DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2010/53

Seismic Acquisition Report - LOMROG II in 2009

Acquisition of reflection and refraction seismic data during Oden's Lomonosov Ridge Off Greenland (LOMROG II) cruise in 2009

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This report has been written in cooperation with the Department of Earth Sciences, University of Aarhus

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Summary

The LOMROG II cruise was organized as a joint Danish-Swedish-Canadian cruise. Furthermore a Russian hydrographer participated in the cruise. The primary objective of the Danish and the Canadian part of LOMROG II was to collect bathymetric, seismic and gravimetric data along the flanks of the Lomonosov Ridge and in the Amundsen Basin in order to acquire the necessary data to document an Extended Continental Shelf beyond 200 nautical miles according to Article 76 in UNCLOS. The Swedish part of the cruise consisting of two science projects was organized by the Swedish Polar Research Secretariat.

During the LOMROG II cruise a total of 380 km of seismic data were acquired on both sides of the Lomonosov Ridge, mostly by *Oden* preparing a track prior to acquisition. This year, none of the seismic gear was lost in the ice as happened during the LOMROG I cruise in 2007 and in many other Arctic seismic experiments. Only one section of the streamer was damaged by the ice. In general, the data quality is better than that obtained during LOMROG I in 2007. 30 sonobuoys were successfully deployed out of a total number of 38 deployments of sonobuoys.

After initial and unsuccessful attempts to acquire seismic data along existing leads in the ice it was decided to have Oden break a 25 nautical mile long lead or track along a 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. This option has some obvious advantages. 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. 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 gear is reduced considerably. However, data acquisition is more time consuming when employing this method.

However; more data could have been acquired if a lead icebreaker had been available. The presence of a lead icebreaker could have reduced the time needed for transit and ice-breaking by up to two weeks, which could have been used to complete the acquisition of bathymetric data along the Lomonosov Ridge and to acquire more seismic data in the Amundsen Basin.

For processing of the seismic data a *User defined spectral shaping filter* proved to be very efficient in addressing some of the inherent noise problems of the seismic data recorded. Overall, the data quality is surprisingly good given the difficult acquisition environment. On all lines collected, the basement arrivals are clear.

On August 22, 2009 at 21:04 (UTC) *Oden* reached the North Pole - the 6th time *Oden* reached the North Pole and the third time on its own.

1. Introduction

By Christian Marcussen, Geological Survey of Denmark and Greenland

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) collecting refraction seismic data from the shelf area north of Greenland and Ellesmere Island to the Lomonosov Ridge. The LOMROG I cruise with *Oden* and *50 let Pobedy* collected bathymetric and seismic data in 2007 (Jakobsson et al. 2008). 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. More information on the Danish Continental Shelf Project is available on www.a76.dk.

The LOMROG II cruise was organized in cooperation with the Swedish Polar Research Secretariat and the Canadian Continental Shelf Project. The Canadian Project paid for five days of ship time, whereas the remaining costs were split between Denmark (80%) and Sweden (20%).

The main objectives of the LOMROG II cruise were

UNCLOS related:

1. Acquisition of bathymetric data on both flanks of the Lomonosov Ridge
2. Acquisition of seismic data in the Amundsen and Makarov basins
3. Acquisition of gravity data along *Oden*'s track

Add-on science:

4. Swedish research projects
5. Research projects from Denmark, Greenland and the USA

In 2009 *Oden* operated without a lead icebreaker in the Arctic Ocean. For this reason, areas with extreme ice conditions close to Greenland were avoided. The LOMROG II cruise started on July 31 in Longyearbyen, Svalbard, where it also ended on September 10. The present report covers acquisition of reflection and refraction seismic data. Other activities are reported separately (Marcussen et al. 2010).

Weather and Ice Conditions

During LOMROG II, weather observations were made every six hours. These were sent to the global weather community via email. In general, low stratus clouds and fog dominated the weather during the cruise with temperatures close to 0°C. However, in late August temperatures were dropping down to -8°C. The weather did not influence the data acquisition but delayed helicopter operations on a few occasions.

The Arctic sea ice conditions during the summer of 2009 have been in general light. At the summer minimum in mid September, the total ice extent was among the three lowest on record (with 2007 and 2008 being the other two). However, most of the reduction in the ice area took place in the part of the Arctic Ocean facing Russia and Alaska. In the part of the Arctic Ocean where the LOMROG-II cruise was conducted, the ice situation was not particularly easy.

The voyage between the ice edge at 80°45'N 15°E and the working area was characterized by a substantial amount of multi-year ice mixed with varying concentrations of first-year ice. In the central Arctic the ice generally consisted of a mixture of 1 to 2-m-thick first-year and 3-m-thick multi-year ice floes. Our first crossing of the Amundsen Basin as well as most of the operation on the Lomonosov Ridge was in difficult ice conditions with a substantial fraction of multi-year ice and pressure ridges. However, ice conditions were substantially lighter during the final passage through the Amundsen Basin. During the last three days in the ice, easterly winds did compact the ice substantially and made advancement very difficult since very few openings were encountered. Air temperatures below -5°C meant that the existing openings were already refrozen making icebreaking more difficult. The many melt ponds encountered on the outward journey were also refrozen at this stage.

References:

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2. Reflection Seismic Survey

By Holger Lykke-Andersen, Per Trinhammer, Anja Kinnberg Gunvald and Esben Villumsen Jørgensen Department of Earth Sciences, University of Aarhus and Christian Marcussen, Geological Survey of Denmark and Greenland

Reflection seismic 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 was planned and tested prior to the LOMROG I expedition in 2007 and modified for the LOMROG II expedition based on the experiences obtained during the LOMROG I expedition.

In the following a brief overview of the reflection seismic equipment used onboard *Oden* on the LOMROG II expedition 2009 is given. Further details are given in Appendix I.

2.1 Seismic Source

A 605 cu.in. linear airgun cluster was used as seismic source consisting of two Sercel guns: one G-gun (250 cu. in.) and one GI-gun (250 and 105 cu. in.) (Fig. 1). The airgun cluster was fired at 180 bar and the pressurized air was produced by two Hamworthy 185E_MK2 70mm Series Air Compressors. A trigger pulse generated by NaviPac was sent to the gun trigger unit, TGS-8 (Fig. 1) which synchronized and triggered the guns.

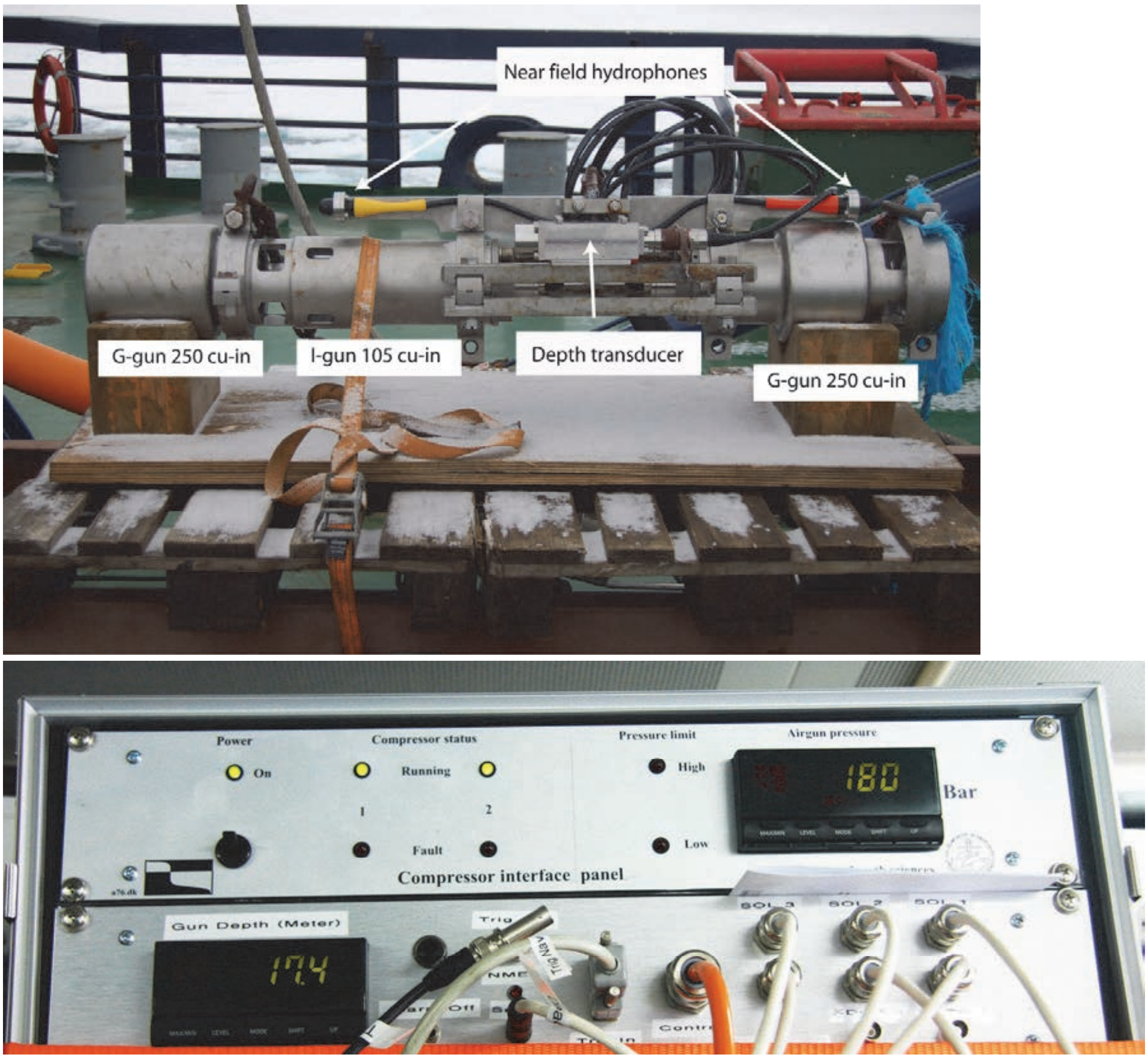


Figure 1. *Sercel 605 cu.in. linear airgun cluster (top). (Bottom) TGS-8 gun trigger unit (cables right side of lower panel), gun depth monitor (left side of lower panel). Compressor monitor and air gun pressure (upper panel).*

A hydrophone was placed adjacent to the firing ports on each G-gun (Fig. 1). The signals from the two hydrophones were used by the TGS-8 trigger unit for synchronization of the two guns. The I-gun (injector) was fired with a delay of 65 ms with the purpose of reducing the amplitude of the bubble pulse.

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.

2.2 Streamer

The streamer was a digital Geometrics GeoEel streamer (Figs. 2, 6 and 8) with four 50 m long live sections (total active length 200 m) and one 50 m long vibration 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 in the rear end of section 4.

Figure 2. *Geometrics GeoEel streamer on deck (left) - for streamer on winch see Figs. 6 and 8. Streamer power supply unit SPSU (right)*

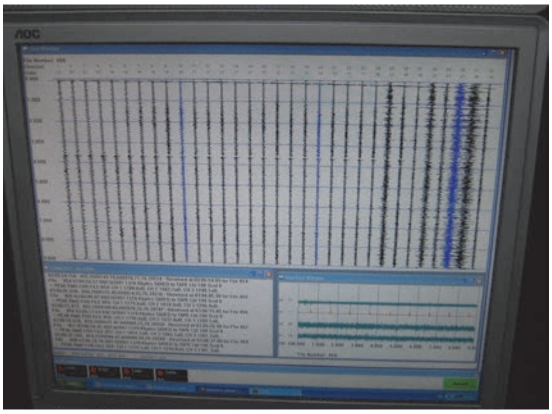
2.3 Recording System

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) (Fig. 2) via Ethernet and receiving the digitized signals from the streamer as well as auxiliary channels 1-4. On auxiliary channels 1, 2 and 4 data from three sonobuoy radio receivers was recorded and on auxiliary channel 3 the PPS pulse from the GPS. (see also sonobuoy report in chapter 8). It turned out that the PPS pulse amplitude had to be reduced. A reduction factor of 10 solved the problem. Data were recorded simultaneously on LTO-2 tapes with a capacity of 200 GB and on a RAID 250 GB hard disk.

The navigation software NaviPac (see below) sent an event trigger every 12 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), water depth (from the center beam of the multi beam), gun depth and the string was transferred to the SEG-D external header on tape and hard disk. The data string is also stored in a log file on the CNT-2 PC with the filename Lomrog2.0000x.Depth.txt.

The seismic controller provided the following display facilities during survey:

- A shot gather window (fig 3) where various display settings could be changed as appropriate.
- A single channel window.
- A real-time brute stack window (Fig. 3) where various processing and display parameters could be changed as necessary.
- A noise window showing noise values in µbar from all 32 channels as a “snapshot” calculated between shots. Another (new) option in this window is to display the S/N ratio.
- 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.



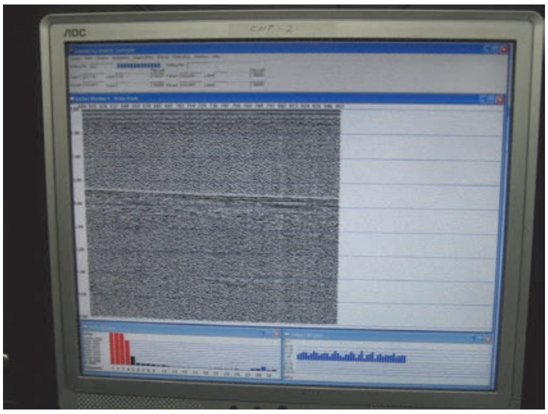


Figure 3. *Seismic controller display facilities: shot gather window (left) and brute stack window (right).*

During the survey the CNT-2 software generated a log file named Lomrog09_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 Lomrog2.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 605 gun array position), depth (from the center beam), 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 and the real-time brute stack in a SEG-Y file. These files were named

Lomrog09.linenumber.Depth.txt and *Lomrog09.linenumber.Gather1.sgy*

respectively.

2.4 Navigation and Positioning System

A separate Thales DG16 GPS was used for positioning of the reflection seismic 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, water depth below transducer (8 m below sea level.) from the center beam of the ships Kongsberg EM120 multibeam echo sounder and gyro course from the ship's Furuno gyro.

The NaviPac system provided the trigger signal for the TGS-8 and an event trigger and data string for the CNT-2 controller. Run lines (survey lines) were generated in the so called Helmsman's display part of NaviPac and the survey is controlled from this display (Fig. 4). The option of distributing runline data to a Helmsman's display on the bridge running in slave mode was not used.

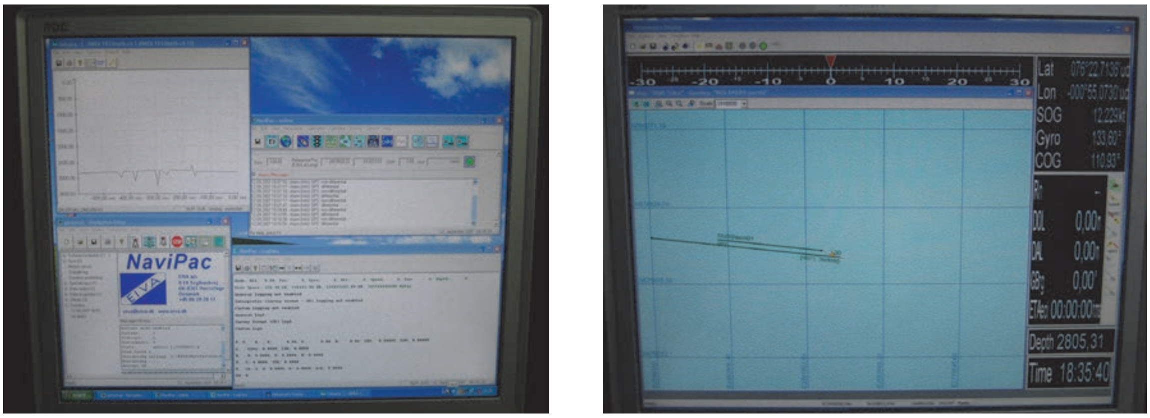


Figure 4. *NaviPac setup window (left) and NaviPac Helmsman's display for survey control (right).*

2.5 Container and Equipment Setup on *Oden*

Several containers were used for the reflection seismic 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 (Fig. 6 cf. Fig 1, 8 and 15). On the starboard side, the compressor container, a gun workshop as well as streamer container and storage containers were placed.

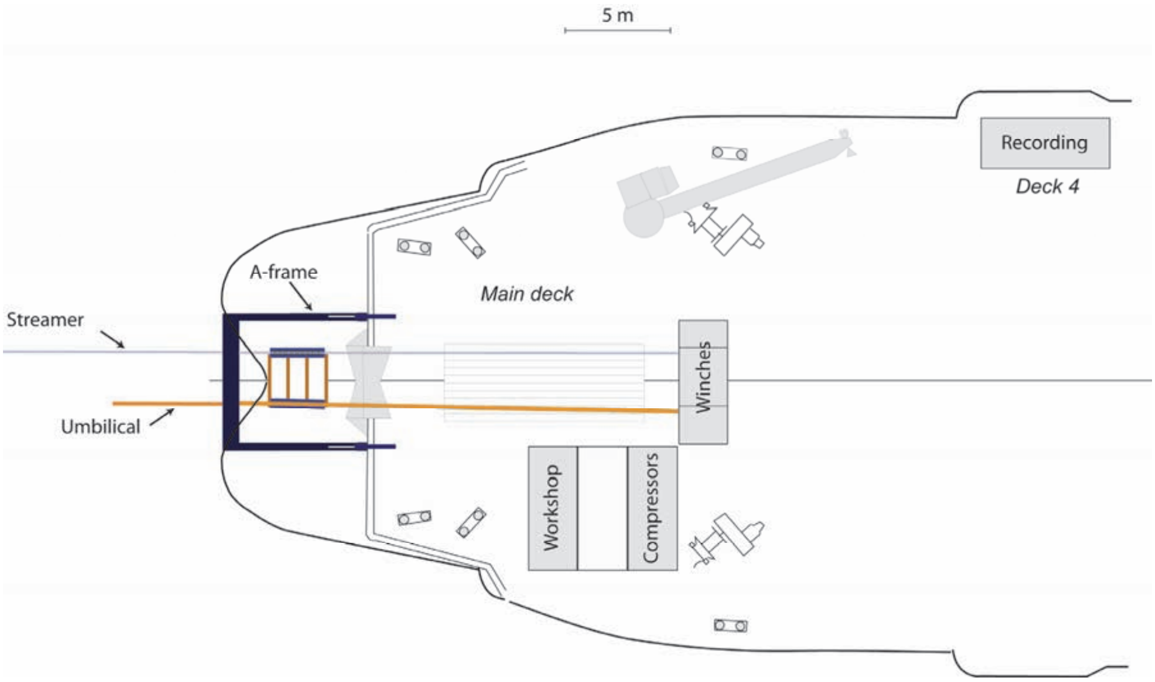


Figure 5. *Plan view showing location of main equipment components on aft deck and deck 4.*

Figure 6. *Containers on aft deck: winches, compressors (white) with storage above (top left), interior of compressor container (bottom left), storage containers on top of compressor and workshop container (top right) and interior of workshop container (bottom right).*

Cables were connecting the umbilical winch and the recording container placed on the port aft side of deck 4 (Fig. 7 cf. Fig 1 and 15). Here the navigation software (NaviPac) and multichannel acquisition system (Geometrics CNT-2, SPSU, TGS-8, Winradio) were installed and operated. Drawings showing the container and equipment setup are enclosed in Appendix I.

Figure 7. *Recording container on deck 4 (left) and interior of the container (right).*

3. Seismic Reflection Equipment for Data Acquisition in Ice

By Holger Lykke-Andersen, Per Trinhammer, Anja Kinnberg Gunvald and Esben Villumsen Jørgensen Department of Earth Sciences, University of Aarhus and Christian Marcussen, Geological Survey of Denmark and Greenland

3.1 General Considerations

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

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 Fig. 8).

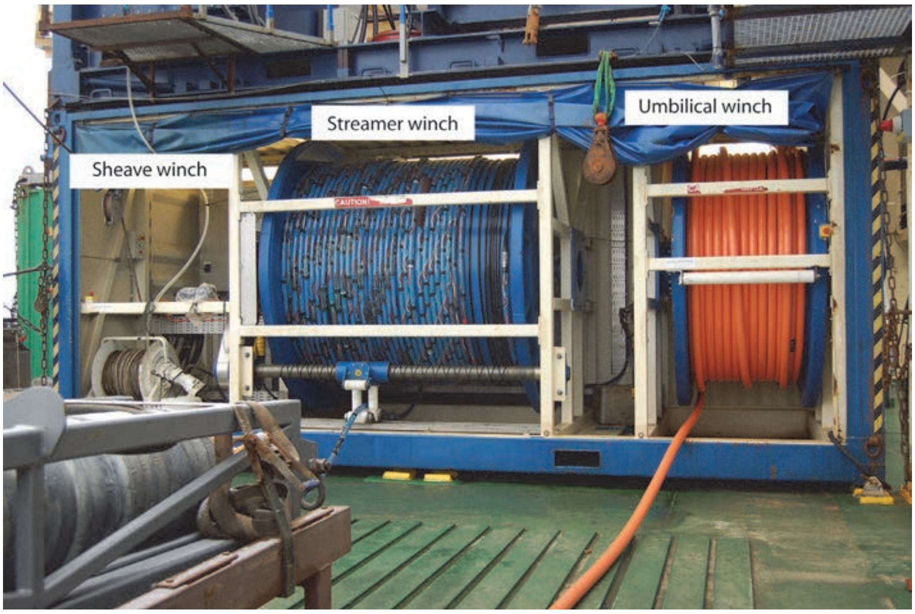


Figure 8. *Winch container*

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 (Fig. 9). 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 9. *The sea end of the umbilical*

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

1) The propeller wash is slightly increased creating a 50-100 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 (Fig. 10) by the wire winch (left hand side in the winch container as seen on Fig. 8), and lowered to the aft deck next to the platform for docking of sheaves for streamer and umbilical (Fig. 11).

Figure 10. Umbilical and air guns lifted in the umbilical sheave.

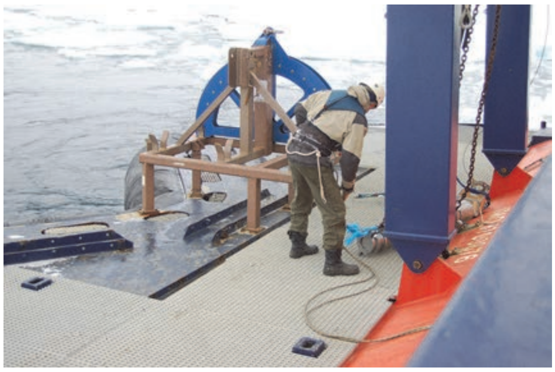


Figure 11. Air guns on aft deck. Streamer sheave in the background (port side).

3) The deployment of the streamer begins by unrolling the streamer from the winch (middle section Fig. 8) and bringing the tail end to the streamer sheave (Fig. 11). 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 (Fig. 12). From this point the streamer is deployed into the water. In order to reduce the risk for collision between streamer and unpredictable ice floes two 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 front end connector of the streamer reaches the sheave the streamer is temporarily fixed by means of a short rope to the deck (Fig. 13) and the connector is opened and the streamer end is connected with the jumper ca-ble (Fig. 13).

Figure 12. *Streamer running through roller ports towards the sheave.*

Figure 13. *The front end of the streamer connected to the jumper cable.*

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 (Fig. 14).

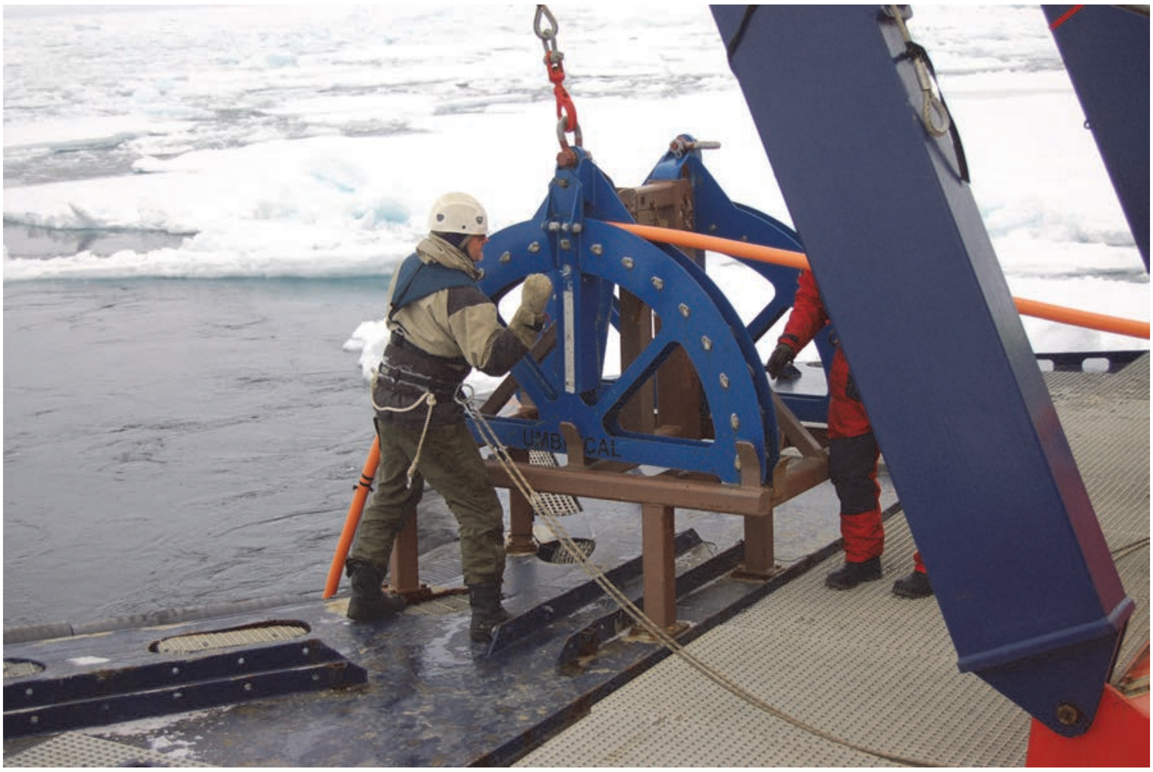


Figure 14. *Umbilical sheave locked and air gun and streamer fully deployed.*

The sketch in Fig. 15 illustrates the complete system when the ship has reached speed of 3 to 5 knots and collection of data is ongoing.

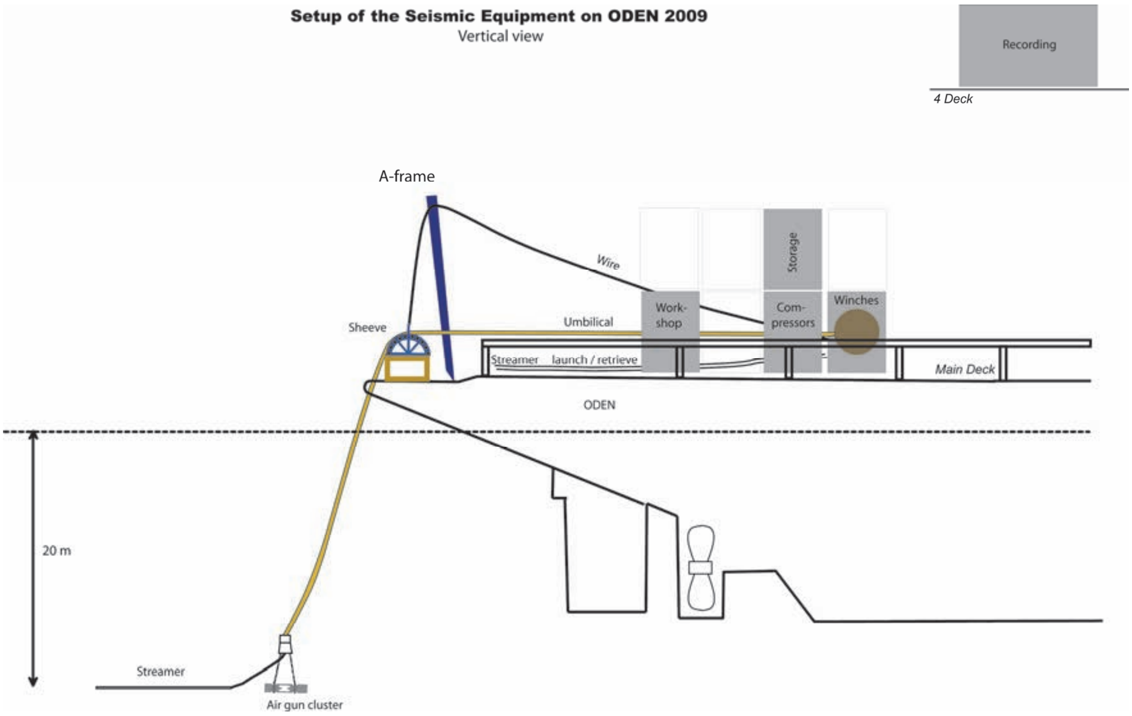


Figure 15. *Vertical view of the setup during data acquisition. Grey rectangles: "seismic containers".*

3.3 Depth Monitoring System

Based on the experiences from LOMROG I the system for monitoring the depth of guns and streamer sections has been improved in order to allow for recording of the depth status for all elements for each shot. Also 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 (Fig. 1). Depth transducers with a range down to 300 m are mounted in one end of the active seismic sections.

3.4 Gun and Streamer Behavior

The records of the depths of the air guns and the streamer sections and of the ships speed are found as graphs in Appendix III. The gun depth data was collected and stored together with navigation data in the NaviPac log files. Speed and depth was extracted from these files.

The depth transducers in the streamer were placed at the front end of sections 1-3 and in the rear end of section 4. Thus, the distances between the guns and the respective streamer transducers were: 50, 100, 150 and 250 m.

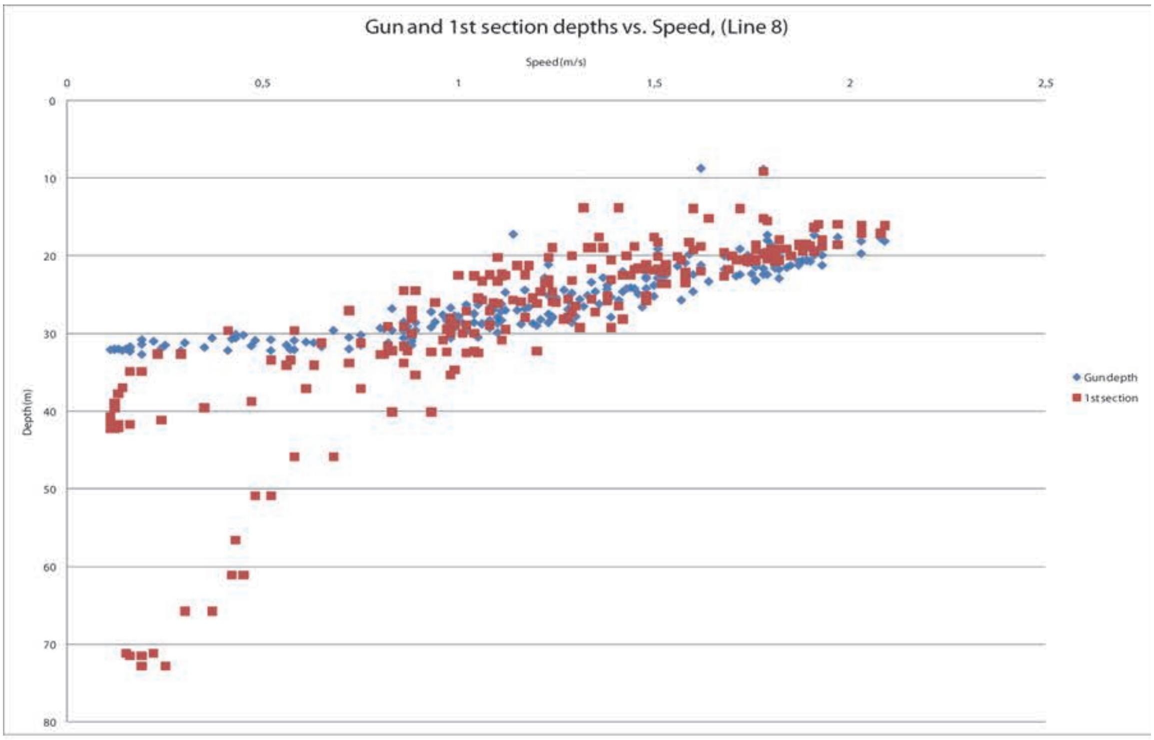
Just before the start of data acquisition the umbilical head was deployed to a depth at 30 m below deck. The position in the water of the umbilical, and the streamer below it, was approximately vertical (cf. streamer depths along the vertical axis at the start of the line (Fig. 16 top)).

The air guns are at a depth of approximately 30 m below sea level to begin with but raises gradually with increasing speed of the ship to shallower depths as shown in Fig.16 (top). Also shown is the behavior of the front end of the first active section of the streamer. The streamer rises quickly upwards and reaches the same depth as the air guns when the ships speed is about 1 m/s (2 knots).

It is noted that there is a bifurcation in the point swarm indicating the streamer depths. It shows that the front end of the streamer largely stays at depths of the air gun even when the ships speed is drastically reduced (the interval indicated by the dashed line in Fig.16 (bottom).

With increasing speed the complete streamer gradually moves upwards to a relatively stable configuration which is largely maintained for speeds between approximately 1.5-2 m/s (3-4 knots). Here the steamer depths are kept in the interval from about 20 m in the front end to about 30 m in the tail end.

Variations in the speed of the ship along the 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 relatively short lived (few minutes) variations in the ships speed only have moderate effects on especially the front half of the streamer.



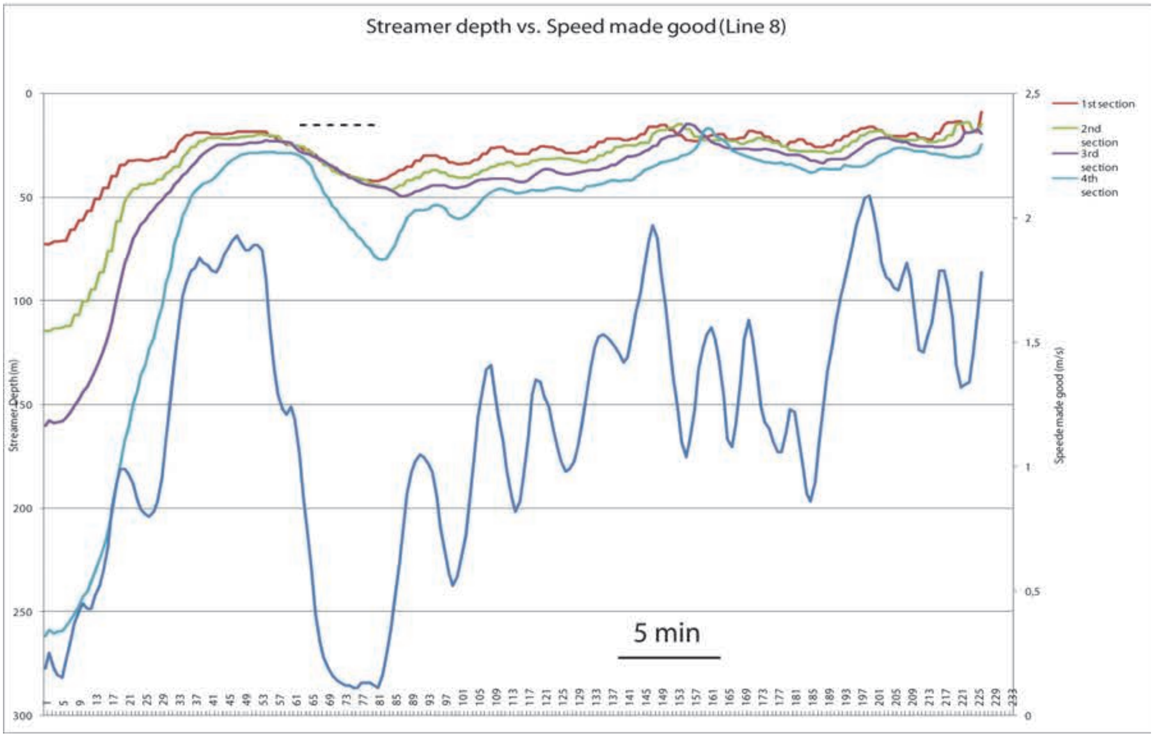


Figure 16. *Cross plot of depth below sea level of air guns (blue diamonds) and front end of first streamer section (brown quadrates) versus ships speed (top).Horizontal axis: shot points along line no. 8. Left vertical axis: depth below sea level of streamer sections (uppermost curves). Right vertical axis: ships velocity (lowermost curve) (bottom).*

4. Reflection Seismic Acquisition Parameters

By Holger Lykke-Andersen, Per Trinhammer, Anja Kinnberg Gunvald and Esben Villumsen Jørgensen Department of Earth Sciences, University of Aarhus and Christian Marcussen, Geological Survey of Denmark and Greenland

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

Table 1. *Summary of acquisition parameters*

Source	1 Sercel G and 1 Sercel GI gun
Chamber volume	605 cu.inch (250 + 250 + 105)
Fire pressure	180 bar (2600 psi)
Mechanical delay	16 ms
Nominal tow depth	20 m
Streamer	Geometrics GeoEel
Length of tow cable	30 m
Length of vibration section	53 m
No. of active sections	4 / 5
Length of active sections	200 / 250 m
No. of groups in each section	8
Total no. of groups	32 / 40
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 / 40
No. of auxiliary channels	4
Shot interval	12 s
Record length	11 s

5. Reflection Seismic Acquisition Geometry and Positioning

By Holger Lykke-Andersen, Per Trinhammer, Anja Kinnberg Gunvald and Esben Villumsen Jørgensen Department of Earth Sciences, University of Aarhus and Christian Marcussen, Geological Survey of Denmark and Greenland

Oden is equipped with GPS and other navigational systems used for navigation. A separate GPS system was used for reflection seismic 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 - was 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 1st 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 vibration 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 vibration 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.

Table 2. *Offset point coordinates*

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 [1]	-17.85 [1,2]	-20.00 [1]
Streamer channel 1	0.0 [1]	-70.1 [1,2]	-20.00 [1]

[1] Relative to Umbilical tow point; [2] Y-coordinates for air gun and streamer in NaviPac setup file erroneously set to -32.25 m and -84.5 m respectively.

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 0° 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.

Table 3. *Geodetic reference system*

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)*
Semi major axis	6.378.388 m
Inverse flattening	298.257223563
Scale factor at pole	0.994
Latitude of true scale	81° 07’ N
False easting	2.000.000 m
False northing	2.000.000 m
Longitude from pole (reference longitude)	0°

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. 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 12 s was chosen as the minimum when a recording length of 11 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. On occasions with relatively high speed this may lead to generation of trigger pulses before termination of the recording of the previous shot.

At low speeds the extended time between consecutive shots may cause compressors to have series of unwanted stop/start sequences as the pressure passes the preset 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
- LC605 gun (position for airgun midpoint) in UPS projection
- Depth from multibeam echo sounder's center beam (in meter below transducer which sits 8 m below sea level).
- 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 to be imported directly into the post processing software “NaviEdit”.

6. Reflection Seismic Data Acquisition

By Holger Lykke-Andersen, Per Trinhammer, Anja Kinnberg Gunvald and Esben Villumsen Jørgensen Department of Earth Sciences, University of Aarhus and Christian Marcussen, Geological Survey of Denmark and Greenland

6.1 Preparations

After passing Svalbard on August 01, 2009 a deployment test was performed of the seismic equipment while the ship was still in ice-free waters. The deployment of the streamer and guns went very well. The problems encountered in 2007 with the "landing" of the umbilical sheave have been eliminated by changing the U-flange from a fixed construction to a horizontally sliding construction (Fig. 17). With this modification the locking of the sheave to the docking frame works smoothly. All other modifications were already tested during a test cruise on *M/V Gunnar Thorson* in March 2009.

Figure 17. *The U-flange that locks the sheave to the docking frame can now slide horizontally and easily grips the vertical stem of the umbilical sheave.*

After deployment, a successful function test of the complete seismic acquisition system was carried out firing the guns at low pressure. The observed tow-depth of the guns at a survey speed around 4 knots was approximately 20 m as expected.

During the LOMROG I expedition with extreme ice conditions it was found difficult at several occasions to deploy the streamer because the streamer tended to float close to the surface with a high risk of colliding with drifting ice. This lead to the idea for development of a heavy device to be put at the tail end of the streamer before deployment, forcing the streamer to sink vertically during deployment. When the complete streamer was rolled out the weight should be dropped. The idea was to control the release of the weight via the 60 volt power cables in the streamer. A prototype was already made during LOMROG I in *Oden*'s mechanical workshop.

Prior to LOMROG II, a device was developed and build by the electronics and mechanic workshop at the Department of Earth Sciences, University of Aarhus. During the test of the device it became clear that the o-ring system in the releasing device was not tight enough and that it has to be improved for water depths down to at least 300 m. The device was removed from the streamer, and replaced by 2-3 kg lead-weights near the tail end of the streamer.

6.2 Acquisition Performance

Through the collection of the test line, the short line 1 and the seismic lines 2-16 the acquisition system generally had a satisfactory performance. Though, a few technical problems during acquisition occurred.

An encounter between ice and streamer resulted in squeezing of the 50 m vibration section of the streamer on line 2. The damage disrupted the communication to the active sections. The vibration section had to be replaced before acquisition could be resumed.

A severe break-down in the communication with the streamer occurred at the start of line 4. This led to an intensive process of trouble shooting resulting in the discovery of a fundamental problem in the communication software (see box below). The problem was temporarily solved by modifications of the upstart procedure for the Geometrics system.

The result of the troubleshooting showed a crosstalk problem in the umbilical. During our work on the steamer and the CNT-2 we had the NaviPac running (sending out a trigger every 12 s) together with gun controller. It turned out that the "trigger wire" for the solenoid on the GI-gun (SOL 1) introduced a burst to the Rx wire pair for the Ethernet to the CNT-2.

As a part of the routine control function of the streamer and the CNT-2 we have to run an "offset correction". This test takes about 30 s with a lot of Ethernet communication with the AD modules on the streamer. The "spike" from the SOL 1 confused the Ethernet, with the result that the CNT-2 program died and a "hard reset" was necessary to get the PC up running again.

To prevent the CNT-2 from going down, we had to set the CNT-2 to "ARMED" before starting the NaviPac and the guns.

The time for trouble shooting was also used to break the ice along the track that was planned for line 4. Thus, line 4 was shot on the way back in an already broken track. This procedure went very well without encounters between ice and air guns and streamer and lead to the adoption of a new navigation procedure for the lines 5-15. Tracks for all these lines were sailed twice by *Oden* before the seismic acquisition was carried out during the third passage of the track (see also chapter 9).

Before the start of line 16 it was decided to make an experiment with the purpose to reduce the propeller noise that had generally been quite high on the first 10 to 16 channels on the streamer. The idea was to add a 50 m vibration section, thus increasing the near offset by 50 m. The experiment failed because of leakage in the extra vibration section. The two vibration sections were replaced by one 50 m active section.

6.3 Acquisition Overview

A line overview log was maintained during the survey. The log sheets are attached in Appendix III. Logs of the ships speed and the depths of guns and streamer sections are attached in Appendix IV.

In Tables 4 and 5 a summary of the key characteristics of the lines are given. Table 4 is based on the line overview logs and Table 5 is based on records of gun depths and ships speed with additional information from the line overview logs.

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

Table 4. *Summary of line overview log*

Line	Record length (s)	Duration (hours)	No. of shots	Shots per hour
LOMROG09-02	11	4:34	1371	300
LOMROG09-03	11	3:33	1065	300
LOMROG09-04	11	1:10	353	300
LOMROG09-05	11	3:13	966	300
LOMROG09-06	11	4:02	1210	300
LOMROG09-07	11	4:04	1223	300
LOMROG09-08	11	0:46	231	300
LOMROG09-09	11	2:33	764	300
LOMROG09-10	11	2:46	831	300
LOMROG09-11	11	6:22	1911	300
LOMROG09-12	11	6:27	1934	300
LOMROG09-13	11	6:43	2018	300
LOMROG09-14	11	6:57	2087	300
LOMROG09-15	11	0:31	156	300
LOMROG09-16	11	6:04	1819	300

Table 5. *Overview of notable ice problems*

Line ID	Number of times *Oden* stuck in ice	Total duration stuck in ice (minutes)	Stuck in ice % of line duration	Umbilical caught by ice. No. of incidents		Gear on ice
				Gun ≤5 m	Gun 5-10 m	No. of incidents*
LOMROG09-**02**	4	31	11	1		
LOMROG09-**03**	3	43	20	2	2	
LOMROG09-**04**						
LOMROG09-**05**	4	27	14			
LOMROG09-**06**				1	2	1
LOMROG09-**07**	1	83 #		1	1	2
LOMROG09-**08**	1	2	4		1	
LOMROG09-**09**	2	13	9			
LOMROG09-**10**						
LOMROG09-**11**						
LOMROG09-**12**						
LOMROG09-**13**				1	5	
LOMROG09-**14**	1	17	4		1	
LOMROG09-**15**						
LOMROG09-**16**	3	41	11		2	

Notes: # deliberately stuck while repair of engine-propeller transmission system, * as noted in the “Line overview log”

Table 6. *Record inventory*

Line	First record	Last record	NaviPac log files *	Tape	Geometrics log files
Lomrog09-**02**	1000.sgd	2370.sgd	090810\20090810_125245_C.npd	102	Lomrog2.0002 Lomrog2.0002.depth Lomrog2.0002.nav
Lomrog09-**03**	2371.sgd	3435.sgd	090811\20090811_064610_C.npd	103	Lomrog2.0003 Lomrog2.0003.depth Lomrog2.0003.nav
Lomrog09-**04**	3440.sgd	3792.sgd	090818\20090818_072019_C.npd	104	Lomrog2.0004 Lomrog2.0004.depth Lomrog2.0004.nav
Lomrog09-**05**	3793.sgd	4758.sgd	090818\20090818_110126_C.npd	105	Lomrog2.0005 Lomrog2.0005.depth Lomrog2.0005.nav
Lomrog09-**06**	4759.sgd	5968.sgd	090819\20090819_013143_C.npd	106	Lomrog2.0006 Lomrog2.0006.depth Lomrog2.0006.nav
Lomrog09-**07**	5969.sgd	7191.sgd	090822\20090822_062331_C.npd	107	Lomrog2.0007 Lomrog2.0007.depth Lomrog2.0007.nav
Lomrog09-**08**	7192.sgd	7422.sgd	090823\20090823_012901_C.npd	108	Lomrog2.0008 Lomrog2.0008.depth Lomrog2.0008.nav
Lomrog09-**09**	7424.sgd	8187.sgd	090823\20090823_123818_C.npd	109	Lomrog2.0009 Lomrog2.0009.depth Lomrog2.0009.nav
Lomrog09-**10**	8188.sgd	9018.sgd	090824\20090824_181506_C.npd	110	Lomrog2.0010 Lomrog2.0010.depth Lomrog2.0010.nav
Lomrog09-**11**	9019.sgd	10929.sgd	090827\20090827_065432_C.npd	111	Lomrog2.0011 Lomrog2.0011.depth Lomrog2.0011.nav
Lomrog09-**12**	10932.sgd	12865.sgd	090828\20090828_094122_C.npd	112	Lomrog2.0012 Lomrog2.0012.depth Lomrog2.0012.nav

Table 6. *Record inventory (continued)*

Line	First record	Last record	NaviPac log files *	Tape	Geometrics log files
Lomrog09-**13**	12866.sgd	14883.sgd	090829\20090829_042806_C.npd	113	Lomrog2.0013 Lomrog2.0013.depth Lomrog2.0013.nav
Lomrog09-**14**	14884.sgd	16970.sgd	090830\20090830_025704_C.npd	114	Lomrog2.0014 Lomrog2.0014.depth Lomrog2.0014.nav
Lomrog09-**15**	16971.sgd	17125.sgd	090830\20090830_004629_C.npd	115	Lomrog2.0015 Lomrog2.0015.depth Lomrog2.0015.nav
Lomrog09-**16**	17126.sgd	18944.sgd	090831\20090831_024801_C.npd	116	Lomrog2.0016 Lomrog2.0016.depth Lomrog2.0016.nav

*Path to files:Lomrog2_files\Navi_Pac_Logs\Logs\YYMMDD\YYYYMMDD_hhmmss_C.n

7. Shipboard Seismic Reflection Processing (Summary)

By John Robert Hopper, Geological Survey of Denmark and Greenland (GEUS)

With limited offsets, the options for processing data are also limited. Fortunately, we operated mostly in deep water and multiple elimination was not an issue. The key steps for producing a reasonable stack primarily involved pre-stack filtering and editing. All data processing was done in ProMAX version 2003.19.1. Here, we do not discuss standard processing such as geometry assignment or stacking. Instead we highlight the processing modules used to deal with specific problems encountered working in ice. Complete details regarding data processing are provided in a separate shipboard seismic processing report (Hopper & Marcussen, 2010).

There are four main issues to deal with when collecting data in ice. First is that the background noise level is extremely high. Noise associated with breaking ice is a problem, but more significant is the noise from the ship. In particular, *Oden* often must increase power to the engines to maintain speed through ice. The wash behind the ship can be significant. The channels nearest to the ship are frequently swamped by this noise. Fortunately, the far channels remain well outside the wash and show strong reflections even when the near channels are effectively useless. The only way to deal with this first sort of noise is in the usual way - stacking and trace-mixing to enhance coherent signal over random noise.

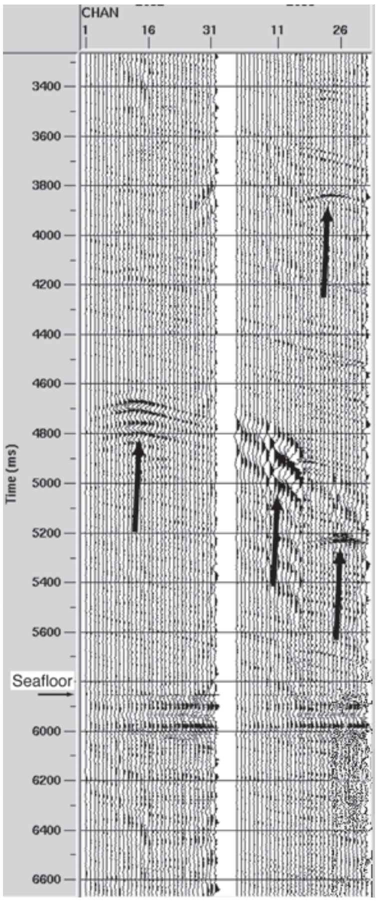


Figure 18. *Example shot records with ice interference. Black arrows mark noise bursts typical of ice hitting the streamer. The seafloor reflection time is marked by an arrow along the time axis.*

The second key problem is the ice itself. Although the streamer and guns are towed deep to reduce risk of damage to the towed equipment, it is fairly common for ice to interfere with the equipment. If the guns are involved, an entire shot can be ruined (e.g. shots triggering with the guns out of the water). Noise bursts are also common on the streamer when ice hits the streamer. An example of this is shown in Fig. 18. Noise burst editing can help to eliminate these, but not all bursts are detected and removed.

The third key problem is linear noise from tugging the cable. An icebreaker cannot make smooth progress forward, resulting in high amplitude, linear noise travelling down the streamer. This noise can be eliminated using *f-k* filters in the shot domain. It is important to apply this filter before any static corrections have been applied, which destroy the simple linear nature of the noise. With the short offsets and deep water, real reflections should have a very high apparent velocity. Thus, it is safe to allow the slope of the pie slice to get very high without affecting primary energy. Figure 19 shows an *f-k* spectrum of a shot before and after filtering. The pie slice is defined by slopes of 500 m/s and 4000 m/s and everything in between is rejected. In addition, the linear noise is aliased in the high frequencies, so we allowed the filter to wrap at Nyquist. This had the further benefit of eliminating all energy over 250 Hz and data were resampled to 2 ms afterward.

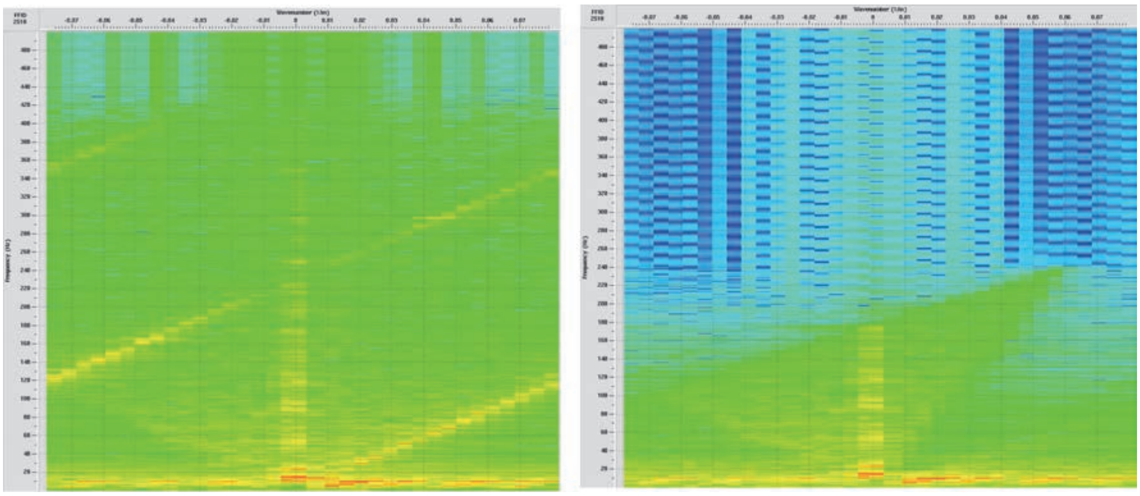


Figure 19. *f-k spectra of a shot record with strong linear noise from tugging. Unfiltered data to the left shows a strong linear trend in that slopes up to the right and wraps twice beyond Nyquist. The spectrum to the right shows the same shot after the pie slice rejection filter is applied. Shot gather examples are shown in Fig. 24.*

The final problem again relates to towing configuration. By towing the guns at 20-25 m depth, the high frequencies are severely compromised. Fig. 20 shows models source spectra for linear clusters of G and GI guns like that used on this cruise. Note that in addition to the standard ghost notches, the low frequencies have considerable power compared to the mid-range frequencies needed for seismic imaging. This gives the source a very ringy character, even though the G and GI guns are known for having an excellent bubble response. Rather than eliminate the low frequencies with a high low-cut, or try to suppress the ringy character with a predictive deconvolution, we instead chose to investigate ProMAX's user defined spectrum filter. With this filter, the user chooses the power and phase spectral characteristics of a filter that will alter the data spectrum to a desired shape. We

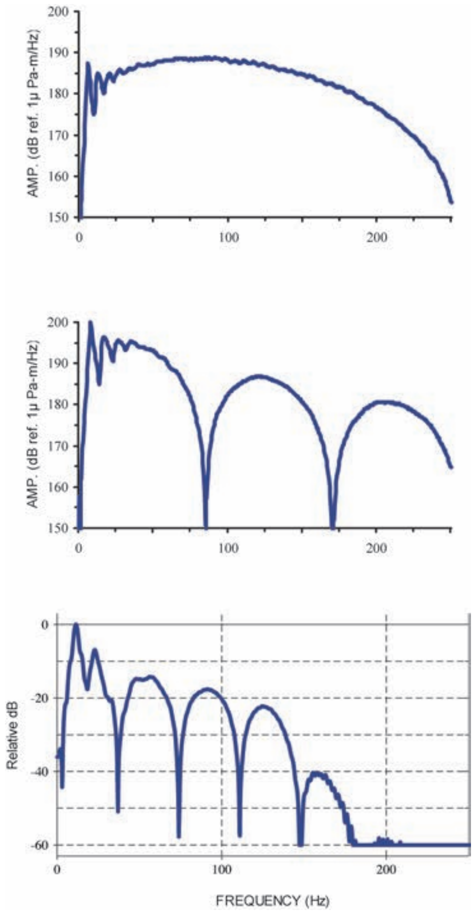


Figure 20. *Comparison of source signature spectra at towing depths of 3 m (top), 9 m (middle), and 20 m (bottom). The top two panels simulate the Aarhus cluster with one G-gun and one GI-gun whereas the bottom panel is for 2 G-guns. Spectra provided by Sercel.*

were able to use this to alter, without completely eliminating, the lower frequencies while boosting the relative power of the mid-range frequencies present in the data. The filter itself is specified as minimum phase with 1% additive noise and cosine tapers from 3-6 Hz at the low end and 450-500 Hz at the high end. The power spectrum is defined as: 8 Hz, -10 dB; 12 Hz, -10 dB, 15 Hz, 0 dB; 18 Hz, 0 dB; 20 Hz, 5 dB; 30 Hz, 15 dB; and 60 Hz, 25 dB. The filter is 500 ms long and is sampled every 1 ms. It is applied to the data as a convolution in the time domain.

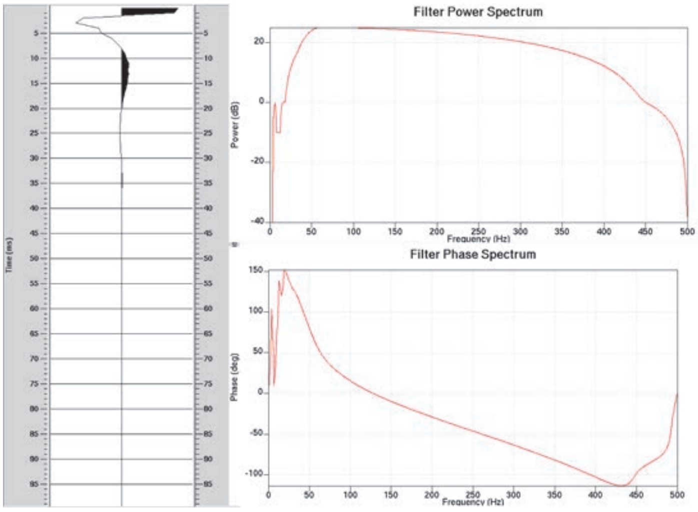


Figure 21. *A) Minimum phase filter function that is convolved with all input traces after simple bandpass filtering. B) Power spectrum of signal in A). C) Phase spectrum of signal in A).*

The filter as well as its power and phase spectra are shown in Fig. 21 and the effect of the filter on the frequency spectrum of actual data traces is shown farther below in Fig. 22.

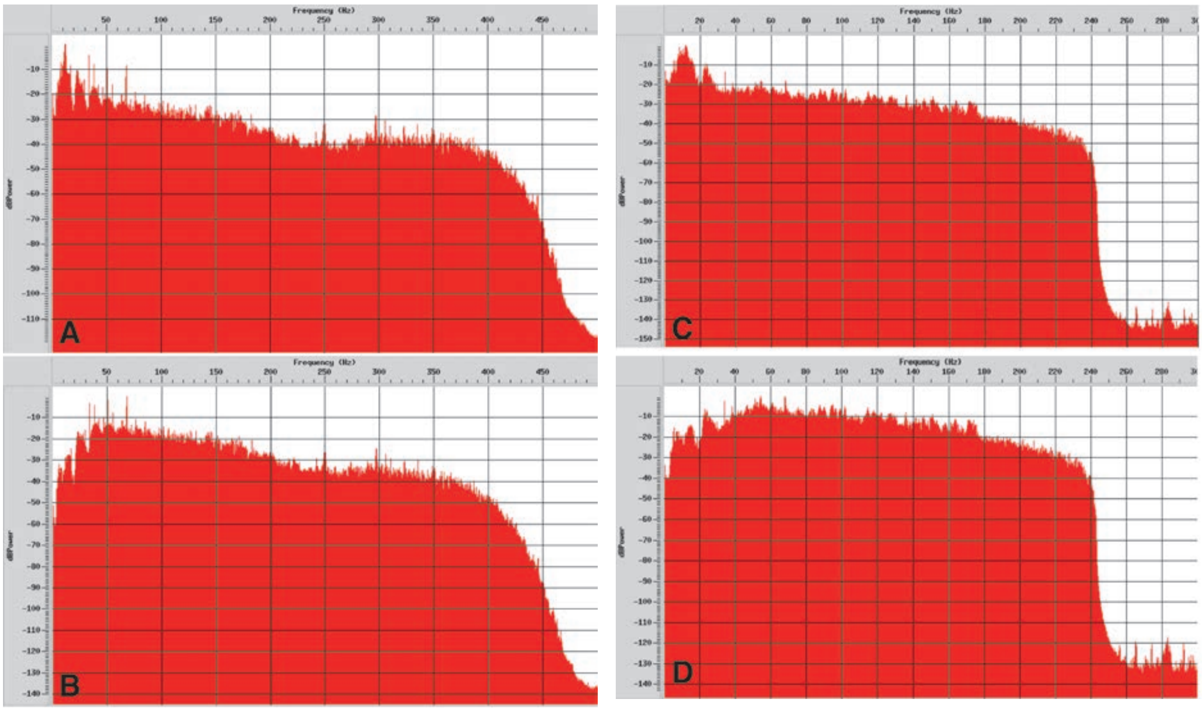


Figure 22. *Average frequency spectra of all traces in a single shot. A) is with only a bandpass filter applied. B) is after a spectral shaping filter is applied. C) is after an f-k filter is applied. D) is after all pre-stack filters are applied. This is a typical spectrum of data used for further processing. The shots for these examples are shown in Fig. 23.*

A comparison of a stack produced with and without the spectral shaping filter is shown in Fig. 23. Finally, Fig. 24 shows a plot of a shot gather with the various filters described here applied. The final panel was used for stacking and migration.

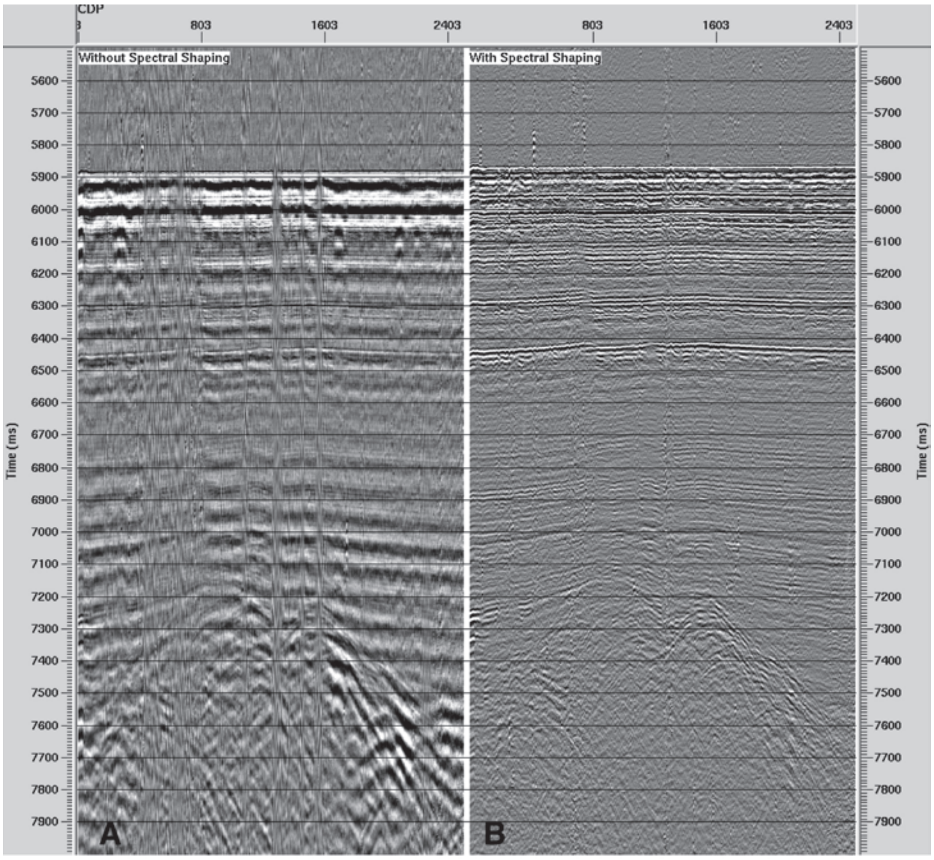


Figure 23. *Brute stack examples with (A) and without (B) the spectral shaping filter applied.*

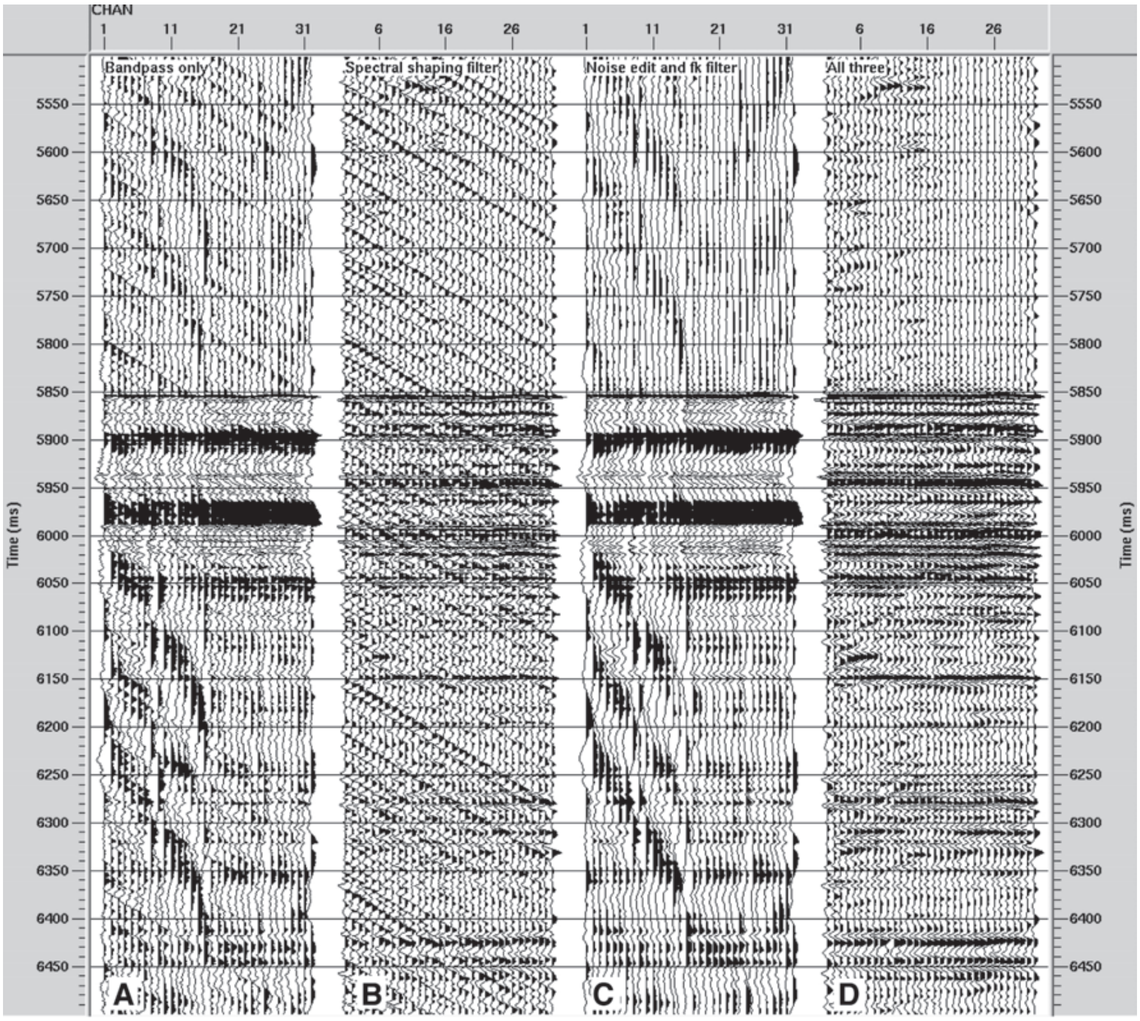


Figure 24. *Detail of the shot gather whose spectra are shown in Fig.22. The seafloor reflection is just below 5850 ms. Sloping linear noise is from tugging. In this shot, the linear noise is fairly weak. A) Bandpass filtered data. B) After spectral shaping filter applied. C) After noise burst editing and f-k filter. D) After spectral shaping, noise burst editing, and f-k filtering.*

Finally, Fig. 25 shows an example migration produced with the standard shipboard processing sequence, which is as follows:

SEG-D read with trace dc bias removal;
Bandpass filter;
User defined spectral shaping filter;
Spike and noise burst editing;
Shot gather *f-k* filter and resample to 2 ms.
Geometry assignment, including gun and cable statics;
Trace equalization;
Trace mixing on shot gathers;
Midpoint sort and stack;
Final geometry and amplitude recovery;
Post-stack constant velocity migrations;
Seafloor mute;
SEG-Y output;
grd conversion and plot.

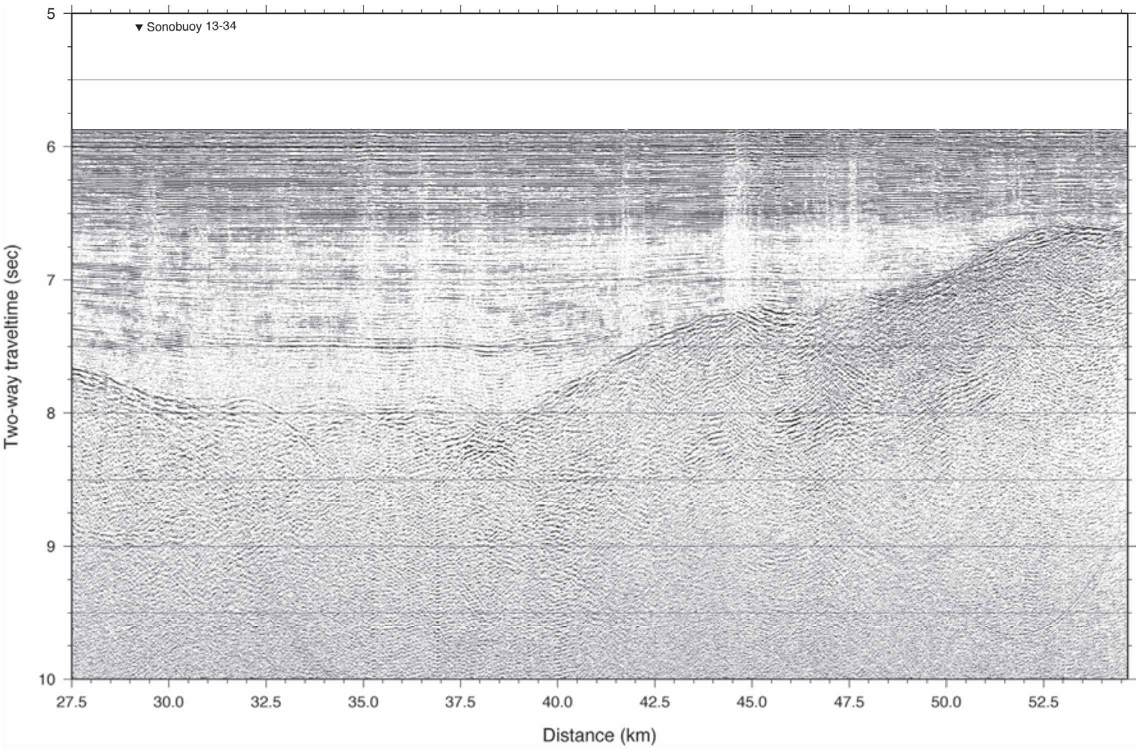


Figure 25. Example migrated stack section from the Amundsen Basin showing typical data quality of the reflection images.

Overall, the data quality is surprisingly good given the difficult acquisition environment. On all lines collected, the basement arrivals are clear. Although in some of the deeper basins with thicker sediments, signal penetration is clearly becoming an issue. In addition, within the Amundsen Basin, the uniformity of the reflectivity pattern in the sediments is obvious on all profiles. Thus, despite the lack of long profiles, establishing stratigraphic correlations in such a uniform depositional environment should not be a major issue.

The table below shows the approximate two-way travel time of the thickest sediment package that can be identified on each of the profiles collected.

Line no.	Max TWT (seconds)
LOMROG09-01	0.8
LOMROG09-02	1.0
LOMROG09-03	2.0
LOMROG09-04	1.3
LOMROG09-05	2.2
LOMROG09-06	0.6
LOMROG09-07	1.9
LOMROG09-08	1.8
LOMROG09-09	1.8
LOMROG09-10	1.9
LOMROG09-11	2.1
LOMROG09-12	2.2
LOMROG09-13	2.4
LOMROG09-14	1.9
LOMROG09-15	0.9
LOMROG09-16	1.2

The major issues to consider for future work involve the gun array. While the linear cluster performs well, the deep towing depth clearly has a negative impact on the signal quality. Some preliminary source signature modelling form Sercel indicates that increasing the chamber sizes will help to boost the mid-range frequencies relative to the low frequencies, although some form of spectral shaping filter will still be required when towing the guns below 20 m. A larger array that can still be fired at least every 16 - 20 seconds might be preferable. However, it should also be noted that this may require shooting on distance unless the triggering system can be reconfigured to randomize the shot time. The larger array will increase the chance that previous shot multiples will interfere with the primary reflections.

Reference:

Hopper, J.R. & Marcussen, C. 2010: Seismic Processing Report – LOMROG II in 2009, Danmarks og Grønlands Geologiske Undersøgelse Rapport **2010/36**, 99pp.

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 reflection seismic data acquisition of the LOMROG II expedition, a Geometrics streamer with a maximum active length of 250 m was used for recording. The streamer consisted of four 50-m long sections with eight channels each on lines 1 through 14; while five sections were used on lines 15 and 16. 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 previous 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 reflection seismic data acquisition.

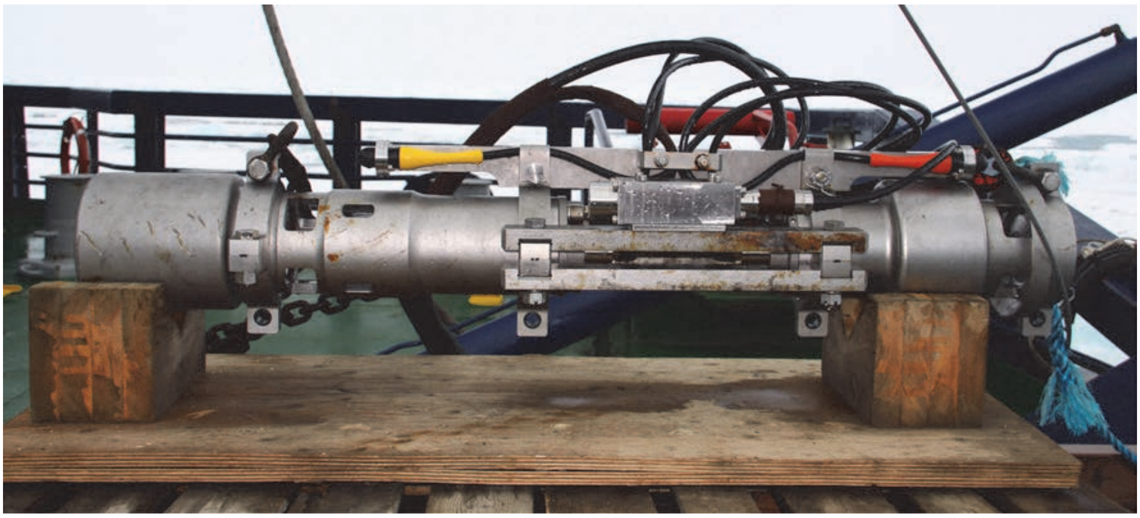


Figure 26. *605 cubic inches G-GI gun cluster used for the seismic experiment. Photo: Thomas Funck.*

The sonobuoys recorded the shots from the reflection seismic experiment with a nominal shot interval of 12 s. The seismic source was a G-GI gun cluster consisting of two G guns with a volume of 250 cubic inches each and a GI-gun with a volume of 105 cubic inches (Fig. 26). The total volume of the array was 605 cubic inches (9.9 L); the nominal air pressure was 3000 psi (200 bar) but for the second part of line 2, the pressure was as little as 100 bar due to a hole in one of the air hoses. Nominal towing depth of the gun system was 30 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 27. *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. Photo: Thomas Funck.*

The sonobuoys were deployed from the afterdeck of *Oden*. A total of 38 sonobuoys of the type AN/SSQ-53D(3) from ULTRA Electronics were available for the experiment (Fig. 27, see also Appendix V-F). A total of 40 sonobuoys were purchased for the LOMROG II cruise. Two of the buoys were used on a test cruise in March 2009 onboard the vessel *Gunnar Thorson*. From this test cruise it was learned that the seawater battery in the buoys does activate too late for a successful deployment once the salinity of the water is below 23 ppt. This information is neither provided in the user's manual nor in the technical data sheet. After contacting the manufacturer, additional details were given. For example, once the buoy descends to depths greater than 12 m, the inflatable float bag cannot overcome the water pressure at that depth preventing the sonobuoy from returning to the surface. This may have caused the two sonobuoy losses on the LOMROG I expedition in 2007, when the buoys were deployed from the helicopter with the parachute removed to avoid entanglement in the blades of the helicopter.

The antenna and receiver configuration during the LOMROG II expedition was changed after completion of seismic line 6. In the first part of the cruise, it was sufficient to have just two radios in operation (Winradio WR-2902e, Fig. 28, see Appendix V-D) that were connected to an antenna mounted on a pole on top of the bridge at a height of ca. 28 m (Fig.

30). This antenna was a VHF antenna (type AV1431-144FN2) belonging to the ship. After line 6, a third Winradio was installed to be able to operate more buoys simultaneously. The third Winradio was a newer type (Winradio WR-G39WSB, Fig. 29) connecting through a USB port to the computer running the Winradio software. This radio could not be connected to the ship's antenna, instead the Moonraker MD HB-G3/HS antenna used during the LOMROG I expedition (see Appendix V-G) was mounted on the railing above the bridge at a height of 25.3 m (Fig. 31).

Overall signal quality of the ship's VHF antenna was better than with the Moonraker antenna. This was probably related to a higher position of the ship's antenna. Between the Winradios and the antennas, a 50-m-long antenna cable, an amplifier and a signal divider were used. Signals from radio 1 were recorded on auxiliary channel 1 of the multichannel acquisition system (Geometrics); radio 2 was recorded on auxiliary channel 2 while radio 3 was recorded on auxiliary channel 4. These auxiliary channels correspond to channels 33, 34, and 36, respectively, in the raw SEGD files of the Geometrics recording system (using four active streamer segments with a total of 32 channels). On lines 15 and 16 with 40 active channels, the four auxiliary channels correspond to channels 41 to 44. The sampling rate was 1 ms (1000 Hz). On the MCS system, the recording length was set to 11 s, which potentially is too little for large shot-receiver distances. This is why the sonobuoy data were also recorded continuously on a Taurus seismometer (manufactured by Nanometrics, Fig. 24, see Appendix V-E) by dividing the signal of the Winradio. Winradios 1 through 3 were recorded on channels 1 through 3 of the Taurus recorder. A total of three Taurus recorders were available onboard, one was owned by GEUS (serial number 1574) and two were provided by the Geological Survey of Canada (serial numbers 538 and 416). The serial number of the Taurus used for recording was 538. The sampling rate was set to the lowest value (2 ms corresponding to 500 Hz).

Figure 28. *Sonobuoy receiving system Winradio WR-2902e. Two receivers were used (left) together with application software (right).Photos: Thomas Funck.*

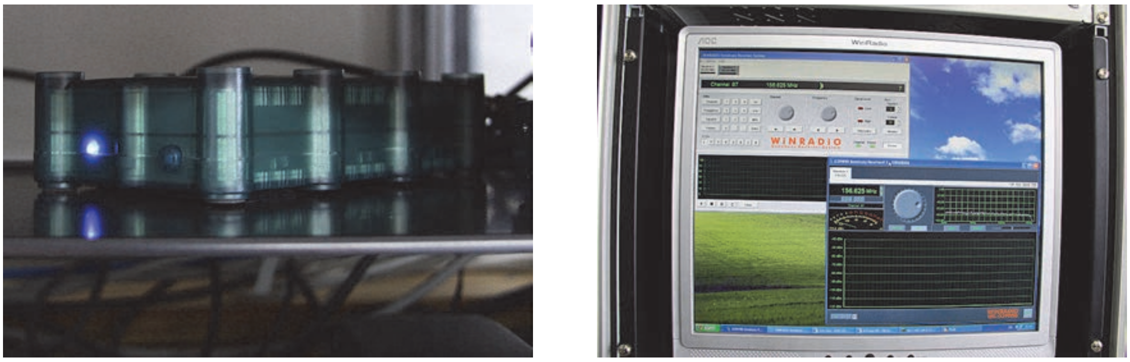


Figure 29. Additional *sonobuoy receiving system Winradio WR-G39WSB used during the second part of the survey (beginning with line 7). Receiver (left) and software (front window, right). Photos: Thomas Funck.*

Figure 30. *VHF base station antenna (AV1431-144FNR) mounted on top of the bridge of Oden on the port side. This configuration was used on lines 1 through 6. Photos: Thomas Funck.*

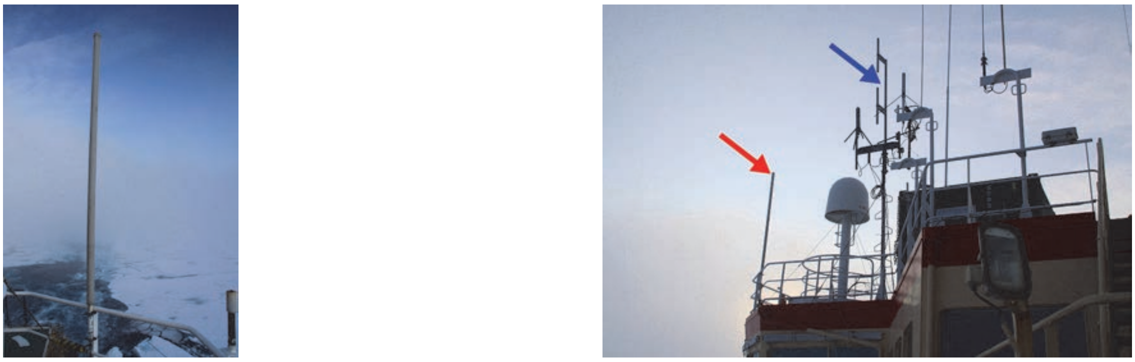


Figure 31. *(left) VHF base station antenna MD HB-G3/HS mounted on top of the bridge of Oden on the port side. The antenna was covered with a pipe and installed after shooting line 6. (right) Antenna MD HB-G3/HS used with Winradio 3 (red arrow) and VHF base station antenna (AV1431-144FNR) used with Winradios 1 and 2 (blue arrow). Photos: Thomas Funck.*

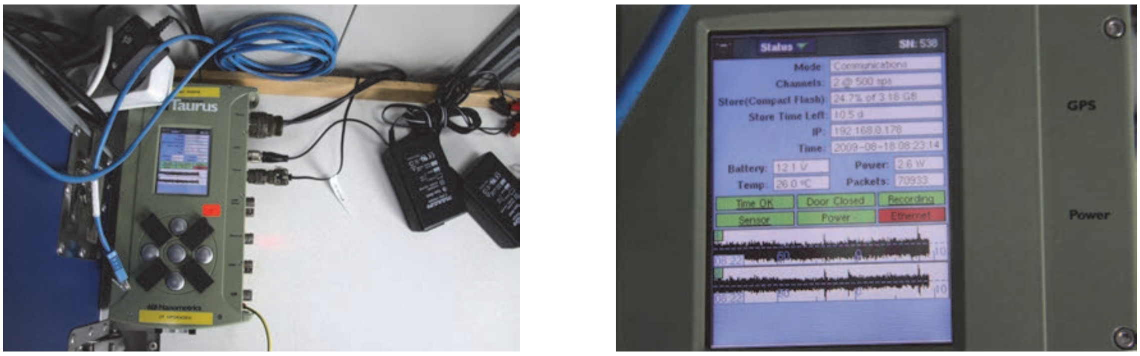


Figure 32. *Taurus seismometer in the recording container on the 4th deck of Oden. Photos: Thomas Funck.*

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 three 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 on the ship's front on the 4th deck (most starboard one container) was used for the preparation of the Taurus seismometers as well as for data processing and analysis, using a UNIX workstation (model Sun Blade 150). In addition, a laptop computer (Hewlett Packard Elite Book) was used for programming the seismometer and for data download (Fig. 33). The laptop computer was also connected to the ship's network via a wireless router located in the container. Sonobuoys were stored in a container on the afterdeck (second container level at the front end of the starboard side).

Figure 33. *Setup of the laboratory container on the fourth deck used for the preparation of seismometers as well as for data processing and analysis. The right photo shows the data download from the Taurus seismometer using the web interface on the laptop computer. Photos: Thomas Funck.*

8.2 Line Locations and Operation

The first seismic line in Amundsen Basin was planned to be 95 nm long, extending from 80 nm north of the Gakkel Ridge to the Eurasian flank of the Lomonosov Ridge. However, this year data had to be acquired in a single-ship operation without a Russian nuclear-powered lead icebreaker as was the case in LOMROG I in 2007. Hence, *Oden* had to break ice and collect seismic data simultaneously. However, for breaking ice *Oden* is heavily depending on reversing and ramming the ice at high speed. With a streamer behind the ship, the ship cannot reverse and the maximum speed is restricted to ca. 5 knots to avoid damage to the seismic equipment. These severe limitations resulted in a segmentation of the originally planned line into three parts (lines 1 through 3). Whenever *Oden* was stuck in the ice, the streamer and airgun had to be retrieved to allow for the necessary manoeuvrability to break ice. Along portions of the first transect no attempt was made to collect data due to unfavourable ice conditions. This was in a way very dissatisfying as *Oden* was well capable to go through the ice with a speed of up to 10 knots when the seismic equipment was aboard the ship. In these ice conditions, *Oden* would have been able to acquire seismic data on a relatively straight and continuous line at an optimum acquisition speed of 4 knots if an appropriate lead icebreaker would have been available.

The line segmentation had a severe impact on the sonobuoy operation. Velocity analysis depends heavily on the observation of refracted arrivals, which require minimum shot-receiver distances of 6 to 10 km in the 4400-m-deep water of Amundsen Basin. On the first transect, consisting of lines 1 through 3, a total of eight sonobuoys were deployed (see Table 7 and Fig. 29) from the lowermost afterdeck (Fig. 26). Three of the buoys did not function and for two others, the line had to be abandoned shortly after deployment without reaching the necessary minimum offsets. This leaves three sonobuoys that are suitable for velocity analysis, although one buoy (2-3) has rather low amplitudes at larger offsets, which is probably related to the low airgun pressure of only 100 bar during the second part of line 2. This was caused by a puncture of the air hose, which to some degree also has to be related to the single-ship operation, which resulted in more wear and tear to the gear due to increased propeller wash. In addition, the shot lines were not straight but rather curved as *Oden* had to choose the path of the least ice resistance. As long as the subsurface layers are stratified horizontally, this does not result in any problems in the data analysis. However, at basement level layers are not horizontal anymore, which complicates the data analysis.

Starting with line 6, a new technique was introduced to ensure seismic lines of a certain length. *Oden* would first break the ice along a track (between 10 and 25 nm long), then the ship would return along this track, turn around and shoot the line. With that technique it was also possible to deploy sonobuoys at either end of the line and this was the reason why an additional Winradio was installed. This leaves the flexibility to deploy an additional buoy somewhere in the middle of the line if an interesting structure or a deep sedimentary sequence appears on the online reflection seismic record.

Table 7. *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 Win-radio	Deployment date (Julian Day)	Time of deployment (UTC)	Longitude	Latitude	Water depth (m)	Remarks
1-1	1	D1=30 m	8 h	87	1 & 2	09 AUG 2009 (JD 221)	09:27:20	62.10246°E	88.26219°N	4370	Deployed in pool of open water
2-2	2	D1=30 m	8 h	87	1 & 2	10 AUG 2009 (JD 222)	12:59:10	63.65762°E	88.36246°N	4370	Surfaced but no radio signal
2-3	2	D1=30 m	8 h	99	1 & 2	10 AUG 2009 (JD 222)	13:23:40	64.06336°E	88.36783°N	4372	Recording on Winradio 2 stopped at ~15:07 UTC
2-4	2	D1=30 m	8 h	87	2	10 AUG 2009 (JD 222)	15:11:45	65.72850°E	88.37861°N	4370	
3-5	3	D1=30 m	8 h	87	1 & 2	11 AUG 2009 (JD 223)	06:51:10	94.41648°E	88.60308°N	4356	Recording on Winradio 2 stopped at ~08:31 UTC
3-6	3	D1=30 m	8 h	99	2	11 AUG 2009 (JD 223)	08:43:05	98.20491°E	88.60263°N	4360	Did not surface
3-7	3	D1=30 m	8 h	95	2	11 AUG 2009 (JD 223)	09:05:25	98.30272°E	88.60121°N	4349	Did not surface
3-8	3	D1=30 m	8 h	97	2	11 AUG 2009 (JD 223)	09:20:40	98.52038°E	88.59620°N	4348	
4-9	4	D1=30 m	8 h	87	1 & 2	18 AUG 2009 (JD 230)	07:27:35	176.81556°W	88.58692°N	~3949	Did not surface
4-10	4	D1=30 m	8 h	84	1 & 2	18 AUG 2009 (JD 230)	07:40:05	176.89924°W	88.57536°N	3944	Recording on Winradio 2 stopped at ~10:55 UTC, Buoy recorded also shots on line 5
5-11	5	D1=30 m	8 h	99	2	18 AUG 2009 (JD 230)	11:04:20	177.24649°W	88.52696°N	3950	Did not surface, deployed while ship was stationary
5-12	5	D1=30 m	8 h	77	2	18 AUG 2009 (JD 230)	11:12:50	177.29433°W	88.52566°N	3950	
6-13	6	D1=30 m	8 h	99	1 & 2	19 AUG 2009 (JD 231)	01:44:10	176.54929°W	87.92877°N	?3439	
7-14	7	D1=30 m	8 h	87	2 & 3	22 AUG 2009 (JD 234)	02:25:25	119.39382°W	89.57020°N	4188	Recording on Winradio 2 stopped at ~09:05 UTC, Oden passed buoy again at 10:14:00 UTC 123.59106°W and 89.58016°N (20 m to starboard)
7-15	7	D1=30 m	8 h	48	1	22 AUG 2009 (JD 234)	06:20:35	126.44949°W	89.44493°N	3493	Did not surface
7-16	7	D1=30 m	8 h	77	2	22 AUG 2009 (JD 234)	09:10:35	124.82111°W	89.51022°N	-	
8-17	8	D1=30 m	8 h	77	1 – 3	23 AUG 2009 (JD 235)	01:27:20	55.02350°E	89.98707°N	4229	Did surface and worked for a minute, but then destroyed by the ice
8-18	8	D1=30 m	8 h	87	1 – 3	23 AUG 2009 (JD 235)	01:43:05	19.86398°E	89.98639°N	4236	Did surface, then disappeared beneath the ice a minute later and later came back to the surface again
9-19	9	D1=30 m	8 h	87	1 – 3	23 AUG 2009 (JD 235)	12:14:30	31.19515°W	89.96678°N	4228	Deployed just prior to streamer deployment
10-20	10	D1=30 m	8 h	87	3	24 AUG 2009 (JD 236)	15:19:16	62.66174°W	89.22776°N	4127	1); Oden passed buoy again at 21:00:30 UTC 62.13325°W and 89.21397°N (~100 m to starboard)

Table 7. *Continued.*

Sono-buoy	MCS line	Depth setting	Ope-rating life	Trans-mission channel	Recorded by Win-radio	Deployment date (Julian Day)	Time of deployment (UTC)	Longitude	Latitude	Water depth (m)	Remarks
10-21	10	D1=30 m	8 h	48	1	24 AUG 2009 (JD 236)	17:45:40	52.61629°W	89.33600°N	4138	1); Surfaced and transmitted noise (hydrophone became disconnected)
10-22	10	D1=30 m	8 h	67	2	24 AUG 2009 (JD 236)	18:32:30	53.20054°W	89.32286°N	4142	1); Did not surface
10-23	10	D1=30 m	8 h	57	2	24 AUG 2009 (JD 236)	18:55:20	54.59706°W	89.31097°N	4136	1); Deployed with rope
11-24	11	D1=30 m	8 h	87	3	27 AUG 2009 (JD 239)	02:46:23	44.84966°W	88.75443°N	4093	1); 2)
11-25	11	D1=30 m	8 h	67	2	27 AUG 2009 (JD 239)	05:02:30	51.10971°W	88.74494°N	2649	2); Deployed with rope¸ Oden passed buoy again at 08:44:06 UTC 49.90587°W and 88.75707°N (~5 m to starboard)
11-26	11	D1=30 m	8 h	48	1	27 AUG 2009 (JD 239)	06:32:15	54.58210°W	88.75537°N	2887	
11-27	11	D1=30 m	8 h	77	1	27 AUG 2009 (JD 239)	09:34:00	37.05184°W	88.78107°N	?4097	Deployed by helicopter (from ice, with rope), Recording started at 09:58:20 UTC
11-28	11	D4= 300m	8 h	88	3	27 AUG 2009 (JD 239)	10:58:20	43.42582°W	88.76811°N	4004	Was not programmed, default settings were used. Recording started not before 11:08:15 UTC when the correct channel was found. Deployed with rope.
12-29	12	D1=30 m	8 h	48	3	28 AUG 2009 (JD 240)	07:45:30	0.98972°E	88.36351°N	4355	Deployed with rope, Oden passed buoy again a ~12:08 UTC at 1.41203°E and 88.36881°N
12-30	12	D1=30 m	8 h	67	2	28 AUG 2009 (JD 240)	09:18:30	3.28763°W	88.46365°N	4350	Deployed with rope
12-31	12	D1=30 m	8 h	87	1	28 AUG 2009 (JD 240)	11:03:00	6.21837°E	88.23455°N	4362	Deployed by helicopter (from ice, with rope), Oden passed buoy at 15:32:20 UTC at 6.80672°E and 88.22160°N (150 m to port)
13-32	13	D1=30 m	8 h	48	3	29 AUG 2009 (JD 241)	01:53:15	9.44655°E	88.02797°N	4363	Deployed with rope, Oden passed buoy at 07:23:55 UTC at 9.79992°E and 87.99668°N (50 m to port)
13-33	13	D1=30 m	8 h	67	2	29 AUG 2009 (JD 241)	04:05:50	7.69044°E	88.18072°N	4360	Deployed with rope
13-34	13	D1=30 m	8 h	87	1	29 AUG 2009 (JD 241)	08:05:20	10.06787°E	87.94040°N	4361	Deployed with rope

Table 7. *Continued.*

Sono-buoy	MCS line	Depth setting	Ope-rating life	Trans-mission channel	Recorded by Win-radio	Deployment date (Julian Day)	Time of deployment (UTC)	Longitude	Latitude	Water depth (m)	Remarks
14-35	14	D1=30 m	8 h	48	3	30 AUG 2009 (JD 242)	00:02:35	11.99355°E	87.70497°N	4368	Deployed with rope, Oden passed buoy at 06:14:20 UTC at 11.61447°E and 87.69151°N (10 m to port)
14-36	14	D1=30 m	8 h	67	2	30 AUG 2009 (JD 242)	02:37:10	8.55709°E	87.83734°N	4366	Deployed with rope
14-37	14	D1=30 m	8 h	87	1	30 AUG 2009 (JD 242)	04:57:00	14.40869°E	87.58892°N	?4366	Deployed by helicopter (from ice, with rope), Oden passed buoy at 08:40:45 UTC at 14.17731°E and 87.58402°N (200 m to starboard)
15-38	15	D1=30 m	8 h	48	1 – 3	30 AUG 2009 (JD 242)	19:19:55	15.09739°E	87.36871°N	4360	Deployed with rope, buoy recorded also shots from line 16

[1)] Due to problems with the handheld Garmin GPS receivers, only the deployment time was noted. The positions of buoys 10-20 and 10-21 are extracted from the shot table, the locations of buoys 10-22, 10-23, and 11-24 are taken from the ship's navigation.
[2)] Taurus recording started first at 10:16:10 UTC on August 27.

Deployment from the afterdeck had a high failure rate, because it takes about a minute for the buoy to come back to the surface after deployment. During this time, the buoy can move substantially due to the propeller wash and the direction of the movement is unpredictable. Often ice has moved in by then preventing the buoy from surfacing (Fig. 35); or the buoys were crushed by ice blocks after surfacing. Fig. 36 shows a sonobuoy eight hours after deployment and indicates how vulnerable the buoy is in the ice. To decrease the failure rate during deployment, a new technique was tried with some of the buoys (starting with buoy 10-23). 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. Once the seawater battery activates, the parachute detaches from the remainder of the buoy. Using this technique, it can be avoided that the buoy surfaces beneath the ice. The later destruction by ice is of course still a possibility.

Three sonobuoys were also deployed by helicopter ahead of the ship. Since the track was already defined by the broken ice, it was ensured that the ship would actually pass the sonobuoy as long as the buoy was deployed into the track or close by. To minimize the risk of destruction when the ship passes the buoy, it was tried to find open water locations close to the track (<200 m distance). The helicopter would land on the ice and then the buoys were deployed with a rope attached to them until the float bag would inflate. None of the buoys were destroyed when the ship passed by and this is also true for the buoys that were deployed from the ship while breaking ice along the track. Although some of these buoys reached their eight-hour operating life before the ship got to their position (due to delays with the ice breaking or due to technical problems with the seismic equipment), there are a total of seven sonobuoys that recorded shots both when the ship was sailing towards the buoy and steaming away from it.

Although some shots were not recorded by the Winradios due to temporary loss of the radio signals from the sonobuoys (probably due to blockage of the line of sight by ice), the overall performance of the buoys in the ice was better than in 2007. Shots were recorded up to offsets of 22 km, something that was only achieved on the ice-free line 4 off NE Greenland in the 2007 expedition.

Figure 34. *Sonobuoy deployment 6-13 from the afterdeck of Oden. Photo: Esben Jørgensen.*

Figure 35. *Sonobuoy 6-13 after deployment. The buoy surfaced between ice blocks but was not damaged. Photo: Esben Jørgensen.*

Figure 36. *Sonobuoy 7-19 eight hours after deployment. The buoy was completely enclosed by ice but was still operational. A few minutes after this picture was taken, the buoy reached the end of its programmed life time and sank to the seafloor. Photo: Thomas Funck.*

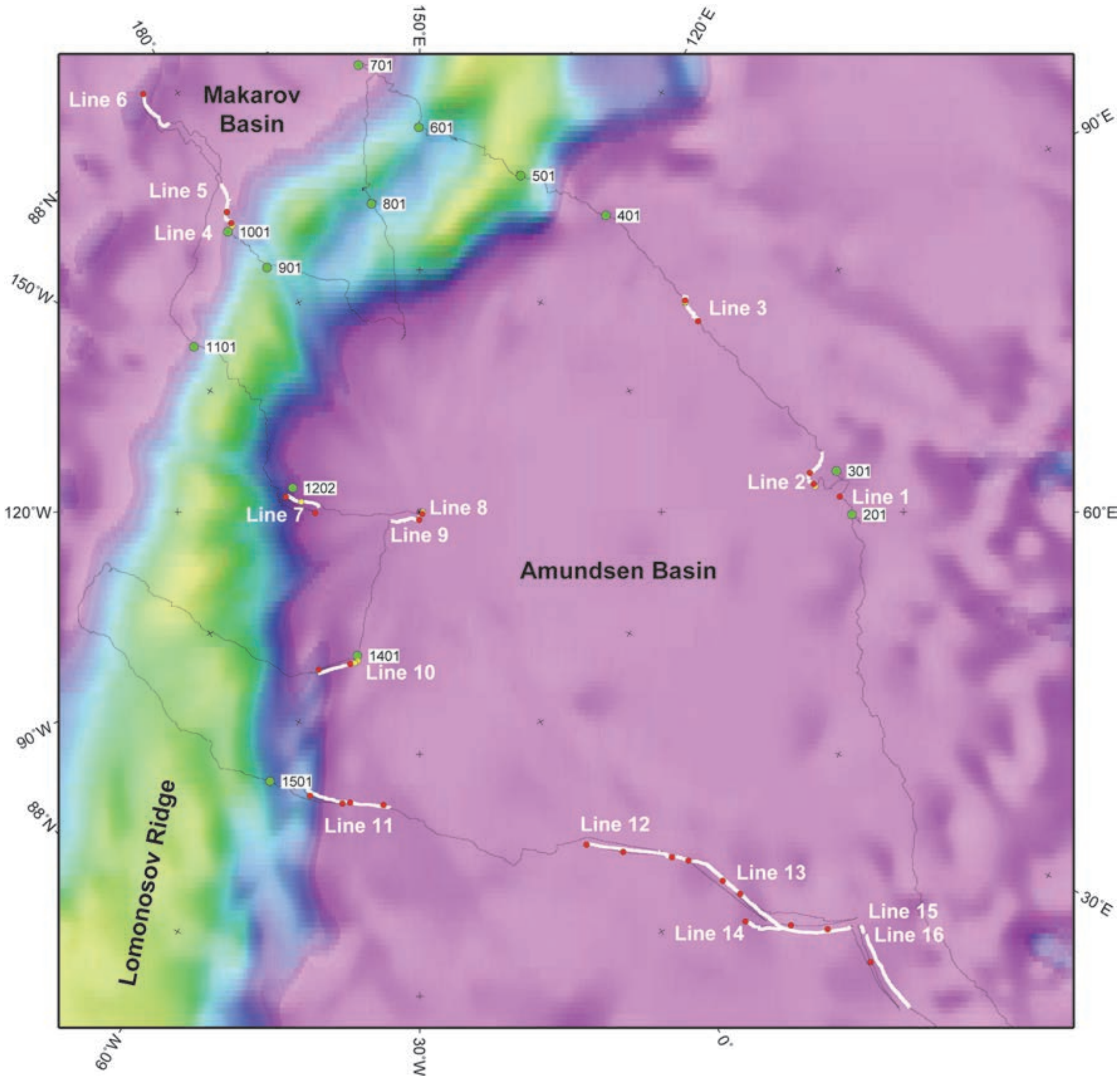


Figure 37. *Bathymetric map (IBCAO) with the location of the LOMROG II (2009) reflection seismic lines (white lines) shown together with sonobuoy deployment positions (red circles for sonobuoys that worked, yellow circles for buoys that did not transmit signals) and the location of the CTD measurements that reached deep water (green circles). The ship track is marked as solid line. 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 *Lomrog2.[line#].Nav.txt*. The shot times in that file do not 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 3 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 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: 0° (Greenwich meridian)
- 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.

The water depths in the navigation files were provided from the ship's multibeam system (central beam) using a water-velocity function obtained from CTD measurements that were carried out prior to each seismic transect. The values are given in meters below the transducer, which was mounted at a depth of 8.3 m below sea level. Depths in the files are raw values; no editing was applied to remove erroneous values. Also the depth of the airgun is written to the NaviPac navigation file, something that was not done during the LOMROG I cruise.

Deployment positions of the sonobuoys (Table 7) were obtained from a handheld GPS unit taken by a person at the afterdeck, located close to the sonobuoy deployer. For this purpose, an Italian GPS receiver (model GEONAV3) was purchased, which does also record the time when a waypoint (i.e., sonobuoy deployment position) is taken. When the GPS unit was first tested on *Oden*, it was noticed that it has a software bug and cannot operate north of 74°20' N. It was also noticed that only the hours and minutes of the waypoint time are stored but not the seconds. In the end, a private GPS unit (model GARMIN geko 201) was used to mark the waypoints and the deployment time was taken from a watch.

After *Oden* reached the North Pole on August 22, all Garmin GPS receivers onboard had problems with the tracking of the satellites. This is the reason why no positions could be taken with the handheld GPS on the afterdeck while deploying sonobuoys on line 10. Instead, the deployment time was noted and with that the position was extracted from the ship's navigation data. At ~89°N and a long waiting time (>1 hour), the Garmin GPS receivers were operational again.

8.3.2 Data Retrieval

Raw SEGD files of all shots were transferred from the Geometrics registration computer to the workstation in the processing container, where processing and further analysis of the sonobuoy data were carried out. Filenames are *[shotnumber].segd*, e.g. *2370.segd.* The shot number corresponds to the "file" number in the NaviPac navigation file.

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 both downloaded in ASCII and in MiniSEED format. In ASCII format, each file is divided into smaller blocks with an ASCII header that specifies the start time and sampling rate of the following block. The data block is a comma separated list with amplitude values for each sample. File names are

Winradio[*Winradio number*]_taurus_[*Taurus serial number*]_[*year*][*month*][*day*]_[*time in hhmmss*].[*data format*]

for example *Winradio2_taurus_0538_20090811_091900.txt* (or *.seed*)

8.3.3 Data Processing

Sonobuoy data recorded on the Geometrics system were converted from SEGD to SEGY format using the software Seismic Unix installed on the SUN workstation. Data recorded on the Taurus seismometers were converted from ASCII to SEGY format by UNIX scripts and FORTRAN programs that extracted the appropriate time windows using the shot times in the navigation file. Shot positions, receiver position (=sonobuoy deployment position), water depth, 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. sono3-5aux1.sgy). Data recorded on the Geometrics system are named *aux(1/2/4)* 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 11 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 for all buoys with exception of 11-28, when 300 m were used), using sea level as reference. The surface water velocity obtained from a CTD measurement close by was used to calculate the static corrections (CTD 201 for lines 1 through 3, CTD 1001 for lines 4 through 6, CTD 1202 for lines 7 through 9, CTD 1401 for line 10, CTD 1501 for lines 11 through 16). 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. Fig. 38 shows the velocity-depth function obtained from CTD measurement CTD00201 and Fig. 39 is the result from the raytracing modelling. Not on all traces the direct wave could be picked. For these shots, a linear interpolation or extrapolation was carried out. It was also found that the final record sections looked much smoother, when the direct wave was not picked on every single trace, since there are often some intervals where the direct wave is more difficult to pick. In sections with good signal-to-noise ratios it was attempted to pick the direct wave every fifth to tenth trace. The new drift-corrected offsets were then written into the SEGY headers 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 are used when the ship approached the buoy during the shooting; offsets are positive when the ship moved away from the buoy.

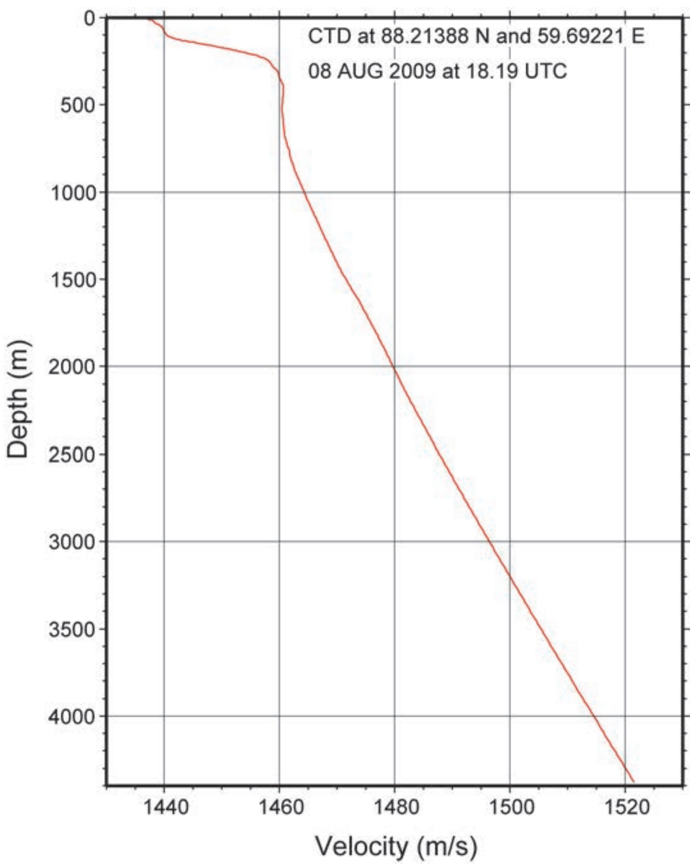


Figure 38. *Velocity-depth function obtained from CTD measurement CTD00201 at 88.21388°N and 59.69221°E.*

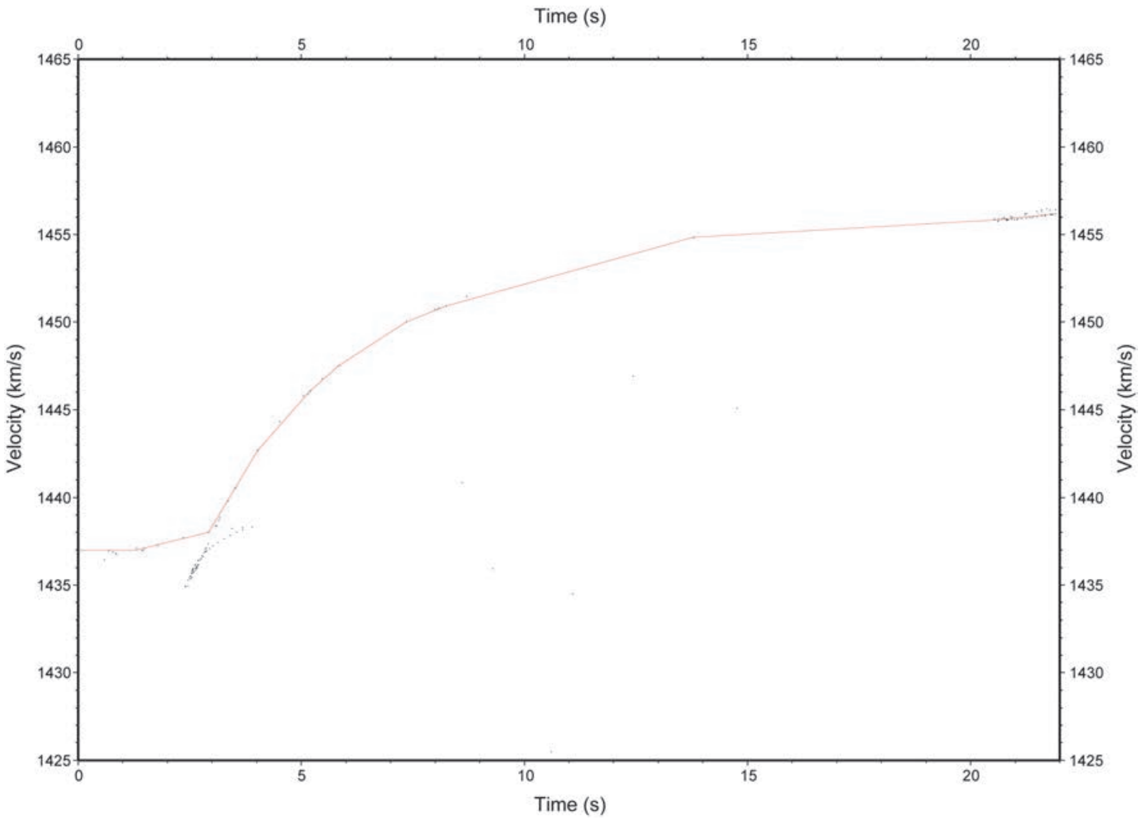


Figure 39. *Average water velocity (offset divided by travel time) as a function of travel time of the direct wave obtained from one-dimensional ray tracing using the velocity function shown in Fig. 38 (CTD 201).*

The Taurus seismometer allowed for continuous recording of the sonobuoy signals, by which there is no limitation to the record length, while the record length on the Geometrics system is restricted to 11 s. However, during the acquisition of line 11, the Taurus recorder was not operational for the first 3.4 hours and, hence, the record length was limited to 11 s for the first part of the line. One record (buoy 11-24) showed strong amplitudes for times >11 s as indicated by “wrap around” seismic energy (arrivals from previous shot). Here a concatenation of the shot with the recording from the next shot could increase the record length, although there remains a gap between 11 and 12 s (see record in Appendix V-A).

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 36 Hz). Travel times are reduced with a reduction velocity of 4.5 km/s. Record sections are displayed with true amplitudes. The data for sonobuoy 10-23 recorded on auxiliary channel 2 were affected by cross talk with auxiliary channel 3 that recorded the PPS pulse. A median filter was able to remove the interfering signal that is also visible on some other records, although less severe.

8.4 Summary and Recommendations

8.4.1 Taurus Seismometers

During the LOMROG I cruise, the Taurus seismometers were powered by a battery pack. In 2009, a power adapter was used providing a voltage of 12.3 V. For line 1, this resulted in severe 50-Hz noise on the recorder, so strong that these signals were clipped and no seismic data could be identified. After the reason for the problem was identified, a simple grounding of the seismometer (Fig. 40) prevented similar spikes on subsequent lines.

Figure 40. *Grounding of the seismometer by using a screw in a hole on the right side of the Taurus recorder. Photo: Thomas Funck.*

Due to the uncertainty of the exact shot time (±10 ms), the sonobuoy records produced from the Taurus data look slightly more noisy than the data recorded on the auxiliary channels of the MCS acquisition system. On the MCS system, the lateral correlation of seismic phases appears smoother than on the Taurus records. While it would be desirable to decrease the uncertainty of the shot times to produce cleaner records from the Taurus data, this has no influence on the velocity modelling. With a few exceptions, the Taurus recordings were essentially not necessary, as the 11-s-record length on the MCS system was sufficient to record all seismic phases relevant to perform a velocity analysis of the sediments.

8.4.2 Interference with Signals from the AIS

On the first three lines, the sonobuoy records showed some interference with rather strong signals of initially unknown source (Fig. 41). These signals could easily be traced from one seismic trace to another, which is why it was speculated that the acquisition unit itself was causing some kind of cross-talk or interference. Comparison with the 2007 expedition where these signals were not observed, suggested that the depth transducers could cause the problems as they were not operational in 2007. However, some laboratory tests after line 3 did not confirm this suspicion. When it was noticed that the strength of the signals varied with the VHF channel used on the sonobuoys, it was investigated if there was interference with other radio equipment on the vessel. It was found that the ship's Automatic Identification System (AIS) is transmitting on two frequencies in the VHF band (161.975

and 162.025 MHz). On subsequent seismic lines the AIS system was turned off when there were no helicopter operations. In addition, sonobuoy transmitting frequencies close to 162 MHz were avoided.

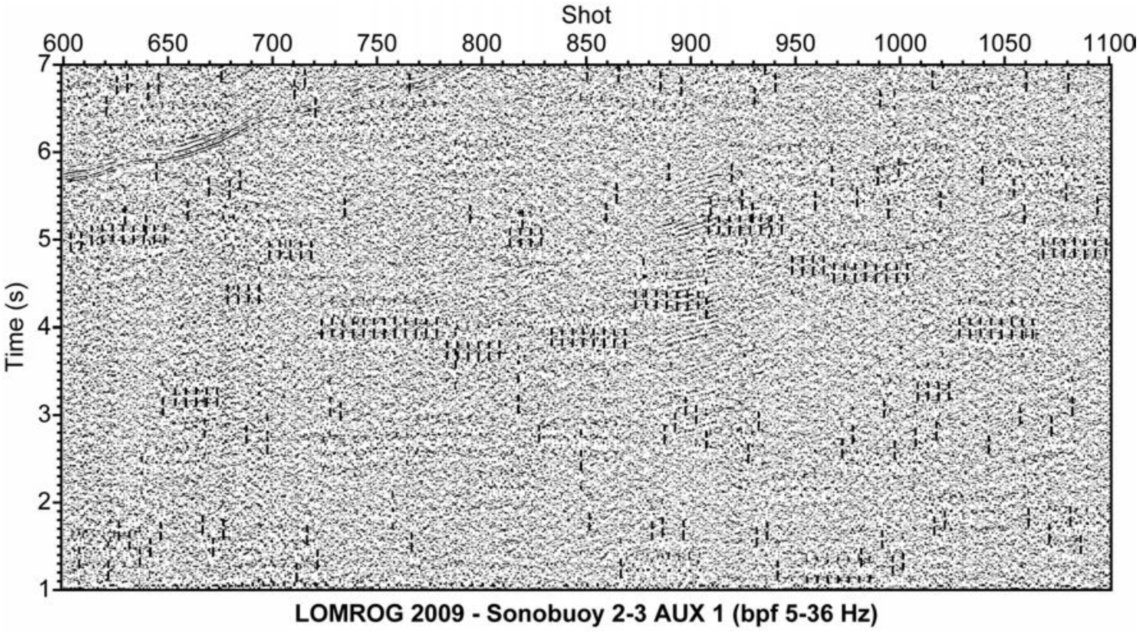


Figure 41. *Record section of sonobuoy 2-3 showing interference with signals from the AIS system.*

The interference was not noticed during the LOMROG 2007 expedition. Possible reasons for this could have been the use of a different VHF antenna that may have been less susceptible to interference with the AIS signals. The AIS is transmitting at regular intervals and, hence, when shooting at time and not at distance as in 2007, the interference becomes more obvious.

8.4.3 Improvements

During the LOMROG II expedition, a number of improvements were made that enhanced the overall sonobuoy performance. This includes:

- Using the ship's VHF's antenna that is mounted higher than the project's Moonraker antenna.
- Deployment of the sonobuoys on a rope prevents the buoy to be trapped beneath the ice.
- Turning off the ship's AIS system during recording to avoid interference with the radio signals from the sonobuoys.
- Grounding the Taurus recorder to avoid 50-Hz signals that otherwise mask all seismic energy.
- Breaking the ice before the start of the seismic data acquisition allowed for sonobuoy deployments within the track, either during the ice breaking or by helicopter. With that, a certain amount of reversed sonobuoy observations were made, which increases the accuracy of the velocity modelling.

8.4.4 Single-Ship Operation

Compared with the data acquisition in 2007 when there was a lead icebreaker (*50 let Pobedy*), the sonobuoy operation in 2009 had to deal with a number of problems that were related to the single-ship data acquisition. This includes

- the segmentation of the reflection seismic lines, which often resulted in shot-receiver offsets that were too little to perform a proper data analysis,
- curved ship tracks that followed the path of the weakest ice with large deviations from a straight line, which causes some problems with the velocity modelling (the assumed two-dimensionality is violated),
- the noise levels during the shooting were very high due to the simultaneous ice breaking, which prevented the identification of any deeper reflectors than the seafloor in the online brute stack; by this it was impossible to find good locations (deep sedimentary basins) for the sonobuoy deployments,
- the overall variation in the signal-to-noise ratio on the seismic records is larger due to very variable noise levels created by *Oden* during the ice breaking, which reduces the lateral correlation of seismic phases.

Some of these disadvantages could be avoided or minimized, when *Oden* started to break a track prior to the seismic data acquisition. However, this was a very time consuming procedure as the ship had to pass each line three times. Also the length of the lines was limited to 25 nm and there was less control on the line location because the ice drift was as large as 0.9 km/h (Table 8) while the preparation of the track could last up to 12 hours.

Sonobuoy	Time between passages (s)	Total drift (m)	Direction of drift	Drift velocity (km/h)
7-14	23975	3632	290°	0.545
10-20	20744	1729	152°	0.300
11-25	13296	3214	65°	0.870
12-29	15750	1463	66°	0.334
12-31	16160	2483	125°	0.553
13-32	19840	3737	158°	0.678
14-37	13425	2260	229°	0.606

Table 8. *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.*

In summary, the overall quality of the sonobuoy data suffered from the one-ship operation in 2009. While the percentage of successful sonobuoy deployments (76.3 %) could be increased compared to 2007, there was a significant share of successful launches with data that cannot be used for the velocity analysis due to noise and limited offsets.

8.4.5 Recommendations

With the new sonobuoy deployment technique on a rope (not suggested by the manufacturer), the success rate was increased to 100 %. All 16 buoys from 10-23 to 15-38 were deployed without incidents. This method should certainly be used in any future experiments in ice-infested waters.

Some cross-talk from auxiliary channel 3 (PPS pulse) were noted on the other auxiliary channels. Although the gain of the PPS pulse was reduced, the interference persisted and this problem should be looked into prior to the next cruise. While interference with the ship's AIS system could be minimized or avoided once the reason was identified, there was also some disturbance from the radios used for intern communication (between the seismic container, bridge, and afterdeck). Hence, use of the radios during sonobuoy data acquisition should be avoided as much as possible.

Sonobuoy records show observations up to shot-receiver offsets of 22 km. In general, most stations show seismic energy up to 14 to 16 km distance. These offsets are sufficient to perform semblance analysis using the recorded reflections. However, semblance analysis is only warranted in case of horizontal layering of the sediments. In other cases, velocity information has to be obtained from raytracing modelling. In this case it is very helpful to have refracted arrivals that provide the best constraints on velocity. Using the 605-cubic inches gun-cluster, refractions are often not observed or are rather weak. The reason for that is the small volume of the gun-cluster and the gun signature with prevalence for high frequencies. It is therefore suggested to look into the option of using a slightly larger airgun chamber size and also increasing the total volume. The Canadian data acquisition in the Arctic uses two to three G-guns with a volume of 520 cubic inches each at a pressure of 2000 psi. This array has proven to give crustal refractions up to 30-40 km distance. Using two 520 cubic inches guns at a pressure of 3000 psi should significantly improve the amount of refracted seismic energy that can be observed on the sonobuoy records. In addition, the basement will be much easier to identify on the multi-channel seismic records, which is the prime target for the Continental Shelf Project.

As outlined throughout the report, the next seismic data acquisition should be carried out with a lead icebreaker for reasons of overall data quality and efficiency during the acquisition.

9. Acquisition of Seismic Data in Arctic Sea Ice – Some Comments

By Christian Marcussen, Thomas Funck, John Hopper and Lars Rödel, Geological Survey of Denmark and Greenland and Holger Lykke-Andersen, Per Trinhammer, Anja Kinnberg Gunvald and Esben Villumsen Jørgensen Department of Earth Sciences, University of Aarhus

One of the main goals of the LOMROG II cruise is to acquire seismic data in the Amundsen and Makarov Basins on both sides of the Lomonosov Ridge (for a map - see field report no. 5). Seismic methods can be used to map sediment thickness, as is commonly done by the oil industry prospecting for oil and gas.

Seismic data are important for the Continental Shelf Project since one of the provisions in Article 76 of the United Nations Convention on the Law of the Sea (UNCLOS) deals with the thickness of sediments:

> *"4. (a) For the purposes of this Convention, the coastal State shall establish the outer edge of the continental margin wherever the margin extends beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured, by either:*
>
> > *(i) a line delineated in accordance with paragraph 7 by reference to the outermost fixed points at each of which the* ***thickness of sedimentary rocks*** *is at least 1 per cent of the shortest distance from such point to the foot of the continental slope;*
> >
> > *(or*
> >
> > *(ii) a line delineated in accordance with paragraph 7 by reference to fixed points not more than 60 nautical miles from the foot of the continental slope.)"*
>
> *(our emphasise)*

In principle the seismic method makes use of a strong sound signal, usually produced by an airgun, which is transmitted through the water column and into the subsurface below the seabed. Boundaries between different geological layers in the subsurface reflect some of the seismic energy back toward the sea surface. The reflections are then registered by a long cable (the "streamer"), which is equipped with pressure sensitive sensors called hydrophones. The streamer is pulled behind the ship in water depths of 6 to 8 meters. The arrival time of the different reflections depends on the depth to the different geological layers, while the strength of the signal to some degree characterizes the boundaries between the layers. Data are stored on a computer and on tape and then must be processed before a useful image of the subsurface is obtained. Processing is not completely automated and typically requires inspection of records to select the correct parameters needed to create the seismic images.

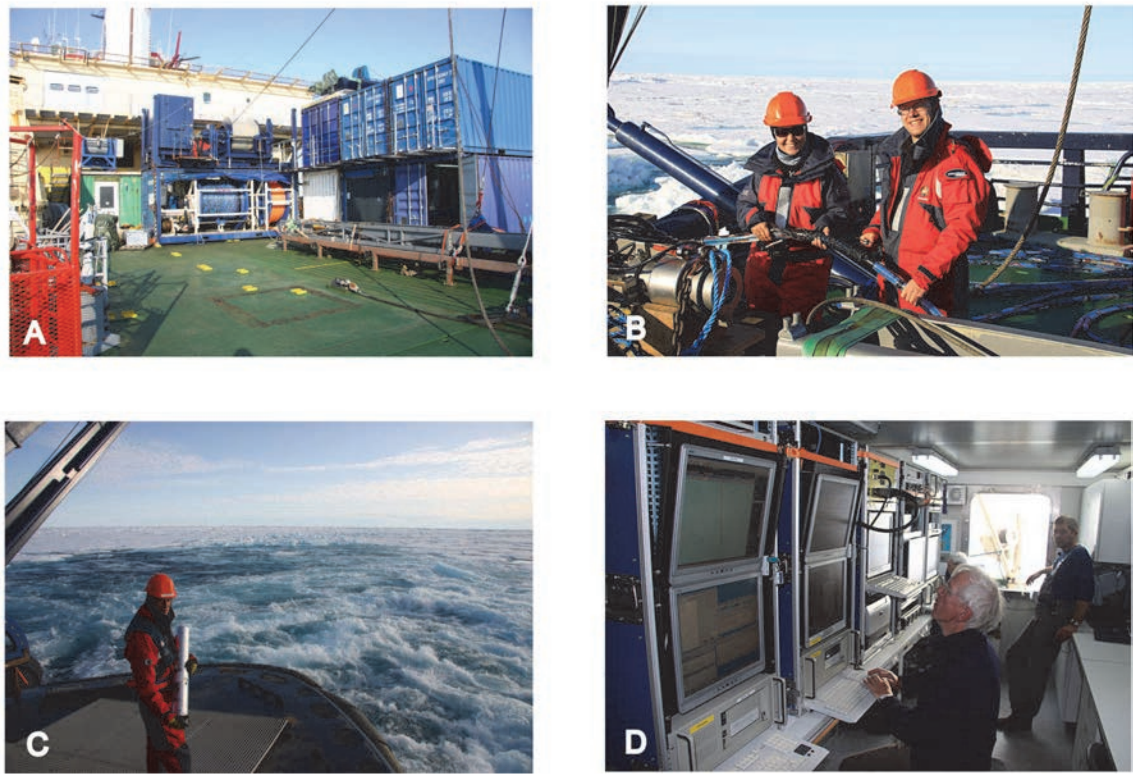


Figure 42. *A – Seismic equipment on Oden's aftdeck: winch container with streamer (blue) and umbilical (orange). B – Anja and Esben holding the streamer. Parts of the airguns can be seen to the left. C – Thomas ready to launch a sonobuoy. D – Holger, Per and John in the registration container monitor the data acquisition.*

Acquisition of seismic data in open water is technically and logistically demanding – especially doing 3D surveys with up to 16 or more streamers for the oil industry. Seismic data acquisition in the ice filled waters of the Arctic Ocean, however, presents unique challenges never encountered by these conventional seismic surveys.

In order to survive under these harsh conditions, the seismic equipment has to be modified considerably. These modifications have been made in cooperation with the Department of Earth Sciences at the Århus University based on previous experience with data acquisition in ice filled waters:

- The streamer is considerably shorter than in open water. For the LOMROG II cruise we use a 250 meter long streamer. There are many advantages to using a short streamer in the Arctic. Seismic streamers are designed to maintain a constant depth in the water only while the ship is in motion, if the ship's speed falls below 2 knots, the streamer will sink. Below 300 meter, the electronics in the streamer will be crushed by the water pressure. With a 250 meter streamer, we are able to deploy and recover the streamer with the ship at a standstill without risk of damage.

- The seismic source is considerably smaller and therefore also more compact than for open water surveys. This simplifies deployment and recovery in the event that equipment must be brought on board quickly, for example when the ship becomes stuck in ice and must backup to free itself.

- Both the streamer and guns are towed at a depth of approximately 20 meters, which is more than twice as deep as normal. This is below the wash from the ship's propellers, which can be a source of considerable noise, especially when extra power is needed to break ice and keep the ship moving forward. In addition, a deep towing depth helps to prevent the equipment from coming in contact with ice, which can cause damage. In addition, the streamer can become pinched in the ice and pulled off.

- Both the airguns and streamer are connected with only one cable to the ship (the "umbilical"). This minimizes the risk of damage by ice and serves to simplify deployment and recovery of gear so that it can be done quickly when necessary.

Because we record only the time it takes for energy to return to the surface, it is necessary to know the seismic velocity of the subsurface to compute the exact thickness of the sediments. This can be derived from processing of data acquired with a long streamer. When a short streamer is used, as in ice filled waters, sonobuoys are deployed instead. These can detect the seismic signals up to 25 km away from the ship. The buoys send the signals back to *Oden* with a radio transmitter, where the data are recorded. The only challenge is to deploy them in the wake of *Oden* without having them destroyed by ice.

Oden's normal mode of operation under heavy ice conditions, such as found in the area north of Greenland, is to break ice at as high a speed as possible. If the ship gets stuck in the ice, it would normally back and ram as many times as necessary to pass the obstacle. However neither high speed nor backing and ramming are possible with seismic gear deployed behind the ship:

- High speed would create an unacceptable noise level behind the ship and the seismic gear is not designed to withstand a high speed.

- As the ship travels faster, the towed gear gets pulled toward the surface, risking damage by ice.

- *Oden* cannot back due to the risk of getting the seismic gear tangled in the propellers.

To meet the above limitations there are different options:

In easier ice conditions, where *Oden* can break ice continuously at 3 to 4 knots approximately along a pre-planned heading, seismic data of reasonable data quality can be acquired. However, long continuous profiles are often not possible since ice conditions change rapidly and evaluation of ice conditions from the helicopter is not always easy or accurate. This is a particular challenge for this project since UNCLOS requires data to be collected at a certain density. The ice conditions often prevent *Oden* from being able to acquire data where needed.

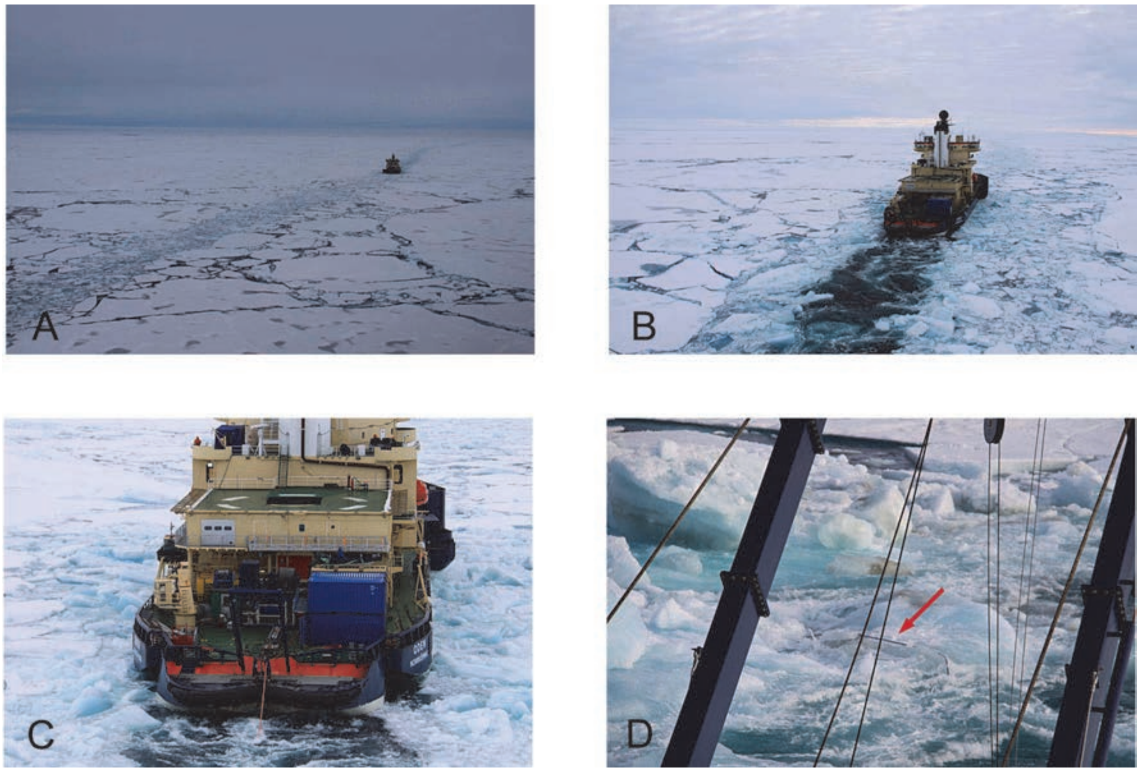


Figure 43. *A – Oden collecting data along a pre-broken track in the sea ice. B – Open lead behind Oden indicates fairly light ice conditions. C – The umbilical (orange) is the only cable connecting the seismic gear with the ship. D – One of the excitements of doing seismic work in dense sea ice: the streamer on top of the ice. Just before the picture was taken the airguns received the same treatment. However the seismic gear survived!*

A second option is to have *Oden* break a 25 nautical mile long lead or track along a 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. This option, which was suggested by the captain of *Oden,* Erik, and the first mate, Thomas, has some obvious advantages. 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. 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 loosing or damaging the seismic gear is reduced considerably. However, data acquisition using this option is more time consuming.

A third option is to use two icebreakers for collection of seismic data in ice filled waters. A lead icebreaker – as powerful as possible – breaks a lead along a pre-planned line, possibly several times in order to prepare as wide a lead as possible. *Oden* trails behind acquiring seismic data. Using two icebreakers will of course increase the cost for the operations considerably. This is however partly balanced out by a faster and better data acquisition as well as providing a way to collect seismic lines longer than 25 nautical miles. A Russian nuclear icebreaker – *50 let Pobedy* – was used for this purpose during the first LOMROG cruise in 2007. Under very severe ice conditions with sea ice under compression, this option also has limitations.

Unfortunately, none of the above mentioned options can guarantee that the necessary seismic data can be acquired. Ice conditions vary considerably from year to year, from month to month, and from week to week. The ice conditions for any particular area are nearly impossible to predict prior to a cruise. Thus we are completely dependent on trying to reach a target area and evaluating the conditions on the spot. If the conditions allow deployment of seismic gear, we can proceed. Otherwise, we must attempt to reach other target areas and hope for better ice conditions.

During the LOMROG II cruise approximately 380 km of seismic data have been acquired mostly by having Oden to break a track (option 2 as described above). This year, none of the seismic gear was lost in the ice as happened during the first LOMROG cruise, and is a common occurrence in arctic seismic experiments. Nevertheless, sometimes it was very close (see photo of streamer on the ice). In fact, only one section of the streamer was damaged by the ice. In general, the data quality is better than that obtained during LOMROG I in 2007. Last but not least the LOMROG II cruise has considerably increased our knowledge on how to operate in ice filled waters. The “learning by doing” principle is especially appropriate when working in the Arctic.

10. Acknowledgement

The successful data acquisition of LOMROG II 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, the Swedish Polar Research Secretariat and the Canadian Continental Shelf Project.

11. Appendices and Enclosures

11.1 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 LC 605 gun signature and spectrum @ 3m
- F Marine sources from Sercel
- G Cold weather operation (Sercel – LC 605 gun)
- 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, Tape Inventory Log and Line Overview logs

Appendix IV: Logs of Air gun and streamer depths and ships speed

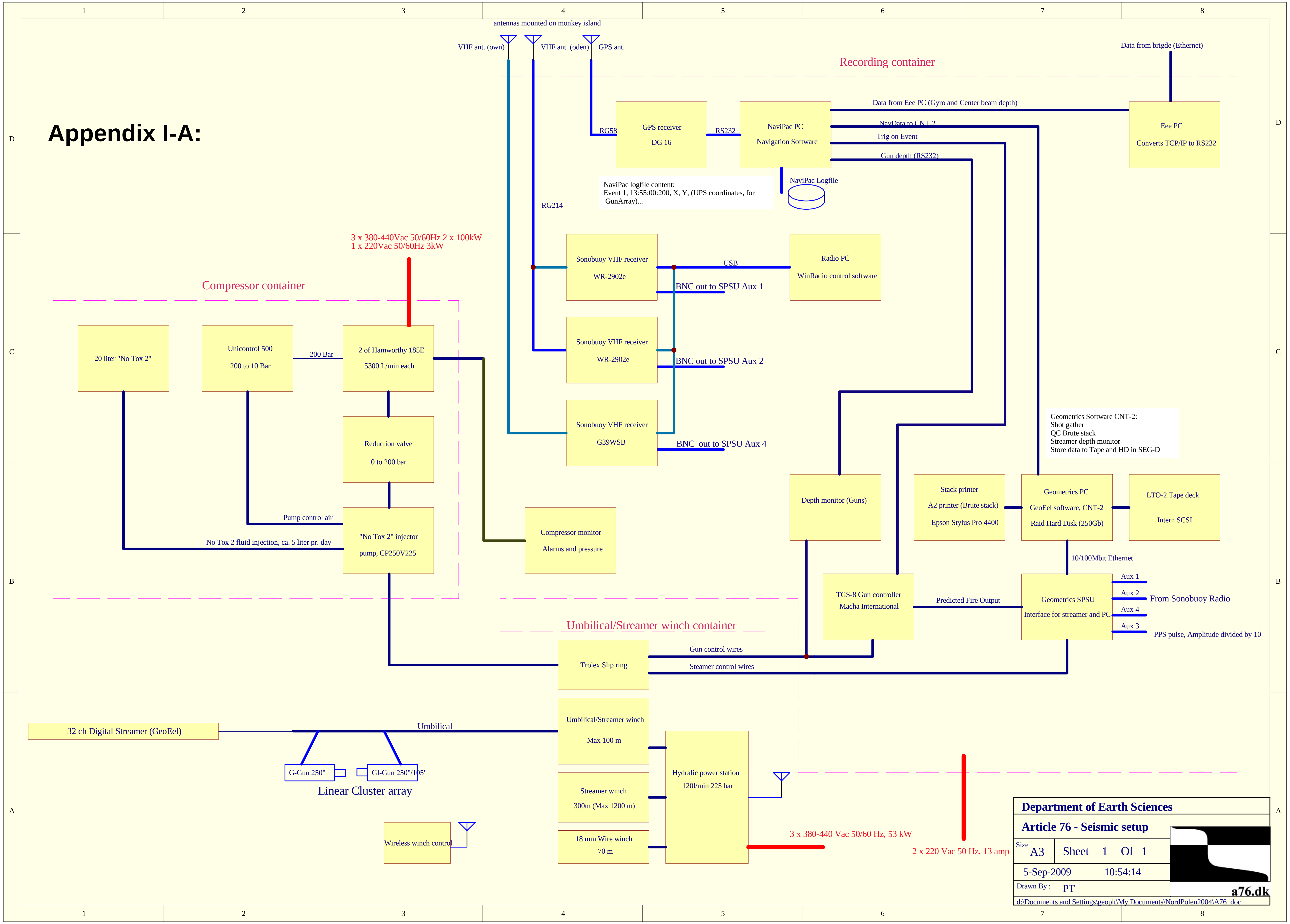
Appendix V: Sonobuoy appendices
- A Record sections of all sonobuoys
- B Location maps for all seismic lines
- C CTD measurements used for offset calculations
- D Technical specifications sonobuoy receiver WR-2902e
- E Technical specifications Taurus seismometer from Nanometrics
- F Technical specifications sonobuoy AN/SSQ-53D(3), ULTRA Electronics
- G Technical specifications VHF antenna MD G3

11.2 Enclosures as digital files on enclosed CD-ROM

Enclosure 1: PDF version of this report
Enclosure 2: PDF version of the LOMROG II Cruise report
Enclosure 3: Navigation data as ASCII files

Appendix I: Seismic equipment setup and specifications

Appendix I-A:



antennas mounted on monkey island
VHF ant. (own)
VHF ant. (oden)
GPS ant.
Data from brigde (Ethernet)
Recording container
RG58
GPS receiver
DG 16
RS232
NaviPac PC
Navigation Software
Data from Eee PC (Gyro and Center beam depth)
NavData to CNT-2
Trig on Event
Gun depth (RS232)
Eee PC
Converts TCP/IP to RS232
NaviPac logfile content:
Event 1, 13:55:00:200, X, Y, (UPS coordinates, for GunArray)...
NaviPac Logfile
RG214
3 x 380-440Vac 50/60Hz 2 x 100kW
1 x 220Vac 50/60Hz 3kW
Compressor container
Sonobuoy VHF receiver
WR-2902e
USB
Radio PC
WinRadio control software
BNC out to SPSU Aux 1
20 liter "No Tox 2"
Unicontrol 500
200 to 10 Bar
200 Bar
2 of Hamworthy 185E
5300 L/min each
Sonobuoy VHF receiver
WR-2902e
BNC out to SPSU Aux 2
Reduction valve
0 to 200 bar
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
Pump control air
No Tox 2 fluid injection, ca. 5 liter pr. day
"No Tox 2" injector
pump, CP250V225
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
TGS-8 Gun controller
Macha International
Predicted Fire Output
Geometrics SPSU
Interface for streamer and PC
Aux 1
Aux 2
Aux 4
Aux 3
From Sonobuoy Radio
PPS pulse, Amplitude divided by 10
Umbilical/Streamer winch container
Trolex Slip ring
Gun control wires
Steamer control wires
32 ch Digital Streamer (GeoEel)
Umbilical
Umbilical/Streamer winch
Max 100 m
G-Gun 250"
GI-Gun 250"/105"
Linear Cluster array
Hydralic power station
120l/min 225 bar
Streamer winch
300m (Max 1200 m)
Wireless winch control
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2 x 220 Vac 50 Hz, 13 amp
Department of Earth Sciences
Article 76 - Seismic setup
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Appendix I-B:

GeoEel Digital Marine Streamer

GEOMETRICS

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

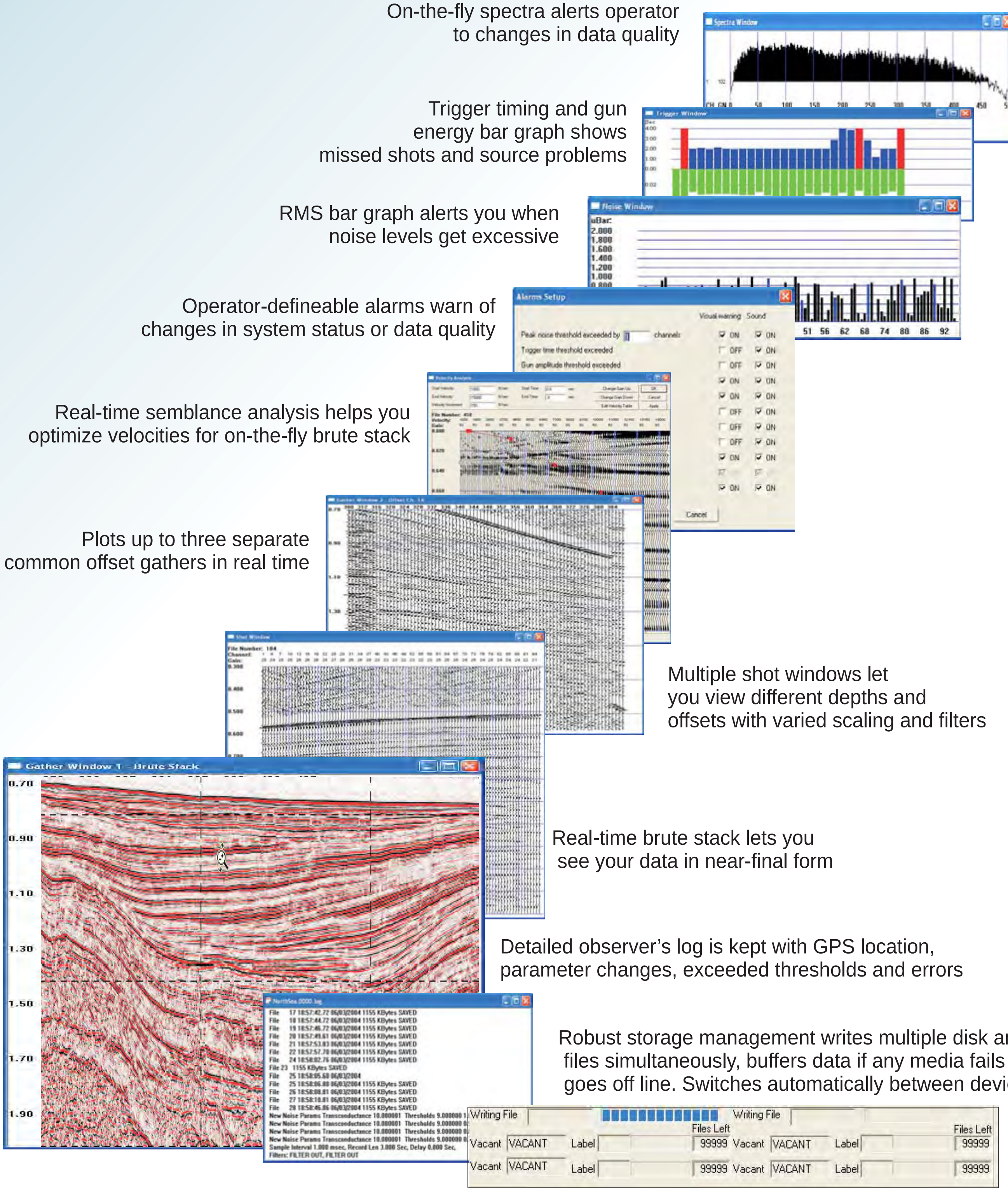
Trigger timing and gun energy bar graph shows missed shots and source problems

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



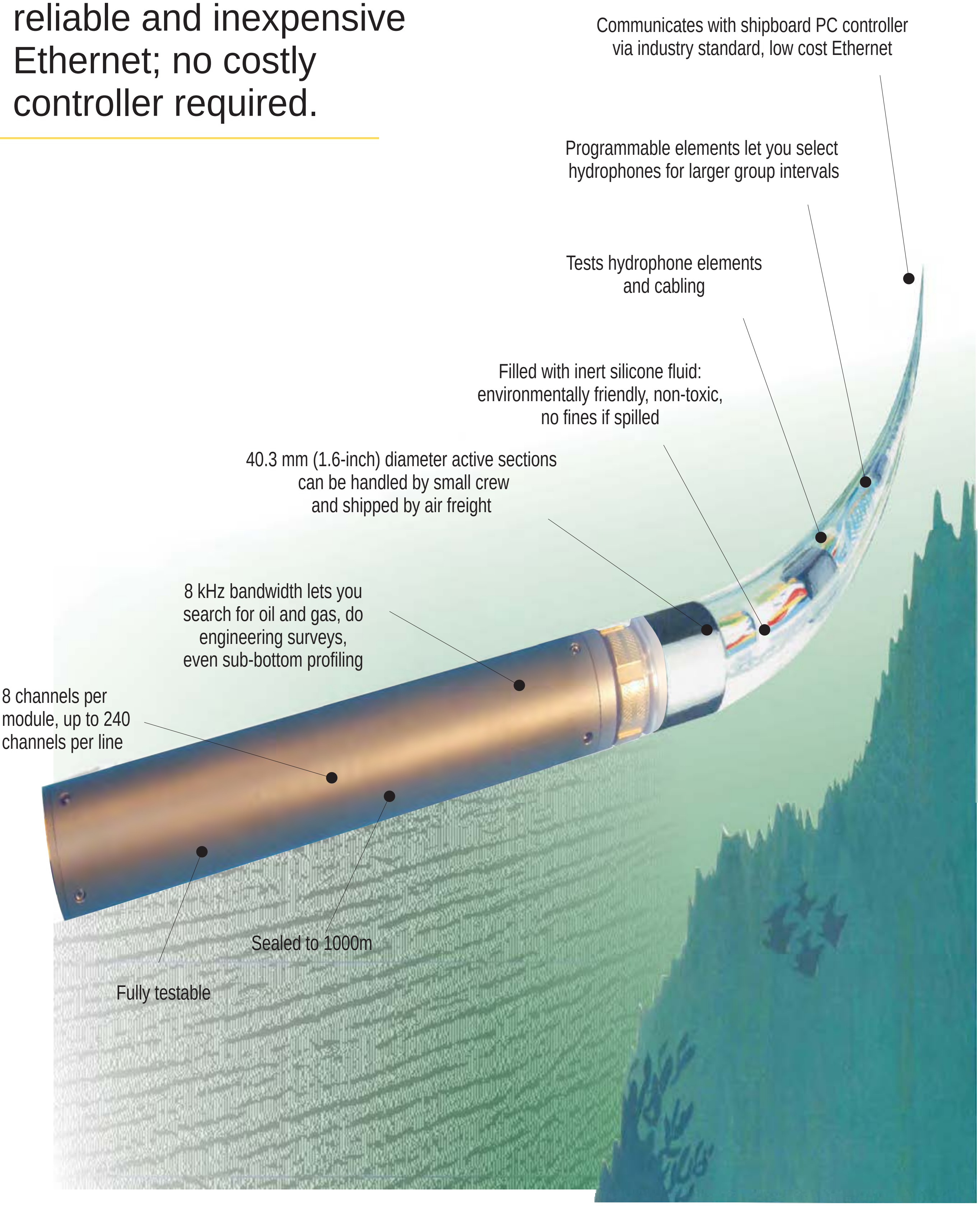
Multiple shot windows let you view different depths and offsets with varied scaling and filters

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

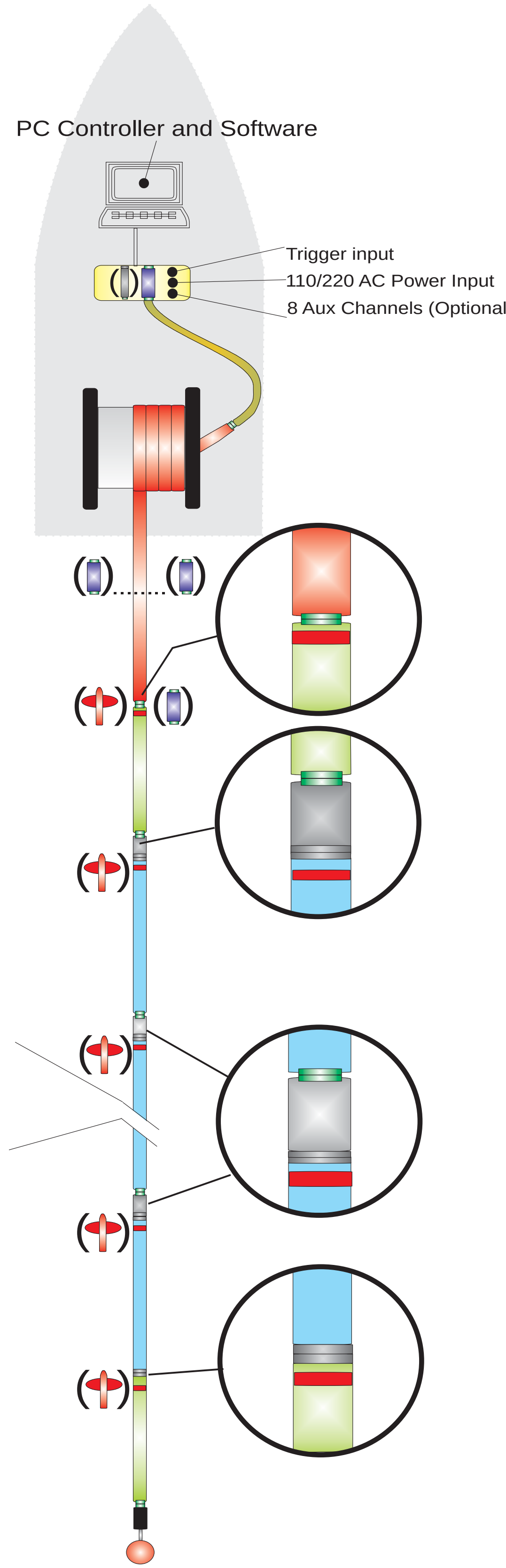
Detailed observer's log is kept with GPS location, parameter changes, exceeded thresholds and errors

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.



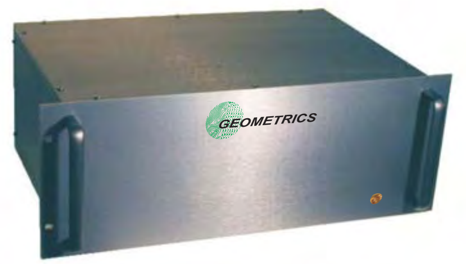
Flexible configuration is easily expandable.



Components:

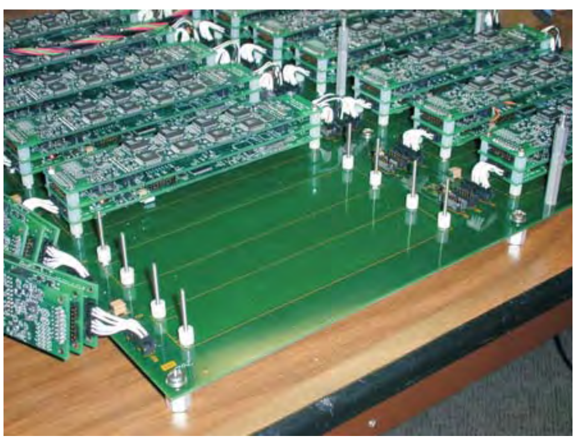
- Streamer Power Supply Unit (SPSU)
- Deck Cable
- Tow Cable
- Repeater Module
- Stretch Section
- A/D Digitizer Module
- Bird
- 8-channel Active Section
- Digital Connector Pair
- Analog/Digital Combo Connector Pair
- Bird Coil
- Tail Swivel
- Tail Buoy
- ( ) Optional

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?

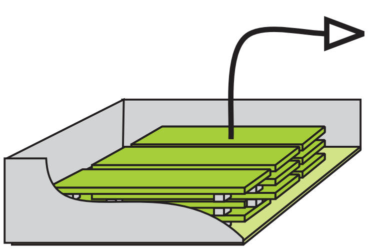
Still have a stock of analog sections with lots of life left in them? Not sure that it is time to make the move to a fully digital system? GeoEel digital electronics can be packaged in a rugged ‘convertible’ rack chassis with up to 120 channels plus 8 aux channels. Each rack mount chassis is controlled 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.



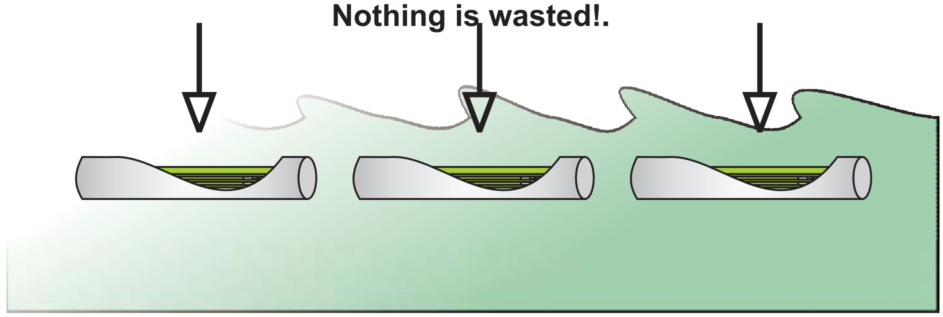
When you are ready to retire your analog system, the electronics can be reassembled in GeoEel waterproof canisters, ready to attach to your new digital hydrophone sections to make a complete, modern digital marine seismic system - at about ½ the price.

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

S P E C I F I C A T I O N S

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.

BENTHOS

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ISO 9001 Certified

Appendix I-D:

Winch system: main data

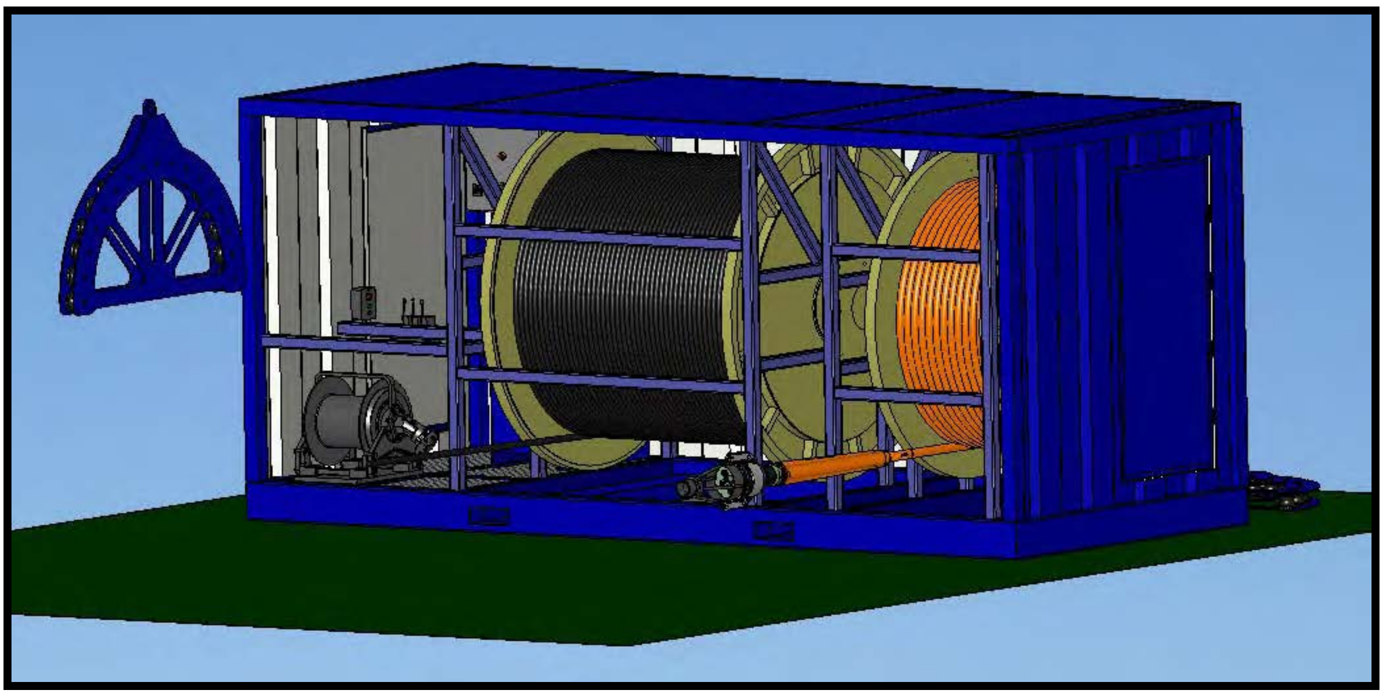
Main data

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.

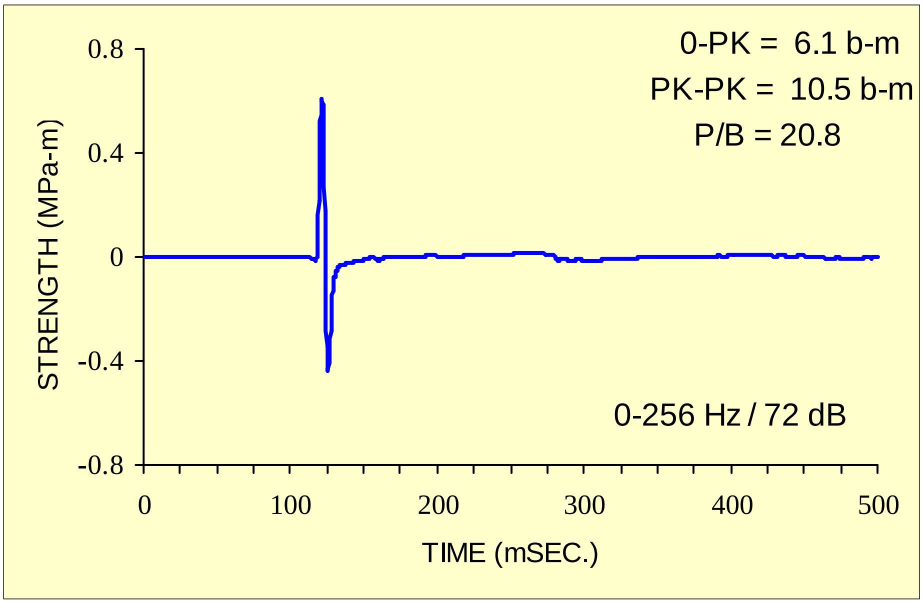
The system is designed for work in polar areas and hence the system is specifically optimized for ice impact in the water column during marine seismic activity.
System delivery includes the AGU cable, with terminations and interface for a durable air gun and streamer mechanical solution. The scope of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

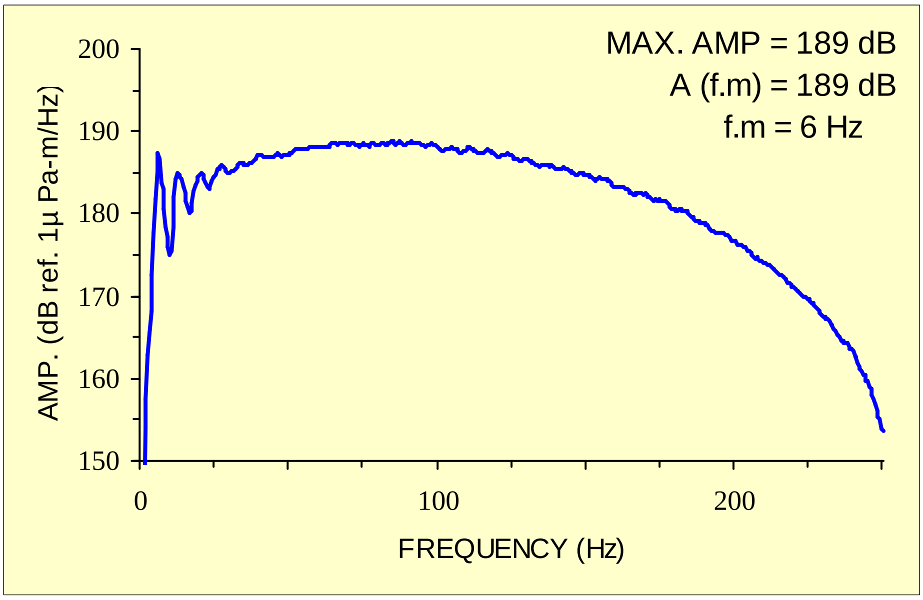


The Container is to be installed on the back deck of a vessel (e.g. Oden) and support the load of other equipment on top of the container. The winches are operated from the winch, via a sheave block mounted in connection with the vessel A-frame, over the stern of the vessel.

Appendix I-E:

LC 605 gun signature and spectrum @ 3m





G / GI GUN Linear Cluster / 605 in^3

(250 in^3) + (G 250 in^3 / I 105 in^3)
Pressure = 2,000 psi
Depth = 3.0 meters

Appendix I-F:

Marine sources from Sercel

Marine Sources

Sound science.
Reliable results.

Sercel

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

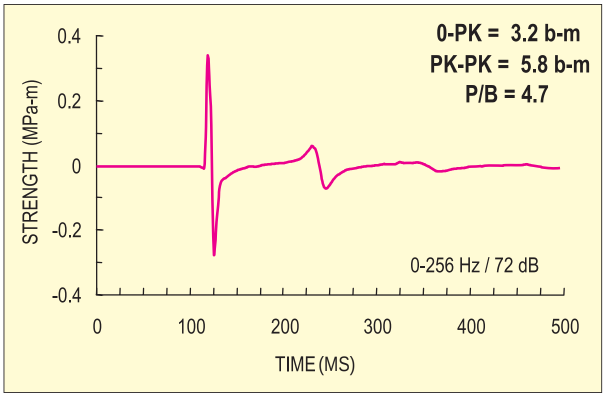
The S15 Watergun is capable of delivering a high-frequency, bubble-free acoustic pulse perfectly suitable for very high resolution applications. Compressed air is used to propel a water jet, which creates a vacuum cavity. When the vacuum cavity implodes from the surrounding hydrostatic pressure, it emits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

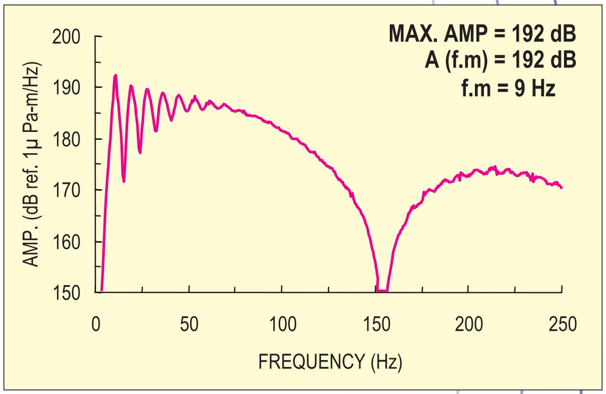
G. GUN 250

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

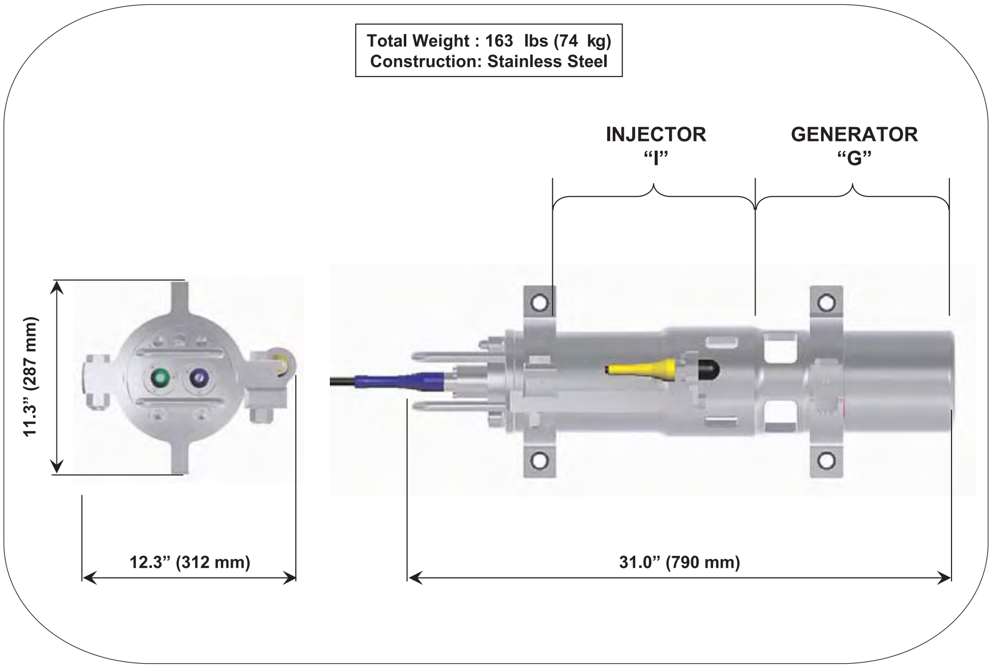
- Weight : 65 kg (143 lbs.)
- Length : 597 mm (23.5 in.)
- Width : 292 mm (11.5 in.)
- Diameter : 287 mm (11.3 in.)

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.

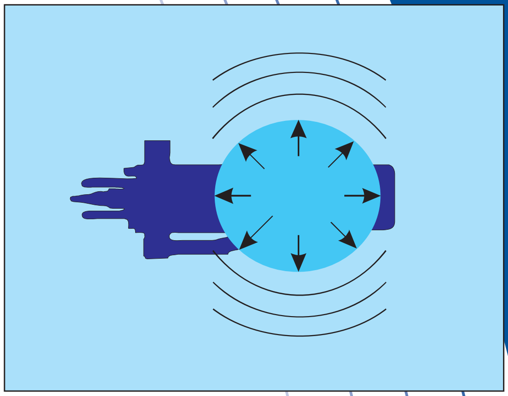
Each gun has its own reservoir, its own shuttle, its own set of exhaust ports, and its own solenoid valve.

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.

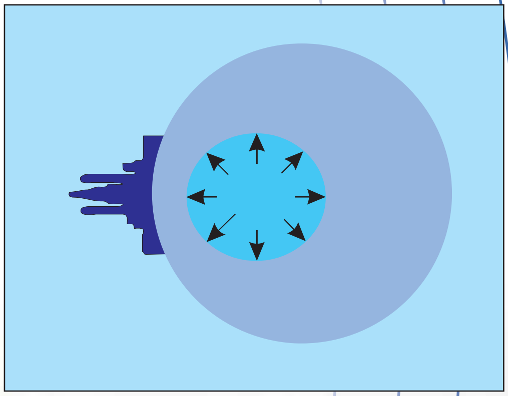


HOW IT WORKS

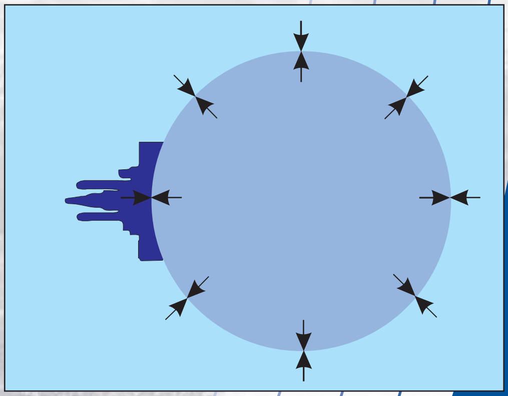
Phase 1 :
The Generator ("g") is fired. The blast of compressed air produces the primary pulse and the bubble starts to expand.



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.

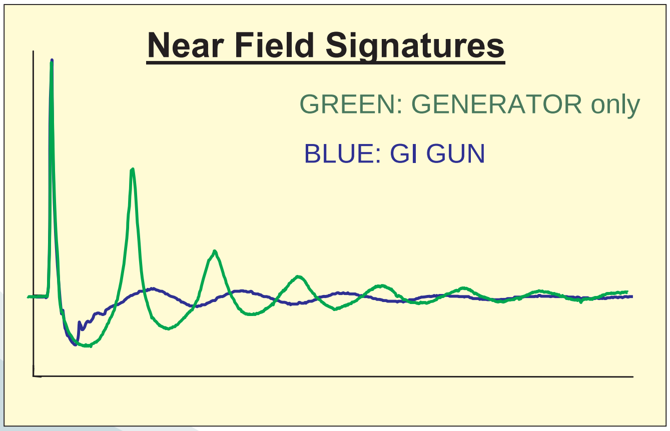
The figures below show how the near field signature and spectrum of the Generator alone (green line) is re-shaped by an optimally tuned injection (blue line). This type of setting is called "true GI mode" and results in an almost total bubble suppression of the bubble oscillation.

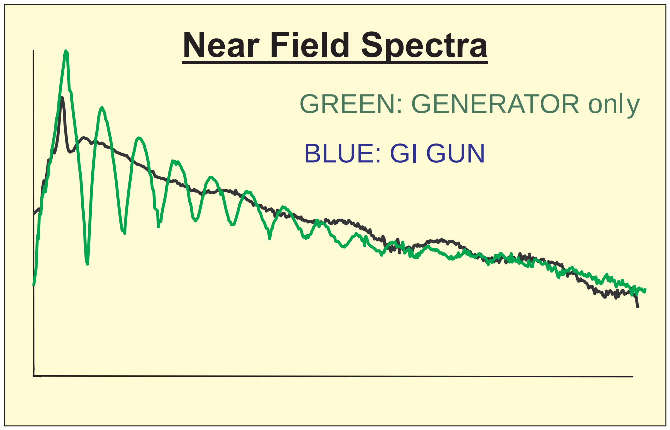
VERSATILITY

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.

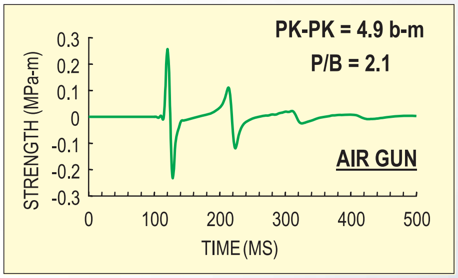
Left (a) : Typical signature of an air gun with a volume of 150 in^3. The peak-to-peak output is maximum, but the primary-to-bubble ratio is poor.

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.

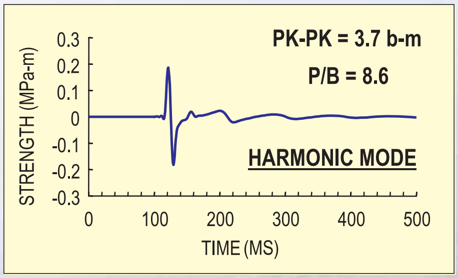
Right (c) : Signature generated by a single GI GUN used in the "true GI mode." The Generator has a volume of 45 in^3 and the Injector has a volume of 105 in^3. Here too, the firing of the Injector has been delayed by about half the time of the Generator fired alone.

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.

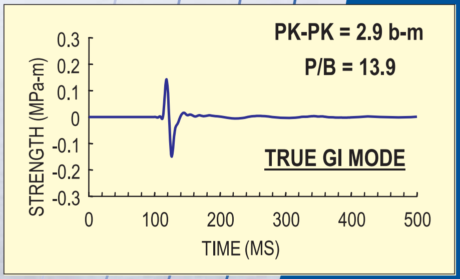
a) AIR GUN
Volume = 150 in^3



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



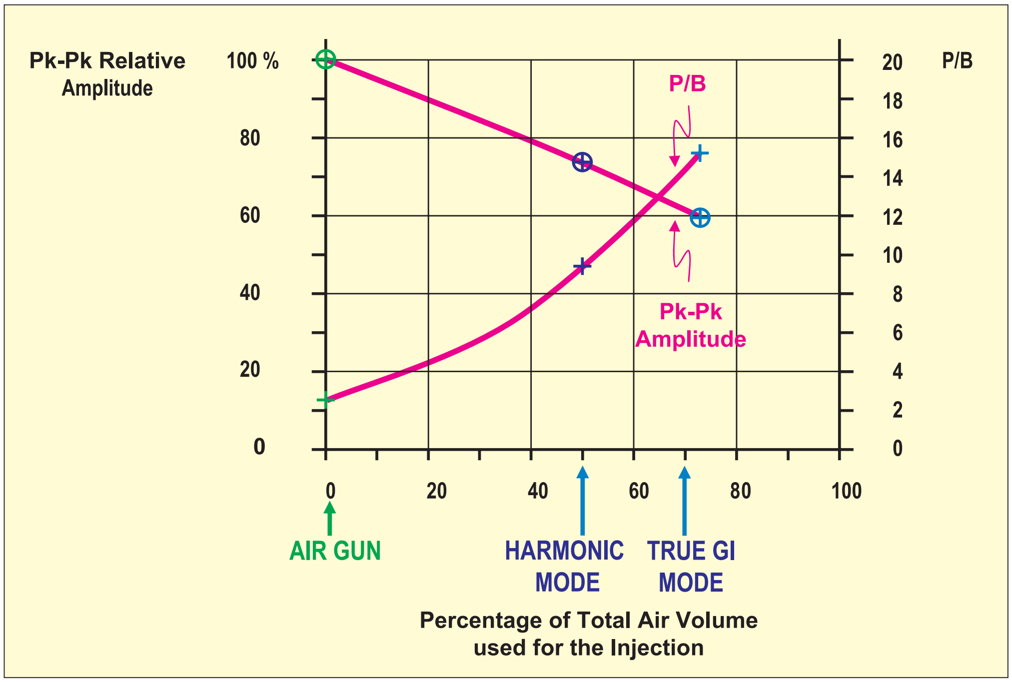
FAR FIELD SIGNATURE COMPARISON WITH SAME TOTAL VOLUME (150 in^3)
Pressure = 2,000 psi - Depth = 6.0 m - Filtered DFS 0 -256 Hz 72 dB/o

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



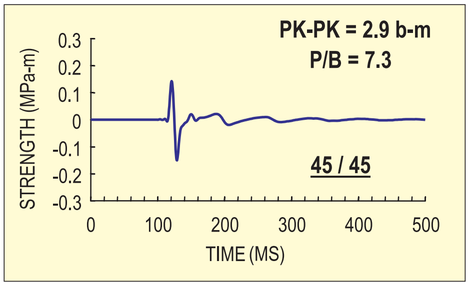
When the Injector has about the same volume as the Generator, the oscillation of the bubble created:

- 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.

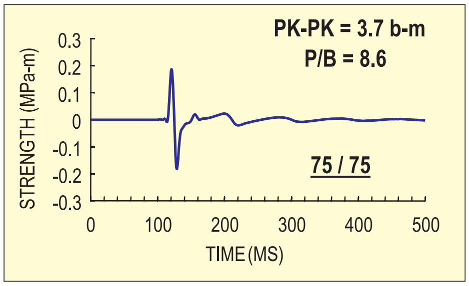
Below are three different harmonic mode far field signatures from a single GI GUN using three different volumes: 90 in^3, 150 in^3 and 210 in^3.

GI GUN HARMONIC MODE - 3 BASIC VOLUMES

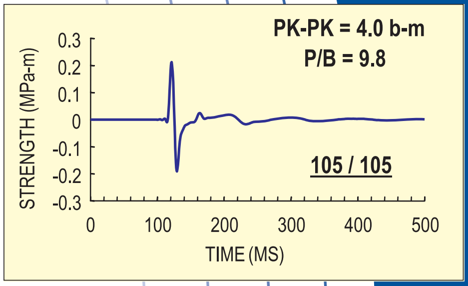
Pressure = 2,000 psi - Depth = 6.0 m - Filtered DFS 0-256 Hz 72 dB/o



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 in^3 (2 * 150 in^3) 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 in^3 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.

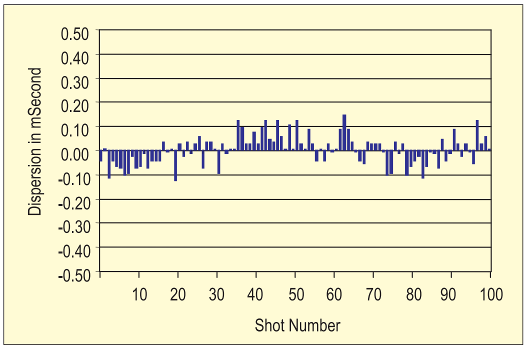
In addition, the smooth harmonic oscillation allows a sub-array of just two GI GUN with different volumes, so that the primaries add up. And, the final oscillation is further reduced by destructive interference and therefore, the primary-to-bubble ratio can reach a value of 14 with only two guns. This can be seen when adding the signature of one GI GUN 90 in^3 (left) with the signature of one GI GUN 210 in^3 (right). This leads to a two GI GUN 300 in^3 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



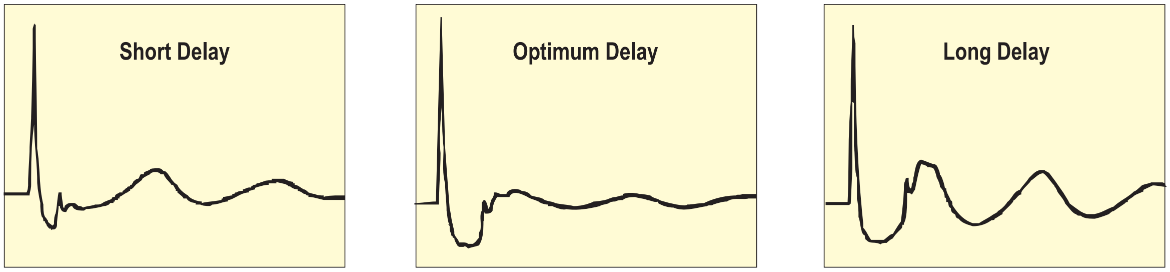
SIGNATURE QC

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.

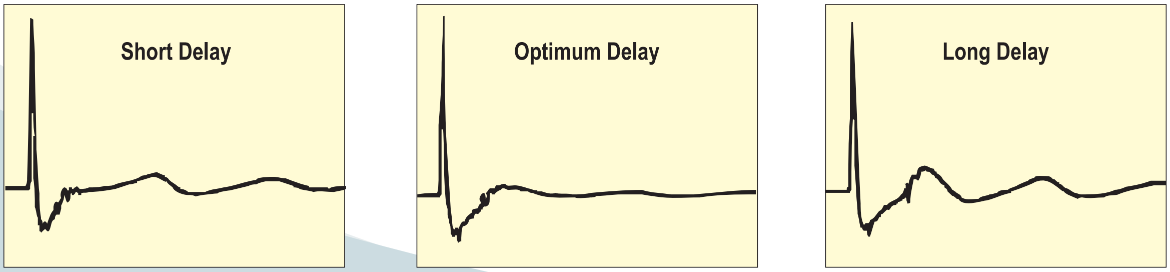
The graphs below compare the signals given by a near field hydrophone (top) with the signals given by the time break hydrophone (TB) located inside the bubble (bottom), for three different delays between the Generator and the Injector.

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

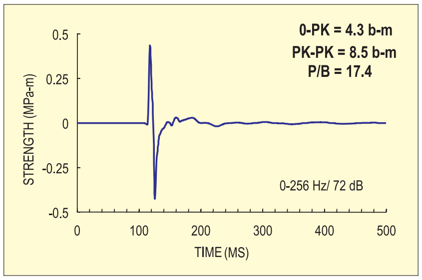
- Weight : 74 kg (163 lbs.)
- Length : 790 mm (31.0 in.)
- Width : 312 mm (12.3 in.)

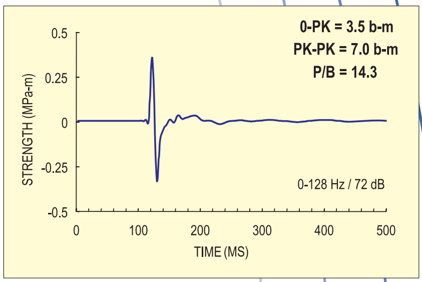
FAR FIELD SIGNATURE AND SPECTRUM

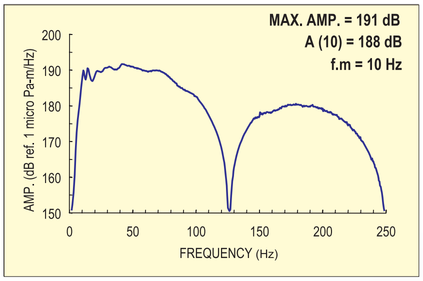
2 * GI GUN 300 in^3 Sub-Array

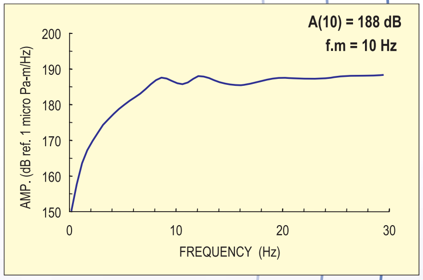
(G45 / I45) + (G105 / I105)

Pressure = 2,000 psi; Depth = 6.0 m







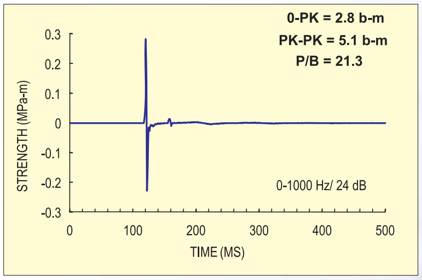


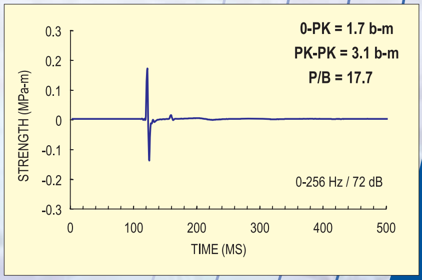
FAR FIELD SIGNATURE AND SPECTRUM

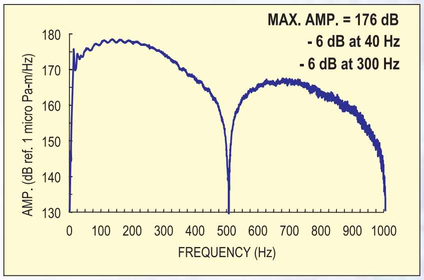
1 * GI GUN / 90 in^3 High Frequency

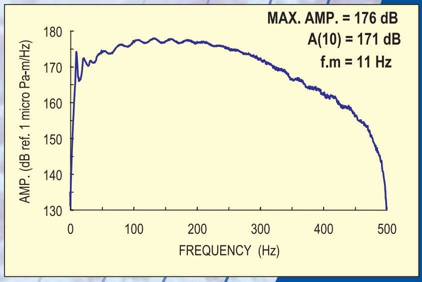
(G45 / I45)

Pressure = 2,000 psi; Depth = 1.5 mm









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www.sercel.com

Ahead of the Curve℠

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

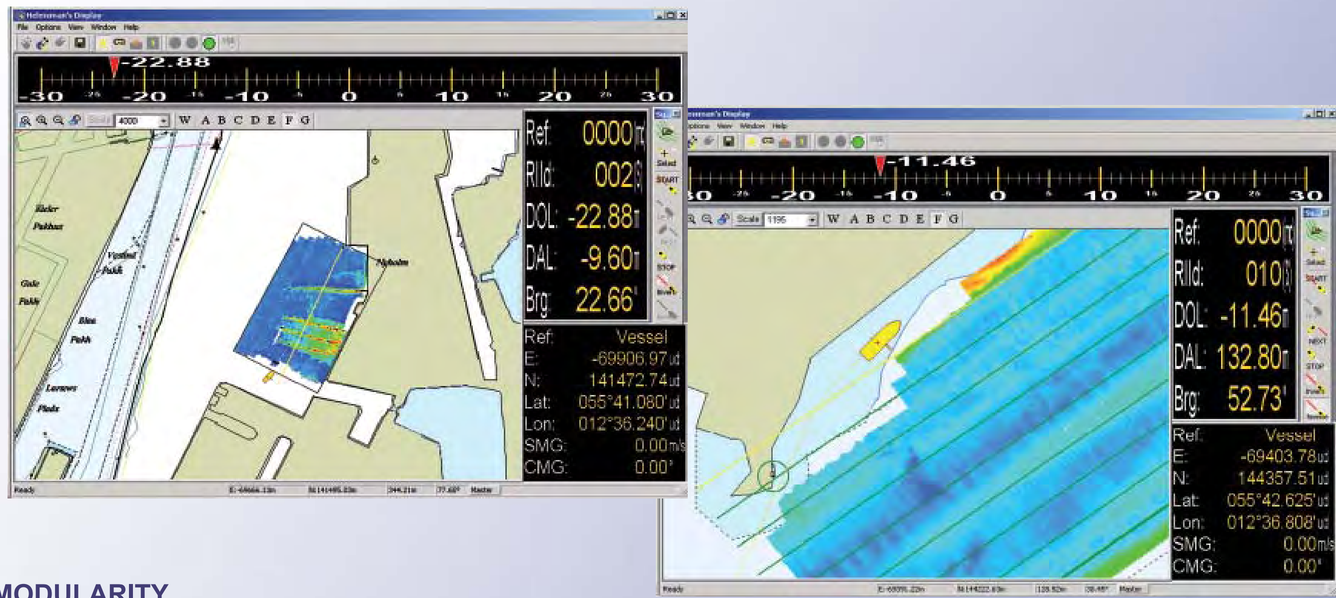
Appendix I-H:

NaviPac: Integrated Navigation Software

NaviPac
Integrated Navigation Software

EIVA

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

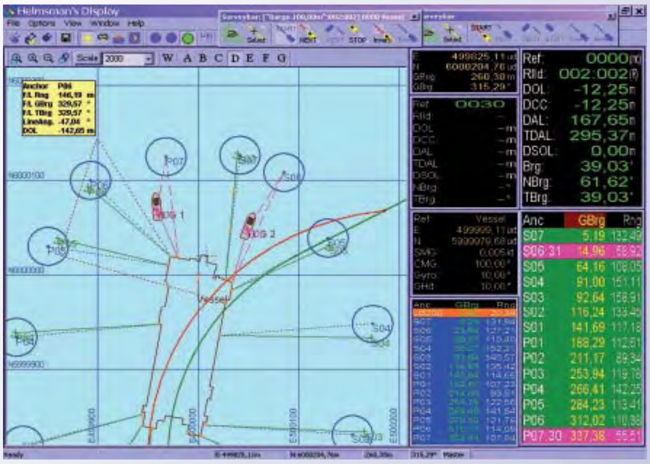
Vessel positions, survey lines (on DXF, DWG and ASCII formats) and objects may be displayed superimposed on C-Map or S57 based electronic chart displays. Coverage of depth information from singlebeam and/or multibeam echosounder as well as DTM's generated on-the-fly can be presented on the Navigation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

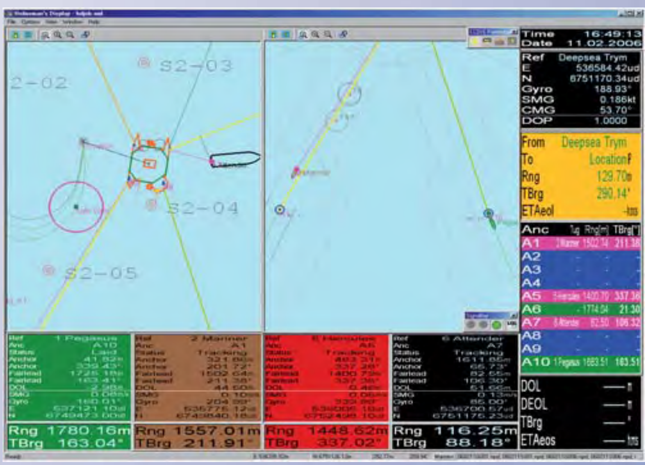
DATA HANDLING

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.

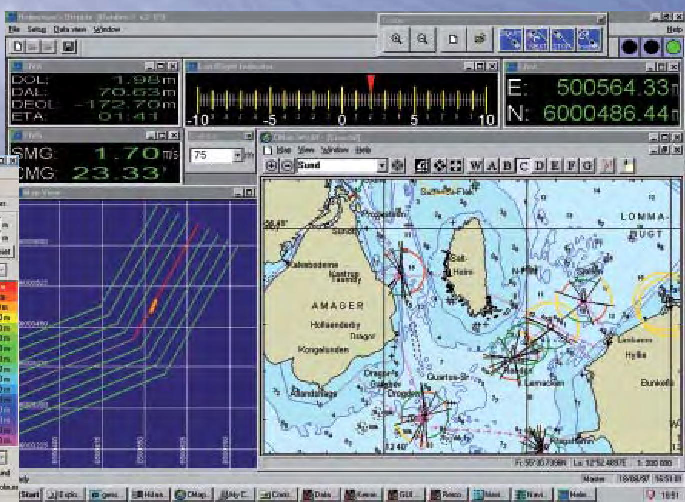
NAVIPAC LITE

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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NaviPac v1, 3/2006

Appendix I-I:

Thales DG16 GPS receiver

THALES

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 of fering 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 Dif ferential 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 dif ferential 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 i mproved 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.

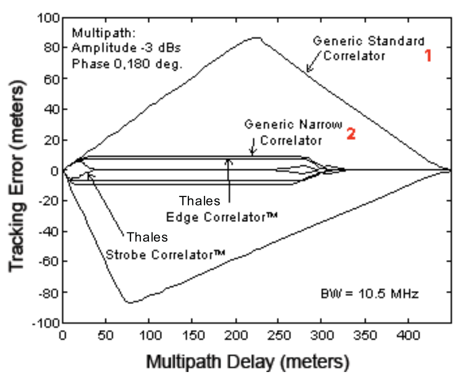
DG16 Development Kit

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

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 20FT 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 -10^0C.

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

TECHNICAL SPECIFICATION

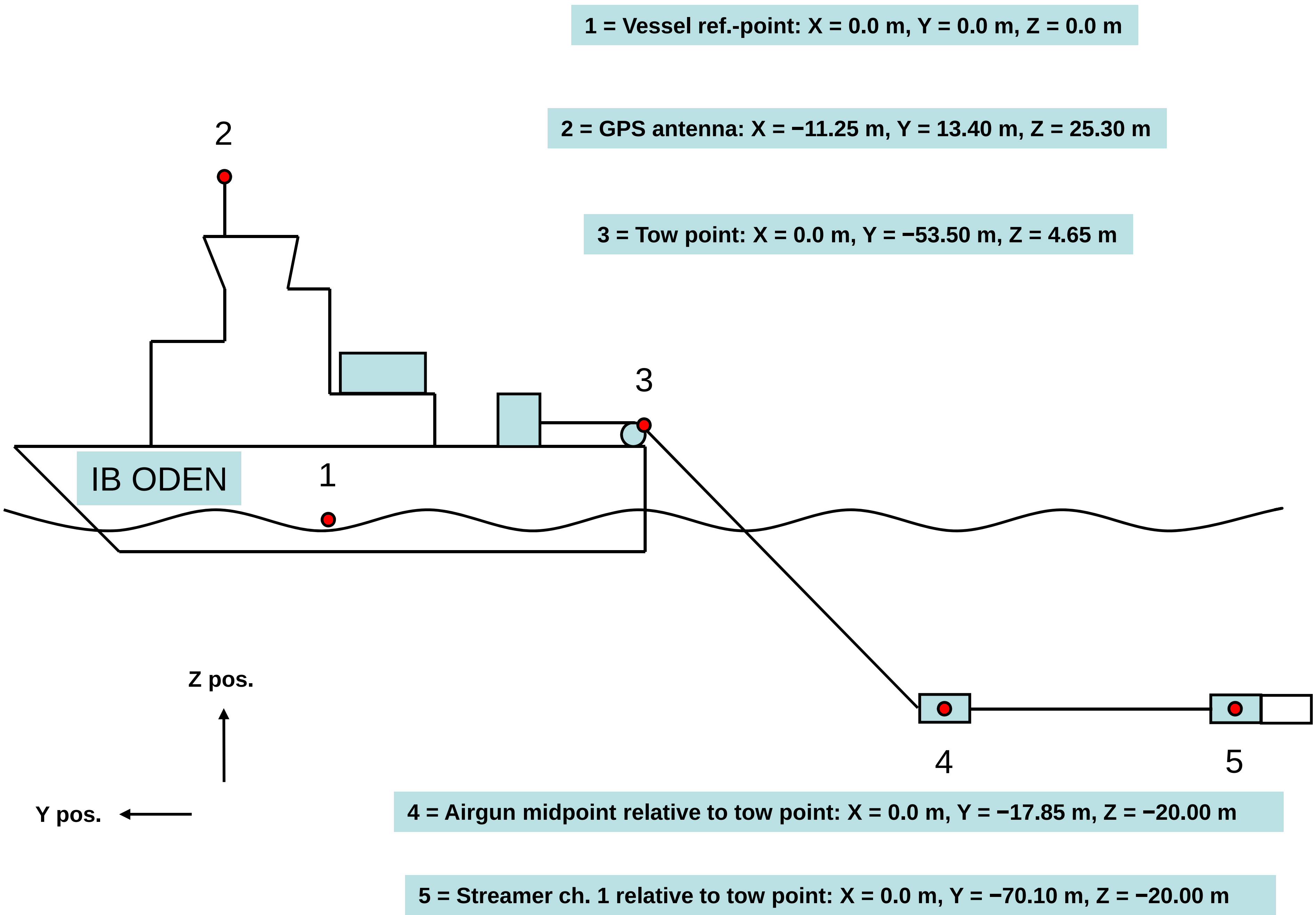
Hamworthy Containerised Model 2 x 185E MK2 in 20^{FT} ISO Container

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

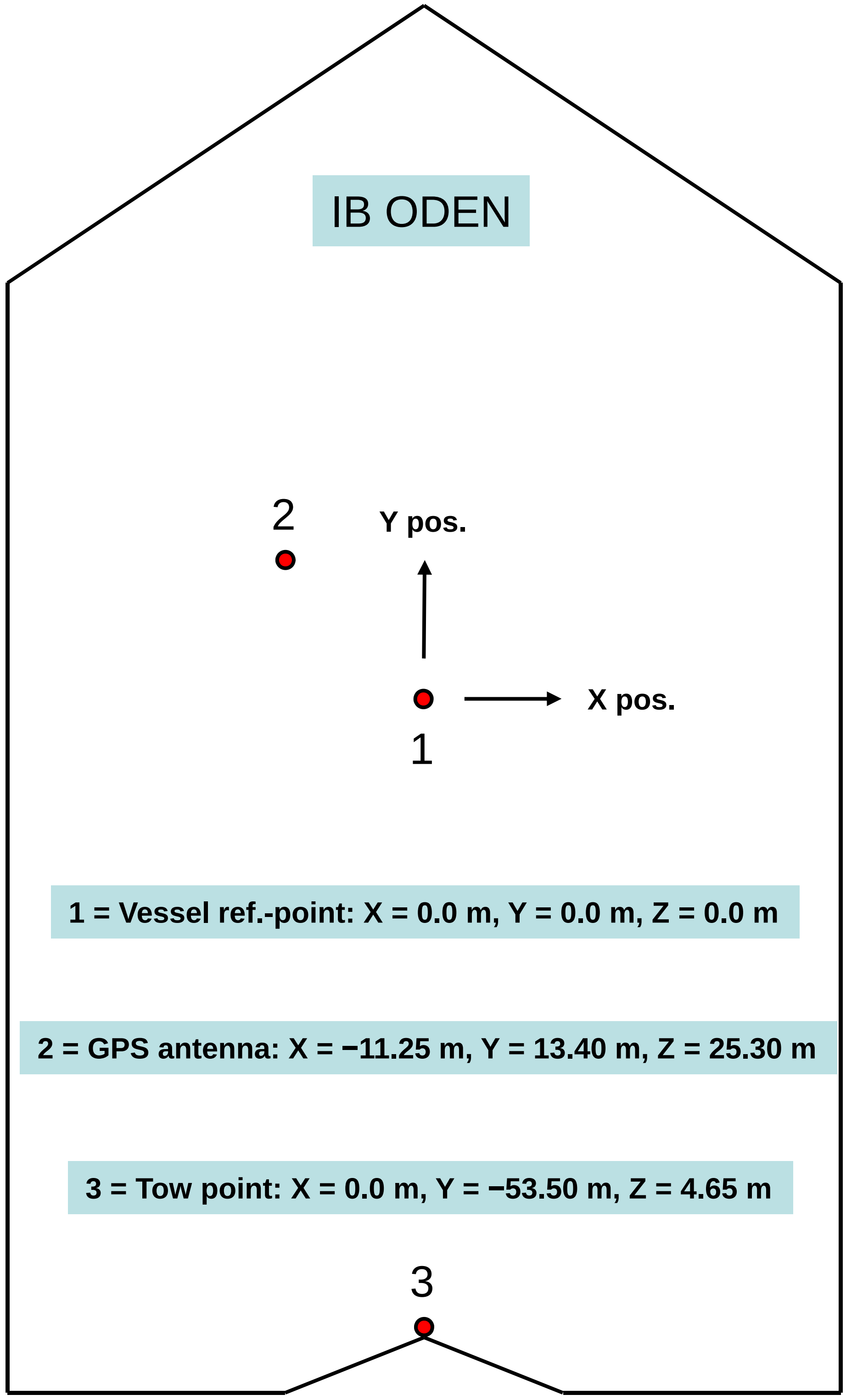
4TH190W70

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



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 m, Y = −53.50 m, Z = 4.65 m
2
3
IB ODEN
1
4
5
Z pos.
Y pos.
4 = Airgun midpoint relative to tow point: X = 0.0 m, Y = −17.85 m, Z = −20.00 m
5 = Streamer ch. 1 relative to tow point: X = 0.0 m, Y = −70.10 m, Z = −20.00 m


IB ODEN
2
Y pos.
X pos.
1
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 m, Y = −53.50 m, Z = 4.65 m
3

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

Date:		Marine Survey - General Information	Line:	LOMROG 2 xx

Cruise:	LOMROG 2	Ship:	IB Oden	Location:	Arctic Ocean

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		53	50	50	50	50		
Serial no. live sections									
Serial no. depth transducer (front of section)				5015	5016	5017	5005		
Serial no. A/D converter (front of section)				1144	1143	1147	1140		

Navigation:	
Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:			
Semimajor axis (m):	6878137	Latitude of true scale:	+ 81° 07'
Inverse flattening:	298,2572	False easting (m):	2000000
Scale factor at pole:	0,994	False northing (m):	2000000

Seismic Energy Source:	
Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
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):	11000
No of recording chs:	32
No of auxilliary chs:	4

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:	N/A
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	N/A
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
Tow length approx. 30 m and gun depth between 20 and 25 m, but values above entered into NaviPac

Date:	1-08-2009	Marine Survey - General Information	Line:	LOMROG 2 Test

Cruise:	LOMROG 2	Ship:	IB Oden	Location:	Arctic Ocean

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		53	50	50	50	50		
Serial no. live sections									
Serial no. depth transducer (front of section)				5015	5016	5017	5005		
Serial no. A/D converter (front of section)				1144	1143	1147	1140		

Navigation:	
Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:			
Semimajor axis (m):	6878137	Latitude of true scale:	+ 81° 07'
Inverse flattening:	298,2572	False easting (m):	2000000
Scale factor at pole:	0,994	False northing (m):	2000000

Seismic Energy Source:	
Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
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):	11000
No of recording chs:	32
No of auxilliary chs:	4

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:	N/A
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	N/A
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
Tow length approx. 30 m and gun depth between 20 and 25 m, but values above entered into NaviPac

Date:	9-08-2009	Marine Survey - General Information	Line:	LOMROG 2 01

Cruise:	LOMROG 2	Ship:	IB Oden	Location:	Arctic Ocean

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		53	50	50	50	50		
Serial no. live sections									
Serial no. depth transducer (front of section)				5015	5016	5017	5005		
Serial no. A/D converter (front of section)				1144	1143	1147	1140		

Navigation:

Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6878137	Latitude of true scale:	+ 81° 07'
Inverse flattening:	298,2572	False easting (m):	2000000
Scale factor at pole:	0,994	False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
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):	11000
No of recording chs:	32
No of auxilliary chs:	4

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:	N/A
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	N/A
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
Tow length approx. 30 m and gun depth between 20 and 25 m, but values above entered into NaviPac
Depth sensor in rear end for section 4

Date:	10-08-2009	Marine Survey - General Information	Line:	LOMROG 2 02

Cruise:	LOMROG 2	Ship:	IB Oden	Location:	Arctic Ocean

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		53	50	50	50	50		
Serial no. live sections										
Serial no. depth transducer (front of section)					5015	5016	5017	5005		
Serial no. A/D converter (front of section)					1144	1143	1147	1140		

Navigation:	
Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:			
Semimajor axis (m):	6878137	Latitude of true scale:	+ 81° 07'
Inverse flattening:	298,2572	False easting (m):	2000000
Scale factor at pole:	0,994	False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
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):	11000
No of recording chs:	32
No of auxilliary chs:	4

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:	N/A
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	N/A
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
Tow length approx. 30 m and gun depth between 20 and 25 m, but values above entered into NaviPac
Depth sensor in rear end for section 4

Date:	11-08-2009	Marine Survey - General Information	Line:	LOMROG 2 03

Cruise:	LOMROG 2	Ship:	IB Oden	Location:	Arctic Ocean

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		53	50	50	50	50		
Serial no. live sections									
Serial no. depth transducer (front of section)				5015	5016	5017	5005		
Serial no. A/D converter (front of section)				1144	1143	1147	1140		

Navigation:	
Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:			
Semimajor axis (m):	6878137	Latitude of true scale:	+ 81° 07'
Inverse flattening:	298,2572	False easting (m):	2000000
Scale factor at pole:	0,994	False northing (m):	2000000

Seismic Energy Source:	
Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
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):	11000
No of recording chs:	32
No of auxilliary chs:	4

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:	N/A
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	N/A
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
Tow length approx. 30 m and gun depth between 20 and 25 m, but values above entered into NaviPac
Depth sensor in rear end for section 4

Date:	18-08-2009	Marine Survey - General Information	Line:	LOMROG 2 04

Cruise:	LOMROG 2	Ship:	IB Oden	Location:	Arctic Ocean

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		53	50	50	50	50		
Serial no. live sections									
Serial no. depth transducer (front of section)				5015	5016	5017	5004		
Serial no. A/D converter (front of section)				1144	1143	1147	1476		

Navigation:	
Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:			
Semimajor axis (m):	6878137	Latitude of true scale:	+ 81° 07'
Inverse flattening:	298,2572	False easting (m):	2000000
Scale factor at pole:	0,994	False northing (m):	2000000

Seismic Energy Source:	
Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
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):	11000
No of recording chs:	32
No of auxilliary chs:	4

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:	N/A
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	N/A
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
Tow length approx. 30 m and gun depth between 20 and 25 m, but values above entered into NaviPac
Depth sensor in rear end for the section 3 and 4

Date:	18-08-2009	**Marine Survey - General Information**	**Line:**	LOMROG 2 05					
Cruise:	LOMROG 2	**Ship:**	IB Oden	**Location:**	Arctic Ocean				

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		53	50	50	50	50		
Serial no. live sections										
Serial no. depth transducer (front of section)					5015	5016	5010	5004		
Serial no. A/D converter (front of section)					1144	1143	1147	1476		

Navigation:	
Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:			
Semimajor axis (m):	6878137	Latitude of true scale:	+ 81° 07'
Inverse flattening:	298,2572	False easting (m):	2000000
Scale factor at pole:	0,994	False northing (m):	2000000

Seismic Energy Source:	
Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
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):	11000
No of recording chs:	32
No of auxilliary chs:	4

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:	N/A
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	N/A
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
Tow length approx. 30 m and gun depth between 20 and 25 m, but values above entered into NaviPac
Depth sensor for section 3 and 4 blocked, due to posible malfunction at depth down to 300 meters of water depth

Date:	19-08-2009	Marine Survey - General Information	Line:	LOMROG 2 06

Cruise:	LOMROG 2	Ship:	IB Oden	Location:	Arctic Ocean

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		53	50	50	50	50		
Serial no. live sections									
Serial no. depth transducer (front of section)				5015	5016	5010	5004		
Serial no. A/D converter (front of section)				1144	1143	1147	1476		

Navigation:	
Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:			
Semimajor axis (m):	6878137	Latitude of true scale:	+ 81° 07'
Inverse flattening:	298,2572	False easting (m):	2000000
Scale factor at pole:	0,994	False northing (m):	2000000

Seismic Energy Source:	
Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
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):	11000
No of recording chs:	32
No of auxilliary chs:	4

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:	N/A
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	N/A
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
Tow length approx. 30 m and gun depth between 20 and 25 m, but values above entered into NaviPac
Depth sensor for section 3 and 4 blocked, due to posible malfunction at depth down to 300 meters of water depth

Date:	22-08-2009	Marine Survey - General Information	Line:	LOMROG 2 07

Cruise:	LOMROG 2	Ship:	IB Oden	Location:	Arctic Ocean

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		53	50	50	50	50		
Serial no. live sections									
Serial no. depth transducer (front of section)				5015	5016	5010	5004		
Serial no. A/D converter (front of section)				1144	1143	1147	1476		

Navigation:

Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6878137	Latitude of true scale:	+ 81° 07'
Inverse flattening:	298,2572	False easting (m):	2000000
Scale factor at pole:	0,994	False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
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):	11000
No of recording chs:	32
No of auxilliary chs:	4

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:	N/A
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	N/A
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
Tow length approx. 30 m and gun depth between 20 and 25 m, but values above entered into NaviPac
Depth sensor for section 3 and 4 open again. Tested sectiion 5017 and 5005 with 30 bars. Worked well - no air leakaged
Depth sensor in rear end of section 5004

Date:	23-08-2009	**Marine Survey - General Information**	**Line:**	LOMROG 2 08

Cruise:	LOMROG 2	**Ship:**	IB Oden	**Location:**	Arctic Ocean

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		53	50	50	50	50		
Serial no. live sections										
Serial no. depth transducer (front of section)					5015	5016	5010	5004		
Serial no. A/D converter (front of section)					1144	1143	1147	1476		

Navigation:

Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6878137	Latitude of true scale:	+ 81° 07'
Inverse flattening:	298,2572	False easting (m):	2000000
Scale factor at pole:	0,994	False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
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):	11000
No of recording chs:	32
No of auxilliary chs:	4

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:	N/A
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	N/A
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
Tow length approx. 30 m and gun depth between 20 and 25 m, but values above entered into NaviPac

Depth sensor in rear end of section 5004

Date:	23-08-2009	Marine Survey - General Information	Line:	LOMROG 2 09

Cruise:	LOMROG 2	Ship:	IB Oden	Location:	Arctic Ocean

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		53	50	50	50	50		
Serial no. live sections									
Serial no. depth transducer (front of section)				5015	5016	5010	5004		
Serial no. A/D converter (front of section)					1143	1147	1476		

Navigation:	
Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:			
Semimajor axis (m):	6878137	Latitude of true scale:	+ 81° 07'
Inverse flattening:	298,2572	False easting (m):	2000000
Scale factor at pole:	0,994	False northing (m):	2000000

Seismic Energy Source:	
Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
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):	11000
No of recording chs:	32
No of auxilliary chs:	4

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:	New vib section
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	N/A
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
Tow length approx. 30 m and gun depth between 20 and 25 m, but values above entered into NaviPac

Depth sensor in rear end of section 5004

Date:	24-08-2009	Marine Survey - General Information	Line:	LOMROG 2 10

Cruise:	LOMROG 2	Ship:	IB Oden	Location:	Arctic Ocean

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		53	50	50	50	50		
Serial no. live sections										
Serial no. depth transducer (front of section)					5015	5016	5010	5004		
Serial no. A/D converter (front of section)					1144	1143	1147	1476		

Navigation:

Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6878137	Latitude of true scale:	+ 81° 07'
Inverse flattening:	298,2572	False easting (m):	2000000
Scale factor at pole:	0,994	False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
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):	11000
No of recording chs:	32
No of auxilliary chs:	4

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:	N/A
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	N/A
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
Tow length approx. 30 m and gun depth between 20 and 25 m, but values above entered into NaviPac

Depth sensor in rear end of section 5004

Date:	27-08-2009	Marine Survey - General Information	Line:	LOMROG 2 11

Cruise:	LOMROG 2	Ship:	IB Oden	Location:	Arctic Ocean

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		53	50	50	50	50		
Serial no. live sections										
Serial no. depth transducer (front of section)					5015	5016	5010	5004		
Serial no. A/D converter (front of section)					1144	1143	1147	1476		

Navigation:

Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6878137	Latitude of true scale:	+ 81° 07'
Inverse flattening:	298,2572	False easting (m):	2000000
Scale factor at pole:	0,994	False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
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):	11000
No of recording chs:	32
No of auxilliary chs:	4

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:	N/A
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	N/A
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
Tow length approx. 30 m and gun depth between 20 and 25 m, but values above entered into NaviPac

Depth sensor in rear end of section 5004

Date:	28-08-2009	Marine Survey - General Information	Line:	LOMROG 2 12

Cruise:	LOMROG 2	Ship:	IB Oden	Location:	Arctic Ocean

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		53	50	50	50	50		
Serial no. live sections									
Serial no. depth transducer (front of section)				5015	5016	5010	5004		
Serial no. A/D converter (front of section)				1144	1143	1147	1476		

Navigation:

Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6878137	Latitude of true scale:	+ 81° 07'
Inverse flattening:	298,2572	False easting (m):	2000000
Scale factor at pole:	0,994	False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
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):	11000
No of recording chs:	32
No of auxilliary chs:	4

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:	N/A
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	N/A
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
Tow length approx. 30 m and gun depth between 20 and 25 m, but values above entered into NaviPac

Depth sensor in rear end of section 5004

Date:	29-08-2009	Marine Survey - General Information	Line:	LOMROG 2 13

Cruise:	LOMROG 2	Ship:	IB Oden	Location:	Arctic Ocean

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		53	50	50	50	50		
Serial no. live sections									
Serial no. depth transducer (front of section)				5015	5016	5010	5004		
Serial no. A/D converter (front of section)				1144	1143	1147	1476		

Navigation:	
Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:			
Semimajor axis (m):	6878137	Latitude of true scale:	+ 81° 07'
Inverse flattening:	298,2572	False easting (m):	2000000
Scale factor at pole:	0,994	False northing (m):	2000000

Seismic Energy Source:	
Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
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):	11000
No of recording chs:	32
No of auxilliary chs:	4

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:	N/A
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	N/A
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
Tow length approx. 30 m and gun depth between 20 and 25 m, but values above entered into NaviPac

Depth sensor in rear end of section 5004

Date:	30-08-2009	Marine Survey - General Information	Line:	LOMROG 2 14

Cruise:	LOMROG 2	Ship:	IB Oden	Location:	Arctic Ocean

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		53	50	50	50	50		
Serial no. live sections										
Serial no. depth transducer (front of section)					5015	5016	5010	5004		
Serial no. A/D converter (front of section)					1144	1143	1147	1476		

Navigation:

Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6878137	Latitude of true scale:	+ 81° 07'
Inverse flattening:	298,2572	False easting (m):	2000000
Scale factor at pole:	0,994	False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
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):	11000
No of recording chs:	32
No of auxilliary chs:	4

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:	N/A
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	N/A
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
Tow length approx. 30 m and gun depth between 20 and 25 m, but values above entered into NaviPac

Depth sensor in rear end of section 5004

Date:	31-08-2009	Marine Survey - General Information	Line:	LOMROG 2 15

Cruise:	LOMROG 2	Ship:	IB Oden	Location:	Arctic Ocean

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)	-20,10
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		3	50	50	50	50	50	
Serial no. live sections									
Serial no. depth transducer (front of section)				5009	5015	5016	5010	5004	
Serial no. A/D converter (front of section)				1477	1144	1143	1147	1476	

Navigation:

Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6878137	Latitude of true scale:	+ 81° 07'
Inverse flattening:	298,2572	False easting (m):	2000000
Scale factor at pole:	0,994	False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
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):	11000
No of recording chs:	32
No of auxilliary chs:	4

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	33
Length of live section (m):	250
No. of live sections:	5
No. of channels:	40
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	Not used
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	N/A
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
Tow length approx. 30 m and gun depth between 20 and 25 m, but values above entered into NaviPac

Depth sensor in rear end of section 5004
OBS ! Added one more vib section, 25 meter

Date:	31-08-2009	Marine Survey - General Information	Line:	LOMROG 2 16

Cruise:	LOMROG 2	Ship:	IB Oden	Location:	Arctic Ocean

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)	-20,10
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		3	50	50	50	50	50	
Serial no. live sections									
Serial no. depth transducer (front of section)				5009	5015	5016	5010	5004	
Serial no. A/D converter (front of section)				1477	1144	1143	1147	1476	

Navigation:

Software:	NaviPac
Projection:	Universal Polar Stereographin, N
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6878137	Latitude of true scale:	+ 81° 07'
Inverse flattening:	298,2572	False easting (m):	2000000
Scale factor at pole:	0,994	False northing (m):	2000000

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. GI-Gun:	4425
Volume GI (cu.inch):	250-105
Serial no. G-Gun:	18391
Volume G (cu.inch):	250
Delay:	**16mS**
Pressure (bar):	200
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):	11000
No of recording chs:	32
No of auxillary chs:	4

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	33
Length of live section (m):	250
No. of live sections:	5
No. of channels:	40
No. of channels/live section:	8
channel interval (m):	6,25
No. of hydrophones/channel:	8
Serial no. Vibration section:	not used
Serial no. 10 Mb repeater:	? (inside slipring)
Serial no. 100 Mb repeater:	N/A
Planned depth (m):	20

Remarks:

Airgun midpoint and Channel 1 midpoint positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 2 sec, one by one - means 8 sec in total
Tow length approx. 30 m and gun depth between 20 and 25 m, but values above entered into NaviPac

Depth sensor in rear end of section 5004
OBS ! Added one more vib section, 25 meter

TAPE INVENTORY LOG

Cruise: LOMROG 2 **Area:** North of Greenland

Cartridge	Line	Date dd-mon-yy	Record length (ms)	Sample interval (ms)	File/SP range	
101	4ads test	9-aug-09	11000	1	3000	5048
102	02	10-aug-09	11000	1	1000	2370
103	03	11-aug-09	11000	1	2371	3435
104	04	18-aug-09	11000	1	3440	3792
105	05	18-aug-09	11000	1	3793	4758
106	06	19-aug-09	11000	1	4759	5968
107	07	22-aug-09	11000	1	5969	7191
108	08	23-aug-09	11000	1	7192	7422
109	09	23-aug-09	11000	1	7424	8187
110	10	24-aug-09	11000	1	8188	9018
111	11	27-aug-09	11000	1	9019	10929
112	12	28-aug-09	11000	1	10932	12865
113	13	29-aug-09	11000	1	12866	14883
114	14	30-aug-09	11000	1	14884	16970
115	15	30-aug-09	11000	1	16971	17125
116	16	31-aug-09	11000	1	17126	18944

Cruise: LOMROG 2 **Ship:** IB Oden **Location:** Arctic Ocean **Page:** 1/3

Line ID	Date d-m-y	SOL/EOL	H:M	Start/End Latitude N	Start/End Longitude E/W(-)	Remarks gun/streamer depths	Data storage LTO-2	Data storage HDD	Data storage Navigation	Navipac
Test	01-08-2009	100	09:45	° ´	° ´	SOL	No data on tape	E:\Lomrog2\Tes	094547_C	151
		357	10:36	° ´	° ´	EOL				409
				° ´	° ´					
1	09-08-2009	100	09:18	° ´	° ´	SOL	No data on tape	E:\Lomrog2\000	091749_C	101
		293	10:20	° ´	° ´	EOL				294
				° ´	° ´					
01x	09-08-2009	294	10:21	° ´	° ´		No data on tape	E:\Lomrog2\000	x	x
		298		° ´	° ´					x
				° ´	° ´					
2	10-08-2009	1000	12:52	° ´	° ´	SOL	102	E:\Lomrog2\000	125245_C	1001
		2370	17:26	° ´	° ´	EOL				2371
				° ´	° ´					
3	11-08-2009	2371	06:46	° ´	° ´	SOL	103	E:\Lomrog2\000	064610_C	2373
		3435	10:19	° ´	° ´	EOL				3438
4	18-08-2009	3440	07:20	° ´	° ´	SOL	104	E:\Lomrog2\000	072019_C	3441
		3464	07:25	° ´	° ´	leakage paa streamer				3463
		3791		° ´	° ´	only 24 ch				
		3792	08:31	° ´	° ´	EOL				3793
5	18-08-2009	3793	11:26	° ´	° ´	SOL	105	E:\Lomrog2\000	110126_C	3812
		3905	12:35	° ´	° ´					3925
		4263		° ´	° ´					4283
		4758	14:14	° ´	° ´	EOL				4778
6	19-08-2009	4759	01:32	° ´	° ´	SOL	106	E:\Lomrog2\000	013143_C	4781
		5064	02:33	° ´	° ´					5086
		5540		° ´	° ´	gun out of water				
		5968	05:33	° ´	° ´	EOL				5990
7	22-08-2009	5969	06:22	° ´	° ´	SOL, ch 24 noisy	107	E:\Lomrog2\000	062331_C	5993
		6050		° ´	° ´	gun slukket				
		6470	08:04	° ´	° ´	gunstart				
		6655	08:41	° ´	° ´	streamer ude af vandet				
		6724		° ´	° ´	kanon og del af streamer u				
		7191		° ´	° ´	EOL				7215
8	23-08-2009	7192	01:30	° ´	° ´	SOL	108	E:\Lomrog2\000	012901_C	7218
		7263	01:44	° ´	° ´	kun I gun paa de naeste 10				7283

E:\NaviPac_Data\NaviPac_logs\Lomrog2\YYMMDD\xxxx_C

Cruise: LOMROG 2 **Ship:** IB Oden **Location:** Arctic Ocean **Page:** 2/3

Line ID	Date	SOL/EOL	H:M	Start/End				Remarks	Data storage			Navipac
	d-m-y			Latitude N		Longitude E/W(-)		gun/streamer depths	LTO-2	HDD	Navigation	
8	23-08-2009	7280	01:48	°	´	°	´	guns runnig again	108	E:\Lomrog2\00(	012901_C	7306
		7422		°	´	°	´	geoeel problem				
9	23-08-2009	7424	12:38	°	´	°	´	SOL, AIS on	109	E:\Lomrog2\00(	123818_C	7455
				°	´	°	´	no depthsensor working				
		8187		°	´	°	´	EOL				8219
10	24-08-2009	8188	18:16	°	´	°	´	SOL	110	E:\Lomrog2\00:	181506_C	8221
		9018	21:00	°	´	°	´	EOL				9052
11	27-08-2009	9019		°	´	°	´	SOL, AIS off	111	E:\Lomrog2\00:	065432_C	
				°	´	°	´	File 9089 to 9030 noise				
		9031	06:55	°	´	°	´					
		9036		°	´	°	´	a few shots missing, not ar				
				°	´	°	´	problem with navipac log, r			065753_C	
		9053	07:00	°	´	°	´	all up running				9083
			09:15	°	´	°	´	AIS on				
		10929		°	´	°	´	EOL				
				°	´	°	´	Niose files 10930 and 1093				
12	28-08-2009	10932	09:42	°	´	°	´	SOL, AIS off	112	E:\Lomrog2\00:	094122_C	10962
		10955		°	´	°	´	gun pressure at 180 bar				
		11735						compressure fault				
		11777						back to 150 bar				
		12865	16:09	°	´	°	´	EOL				
13	29-08-2009	12866	04:29	°	´	°	´	SOL, AIS off	113	E:\Lomrog2\00:	042806_c	12897
		12907		°	´	°	´	gun pressure at 180 bar				
		12927		°	´	°	´	power drop on ship - comp				
		12944		°	´	°	´	pressure up again				
		13495		°	´	°	´	power drop on ship - comp				
		13525		°	´	°	´	pressure up again				
		13612		°	´	°	´	power drop on ship - comp				
		13641		°	´	°	´	pressure up again				
		14883	11:11	°	´	°	´	EOL				14914
14	30-08-2009	14884	02:58	°	´	°	´	SOL, AIS off Pressure low.		E:\Lomrog2\00:	025704_C	14920
		14999		°	´	°	´	pressure 190 bar				
		15013		°	´	°	´	GunSyncProblemRep Tres				
		15355		°	´	°	´	AIS on				15396

E:\NaviPac_Data\NaviPac_logs\Lomrog2\YYMMDD\xxxx_C

Cruise:	LOMROG 2	**Ship:**	IB Oden	**Location:**	Arctic Ocean	**Page:**	3/3

Line ID	**Date** d-m-y	**SOL/EOL**	**H:M**	**Start/End** Latitude N	Longitude E/W(-)	**Remarks** **gun/streamer depths**	**Data storage** LTO-2	HDD	Navigation	**Navipac**
14	30-08-2009	15456		° ´	° ´	Pressure low 2 comp down				
		15475		° ´	° ´	pressure 190 bar				
		15924		° ´	° ´	Only Injector; ship stuck in				
		16033		° ´	° ´	Guns:Full power & Ship: fu				
		16970		° ´	° ´	EOL				17011
15	30-08-2009	16971	00:46	° ´	° ´	SOL, AIS off	115	E:\Lomrog2\00	004629_C	17014
		17035		° ´	° ´	gun pressure 140				
		17125		° ´	° ´	EOL				17168
16	31-08-2009	17126	02:48	° ´	° ´	SOL, AIS off	116	E:\Lomrog2\00	024801_C	
		17430		° ´	° ´	Stuck - guns off				
		17549		° ´	° ´	guns on				
		17570		° ´	° ´	Stuck - guns off				
		17575		° ´	° ´	guns on				
		17950		° ´	° ´	narrow passage w. heavy i				
		17985		° ´	° ´	approx normal conditions				
		18134		° ´	° ´	Guns shut down; ships eng				18179
		18170	06:17	° ´	° ´	Gun on again				
		18944	08:51	° ´	° ´	EOL				18989
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
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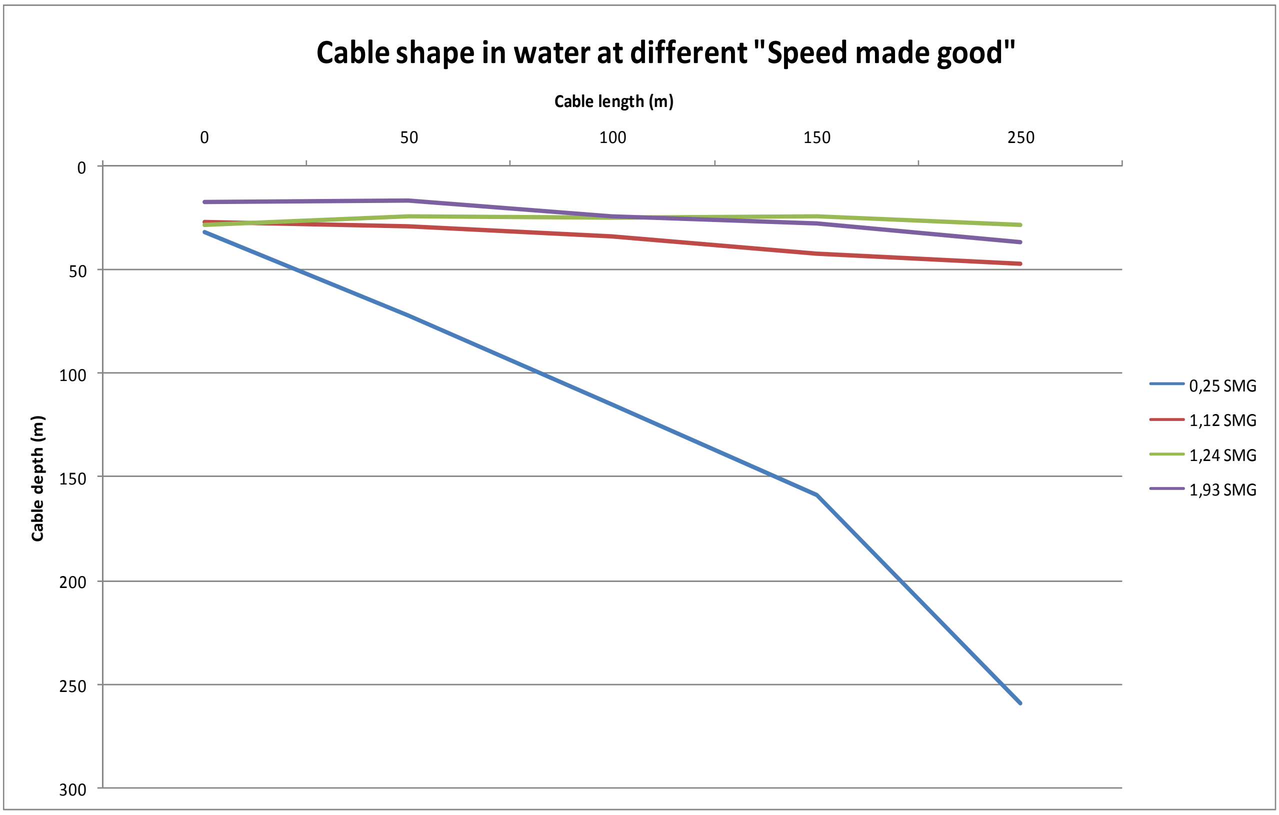
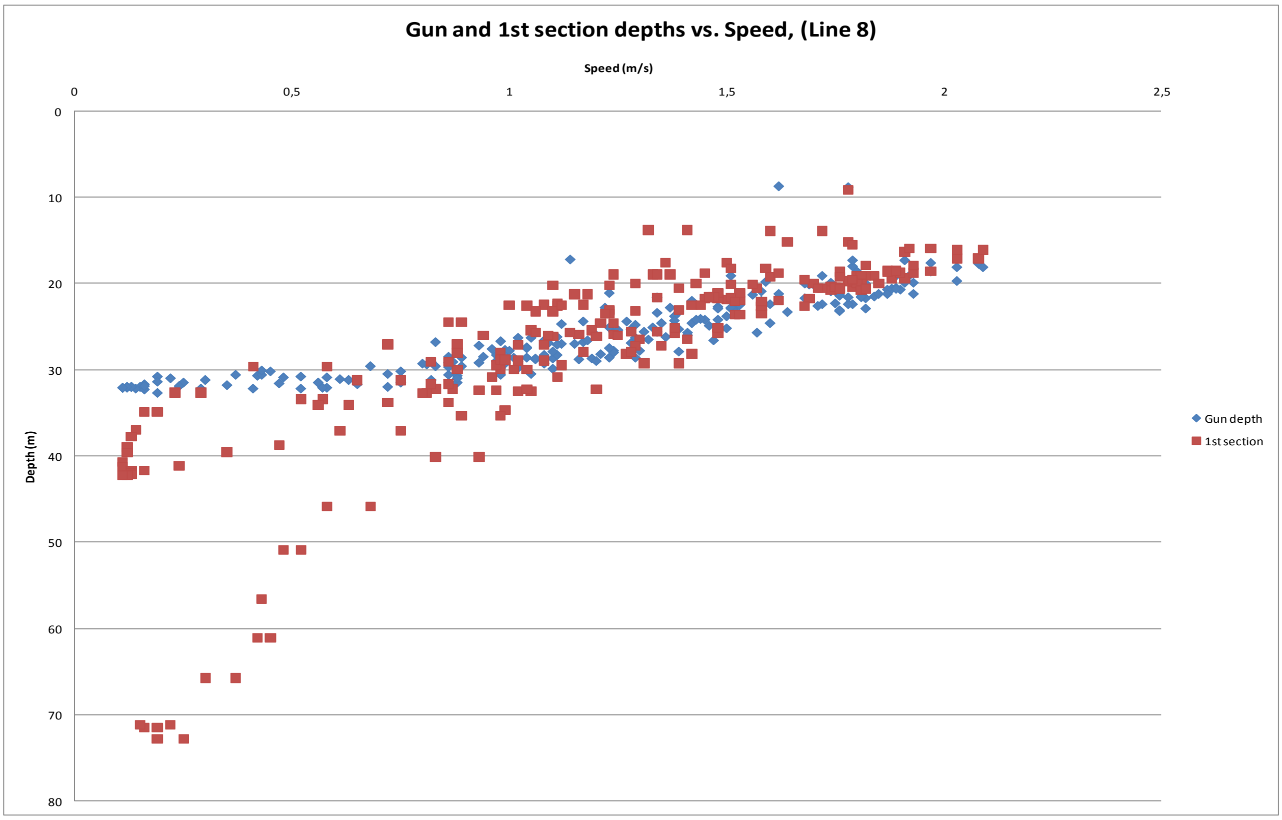
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					

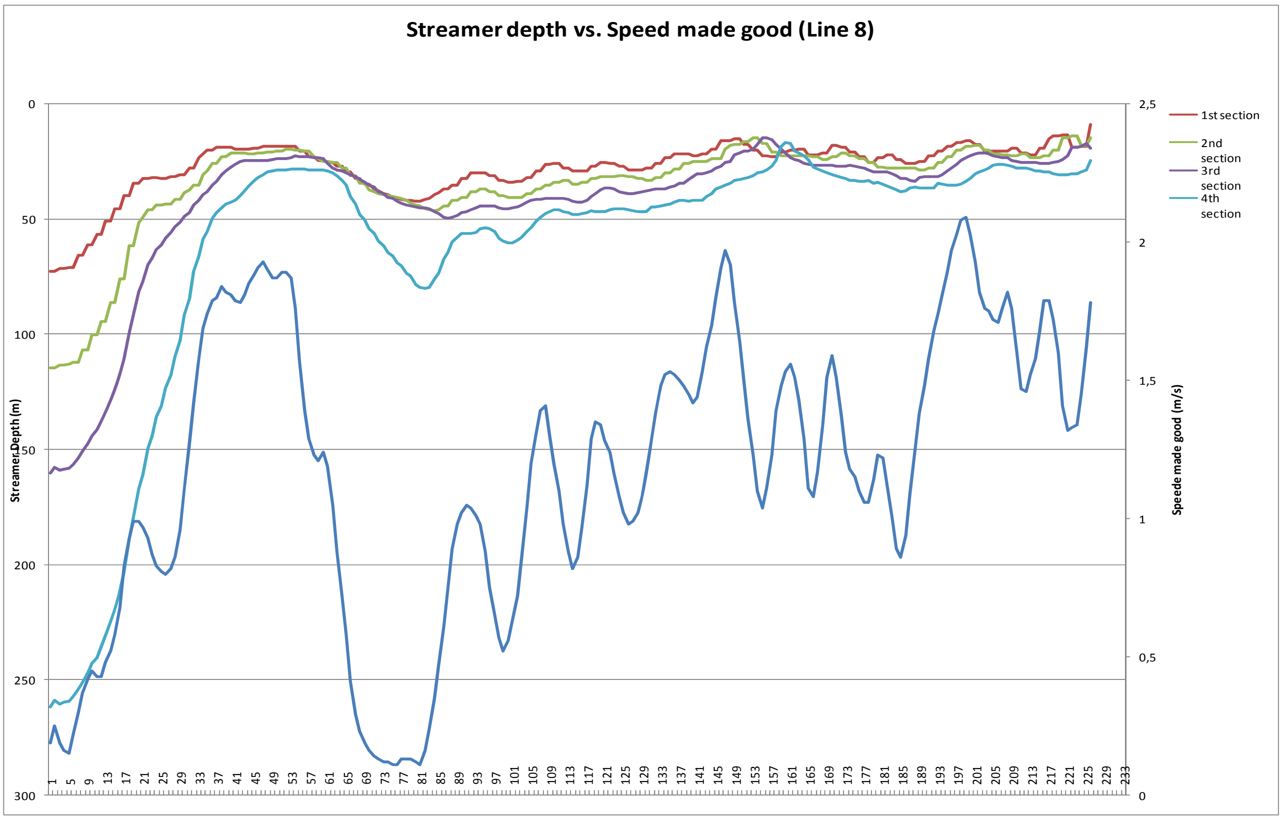
E:\NaviPac_Data\NaviPac_logs\Lomrog2\YYMMDD\xxxx_C

Appendix IV: Logs of Air gun and streamer depths and ships speed

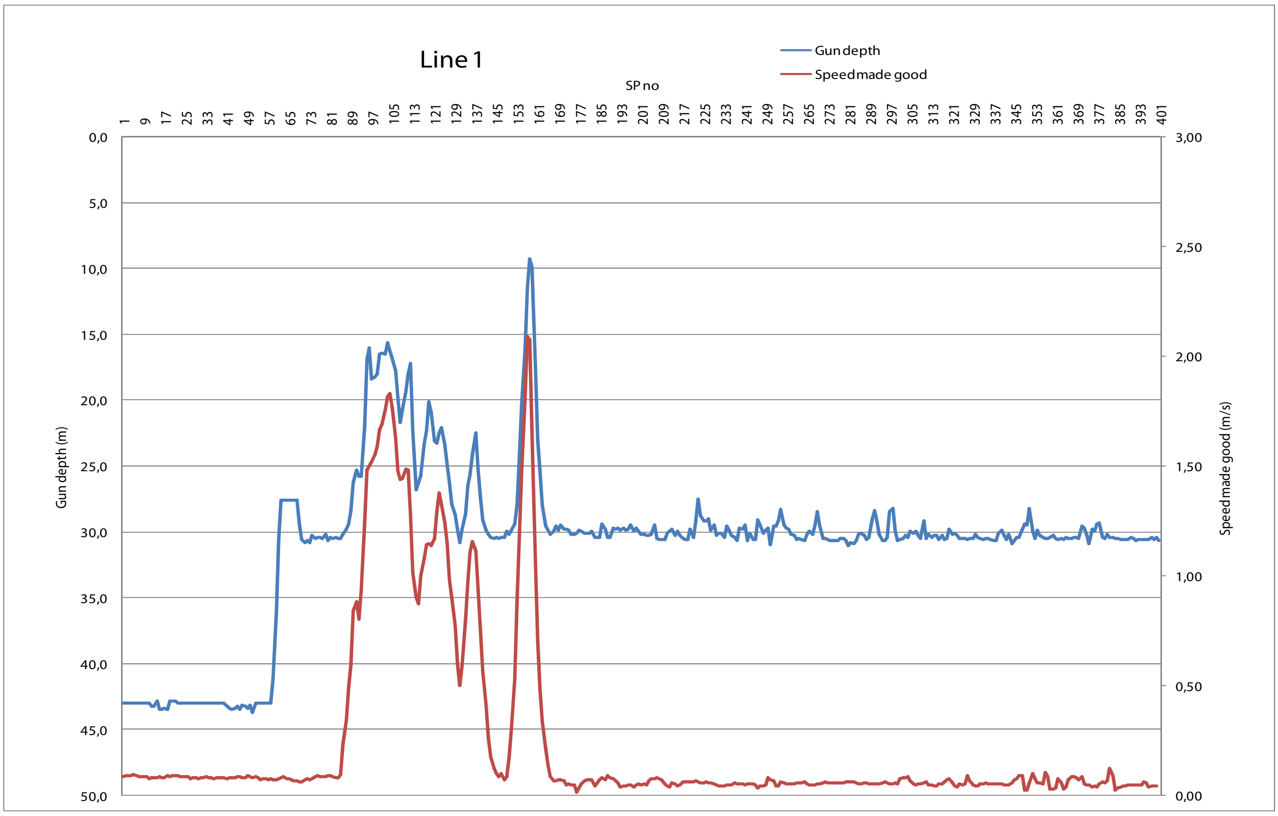

Cable shape in water at different "Speed made good"
Cable length (m)
0
50
100
150
250
Cable depth (m)
0
50
100
150
200
250
300
0,25 SMG
1,12 SMG
1,24 SMG
1,93 SMG

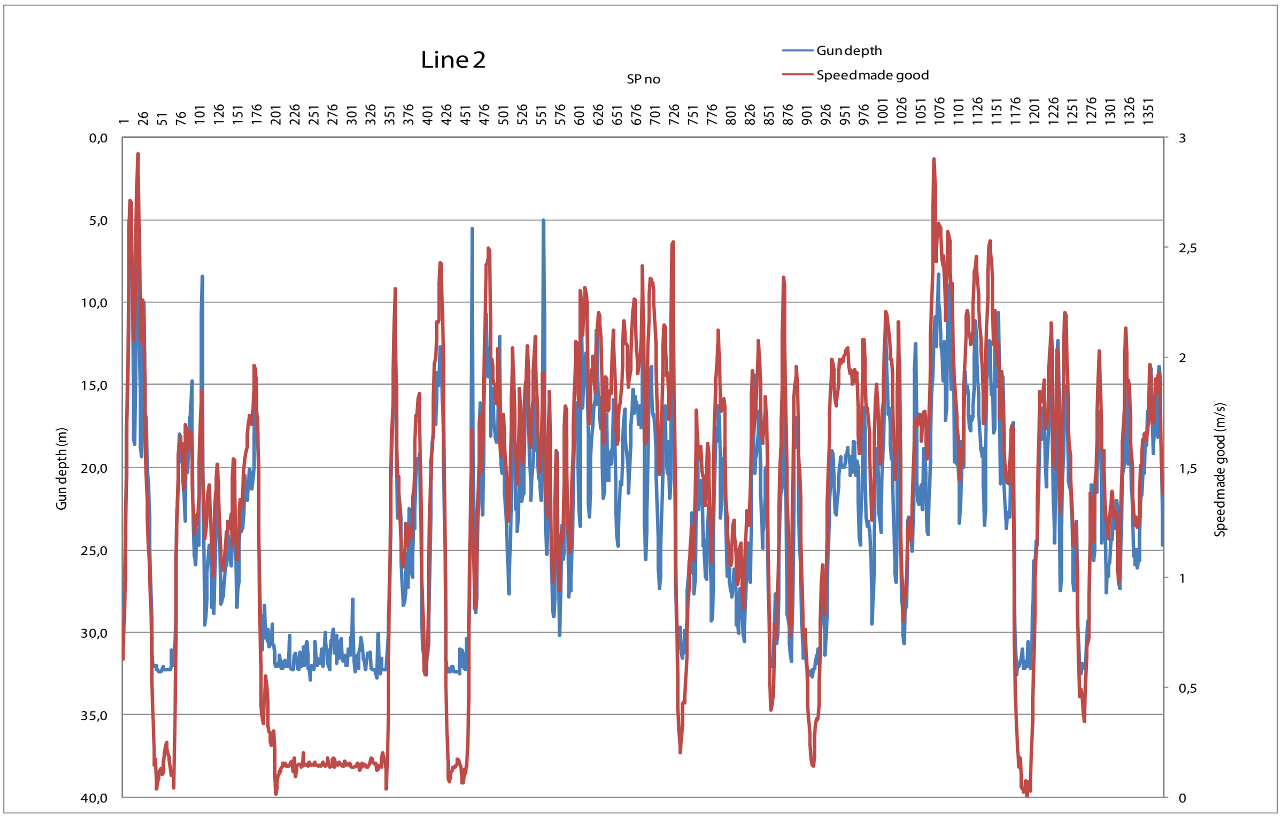


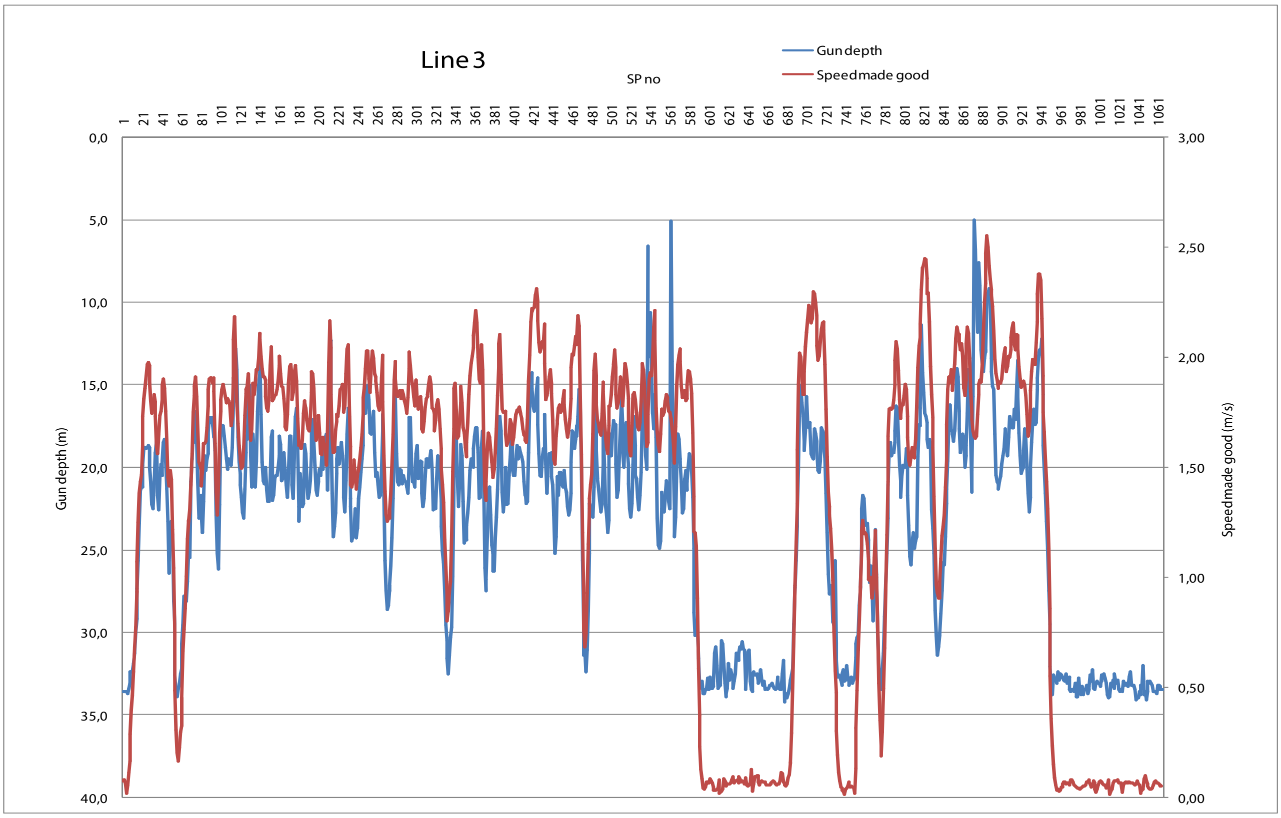
Gun and 1st section depths vs. Speed, (Line 8)
Speed (m/s)
Depth (m)
Gun depth
1st section



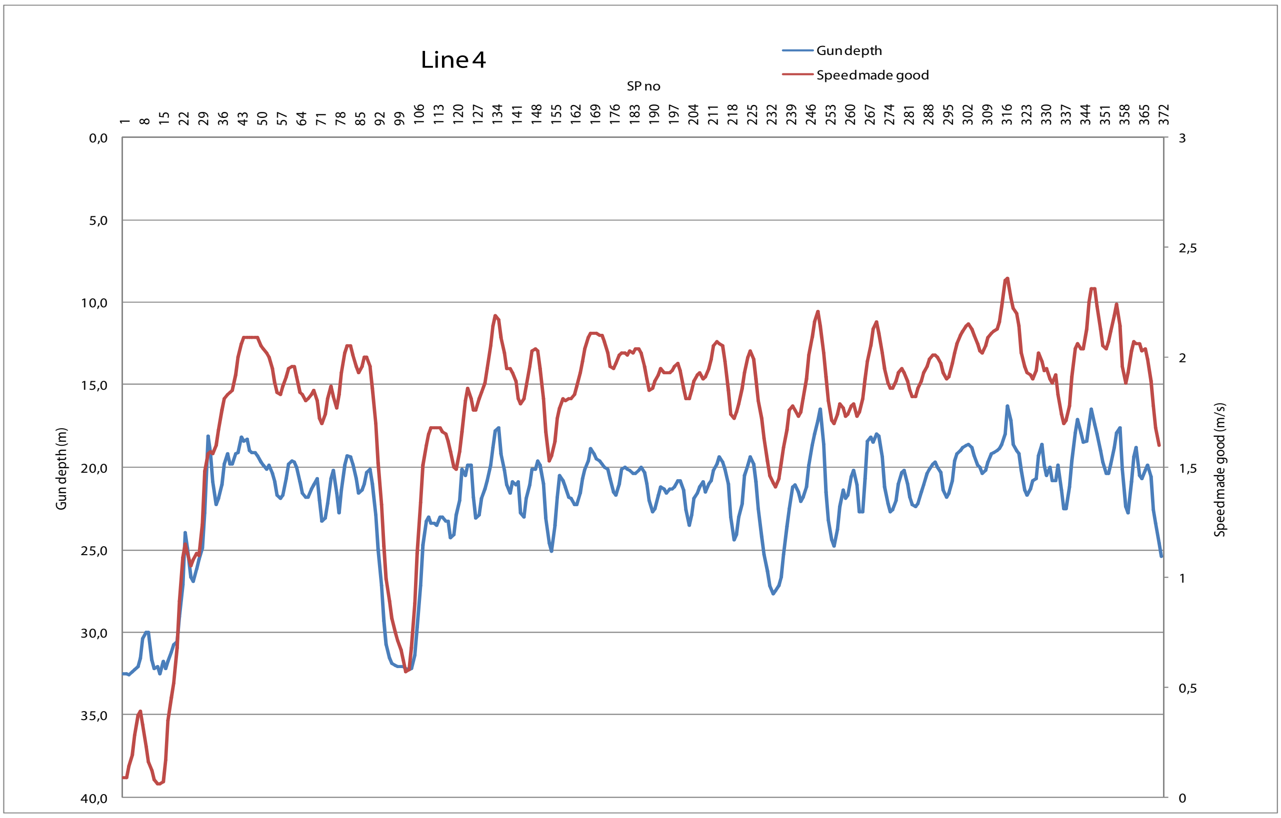
Streamer depth vs. Speed made good (Line 8)
Streamer Depth (m)
Speede made good (m/s)
1st section
2nd section
3rd section
4th section


Line 1
Gun depth
Speed made good
SP no
1 9 17 25 33 41 49 57 65 73 81 89 97 105 113 121 129 137 145 153 161 169 177 185 193 201 209 217 225 233 241 249 257 265 273 281 289 297 305 313 321 329 337 345 353 361 369 377 385 393 401
Gun depth (m)
0,0 5,0 10,0 15,0 20,0 25,0 30,0 35,0 40,0 45,0 50,0
Speed made good (m/s)
3,00 2,50 2,00 1,50 1,00 0,50 0,00

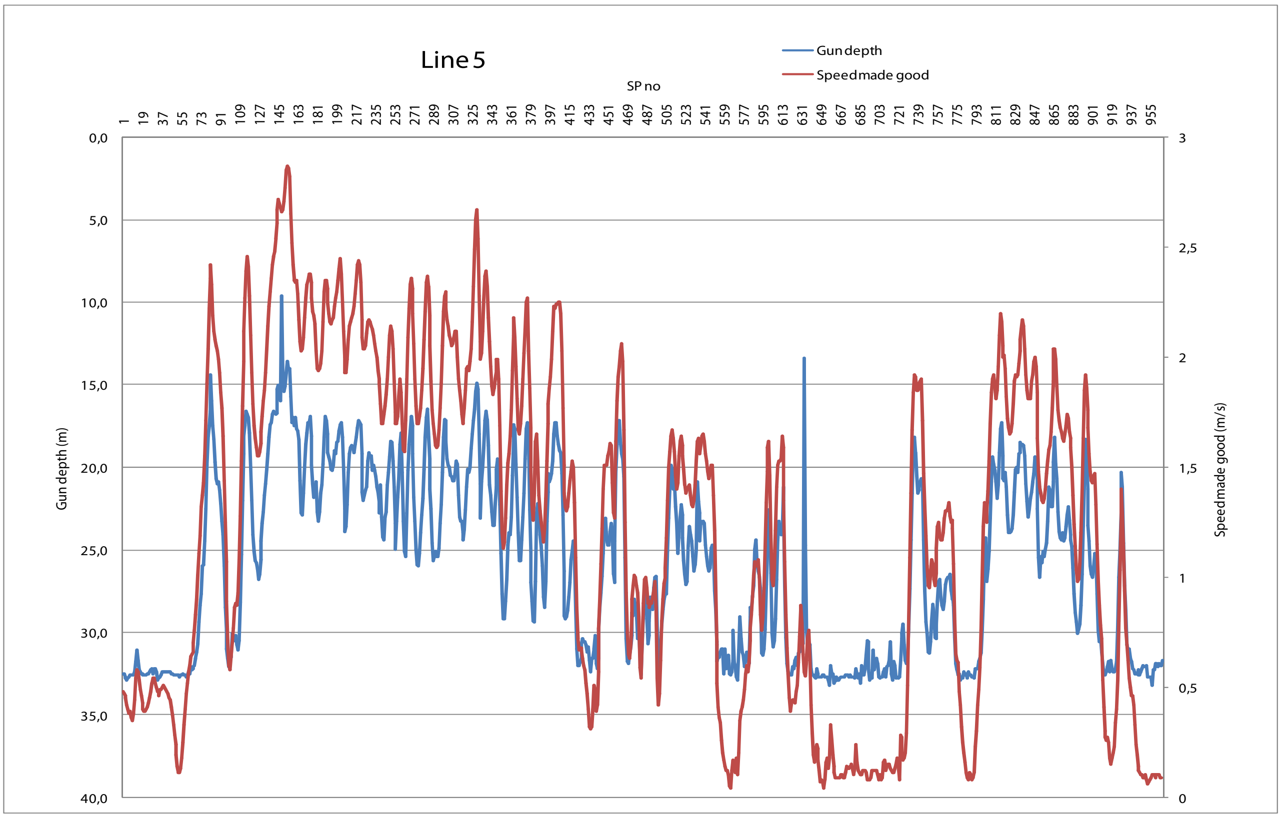

Line 2
Gun depth
Speed made good
SP no
1 26 51 76 101 126 151 176 201 226 251 276 301 326 351 376 401 426 451 476 501 526 551 576 601 626 651 676 701 726 751 776 801 826 851 876 901 926 951 976 1001 1026 1051 1076 1101 1126 1151 1176 1201 1226 1251 1276 1301 1326 1351
Gun depth (m)
0,0 5,0 10,0 15,0 20,0 25,0 30,0 35,0 40,0
Speed made good (m/s)
3 2,5 2 1,5 1 0,5 0



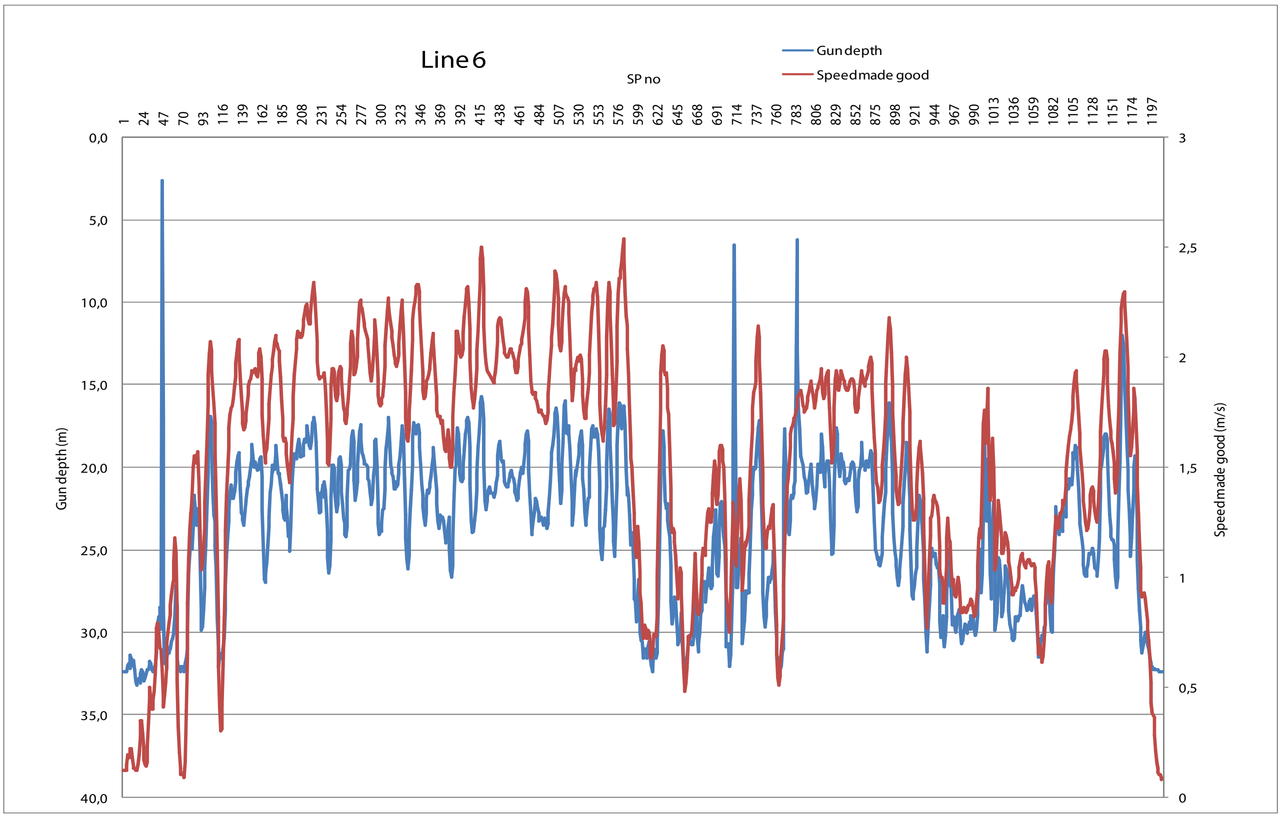
Line 3
SP no
Gun depth
Speed made good
Gun depth (m)
Speed made good (m/s)



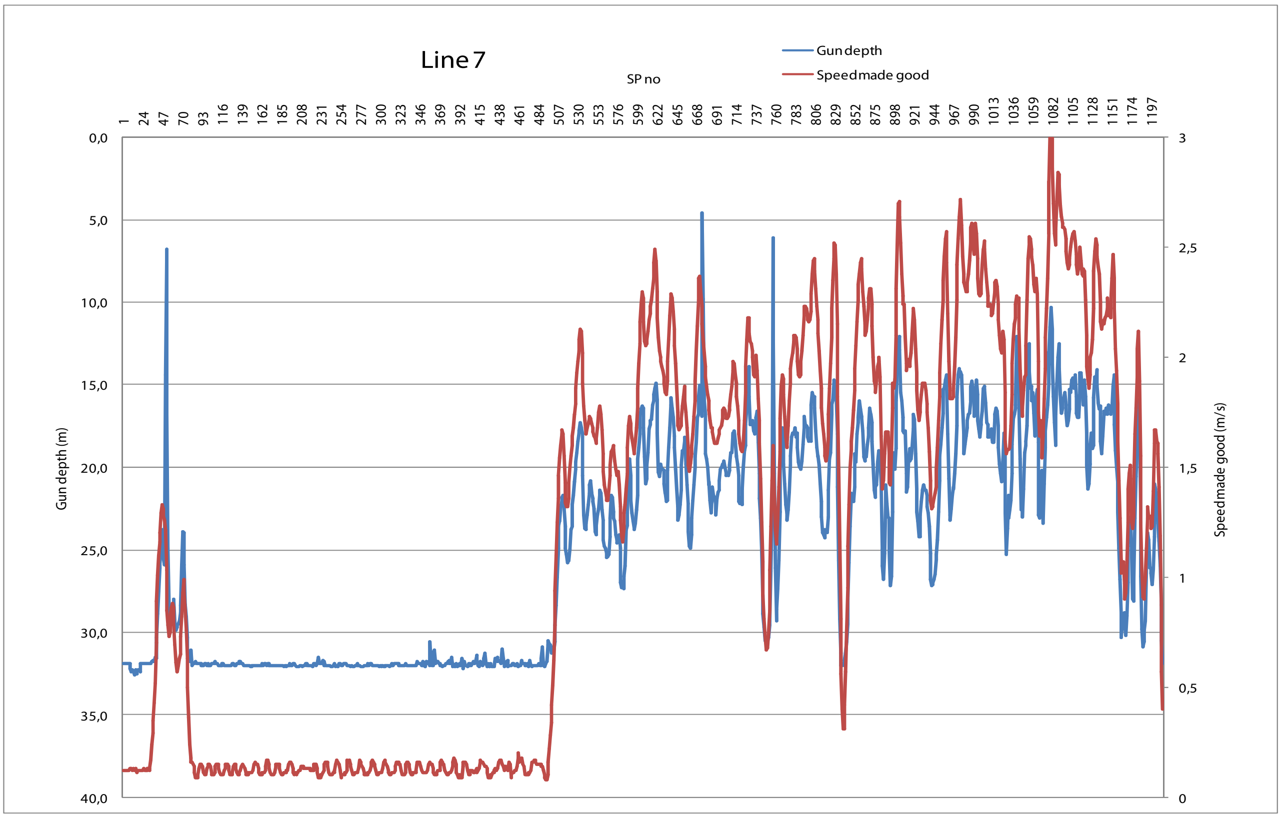
Line 4
SP no
Gun depth
Speed made good
Gun depth (m)
Speed made good (m/s)



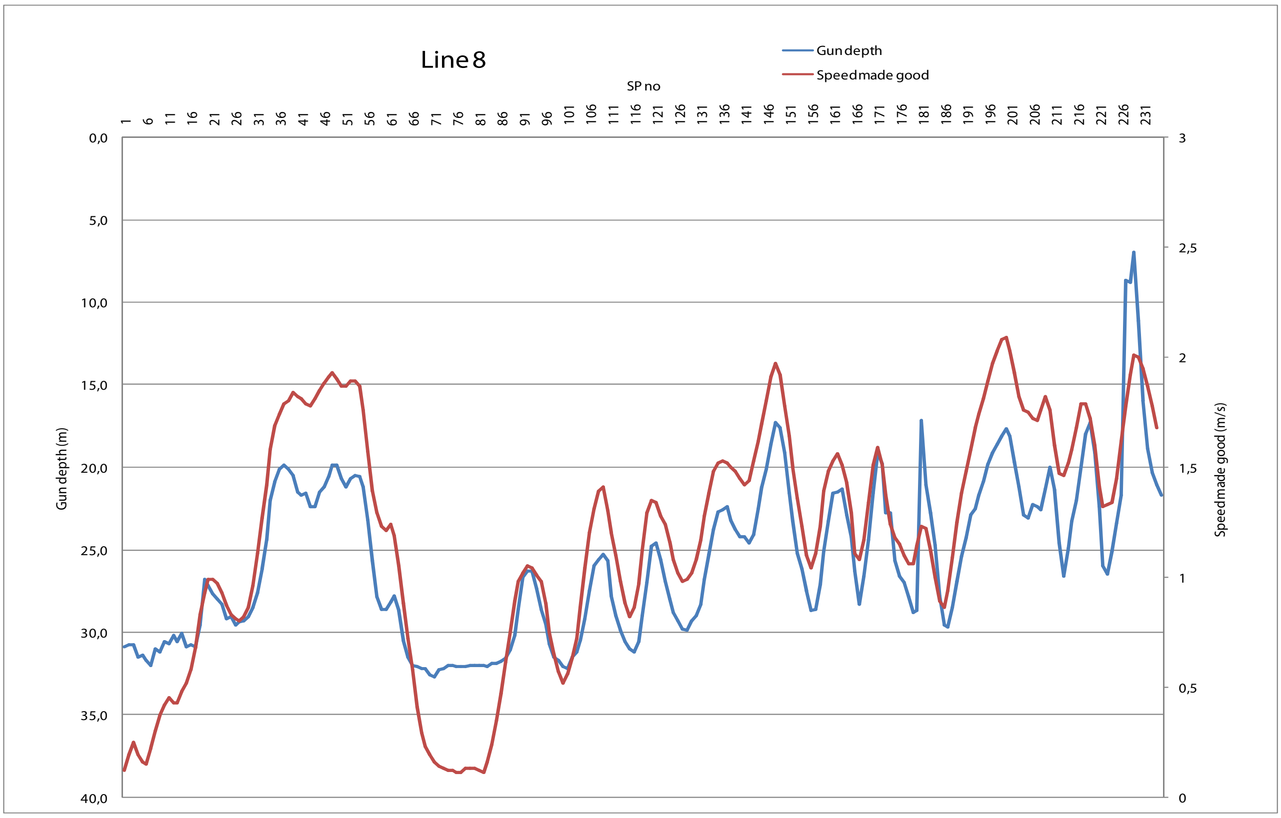
Line 5
Gun depth
Speed made good
SP no
Gun depth (m)
Speed made good (m/s)
0,0
5,0
10,0
15,0
20,0
25,0
30,0
35,0
40,0
3
2,5
2
1,5
1
0,5
0



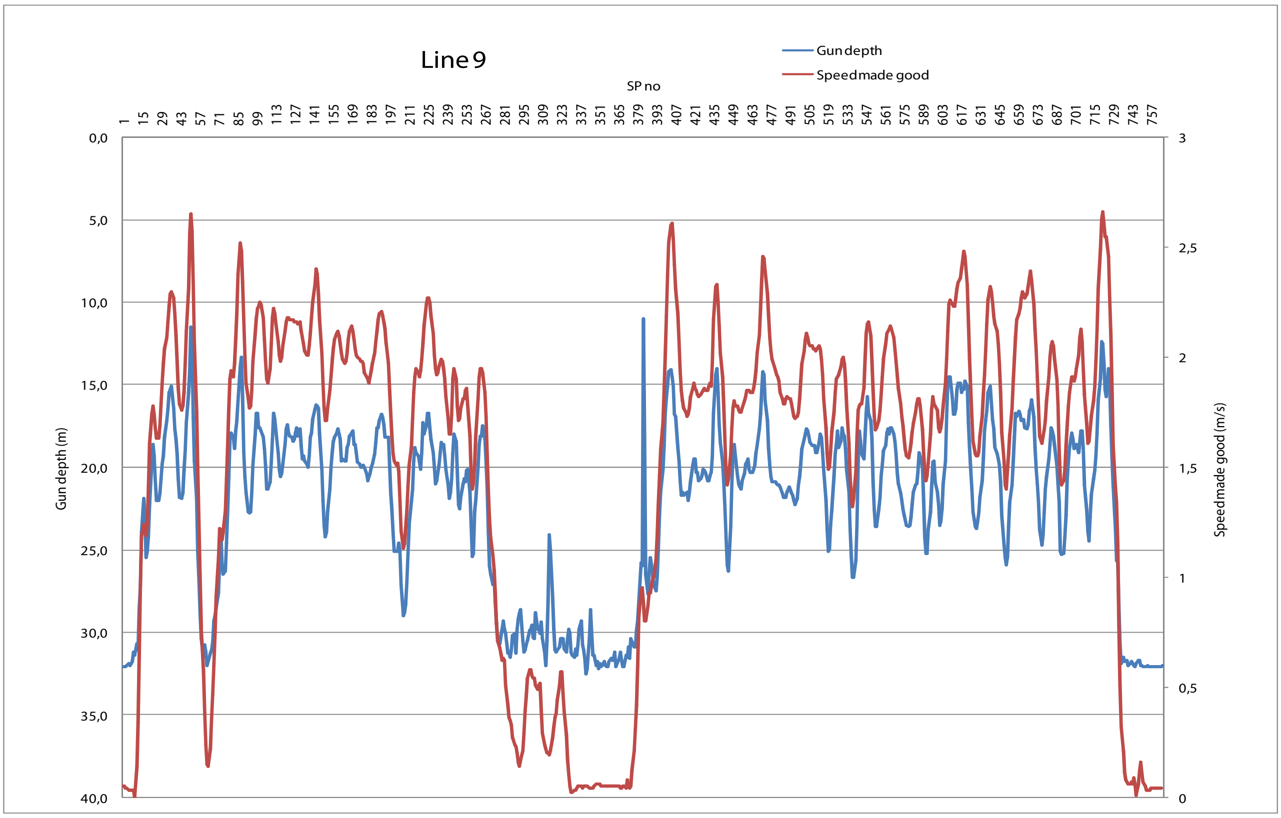
Line 6
Gun depth
Speed made good
SP no
Gun depth (m)
Speed made good (m/s)
0,0
5,0
10,0
15,0
20,0
25,0
30,0
35,0
40,0
3
2,5
2
1,5
1
0,5
0

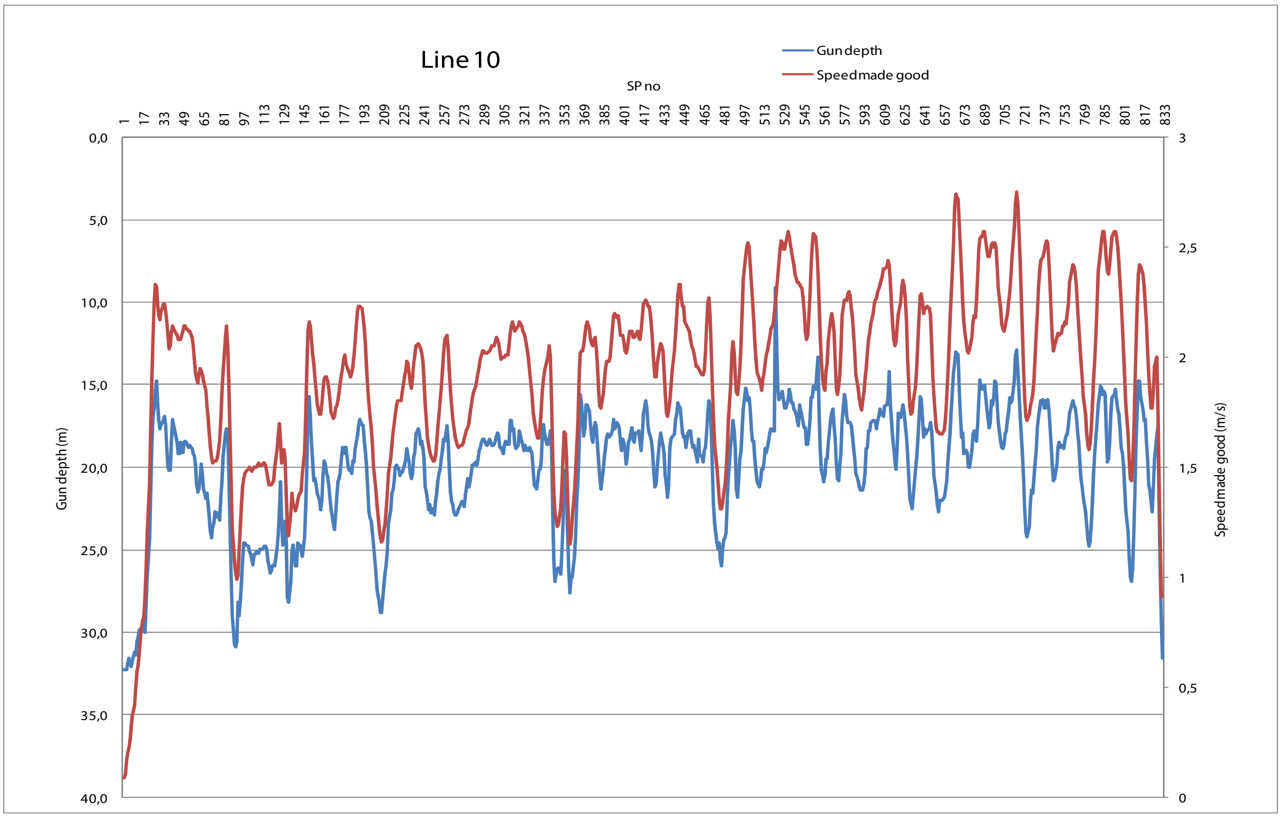


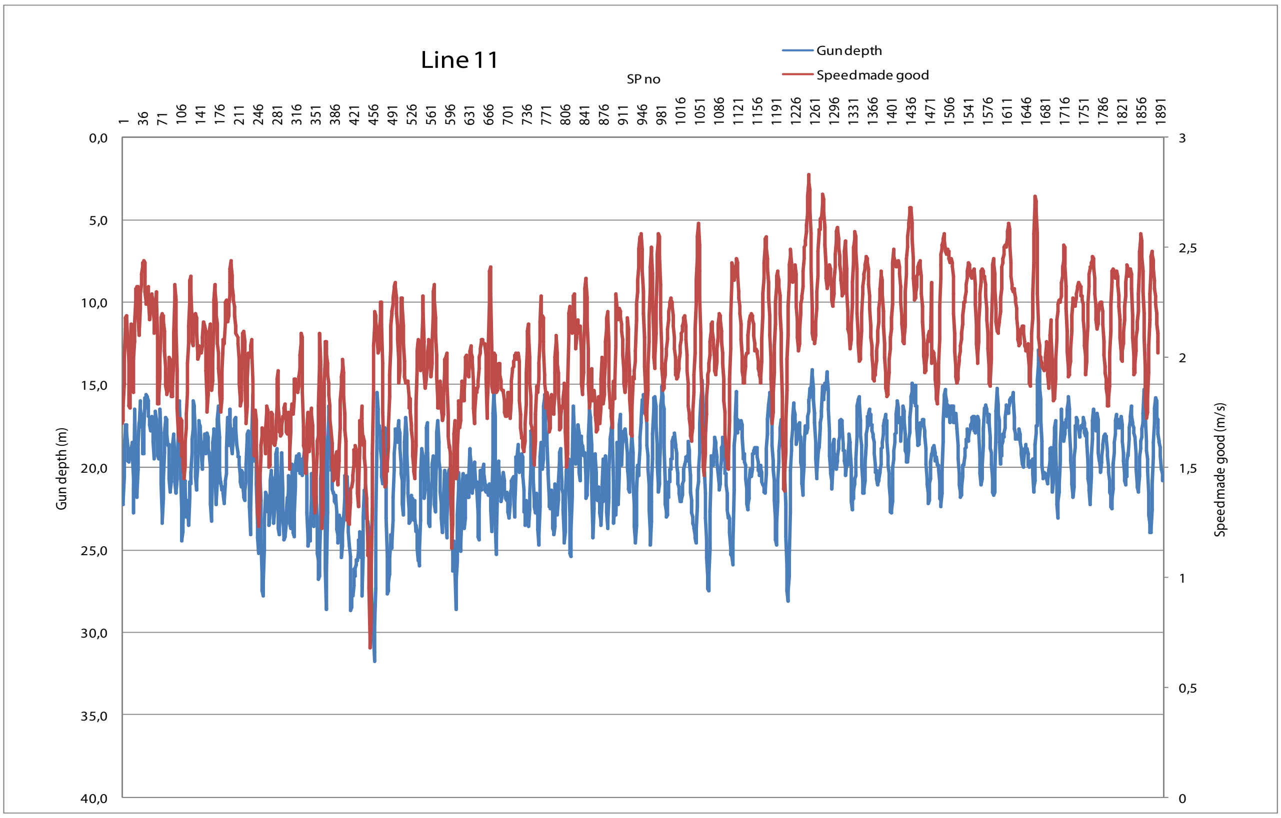
Line 7
Gun depth
Speed made good
SP no
Gun depth (m)
Speed made good (m/s)



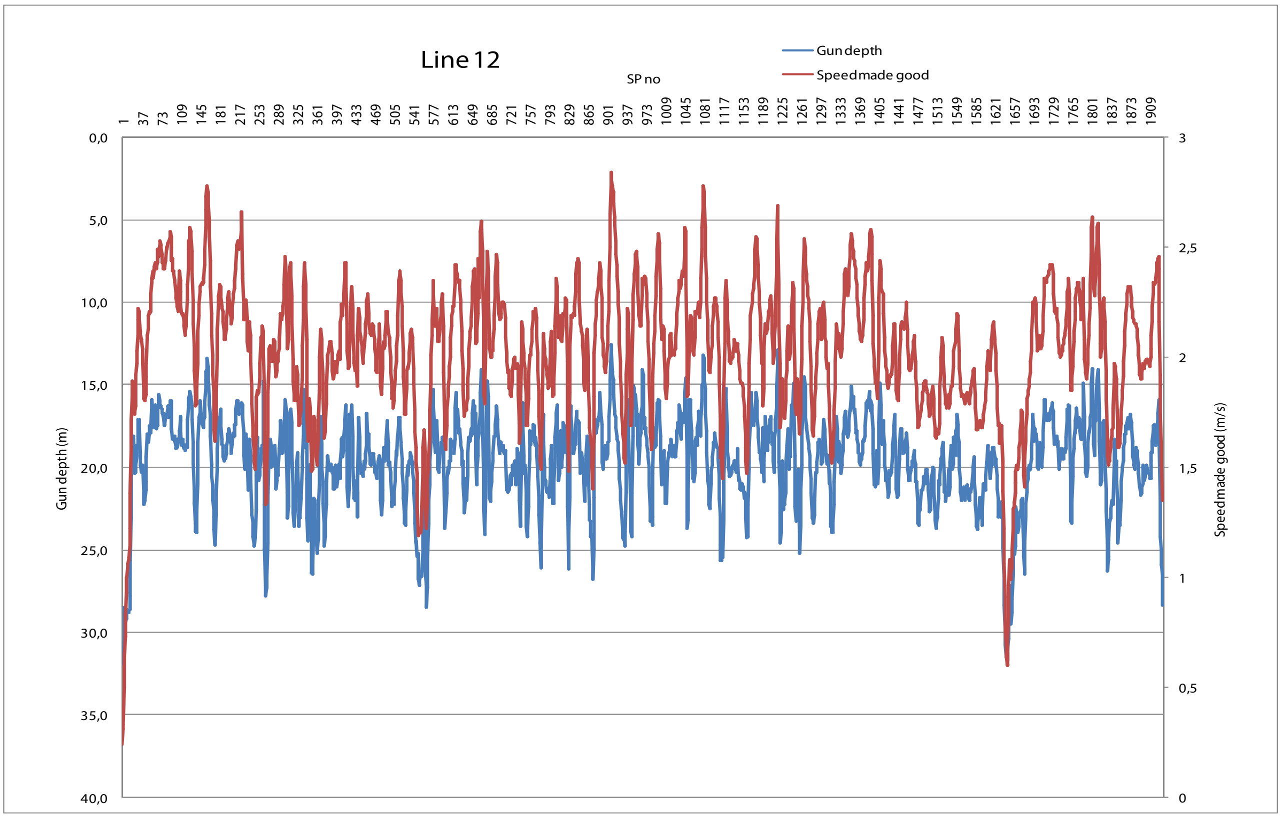
Line 8
Gun depth
Speed made good
SP no
Gun depth (m)
Speed made good (m/s)


Line 9
Gun depth
Speed made good
SP no
Gun depth (m)
Speed made good (m/s)

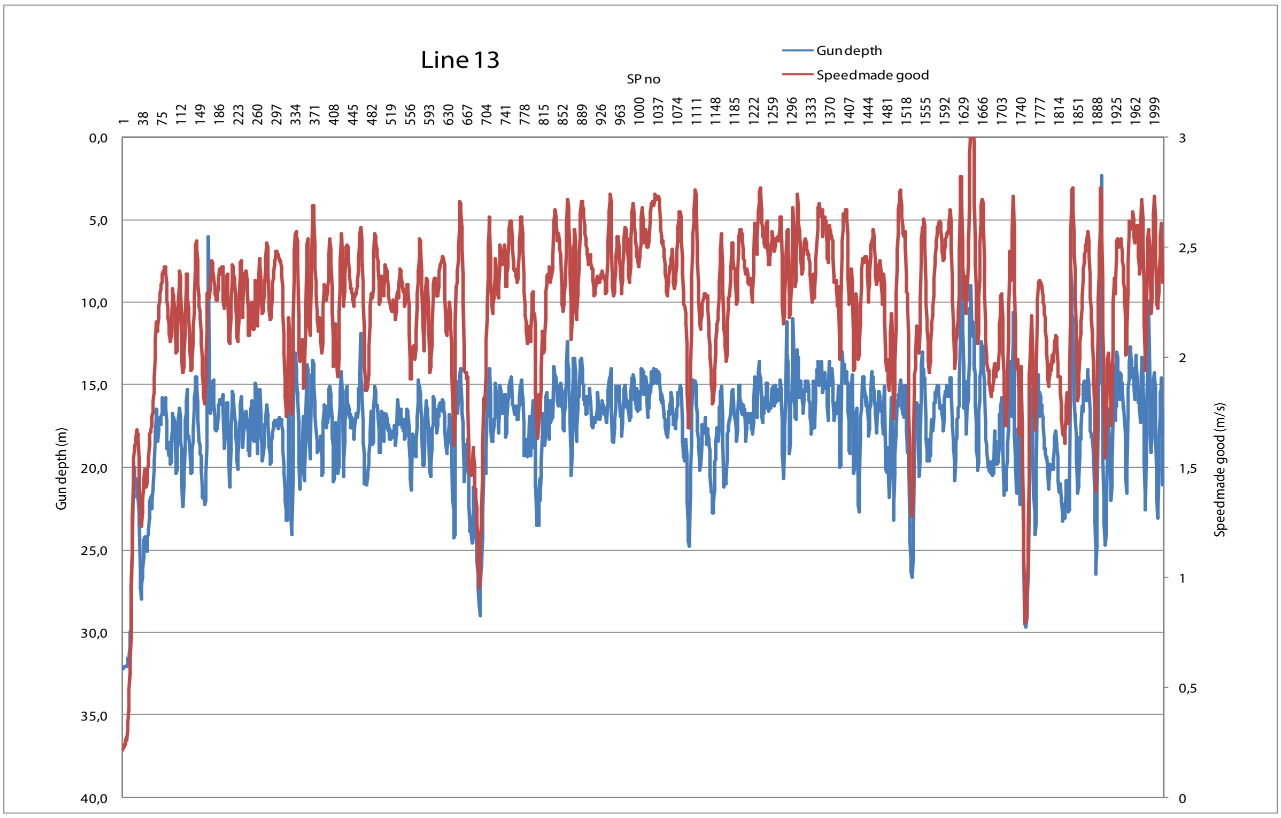

Line 10
Gun depth
Speed made good
SP no
Gun depth (m)
Speed made good (m/s)

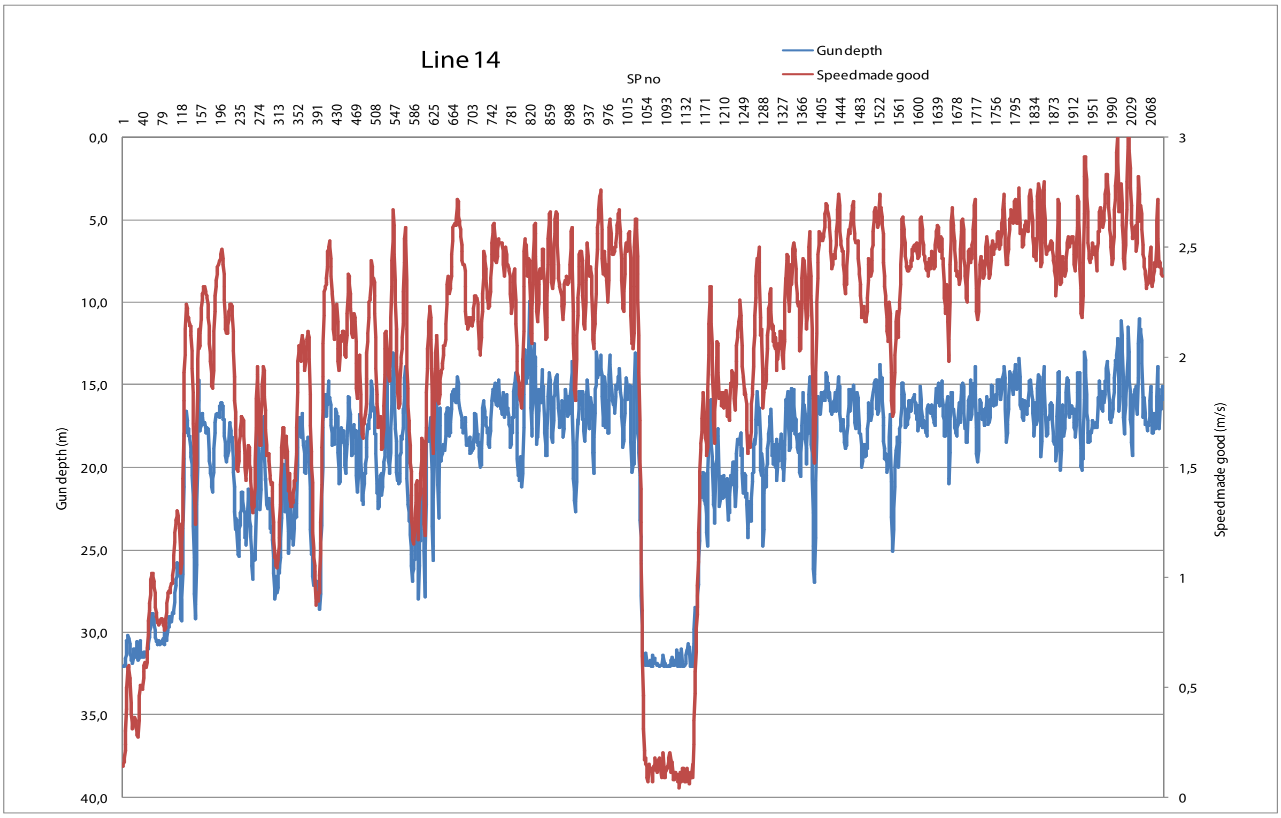


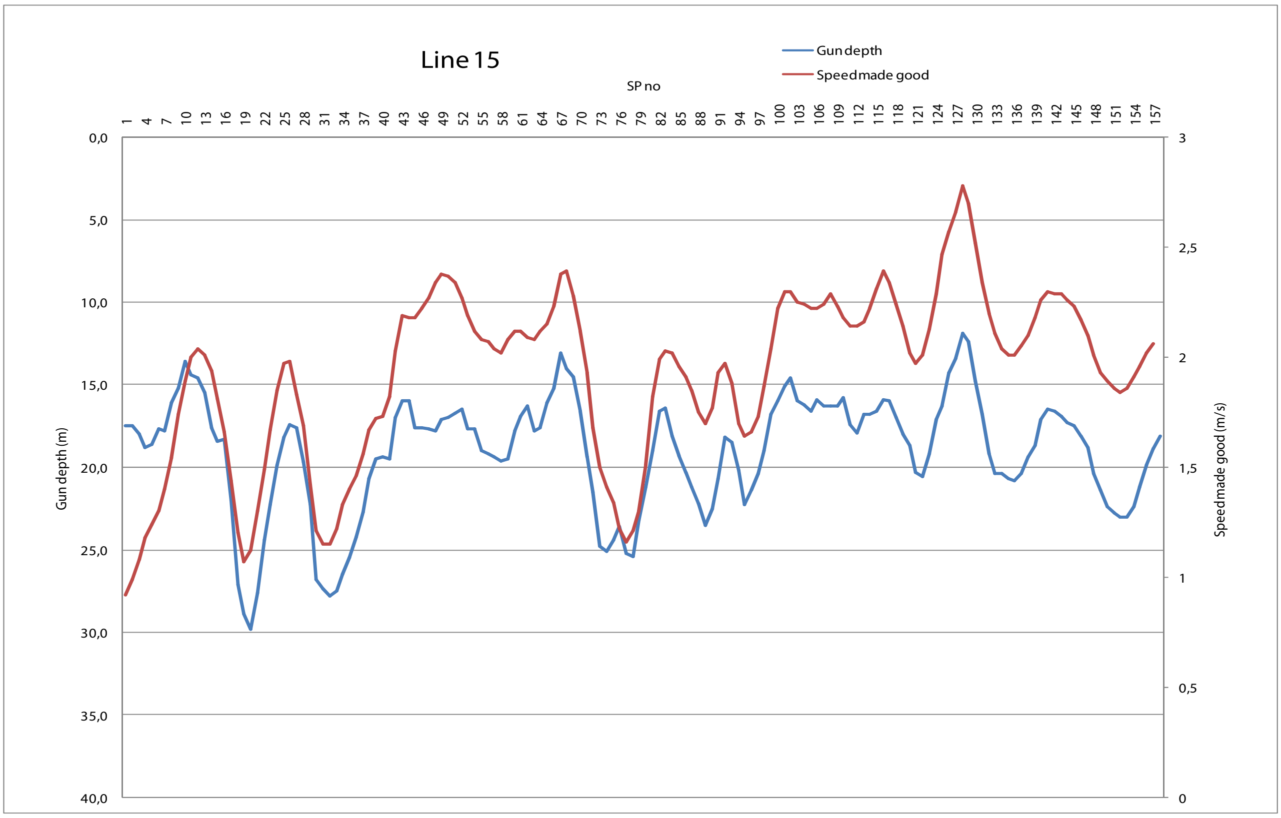
Line 11
Gun depth
Speed made good
SP no
Gun depth (m)
Speed made good (m/s)

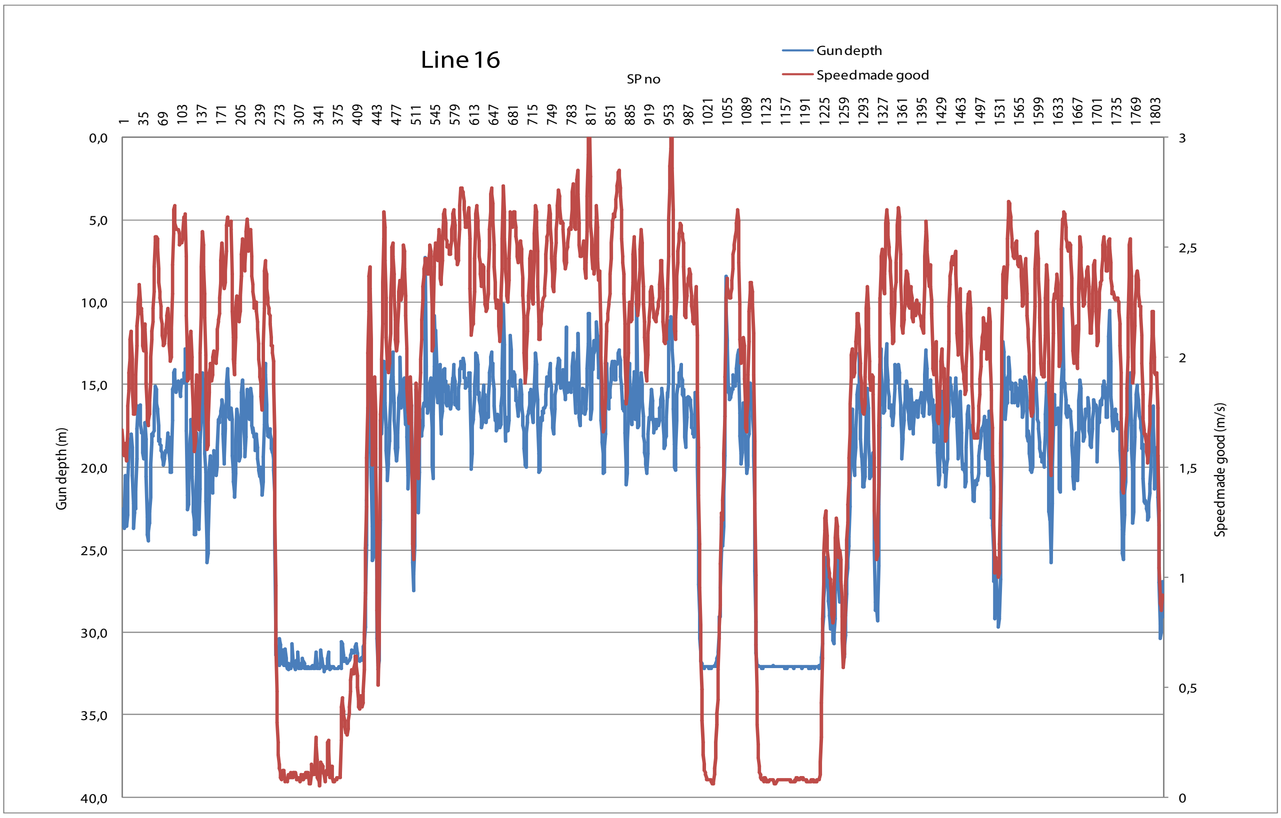


Line 12
Gun depth
Speed made good
SP no
Gun depth (m)
Speed made good (m/s)


Line 13
Gun depth
Speed made good
SP no
Gun depth (m)
Speed made good (m/s)
0,0
5,0
10,0
15,0
20,0
25,0
30,0
35,0
40,0
3
2,5
2
1,5
1
0,5
0


Line 14
Gun depth
Speed made good
SP no
Gun depth (m)
Speed made good (m/s)
0,0
5,0
10,0
15,0
20,0
25,0
30,0
35,0
40,0
3
2,5
2
1,5
1
0,5
0


Line 15
Gun depth
Speed made good
SP no
Gun depth (m)
Speed made good (m/s)

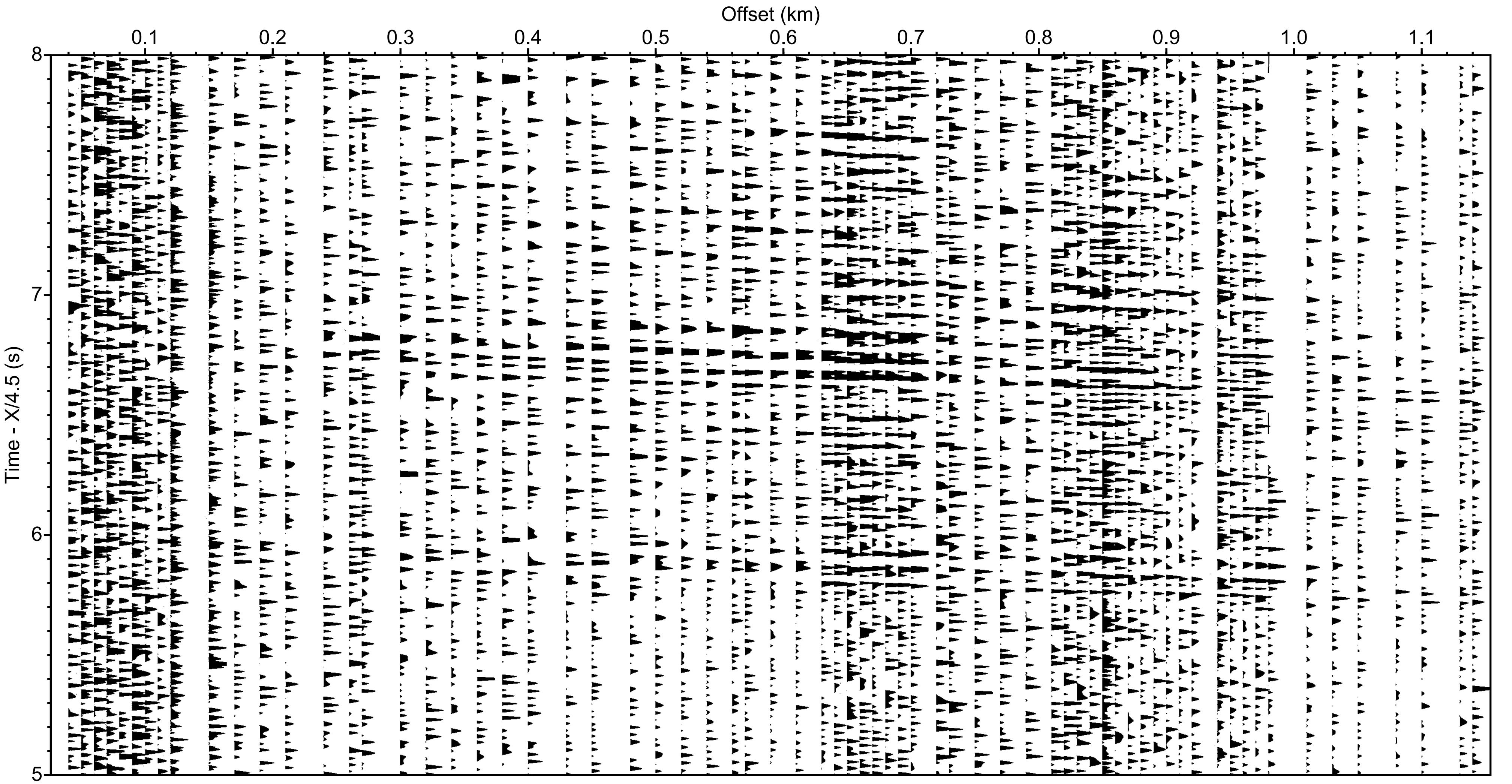

Line 16
Gun depth
Speed made good
SP no
Gun depth (m)
Speed made good (m/s)

Appendix V: Sonobuoy appendices

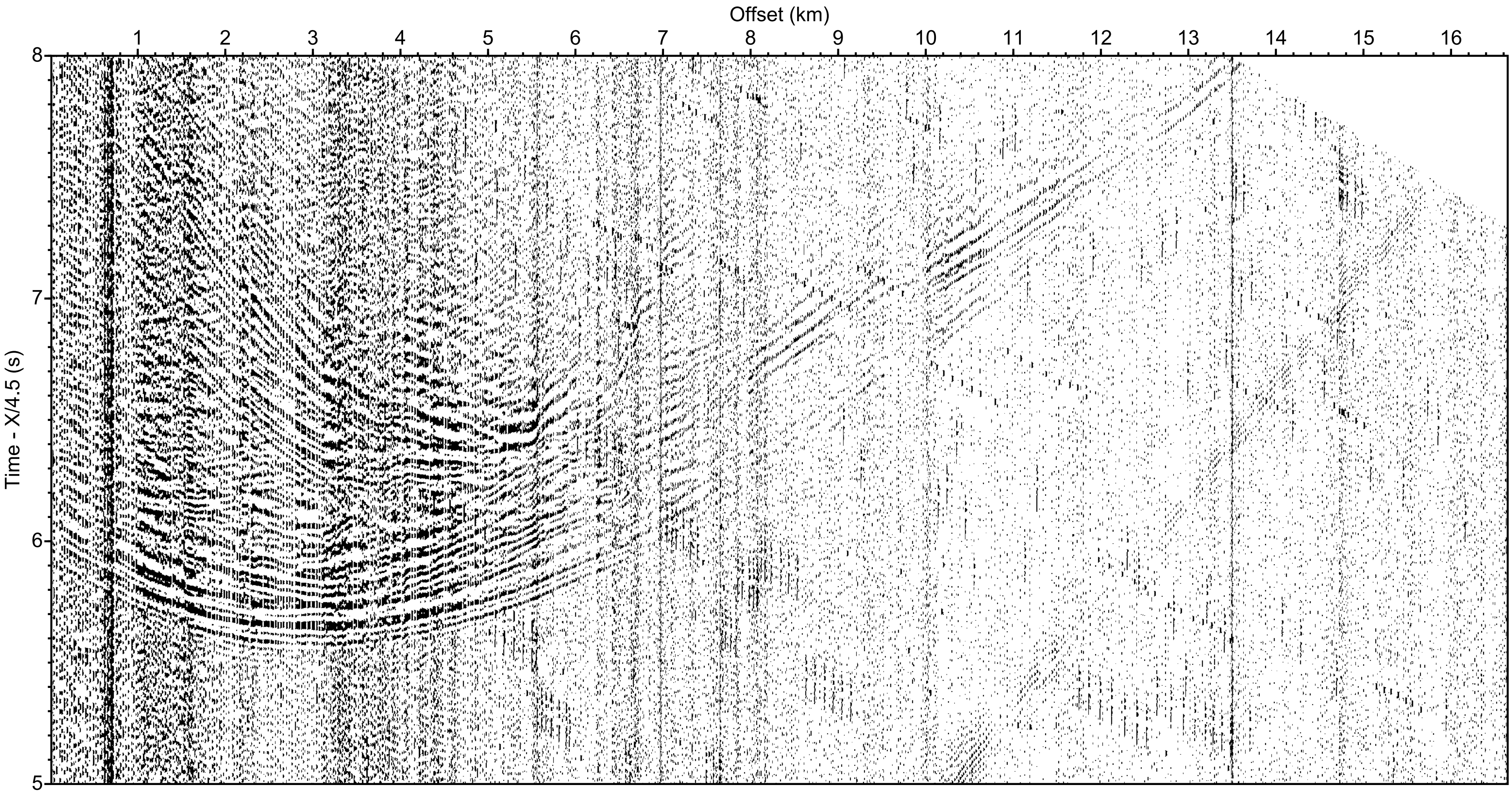
Appendix V-A:

Record Sections of all Sonobuoys

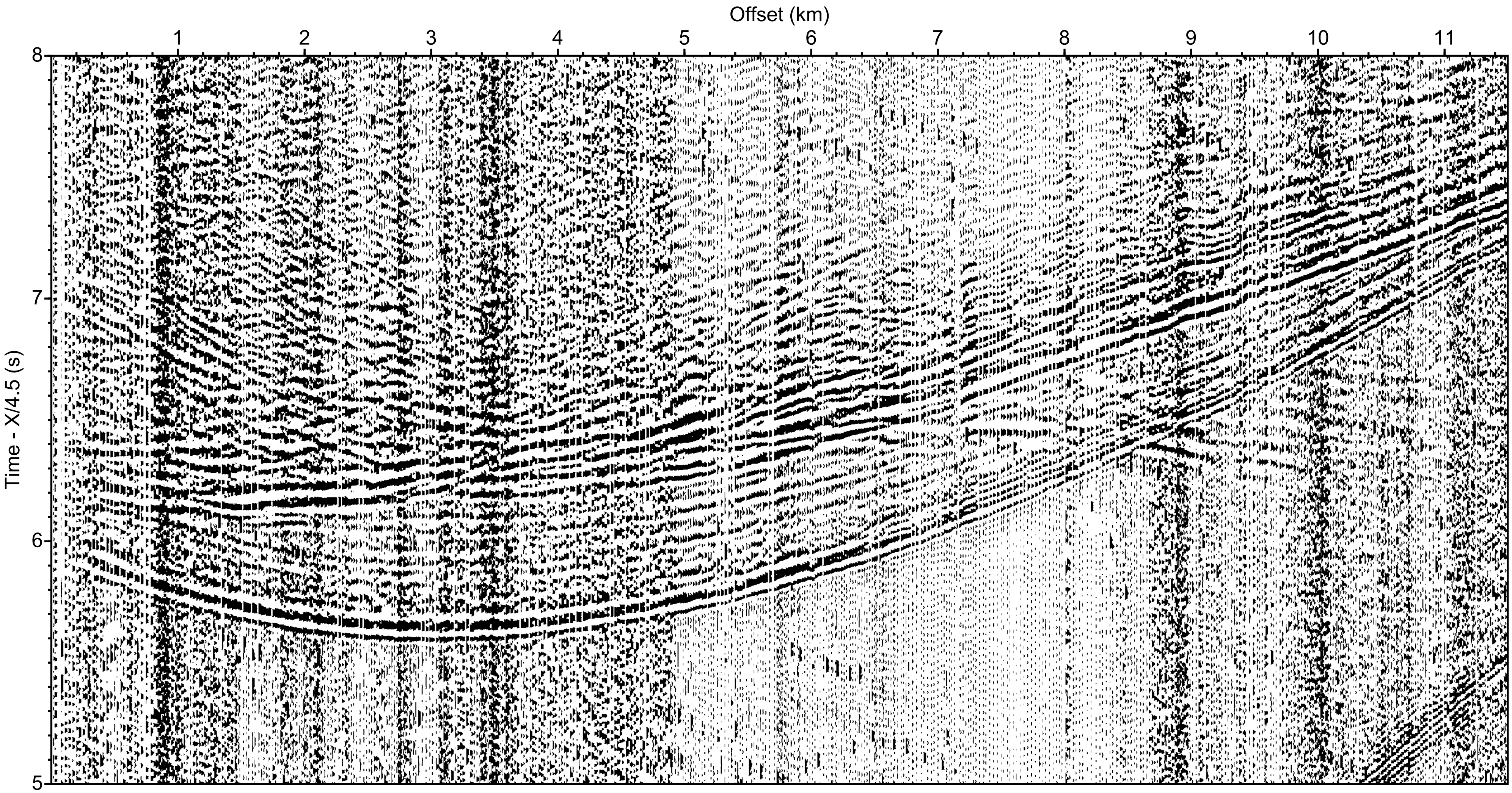
Shot-receiver offsets (horizontal scale) in the record sections are corrected for the drift of the sonobuoys. Vertical scale is the travel time reduced with a reduction velocity of 4.5 km/s.



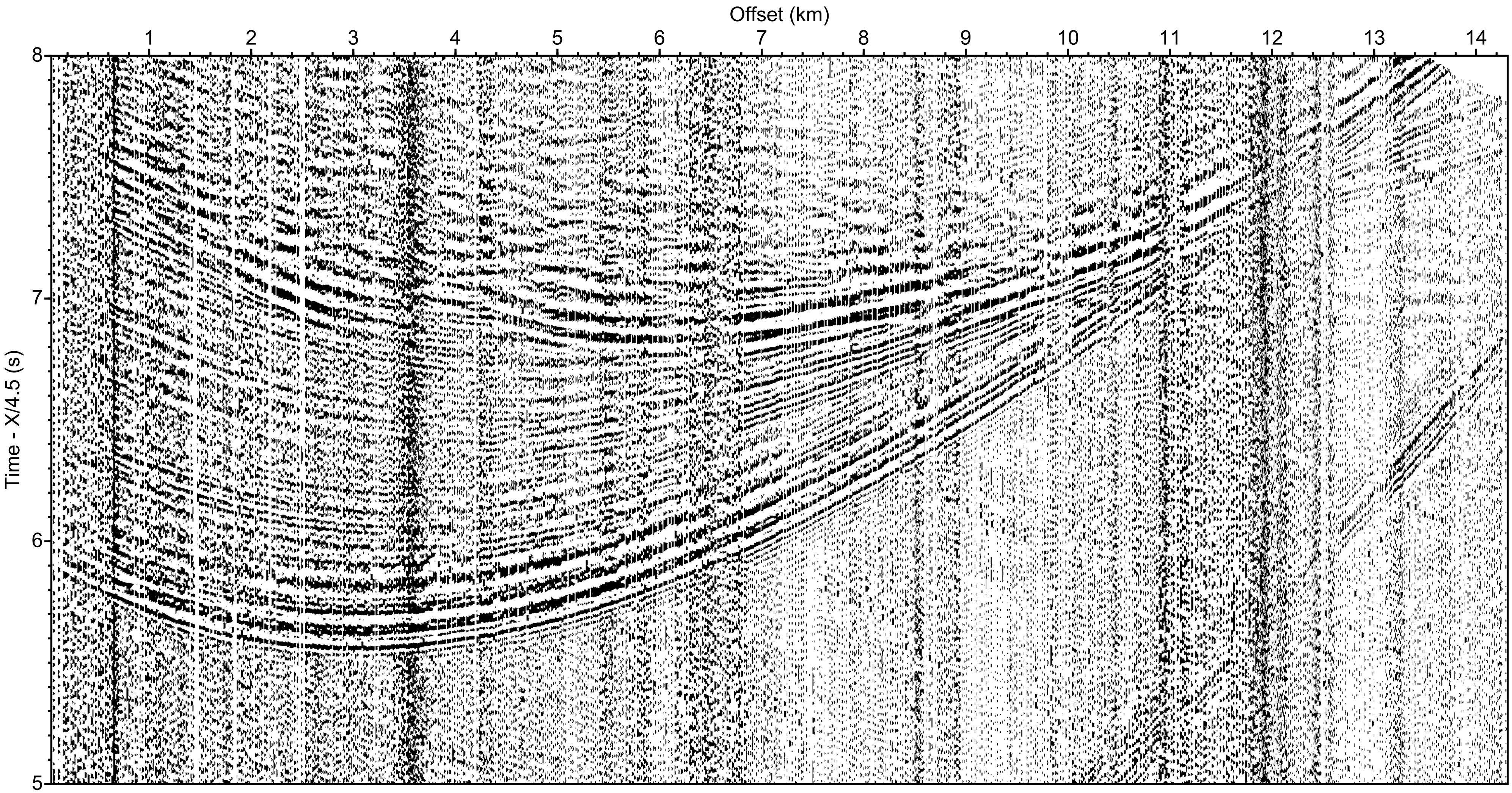
LOMROG 2009 - Sonobuoy 1-1 AUX 1 (deconv., bpf 5-36 Hz)



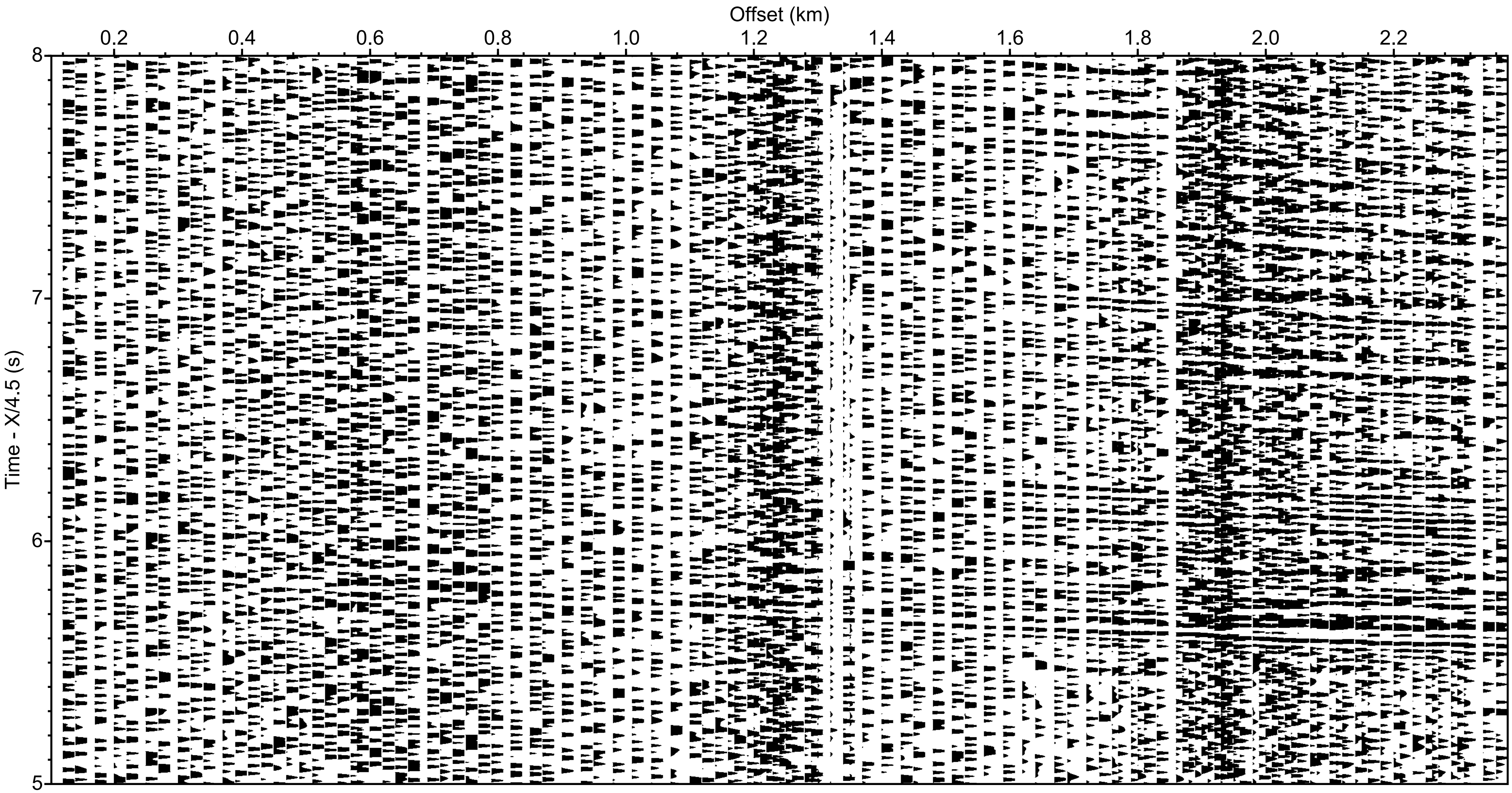
LOMROG 2009 - Sonobuoy 2-3 AUX 1 (deconv., bpf 5-36 Hz)



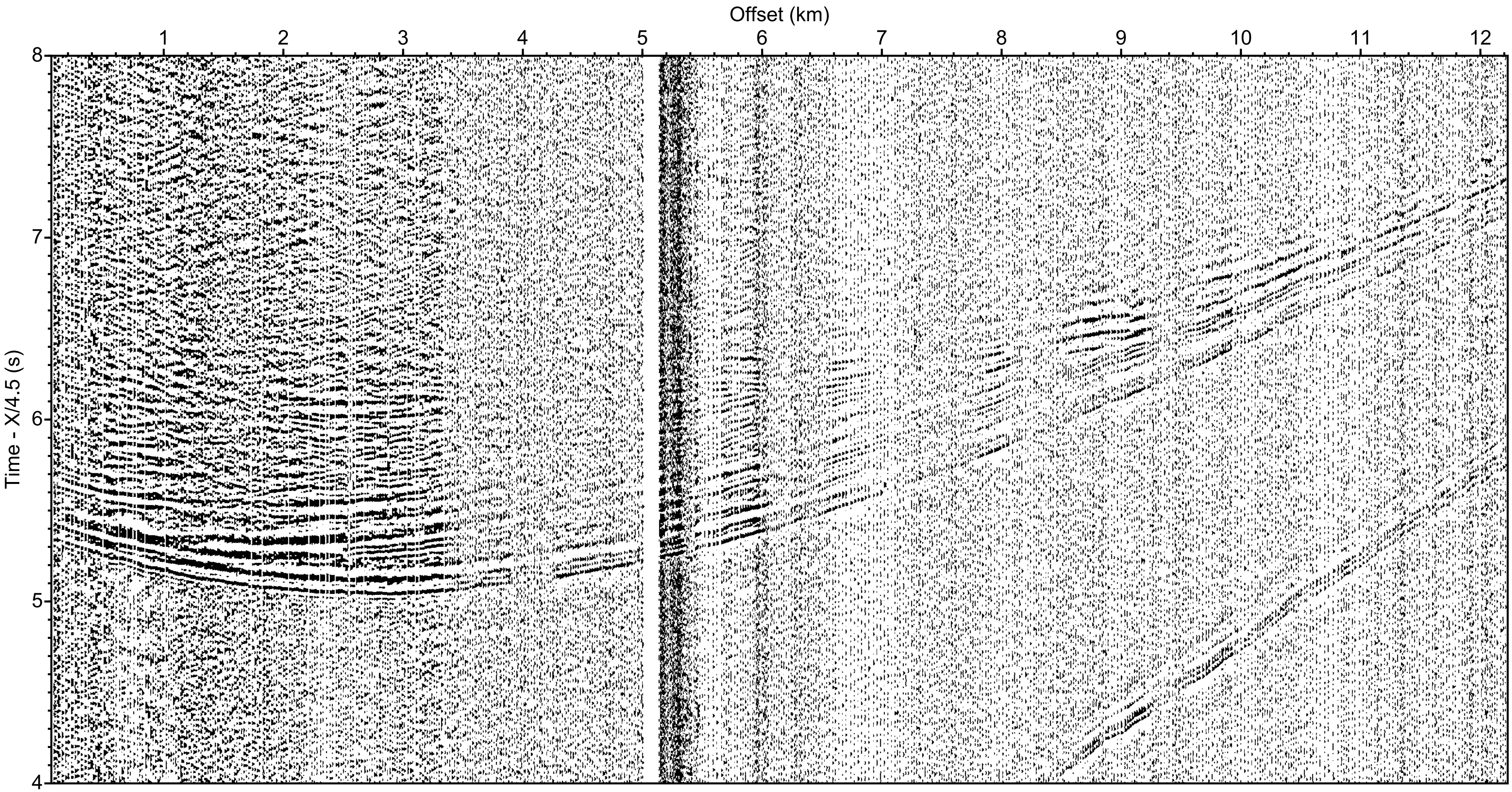
LOMROG 2009 - Sonobuoy 2-4 AUX 2 (deconv., bpf 5-36 Hz)



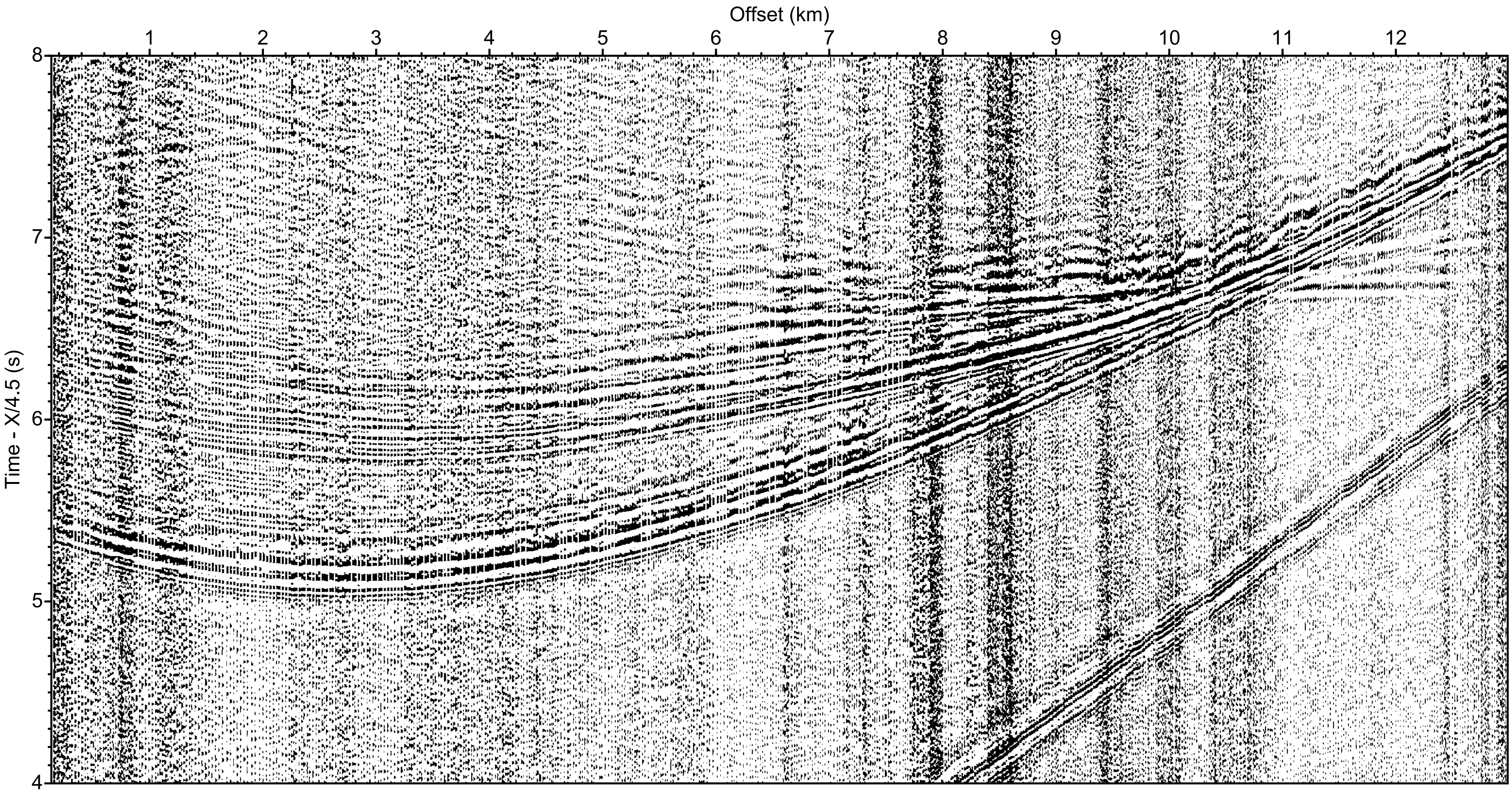
LOMROG 2009 - Sonobuoy 3-5 AUX 1 (deconv., bpf 5-36 Hz)



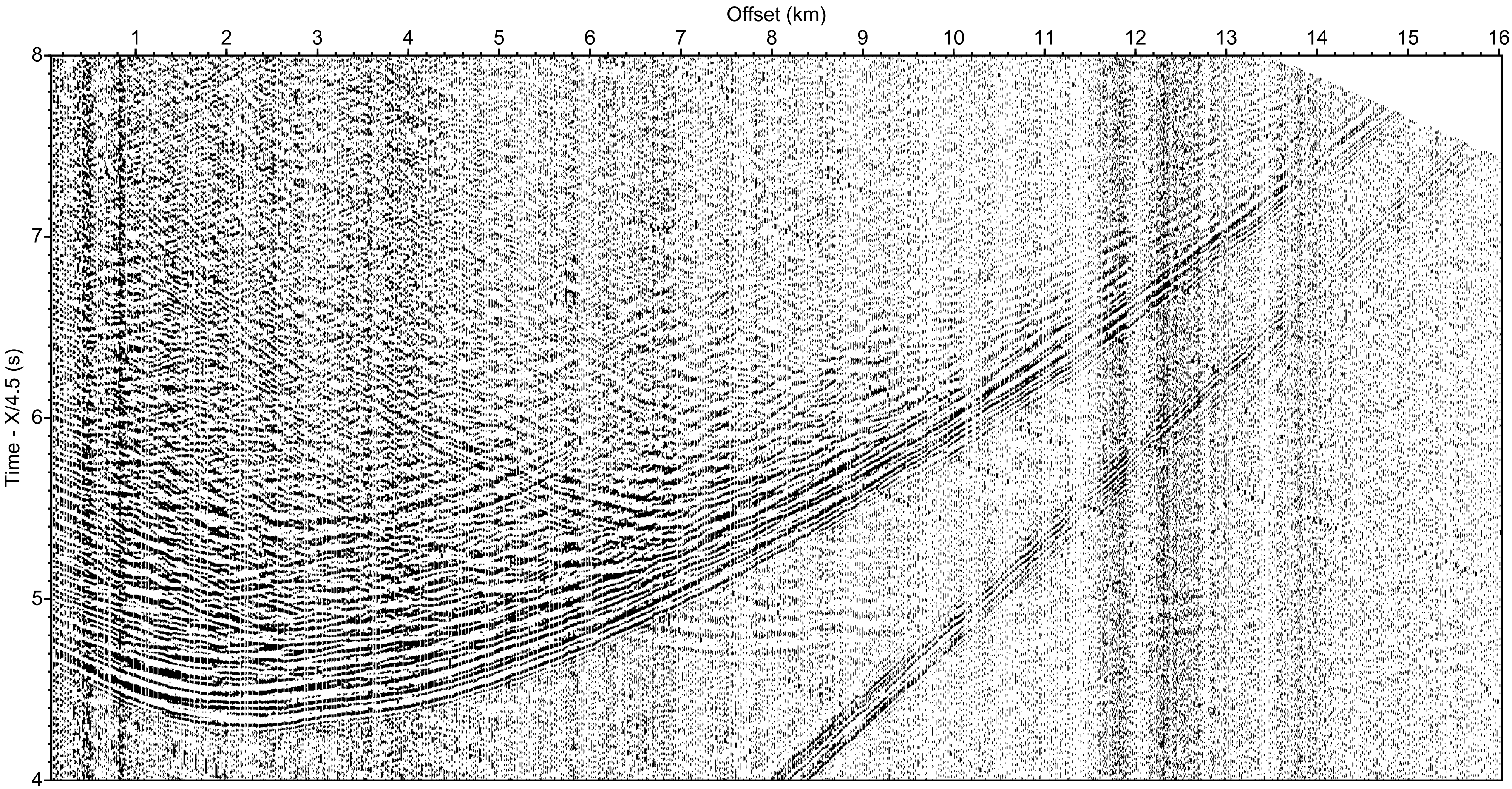
LOMROG 2009 - Sonobuoy 3-8 AUX 2 (deconv., bpf 5-36 Hz)



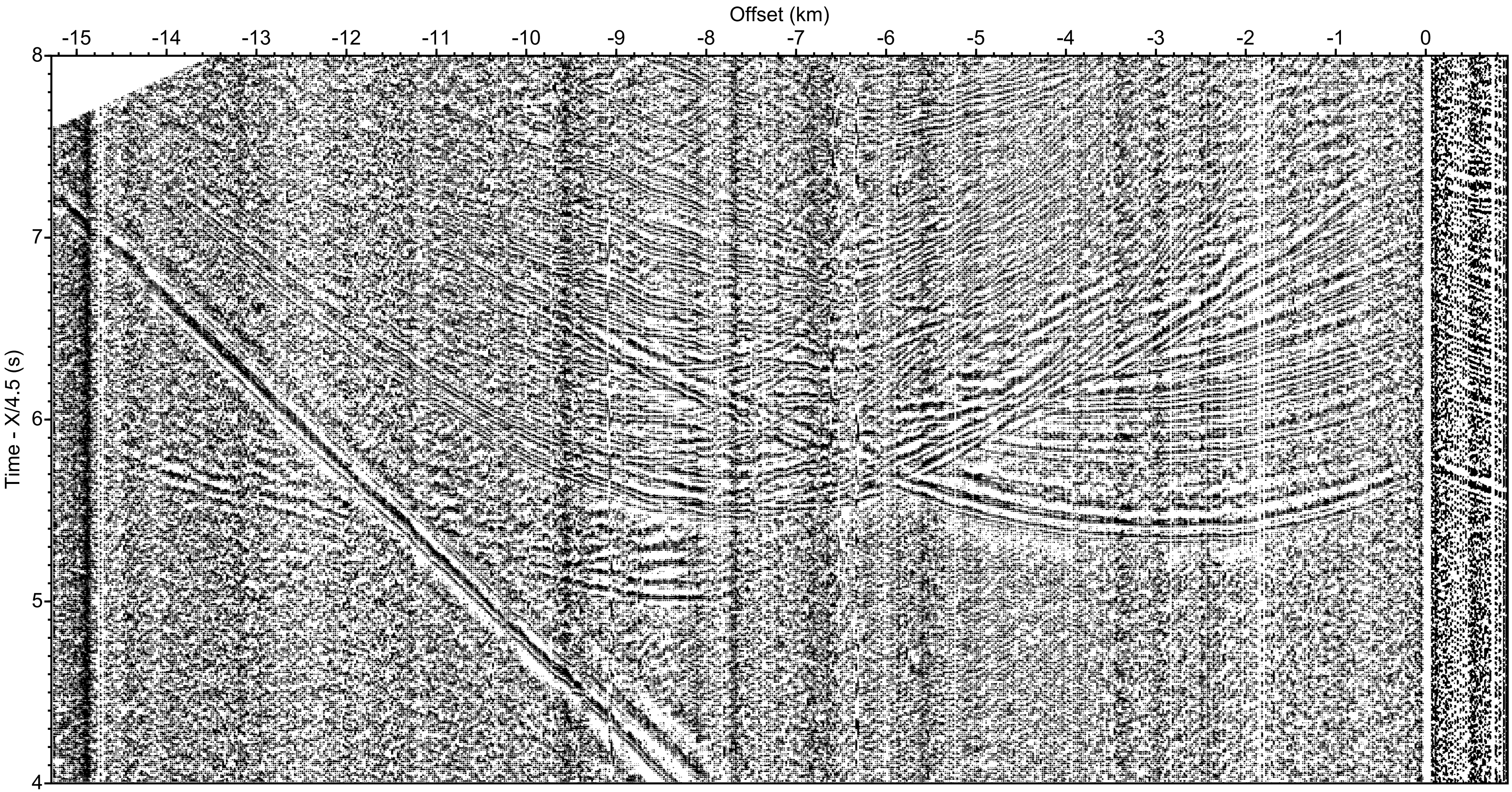
LOMROG 2009 - Sonobuoy 4-10 AUX 1 (deconv., bpf 5-36 Hz)



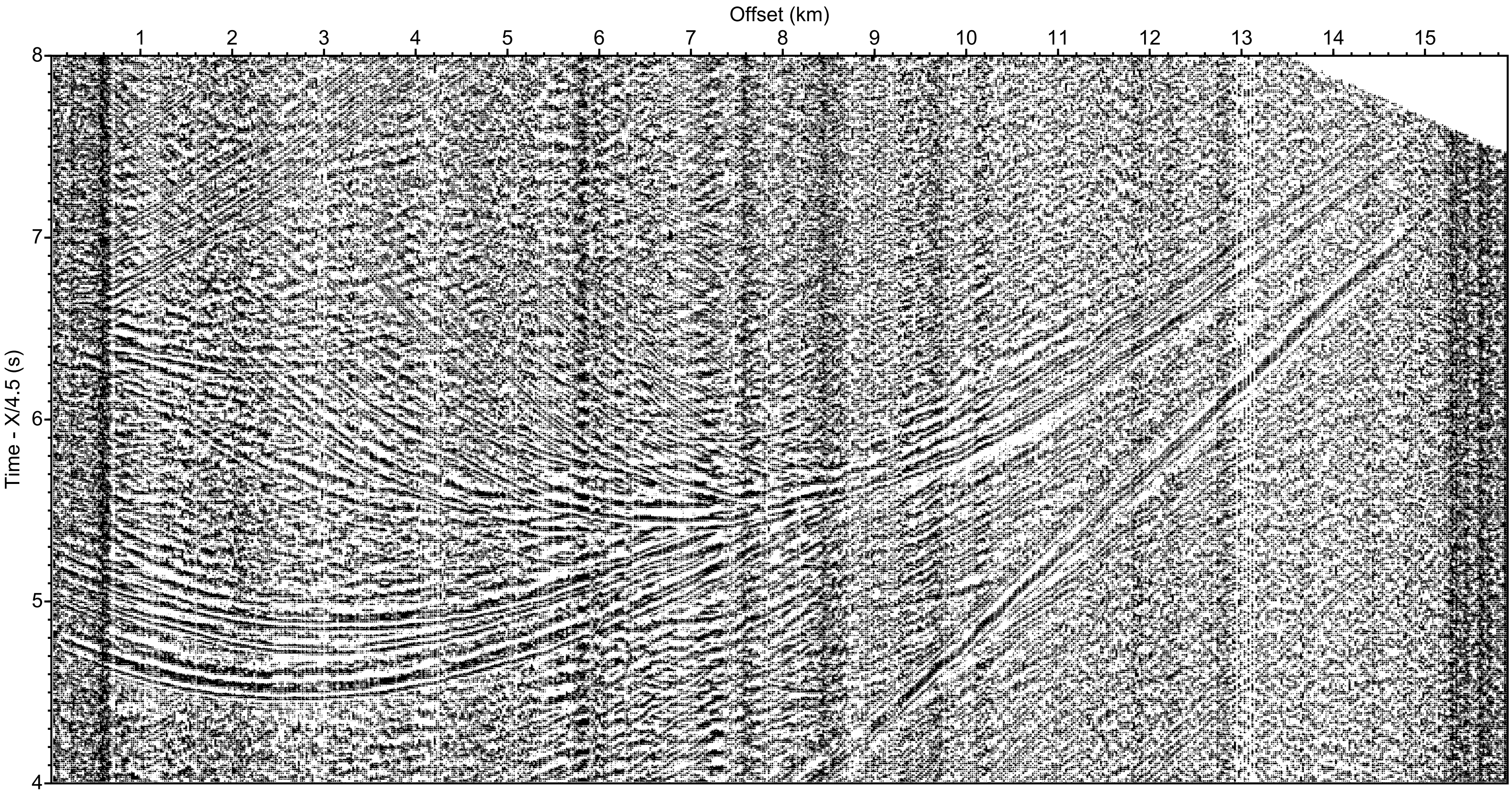
LOMROG 2009 - Sonobuoy 5-12 AUX 2 (deconv., bpf 5-36 Hz)



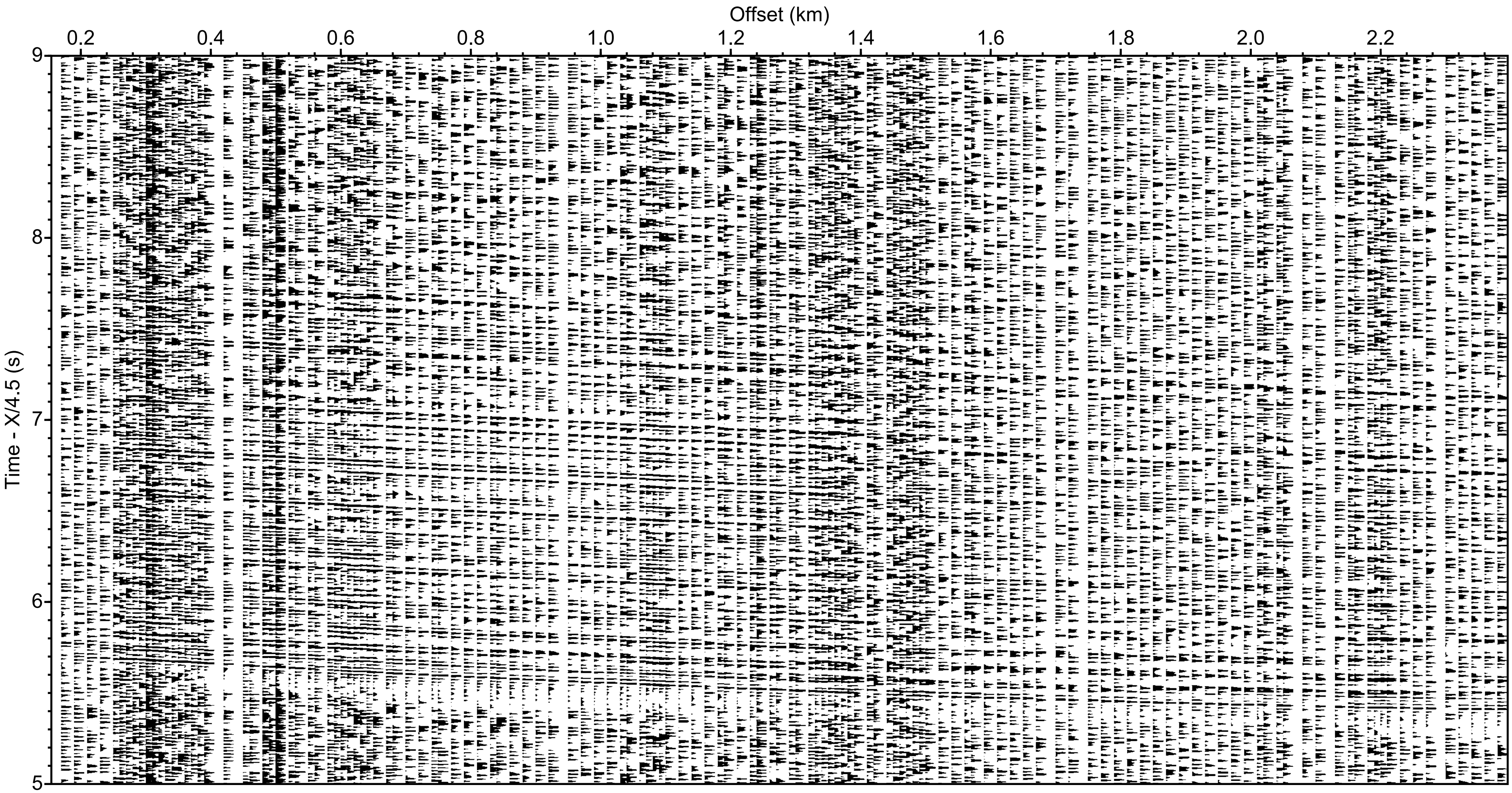
LOMROG 2009 - Sonobuoy 6-13 AUX 2 (deconv., bpf 5-36 Hz)



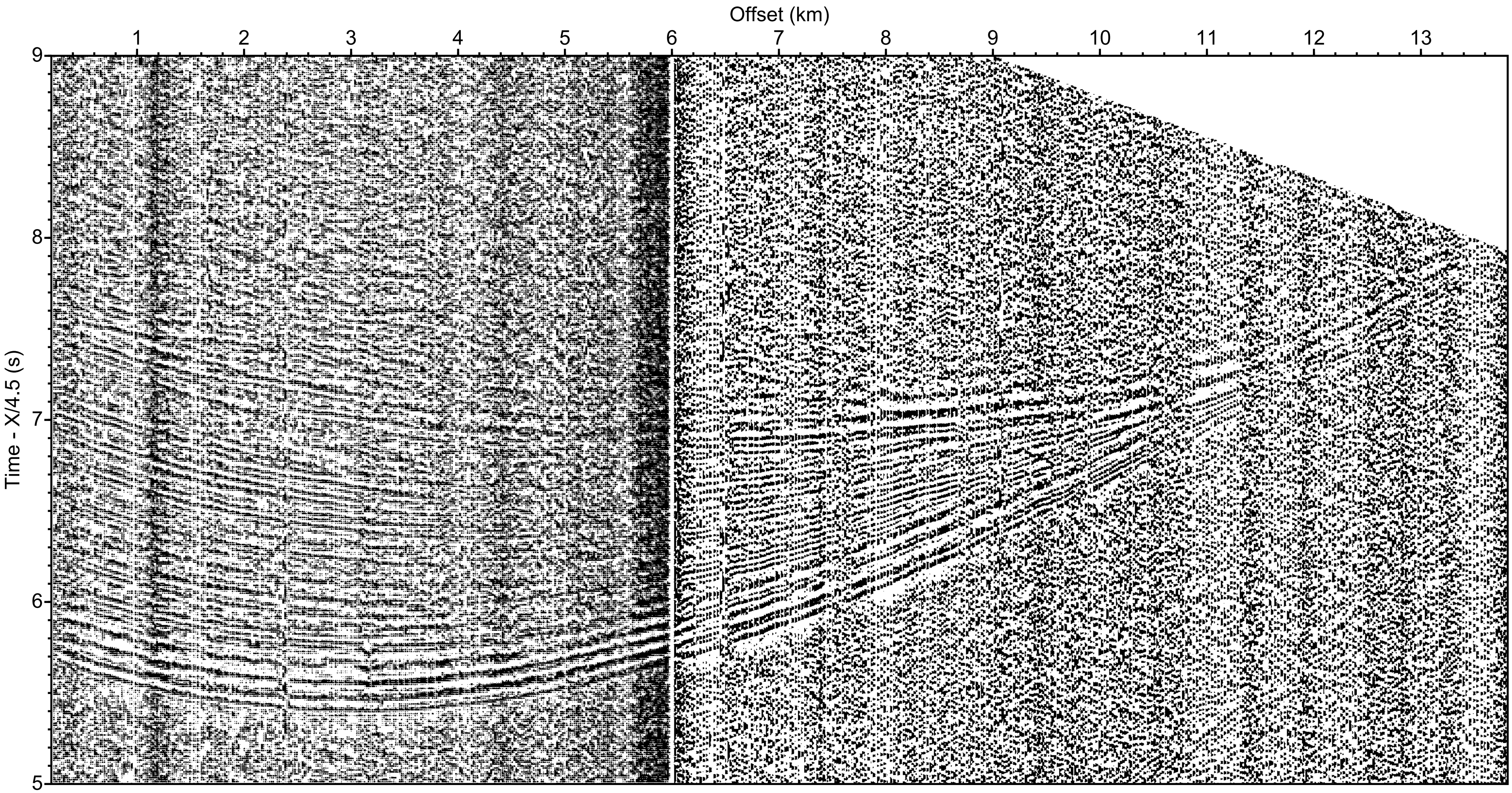
LOMROG 2009 - Sonobuoy 7-14 AUX 4 (deconv., bpf 5-36 Hz, AGC 300 ms)



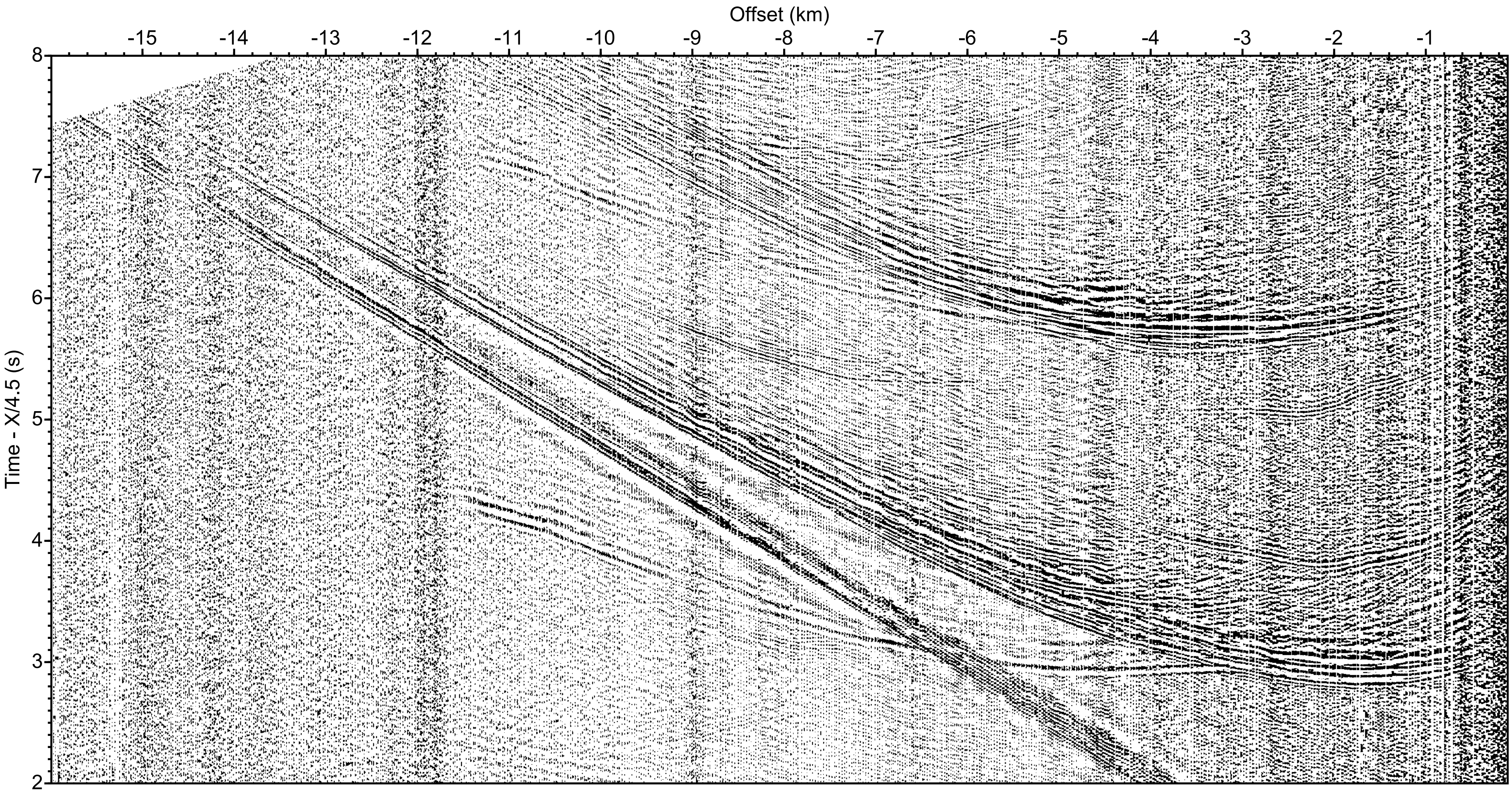
LOMROG 2009 - Sonobuoy 7-15 AUX 1 (deconv., bpf 5-36 Hz, AGC 300 ms)



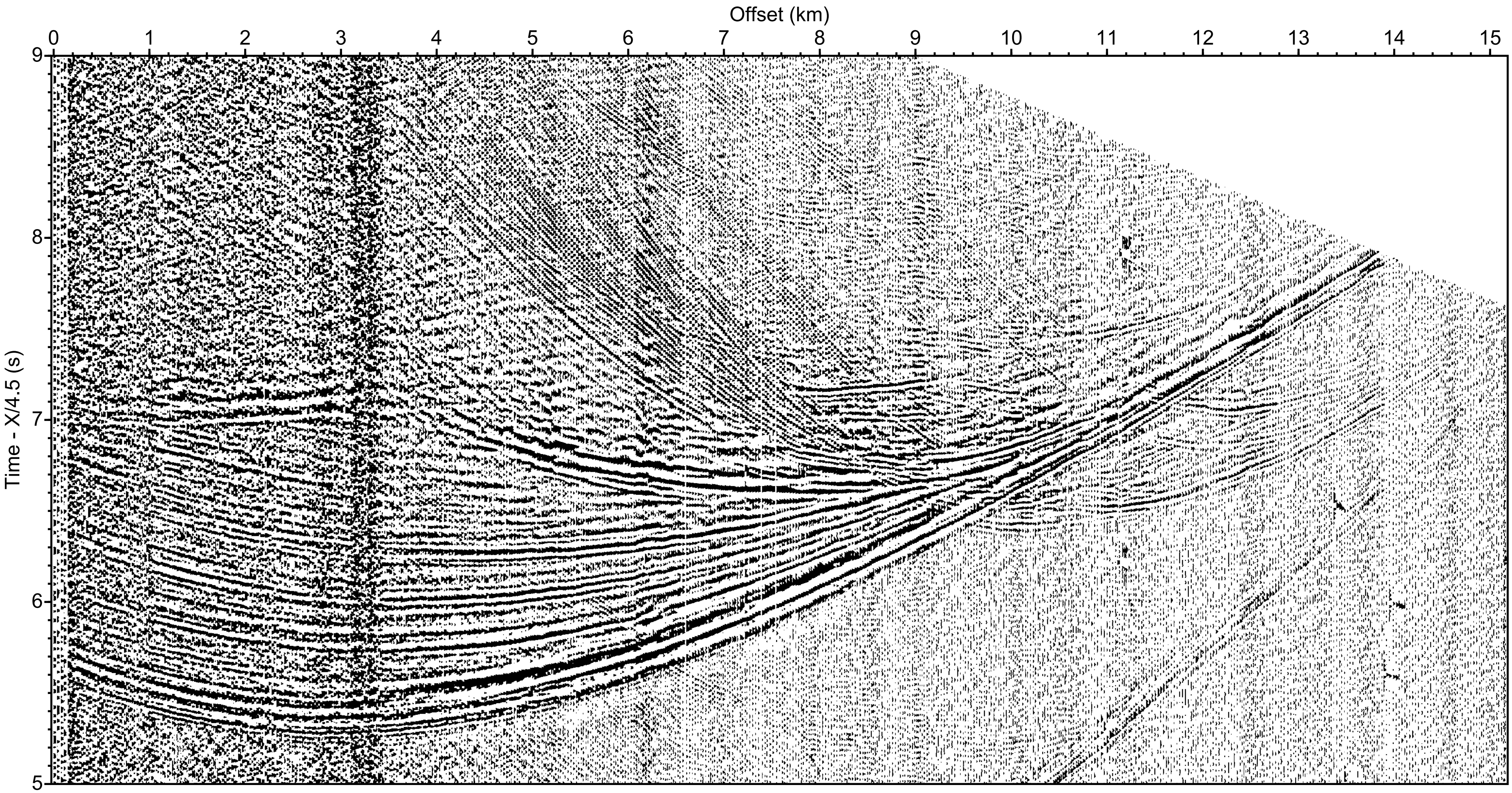
LOMROG 2009 - Sonobuoy 8-18 AUX 4 (deconv., bpf 5-56 Hz, AGC 300 ms)



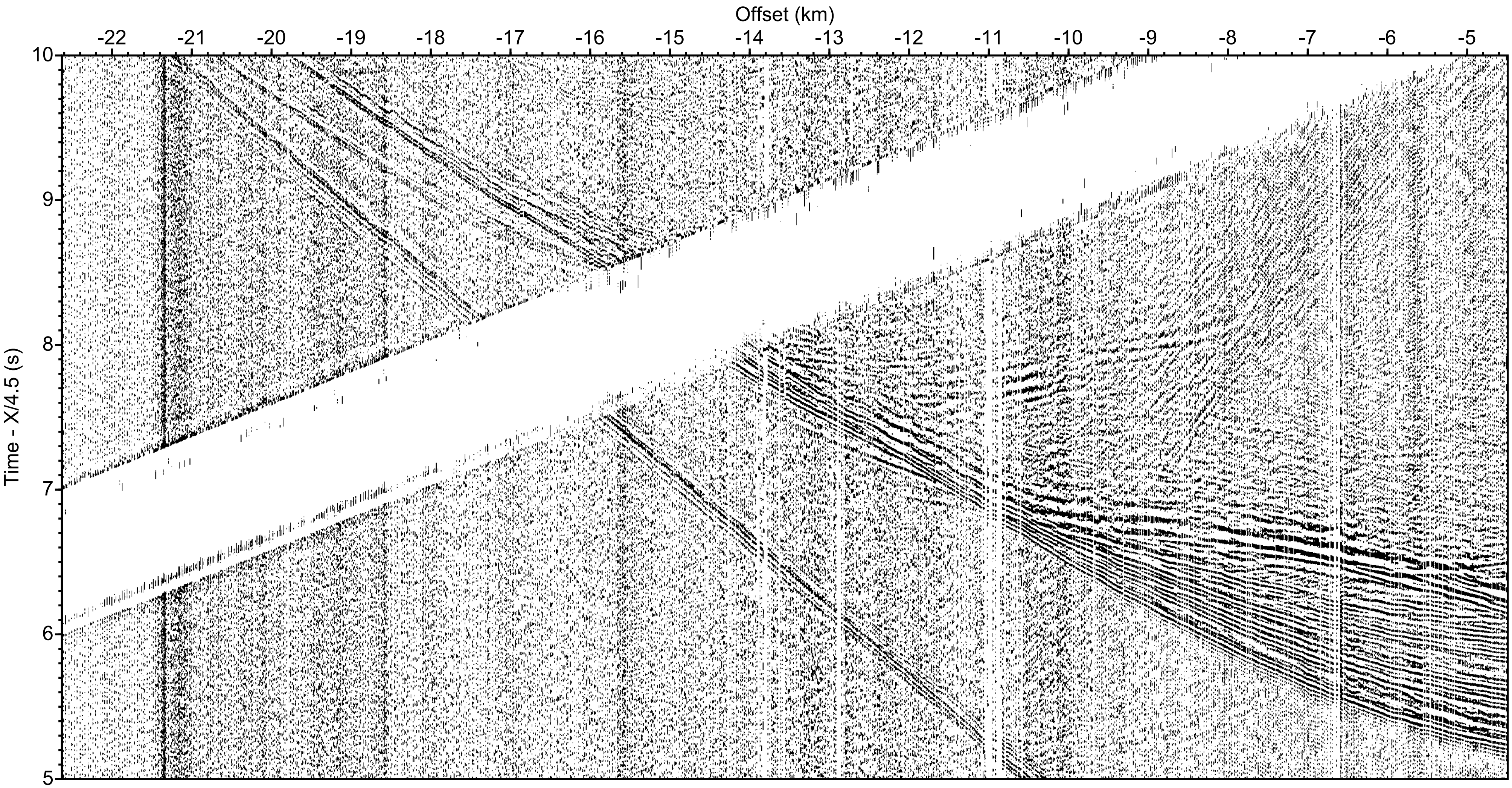
LOMROG 2009 - Sonobuoy 9-19 AUX 4 (deconv., bpf 5-36 Hz, AGC 300 ms)



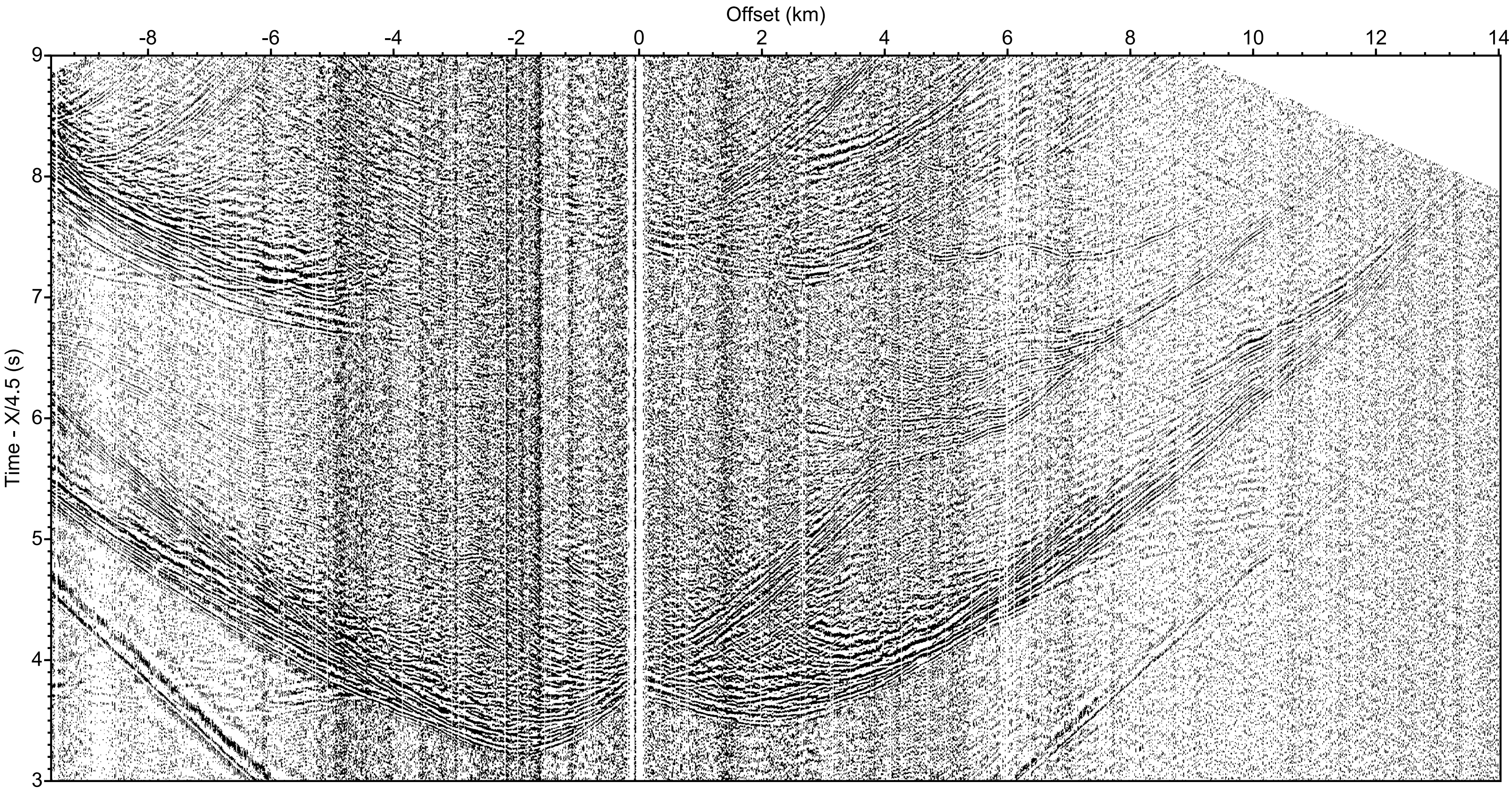
LOMROG 2009 - Sonobuoy 10-20 AUX 4 (deconv., bpf 5-36 Hz)



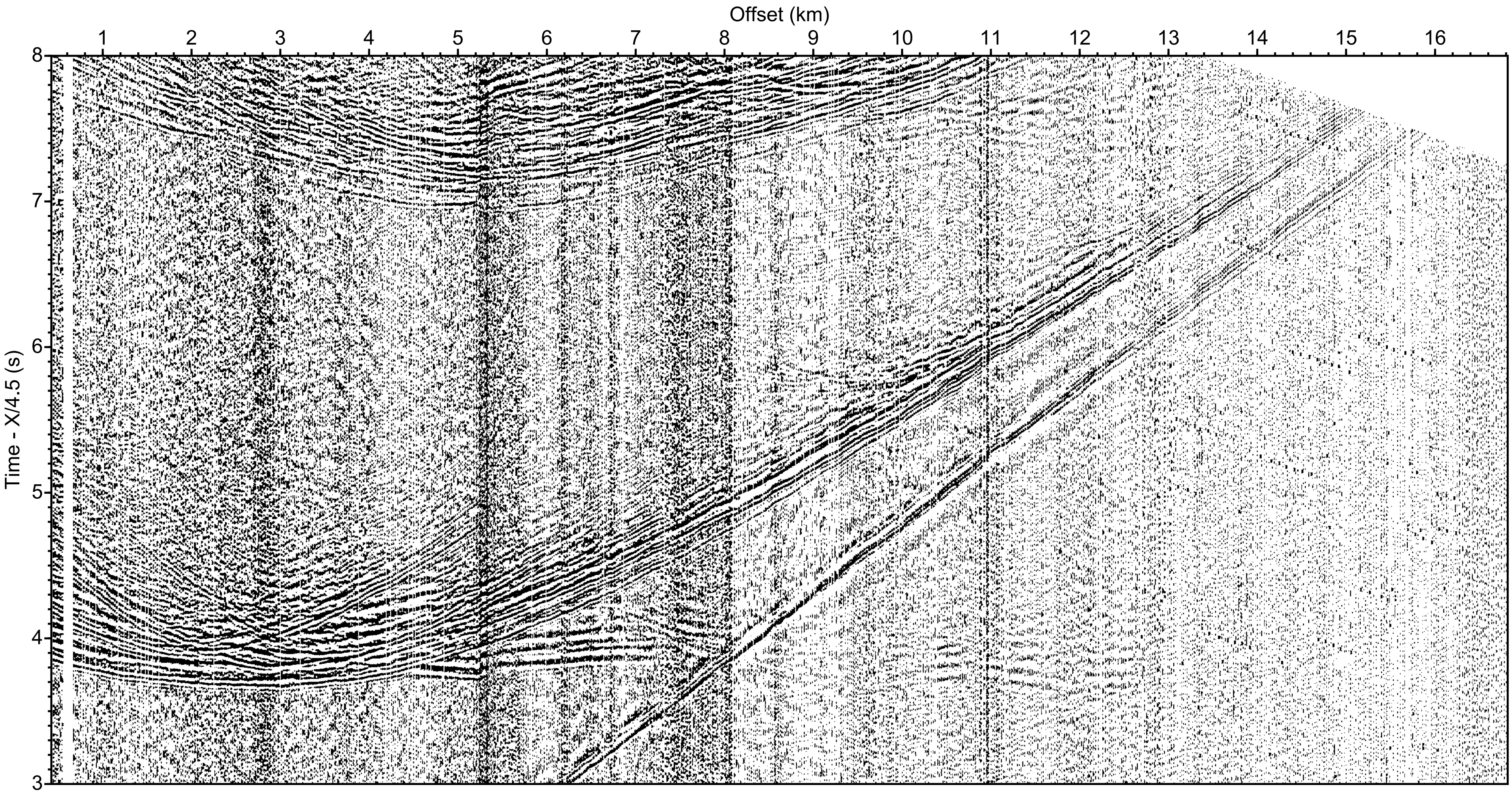
LOMROG 2009 - Sonobuoy 10-23 AUX 2 (median filter, deconv., bpf 5-36 Hz)



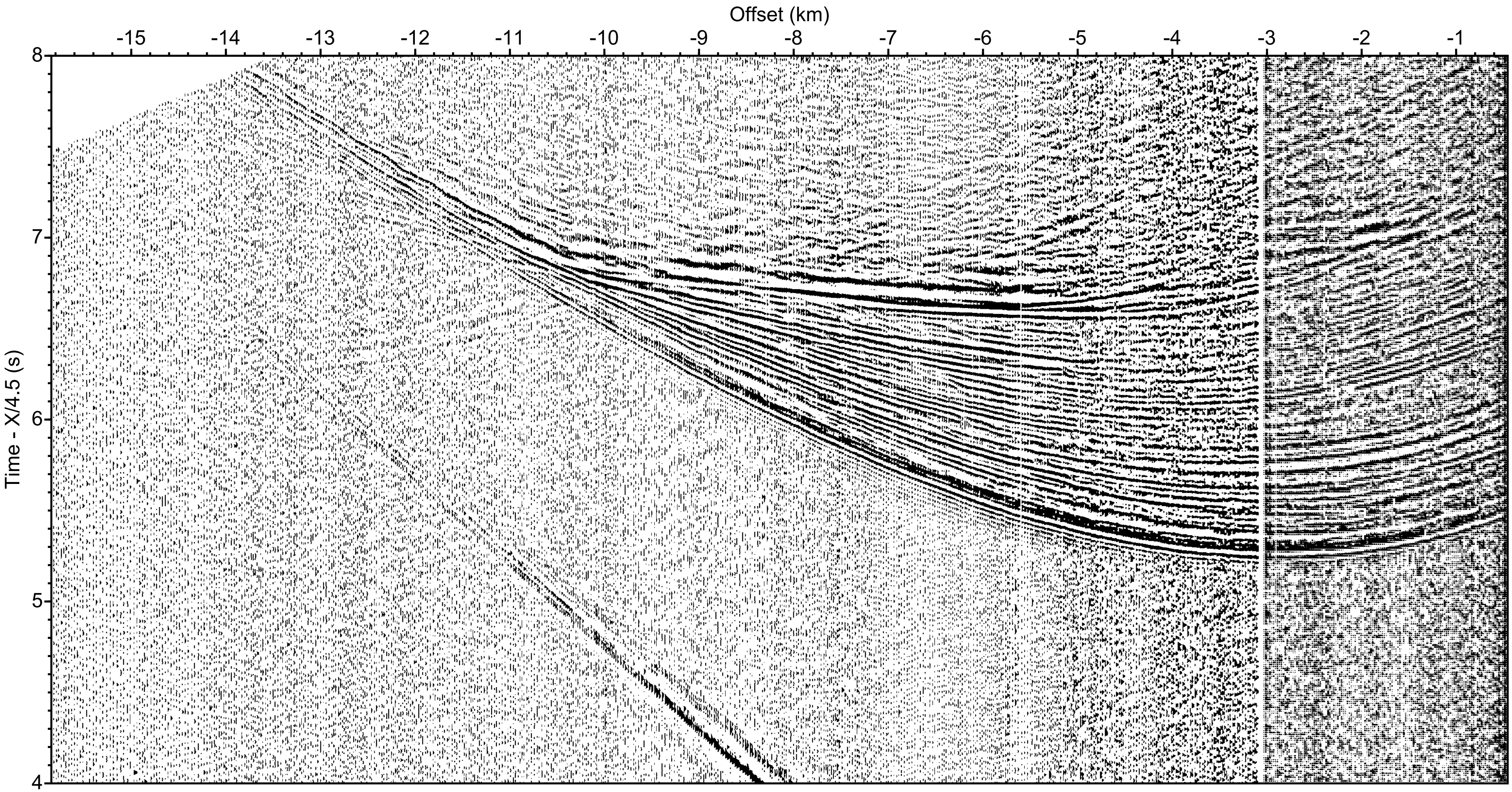
LOMROG 2009 - Sonobuoy 11-24 AUX 4 (deconv., bpf 5-36 Hz)



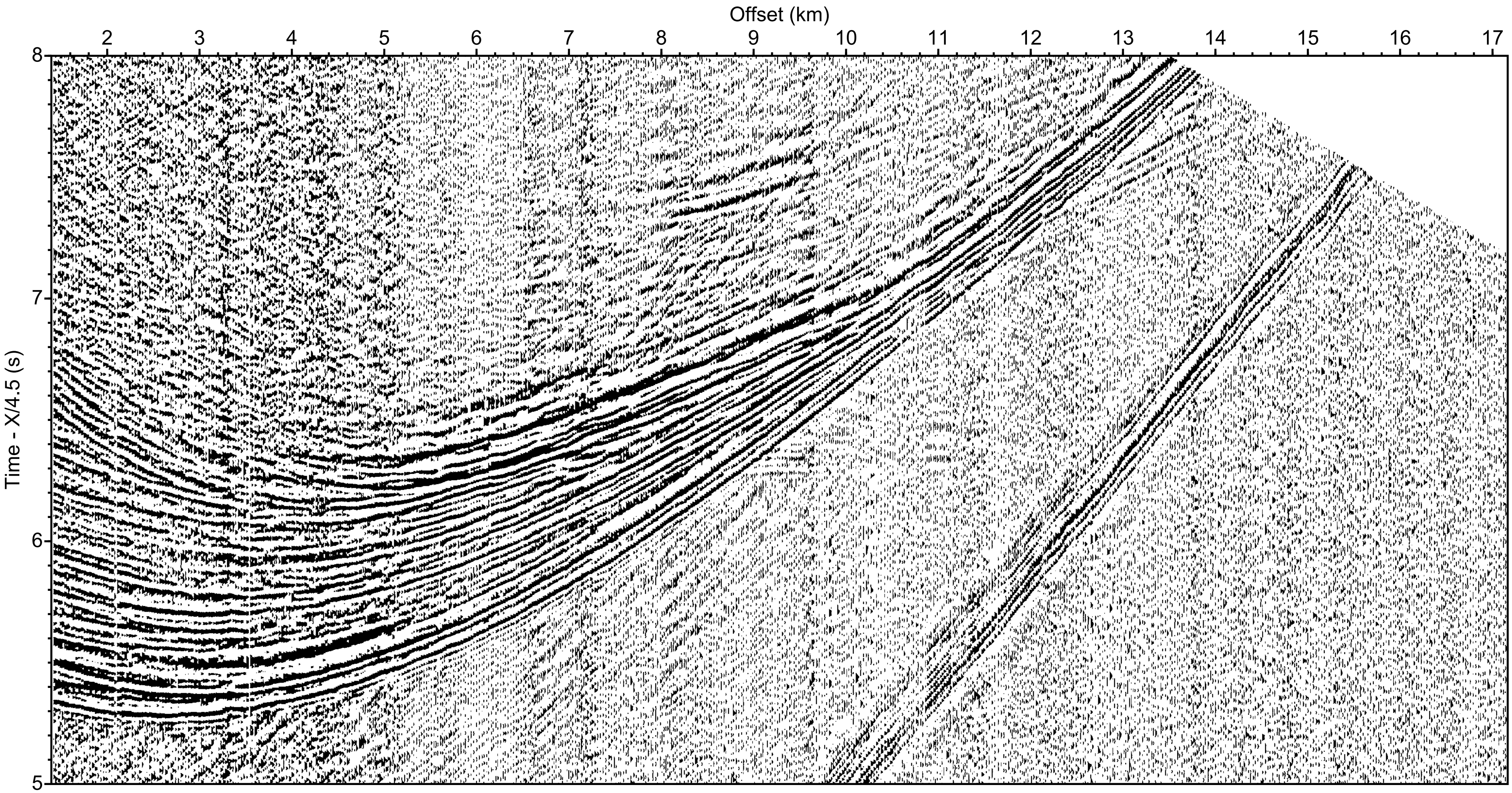
LOMROG 2009 - Sonobuoy 11-25 AUX 2 (deconv., bpf 5-36 Hz)



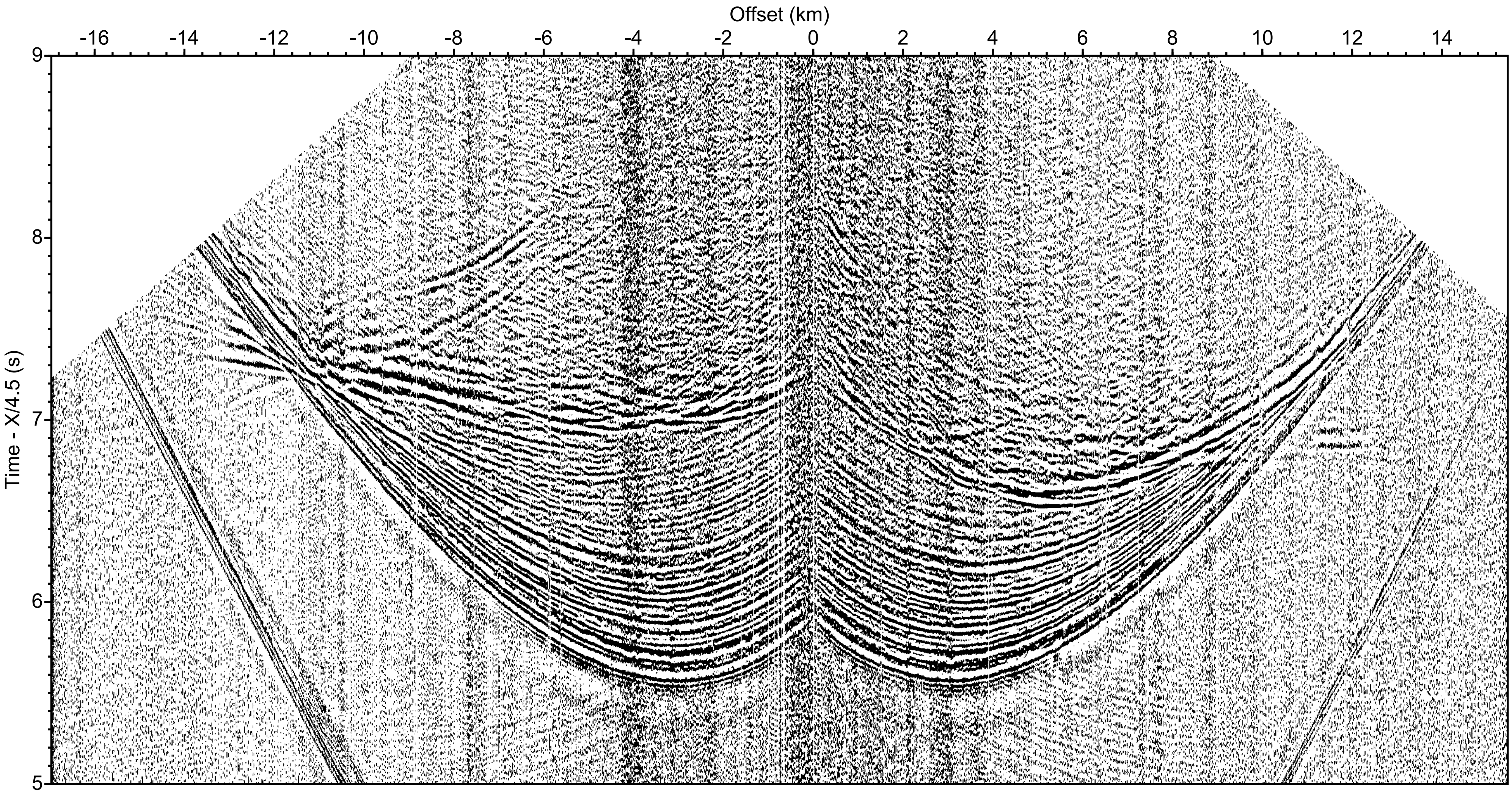
LOMROG 2009 - Sonobuoy 11-26 AUX 1 (deconv., bpf 5-36 Hz)



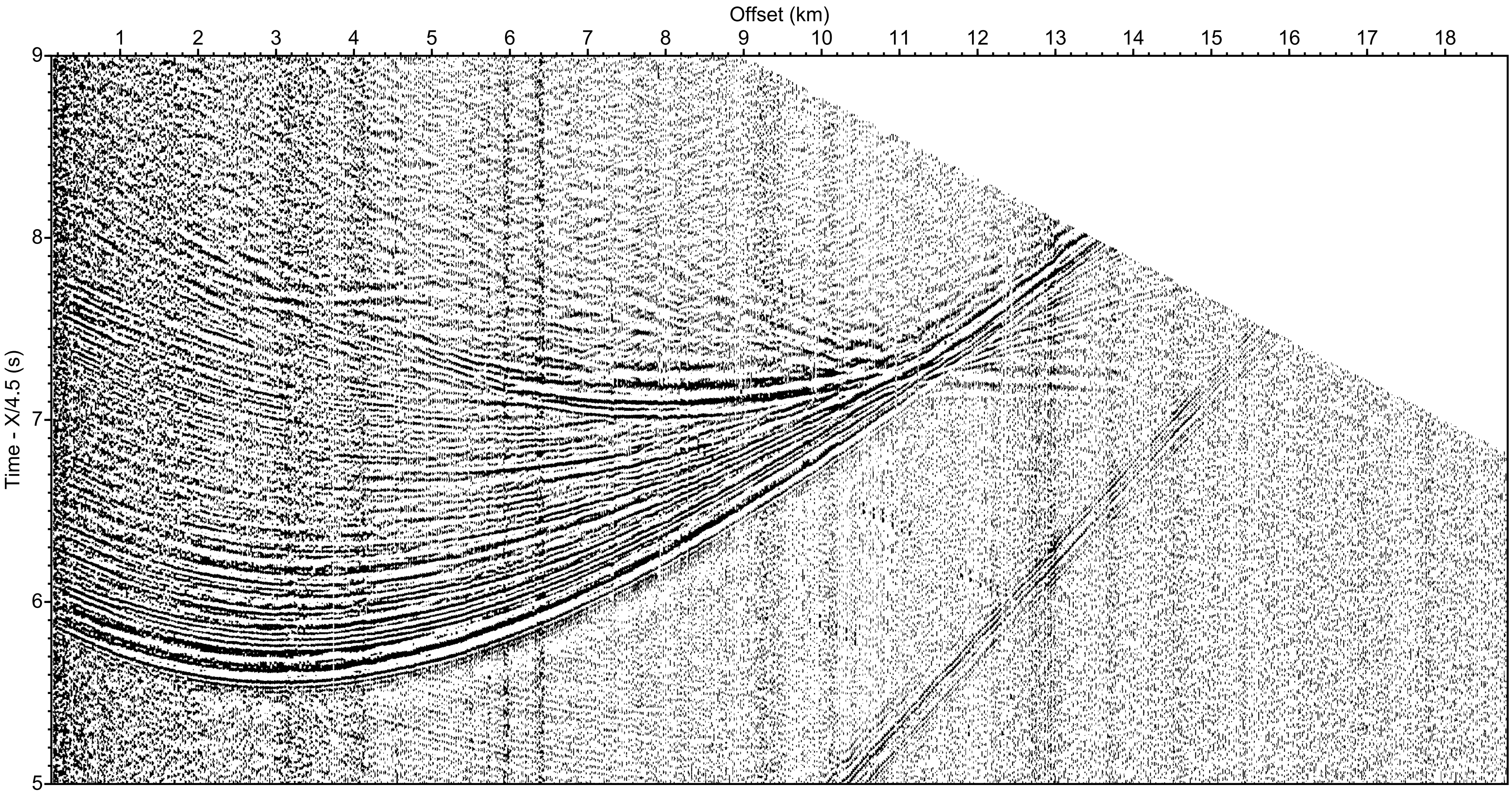
LOMROG 2009 - Sonobuoy 11-27 AUX 1 (deconv., bpf 5-36 Hz)



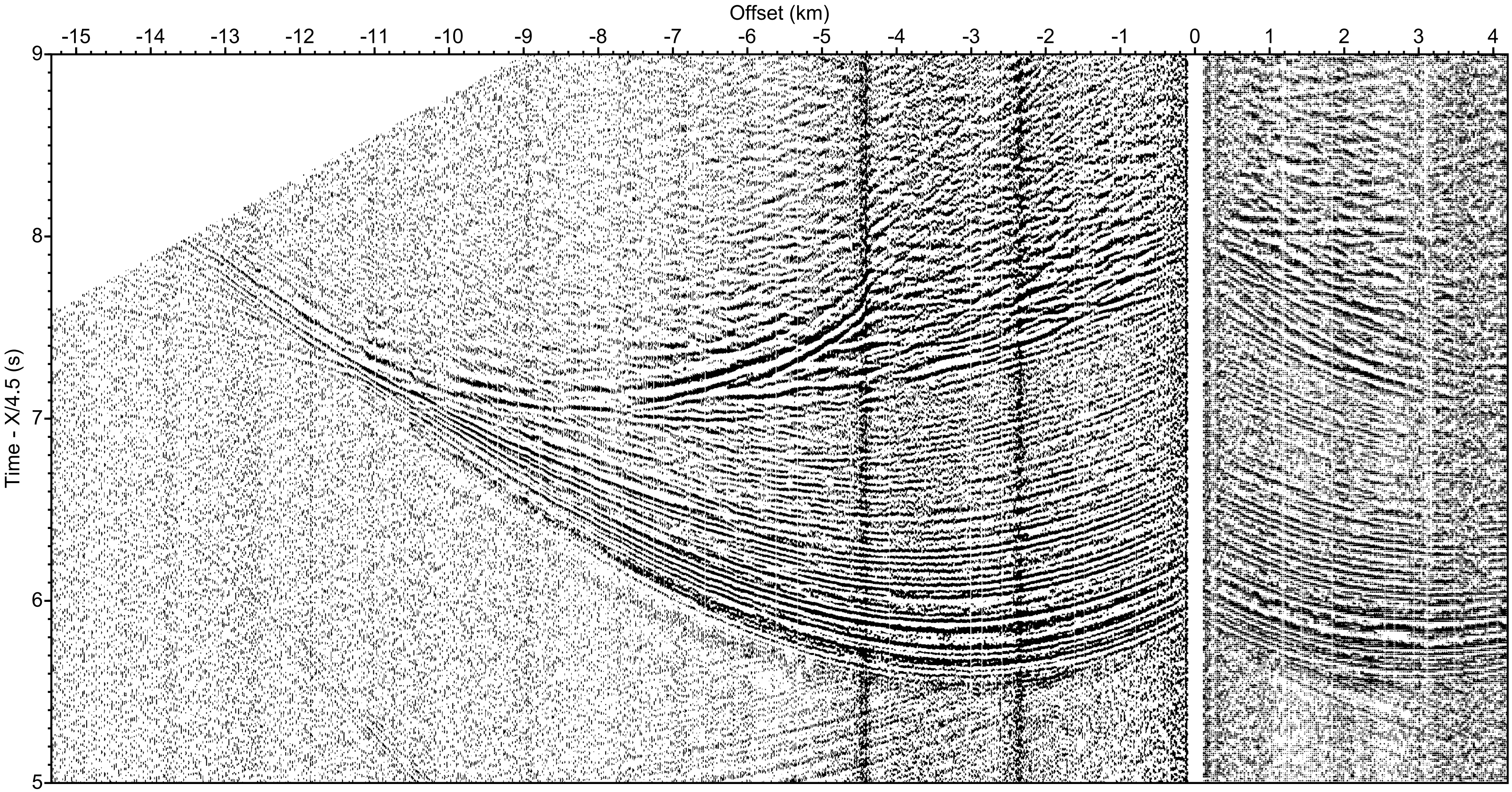
LOMROG 2009 - Sonobuoy 11-28 AUX 4 (deconv., bpf 5-36 Hz)



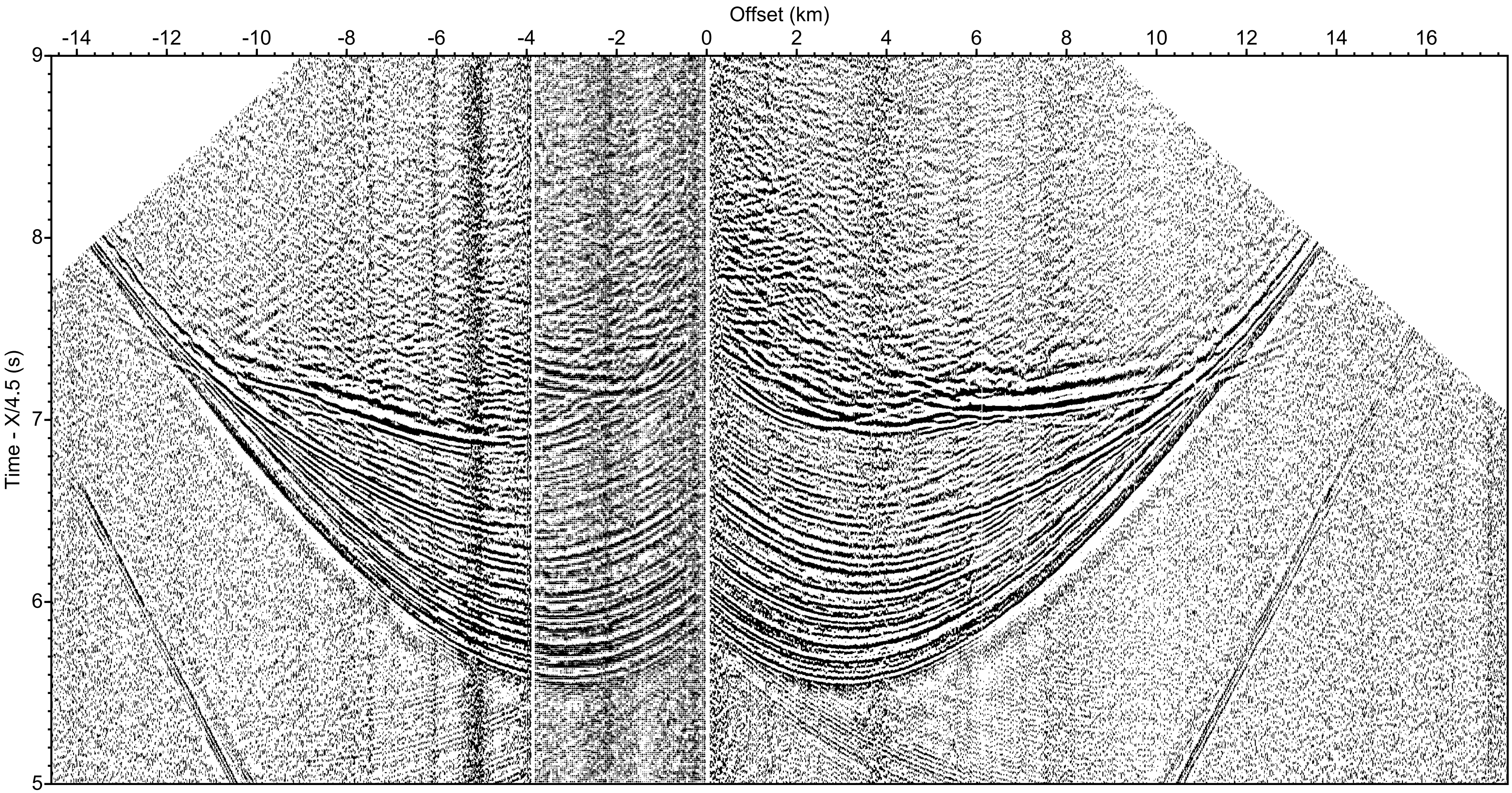
LOMROG 2009 - Sonobuoy 12-29 AUX 4 (deconv., bpf 5-36 Hz)



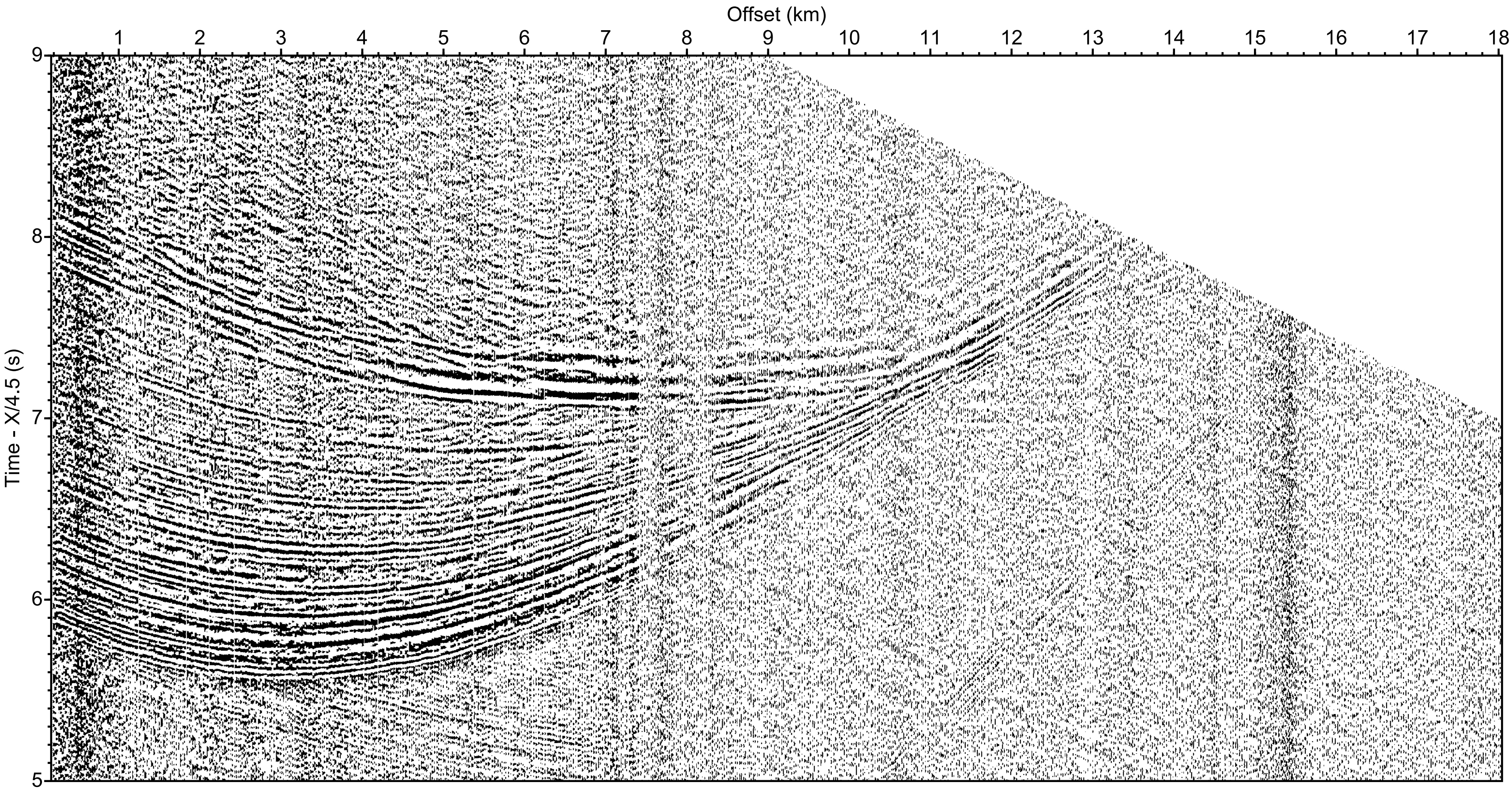
LOMROG 2009 - Sonobuoy 12-30 AUX 2 (deconv., bpf 5-36 Hz)



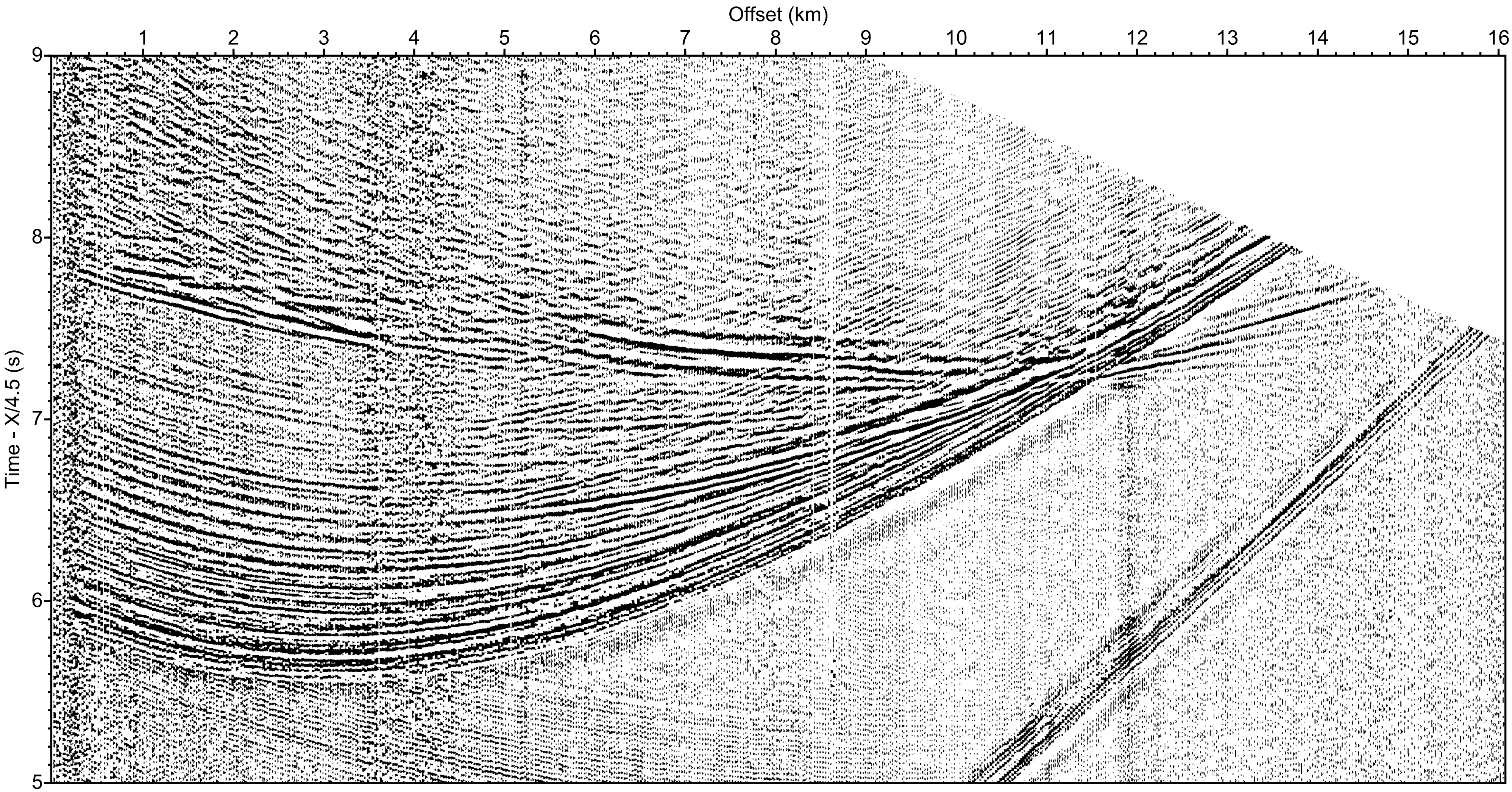
LOMROG 2009 - Sonobuoy 12-31 AUX 1 (deconv., bpf 5-36 Hz)



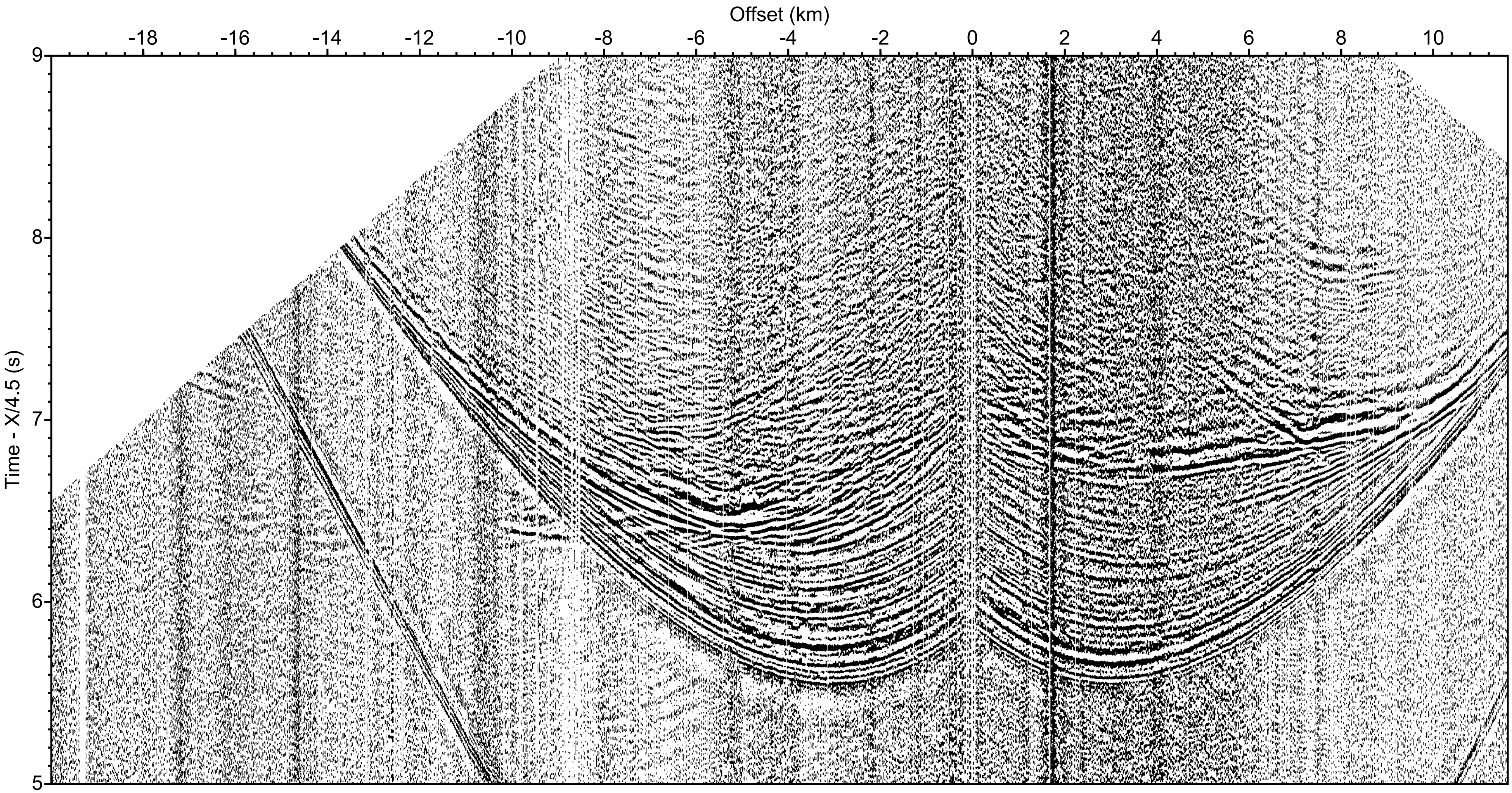
LOMROG 2009 - Sonobuoy 13-32 AUX 4 (deconv., bpf 5-36 Hz)



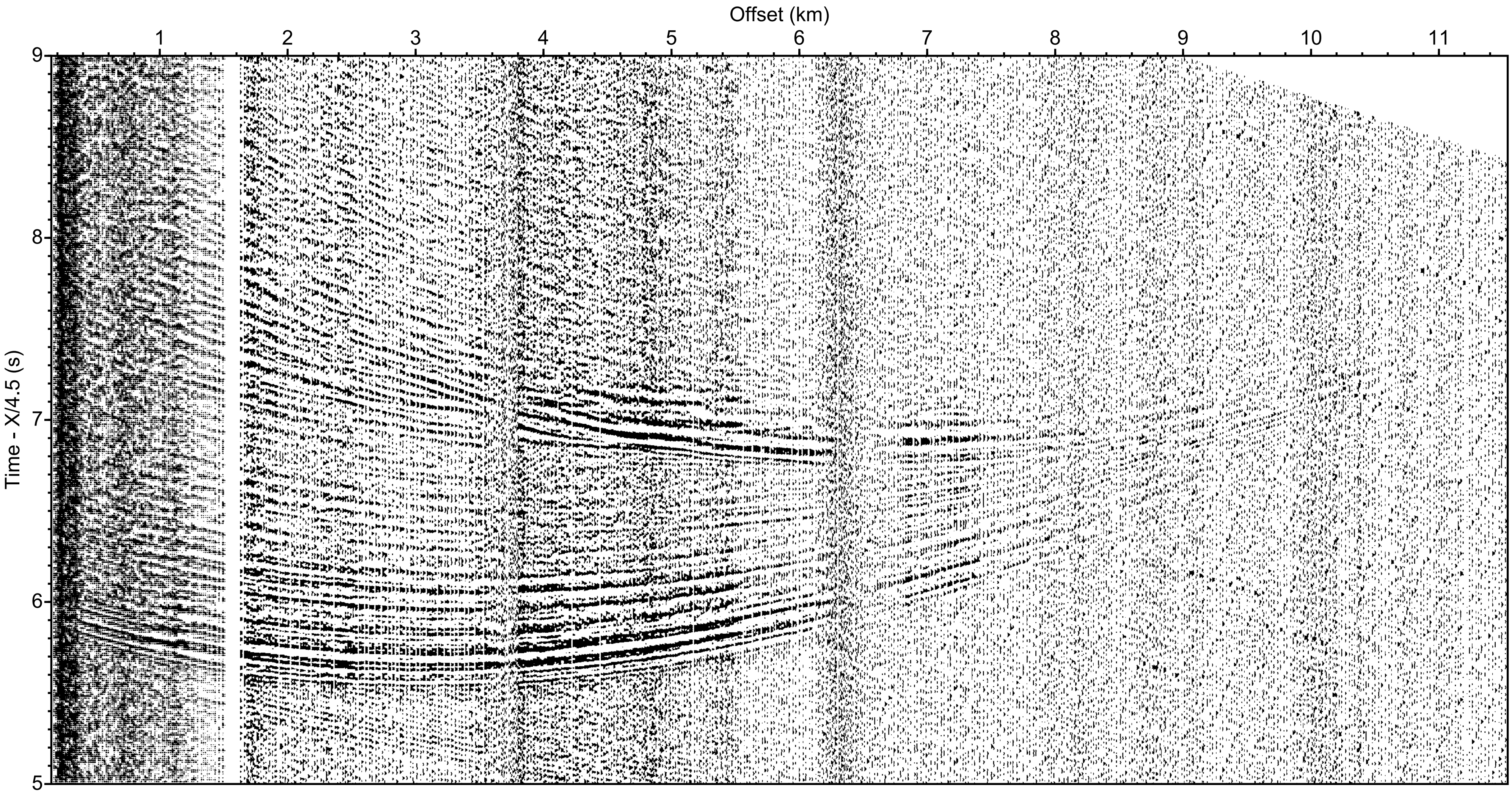
LOMROG 2009 - Sonobuoy 13-33 AUX 2 (deconv., bpf 5-36 Hz)



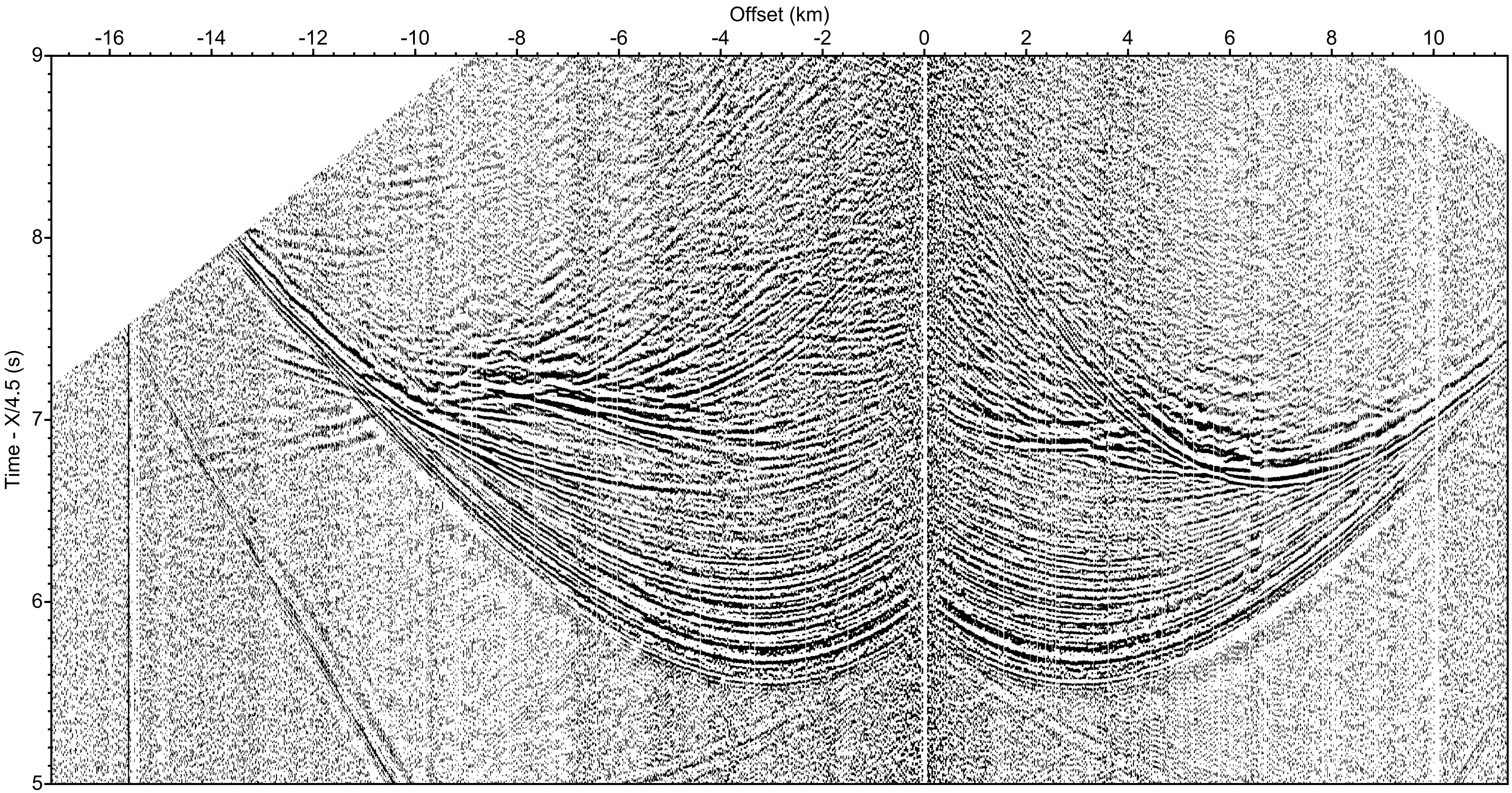
LOMROG 2009 - Sonobuoy 13-34 AUX 1 (deconv., bpf 5-36 Hz)



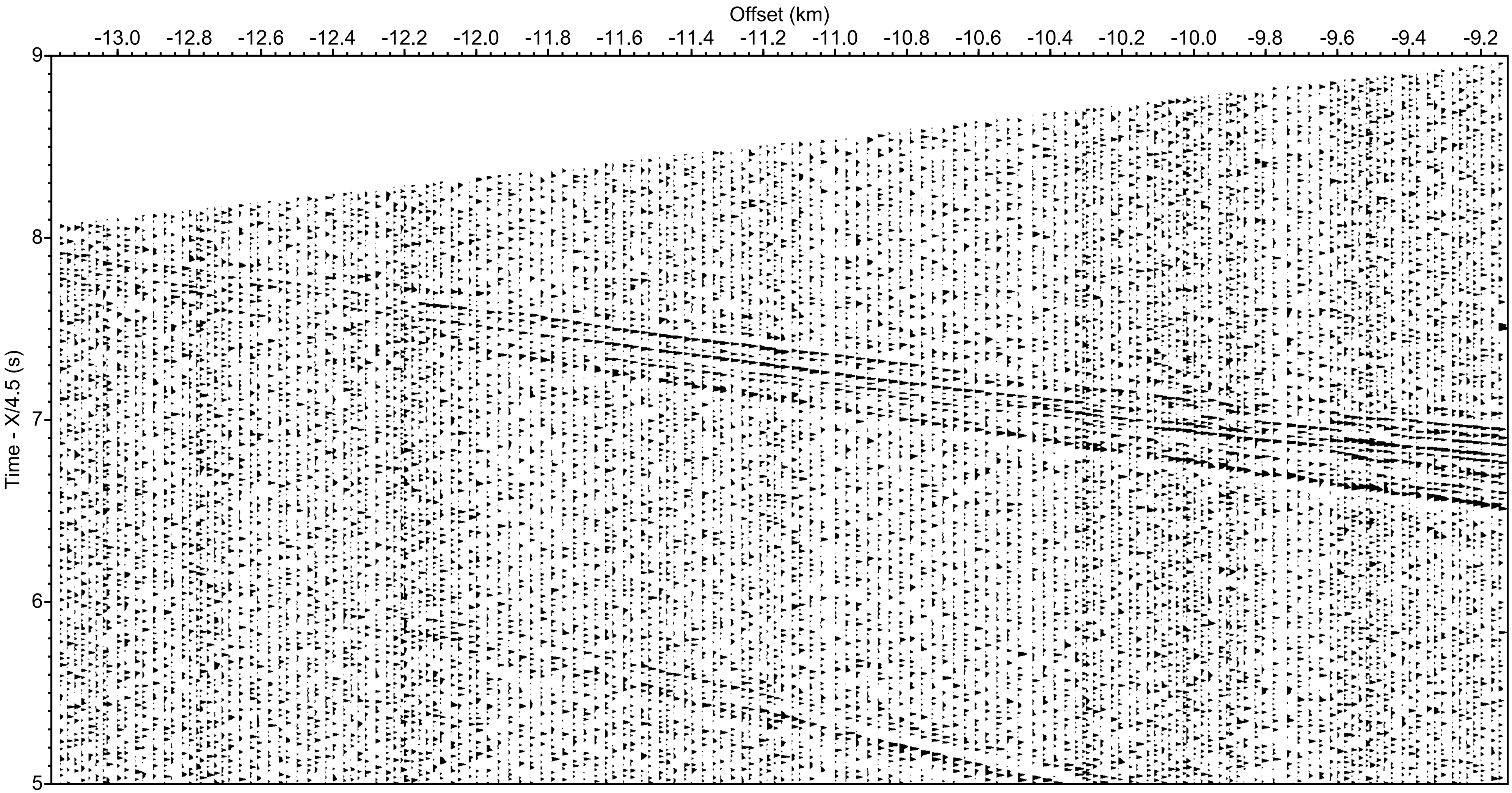
LOMROG 2009 - Sonobuoy 14-35 AUX 4 (deconv., bpf 5-36 Hz)



LOMROG 2009 - Sonobuoy 14-36 AUX 2 (deconv., bpf 5-36 Hz)



LOMROG 2009 - Sonobuoy 14-37 AUX 1 (deconv., bpf 5-36 Hz)

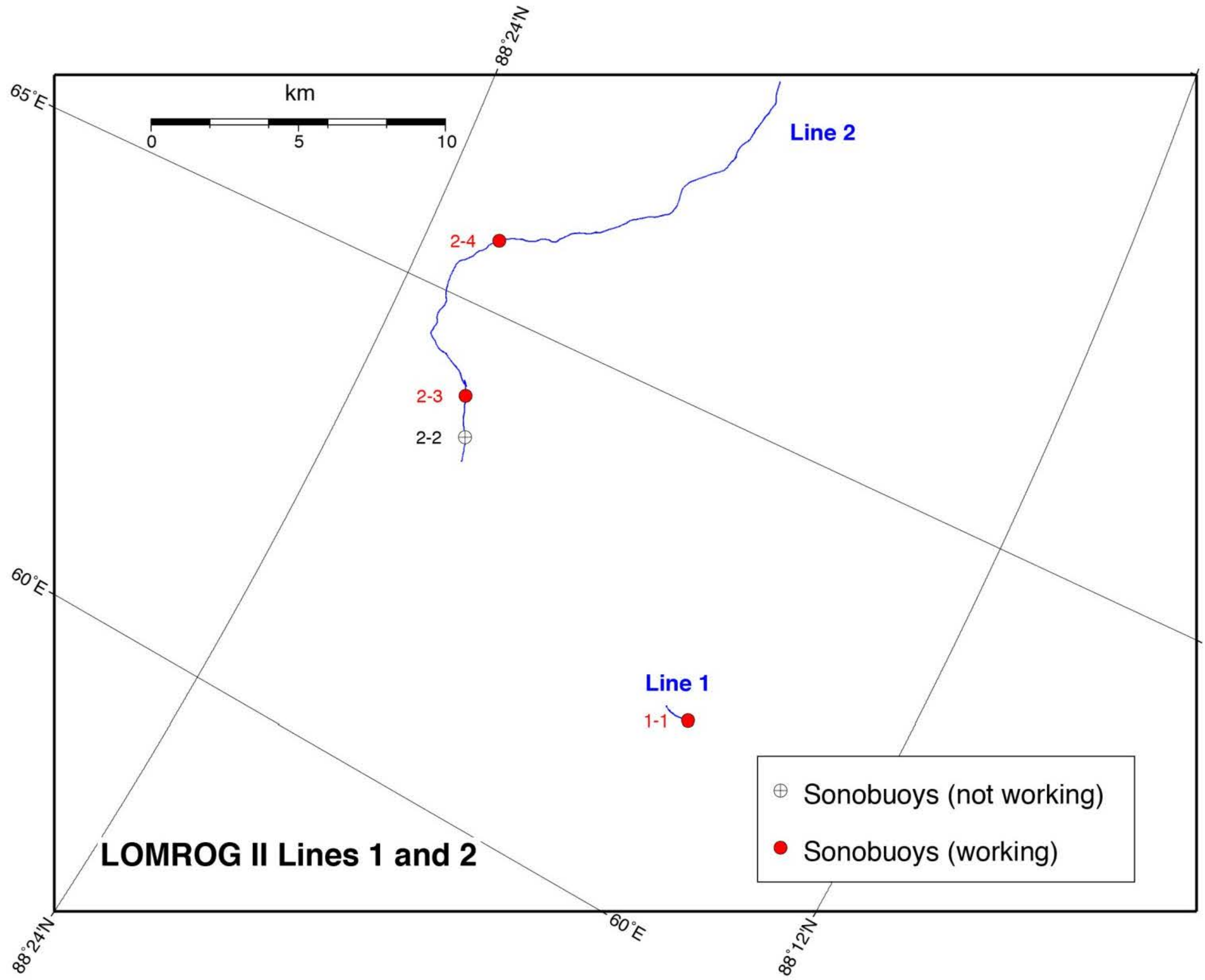


LOMROG 2009 - Sonobuoy 15-38 AUX 4 (deconv., bpf 5-36 Hz)

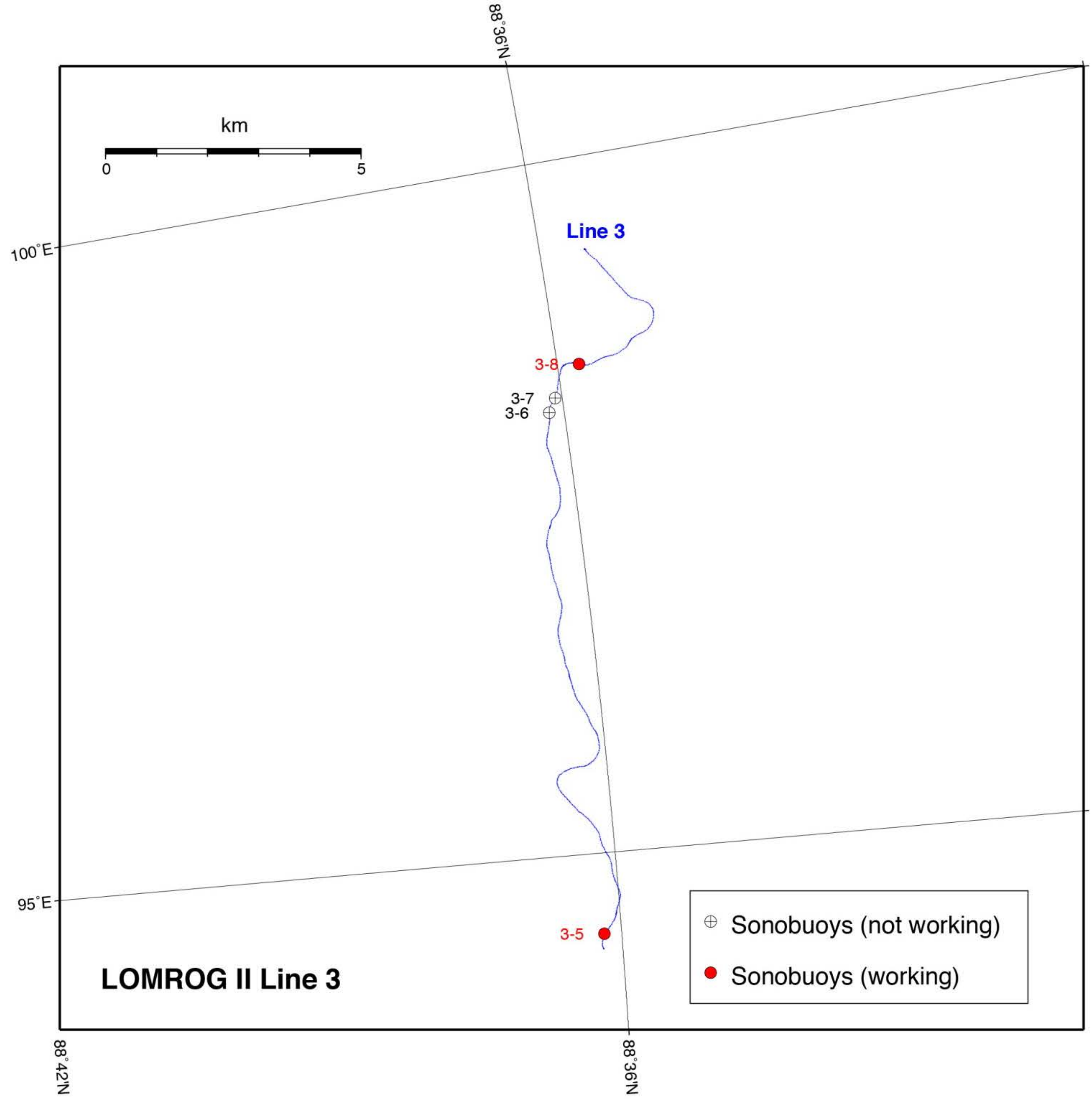
Appendix V-B:

Location Maps for all Seismic Lines

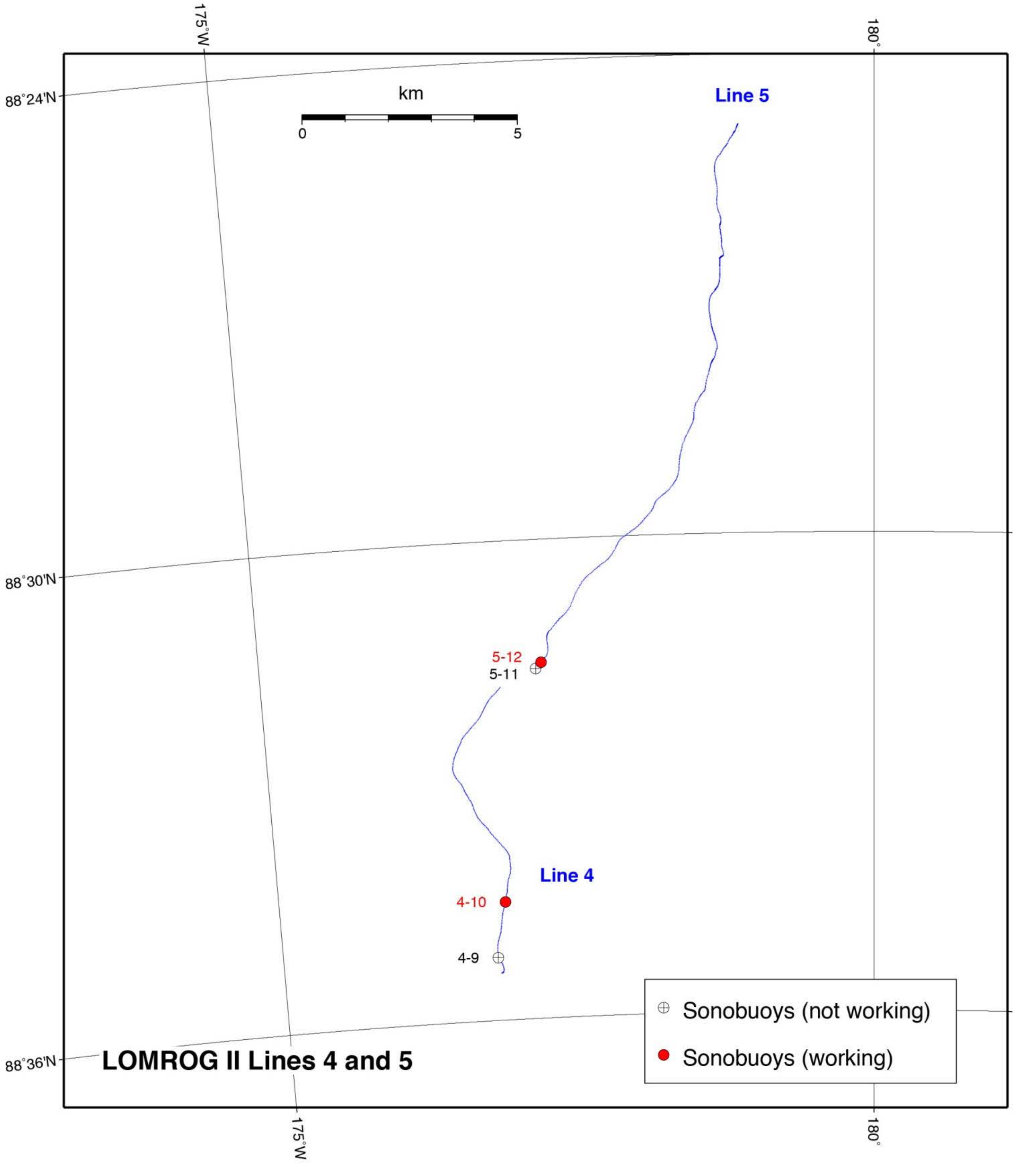
Blue lines show the shot locations of the reflection seismic lines. Red circles indicate the deployment position of sonobuoys from which data were recorded. Unsuccessful sonobuoy launches are indicated by circles with a cross. A number of sonobuoys were deployed during the preparation of the track (ice 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 green circle (connected with a green line to the original deployment position). Hence, the green 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.



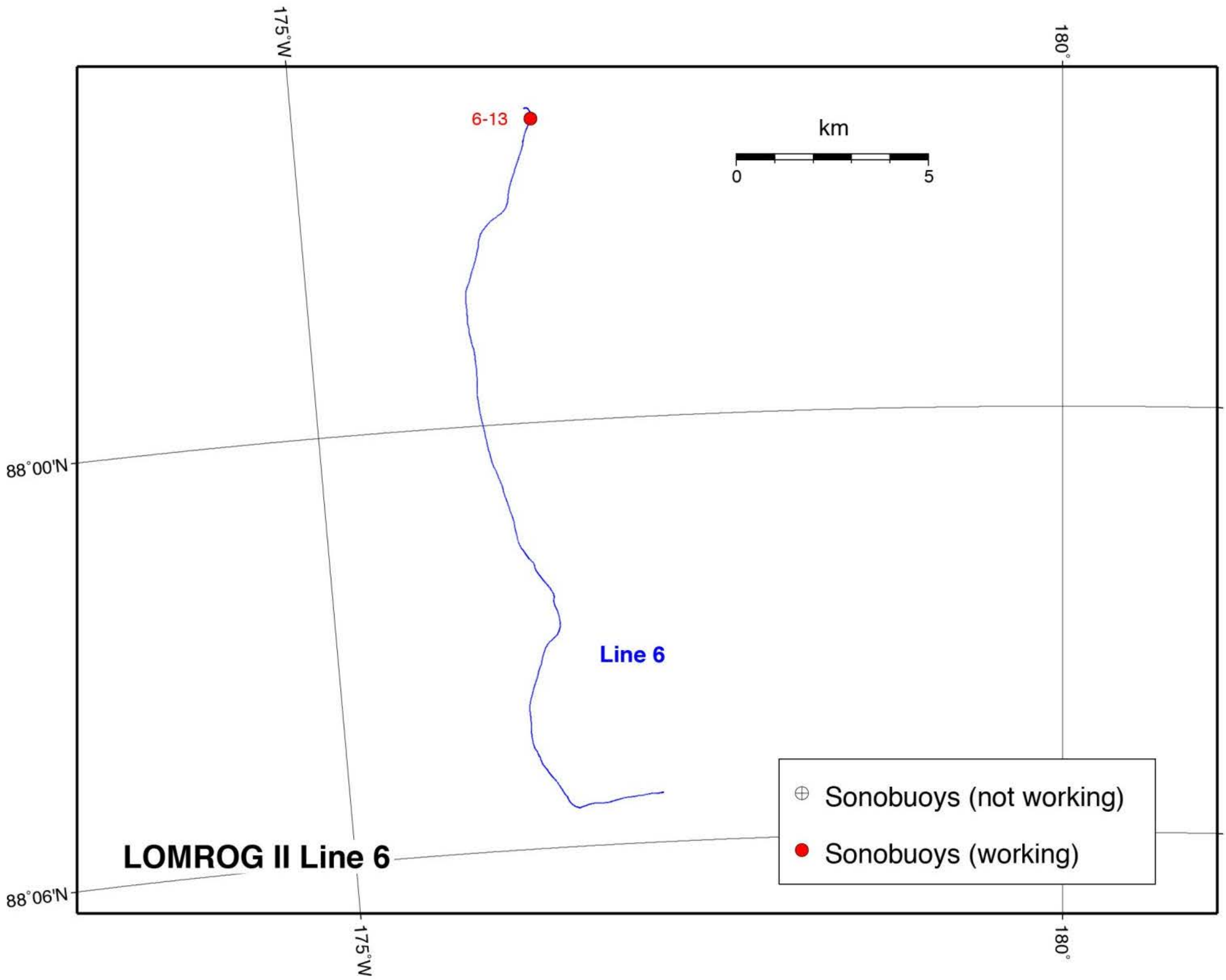
88°24'N
65°E
km
0
5
10
Line 2
2-4
2-3
2-2
60°E
Line 1
1-1
Sonobuoys (not working)
Sonobuoys (working)
LOMROG II Lines 1 and 2
88°24'N
60°E
88°12'N

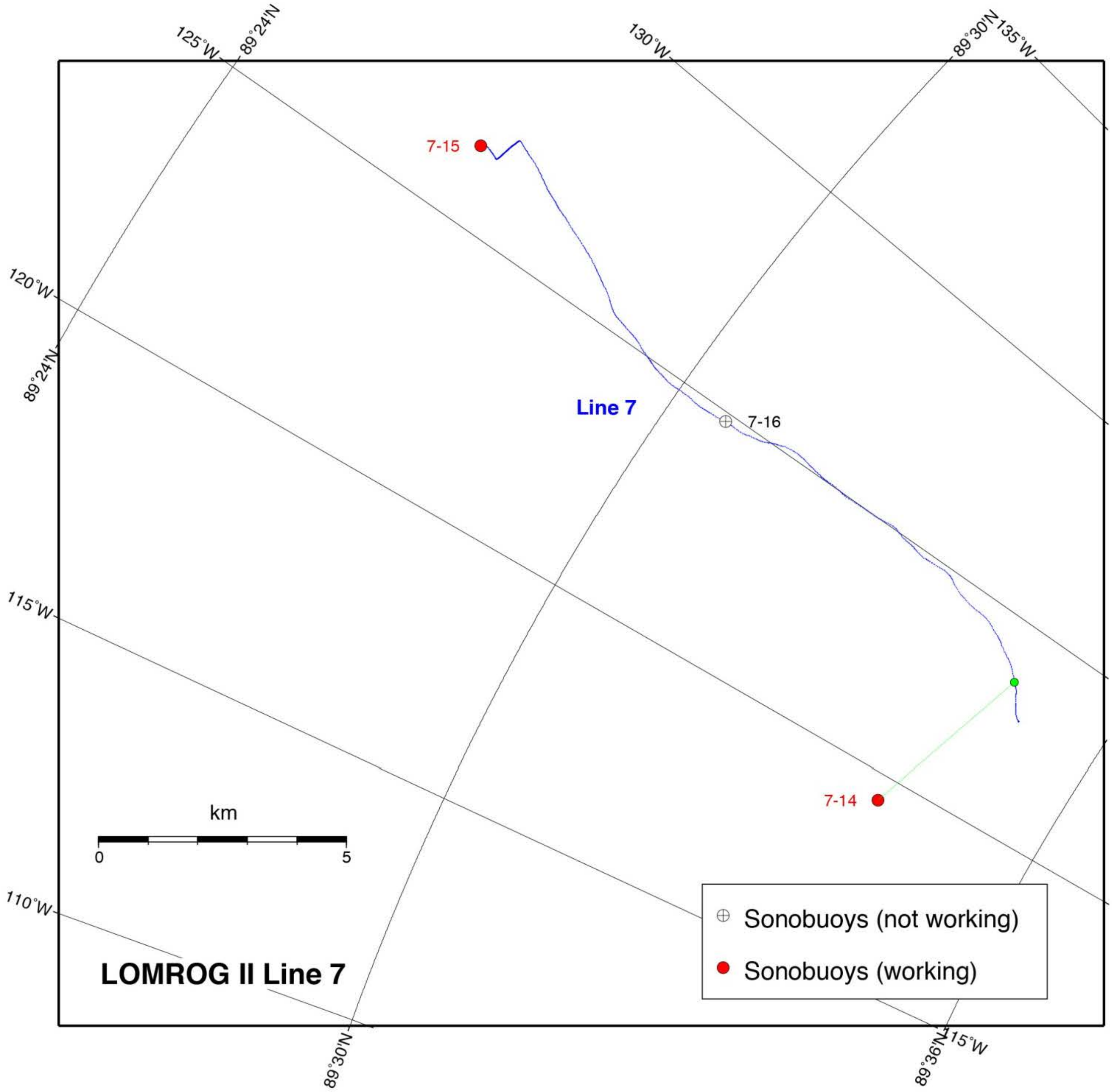


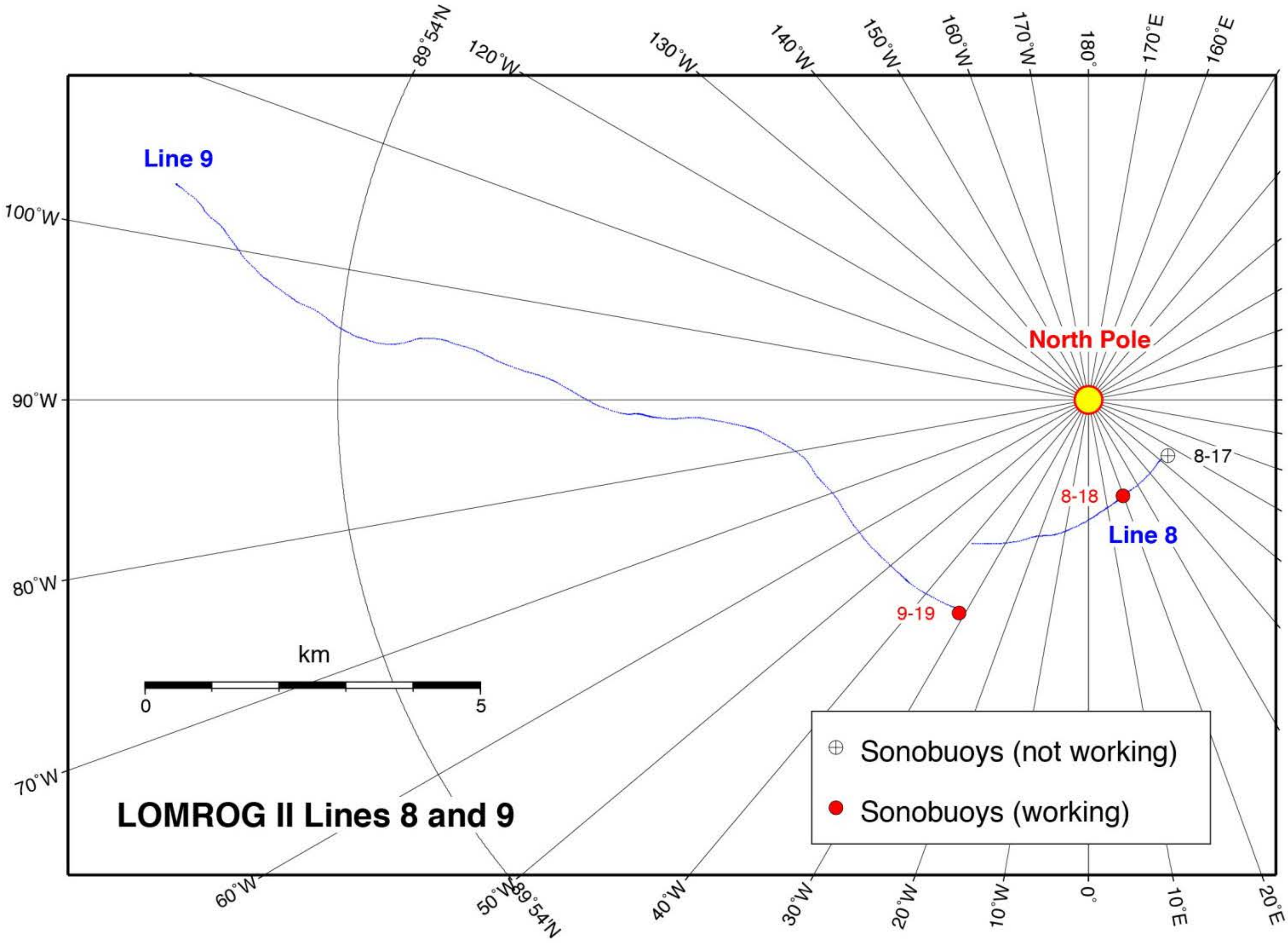
88°36'N
km
0
5
100°E
Line 3
3-8
3-7
3-6
95°E
3-5
Sonobuoys (not working)
Sonobuoys (working)
LOMROG II Line 3
88°42'N
88°36'N



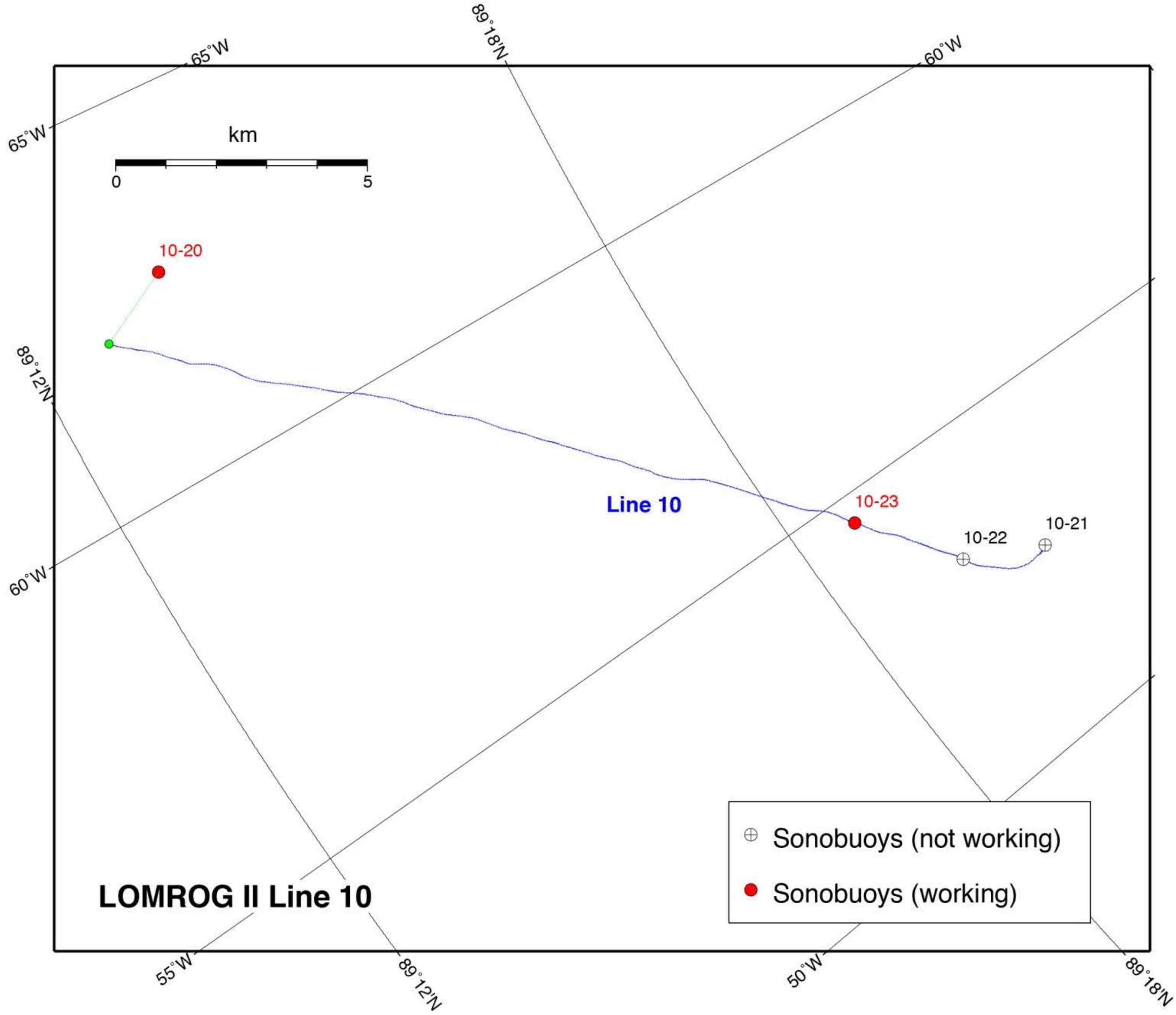
175°W
180°
88°24'N
km
0
5
Line 5
88°30'N
5-12
5-11
Line 4
4-10
4-9
Sonobuoys (not working)
Sonobuoys (working)
88°36'N
LOMROG II Lines 4 and 5
175°W
180°


175°W
180°
6-13
km
0
5
88°00'N
Line 6
Sonobuoys (not working)
Sonobuoys (working)
LOMROG II Line 6
88°06'N
175°W
180°

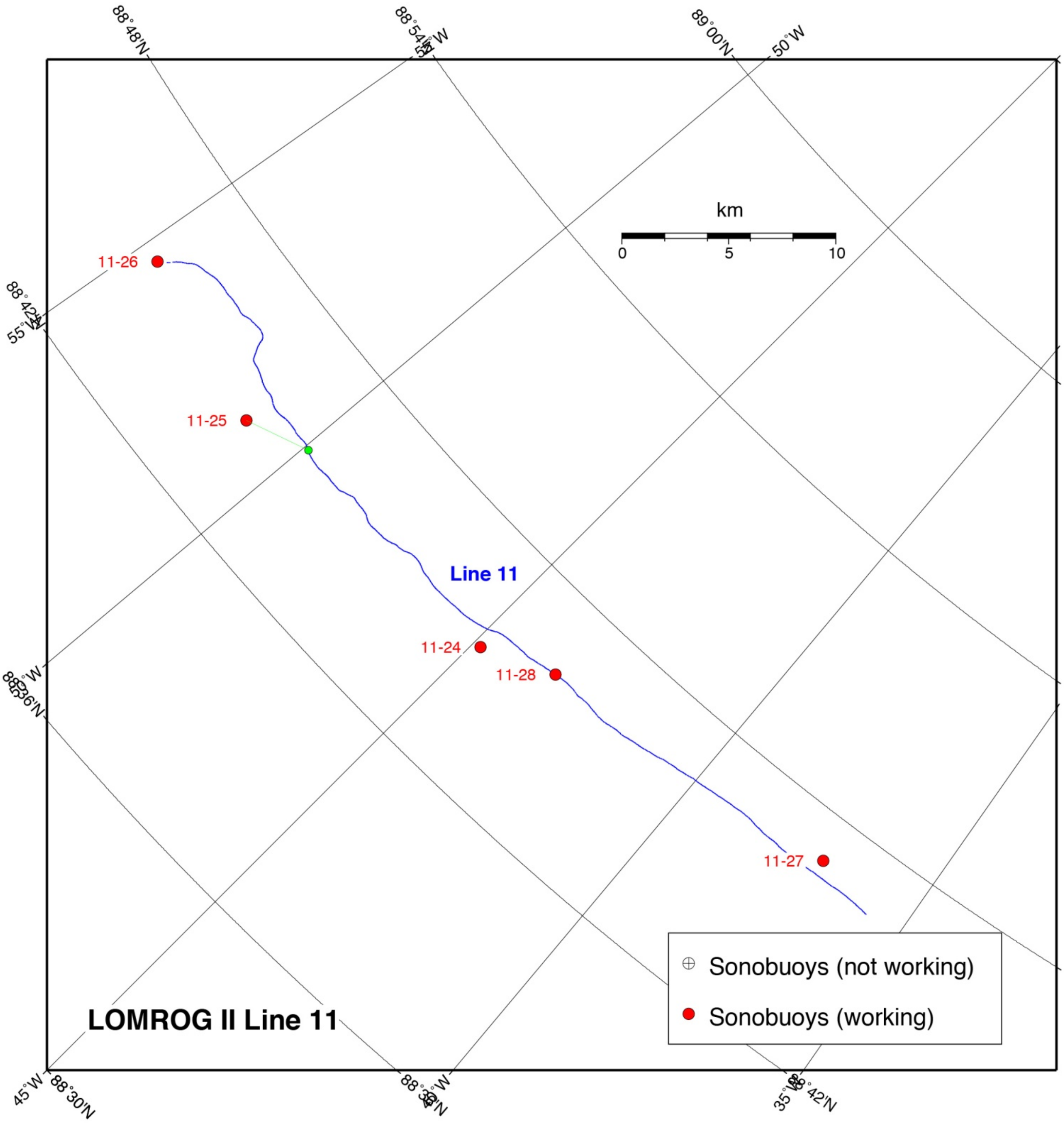

125°W
89°24'N
130°W
89°30'N
135°W
120°W
89°24'N
115°W
110°W
89°30'N
89°36'N
115°W
7-15
Line 7
7-16
7-14
km
0
5
Sonobuoys (not working)
Sonobuoys (working)
LOMROG II Line 7



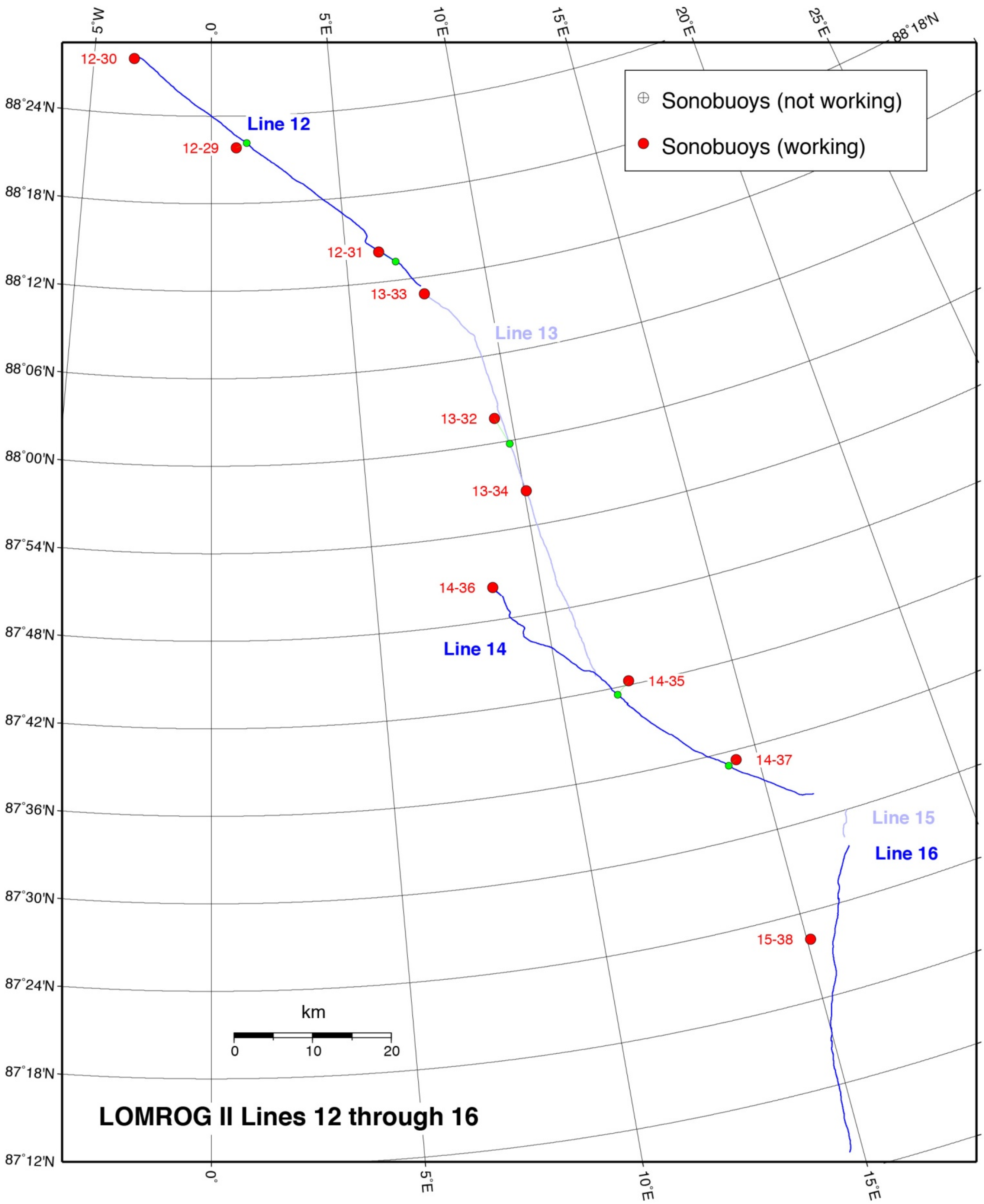
Line 9
North Pole
8-17
8-18
Line 8
9-19
km
0
5
Sonobuoys (not working)
Sonobuoys (working)
LOMROG II Lines 8 and 9
89°54'N
120°W
130°W
140°W
150°W
160°W
170°W
180°
170°E
160°E
100°W
90°W
80°W
70°W
60°W
50°W
40°W
30°W
20°W
10°W
0°
10°E
20°E



65°W
65°W
89°18'N
60°W
km
0
5
10-20
89°12'N
Line 10
10-23
10-22
10-21
60°W
Sonobuoys (not working)
Sonobuoys (working)
LOMROG II Line 10
55°W
89°12'N
50°W
89°18'N



88°48'N
88°54'N
55°W
89°00'N
50°W
km
0
5
10
11-26
88°42'N
55°W
11-25
Line 11
11-24
11-28
88°36'N
11-27
Sonobuoys (not working)
Sonobuoys (working)
LOMROG II Line 11
45°W
88°30'N
40°W
35°W

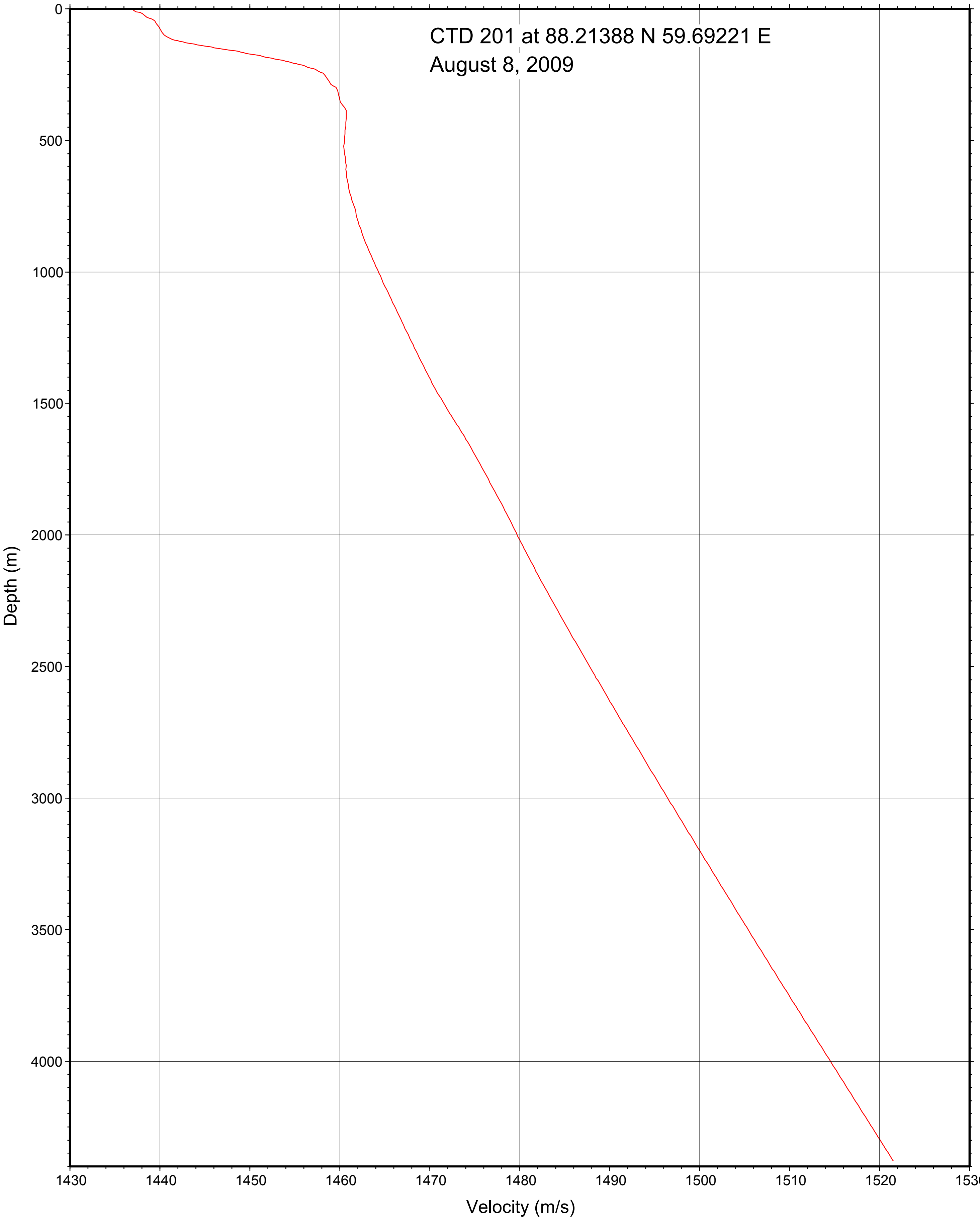


Sonobuoys (not working)
Sonobuoys (working)
Line 12
Line 13
Line 14
Line 15
Line 16
12-30
12-29
12-31
13-33
13-32
13-34
14-36
14-35
14-37
15-38
km
0
10
20
88°24'N
88°18'N
88°12'N
88°06'N
88°00'N
87°54'N
87°48'N
87°42'N
87°36'N
87°30'N
87°24'N
87°18'N
87°12'N
5°W
0°
5°E
10°E
15°E
20°E
25°E
LOMROG II Lines 12 through 16

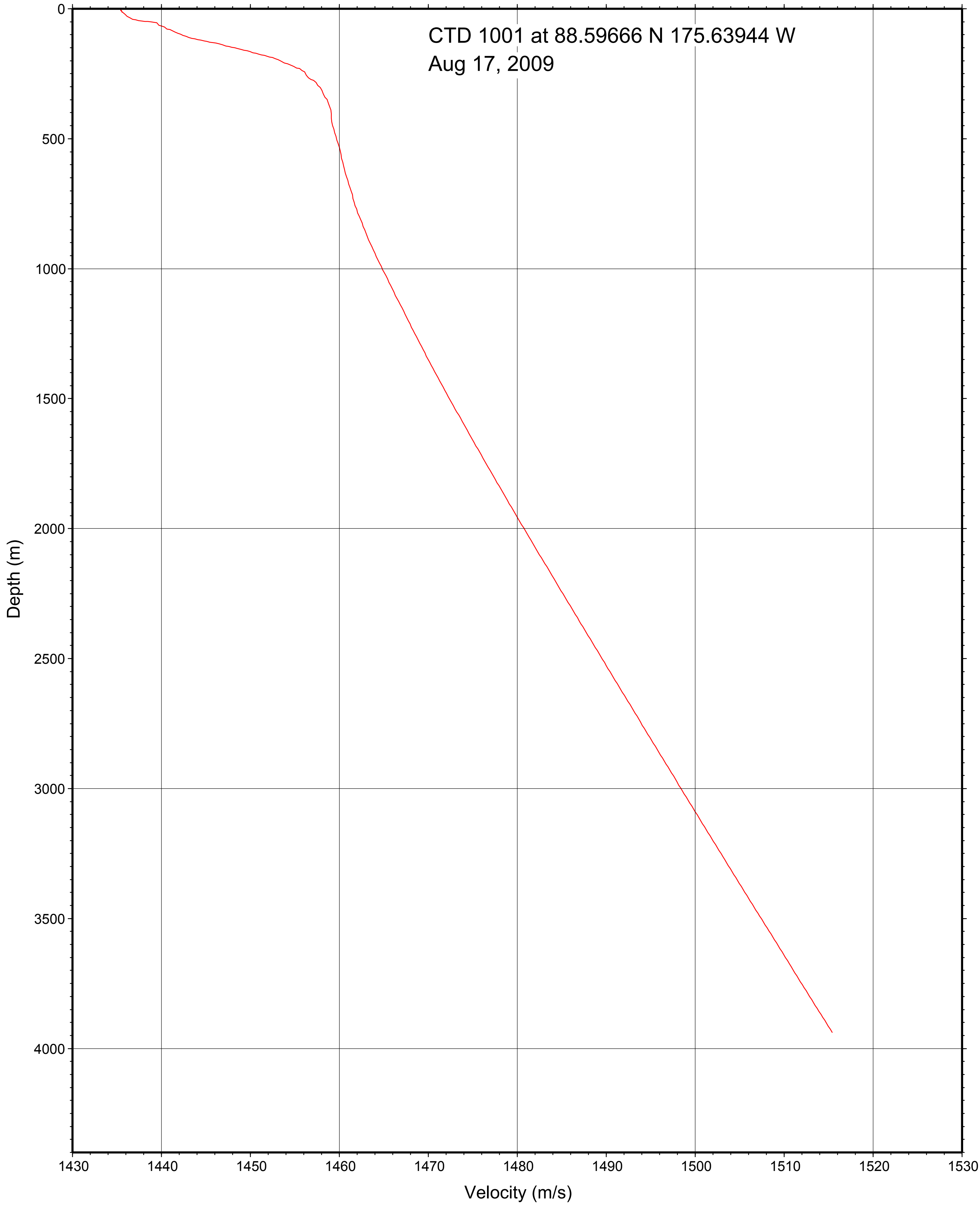
Appendix V-C:

CTD Measurements used for Offset Calculations

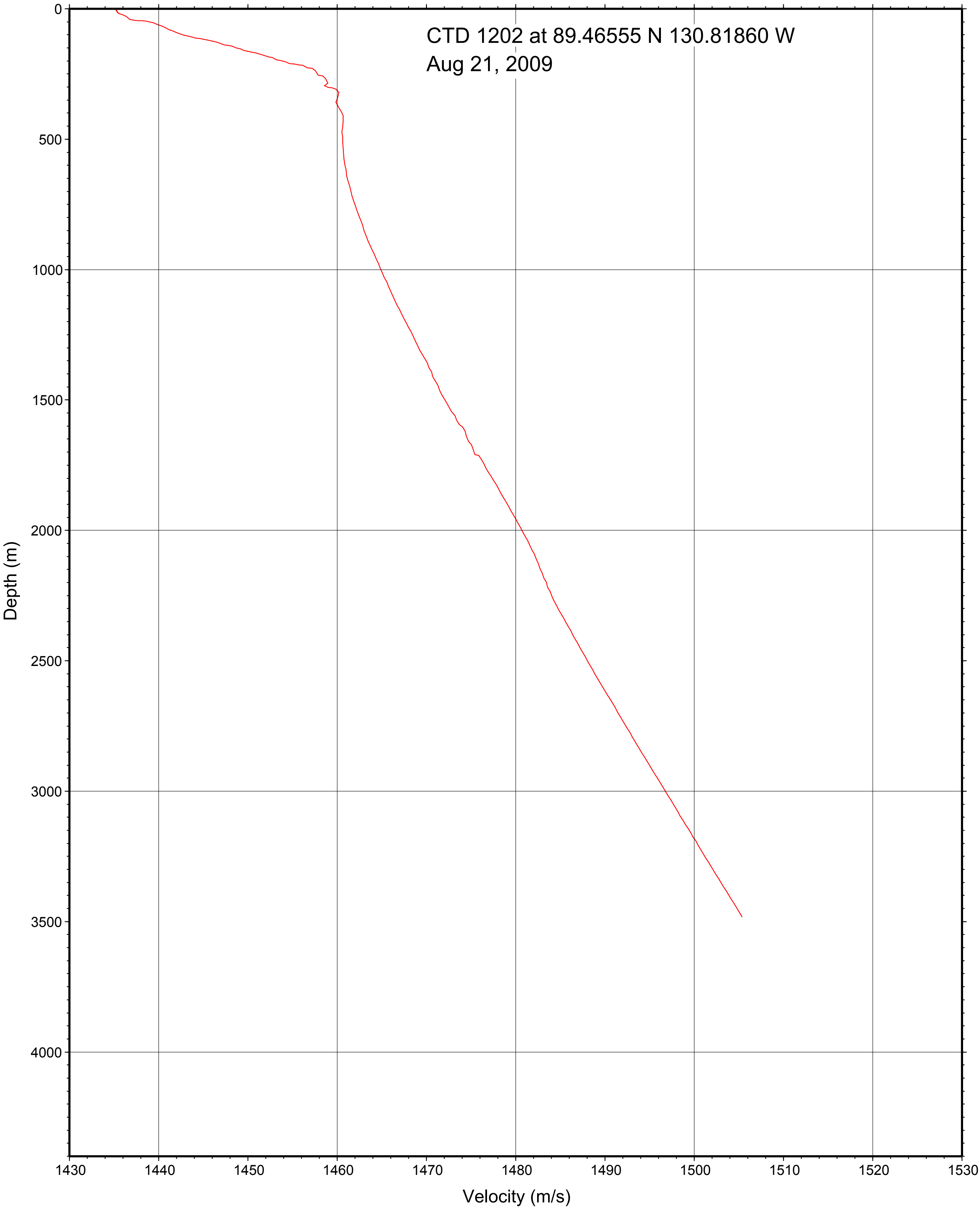
Velocity-depth functions used for the calculation of the drift correction of the sonobuoys are shown in this appendix. CTD 201 was used for seismic lines 1 through 3,CTD 1001 for lines 4 through 6, CTD 1202 for lines 7 through 9, CTD 1401 for line 10, and CTD 15 for lines 11 through 15.

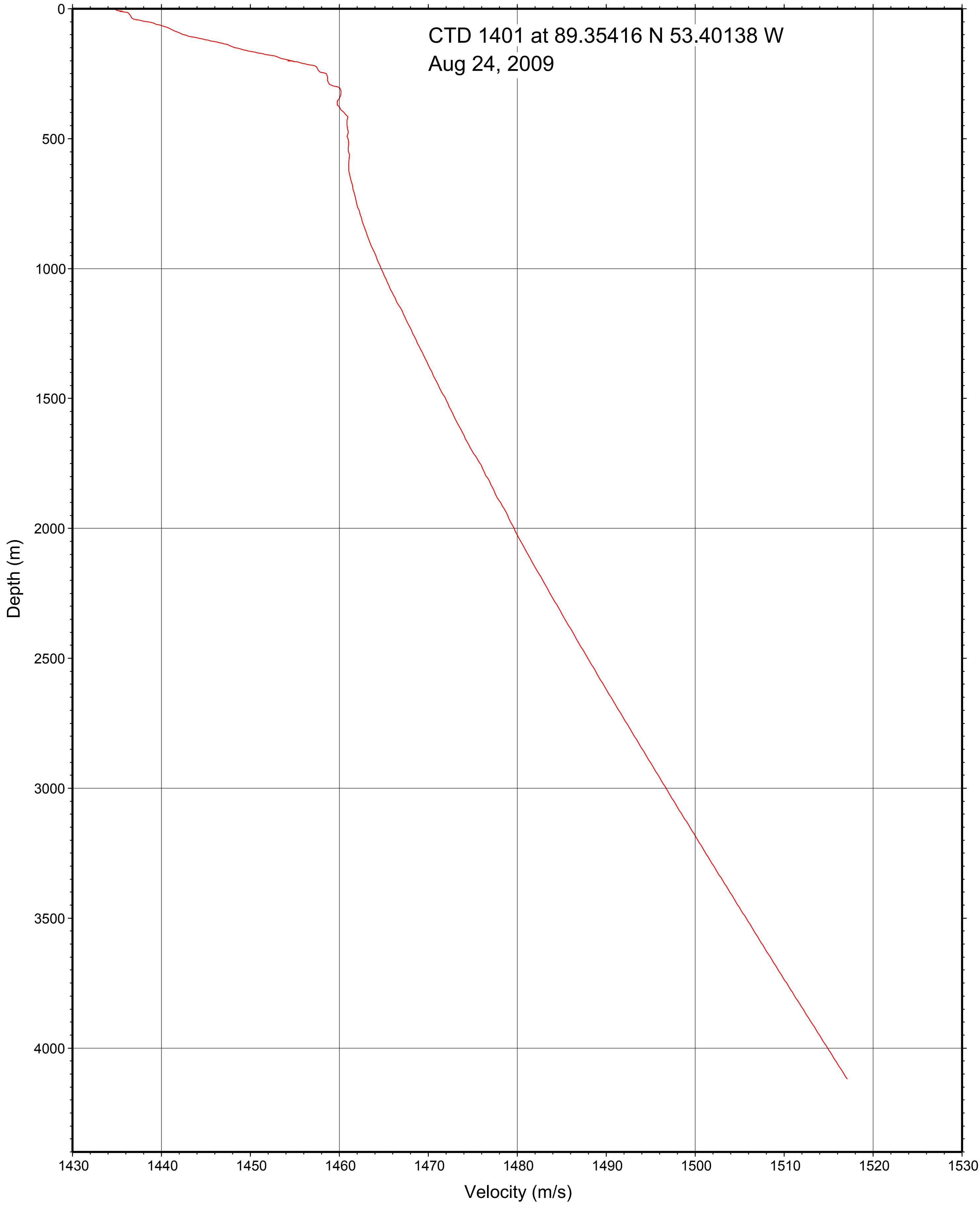


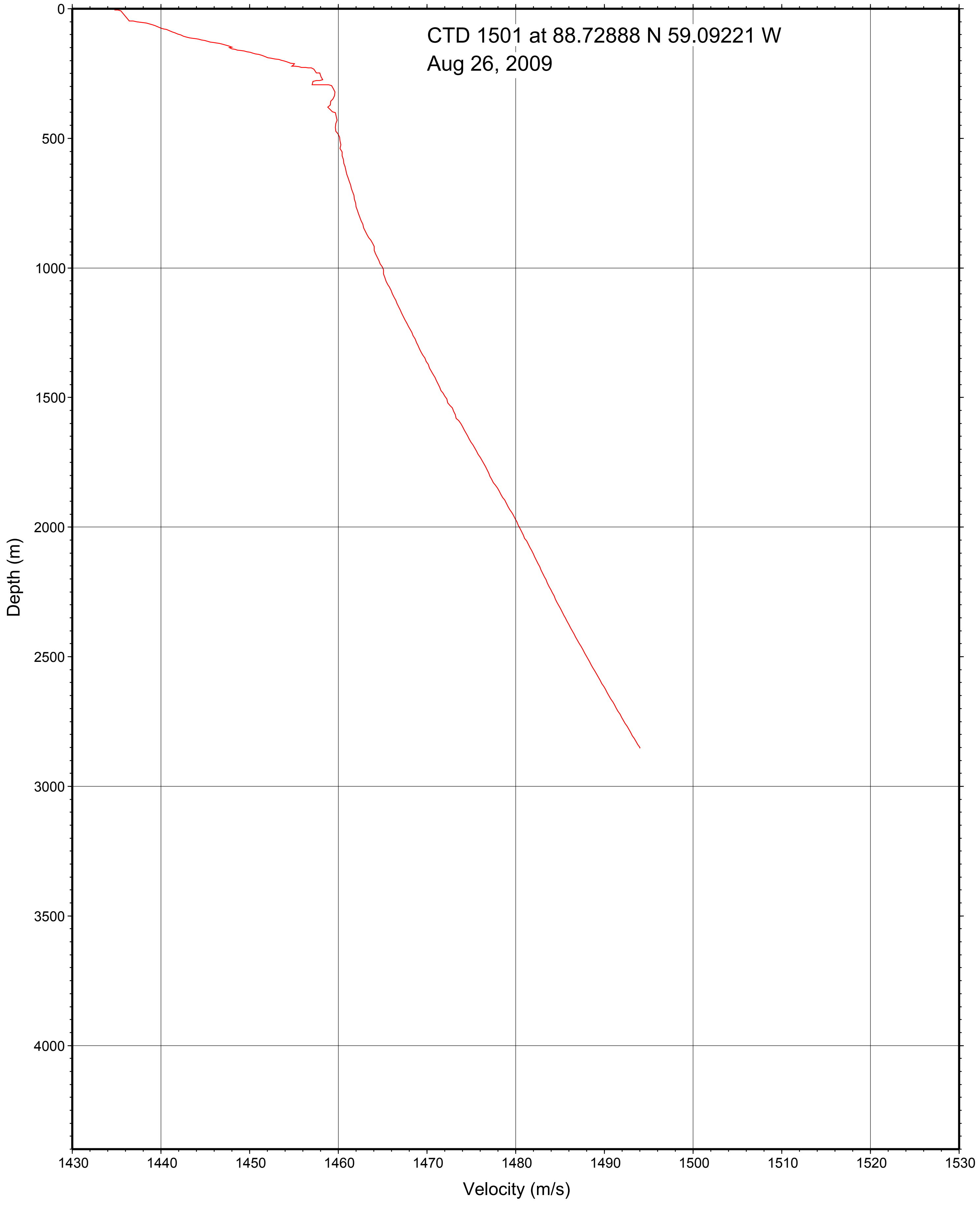
CTD 201 at 88.21388 N 59.69221 E
August 8, 2009
Depth (m)
0
500
1000
1500
2000
2500
3000
3500
4000
1430
1440
1450
1460
1470
1480
1490
1500
1510
1520
1530
Velocity (m/s)



CTD 1001 at 88.59666 N 175.63944 W
Aug 17, 2009
Depth (m)
0
500
1000
1500
2000
2500
3000
3500
4000
Velocity (m/s)
1430
1440
1450
1460
1470
1480
1490
1500
1510
1520
1530


CTD 1202 at 89.46555 N 130.81860 W
Aug 21, 2009
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


CTD 1401 at 89.35416 N 53.40138 W
Aug 24, 2009
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


CTD 1501 at 88.72888 N 59.09221 W
Aug 26, 2009
Depth (m)
0
500
1000
1500
2000
2500
3000
3500
4000
Velocity (m/s)
1430
1440
1450
1460
1470
1480
1490
1500
1510
1520
1530

Appendix V-D:

Technical Specifications Sonobuoy Receiver WR-2902e

WR-2902e

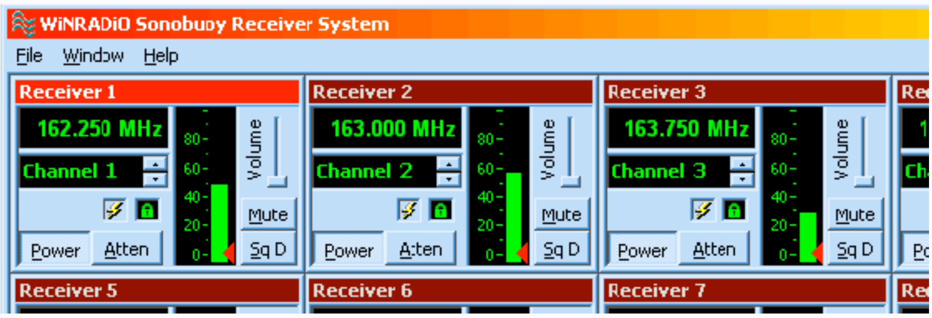
The WiNRADiO WR-2902e VHF/UHF Sonobuoy Telemetry Receiver is designed to receive signals from analogue (DIFAR) and digital (BARRA) sonobuoy transmitters, operating in the 136 to 173.5 MHz frequency range. This standard frequency range can be easily extended up to 1.5 GHz to suit special requirements.

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.)

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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Fax: 613-592-5929
info@nanometrics.ca
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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

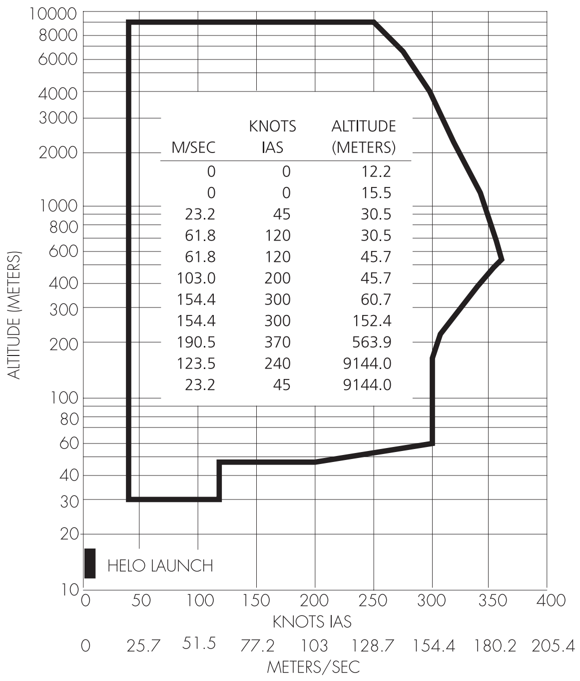
Acoustic Frequency .... *5-2400 Hz Range*

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

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03/03/AN/SSQ–53D(3)
Printed in Canada, 2003

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

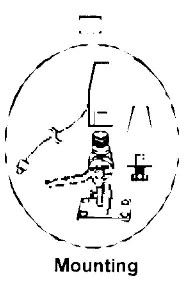
A rugged lightweight 5/8 wave ground independent collinear to give efficient and dependable performance.

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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Website: www.moonraker.com.au Telephone 61 (0)3 6273 1533 Fax: 61 (0)3 6273 1749 Email: radiocom@moonraker.com.au