′		°		′						
					°		′		°		′						

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Cruise: LOMROG 3	**Ship:** IB Oden	**Location:** Arctic Ocean	**Page:** 1/

Line ID	**Date** d-m-y	**SOL/EOL**	**H:M UTC**	**Start/End** Latitude N	Longitude E/W(-)	**Remarks gun/streamer depths**	**Data storage** LTO-2	USB HDD	HDD	Navigation	**Navipac**
14	03-09-2012	101	10:16	° ´	° ´	SOL	118	No USB	E:\\lomrog3\0014	20120903_101622_C	101
		104		° ´	° ´	Shooting stopped due to deployment of sonobouy					106
				° ´	° ´						
		105	10:18	° ´	° ´	SOL	118			20120903_101844_C	105
		808		° ´	° ´	gun towed shallow 6m, streamer towed shallow the next 10 shots					
		1200				heavy ice conditions ahead					
		1319		° ´	° ´	gun towed shallow 6m, streamer towed shallow the next 10 shots					
		1390		° ´	° ´	Leakage alarm, leakage generally rising					
		1467		° ´	° ´	gun towed at 1.5 m					
		1470		° ´	° ´	gun towed at 4m					
		1487		° ´	° ´	Leakage alarm, leakage generally rising					
		1517	15:48	° ´	° ´	EOL					1520
				° ´	° ´						

E:\NaviPac_Data\NaviPac_logs\Lomrog3\YYMMDD\xxxx_C
Time is in UTC

Cruise: LOMROG 3 | **Ship:** IB Oden | **Location:** Arctic Ocean | **Page:** 1

Line ID	**Date** d-m-y	**SOL/EOL**	**H:M UTC**	**Start/End** Latitude N	Longitude E/W(-)	**Remarks gun/streamer depths**	**Data storage** LTO-2	USB HDD	HDD	Navigation	**Navipac**
15	04-09-2012	101	07:43	° ′	° ′	SOL, TGS-8 shot no 17852	114	No USB	E:\\lomrog3\0015	20120904_074253_C	101
		102		° ′	° ′	Only gun 2 shooting					
		103		° ′	° ′	All guns shooting, gun 1 out of sync for the next 10 shots					
		162		° ′	° ′	Bauer compressor defect first stage valve, but still shooting at lower pressure170-175 bar					
		257		° ′	° ′	Guns out of sync, still shooting at lower pressure 170 bar					
		297				Pressure back up to 185-					
		1501		° ′	° ′	gun towed at 9 m, heavy ice conditions in the track					
		1527		° ′	° ′	TGS-8 shot no 19278					
		1549	13:21	° ′	° ′	EOL					1550
				° ′	° ′						
				° ′	° ′						

E:\NaviPac_Data\NaviPac_logs\Lomrog3\YYMMDD\xxxx_C
Time is in UTC

Cruise: LOMROG 3	Ship: IB Oden	Location: Arctic Ocean	Page: 1

Line ID	Date d-m-y	SOL/EOL	H:M UTC	Start/End Latitude N		Start/End Longitude E/W(-)		Remarks gun/streamer depths	Data storage LTO-2	Data storage USB HDD	Data storage HDD	Data storage Navigation	Navipac
16	05-09-2012	1001	01:00	°	′	°	′	SOL, TGS-8 shot no 19303, ship running on all 4 engines	105	No USB	E:\\lomrog3\0016	20120905_010017_C	1001
		1020		°	′	°	′	Pressure coming up to 190 bar					
		1444		°	′	°	′	Heavy ice conditions, very noisy data					
		1464		°	′	°	′	Last two streamer sections towed very shallow, 5-8 m					
		1477		°	′	°	′	Gun towed at 7 m					
		1480						Gun towed at 7 m and streamer towed shallow less than 10 m					
		1688		°	′	°	′	Gun towed at 5 m, streamer towed shallow less than 10 m					
		1745	03:54	°	′	°	′	EOL, line terminated early due to severe ice conditions					1745
				°	′	°	′						
				°	′	°	′						

E:\NaviPac_Data\NaviPac_logs\Lomrog3\YYMMDD\xxxx_C
Time is in UTC

Cruise: LOMROG 3 **Ship:** IB Oden **Location:** Arctic Ocean **Page:** 1

Line ID	Date	SOL/EOL	H:M	Start/End								Remarks	Data storage				Navipac
	d-m-y		UTC	Latitude N				Longitude E/W(-)				gun/streamer depths	LTO-2	USB HDD	HDD	Navigation	
17	05-09-2012	1001	15:15		°		´		°		´	SOL, TGS-8 shot no 20050	104	No USB	E:\\lomrog	151506_C	1001
		1329			°		´		°		´	TGS-8 shot no 20379					
		1599	17:35		°		´		°		´	EOL					1600
					°		´		°		´						
					°		´		°		´						

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Time is in UTC

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Cruise:		LOMROG 3	
Tape	100	Writen to tape: 11/09/12	
Line	Acq. Date	Start File No	End File No
1	06-08-2012	101	406
1A	06-08-2012	409	1362
2	07-08-2012	101	1000
4	07-08-2012	101	788
5	17-08-2012	101	148
5a	17-08-2012	149	248
5b	17-08-2012	249	338
6	21-08-2012	101	121
6d	21-08-2012	101	1613
7	28-08-2012	101	1839
8	29-08-2012	101	1332
9	30-08-2012	101	1646
10	31-08-2012	101	1056
10A	31-08-2012	101	216
10D	31-08-2012	101	270
11	01-09-2012	1	29
11B	01-09-2012	101	1193
12	01-09-2012	101	904
13	02-09-2012	101	1060
14	03-09-2012	101	1517
15	04-09-2012	101	1549
16	05-09-2012	1001	1745
17	05-09-2012	1001	1599

Tape Inventory Log

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Appendix IV: Configuration of the Geometrics GeoEel streamer

LOMROG III 2012 - Geometrics streamer configuration and serial numbers

Schematic showing the serial numbers of the different elements of the Geometrics seismic acquisition system where ablicable. If other components have been changed which doesn't have serial numbers "changed" will occur in their respective boxes. The depth transduceres position on the streamer is indicated by which box is filled in under the active section.

Date: 06-08-2012 - LOMROG3 - 01 and 01A

Geometrics SPSU	Deck cable	Ship ring	Umbilical	Jumper	Tow cable	Repeater	Stretch section	ADC	1 active section		ADC	2 active section		ADC	3 active section		ADC	4 active section	
									Depth Trans			Depth Trans			Depth Trans			Depth Trans	
PS1071				Jumper#1		RP1083	S1101	1477	5004		1497	5015		1143	5016		1146	5010	

Date: 06-08-2012 - LOMROG3 - 02

Geometrics SPSU	Deck cable	Slip ring	Umbilical	Jumper	Tow cable	Repeater	Stretch section	ADC	1 active section		ADC	2 active section		ADC	3 active section		ADC	4 active section	
									Depth Trans			Depth Trans			Depth Trans			Depth Trans	
PS1071				Jumper#1		RP1105	S1101	1477	5004		1497	5015		1143	5016		1146	5010	

Date: 08-08-2012 - LOMROG3 - 03

Geometrics SPSU	Deck cable	Slip ring	Umbilical	Jumper	Tow cable	Repeater	Stretch section	ADC	1 active section		ADC	2 active section		ADC	3 active section		ADC	4 active section	
									Depth Trans			Depth Trans			Depth Trans				Depth Trans
PS1071				Jumper#2		RP1105	S1100	NA	5022		1675	5021		1674	5008		1481		5018

Date: 08-08-2012 - LOMROG3 - 04

Geometrics SPSU	Deck cable	Slip ring	Umbilical	Jumper	Tow cable	Repeater	Stretch section	ADC	1 active section		ADC	2 active section		ADC	3 active section		ADC	4 active section	
									Depth Trans			Depth Trans			Depth Trans				Depth Trans
PS1071				Jumper#2		RP1105	S1100	NA	5022		1675	5021		1674	5008		1481		5009

Date: 13-08-2012 - LOMROG3 - 05, 5a and 5b

Geometrics SPSU	Deck cable	Slip ring	Umbilical	Jumper	Tow cable	Repeater	Stretch section	ADC	1 active section		ADC	2 active section		ADC	3 active section		ADC	4 active section	
									Depth Trans			Depth Trans			Depth Trans				Depth Trans
PS1073				Jumper#2		RP1105	S1100	NA	5022		1675	5021		1142	5008		1481		5009

LOMROG III 2012 - Geometrics streamer configuration and serial numbers

Schematic showing the serial numbers of the different elements of the Geometrics seismic acquisition system where ablicable. If other components have been changed which doesn't have serial numbers "changed" will occur in their respective boxes. The depth transduceres position on the streamer is indicated by which box is filled in under the active section.

Date: 18-08-2012 - LOMROG3 - 06

Geometrics SPSU	Deck cable	Slip ring	Umbilical	Jumper	Tow cable	Repeater	Stretch section	ADC	1 active section		ADC	2 active section		ADC	3 active section		ADC	4 active section	
									Depth Trans			Depth Trans			Depth Trans				Depth Trans
PS1073				Jumper#2		RP1080	S1098	1480	5022		1675	5021		1142	5008		1481		5009

Date: 28-08-2012 - LOMROG3 - 07

Geometrics SPSU	Deck cable	Slip ring	Umbilical	Jumper	Tow cable	Repeater	Stretch section	ADC	1 active section		ADC	2 active section		ADC	3 active section		ADC	4 active section	
									Depth Trans			Depth Trans			Depth Trans				Depth Trans
PS1073				Jumper#2		RP1080	S1098	1480	5022		1675	5021		1142	5008		1481		5009

Date: 29-08-2012 - LOMROG3 - 08

Geometrics SPSU	Deck cable	Slip ring	Umbilical	Jumper	Tow cable	Repeater	Stretch section	ADC	1 active section		ADC	2 active section		ADC	3 active section		ADC	4 active section	
									Depth Trans			Depth Trans			Depth Trans				Depth Trans
PS1073				Jumper#2		RP1080	S1098	1480	5022		1675	5021		1142	5008		1481		5009

Date: 30-08-2012 - LOMROG3 - 09

Geometrics SPSU	Deck cable	Slip ring	Umbilical	Jumper	Tow cable	Repeater	Stretch section	ADC	1 active section		ADC	2 active section		ADC	3 active section		ADC	4 active section	
									Depth Trans			Depth Trans			Depth Trans				Depth Trans
PS1073				Jumper#2		RP1105	S1098	1480	5022		1675	5021		1142	5008		1481		5009

Date: 31-08-2012 - LOMROG3 - 10

Geometrics SPSU	Deck cable	Slip ring	Umbilical	Jumper	Tow cable	Repeater	Stretch section	ADC	1 active section		ADC	2 active section		ADC	3 active section		ADC	4 active section	
									Depth Trans			Depth Trans			Depth Trans				Depth Trans
PS1073				Jumper#2		RP1105	S1098	1480	5022		1675	5021		1142	5008		1481		5009

Date: 31-08-2012 - LOMROG3 - 10D

Geometrics SPSU	Deck cable	Slip ring	Umbilical	Jumper	Tow cable	Repeater	Stretch section	ADC	1 active section		ADC	2 active section		ADC	3 active section		ADC	4 active section	
									Depth Trans			Depth Trans			Depth Trans			Depth Trans	
PS1073				Jumper#2		RP1105	S1098	1477	5004		1497	5015		1143	5016		1146	5010	

LOMROG III 2012 - Geometrics streamer configuration and serial numbers

Schematic showing the serial numbers of the different elements of the Geometrics seismic acquisition system where ablicable. If other components have been changed which doesn't have serial numbers "changed" will occur in their respective boxes. The depth transduceres position on the streamer is indicated by which box is filled in under the active section.

Date: 01-09-2012 - LOMROG3 - 11

Geometrics SPSU	Deck cable	Ship ring	Umbilical	Jumper	Tow cable	Repeater	Stretch section	ADC	1 active section		ADC	2 active section		ADC	3 active section		ADC	4 active section	
									Depth Trans			Depth Trans			Depth Trans			Depth Trans	
PS1073				Jumper#2		RP1105	S1098	1477	5004		1497	5015		1143	5016		1146	5010	

Date: 01-09-2012 - LOMROG3 - 11B

Geometrics SPSU	Deck cable	Ship ring	Umbilical	Jumper	Tow cable	Repeater	Stretch section	ADC	1 active section		ADC	2 active section		ADC	3 active section		ADC	4 active section	
									Depth Trans			Depth Trans			Depth Trans			Depth Trans	
PS1073				Jumper#2		RP1105	S1098	1477	5004		1497	5015		1143	5016		1146	5010	

Date: 01-09-2012 - LOMROG3 - 12

Geometrics SPSU	Deck cable	Ship ring	Umbilical	Jumper	Tow cable	Repeater	Stretch section	ADC	1 active section		ADC	2 active section		ADC	3 active section		ADC	4 active section	
									Depth Trans			Depth Trans			Depth Trans			Depth Trans	
PS1073				Jumper#2		RP1105	S1098	1477	5004		1497	5015		1143	5016		1146	5010	

Date: 02-09-2012 - LOMROG3 - 13

Geometrics SPSU	Deck cable	Ship ring	Umbilical	Jumper	Tow cable	Repeater	Stretch section	ADC	1 active section		ADC	2 active section		ADC	3 active section		ADC	4 active section	
									Depth Trans			Depth Trans			Depth Trans			Depth Trans	
PS1073				Jumper#2		RP1105	S1098	1477	5004		1497	5015		1143	5016		1146	5010	

Date: 03-09-2012 - LOMROG3 - 14

Geometrics SPSU	Deck cable	Ship ring	Umbilical	Jumper	Tow cable	Repeater	Stretch section	ADC	1 active section		ADC	2 active section		ADC	3 active section		ADC	4 active section	
									Depth Trans			Depth Trans			Depth Trans			Depth Trans	
PS1073				Jumper#3		RP1105	S1098	1477	5004		1497	5015		1143	5016		1146	5010	

Date: 03-09-2012 - LOMROG3 - 15

Geometrics SPSU	Deck cable	Ship ring	Umbilical	Jumper	Tow cable	Repeater	Stretch section	ADC	1 active section		ADC	2 active section		ADC	3 active section		ADC	4 active section	
									Depth Trans			Depth Trans			Depth Trans			Depth Trans	
PS1073				Jumper#3		RP1105	S1098	1477	5004		1497	5015		1143	5016		1146	5010	

LOMROG III 2012 - Geometrics streamer configuration and serial numbers

Schematic showing the serial numbers of the different elements of the Geometrics seismic acquisition system where ablicable. If other components have been changed which doesn't have serial numbers "changed" will occur in their respective boxes. The depth transduceres position on the streamer is indicated by which box is filled in under the active section.

Date: 05-09-2012 - LOMROG3 - 16

Geometrics SPSU	Deck cable	Ship ring	Umbilical	Jumper	Tow cable	Repeater	Stretch section	ADC	1 active section		ADC	2 active section		ADC	3 active section		ADC	4 active section	
									Depth Trans			Depth Trans			Depth Trans			Depth Trans	
PS1073				Jumper#3		RP1105	S1098	1477	5004		1497	5015		1143	5016		1146	5010	

Date: 05-09-2012 - LOMROG3 - 17

Geometrics SPSU	Deck cable	Ship ring	Umbilical	Jumper	Tow cable	Repeater	Stretch section	ADC	1 active section		ADC	2 active section		ADC	3 active section		ADC	4 active section	
									Depth Trans			Depth Trans			Depth Trans			Depth Trans	
PS1073				Jumper#3		RP1105	S1098	1477	5004		1497	5015		1143	5016		1146	5010	

Appendix V-A:

Record Sections of all Sonobuoys

Shot-receiver offsets (horizontal scale) in the record sections are corrected for the drift of the sonobuoys. Vertical scale is the travel time reduced with a reduction velocity of 6.8 km/s.

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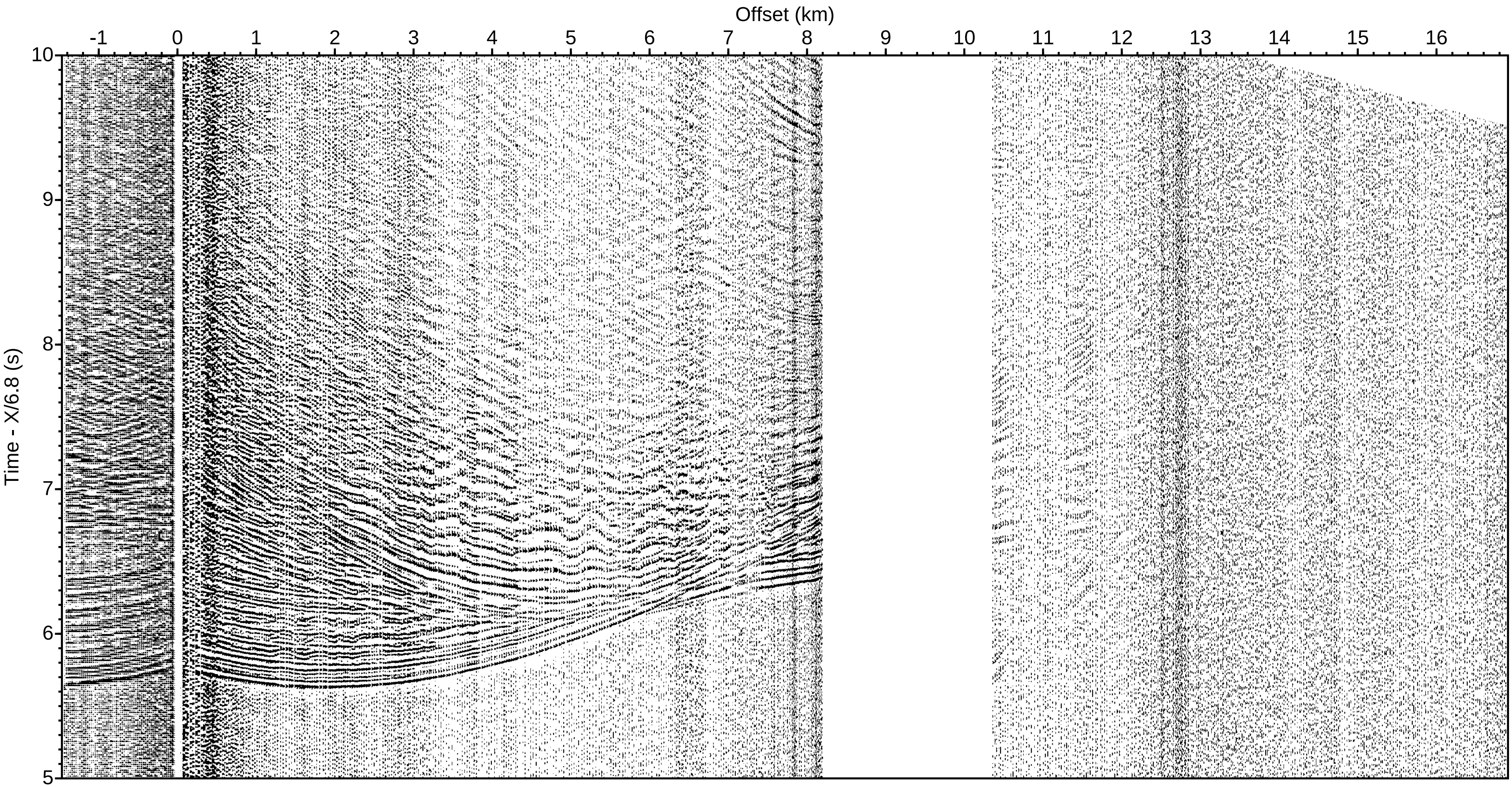
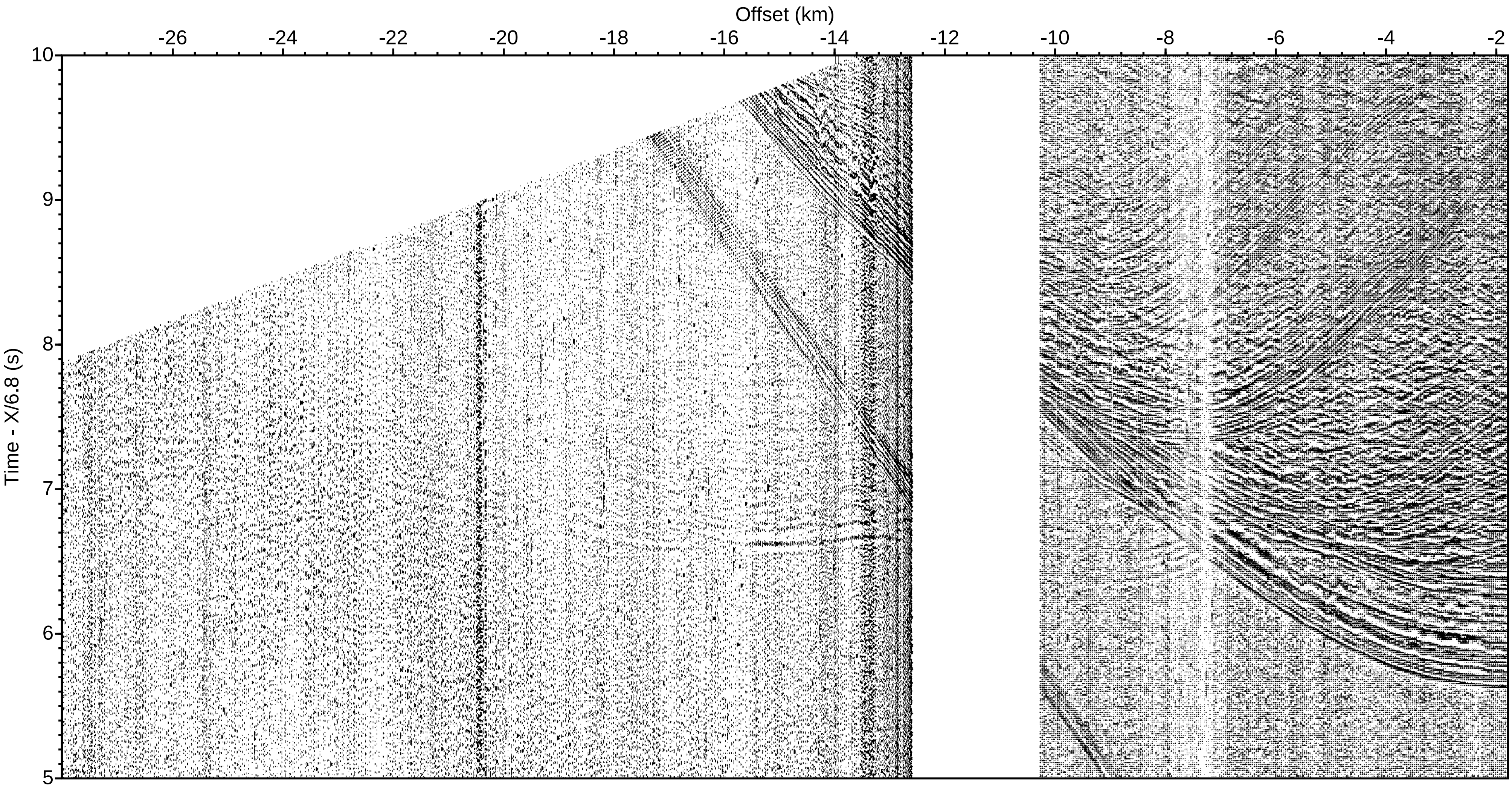
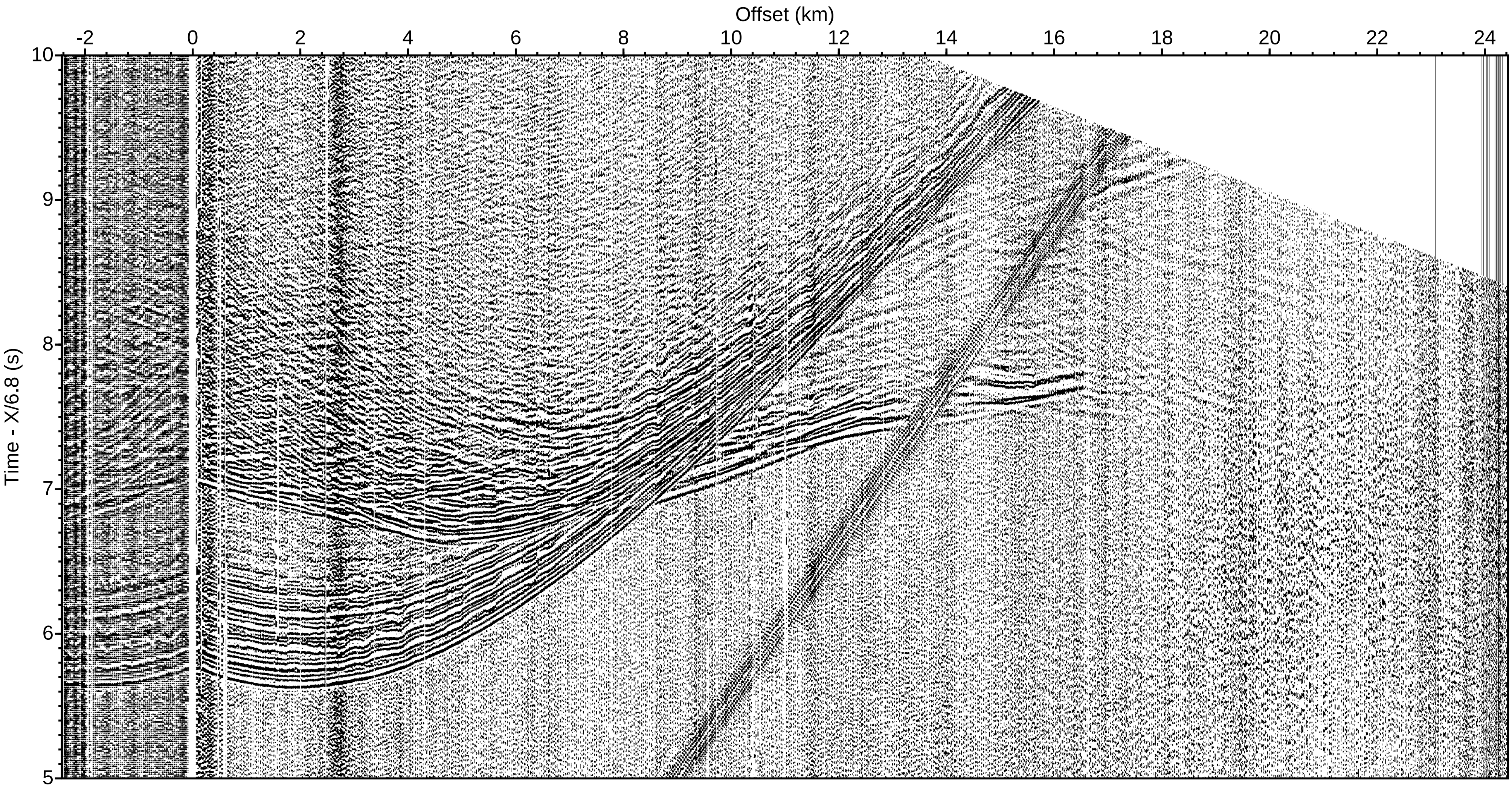


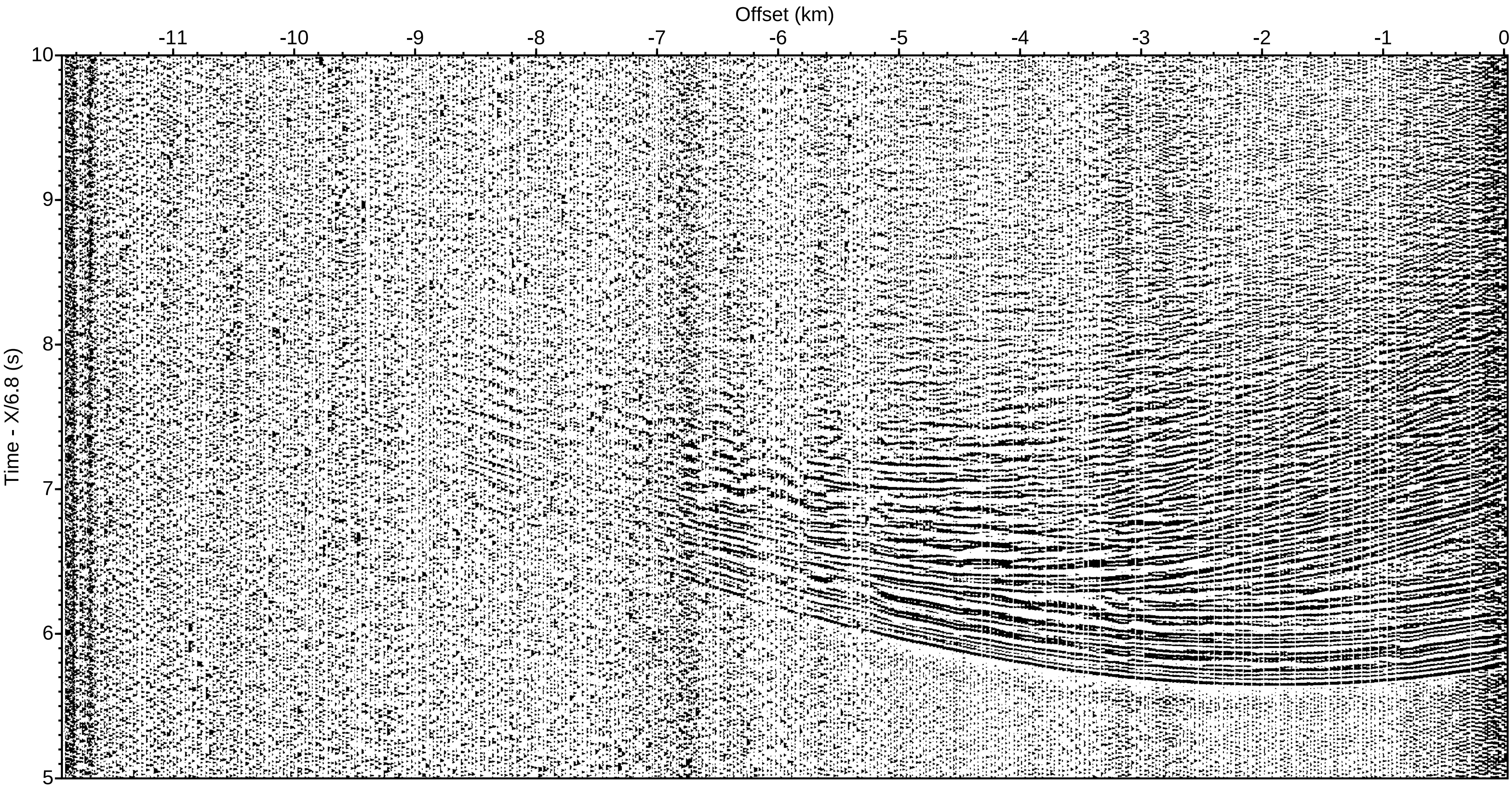
LOMROG III (2012) - Line 1 Sonobuoy 1-1 aux ch 4 (drift correction, deconv., bpf 5-40 Hz)



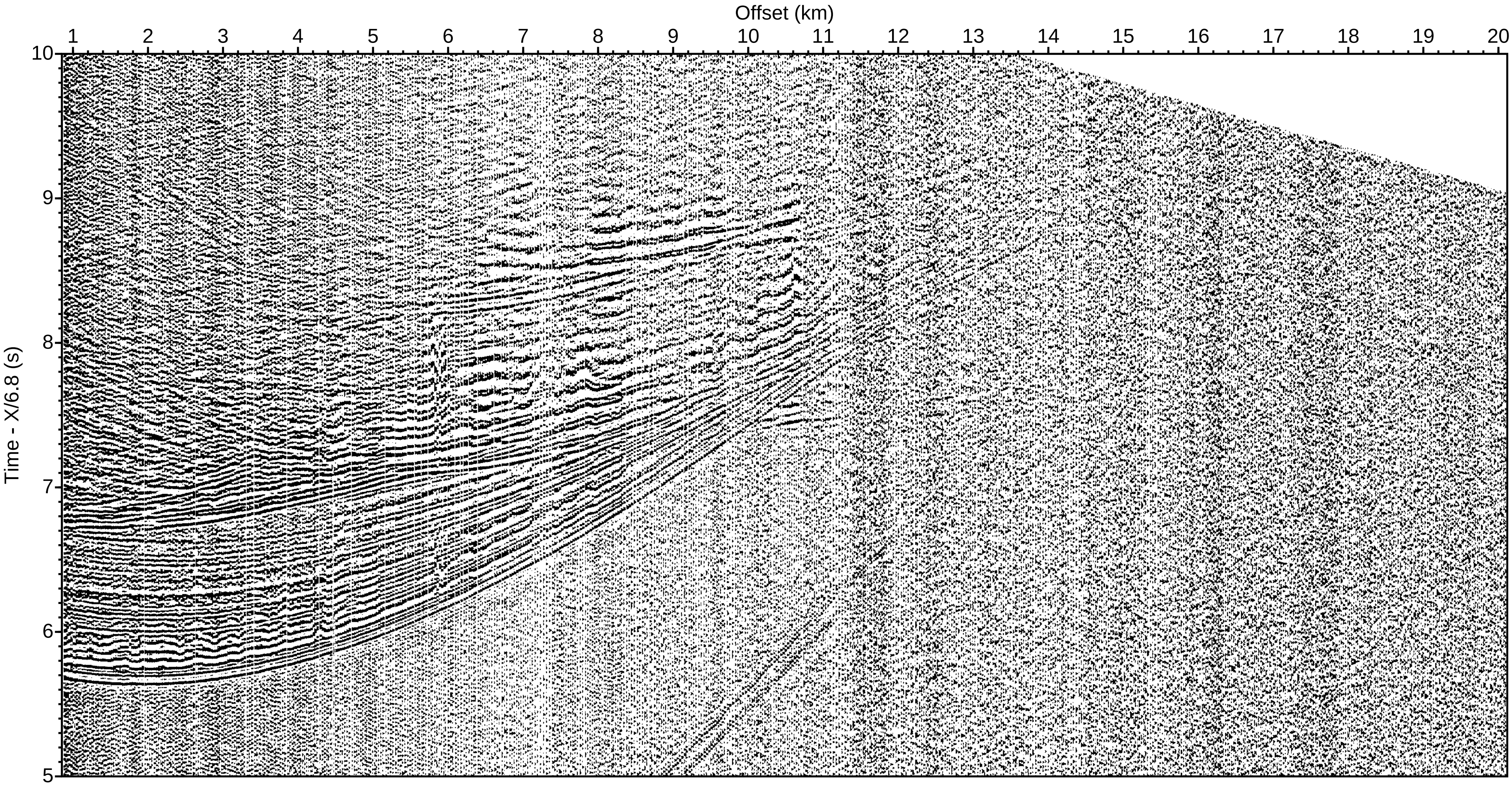
LOMROG III (2012) - Line 1 Sonobuoy 1-2 aux ch 1 (drift correction, deconv., bpf 5-40 Hz)



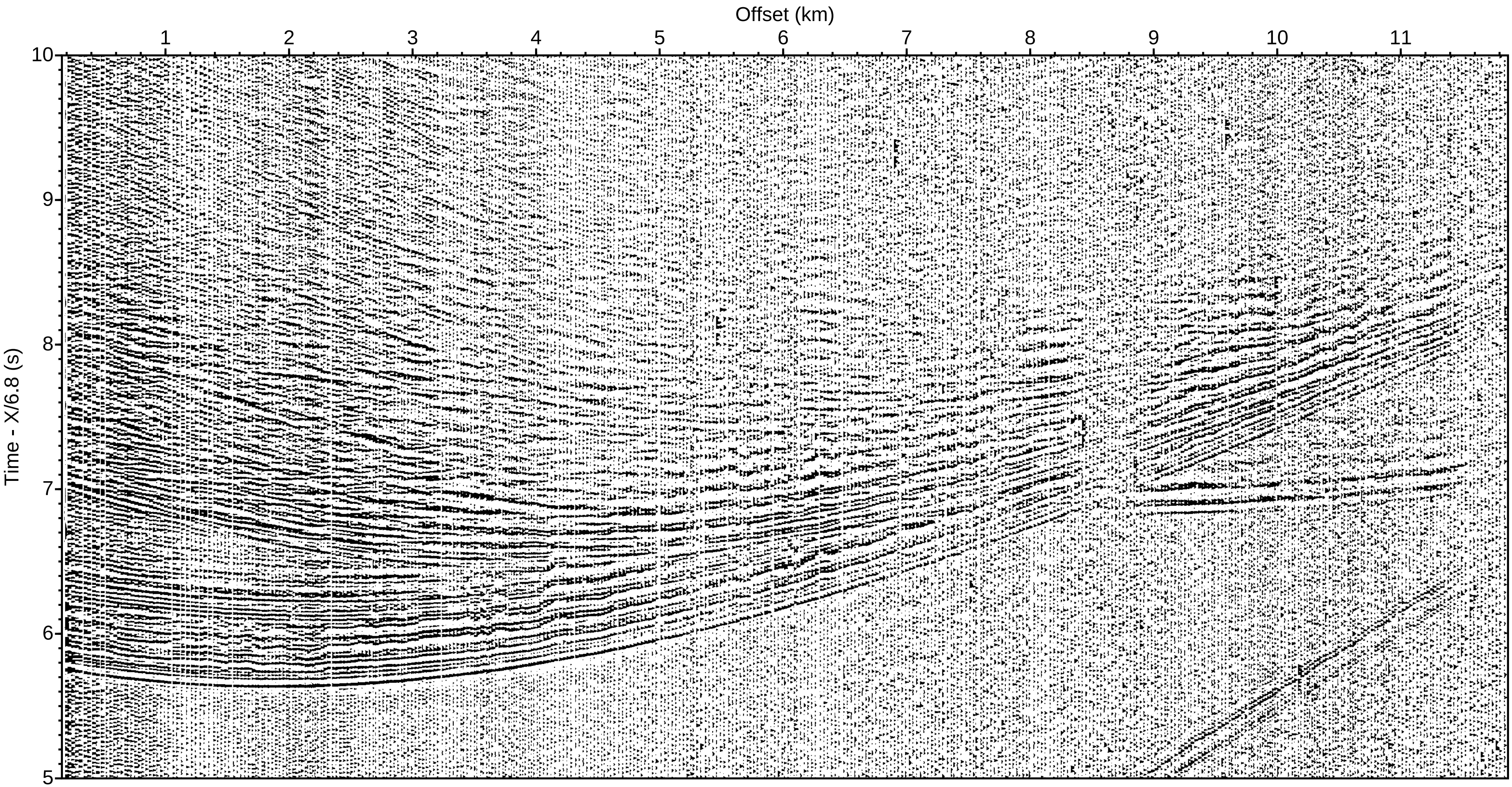
LOMROG III (2012) - Line 1 Sonobuoy 1-3 aux ch 3 (drift correction, deconv., bpf 5-40 Hz)



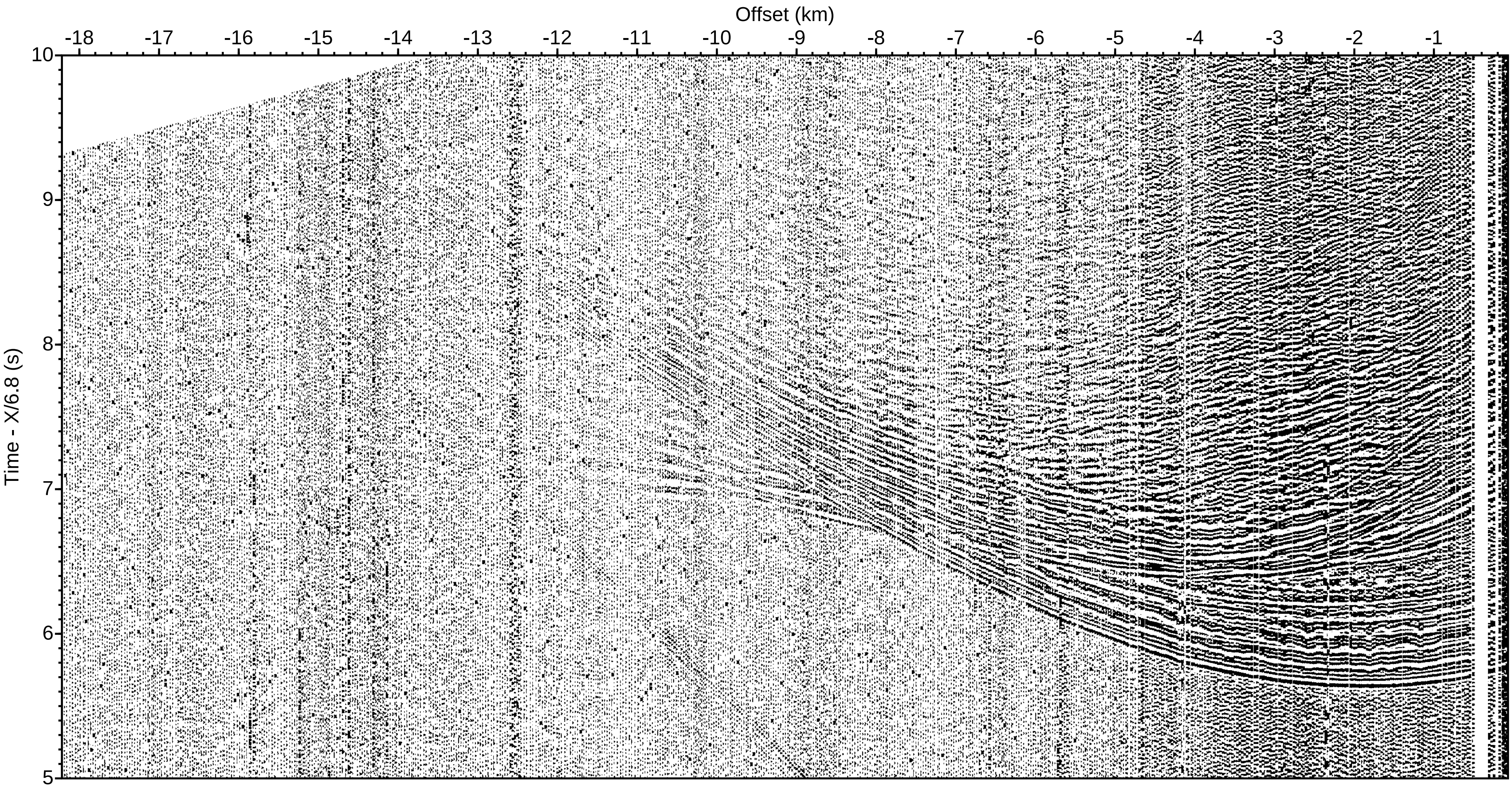
LOMROG III (2012) - Line 1 Sonobuoy 1-5 aux ch 4 (drift correction, deconv., bpf 5-40 Hz)



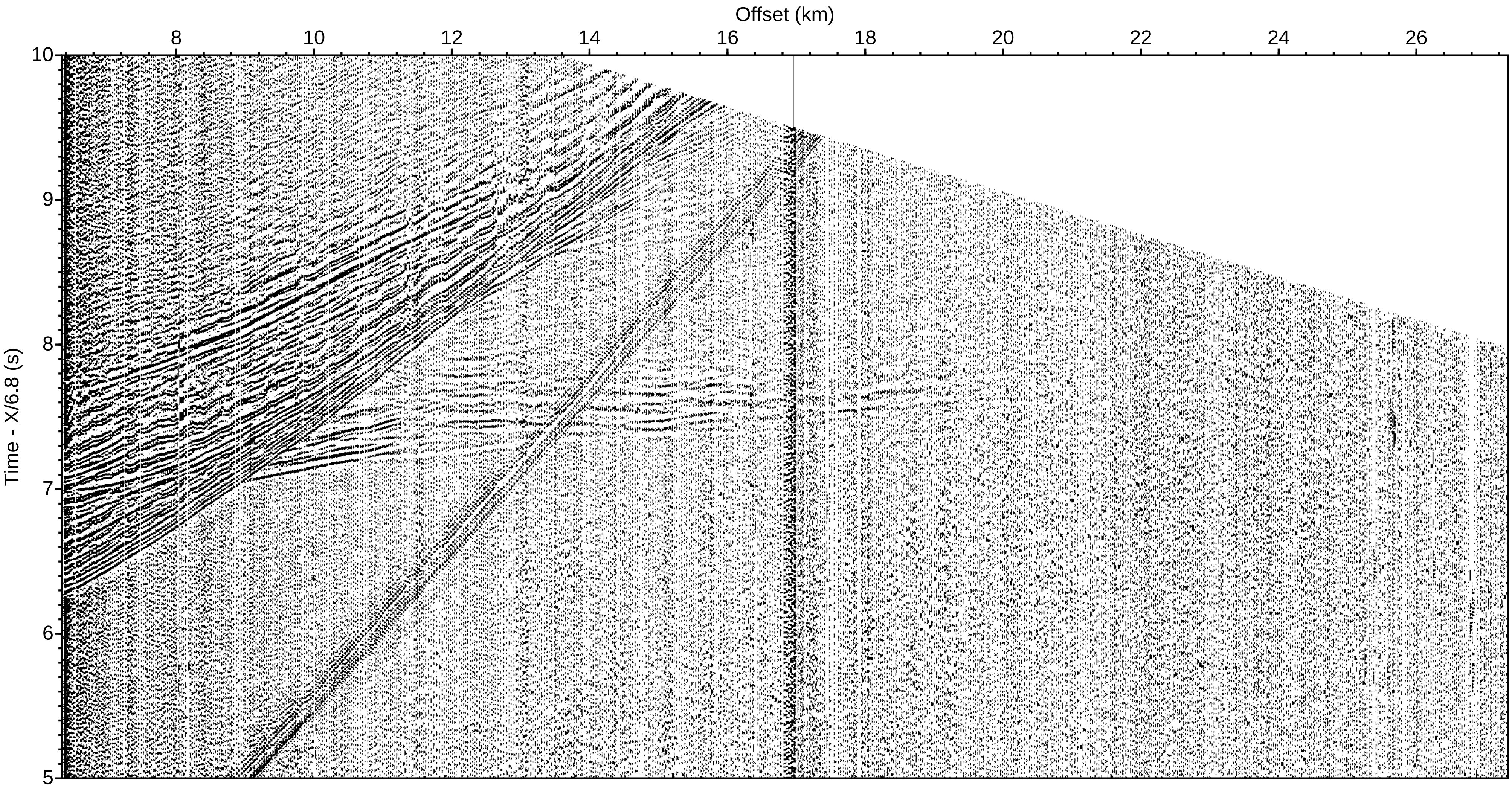
LOMROG III (2012) - Line 2 Sonobuoy 2-6 aux ch 4 (drift correction, deconv., bpf 5-40 Hz)



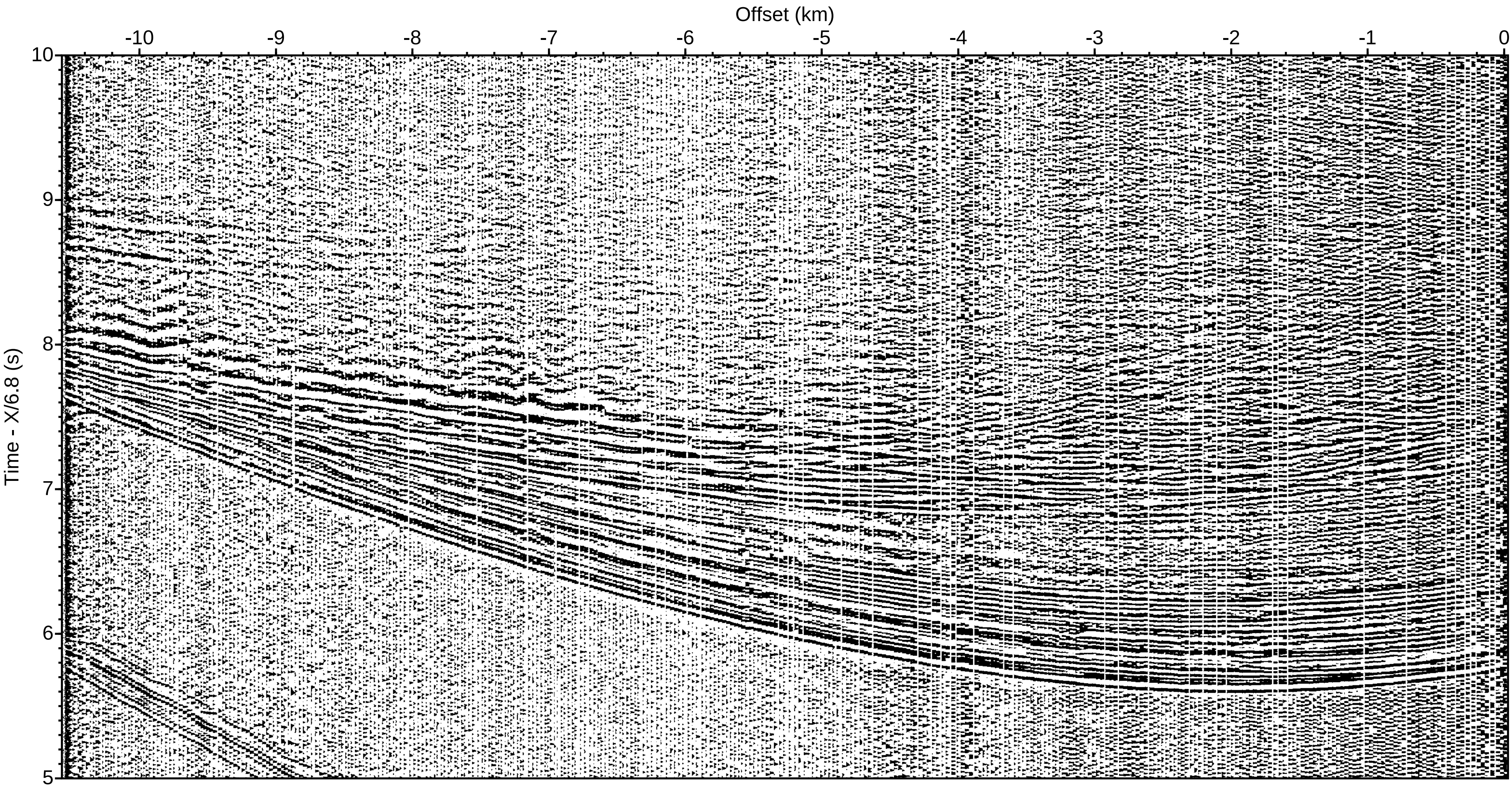
LOMROG III (2012) - Line 2 Sonobuoy 2-7 aux ch 3 (drift correction, deconv., bpf 5-40 Hz)



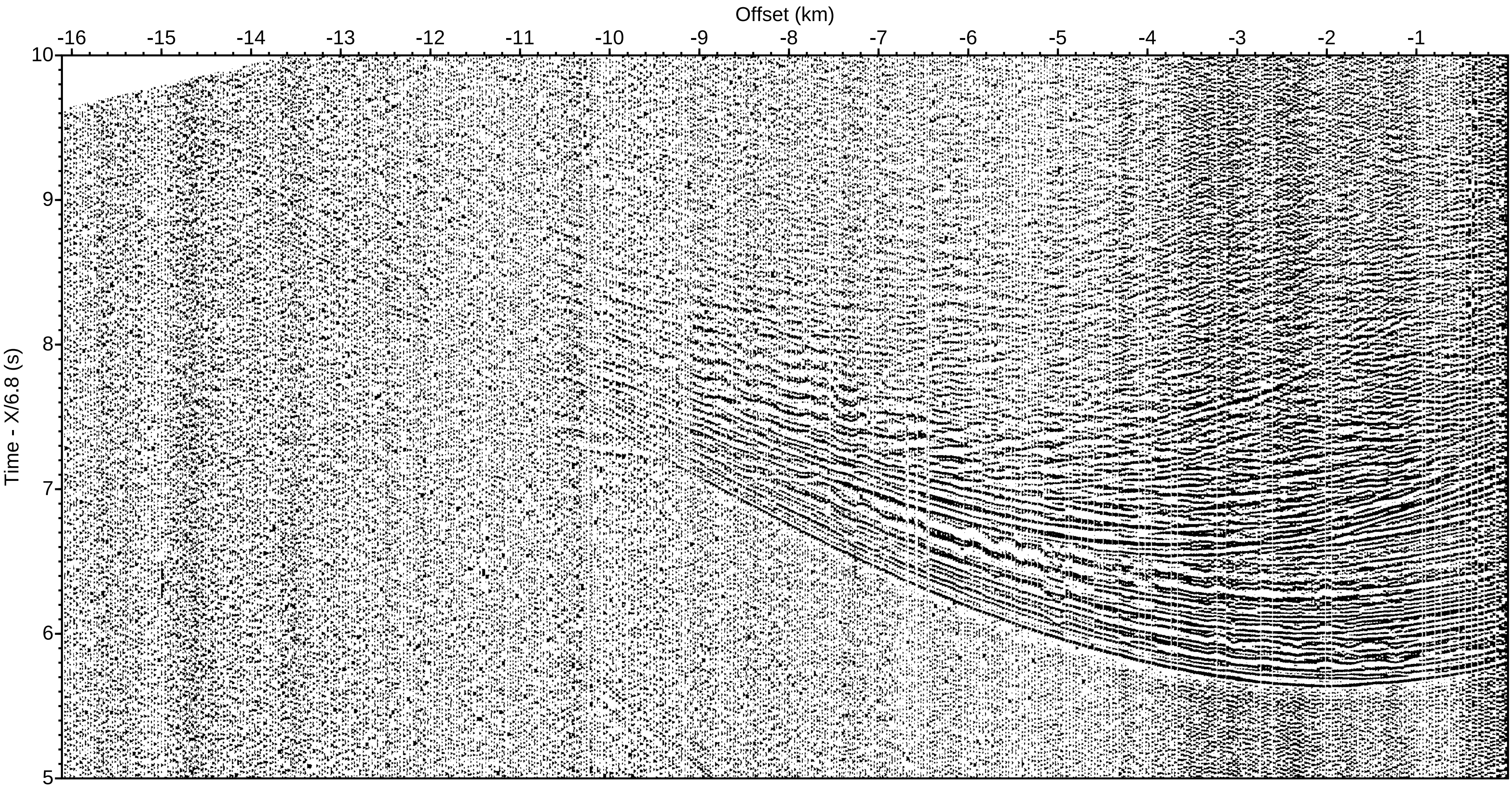
LOMROG III (2012) - Line 2 Sonobuoy 2-8 aux ch 2 (drift correction, deconv., bpf 5-40 Hz)



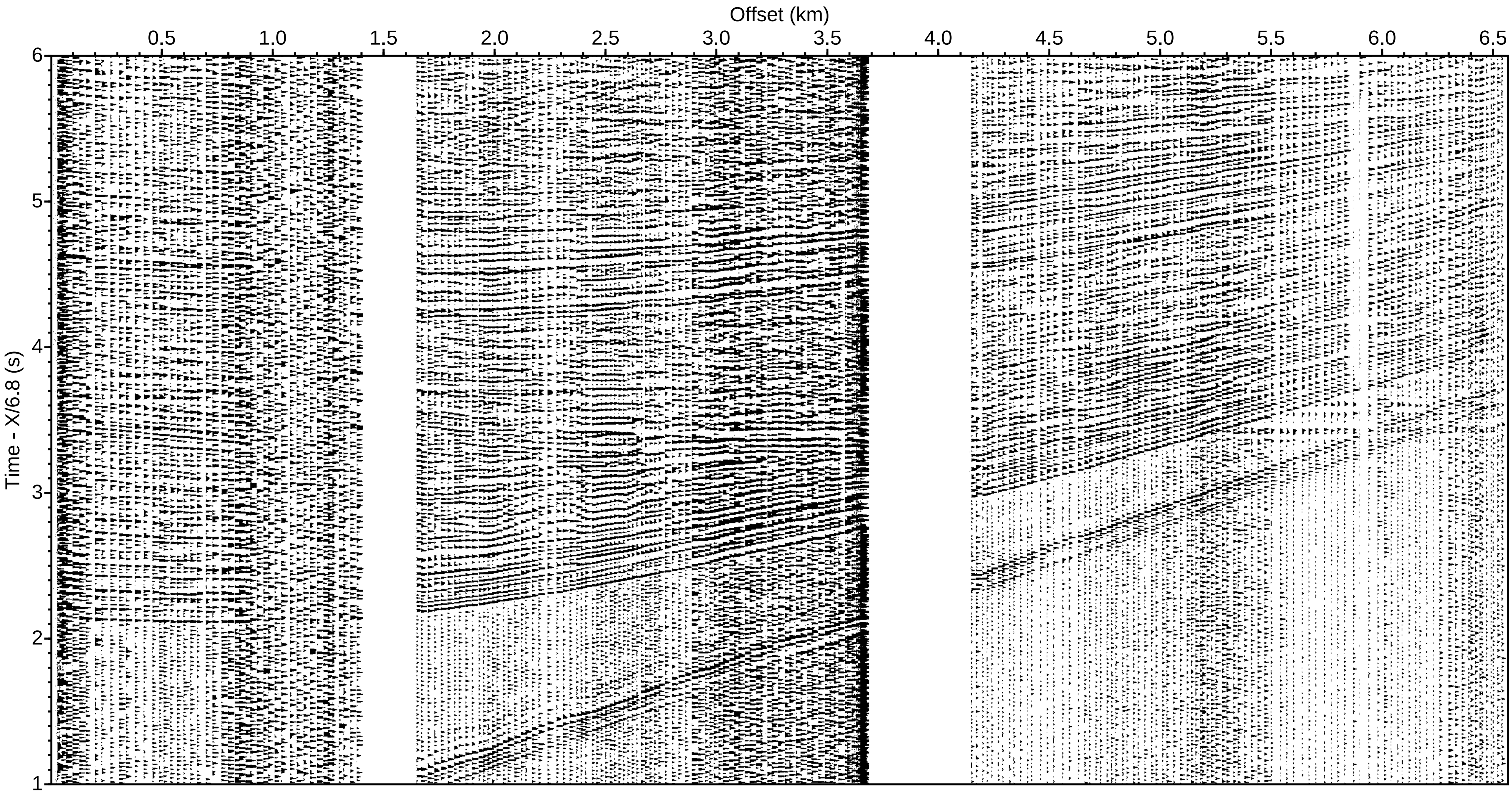
LOMROG III (2012) - Line 2 Sonobuoy 2-9 aux ch 1 (drift correction, deconv., bpf 5-40 Hz)



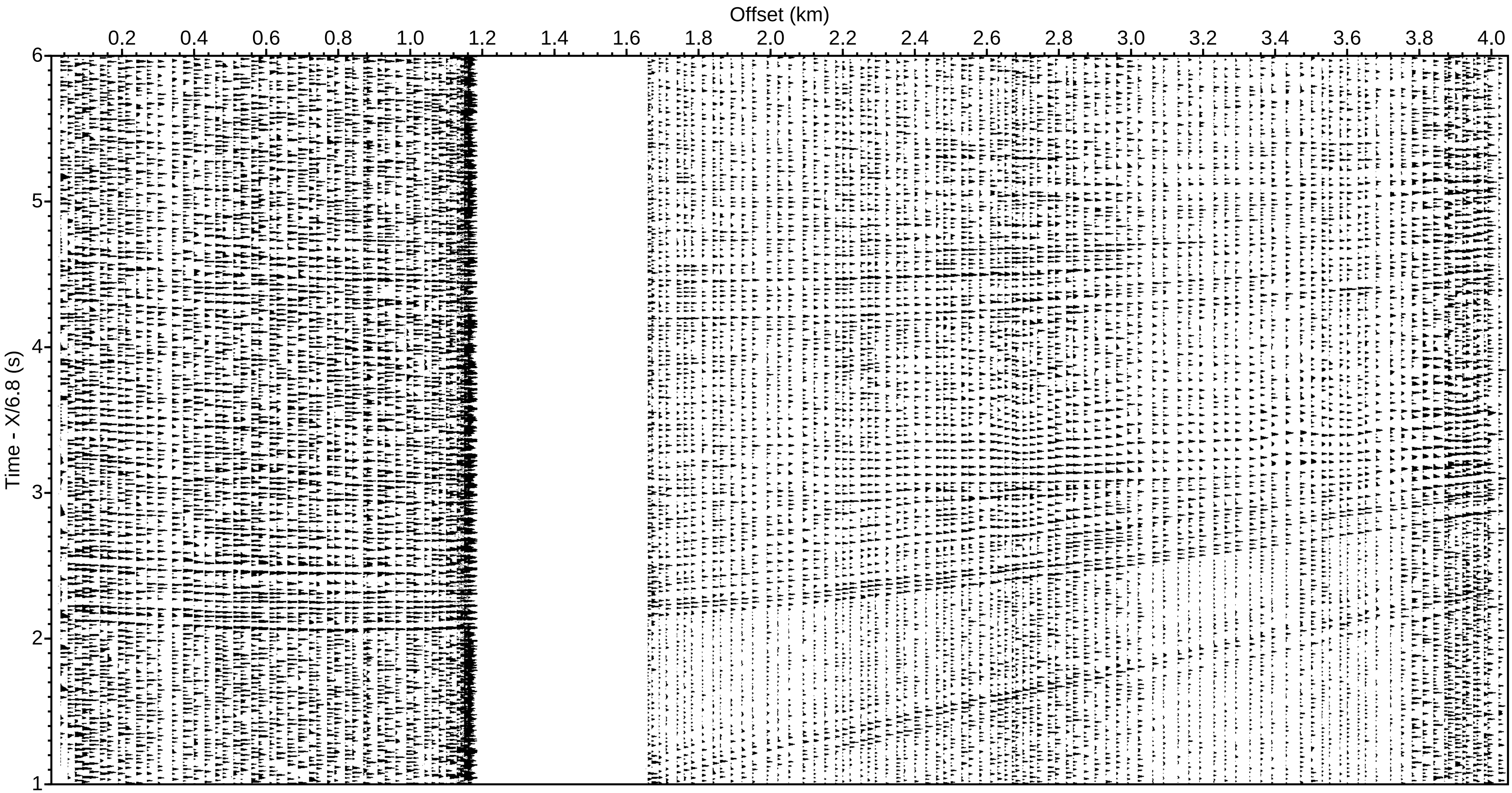
LOMROG III (2012) - Line 2 Sonobuoy 2-10 aux ch 3 (drift correction, deconv., bpf 5-40 Hz)



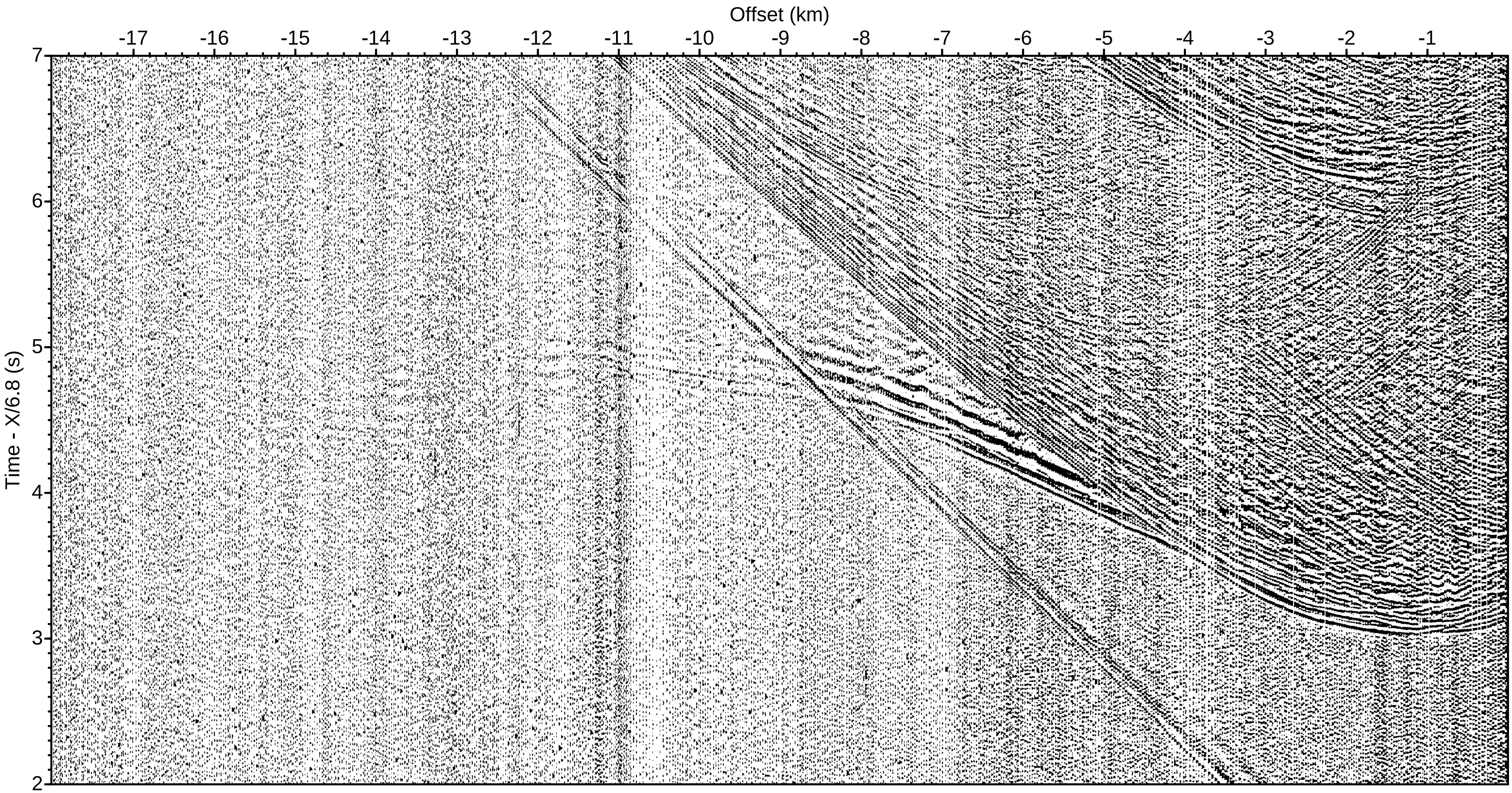
LOMROG III (2012) - Line 4 Sonobuoy 4-11 aux ch 1 (drift correction, deconv., bpf 5-40 Hz)



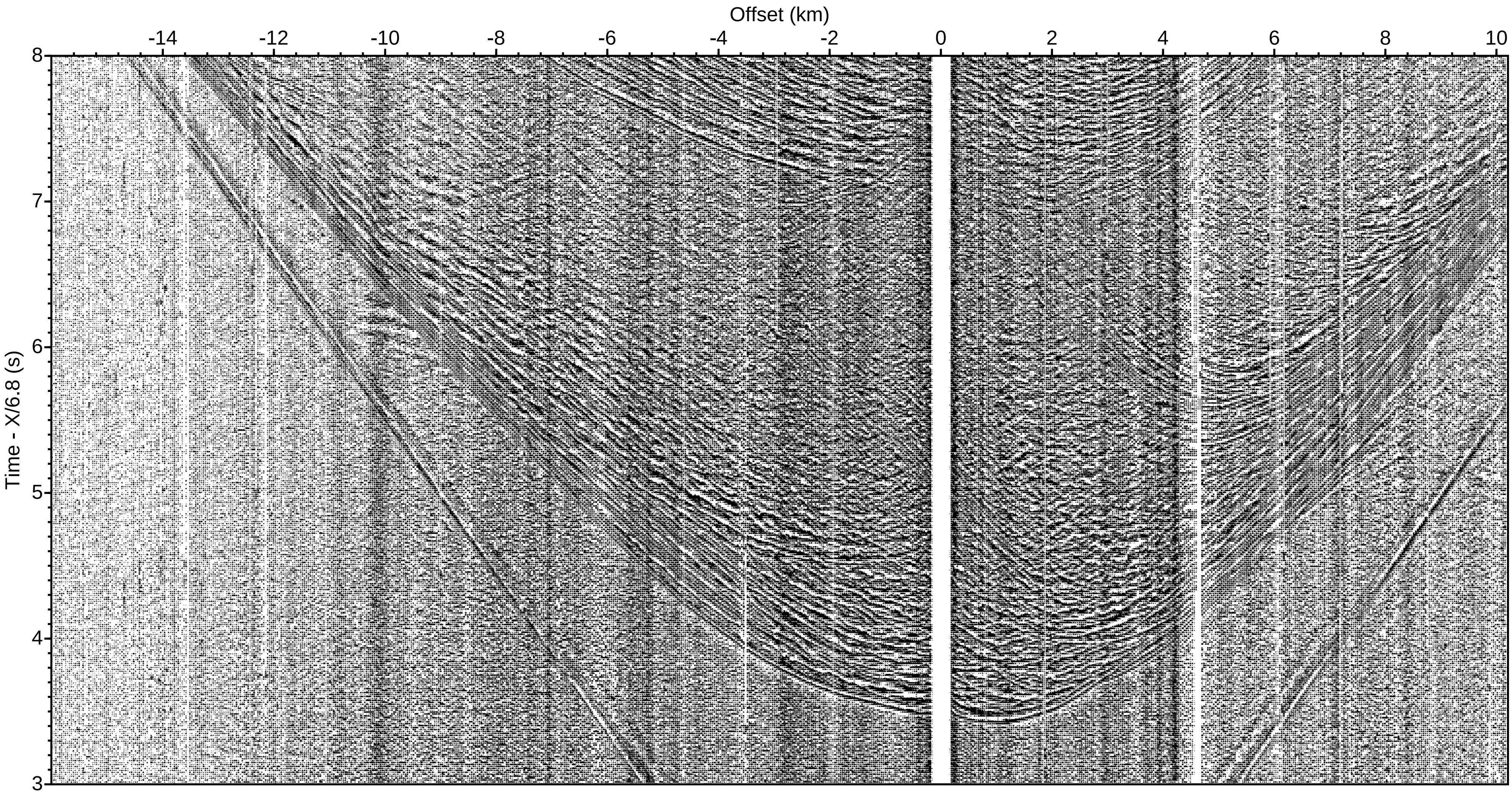
LOMROG III (2012) - Line 5 Sonobuoy 5-13 aux ch 1 (drift correction, deconv., bpf 5-40 Hz)



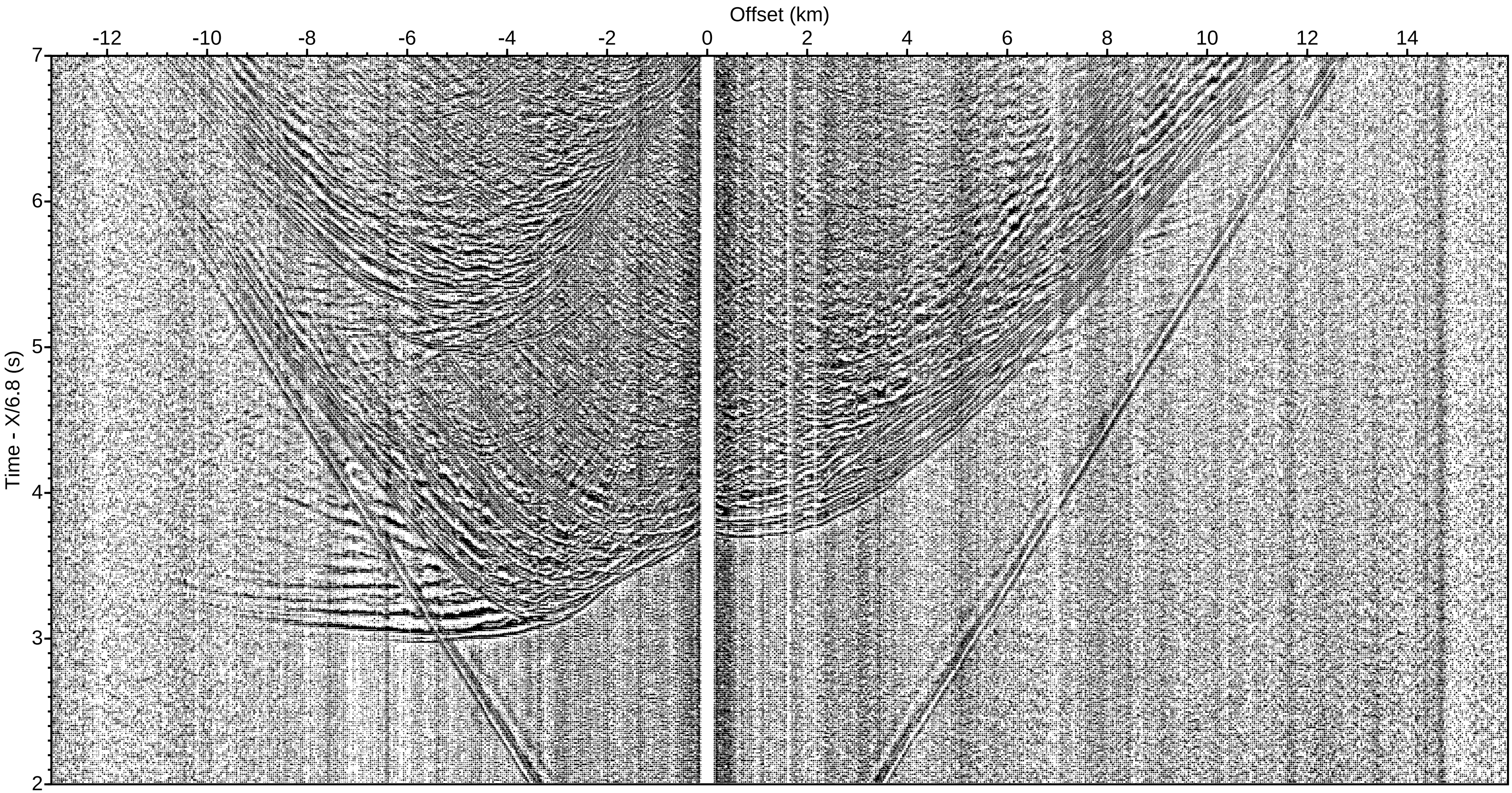
LOMROG III (2012) - Line 5 Sonobuoy 5-14 aux ch 1 (drift correction, deconv., bpf 5-40 Hz)



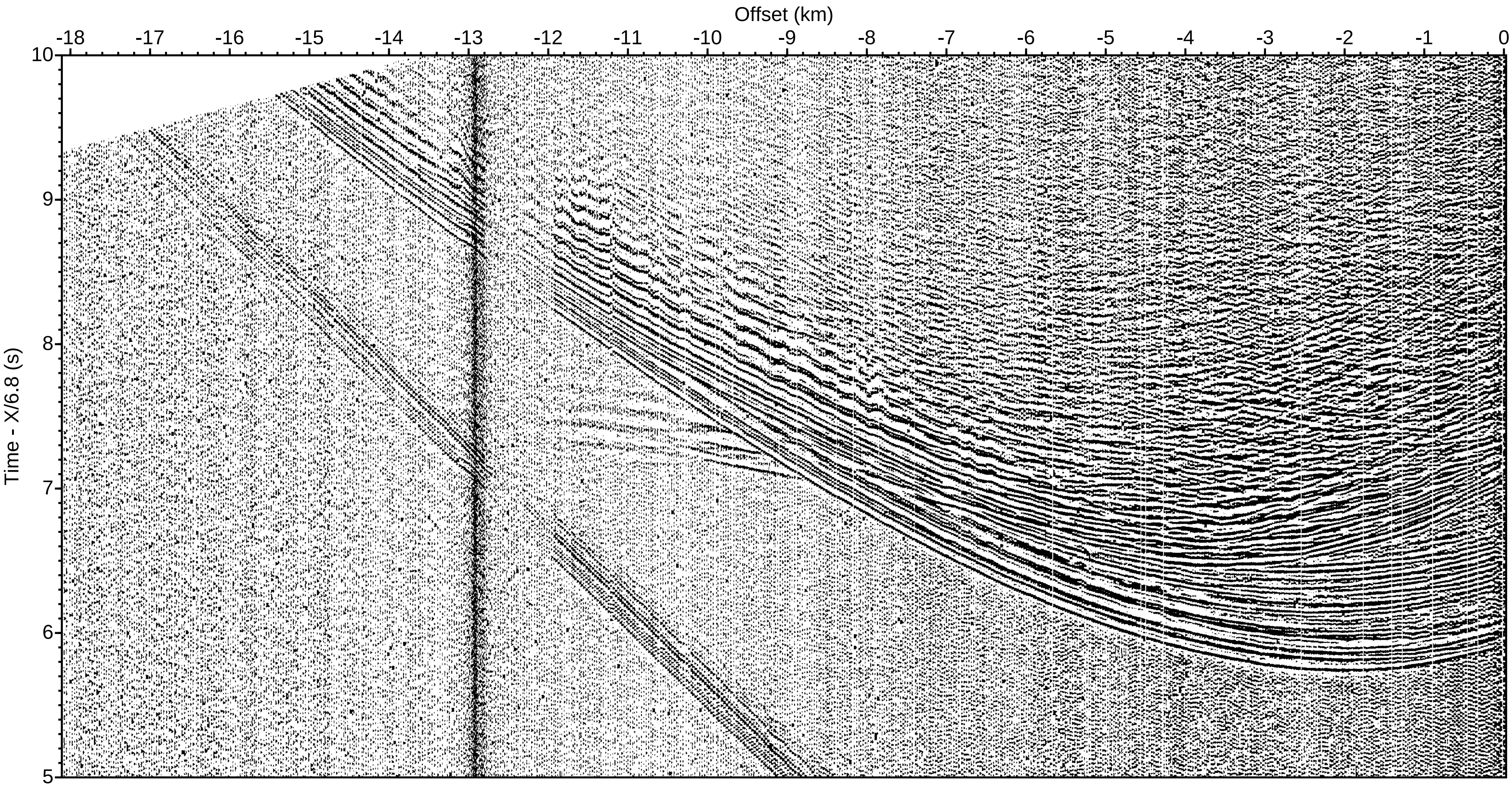
LOMROG III (2012) - Line 6 Sonobuoy 6-15 aux ch 1 (drift correction, deconv., bpf 5-40 Hz)



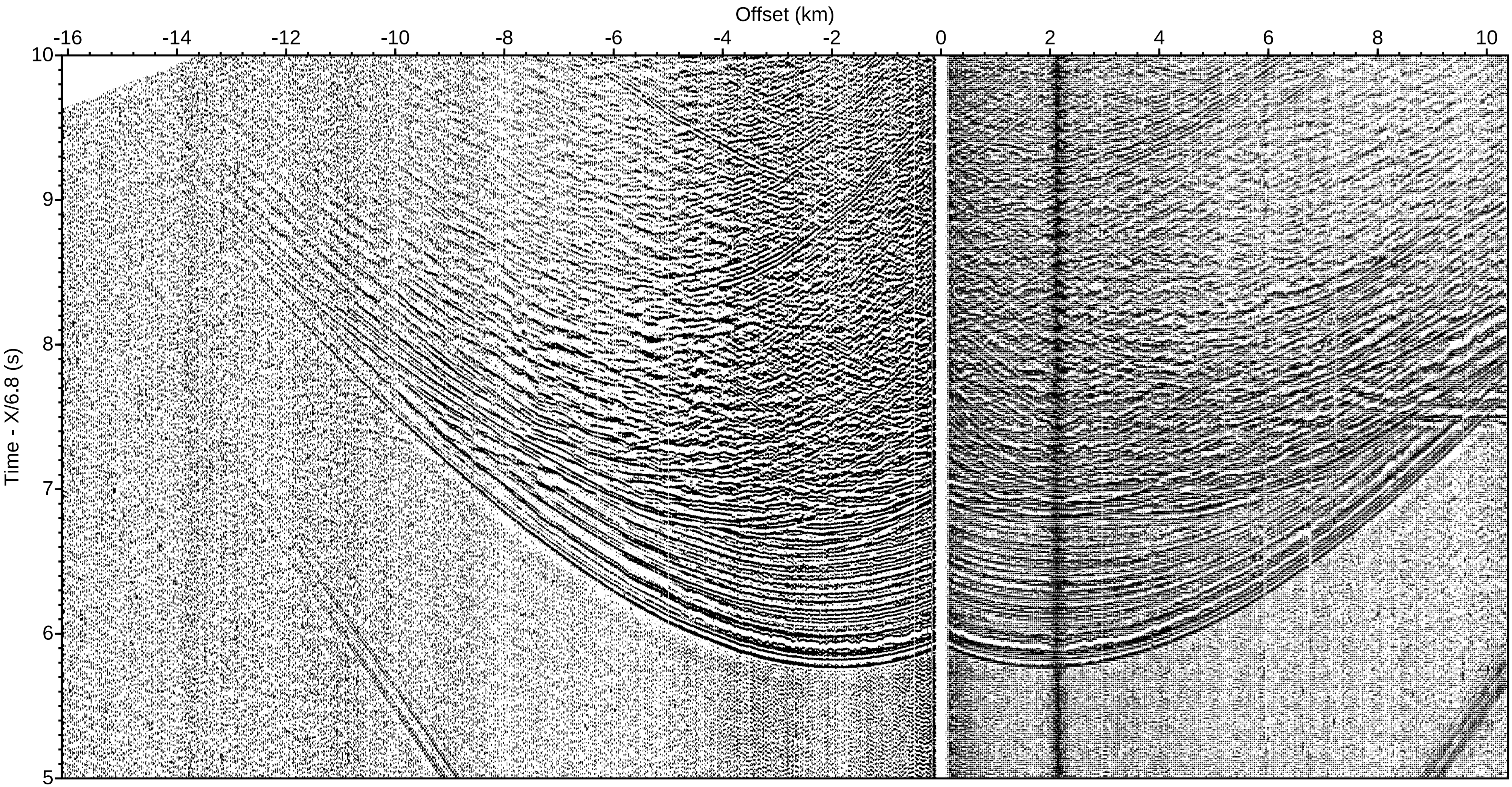
LOMROG III (2012) - Line 6 Sonobuoy 6-16 aux ch 2 (drift correction, deconv., bpf 5-40 Hz)



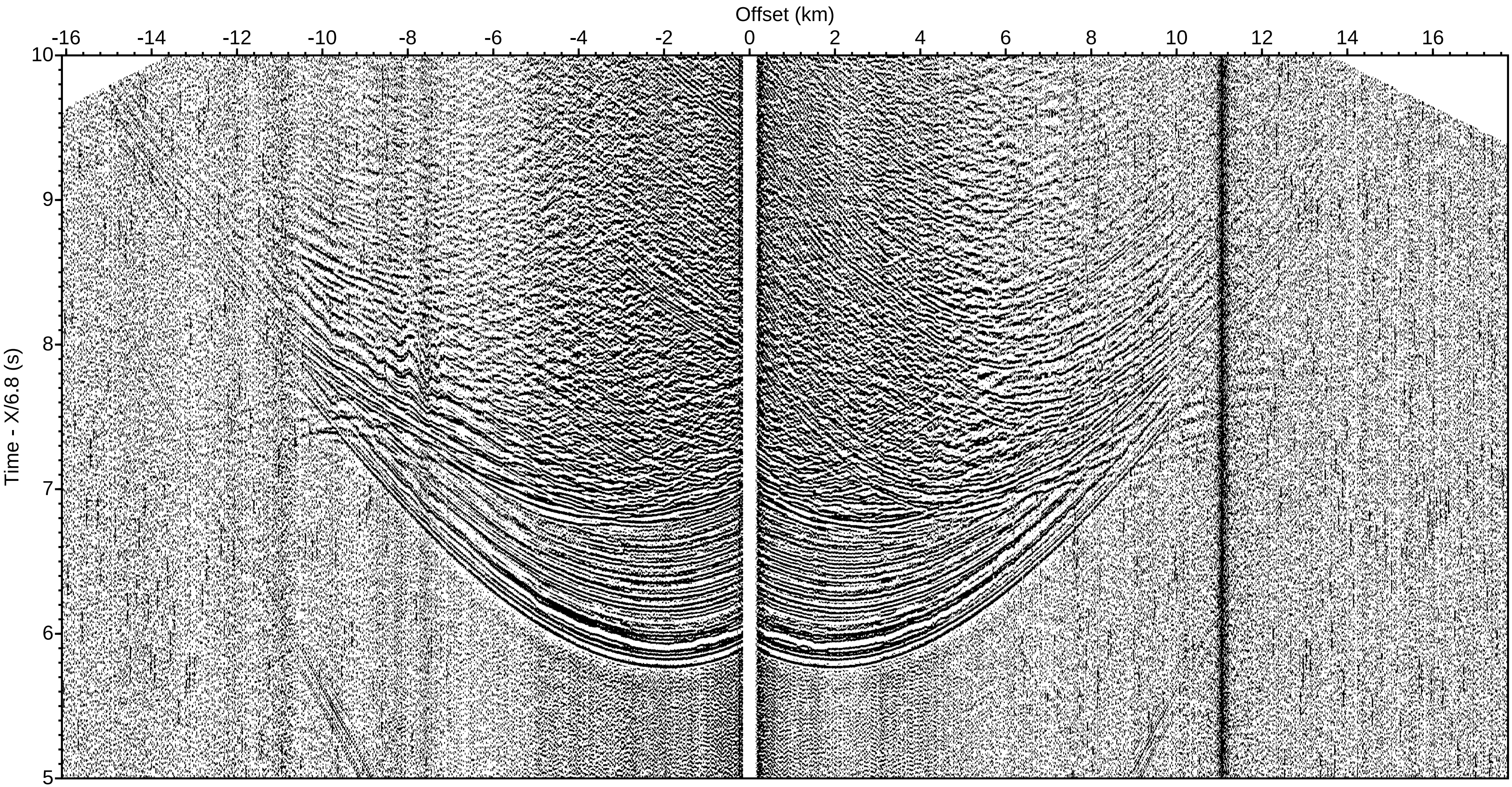
LOMROG III (2012) - Line 6 Sonobuoy 6-17 aux ch 3 (drift correction, deconv., bpf 5-40 Hz)



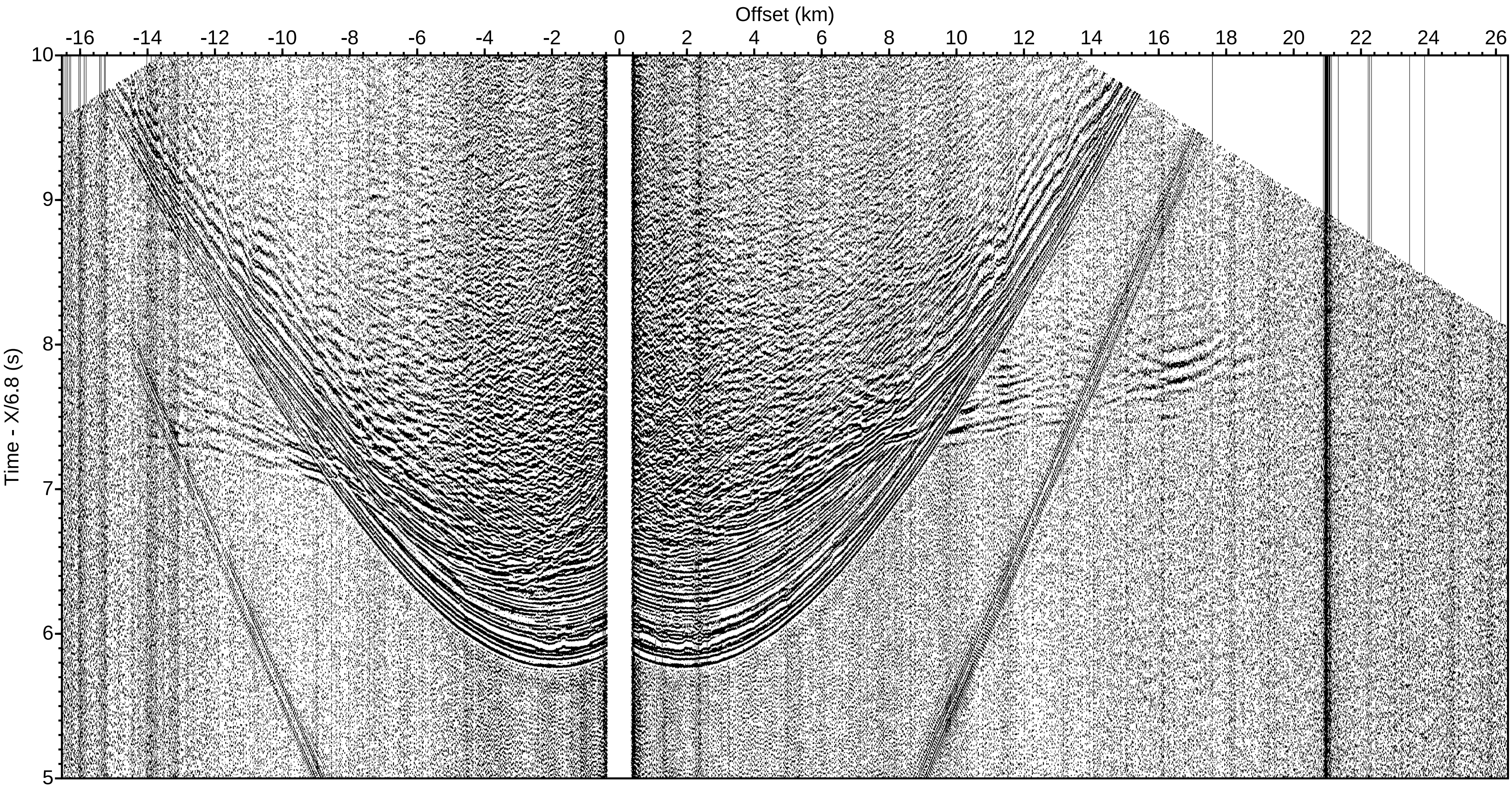
LOMROG III (2012) - Line 7 Sonobuoy 7-19 aux ch 1 (drift correction, deconv., bpf 5-40 Hz)



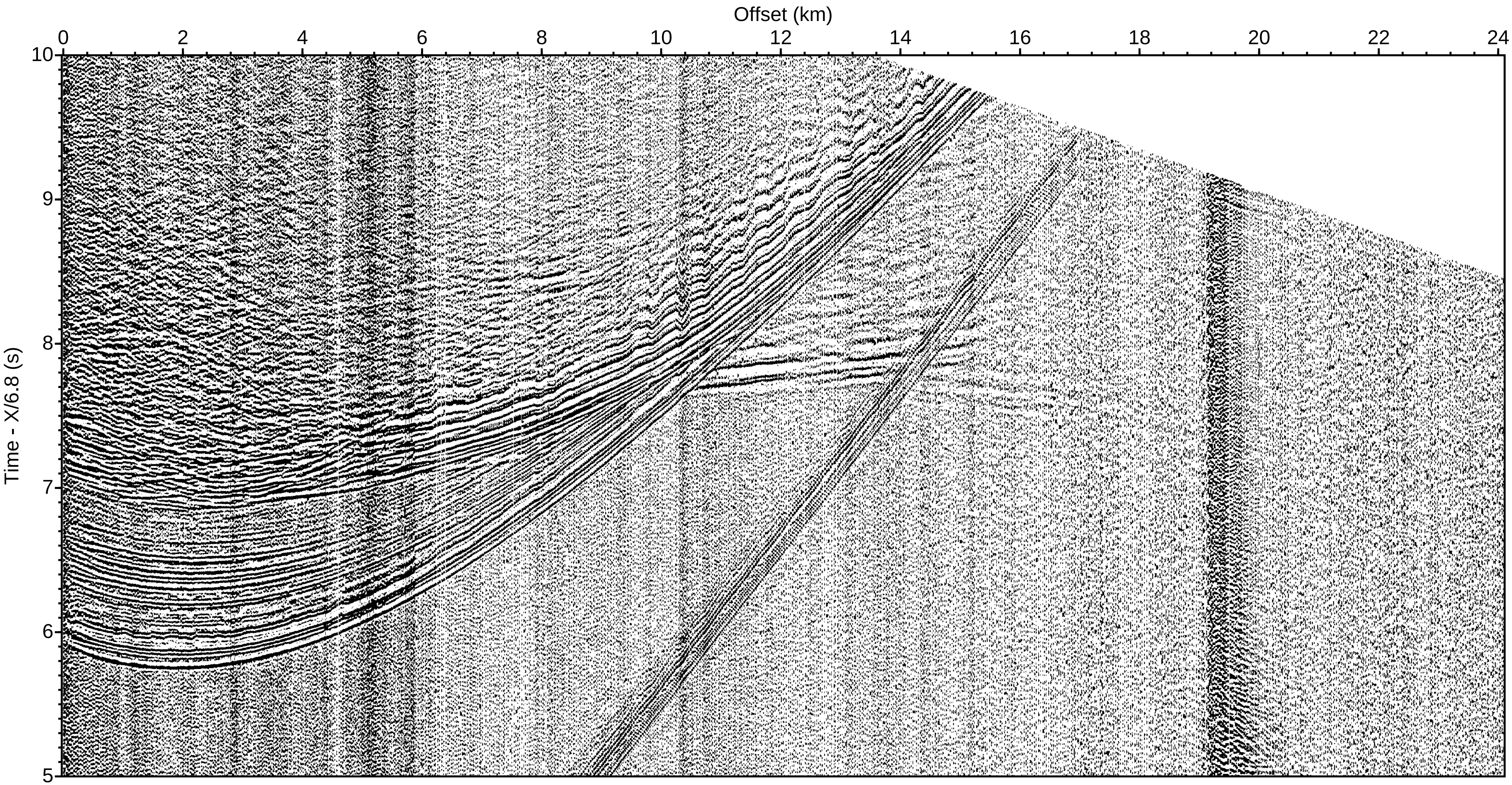
LOMROG III (2012) - Line 7 Sonobuoy 7-20 aux ch 4 (drift correction, deconv., bpf 5-40 Hz)



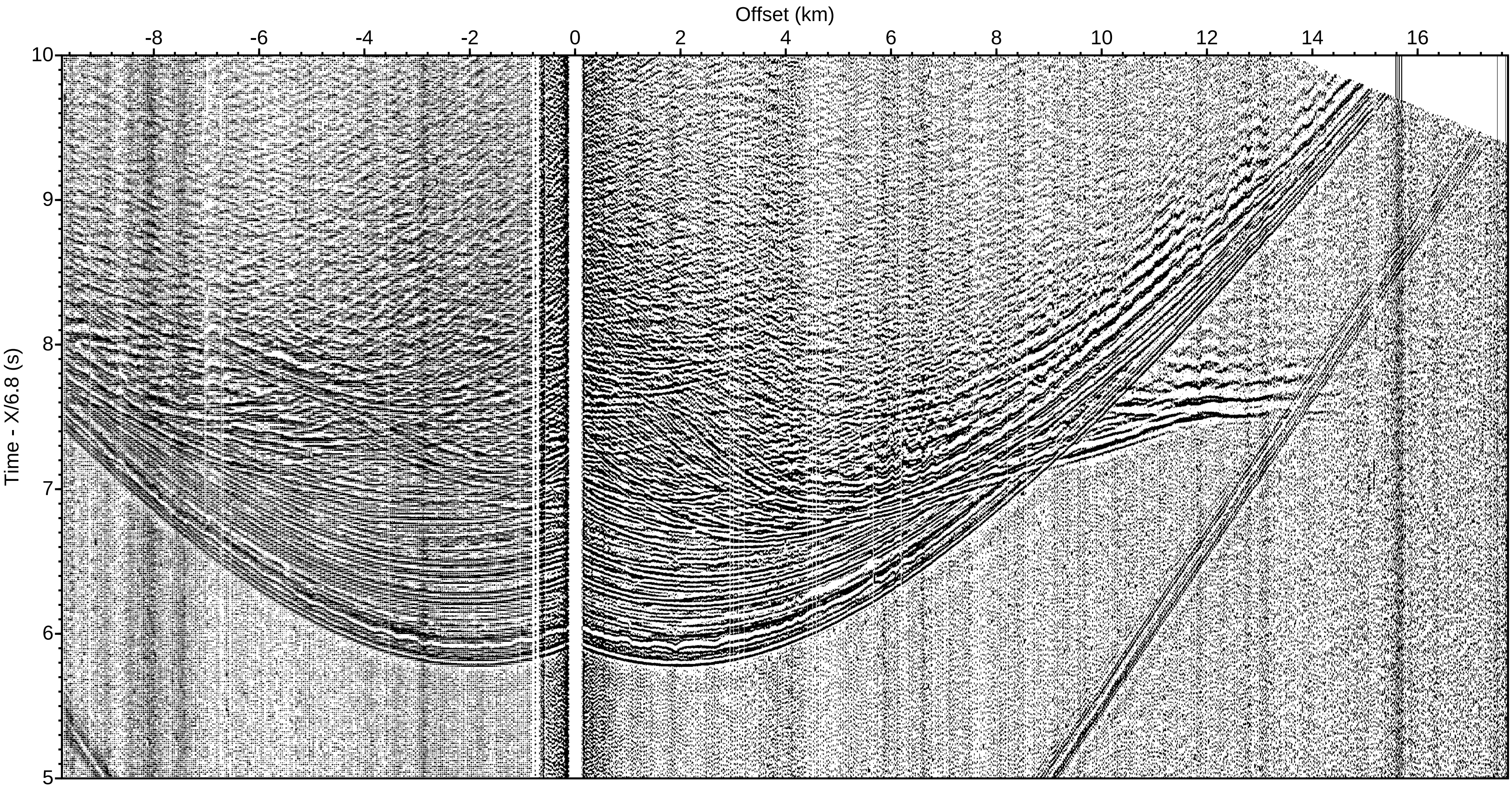
LOMROG III (2012) - Line 7 Sonobuoy 7-21 aux ch 2 (drift correction, deconv., bpf 5-40 Hz)



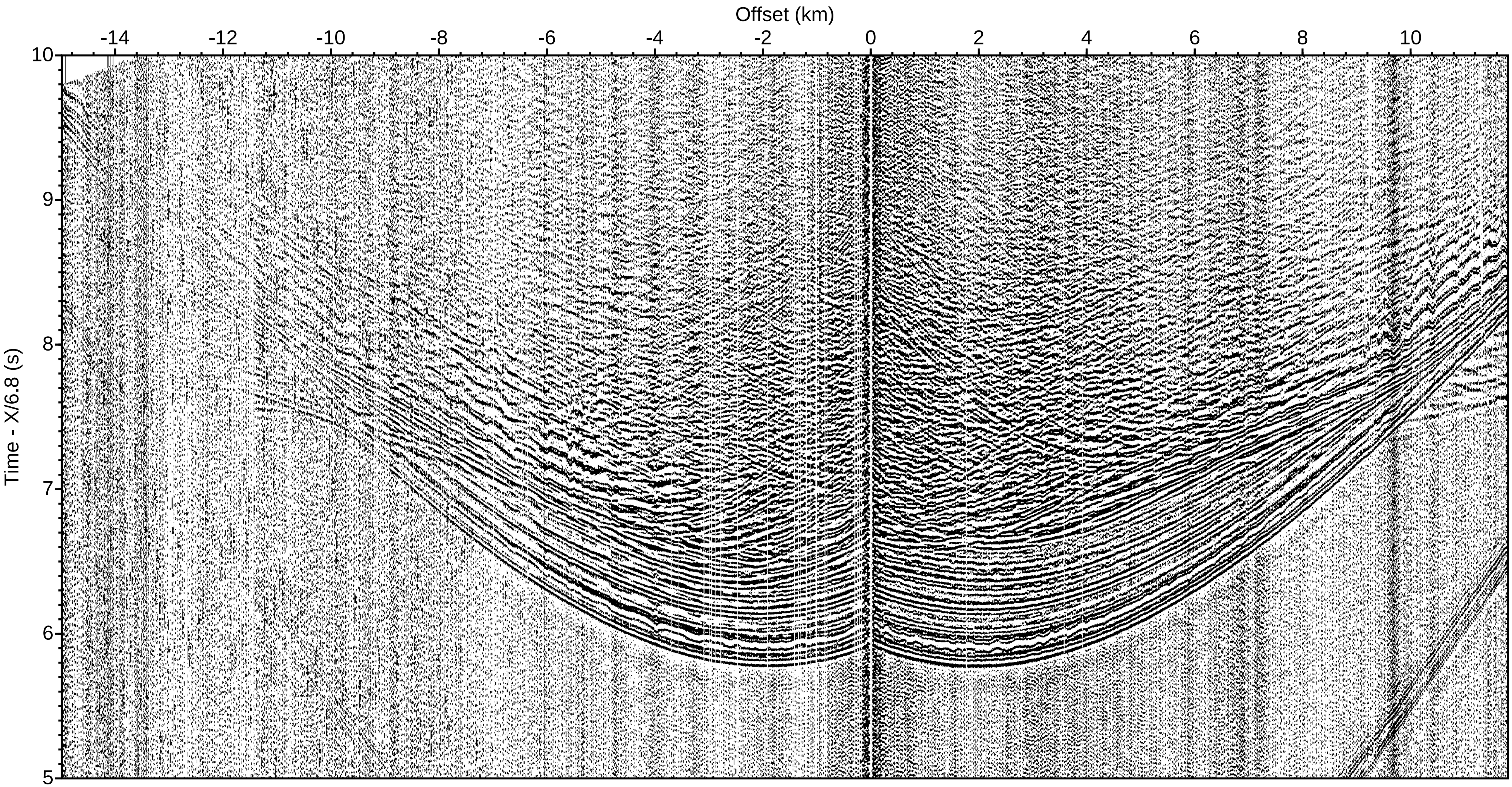
LOMROG III (2012) - Line 7 Sonobuoy 7-22 aux ch 3 (drift correction, deconv., bpf 5-40 Hz)



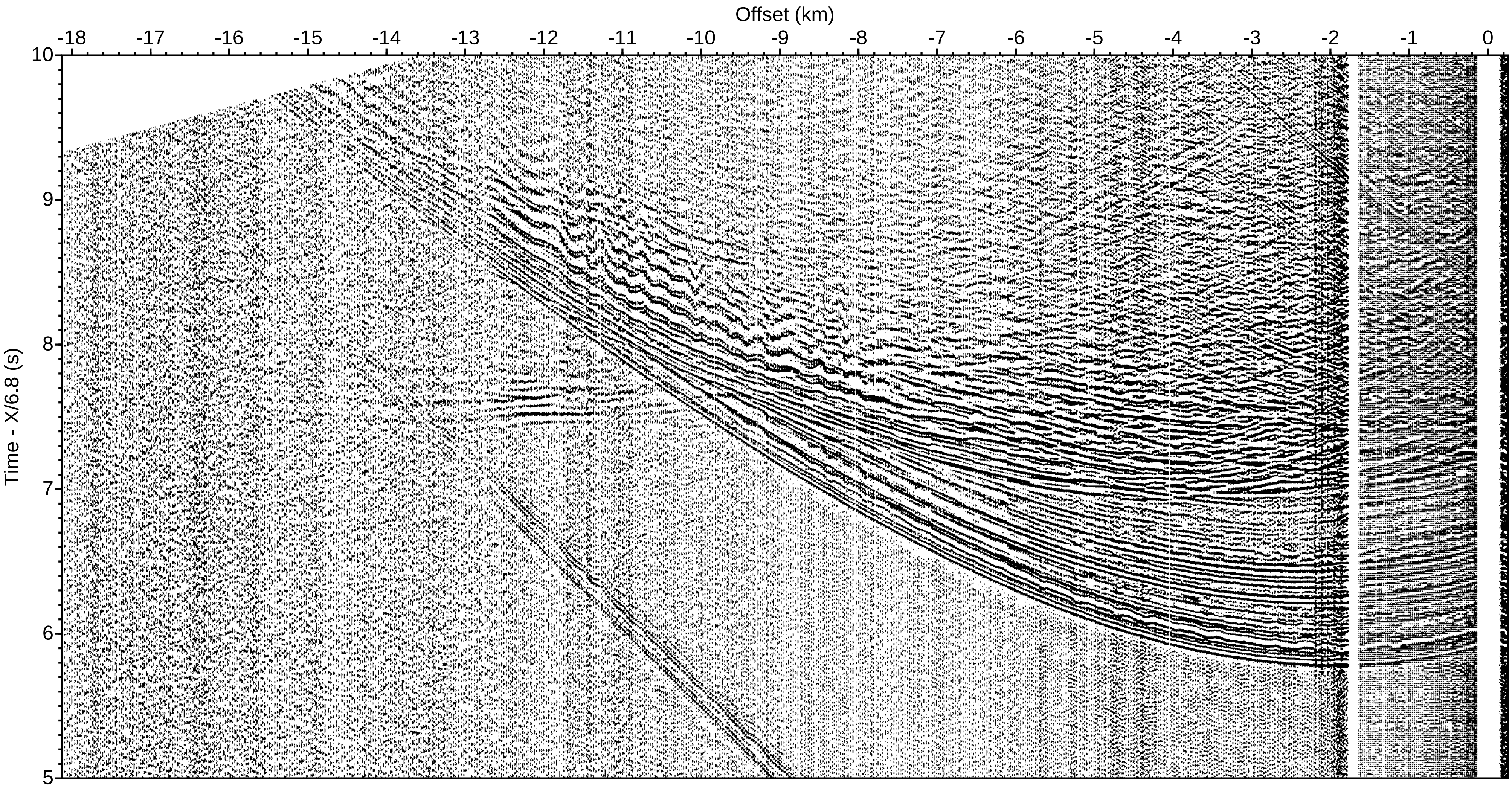
LOMROG III (2012) - Line 8 Sonobuoy 8-23 aux ch 1 (drift correction, deconv., bpf 5-40 Hz)



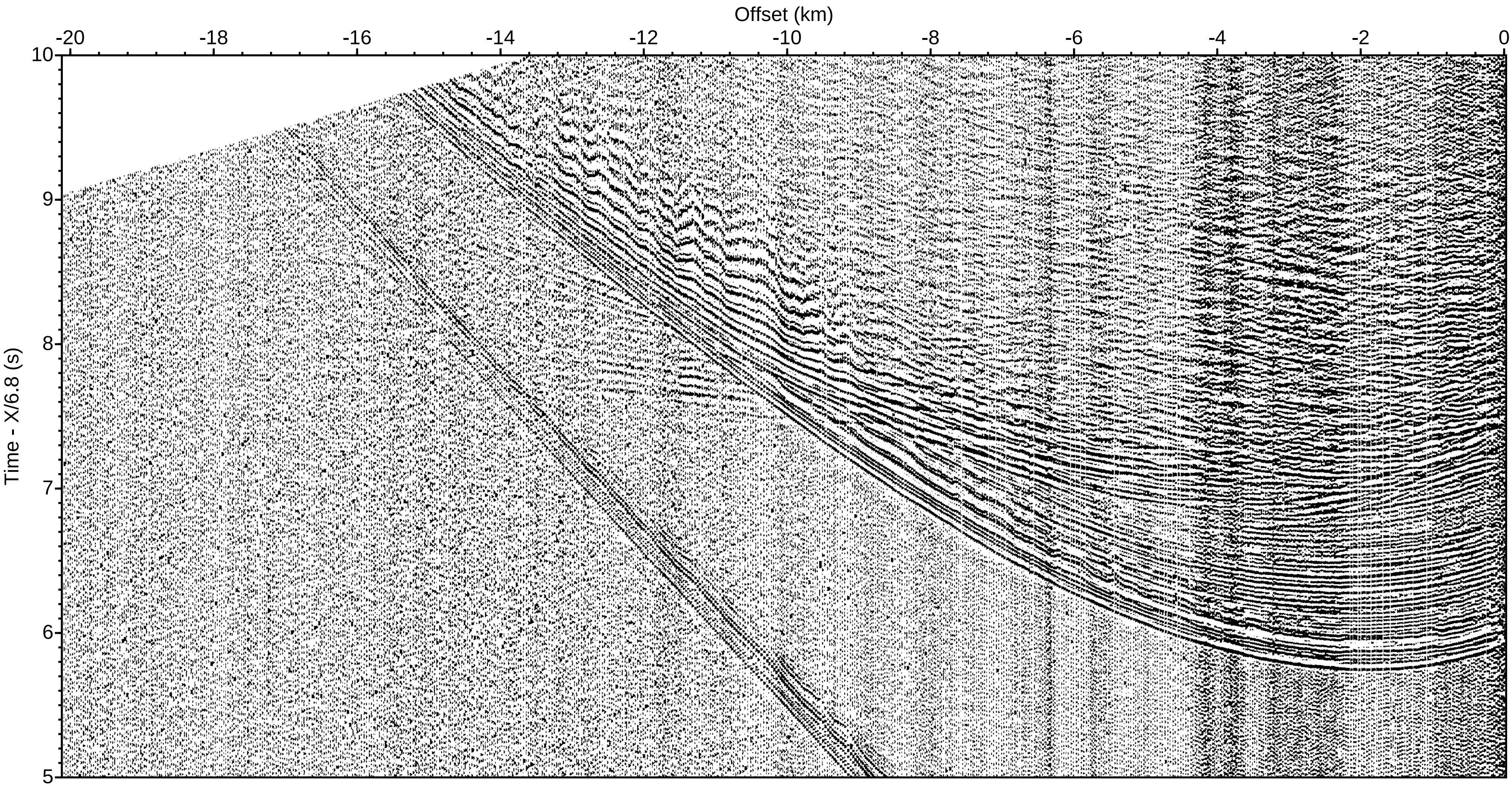
LOMROG III (2012) - Line 8 Sonobuoy 8-24 aux ch 4 (drift correction, deconv., bpf 5-40 Hz)



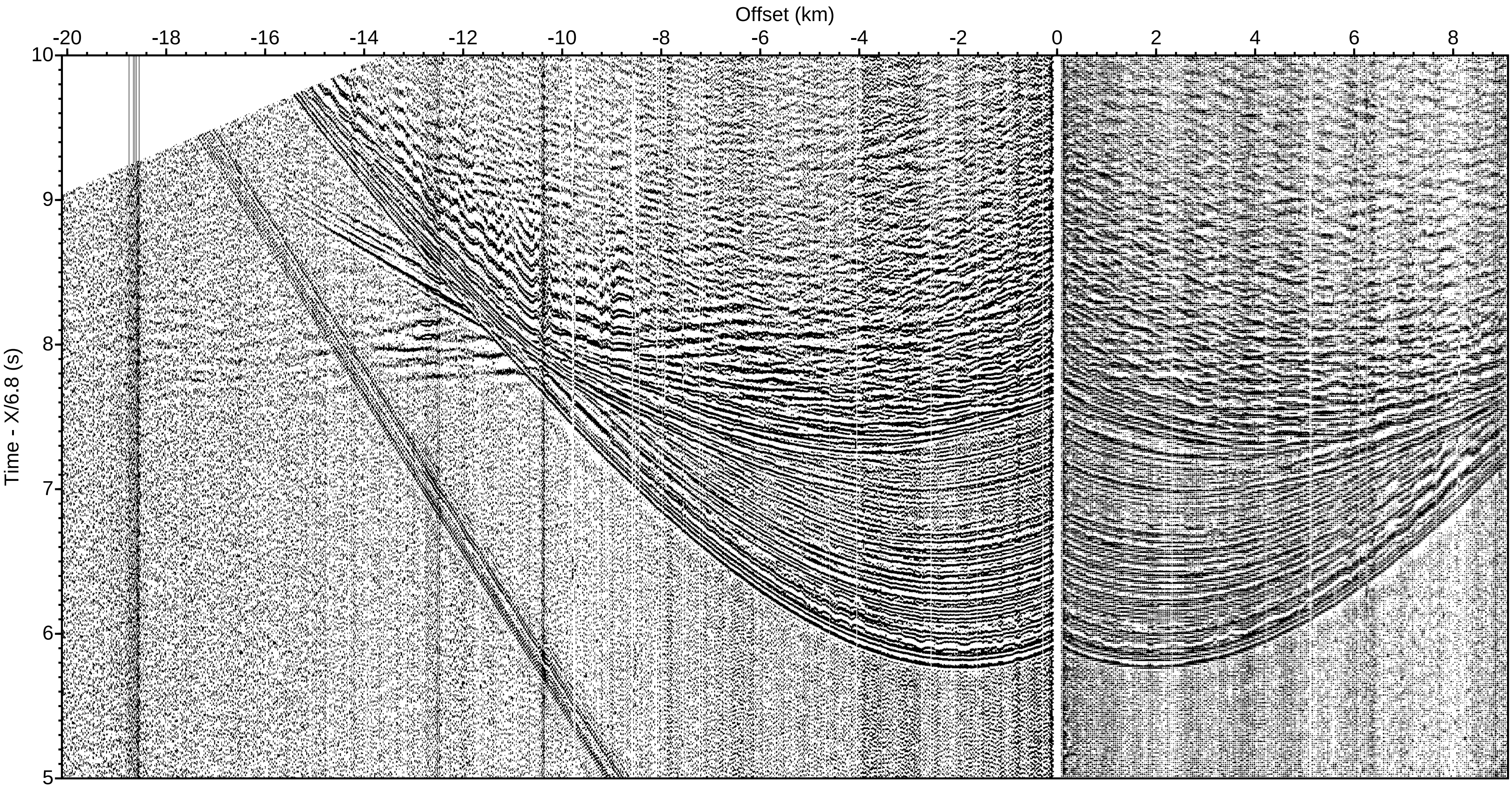
LOMROG III (2012) - Line 8 Sonobuoy 8-25 aux ch 2 (drift correction, deconv., bpf 5-40 Hz)



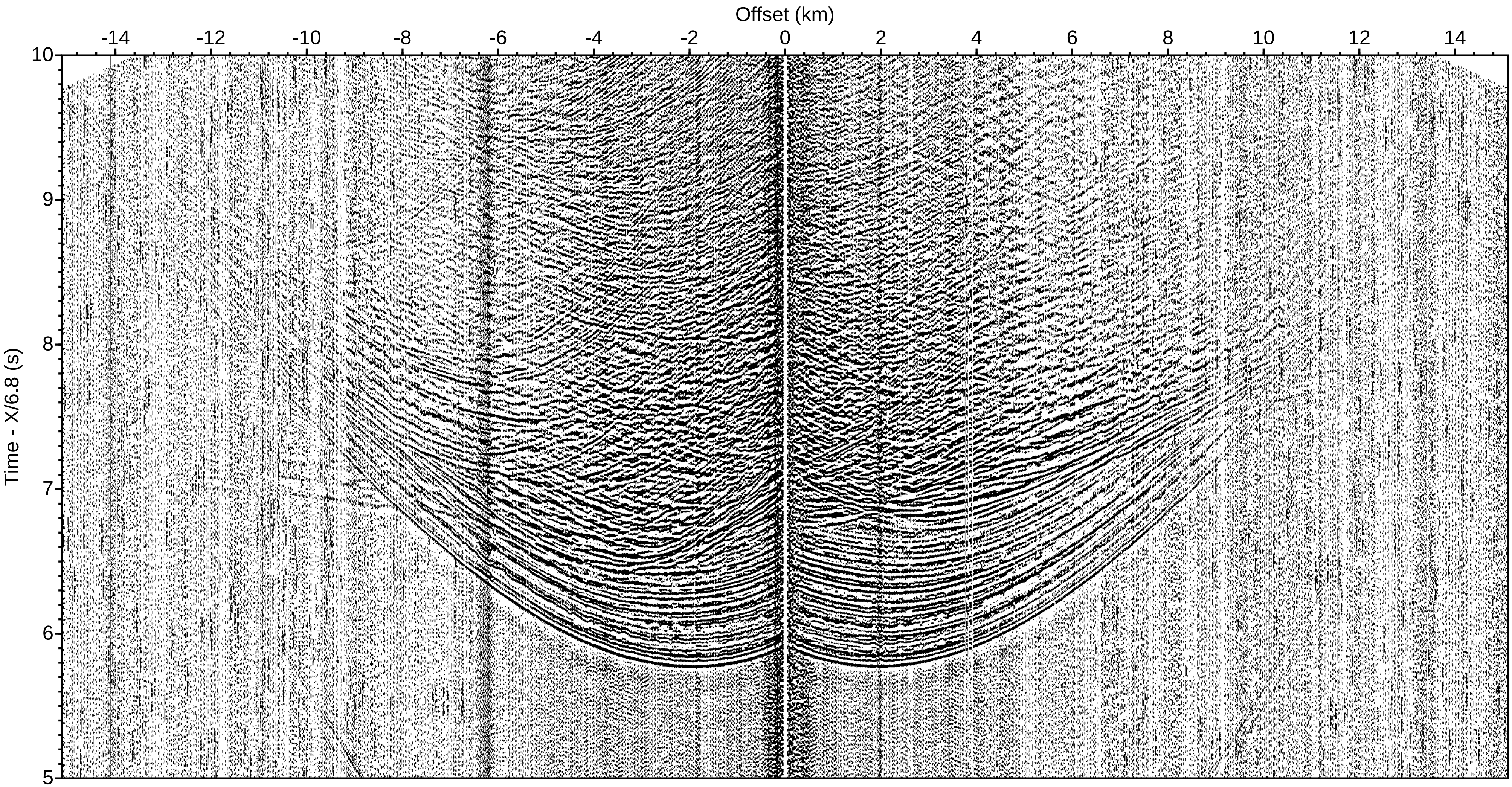
LOMROG III (2012) - Line 8 Sonobuoy 8-26 aux ch 3 (drift correction, deconv., bpf 5-40 Hz)



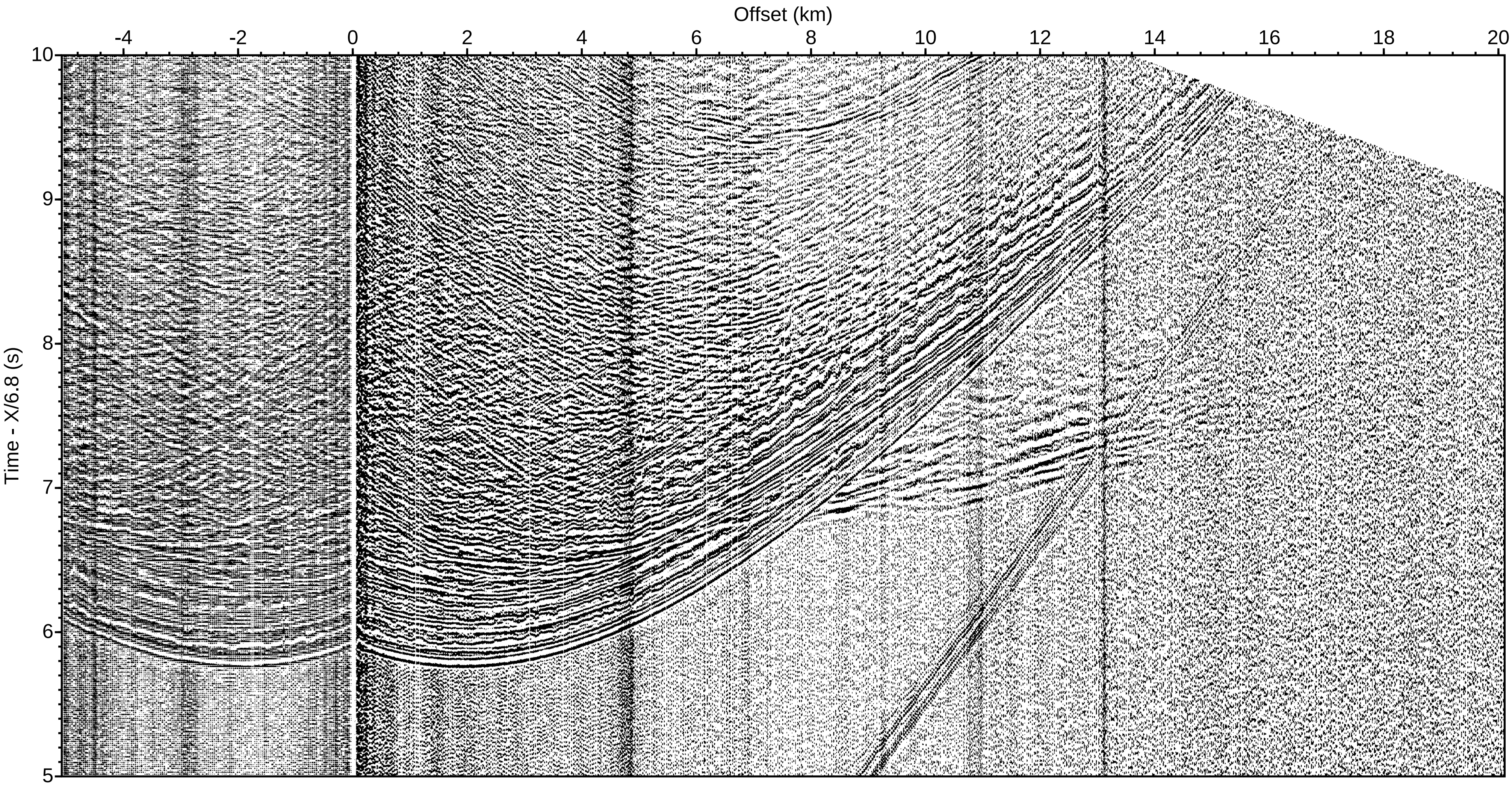
LOMROG III (2012) - Line 9 Sonobuoy 9-27 aux ch 1 (drift correction, deconv., bpf 5-40 Hz)



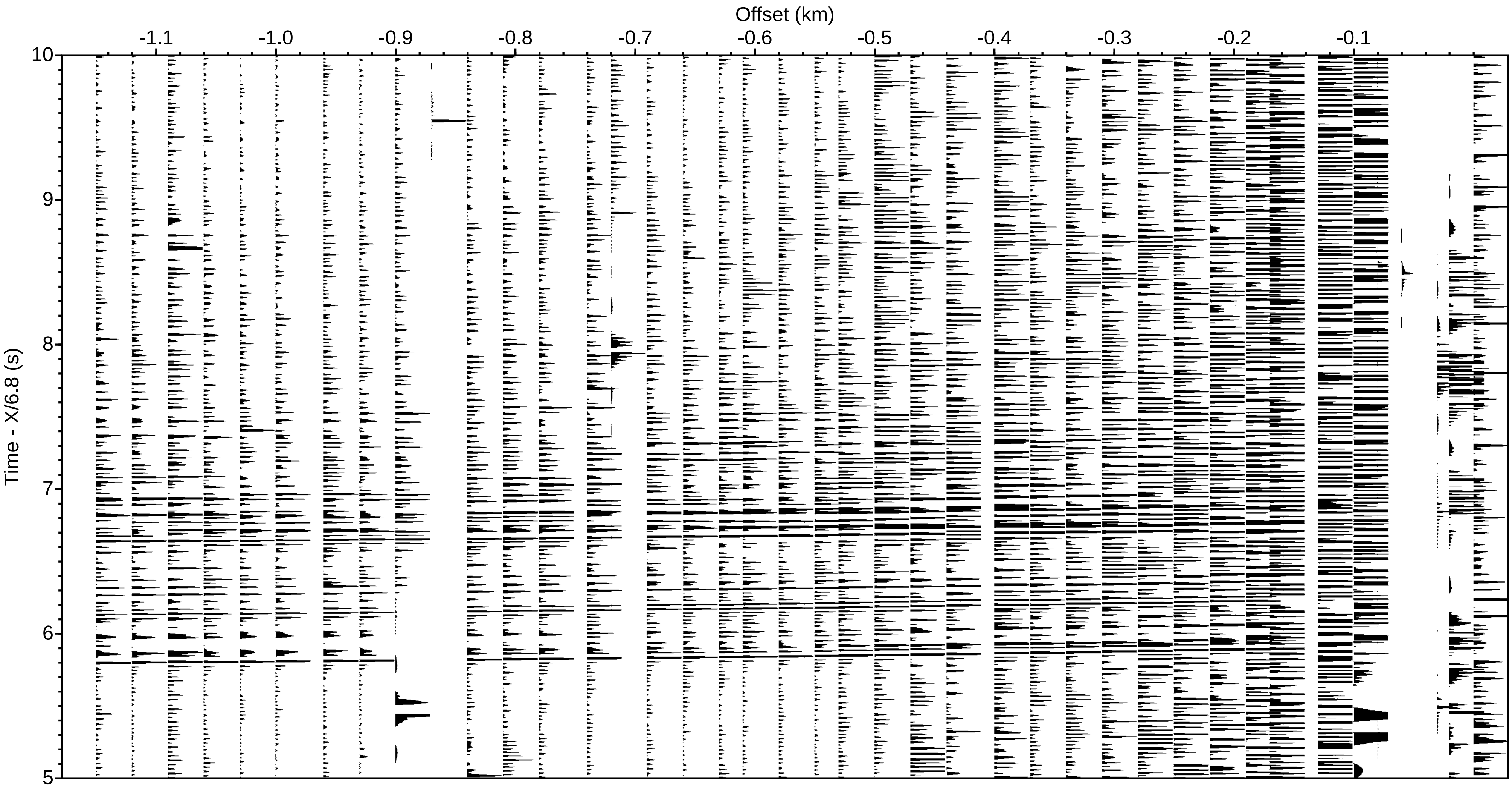
LOMROG III (2012) - Line 9 Sonobuoy 9-28 aux ch 4 (drift correction, deconv., bpf 5-40 Hz)



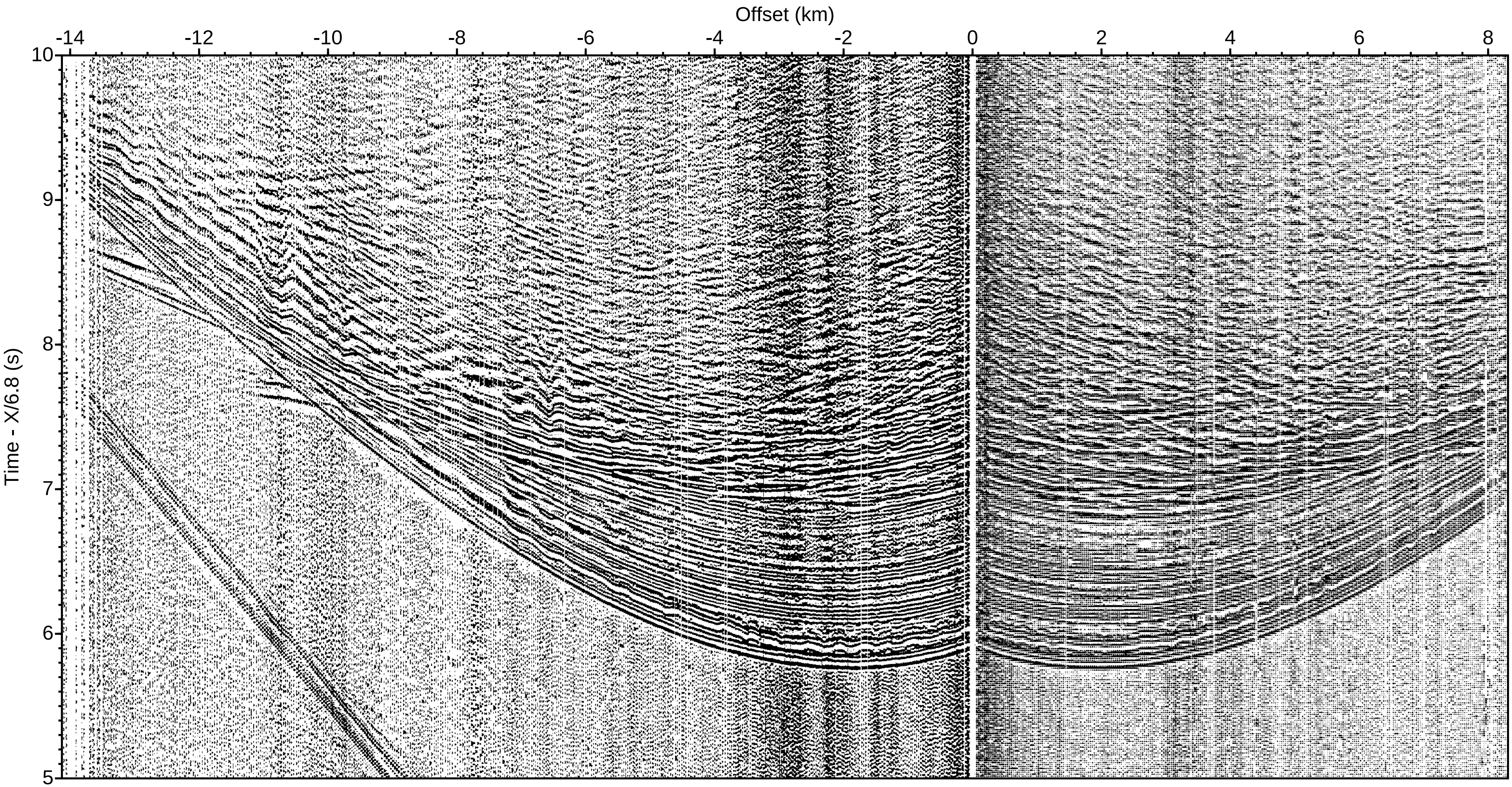
LOMROG III (2012) - Line 9 Sonobuoy 9-29 aux ch 2 (drift correction, deconv., bpf 5-40 Hz)



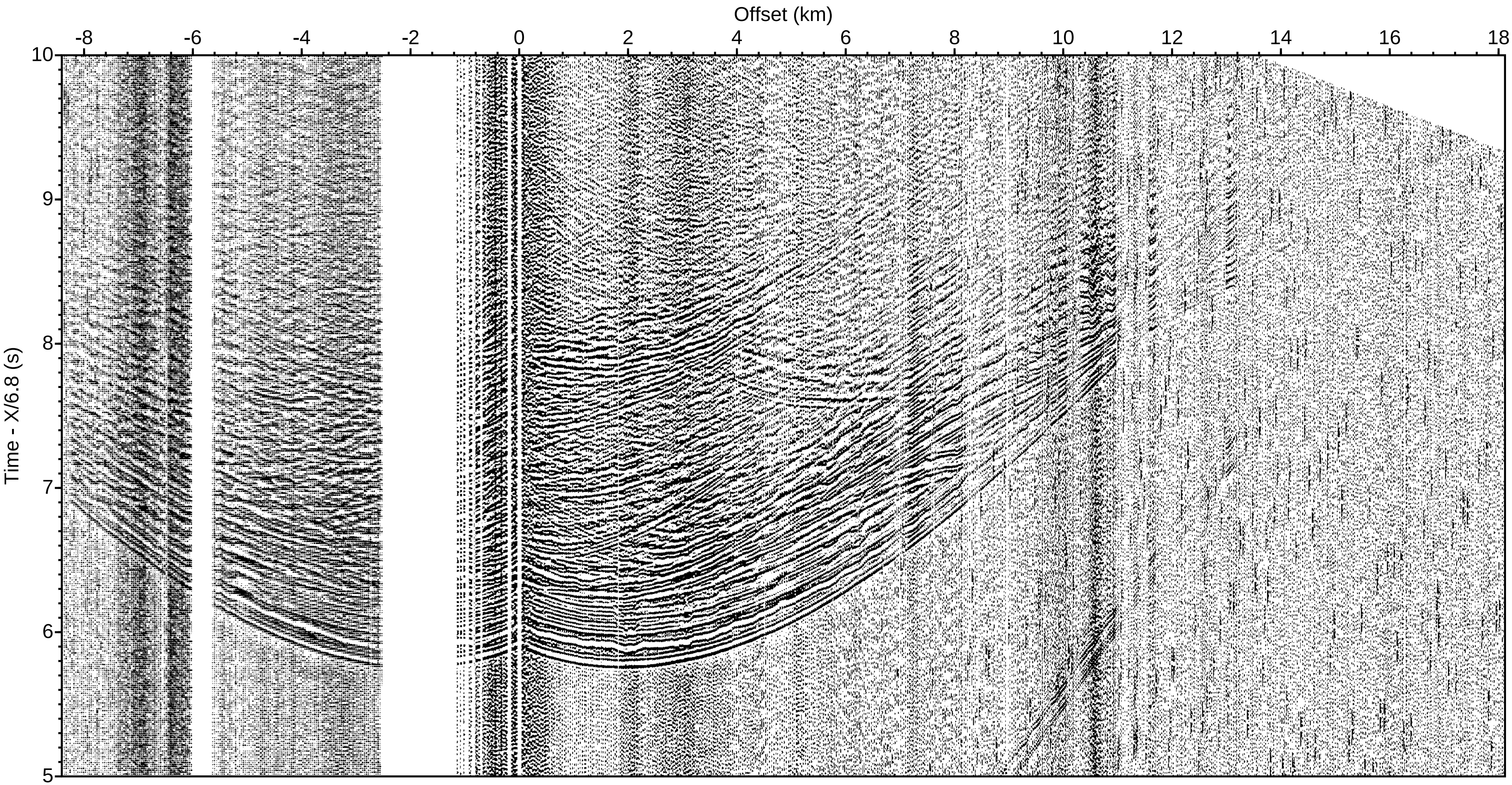
LOMROG III (2012) - Line 9 Sonobuoy 9-30 aux ch 3 (drift correction, deconv., bpf 5-40 Hz)



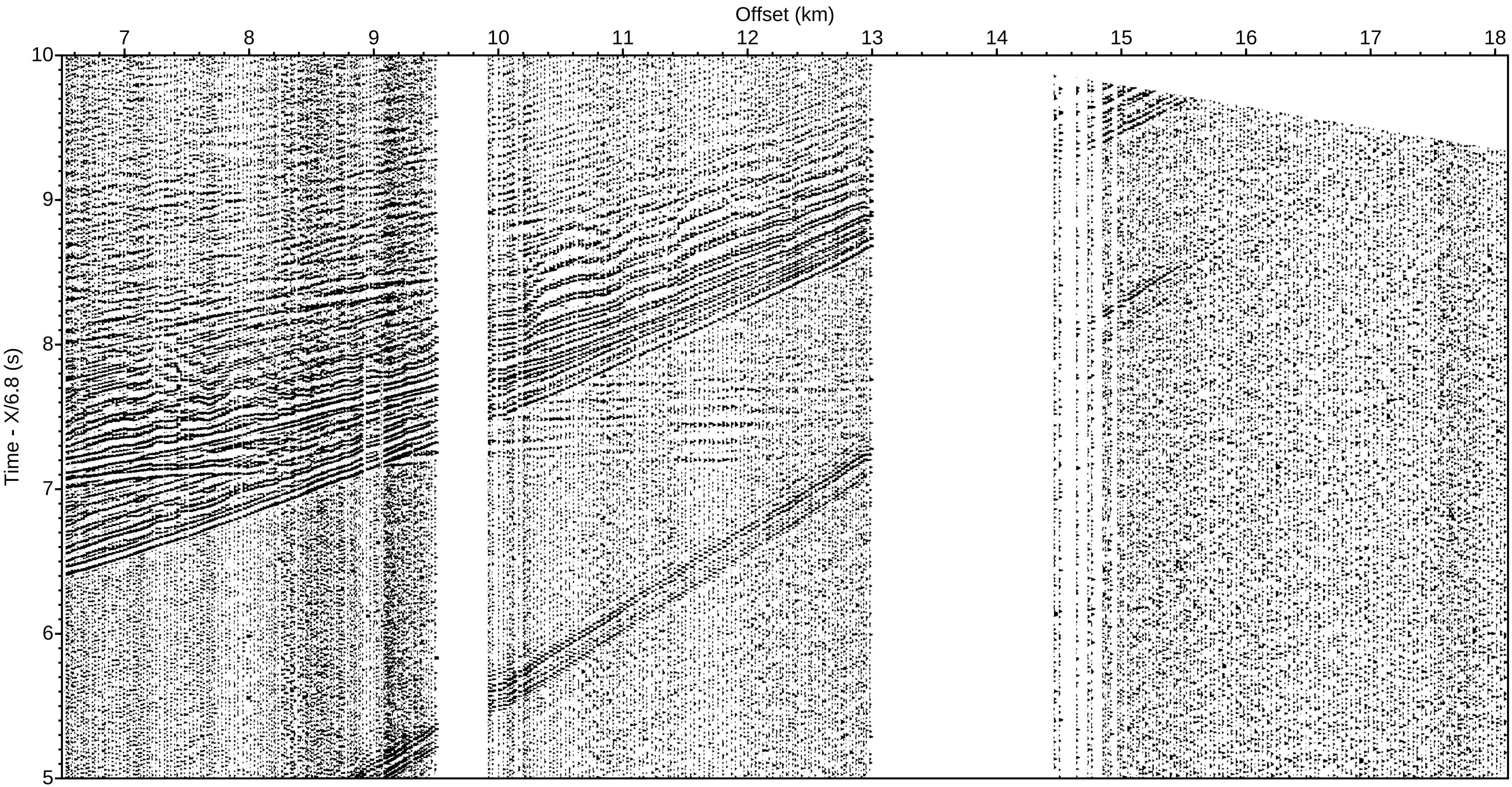
LOMROG III (2012) - Line 10 Sonobuoy 10-31 aux ch 1 (drift correction, deconv., bpf 5-40 Hz)



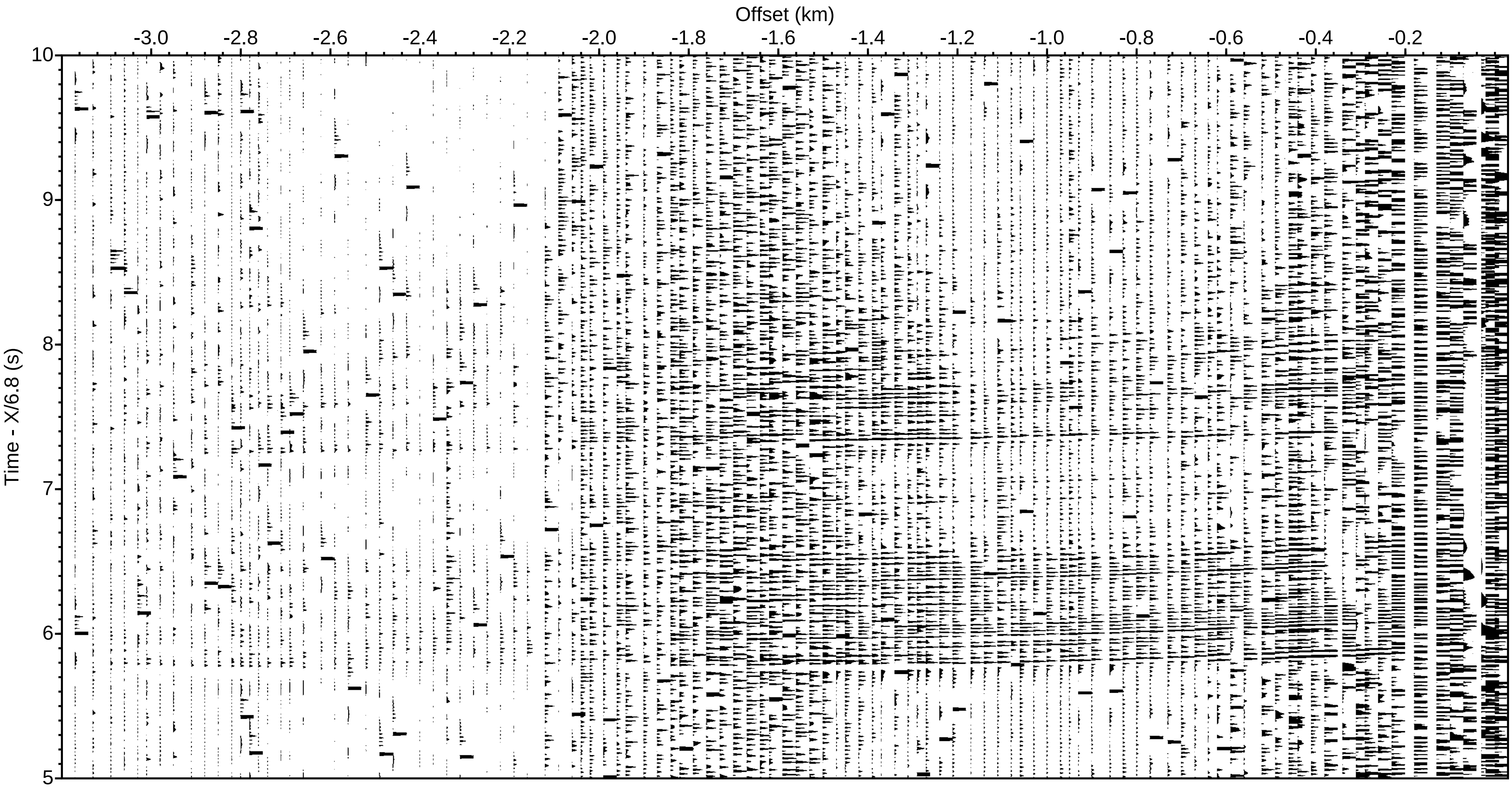
LOMROG III (2012) - Line 10 Sonobuoy 10-32 aux ch 4 (drift correction, deconv., bpf 5-40 Hz)



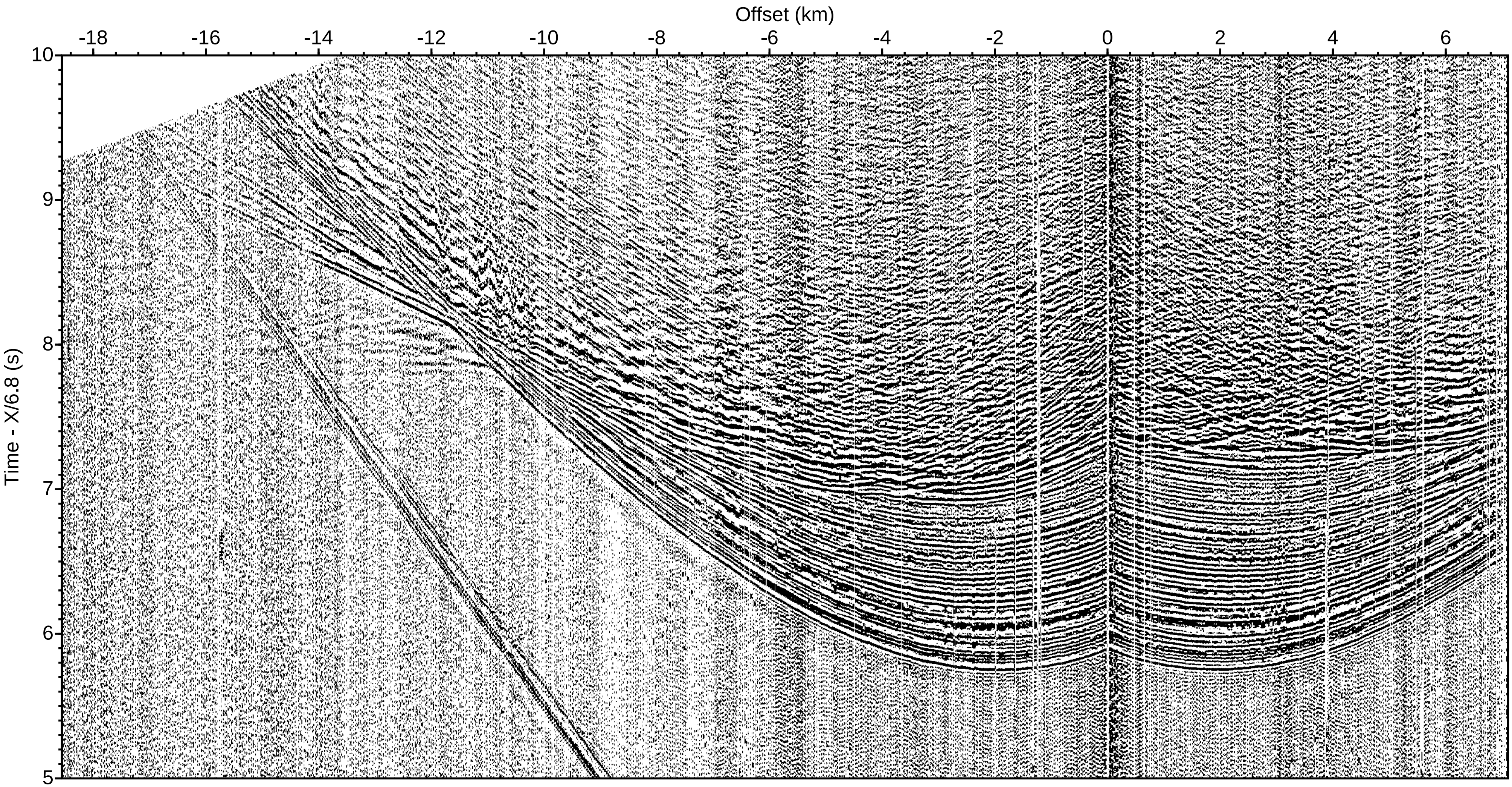
LOMROG III (2012) - Line 10 Sonobuoy 10-33 aux ch 2 (drift correction, deconv., bpf 5-40 Hz)



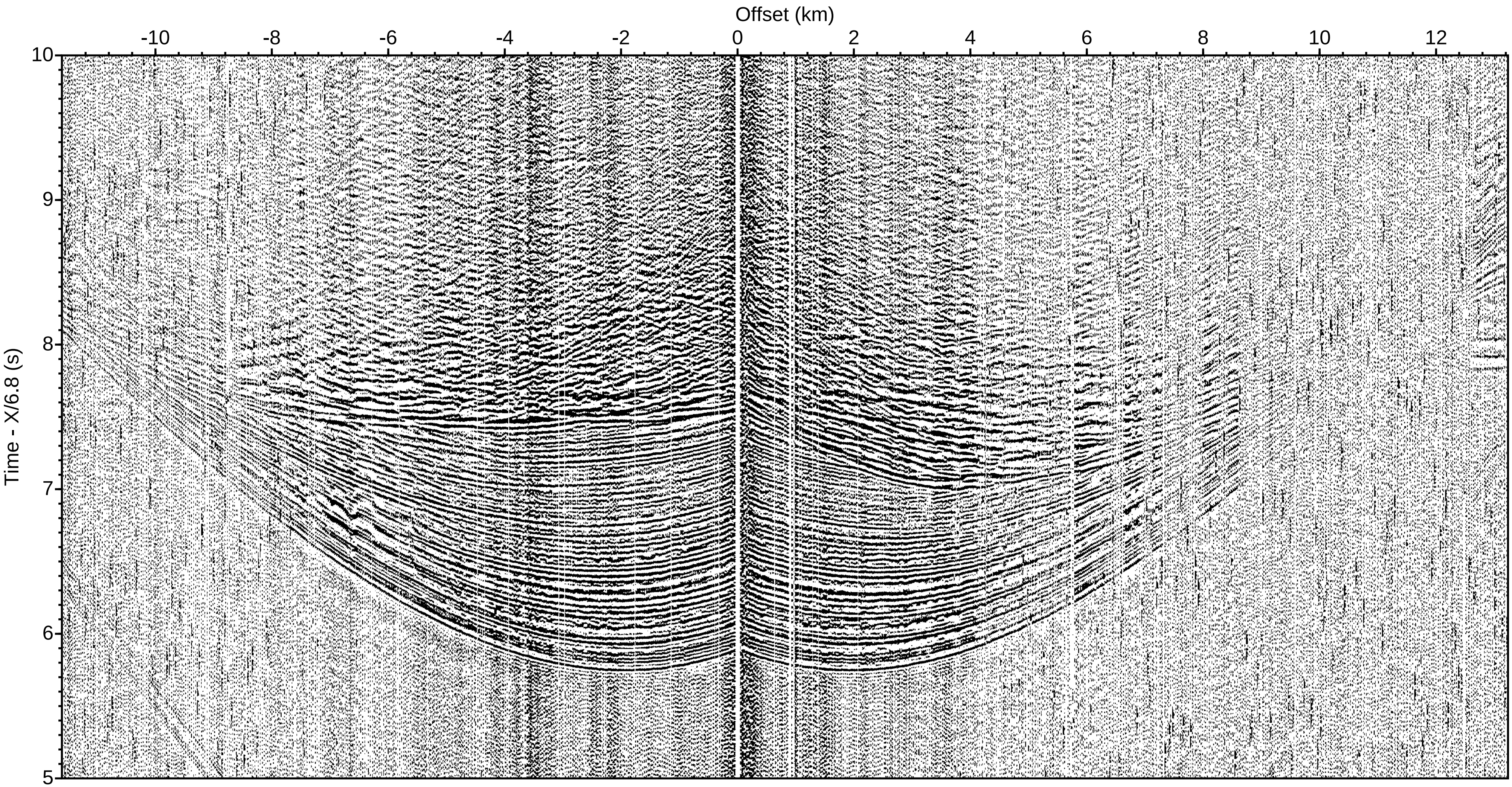
LOMROG III (2012) - Line 10 Sonobuoy 10-34 aux ch 3 (drift correction, deconv., bpf 5-40 Hz)



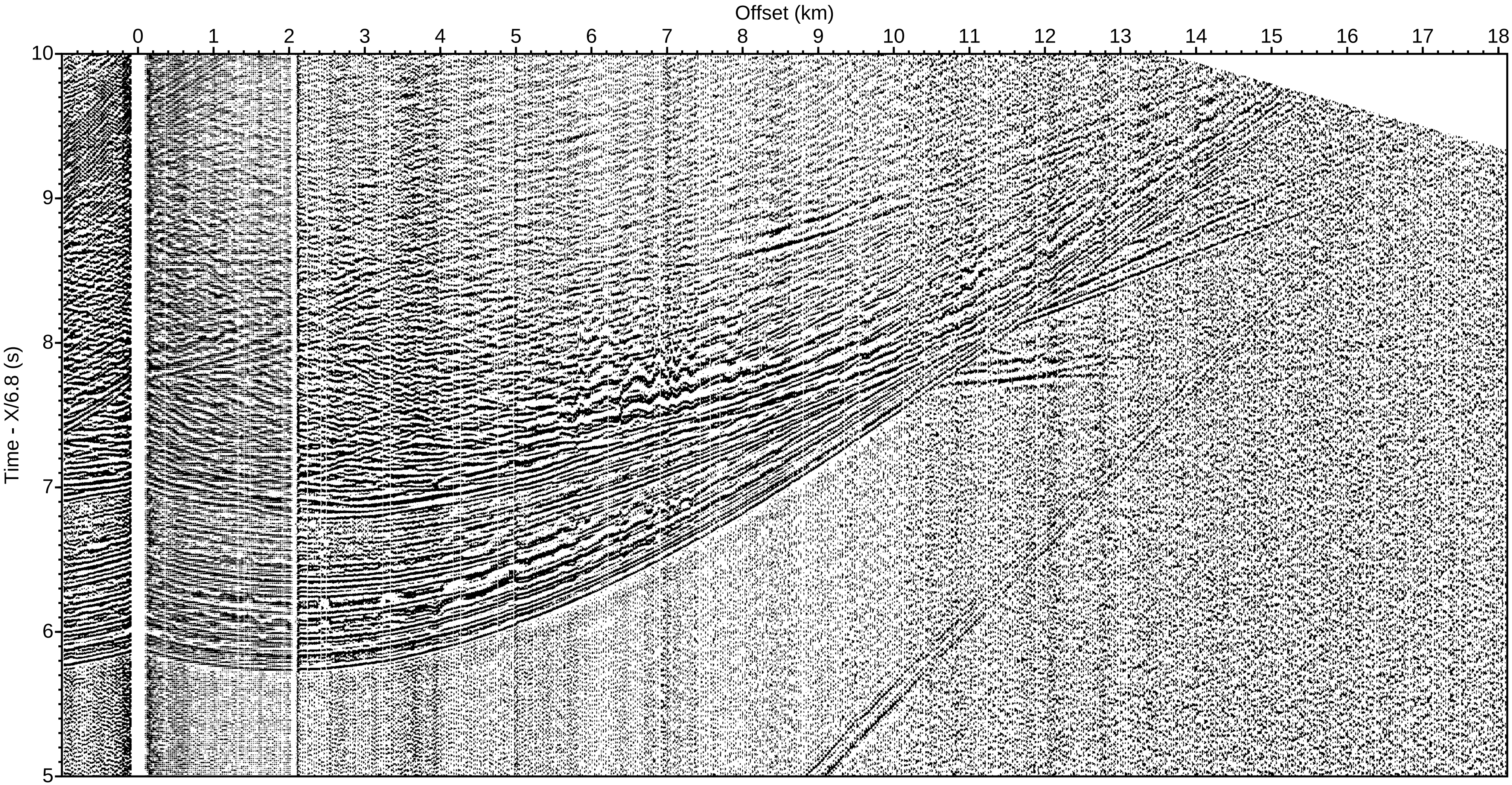
LOMROG III (2012) - Line 11 Sonobuoy 11-36 aux ch 1 (drift correction, deconv., bpf 5-40 Hz)



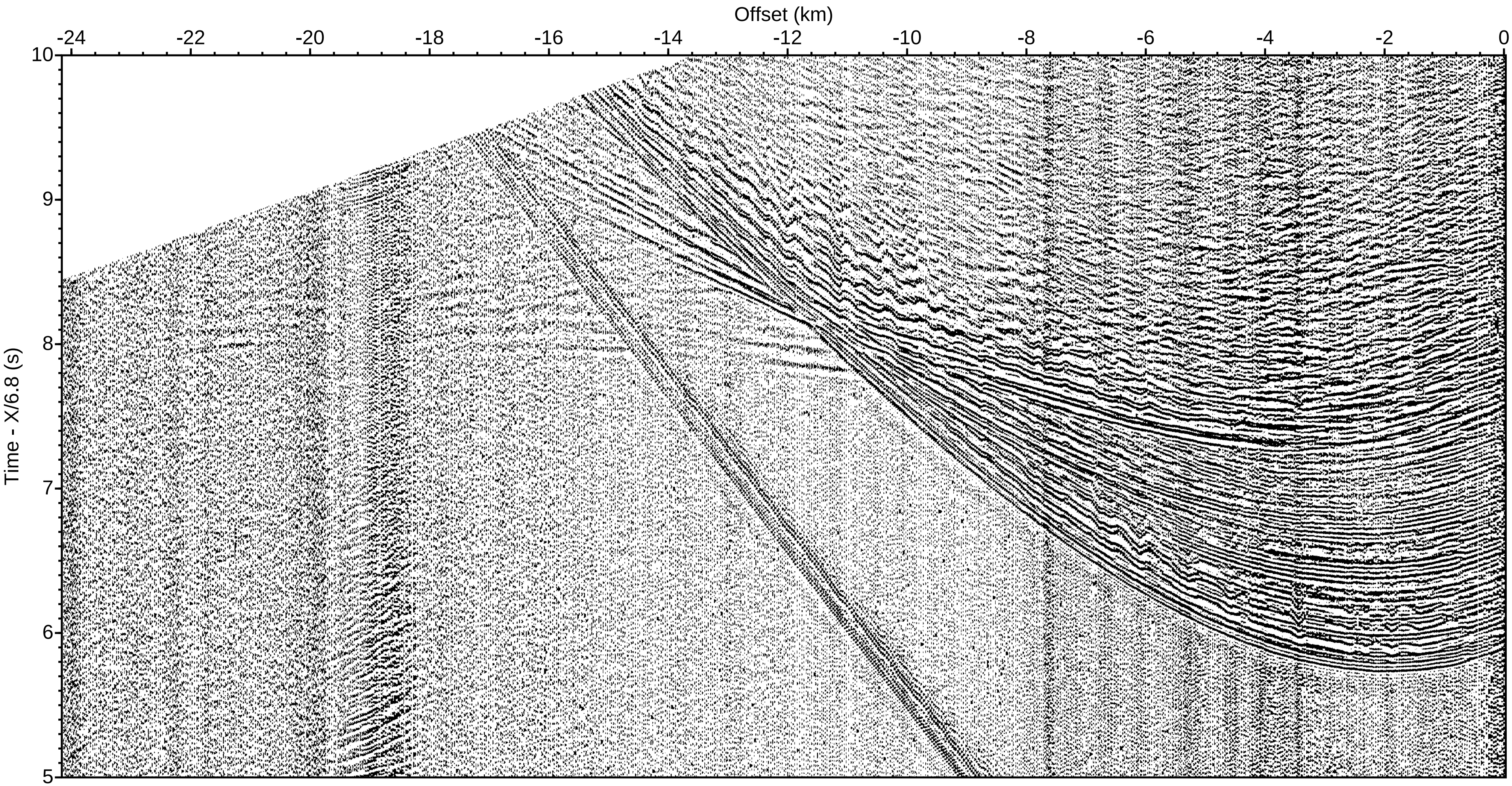
LOMROG III (2012) - Line 11 Sonobuoy 11-37 aux ch 4 (drift correction, deconv., bpf 5-40 Hz)



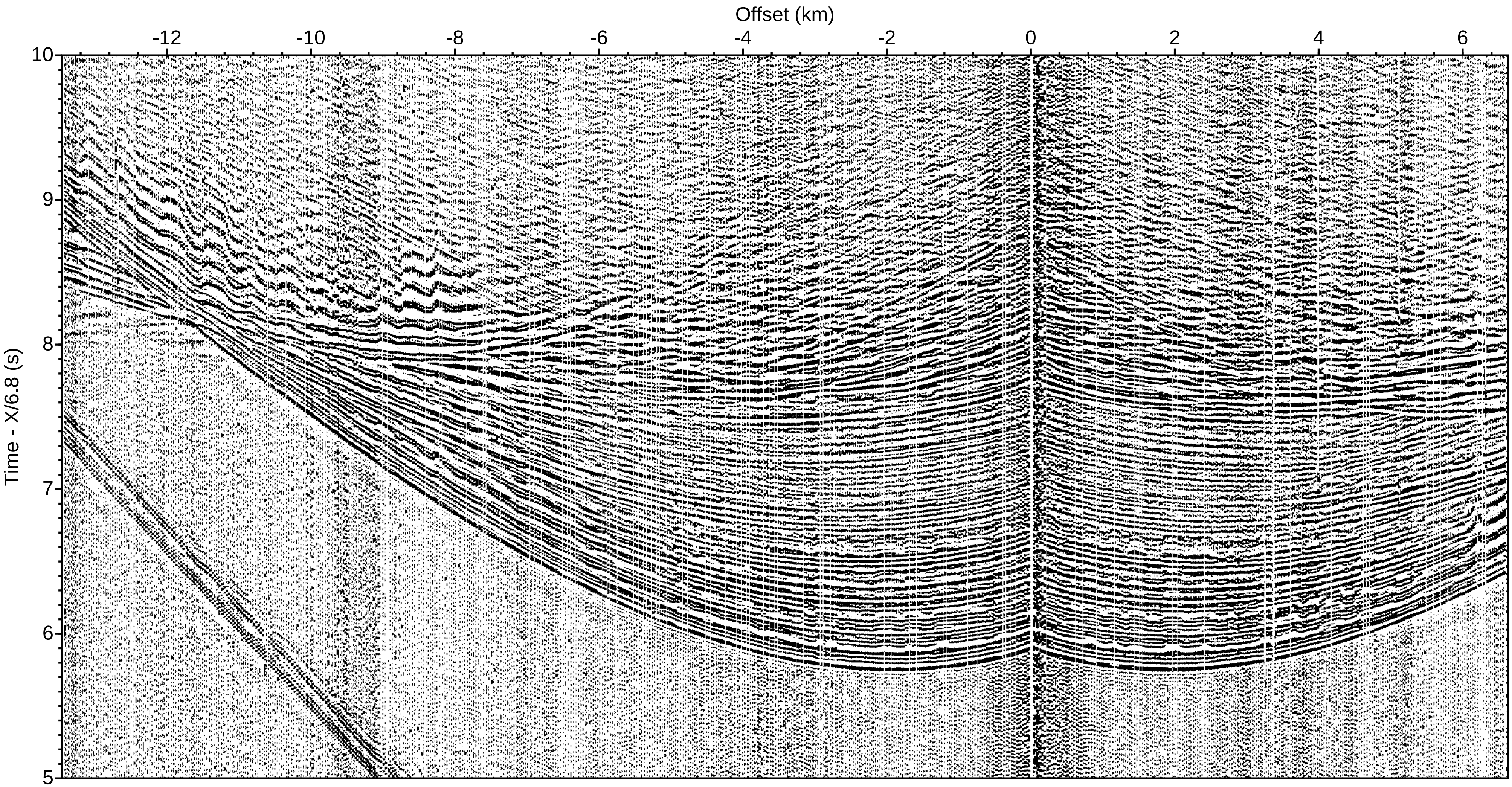
LOMROG III (2012) - Line 11 Sonobuoy 11-38 aux ch 2 (drift correction, deconv., bpf 5-40 Hz)



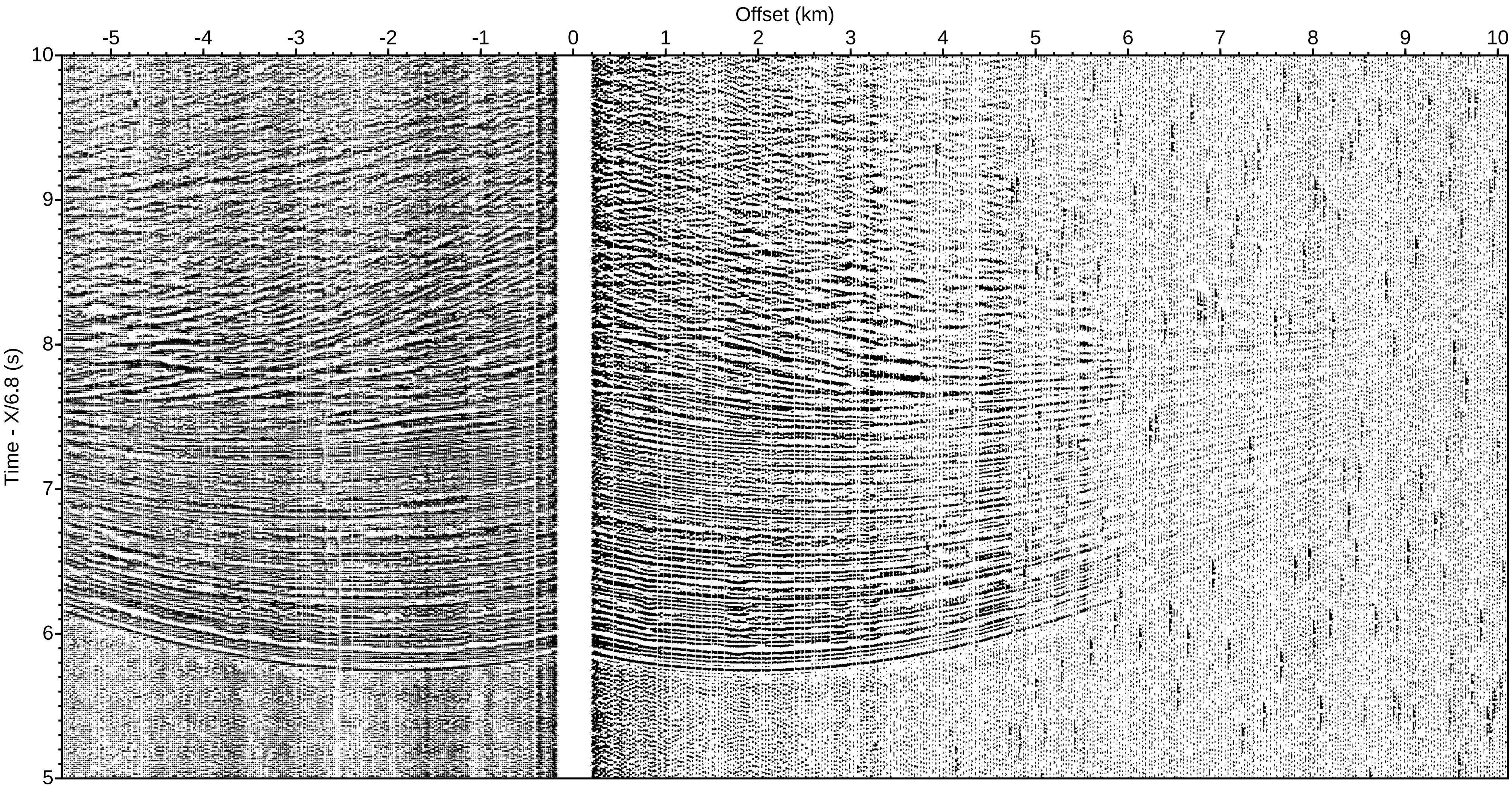
LOMROG III (2012) - Line 11 Sonobuoy 11-39 aux ch 3 (drift correction, deconv., bpf 5-40 Hz)



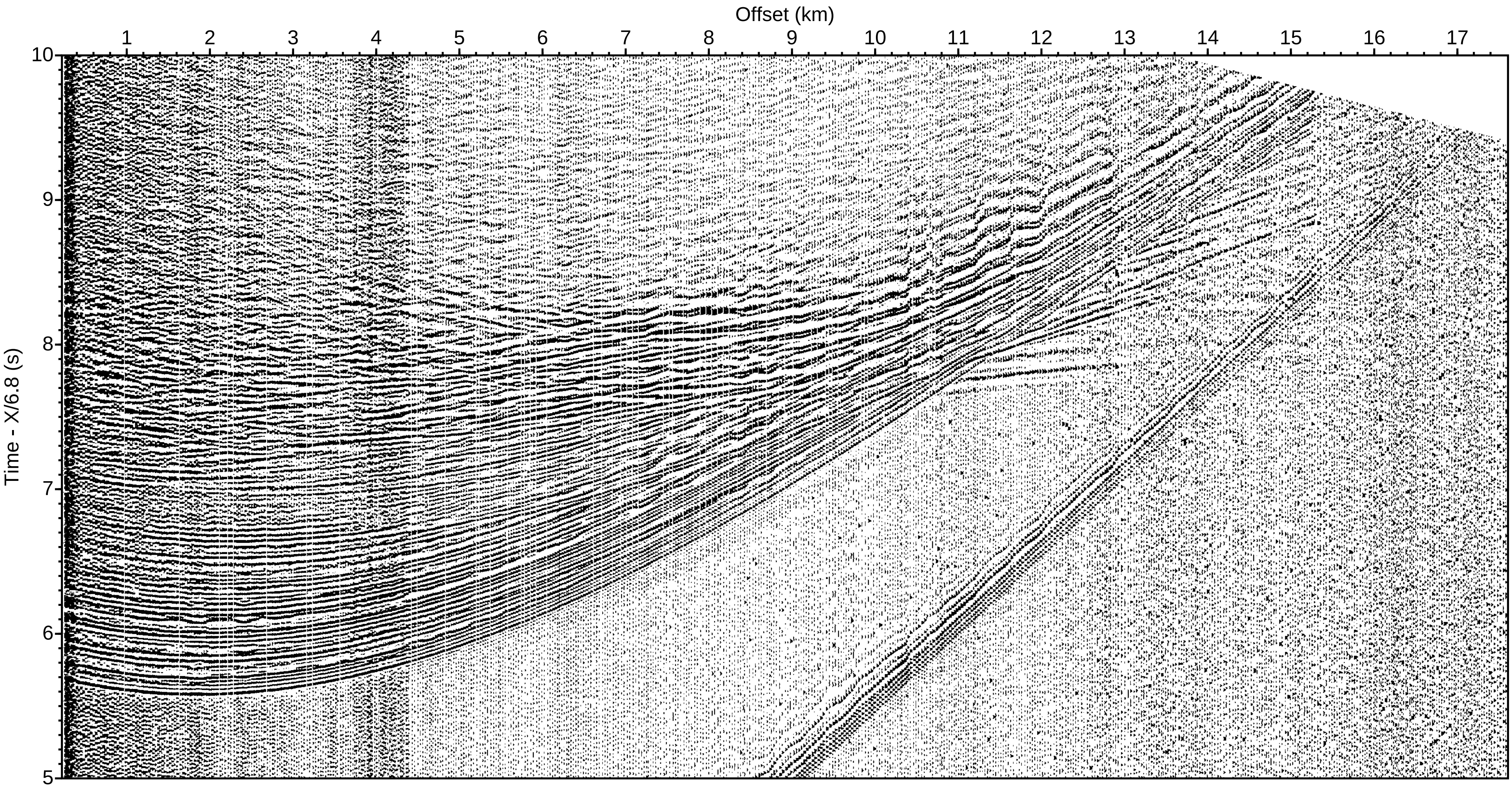
LOMROG III (2012) - Line 12 Sonobuoy 12-40 aux ch 1 (drift correction, deconv., bpf 5-40 Hz)



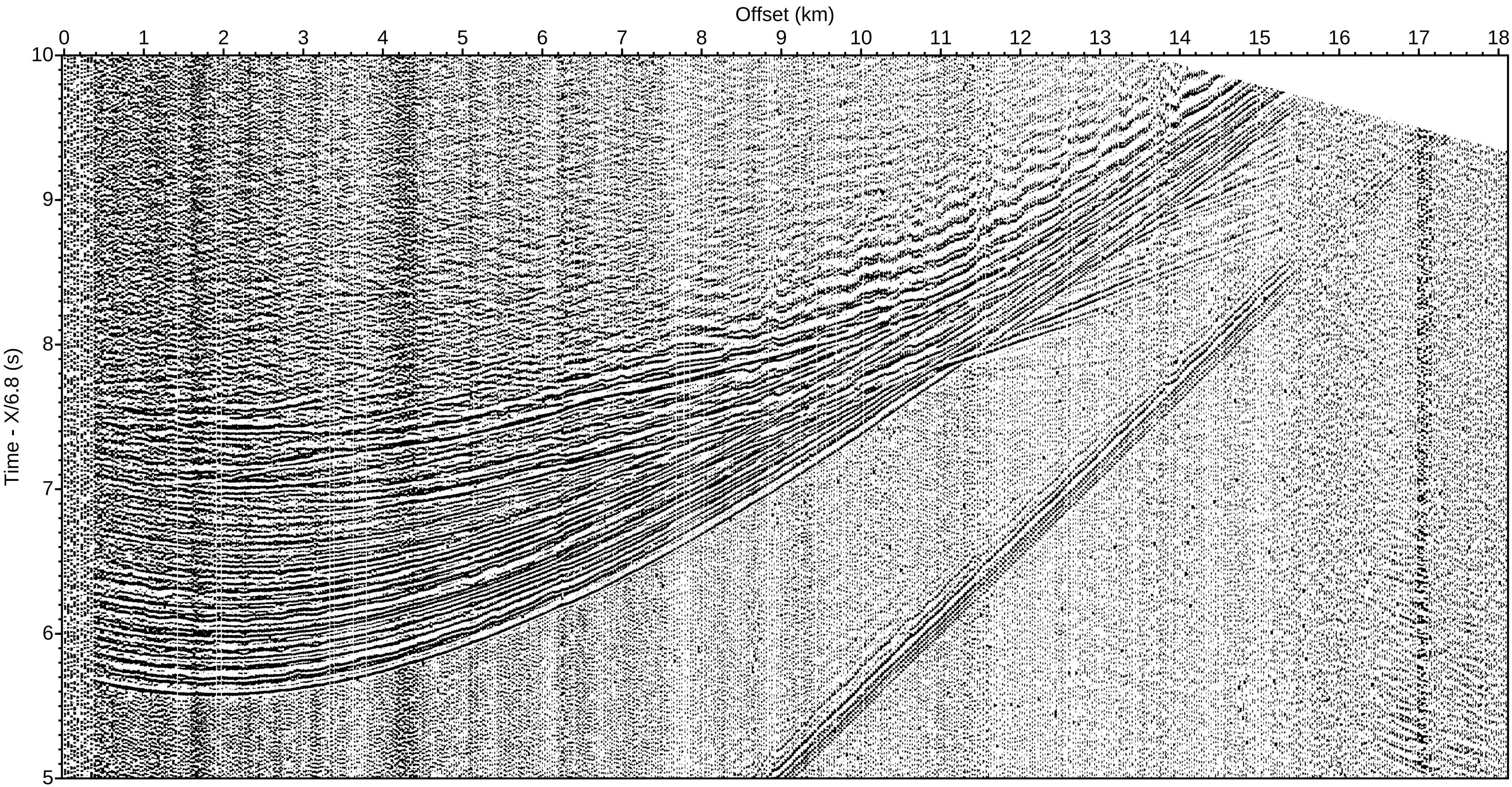
LOMROG III (2012) - Line 12 Sonobuoy 12-41 aux ch 4 (drift correction, deconv., bpf 5-40 Hz)



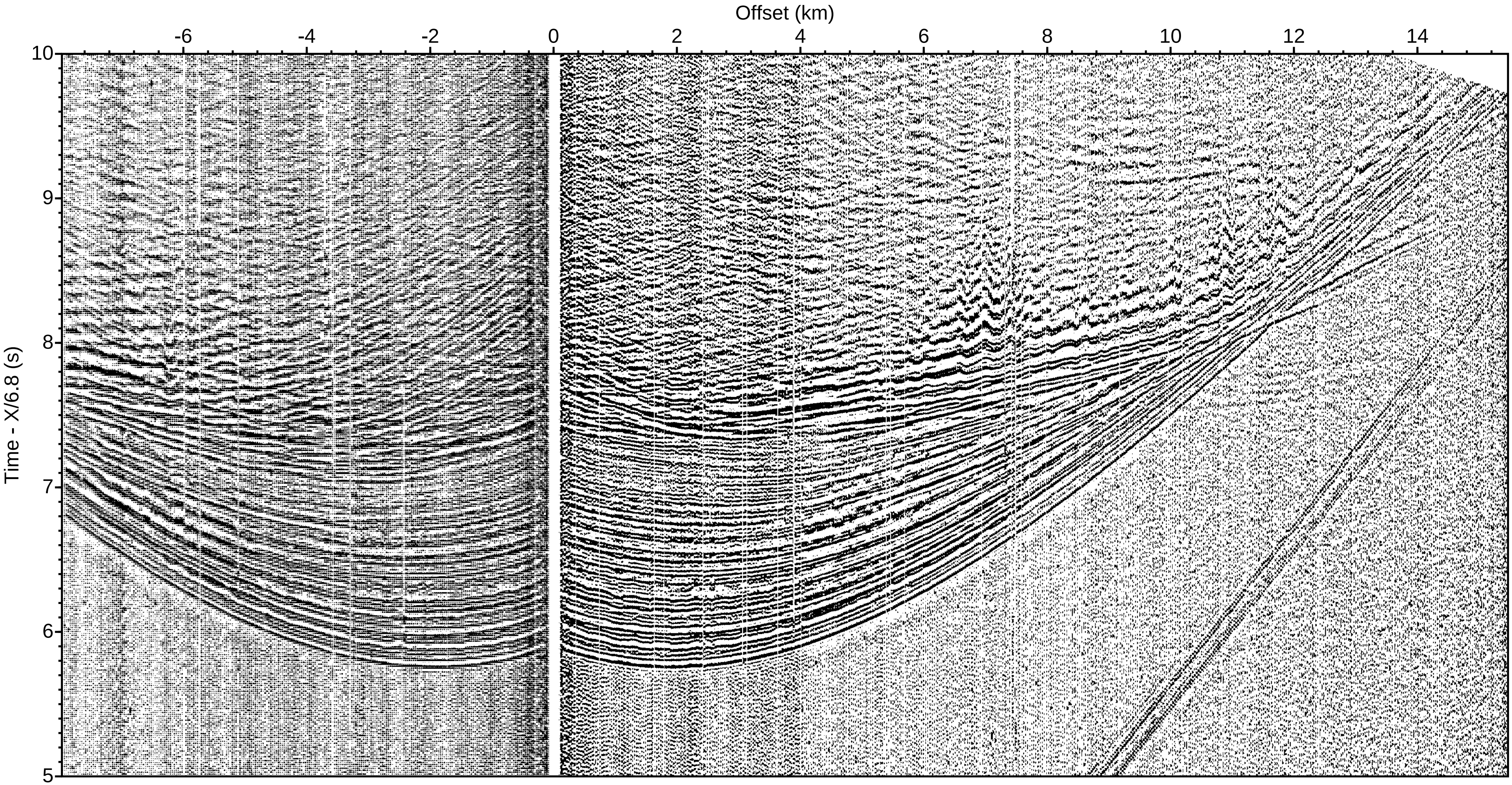
LOMROG III (2012) - Line 12 Sonobuoy 12-42 aux ch 2 (drift correction, deconv., bpf 5-40 Hz)



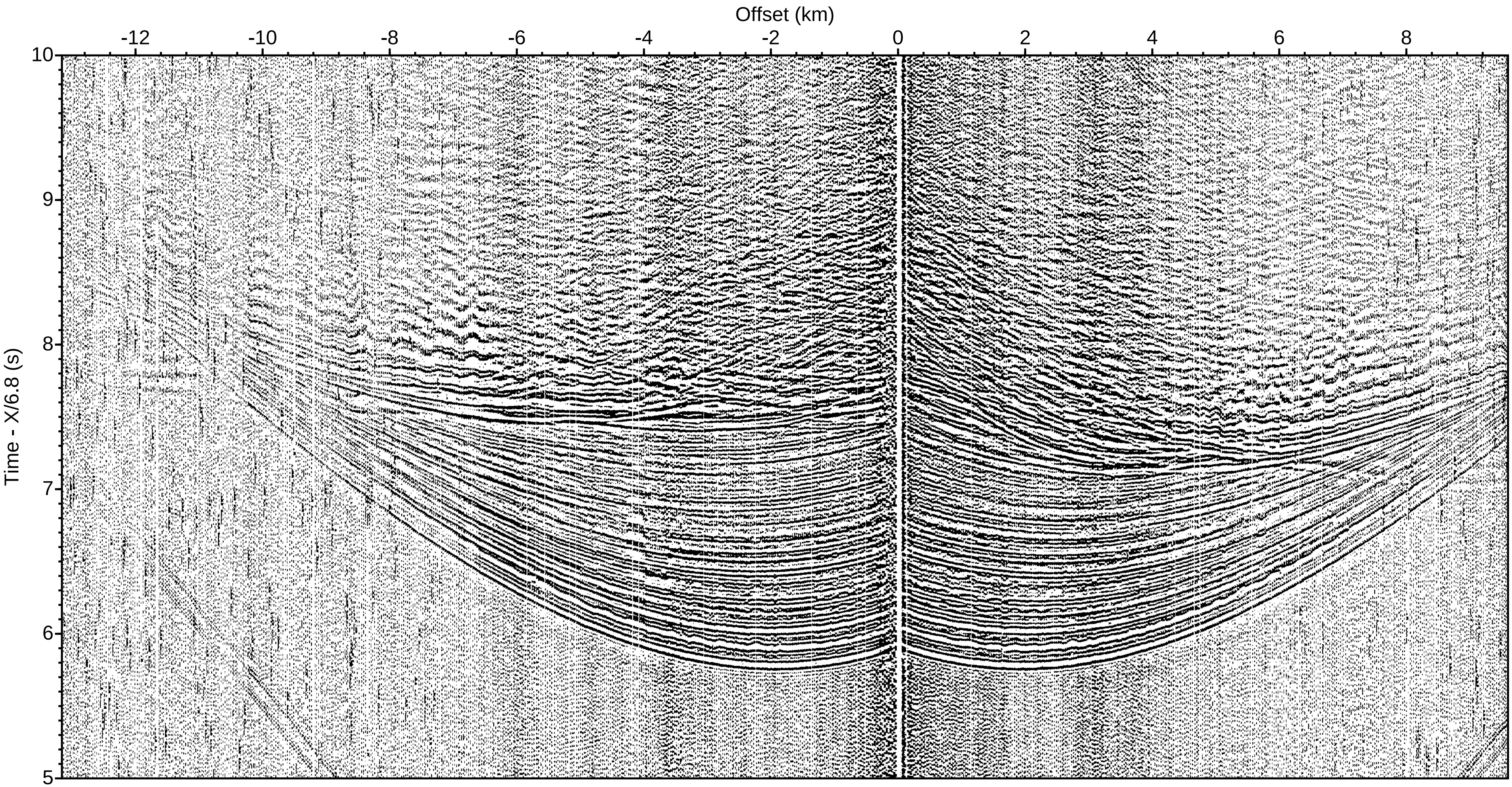
LOMROG III (2012) - Line 12 Sonobuoy 12-43 aux ch 3 (drift correction, deconv., bpf 5-40 Hz)



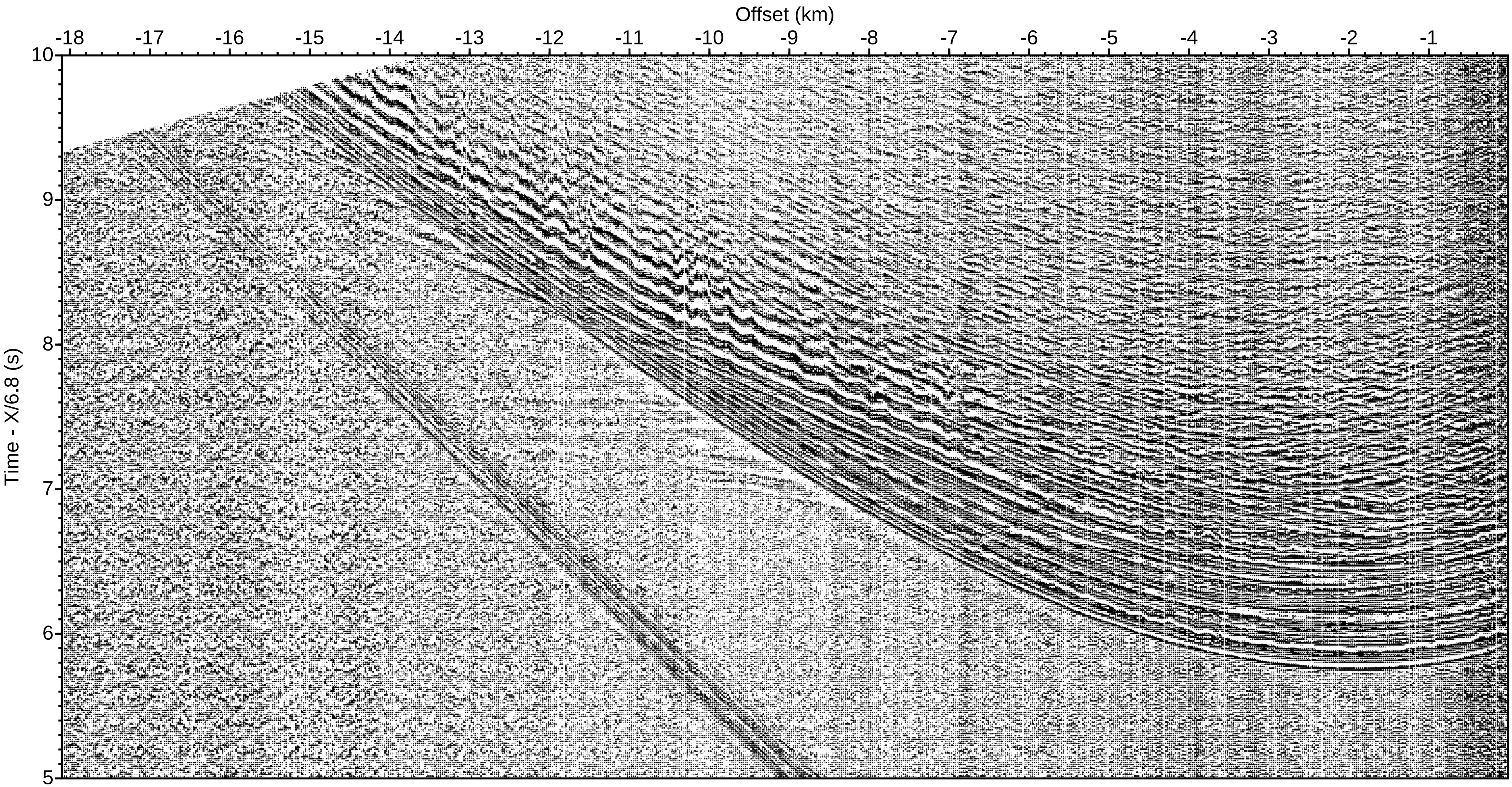
LOMROG III (2012) - Line 13 Sonobuoy 13-44 aux ch 1 (drift correction, deconv., bpf 5-40 Hz)



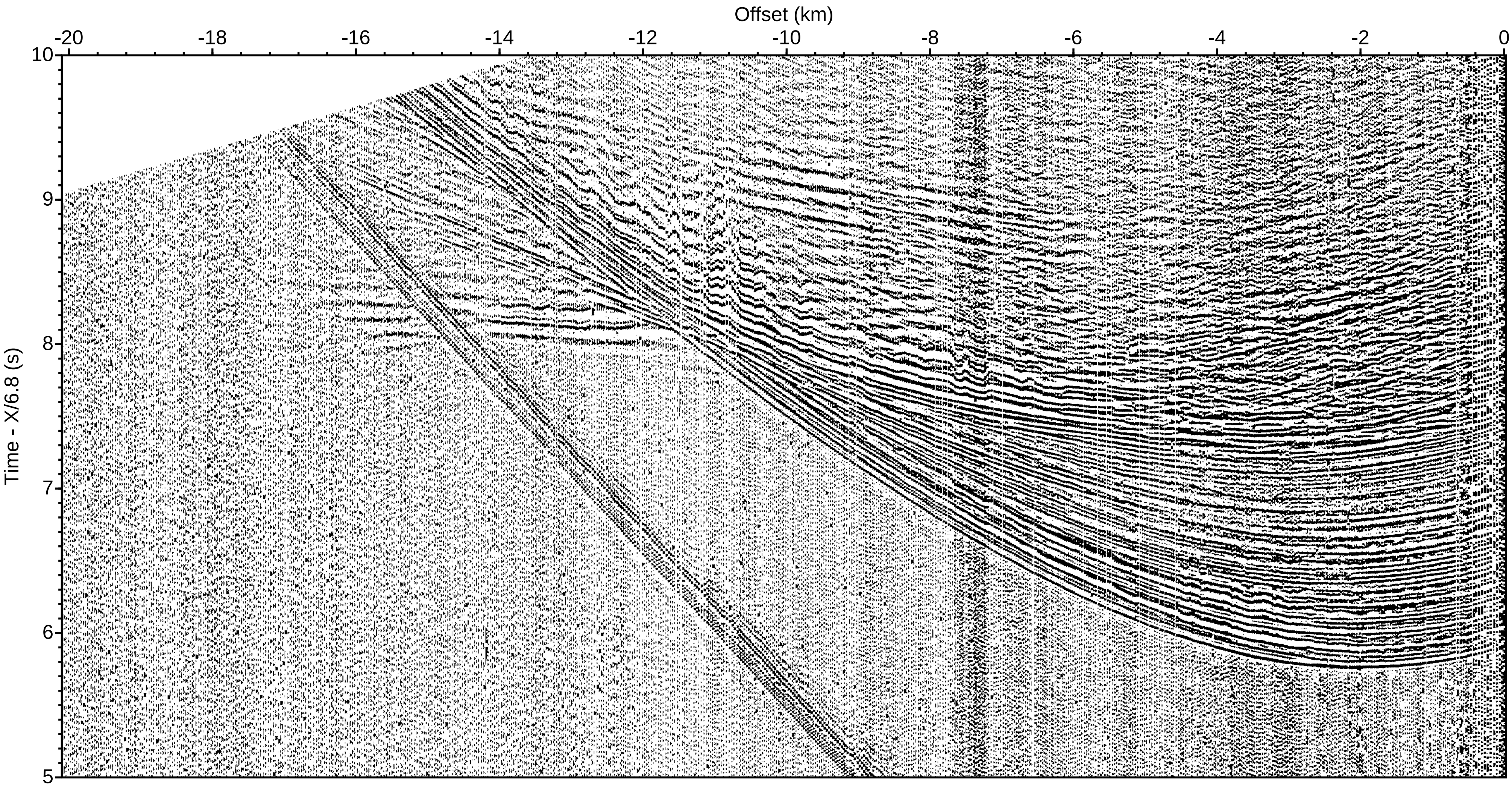
LOMROG III (2012) - Line 13 Sonobuoy 13-45 aux ch 4 (drift correction, deconv., bpf 5-40 Hz)



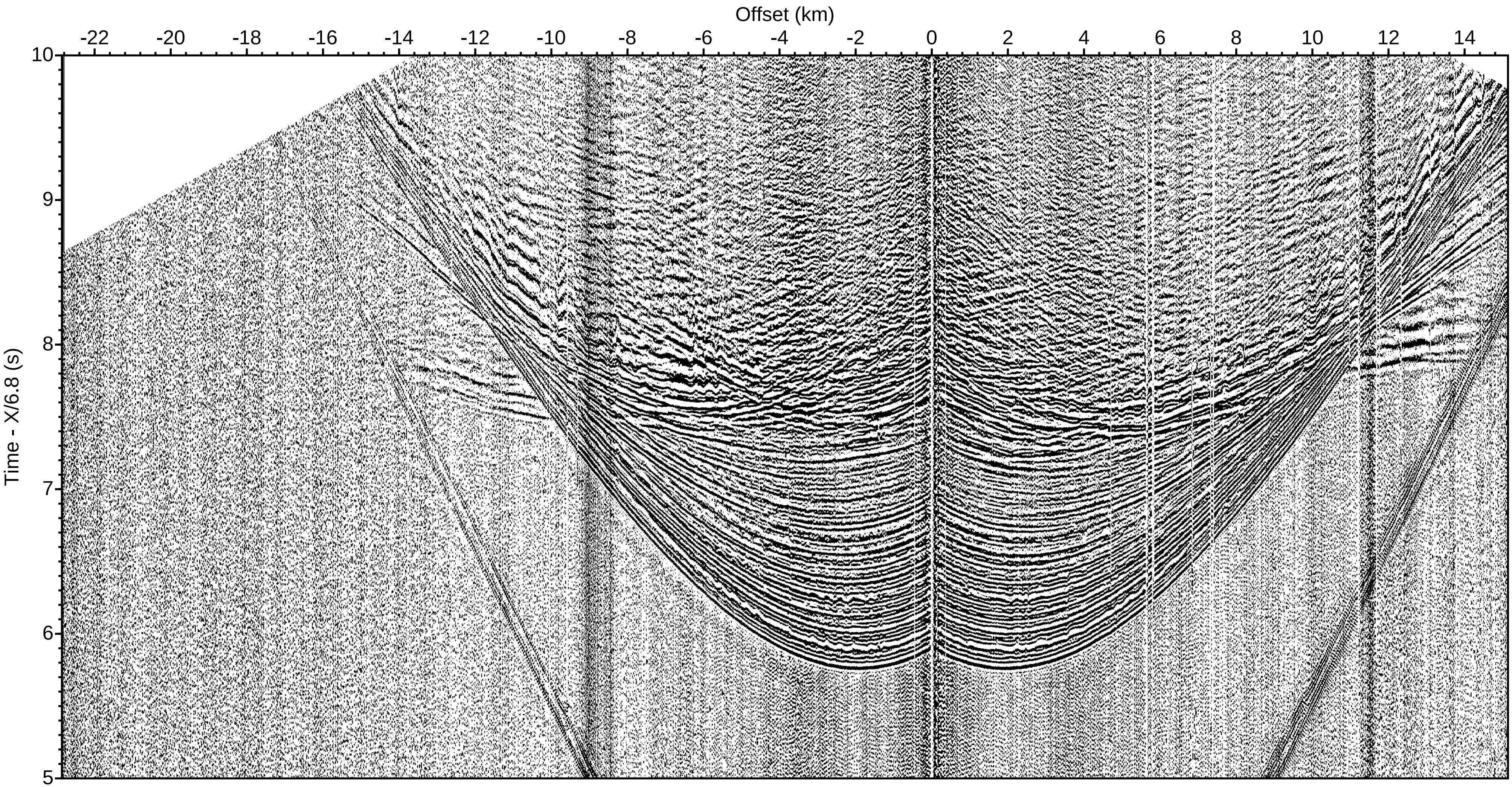
LOMROG III (2012) - Line 13 Sonobuoy 13-46 aux ch 2 (drift correction, deconv., bpf 5-40 Hz)



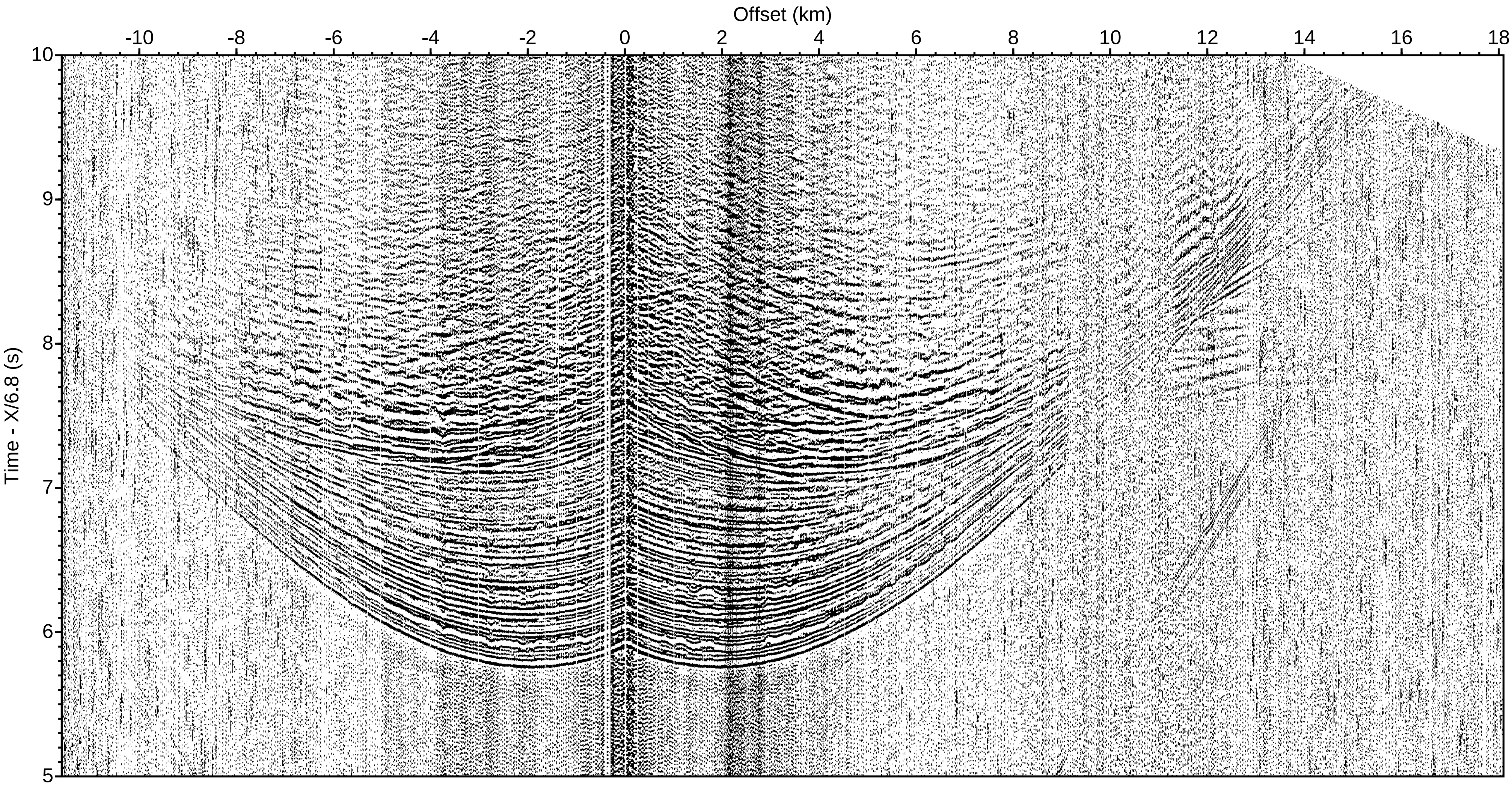
LOMROG III (2012) - Line 13 Sonobuoy 13-47 aux ch 3 (drift correction, deconv., bpf 5-40 Hz)



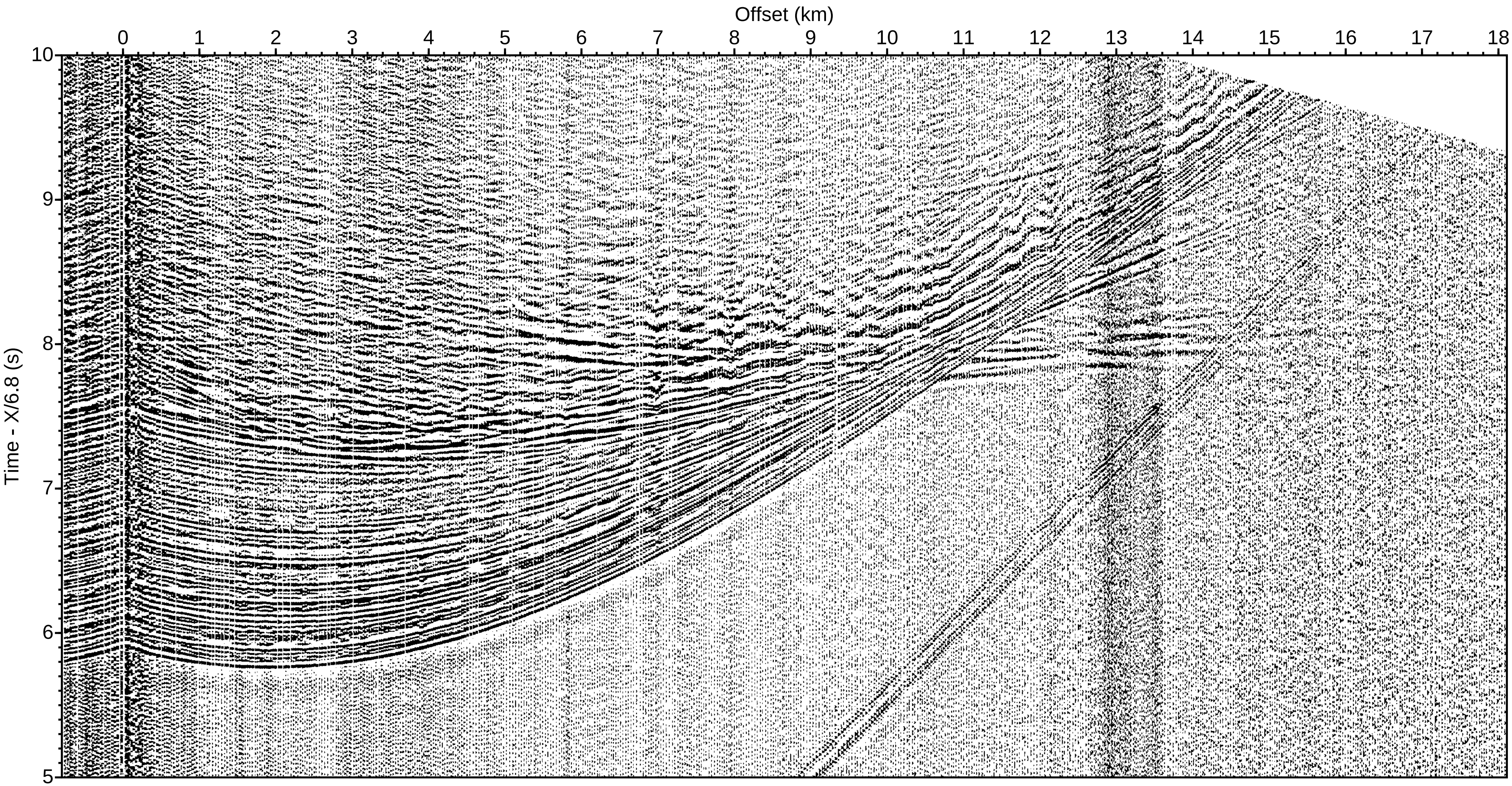
LOMROG III (2012) - Line 14 Sonobuoy 14-48 aux ch 1 (drift correction, deconv., bpf 5-40 Hz)



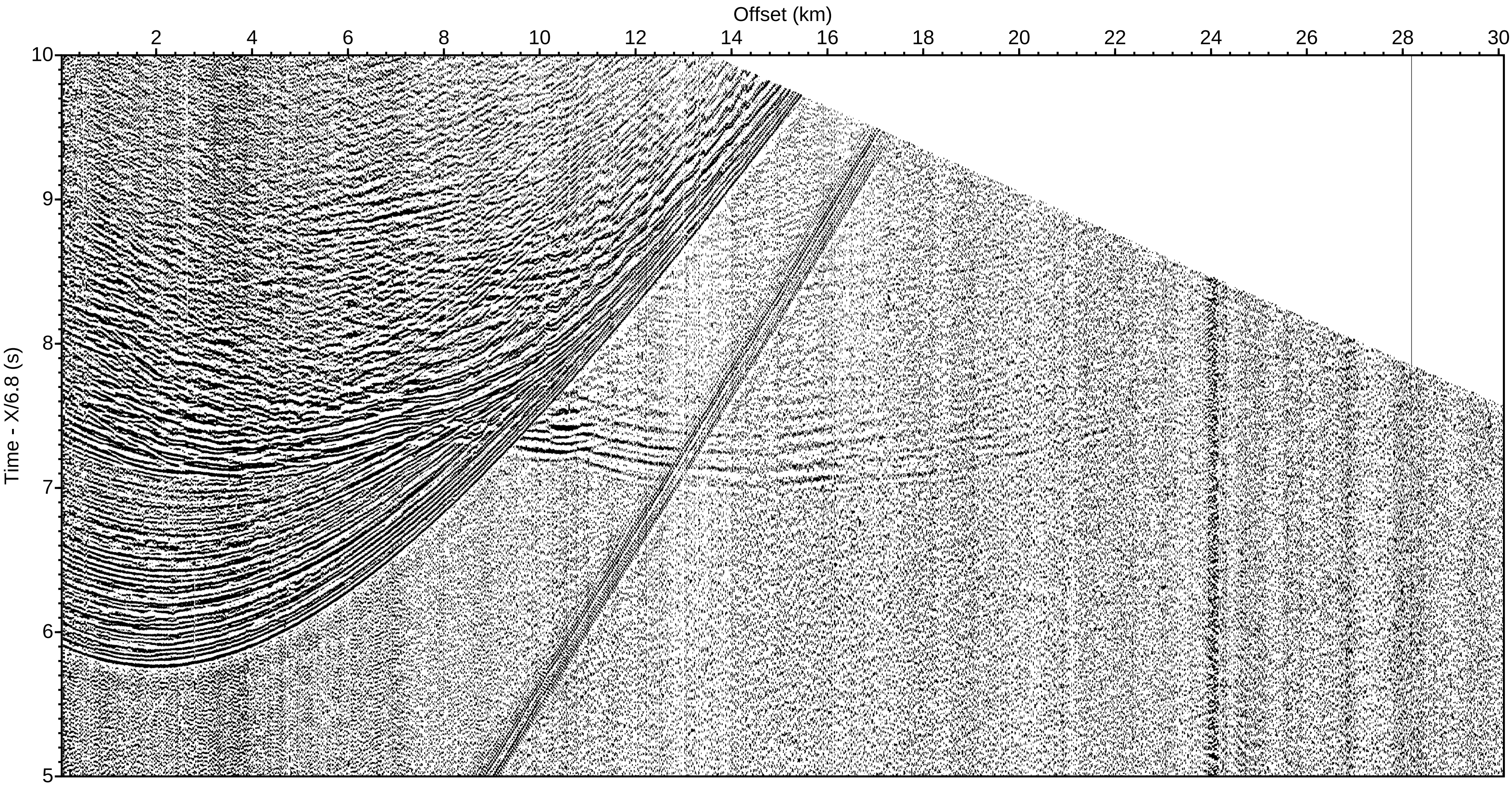
LOMROG III (2012) - Line 14 Sonobuoy 14-49 aux ch 4 (drift correction, deconv., bpf 5-40 Hz)



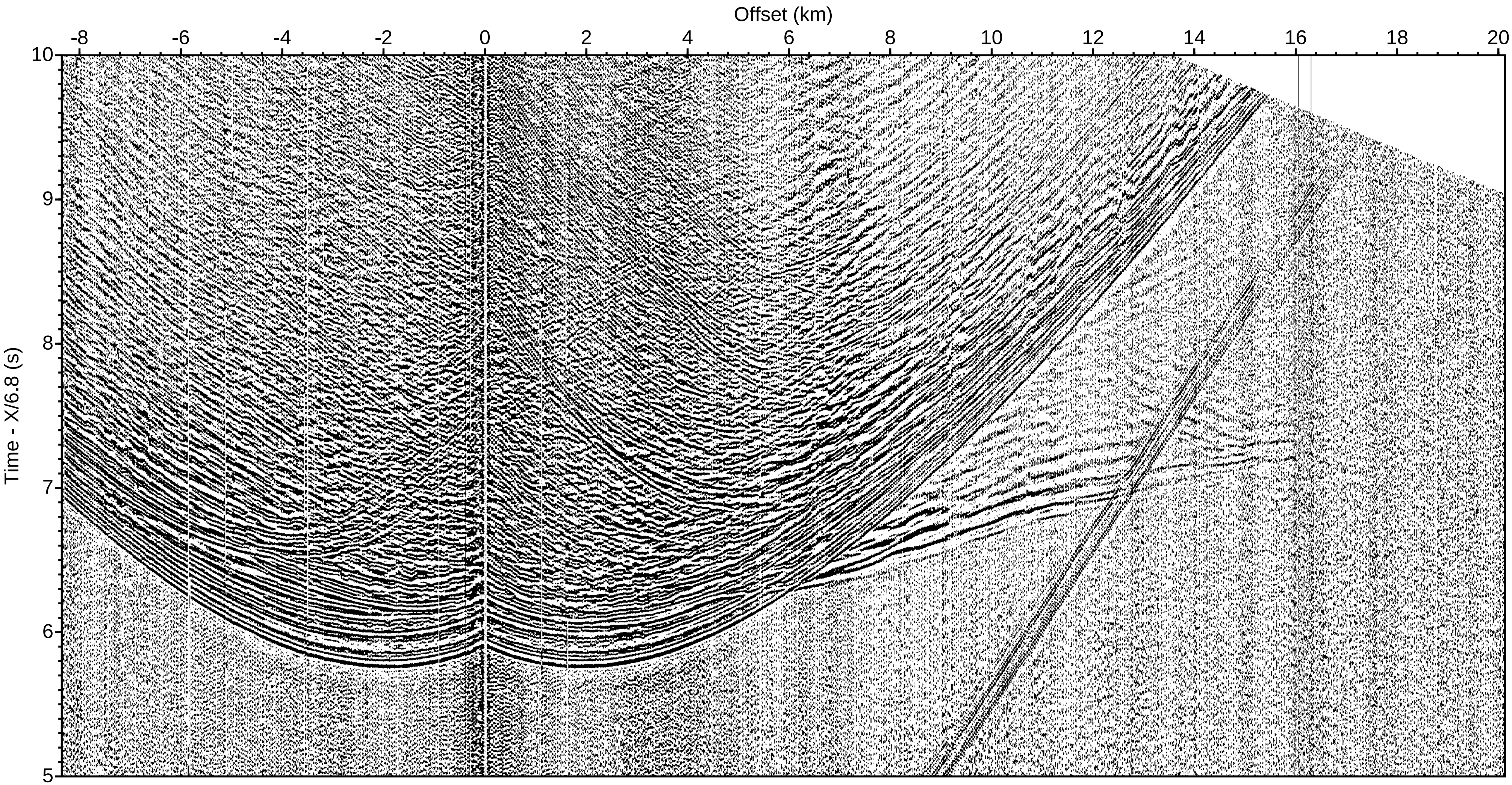
LOMROG III (2012) - Line 14 Sonobuoy 14-50 aux ch 2 (drift correction, deconv., bpf 5-40 Hz)



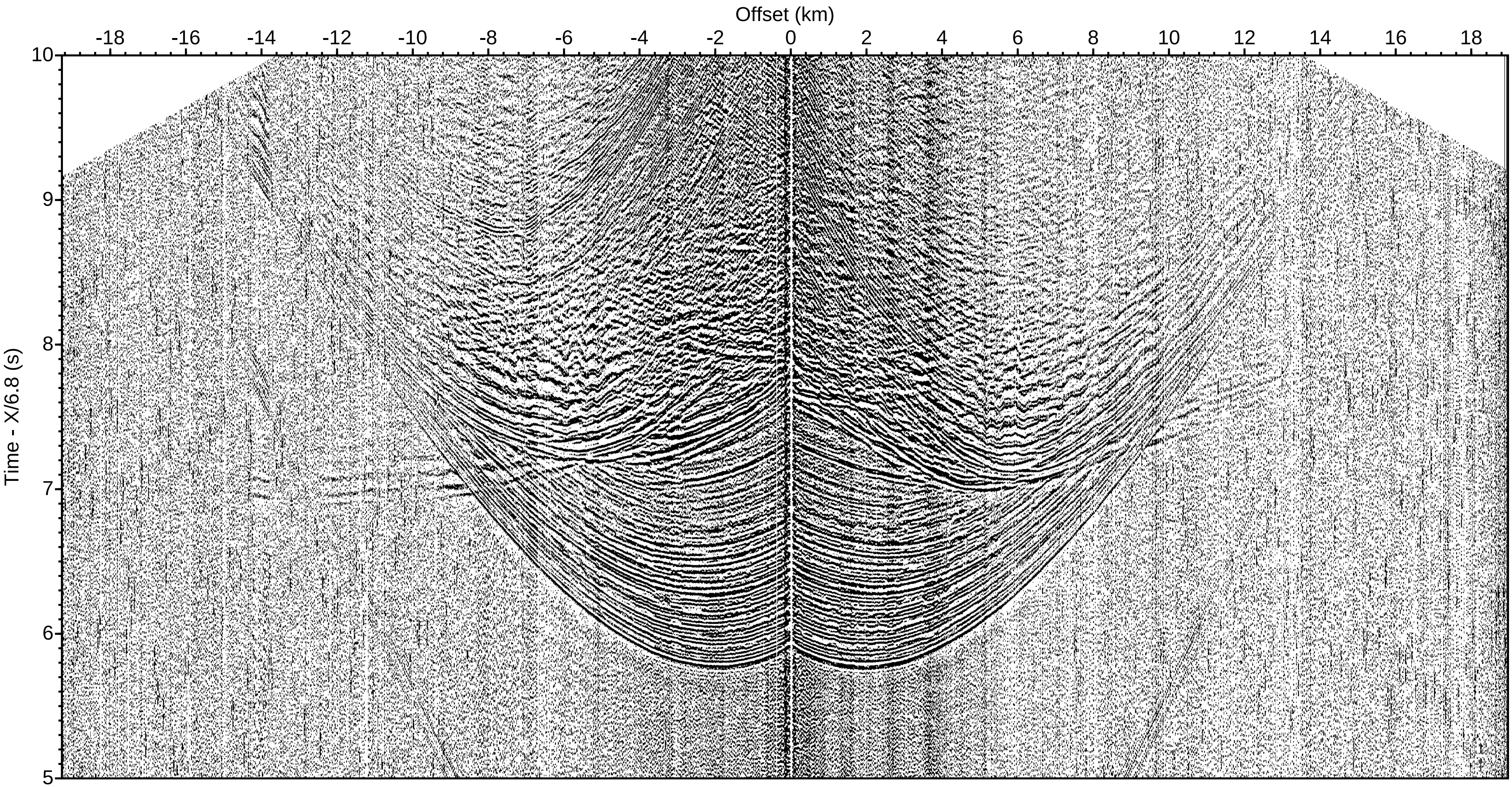
LOMROG III (2012) - Line 14 Sonobuoy 14-51 aux ch 3 (drift correction, deconv., bpf 5-40 Hz)



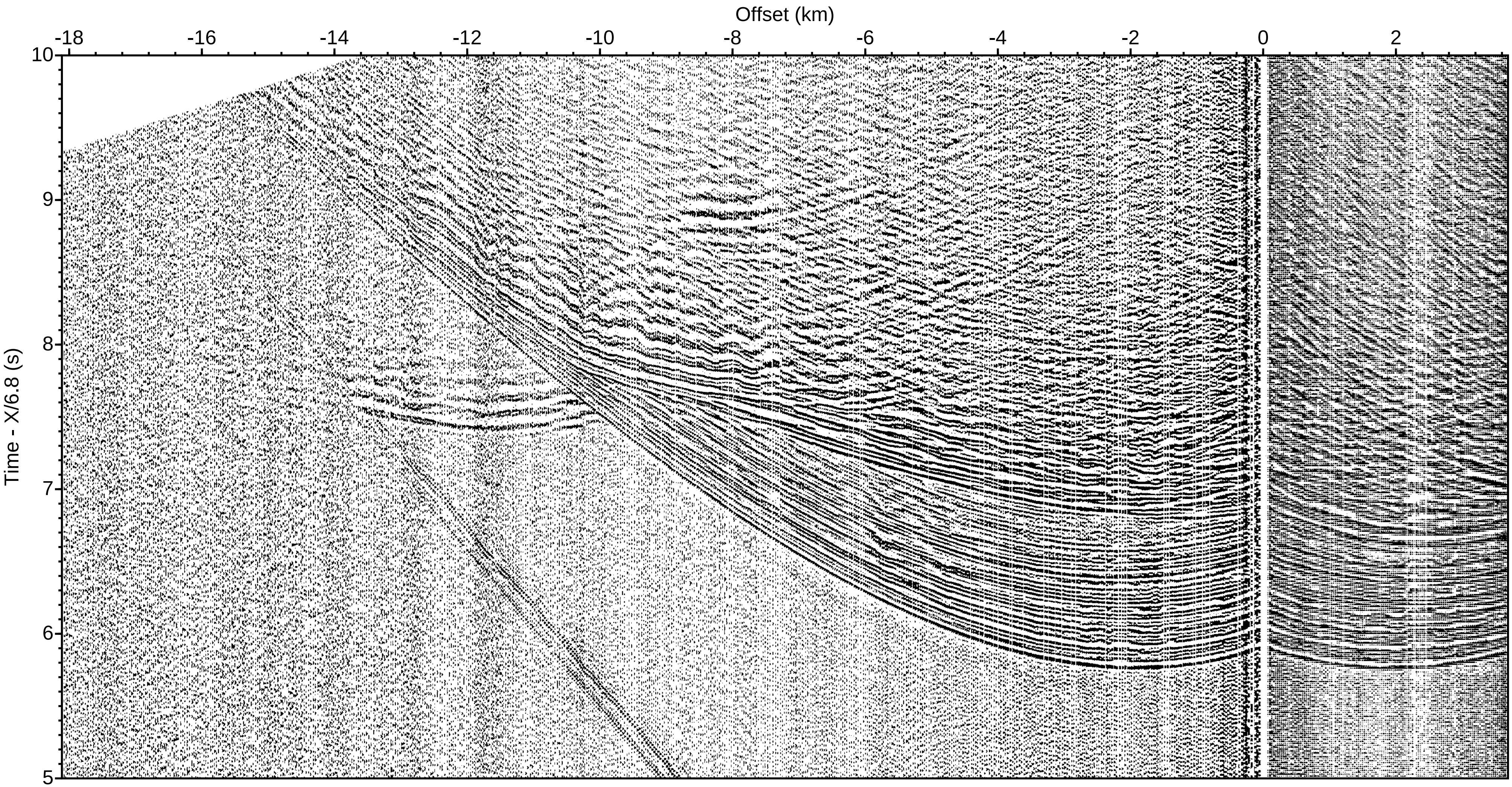
LOMROG III (2012) - Line 15 Sonobuoy 15-52 aux ch 1 (drift correction, deconv., bpf 5-40 Hz)



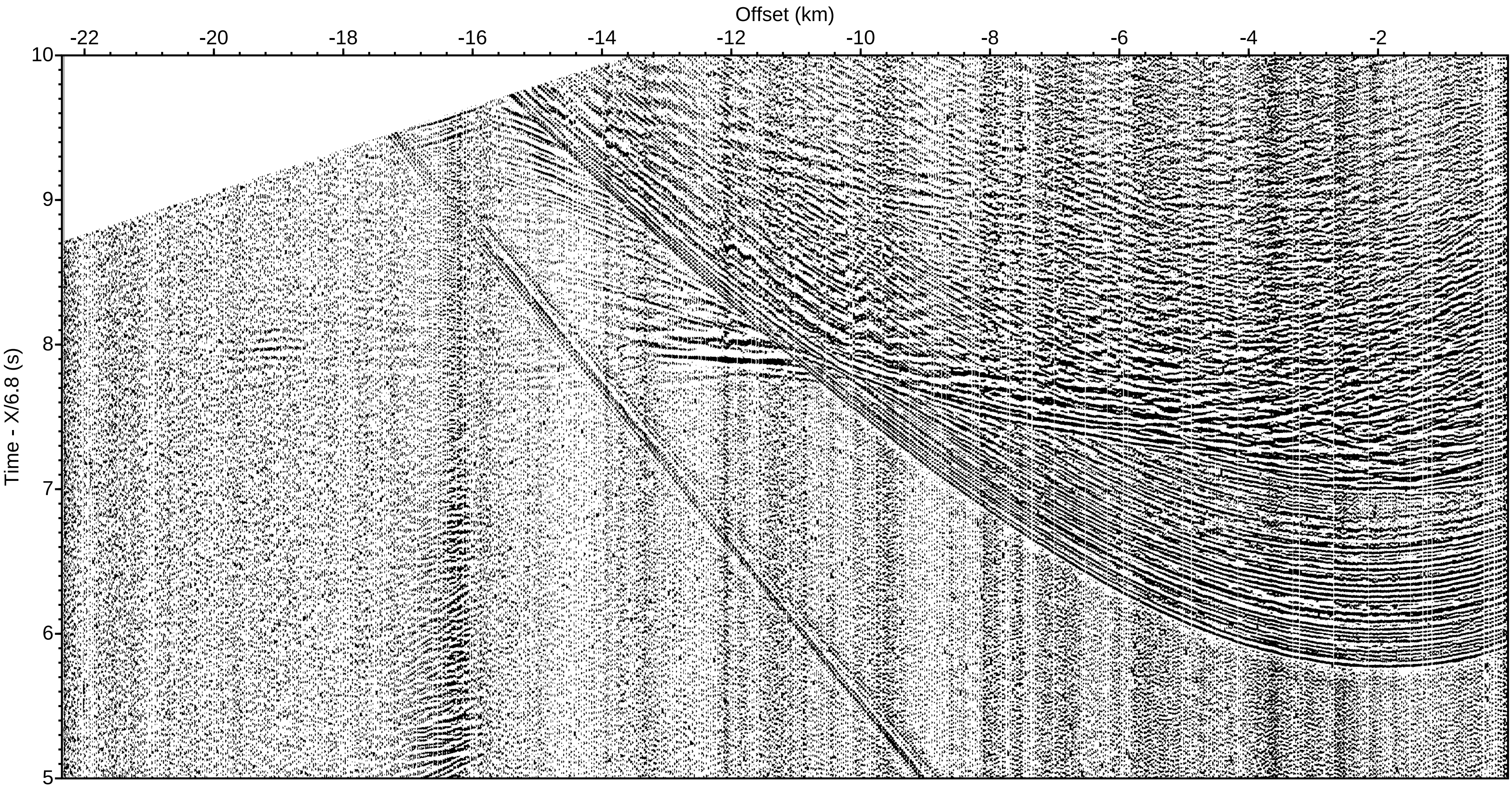
LOMROG III (2012) - Line 15 Sonobuoy 15-53 aux ch 4 (drift correction, deconv., bpf 5-40 Hz)



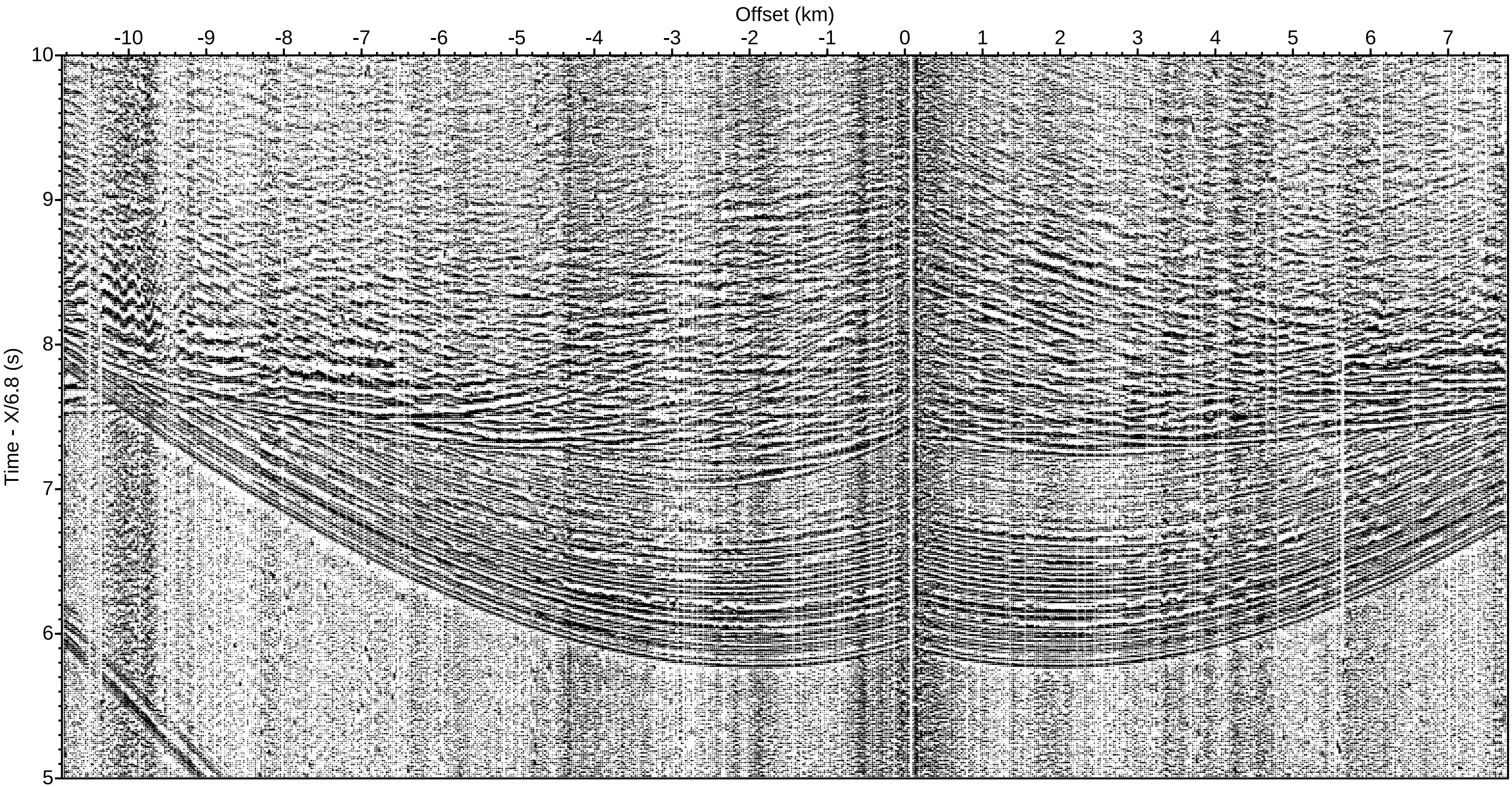
LOMROG III (2012) - Line 15 Sonobuoy 15-54 aux ch 2 (drift correction, deconv., bpf 5-40 Hz)



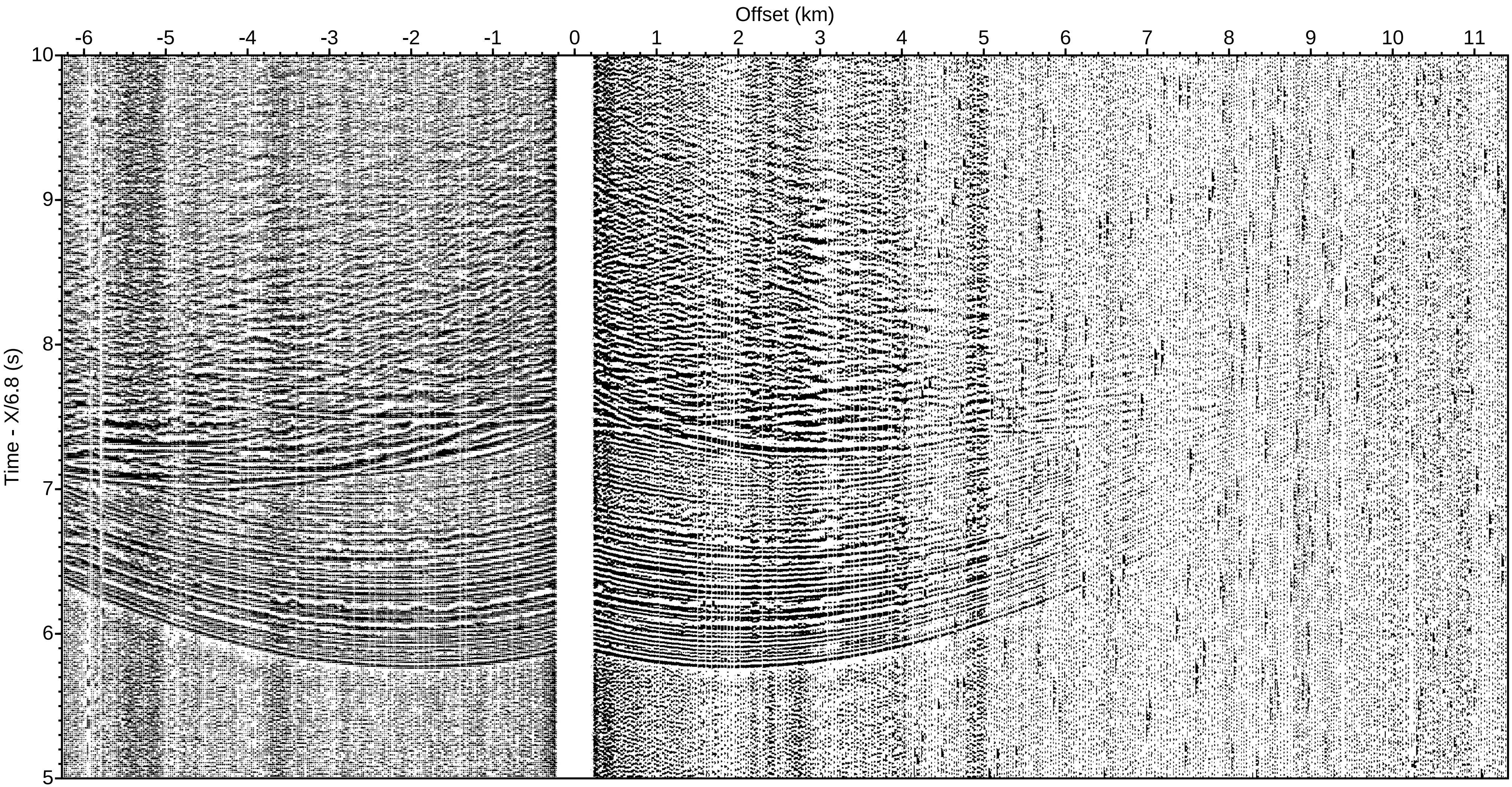
LOMROG III (2012) - Line 15 Sonobuoy 15-55 aux ch 3 (drift correction, deconv., bpf 5-40 Hz)



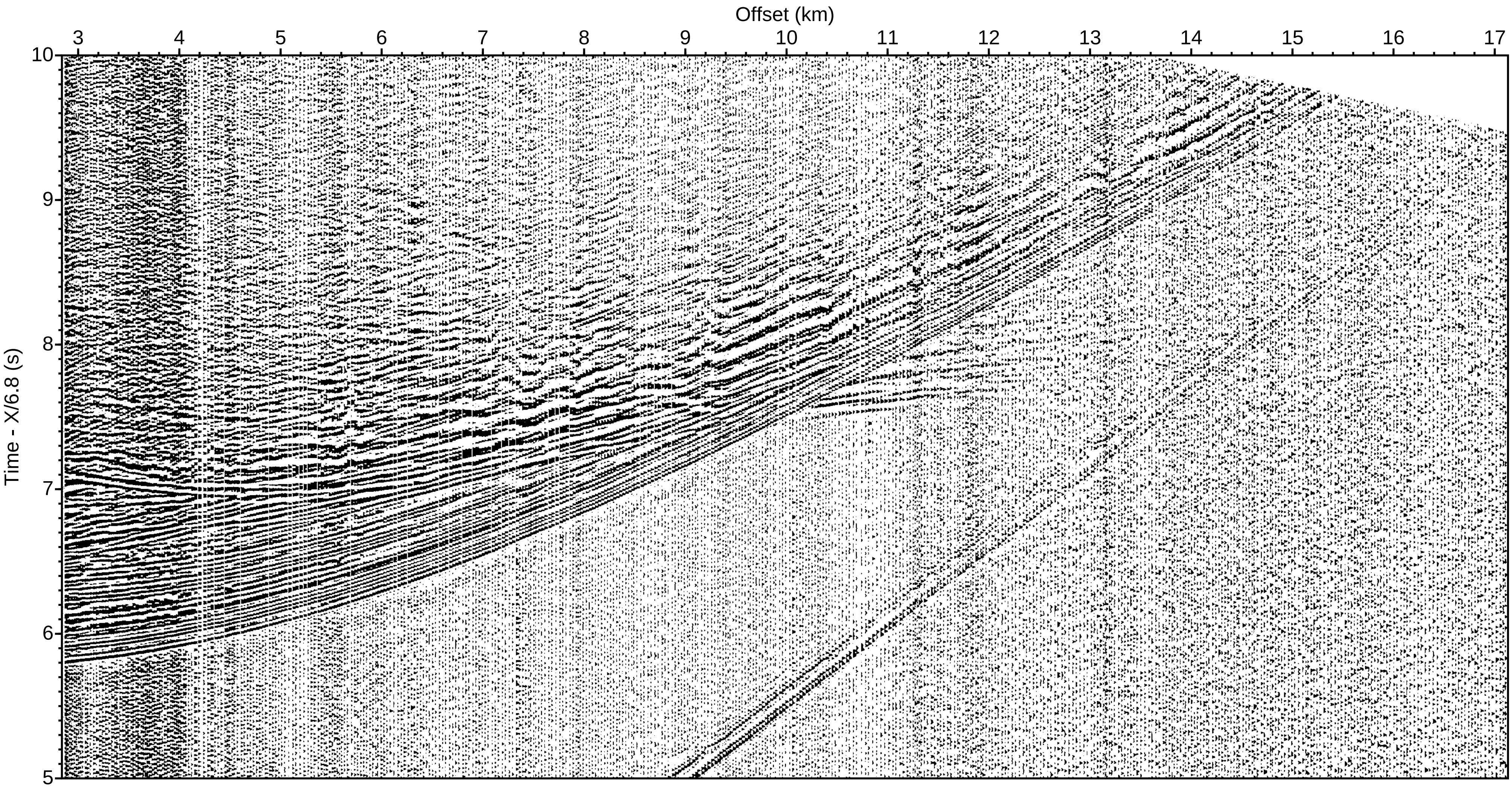
LOMROG III (2012) - Line 16 Sonobuoy 16-56 aux ch 1 (drift correction, deconv., bpf 5-40 Hz)



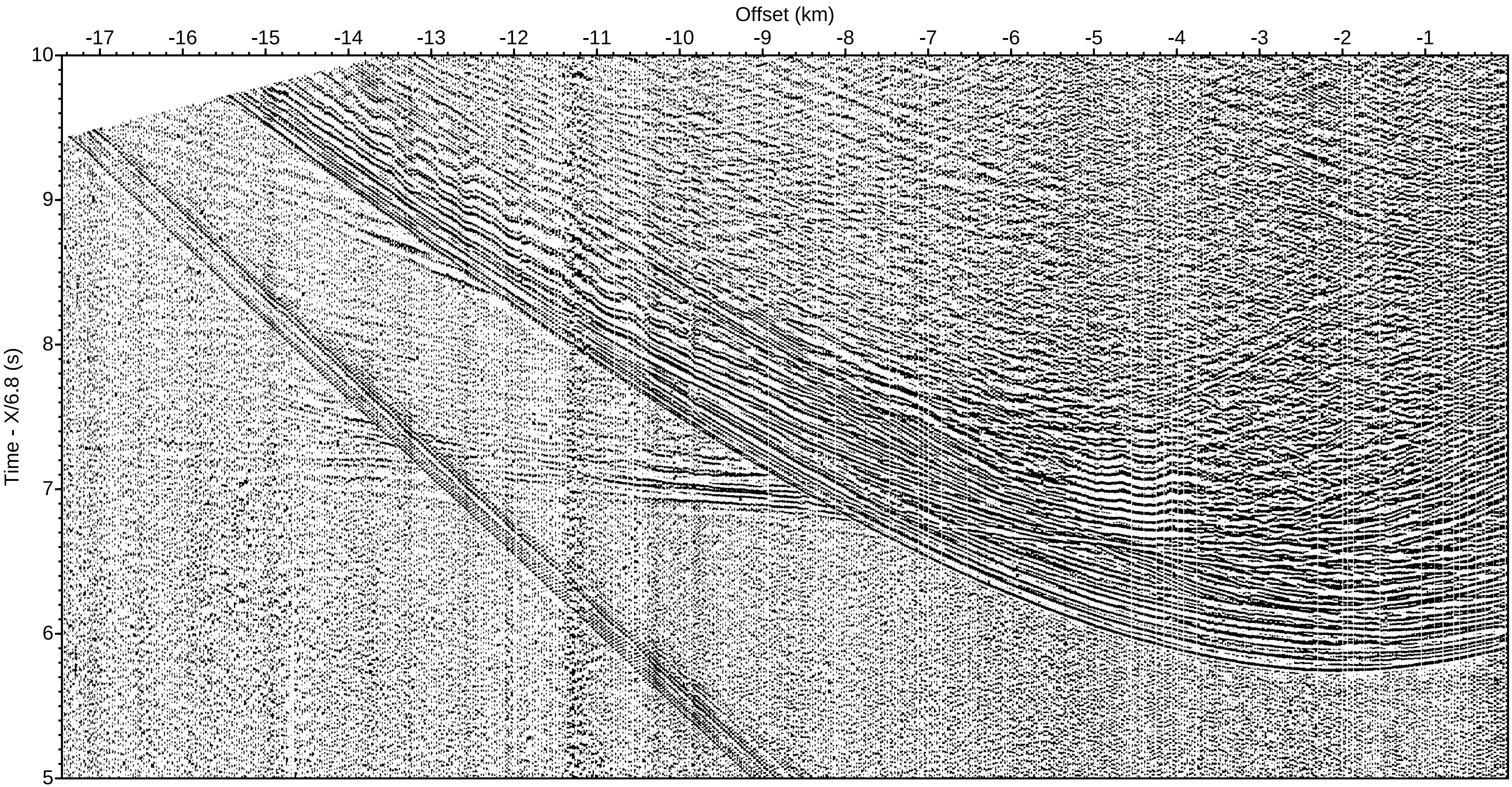
LOMROG III (2012) - Line 16 Sonobuoy 16-57 aux ch 4 (drift correction, deconv., bpf 5-40 Hz)



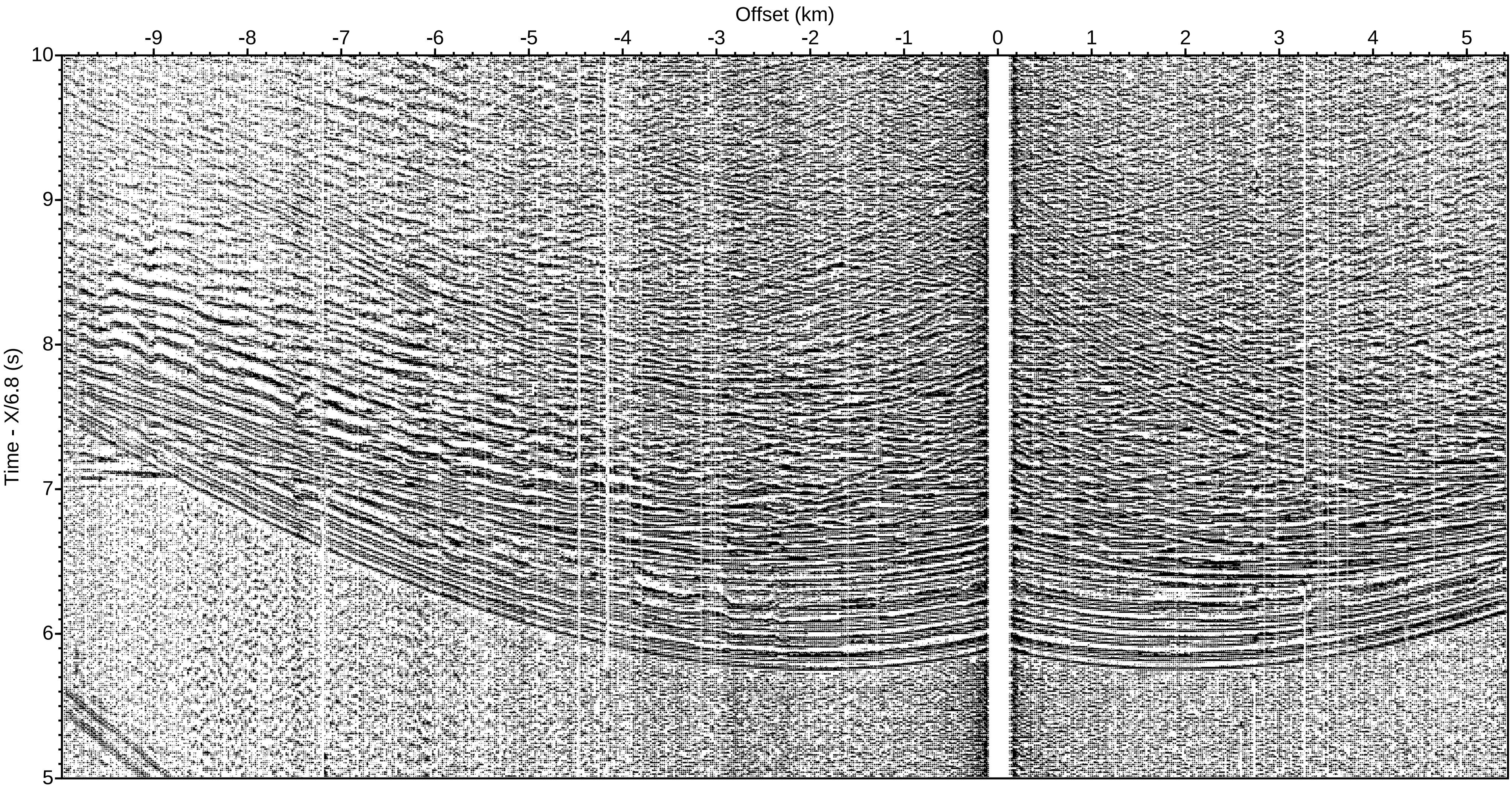
LOMROG III (2012) - Line 16 Sonobuoy 16-58 aux ch 2 (drift correction, deconv., bpf 5-40 Hz)



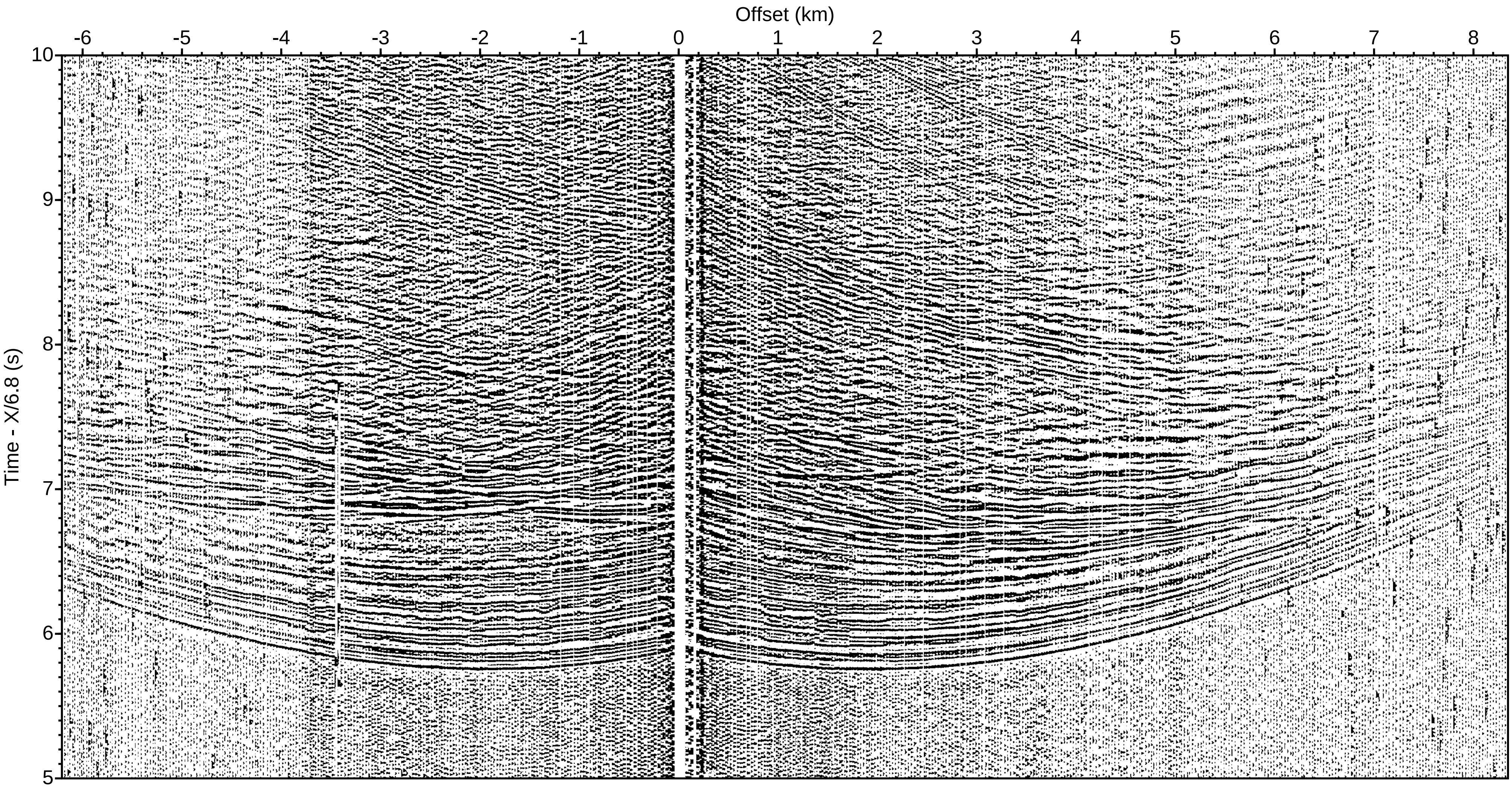
LOMROG III (2012) - Line 16 Sonobuoy 16-59 aux ch 3 (drift correction, deconv., bpf 5-40 Hz)



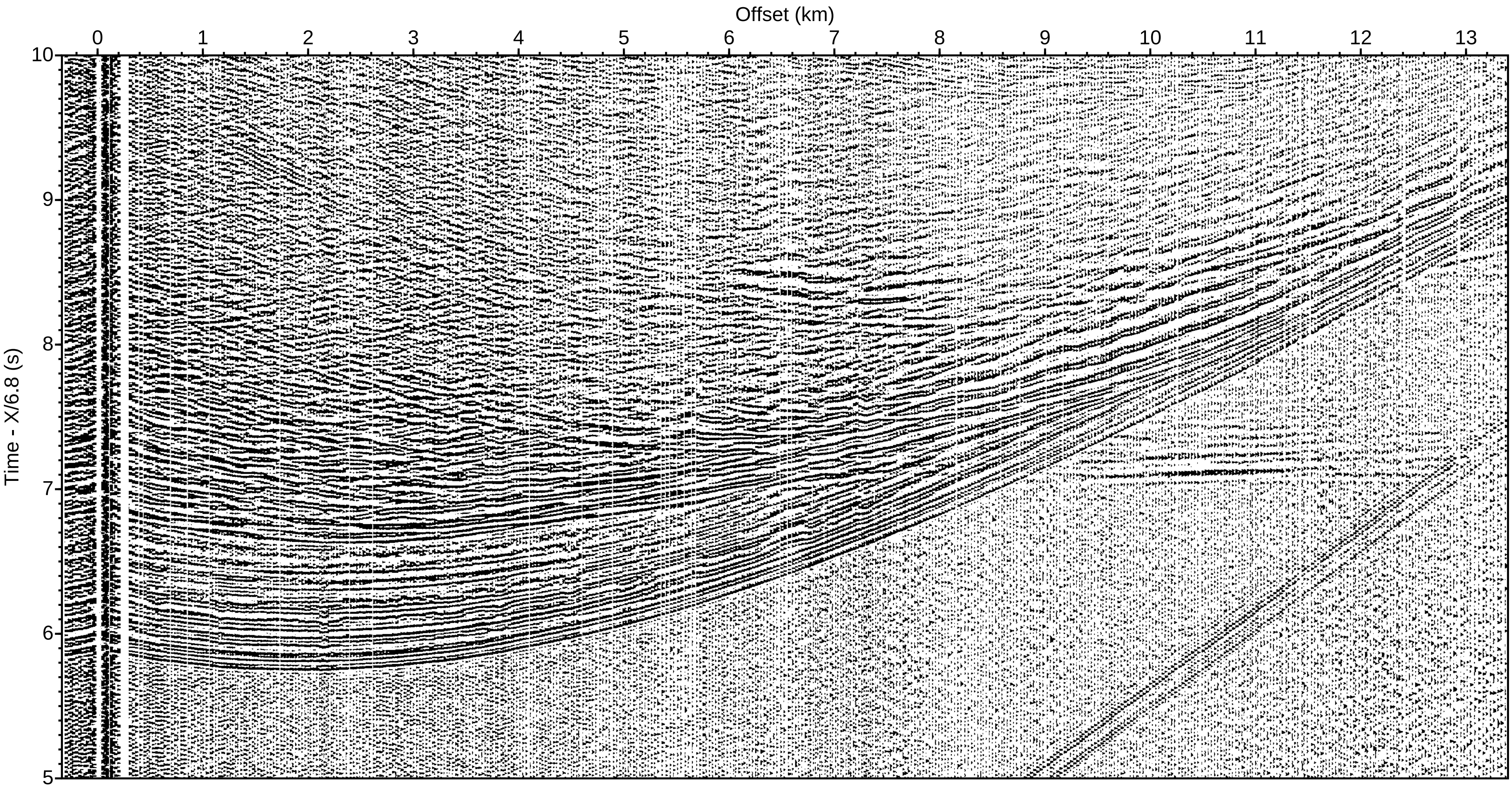
LOMROG III (2012) - Line 17 Sonobuoy 17-60 aux ch 1 (drift correction, deconv., bpf 5-40 Hz)



LOMROG III (2012) - Line 17 Sonobuoy 17-61 aux ch 4 (drift correction, deconv., bpf 5-40 Hz)



LOMROG III (2012) - Line 17 Sonobuoy 17-62 aux ch 2 (drift correction, deconv., bpf 5-40 Hz)



LOMROG III (2012) - Line 17 Sonobuoy 17-63 aux ch 3 (drift correction, deconv., bpf 5-40 Hz)

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Appendix V-B:

Location Maps for all Seismic Lines

White and grey lines show the shot locations of the reflection seismic lines. Red circles indicate the deployment position of sonobuoys from which data were recorded. Unsuccessful sonobuoy launches are indicated by yellow circles. A number of sonobuoys were deployed during the preparation of the track (ice breaking prior to the shooting) or by helicopter. These deployment positions plot off the shot lines. However, as the buoys were deployed within the track and moved with the ice, the buoys were located exactly on the shot line, when the ship passed. The position of the buoy at the time the ship passed is given by a white circle (connected to the original deployment position by a red line). Hence, the red lines indicate the direction and amount of ice drift. Some buoys reached the end of the operational life (8 hours) before the ship passed the buoys. Here no passage position is indicated. Filled green circles mark the locations of CTD measurements. The bathymetry is taken from the IBCAO 3.0 grid, the contour interval is 100 m.

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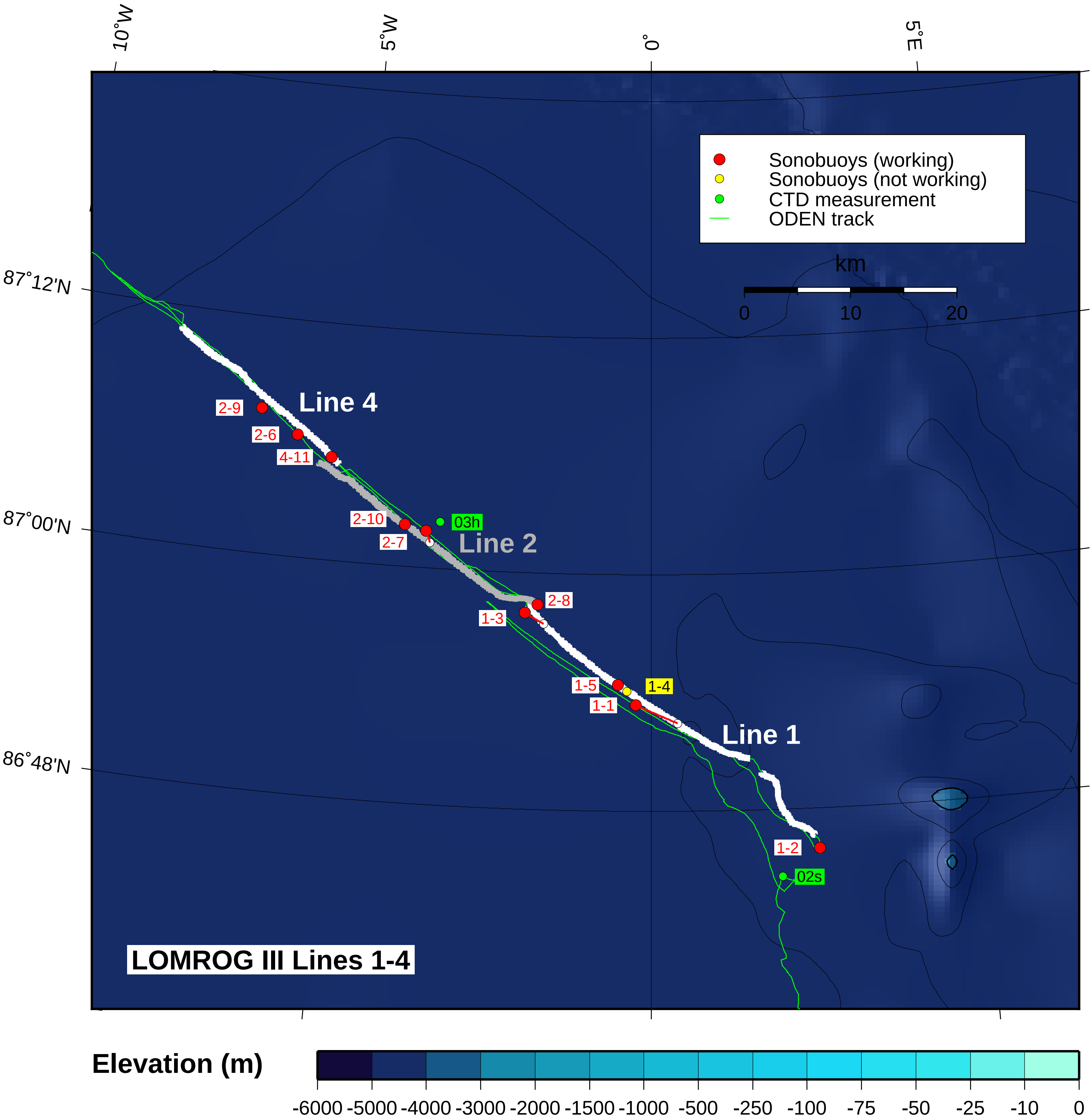
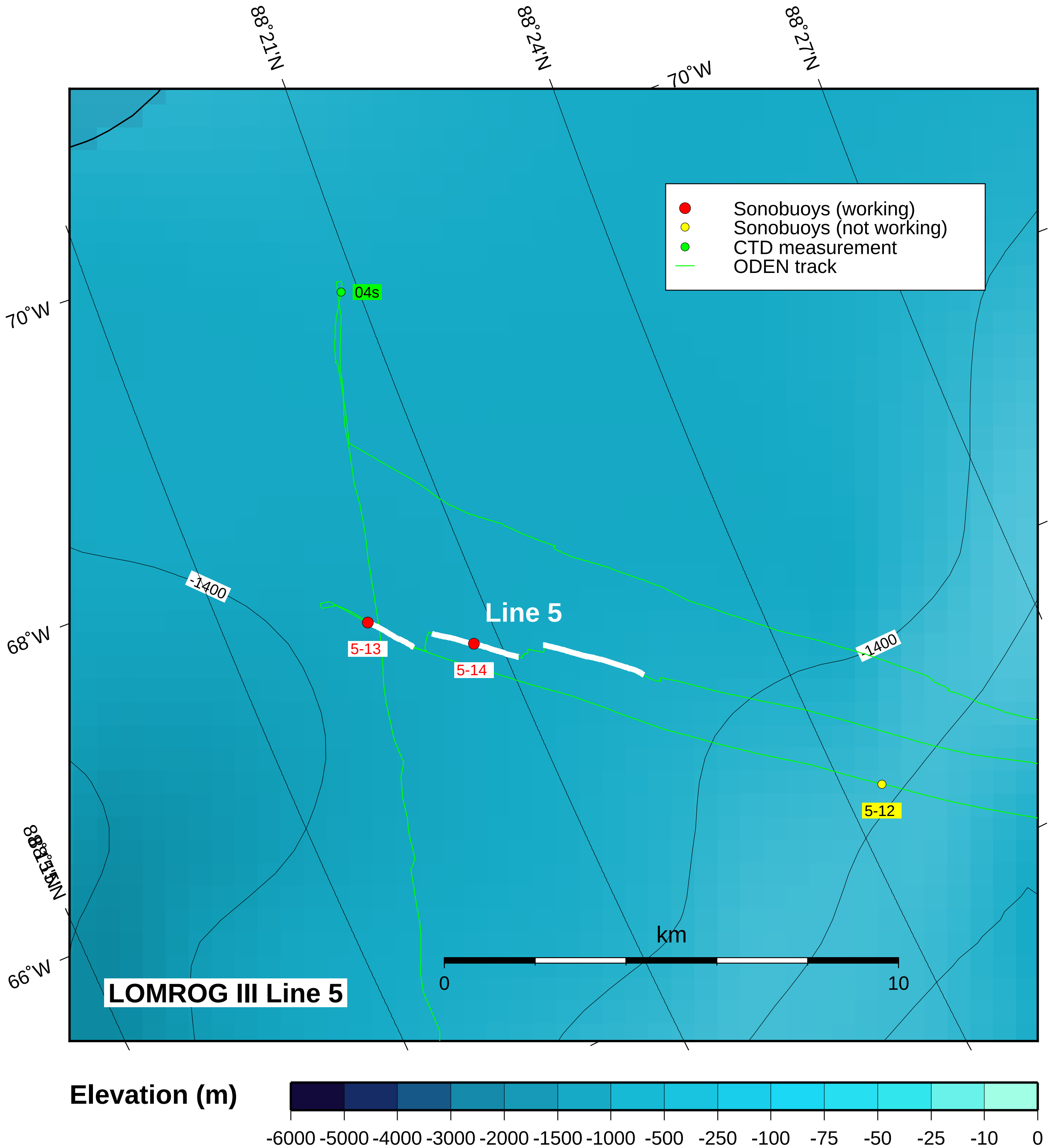
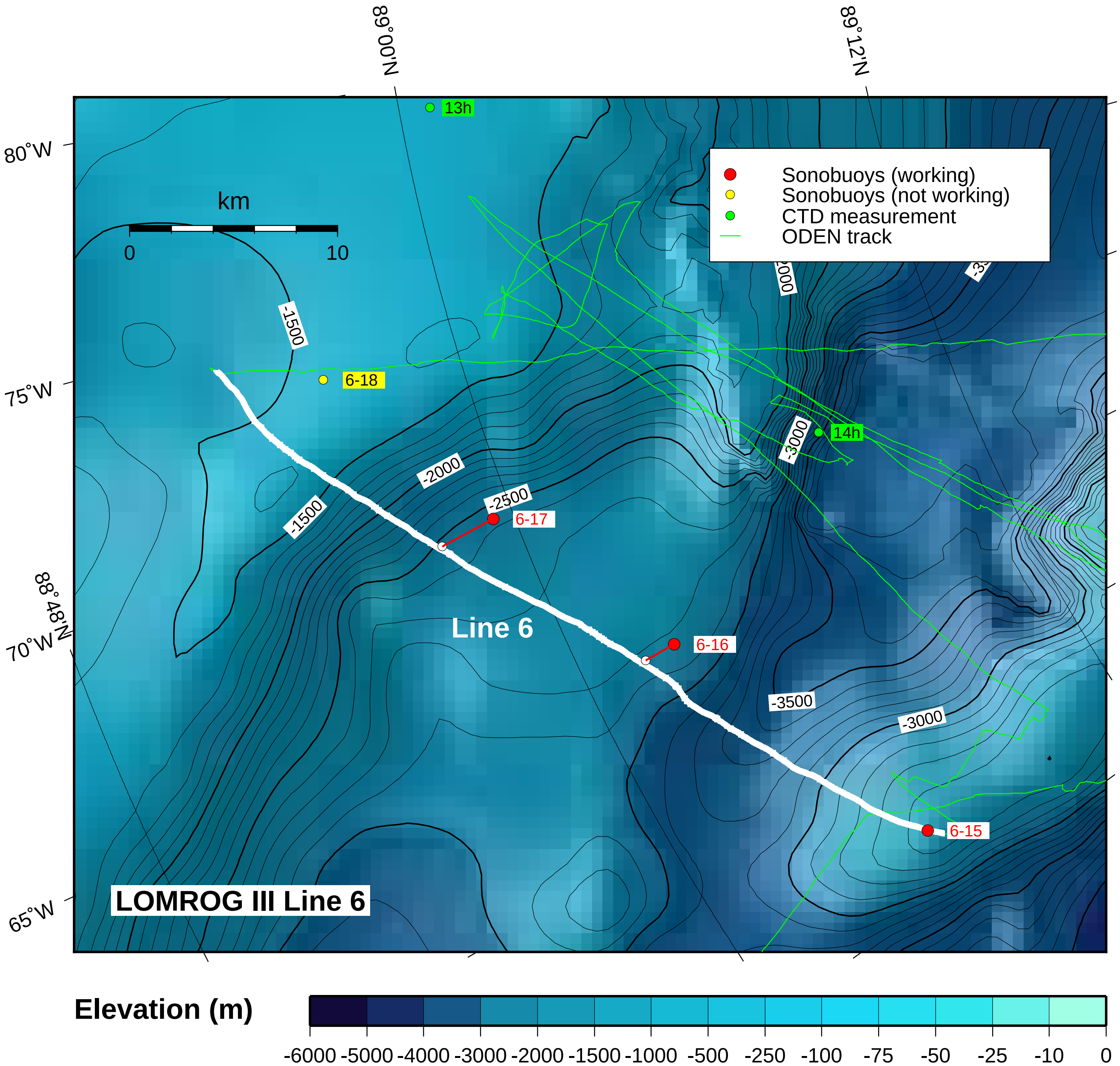


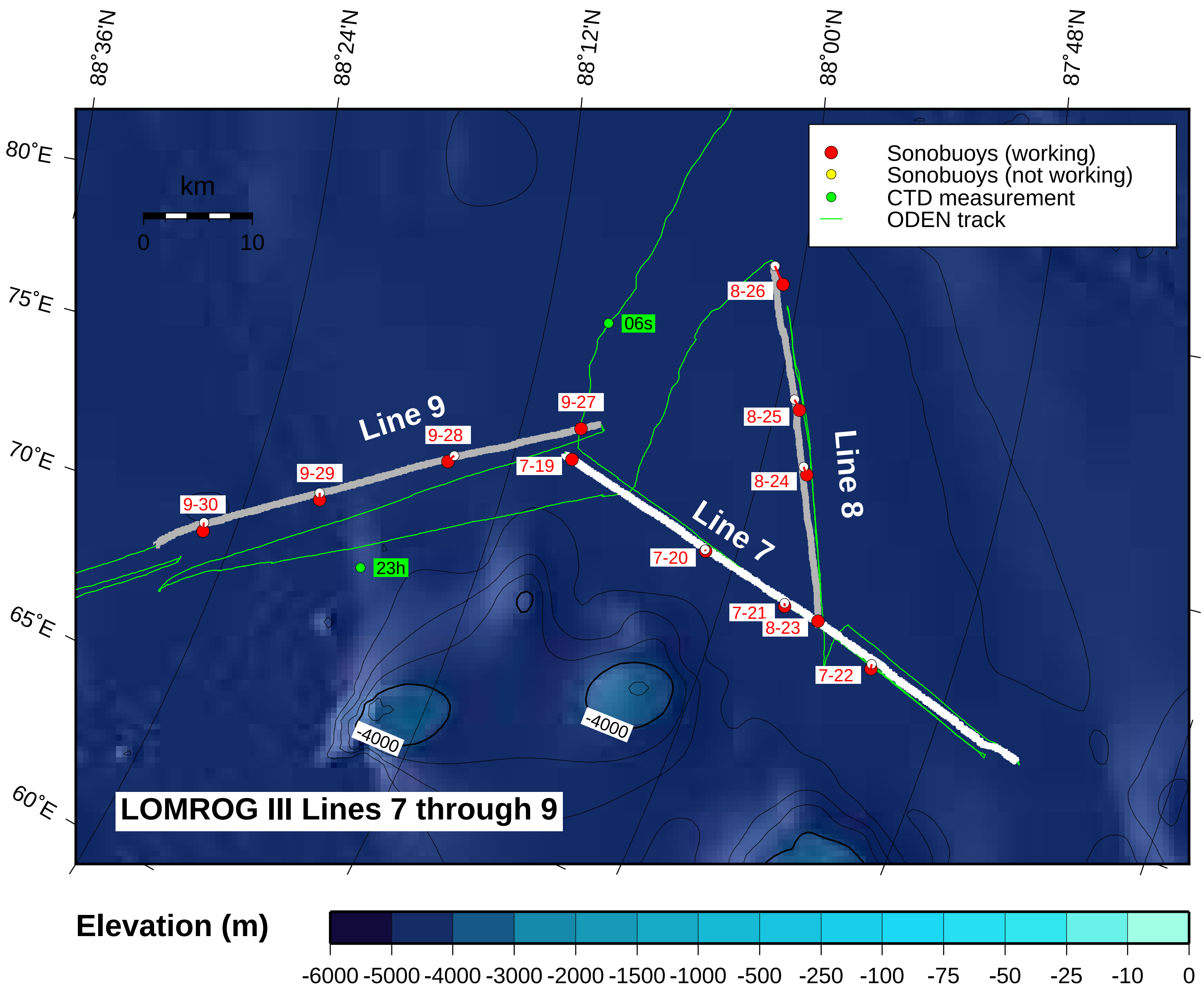
10°W
5°W
0°
5°E
87°12'N
87°00'N
86°48'N
Sonobuoys (working)
Sonobuoys (not working)
CTD measurement
ODEN track
km
0
10
20
Line 4
Line 2
Line 1
2-9
2-6
4-11
2-10
2-7
03h
2-8
1-3
1-5
1-4
1-1
1-2
02s
LOMROG III Lines 1-4
Elevation (m)
-6000 -5000 -4000 -3000 -2000 -1500 -1000 -500 -250 -100 -75 -50 -25 -10 0

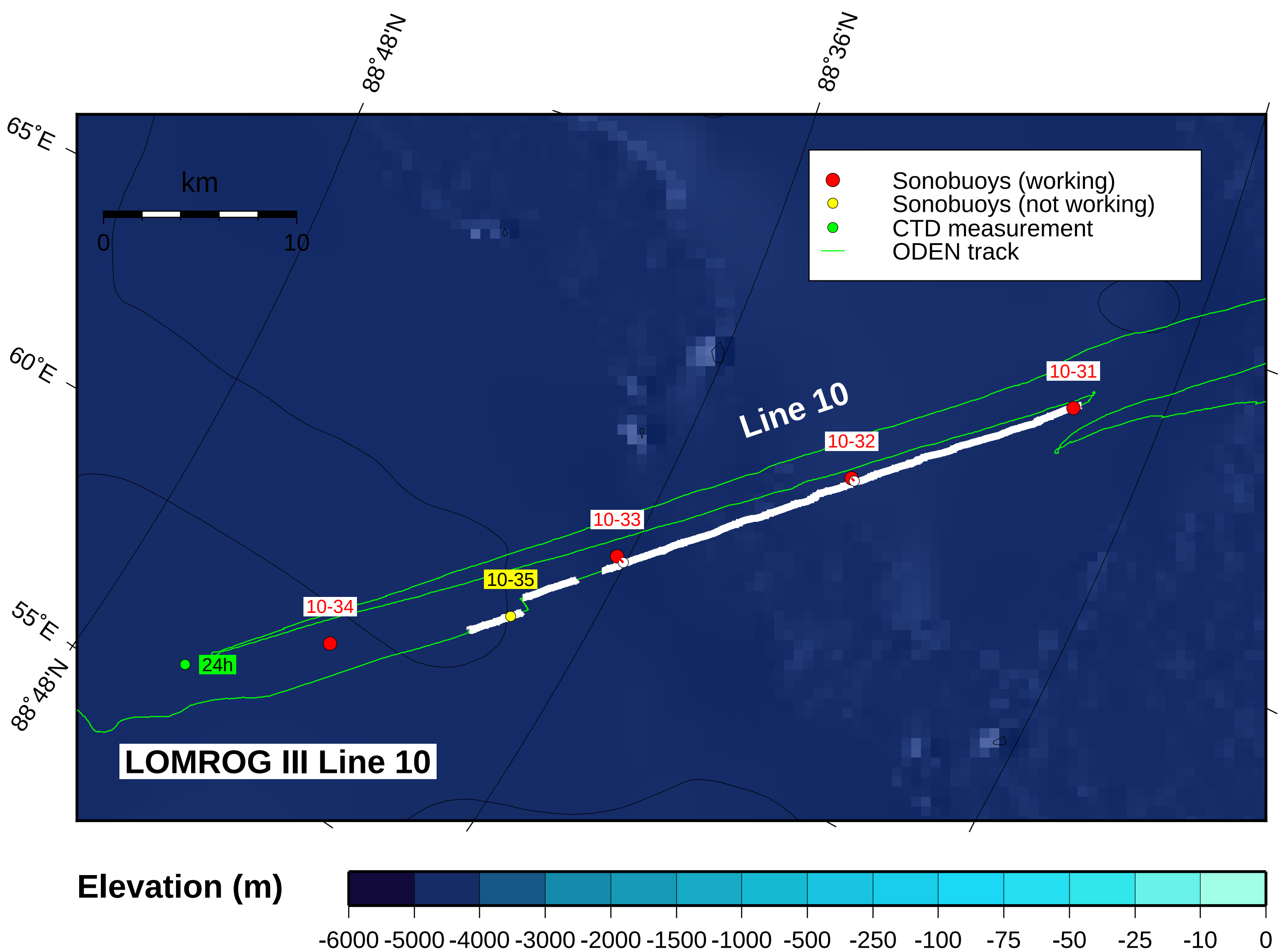


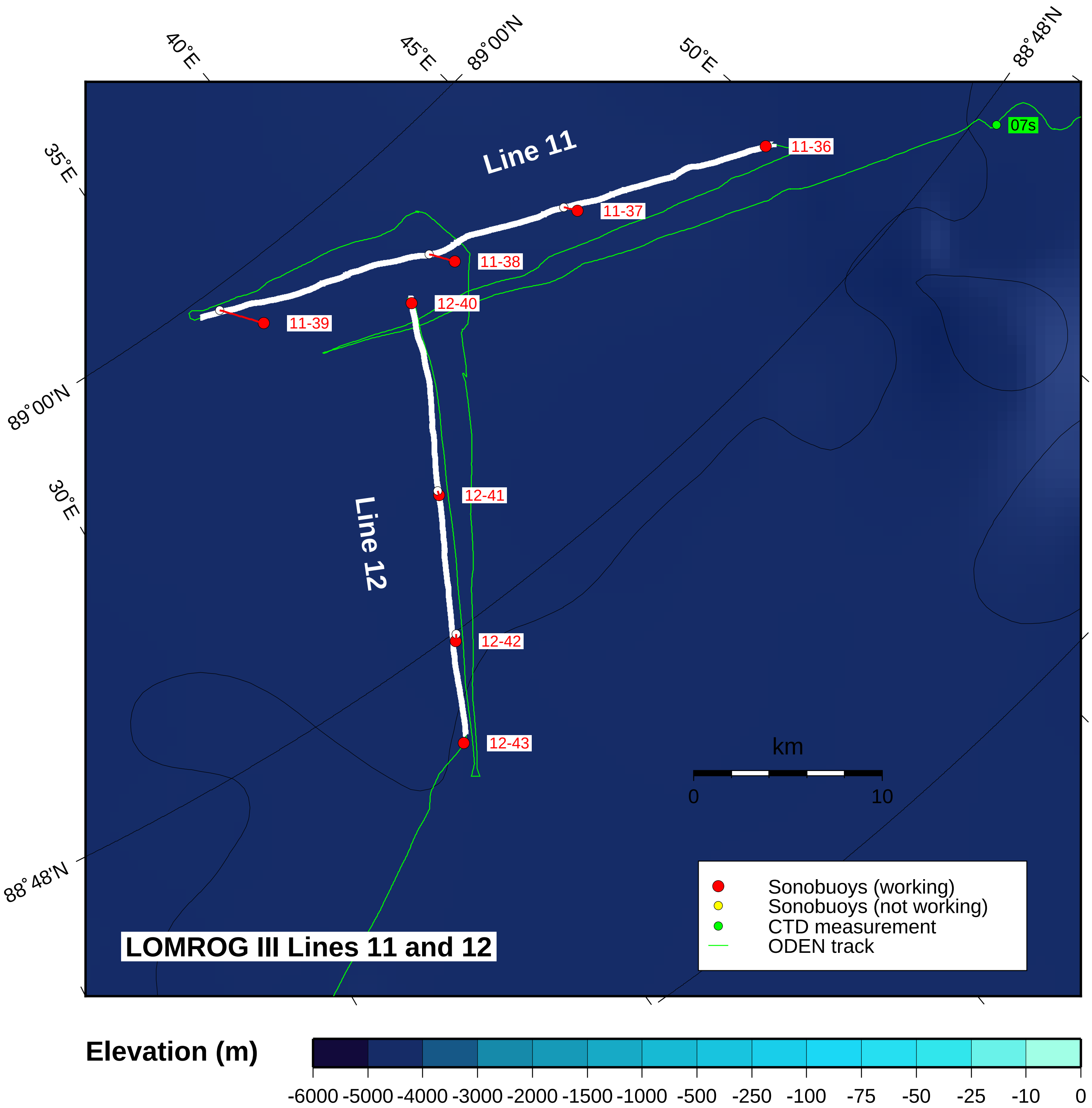
88°21'N
88°24'N
88°27'N
70°W
70°W
68°W
66°W
Sonobuoys (working)
Sonobuoys (not working)
CTD measurement
ODEN track
04s
-1400
-1400
Line 5
5-13
5-14
5-12
km
0
10
LOMROG III Line 5
Elevation (m)
-6000 -5000 -4000 -3000 -2000 -1500 -1000 -500 -250 -100 -75 -50 -25 -10 0



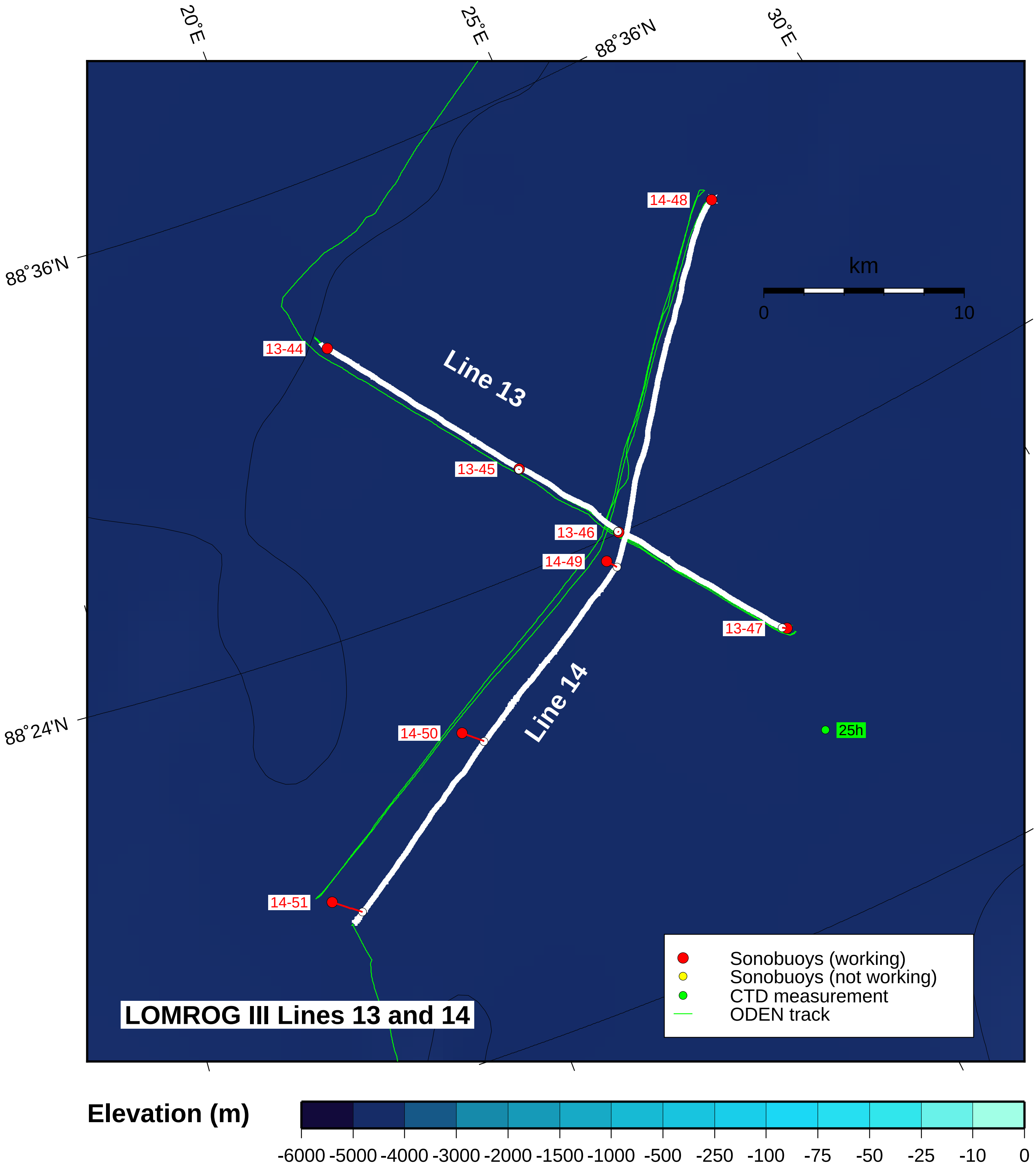
89°00'N
89°12'N
88°48'N
80°W
75°W
70°W
65°W
km
0
10
Sonobuoys (working)
Sonobuoys (not working)
CTD measurement
ODEN track
13h
14h
6-18
6-17
6-16
6-15
-1500
-2000
-2500
-3000
-3500
Line 6
LOMROG III Line 6
Elevation (m)
-6000 -5000 -4000 -3000 -2000 -1500 -1000 -500 -250 -100 -75 -50 -25 -10 0

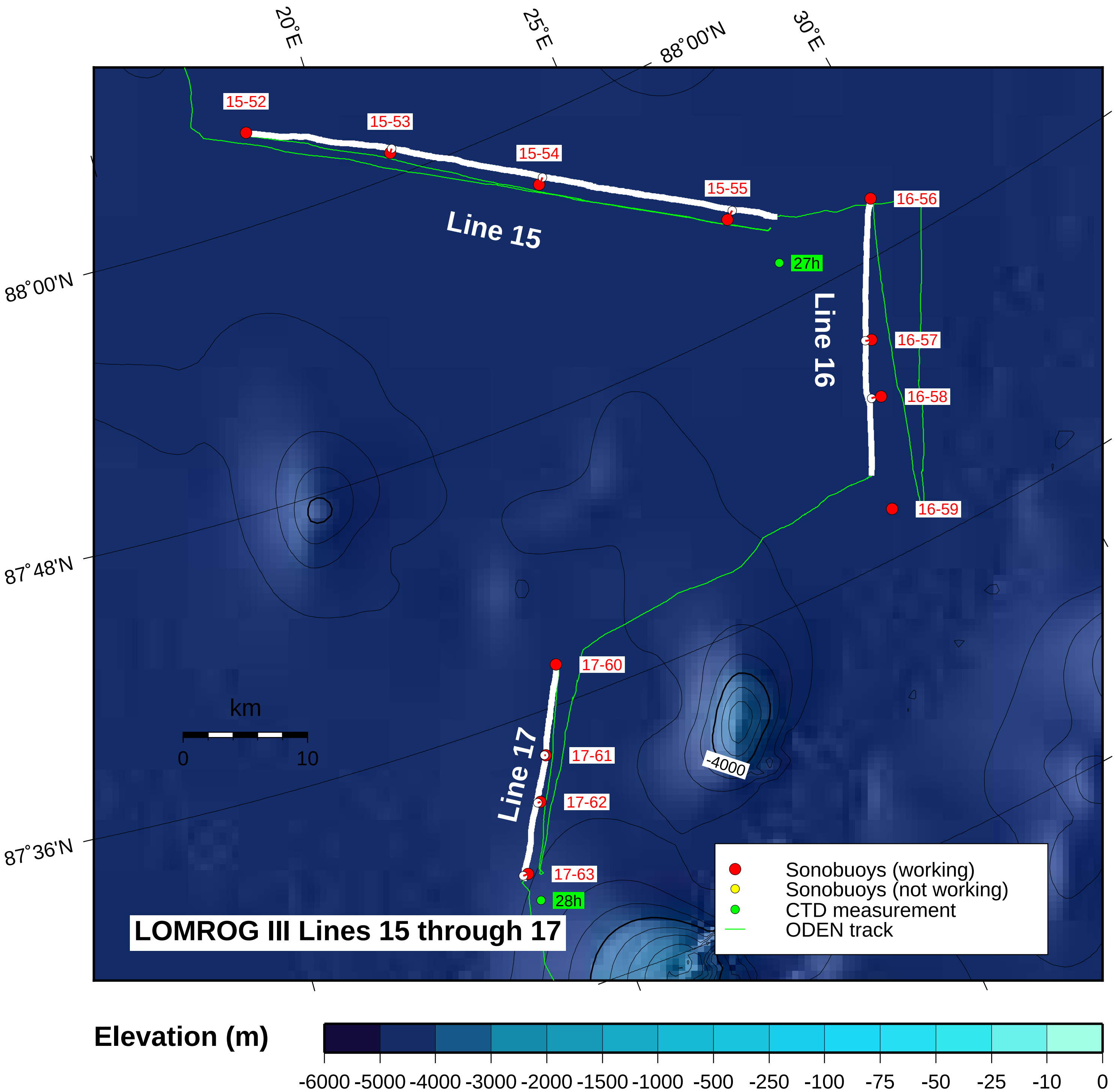

88°36'N
88°24'N
88°12'N
88°00'N
87°48'N
80°E
75°E
70°E
65°E
60°E
km
0
10
Sonobuoys (working)
Sonobuoys (not working)
CTD measurement
ODEN track
8-26
06s
9-27
Line 9
9-28
8-25
Line 8
7-19
9-29
8-24
9-30
Line 7
7-20
23h
7-21
8-23
7-22
-4000
-4000
LOMROG III Lines 7 through 9
Elevation (m)
-6000 -5000 -4000 -3000 -2000 -1500 -1000 -500 -250 -100 -75 -50 -25 -10 0


88°48'N
88°36'N
65°E
60°E
55°E
88°48'N
km
0
10
Sonobuoys (working)
Sonobuoys (not working)
CTD measurement
ODEN track
Line 10
10-31
10-32
10-33
10-35
10-34
24h
LOMROG III Line 10
Elevation (m)
-6000 -5000 -4000 -3000 -2000 -1500 -1000 -500 -250 -100 -75 -50 -25 -10 0



40°E
45°E
89°00'N
50°E
88°48'N
35°E
89°00'N
30°E
88°48'N
Line 11
Line 12
11-36
11-37
11-38
11-39
12-40
12-41
12-42
12-43
07s
km
0
10
Sonobuoys (working)
Sonobuoys (not working)
CTD measurement
ODEN track
LOMROG III Lines 11 and 12
Elevation (m)
-6000 -5000 -4000 -3000 -2000 -1500 -1000 -500 -250 -100 -75 -50 -25 -10 0


20°E
25°E
30°E
88°36'N
88°36'N
88°24'N
14-48
km
0
10
13-44
Line 13
13-45
13-46
14-49
13-47
Line 14
14-50
25h
14-51
Sonobuoys (working)
Sonobuoys (not working)
CTD measurement
ODEN track
LOMROG III Lines 13 and 14
Elevation (m)
-6000
-5000
-4000
-3000
-2000
-1500
-1000
-500
-250
-100
-75
-50
-25
-10
0


20°E
25°E
30°E
88°00'N
87°48'N
87°36'N
15-52
15-53
15-54
15-55
Line 15
16-56
16-57
16-58
16-59
Line 16
27h
17-60
17-61
17-62
17-63
Line 17
28h
-4000
km
0
10
Sonobuoys (working)
Sonobuoys (not working)
CTD measurement
ODEN track
LOMROG III Lines 15 through 17
Elevation (m)
-6000 -5000 -4000 -3000 -2000 -1500 -1000 -500 -250 -100 -75 -50 -25 -10 0

Appendix V-C:

CTD Measurements used for Offset Calculations

List of all CTD locations (until September 5, 2012) during the LOMROG III expedition.

Velocity-depth functions used for the calculation of the drift correction of the sonobuoys are shown in this appendix. CTD S02 was used for seismic lines 1 through 4, CTD S04 for line 5, CTD H14 for line 6, CTD S06 for lines 7 through 12, CTD H25 for lines 13 and 14, CTD H27 for lines 15 through 17

Average “horizontal” water velocity is shown as a function of the travel time of the direct wave. These average velocities were determined from one-dimensional raytracing using the indicated CTD measurement. Black dots indicate the calculated travel time of these rays, the red line is the smoothed approximation to these dots.

CTD data courtesy of Steffen Olsen and Rasmus Tonboe, Dansk Meteorologisk Institut (DMI).

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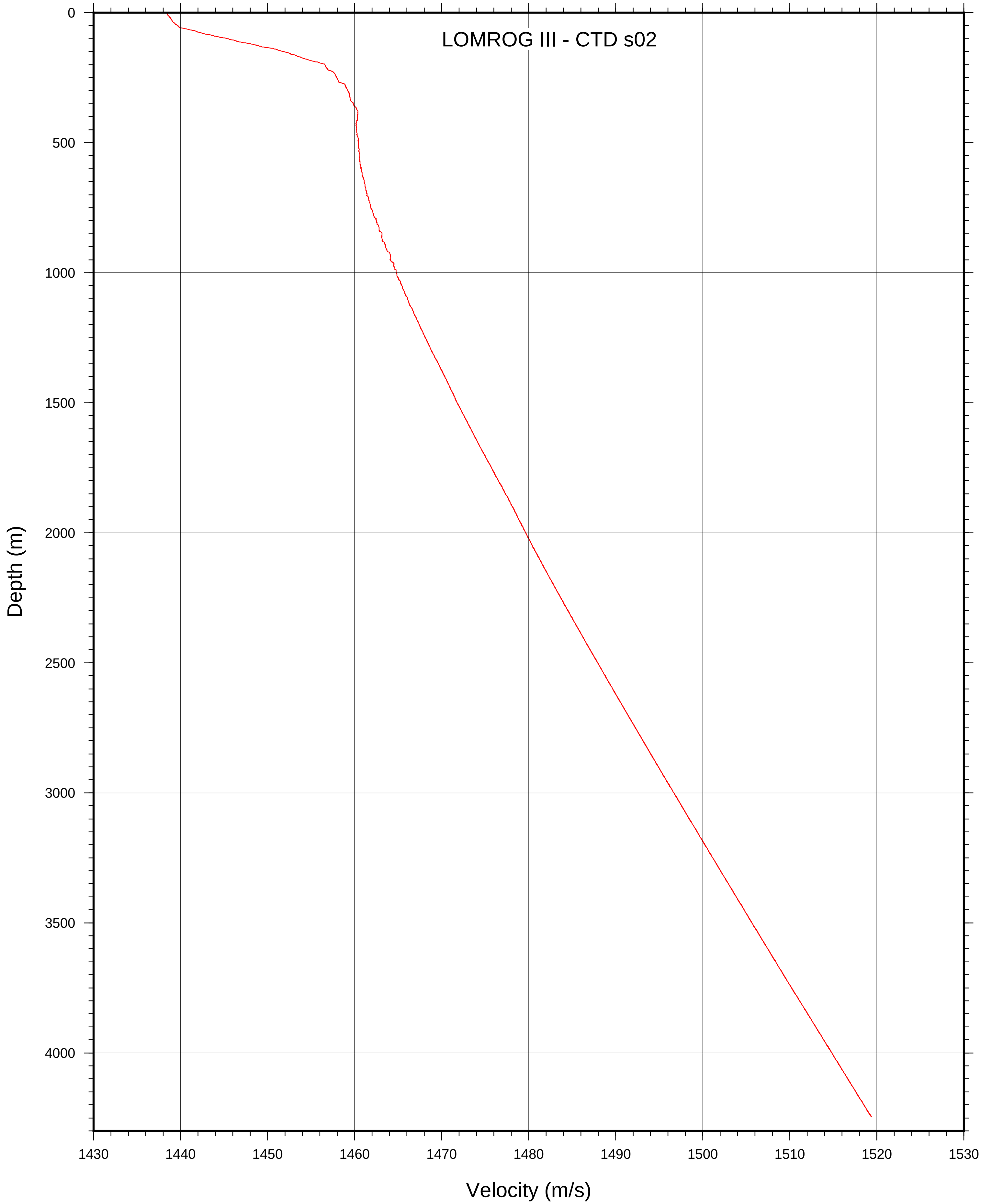
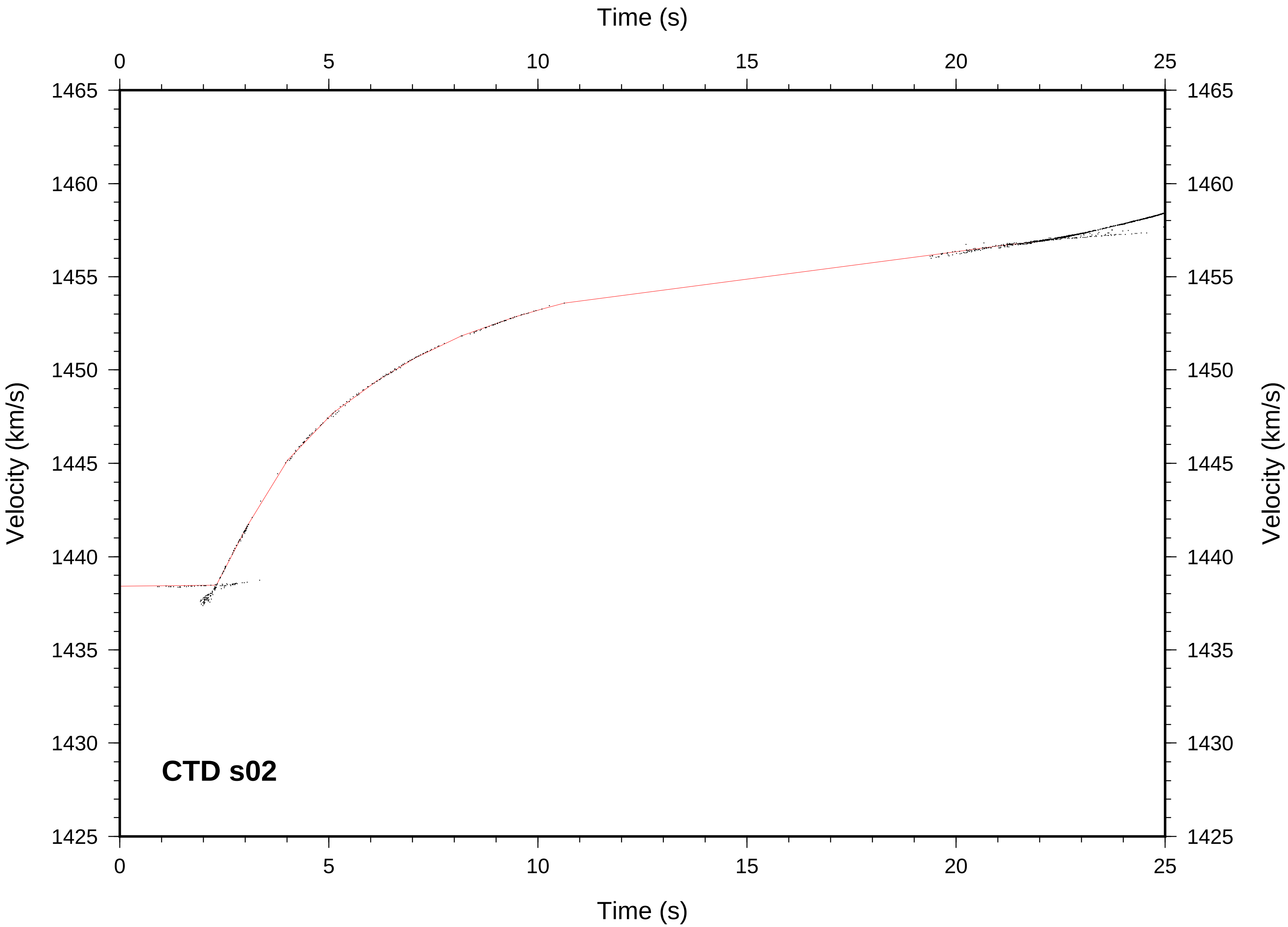
CTD locations - LOMROG III expedition

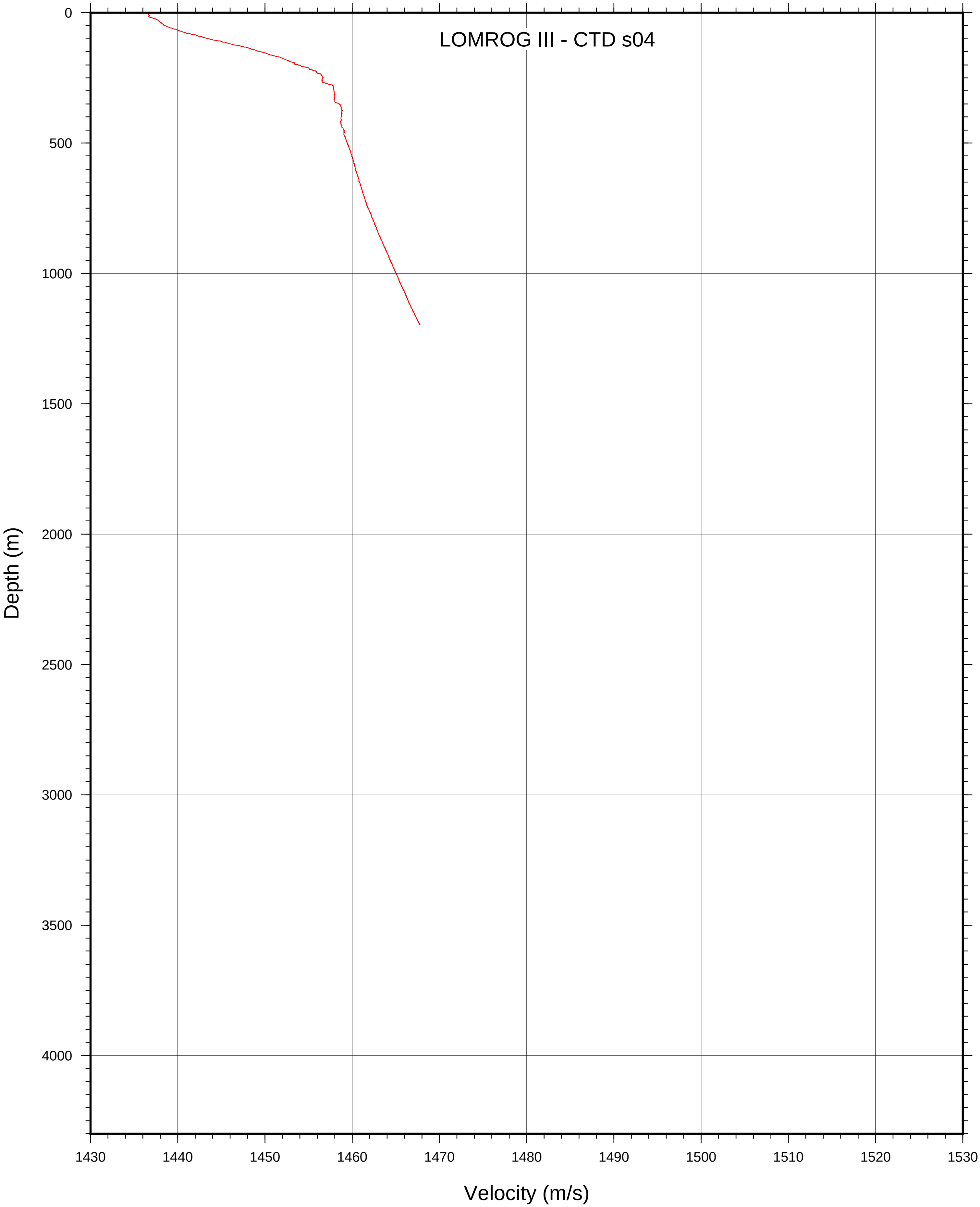
	Date	Time UTC	Longitude	Latitude	Cast	Type
Station ID	*dd-mm-yyyy*	*hh:mm*	*ddd:mm.mm*	*dd:mm.mm*	*m*	
LR12s01	2-08-2012	11:35	014:55.98 E	82:57.48 N	2625	Ship
LR12h01	3-08-2012	15:30	013:20.25 E	84:32.14 N	1889	Heli
LR12h02	4-08-2012	12:21	006:27.48 E	85:33.07 N	2012	Heli
LR12s02	5-08-2012	17:03	001:57.31 E	86:44.59 N	4248	Ship
LR12h03	6-08-2012	14:40	003:27.35 W	87:02.38 N	1996	Heli
LR12h04	7-08-2012	23:20	013:27.91 W	87:19.50 N	2006	Heli
LR12h05	8-08-2012	21:23	026:58.48 W	87:44.27 N	1996	Heli
LR12s03	9-08-2012	13:09	037:45.45 W	87:46.20 N	3746	Ship
LR12h06	10-08-2012	12:19	047:44.52 W	87:45.14 N	2014	Heli
LR12h07	11-08-2012	12:01	058:53.27 W	87:39.47 N	1209	Heli
LR12h08	12-08-2012	15:00	068:55.88 W	87:38.35 N	1128	Heli
LR12h09	13-08-2012	19:27	043:10.52 W	88:15.93 N	2010	Heli
LR12h10	14-08-2012	17:30	029:57.05 W	88:14.09 N	2018	Heli
LR12h11	15-08-2012	14:20	058:01.00 W	88:16.32 N	1507	Heli
LR12s04	16-08-2012	05:10	069:24.69 W	88:20.80 N	1197	Ship
LR12h12	17-08-2012	17:49	057:33.00 W	88:38.10 N	1993	Heli
LR12h13	18-08-2012	12:30	079:18.13 W	89:00.80 N	1084	Heli
LR12s05	20-08-2012	05:10	058:50.83 W	89:15.90 N	3731	Ship
LR12h14	20-08-2012	14:08	068:01.76 W	89:08.16 N	1924	Heli
LR12h15	21-08-2012	18:24	090:53.25 W	88:53.78 N	1223	Heli
LR12h16	22-08-2012	17:21	155:31.52 E	89:59.55 N	2003	Heli
LR12h17	23-08-2012	13:22	133:12.10 E	89:30.44 N	2006	Heli
LR12x01	24-08-2012	10:37	136:54.11 E	88:42.43 N	1166	XCTD
LR12h18	24-08-2012	15:15	149:59.50 E	88:24.73 N	1850	Heli
LR12h19	24-08-2012	22:07	145:16.56 E	88:03.58 N	1243	Heli
LR12h20	25-08-2012	08:09	124:55.48 E	87:56.07 N	1992	Heli
LR12h21	25-08-2012	18:12	114:41.68 E	87:52.88 N	1981	Heli
LR12h22	26-08-2012	17:53	104:30.29 E	87:59.35 N	1994	Heli
LR12s06	27-08-2012	11:21	078:14.56 E	88:08.96 N	4354	Ship
LR12h23	29-08-2012	15:29	070:10.86 E	88:17.53 N	1991	Heli
LR12h24	30-08-2012	15:52	056:02.99 E	88:45.11 N	2009	Heli
LR12s07	31-08-2012	13:56	053:06.18 E	88:47.43 N	4351	Ship
LR12h25	2-09-2012	08:30	025:17.19 E	88:16.87 N	2022	Heli
LR12h26	3-09-2012	13:20	011:21.11 E	88:09.54 N	2003	Heli
LR12h27	4-09-2012	10:25	027:16.14 E	87:49.71 N	2004	Heli
LR12h28	5-09-2012	08:26	018:58.52 E	87:28.24 N	1991	Heli

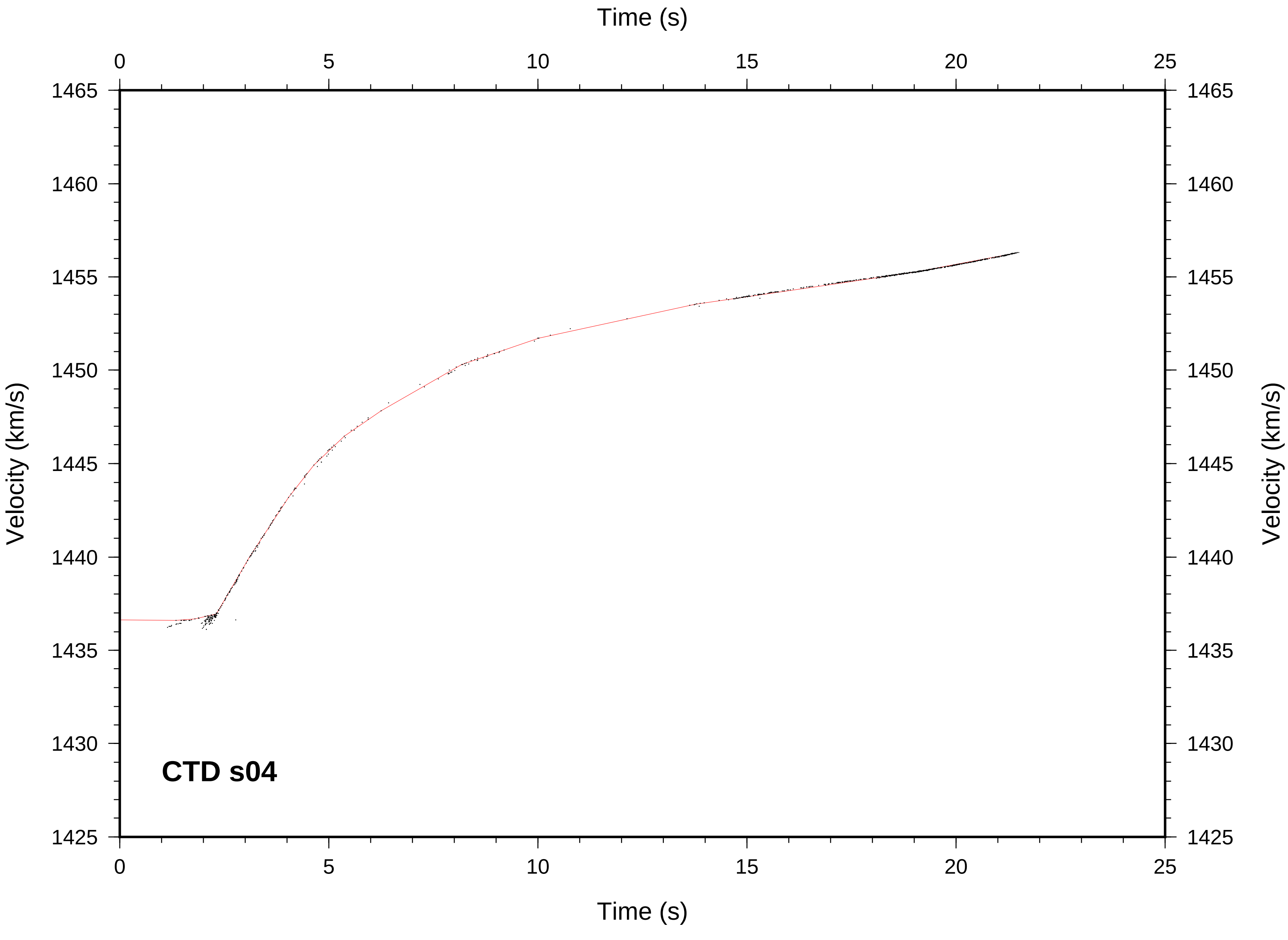


LOMROG III - CTD s02
Depth (m)
0
500
1000
1500
2000
2500
3000
3500
4000
1430
1440
1450
1460
1470
1480
1490
1500
1510
1520
1530
Velocity (m/s)

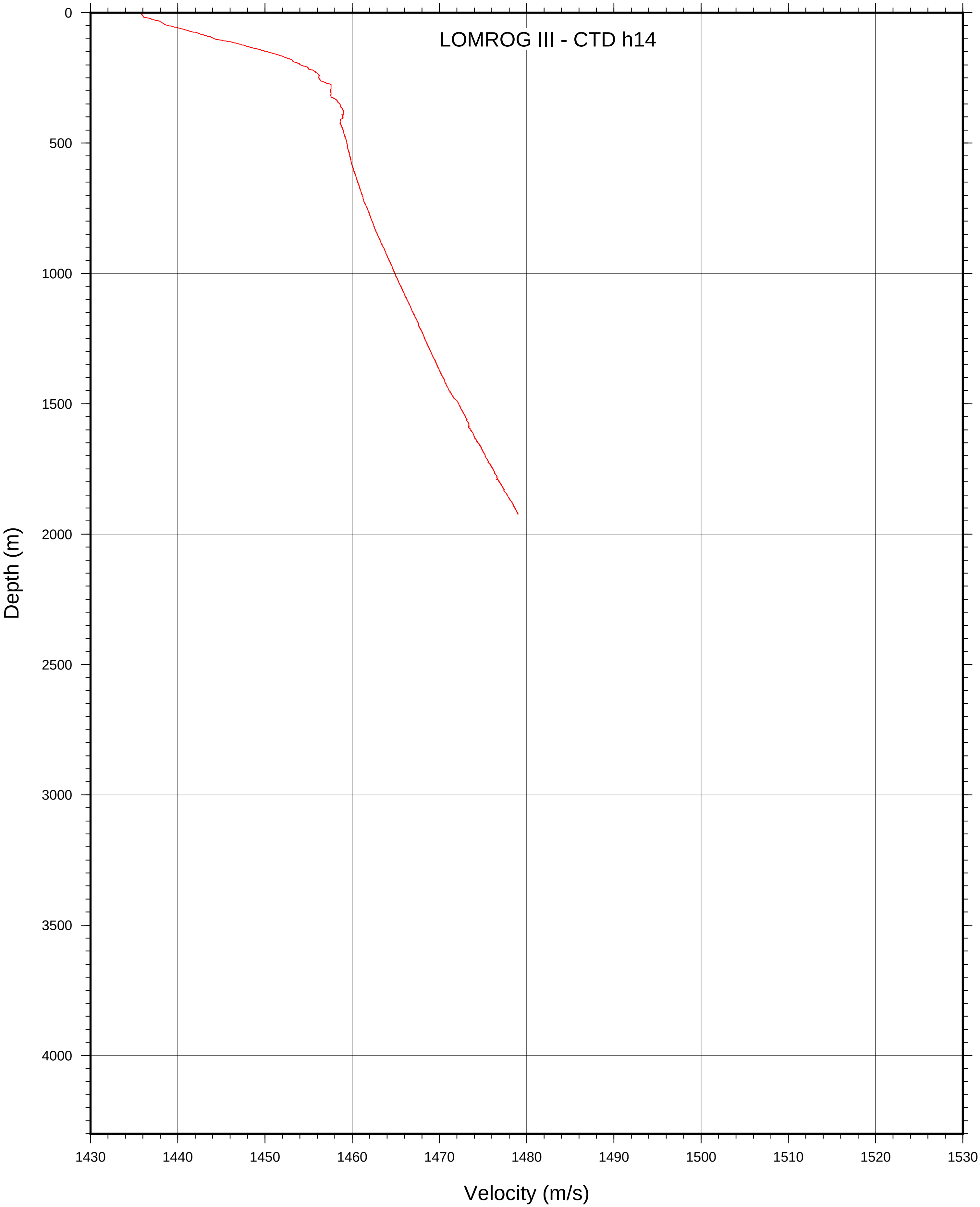


Time (s)
0
5
10
15
20
25
1465
1460
1455
1450
1445
1440
1435
1430
1425
Velocity (km/s)
CTD s02

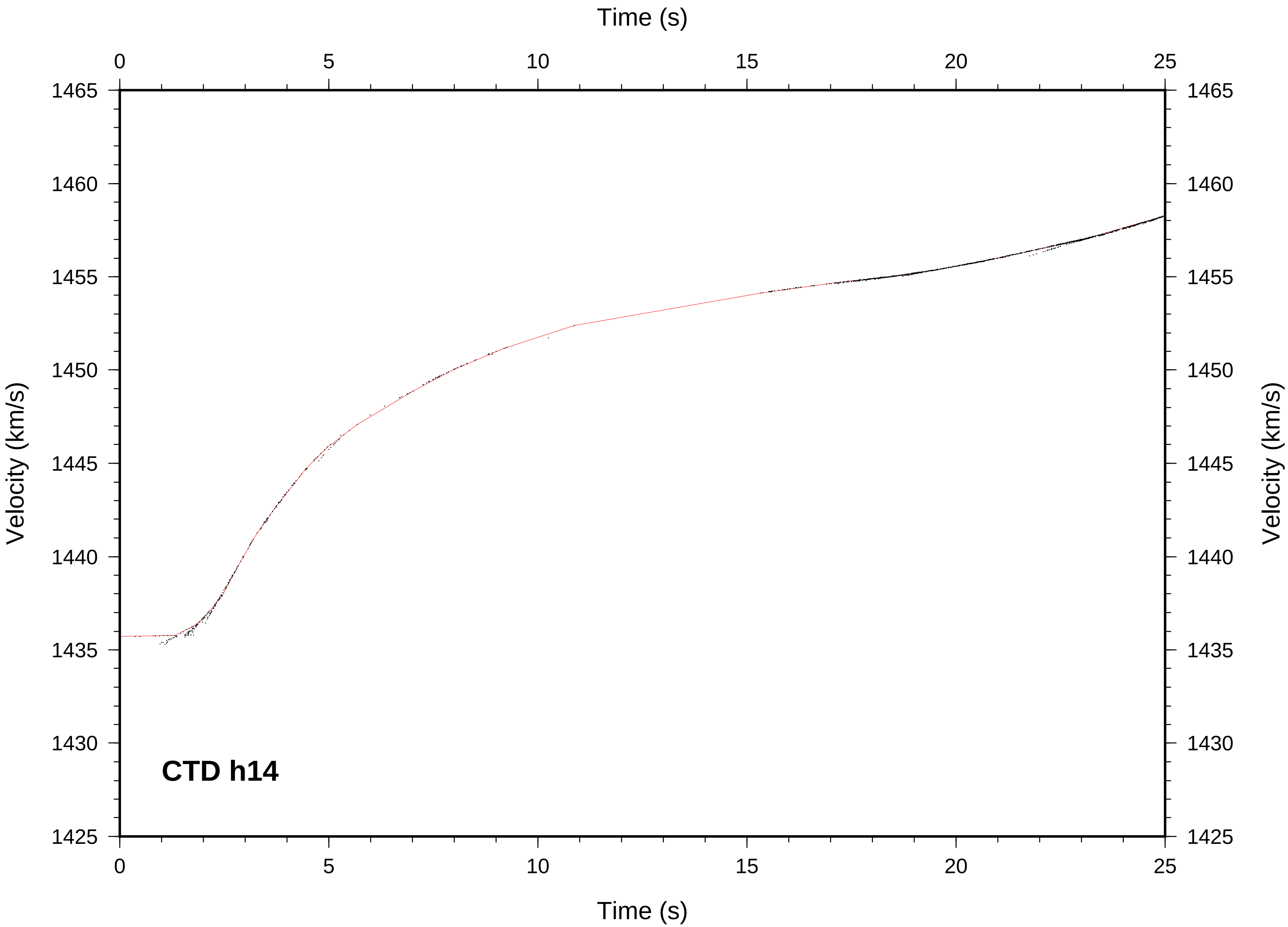

LOMROG III - CTD s04
Depth (m)
Velocity (m/s)
0
500
1000
1500
2000
2500
3000
3500
4000
1430
1440
1450
1460
1470
1480
1490
1500
1510
1520
1530



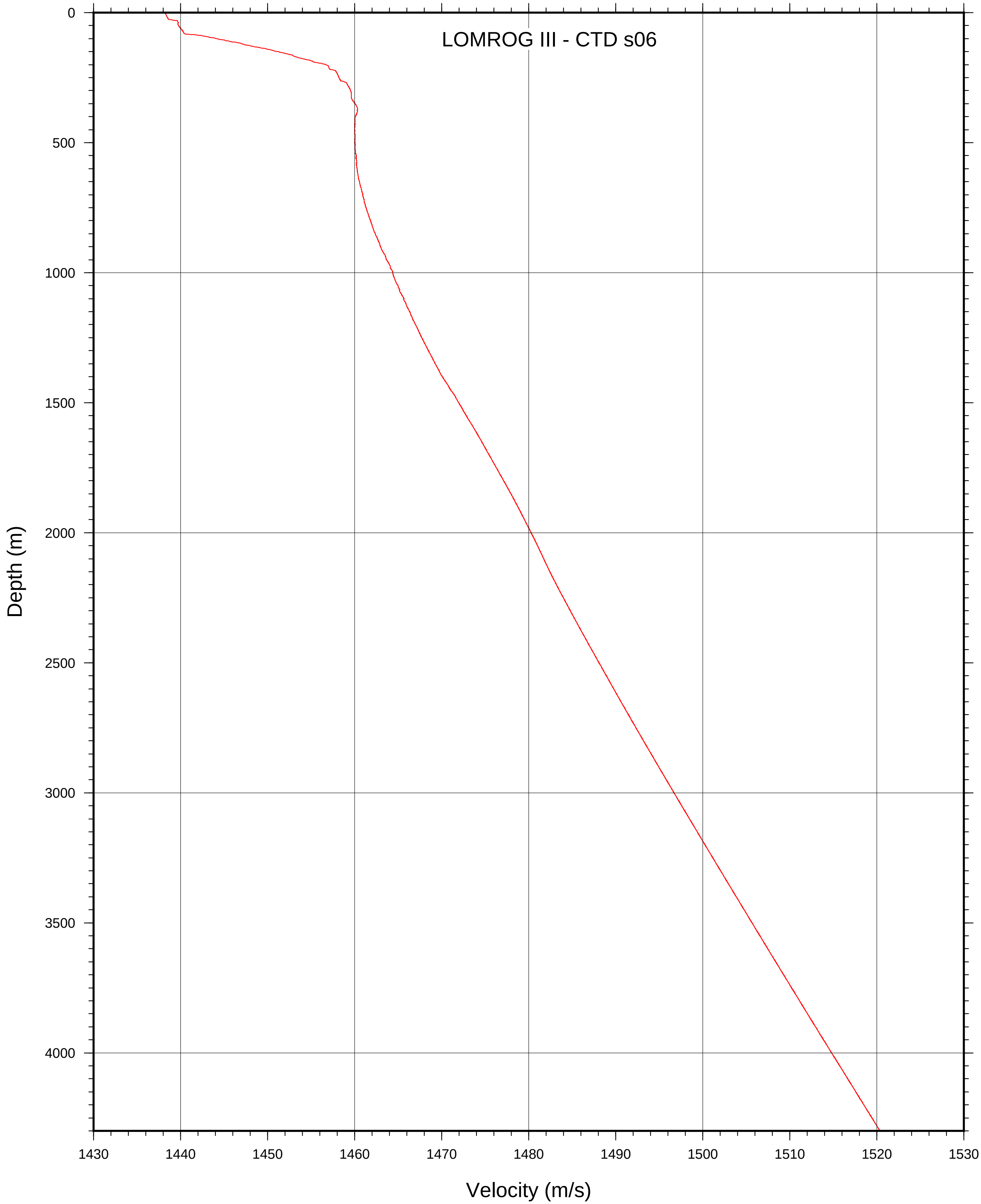
Time (s)
0
5
10
15
20
25
1465
1460
1455
1450
1445
1440
1435
1430
1425
Velocity (km/s)
CTD s04

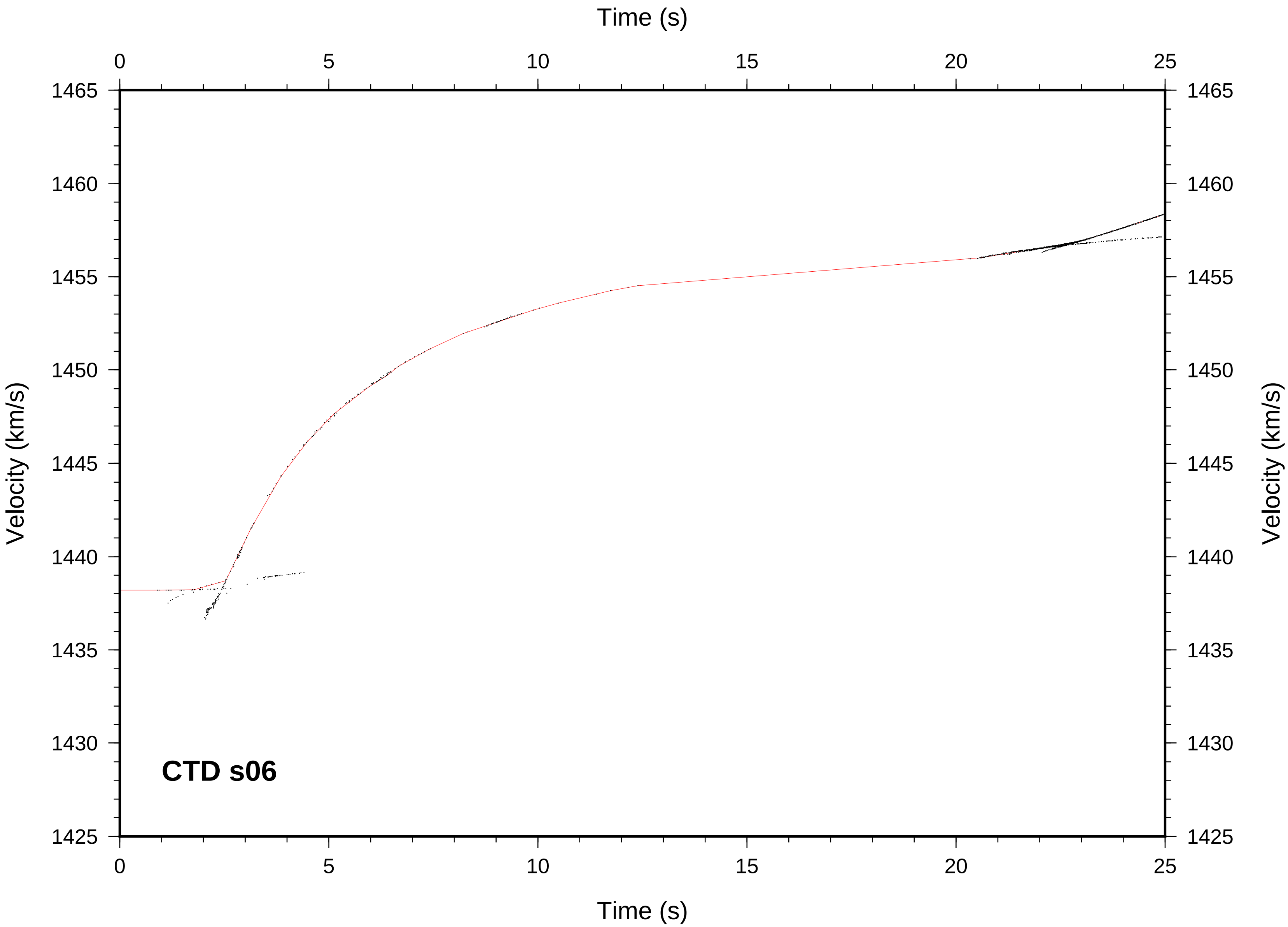


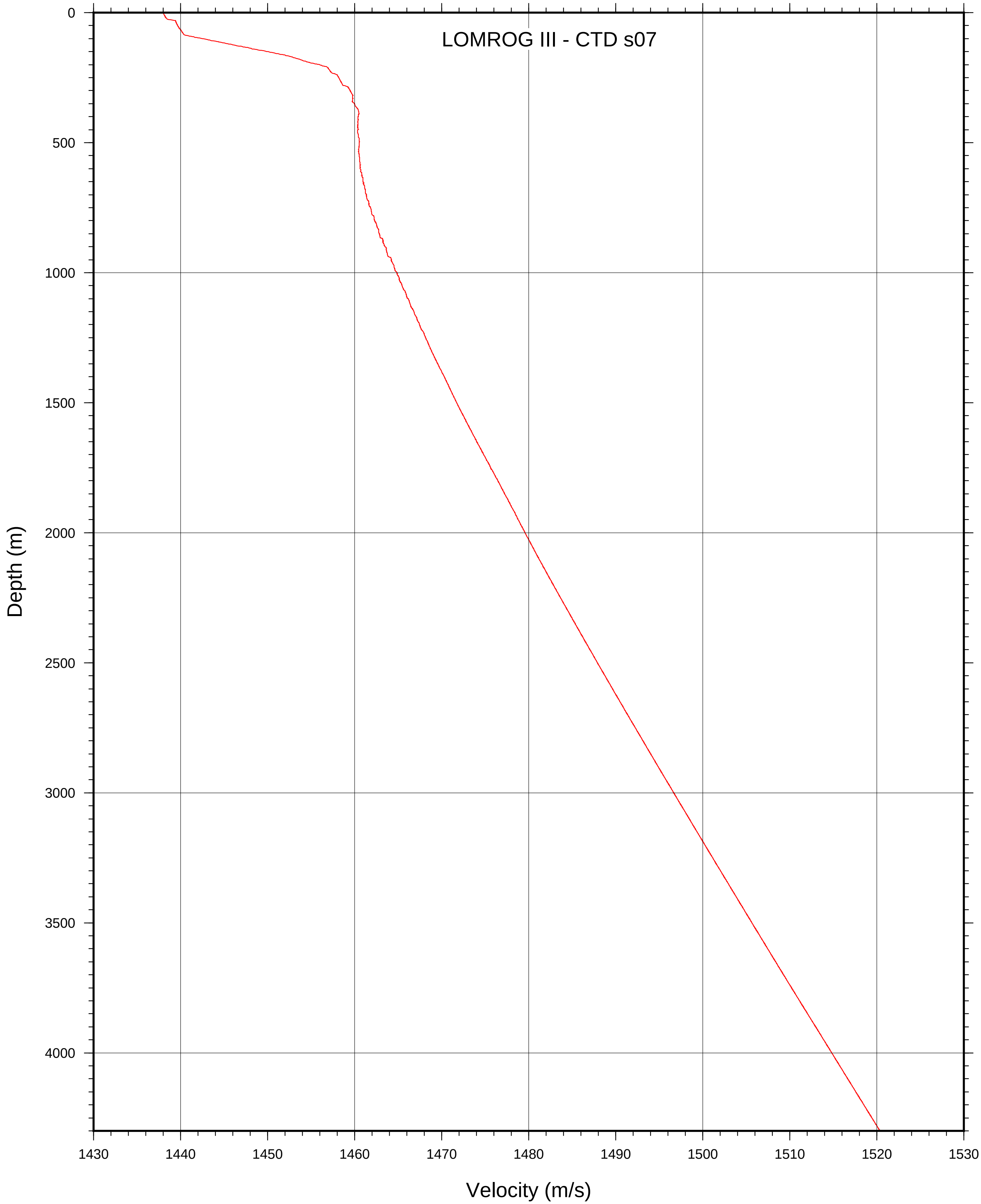
LOMROG III - CTD h14
Depth (m)
0
500
1000
1500
2000
2500
3000
3500
4000
1430
1440
1450
1460
1470
1480
1490
1500
1510
1520
1530
Velocity (m/s)



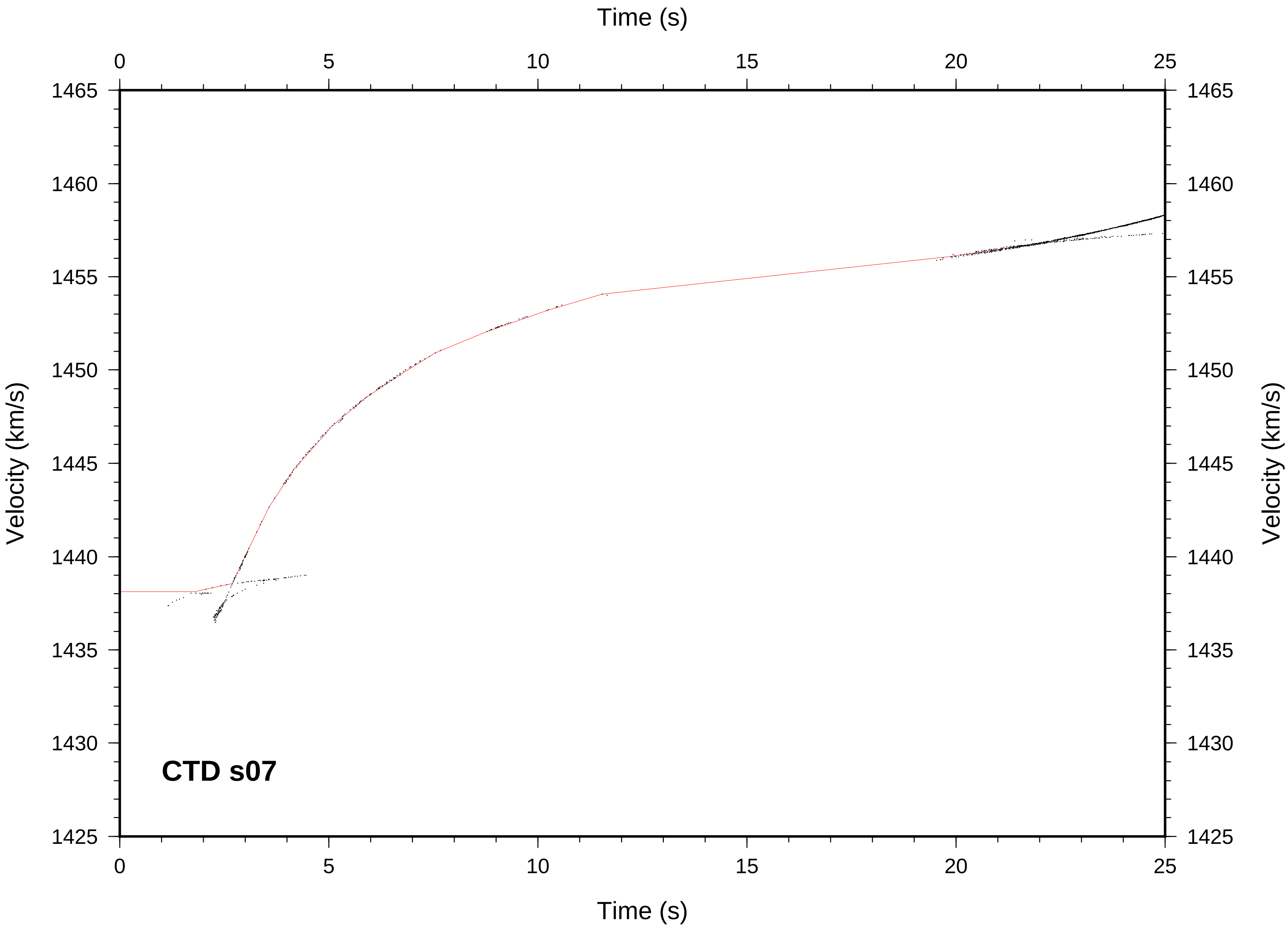
Time (s)
0
5
10
15
20
25
1465
1460
1455
1450
1445
1440
1435
1430
1425
Velocity (km/s)
CTD h14

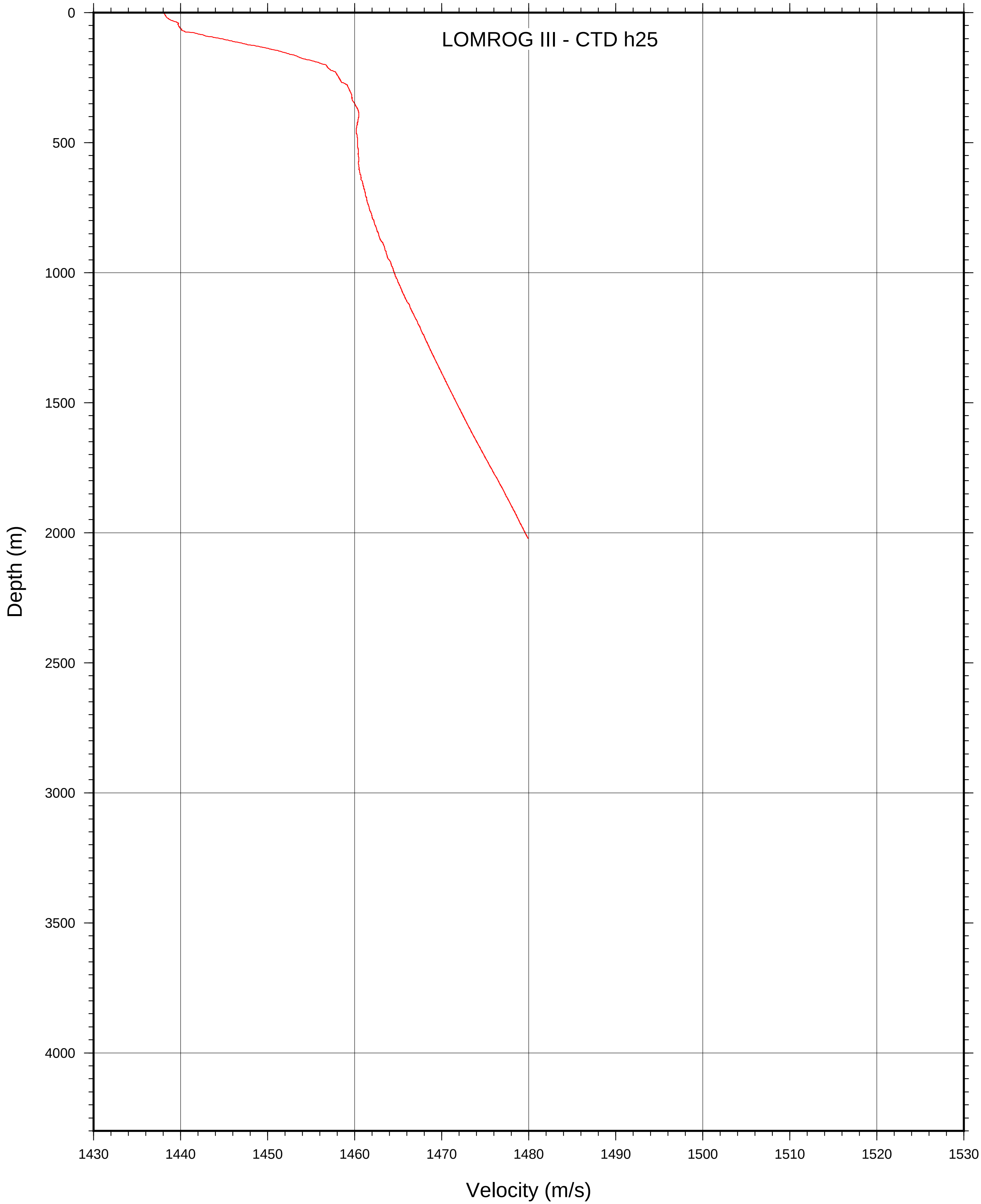

LOMROG III - CTD s06
Depth (m)
0
500
1000
1500
2000
2500
3000
3500
4000
1430
1440
1450
1460
1470
1480
1490
1500
1510
1520
1530
Velocity (m/s)


Time (s)
0
5
10
15
20
25
1465
1460
1455
1450
1445
1440
1435
1430
1425
Velocity (km/s)
CTD s06

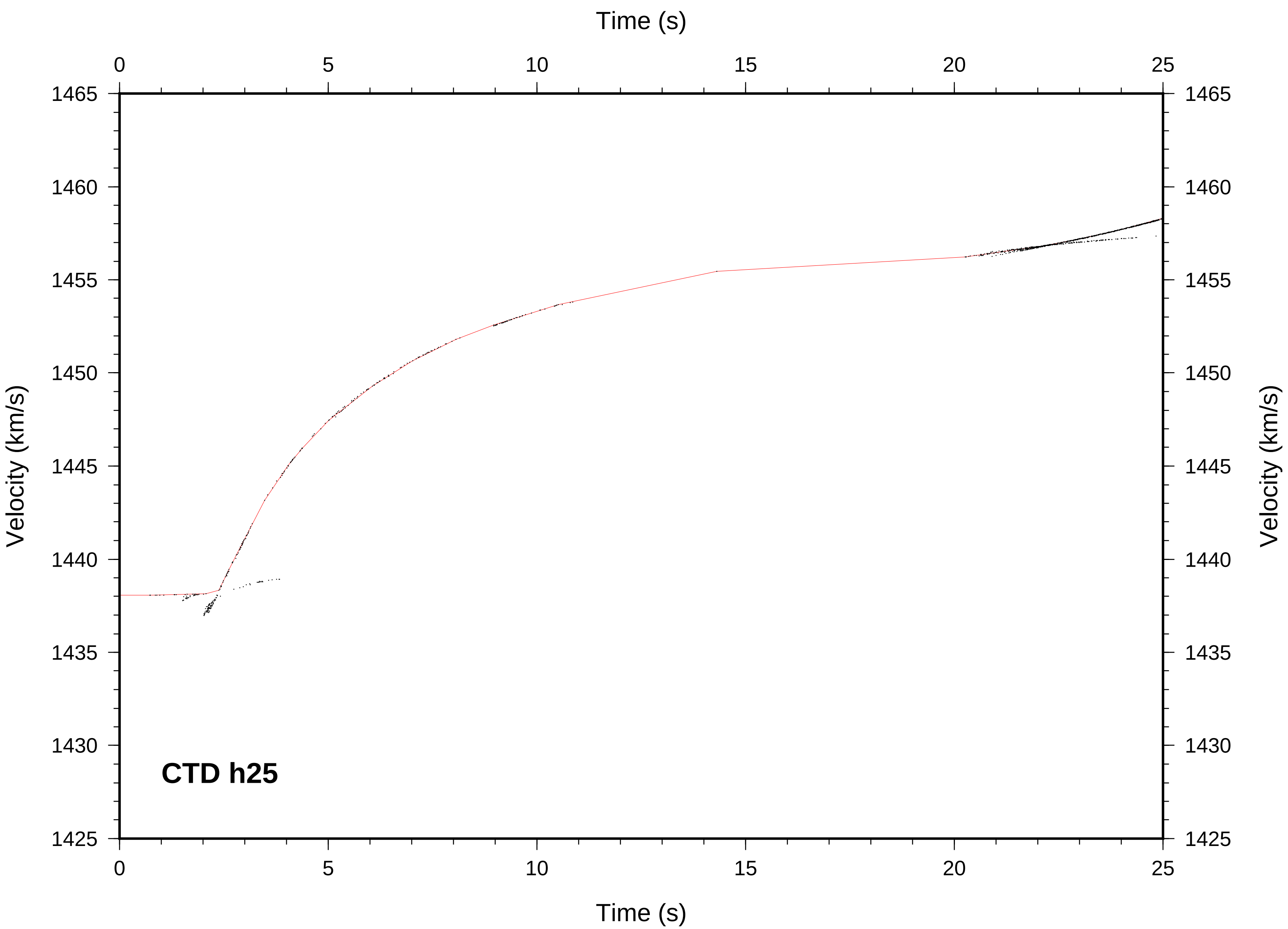


LOMROG III - CTD s07
0
500
1000
1500
2000
2500
3000
3500
4000
Depth (m)
1430
1440
1450
1460
1470
1480
1490
1500
1510
1520
1530
Velocity (m/s)

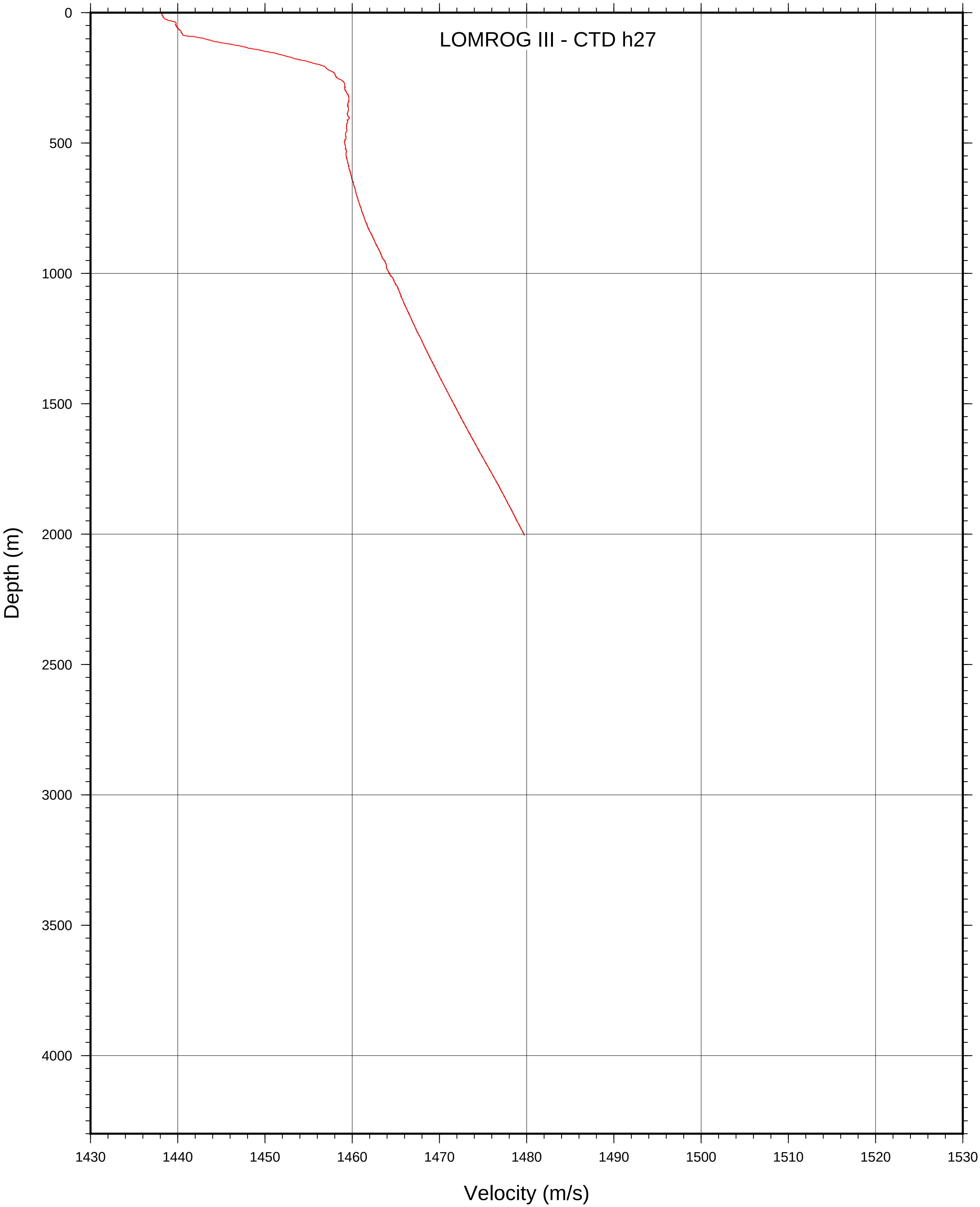

Time (s)
0
5
10
15
20
25
1465
1460
1455
1450
1445
1440
1435
1430
1425
Velocity (km/s)
CTD s07

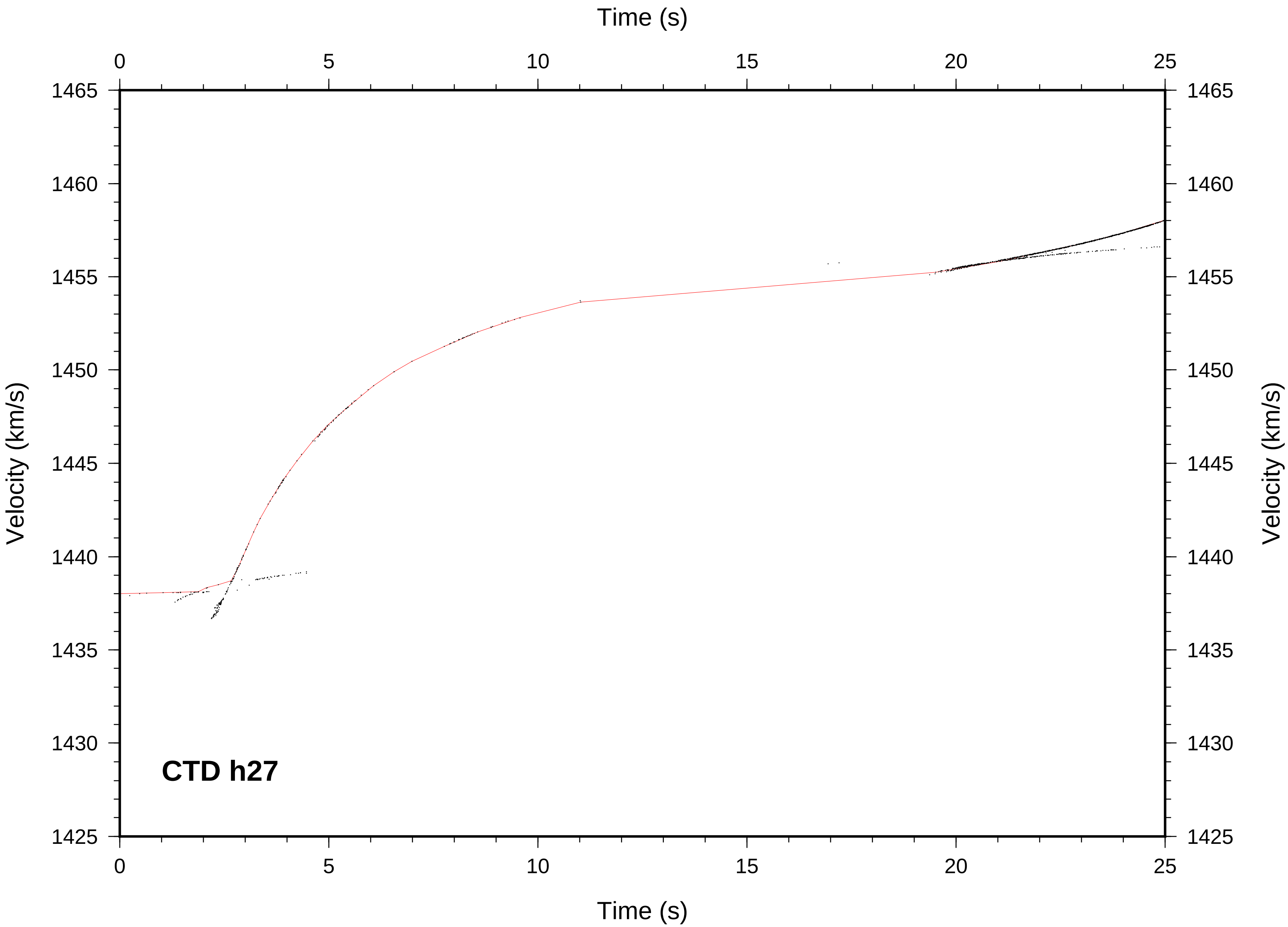


LOMROG III - CTD h25
Depth (m)
0
500
1000
1500
2000
2500
3000
3500
4000
1430
1440
1450
1460
1470
1480
1490
1500
1510
1520
1530
Velocity (m/s)



Time (s)
0
5
10
15
20
25
1465
1460
1455
1450
1445
1440
1435
1430
1425
Velocity (km/s)
CTD h25


LOMROG III - CTD h27
Depth (m)
0
500
1000
1500
2000
2500
3000
3500
4000
1430
1440
1450
1460
1470
1480
1490
1500
1510
1520
1530
Velocity (m/s)


Time (s)
0
5
10
15
20
25
1465
1460
1455
1450
1445
1440
1435
1430
1425
Velocity (km/s)
CTD h27

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Appendix V-D:

Technical Specifications Sonobuoy Receiver WR-2902e

WR-2902e

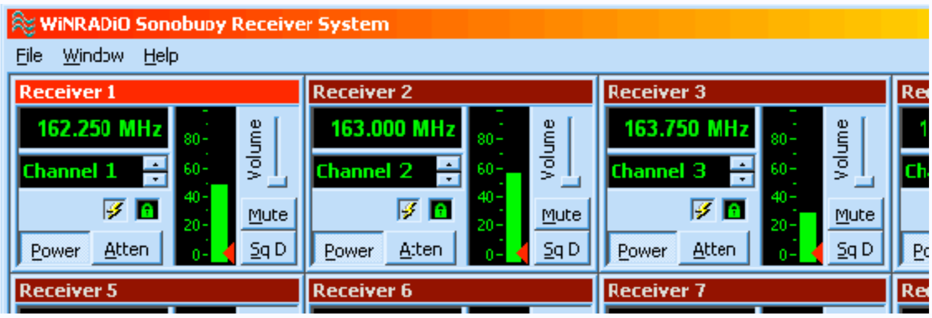
The WiNRADiO WR-2902e VHF/UHF Sonobuoy Telemetry Receiver is designed to receive signals from analogue (DIFAR) and digital (BARRA) sonobuoy transmitters, operating in the 136 to 173.5 MHz frequency range. This standard frequency range can be easily extended up to 1.5 GHz to suit special requirements.

The WR-2902e is a triple conversion superheterodyne receiver. It features a single antenna input, separate analog and digital signal outputs, and an audio output for monitoring.

The receiver is enclosed in a ruggedized aluminium enclosure and can be connected to any standard computer either via a serial port, or (optionally) via USB or PCMCIA ports. As all RF signal processing is performed by the receiver, the computer hardware and software requirements are modest and a standard laptop can be used to control the receiver. More than one receiver can be connected to a single computer, the number depending only on the availability of ports.

The WR-2902e receiver is supplied with Windows based application software and a DLL library developed for easy system integration into custom designed sonobuoy systems.

The Windows application software shows a graphical representation of all installed receivers (a virtual control panel), making it possible to observe the status of all receivers at a glance and make individual adjustments if necessary. Each receiver can be monitored, and a mixing facility is provided where a particular receiver can be selected for audio monitoring by simply clicking on the corresponding receiver panel.



WR-2902e Control Panel (a portion only shown)

Technical Specifications

Frequency range	136.000-173.500 MHz
Channel spacing	375 kHz
Modes	Analogue FM (DIFAR), High speed digital (BARRA)
Sensitivity	0.9 µV (DIFAR), 1.5uV (BARRA)
IF bandwidth	230kHz @ -6dB

Skirt selectivity	470kHz @ -25dB 730kHz @ -60dB
Frequency response	Less than ± 1 dB variation from 5 Hz to 25 kHz (analog) 5Hz to 150kHz (digital)
Output level	1.0 ± 0.1V rms @ 75kHz devn. and 1kHz mod. frequency (DIFAR), TTL compatible (BARRA)
RSSI range	Exceeds 60dB for 5dB linearity
Image rejection	80 dB or better
Frequency stability	±20 ppm or better
Input impedance	50 ohm (nominal)
Connectors	RF input (BNC), DIFAR output (SMA), BARRA output (SMA); 3.5mm audio jack for monitoring
Power requirements	+12V @ 420 mA
Total power consumption	5 W max
Dimensions	216 x 121 x 45 mm (8.5" x 4.75" x 1.75")
Mass	1350 g (47.25 oz)
Ambient temperature	Storage: -20º to +75º C Operation: 0º to +45º C

(Specifications are subject to change without notice.)

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Appendix V-E:

Technical Specifications Taurus Seismometer from Nanometrics

(ACTUAL SIZE)

Taurus Technical Specifications

Sensor inputs

Channels	3 standard, field upgradeable to 6 or 9 with addition of external Trident digitisers
Sampling	Simultaneous
Input voltage range	40 V peak-to-peak differential (at gain=0.4)
Nominal sensitivity	1 count/ μV (gain=1)
Hardware gain selection	Software configurable 0.4, 1, 2, 4, 8
Software gain	User configurable 0.001 to 100
High pass filter	User configurable in mHz

Digitiser performance

Type	Proprietary high order sigma-delta
Digital filter	140 dB attenuation at output Nyquist
Filter type	Linear phase (consult factory for other options)
Dynamic range	>138 dB @ 100 sps (max sine wave above shorted input)
Sample rates	10, 20, 40, 50, 80, 100, 120, 200, 250, 500 sps

Sensor support

Sensor types	Broadband active and short period passive
Control lines	3; typically used for Cal enable, mass center and mass lock/unlock Logic level configurable; High: 5 V, 12 V, open drain. Low: 0 V, open drain
Sensor power	Supply power pass-through to sensor (9-36 VDC). Protected against short circuit. Sensor power can be switched on/off from user interface.
Auto mass centering	Configurable mass position threshold with autocentering or centering scheduled with configurable repeat interval. In autocentering mode, mass centering will be repeated until masses are within limits.
Sensor management	Supports digital interface to Nanometrics Trillium 120 seismometer

Calibration output

Calibration signal	Ramped sine wave, configurable frequency and amplitude Pseudo-random binary
Calibration initiation	User interface (local or remote)
Calibration mode	Voltage or current

Timing

Timing system	Internal DCXO clock disciplined to GPS
GPS receiver	Internal 8 channel receiver
GPS antenna	External active antenna supplied with 5 meter cable
Duty cycle	Software configurable

Instrument state-of-health

Taurus records continuous instrument state-of-health including:

- Power supply voltage
- Seismometer mass position
- Calibration enabled bit for each channel
- GPS state-of-health
- Instrument temperature
- Signal clip indication bit

User accessible SOH	4 external SOH channels (12-bit)
Configuration	Complete configuration audit trail
Communications	Complete audit trail with cumulative good/bad packet counts
Log file	All software generated log messages are stored with the data

Internal data storage

Standard	Single, 1.8" ATA disk drive slot Single, Type I/II Compact Flash slot Both storage options are removable. Storage media are accessed via the media door on the end of the unit.

The following media options are available:

Compact Flash	Standard and industrial grade Type I/II. 1 or 2 Gbyte; Contact factory for larger capacity options.
1.8" ATA disk drive	10 or 30 Gbyte
Duration	>600 days continuous recording, 3-channels @ 100 sps on 30 GByte ATA drive (~40 days on 2 Gbyte Compact Flash)
Recording modes	Continuous; write once or ringbuffer (overwrites oldest data) Continuous with STA/LTA trigger flags
File system	FAT32
Storage format	Nanometrics Store. Direct data output in MiniSEED and Nanometrics formats.

Data retrieval

Media exchange	Compact Flash and ATA drives are field swappable
Download interfaces	10/100 Base-T Ethernet

Real-time data communications

Interfaces	10/100 Base-T Ethernet, RS-232 serial
Protocols	UDP/IP unicast/multicast HTTP (POST and GET) RS-232 serial with IP drivers

Integrated user interface

LCD display	240*320 colour graphics display with backlight
Interface	Web browser with five button navigation
LED	System status tri-colour LED, Ethernet communications LED, Media status LED.

Configuration

Taurus is configurable locally via the colour LCD display and onboard browser or remotely using any web browser connected to the unit. Multiple unit configuration is achieved using an optional group configuration web server. Consult factory for further information.

Software

Operating system	Linux
Applications software	Nanometrics next generation NAQS Server with web interface

Connectors

Sensor connector	26-pin mil circular. Primary data channels, sensor control lines, protected/switchable sensor power, digital serial sensor management interface
Serial/USB	19-pin mil circular Serial port 1; Rx, Tx, RTS, CTS, DTR, DSR, CD, RI Serial port 2; Rx, Tx, RTS, CTS (data collection from serial devices) USB master; Data, Pwr (5 V, 100 mA) Serial device power (pass through supply voltage)
GPS	TNC, active antenna connection (3.3 V)
Ethernet	4-pin mil circular, 10/100 Base-T
User SOH	7-pin mil circular, 4 analog SOH inputs, SOH ref., 3.3 V @ 10 mA power
NMXBus	4-pin mil circular, NMXbus data and power
Power	3-pin mil circular, 9-36 VDC
USB	USB master/slave accessible behind media door

Power

Power system	Protected fuseless design with configurable low power disconnect, reverse protection and short circuit protection
Ultra-low power mode	650 mW @ 12 Volts. 3-channel continuous recording @ 100 sps, <100 μsec timing precision, Compact Flash recording
Low power	1.1 Watt @ 12 Volts; 3-channel continuous recording @ 100 sps, continuous serial data acquisition (external geodetic GPS or equivalent), <100 μsec timing precision, internal disk or Compact Flash recording.
Communications mode	1.5 Watt typical; 3-channel continuous recording @ 100 sps, <100 μsec timing precision, real-time Ethernet or serial communications
Configuration	<3.5 Watts. All systems operational including colour graphics display.
Low voltage disconnect	Software configurable

Environmental

Operating temp.	-20°C to +60°C base unit using Compact Flash storage +5°C to +55°C base unit using 1.8" ATA disk storage
Storage temp.	-40°C to +70°C
Humidity	100%
Length	264 mm
Width	147 mm
Depth	60 mm
Weight	1.8 Kg

Nanometrics INC.
SEISMOLOGICAL INSTRUMENTS

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Kanata Ontario, Canada K2K 2A1
613-592-6776
Fax: 613-592-5929
info@nanometrics.ca
www.nanometrics.ca

Appendix V-F:

Technical Specifications Sonobuoy AN/SSQ-53D(3) from ULTRA Electronics

AN/SSQ–53D(3)

Directional Passive Sonobuoy

Search, localization, and tracking of sub-surface and surface targets of interest

Ultra Electronics AN/SSQ-53D(3) DIFAR sonobuoy offers world-leading passive acoustic performance. Optimized for low frequency detection, this sonobuoy is an enhancement of Ultra's AN/SSQ-53D(2) sonobuoy. Using its proven 'ambient noise limited' directional hydrophone and complementary suspension system, the AN/SSQ-53D(3) is qualified for operation in Sea State Six. For improved performance in the littoral environment, a fourth operating depth has been implemented, allowing operator selection of sensor deployment to 30, 60, 120, or 300 metres.

- ”A“ size high-performance DIFAR sonobuoy
  - Exceeds requirements of MIL-S-81487E (AS)
  - Lightest weight ”A“ size DIFAR available
  - Compatible with all known airborne acoustic processors
- Proven reliability
- Competitively priced with lesser capable passive sonobuoys
- Electronic Function Select (EFS) permits operator predeployment selection of:
  - One of 99 VHF-FM data uplink frequencies;
  - One of five different operating periods; and
  - One of four hydrophone depths.

Reliable, high performance at a competitive price

Ultra ELECTRONICS

SPECIFICATIONS

GENERAL DESCRIPTION

Description .... *DIFAR, passive, directional*

Function .... *Search, localization, surveillance*

Applicable Specification .. *US Navy Production Sonobuoy Specification dated 26 Oct 94 as modified by the Canadian Armed Forces*

Dimensions .... *36.00 in (914 mm) long by 4.875 in (124 mm) diameter*

Weight .... *16.5 lbs (7.5 kg)*

Power Source .... *Seawater activated battery (main power source) Lithium battery (EFS display and memory)*

Stabilization Time (after splash) .... *Up to 100 seconds (shallow) 125 seconds (medium 1) 160 seconds (medium 2) 240 seconds (deep)*

Operating Life .... *0.5, 1, 2, 4, or 8 hours preselectable*

Scuttling Time .... *At 8 hours, regardless of operating life*

NATO Stock Number *5845-21-921-2055*

Shelf Life .... *5 years in sealed container*

Unpacked Storage Life (minimum) .... *90 days*

TRANSMITTER CHARACTERISTICS

Frequency Range .... *136 MHz to 173.5 MHz*

Transmission Channels .... *99 preselectable, with EFS display*

Transmitter RF Power .... *1 W minimum*

SENSOR CHARACTERISTICS

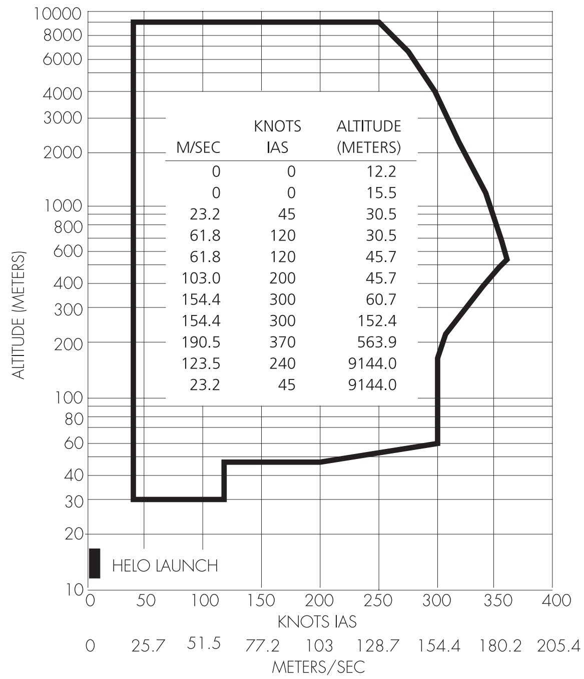
Acoustic Frequency .... *5-2400 Hz Range*

Sensitivity, Directional .... *122 ± 3 dB rel 1 µPa at 100 Hz = 40kHz pk dev*

Sensitivity, Omnidirectional .... *122 ± 3 dB rel 1 µPa at 100 Hz = 25 kHz pk dev*

Operating Depth .... *30 metres, 60 metres, 120 metres, and 300 metres preselectable*

Descent time (in water) .... *40 seconds (shallow) 65 seconds (medium 1) 100 seconds (medium 2) 180 seconds (deep)*



M/SEC	KNOTS IAS	ALTITUDE (METERS)
0	0	12.2
0	0	15.5
23.2	45	30.5
61.8	120	30.5
61.8	120	45.7
103.0	200	45.7
154.4	300	60.7
154.4	300	152.4
190.5	370	563.9
123.5	240	9144.0
23.2	45	9144.0

Ultra ELECTRONICS

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UnderSea Sensor Systems Inc.
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Fax: 260.248.3510
email: mktg@undersea-sensors.com

www.ultra-ussg.com

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03/03/AN/SSQ–53D(3)
Printed in Canada, 2003

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Appendix V-G:

Technical Specifications VHF Antenna MD G3

MOONRAKER
Type MD-G3

High Gain Broadband Collinear
for marine or land VHF Marine Band communications

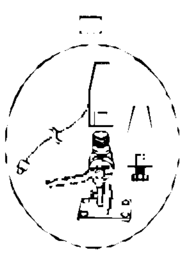
A rugged lightweight 5/8 wave ground independent collinear to give efficient and dependable performance.

The type MD-G3 has been designed as a robust, high gain antenna system and is ideally suited for base station and marine mobile use. It is constructed of marine grade, low corrosion, tempered aluminium alloy tubing which is completely coated with black (option of white) PVC to provide maximum protection from harsh environments and ultra-violet radiation. all metal parts are at DC earth potential for static discharge and fittings are of nylon and chromed bronze.

Mounting is easily effected by way of nylon side mount insulators,(or by straps or clamps to mast or tower section), by 12mm metric base bolt or by a heavy duty stainless steel swingdown mount adjustable in two planes.

Specifications

VHF Band	**150-170 MHz**
Overall Length	2.78 metres (9.12 ft)
Base Section Diameter	22.24 (7/8 in)
Top Section Diameter	10 mm (0.4 in)
Pattern	Omnidirectional
Polarisation	Vertical
Frequency Range	Standard Version: full marine band 156-162 MHz
Bandwidth	7 MHz at <1.5:1 VSWR; 20 MHz at <2:1 VSWR
Gain	5 dBi
Impedance	50Ω nominal
Wind Loading	2.35 kg at 100 km/h (5.2 lbs at 60 mph) 3.56 kg at 120 km/h (7.8 lbs at 75 mph)
Power Capability	75 watts
Mountings	Either two 63 mm (2.5 in) nylon clamp type insulators, 35 mm diameter (1 3/8 in), threaded to take M10 set screw, or heavy duty galvanised hose clamps (recommended spacing not less than 25 cm (9.8 in) apart); stainless steel swingdown mount (1" thread) adjustable in both planes (not supplied); or base mounted 12mm metric bolt (not supplied).
Connection	5 metres RG58 coaxial cable with PL259 (UHF) connector; or female N Type connector permanently fitted in base of mounting tube (sidemount type)
Packed Weight	3 kg (6.6 lbs)



Mounting options

Specifications subject to change 5/04

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Appendix V-H:

Technical Specifications of Yagi antenna R2-10L

R 2-8/..., R 2-10/...

Directional Antennas with 8 and 10 dBd Gain for the 160 MHz Band

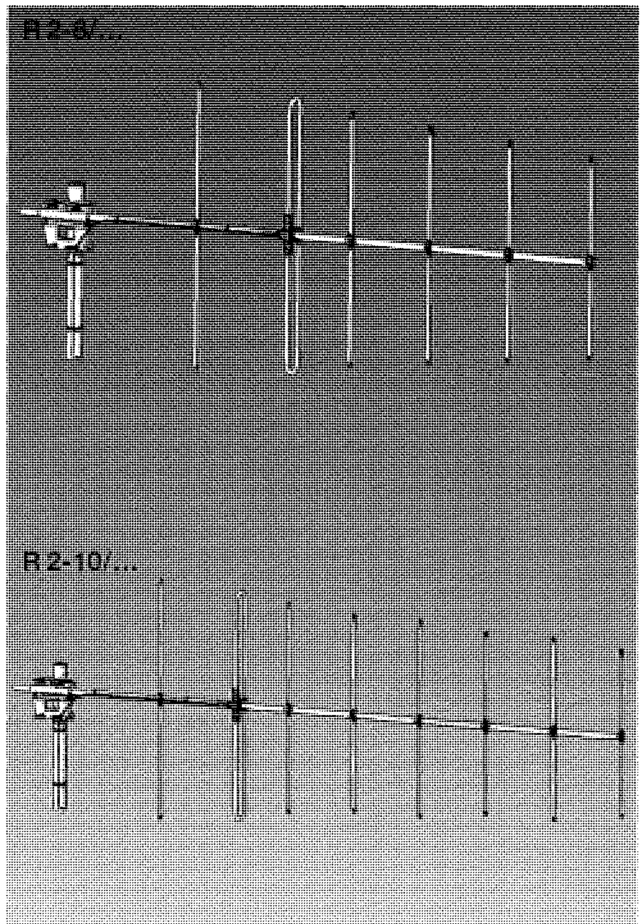
PROCOM

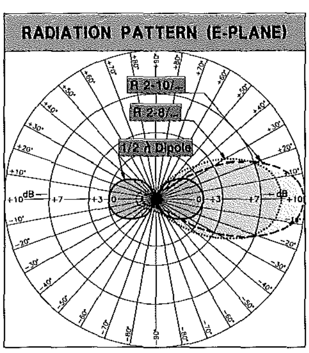
DESCRIPTION:

- ★ These antennas are 6- and 8-element Yagi antennas with 8 and 10 dBd gain, respectively.
- ★ When mounted for vertical polarization the horizontal coverage is R 2-8: 64° and R 2-10: 50°.
- ★ R 2-8/... and R 2-10/... cover the 160 MHz band in two models.
- ★ These Yagis incorporate baluns optimized for wide bandwidth and accurate matching.
- ★ The entire balun unit and feeder cable inlet are completely sealed in a polythene moulding ensuring permanent waterproof connections. The antennas are supplied with a 3m "tail" of RG 213 terminated with an N-female connector.
- ★ Radiating elements, supporting booms and adjoining metal castings have been constructed in high quality aluminium alloys to prevent corrosion. All metal parts are DC-grounded.
- ★ The antennas are designed for back mounting and are provided with rear extended booms.
- ★ These antennas can be stacked and fed in phase with a matching harness for increased gain.
- ★ A mast clamp for fixation on 30-58 mm diameter mast tube is enclosed.

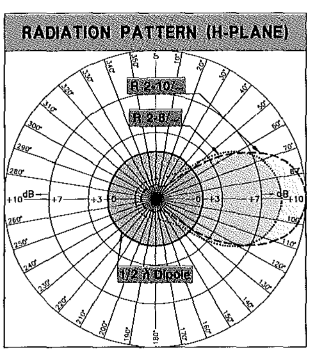
SPECIFICATIONS:

	R 2-8/...	R 2-10/...
ELECTRICAL		
ANTENNA TYPE	6-element Yagi	8-element Yagi
FREQUENCY	l: 140-155 MHz h: 155-175 MHz	l: 145-165 MHz h: 156-175 MHz
IMPEDANCE	50 Ω	
POLARIZATION	Vertical or horizontal	
GAIN	8 dBd (10.15 dBi)	10 dBd (12.15 dBi)
FRONT TO BACK RATIO	16 dB	20 dB
HALF-POWER BEAMWIDTH	E-plane: 50° H-plane: 64°	E-plane: 40° H-plane: 50°
BANDWIDTH	20 MHz	
SWR	≤ 1.5	
MAX. POWER	150 watt	
ANTISTATIC PROTECTION	All metal parts DC-grounded (Connector shows a DC-short)	
MECHANICAL		
CONNECTION	3m tail of RG 213 terminated with type "N" female connector	
WIND SURFACE	0.139 m²	0.15 m²
WIND LOAD	154 N (at 150 km/h)	180 N (at 150 km/h)
COLOUR	"Aluminium"	
MATERIALS	Elements/Boom/Saddle clamps: Aluminium alloys. Fittings: Stainless steel	
BOOM LENGTH	Approx. 2.7 m	Approx. 3.4 m
BOOM DIA.	31.8 mm	
MAX. ELEMENT LENGTH	1.06 m	
DIA. OF ELEMENTS	19 mm	
WEIGHT	Approx. 4.8 kg	Approx. 5.2 kg
MOUNTING	Supplied with mast bracket suiting 30-58 mm dia. mast tube	





If the antennas are mounted for vertical polarization these curves show the radiation patterns in the vertical plane.



If the antennas are mounted for vertical polarization these curves show the radiation patterns in the horizontal plane (horizontal coverage).

ORDERING DESIGNATIONS

TYPE / FREQ.	6-element Yagi 8 dBd	8-element Yagi 10 dBd
140-155 MHz	R 2-8/l	–
145-165 MHz	–	R 2-10/l
155-175 MHz	R 2-8/h	R 2-10/h