DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2011/108

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G E U S

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Summary

The EAGER 2011 cruise with the Swedish icebreaker *Oden* was organized in cooperation with the Swedish Polar Research Secretariat. The cruise started from Longyearbyen on Svalbard on August 17, 2011, where it also ended on September 10, 2011.

The purpose of the cruise was to map the East Greenland Ridge and the East Greenland continental slope south of the ridge both geomorphologically and geologically by acquisition of multibeam bathymetric data, refraction seismic data (ocean bottom seismometers and sonobuoys), reflection seismic data and gravity data.

Seismic data were acquired to investigate how the East Greenland Ridge is attached to the North-East Greenland Shelf. The seismic equipment developed for the LOMROG I and LOMROG II cruises was used to acquire the seismic data. However, a larger source array was used for the acquisition of refraction seismic data during EAGER 2011. Ocean bottom seismometers (OBS) and sonobuoys were used for the recording of wide-angle reflections and refractions. Reflection seismic data were acquired using a short streamer with an active length of 200 meters. The seismic source was either a 2080 cu. inch array consisting of four G-guns or a linear array with a volume of 1040 cu. inch consisting of two G-guns.

A total of three seismic lines were acquired: for Line 1 (length of 125 km) two runs were accomplished so both dedicated refraction and reflection data were recorded, for Line 2 (163 km) only one run for refraction data was possible due to problems with the large airgun array, and for Line 3 two runs were possible along the 66-km-long ice-free portion of the line. Another 66-km-long segment of Line 3 was located on the ice-covered shelf off North-East Greenland, where one run was completed. Since the streamer was deployed whenever seismic data were acquired, reflection seismic data were collected on all runs, however with a variable shot interval. All 15 OBS deployments and 42 out of 46 sonobuoy deployments were successful.

The sea ice conditions encountered did not constrain the operations with *Oden* during EAGER2011.

1. Introduction

By Christian Marcussen, Geological Survey of Denmark and Greenland

The area northeast of Greenland is one of three potential areas off Greenland where the continental shelf can be extended beyond 200 nautical miles (NM) 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. In 2002, a first expedition was carried out (GEUS2002NEG) to collect seismic data on the East Greenland Ridge (Døssing et al. 2008). In 2007, further multibeam bathymetric, seismic and gravity data were acquired on the ridge area during the LOMROG I expedition (Jakobsson et al. 2008).

The EAGER (**EA**st **G**r**E**enland **R**idge) 2011 cruise with the Swedish icebreaker *Oden* was organized in cooperation with the Swedish Polar Research Secretariat. The cruise started on August 17, 2011 in Longyearbyen, Svalbard, where it also ended on September 10, 2011. The present report covers the acquisition of reflection and refraction seismic data. Other activities are reported separately (Marcussen et al. 2011).

The main objectives of the EAGER 2011 cruise were UNCLOS related:

1. Acquisition of multibeam bathymetric data covering the East Greenland Ridge and the continental slope of the North-East Greenland Margin south of the ridge.
2. Acquisition of seismic data covering the inner parts of the ridge and the shelf area were the ridge is connected to the continental shelf of Northeast Greenland.
3. Acquisition of gravity data along *Oden*'s track.

Add-on science:

4. Oceanography in order to support the acquisition of the multibeam bathymetric data and to aid the analysis of the refraction seismic data.
5. A Danish project to study *Roseobacter* bacteria populations in the Greenland Sea.
6. Observations of birds and marine mammals by an ornithological observer from the National Environmental Research Institute (Aarhus University, Denmark).

During the EAGER 2011 expedition, refraction/wide-angle reflection (R/WAR) seismic data were acquired along three lines (Figure 1). Both sonobuoys (SB) and ocean bottom seismometers (OBS) were used for the recording of the seismic pulses generated by an airgun array consisting of up to four individual 520 cubic inches (8.5 L) Sercel G-guns. The objective of the study was to determine the velocity structure of the East Greenland Ridge (EGR) and how the ridge is connected to the continental shelf of Northeast Greenland. In addition, the crustal structure in the Boreas and Greenland basins was analyzed by a seismic line across the EGR. This will allow for a better assessment of the crustal character of the EGR.

Multibeam bathymetric and gravity data were acquired continuously during the EAGER 2011 cruise. The innermost parts of the EGR and the south-west facing flank of the EGR were fully mapped with Oden's swath bathymetric system.

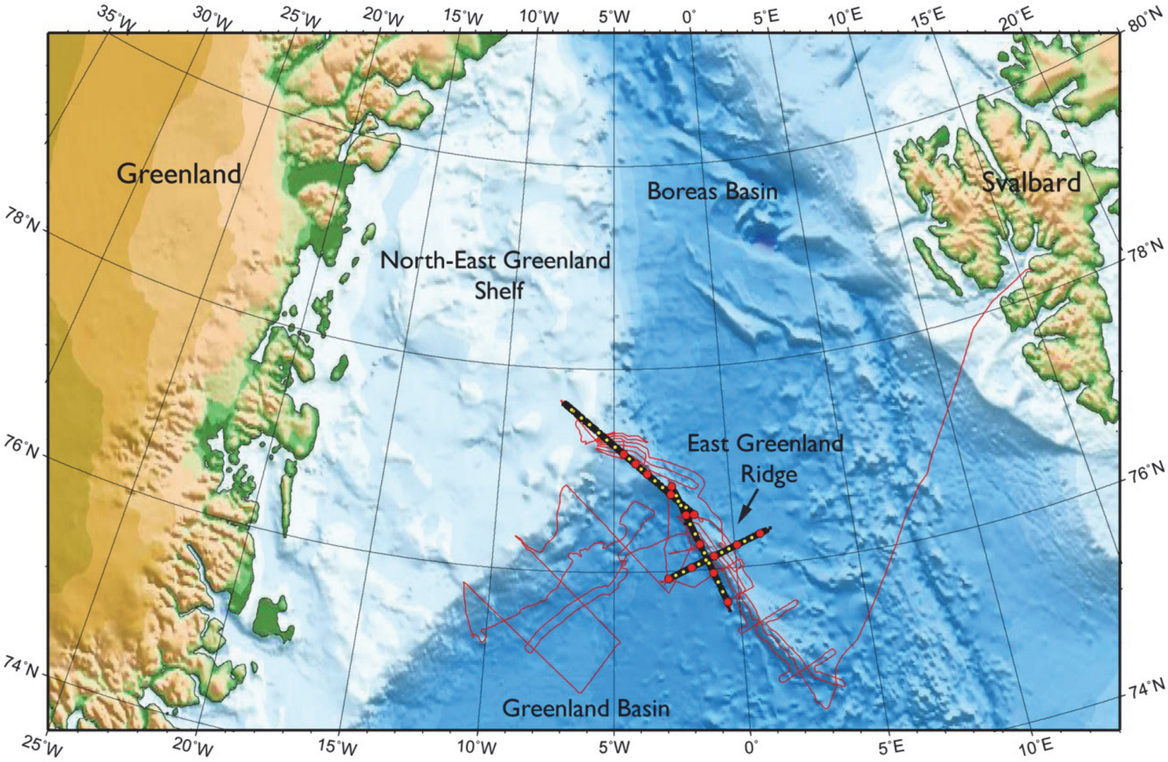

Figure 1. *EAGER 2011 ship track. The heavy black lines indicate the position of the seismic lines, where red dots show the position of OBS and the yellow dots the position of the sonobuoys. Multibeam bathymetric and gravity data were acquired continuously during the EAGER 2011 cruise.*

1.1 Weather and Ice Conditions

During the expedition, weather observations (SHIP-obs) were made manually every six hours. They were sent via email to the Swedish Meteorological and Hydrological Institute (SMHI) and then further distributed to the global meteorological community. Various weather data were collected during the expedition and were available through the on-board network on *Oden*. The data can be obtained from the Swedish Polar Research Secretariat (SPRS) and consists of measurements of temperature, humidity, wind direction and speed (both true and relative to the ship), pressure, water temperature, cloud base, NOAA-Satellite images and analysis of mean sea level pressure (MSL) and 10 m-winds.

The expedition started with fair weather and smooth conditions. Upon leaving Isfjorden increasing southeasterly winds (10-13 m/s) and waves (2-3 m) were observed. The waves decreased to approximately 1.5 m late on August 21. Synoptic scale weather systems were in general absent or weak with very little impact. The most significant system was the cy-clone formed over the western Norwegian Sea, moving NE while intensifying between September 6 to 7. This low, in combination with a stationary high over Greenland generated increasing NE winds over the Greenland Sea, periodically reaching gale force.

The dominating wind directions were from SE and around N (see Figure 2) and with most frequent wind speeds between 4-8 m/s. The relative humidity observed was most common around 90-95% (see Figure 3). Fog or low stratus clouds were common during the expedition in general, both on open water and in the ice. The relative frequency of temperature is shown in Figure 2. Over open water it usually varied between +4ºC and +6 ºC, while dropping rapidly when approaching the ice edge to -2ºC to -0,5 ºC.

The weather impact on the expedition was fairly low, but had a significant effect in the end of the cruise when the multibeam-measurements had to be aborted on September 7 due to high sea state. On other occasions the sea state prohibited CTD (conductivity, temperature, depth) measurements. Weather had no significant impact on the short-range operation of the on-board helicopter.

Using the record of satellite microwave data since 1978 for establishing the sea ice extent normal, the August/September 2011 conditions were near normal and extending to the shelf break at 76°N. During the last ten years, ice conditions have been much lighter in some years and the EAGER 2011 study area has been virtually ice free during the summer minimum. The overall ice situation is shown in Figure 4 for the beginning and end of the cruise.

The sea ice conditions in the Greenland Sea (GS) are dominated by the Arctic Ocean outflow through Fram Strait. During the winter, there is new ice formation in leads, openings and along the ice edge. The oldest and thickest ice has virtually disappeared from the Arctic Ocean in particular since 2002. During the EAGER 2011 cruise, mainly second-year ice with some fractions of first-year ice was encountered close to the ice edge. The second-year ice had well developed melt-ponds.

The floe size distribution was rather uniform with floes about 10-30m in diameter. There was some dirty ice indicating a possible Siberian shelf origin with a transit time of about 1.5 - 2 years to the GS. Satellite data indicated the presence of km-size floes within the pack ice however, these were not encountered during EAGER in 2011.The ice conditions encountered were typical for the marginal ice zone near the ice edge. The ice edge is very dynamic with high drift speeds from north to south. During 16 hours on August 23 (20:43 UTC) to August 24 (11:51) ice displacement in the marginal ice zone was up to 20 NM corresponding to 30 NM/day. The drift vectors are shown in Figure 5. The edge is undulating and constantly changes position. The ice drift speed is lower within the pack ice.

The satellite images were delivered via e-mail by Leif Toudal (Danish Meteorological Institute) during office hours. Because of the dynamic ice edge, a real time access to the data would have helped with the track planning near the ice edge. The Syntehtic Aperture Radar (SAR) scene in Figure 5 shows the bright band with small floes in the marginal ice zone and the darker and larger floes within the pack ice.

The sea ice conditions encountered during EAGER 2011 did not constrain the operations with *Oden* but imposed operational difficulties on the commercial seismic activities on the North East Greenland Shelf.

1.2 Other Seismic Activities in the Area

In order to acquire reflection seismic data for the upcoming license round, two commercial seismic companies operated on the North-East Greenland shelf during August and September: GX Technology as a continuation of their SPAN surveys in 2009 and 2011 and TGS-Nopec as a continuation of their 2008 survey. These operations did not disturb the seismic data acquisition during the EAGER 2011 cruise since Oden acquired seismic data during technical downtime or crew change on the GX Technology survey. The TGS-Nopec survey did not start before the end of the seismic data acquisition on Oden.

1.3 References

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2. Reflection Seismic Survey

By Thomas Vangkilde-Pedersen, Geological Survey of Denmark and Greenland and Per Trinhammer, Department of Earth Science, Aarhus University

Reflection seismic data were collected with an acquisition system consisting of standard seismic equipment modified for data acquisition in sea ice as expected during the EAGER 2011 expedition off Northeast Greenland.

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

The setup of the entire system was planned and tested prior to the LOMROG I expedition in 2007, modified for the LOMROG II expedition in 2009 and modified again for the EAGER 2011 expedition based on the experiences obtained during the LOMROG I and II expeditions and the expected lighter ice conditions in the survey area.

In the following a brief overview of the reflection seismic equipment used on-board *Oden* during the EAGER 2011 expedition is given. Further details are given in Appendix I.

2.1 Seismic Source

Two 1040 cu.in. linear airgun clusters, each consisting of two Sercel 520 cu. in. G-guns (rebuild from Sercel 250 cu. in. G-guns), were used as seismic source (Figure 2). The pressurized air was produced by two Hamworthy 185E_MK2 70mm Series Air Compressors and two Bauer K23 High Pressure Compressor units. A trigger pulse generated by NaviPac was sent to the gun trigger unit, TGS-8 (Figure 2) which synchronized and triggered the guns.

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

2.2 Streamer

The streamer was a digital Geometrics GeoEel streamer (Figures 3, 7 and 10) with four 50 m long active sections (total active length 200 m) and one or two 50 m stretch sections. The active sections contained in total 32 hydrophone groups each composed of 8 Benthos GeoPoint hydrophones. The group midpoint spacing was 6.25 m and hydrophone spacing 0.78 m. Power supply unit (SPSU) to the streamer and all data communication from the streamer took place through either a normal tow cable or through the umbilical cable, depending on the actual setup. In the front end of each active section was an A/D module; in the front of the stretch sections 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 the front end.

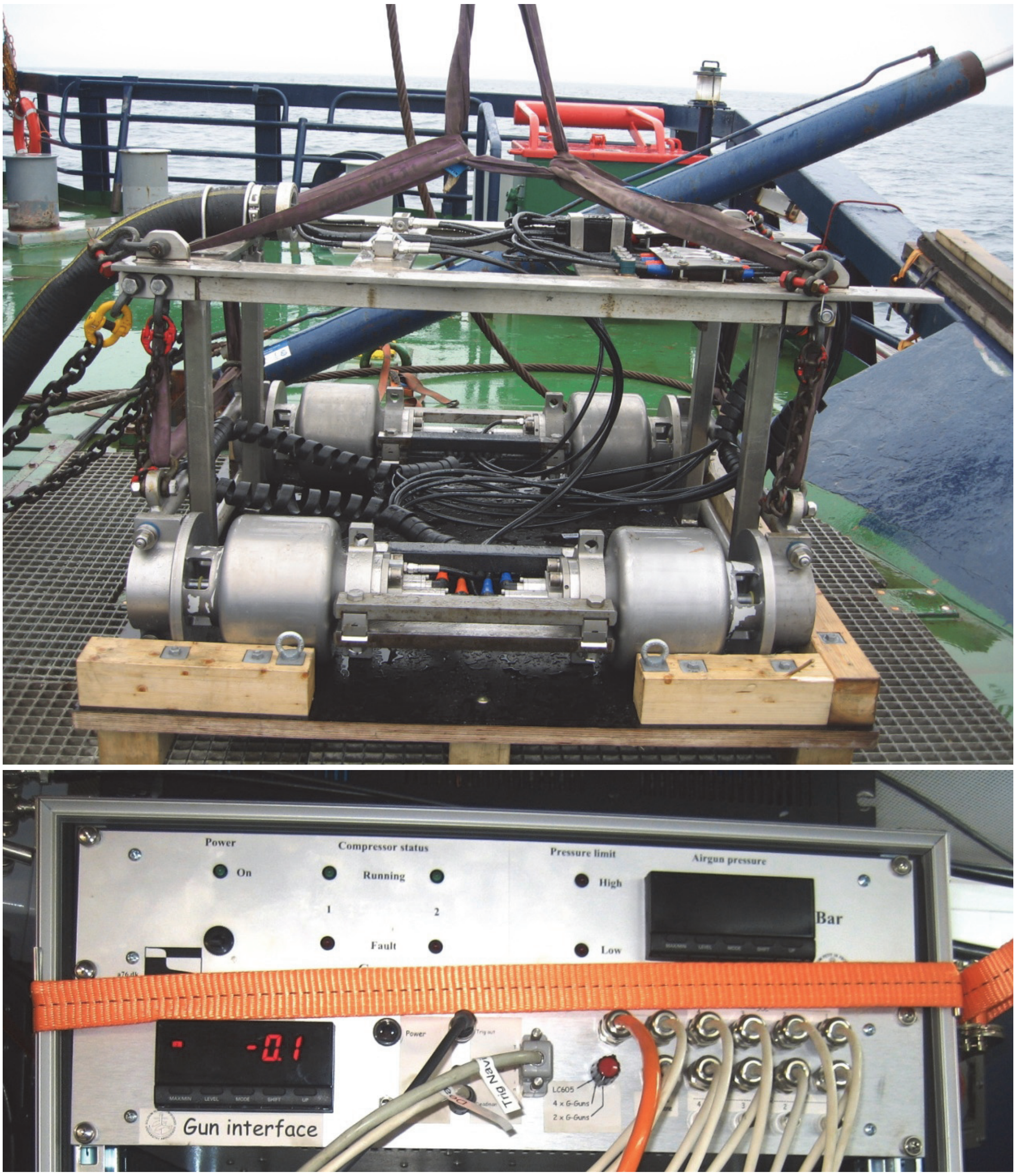


Figure 2. *Two Sercel 1040 cu.in. (2080 cu.in. in total) linear airgun clusters (top). (Bottom) TGS-8 gun trigger unit (cables right side of lower panel), gun depth monitor (left side of lower panel). Compressor monitor and airgun pressure (upper panel).*

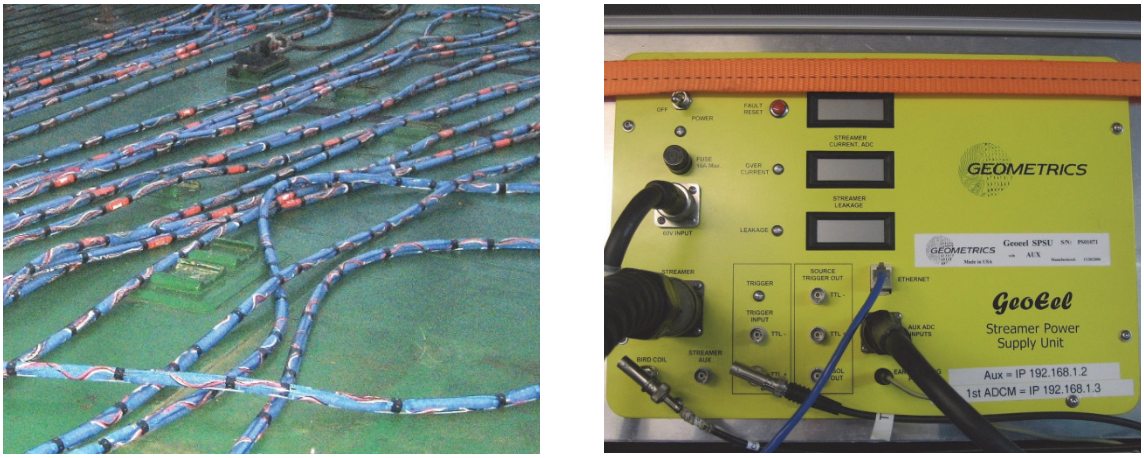


Figure 3. *Geometrics GeoEel streamer on deck (left) - for streamer on winch (see Figures 6 and 9). Streamer power supply unit SPSU (right).*

2.3 Recording System

Data were recorded in SEG-D format (8058 revision 1) on a PC running Geometrics GeoEel controller software CNT-2. The controller was connected to the streamer power supply unit (SPSU) (Figure 3) via Ethernet and receiving the digitized signals from the streamer as well as auxiliary channels 1-8. On auxiliary channels 1-4 data from four sono-buoy radio receivers were recorded and on auxiliary channel 5 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 a RAID 250 GB hard disk and a 1 TB USB disk.

The navigation software NaviPac (see below) sent an event trigger 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) and the string was transferred to the SEG-D external header on hard disk.

The seismic controller provided the following display facilities during survey:

- A shot gather window (Figure 5) where various display settings could be changed as appropriate.
- A real-time single trace window based on a specified channel and where various display settings could be changed as appropriate.
- A noise window showing noise values in µbar from all 40 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 a specified time interval.
- A streamer depth window displaying the depth from each depth transducer module.

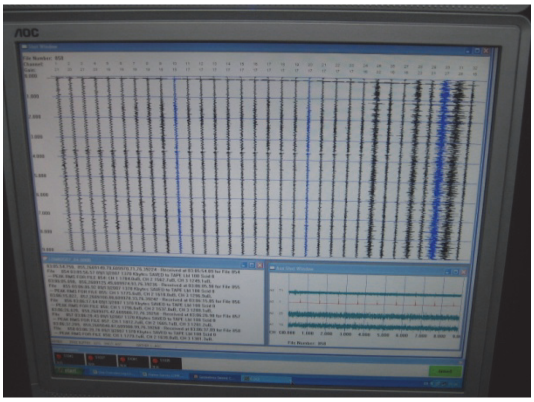
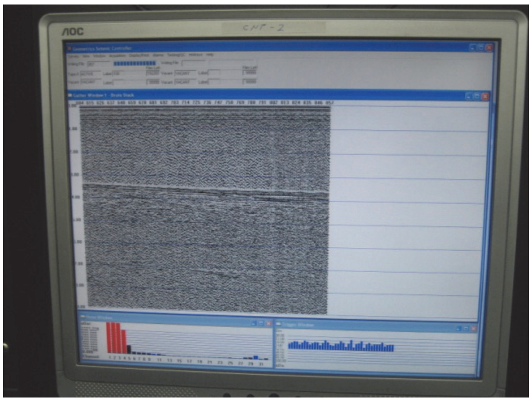
 

Figure 4. *Seismic controller display facilities: shot gather window (left) and single trace stack window (right).*

During the survey the CNT-2 software generated a log file named *Surveyname.Linename.txt* 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). The format of the string is: time HH:MM:SS:sss (UTC, exact trigger time including jitter if generated by the NaviPac software, see below), event number, X pos, Y pos (UTM29, WGS 84, gun array position) <CR> <LF>.
- Second line is file no., exact CNT-2 trigger time and size in Kb.

Two other logfiles are stored on the CNT-2 PC: *Surveyname.Linename.depth.txt* with file no. and readings from the depth transducers in the front end of each streamer active0110531249 section, and *Surveyname.Linename.Nav.txt* with file no., time (UTC, exact trigger time including jitter if generated by the NaviPac software, see below), event number, airgun position (UTM29, WGS 84) and apparent CNT-2 trigger time (trigger time without jitter generated by the NaviPac software, see below).

Furthermore single trace data were stored in SEG-Y files named *Surveyname.linename.Gatherx.sgy* with *x* being the single trace window number monitored.

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 built-in beacon and WAAS receivers for 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. Runlines (survey lines) were generated in the so called Helmsman's display part of NaviPac and the survey is controlled from this display (Figure 5). The option of distributing runline data to a Helmsman's display on the bridge running in slave mode was not used.

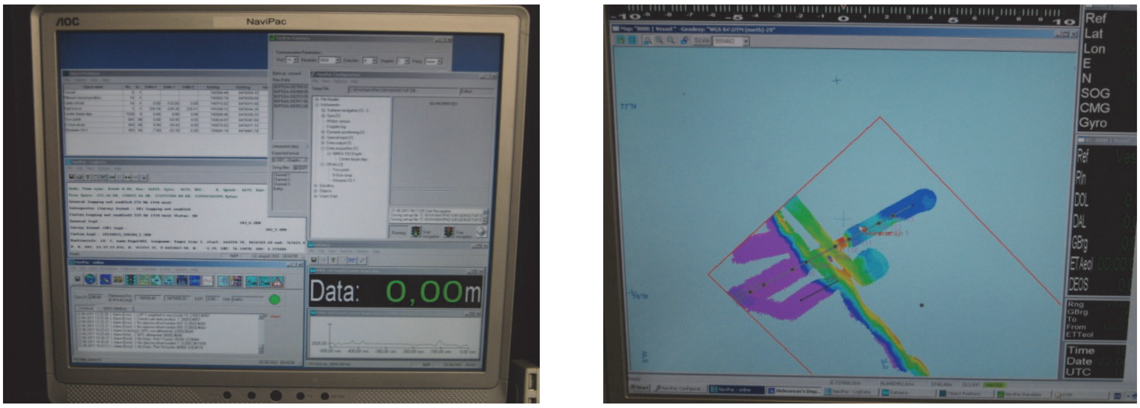


Figure 5. *NaviPac setup window (left) and NaviPac Helmsman's display for survey control (right).*

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 (Figure 6, cf. Figure 7, 10 and 16). On the starboard side, two compressor containers, a gun workshop as well as two storage containers were placed.

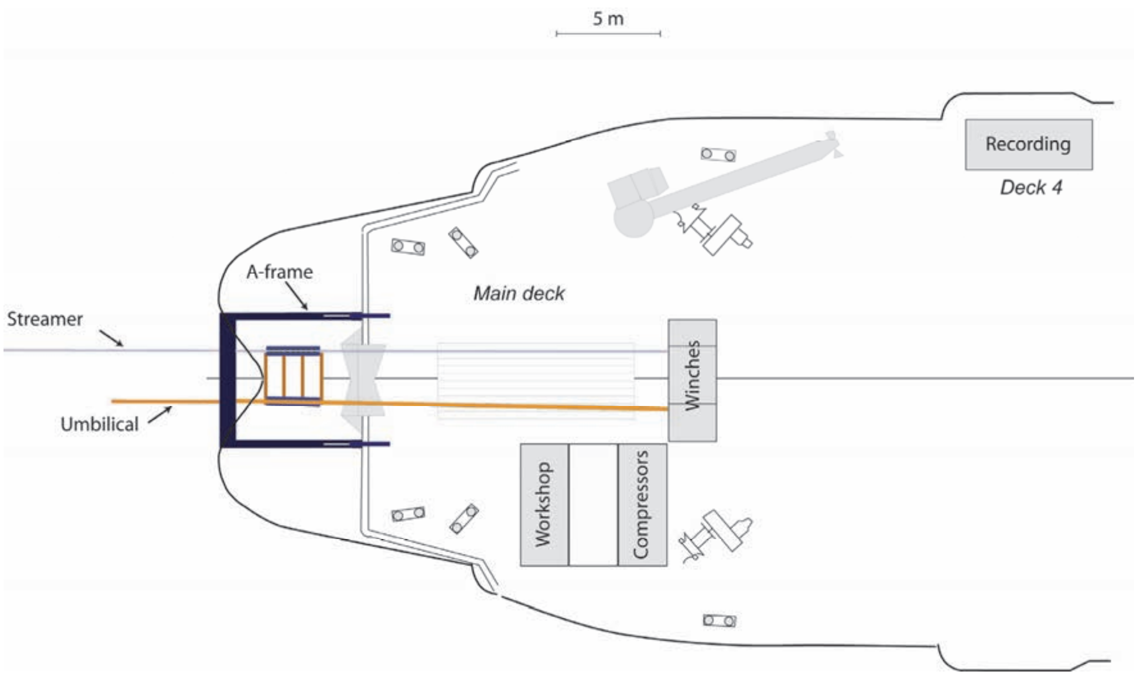


Figure 6. *Plan view showing location of main equipment components on aft deck and deck 4.*

Figure 7. *Containers on aft deck: winches (top left), compressors (white and green), storage (blue) and workshop containers (open) (top right), interior of compressor containers (bottom left) and interior of airgun workshop container (bottom right).*

Cables were connecting the umbilical and streamer winches and the recording container placed on the port aft side of deck 4 (Figure 8 cf. Fig 6 and 16). 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 8. *Recording container on deck 4 (left) and interior of the container (right).*

3. Seismic Reflection Equipment for Data Acquisition in Ice Free Waters and Light Ice Conditions

By Thomas Vangkilde-Pedersen, Geological Survey of Denmark and Greenland and Per Trinhammer, Department of Earth Science, Aarhus University

3.1 General Considerations

The strategy and procedures for handling of airguns and streamer as practiced on EAGER 2011 was based on experiences obtained during the LOMROG I and II cruises in 2007 and 2009 supplemented with the experience learned by other workers on previous seismic cruises in the Arctic Ocean and modified according to expected lighter ice conditions in the survey area.

Large parts of the survey area were expected to be ice free and other parts to be covered with open/broken mainly first year ice with the possibility of heavier ice conditions.

For seismic work in heavy ice conditions 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.

For seismic work in ice free waters the two prime concerns were: 1) to obtain the best possible data quality and 2) minimize the risk during deployment and recovery of the equipment.

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

1. Tow source and streamer in a constant predefined depth.
2. Deploy and tow source and streamer separately.

In order to cover the expected range of ice conditions from ice free waters to heavy ice, the seismic setup therefore included the following possibilities:

1. Open water: towing the airguns and streamer separately and depth balanced using two buoys and depth controllers (“birds”), respectively.

2. Light ice conditions: towing both airguns and streamer in the airgun umbilical, depth balancing the umbilical head with a single buoy and using the streamer without the vulnerable depth controller birds.
3. Heavy ice conditions: towing both airguns and streamer in the airgun umbilical without any depth balancing.

Passive depth transducers with a range down to 300 m were installed in the streamer in order to monitor the streamer depths, especially in the un-balanced situation without birds. A depth transducer was mounted in the front end of each active streamer section in order to obtain sufficiently reliable depths to secure high-quality stacked sections. An option for installing a passive depth transducer with a depth range of 0-60 m at the source was also prepared, should it be necessary to tow the airgun array without buoys for balancing the depth.

3.2 Source Array Configuration

For data acquisition in ice free waters an airgun array of two 1040 cu.in. linear airgun clusters, each consisting of two Sercel 520 cu. in. G-guns (rebuild from Sercel 250 cu. in. G-guns), was used as seismic source (Figure 2). The array was either used in a two- or four-gun configuration. In the four-gun configuration the firing interval was 60 seconds and the firing pressure was 200 bar. The pressurized air was produced by the two Hamworthy compressors alone. In the two-gun configuration the firing interval was 12 seconds and the firing pressure was 180 bar. One gun from each linear cluster was used. The pressurized air was produced by the two Hamworthy compressors supplemented with the two Bauer compressors.

For data acquisition in light ice conditions one 1040 cu.in. linear airgun cluster, consisting of two Sercel 520 cu. in. G-guns (rebuild from Sercel 250 cu. in. G-guns), was used as seismic source (Figure 9). The firing interval was 12 and 40 seconds and the firing pressure was 180 and 200 bar, respectively. The pressurized air was produced by the two Hamworthy compressors supplemented with the two Bauer compressors and the two Hamworthy compressors alone, respectively.

Data acquisition in heavy ice conditions did not take place during the EAGER 2011 expedition.

3.3 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 airguns (hoses for compressed air, triggering cables, cables for near field hydrophones and depth transducer) and the streamer (data communications with the A/D modules and the hydrophones, cables to depth transducers, power cables). The umbilical sits on a hydraulic winch (right side in Figure 10).

Figure 9. *Airgun array for light ice conditions.*

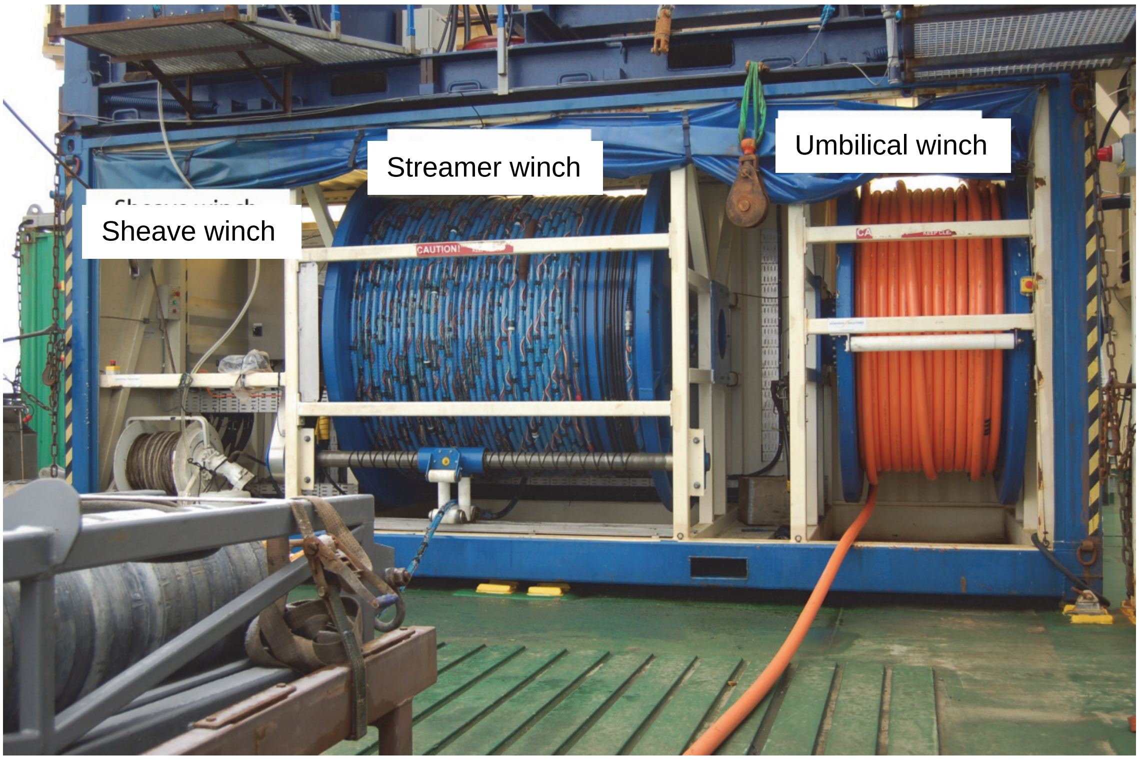


Figure 10. *Winch container.*

The sea-end of the umbilical is terminated in a robust stainless steel head with all cable and hose terminals placed on the plane lower surface of the head and protected in a cone of steel sleeves and rods (Figure 11, right). The streamer can be 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 airguns.

For operation in ice free waters, the streamer can be towed separately and connected to the recording system directly through the streamer winch.

Figure 11. *Deployment of array for ice free waters (left), for light ice conditions (middle) and close-up of the sea end of the umbilical in light ice conditions (right).*

3.3.1 Operation in Ice Free Waters

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

1. The ship speed is reduced to 2.5 knots.
2. The deployment of the streamer begins by unrolling the streamer from the winch (middle section Figure 10) and bringing the tail end to the streamer sheave (Figure 9). On its way to the sheave it is guided by four three-sided roller ports along the aft

deck (Figure 12, left). From this point the streamer is deployed into the water. During deployment the depth controller birds are mounted on the streamer (Figure 12, right).

3. When the streamer is fully deployed, the deck cable is lifted out of the streamer sheave and fixed at a tow point on the port side of the aft deck (see Fig 13 and Appendix II) by means of a rope.

4. The umbilical with the airguns is now lifted in the sheave (Figure 11, left) by the wire winch (left hand side in the winch container as seen on Figure 10). At the same time the A-frame is turned outwards to establish free passage for the umbilical with airguns to be deployed. Just before the airguns are lowered into the water, they are pressurized with 20 bar. When the airguns are deployed, the umbilical sheave is locked in the sheave docking platform (Figure 14, left), the guns brought in the desired position and pressurized to the desired firing pressure (Figure 14, right).

Figure 12. *Roller ports for the streamer along the aft deck (left) and mounting of depth controller bird on streamer before deployment (right).*

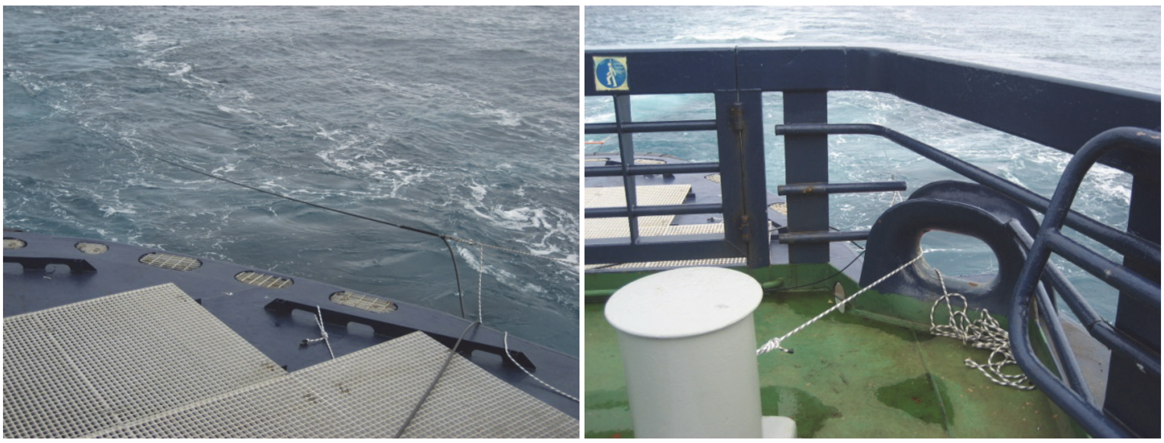


Figure 13. *Towing streamer from a tow point on the port side of the aft deck.*

Figure 14. *Umbilical sheave docking platform (left), guns and streamer in final position (right).*

3.3.2 Operation in Light Ice Conditions

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

1. The ship speed is reduced to 2.5 knots.
2. The deployment of the streamer begins by unwinding the streamer from the winch (middle section Figure 10) and bringing the tail end to the streamer sheave (Figure 9). On its way to the sheave it is guided by four three-sided roller ports along the aft deck (Figure 12, left). From this point the streamer is deployed into the water. When the front end connector of the streamer reaches the sheave the streamer is temporarily fixed to the deck by means of a short rope (Figure 15, right).
3. The umbilical in the umbilical sheave and the airgun cluster is lifted in the A-frame (Figure 15, right) by the wire winch (left hand side in the winch container as seen on Figure 10), and lowered to the aft deck next to the sheave docking platform (Figure 14, left). The front end of the streamer is now connected with the jumper cable on the umbilical (Figure 15, right).
4. The umbilical with the airguns and the streamer is now lifted in the sheave (Figure 11, middle) and at the same time the A-frame is turned outwards to establish free passage for the umbilical with airguns to be deployed. Just before the airguns are lowered into the water, they are pressurized with 20 bar. When the airguns are deployed, the umbilical sheave is locked in the sheave docking platform (Figure 14, left), the guns brought in the desired position and pressurized to the desired firing pressure.

The sketch in Figure 16 illustrates the complete system for light ice conditions when the ship has reached a speed of 4.5 knots and data collection is ongoing.

Figure 15. *Umbilical and airguns are lifted in the sheave (left). The front end of the streamer is connected to the jumper cable (right).*

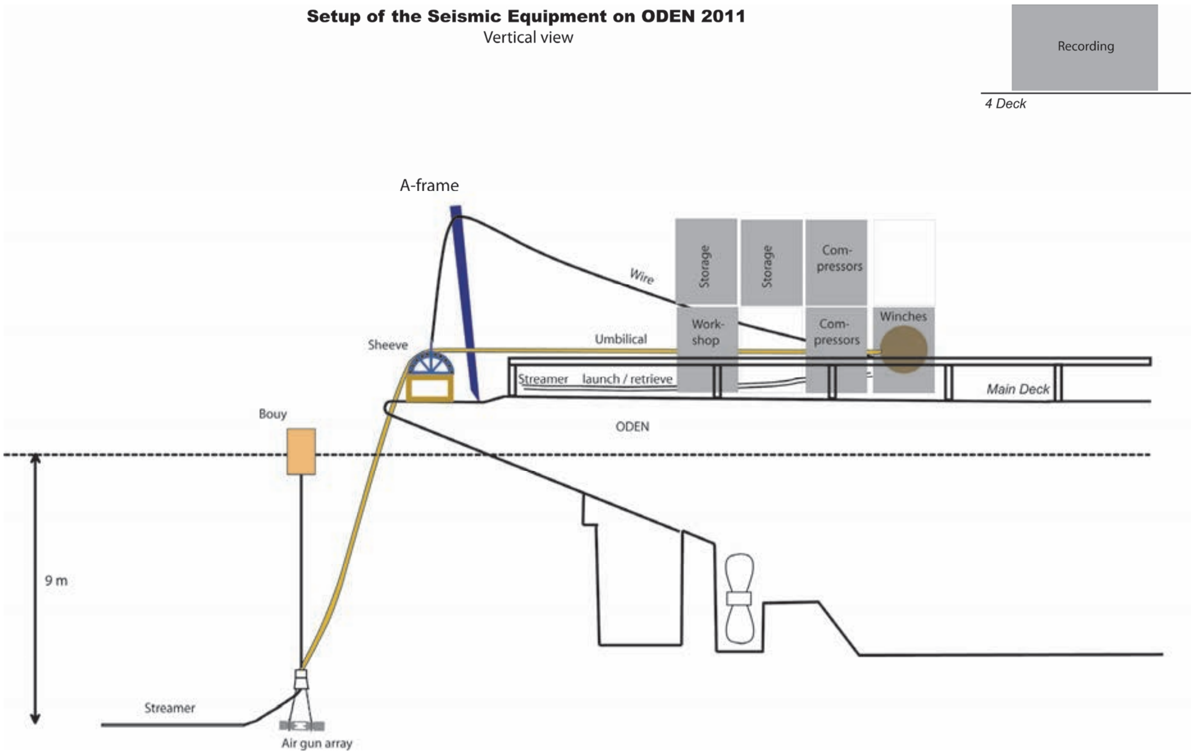


Figure 16. *Vertical view of the setup during data acquisition in light ice conditions. Grey rectangles: “seismic” containers.*

3.3.3 Operation in Heavy Ice Conditions

Heavy ice conditions as experienced on the LOMROG I and II expeditions in 2007 and 2009 were not encountered during the EAGER 2011 expedition. Detailed descriptions of the procedures for handling source and streamer under heavy ice conditions can be found in the acquisition reports for the LOMROG I and II expeditions (Marcussen et al. 2008 and Marcussen et al. 2010).

3.4 Gun and Streamer Behaviour

In ice free waters, the airgun array was depth balanced in c. 9 m using two large US Fenders (buoys, Figure 17, left), both connected to the array with a rope in each end of the buoy. The tow depth was not monitored, but expected to be constant. In light ice conditions the airgun array was depth balanced in c. 9.65 m using only one large US Fender (Figure 17, right) connected to the array with a single rope in one end of the buoy. The tow depth was monitored (but not recorded), and appeared to be fairly constant at 8.5 m, but with variations between 5 and 10 m depending on the strength of the propeller wash.

Figure 17. *Towing airgun array in two US Fender buoys in ice free waters (left) and in one US Fender buoy in light ice conditions (right).*

In ice free waters, the streamer was towed from a tow point on the port side of the aft deck (Figure 13) and depth balanced in c. 6 m using four active depth controllers, so-called “birds”, supplemented with thin plates of led at strategic positions. The birds were mounted in the front end of each active section together with passive depth transducers (Figure 12, right). Thus, the distances between channel one and the respective birds and streamer transducers were: 0, 50, 100 and 150 m. The streamer depth was monitored and appeared to be fairly constant between 5 and 7 m. Records of the depths of each active streamer section were stored in the Geometrics logfile *Surveyname.Linename.Depth.txt*.

In light ice conditions the streamer was towed from the umbilical head in a depth of c. 7 m. The depth controller birds were not used because of the risk of getting caught by ice floes, but the streamer depth was balanced using thin plates of led at strategic positions. Like in ice free waters the streamer depth was monitored using the passive depth transducers in the front end of each active section. The streamer depth appeared to be fairly constant at 7 m, but with variations between 5 and 15 m, depending on the vessel speed. Records of the depths of each active streamer section were stored in the Geometrics logfile *Surveyname.Linename.Depth.txt*.

4. Reflection Seismic Acquisition Parameters

By Thomas Vangkilde-Pedersen, Geological Survey of Denmark and Greenland and Per Trinhammer, Department of Earth Science, Aarhus University

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

Source	Sercel G guns
Number of guns in array	2 / 4
Chamber volume	520 cu. inch per gun
Total volume of array	1040 / 2080 cu. inch
Fire pressure	180 / 200 bar (2600 / 3000 psi)
Mechanical delay	0 ms (automatically corrected)
Nominal tow depth	9 m / 9.65 m
Length of tow cable	30 m / 32.2 m / 52.2 m
Streamer	Geometrics GeoEel
Length of tow cable	30 m
Length of vibration section	53 m / 103 m
No. of active sections	4
Length of active sections	200 m
No. of groups in each section	8
Total no. of groups	32
Group interval	6.25 m
No. of hydrophones in each group	8
Depth sensors	In front of each active section
Nominal tow depth	6 m / 7 m
Acquisition system	Geometrics GeoEel controller
Sample rate	1 ms / 2 ms
Low-cut filter	Out
High-cut filter	Anti-alias (405 Hz / 202.5 Hz)
Gain setting	0 dB
No. of recording channels	32
No. of auxiliary channels	8
Shot interval	12 s / 40 s / 60 s
Record length	10 s / 35 s / 55 s

Table 1. *Summary of acquisition parameters (for exact geometry, see Appendix II).*

5. Reflection Seismic Acquisition Geometry and Positioning

By Thomas Vangkilde-Pedersen, Geological Survey of Denmark and Greenland and Per Trinhammer, Department of Earth Science, Aarhus University

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 centerbeam from 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 on-board *Oden*. Drawings showing the measured points and a list of local coordinates for the different seismic acquisition configurations 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 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, 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) relative to the tow point. The local coordinates of the airgun midpoint relative to the tow point were defined measuring the length of the umbilical from the tow point to the airgun midpoint and taking into consideration the height of the tow point as well as the tow depth using Pythagoras' theorem. The local coordinates of the 1st hydrophone of channel 1 on the streamer relative to the tow point were defined measuring the distance along the streamer and taking into consideration the height of the tow point as well as the tow depth using Pythagoras' theorem. When the streamer was towed from a point on the port side of the aft deck the offset in the x-direction was also taken into consideration.

The airgun midpoint and channel 1 coordinates 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 as a function of survey lines.

Offset point [1]	**X (m)**	**Y (m)**	**Z (m)**
Vessel reference point	0.00	0.00	0.00
GPS antenna	-11.25	13.40	25.30
Umbilical tow point	0.00	-53.50	4.65
Line 1A, 2A, 2A_2 [2]	**X (m)**	**Y (m)**	**Z (m)**
Airgun midpoint	0.00	-50.40	-13.65 [3]
Streamer channel 1	-7.60	-82.30	-10.65 [4]
Near trace offset (airgun midpoint to streamer channel 1)			32.80
Line 1B [2]	**X (m)**	**Y (m)**	**Z (m)**
Airgun midpoint	0.00	-29.20 [5]	-13.65 [3]
Streamer channel 1	-7.60	-82.30	-10.65 [4]
Near trace offset (airgun midpoint to streamer channel 1)			53.70
Line 3A, 3A_2, 3B, 3B_2 [2]	**X (m)**	**Y (m)**	**Z (m)**
Airgun midpoint	0.00	-50.40	-13.65 [3]
Streamer channel 1	-7.60	-132.60	-10.65 [4]
Near trace offset (airgun midpoint to streamer channel 1)			82.50
Line 4A, 4B [2]	**X (m)**	**Y (m)**	**Z (m)**
Airgun midpoint	0.00	-28.00	-14.30
Streamer channel 1	0.00	-80.30	-11.65
Near trace offset (airgun midpoint to streamer channel 1)			52.30

[1] Relative to vessel reference point; [2] Relative to umbilical tow point; [3] Z-coordinate for airgun midpoint erroneously set to -9.00 m in NaviPac setup file; [4] Z-coordinate for streamer channel 1 erroneously set to -6.00 m in NaviPac setup file; [5] Y-coordinate for airgun midpoint erroneously set to -50.40 m in NaviPac setup file.

Table 2. *Offset point coordinates.*

5.2 Geodetic Reference System

The geodetic datum for all positions recorded or calculated (except for offset 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 Transversal Mercator Zone 29 North projection (UTM29N) and all x and y coordinates are given in UTM29N projection and WGS84 datum with 0° as reference meridian. All coordinates processed in *NaviPac*, were transformed to the UTM29N projection, meaning that all logged geographical coordinates were transformed to UTM29N and back to latitude and longitude. Details are given in Table 3.

Geodetic datum	WGS84
Ellipsoid	*WGS84*
Semi-major axis (a)	6378137
Inverse flattening (1/f)	298.257223563
Eccentricity sq. (e^2)	0.081819190843
Projection	*Universal Transversal Mercator (UTM29N)*
Semi major axis	6378137
Inverse flattening	298.257223563
Scale at origin	0.9996
Longitude at origin	-9° 0' 0"
Latitude at origin	0° 0' 0"
False easting	500,000 m
False northing	0 m

Table 3. *Geodetic reference system*

5.3 Navigation, Positioning and Trigger Generation

Runlines (the desired survey lines) were distributed to the bridge as waypoint coordinates and the vessel was navigated using its own navigation system. A NaviPac Helmsman's display was not set up on the bridge to aid navigation.

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 local offset coordinates and 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 and shot intervals of 12, 40 and 60 s was chosen depending on the actual seismic acquisition configuration.

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
- Depth from multibeam echo sounder's center beam (in meter below transducer which sits 8 m below sea level).
- Filtered vessel positions (vessel reference point Easting, Northing, Lat., Long.)

The general file and survey file also contains the above data plus other navigation data, such as projections, offset points (in UTM29N 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 Thomas Vangkilde-Pedersen, Geological Survey of Denmark and Greenland and Per Trinhammer, Department of Earth Science, Aarhus University Staffing

6.1 Staffing

The reflection seismic operation was carried out by eight members of the scientific crew on-board *Oden* as listed in Table 4.

Name	Affiliation	Function
Thomas Vangkilde-Pedersen	GEUS	Geophysicist
Lars Georg Rödel	GEUS	Technician
John R. Hopper	GEUS	Processing geophysicist
Emil Kousted Mauritzen	GEUS, Aarhus University	Watch keeper and deck hand
Jens Andreas Rasmussen	GEUS, Aarhus University	Watch keeper and deck hand
Knud Karkov	GEUS, Aarhus University	Watch keeper and deck hand
Erik Labahn	KUM GmbH	Gun and compressor technician
Tom Oliva	TTSurvey, UK	Gun and compressor technician

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

6.2 Preparations

After leaving Svalbard a deployment test of the airgun array was performed on August 18, 2011 while the ship was in ice-free waters. The deployment of the guns went very well. Also towing the airgun array in two buoys (two large US Fenders) went well and apparently resulted in a relatively constant tow depth of approximately 9 m as expected with a survey speed around 4.5 knots.

After deployment, a function test was carried out firing the guns at 200 bar for approx. one hour. The construction of the airgun array and using buoys for balancing the tow depth was new compared to the LOMROG I and II expeditions in 2007 and 2009. The array had been tested during a test cruise on *M/V Gunnar Thorson* in August 2010, for a very short period of time only, due to bad weather conditions. During the function test there was problems with the Time Break signal (T/B) from the airguns and hence with the automatic correction of mechanical delay in the guns. After recovering the guns, it was clear that the problems were caused by broken and damaged signal cables (Figure 18, left). Parts of the construction of the airgun array were apparently too weak. Consequently the construction of the array was reinforced and the damage cables replaced (Figure 18, middle).

On August 19, 2011 a successful function test of the complete seismic acquisition system was carried out firing the guns for approx. half an hour in both the four-gun and the two-gun configuration. After the function test further improvements of the airgun array was carried out (Figure 18, right).

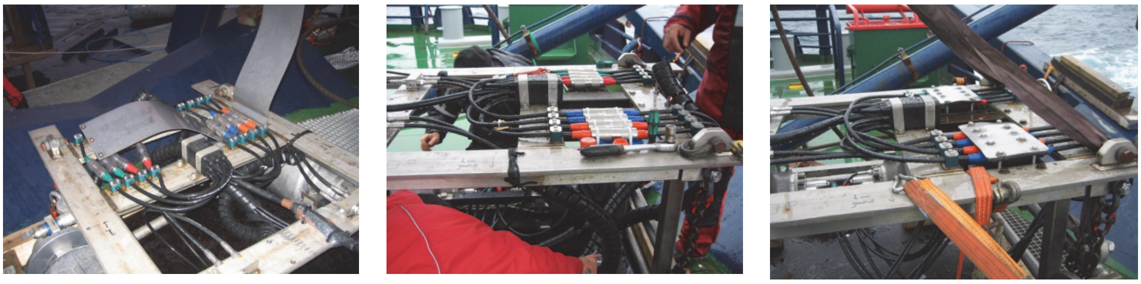


Figure 18. *Damaged airgun array after function test (left) and airgun array after reinforcement of the construction (middle and right).*

6.3 Planned Seismic Acquisition Programme

The planned seismic programme included three survey lines with both reflection and refraction seismic data acquisition planned along all lines. For reflection seismic the seismic streamer should be used as receiver and for refraction seismic OBS (Ocean Bottom Seismometers) and sonobuoys should be used as receivers (see also section 8). The planned programme included sailing each survey line four times. During the first sail through, the OBS' should be deployed at predefined positions. During the second sail through in the opposite direction, shooting should take place with the entire four-gun array (see also section 3.2) fired at 200 bar, every 60 seconds in order to obtain the strongest possible signal for the refraction data to be recorded by the OBS' (seismic line: *Line-number* A). During this second sail through, sonobuoys should also be deployed at predefined positions, recording refraction seismic data. Before the third sail through of the survey line the seismic streamer should be deployed for recording reflection seismic data. During this sail through, shooting should take place with a two-gun array configuration fired at 180 bar, every 12 seconds in order to achieve the best possible resolution and stacking fold in the reflection seismic data recorded by the streamer (seismic line: *Linenumber* B).

The OBS' should still be recording data during this third sail through and again sonobuoys should be deployed at predefined positions. In this way refraction data acquisition from opposite directions would be achieved for both OBS and sonobuoy recording. During the fourth sail through of the survey line the OBS' should be recovered.

6.4 Acquisition Performance and Actual Performed Programme

Through the collection of the seismic lines 1-4, the acquisition system generally had a satisfactory performance. Though, a few technical problems during acquisition occurred, especially with the airgun array.

During the function test it was clear that deployment and recovery of the streamer with the depth controller birds could not take place with the airgun array in the water because of the risk for the birds to get caught by the array. Deployment and recovery of the airgun array, however, is a critical operation with risk of damaging the array. In order to reduce the number of times this critical operation should be carried out, it was therefore decided to deploy the streamer prior to the “refraction sail through” of each seismic line and hence also record reflection data in “refraction operation mode”.

The acquisition of both refraction line 1A and reflection line 1B went well without any problems with the equipment. After only c. 20 minutes of data acquisition on refraction line 2A an air hose was leaking on the gun array and repair was needed. After further c. 13 hours of data acquisition the two US Fender buoys was tangled together and the airguns had to be recovered. The airgun array turned out to be in a poor condition with one chain broken, a few nuts missing and some cables damaged.

After repair and more improvements of the airgun array (Figure 19), data acquisition was continued on refraction line 2A_2. At the end of this line the streamer was showing leakage, but it was, however possible to finish the line as planned. Until now considerable time had been lost because of problems with the airgun array, and it was decided to skip reflection line 2B. This left time for fault finding on the streamer and further improvements to the airgun array.

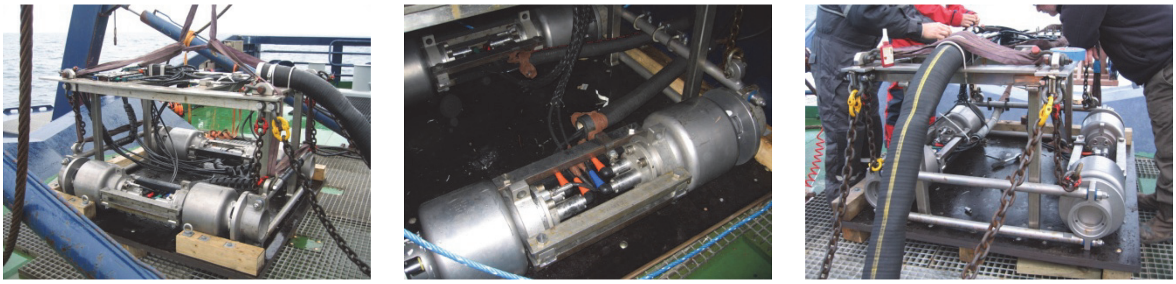


Figure 19. *Improvements of the airgun array by means of different ways of protecting the air hoses and signal cables.*

Fault finding on the streamer proved to be difficult as no leakage appeared when the streamer was on deck. After re-deployment in the water the leakage was, however, present again. Hence it was decided to test all connections on the streamer in a plastic barrel filled with sea water and using a ground wire to the sea. In this way the bad streamer section was identified and replaced and data acquisition on refraction line 3A could commence. Line 3A and 3B was modified in order to end the lines at the edge of the ice off Northeast Greenland. The original part of line 3 in the ice was renamed to line 4.

After approx. eight hours of data acquisition on refraction line 3A, an air hose was leaking on the gun array and repair was needed. After further seven hours of data acquisition on refraction line 3A_2, the line was finished and data acquisition was started on reflection line 3B. After c. 12 hours of data acquisition on reflection line 3B an air hose was leaking again on the airgun array. The airhose was replaced and data acquisition continued on reflection line 3B_2, but after only c. 20 minutes another air hose leak occurred. After repair and c. 3 hours more of data acquisition an air hose broke again and it was decided to end the line.

Now the airgun array was rebuild for light ice conditions and data acquisition on reflection line 4B commenced. When test shooting the airguns after deployment, a fault in the Geometrics software blocked the PC and it was necessary with a “hard reset” to get the PC up and running again. The fault was caused by trigger signals send through the umbilical at the same time as when the Geometrics software was communicating with the streamer. This is a cross talk problem that occurs when both streamer and airguns are connected through the umbilical as they are in “ice condition mode”, and when trigger signals is send before the Geometrics software is “armed” and has finished communication with the streamer. The problem is described in the LOMROG II Seismic Data Acquisition Report (Lykke-Andersen et al., 2010). After restarting the Geometrics PC, data acquisition on reflection line 4B and refraction line 4A was completed without further problems.

6.5 Acquisition Overview

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

In Table 5 a summary of the key characteristics of the lines are given based on the line overview logs and in Table 6 a record inventory is given.

Line	Record length (s)	Duration (hours)	No. of shots	Shots per hour
EAGER2011_1A*	55	00:21	7	-
EAGER2011_1A**	55	14:37	878	60
EAGER2011_1B	10	15:34	4673	300
EAGER2011_2A*	55	0:21	22	60
EAGER2011_2A**	55	13:09	789	60
EAGER2011_2A_2	55	6:06	367	60
EAGER2011_3A	55	7:49	470	60
EAGER2011_3A_2	55	7:37	455	60
EAGER2011_3B	10	11:39	3357	300
EAGER2011_3B_2*	10	0:22	113	300
EAGER2011_3B_2**	10	2:57	885	300
EAGER2011_4A[#]	35	7:43	695	90
EAGER2011_4B[#]	10	5:23	1622	300

[#] Please note that line EAGER2011_4A has been renamed to EAGER2011_3D and line EAGER2011_4B to EAGER2011_3C in processing and relative to OBS and sonobuoy data acquisition.

Table 5. *Summary of line overview log*

Line	First record	Last record	NaviPac logfiles	Geometrics logfiles
EAGER2011_1A*	1	7	20110821_040531_G 20110821_040531_S 20110821_040532_C	Refrac_survey.1A.Depth Refrac_survey.1A.Nav Refrac_survey.1A
EAGER2011_1A**	8	885	20110821_042711_G 20110821_042712_S 20110821_042712_C	Refrac_survey.1A.Depth Refrac_survey.1A.Nav Refrac_survey.1A
EAGER2011_1B	1	4673	20110821_200303_G 20110821_200303_S 20110821_200304_C	Reflec_survey.1B.Depth Reflec_survey.1B.Nav Reflec_survey.1B
EAGER2011_2A*	1	22	20110823_224625_G 20110823_224625_S 20110823_224626_C	Refrac_survey.2A.Depth Refrac_survey.2A.Nav Refrac_survey.2A
EAGER2011_2A**	23	811	20110824_011447_G 20110824_011447_S 20110824_011448_C	Reflec_survey.2A.Depth Reflec_survey.2A.Nav Reflec_survey.2A
EAGER2011_2A_2	1	367	20110825_020651_G 20110825_020652_S 20110825_020652_C	Refrac_survey.2A_2.Depth Refrac_survey.2A_2.Nav Refrac_survey.2A_2
EAGER2011_3A	1	470	20110826_212957_G 20110826_212957_S 20110826_212958_C	Refrac_survey.3A.Depth Refrac_survey.3A.Nav Refrac_survey.3A
EAGER2011_3A_2	1	455	20110827_065903_G 20110827_065903_S 20110827_065903_C	Refrac_Survey.3A_2.Depth Refrac_Survey.3A_2.Nav Refrac_Survey.3A_2
EAGER2011_3B	1	3357	20110827_151405_G 20110827_151406_S 20110827_151406_C	Reflec_survey.3B.Depth Reflec_survey.3B.Nav Reflec_survey.3B
EAGER2011_3B_2*	1	113	20110828_045328_G 20110828_045328_S 20110828_045329_C	Reflec_survey.3B_2.Depth Reflec_survey.3B_2.Nav Reflec_survey.3B_2
EAGER2011_3B_2**	a1 114	a113 885	20110828_073621_G 20110828_073621_S 20110828_073621_C	Reflec_survey.3B_2.Depth Reflec_survey.3B_2.Nav Reflec_survey.3B_2
EAGER2011_4A#	1	695	20110829_191044_G 20110829_191045_S 20110829_191045_C	Refrac_survey.4A.Depth Refrac_survey.4A.Nav Refrac_survey.4A
EAGER2011_4B#	1	1622	20110829_134243_G 20110829_134243_S 20110829_134243_C	Reflec_survey.4B.Depth Reflec_survey.4B.Nav Reflec_survey.4B

Please note: line EAGER2011_4A has been renamed to EAGER2011_3D and line EAGER2011_4B to EAGER2011_3C in processing and relative to OBS and sonobuoy data acquisition.

Table 6. *Record inventory*

6.6 References

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

7. Shipboard Seismic Reflection Processing (Summary)

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

7.1 Summary

With limited offsets, the options for processing data are also limited. Except for lines 3C and 3D, we operated in deep water where 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. Complete details regarding setup of the processing computer are provided in Appendix B of the LOMROG II processing report (Hopper and Marcussen, 2010). The setup for EAGER2011 was identical except for the following: the main OS was upgraded to 10.6; the memory was upgraded to 8GB, the internal hard disk was upgraded to 750GB, the backup disk was upgraded to 1TB, and GMT was upgraded to version 4.5.3.

Many of the scripts and processing flows used on LOMROG II were used on this cruise as well. In particular, the scripts to format data between Navipac, Geometrics and ProMAX were updated for this cruise. Modifications were minor and not reproduced here. Refer to Appendix C of the LOMROG II processing report for the key scripts (Hopper and Marcussen, 2010).

Because we mostly worked in ice free areas, the towing arrangement was generally better as summarised in the acquisition chapters. In particular the more shallow towing depth and better depth control meant that the spectral shaping filter and careful checking of the static corrections was unnecessary.

Finally, the larger gun array resulted in better signal penetration and clear basement reflections are visible on all the data collected. In addition, on lines 3C and 3D, clear primary energy can still be interpreted in many areas below the multiple. A notable exception to the good signal penetration is on line 1 where the basement reflection deepens into the southern scarp of the East Greenland Ridge. It is not clear, however, if this is loss of signal penetration, or a geometric problem of imaging the corner near the steep scarp using a short streamer.

7.2 Processing Sequence and Key Acquisition Parameters

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

1. SEG-D read with trace dc bias removal;
2. Geometry assignment including gun and cable statics;
3. Bandpass filter;
4. Amplitude scaling;
5. Trace equalization;
6. Predictive deconvolution;
7. Trace mixing on shot gathers;

8. Resample to 2 ms (on lines recorded with 1 ms)
9. f-k filtering of shot gathers;
10. Midpoint sort and stack;
11. Post-stack trace mixing (on lines with 40 s or 60 s shot intervals)
12. Merge stacks;
13. Post-stack constant velocity migrations;
14. Seafloor mute;
15. SEG-Y output;
16. GRD conversion and plot.

7.2.1 SEG-D Read with Trace dc Bias Removal

As a precaution, a dc bias removal was applied as a standard procedure reading the data into ProMAX.

7.2.2 Geometry Assignment

Geometry assignment assumes a simple 2D marine geometry where X-locations are calculated as distance along track and gun and cable statics are applied during geometry assignment. Note that the gun array for all lines except 3C and 3D did not have a depth transducer. For lines 3C and 3D, the towing depth seemed fairly stable between 8.5 and 10.5 m, but was not recorded in the geometrics logs. The gun statics assume 9 m for all lines.

The towing geometry and shooting pattern varied during the cruise. Key parameters relevant for processing are summarised in Table 7. Full details are described in the acquisition chapters.

<table>
<tr><th>Seismic Line</th><th>Key Parameters</th></tr>
<tr><td>1A, 2A, 2A_2</td><td>Shot interval 60 s
Group interval 6.25 m
Number of channels 32
Dist. source to near channel 32.8 m
Cable target depth 6 m
Sample rate 2 ms
Record length 55000 ms
Filter high cut 250 Hz/24dB/oct
Filter low cut 0 Hz/0 dB/oct
Source 4x520 cu. in. G-guns
Source target depth 9 m
Gun pressure 200 bar</td></tr>
<tr><td>1B</td><td>Shot interval 12 s ± 1 s
Group interval 6.25 m
Number of channels 32
Dist. source to near channel 53.5 m
Cable target depth 6 m
Sample rate 1 ms
Record length 10000 ms
Filter high cut 500 Hz/24dB/oct
Filter low cut 0 Hz/0 dB/oct
Source 2x520 cu. in. G-guns
Source target depth 9 m
Gun pressure 180 bar</td></tr>
<tr><td>3A, 3A_2</td><td>Shot interval 60 s
Group interval 6.25 m
Number of channels 32
Dist. source to near channel 82.5 m
Cable target depth 6 m
Sample rate 2 ms
Record length 55000 ms
Filter high cut 250 Hz/24dB/oct
Filter low cut 0 Hz/0 dB/oct
Source 4x520 cu. in. G-guns
Source target depth 9 m
Gun pressure 200 bar</td></tr>
<tr><td>3B, 3B_2</td><td>Shot interval 12 s ± 1 s
Group interval 6.25 m
Number of channels 32
Dist. source to near channel 82.5 m
Cable target depth 6 m
Sample rate 1 ms
Record length 10000 ms
Filter high cut 500 Hz/24dB/oct
Filter low cut 0 Hz/0 dB/oct
Source 2x520 cu. in. G-guns
Source target depth 9 m
Gun pressure 180 bar</td></tr>
<tr><td>3C</td><td>Shot interval 12 s ± 1 s
Group interval 6.25 m
Number of channels 32
Dist. source to near channel 52.3 m
Cable target depth 9 m
Sample rate 1 ms
Record length 10000 ms
Filter high cut 500 Hz/24dB/oct
Filter low cut 0 Hz/0 dB/oct
Source 2x520 cu. in. G-guns
Source target depth 9 m
Gun pressure 180 bar</td></tr>
</table>

Seismic Line	Key Parameters	
3D	**Shot interval**	40 s
	Group interval	6.25 m
	Number of channels	32
	Dist. source to near channel	52.3 m
	Cable target depth	9 m
	Sample rate	2 ms
	Record length	35000 ms
	Filter high cut	250 Hz/24dB/oct
	Filter low cut	0 Hz/0 dB/oct
	Source	2x520 cu. in. G-guns
	Source target depth	9 m
	Gun pressure	200 bar

Table 7. *Key acquisition parameters by line*

Figure 20 shows a plan view of the four towing configurations used. Note that the small X-offset to the streamer was ignored during geometry assignment since the error in assigning offsets and bins is only a few meters. The streamer is assumed to follow straight along the track.

Data shot primarily for the reflection imaging used a randomised shot interval of 12 ± 1 s. The shot time was set to 12 s and was allowed to vary randomly between 11 to 13 s (so called "jitter"). This was a modification to the Navipac event triggering system requested after LOMROG II in 2009. The purpose of shooting on time this way is to ensure that long period multiple energy which appears in the records from previous shots does not stack after CDP binning. Figure 21 shows the actual shot interval times from lines 1B, 3B, 3B_2, and 3C, which were shot with this function enabled. The new feature worked perfectly. Inspection of shot records shows strong multiple energy from previous shots in many cases (Figure 22), but these did not affect the stack.

Data shot primarily for refraction recording used a long shot interval of either 40 or 60 seconds. No randomization or jitter was used in these cases. At 4.5 kts, the nominal shot spacing for these lines is approximately 90 and 140 m, respectively.

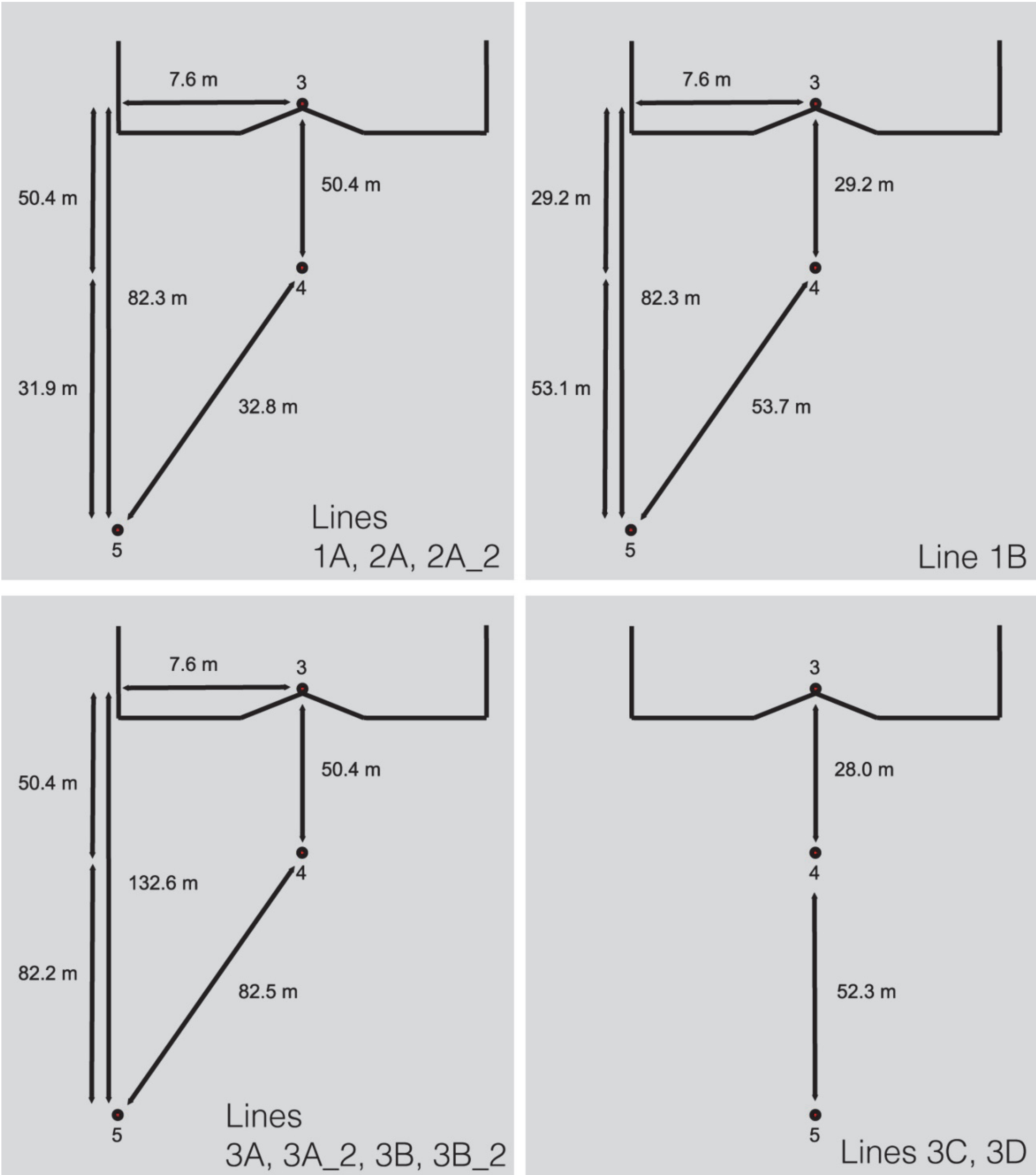


Figure 20. *Plan view of towing geometries for processing. First channel offset is given as the actual distance between source and receiver, otherwise the 7.6 meter X-offset of the streamer is not used in processing (see also Appendix II).*

The short streamer length results in low fold data using standard midpoint binning procedures. For the 12 s shot interval, the nominal fold is 4, while for the 40 and 60 s shooting, the fold goes to 0 for a significant number of bins. To increase the data fold, the 12 s data was binned at 12.5 m (fold of 12-16). The 40 and 60 s data was binned at 50 m. At 40 s, the fold is 16-24, while at 60 s the fold is up to 16. Table 8 summarises the bin size by line and Figure 23 shows data fold plots of each line.

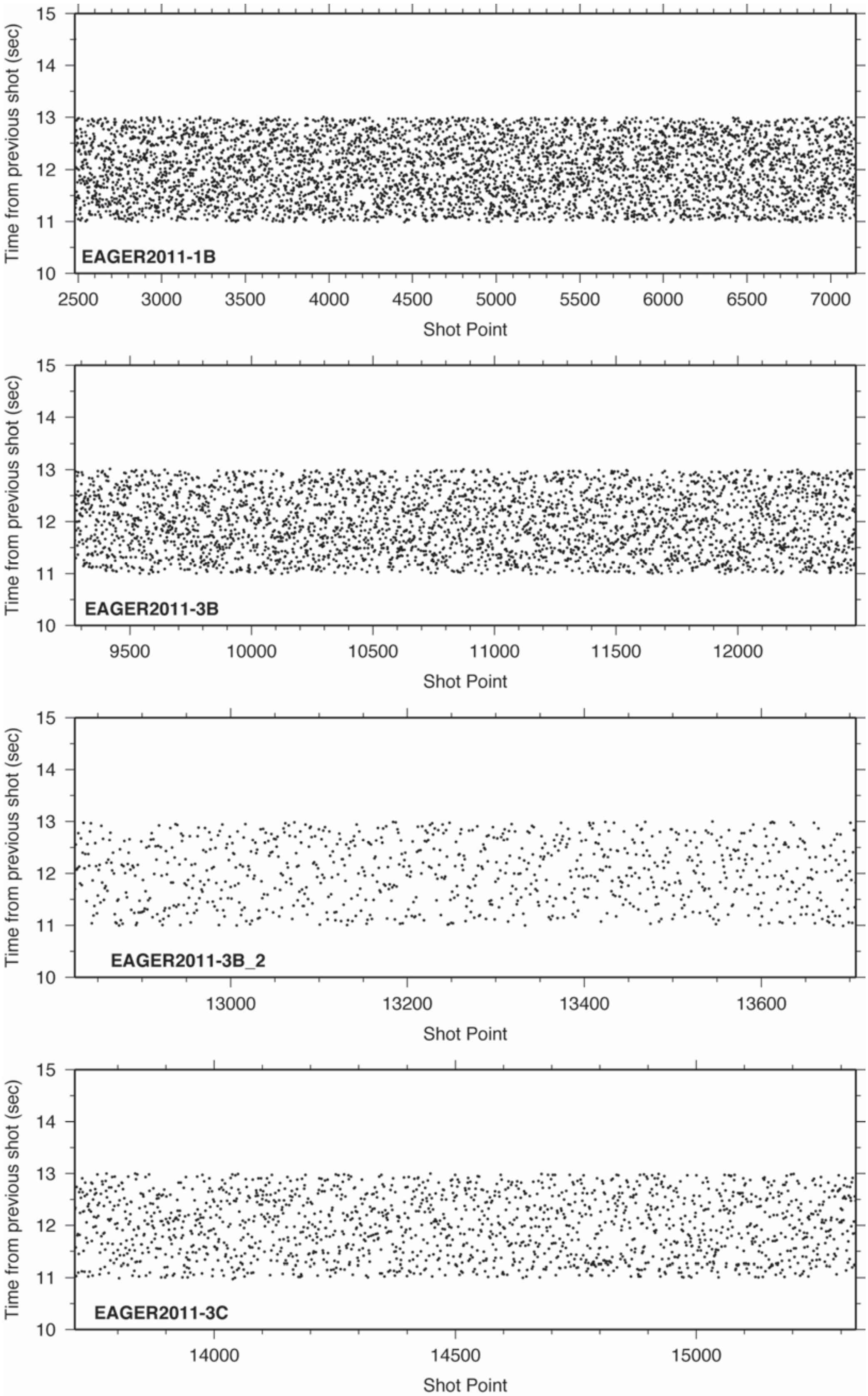


Figure 21. *Scatter plot of actual shot time minus previous shot time. Shot interval was set at 12 s and randomised by ± 1s (jitter). Plots show that shot times are indeed random between 11 and 13 s.*

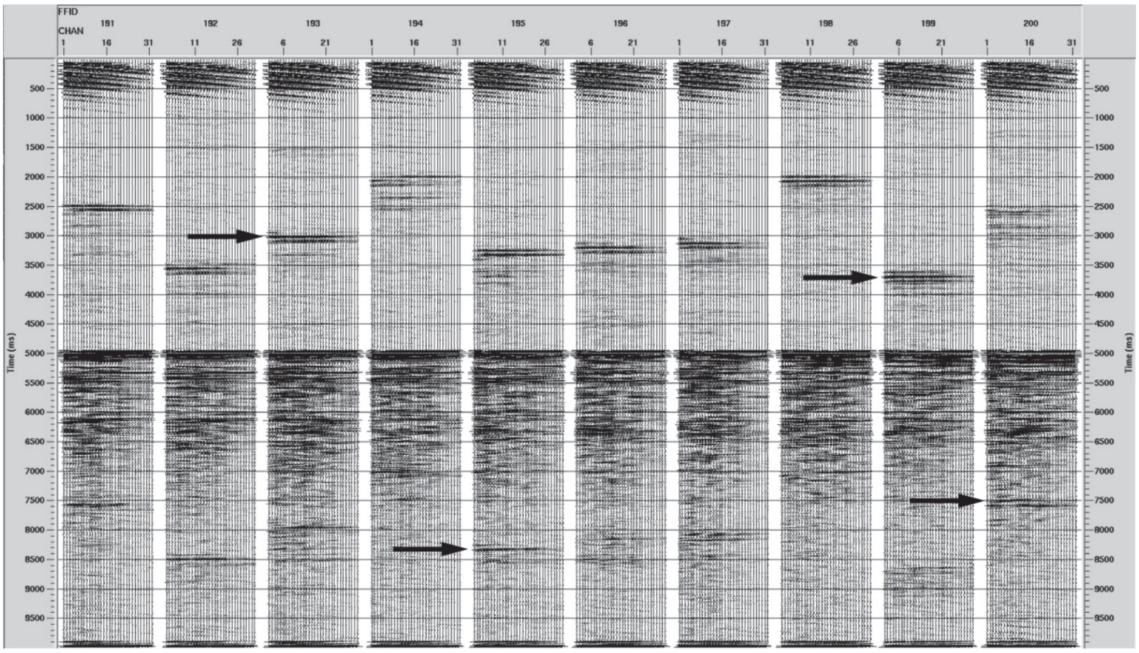


Figure 22. *10 shots from line 1B showing that long period multiples from previous shots are strong on this data set. Arrows point to just a few examples of multiple energy in a shot record from a previous shot. With randomisation of the shot time, the multiple time from previous shots is no longer predictable and does not stack after midpoint binning.*

Bin Size	Seismic Line
12.5 m	1B, 3B, 3B_2, 3C
50 m	1A, 2A, 2A_2, 3A, 3A_2, 3D

Table 8. *Summary of midpoint binning*

A final note regarding the geometry is that the target towing depths were much better here compared to the previous LOMROG cruises. In addition, operating in ice free areas enabled birds to be deployed on the streamer. Exceptions were lines 3C and 3D, which were in ice and used the ice array procedures. Figure 24 shows plots of cable depth for each line. At the beginning of the cruise (line 1A), the front of the streamer was too buoyant and lead weight was added for the subsequent lines. The streamer was very stable and well balanced for shooting lines 1B through 3B_2.

Shooting in the ice (Lines 3C and 3D), however, shows a clear difference in streamer stability. Note that on 3C, the depth transducers for section 1 and 2 did not function properly. The last depths recorded by each, however, were reasonable values to use in the absence of any other depth information and were not very different from the values of the two working transducers. Therefore the values recorded in the geometrics log files were used anyway, since this allowed the use of the standard scripts and flows to enter cable depths into the ProMAX geometry database.

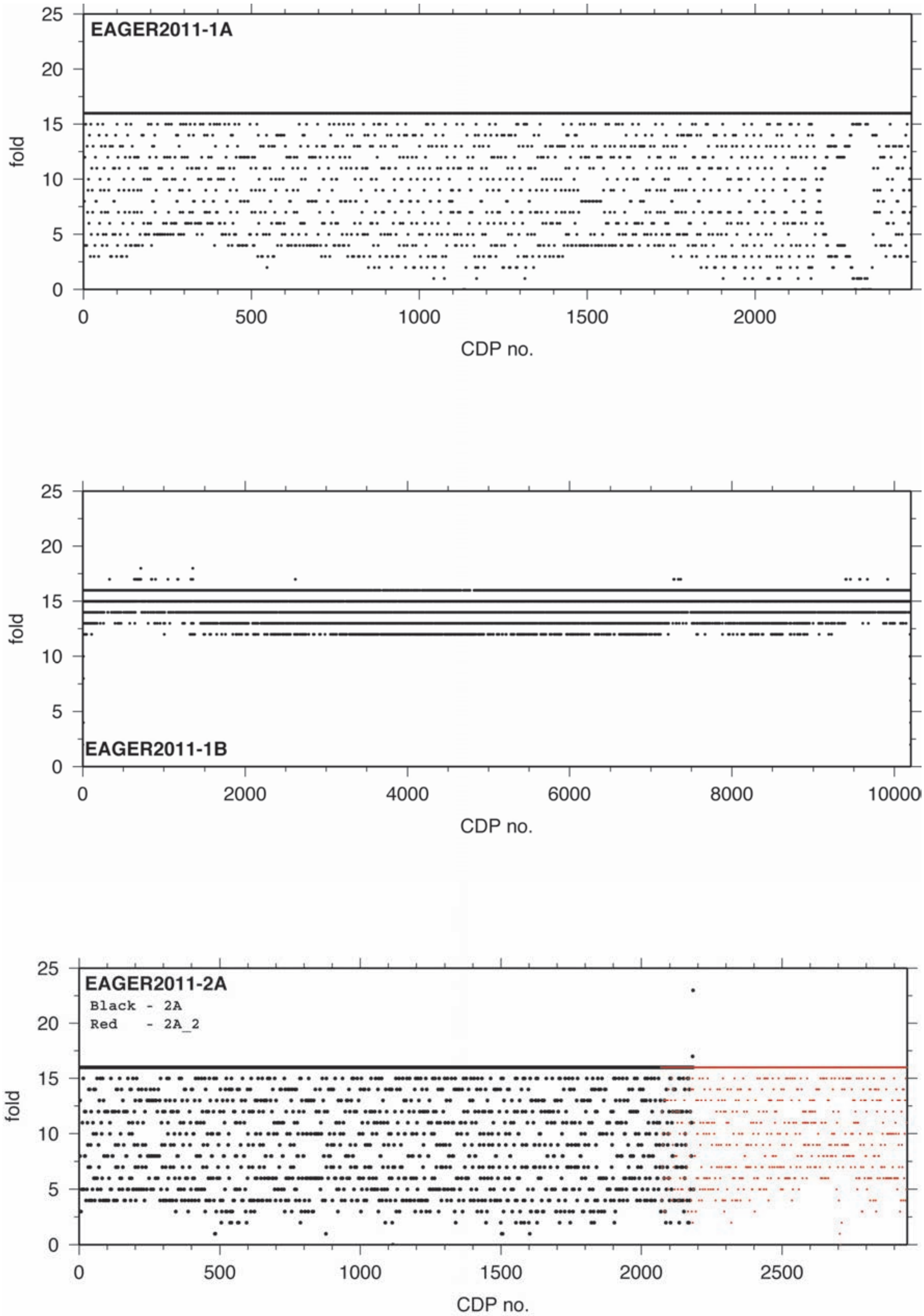
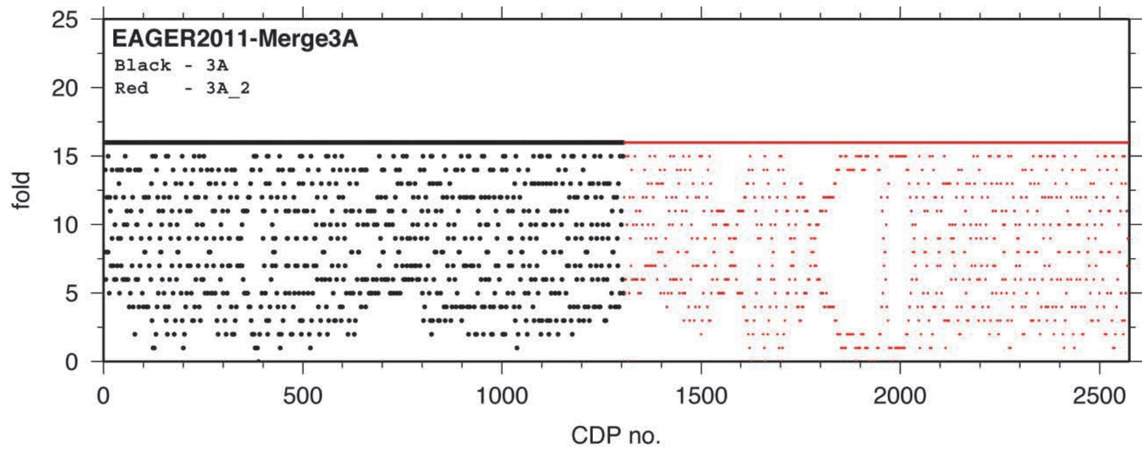
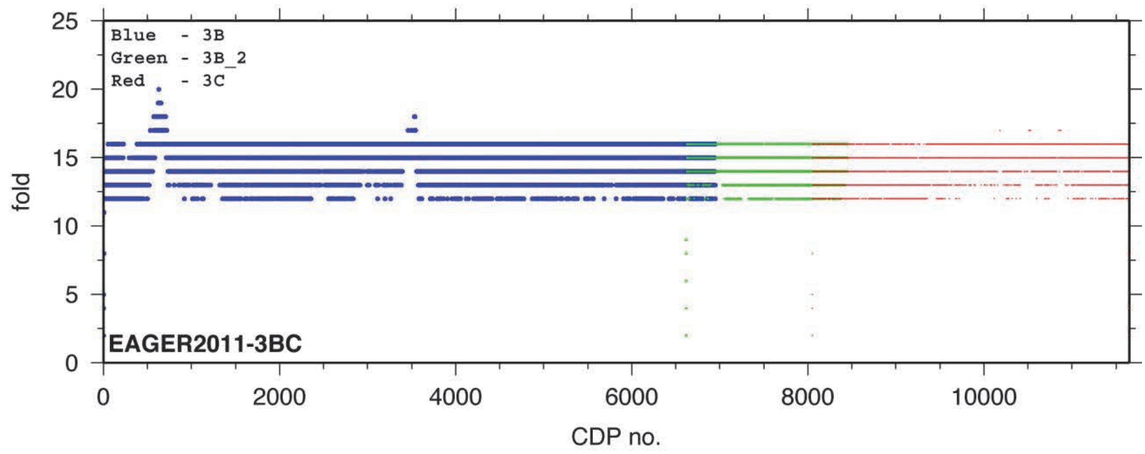


Figure 23. *CDP bin fold of each line. Merged lines are shown in color to highlight overlap areas.*





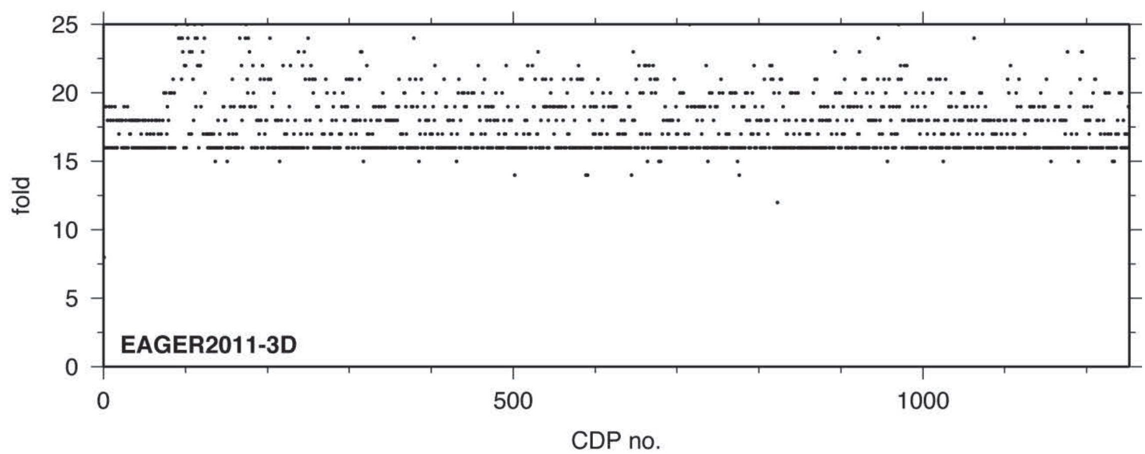


Figure 23 (cont.) *CDP bin fold of each line. Merged lines are shown in color to highlight overlap areas.*

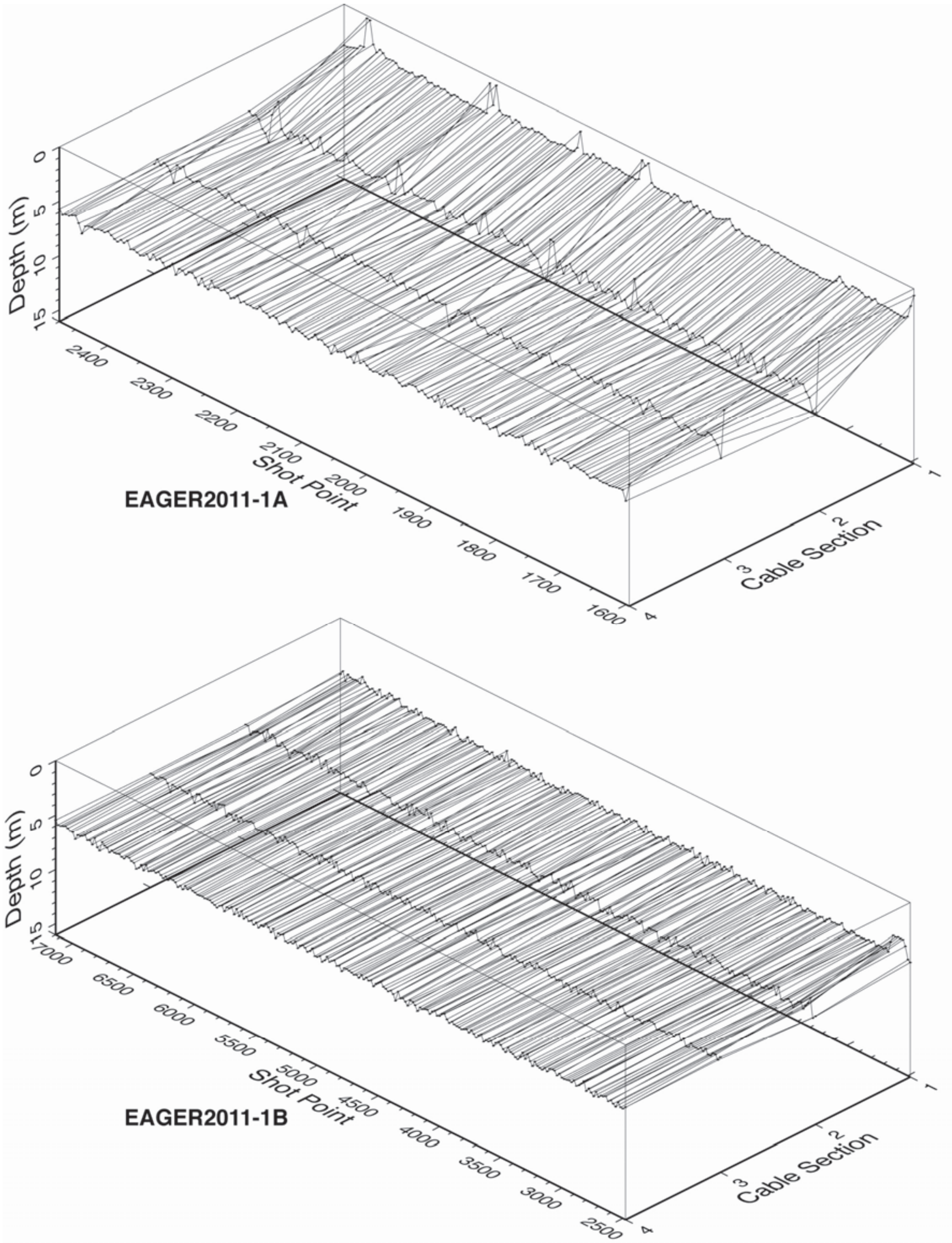


Figure 24. *Perspective view plots of streamer cable depths recorded by the depth transducers. Lines 1A, 2A, 2A_2, 3A, 3A_2, and 3D show every 5th shot; Lines 1B, 3B, 3B_2, and 3C show every 20th shot.*

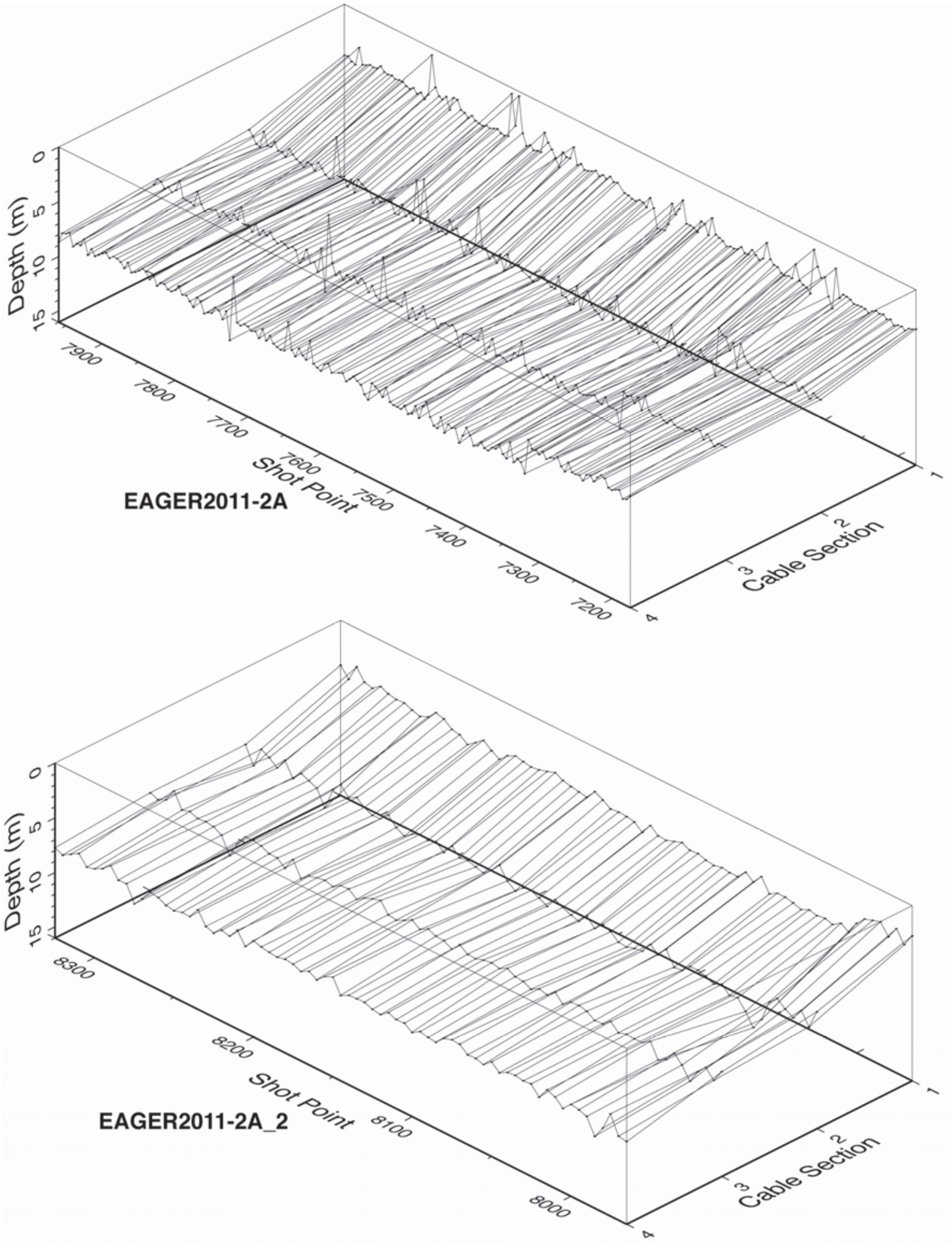
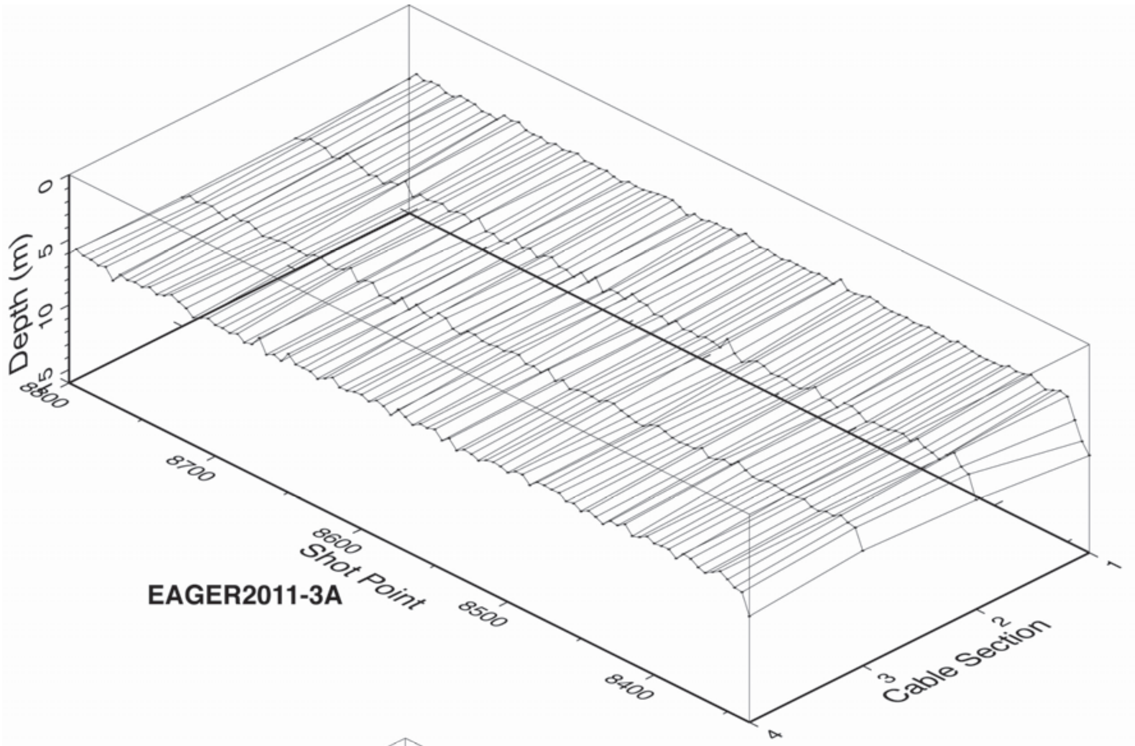


Figure 24 (cont.) *Perspective view plots of streamer cable depths recorded by the depth transducers. Lines 1A, 2A, 2A_2, 3A, 3A_2, and 3D show every 5th shot; Lines 1B, 3B, 3B_2, and 3C show every 20th shot.*



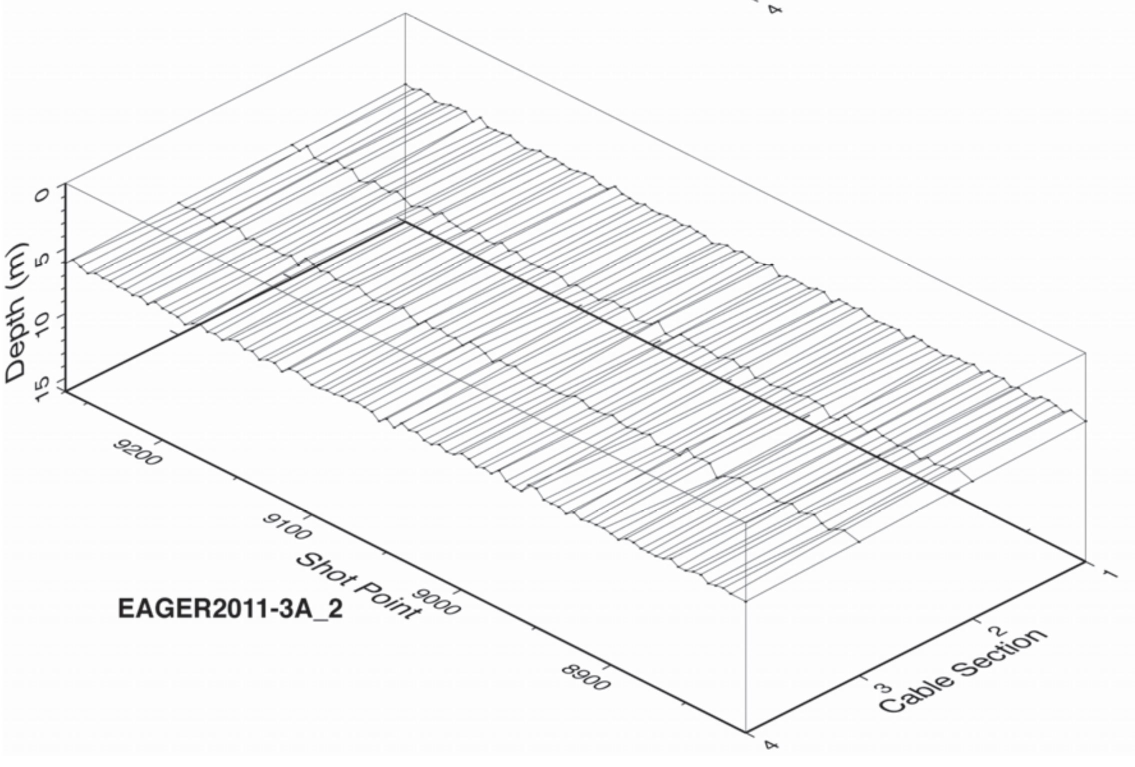


Figure 24 (cont.) *Perspective view plots of streamer cable depths recorded by the depth transducers. Lines 1A, 2A, 2A_2, 3A, 3A_2, and 3D show every 5th shot; Lines 1B, 3B, 3B_2, and 3C show every 20th shot.*

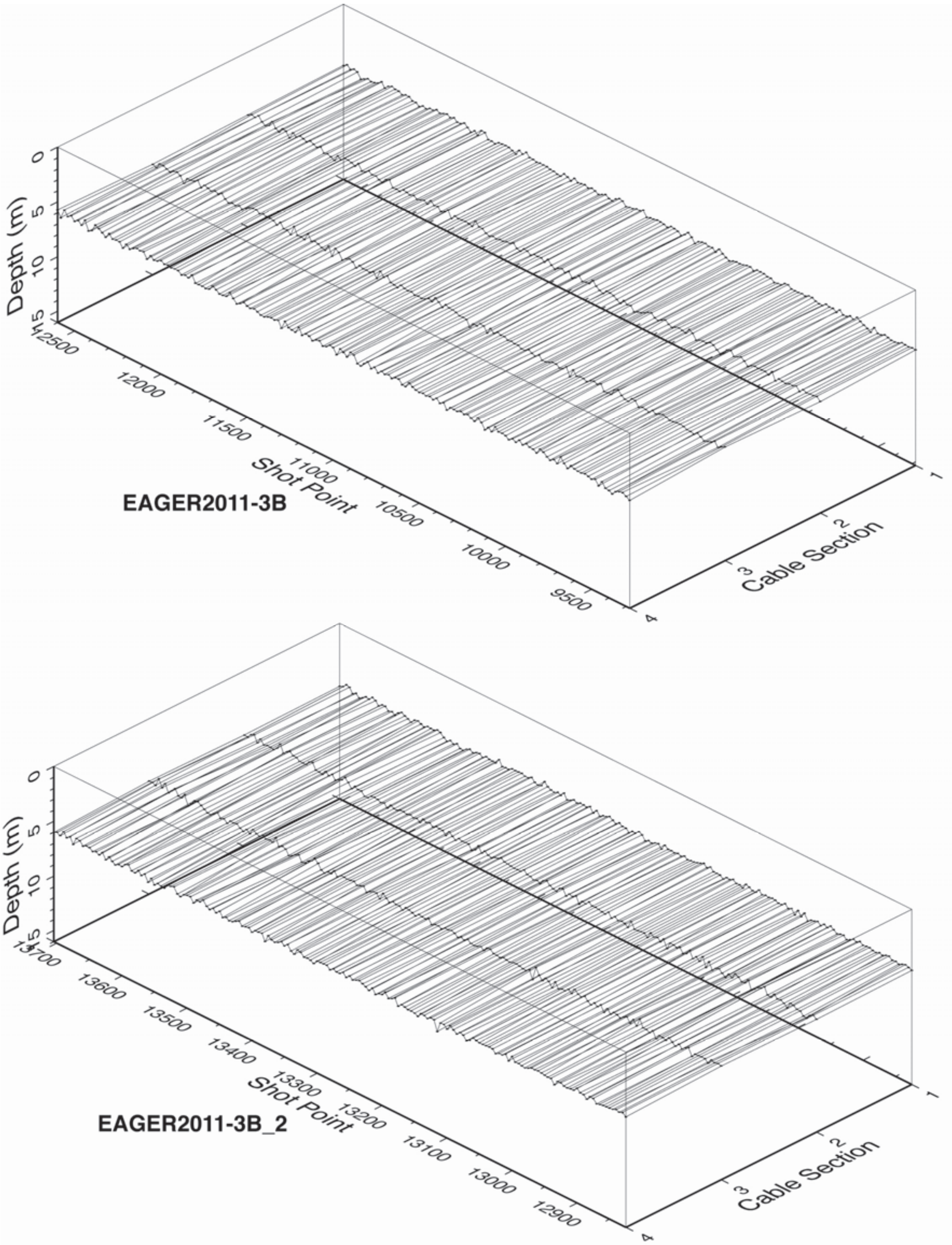


Figure 24 (cont.) *Perspective view plots of streamer cable depths recorded by the depth transducers. Lines 1A, 2A, 2A_2, 3A, 3A_2, and 3D show every 5th shot; Lines 1B, 3B, 3B_2, and 3C show every 20th shot.*

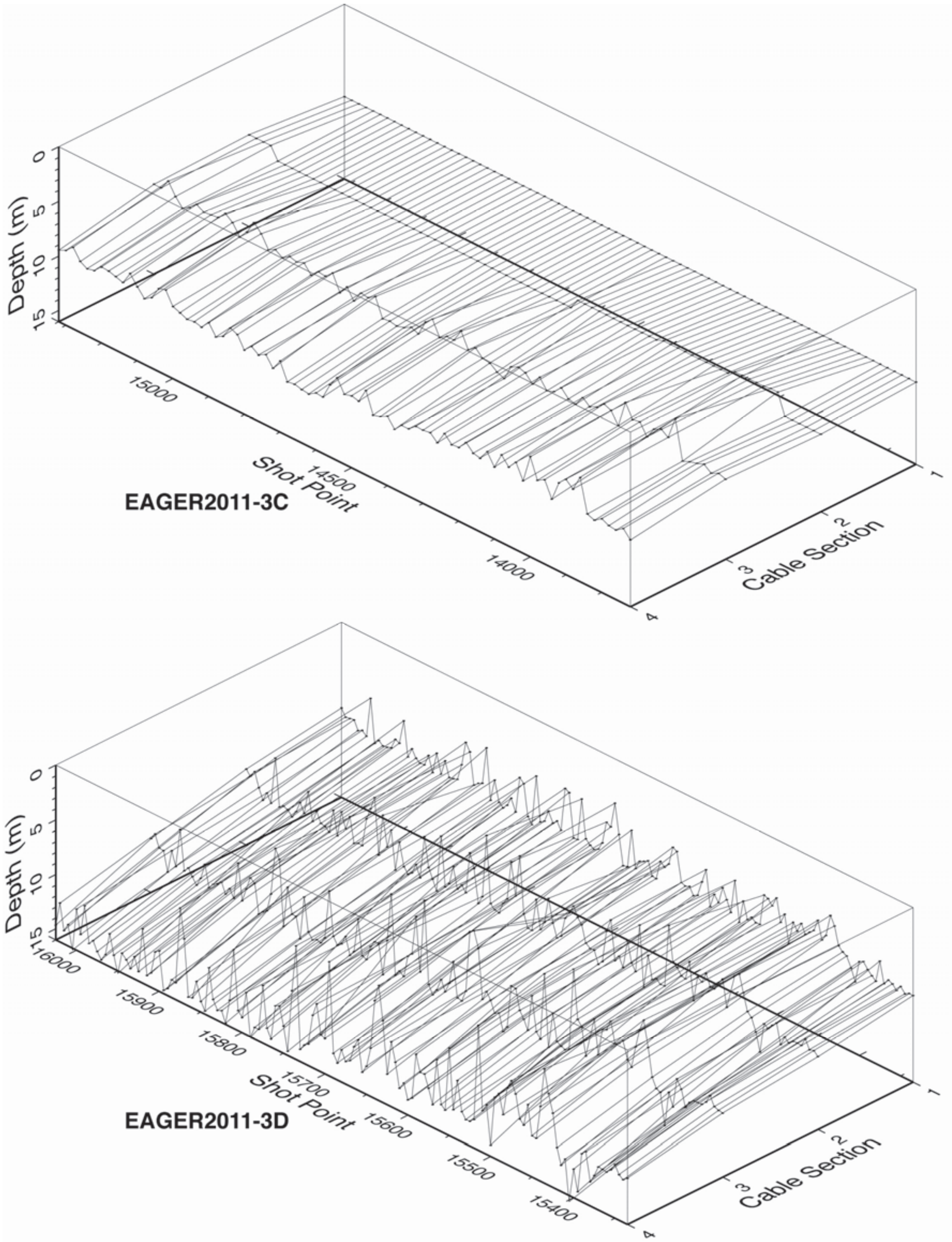


Figure 24 (cont.) *Perspective view plots of streamer cable depths recorded by the depth transducers. Lines 1A, 2A, 2A_2, 3A, 3A_2, and 3D show every 5th shot; Lines 1B, 3B, 3B_2, and 3C show every 20th shot.*

7.2.3 Bandpass Filter

Inspection of the spectra from the early shots shows that there is a significant loss of energy for frequencies over 100 Hz. A standard minimum phase Butterworth bandpass with a low cut of 8 Hz and 24 dB taper and a high cut of 100 Hz and 60 dB taper was used throughout the processing sequence. For display, increasing the low cut to 15 or 20 Hz helps to obscure the bubble pulse and decreasing the high cut to 85 Hz gives a cleaner appearance.

7.2.4 Amplitude Scaling

The amplitude scaling proved to be somewhat tricky because of the large variation in water depth. A scaling factor tied to the water bottom is probably the best solution. However, some experimentation showed that using a time power constant of 0.3 gave sufficient boost to the end of the record relative to the shallow data to give reasonable amplitude balance through time.

7.2.5 Trace Equalization

Despite the better acquisition parameters, there was often considerable variation in noise levels on various channels and at various times depending on weather, streamer stability, etc. Trace equalization was applied to suppress noisy channels without eliminating them entirely. On the deep water data, the equalization gate was in the water column below the direct arrival from 1-2 s. Lines 3C and 3D, however, were in water depths of less than 2 s. On these lines, the equalization gate was from 8-9 s.

7.2.6 Predictive Deconvolution

The bubble pulse from the gun array was surprisingly strong in much of the data. After some experimentation, a minimum phase predictive deconvolution using an operator length of 36 ms and a prediction distance of 132 ms was chosen. Because there were frequently problems with the gun array, especially later in the cruise shooting lines 3A, 3A_2, 3B, and 3B_2, no single predictive deconvolution filter will succeed. In addition, lines 3C and 3D used a different towing arrangement and it is likely that there is much greater variation in the towing depth of the array for these lines. Nevertheless, the deconvolution filter designed for the early lines did not appear to have a negative impact on line 3 and was kept in the basic processing flows for these lines. There did not appear to be large difference in the bubble response between the 2 gun arrangement and the 4 gun arrangement.

7.2.7 Trace Mixing on Shot Gathers

To further enhance coherent events, a 1-2-3-2-1 trace mix was applied on the shot gathers. No NMO was applied prior to mixing.

7.2.8 Resample to 2 ms (on lines recorded with 1 ms)

Data recorded at 1 ms was resampled to 2 ms at this point. In principle, this could be done after the initial bandpass filter. However, no computationally intensive processing was done up to this point so the exact placement of the resampling in the processing flow is not too important.

7.2.9 f-k Filtering of Shot Gathers

Strong linear noise is present on the shot gathers. Strong linear noise with a negative dip is apparent and probably results from tugging by the "tail buoy" arrangement used at the end of the streamer. In addition, tugging from the ship results in a linear noise with a positive dip although this is less severe than the negative dip noise.

f-k filtering was applied in two steps to eliminate the linear noise. The first transform and filter eliminated the positive dip and a second transform and filter eliminated the negative dip. Pie slices were defined by velocities of 100 to 1000 m/s from 1 to 500 Hz and -10 to -20000 m/s from 1 to 100 Hz respectively. No wrap past Nyquist was used.

7.2.10 Midpoint Sort and Stack

The data were sorted and stacked after all the pre-processing was done. With the exception of line 3D, the moveout of the seafloor reflection was less than 5 ms over 200 m at the water depths of this survey. At a water depth of 2.5 s, the moveout over 200 m is only 6 ms. In the absence of velocity control, NMO was ignored for all but line 3D. Data were simply sorted according to the binning procedure described earlier and averaged. For line 3D, no velocity analysis or control is possible with a 200 m streamer. Nevertheless, some sort of NMO is needed since the moveout is significant. A simple velocity function was picked starting at the seafloor with a velocity of 1475 m/s. The function was increased slowly to a maximum RMS of 3000 m/s approximately 2 s below the seafloor.

7.2.11 Post-stack Trace Mixing (on Lines with 40 s or 60 s Shot Intervals)

The resolution and data quality of the lines shot at 40 and 60 s is generally poor due to the large bin size and low data fold. For the 60 s case, midpoint bins frequently have a data fold as low as 4, significantly degrading the final image. A simple post-stack trace mix helped to produce a better stack. This effectively allows the low fold bins to "borrow" traces from neighbouring bins. Although this reduces the horizontal resolution even further, the image quality improved significantly by applying the trace mix.

7.2.12 Merge Stacks and Final Geometry

At this stage, the geographic X-Y coordinates of the cdp bins were calculated from the shot navigation files. UTM projected X-Y coordinates were placed into trace headers ACTUAL_X and ACTUAL_Y so that the original 2D processing coordinates are preserved. The projection and datums are the same as the acquisition system (UTM Zone 29, false easting of 500000 and WGS84). Note that these are CDP bin locations - not source point locations.

Frequent acquisition problems during lines 2 and 3 resulted in having to bring equipment on board for repair. We circled and reshot portions of the lines in these cases. Merging the stacks was accomplished by finding closest CDP locations between the lines to be merged and finding a single, constant cdp number to add to one of the lines to overlap the data. Table 9 shows the constant added to the CDP numbers for line merges. Traces were stacked in the overlap areas.

Seismic Line	Constant
Line 2A Merge 2A 2A_2	 -- 1978
Line 3A Merge 3A 3A_2	 -- 1250
Line 3BC Merge 3B 3B_2 3C	 -- 6618 8048

Table 9. *CDP constants for line merges*

7.2.13 Post-stack Constant Velocity Migrations

In the absence of velocity control, migrations are not possible at this stage. To help clean up the data and reduce the diffractive energy present, a Stolt phase shift constant velocity migration was applied assuming a velocity of 1400 m/s.

7.2.14 Seafloor Mute

The seafloor was picked and a mute applied to eliminate the water column prior to SEG-Y output and plotting.

7.2.15 SEG-Y Output

SEG-Y files of the unmigrated and migrated stacks were output for archiving. The EBCDIC header contains basic information about the files. All files use IBM floating point data. CDP locations (ACUAL_X and ACTUAL_Y) were placed into trace header bytes 181 and 185.

7.3 GRD Conversion and Plot

The cruise report plots were produced by using SioSEIS to convert the SEG-Y files to GMT compatible netcdf gridded data files (see Appendix IV). Amplitudes were not rescaled. The data are plotted as black and white variable area plots with grdimage. All plots use the same horizontal and vertical scales to facilitate comparison. We did not spend much time adjusting clipping parameters. However, the grdimage command line is included for reference on each plot.

7.4 Reference

Hopper, J.R., and Marcussen, C., 2010, Seismic Processing Report - LOMROG II in 2009: Acquisition of reflection and refraction seismic data during Oden's Lomonosov Ridge Off Greenland (LOMROG II) cruise in 2009. Confidential report, Danmarks og Grønlands Geologiske Undersøgelse Rapport **2010/36**, 99pp + 3 DVD’s.

8. Refraction/Wide-angle Reflection Seismic Data Acquisition

By Thomas Funck, Geological Survey of Denmark and Greenland (GEUS), Emil Kousted Mauritzen University of Aarhus, Tobias Hermann, Alfred Wegener Institute for Polar and Marine Research (AWI) & Jürgen Gossler K.U.M. Umwelt-und Meerestechnik Kiel GmbH,

8.1 Introduction

During the EAGER (**EA**st **G**r**E**enland **R**idge) 2011 expedition, refraction/wide-angle reflection (R/WAR) seismic data were acquired along three lines (Figure 25). Both sonobuoys (SB) and ocean bottom seismometers (OBS) were used for the recording of the seismic pulses generated by an airgun array consisting of up to four individual 520 cubic inches (8.5 L) Sercel G-guns. The objective of the study was to determine the velocity structure of the East Greenland Ridge (EGR) and how the ridge is connected to the continental shelf of Northeast Greenland. In addition, the crustal structure in the Boreas and Greenland basins was analyzed by a seismic line across the EGR. This will allow for a better assessment of the crustal character of the EGR.

The cruise was part of the Continental Shelf Project of the Kingdom of Denmark and is the third dedicated expedition to the EGR. In 2002, a first expedition was carried out (GEUS2002NEG) to collect seismic data on the ridge. As part of that cruise, two R/WAR seismic lines were acquired (Figure 25) using OBS and airguns (Døssing et al. 2008; Døssing & Funck submitted). During the LOMROG 2007 expedition, parts of the study area were mapped using a swath-bathymetric system. In addition, a reflection seismic line (Figure 25) was acquired. Sonobuoys were deployed along the line (Døssing & Funck, submitted) to determine the P-wave velocities of the sedimentary column and the basement.

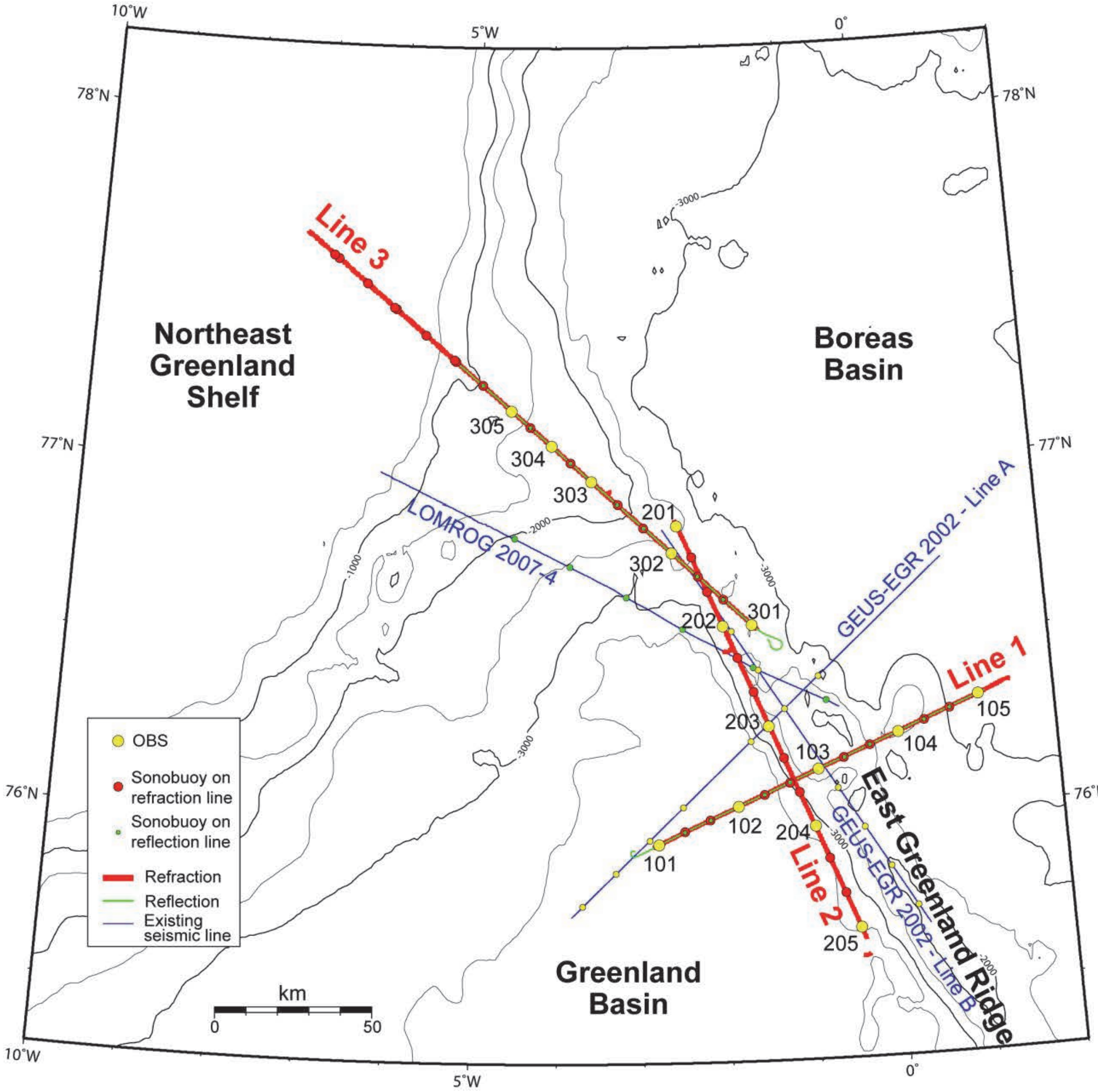


Figure 25. *Location map showing the three seismic lines of the EAGER 2011 expedition. Red lines indicate the segments of the lines that were shot for the R/WAR seismic data acquisition (40 to 60 s shot interval with mostly four air guns at a pressure of 200 bar). Green lines indicate segments along which reflection seismic data were acquired (12 s shot interval with two guns at a pressure of 180 bar). Existing lines with R/WAR seismic data are shown in blue. Contour interval of the bathymetry (IBCAO grid) is 500 m.*

8.2 Staffing

The sonobuoy and OBS operation was carried out by six members of the scientific crew onboard *Oden* as listed in Table 10. Additional support for the recording of the data and the airgun operation was obtained from the technical staff of the seismic crew (see chapter 6).

Name	Affiliation	Function
Thomas Funck	GEUS	Head of R/WAR program
Emil Kousted Mauritzen	Aarhus University	Sonobuoy deployment
Jens Andreas Rasmussen	Aarhus University	Sonobuoy deployment
Knud Karkov	Aarhus University	Sonobuoy deployment
Jürgen Gossler	KUM GmbH	OBS technician
Tobias Hermann	AWI	Support OBS operation

Table 10. *Staffing of the R/WAR seismic group.*

8.3 Line Location and General Operation

As source for the R/WAR seismic survey, two different airgun arrays were used. In the ice-free waters outside the Northeast Greenland shelf, the large airgun array was used consisting of four Sercel 520 cubic inches G guns (Figure 26). All four guns were used for the segments of the line that were acquired at 60 s shot interval (generally referred to as refraction lines). The array was fired at a nominal pressure of 200 bar and was towed 50 m behind the ship at a depth of 9 m. The required air was provided by two Hamworthy compressors.

When the array was used for the reflection seismic segments of the lines (12 s shot interval) only two of the four air guns in the array were operated at a pressure of 180 bar. All four compressors (Hamworthy and Bauer) had to be used to produce the required amount of air. In this setup, the array was towed 30 m behind the ship at a depth of 9 m.

In the ice-covered area at the north-western end of line 3, the ice-array (Figure 27) was used. This array consisted of two 520 cubic inches Sercel G-guns utilizing the mounting system used during the LOMOG I and II cruises but with one float attached to the array keeping it at a depth of 5 to 10 m (average of 8.5 m). The distance of the array to the ship was 30 m. For the reflection seismic data (Line 3C), the array was fired every 12 s at a pressure of 180 bar (using all compressors). For the refraction shots (Line 3D), a shot interval of 40 s was used at a pressure of 200 bar (using only the Hamworthy compressor). The shot interval along line 3 was reduced to 40 s compared to the other refraction lines as no separate reflection seismic data were acquired along this line segment.

The general acquisition scheme for the three seismic lines was divided into four phases. During the first phase, OBS were deployed along the line. In the second phase, the refraction seismic shots were fired using the large array at shot intervals of 60 s or the ice-array at 40 s. For better data coverage, additional sonobuoys were deployed during the shooting. In most cases, two sonobuoys were used between two adjacent OBS. During the third phase, reflection seismic data were acquired using two airguns at a shot interval of 12 s. Additional sonobuoys were used in this phase to increase the data density but also to obtain a better reversed ray coverage. Finally, the OBS were released from the seafloor and retrieved by *Oden*.

Figure 26. *Large airgun array consisting of four 520 cubic inches Sercel G-guns. Photo: Thomas Funck*

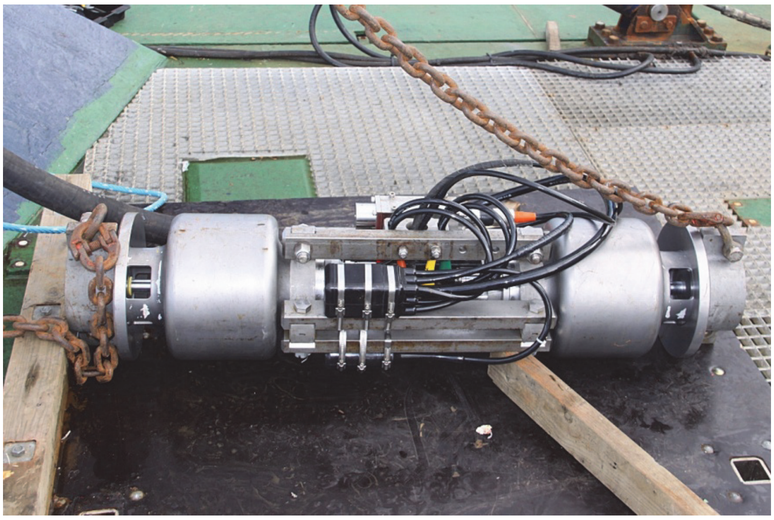


Figure 27. *Arctic array consisting of two 520 cubic inches Sercel G-guns. Photo: Thomas Funck*

Line 1 extends from the Greenland Basin, across the central segment of the East Greenland Ridge into the Boreas Basin (Figure 28). The refraction seismic part of line 1 is named Line 1A and consists of 885 shots. The line was shot from the NE to the SW and eight sonobuoys (SB1A-1 through SB1A-8) were deployed during the shooting. After completion of the refraction part, the coincident reflection seismic Line 1B was shot consisting of 4674 shots. The first 140 shots were fired while *Oden* was doing the loop to return to the line. Shooting direction was to the NE and eight sonobuoys (SB1B-9 through SB1B-16) were deployed at approximately the same location as the buoys on line 1A.

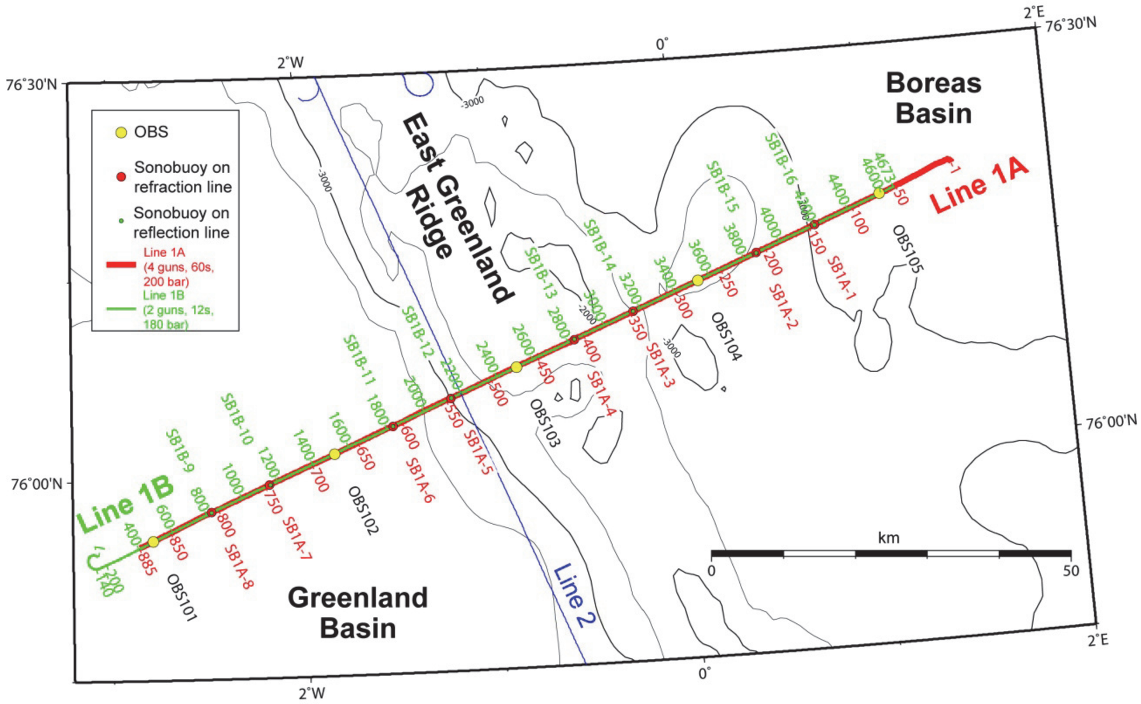


Figure 28. *Location map showing seismic line 1 of the EAGER 2011 expedition. Numbers next to the line indicate the shot numbers. Contour interval of the bathymetry (IBCAO grid) is 500 m.*

Line 2 is a cross line to Line 1 and extends from the NW segment of the East Greenland Ridge (EGR) into the Greenland Basin and the Greenland Fracture Zone that is located just to the south of the EGR (Figure 29). Due to time constraints it was decided not to shoot a second time with the shorter 12 s shot interval. As there was a short time window during which another commercial seismic vessel left the general area for a crew change and before an additional seismic vessel would arrive from the south, there was pressure to finish lines 2 and 3 as fast as possible. The 60 s refraction seismic shots were also recorded by a streamer. An initial brute stack of these data indicated that general features of the sedimentary column and the basement geometry can be recognized. This lower resolution reflection seismic image is sufficient to guide the modelling of the R/WAR data. In consequence, the additional reflection seismic shooting with a 12 s shot interval was cancelled.

Refraction seismic Line 2A consists of three segments: lines 2A-0, 2A-1, and 2A-2. Line 2A-0 consists of 22 shots that were fired off line during a loop to the start point of the profile. Due to its location off line and the shot gap to the start of the line, this segment was excluded from further data processing although it is included in the raw recordings. The next segment (Line 2A-1) consists of shot points 23 through 811, after which the airgun array had to be repaired. The final segment (Line 2A-2) comprises 367 shot points. The first 35 shots of this segment were fired off line when the ship was on a loop returning to the shot line. Shots 36 to 81 overlap with shots 766 through 811 on Line 2A-1.

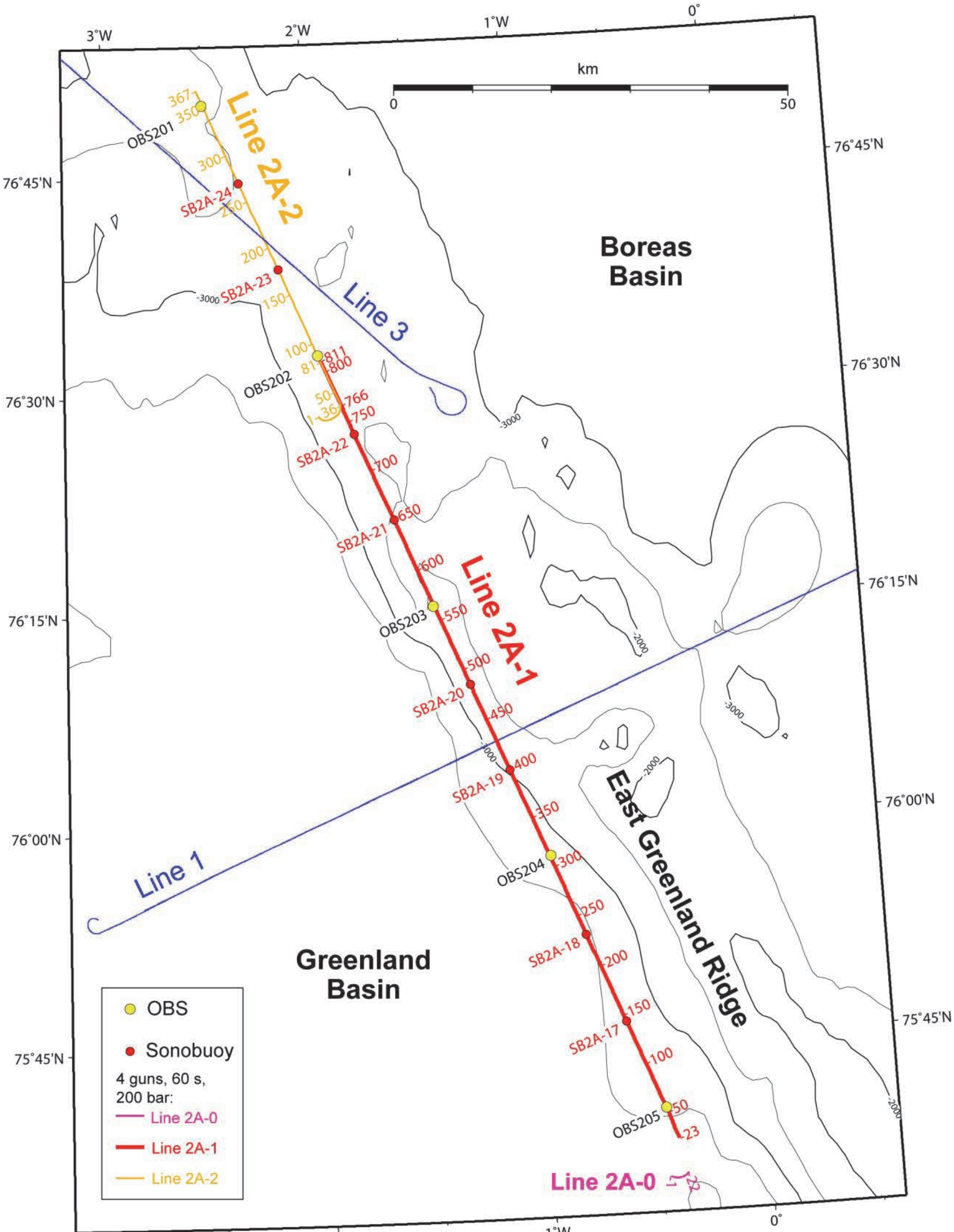


Figure 29. *Location map showing seismic line 2 of the EAGER 2011 expedition. Numbers next to the line indicate the shot numbers. Contour interval of the bathymetry (IBCAO grid) is 500 m.*

Line 3 (Figures 30 and 31) runs from the north-western part of the EGR onto the Northeast Greenland continental shelf. Due to the ice cover on the shelf, the line was divided into four portions. Lines 3A and 3D are the refraction seismic shots (60 s) in the ice-free and ice-covered areas, respectively. Line 3B is the reflection seismic part of the line (12 s shot interval) but the shooting had to be finished before the starting point of line 3A was reached. This was again due to problems with the airgun array. It was then decided to swap the large array with the ice array. Reflection seismic shots (12 s interval) were fired along Line 3C. When the starting point of Line 3A was passed, the shot interval was increased to 40 s along Line 3D onto the shelf. No separate reflection seismic shots were fired along this portion of the line as the short streamer (200 m active length) would prevent a removal of the multiples in the shallow water. Hence, the reflection seismic data would have been of limited value. General time constraints resulted in a shortening of the line in the NW by some 62 km compared to the original plan.

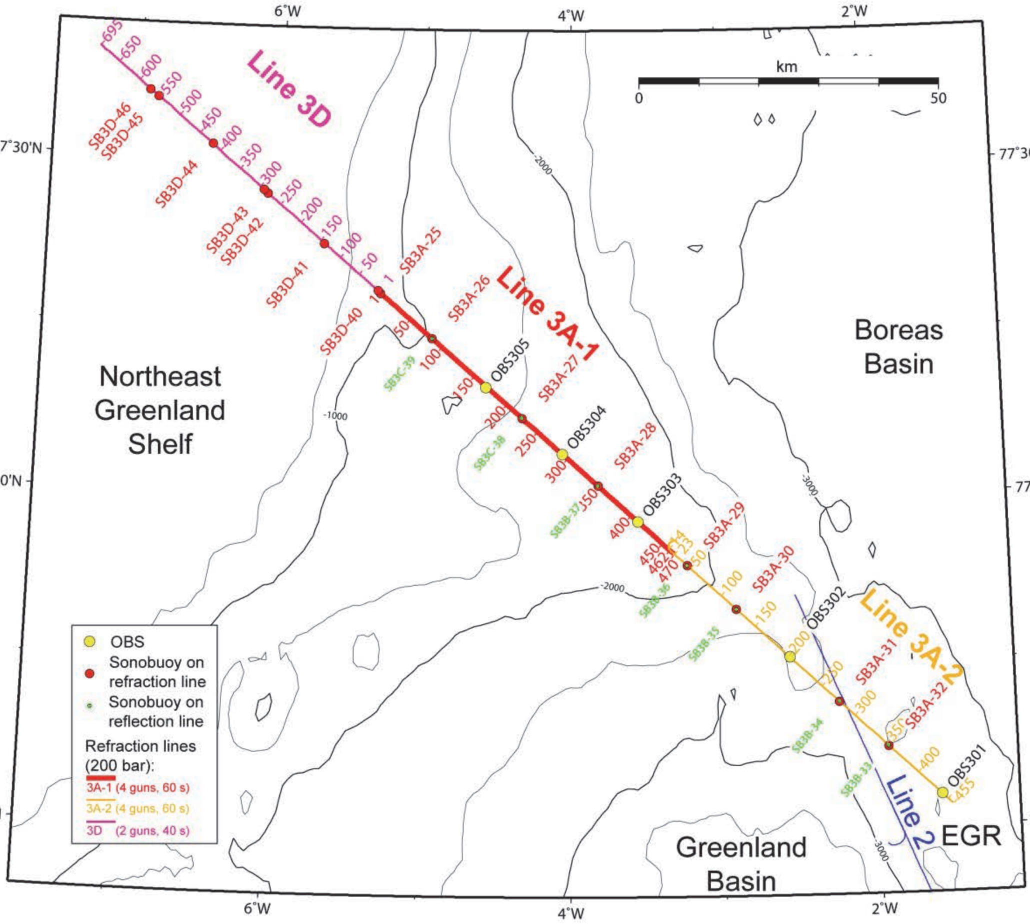


Figure 30. *Location map showing the refraction seismic shots of seismic line 3 of the EAGER 2011 expedition (lines 3A and 3D). Numbers next to the line indicate the shot numbers. Contour interval of the bathymetry (IBCAO grid) is 500 m.*

Sonobuoys on lines 3B and 3C were deployed at the same waypoints as one Line 3A. That way, observations could be made in either direction of these waypoints as the shooting direction on these two lines was opposite. OBS 305 was closest to the ice edge (located around sonobuoy position SB3A-25). Towards the NW from this position, sonobuoys were deployed with a spacing of ~12.5 km and a shooting direction to the NW along line 3D (Figure 30).

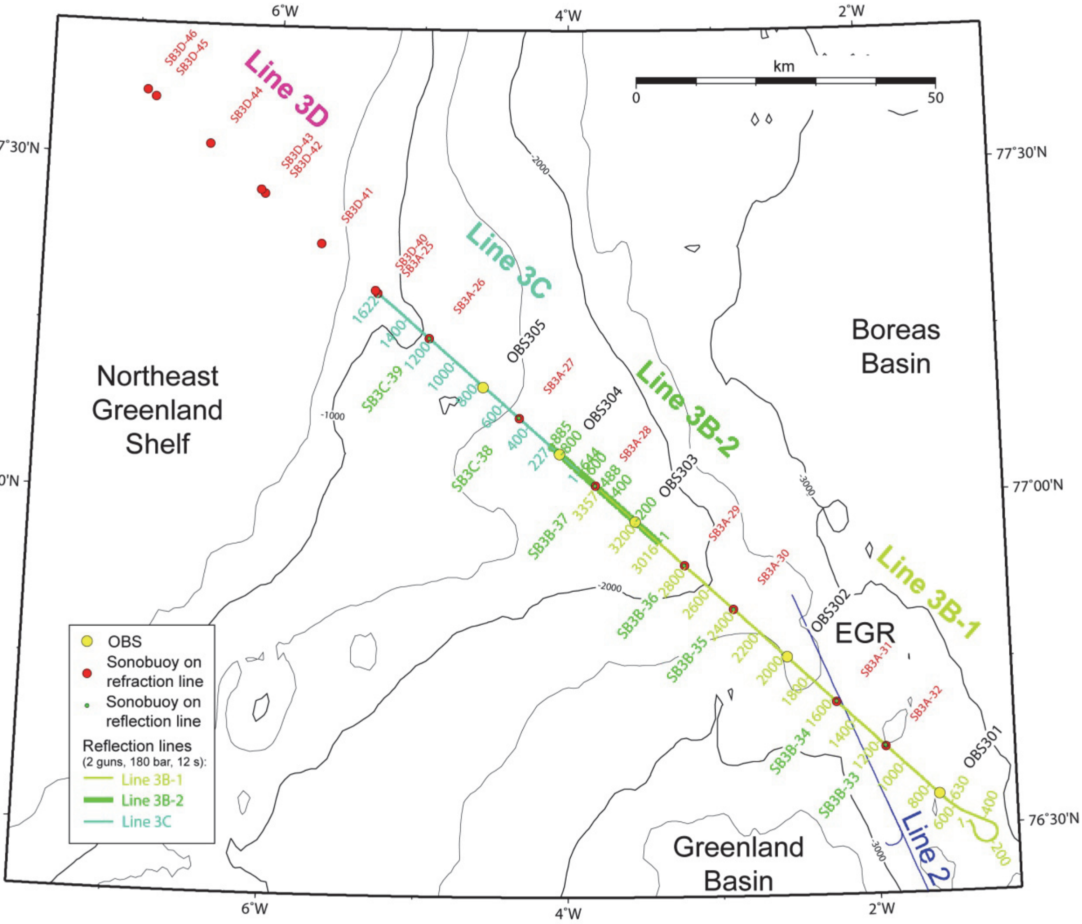


Figure 31. *Location map showing the reflection seismic shots of seismic line 3 of the EAGER 2011 expedition (lines 3B and 3C). Numbers next to the line indicate the shot numbers. Contour interval of the bathymetry (IBCAO grid) is 500 m. Abbreviation EGR is East Greenland Ridge.*

Due to necessary repairs to the airgun array, both Line 3A and Line 3B are divided into two segments each (lines 3A-1 and 3A-2; and lines 3B-1 and 3B-2). This resulted in some overlap. Shots 462 through 470 on Line 3A-1 overlap with shots 14 through 23 on Line 3A-2. The first 13 shots on Line 3A-2 were fired off line. Similarly, the first 630 shots on Line 3B-1 were fired off line. Shots 3016 through 3357 on Line 3B-1 overlap with shots 1 through 488 on Line 3B-2. An additional overlap occurs between lines 3B-2 (shots 644 through 885) and 3C (shots 1 through 227).

8.4 Sonobuoy Operation

8.4.1 Sonobuoys and Recording System

A Geometrics streamer was deployed during both the R/WAR and reflection seismic data acquisition. The streamer consisted of four 50-m long sections with eight channels each. The active length of the streamer was 200 m.

A total of 69 sonobuoys were brought onto the ship. The buoys are the seismic version of type AN/SSQ-53D(3) from ULTRA Electronics (Figure 32, see also Appendix V-F). This is a special purpose version of the AN/SSQ-53D(3) DIFAR sonobuoy in which the omni channel response is altered to be suitable to the amplitude and frequency response of R/WAR seismic experiments. The frequency response is changed to increase the low frequency sensitivity up to 15 dB in the 5-60 Hz band of interest. High frequency response above 200 Hz is suppressed.

The buoys were stored in the material container at the upper container level on the afterdeck. For easy access, up to 15 sonobuoys were moved to the workshop container at the lower level, where a custom-built rack was used for storage. A total of 46 sonobuoys were deployed during the expedition. The sonobuoys were deployed on the starboard side of the afterdeck of *Oden* (Figure 33). However, when the ship reached the ice, the deployment procedure was changed to the method used during the LOMROG II expedition. Here, a rope was attached to the parachute of the buoy. The buoy was then deployed from the far end of the afterdeck on port side, holding the rope until the buoy expanded itself. This method was used for five buoys (SB3D-41 through SB3D-45) Sonobuoys were launched during both shot segments (R/WAR and reflection seismic). This provides additional reversed observations as the shooting direction was opposite during both segments. The additional observations at 12 s shot interval also provide a higher spatial resolution compared to the 60 s shots. This will improve the characterisation of the sedimentary column and the upper crustal layer.

Figure 32. *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.*

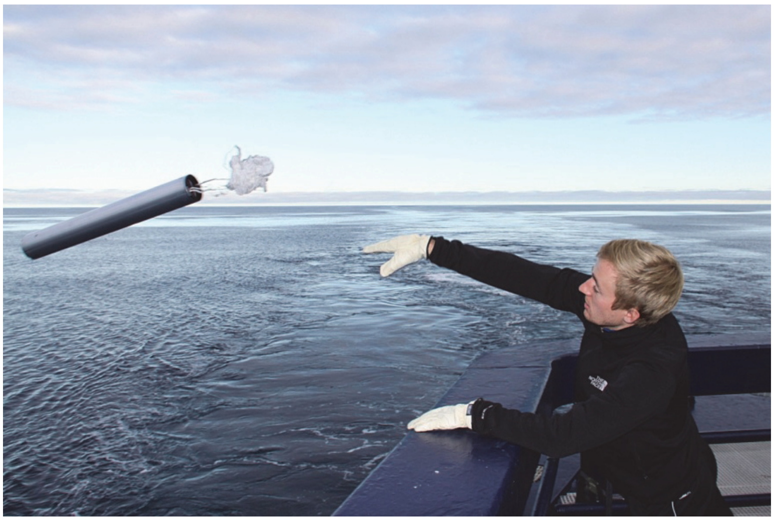


Figure 33. *Student Emil Kousted Mauritzen deploying a sonobuoy from the starboard side of the after-deck of Oden. Photo: Thomas Funck.*

A second person was standing next to the sonobuoy deployer and marked a waypoint on a handheld GPS receiver at the time of deployment. The receiver was a GARMIN GPSmap 60CSx unit and stored both the position and time of the waypoint. The same GPS receiver was also used to mark the deployment positions of the OBS.

Figure 34. *Sonobuoy receiving system. The two older Winradios (type WR-2902e; black boxes) are controlled by Winradio software (upper left window on computer display). The two newer Winradios (type WR-G39WSB; green boxes) were controlled by the Winradio software in the lower right window on the computer display. Photos: Thomas Funck.*

The antenna and receiver configuration consisted of four Winradios (Figure 34) and one VHF-antenna (Figure 35). The antenna was a Moonraker MD HB-G3/HS (see Appendix V-G) mounted on top of the bridge on the port side at a height of 27.7 m. The antenna was connected to a notch filter to eliminate the ship's AIS frequencies (161.975 and 162.025 MHz) and further to a signal divider in the registration container on the 4th deck from where the signals were distributed to the four Winradios. There were two radios of the older type Winradio WR-2902e (see Appendix V-D) and two of the newer type Winradio WR-G39WSB. All radios were controlled by software installed on a PC running Windows XP (Figure 34).

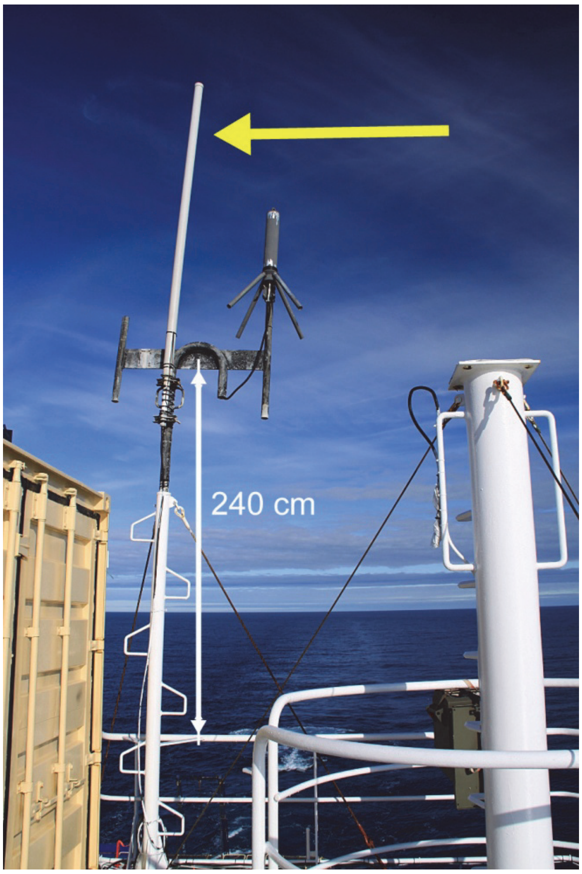


Figure 35. *VHF base station antenna MD HB-G3/HS mounted on top of the bridge of Oden on the port side. The antenna was covered by a pipe. Photo: Thomas Funck.*

The output of the Winradios was split (Figure 36) to be recorded both on the Geometrics recording system and on a Taurus digital seismometer manufactured by Nanometrics (Figure 27). Table 11 specifies on which channels the individual Winradios were recorded on the Geometrics and Taurus system. The auxiliary channels correspond to channels 33 through 36 in the raw SEGD files of the Geometrics recording system (using four active streamer segments with a total of 32 channels). Signals on the Geometrics system were recorded with a record length of 10 s at a sampling rate of 1 ms during the reflection seismic shooting. Due to limitations of the maximum number of samples in a single trace, the sampling rate had to be reduced to 2 ms during the refraction seismic shooting. Then the record length was 55 s with exception of Line 3D when the record length was 35 s.

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

Table 11. *Recording and software control of the four Winradios.*

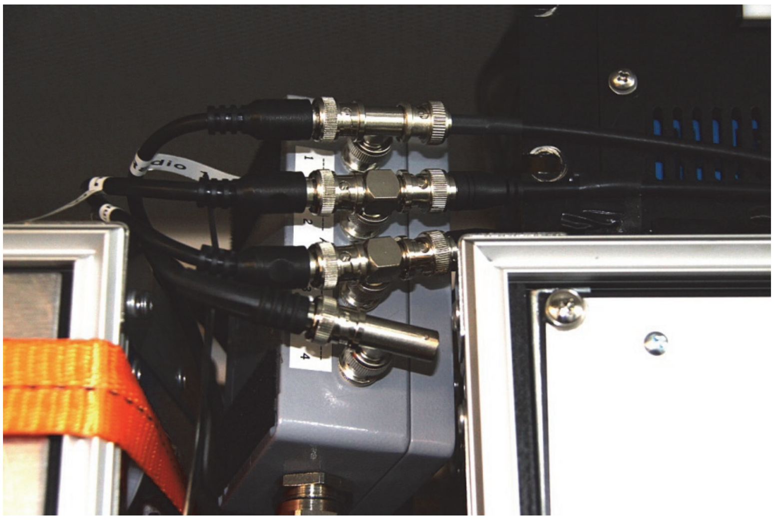


Figure 36. *The output signal of the Winradio was split to go the auxiliary channels (1 through 4) on the Geometrics recording system and to the Taurus seismometer (cables to the right). Note: The fourth Winradio is not recorded on the Taurus. Photo: Thomas Funck.*

In contrast, the Taurus seismometer (see Appendix V-E) recorded the signals continuously. The sampling rate was set to the lowest possible value of 2 ms corresponding to 500 Hz. However, as there was only one seismometer available (serial number 1574, owned by GEUS), only three radios could be recorded (Winradios 1 through 3). No Taurus records exist for Winradio 4.

Figure 37. *Taurus digital seismometer produced by Nanometrics. The unit is recording the signals of Winradios 1 through 3 at a sampling rate of 50 Hz. Photo: Thomas Funck.*

During the EAGER 2011 expedition, the Taurus seismometer was powered by an adapter that provided a voltage of 12.3 V. To avoid severe 50-Hz noise on the recorder, the seismometer was grounded (Figure 38). Not using the grounding results in data spikes as noticed during the LOMROG II expedition in 2009.

Figure 38. *Connectors at the Taurus seismometer (left). The green-yellow cable at the far left connects to the ground plug (Earth Binding Post) of the GeoEel streamer power supply unit (right). Photos: Thomas Funck.*

8.4.2 Container and Laboratory Setup

Several laboratory and storage spaces were used for the sonobuoy and seismometer operation. On the port side of deck 4, the seismic registration container was located. Here the navigation software (NaviPac) and multichannel registration software (Geometrics) were installed. Also the four Winradios for the sonobuoy reception were in this container, in addition to the Taurus recorder for which a GPS antenna cable was run to the outside through a cable-funnel in the container. The GPS antenna was mounted on top of the container (aft end starboard corner of the container).

A laboratory container (three combined 20 ft containers) on the ship's front on the 4th deck on the port side was used for the preparation of the Taurus seismometer 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 the programming of the seismometer and for the data download. 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 on the starboard side).

Figure 39. *Setup of the laboratory container on the fourth deck used for the preparation of the Taurus seismometer as well as for data processing and analysis. Photo: Thomas Funck.*

8.4.3 Sonobuoy Deployments

After completion of each line, the waypoints marked during the sonobuoy deployments were downloaded from the GPS receiver. These positions are shown in Table 12 together with the water depth and recording parameters. The water depth was extracted from the centre beam of the EM122 multibeam system, available from the ship's server (saved separately for each day in Excel files with the name "depth_2011-[MM]-[DD].us.cv"; with MM being the month and DD the day). Individual sonobuoys were named by the line number, separated by a hyphen from a successive deployment number (starting with 1 for the first buoy and 46 for the last buoy). Some buoys recorded also on other lines than the one they were deployed on.

The sonobuoy deployments in the open water had a 100 % success rate. In the ice, some failures occurred. One buoy (3D-42) did not expand even after it was towed several minutes in the water. This indicates a possible malfunctioning of the buoy as it can happen according to the manufacturer. Another buoy (3D-45) was caught by the airgun array. This damaged the hydrophone and only the carrier signal was transmitted back to the ship. A second buoy (3D-46) was deployed over the starboard side shortly thereafter to replace SB 3D-45. This buoy passed the airgun array without incidents but then it got caught in a strong current created by the propeller wash of *Oden*. This caused the buoy to move with high speed into the ice. Inspection of the corresponding auxiliary channel during the acquisition indicated damage to the hydrophone.

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

Sono-buoy	Seis-mic 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
1A-1	1A	D1=30 m	8 h	48	1	21 AUG 2011 (JD 233)	06:43:27	0.73500°E	76.27957°N	3183	Initially recorded on all 4 Winradios
1A-2	1A	D1=30 m	8 h	58	2	21 AUG 2011 (JD 233)	07:49:26	0.41824°E	76.25055°N	2752	Water depth from 1B-15
1A-3	1A	D1=30 m	8 h	67	3	21 AUG 2011 (JD 233)	10:06:26	0.24977°W	76.18761°N	2894	
1A-4	1A	D1=30 m	8 h	77	4	21 AUG 2011 (JD 233)	11:09:26	0.56489°W	76.15714°N	2180	
1A-5	1A	D1=30 m	8 h	87	1	21 AUG 2011 (JD 233)	13:24:27	1.22503°W	76.09171°N	2900	
1A-6	1A	D1=30 m	8 h	43	2	21 AUG 2011 (JD 233)	14:30:26	1.53243°W	76.05985°N	3708	
1A-7	1A	D1=30 m	8 h	63	3	21 AUG 2011 (JD 233)	16:45:25	2.18195°W	75.99175°N	3692	
1A-8	1A	D1=30 m	8 h	73	4	21 AUG 2011 (JD 233)	17:46:25	2.48413°W	75.95940°N	3676	
1B-9	1B	D1=30 m	8 h	83	1	21 AUG 2011 (JD 233)	22:46:54	2.48540°W	75.95900°N	3673	
1B-10	1B	D1=30 m	8 h	93	2	21 AUG 2011 (JD 233)	23:53:18	2.17788°W	75.99188°N	3685	
1B-11	1B	D1=30 m	8 h	48	3	22 AUG 2011 (JD 234)	02:08:29	1.53035°W	76.05991°N	3708	
1B-12	1B	D1=30 m	8 h	58	4	22 AUG 2011 (JD 234)	03:11:23	1.22113°W	76.09196°N	2860	
1B-13	1B	D1=30 m	8 h	67	1	22 AUG 2011 (JD 234)	05:28:21	0.56370°W	76.15714°N	2161	
1B-14	1B	D1=30 m	8 h	77	2	22 AUG 2011 (JD 234)	06:33:34	0.24965°W	76.18761°N	2894	Water depth from 1A-3
1B-15	1B	D1=30 m	8 h	87	3	22 AUG 2011 (JD 234)	08:55:33	0.41790 °E	76.25032°N	2752	
1B-16	1B	D1=30 m	8 h	43	4	22 AUG 2011 (JD 234)	10:02:26	0.73578 °E	76.27937°N	3182	
2A-17	2A	D1=30 m	8 h	48	1	24 AUG 2011 (JD 236)	03:15:15	0.63118°W	75.76960°N	3699	Initially recorded on all 4 Winradios
2A-18	2A	D1=30 m	8 h	58	2	24 AUG 2011 (JD 236)	04:42:16	0.79672°W	75.87123°N	3703	
2A-19	2A	D1=30 m	8 h	67	3	24 AUG 2011 (JD 236)	07:30:13	1.11425°W	76.06325°N	2654	
2A-20	2A	D1=30 m	8 h	77	4	24 AUG 2011 (JD 236)	08:57:14	1.28270°W	76.16309°N	2195	
2A-21	2A	D1=30 m	8 h	87	1	24 AUG 2011 (JD 236)	11:42:14	1.61538°W	76.35423°N	2355	
2A-22	2A	D1=30 m	8 h	43	2	24 AUG 2011 (JD 236)	13:09:14	1.79302°W	76.45377°N	2668	
2A-23	2A	D1=30 m	8 h	63	3	25 AUG 2011 (JD 237)	05:02:12	2.13828°W	76.64467°N	3421	
2A-24	2A	D1=30 m	8 h	73	4	25 AUG 2011 (JD 237)	06:35:13	2.32215°W	76.74405°N	2469	
3A-25	3A	D1=30 m	8 h	48	3	26 AUG 2011 (JD 238)	21:32:00	5.29978°W	77.30372°N	875	
3A-26	3A	D1=30 m	8 h	58	4	26 AUG 2011 (JD 238)	22:54:14	4.94470°W	77.23730°N	1226	
3A-27	3A	D1=30 m	8 h	67	1	27 AUG 2011 (JD 239)	01:14:55	4.33045°W	77.11900°N	1628	
3A-28	3A	D1=30 m	8 h	77	2	27 AUG 2011 (JD 239)	03:18:54	3.82002°W	77.01762°N	1844	
3A-29	3A	D1=30 m	8 h	87	3	27 AUG 2011 (JD 239)	07:46:54	3.23033°W	76.89720°N	1834	
3A-30	3A	D1=30 m	8 h	43	4	27 AUG 2011 (JD 239)	09:04:55	2.91077°W	76.83065°N	2140	
3A-31	3A	D1=30 m	8 h	63	1	27 AUG 2011 (JD 239)	11:38:55	2.24848°W	76.68877°N	2798	
3A-32	3A	D1=30 m	8 h	73	2	27 AUG 2011 (JD 239)	12:55:54	1.93858°W	76.62048°N	2591	
3B-33	3B	D1=30 m	8 h	83	3	27 AUG 2011 (JD 239)	19:03:13	1.93875°W	76.62127°N	2593	
3B-34	3B	D1=30 m	8 h	93	4	27 AUG 2011 (JD 239)	20:25:08	2.25000°W	76.68929°N	2705	
3B-35	3B	D1=30 m	8 h	48	1	27 AUG 2011 (JD 239)	23:13:09	2.90992°W	76.83048°N	2139	
3B-36	3B	D1=30 m	8 h	58	2	28 AUG 2011 (JD 240)	00:34:05	3.23213°W	76.89723°N	1835	
3B-37	3B	D1=30 m	8 h	67	3	28 AUG 2011 (JD 240)	09:19:42	3.82193°W	77.01798°N	1843	
3C-38	3C	D1=30 m	8 h	77	4	29 AUG 2011 (JD 241)	15:16:34	4.33325°W	77.11942°N	1622	
3C-39	3C	D1=30 m	8 h	87	1	29 AUG 2011 (JD 241)	17:44:20	4.94493°W	77.23732°N	1222	
3D-40	3D	D1=30 m	8 h	43	2	29 AUG 2011 (JD 241)	19:11:58	5.31835°W	77.30766°N	897	
3D-41	3D	D1=30 m	8 h	63	3	29 AUG 2011 (JD 241)	20:43:27	5.69488°W	77.37660°N	463	Deployed with rope
3D-42	3D	D1=30 m	8 h	73	4	29 AUG 2011 (JD 241)	22:16:52	6.09238°W	77.44918°N	272	Deployed with rope – did not expand.
3D-43	3D	D1=30 m	8 h	93	4	29 AUG 2011 (JD 241)	22:23:28	6.12182°W	77.45457°N	271	Deployed with rope

Table 12. *Continued.*

Sono-buoy	Seis-mic 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
3D-44	3D	D1=30 m	8 h	83	1	29 AUG 2011 (JD 241)	23:48:53	6.48622°W	77.52057°N	242	Deployed with rope. Hydrophone probably damaged.
3D-45	3D	D1=30 m	8 h	58	2	30 AUG 2011 (JD 242)	01:21:00	6.87917°W	77.58839°N	226	Deployed with rope. Caught and damaged in airgun array.
3D-46	3D	D1=30 m	8 h	77	2	30 AUG 2011 (JD 242)	01:31:49	6.93778°W	77.59811°N	229	Hydrophone probably damaged a few shots after deployment.

8.4.4 Data Retrieval and Processing

The onboard data processing was limited due to a hardware failure of the SUN workstation on August 23, 2011. The heavy vibrations of the ship in the ice and in the waves (even in light seas!) probably caused the disks of the workstation to fail, taking into consideration that the workstation was exposed to a similar environment during the two LOMROG expeditions on *Oden*. Some of the processing could be carried out on the laptop computer but no SEGY files could be compiled for the sonobuoys. The data retrieval and archival was not affected by this computer problem.

Raw SEGY files were created immediately after the cruise, when all data were transferred to the UNIX network at GEUS. Here the processing scripts written on-board were applied.

With the failure of the workstation, no initial quality control of the sonobuoys was possible with exception of the Geometrics recordings on line 1, where no problems were noticed. For lines 2 and 3, quality control was restricted to the monitoring of the OBS records.

8.4.4.1 Navigation

Shot times and positions were stored in ASCII format on the NaviPac navigation computer; file names are "*[Refrac/Reflec]_survey.[line-segment#].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 5 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 in 2007 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. Alternatively, a more labour intensive manual picking of the PPS pulse may result in an improvement of the 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 Transverse Mercator (UTM) projection with the following projection parameters:

- Reference longitude: 9° W
- UTM zone: 29
- Reference ellipsoid: WGS 84

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

In contrast to the LOMROG II cruise, the water depth was not written into the navigation file. Instead, the hydrography group compiled the water depth along the three seismic transects using cleaned data of the ship's EM122 swath-bathymetric system. The files are stored as "*EAGER2011_seis[line-number]_200m.txt*". The values are given in meters below sea level (corrected for the transducer depth of 8.3 m below sea level). Water depths were not written into any of the raw SEGY files of the sonobuoys and OBS.

Deployment positions of the sonobuoys (Table 12) were obtained from a handheld GPS unit. Here the waypoint was taken by a person standing next to the sonobuoy deployer. All GPS waypoints were downloaded from the unit and saved in a waypoint file.

8.4.4.2 Data Retrieval

Raw SEGD files of all shots were transferred from the Geometrics registration computer to the workstation in the processing container, where the 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 downloaded in MiniSEED format. File names are

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

for example *Winradio_taurus_1574_20110829_130000_ch1.seed* for channel 1 recorded on the Taurus recorder 1574, with a start time at 13:00:00 UTC on August 29, 2011.

8.4.4.3 Data Processing

Post cruise, raw SEGY files were calculated from the SEGD files using the program package Seismic Unix. The MiniSEED files from the Taurus recorders were initially converted to ASCII files using the software mseed2ascii. This program outputs the amplitude value for each sample in ASCII format. Using Fortran code developed onboard, data for the shot times were extracted from these ASCII files and converted to SEGY format in Seismic Unix. Shot positions, receiver position (=sonobuoy deployment position), gun depth, shot time, and offset were subsequently written into the header. The offset was calculated from the shot and receiver positions, no drift corrections were applied. These raw SEGY files 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(1/2/3/4)* with the number indicating the auxiliary channel; file names with *taurus(1/2/3)* identify the recording channel of the Taurus system. Occasionally, sonobuoys recorded on two different lines. For example, SB 1A-8 was deployed at the end of Line 1A and was still active when the shooting on Line 1B began. In this case, the sonobuoy name was changed to SB 1B-8 in the SEGY files to distinguish between these files. When a buoy was recording during two line segments (e.g., lines 2A-1 and 2A-2), two separate SEGY files were compiled using the additional identifier “p1” and “p2”.

Record lengths for the SEGY files derived from the Geometrics recordings were given by the chosen record length of the Geometrics system (10 s for reflection shots, 55 s for refraction shots, and 35 s on Line 3D). For the Taurus recordings, a record length of 30 s was used.

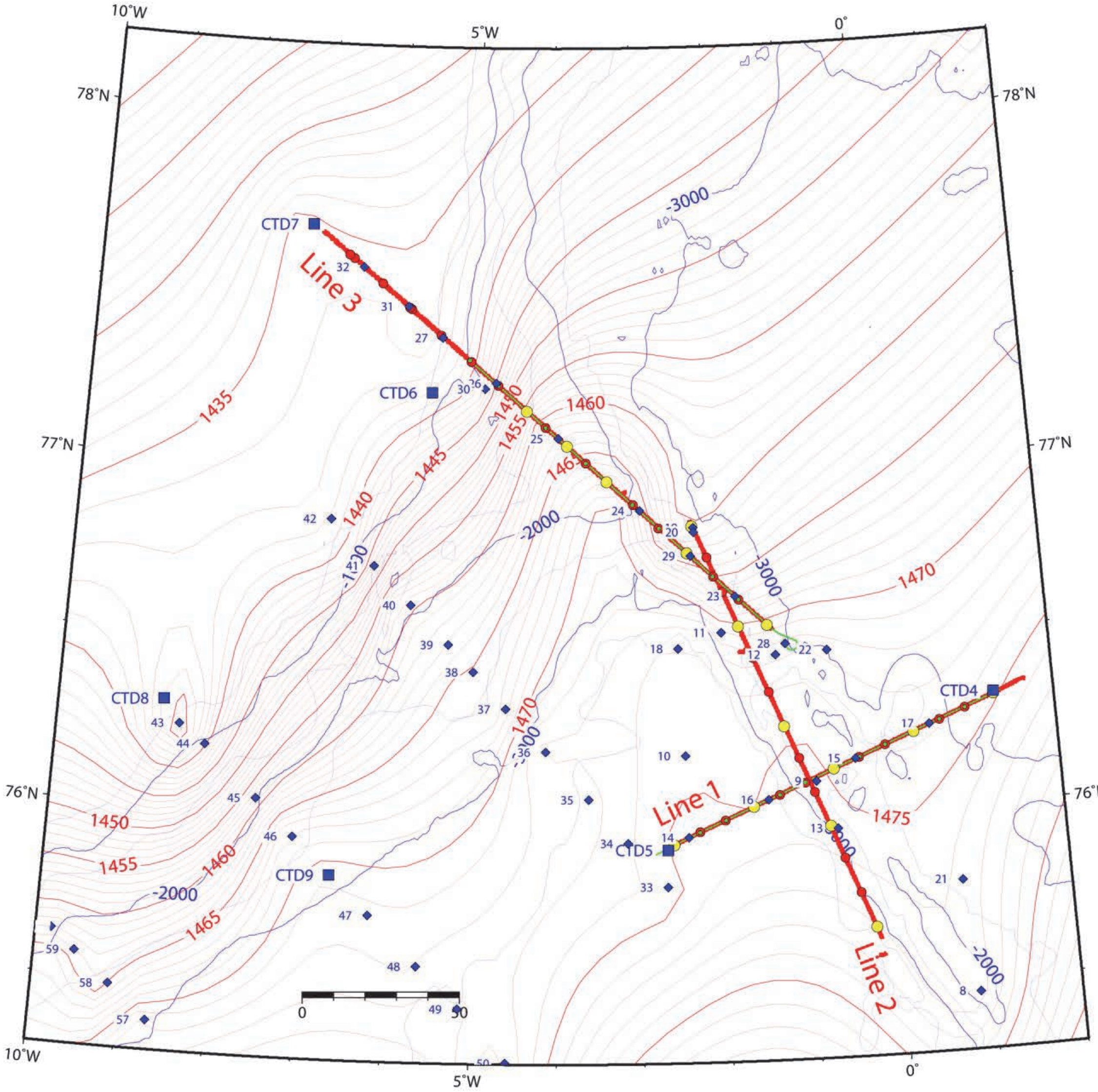


Figure 40. *Water velocities (red lines, contour interval 1 m/s, values in m/s) at the surface shown together with the location of the seismic lines (red and green lines). Yellow circles show the location of OBS, red and green circles indicate the sonobuoy deployment positions. The map was compiled from the uppermost measurement at each CTD (blue square,) and XBT and XCTD (blue diamond) station. Blue numbers refer to the station number. Data were collected during the EAGER 2011 expedition by Steffen Olsen and Rasmus Tonboe. The bathymetry is indicated by blue lines (contour interval 500 m, data source IBCAO grid).*

Static corrections were applied using sea level as reference (note that no static corrections were applied to the OBS data). For this correction, an airgun depth of 9 m and a hydrophone depth of 30 m were assumed, using a water velocity of 1474 m/s. The surface water velocity in the study area is quite variable (from 1435 to 1477 m/s, see Figure 40) but using a velocity of 1474 m/s will not result in any errors >1 ms.

For further processing, the correct distance of the sonobuoy from the shot position has to be calculated. This is necessary because the sonobuoys were drifting freely in the water and only the deployment position was known. The shot-receiver distance can be calculated from picking the arrival time of the direct water wave. The time can be converted to distance using seismic raytracing through the water column with an appropriate velocity-depth function. Velocity-depth curves were measured during the EAGER 2011 cruise by CTD (conductivity, temperature, depth), XCTD (expendable CTD) and XBT (expendable bathythermograph) measurements. Figure 40 indicates the location of these measurements in relation to the seismic lines. All measurements are part of the digital data archive for the OBS and sonobuoy data. Velocity-depth curves for the CTD measurements are shown in Appendix V-C (red and blue curves show the down and up going measurements, respectively).

Record sections of selected sonobuoys are shown in Appendix V-A. The record sections are plotted versus offset but are not corrected for the drift of the buoy. Data were debiased, followed by deconvolution and a band pass filter (5 to 36 Hz). Travel times are reduced with a reduction velocity of 6.0 km/s.

8.5 Ocean Bottom Seismometer (OBS) Operation

8.5.1 Technical Description of the AWI Broadband OBS

The Alfred Wegener Institute (AWI) in Bremerhaven operates the German ocean bottom seismometer (OBS) instrument pool DEPAS consisting of 80 broadband OBS of the type Longterm Ocean Bottom Seismometer for Tsunami and Earthquake Research (LOBSTER). During the EAGER 2011 expedition, five DEPAS OBS were used, which have been deployed along three seismic lines in the area of the East Greenland Ridge.

Each OBS is equipped with a Güralp 60-s three-component broadband seismometer and a High Tech broadband hydrophone. The AWI OBS (Figure 41) is manufactured by Umwelt- und Meerestechnik GmbH (KUM) in Kiel, Germany. Major parts of the OBS are supplied from other manufacturers like Güralp Systems Ltd. (seismometer), SEND GmbH (recording unit) and High Tech Inc. (hydrophone).

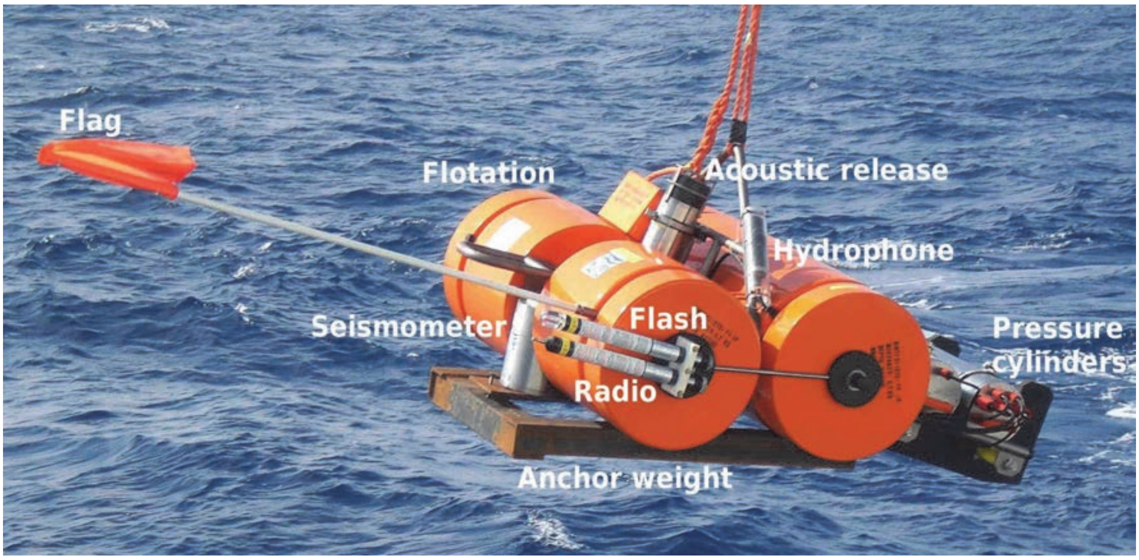


Figure 41. *The AWI ocean bottom seismometer LOBSTER during deployment. The main instrument components are indicated.*

The main goal of the LOBSTER design was to develop a compact OBS that can be easily assembled on board a vessel. A compact size helps to minimize noise signals from bottom water currents. Further developments of the LOBSTER system have been:

- Simplified programming and data read-out procedures between subsequent deployments in refraction seismic experiments.
- An extended maximum operation interval of well above one year for seismicity and tsunami studies.
- The use of broadband sensors to register a wide frequency spectrum.

The LOBSTER system consists of a titanium frame that holds four (or eight) floatation units, one (or two) titanium pressure cylinders for the recording unit and the batteries, a three-component 60-s broadband seismometer built into a titanium case, a broadband hydrophone, a 24-bit recorder, an acoustic release unit, a flash and radio beacon, and an anchor weight (Figure 41).

The heart of the LOBSTER system is a low power consuming (<0.65 W) SEND Geolon MCS 24-bit A/D converting and recording device providing three channels for the seismometer input signals and one for high impedance hydrophones. The sampling rate can be adjusted in steps from 1 to 1000 Hz. The pre-amplifier gain of each channel can be set individually to 1, 2, 4, 8, 16 and 32. All parameters can be set by the SENDCOM software using a connected laptop. On EAGER 2011, the sampling rate for the recording was set to 500 Hz. The gain of the hydrophone channel and the three seismometer channels was set to 4 and 1, respectively. In addition, the software can test the functionality of the sensor components prior to deployment. While on the seafloor, data are stored on a 20 GB hard disk that can be accessed after recovery using a 1 GB/min FireWire interface. Programming, GPS synchronization, and data retrieval can be performed while the recorder is located in its pressure housing, which is connected via a GPD30 break-out box to an external GPS clock and a laptop computer (Figure 42).

Figure 42. *Connecting the LOBSTER via the yellow GPD30 box to an external GPS clock and a laptop computer to start or stop data acquisition. Photo: Thomas Funck.*

The Güralp CMG-40T 60-s three-component broadband seismometer operates in a frequency range between 0.0167 Hz (corresponding to 60 s) and 50 Hz. After settling on the seafloor, it can be levelled horizontally in a range of ±50°. The first levelling time and for long-term deployments subsequent levelling intervals can be set by the software during parameter set-up. The MCS recorder then sends levelling pulses to the seismometer's gimbal system at the programmed time. The High Tech HTI-04-PCA/ULF broadband hydrophone operates in a frequency band between 0.01 Hz (100 s) and 8 kHz.

To recover the OBS, hydro-acoustic signals (12 kHz) are sent from the vessel to the KUM K/MT 562 acoustic release unit, which connects the anchor weight to the OBS frame. When these signals are sent, the release hook is opened and the OBS detaches from its anchor. An automatic time release can also be set as a backup. When the OBS has returned to the sea surface, a Novatec ST-400A flash light and a Novatec RF-700A1 radio beacon are activated automatically by pressure switches to allow for an easy detection of the OBS at the water surface.

8.5.2 Deployment and Recovery of the OBS

The AWI OBS were deployed on three seismic lines on the East Greenland Ridge (Figures 25 - 29). The deployment of the instruments was done from the icebreaker *Oden* (Figure 43), while the recovery of the OBS was carried out by the ship's helicopter (Figure 44). For the recovery by helicopter, an additional swimming rope with an eye of approximately one meter in diameter was attached to the OBS. With a large hook fixed to a 15-m-long rope below the helicopter, the OBS was retrieved from the water and flown back to *Oden*. The OBS positions vary slightly between deployment and recovery. Table 13 summarizes the deployment position of the OBS and the time drift of the internal clock of the OBS (skew). A positive skew value means that the internal clock of the OBS was too slow compared to GPS time (i.e., the OBS time is behind GPS time).

Figure 43. *Deployment of the ocean bottom seismometers (OBS). Photos: Thomas Funck.*

Though most of the OBS had been operating without any failures, a few technical problems occurred. A common problem, which is not really solved yet, is that the gimbal system of the seismometer sometimes fails. Leveling of the seismometer components is necessary to ensure that they are in a horizontal position after settling down on the seafloor. Some stations were affected by a sudden offset of the hydrophone channel from the zero level by which all signals were clipped. The reason for this is unclear. Table 14 gives an overview of the technical problems encountered at individual OBS.

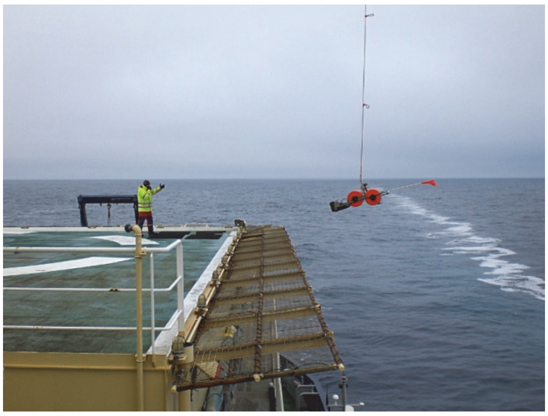
 

Figure 44. *Recovery of the OBS by helicopter. Photos: Jürgen Gossler.*

OBS-Station	Deployment Latitude	Deployment Longitude	Depth (m)	Skew (µs)	Recording length days hh:mm:ss
			Line 1		
101	75.92451°N	2.78883°W	3923	5656	2d 08:25:40
102	76.02787°N	1.83945°W	3704	2687	2d 05:26:40
103	76.12680°N	0.87578°W	2138	-	1d 22:39:58
104	76.22086°N	0.10075°E	2915	500	1d 21:30:12
105	76.31243°N	1.08960°E	3191	7843	1d 17:11:18
			Line 2		
201	76.83348°N	2.49787°W	2710	250	1d 22:02:31
202	76.54501°N	1.95650°W	2269	625	1d 23:47:45
203	76.25373°N	1.44453°W	2375	0	2d 00:37:13
204	75.96381°N	0.94238°W	3342	1562	2d 00:52:00
205	75.66888°N	0.46995°W	3701	1093	2d 01:58:39
			Line 3		
301	76.54630°N	1.60218°W	2855	1165	4d 18:36:25
302	76.75748°N	2.56508°W	2238	1343	4d 09:43:10
303	76.96362°N	3.55443°W	1790	8562	4d 05:27:07
304	77.06541°N	4.05917°W	1758	1343	4d 02:03:54
305	77.16512°N	4.57603°W	1482	812	3d 23:16:47

Table 13. *Deployment positions of the OBS, water depths, skew values, and recording times. For station 103 no skew value is available due to an external shock to the recorder's pressure housing during recovery. Station 203 has a wrong time synchronization caused by two reboots during recovery. Therefore a skew of 0 µs is assumed.*

For the data retrieval from the OBS, the SENDCOM3 program was used. The SEND2X version 2.71 software performed the data conversion to the SEND specific s2x format. Both programs are developed by SEND GmbH. Subsequently, the data were converted from s2x format to SEGY. Unfortunately, the software does not write the shot offsets into the SEGY headers. Another shortcoming of the program is that each trace is clipped at the time of the following shot. Hence, the actual seismic data in the SEGY files is limited to the shot interval (Table 15) used during the data acquisition even if a longer record length

OBS-Station	Remarks
	Line 1
101	- ok
102	- hydrophone sometimes offset
103	- OBS hit A-frame during recovery → recorder has to be re-booted → no time synchronization available at the end of recording; skew set to 0 - recordings ok
104	- ok
105	- ok
	Line 2
201	- levelling failed on both horizontal components - hydrophone with some leakages
202	- hydrophone completely offset → no usable data - seismometer ok
203	- horizontal components failed (seismometer probably damaged on first profile's recovery) - two reboots during recovery → wrong time synchronization (6.8 sec) → skew = 0 assumed - hydrophone and vertical component ok
204	- ok
205	- levelling failed on one horizontal (Y) component
	Line 3
301	- hydrophone completely offset → no usable data - X-component not levelled → shots may be used - vertical (Z) and horizontal (Y) components ok
302	- hydrophone offset → no usable data - seismometer ok
303	- hydrophone sometimes spiky and offset → ok during shooting - seismometer ok
304	- ok
305	- levelling failed on X-component - Z-, Y-components and hydrophone ok

Table 14. *Overview of the technical failures of individual OBS.*

is selected for the creation of the SEGY files. For the three geophone channels, the SEG-YWRITE command erroneously omits the last shot in the shot table. This problem can be bypassed by adding a dummy shot at the end of the table. However, this software failure was first recognized at the end of the expedition and, hence, no new SEGY files were produced for the geophone channels. For possible seismicity studies, continuous MiniSEED files were created with 12 hours of data in each file. No time skew is incorporated into these files. Selected OBS records are shown in Appendix V-B. Shot receiver offsets in these plots were calculated from the OBS deployment position specified in Table 13. No relocalization of the OBS at the seafloor was carried out.

Line	Shot interval (s)	Record length (s)
1A	60	60
1B	12±1	30
2A	60	60
3A	60	60
3B	12±1	11
3C	12±1	11
3D	40	40

Table 15. Shot intervals and r*ecord lengths of the SEGY files on individual lines. For the seismic reflection lines 1B, 3B and 3C the shot interval varies along the profile in range of ±1 s (a random jitter around the programmed shot length of 12 s to avoid processing problems in the refection seismic data). Lines 1A, 2A, 3A and 3D are refraction lines.*

8.6 References

Døssing, A., Dahl-Jensen, T., Thybo, H., Mjelde, R. & Nishimura, Y. 2008: East Greenland Ridge in the North Atlantic Ocean: An integrated geophysical study of a continental sliver in a boundary transform fault setting. Journal of Geophysical Research **113**, B10107.

Døssing, A. & Funck, T. submitted: Greenland Fracture Zone East Greenland Ridge(s) revisited: Indications of a C22-change in plate motion. Journal of Geophysical Research.

9. Acknowledgement

The successful outcome of the EAGER 2011 cruise could not have been achieved without the excellent cooperation between the crew of *Oden*, the helicopter crew and the science party.

We especially acknowledge the technical support from the Swedish Polar Research Secretariat and the last minute technical support from KUM (Kiel, Germany) and TTSurveys (Cornwall, UK). Coordination and time sharing of the seismic work with GX Technology and TGS-Nopec was accomplished without any problems due to the good communication between the different parties.

The EAGER 2011 cruise is part of the Continental Shelf Project of the Kingdom of Denmark which is founded by the Ministry for Science, Technology and Higher Education.

10. Appendices and Enclosures

10.1 Appendices

Appendix I: Seismic equipment setup and specifications

- A Seismic equipment setup
- B GeoEel Digital Marine Streamer
- C Geopoint hydrophone (hydrophone in streamer)
- D Winch system: main data
- E 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

- A Geometry configuration 1 for line EAGER2011_1A, EAGER2011_1B, EAGER2011_2A & EAGER2011_2A_2
- B Geometry configuration 1 for line EAGER2011_3A, EAGER2011_3A_2, EAGER2011_3B & EAGER2011_3B_2
- C Geometry configuration 3 for line EAGER2011_4A and line EAGER2011_4B (alias line EAGER2011_3D and line EAGER2011_3C)

Appendix III: Marine Survey – General Information and Line Overview logs

Appendix IV: Plot of unmigrated shipboard stack for all reflection seismic lines acquired during EAGER2011

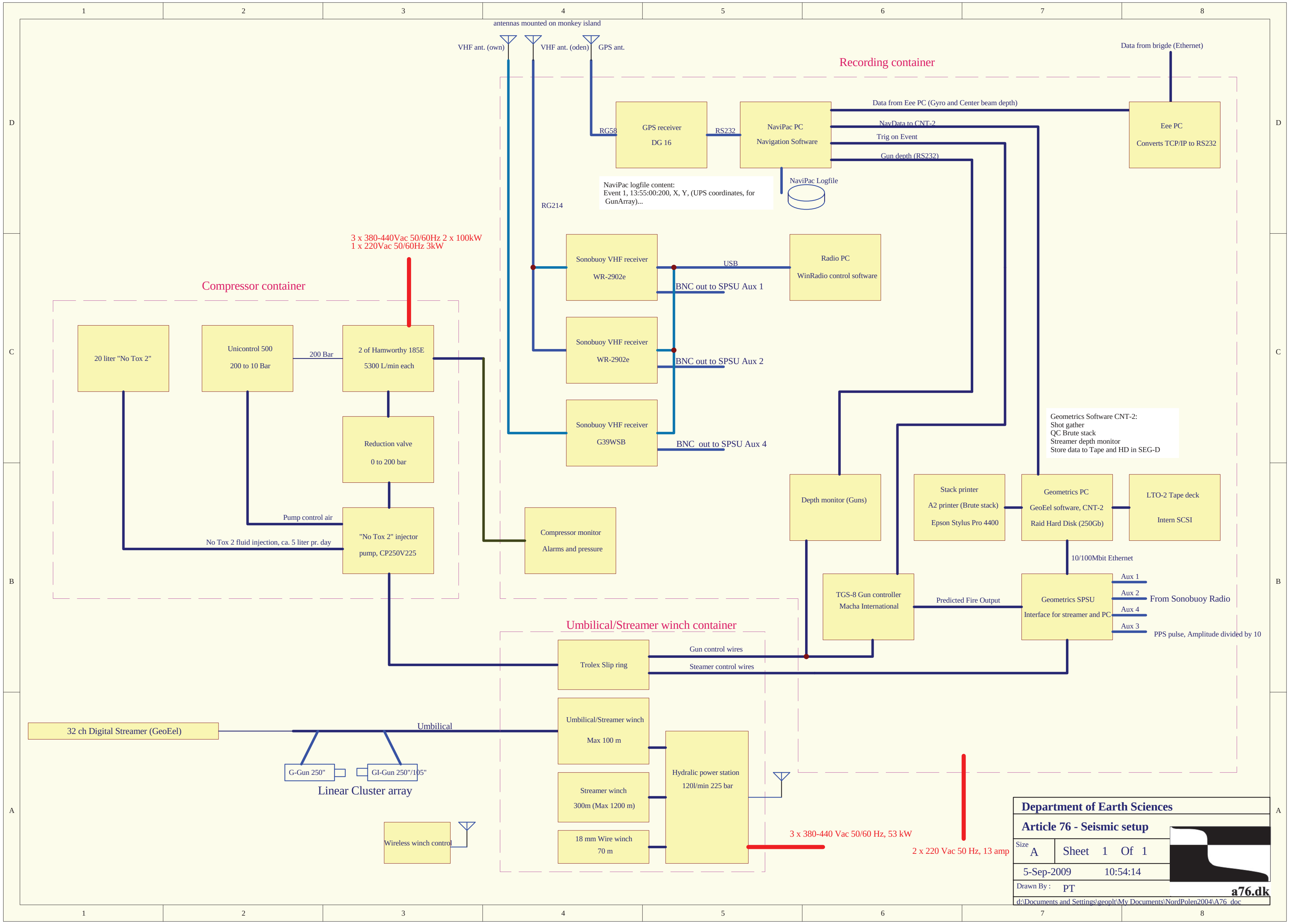
Appendix V: Sonobuoy appendices

- A Raw record sections of selected sonobuoys
- B Raw record sections of selected ocean bottom seismometers
- C Water velocities from CTD measurements
- D Technical specifications sonobuoy receiver WR-2902e
- E Technical specifications Taurus seismometer from Nanometrics
- F Technical specifications sonobuoy AN/SSQ-53D(3) from ULTRA Electronics
- G Technical specifications VHF antenna MD G3

10.2 Enclosures as digital files on enclosed CD-ROM

Enclosure 1: PDF version of this report
Enclosure 2: PDF version of EAGER 2011 Cruise report
Enclosure 3: Navigation data

Appendix I: Seismic equipment setup and specifications



antennas mounted on monkey island
VHF ant. (own)
VHF ant. (oden)
GPS ant.
Data from brigde (Ethernet)
Recording container
GPS receiver
DG 16
RG58
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
Sonobuoy VHF receiver
WR-2902e
BNC out to SPSU Aux 2
Sonobuoy VHF receiver
G39WSB
BNC out to SPSU Aux 4
20 liter "No Tox 2"
Unicontrol 500
200 to 10 Bar
200 Bar
2 of Hamworthy 185E
5300 L/min each
Reduction valve
0 to 200 bar
Pump control air
No Tox 2 fluid injection, ca. 5 liter pr. day
"No Tox 2" injector
pump, CP250V225
Compressor monitor
Alarms and pressure
Geometrics Software CNT-2:
Shot gather
QC Brute stack
Streamer depth monitor
Store data to Tape and HD in SEG-D
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)
18 mm Wire winch
70 m
Wireless winch control
3 x 380-440 Vac 50/60 Hz, 53 kW
2 x 220 Vac 50 Hz, 13 amp
Department of Earth Sciences
Article 76 - Seismic setup
Size
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Sheet 1 Of 1
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Appendix I-B:

GeoEel Digital Marine Streamer

GeoEel Digital Marine Streamer

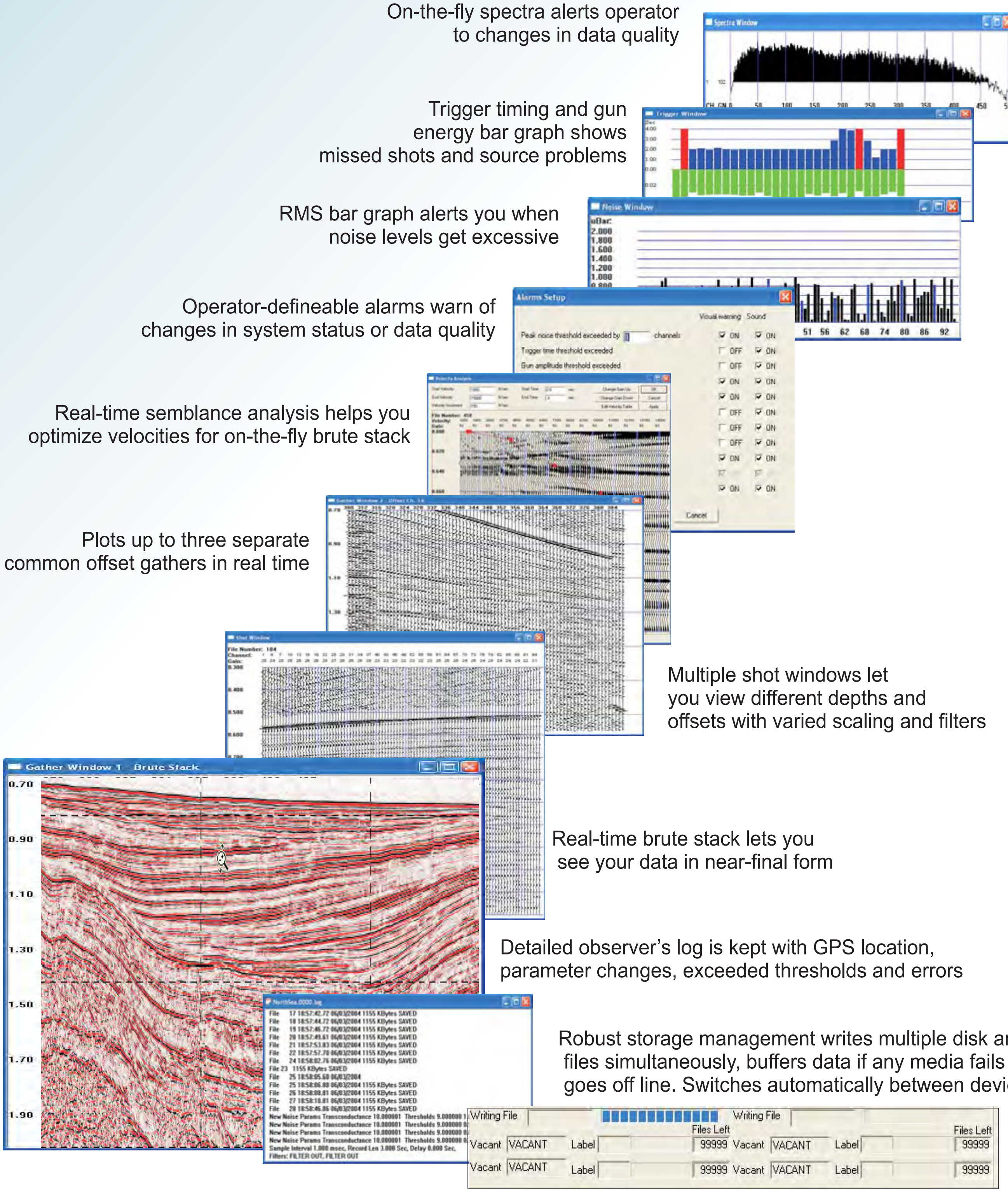
- **Light and Easy to Handle: 40.3 mm diameter, up to 240 channels in 8 channel sections**
- **Environmentally friendly and non-flamable: filled with inert silicone oil, ships by air.**
- **Wide bandwidth means more applications: 1/16 to 4 ms for petroleum, engineering or sub-bottom profiling**
- **Digital 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

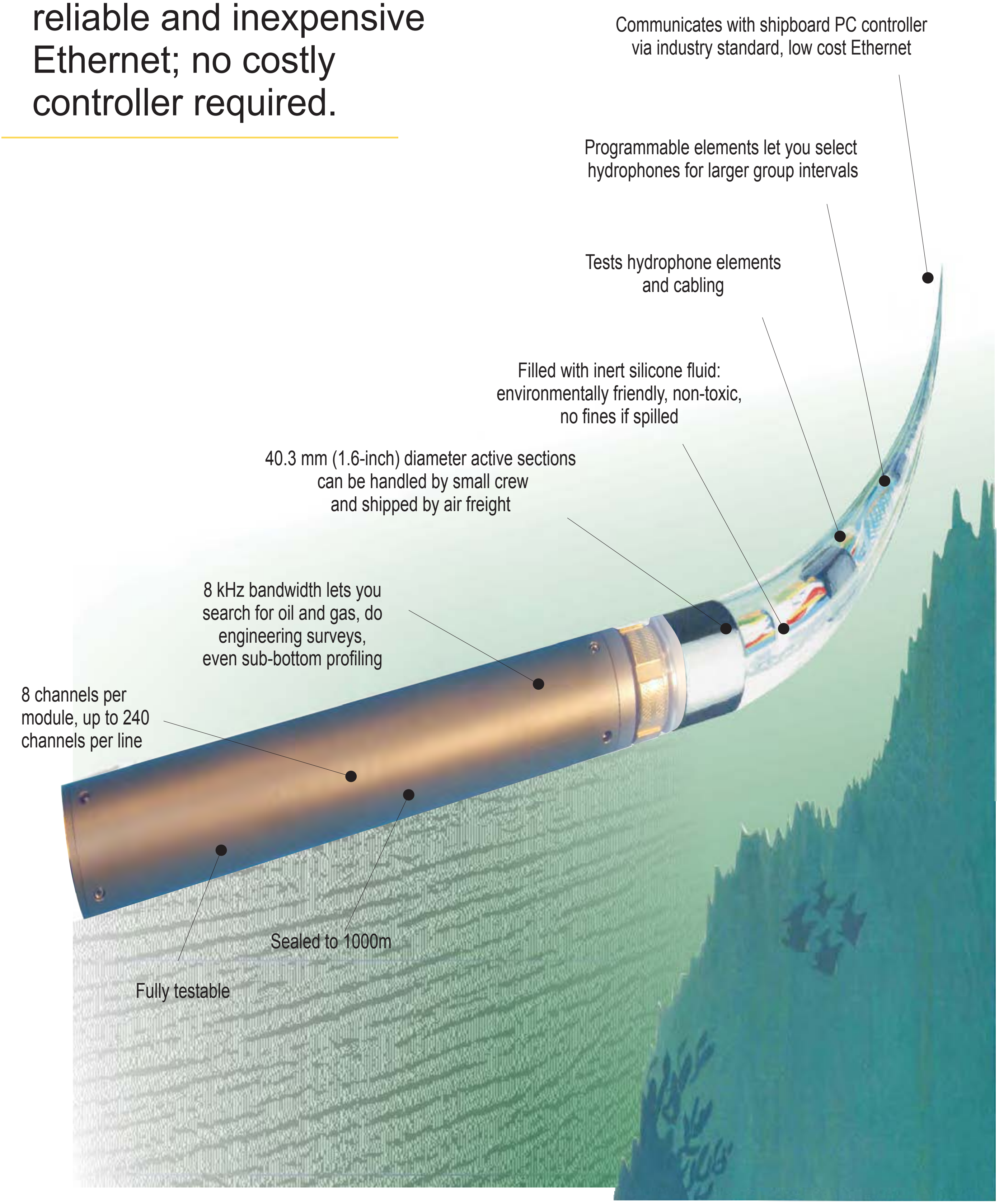
Multiple shot windows let you view different depths and offsets with varied scaling and filters

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

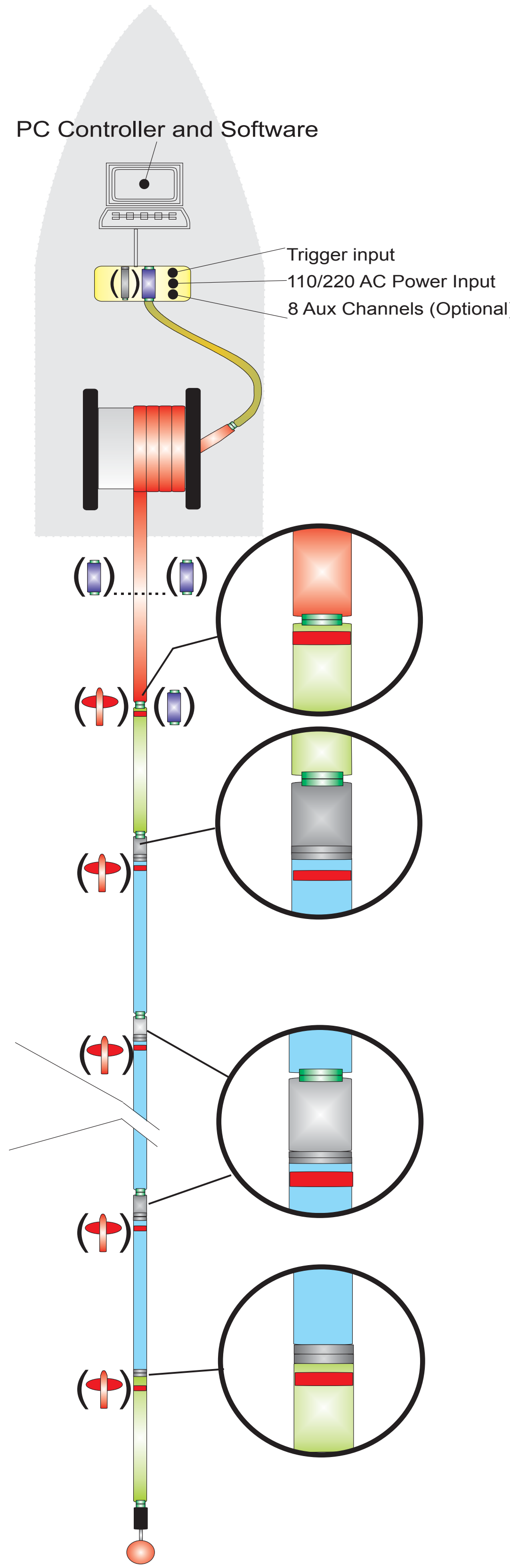
Detailed observer's log is kept with GPS location, parameter changes, exceeded thresholds and errors

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.

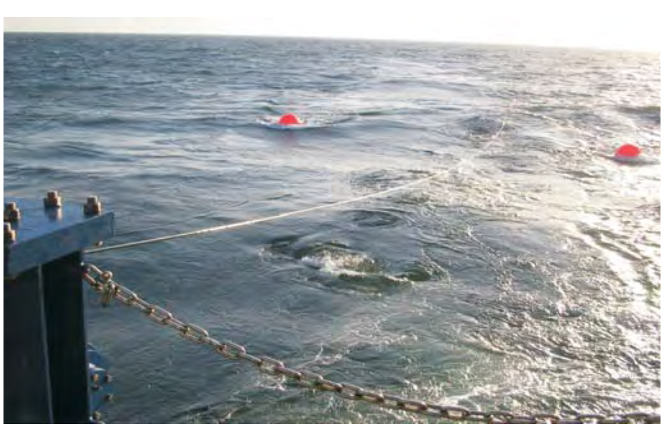


Flexible configuration is easily expandable.

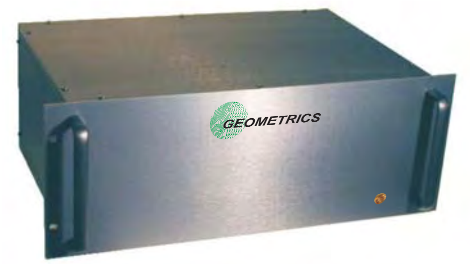


Components:

- 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

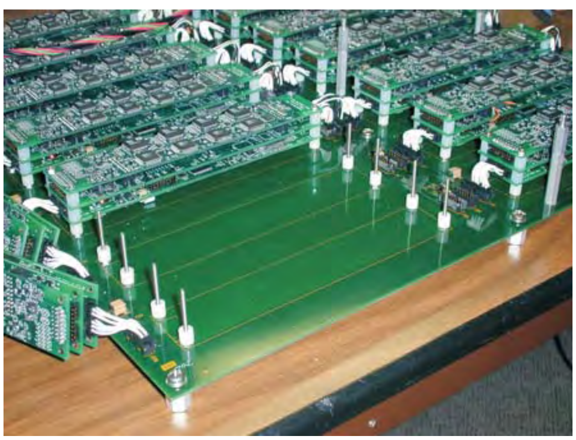


GeoEel Analog Streamer ‘Convertible’ Configuration



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

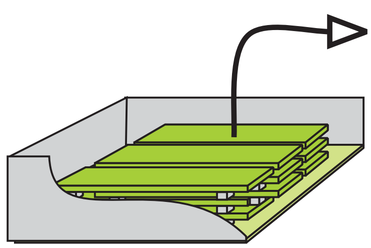
Still have a stock of analog sections with lots of life left in them? Not sure that it is time to make the move to a fully digital system? GeoEel digital electronics can be packaged in a rugged ‘convertible’ rack chassis with up to 120 channels plus 8 aux channels. Each rack mount chassis is controlled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



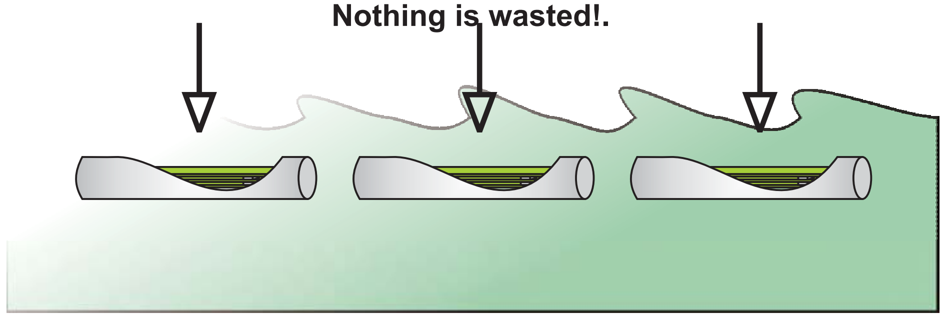
When you are ready to retire your analog system, the electronics can be reassembled in GeoEel waterproof canisters, ready to attach to your new digital hydrophone sections to make a complete, modern digital marine seismic system - at about ½ the price.

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.

GEOMETRICS INC.	2190 Fortune Drive, San Jose, California 95131, USA Tel: 408-954-0522 Fax: 408-954-0902 Email: sales@geometrics.com
GEOMETRICS EUROPE	20 Eden Way, Pages Industrial Park, Leighton Buzzard LU7 4TZ, UK Tel: 44-1525-383438 Fax: 44-1525-382200 Email: chris@georentals.co.uk
GEOMETRICS CHINA	Laurel Technologies, Ste 1807-1810, Kun Tai Int'l Mansion, #12B, Chaowai St., Beijing 100020, China Tel: 86-10-5879-0099 Fax: 86-10-5879-0989 Email: laurel@laureltech.com.cn

Appendix I-C:

Geopoint hydrophone (hydrophone in streamer)

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**

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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49 Edgerton Drive
North Falmouth, Massachusetts 02556-2826 USA
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Toll Free (USA only): 1-800-446-1222
Fax: 1-508-563-6444
E-mail: info@benthos.com
Web: www.benthos.com

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Suite F-104
11251 Richmond Avenue
Houston, TX 77082 USA
Tel: 1-281-293-9696
Fax: 1-281-293-0360

ISO 9001 Certified

Appendix I-D:

Winch system: main data

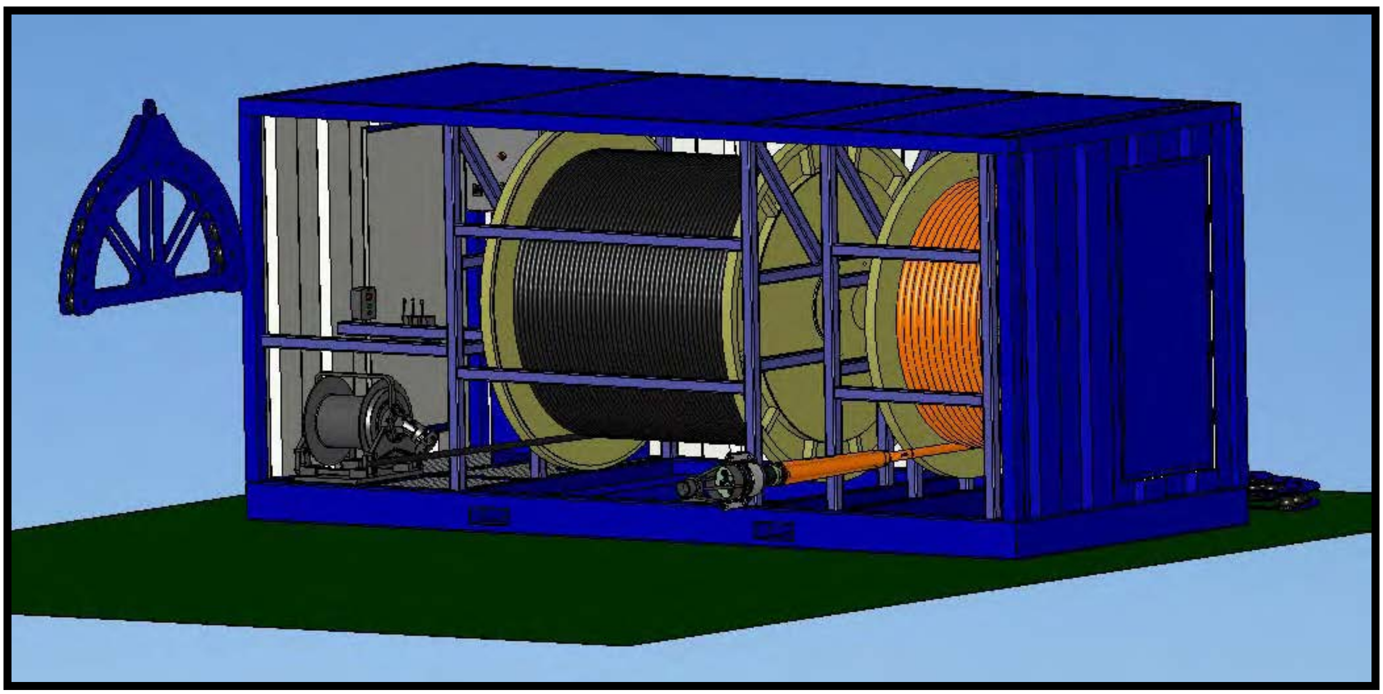
Main data

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.



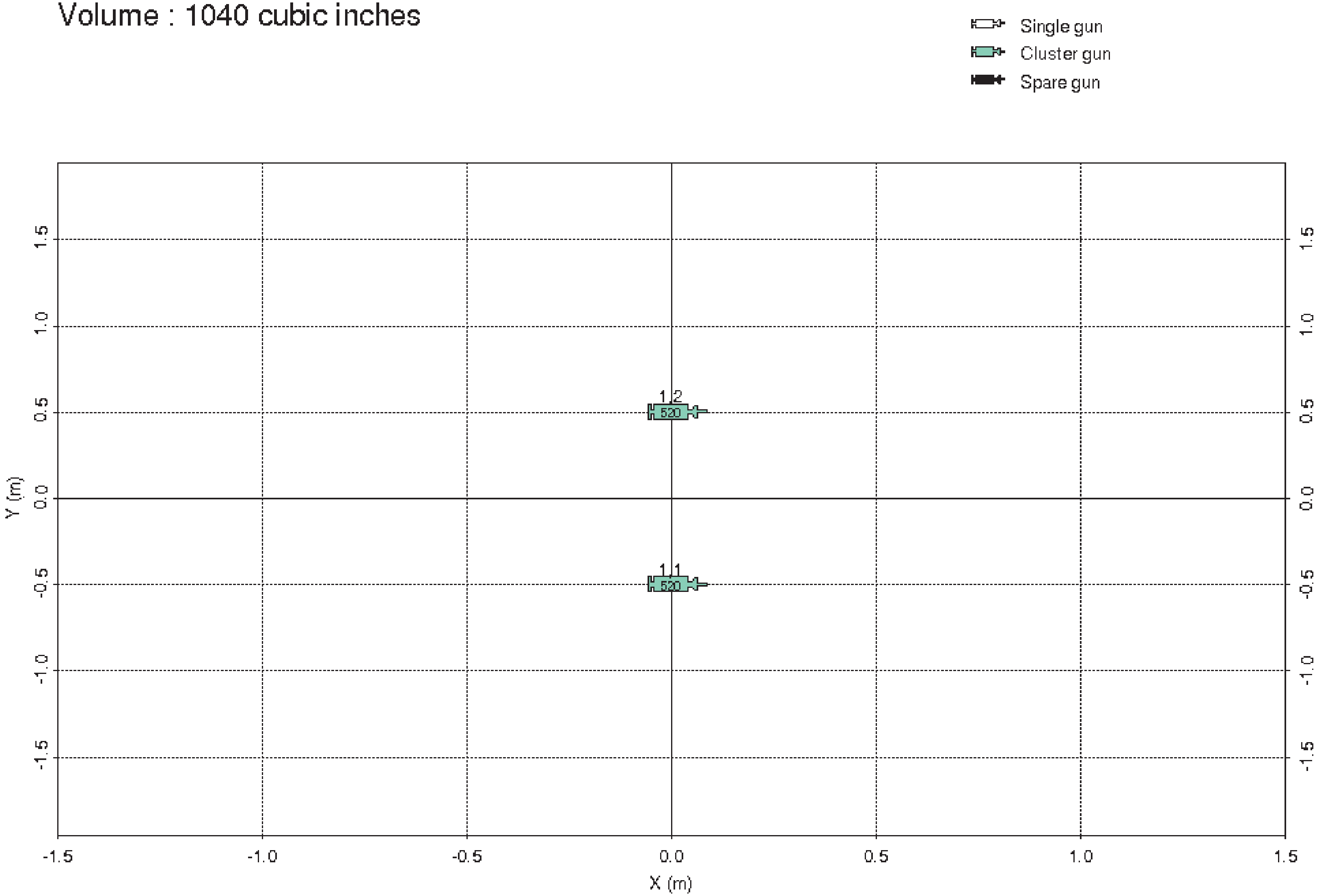
The Container is to be installed on the back deck of a vessel (e.g. Oden) and support the load of other equipment on top of the container. The winches are operated from the winch, via a sheave block mounted in connection with the vessel A-frame, over the stern of the vessel.

Appendix I-E

Air gun signature and spectrum @ 9m

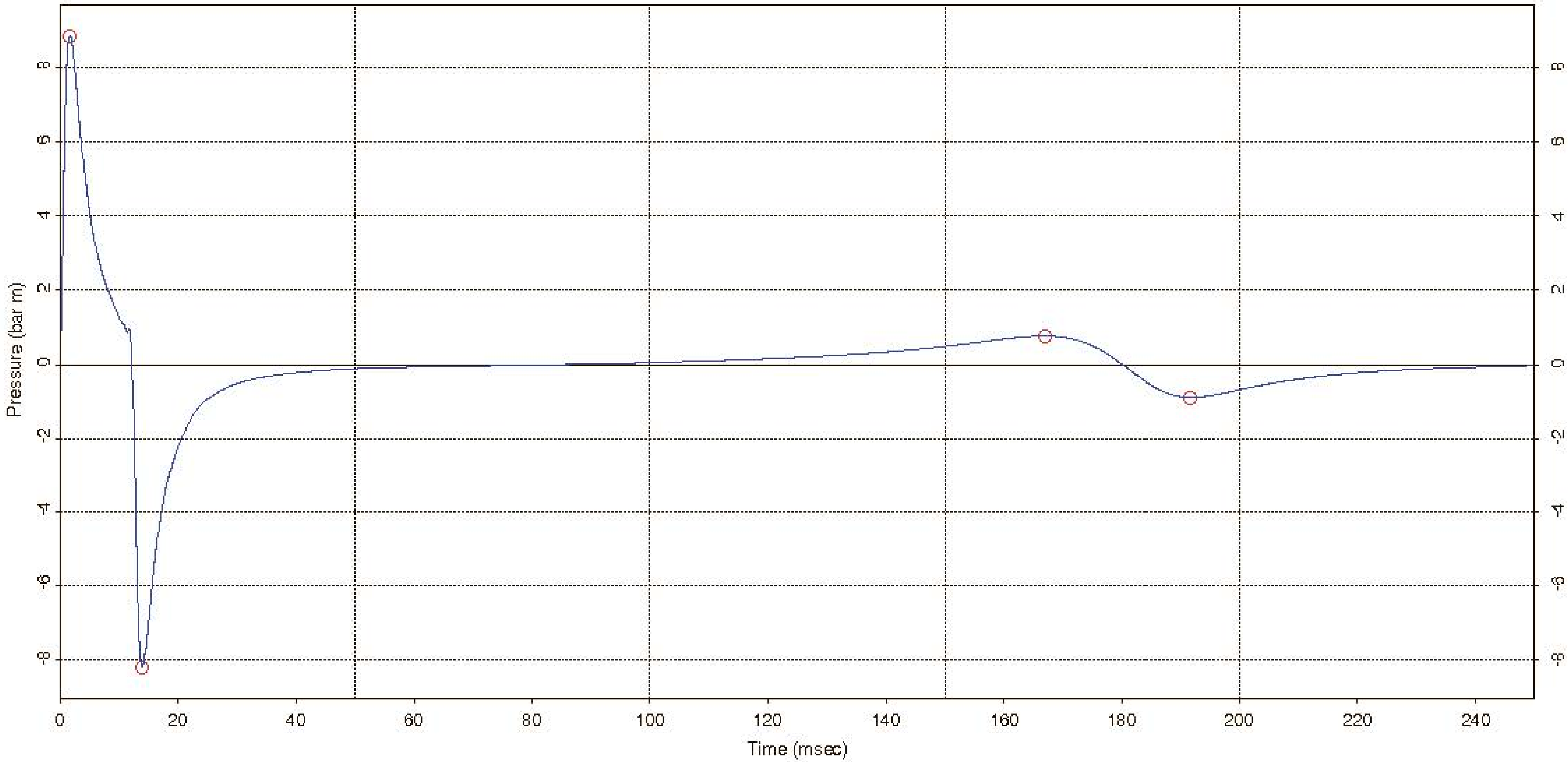
Array : 1040GG3000_9

Volume : 1040 cubic inches



Farfield signature : 1040GG3000_9

Distance: 9000 m	P/B ratio : 10.3	Filter : Unfiltered	Water temp. : 7.00 C	Ghost strength : -1.00
Dip: 0 deg	Geom. spr. : 2.00	Volume : 1040 cu.in	Source depth : 9.00 m	Water velocity : 1478.9 m/s
Azimuth: 0 deg	Primary : 8.9 bar m	Pressure : 3000 psi	Peak-peak : 17.0 bar m	Period (+/-) : 165.1/177.8 msec

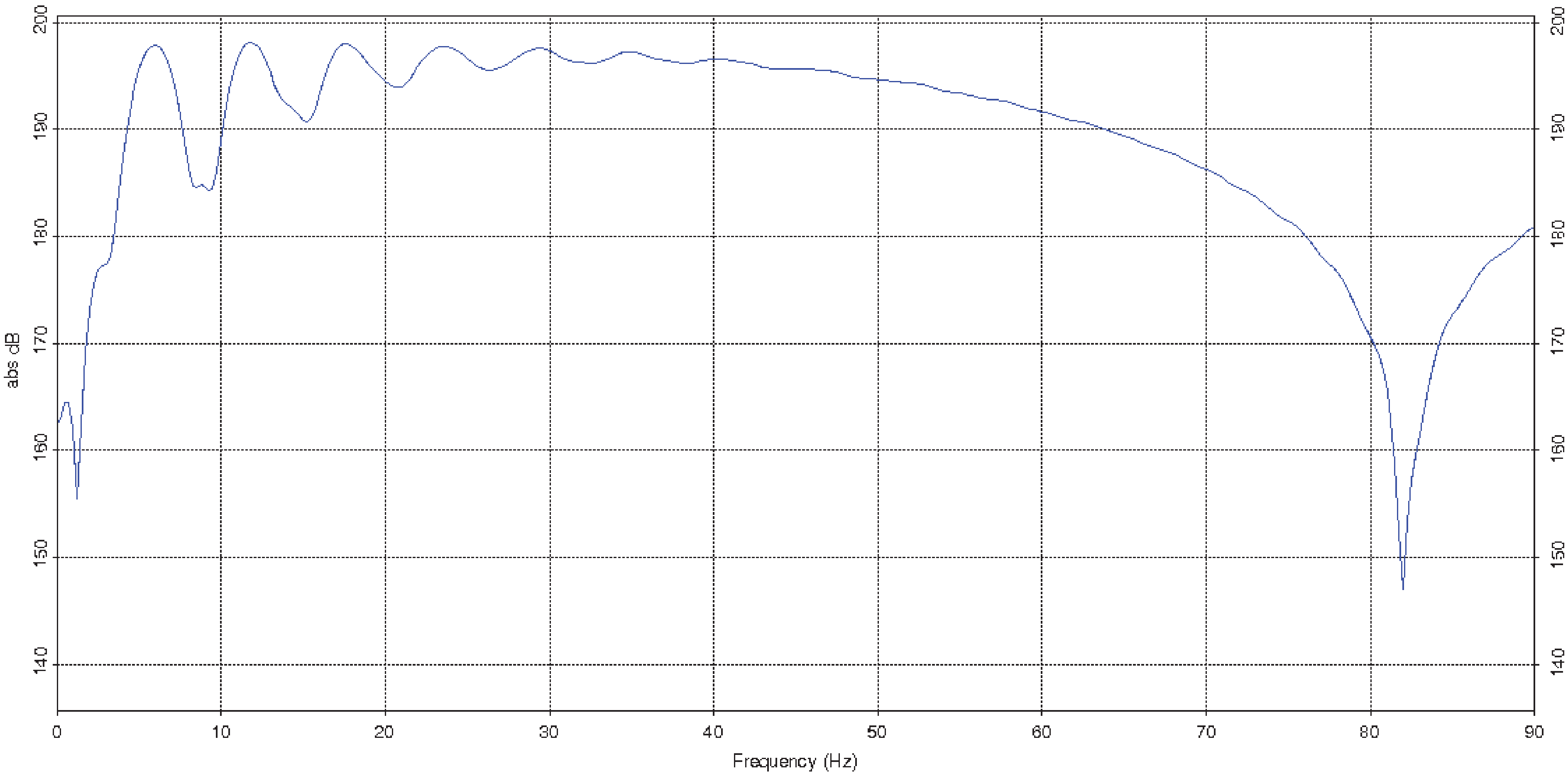


Farfield signature : 1040GG3000_9

Distance: 9000 m

Dip: 0 deg

Azimuth: 0 deg



Appendix I-F:

Marine sources from Sercel

Marine Sources

Sound science.
Reliable results.

Ahead of the Curve℠

Ahead of the Curve

Index

Marine sources

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

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

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

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

The G. GUN

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

Special features include:

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

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

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

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

The GI GUN

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

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

A GI GUN comprises:

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

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

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

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

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

The GI GUN arrays are also used:

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

The Watergun

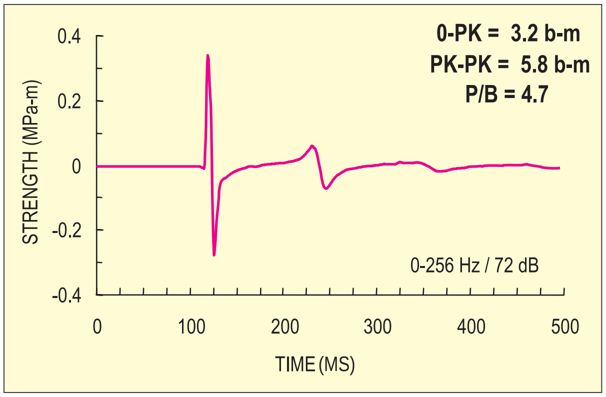
The S15 Watergun is capable of delivering a high-frequency, bubble-free acoustic pulse perfectly suitable for very high resolution applications. Compressed air is used to propel a water jet, which creates a vacuum cavity. When the vacuum cavity implodes from the surrounding hydrostatic pressure, it emits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

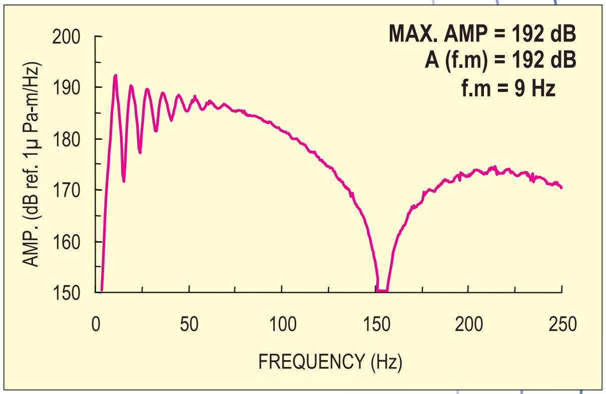
G. GUN 250

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

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

FAR FIELD SIGNATURE AND SPECTRUM





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

Specifications

Physical G. GUN 250

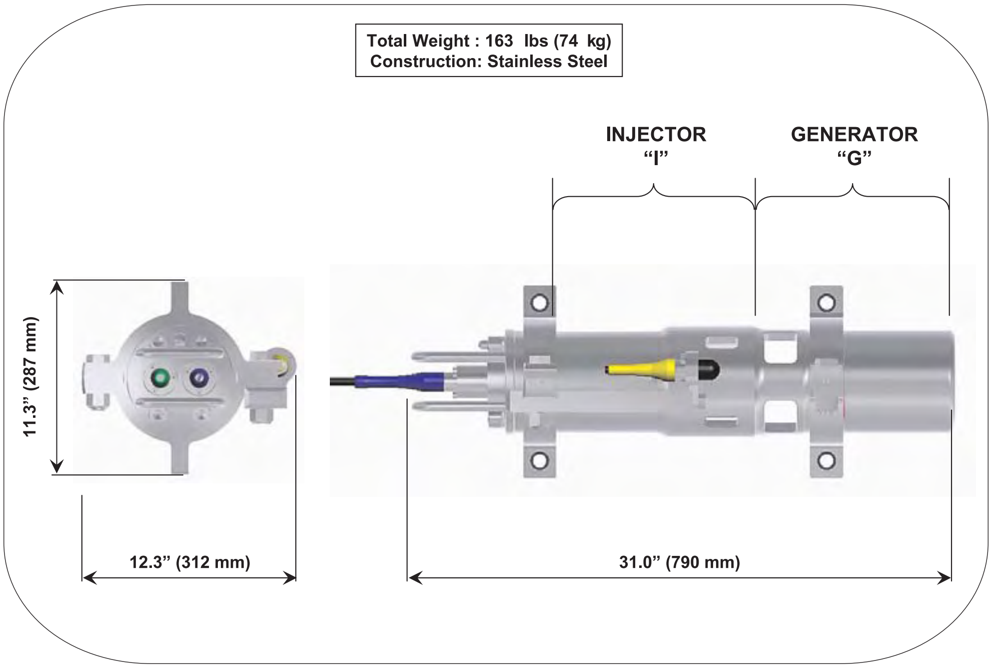
- Weight : 65 kg (143 lbs.)
- Length : 597 mm (23.5 in.)
- Width : 292 mm (11.5 in.)
- Diameter : 287 mm (11.3 in.)

GI GUN

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

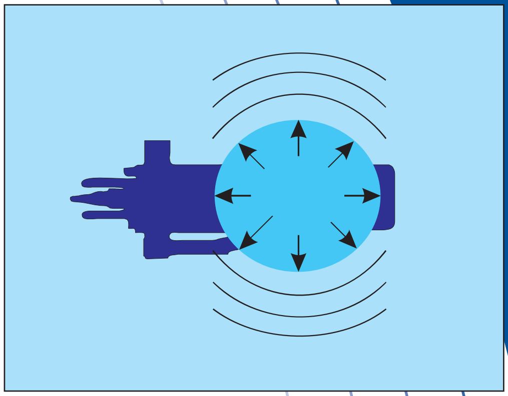
Each gun has its own reservoir, its own shuttle, its own set of exhaust ports, and its own solenoid valve.

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

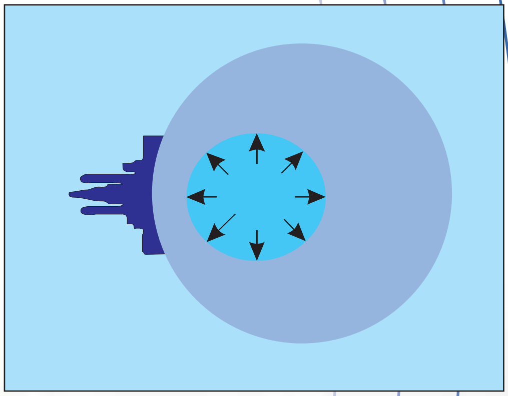


HOW IT WORKS

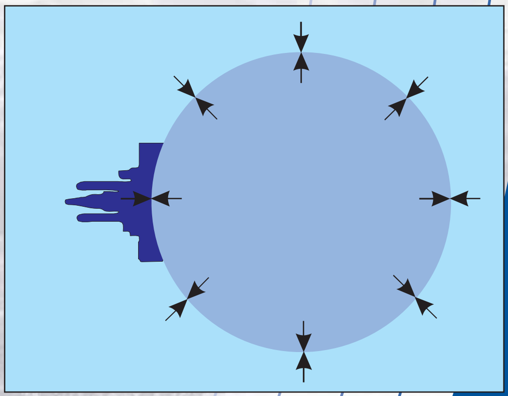
Phase 1 :
The Generator ("g") is fired. The blast of compressed air produces the primary pulse and the bubble starts to expand.



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



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



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

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

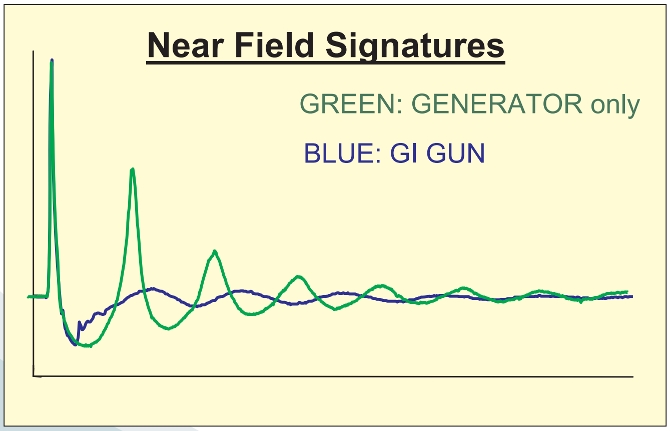
The figures below show how the near field signature and spectrum of the Generator alone (green line) is re-shaped by an optimally tuned injection (blue line). This type of setting is called "true GI mode" and results in an almost total bubble suppression of the bubble oscillation.

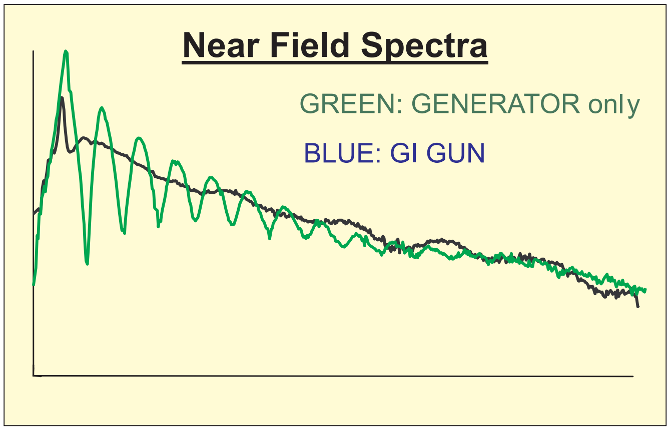
VERSATILITY

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

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

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





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

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

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

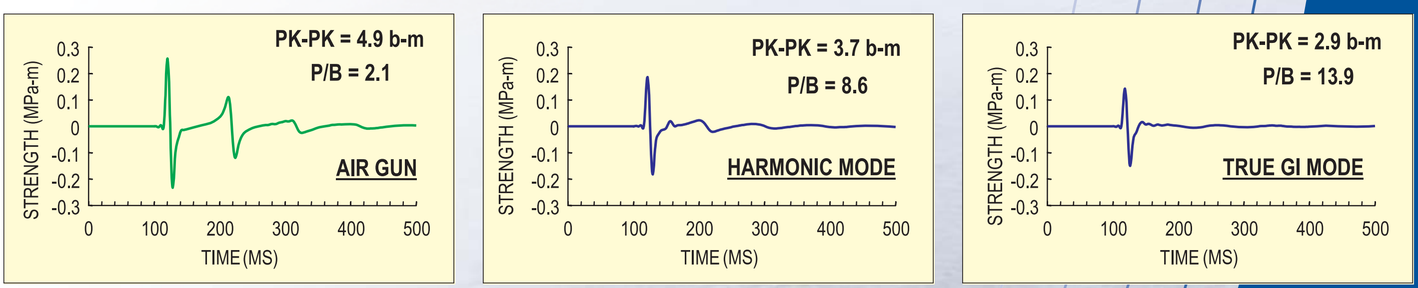
Right (c) : Signature generated by a single GI GUN used in the "true GI mode." The Generator has a volume of 45 in^3 and the Injector has a volume of 105 in^3. Here too, the firing of the Injector has been delayed by about half the time of the Generator fired alone.

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

a) AIR GUN
Volume = 150 in^3

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

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



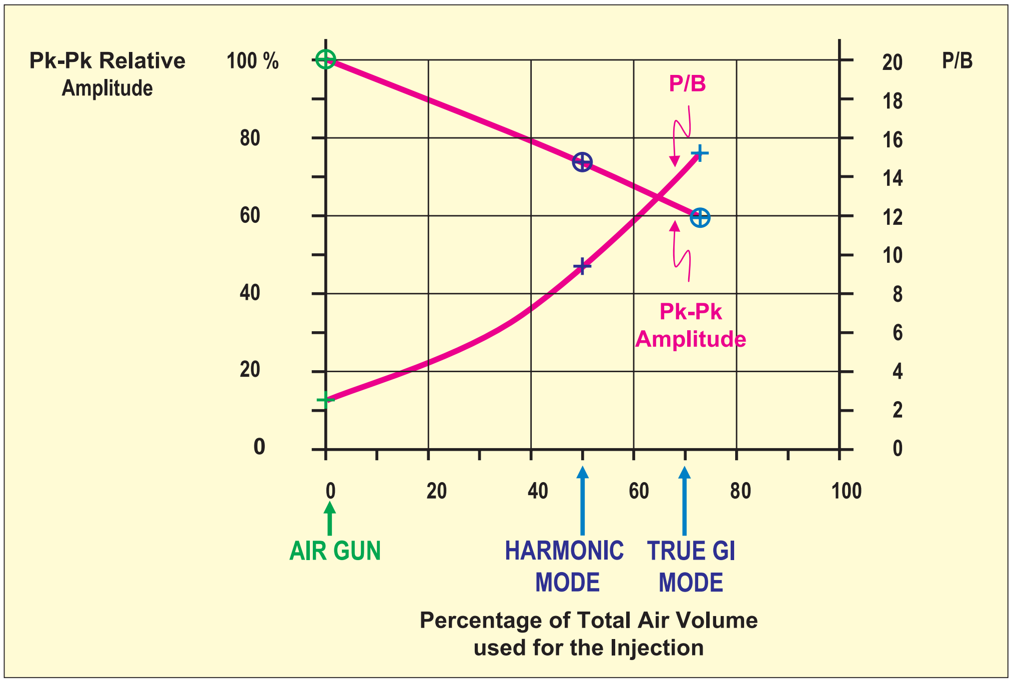
FAR FIELD SIGNATURE COMPARISON WITH SAME TOTAL VOLUME (150 in^3)
Pressure = 2,000 psi - Depth = 6.0 m - Filtered DFS 0 -256 Hz 72 dB/o

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

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

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

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



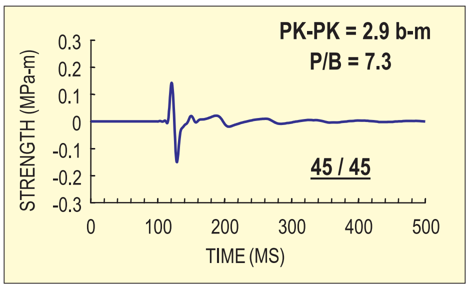
When the Injector has about the same volume as the Generator, the oscillation of the bubble created:

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

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

GI GUN HARMONIC MODE - 3 BASIC VOLUMES

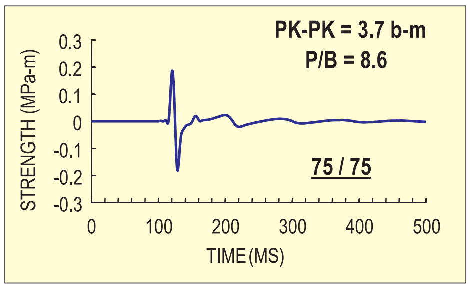
Pressure = 2,000 psi - Depth = 6.0 m - Filtered DFS 0-256 Hz 72 dB/o



GI GUN 90 **in³**

G = 45 **in³**

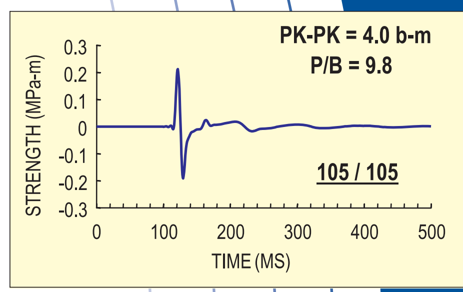
I = 45 **in³** - Delayed



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.

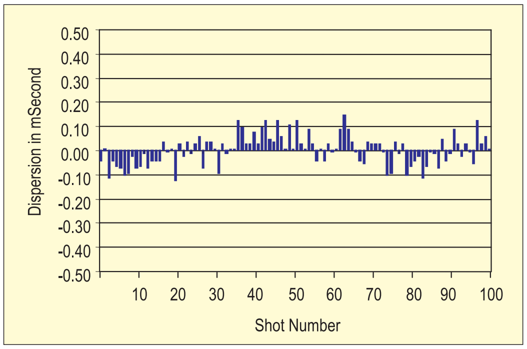
In addition, the smooth harmonic oscillation allows a sub-array of just two GI GUN with different volumes, so that the primaries add up. And, the final oscillation is further reduced by destructive interference and therefore, the primary-to-bubble ratio can reach a value of 14 with only two guns. This 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

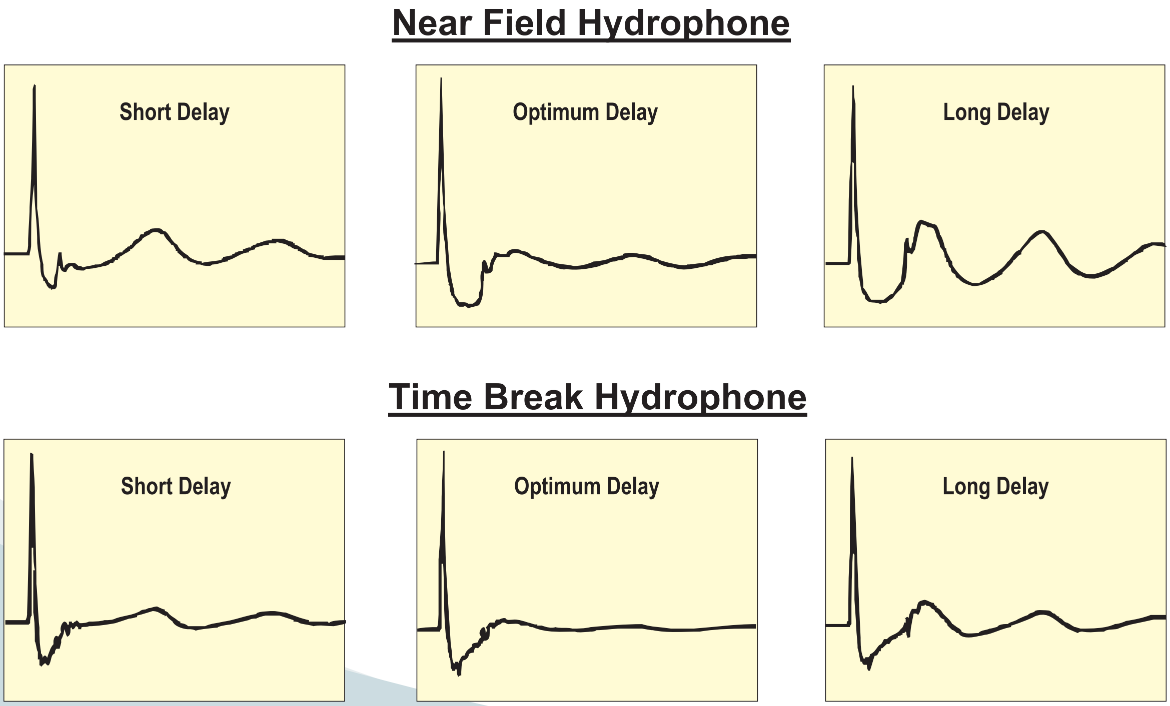


SIGNATURE QC

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.



Specifications

Physical GI GUN 210

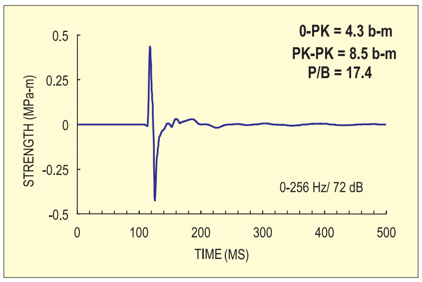
- Weight : 74 kg (163 lbs.)
- Length : 790 mm (31.0 in.)
- Width : 312 mm (12.3 in.)

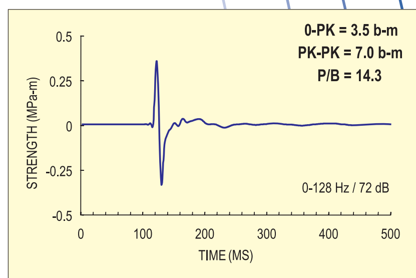
FAR FIELD SIGNATURE AND SPECTRUM

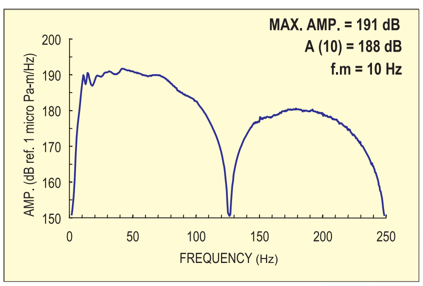
2 * GI GUN 300 in^3 Sub-Array

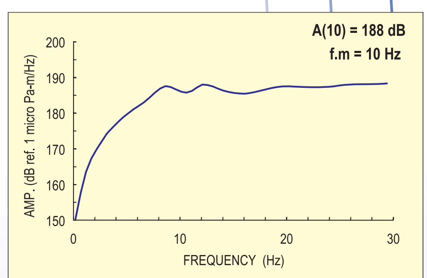
(G45 / I45) + (G105 / I105)

Pressure = 2,000 psi; Depth = 6.0 m







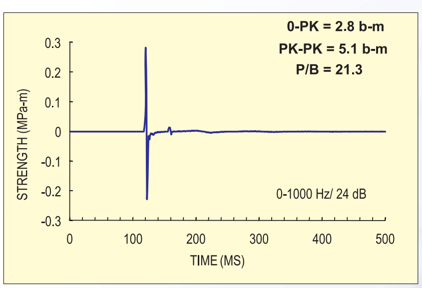


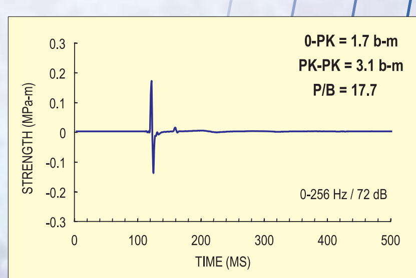
FAR FIELD SIGNATURE AND SPECTRUM

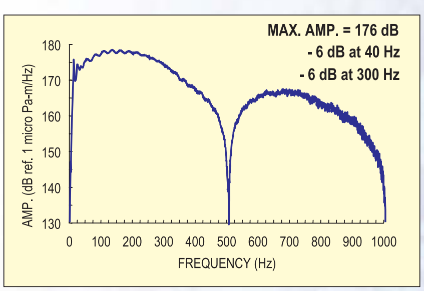
1 * GI GUN / 90 in^3 High Frequency

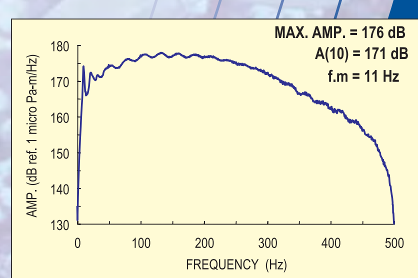
(G45 / I45)

Pressure = 2,000 psi; Depth = 1.5 mm









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S.A. au capital de 2 000 000 €
Siège Social: 16 rue de Bel-Air 44470 Carquefou
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17200 Park Row
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Fax: (1) 281 579 7505
E-mail: sales.hou@sercelus.com

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

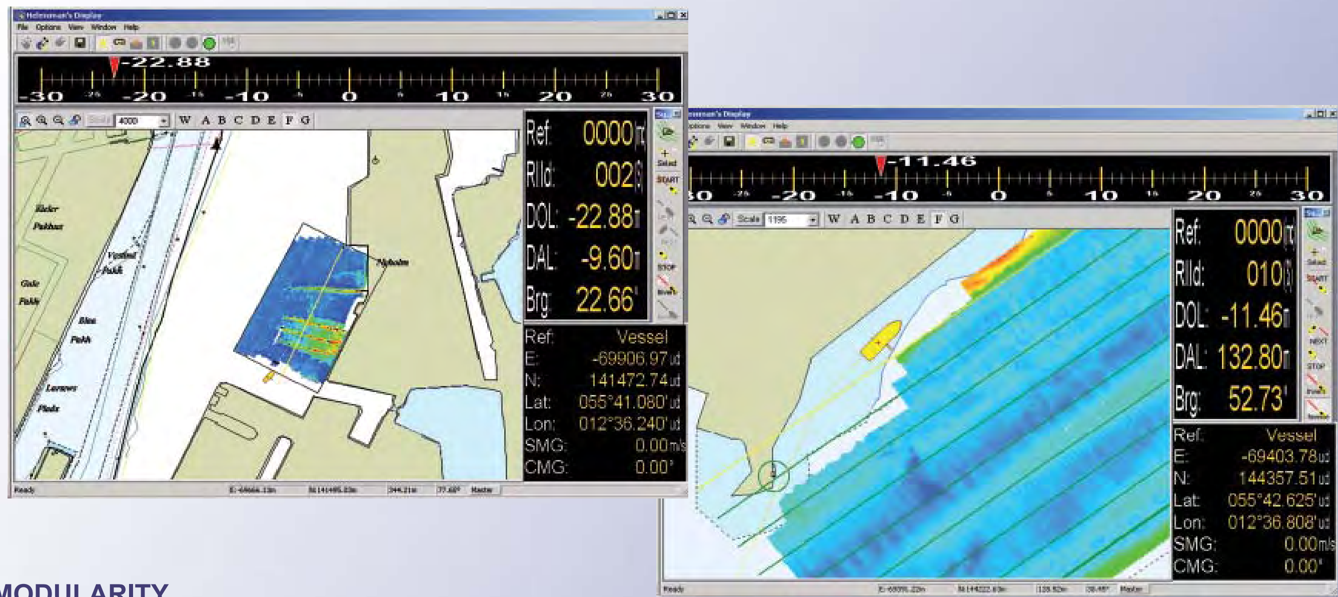
Appendix I-H:

NaviPac: Integrated Navigation Software

NaviPac

Integrated Navigation Software

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

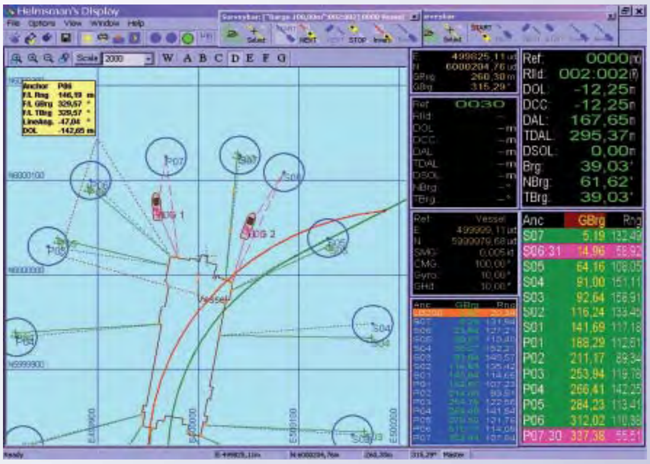
Vessel positions, survey lines (on DXF, DWG and ASCII formats) and objects may be displayed superimposed on C-Map or S57 based electronic chart displays. Coverage of depth information from singlebeam and/or multibeam echosounder as well as DTM's generated on-the-fly can be presented on the Navigation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

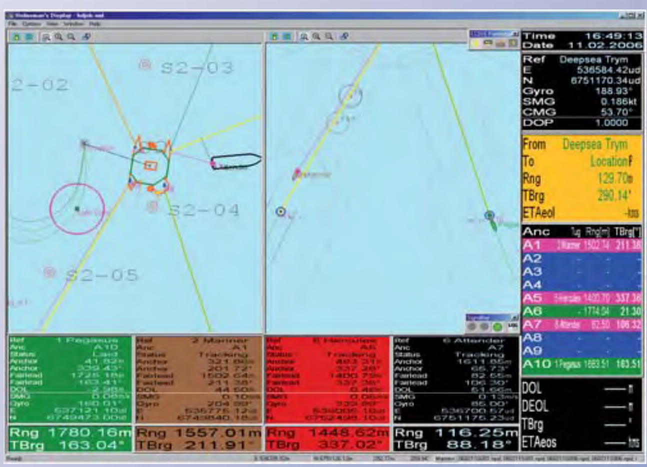
DATA HANDLING

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.

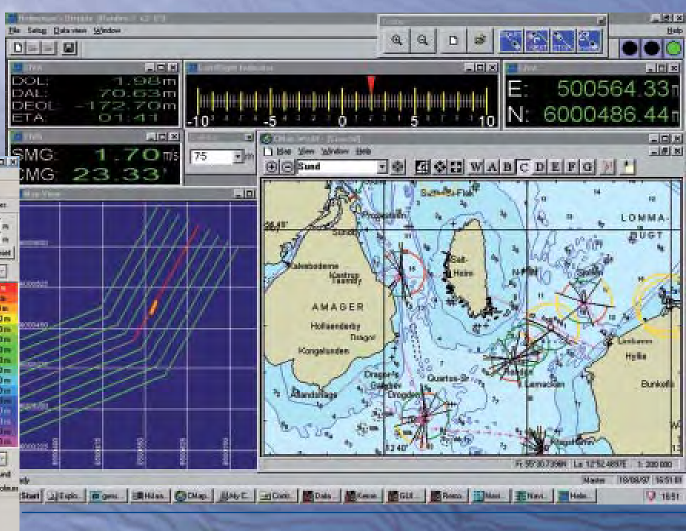
NAVIPAC LITE

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

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

DG14 Receiver

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

Compatibility

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

DG16 AND DG14 RECEIVERS

MULTIPATH MITIGATION

Multipath is the single largest cause of 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.

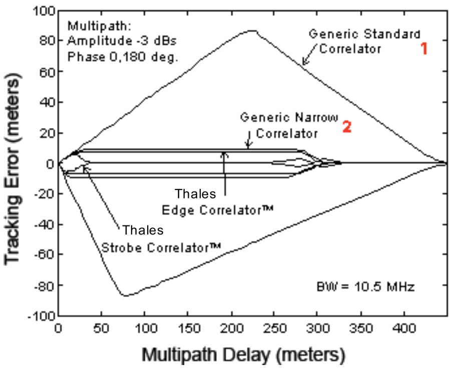
DG16 Development Kit

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° 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 indicato r mounted on anti vibration mounts with digital display and selectable inputs from:-

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

Protection And Safety Devices

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

Coolers, Separators And Drainage

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

  Liquid piped to an integral condensate manifold.

  Solenoid unloader valves SV2
  SV5

Air inlet

- Air suction filter and silencer

Water Cooling System

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

TECHNICAL SPECIFICATION

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

Lubrication

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

Ancillary Items

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

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

Drain Silencer and Demister Assembly [Bentley Filters Ltd]

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

Air Receivers

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

Adjustable Final Air Pressure Control Valve with System Pressure Gauge

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

Air Pressure Safety Valve

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

Contract Documentation

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

TECHNICAL SPECIFICATION

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

Local Starter/Control Equipment

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

General:

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

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

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

Description of Operation

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

Hand Operation – Compressor

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

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

TECHNICAL SPECIFICATION

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

Automatic Start/Stop Operation

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

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

Emergency Stopping

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

Cooling Water Pump

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

Ventilation Fan

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

Warning Alarm and Shutdown

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

Compressor Protection

Under fault conditions of:

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

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

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

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

TECHNICAL SPECIFICATION

Hamworthy Containerised Model 2 x 185E MK2 in 20FT 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 20FT 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

20^{FT} ISO Container

General

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

Dimensions

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

Description

Externally

Side panels 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.

Lifting points/holding down fixtures 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.

INTERNALLY

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

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

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

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

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

TECHNICAL SPECIFICATION

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

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

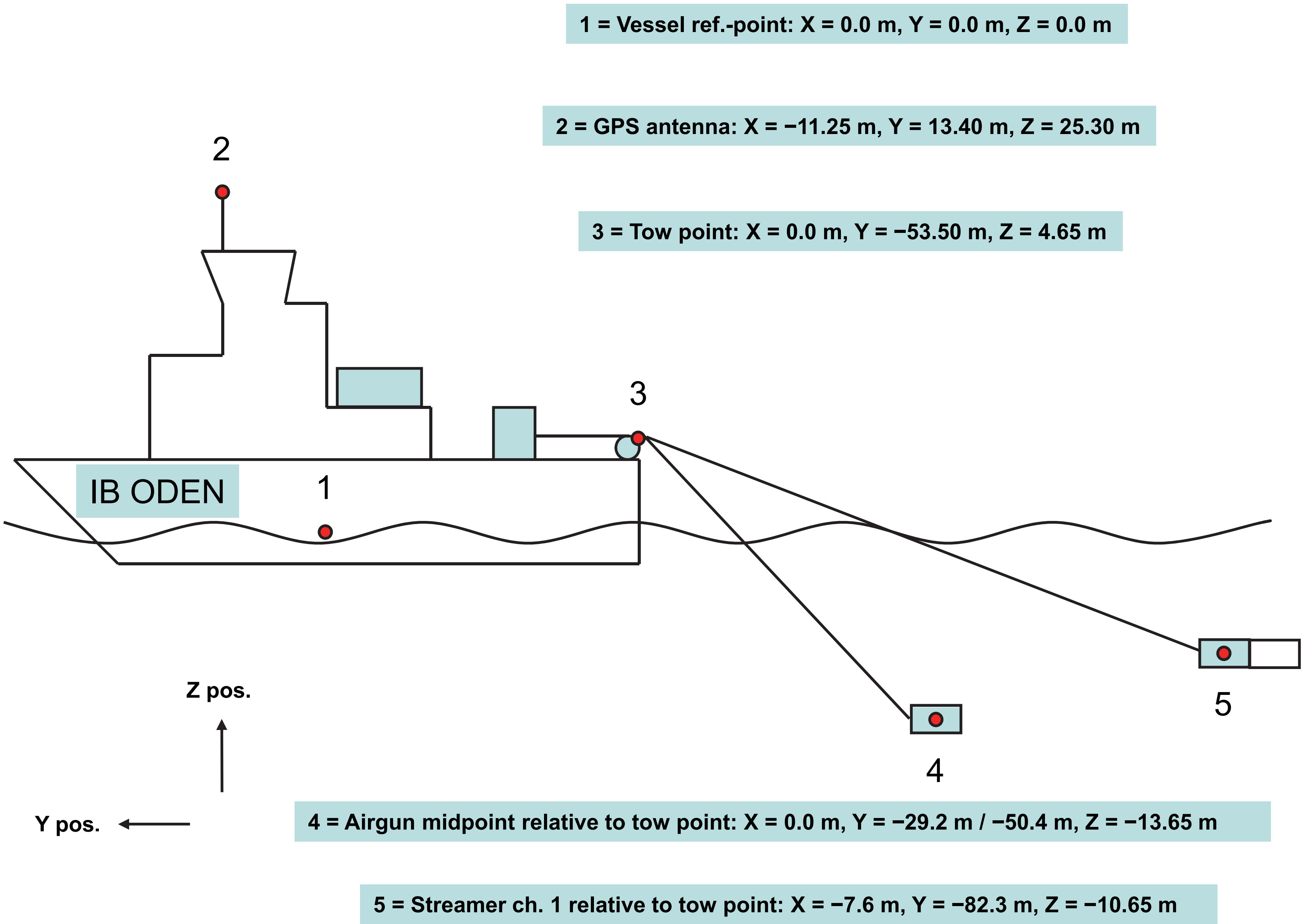
4TH190W70

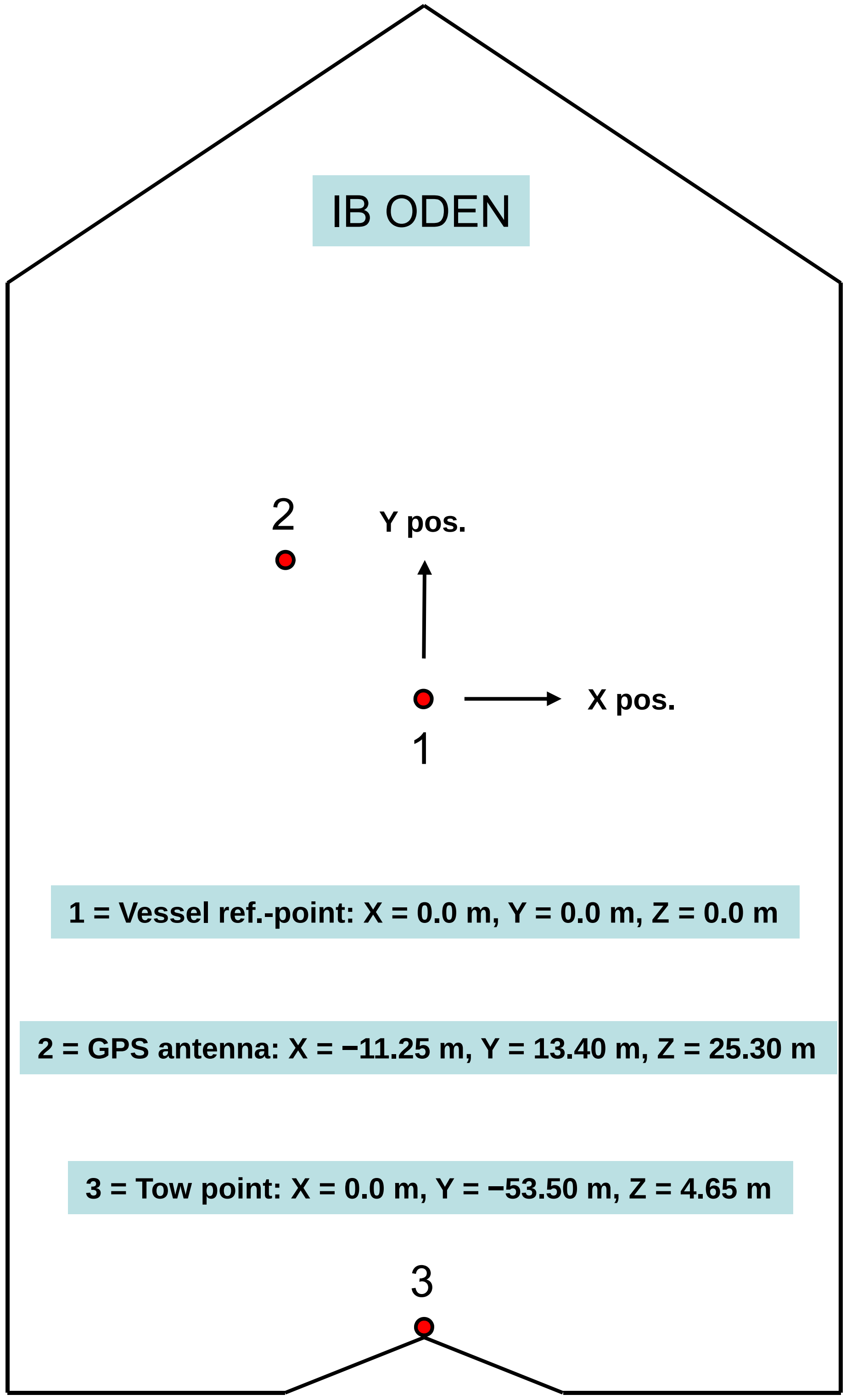
2 No - seismic air compressor with electric motor and heat exchanger and water circulating pump
4 No – air bottles
1 No – condensate blowdown system filter
All ancillary items
2 No – compressor starter control box
1 No – internal and external emergency stop with klaxon and visual indicator for compressor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

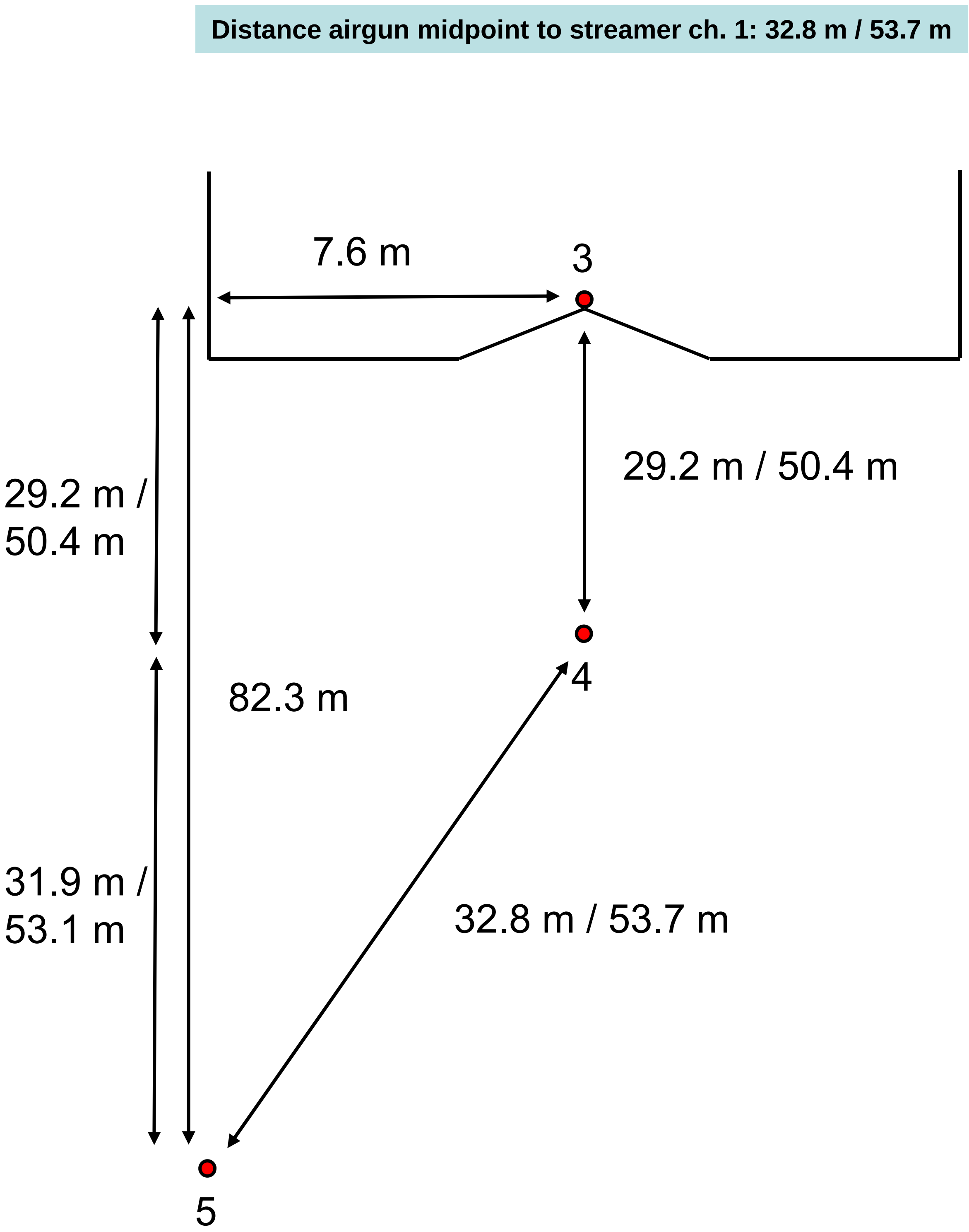
Appendix II: Definitions of offset points

Appendix II-A

Geometry configuration 1 for line EAGER2011_1A, EAGER2011_1B, EAGER2011_2A & EAGER2011_2A_2

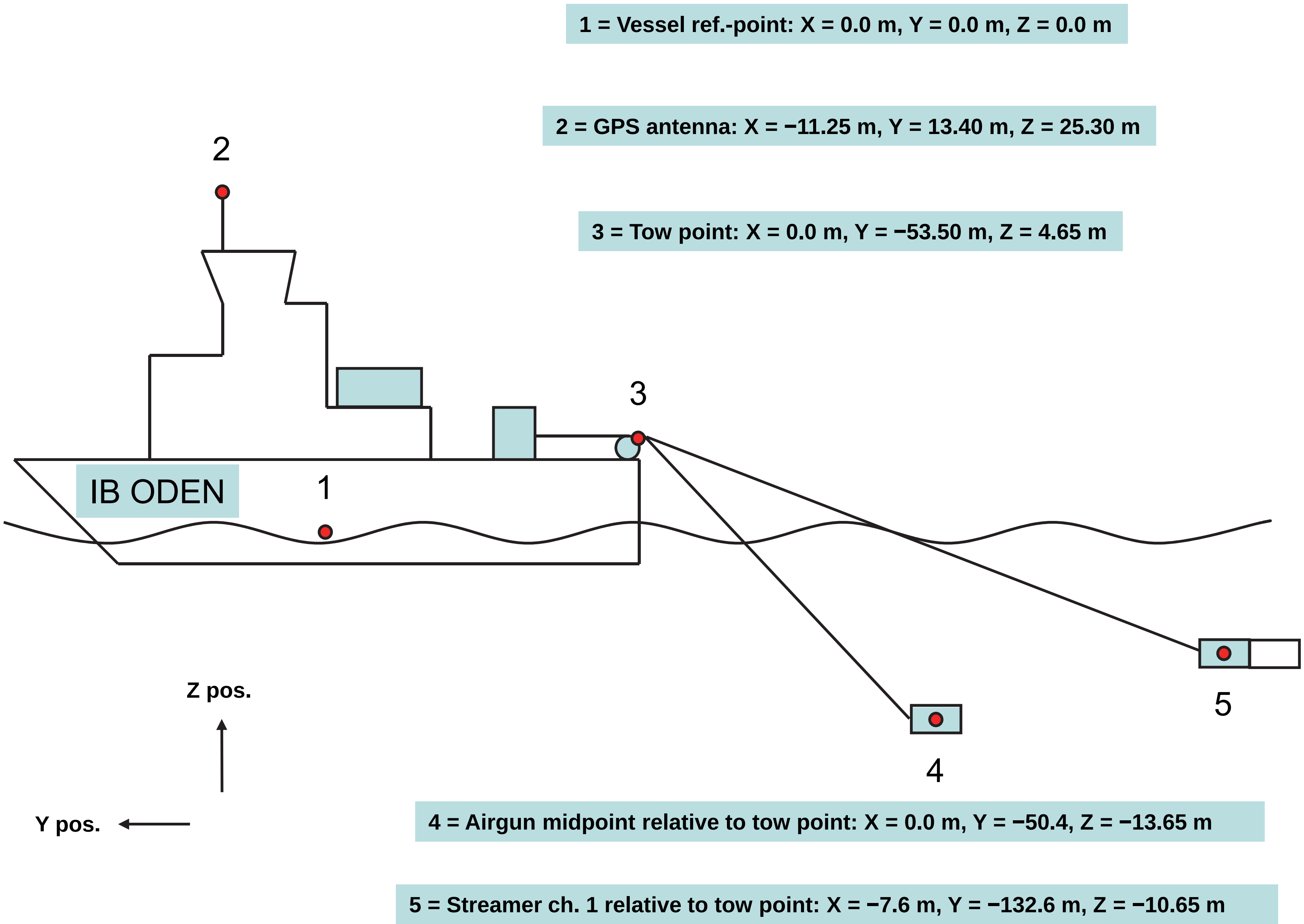

1 = Vessel ref.-point: X = 0.0 m, Y = 0.0 m, Z = 0.0 m
2 = GPS antenna: X = −11.25 m, Y = 13.40 m, Z = 25.30 m
3 = Tow point: X = 0.0 m, Y = −53.50 m, Z = 4.65 m
2
3
IB ODEN
1
5
4
Z pos.
Y pos.
4 = Airgun midpoint relative to tow point: X = 0.0 m, Y = −29.2 m / −50.4 m, Z = −13.65 m
5 = Streamer ch. 1 relative to tow point: X = −7.6 m, Y = −82.3 m, Z = −10.65 m

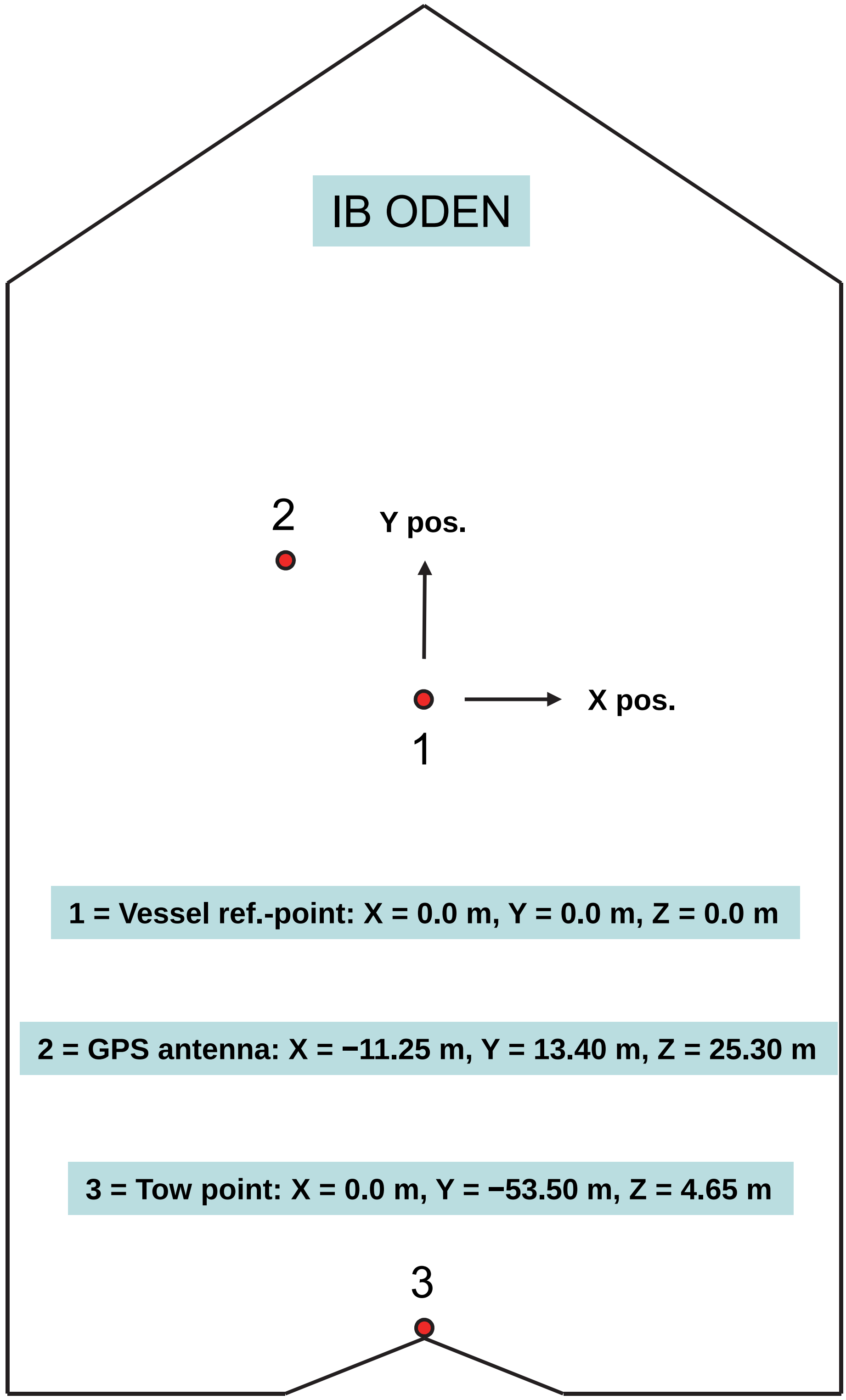

IB ODEN
2
Y pos.
X pos.
1
1 = Vessel ref.-point: X = 0.0 m, Y = 0.0 m, Z = 0.0 m
2 = GPS antenna: X = −11.25 m, Y = 13.40 m, Z = 25.30 m
3 = Tow point: X = 0.0 m, Y = −53.50 m, Z = 4.65 m
3


Distance airgun midpoint to streamer ch. 1: 32.8 m / 53.7 m
7.6 m
3
29.2 m / 50.4 m
29.2 m /
50.4 m
4
82.3 m
31.9 m /
53.1 m
32.8 m / 53.7 m
5

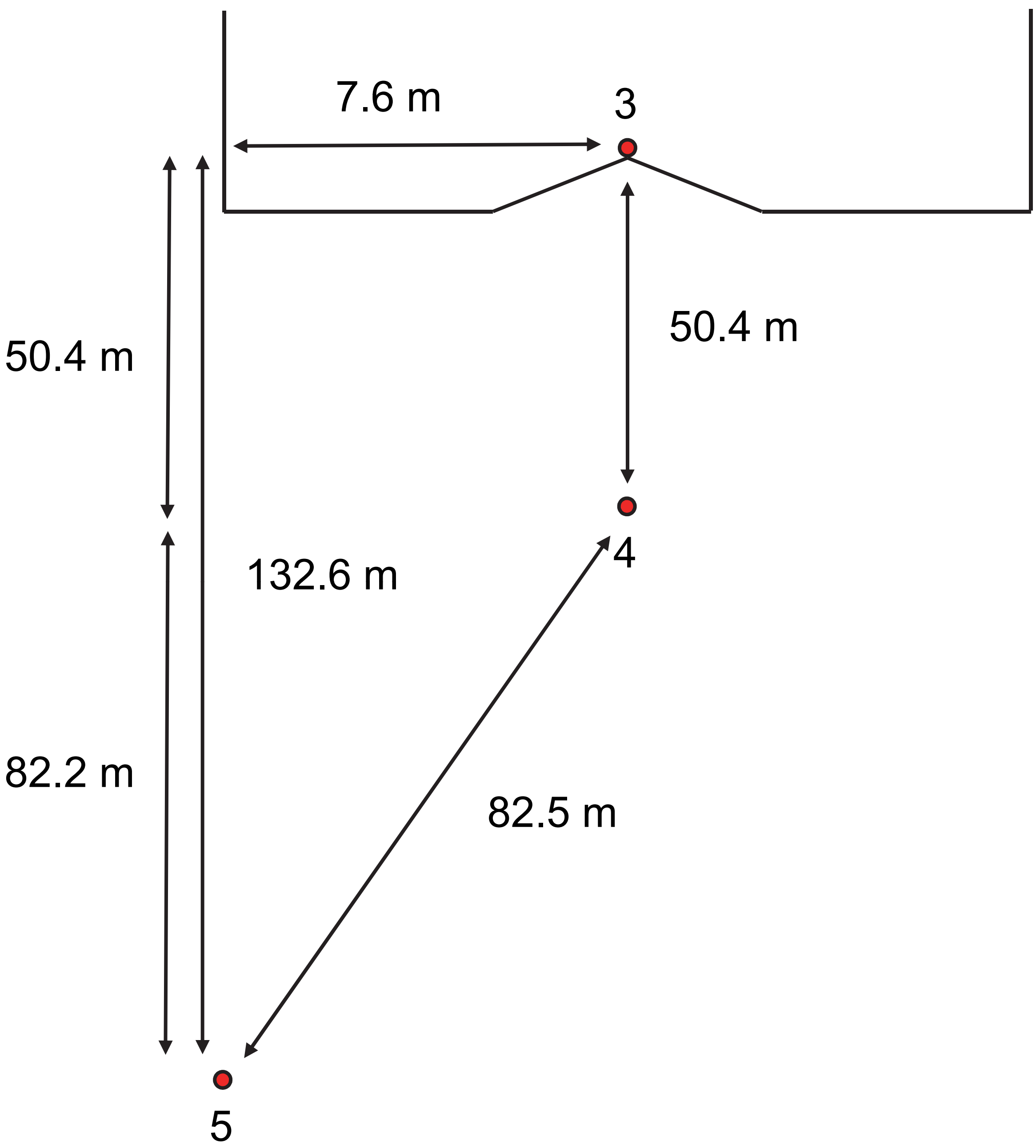
Appendix II-B

Geometry configuration 1 for line EAGER2011_3A, EAGER2011_3A_2, EAGER2011_3B & EAGER2011_3B_2


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
5
4
Z pos.
Y pos.
4 = Airgun midpoint relative to tow point: X = 0.0 m, Y = −50.4, Z = −13.65 m
5 = Streamer ch. 1 relative to tow point: X = −7.6 m, Y = −132.6 m, Z = −10.65 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

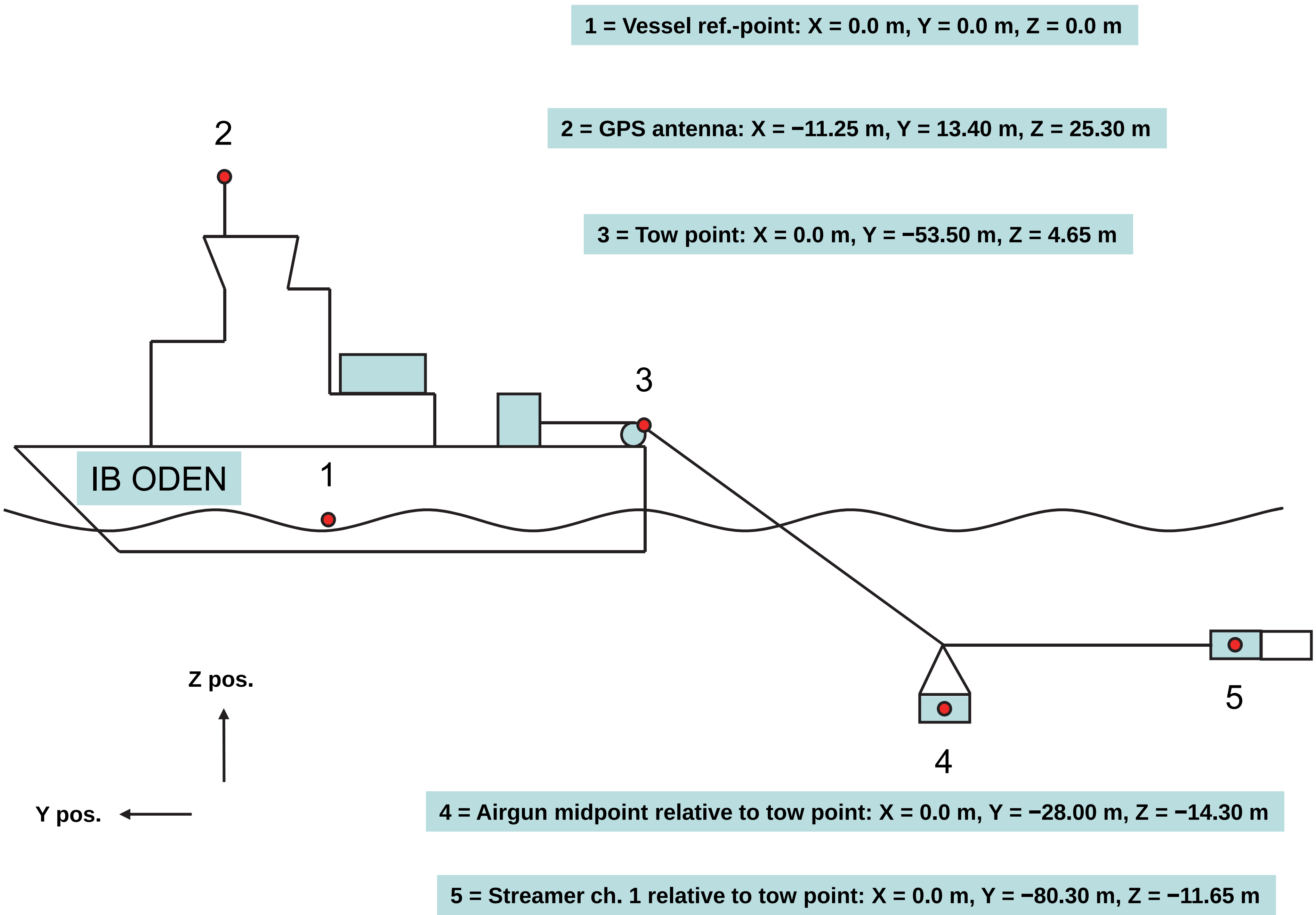
Distance airgun midpoint to streamer ch. 1: 82.5 m

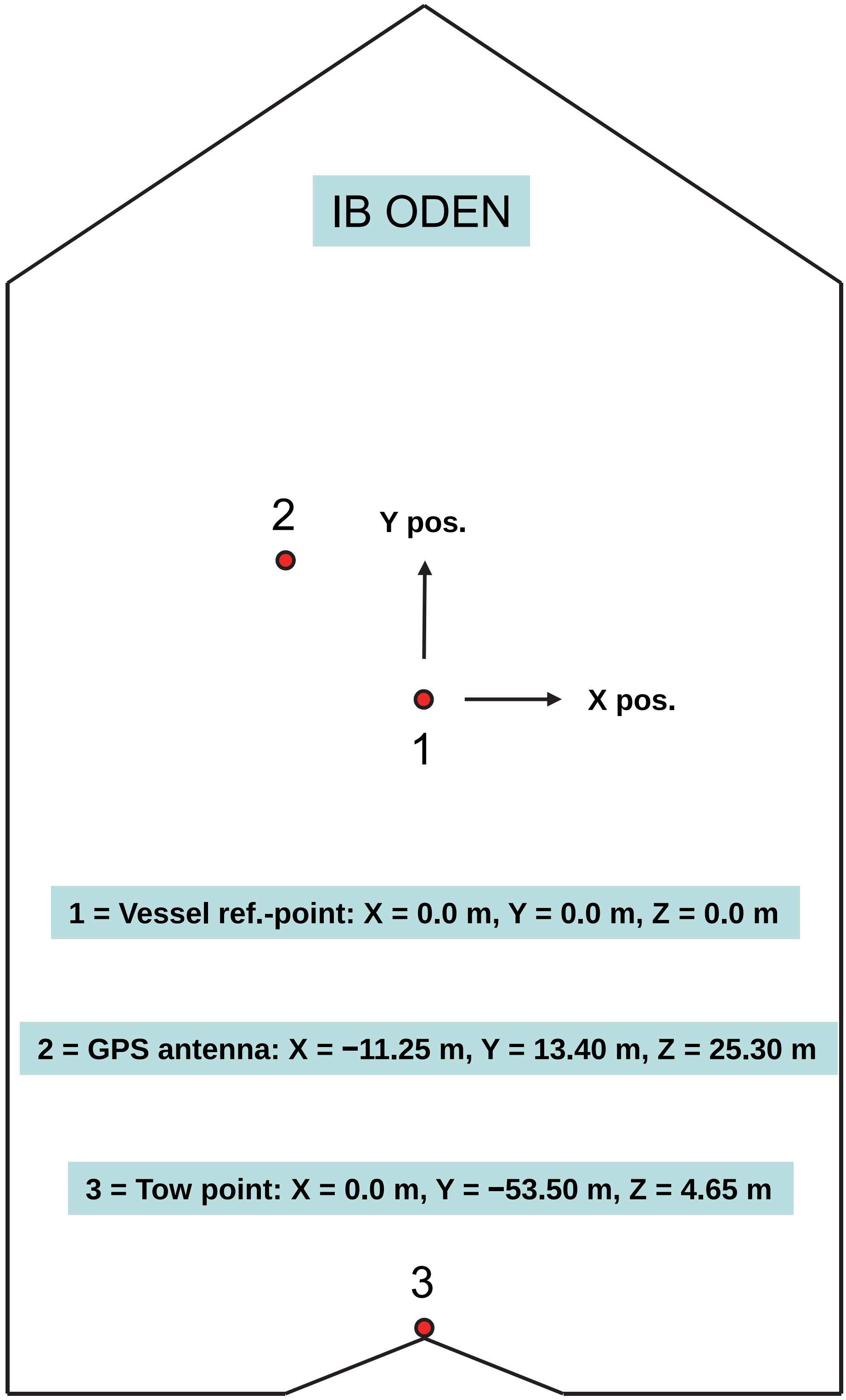


Appendix II-C

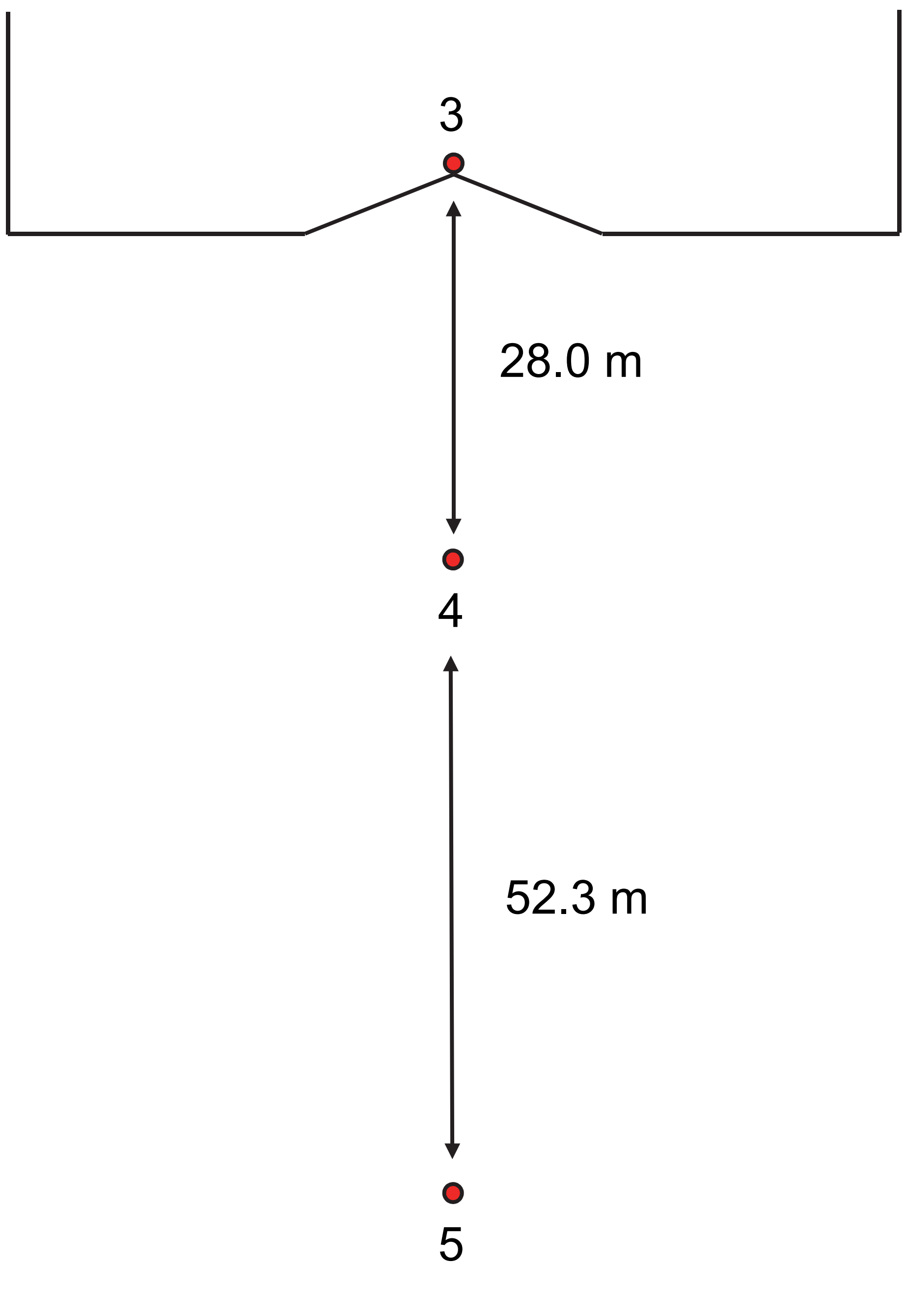
Geometry configuration 3 for line EAGER2011_4A and line EAGER2011_4B

Please note: line EAGER2011_4A has been renamed to EAGER2011_3D and line EAGER2011_4B to EAGER2011_3C in processing and relative to OBS and sonobuoy data acquisition.


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 = −28.00 m, Z = −14.30 m
5 = Streamer ch. 1 relative to tow point: X = 0.0 m, Y = −80.30 m, Z = −11.65 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

Distance airgun midpoint to streamer ch. 1: 52.3 m



Appendix III

Marine Survey – General Information and Line Overview logs

Date:	21-08-2011	Marine Survey - General Information	Line:	EAGER2011_1A

Cruise:	EAGER2011	Ship:	IB Oden	Location:	East Greenland Ridge

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)	-7,60
Y (m)	-53,25	Y (m)	-50,40	Y (m)	-82,30
Z (m)	4,65	Z (m)	-13,65	Z (m)	-10,65

	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. birds					2 / 14514	3 / 14510	4 / 14497	5 / 26567		
Serial no. depth transducer (front of section)					5009	5015	5016	5010		
Serial no. A/D converter (front of section)					1477	1497	1143	1476		

Navigation:

Software:	NaviPac
Projection:	UTM Zone 29
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378137	Longitude at Origin	-9° 0' 0.0"
Inverse flattening:	298,2572	False easting (m):	500000
Scale at Origin	0,9996	False northing (m):	0

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. G-Gun:	1
Volume G (cu.inch):	520
Serial no. G-Gun:	2
Volume G (cu.inch):	520
Serial no. G-Gun:	3
Volume G (cu.inch):	520
Serial no. G-Gun:	4
Volume G (cu.inch):	520
Delay:	**Autoadjusted (0 mS)**
Pressure (bar):	200
Planned depth (m):	9

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):	2
Record Length (ms):	55000
No of recording chs:	32
No of auxilliary chs:	8
Shot interval (s)	60

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):	6

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 60 sec, one by one - means 240 sec in total
Total delay to be used for refraction is 301 ms
Sonar buoys on aux 1-4, pps pulse on aux 5
* Z has been set to -9 m in Navipac
** Z has been set to -6 m in Navipac

Date:	21-08-2011	**Marine Survey - General Information**	**Line:**	EAGER2011_1B

Cruise:	EAGER2011	**Ship:**	IB Oden	**Location:**	East Greenland Ridge

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)	-7,60
Y (m)	-53,25	Y (m)	-29,20	Y (m)	-82,30
Z (m)	4,65	Z (m)	-13,65	Z (m)	-10,65

	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. birds					2 / 14514	3 / 14510	4 / 14497	5 / 26567		
Serial no. depth transducer (front of section)					5009	5015	5016	5010		
Serial no. A/D converter (front of section)					1477	1497	1143	1476		

Navigation:

Software:	NaviPac
Projection:	UTM Zone 29
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378137	Longitude at Origin	-9° 0' 0.0"
Inverse flattening:	298,2572	False easting (m):	500000
Scale at Origin	0,9996	False northing (m):	0

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	3
Volume G (cu.inch):	520
Serial no. G-Gun:	4
Volume G (cu.inch):	520
Delay:	**Autoadjusted (0 mS)**
Pressure (bar):	180
Planned depth (m):	9

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):	10000
No of recording chs:	32
No of auxilliary chs:	8
Shot interval (s)	12 (+-1 s)

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):	6

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 12 sec, one by one - means 48 sec in total
Total delay to be used for refraction is 301 ms
Sonar buoys on aux 1-4, pps pulse on aux 5
* Z has been set to -9 m in Navipac, ** Z has been set to -6 m in Navipac
Wrong airgun midpoint Y coordinate entered in Navipac. -50.4 m entered, should have been -29.2 m

Date:	21-08-2011	Marine Survey - General Information	Line:	EAGER2011_2A

Cruise:	EAGER2011	Ship:	IB Oden	Location:	East Greenland Ridge

GPS antenna		Refpoint ship		Gyro		10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
X (m)	-11,25	X (m)	0,00	X (m)	2,15		30		53	50	50	50	50		
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00	Serial no. birds				2 / 14514	3 / 14510	4 / 14497	5 / 26567		
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00	Serial no. depth transducer (front of section)				5009	5015	5016	5010		
Towpoint ship		Airgun midpoint relative to towpoint*		1st hydroph of Ch 1 relative to towpoint**		Serial no. A/D converter (front of section)				1477	1497	1143	1476		

Towpoint ship		Airgun midpoint relative to towpoint*		1st hydroph of Ch 1 relative to towpoint**		Navigation:		Transformation parameters:			
X (m)	0,00	X (m)	0,00	X (m)	-7,60	Software:	NaviPac	Semimajor axis (m):	6378137	Longitude at Origin	-9° 0' 0.0"
Y (m)	-53,25	Y (m)	-50,40	Y (m)	-82,30	Projection:	UTM Zone 29	Inverse flattening:	298,2572	False easting (m):	500000
Z (m)	4,65	Z (m)	-13,65	Z (m)	-10,65	Datum:	WGS84	Scale at Origin	0,9996	False northing (m):	0

Seismic Energy Source:		Seismic Instruments:		Streamer:	
Type:	Cluster w. Sercel GI and G gun	Type:	Geometrics GeoEel contoller	Type:	Geometrics GeoEel
Serial no. G-Gun:	1	Lowcut filter (Hz):	out	Length of tow section (m):	83
Volume G (cu.inch):	520	Lowcut filt. (dB/Oct):	out	Length of live section (m):	200
Serial no. G-Gun:	2	Highcut filter (Hz):	anti-alias	No. of live sections:	4
Volume G (cu.inch):	520	Highcut filt. (dB/Oct):	anti-alias	No. of channels:	32
Serial no. G-Gun:	3	Gain Setting (dB):	0	No. of channels/live section:	8
Volume G (cu.inch):	520	Sample Rate (ms):	2	channel interval (m):	6,25
Serial no. G-Gun:	4	Record Length (ms):	55000	No. of hydrophones/channel:	8
Volume G (cu.inch):	520	No of recording chs:	32	Serial no. Vibration section:	N/A
Delay:	**Autoadjusted (0 mS)**	No of auxilliary chs:	8	Serial no. 10 Mb repeater:	? (inside slipring)
Pressure (bar):	200	Shot interval (s)	60	Serial no. 100 Mb repeater:	N/A
Planned depth (m):	9			Planned depth (m):	6

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 60 sec, one by one - means 240 sec in total
Total delay to be used for refraction is 301 ms
Sonar buoys on aux 1-4, pps pulse on aux 5
* Z has been set to -9 m in Navipac
** Z has been set to -6 m in Navipac

Date:	21-08-2011	Marine Survey - General Information	Line:	EAGER2011_2A_2

Cruise:	EAGER2011	Ship:	IB Oden	Location:	East Greenland Ridge

GPS antenna		Refpoint ship		Gyro		10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)	Length section 5 (m)	Length section 6 (m)
X (m)	-11,25	X (m)	0,00	X (m)	2,15		30		53	50	50	50	50		
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00	Serial no. birds				2 / 14514	3 / 14510	4 / 14497	5 / 26567		
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00	Serial no. depth transducer (front of section)				5009	5015	5016	5010		
Towpoint ship		Airgun midpoint relative to towpoint*		1st hydroph of Ch 1 relative to towpoint**		Serial no. A/D converter (front of section)				1477	1497	1143	1476		
						Navigation:				**Transformation parameters:**					
X (m)	0,00	X (m)	0,00	X (m)	-7,60	Software:	NaviPac			Semimajor axis (m):		6378137	Longitude at Origin		-9° 0' 0.0"
Y (m)	-53,25	Y (m)	-50,40	Y (m)	-82,30	Projection:	UTM Zone 29			Inverse flattening:		298,2572	False easting (m):		500000
Z (m)	4,65	Z (m)	-13,65	Z (m)	-10,65	Datum:	WGS84			Scale at Origin		0,9996	False northing (m):		0

Seismic Energy Source:		Seismic Instruments:		Streamer:	
Type:	Cluster w. Sercel GI and G gun	Type:	Geometrics GeoEel contoller	Type:	Geometrics GeoEel
Serial no. G-Gun:	1	Lowcut filter (Hz):	out	Length of tow section (m):	83
Volume G (cu.inch):	520	Lowcut filt. (dB/Oct):	out	Length of live section (m):	200
Serial no. G-Gun:	2	Highcut filter (Hz):	anti-alias	No. of live sections:	4
Volume G (cu.inch):	520	Highcut filt. (dB/Oct):	anti-alias	No. of channels:	32
Serial no. G-Gun:	3	Gain Setting (dB):	0	No. of channels/live section:	8
Volume G (cu.inch):	520	Sample Rate (ms):	2	channel interval (m):	6,25
Serial no. G-Gun:	4	Record Length (ms):	55000	No. of hydrophones/channel:	8
Volume G (cu.inch):	520	No of recording chs:	32	Serial no. Vibration section:	N/A
Delay:	**Autoadjusted (0 mS)**	No of auxilliary chs:	8	Serial no. 10 Mb repeater:	? (inside slipring)
Pressure (bar):	200	Shot interval (s)	60	Serial no. 100 Mb repeater:	N/A
Planned depth (m):	9			Planned depth (m):	6

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 60 sec, one by one - means 240 sec in total
Total delay to be used for refraction is 301 ms
Sonar buoys on aux 1-4, pps pulse on aux 5
* Z has been set to -9 m in Navipac
** Z has been set to -6 m in Navipac

Date:	26-08-2011	Marine Survey - General Information	Line:	EAGER2011_3A

Cruise:	EAGER2011	Ship:	IB Oden	Location:	East Greenland Ridge

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)	-7,60
Y (m)	-53,25	Y (m)	-50,40	Y (m)	-132,60
Z (m)	4,65	Z (m)	-13,65	Z (m)	-10,65

	10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	10 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)
		30		53		50	50	50	50	50
Serial no. birds							2 / 14514	3 / 14510	4 / 14497	5 / 26567
Serial no. depth transducer (front of section)							5004	5015	5016	5010
Serial no. A/D converter (front of section)							1477	1497	1143	1476

Navigation:

Software:	NaviPac
Projection:	UTM Zone 29
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378137	Longitude at Origin	-9° 0' 0.0"
Inverse flattening:	298,2572	False easting (m):	500000
Scale at Origin	0,9996	False northing (m):	0

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. G-Gun:	1
Volume G (cu.inch):	520
Serial no. G-Gun:	2
Volume G (cu.inch):	520
Serial no. G-Gun:	3
Volume G (cu.inch):	520
Serial no. G-Gun:	4
Volume G (cu.inch):	520
Delay:	**Autoadjusted (0 mS)**
Pressure (bar):	200
Planned depth (m):	9

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):	2
Record Length (ms):	55000
No of recording chs:	32
No of auxilliary chs:	8
Shot interval (s)	60

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	133
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):	6

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 60 sec, one by one - means 240 sec in total
Total delay to be used for refraction is 301 ms
Sonar buoys on aux 1-4, pps pulse on aux 5
Section 5009 replaced with section 5004 due to leakage (100-400)
* Z has been set to -9 m in Navipac, ** Z has been set to -6 m in Navipac

Date:	26-08-2011	Marine Survey - General Information	Line:	EAGER2011_3A_2

Cruise:	EAGER2011	Ship:	IB Oden	Location:	East Greenland Ridge

GPS antenna		Refpoint ship		Gyro		10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	10 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)
X (m)	-11,25	X (m)	0,00	X (m)	2,15		30		53		50	50	50	50	50
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00	Serial no. birds						2 / 14514	3 / 14510	4 / 14497	5 / 26567
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00	Serial no. depth transducer (front of section)						5004	5015	5016	5010
Towpoint ship		Airgun midpoint relative to towpoint*		1st hydroph of Ch 1 relative to towpoint**		Serial no. A/D converter (front of section)						1477	1497	1143	1476

Towpoint ship		Airgun midpoint relative to towpoint*		1st hydroph of Ch 1 relative to towpoint**		Navigation:		Transformation parameters:			
X (m)	0,00	X (m)	0,00	X (m)	-7,60	Software:	NaviPac	Semimajor axis (m):	6378137	Longitude at Origin	-9° 0' 0.0"
Y (m)	-53,25	Y (m)	-50,40	Y (m)	-132,60	Projection:	UTM Zone 29	Inverse flattening:	298,2572	False easting (m):	500000
Z (m)	4,65	Z (m)	-13,65	Z (m)	-10,65	Datum:	WGS84	Scale at Origin	0,9996	False northing (m):	0

Seismic Energy Source:		Seismic Instruments:		Streamer:	
Type:	Cluster w. Sercel GI and G gun	Type:	Geometrics GeoEel contoller	Type:	Geometrics GeoEel
Serial no. G-Gun:	1	Lowcut filter (Hz):	out	Length of tow section (m):	133
Volume G (cu.inch):	520	Lowcut filt. (dB/Oct):	out	Length of live section (m):	200
Serial no. G-Gun:	2	Highcut filter (Hz):	anti-alias	No. of live sections:	4
Volume G (cu.inch):	520	Highcut filt. (dB/Oct):	anti-alias	No. of channels:	32
Serial no. G-Gun:	3	Gain Setting (dB):	0	No. of channels/live section:	8
Volume G (cu.inch):	520	Sample Rate (ms):	2	channel interval (m):	6,25
Serial no. G-Gun:	4	Record Length (ms):	55000	No. of hydrophones/channel:	8
Volume G (cu.inch):	520	No of recording chs:	32	Serial no. Vibration section:	N/A
Delay:	**Autoadjusted (0 mS)**	No of auxilliary chs:	8	Serial no. 10 Mb repeater:	? (inside slipring)
Pressure (bar):	200	Shot interval (s)	60	Serial no. 100 Mb repeater:	N/A
Planned depth (m):	9			Planned depth (m):	6

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 60 sec, one by one - means 240 sec in total
Total delay to be used for refraction is 301 ms
Sonar buoys on aux 1-4, pps pulse on aux 5
Section 5009 replaced with section 5004 due to leakage (100-400)
* Z has been set to -9 m in Navipac, ** Z has been set to -6 m in Navipac

Date:	26-08-2011	Marine Survey - General Information	Line:	EAGER2011_3B

Cruise:	EAGER2011	Ship:	IB Oden	Location:	East Greenland Ridge

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)	-7,60
Y (m)	-53,25	Y (m)	-50,40	Y (m)	-132,60
Z (m)	4,65	Z (m)	-13,65	Z (m)	-10,65

	10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	10 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)
		30		53		50	50	50	50	50
Serial no. birds							2 / 14514	3 / 14510	4 / 14497	5 / 26567
Serial no. depth transducer (front of section)							5004	5015	5016	5010
Serial no. A/D converter (front of section)							1477	1497	1143	1476

Navigation:

Software:	NaviPac
Projection:	UTM Zone 29
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378137	Longitude at Origin	-9° 0' 0.0"
Inverse flattening:	298,2572	False easting (m):	500000
Scale at Origin	0,9996	False northing (m):	0

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. G-Gun:	1
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	4
Volume G (cu.inch):	520
Delay:	**Autoadjusted (0 mS)**
Pressure (bar):	180
Planned depth (m):	9

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):	10000
No of recording chs:	32
No of auxilliary chs:	8
Shot interval (s)	12 (+-1 s)

Streamer:

Type:	Geometrics GeoEel
Length of tow section (m):	133
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):	6

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 12 sec, one by one - means 48 sec in total
Total delay to be used for refraction is 301 ms
Sonar buoys on aux 1-4, pps pulse on aux 5
Section 5009 replaced with section 5004 due to leakage (100-400)
* Z has been set to -9 m in Navipac, ** Z has been set to -6 m in Navipac

Date:	26-08-2011	Marine Survey - General Information	Line:	EAGER2011_3B_2

Cruise:	EAGER2011	Ship:	IB Oden	Location:	East Greenland Ridge

GPS antenna		Refpoint ship		Gyro		10 Mb repeater	Length Tow cable	100 Mb repeater	Length stretch section	10 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)
X (m)	-11,25	X (m)	0,00	X (m)	2,15		30		53		50	50	50	50	50
Y (m)	13,4	Y (m)	0,00	Y (m)	7,00	Serial no. birds						2 / 14514	3 / 14510	4 / 14497	5 / 26567
Z (m)	25,3	Z (m)	0,00	Z (m)	34,00	Serial no. depth transducer (front of section)						5004	5015	5016	5010
Towpoint ship		Airgun midpoint relative to towpoint*		1st hydroph of Ch 1 relative to towpoint**		Serial no. A/D converter (front of section)						1477	1497	1143	1476

Towpoint ship		Airgun midpoint relative to towpoint*		1st hydroph of Ch 1 relative to towpoint**		Navigation:		Transformation parameters:			
X (m)	0,00	X (m)	0,00	X (m)	-7,60	Software:	NaviPac	Semimajor axis (m):	6378137	Longitude at Origin	-9° 0' 0.0"
Y (m)	-53,25	Y (m)	-50,40	Y (m)	-132,60	Projection:	UTM Zone 29	Inverse flattening:	298,2572	False easting (m):	500000
Z (m)	4,65	Z (m)	-13,65	Z (m)	-10,65	Datum:	WGS84	Scale at Origin	0,9996	False northing (m):	0

Seismic Energy Source:		Seismic Instruments:		Streamer:	
Type:	Cluster w. Sercel GI and G gun	Type:	Geometrics GeoEel contoller	Type:	Geometrics GeoEel
Serial no. G-Gun:	1	Lowcut filter (Hz):	out	Length of tow section (m):	133
Volume G (cu.inch):	520	Lowcut filt. (dB/Oct):	out	Length of live section (m):	200
Serial no. G-Gun:		Highcut filter (Hz):	anti-alias	No. of live sections:	4
Volume G (cu.inch):		Highcut filt. (dB/Oct):	anti-alias	No. of channels:	32
Serial no. G-Gun:		Gain Setting (dB):	0	No. of channels/live section:	8
Volume G (cu.inch):		Sample Rate (ms):	1	channel interval (m):	6,25
Serial no. G-Gun:	4	Record Length (ms):	10000	No. of hydrophones/channel:	8
Volume G (cu.inch):	520	No of recording chs:	32	Serial no. Vibration section:	N/A
Delay:	**Autoadjusted (0 mS)**	No of auxilliary chs:	8	Serial no. 10 Mb repeater:	? (inside slipring)
Pressure (bar):	180	Shot interval (s)	12 (+-1 s)	Serial no. 100 Mb repeater:	N/A
Planned depth (m):	9			Planned depth (m):	6

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 12 sec, one by one - means 48 sec in total
Total delay to be used for refraction is 301 ms
Sonar buoys on aux 1-4, pps pulse on aux 5
Section 5009 replaced with section 5004 due to leakage (100-400)
* Z has been set to -9 m in Navipac, ** Z has been set to -6 m in Navipac

Date:	29-08-2011	Marine Survey - General Information	Line:	EAGER2011_4B

Cruise:	EAGER2011	Ship:	IB Oden	Location:	East Greenland Ridge

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)	-28,00	Y (m)	-80,30
Z (m)	4,65	Z (m)	-14,30	Z (m)	-11,65

	10 Mb repeater	Length Tow cable	10 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)		
		30		53	50	50	50	50		
Serial no. birds										
Serial no. depth transducer (front of section)					5004	5015	5016	5010		
Serial no. A/D converter (front of section)					1477	1497	1143	1476		

Navigation:

Software:	NaviPac
Projection:	UTM Zone 29
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378137	Longitude at Origin	-9° 0' 0.0"
Inverse flattening:	298,2572	False easting (m):	500000
Scale at Origin	0,9996	False northing (m):	0

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. G-Gun:	1
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	3
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (0 mS)**
Pressure (bar):	180
Planned depth (m):	9,65

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):	10000
No of recording chs:	32
No of auxilliary chs:	8
Shot interval (s)	12 (+-1 s)

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):	7

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 12 sec, one by one - means 48 sec in total
Total delay to be used for refraction is 301 ms
Sonar buoys on aux 1-4, pps pulse on aux 5
Section 5009 replaced with section 5004 due to leakage (100-400)
Please note: line EAGER2011_4B has been renamed to EAGER2011_3C in processing and relative to OBS and sonobuoy data acquisition.

Date:	29-08-2011	Marine Survey - General Information	Line:	EAGER2011_4A

Cruise:	EAGER2011	Ship:	IB Oden	Location:	East Greenland Ridge

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)	-28,00	Y (m)	-80,30
Z (m)	4,65	Z (m)	-14,30	Z (m)	-11,65

10 Mb repeater	Length Tow cable	10 Mb repeater	Length stretch section	Length section 1 (m)	Length section 2 (m)	Length section 3 (m)	Length section 4 (m)		
	30		53	50	50	50	50		
Serial no. birds									
Serial no. depth transducer (front of section)				5004	5015	5016	5010		
Serial no. A/D converter (front of section)				1477	1497	1143	1476		

Navigation:

Software:	NaviPac
Projection:	UTM Zone 29
Datum:	WGS84

Transformation parameters:

Semimajor axis (m):	6378137	Longitude at Origin	-9° 0' 0.0"
Inverse flattening:	298,2572	False easting (m):	500000
Scale at Origin	0,9996	False northing (m):	0

Seismic Energy Source:

Type:	Cluster w. Sercel GI and G gun
Serial no. G-Gun:	1
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Serial no. G-Gun:	3
Volume G (cu.inch):	520
Serial no. G-Gun:	
Volume G (cu.inch):	
Delay:	**Autoadjusted (0 mS)**
Pressure (bar):	200
Planned depth (m):	9,65

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):	2
Record Length (ms):	35000
No of recording chs:	32
No of auxilliary chs:	8
Shot interval (s)	40

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):	7

Remarks:

Airgun midpoint and first hydrophone of channel 1 positions calculated in NaviPac as drag from Towpoint
Streamer depth scanned every 40 sec, one by one - means 160 sec in total
Total delay to be used for refraction is 301 ms
Sonar buoys on aux 1-4, pps pulse on aux 5
Section 5009 replaced with section 5004 due to leakage (100-400)
Please note: line EAGER2011_4A has been renamed to EAGER2011_3D in processing and relative to OBS and sonobuoy data acquisition.

Cruise: EAGER2011 **Ship:** IB Oden **Location:** East Greenland Ridge Page 1/4

Line ID	Date d-m-y	SOL/EOL File no.	H:M	Start/End Latitude N	Start/End Longitude E/W(-)	Remarks gun/streamer depths	Data storage extra disk	Data storage HDD	Data storage Navigation	Navipac event no.
1A	21-08-2011	1	04:05	° ´	° ´	Misfires from Navipac	F:\EAGER2011	E:\EAGER2011	040531_C.npd	1593
		7		° ´	° ´					
1A		8	04:27	° ´	° ´	SOL	F:\EAGER2011	E:\EAGER2011	042712_C.npd	1599
				° ´	° ´	Gun 2 is often 3-4 ms off				
		108	06:07	° ´	° ´	T/B signal poor on G1 (and partly 4 on some shots)				1700
				° ´	° ´	Problems with gun energy due to poor T/B signal (c. 2 mbar at ch.16 0-200 ms)				
		262	08:55	° ´	° ´					1855
		321	09:42	° ´	° ´					1914
		699	15:58	° ´	° ´	Missing T/B from gun 4 (on and off)				2291
		720		° ´	° ´	Gun energy decreasing to 1 mbar				2312
		755		° ´	° ´	Gun energy back to 2 mbar				2347
		885	19:04	° ´	° ´	EOL				2477
1B		1	20:03	° ´	° ´	SOL	F:\EAGER2011	E:\EAGER2011	200304_C.npd	2478
				° ´	° ´	360 turn on to line, gun offset coord. in navipac not changed from 50.4 to 29.2				
				° ´	° ´	Finished turn, heading towards line. Changed gun offset coord. in Navipac				
						from 50.4 to 29.2, but probably not applied				
				° ´	° ´	Pressure 180 bar				
	22-08-2011	2565	04:35	° ´	° ´	Pressure 165 bar				5043
			c. 06:00	° ´	° ´	No depths from MBE, they changed something, but don't know what				
	22-08-2011		c.10:50	° ´	° ´	Sometimes poor signal g4, low pressure 150bar, bauer II, high temp stage 4				
		7151	11:37	° ´	° ´	EOL				4673
				° ´	° ´	Change of gun offset coord. in Navipac apparently not effective on calc. coord				
				° ´	° ´	This is probably because it was done on the fly without stopping				
				° ´	° ´	and starting survey				
				° ´	° ´					
				° ´	° ´	**Problems with tape drive, recording on external usb disk instead**				
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					

Cruise: EAGER2011 **Ship:** IB Oden **Location:** East Greenland Ridge

Line ID	Date d-m-y	SOL/EOL File no.	H:M	Start/End Latitude N	Start/End Longitude E/W(-)	Remarks gun/streamer depths	Data storage USB	Data storage HDD	Data storage Navigation	Navipac
2A*	23-08-2011	1	22:47	° ´	° ´	SOL, turning onto line	F:\EAGER2011	E:\EAGER2011	224626_C	7151
		22	23:08	° ´	° ´	EOL, break due to airleak				7172
2A**	24-08-2011	23	01:15	° ´	° ´	SOL, after fixing gun array	F:\EAGER2011	E:\EAGER2011	011448_C	7175
		165	03:37	° ´	° ´	Streamer target depth set to 8 m - front sections shallow and streamer not				7317
	24-08-2011		11:35	° ´	° ´	gun 3 time break sig missing				7794
	24-08-2011	811	14:24	° ´	° ´	Stopped shooting. Gun buoys stuck together making guns drifting towards				7964
2A_2	25-08-2011	1	02:07	° ´	° ´	SOL, turning onto line	F:\EAGER2011	E:\EAGER2011	020652_C.npd	7962
		35		° ´	° ´	on line				7996
		85	03:32	° ´	° ´	Past breakpoint from 1st run				8046
			c.07:00	° ´	° ´	Streamer shows leakage: c. 400				
	25-08-2011	367	08:13	° ´	° ´	EOL				8328
				° ´	° ´					
				° ´	° ´	**Problems with tape drive, recording on external usb disk instead**				
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
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				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
* Logfiles named Refrac_survey.2A.xxx				° ´	° ´					
** Logfiles named Reflec_survey.2A.xxx				° ´	° ´					
				° ´	° ´					
				° ´	° ´					
				° ´	° ´					

Cruise: EAGER2011	**Ship:** IB Oden	**Location:** East Greenland Ridge	Page 3/4

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 usb/disk	Data storage HDD	Data storage Navigation	Navipac
3A	26-08-2011	1	21:31	77° 21´	4° 81´	SOL	F:\EAGER2011	E:\EAGER2011	212958_C.npd	8330
	27-08-2011	c. 450	c. 04:00			Pressure only 100 bar				8780
		470	05:20			EOL, airhose leaking				8800
3A_2	27-08-2011	1	06:59			SOL, turning on to line	F:\EAGER2011	E:\EAGER2011	065903_C.npd	8809
						No pressure to guns, several misfires and mistriggers				
		20	07:21			All guns ok again and back on line				8830
		455	14:36			EOL				9266
3B	27-08-2011	1	15:14			SOL turning onto line	F:\EAGER2011	E:\EAGER2011	151406_C.npd	9273
		633	17:20			straight on line				9905
	28-08-2011	3172	01:47			Gun pressure low for last 30 minutes (160) falling to 140				
		3214	01:55			Compressor problem: low pressure, shot rate to 24 s while Tom works on it				
		3223				Increase shot time to 30 sec pressure at 130				
		3228				Increase shot time to 60 sec, pressure at 140				
		3236				Shot time to 30 sec pressure at 165				
		3281				Shot time to 12 sec - pressure at 145-150				
		3345				Guns disabled to see if pressure comes up, all compr. working, still recording.				
		3357	03:07:00			EOL Air leak -				
3B_2	28-08-2011	1	04:53			SOL	F:\EAGER2011	E:\EAGER2011	045329_C.npd	12707
						Gun pressure low				
		113	05:15			EOL Air leak -				12820
3B_2	28-08-2011	a1	07:36			SOL	F:\EAGER2011	E:\EAGER2011	073621_C.npd	12823
		a113	07:58			Be aware of file names a1-a113 and then 114-885				12935
		114	07:58							12936
		830	10:25			Gun pressure low				13475
		885	10:34			EOL Air leak -				13707
						Problems with tape drive, recording on external usb disk instead				

Cruise: EAGER2011 **Ship:** IB Oden **Location:** East Greenland Ridge

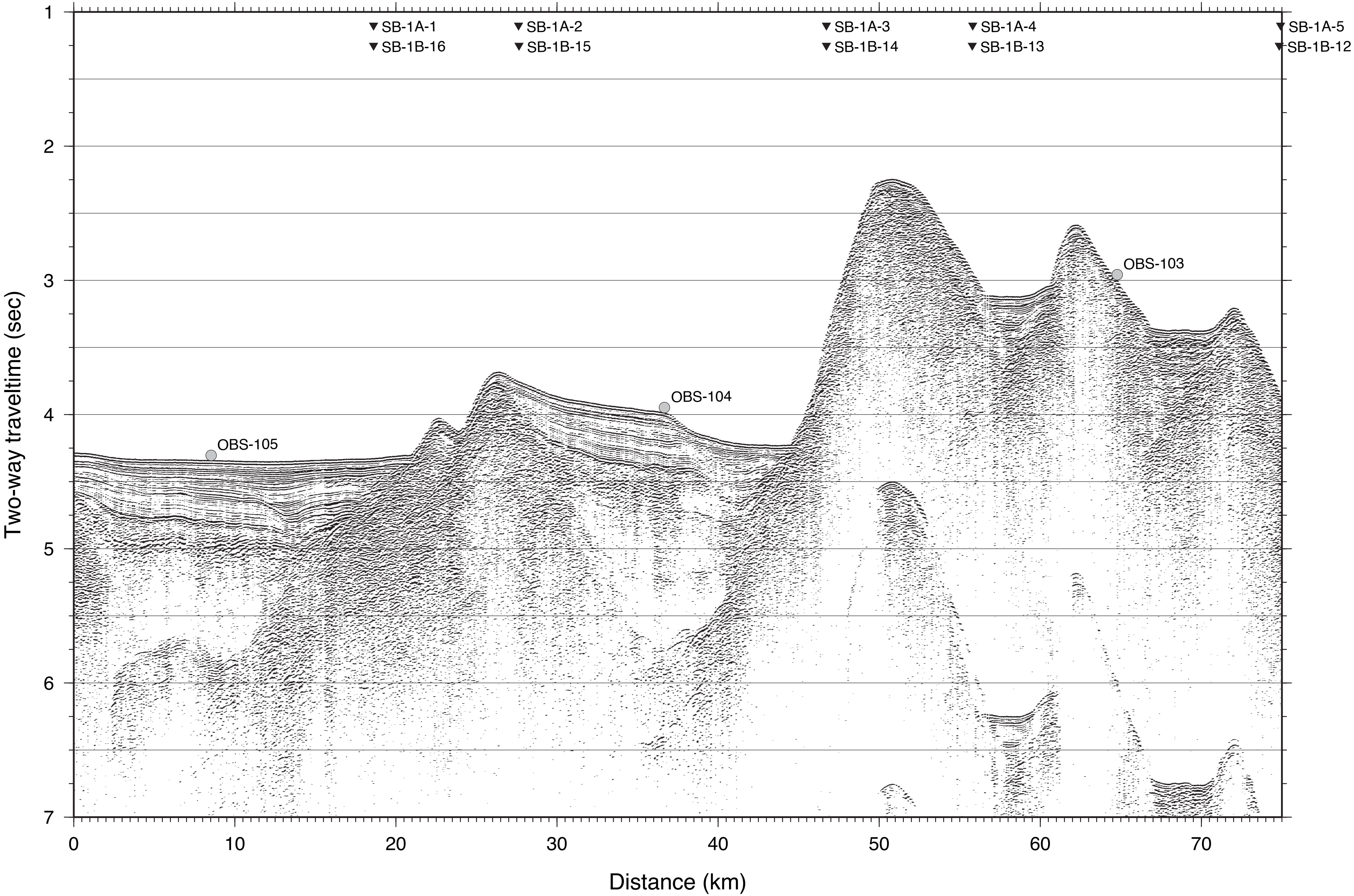
Line ID	Date d-m-y	SOL/EOL	H:M	Start/End Latitude N	Start/End Longitude E/W(-)	Remarks gun/streamer depths	Data storage usb/disk	Data storage HDD	Data storage Navigation	Navipac
4B	29-08-2011	1	13:42			SOL gun depth 8,5 m	F:\EAGER2011	E:\EAGER2011	134243_C.npd	13709
			15:00			First two depth transducers not working				
		1471	18:36			gun depth 7,8 m				15180
		1622	19:06			EOL				15331
4A	29-08-2011	1	19:11			SOL gun depth 8,0 m	F:\EAGER2011	E:\EAGER2011	191045_C.npd	15334
			23:24			gun depth around 5 m				
			23:27			gun depth around 8m				
			23:51			gun depth around 5 m				
	30-08-2011	695	02:53			EOL				16028
						Problems with tape drive, recording on external usb disk instead				

Please note: line EAGER2011_4A has been renamed to EAGER2011_3D and line EAGER2011_4B to EAGER2011_3C in processing and relative to OBS and sonobuoy data acquisition.

Appendix IV

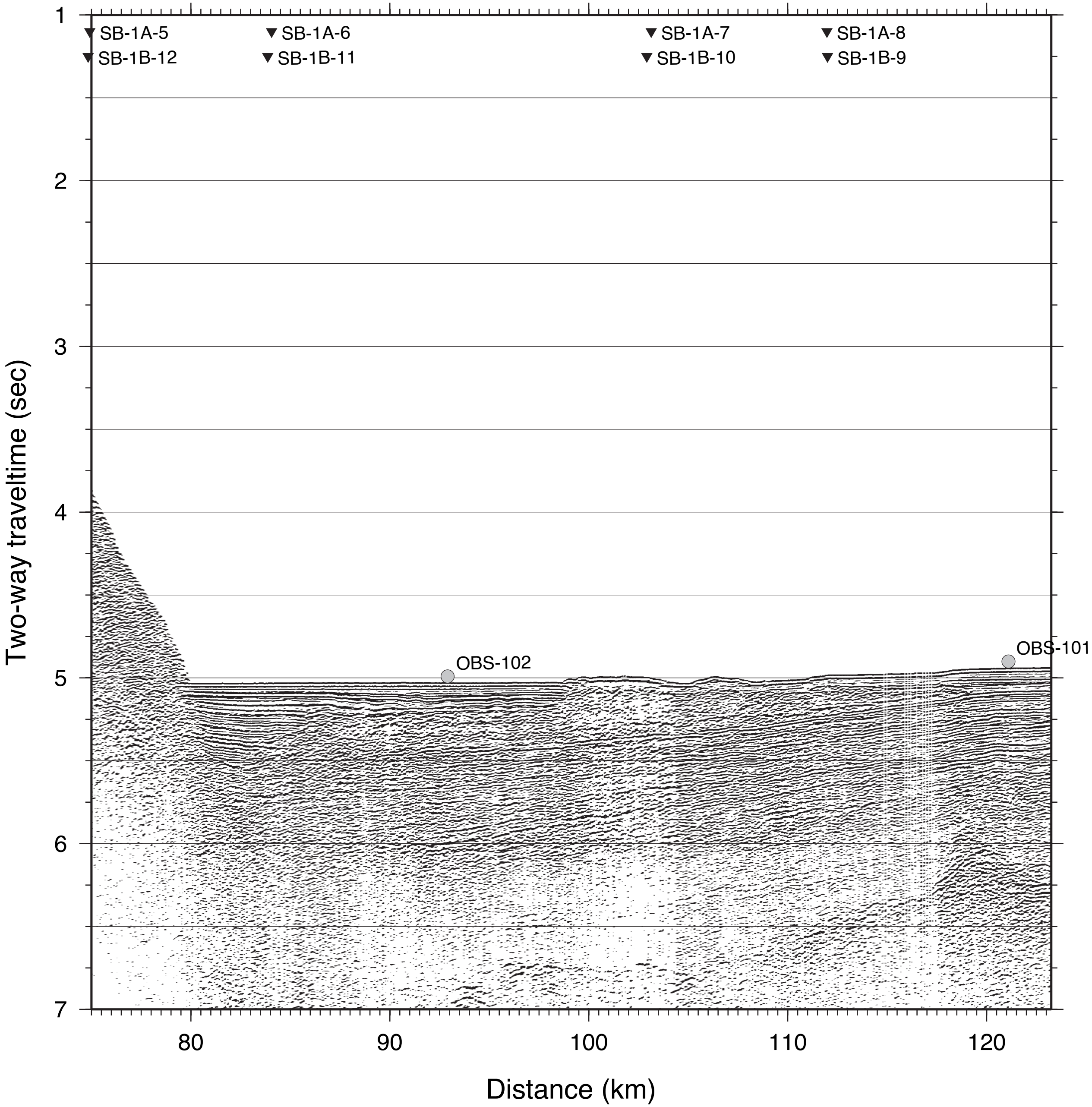
Plot of unmigrated shipboard stack for all reflection seismic lines acquired during EAGER2011

EAGER2011-1A unmigrated shipboard stack



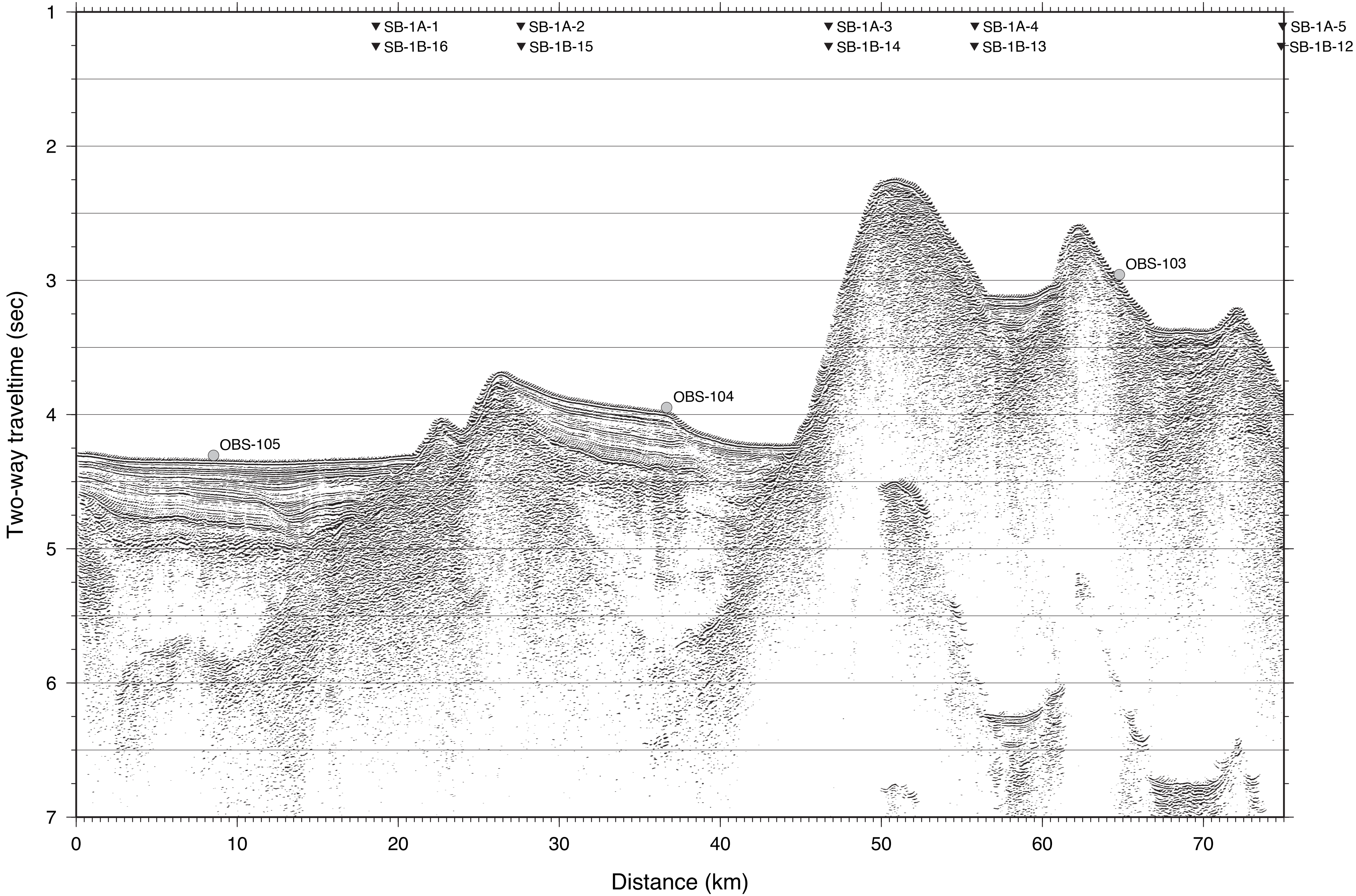
grdimage 1A/stack-final.grd -R0/75/1/7.0 -Jx0.12/-1.0 -C./CLIP/04.cpt

EAGER2011-1A unmigrated shipboard stack



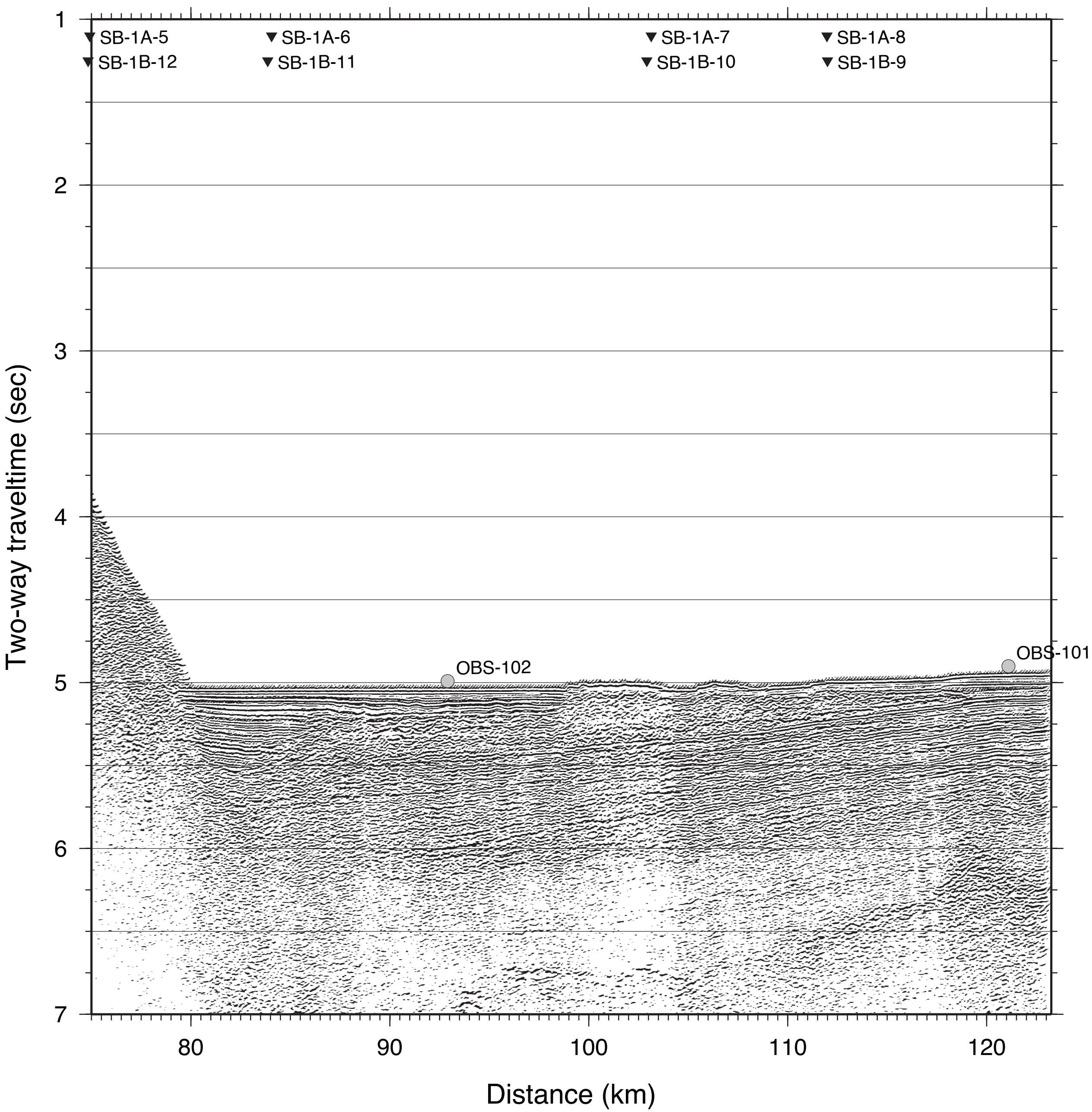
grdimage 1A/stack-final.grd -R75/123.25/1/7.0 -Jx0.12/-1.0 -C./CLIP/04.cpt

EAGER2011-1A migrated shipboard stack



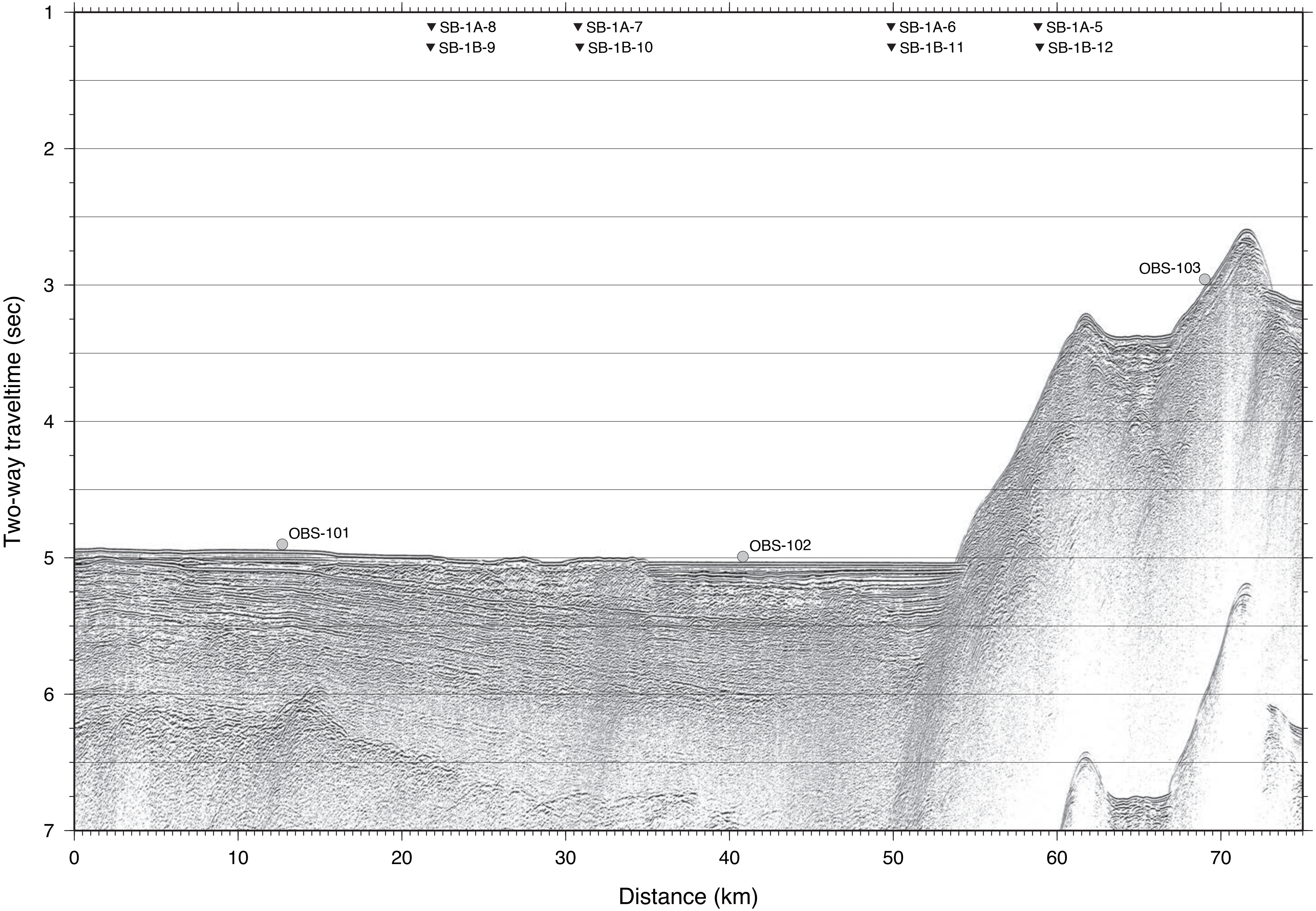
grdimage 1A/stack-mig.grd -R0/75/1/7.0 -Jx0.12/-1.0 -C./CLIP/04.cpt

EAGER2011-1A migrated shipboard stack



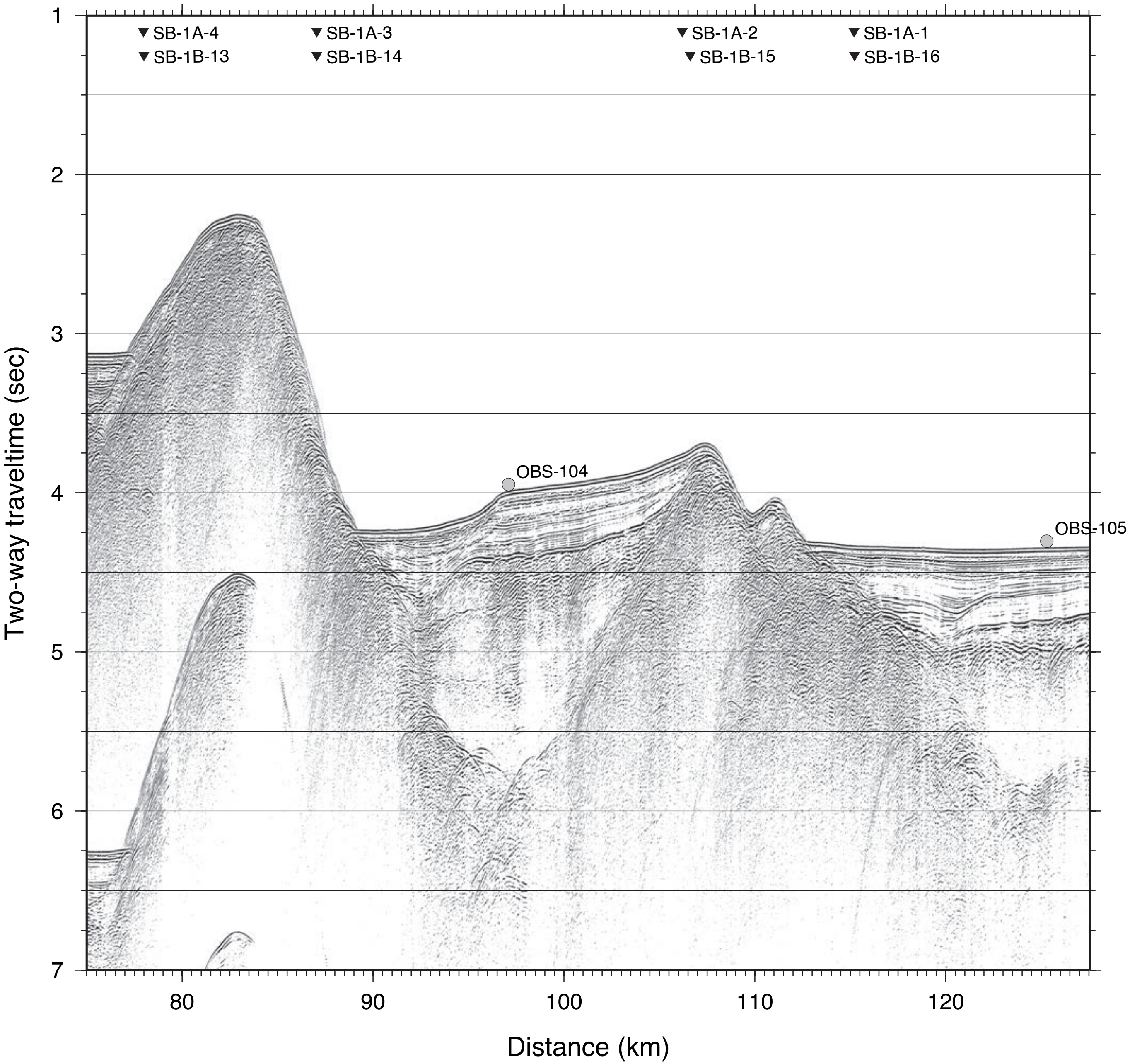
grdimage 1A/stack-mig.grd -R75/123.25/1/7.0 -Jx0.12/-1.0 -C./CLIP/04.cpt

EAGER2011-1B unmigrated shipboard stack



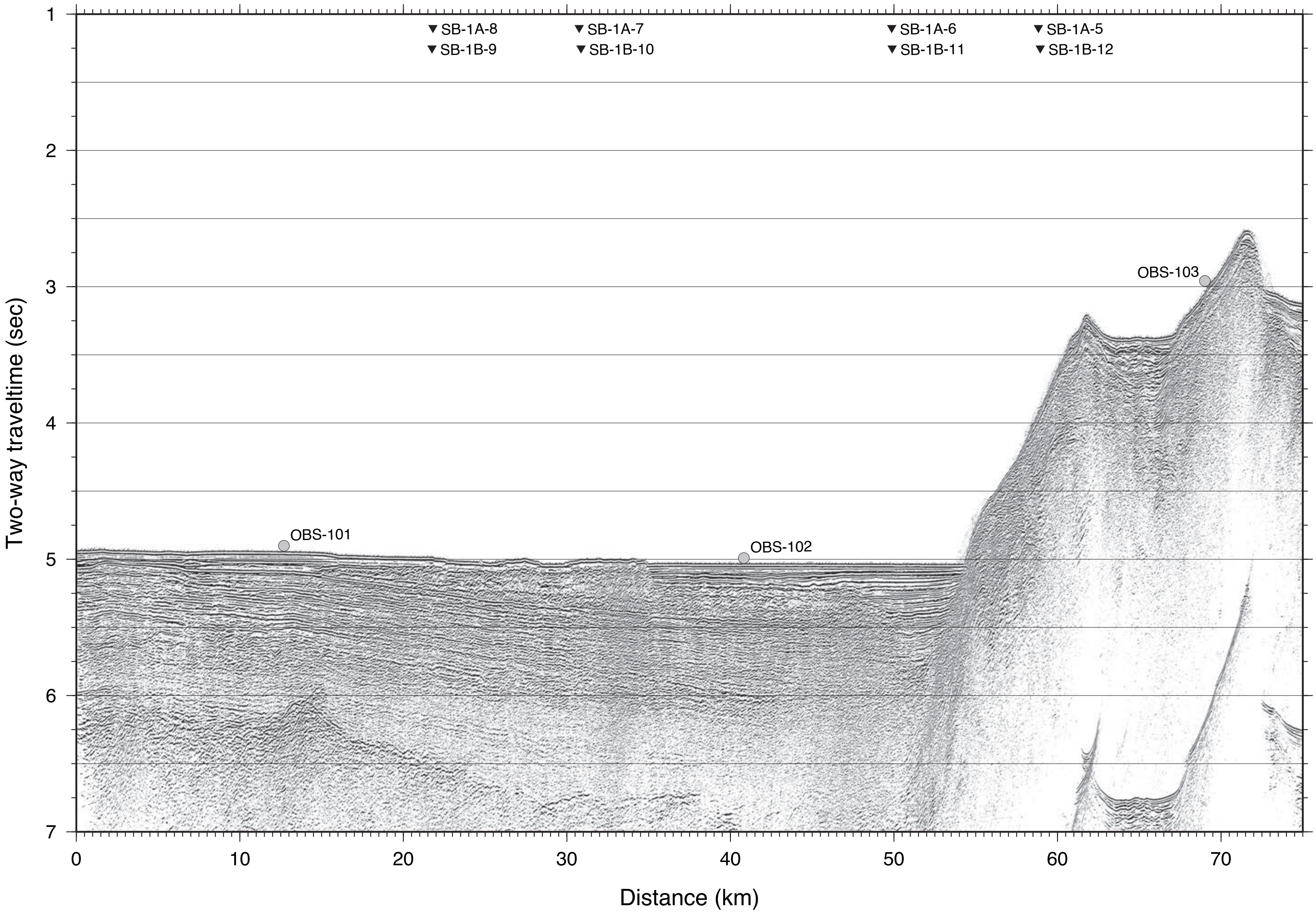
grdimage 1B/stack-final.grd -R0/75/1/7.0 -Jx0.12/-1.0 -C./CLIP/04.cpt

EAGER2011-1B unmigrated shipboard stack



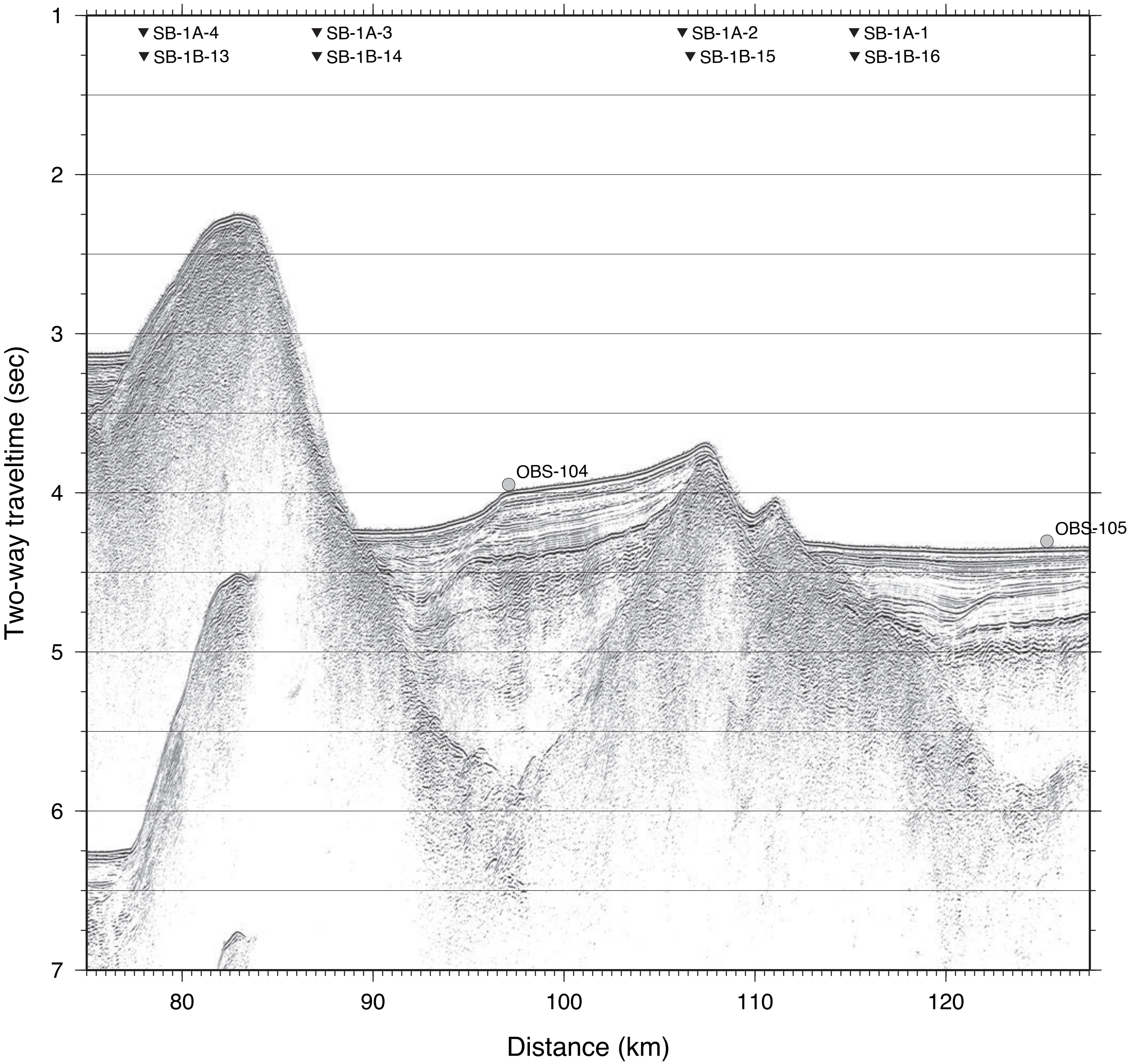
grdimage 1B/stack-final.grd -R75/127.5375/1/7.0 -Jx0.12/-1.0 -C./CLIP/04.cpt

EAGER2011-1B migrated shipboard stack



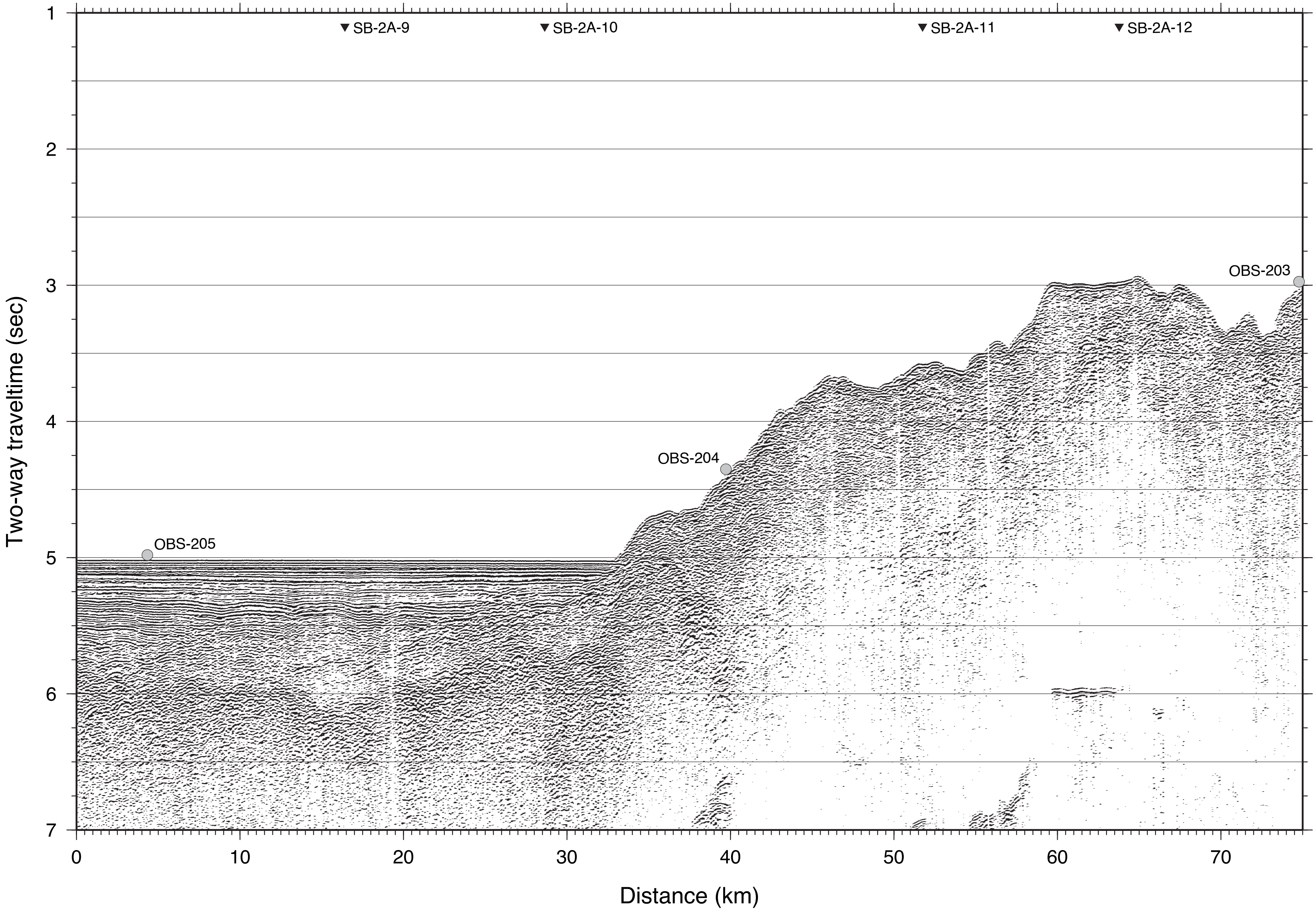
grdimage 1B/stack-mig.grd -R0/75/1/7.0 -Jx0.12/-1.0 -C./CLIP/04.cpt

EAGER2011-1B migrated shipboard stack



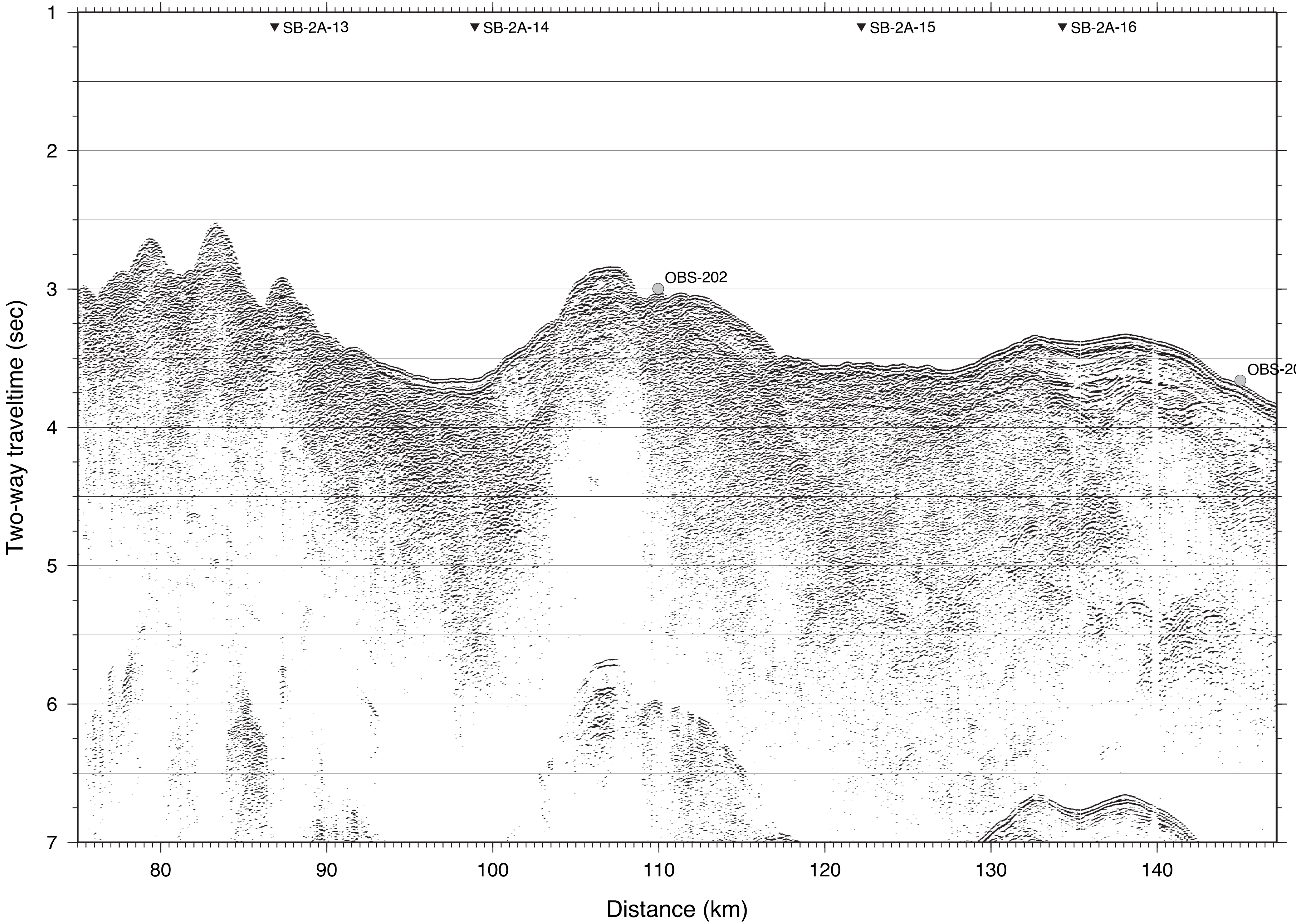
grdimage 1B/stack-mig.grd -R75/127.5375/1/7.0 -Jx0.12/-1.0 -C./CLIP/04.cpt

EAGER2011-Merge2A unmigrated shipboard stack



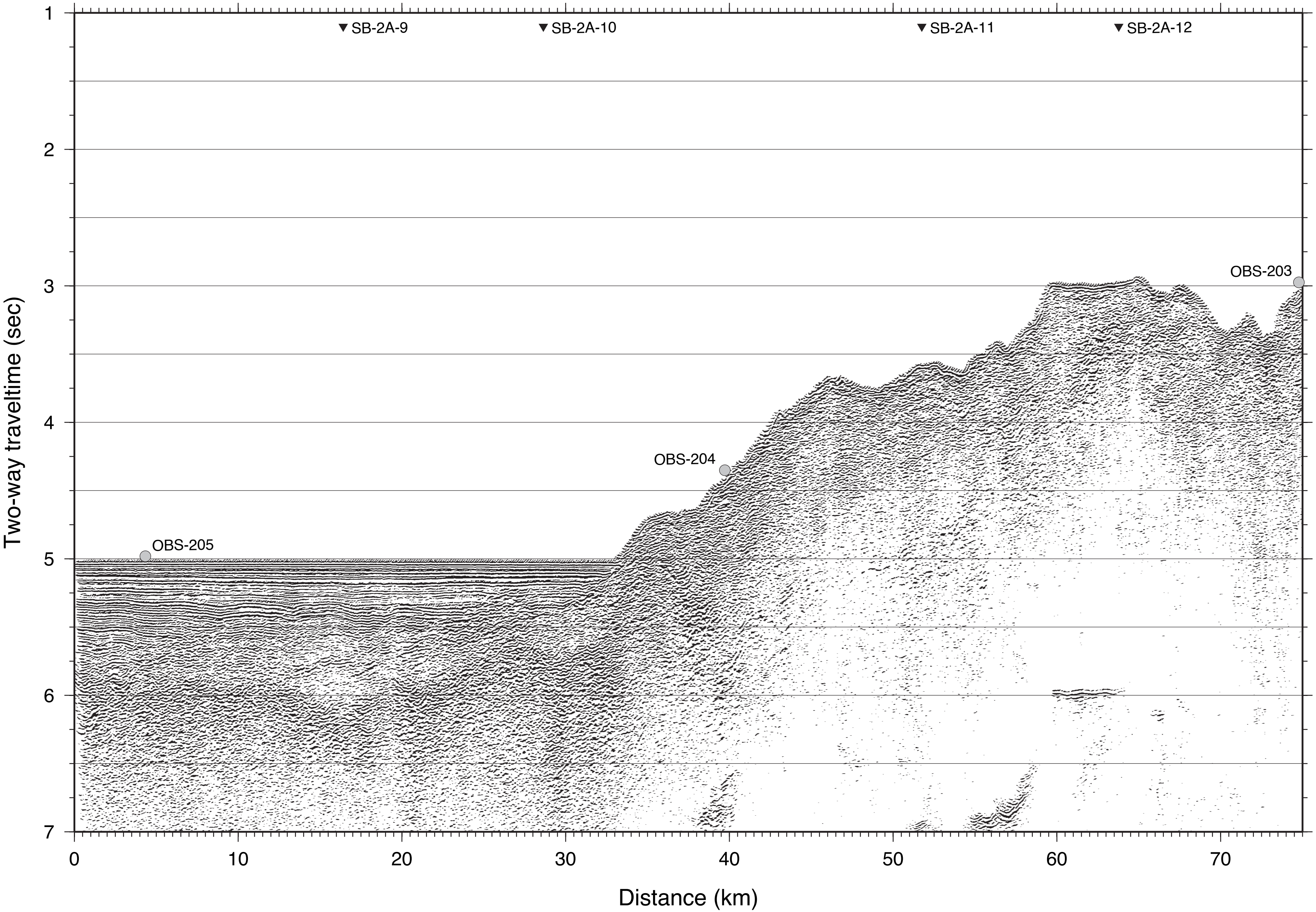
grdimage Merge2A/stack-final.grd -R0/75/1/7.0 -Jx0.12/-1.0 -C./CLIP/04.cpt

EAGER2011-Merge2A unmigrated shipboard stack



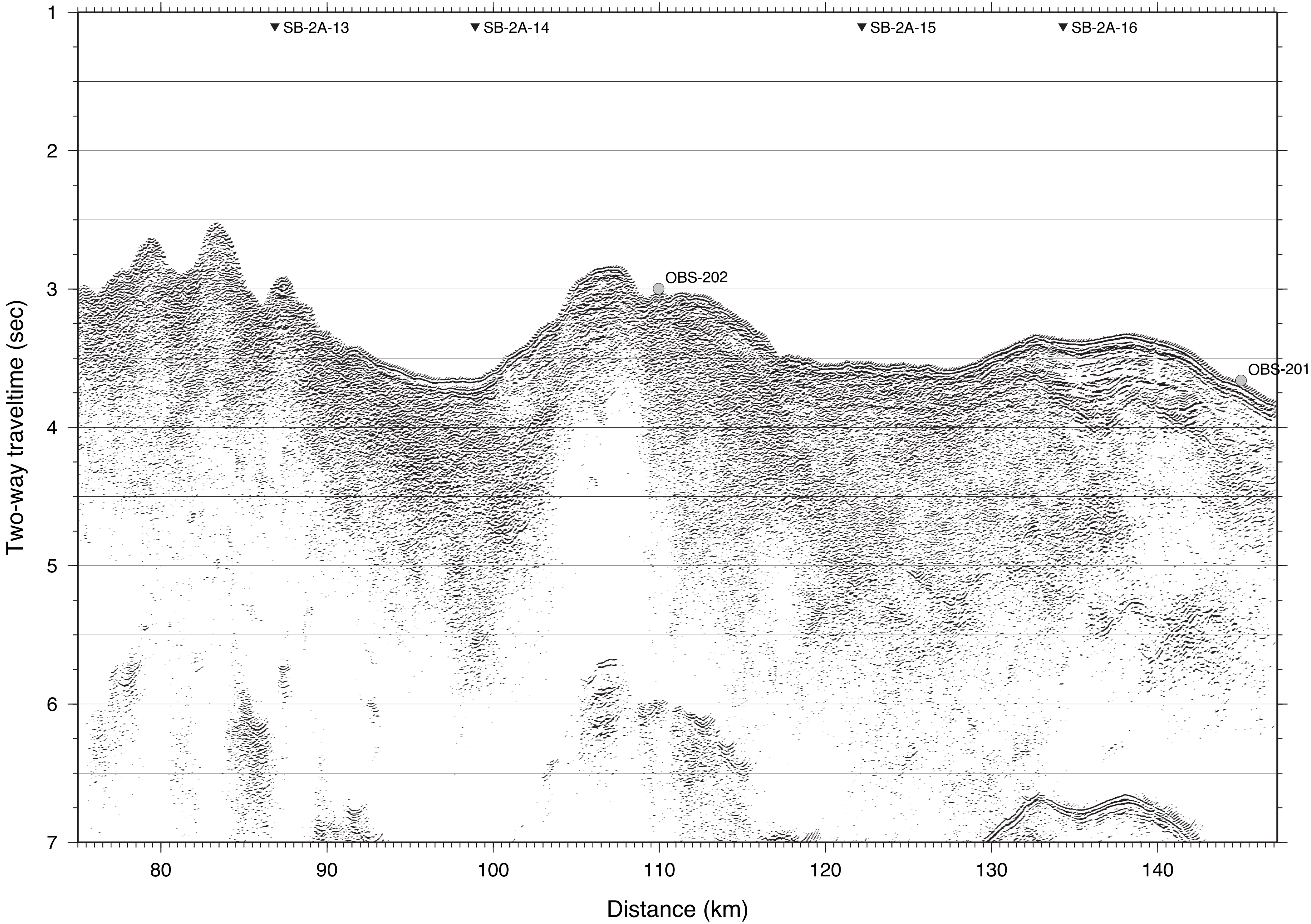
grdimage Merge2A/stack-final.grd -R75/147.2/1/7.0 -Jx0.12/-1.0 -C./CLIP/04.cpt

EAGER2011-Merge2A migrated shipboard stack



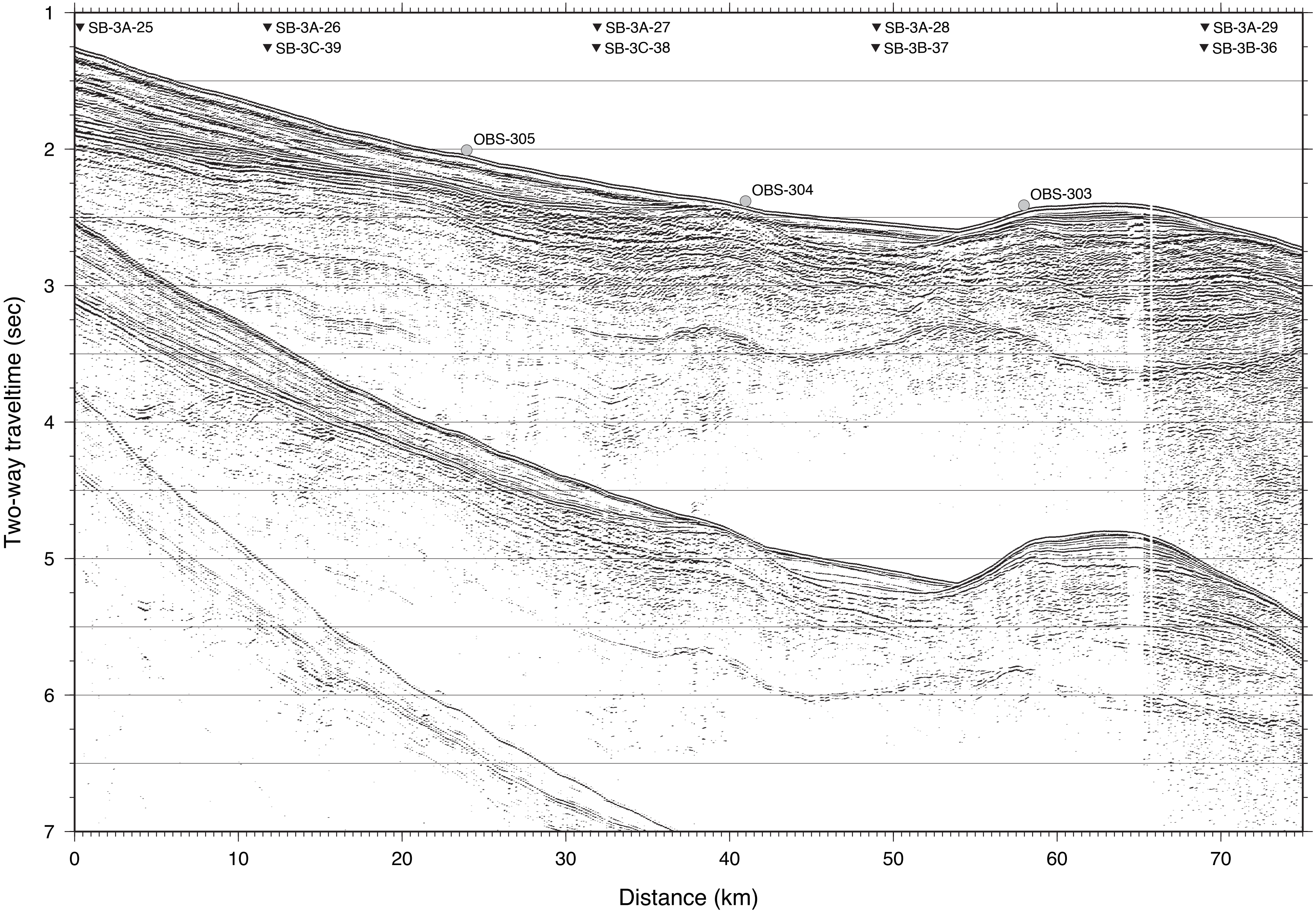
grdimage Merge2A/stack-mig.grd -R0/75/1/7.0 -Jx0.12/-1.0 -C./CLIP/04.cpt

EAGER2011-Merge2A migrated shipboard stack



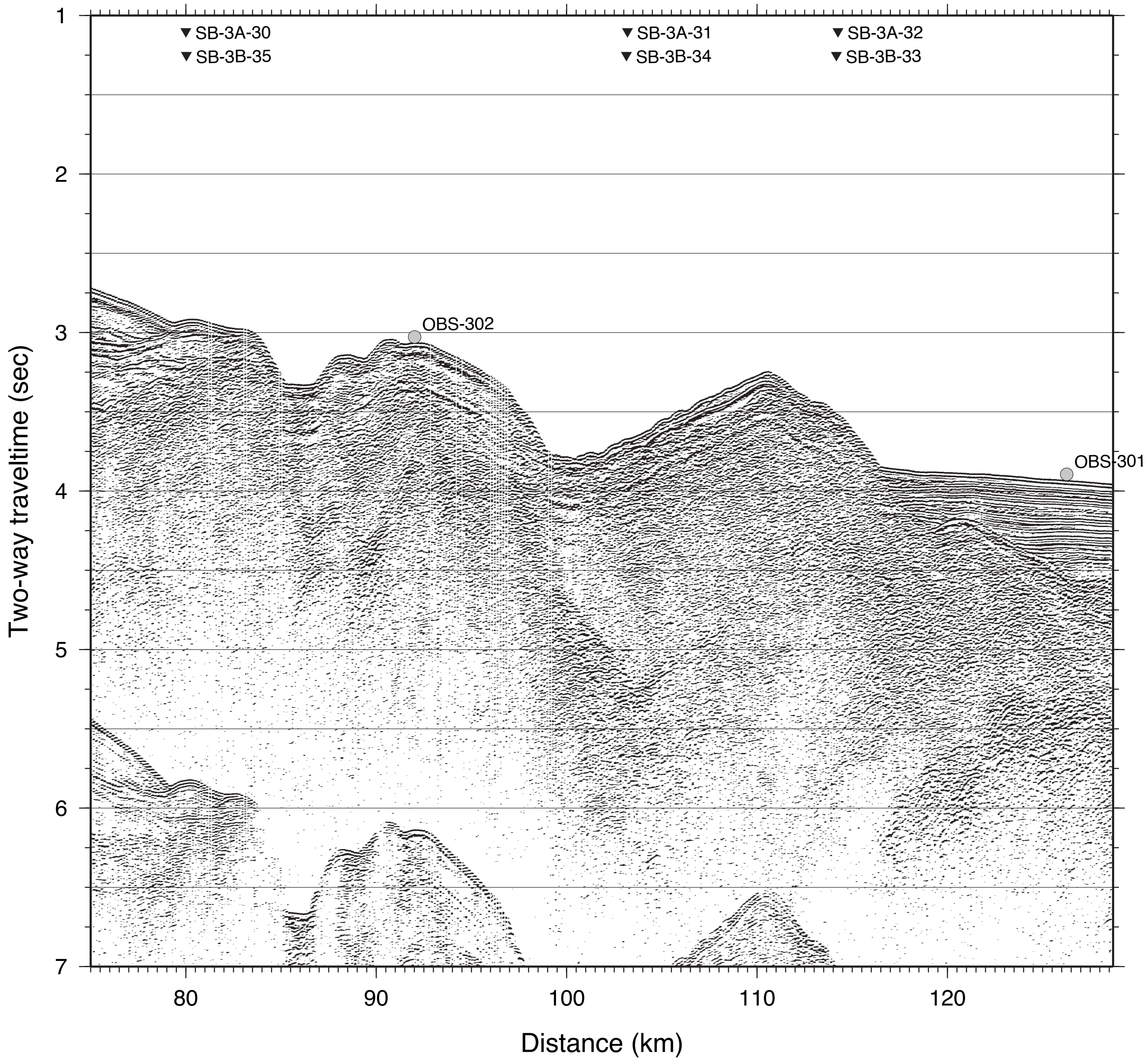
grdimage Merge2A/stack-mig.grd -R75/147.2/1/7.0 -Jx0.12/-1.0 -C./CLIP/04.cpt

EAGER2011-Merge3A unmigrated shipboard stack



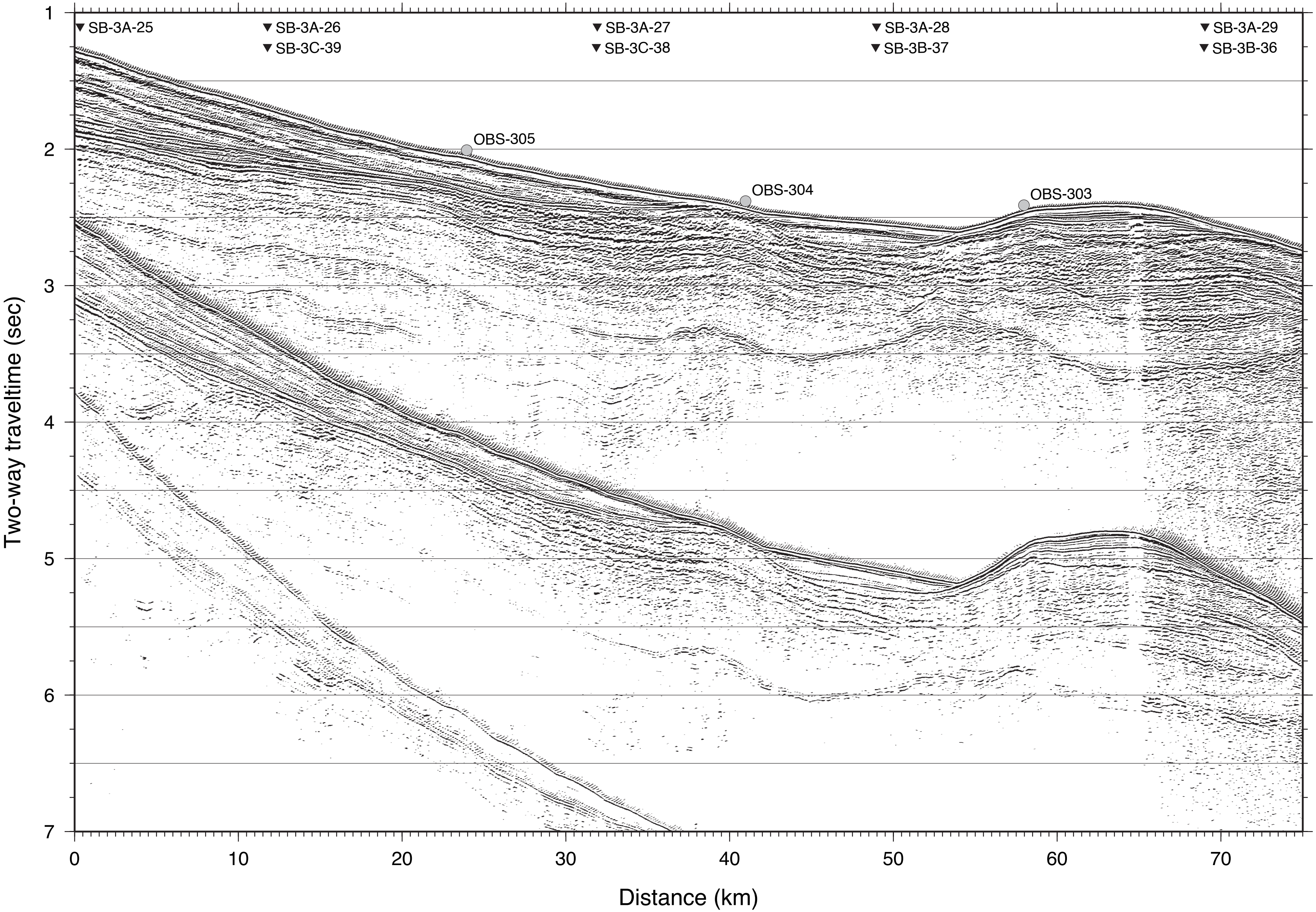
grdimage Merge3A/stack-final.grd -R0/75/1/7.0 -Jx0.12/-1.0 -C./CLIP/04.cpt

EAGER2011-Merge3A unmigrated shipboard stack



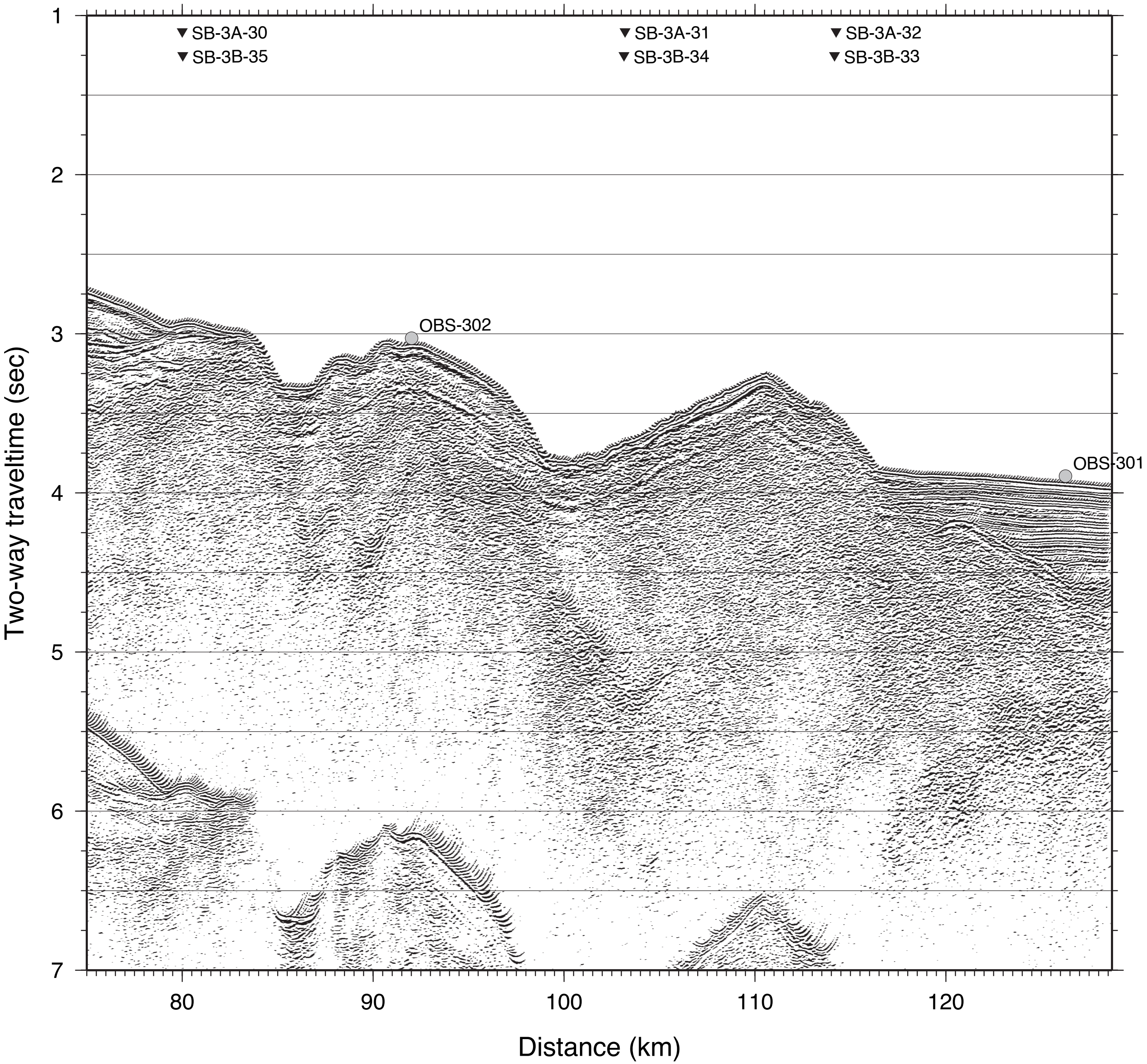
grdimage Merge3A/stack-final.grd -R75/128.7/1/7.0 -Jx0.12/-1.0 -C./CLIP/04.cpt

EAGER2011-Merge3A migrated shipboard stack



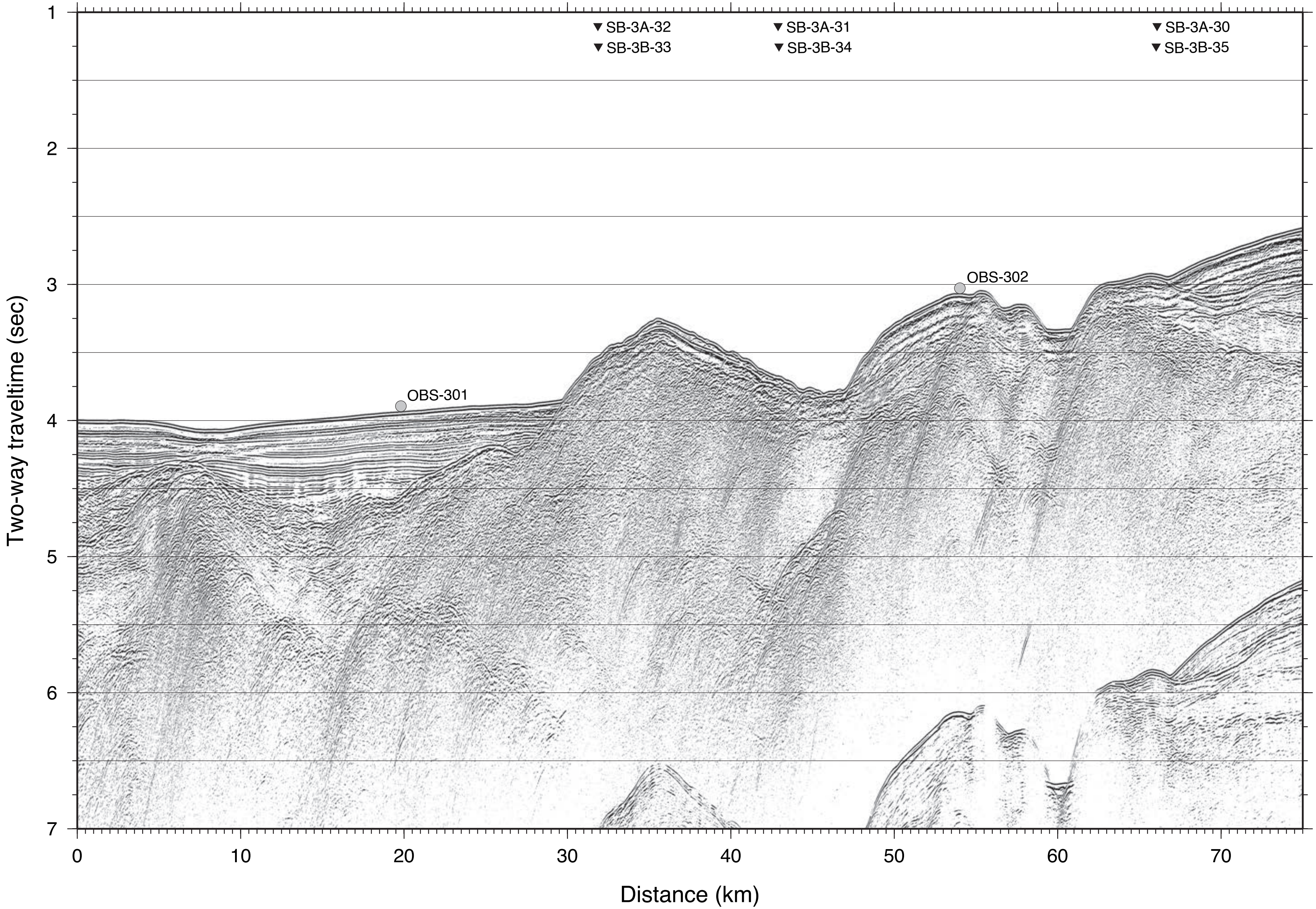
grdimage Merge3A/stack-mig.grd -R0/75/1/7.0 -Jx0.12/-1.0 -C./CLIP/04.cpt

EAGER2011-Merge3A migrated shipboard stack



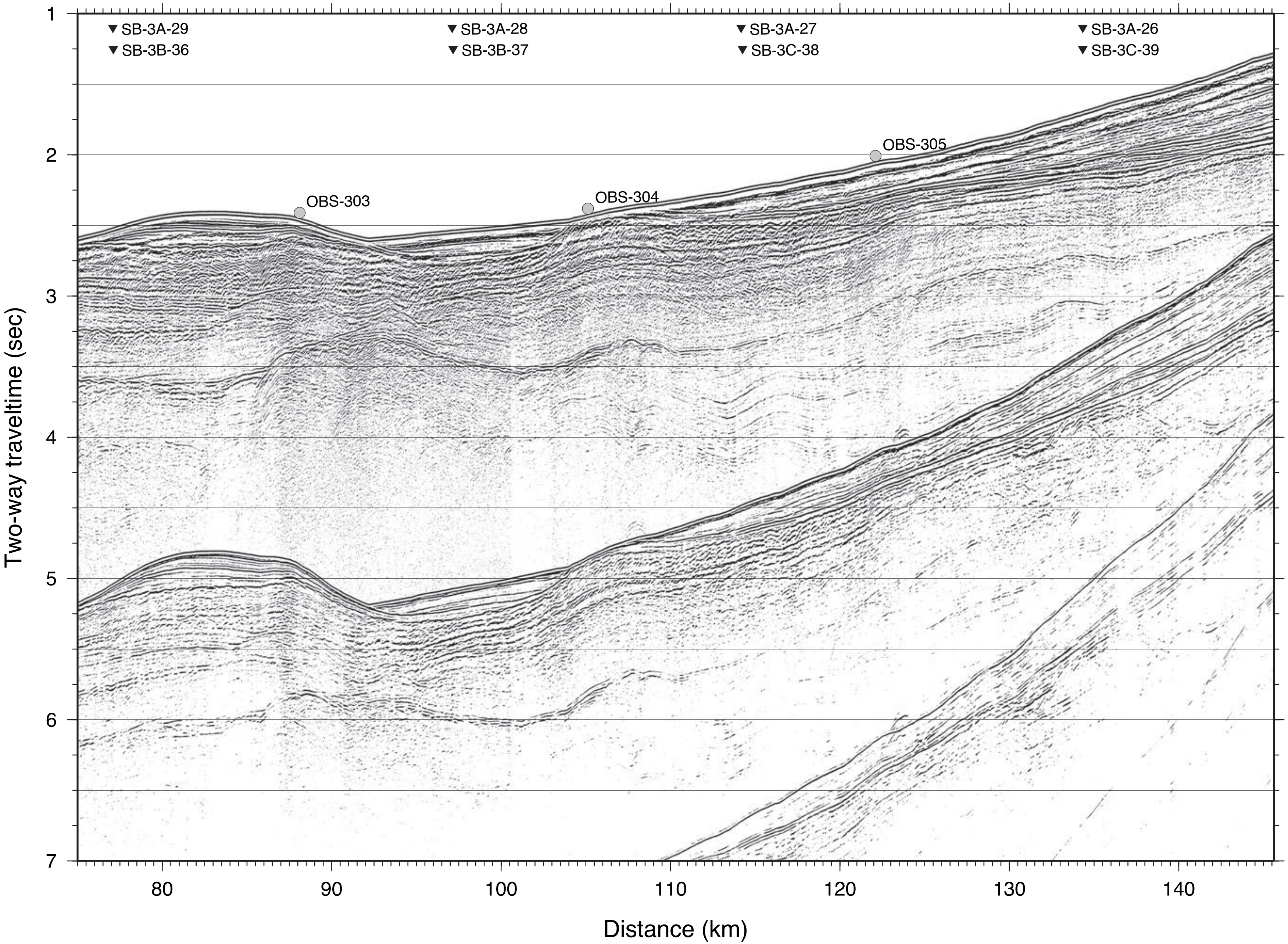
grdimage Merge3A/stack-mig.grd -R75/128.7/1/7.0 -Jx0.12/-1.0 -C./CLIP/04.cpt

EAGER2011-Merge3BC unmigrated shipboard stack



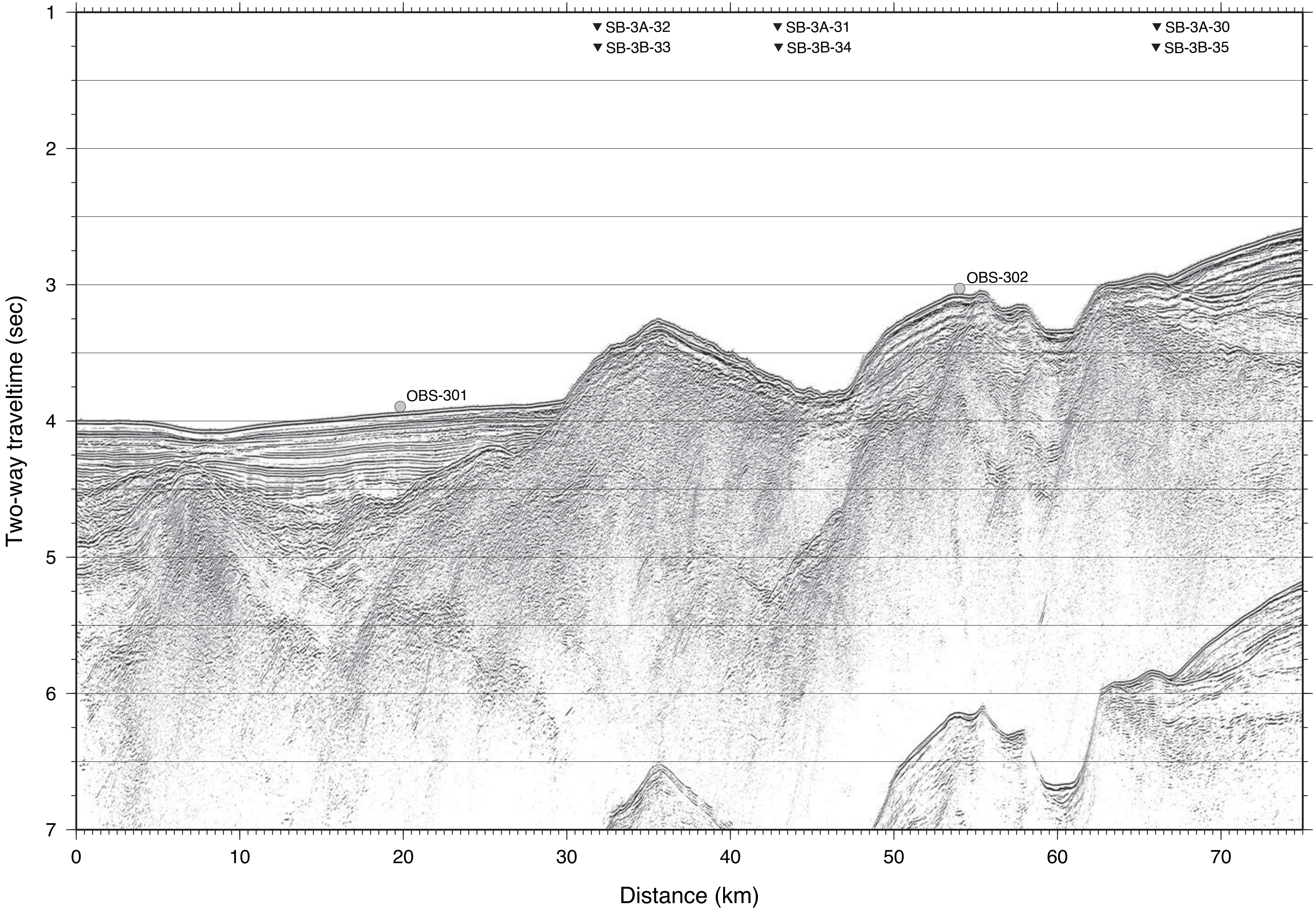
grdimage Merge3BC/stack-final.grd -R0/75/1/7.0 -Jx0.12/-1.0 -C./CLIP/04.cpt

EAGER2011-Merge3BC unmigrated shipboard stack



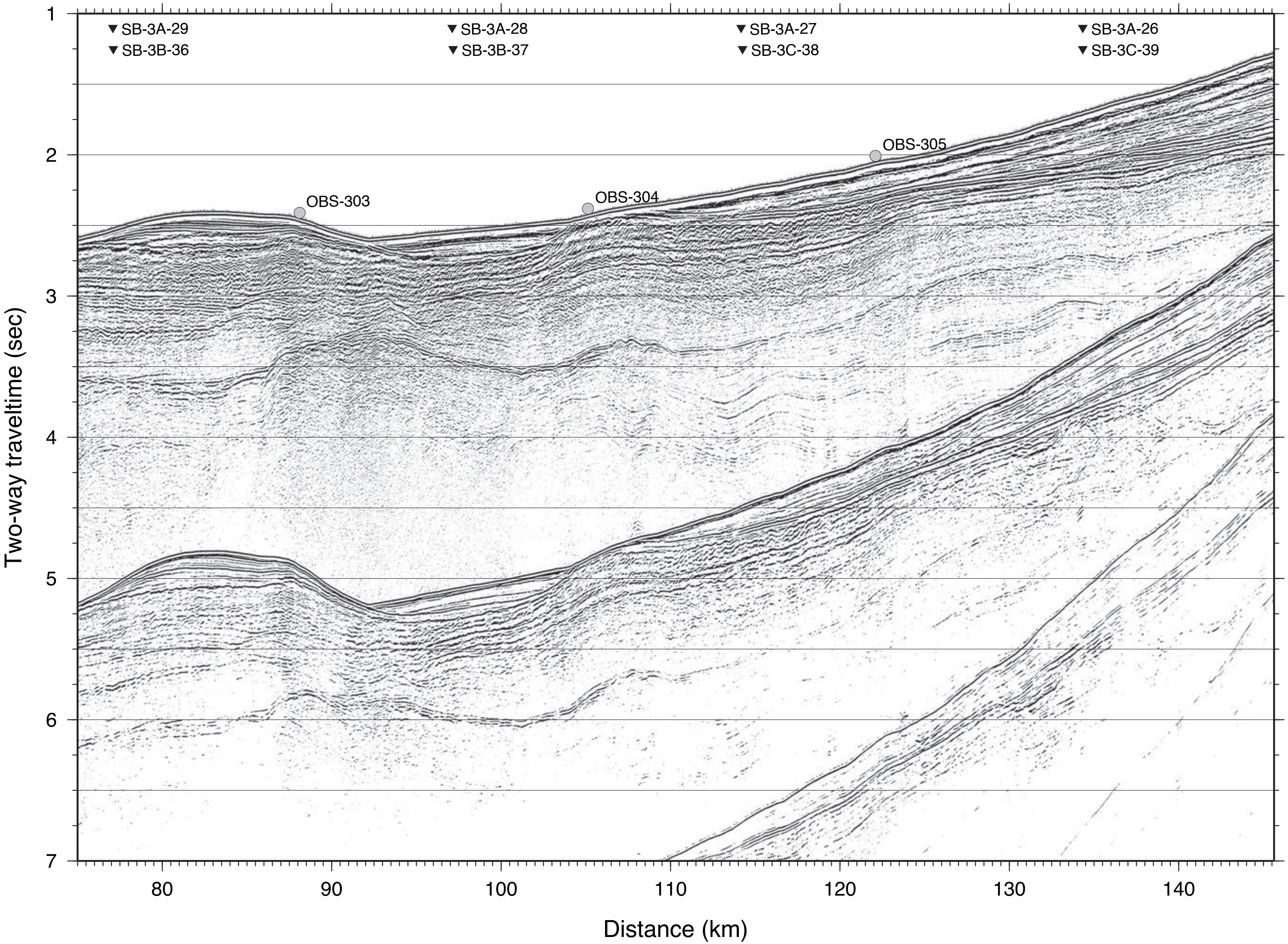
grdimage Merge3BC/stack-final.grd -R75/145.625/1/7.0 -Jx0.12/-1.0 -C./CLIP/04.cpt

EAGER2011-Merge3BC migrated shipboard stack



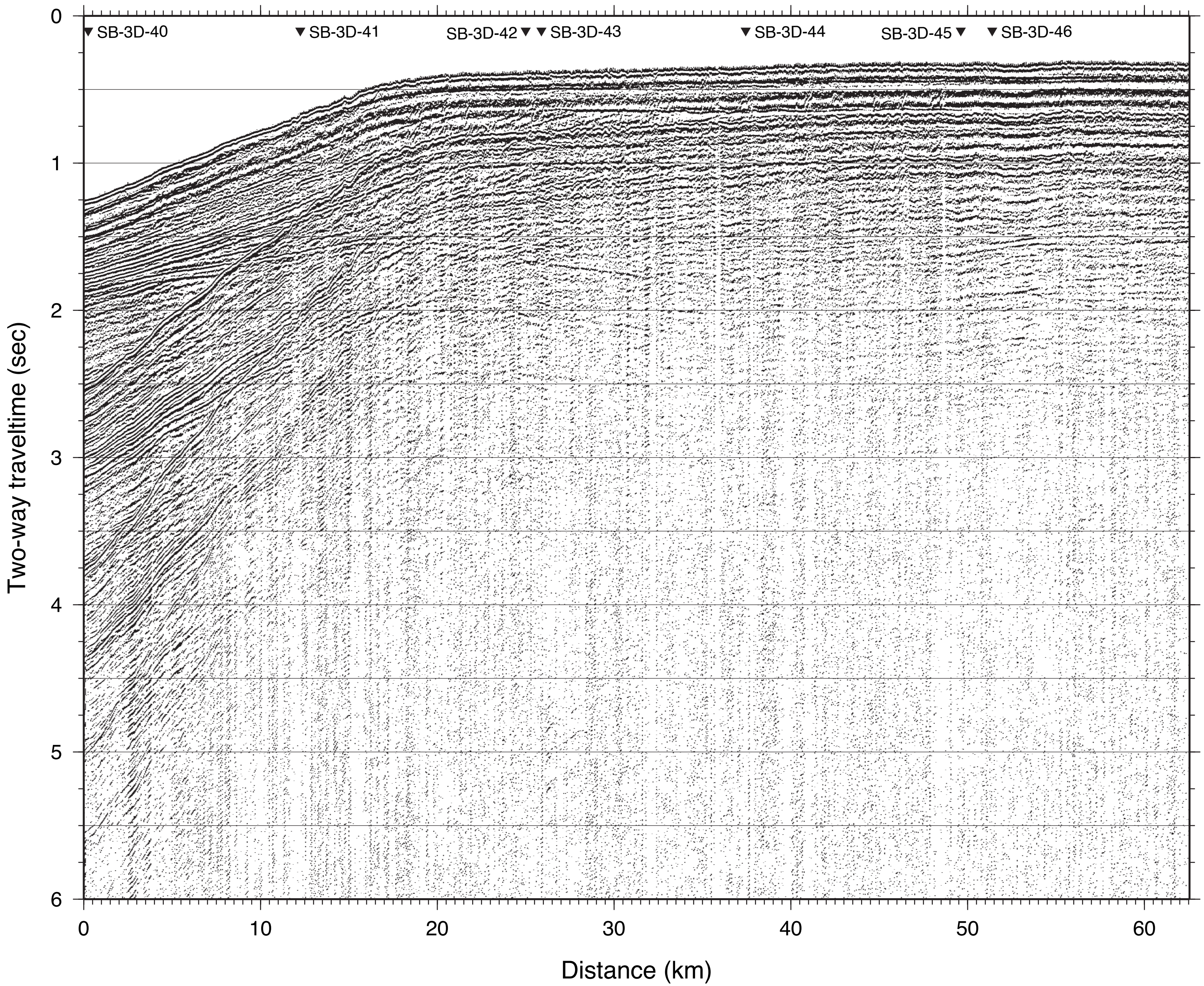
grdimage Merge3BC/stack-mig.grd -R0/75/1/7.0 -Jx0.12/-1.0 -C./CLIP/04.cpt

EAGER2011-Merge3BC migrated shipboard stack



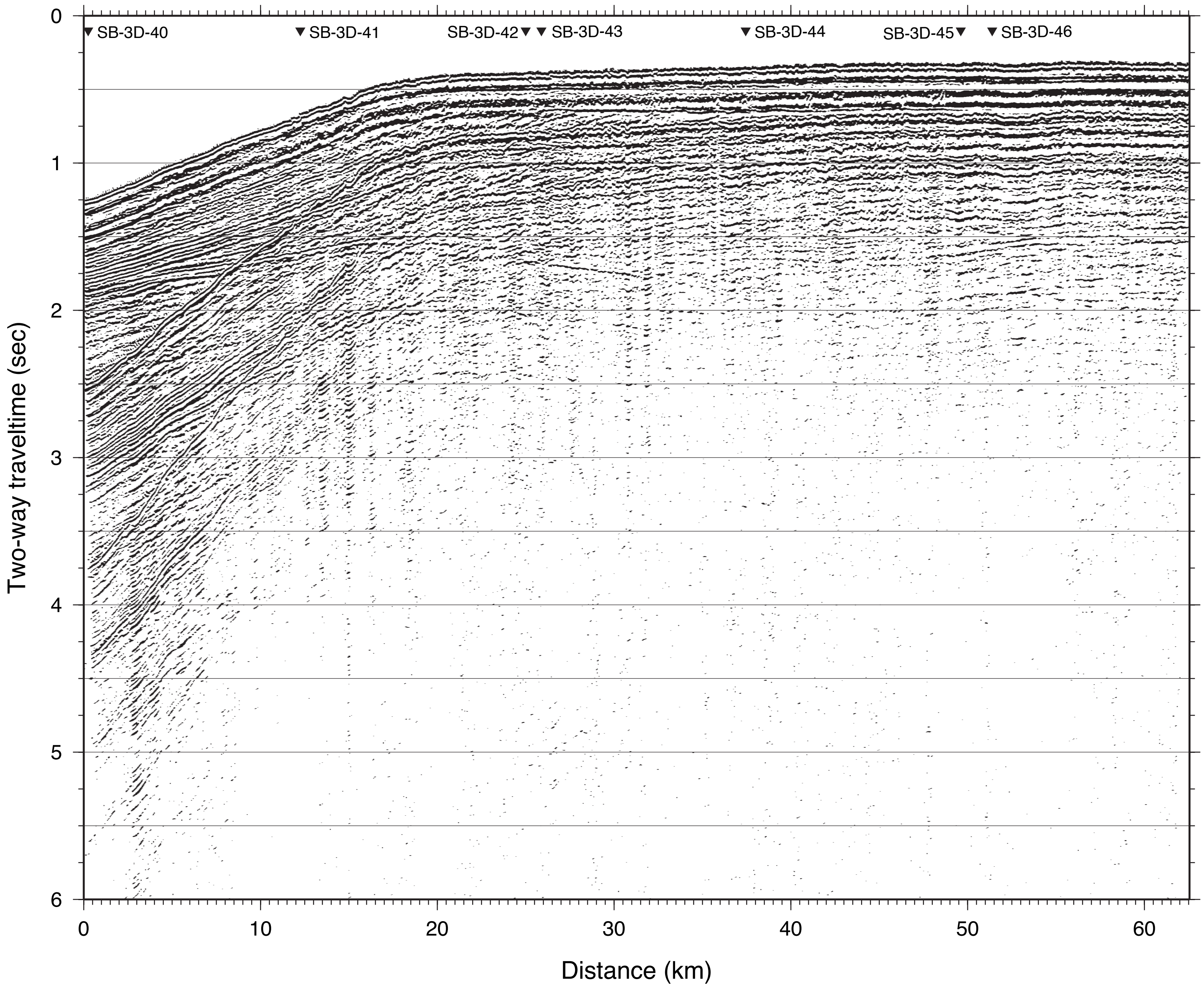
grdimage Merge3BC/stack-mig.grd -R75/145.625/1/7.0 -Jx0.12/-1.0 -C./CLIP/04.cpt

EAGER2011-3D unmigrated shipboard stack



grdimage 3D/stack-final.grd -R0/62.55/0/6.0 -Jx0.12/-1.0 -C./CLIP/02.cpt

EAGER2011-3D migrated shipboard stack

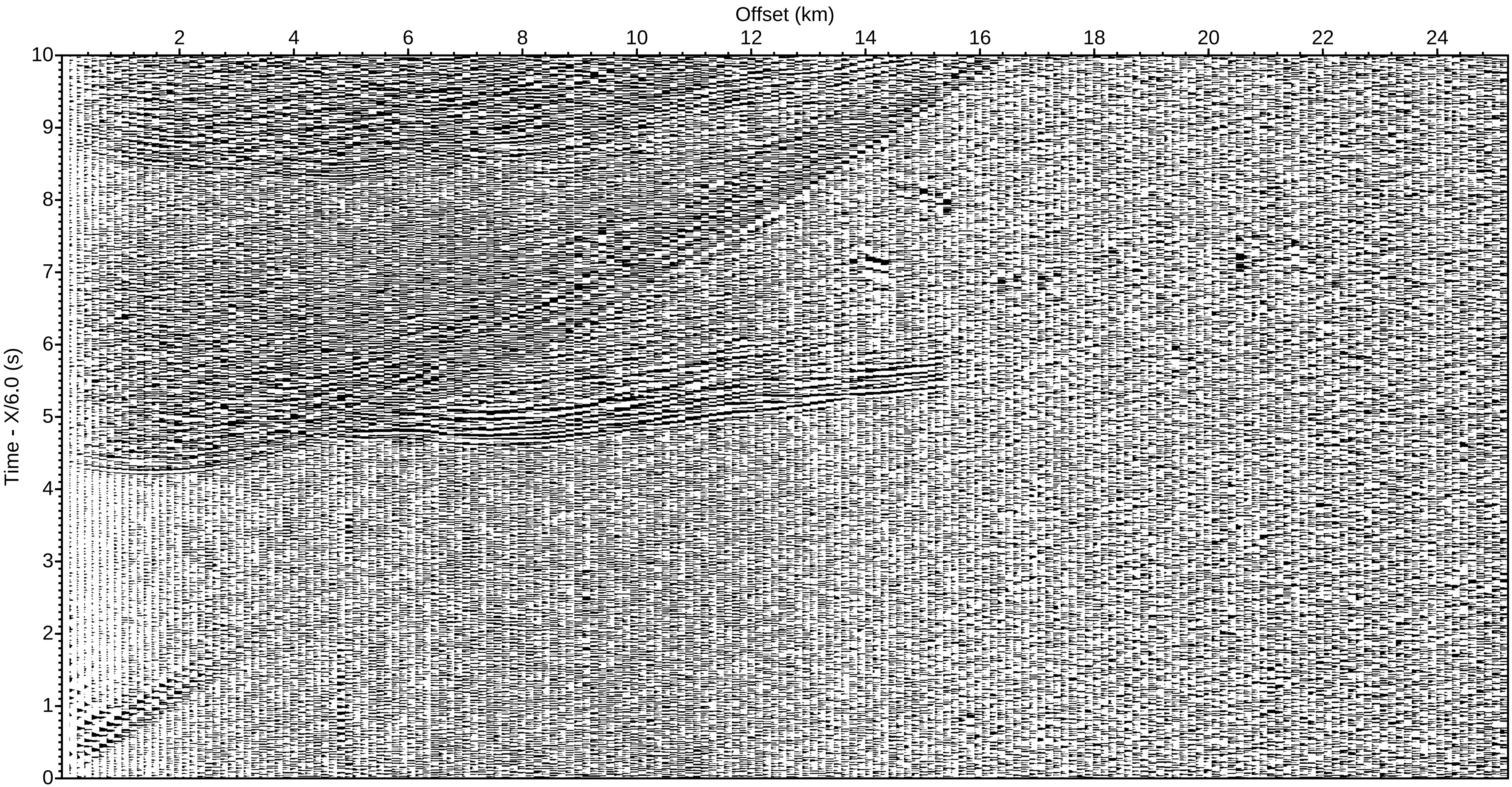


grdimage 3D/stack-mig.grd -R0/62.55/0/6.0 -Jx0.12/-1.0 -C./CLIP/02.cpt

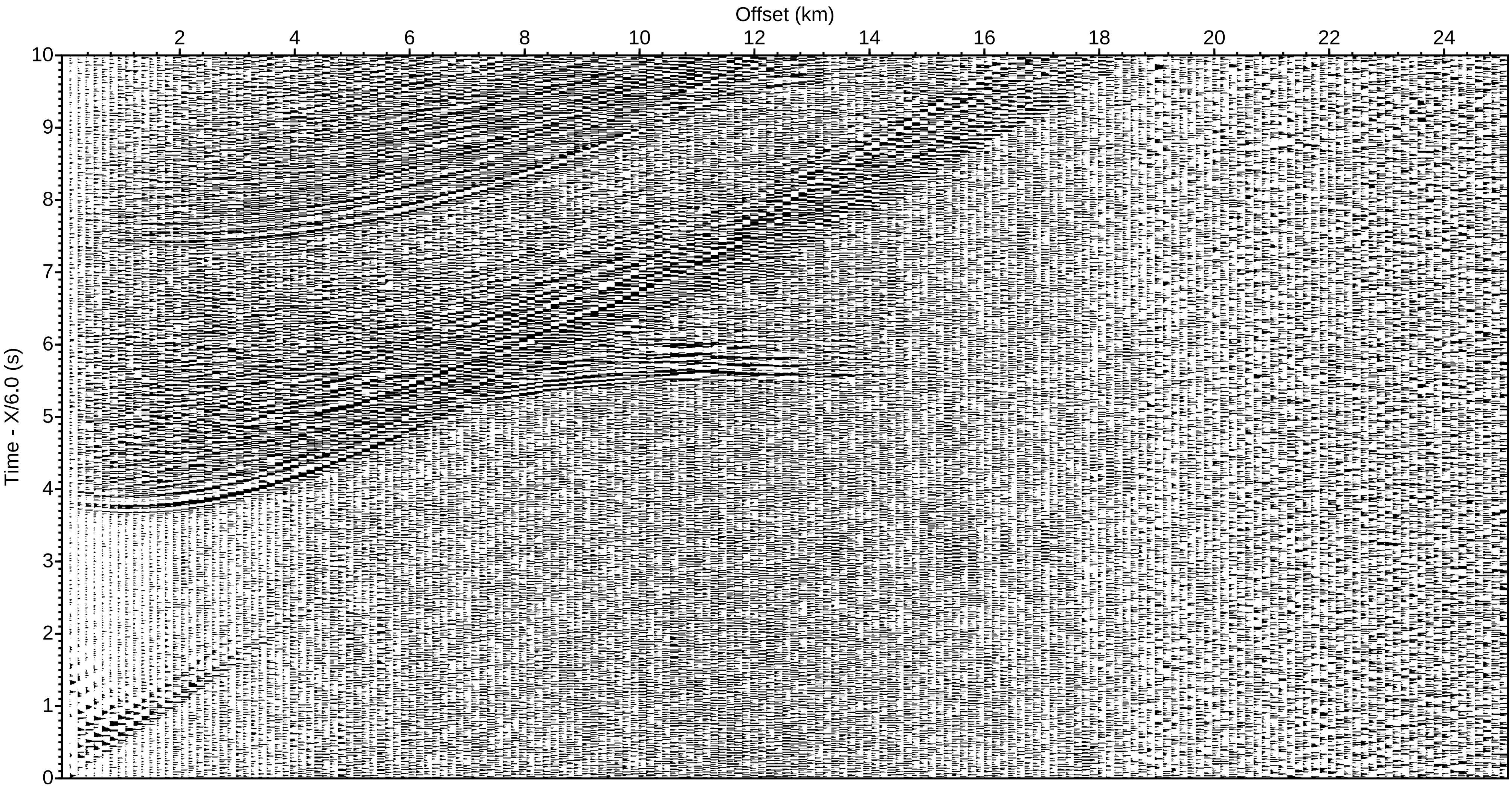
Appendix V-A

Raw Record Sections of Selected Sonobuoys

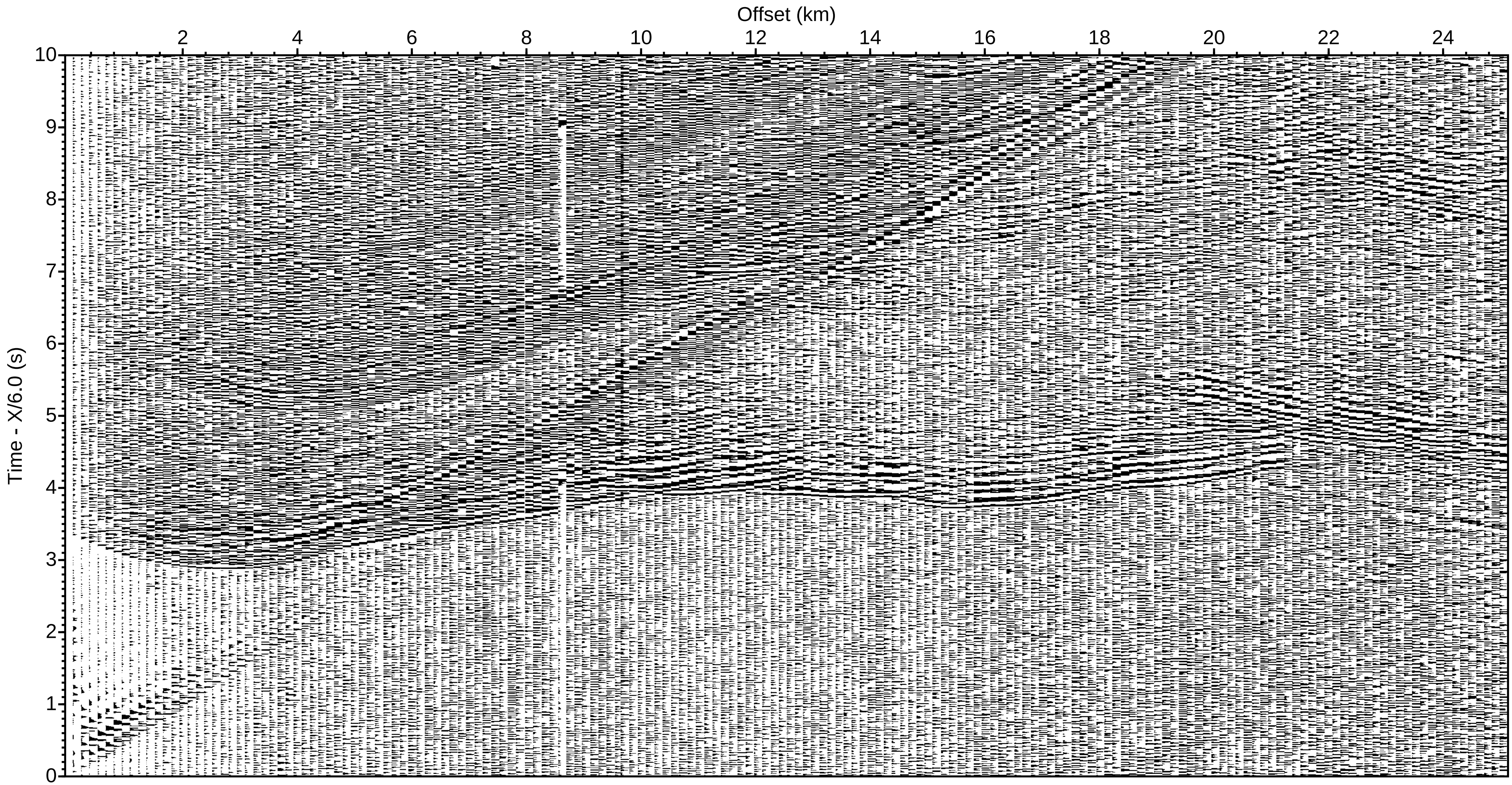
Shot-receiver offsets (horizontal scale) in the record sections are not corrected for the drift of the sonobuoys. Vertical scale is the travel time reduced with a reduction velocity of 6.0 km/s.



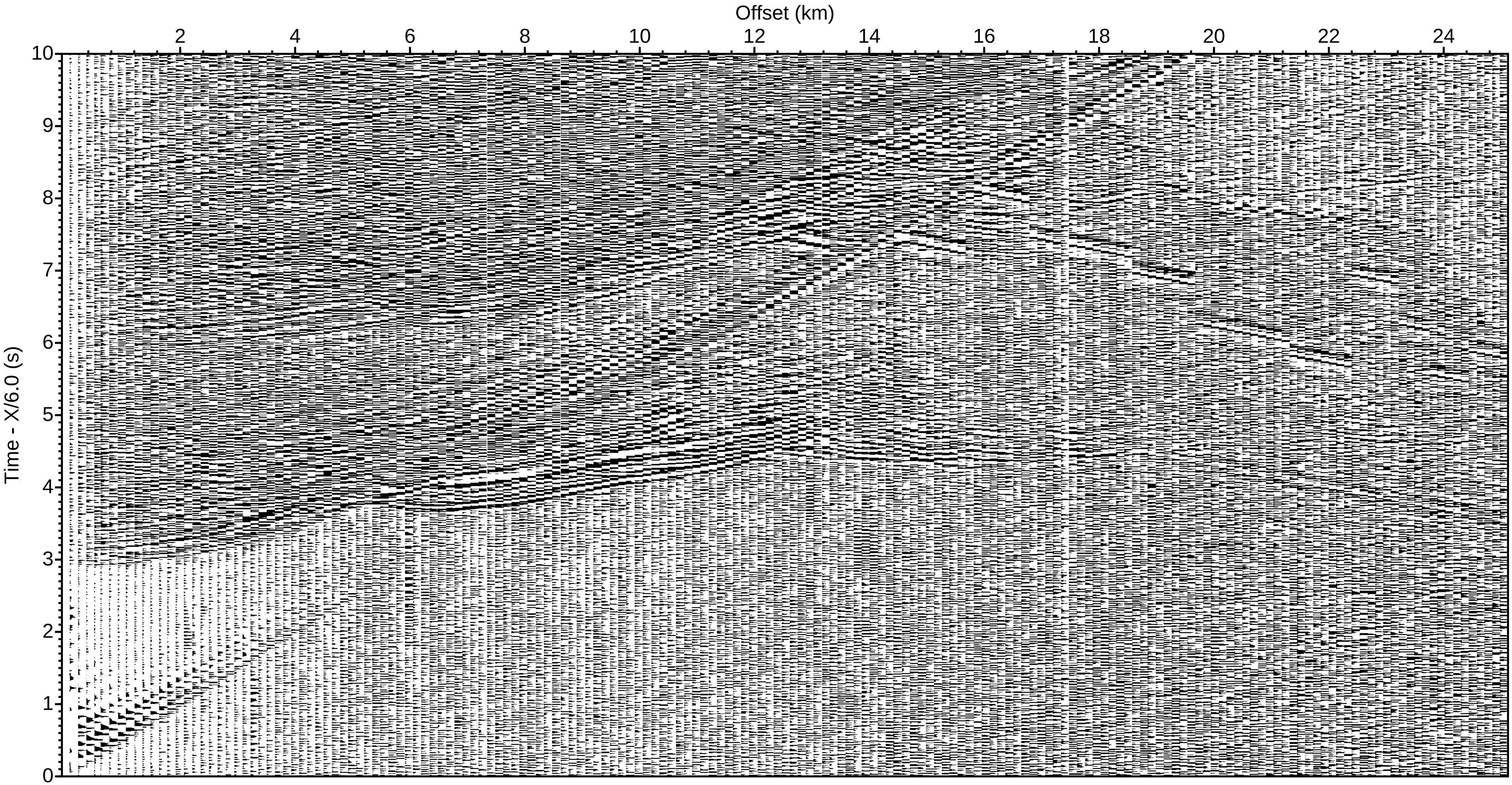
EAGER 2011 - Sonobuoy 1A-1aux1 (deconv., bpf 5-36 Hz)



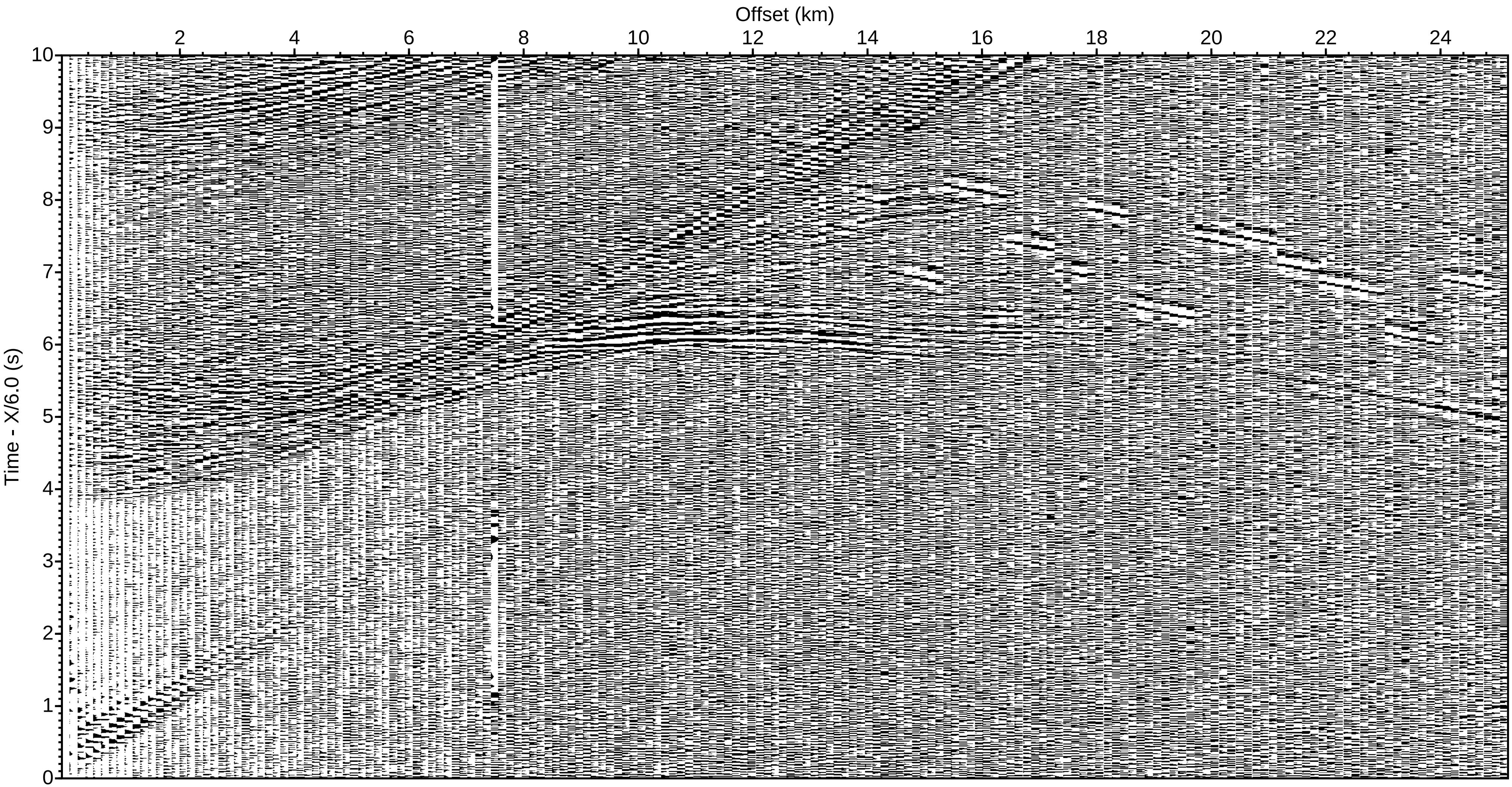
EAGER 2011 - Sonobuoy 1A-2aux2 (deconv., bpf 5-36 Hz)



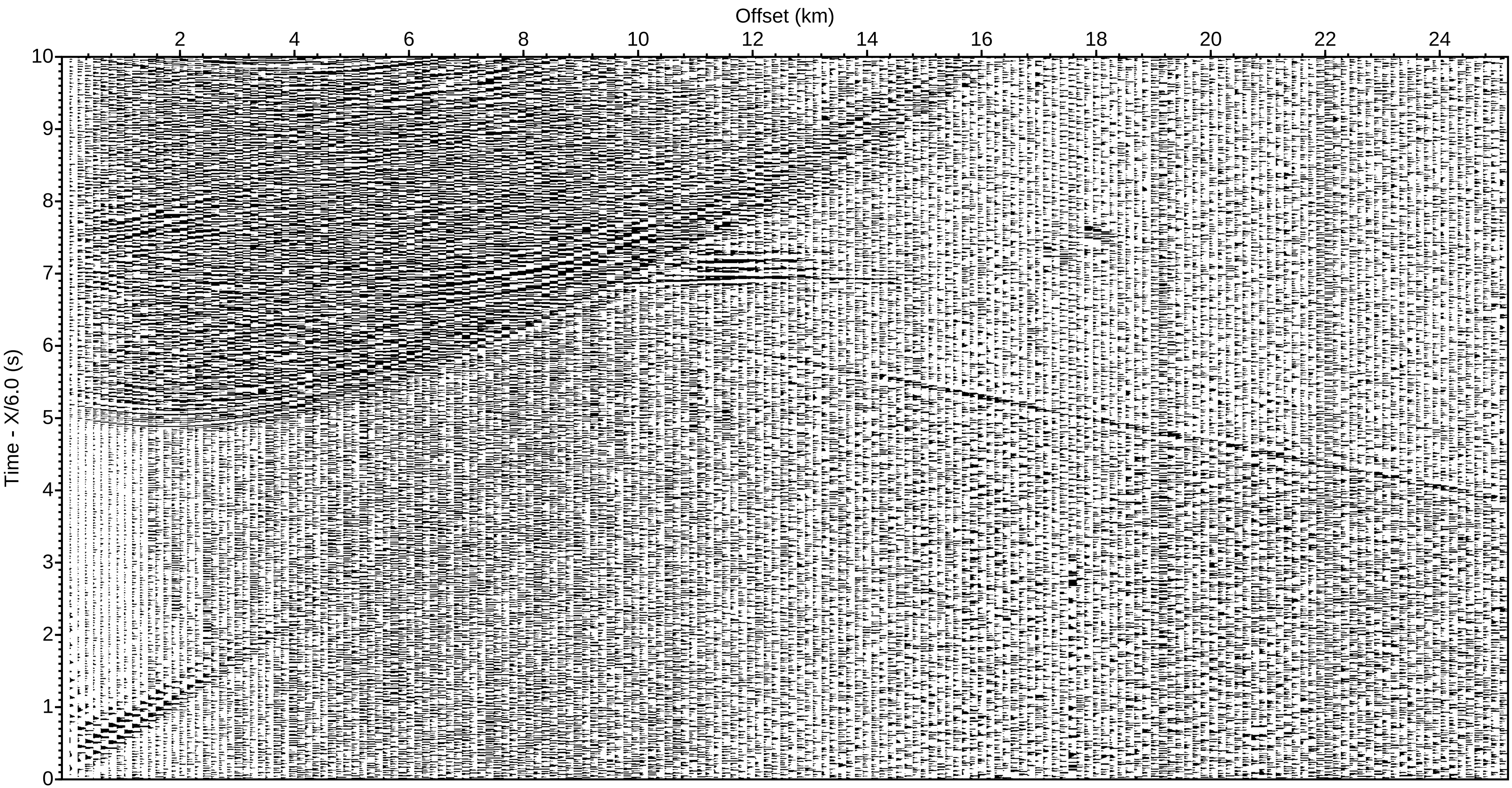
EAGER 2011 - Sonobuoy 1A-3aux3 (deconv., bpf 5-36 Hz)



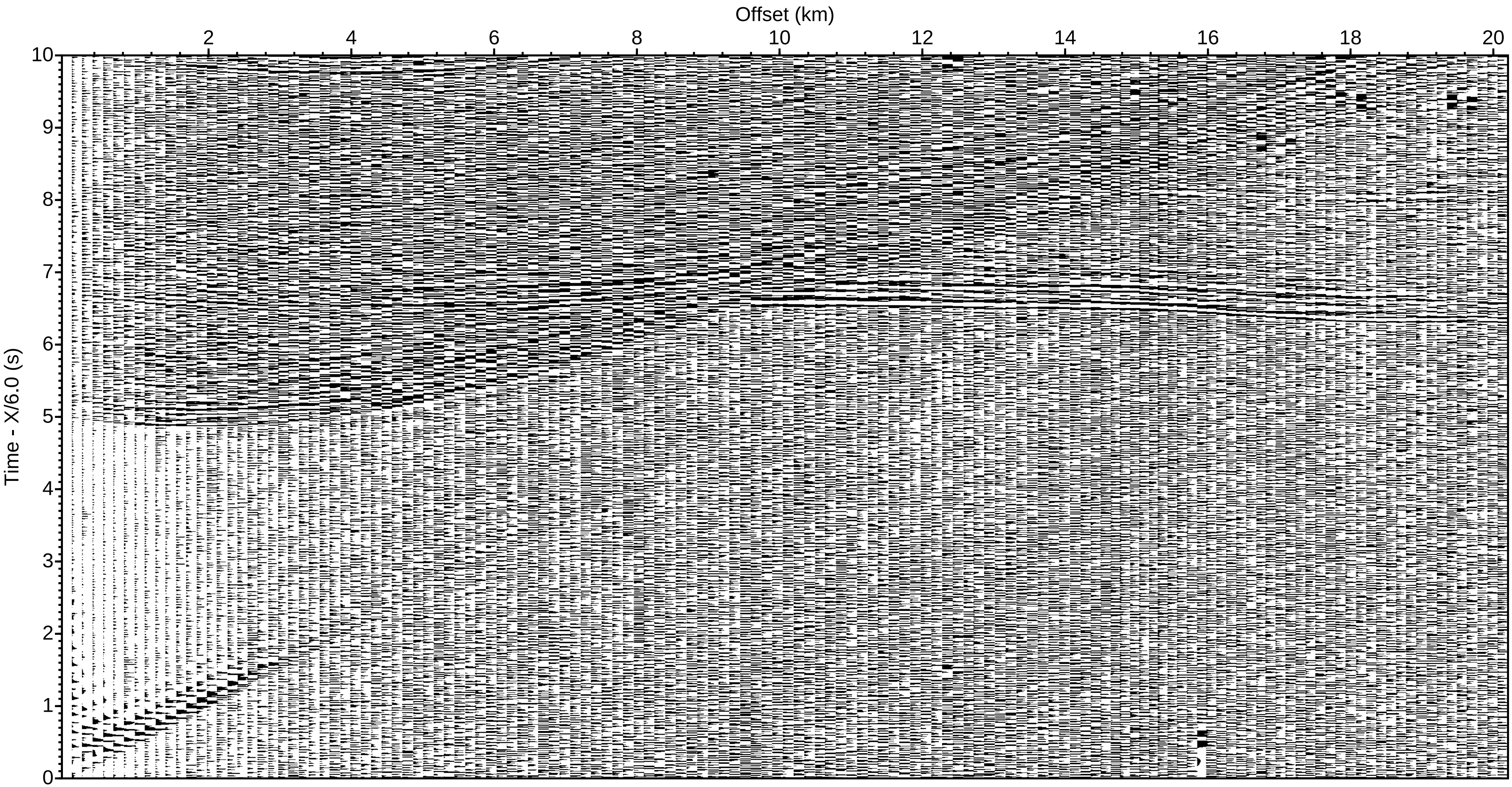
EAGER 2011 - Sonobuoy 1A-4aux4 (deconv., bpf 5-36 Hz)



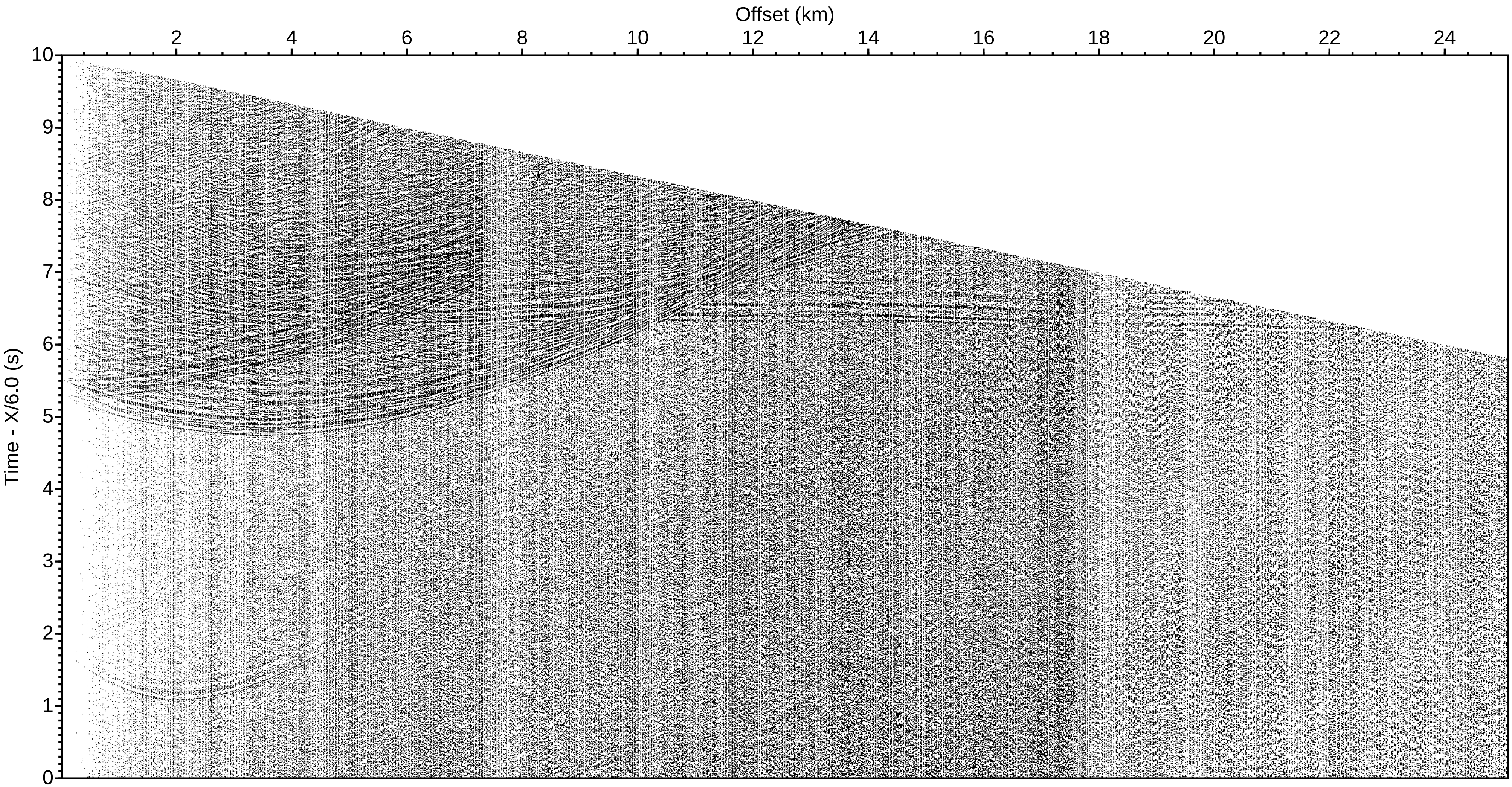
EAGER 2011 - Sonobuoy 1A-5aux1 (deconv., bpf 5-36 Hz)



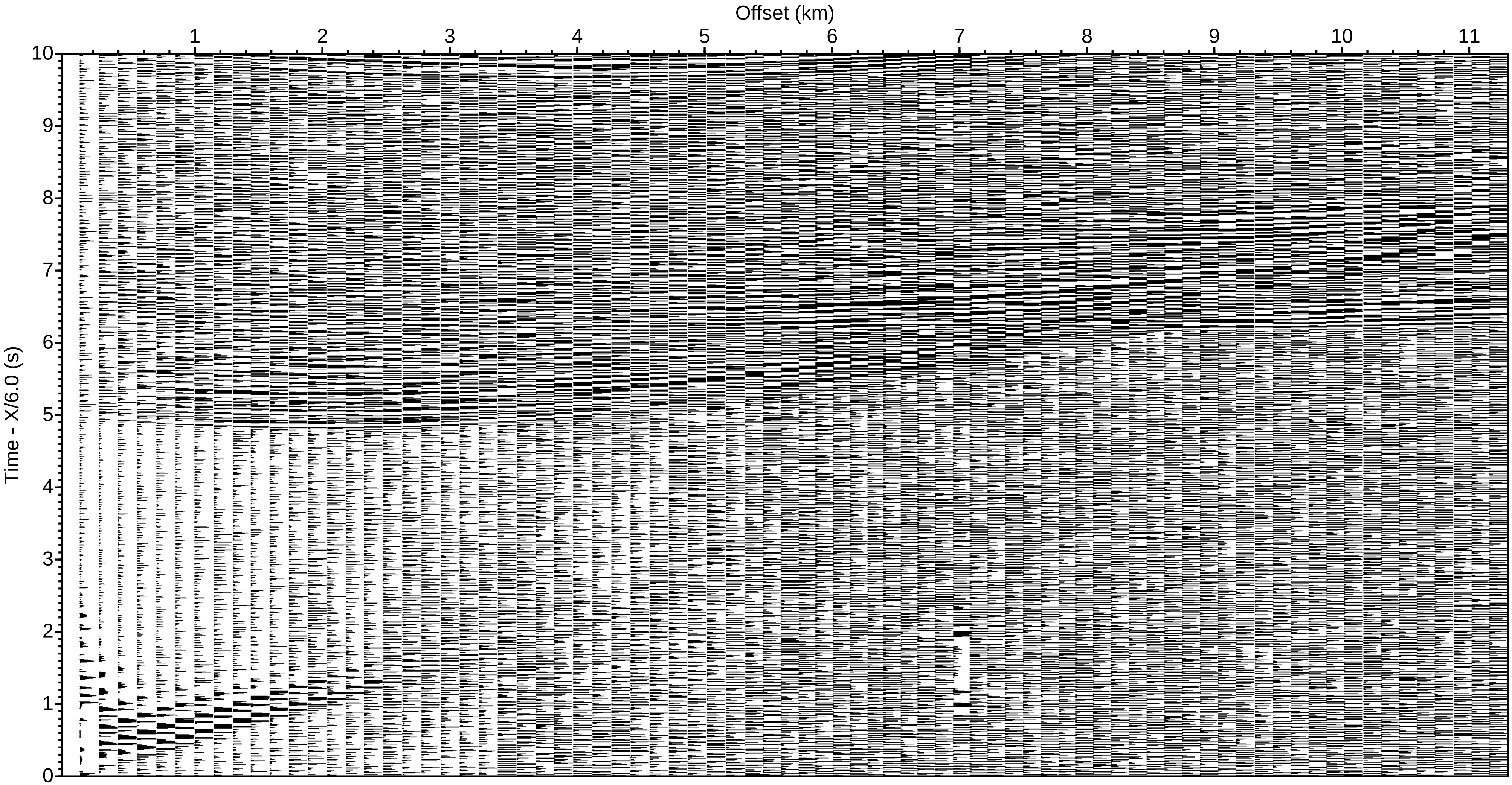
EAGER 2011 - Sonobuoy 1A-6aux2 (deconv., bpf 5-36 Hz)



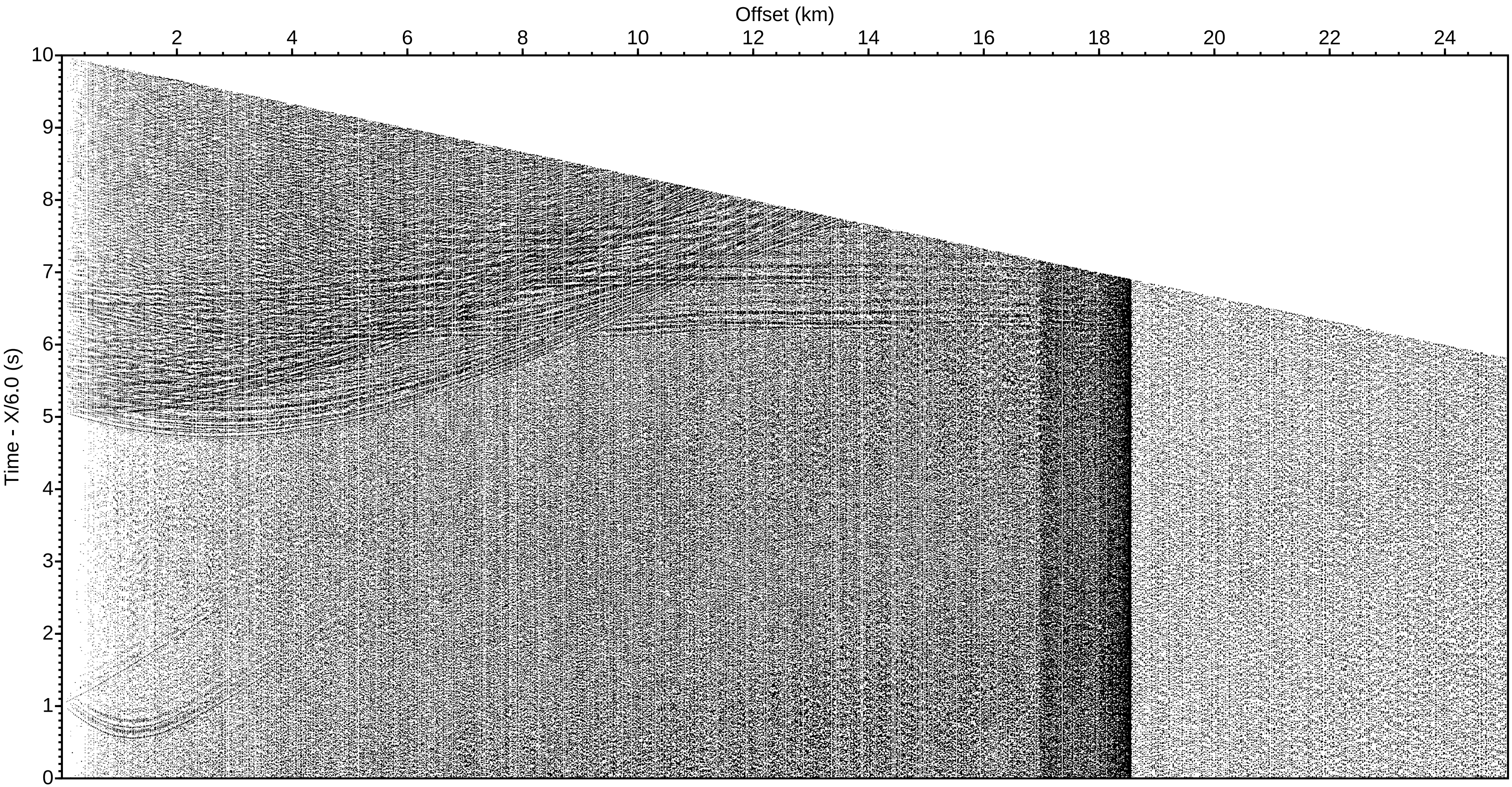
EAGER 2011 - Sonobuoy 1A-7aux3 (deconv., bpf 5-36 Hz)



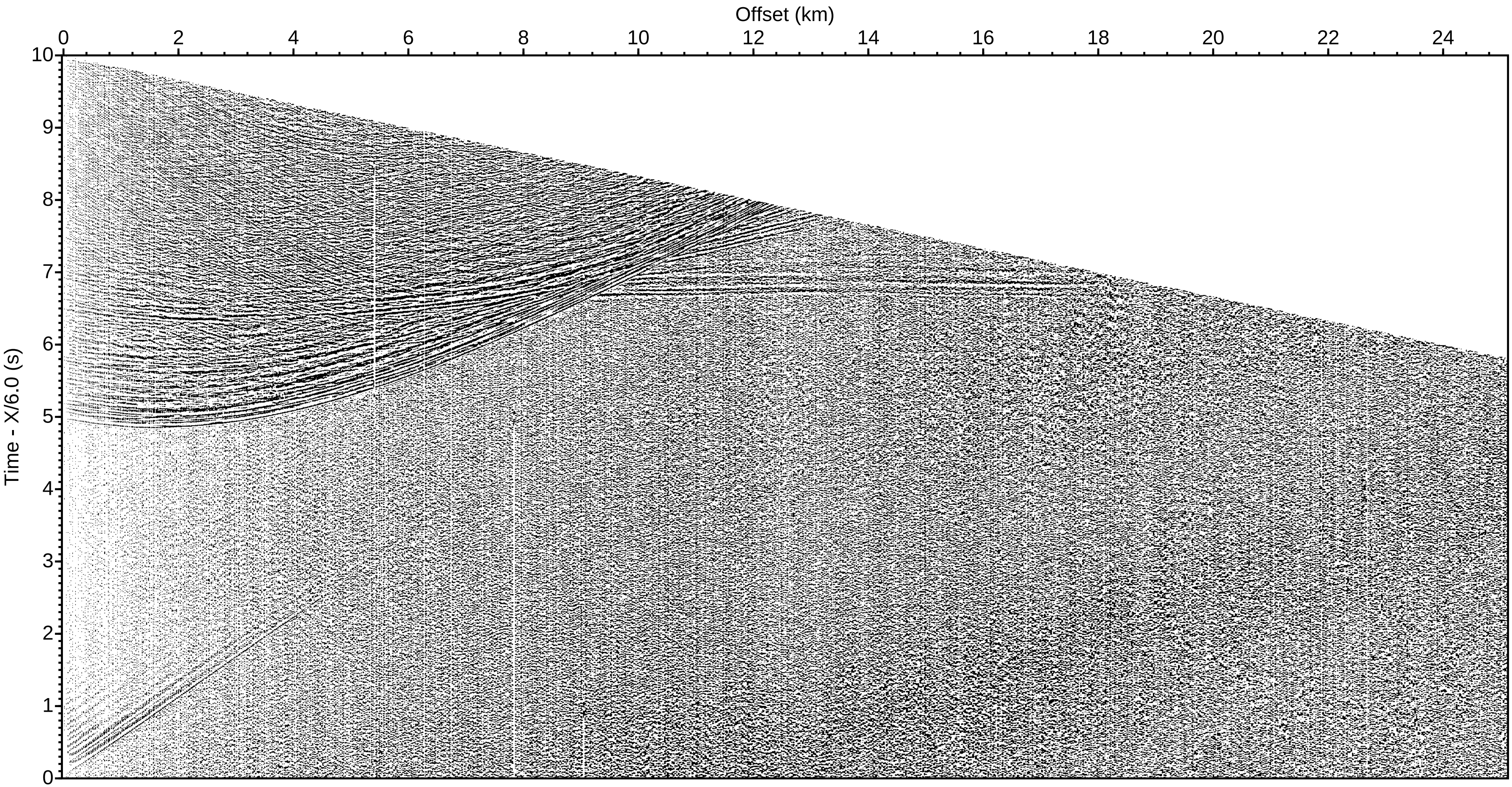
EAGER 2011 - Sonobuoy 1B-7aux3 (deconv., bpf 5-36 Hz)



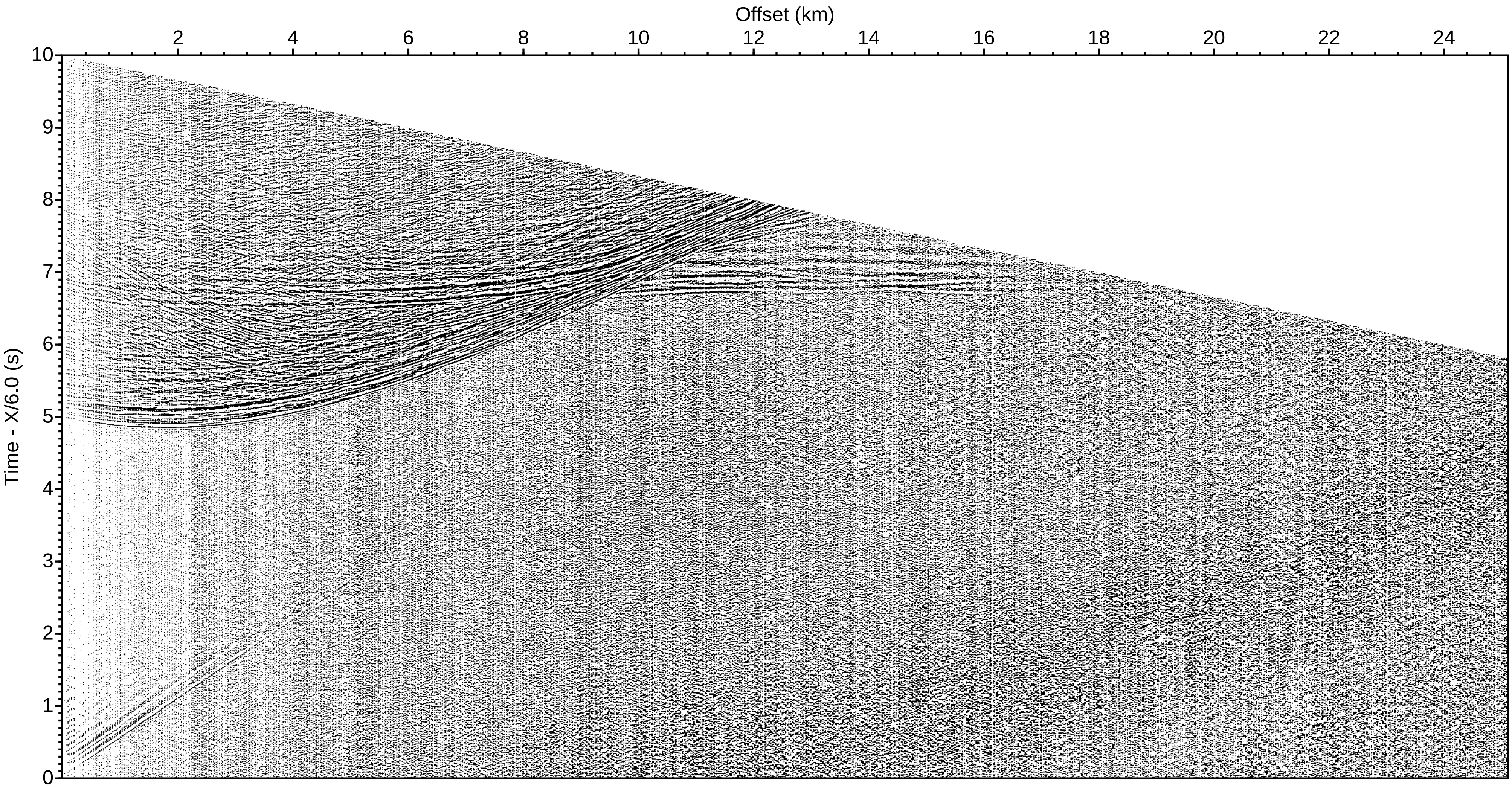
EAGER 2011 - Sonobuoy 1A-8aux4 (deconv., bpf 5-36 Hz)



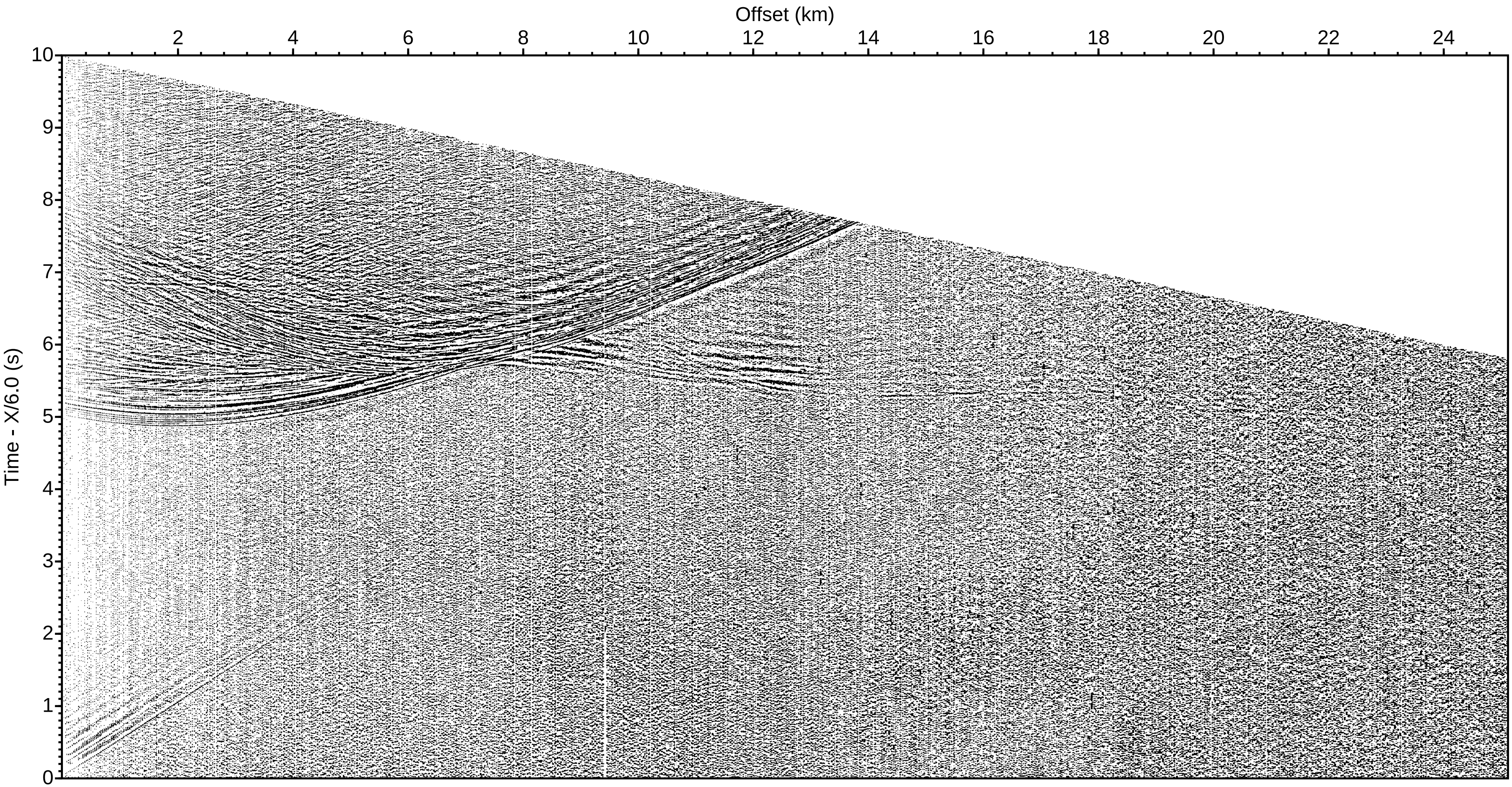
EAGER 2011 - Sonobuoy 1B-8aux4 (deconv., bpf 5-36 Hz)



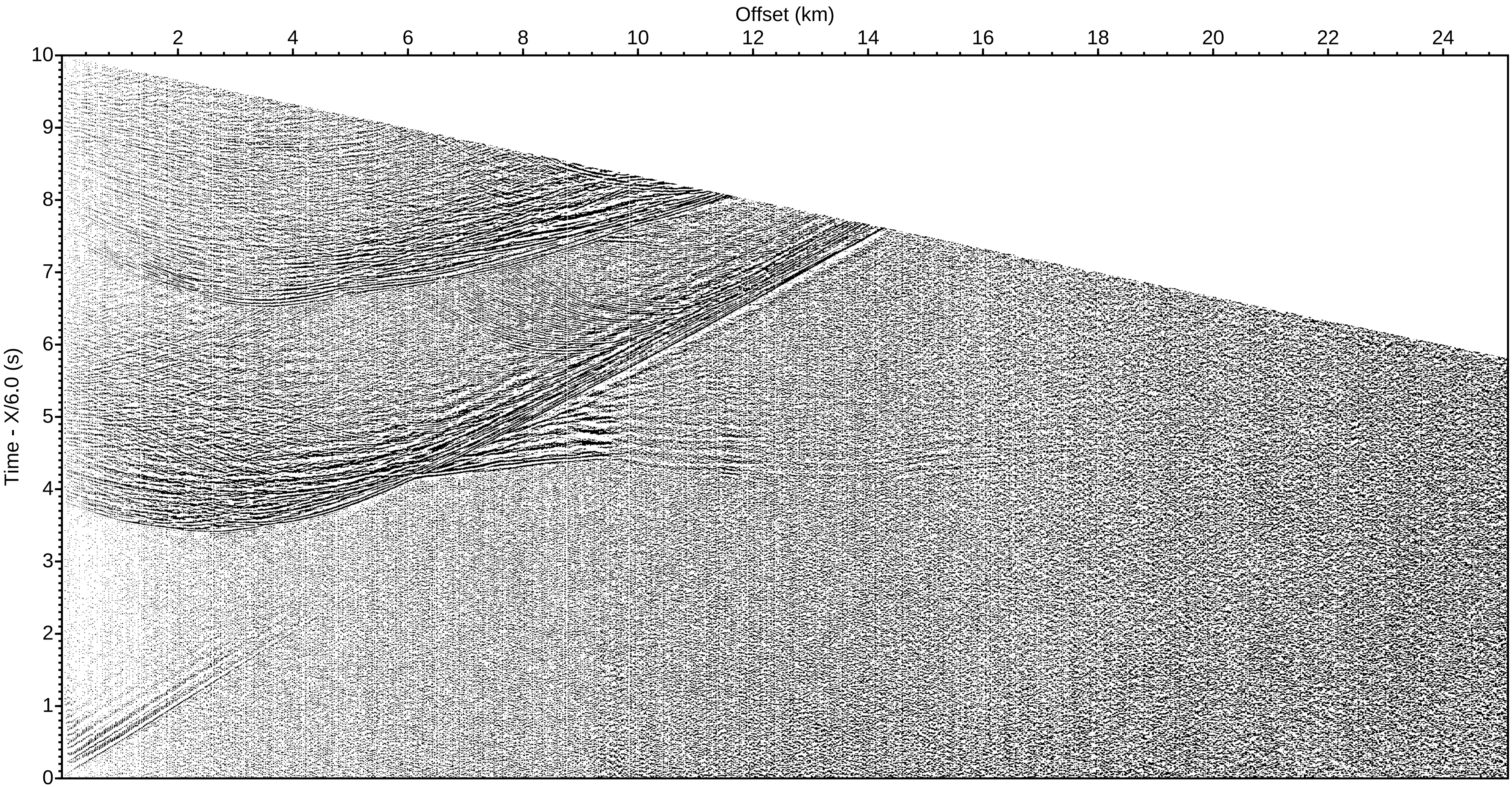
EAGER 2011 - Sonobuoy 1B-9aux1 (deconv., bpf 5-36 Hz)



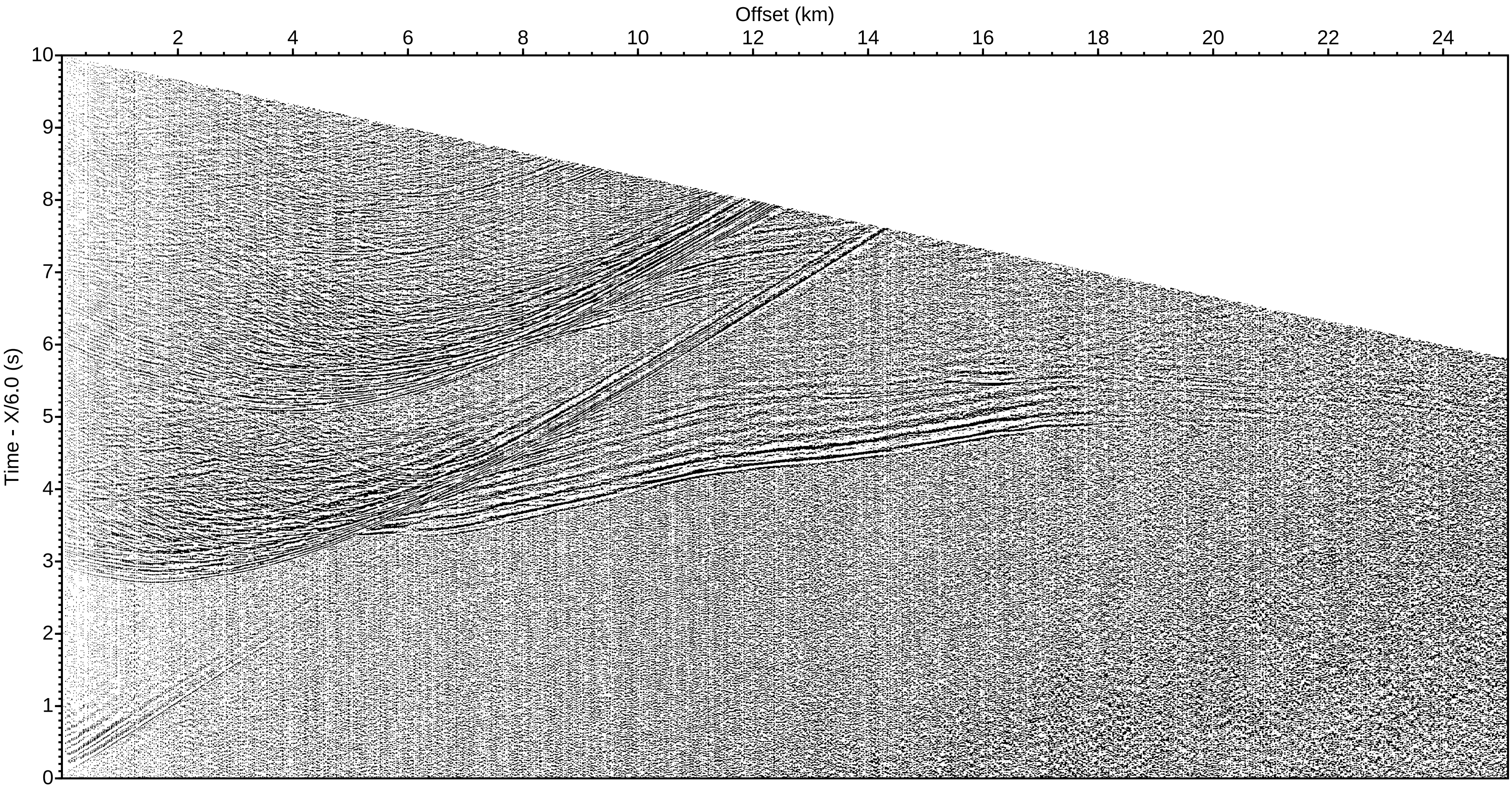
EAGER 2011 - Sonobuoy 1B-10aux2 (deconv., bpf 5-36 Hz)



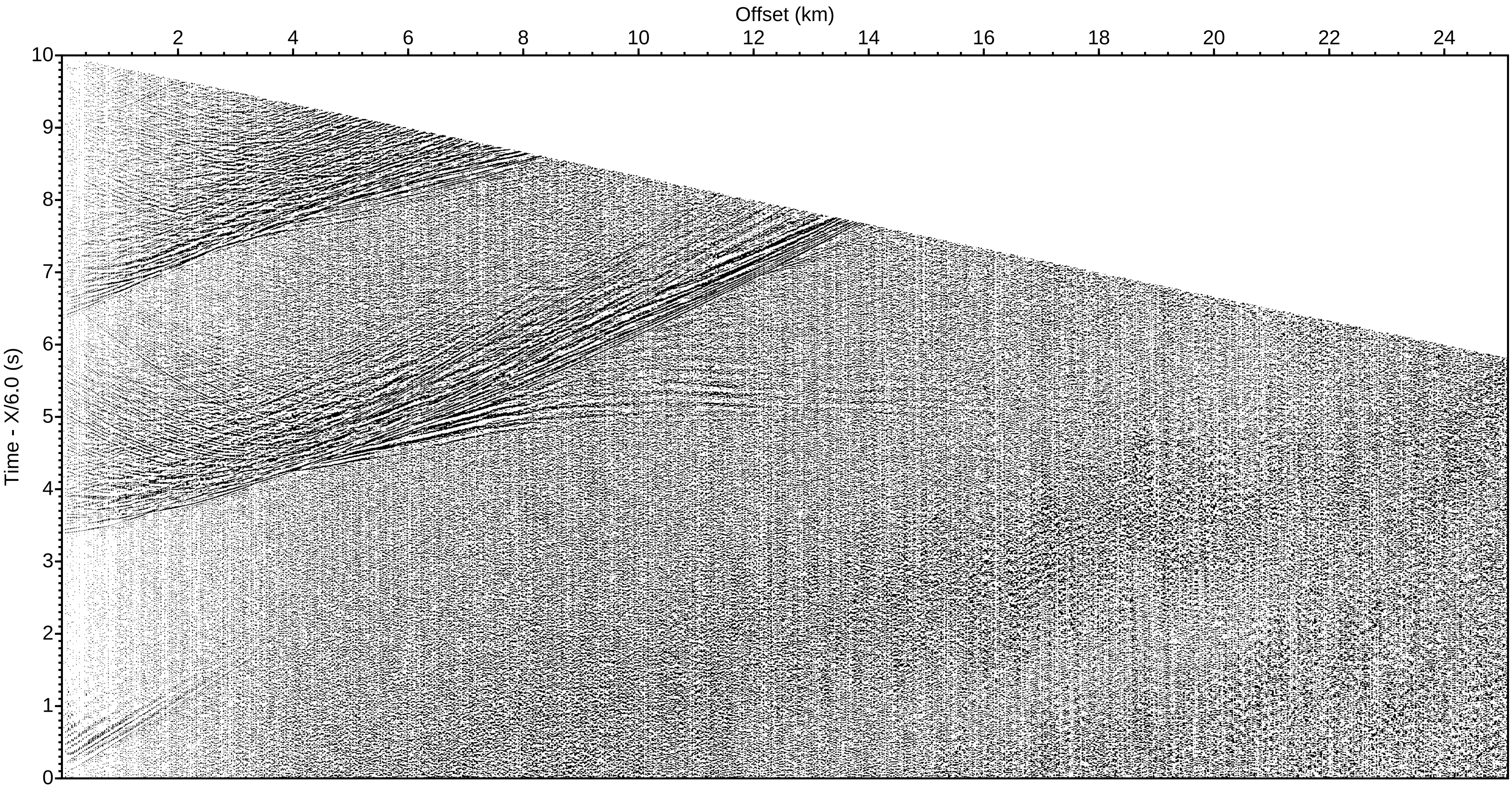
EAGER 2011 - Sonobuoy 1B-11aux3 (deconv., bpf 5-36 Hz)



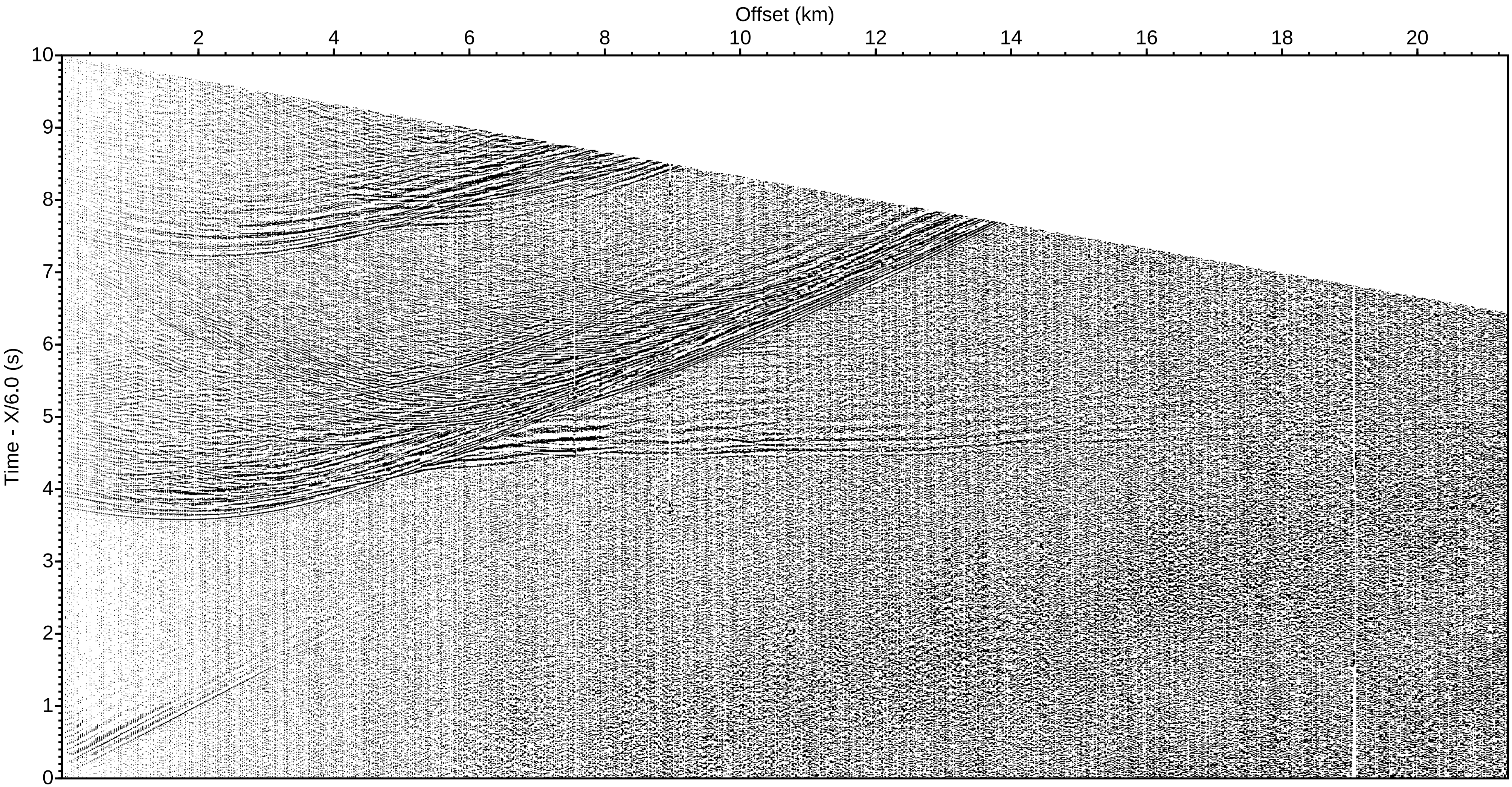
EAGER 2011 - Sonobuoy 1B-12aux4 (deconv., bpf 5-36 Hz)



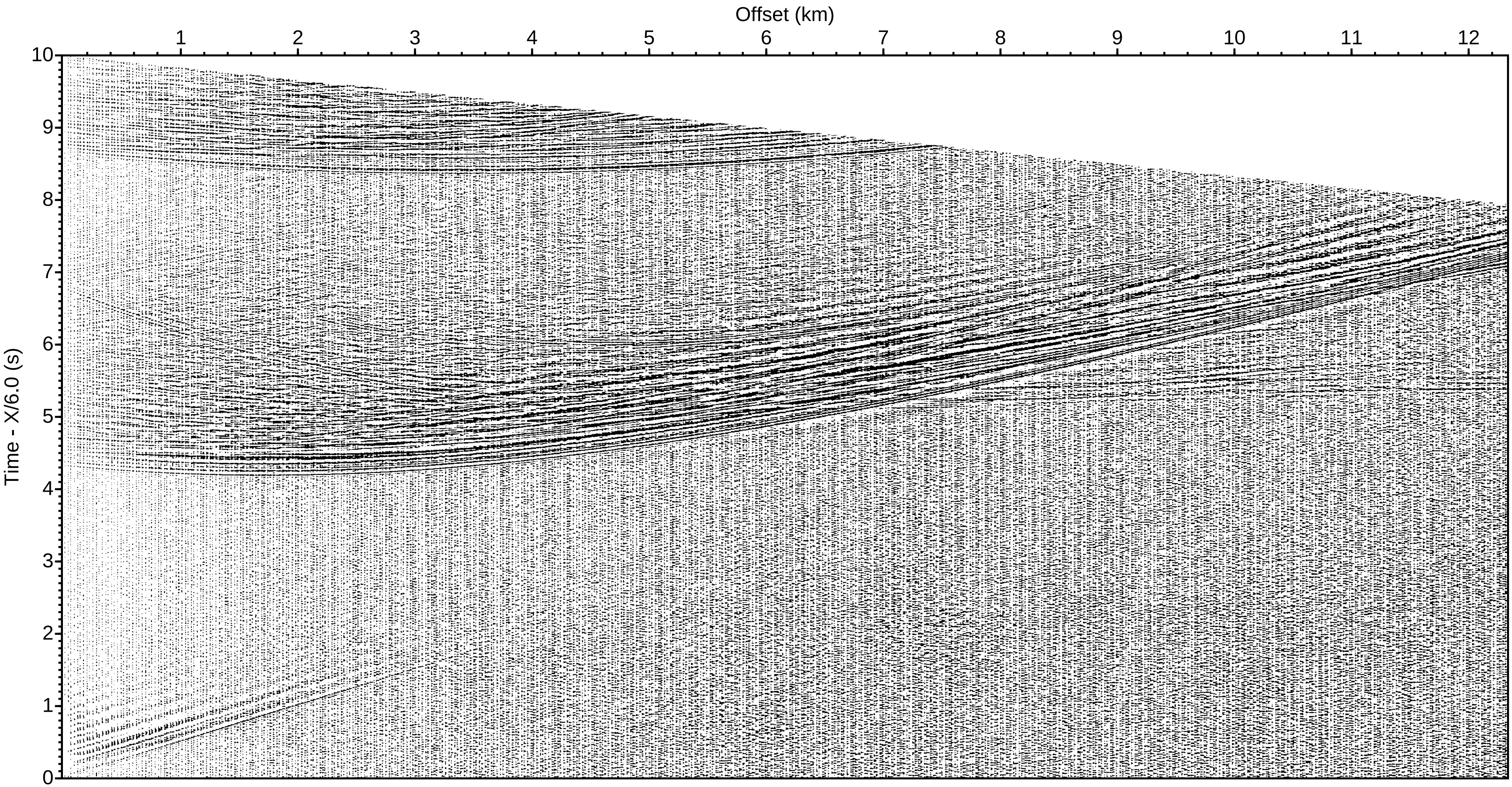
EAGER 2011 - Sonobuoy 1B-13aux1 (deconv., bpf 5-36 Hz)



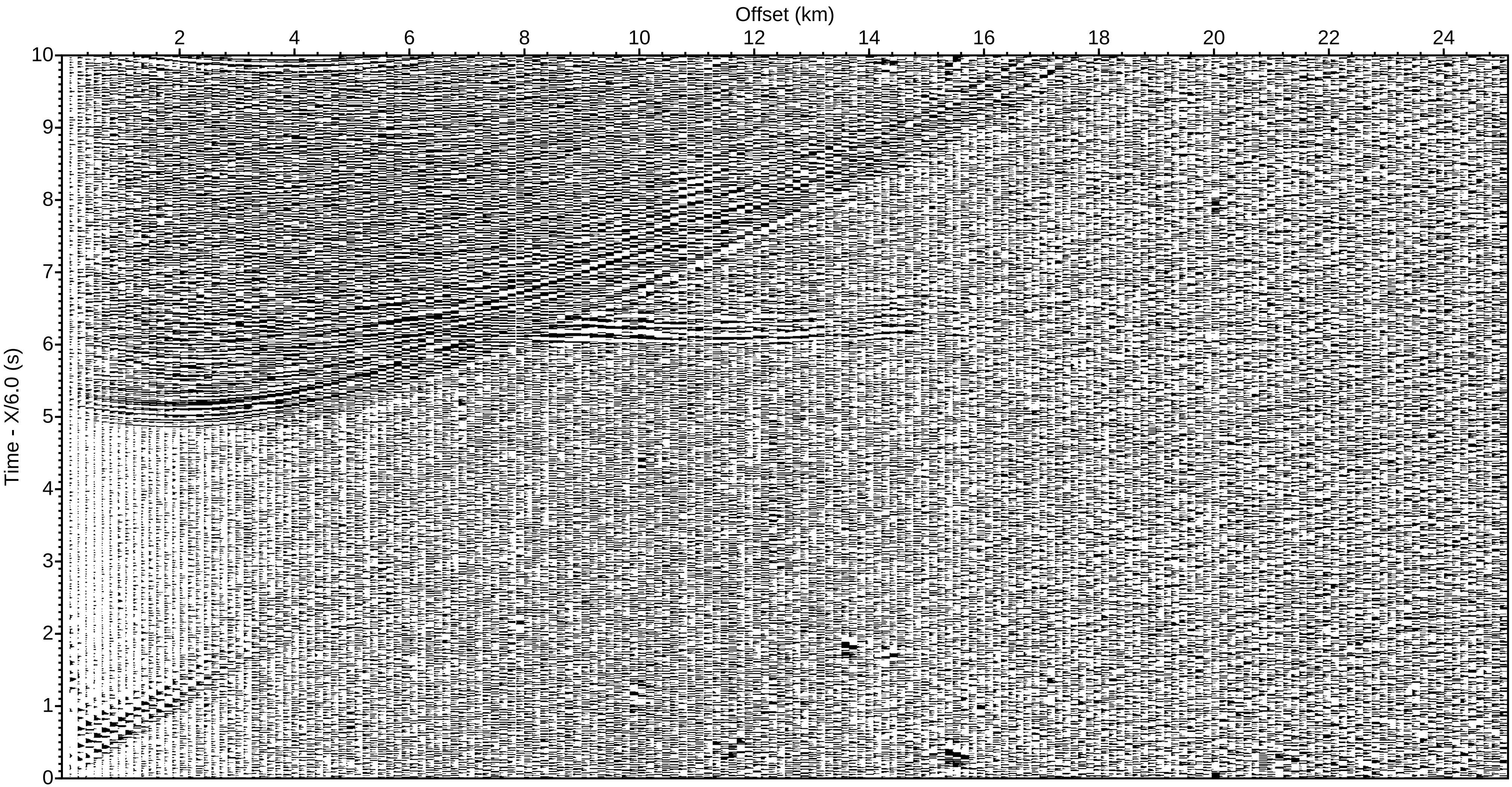
EAGER 2011 - Sonobuoy 1B-14aux2 (deconv., bpf 5-36 Hz)



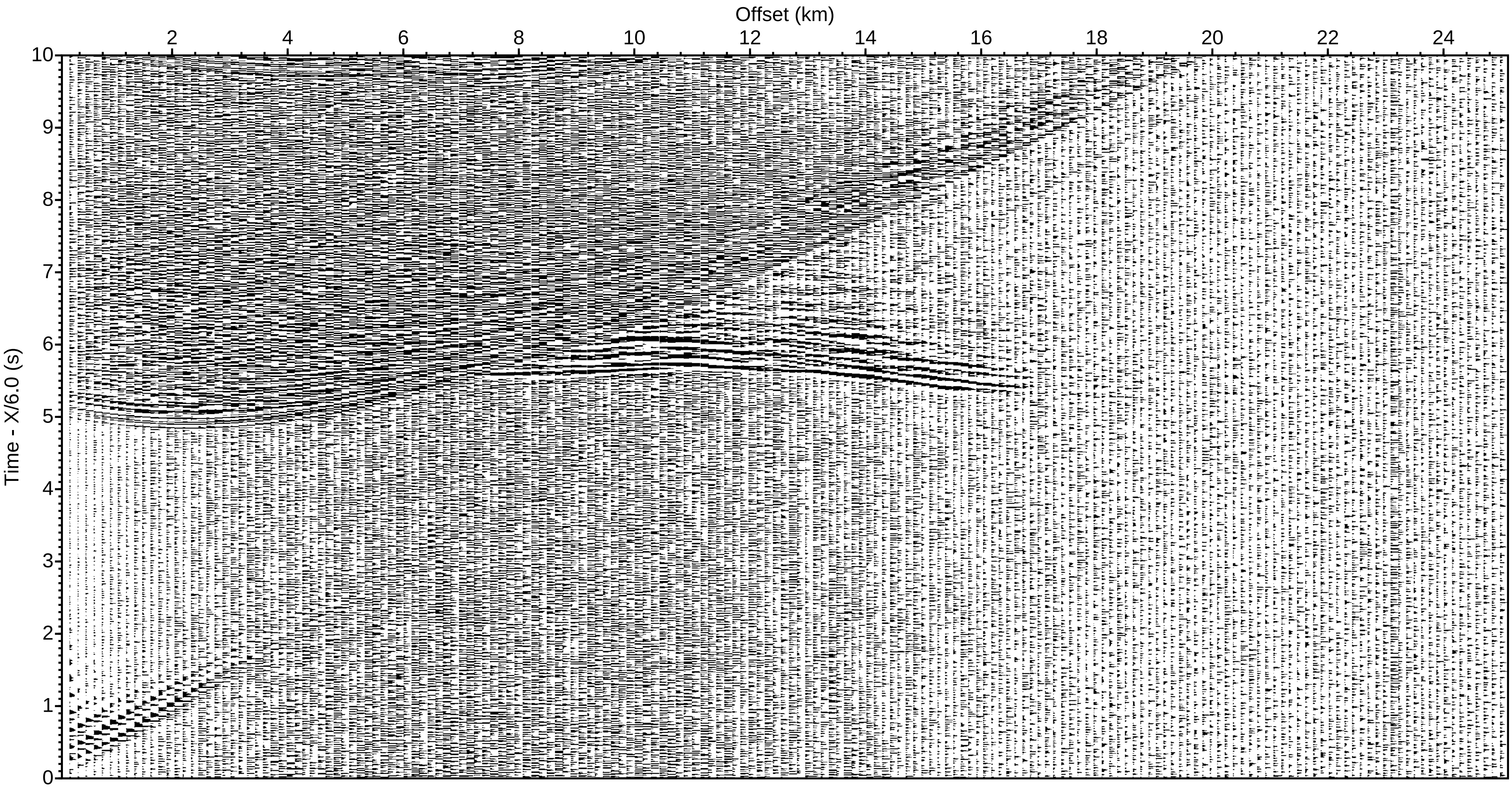
EAGER 2011 - Sonobuoy 1B-15aux3 (deconv., bpf 5-36 Hz)



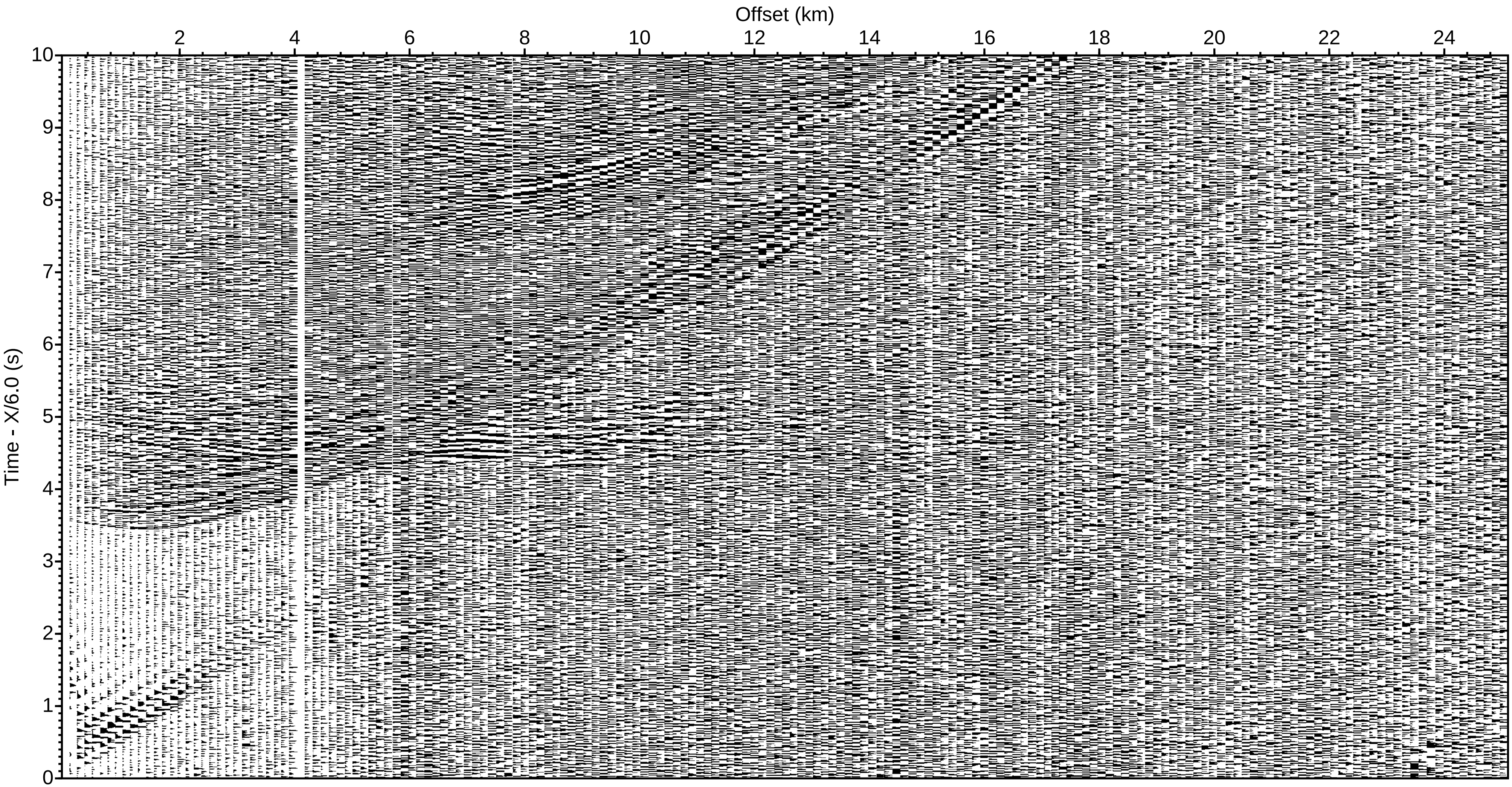
EAGER 2011 - Sonobuoy 1B-16aux4 (deconv., bpf 5-36 Hz)



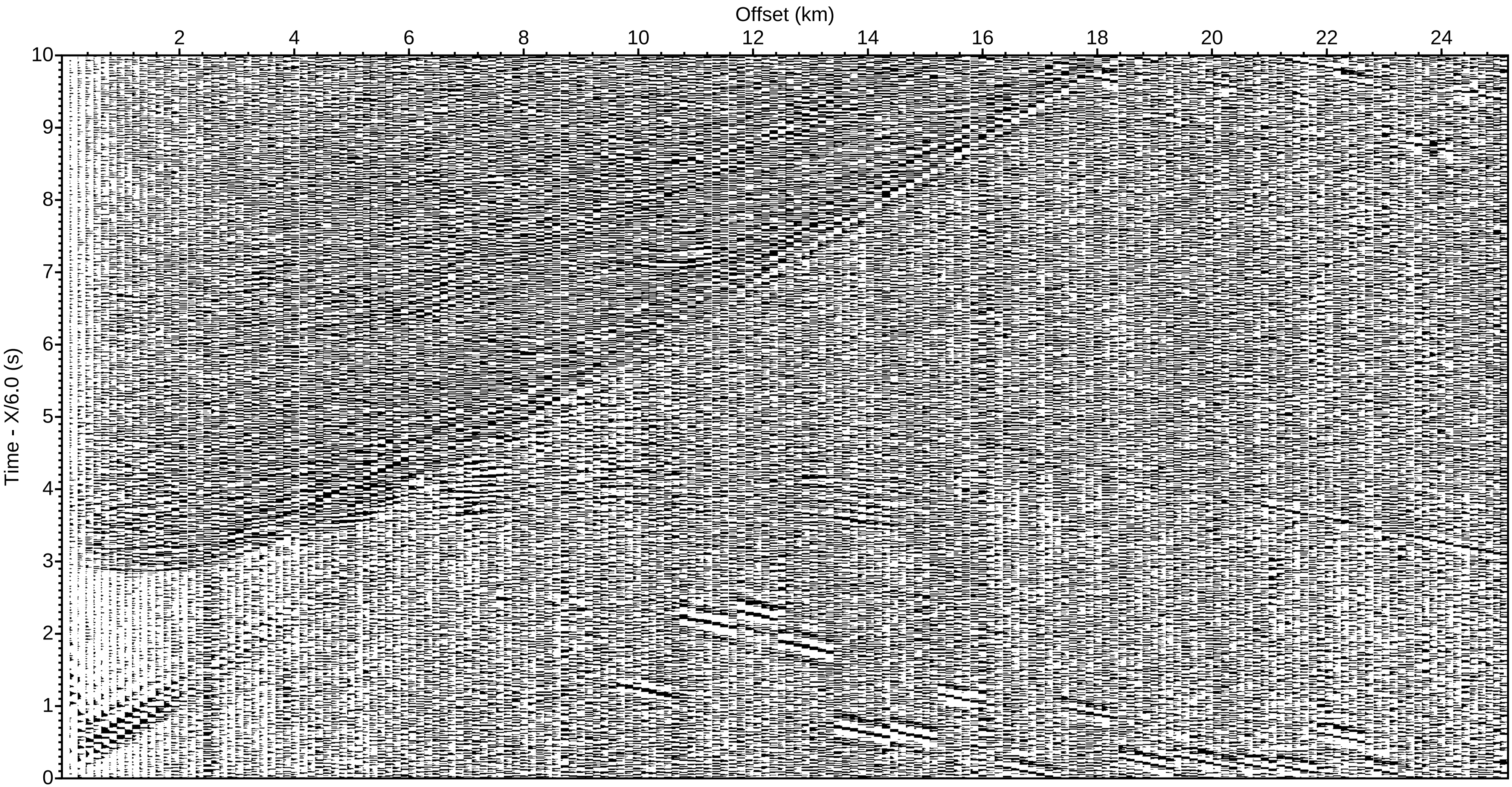
EAGER 2011 - Sonobuoy 2A-17aux1 (deconv., bpf 5-36 Hz)



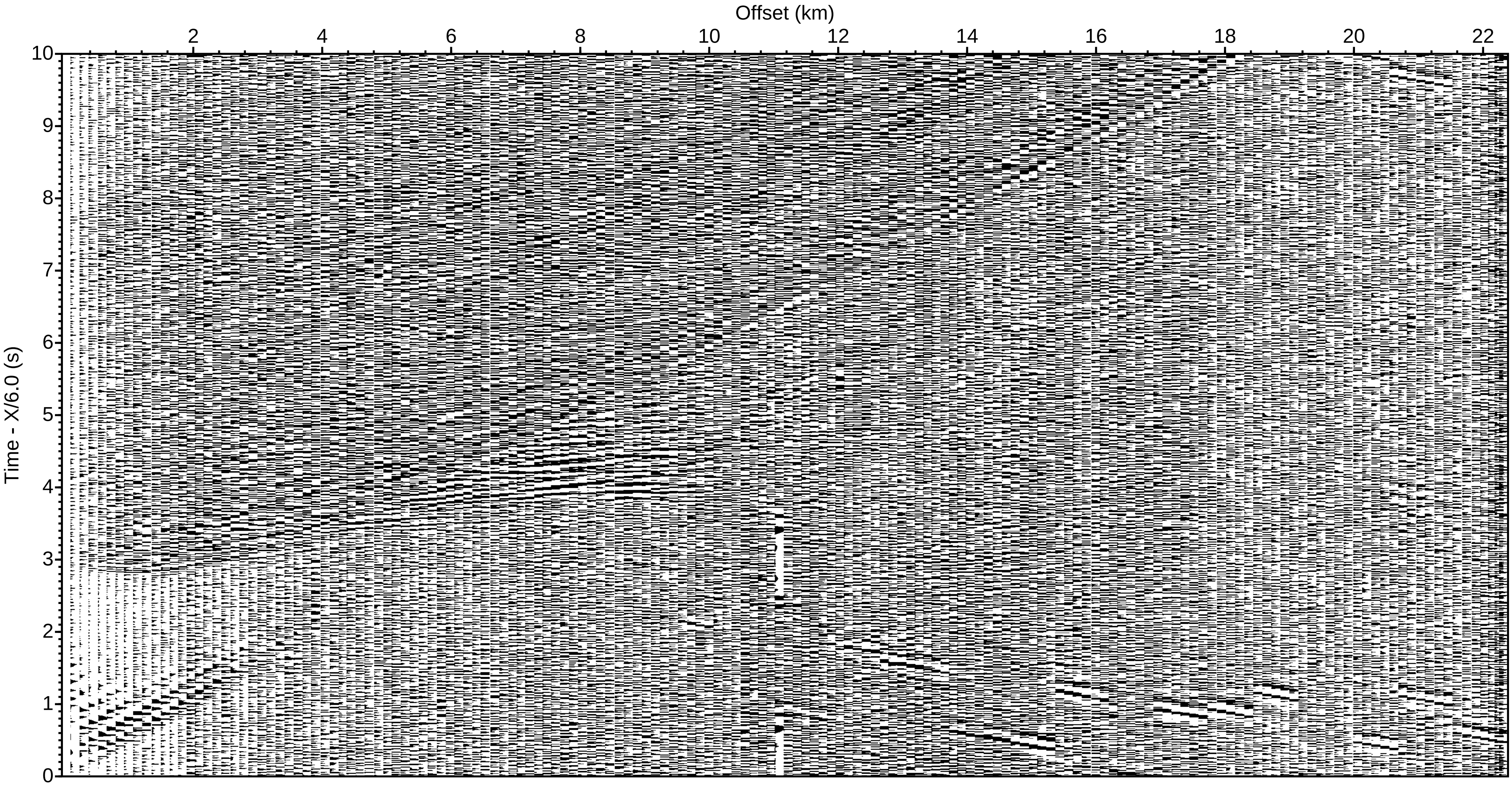
EAGER 2011 - Sonobuoy 2A-18aux2 (deconv., bpf 5-36 Hz)



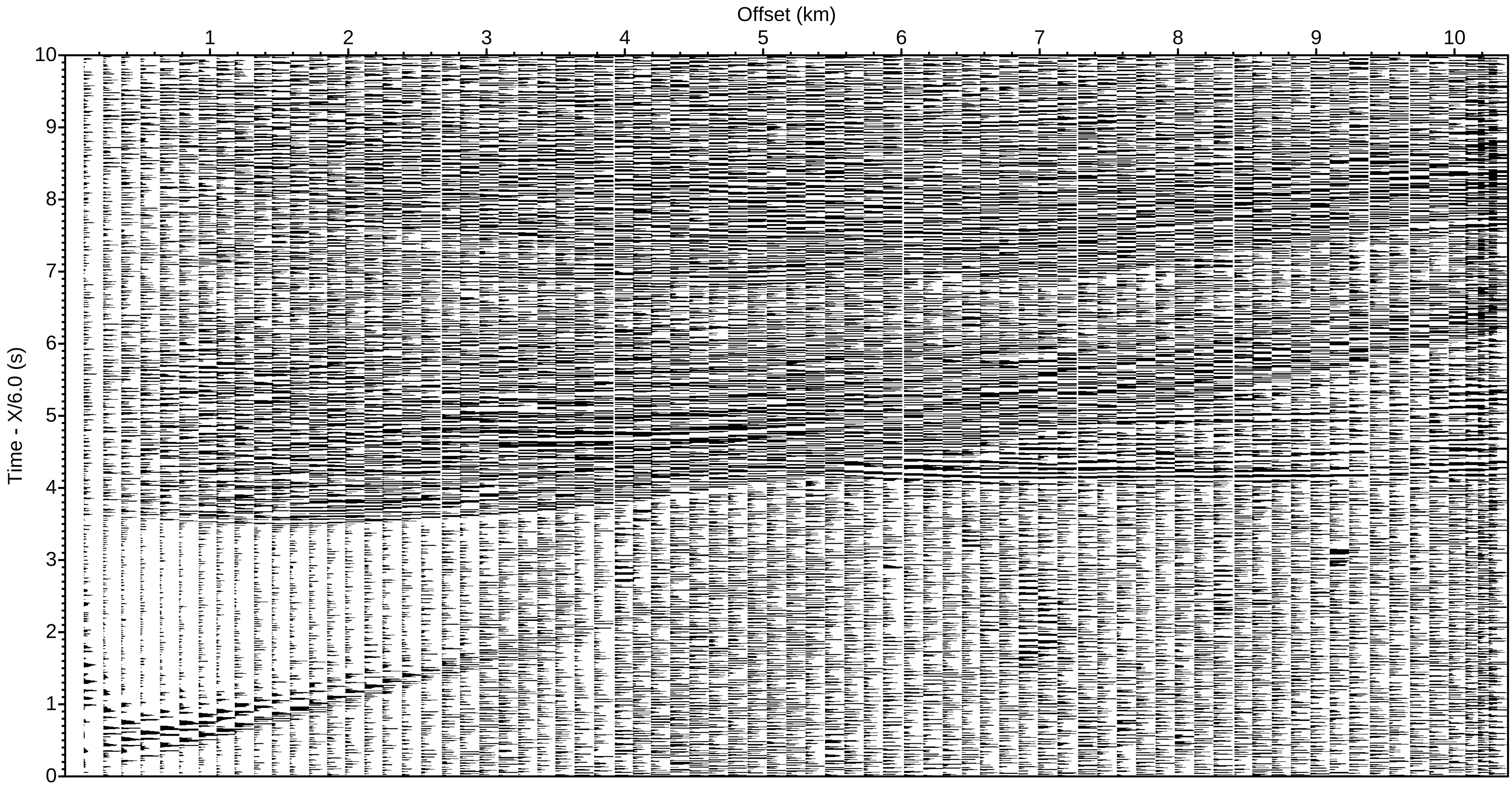
EAGER 2011 - Sonobuoy 2A-19aux3 (deconv., bpf 5-36 Hz)



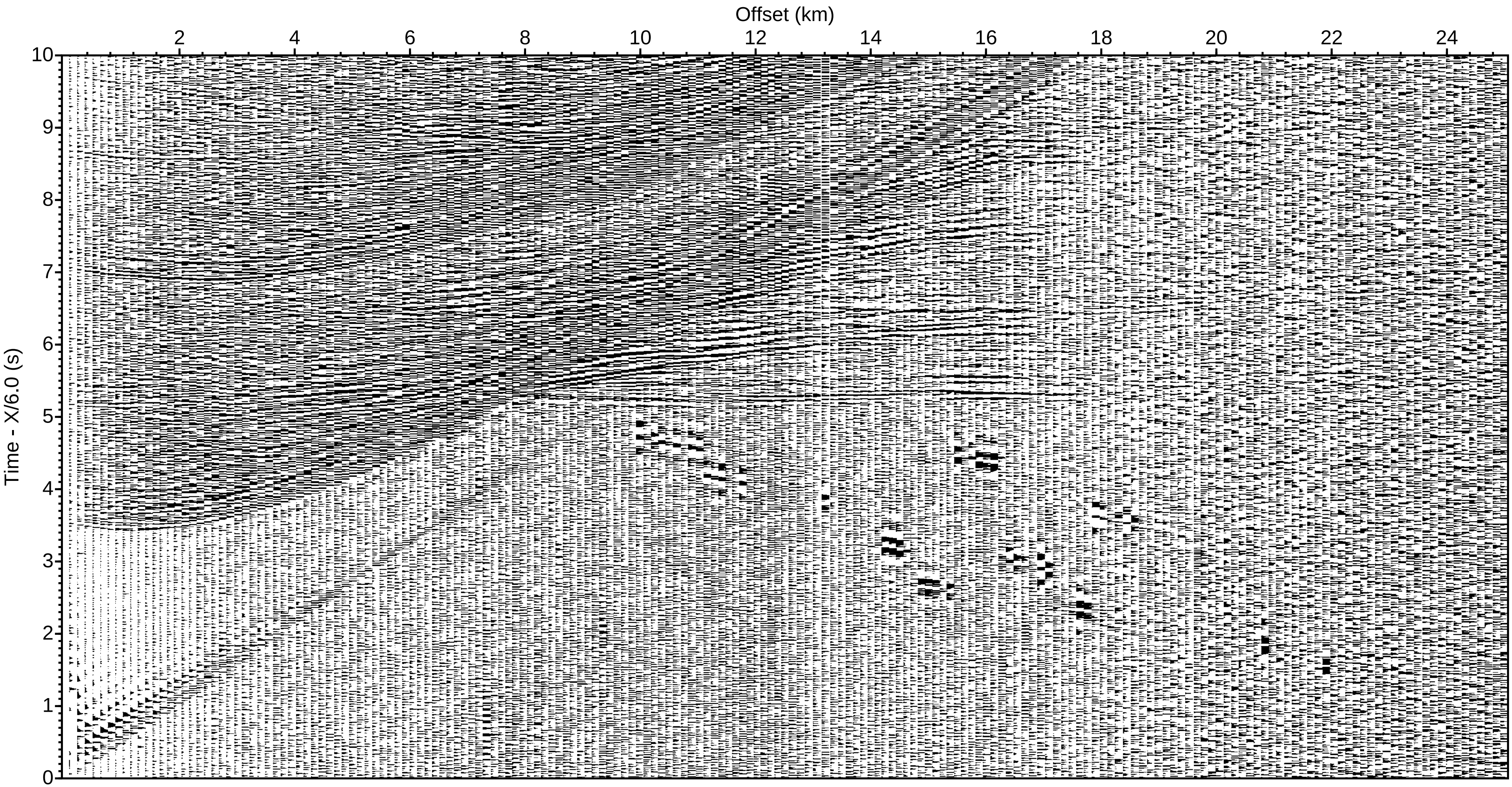
EAGER 2011 - Sonobuoy 2A-20aux4 (deconv., bpf 5-36 Hz)



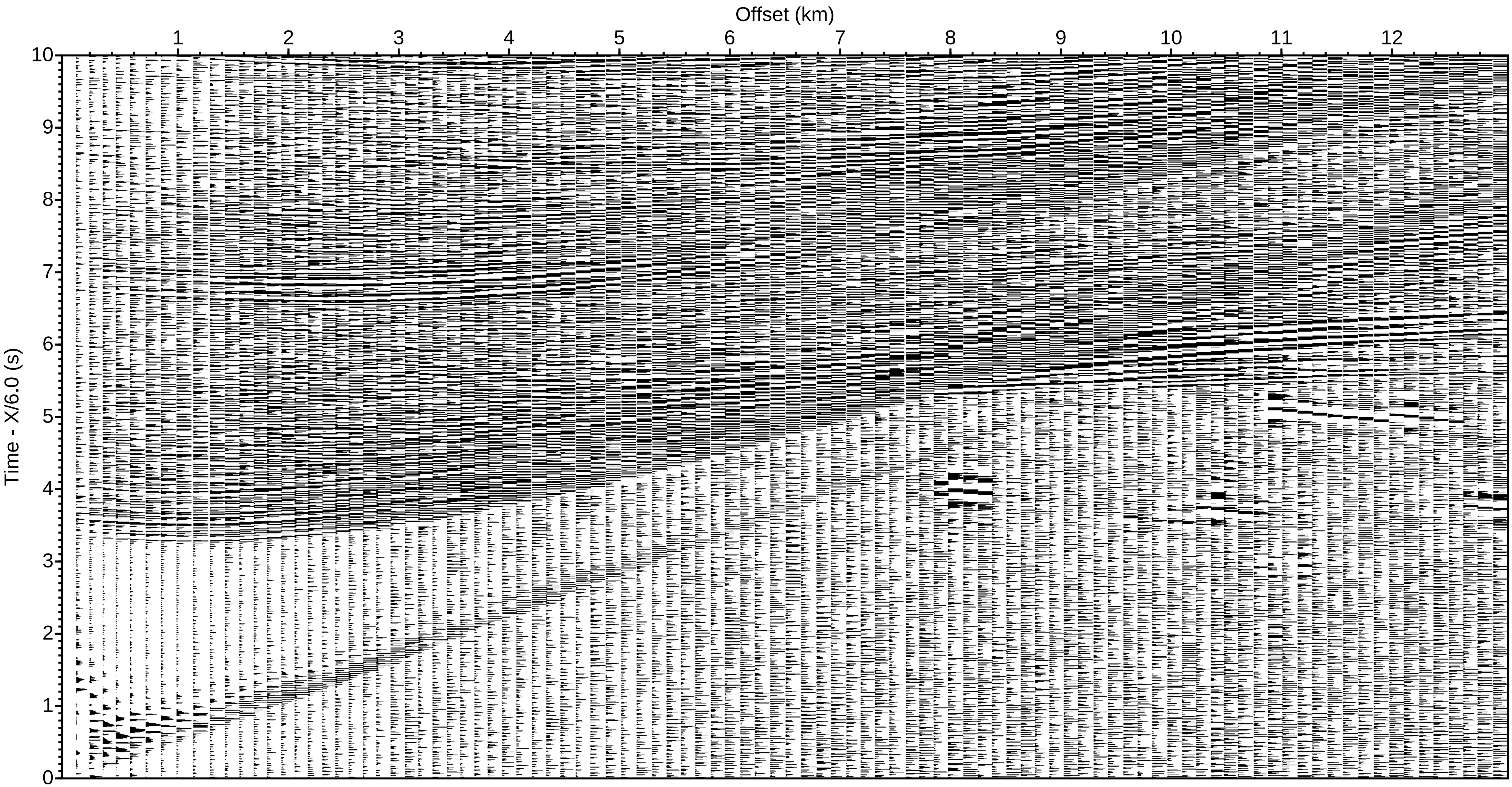
EAGER 2011 - Sonobuoy 2A-21aux1 (deconv., bpf 5-36 Hz)



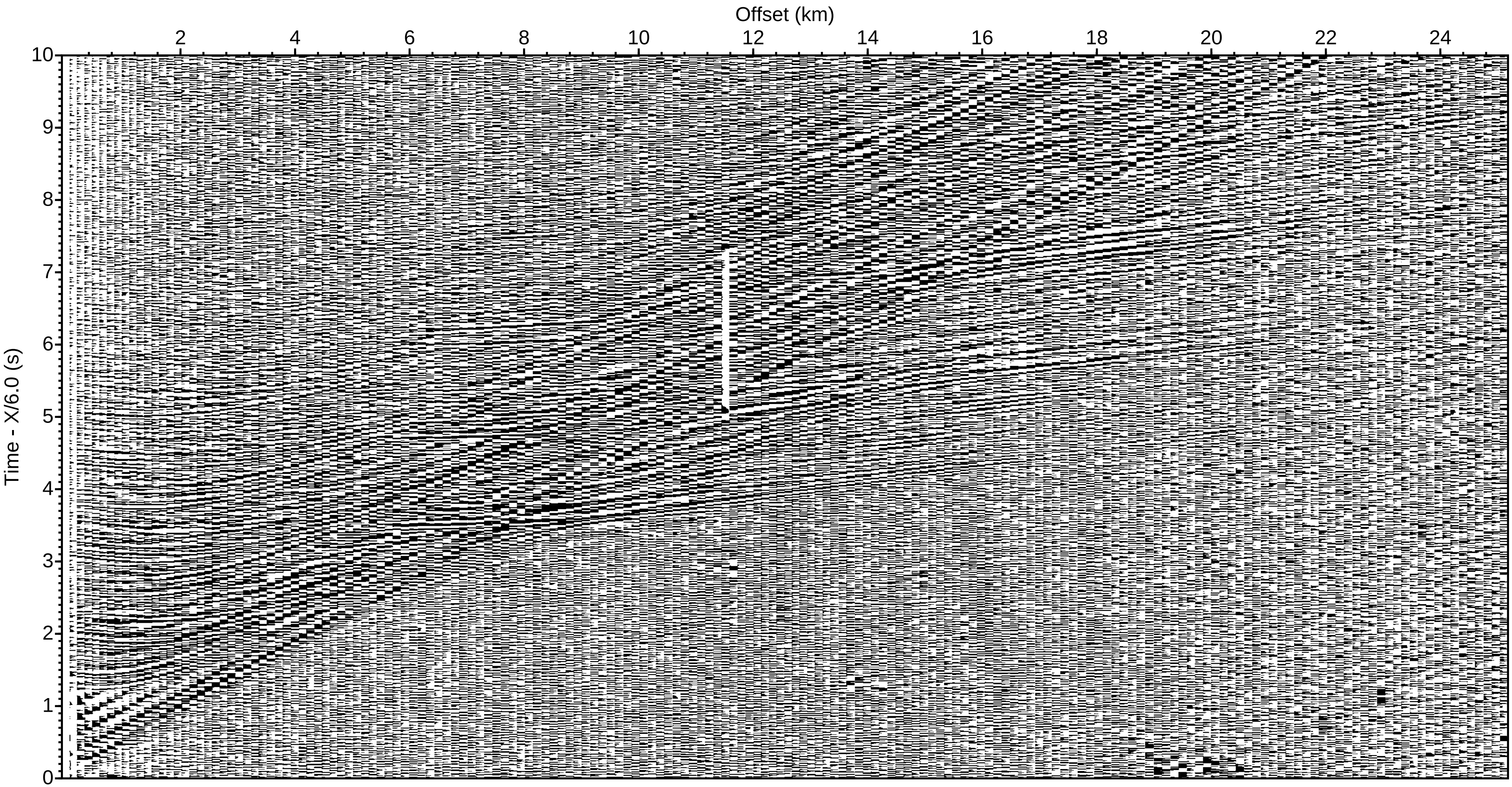
EAGER 2011 - Sonobuoy 2A-22aux2 (deconv., bpf 5-36 Hz)



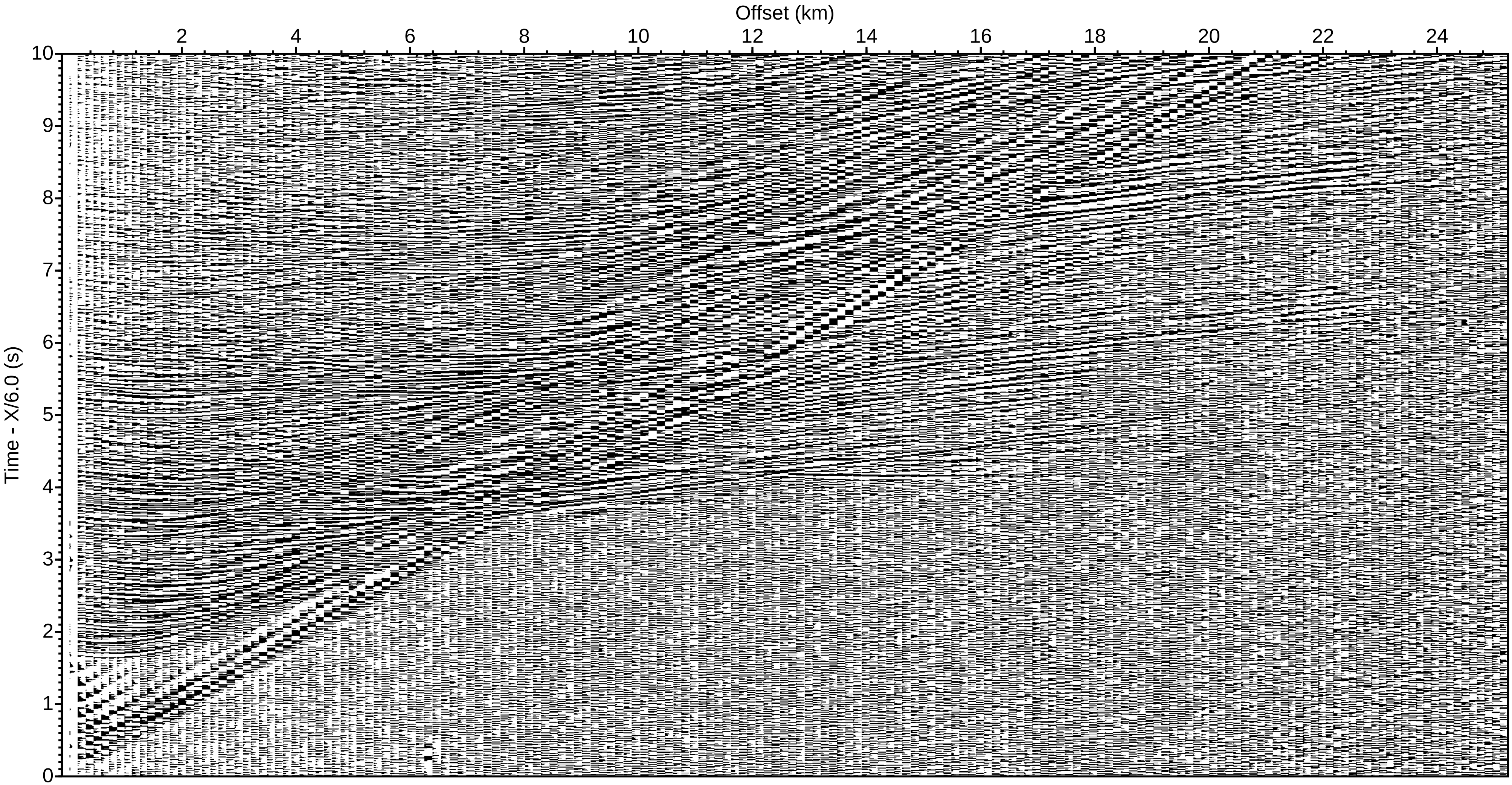
EAGER 2011 - Sonobuoy 2A-23aux3 (deconv., bpf 5-36 Hz)



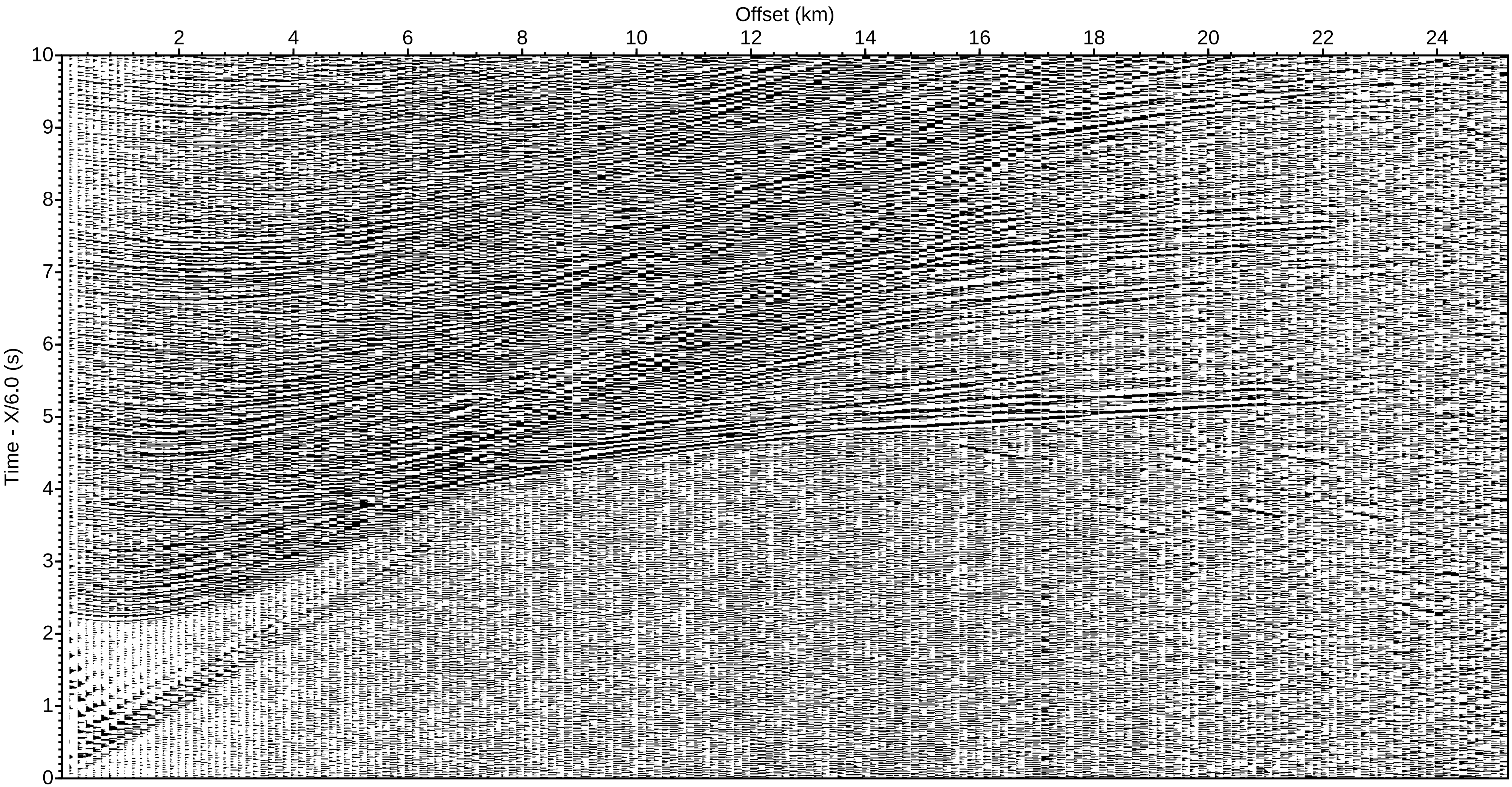
EAGER 2011 - Sonobuoy 2A-24aux4 (deconv., bpf 5-36 Hz)



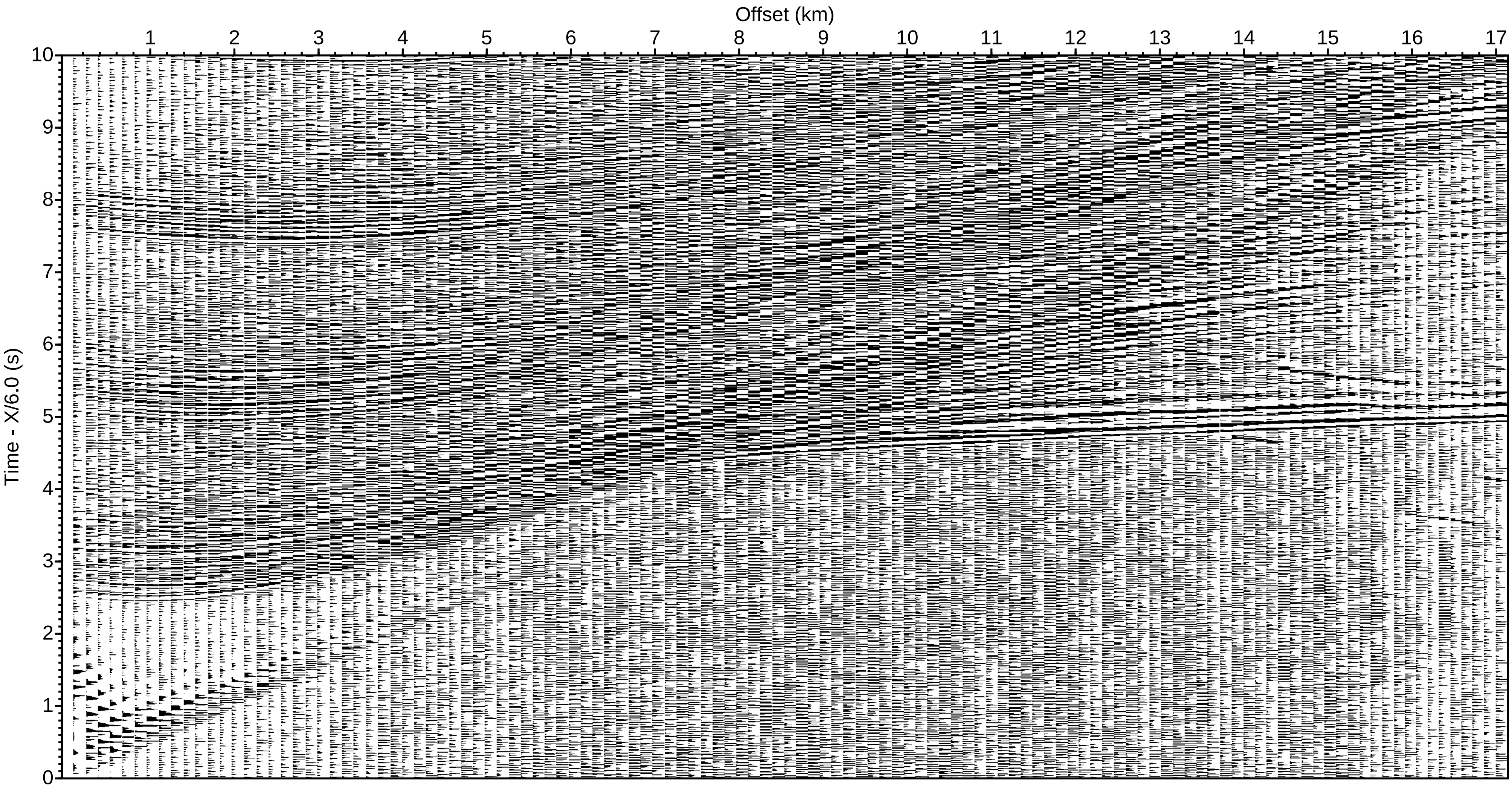
EAGER 2011 - Sonobuoy 3A-25aux3 (deconv., bpf 5-36 Hz)



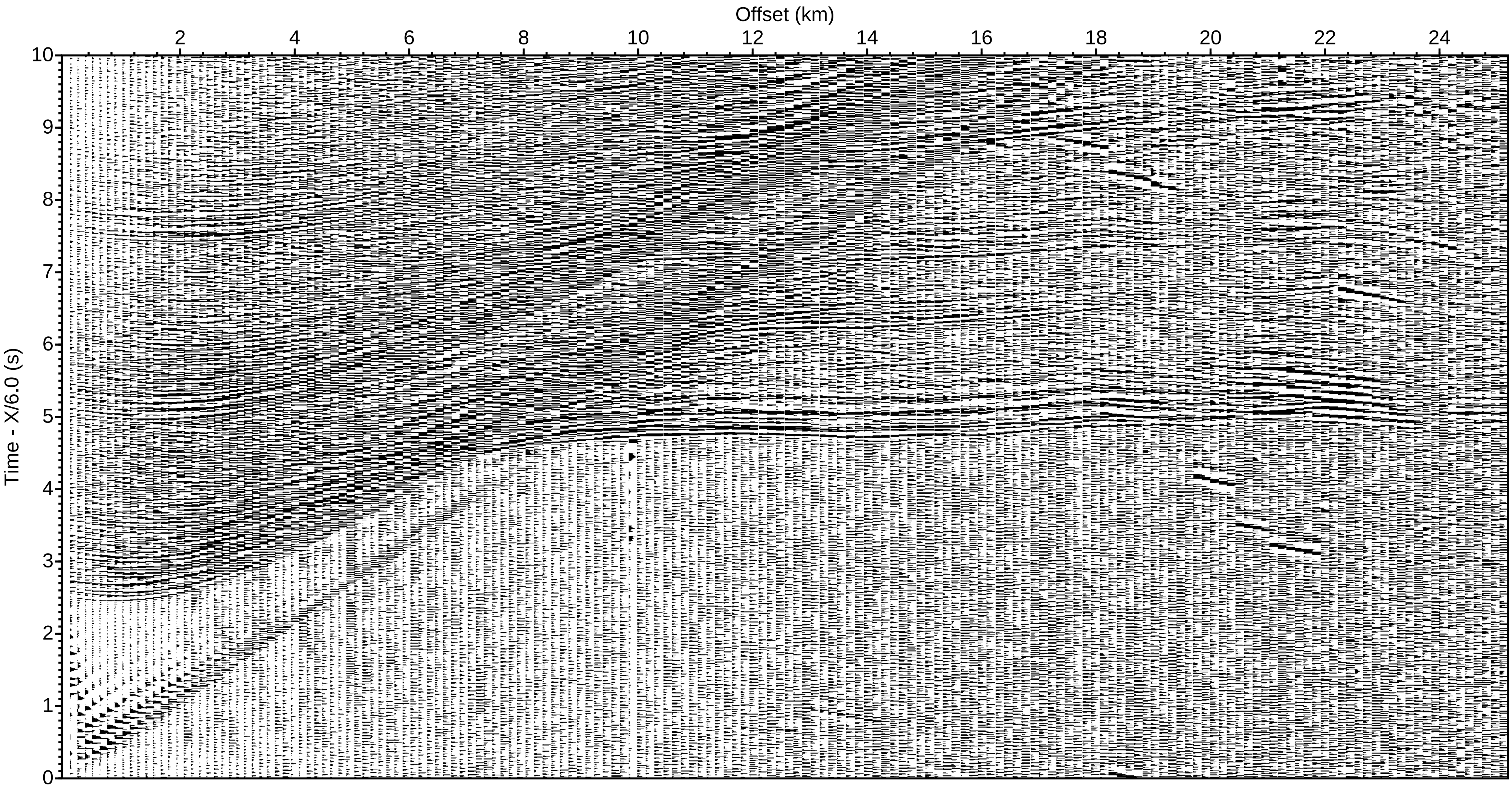
EAGER 2011 - Sonobuoy 3A-26aux4 (deconv., bpf 5-36 Hz)



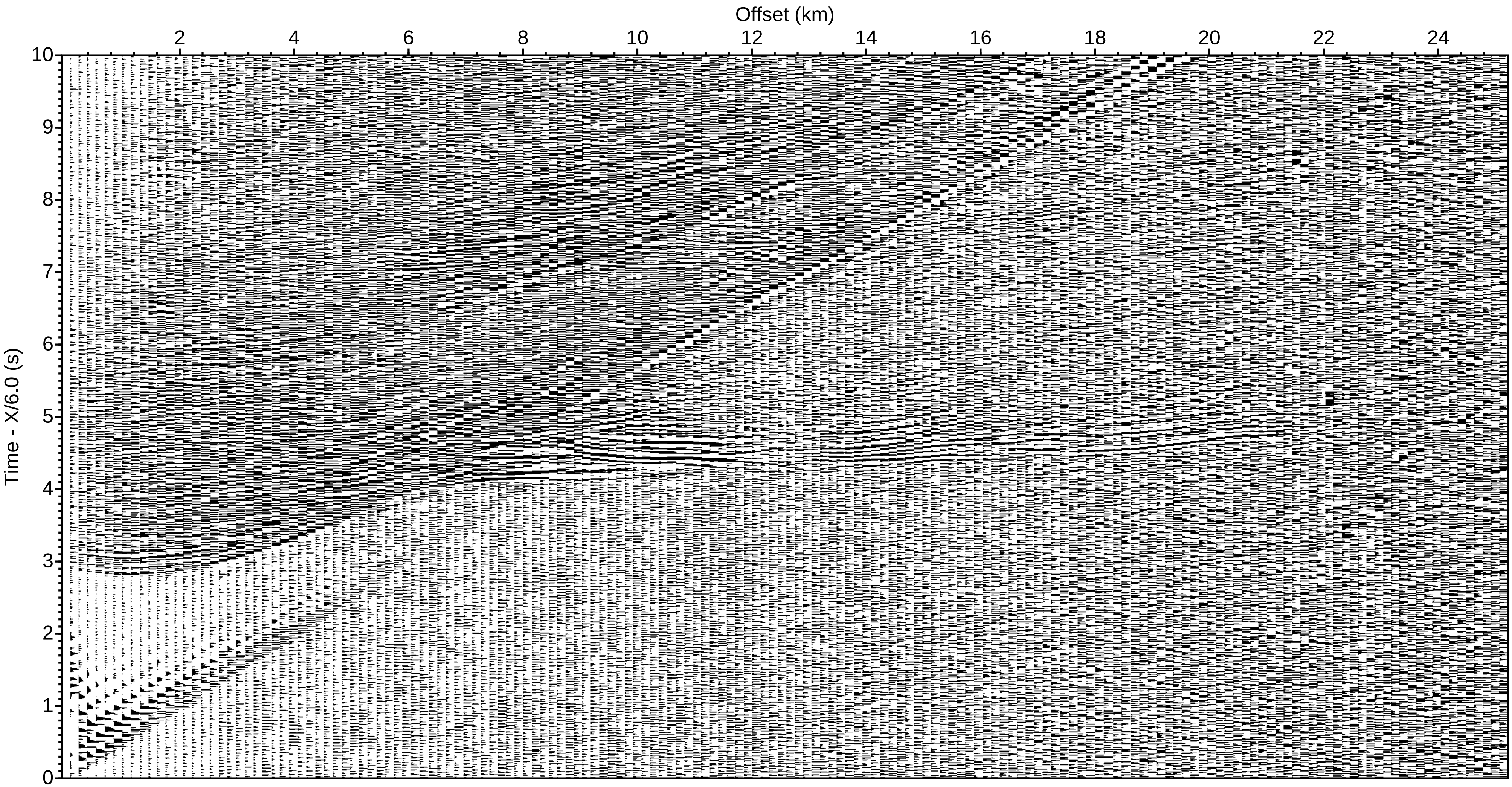
EAGER 2011 - Sonobuoy 3A-27aux1-p1 (deconv., bpf 5-36 Hz)



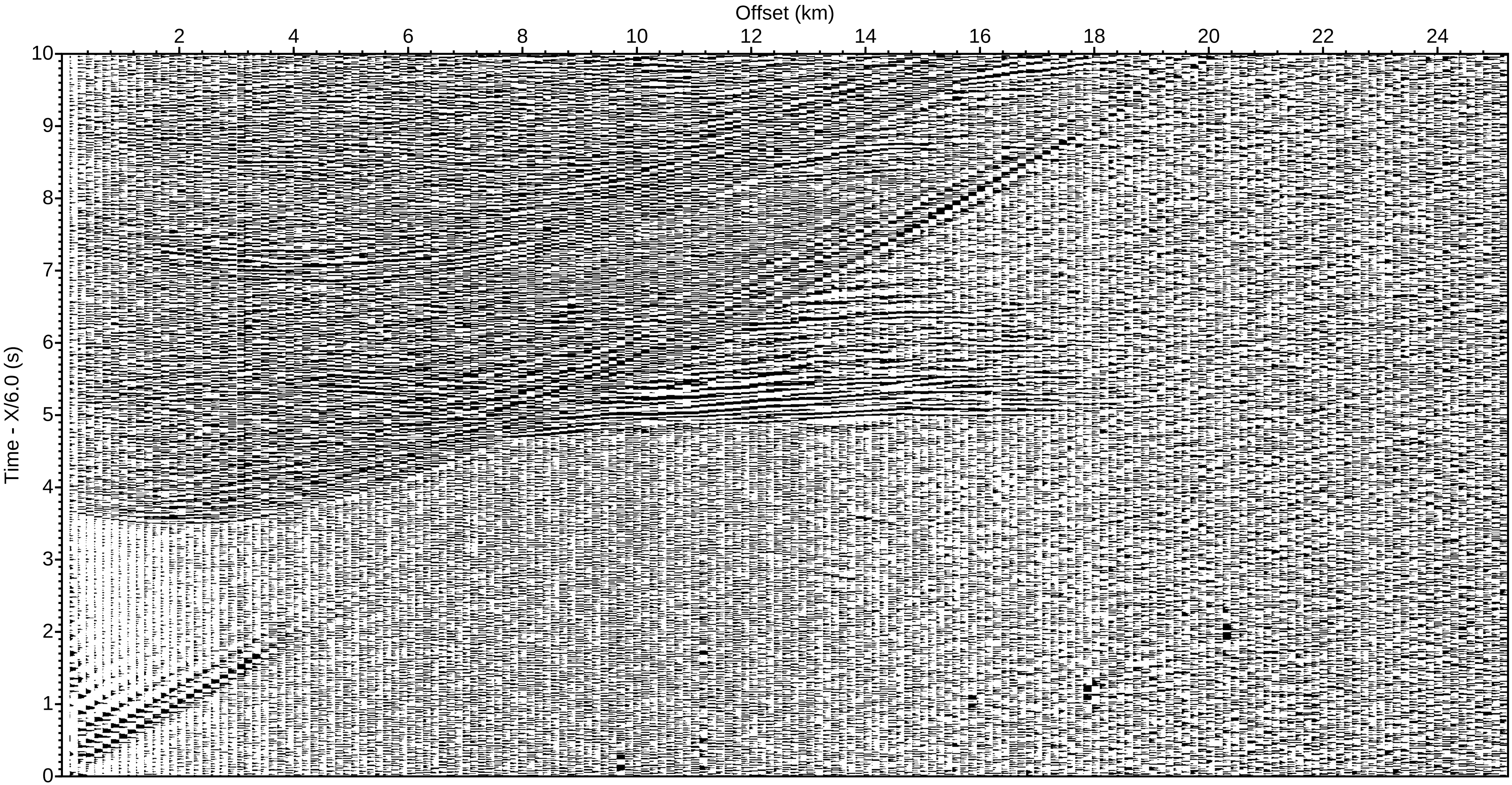
EAGER 2011 - Sonobuoy 3A-28aux2-p1 (deconv., bpf 5-36 Hz)



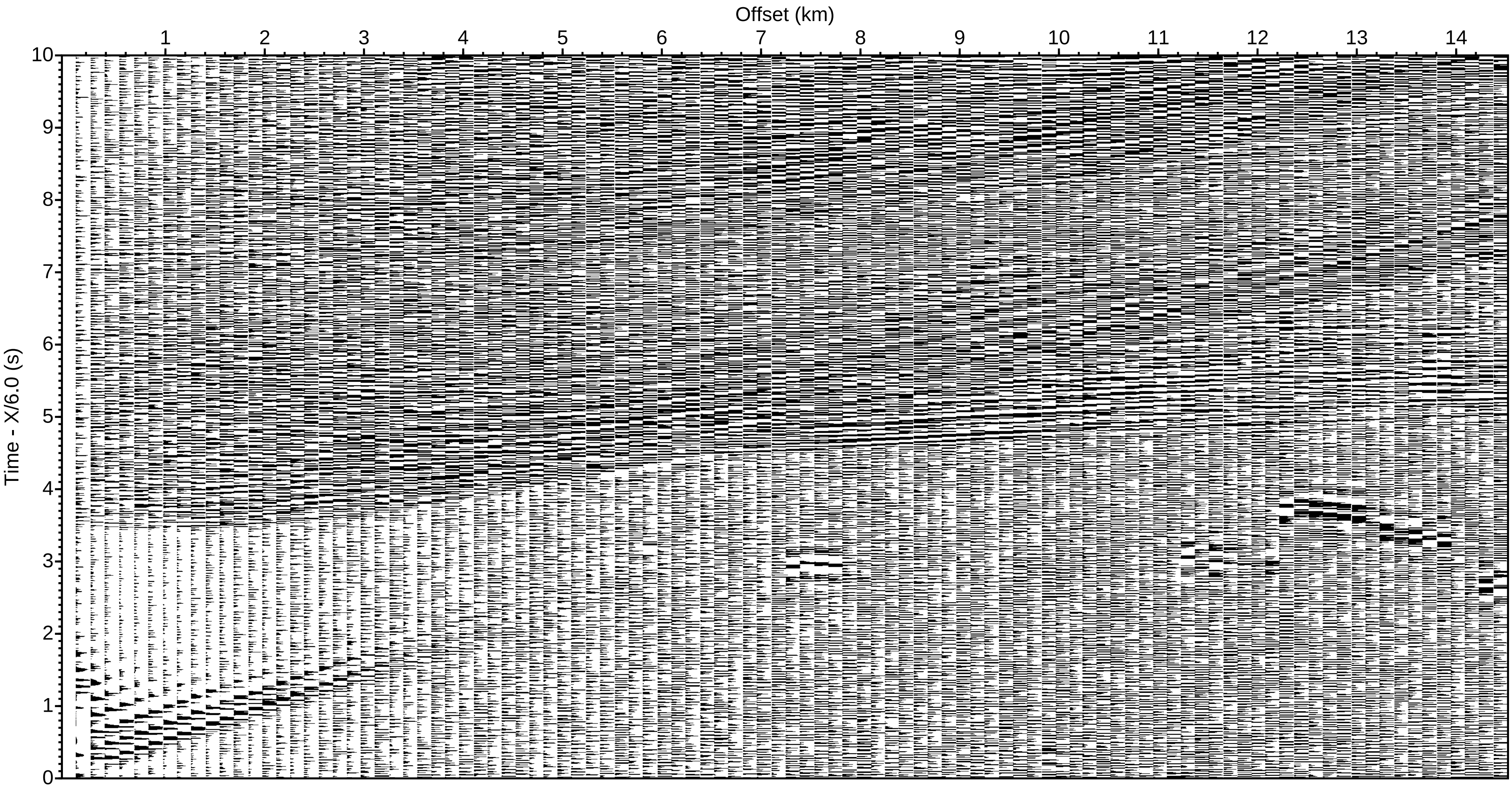
EAGER 2011 - Sonobuoy 3A-29aux3 (deconv., bpf 5-36 Hz)



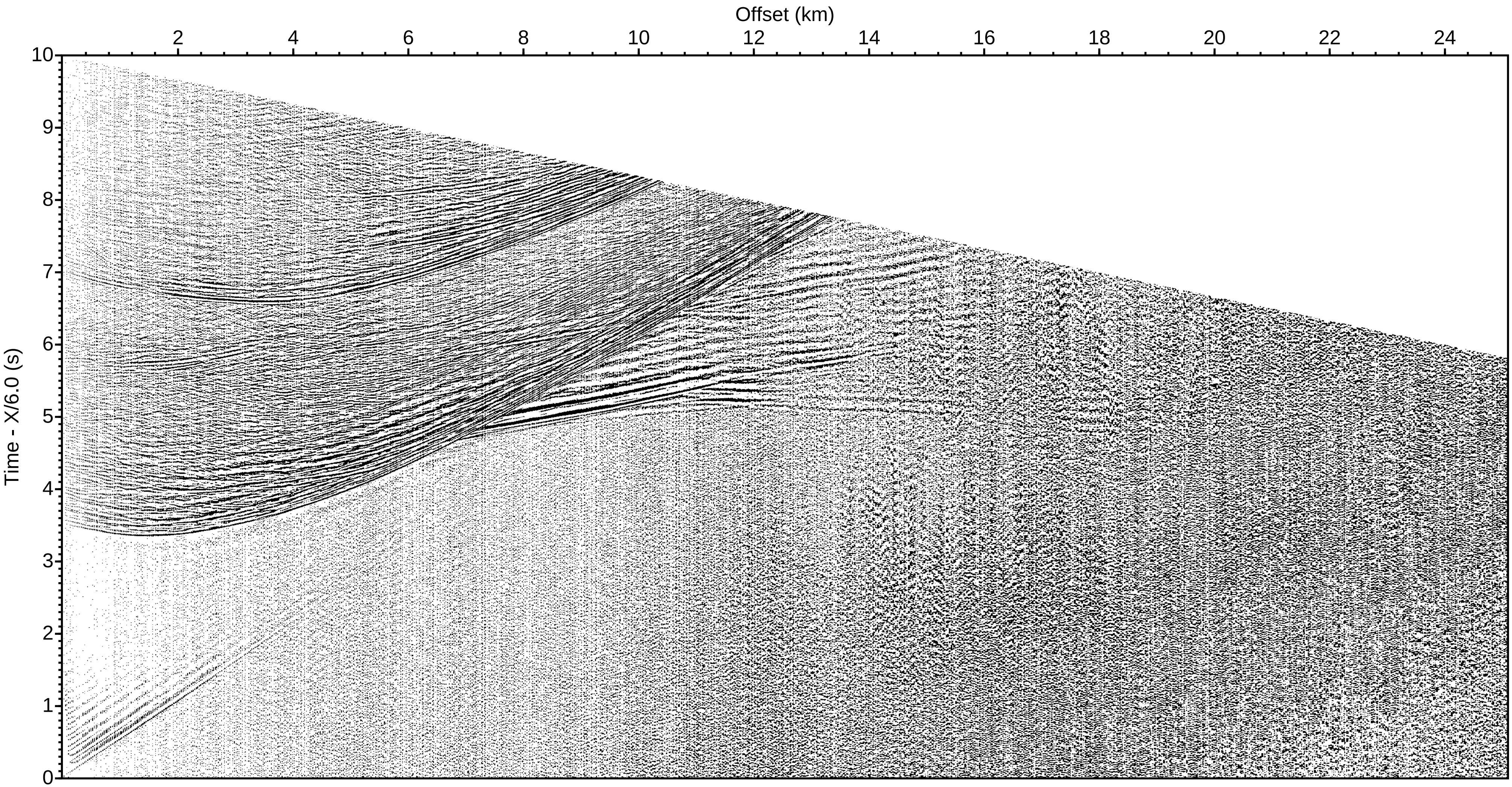
EAGER 2011 - Sonobuoy 3A-30aux4 (deconv., bpf 5-36 Hz)



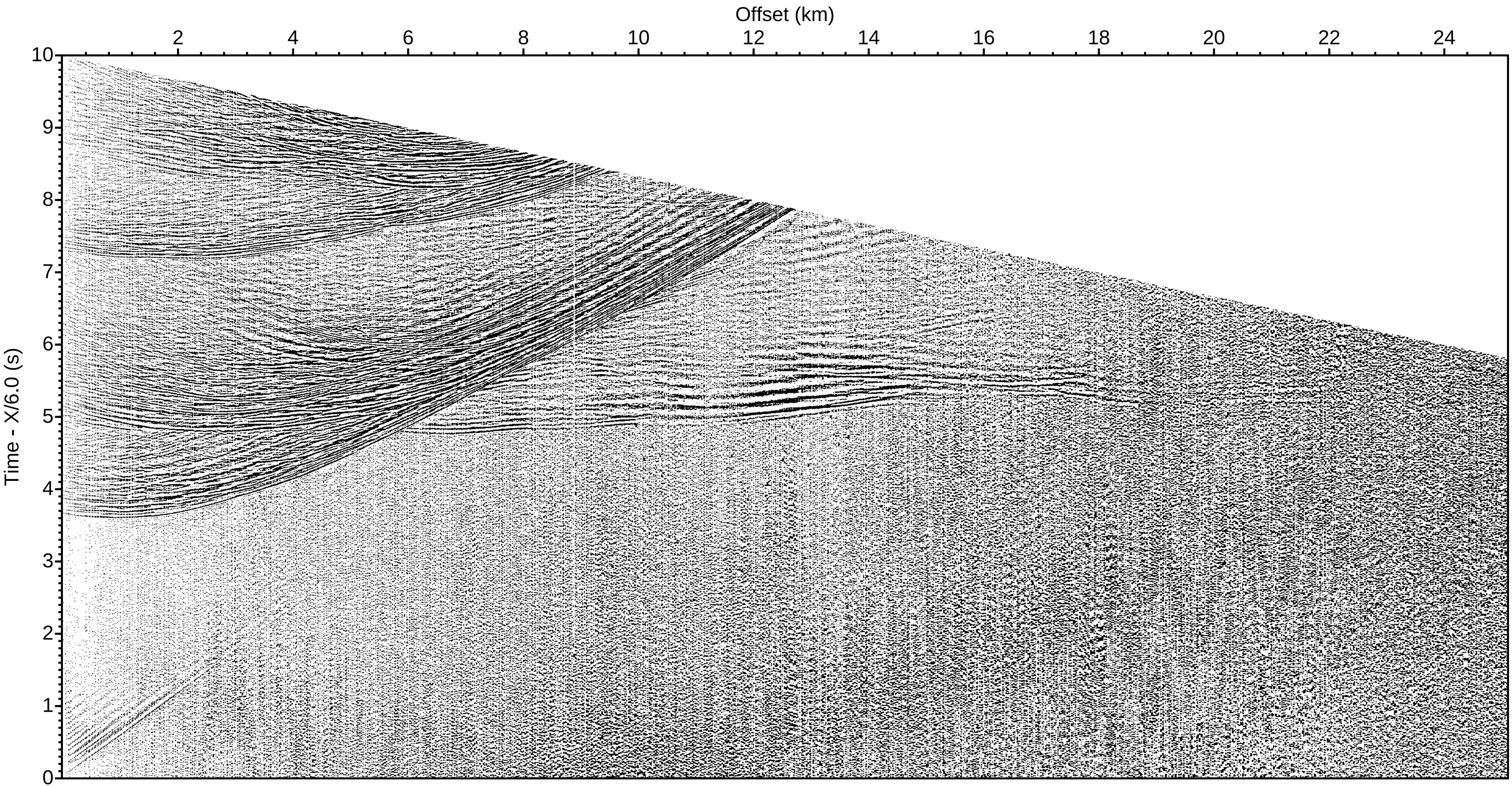
EAGER 2011 - Sonobuoy 3A-31aux1 (deconv., bpf 5-36 Hz)



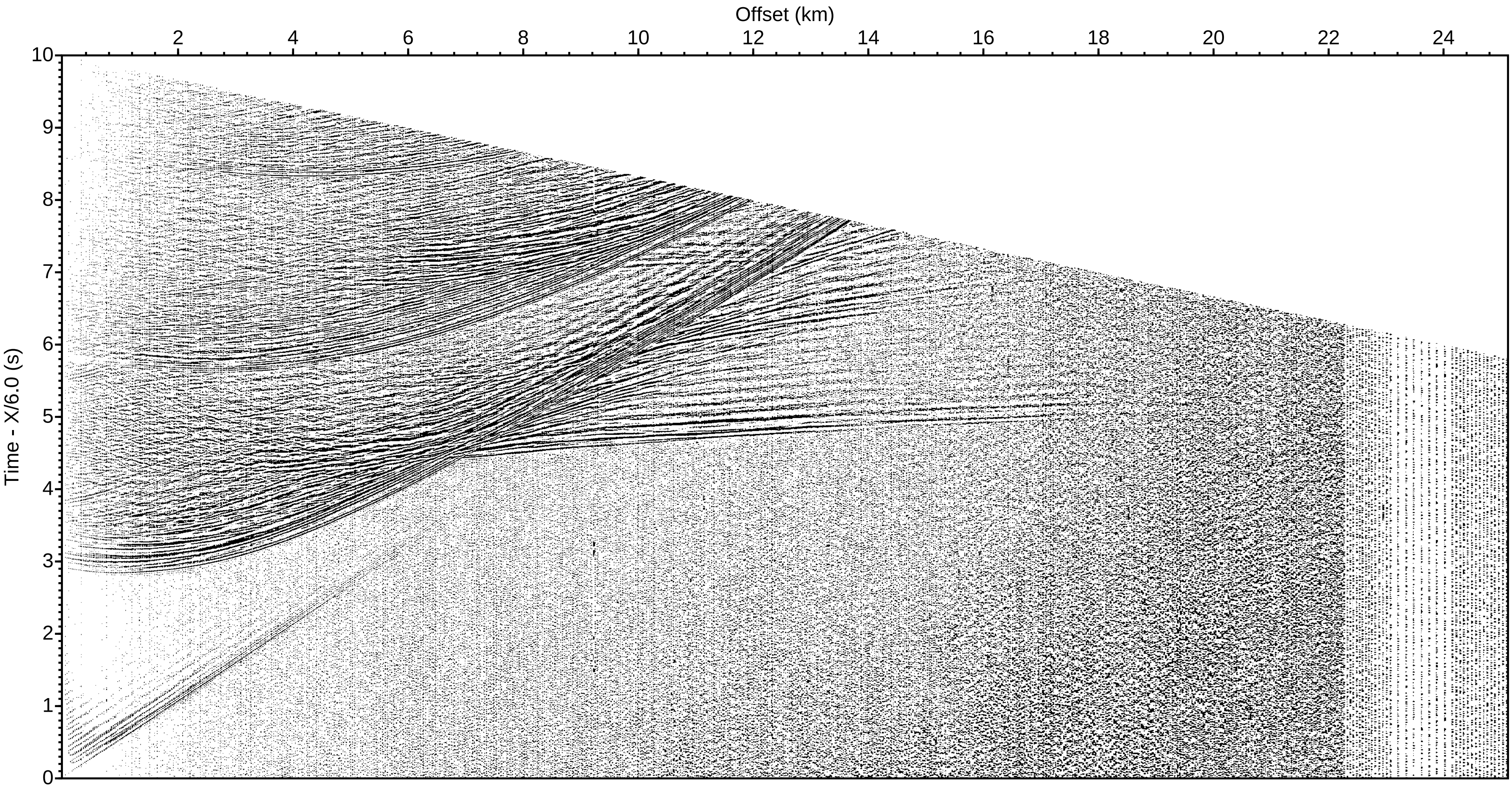
EAGER 2011 - Sonobuoy 3A-32aux2 (deconv., bpf 5-36 Hz)



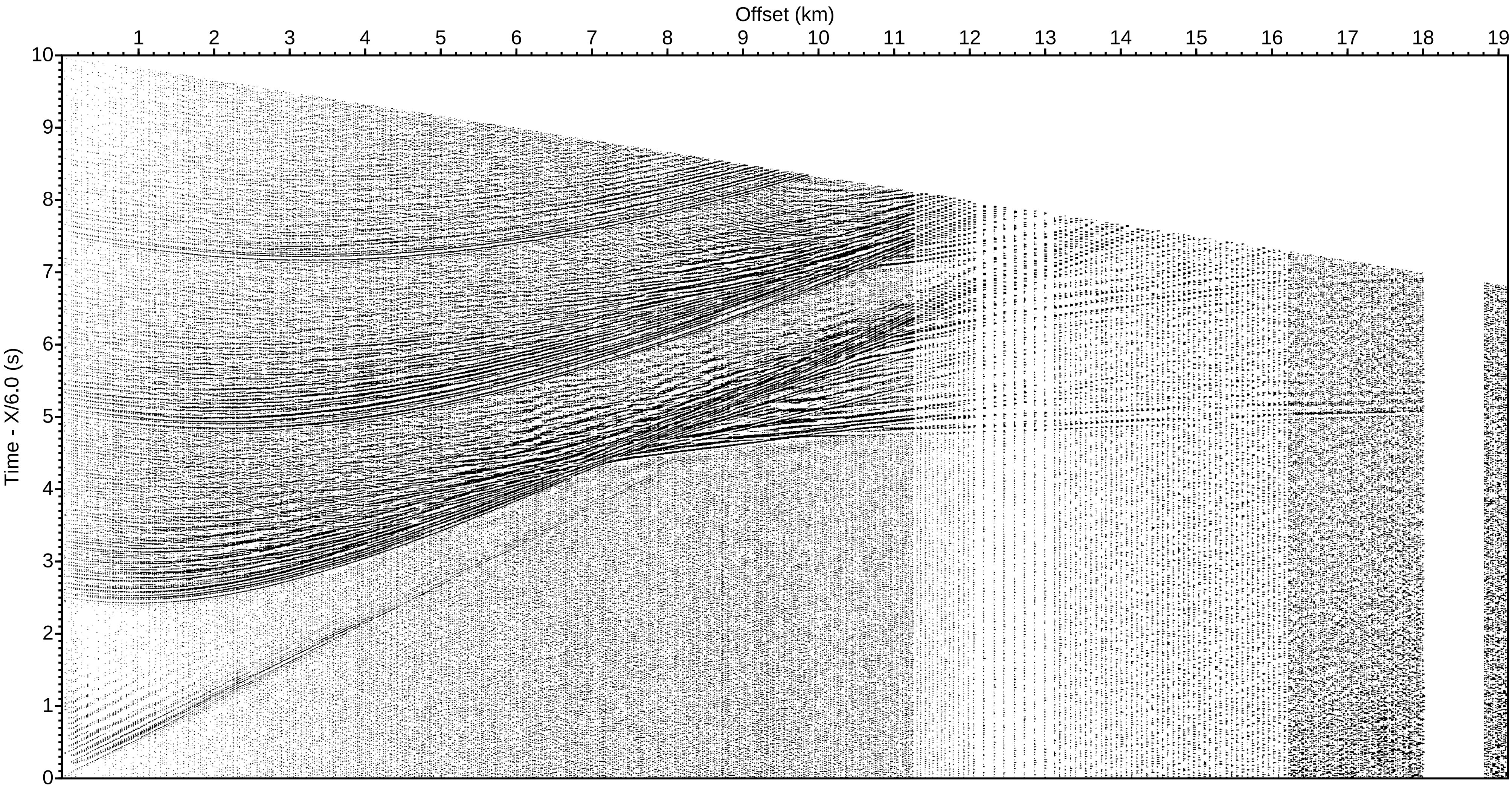
EAGER 2011 - Sonobuoy 3B-33aux3 (deconv., bpf 5-36 Hz)



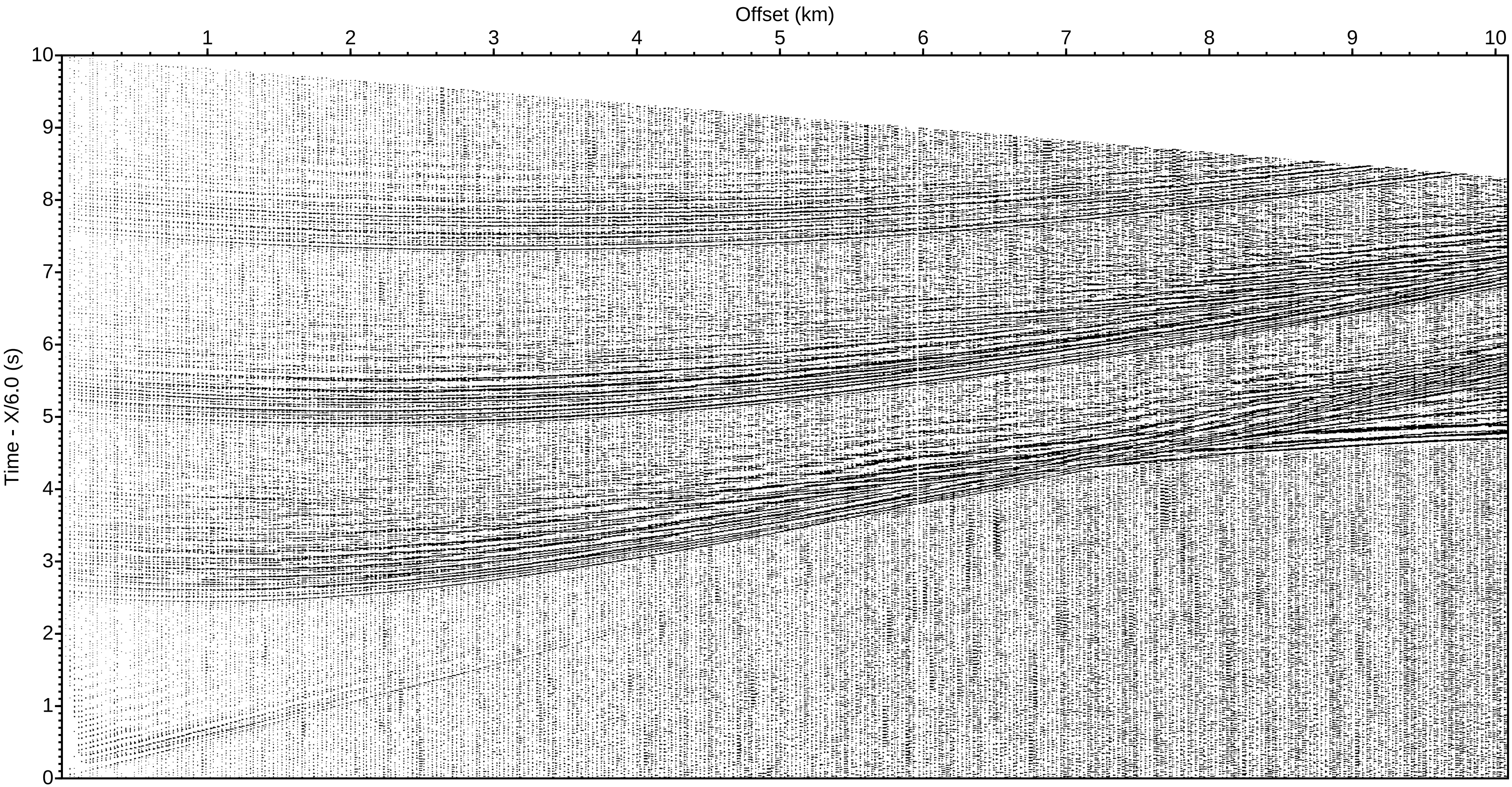
EAGER 2011 - Sonobuoy 3B-34aux4 (deconv., bpf 5-36 Hz)



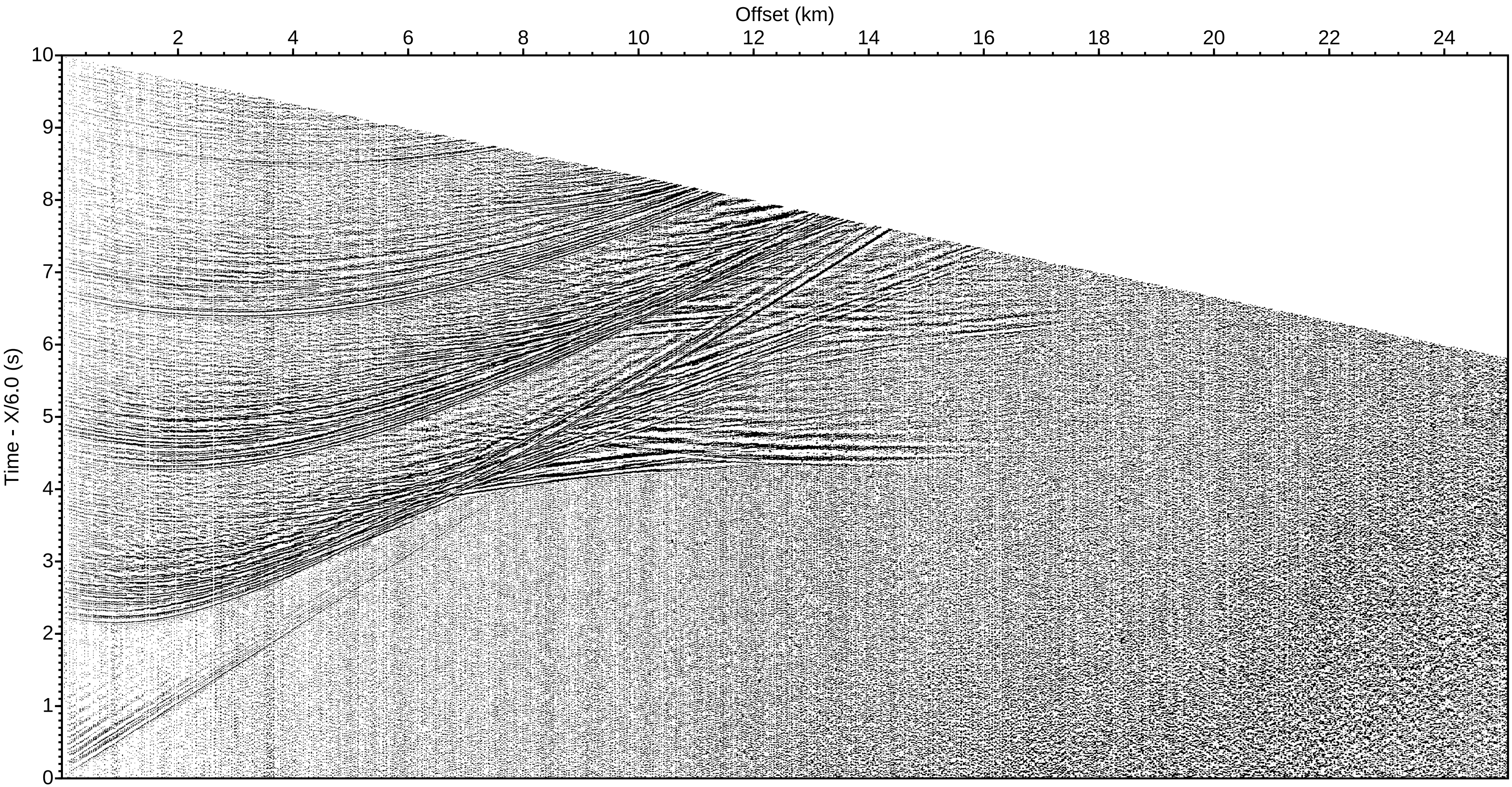
EAGER 2011 - Sonobuoy 3B-35aux1 (deconv., bpf 5-36 Hz)



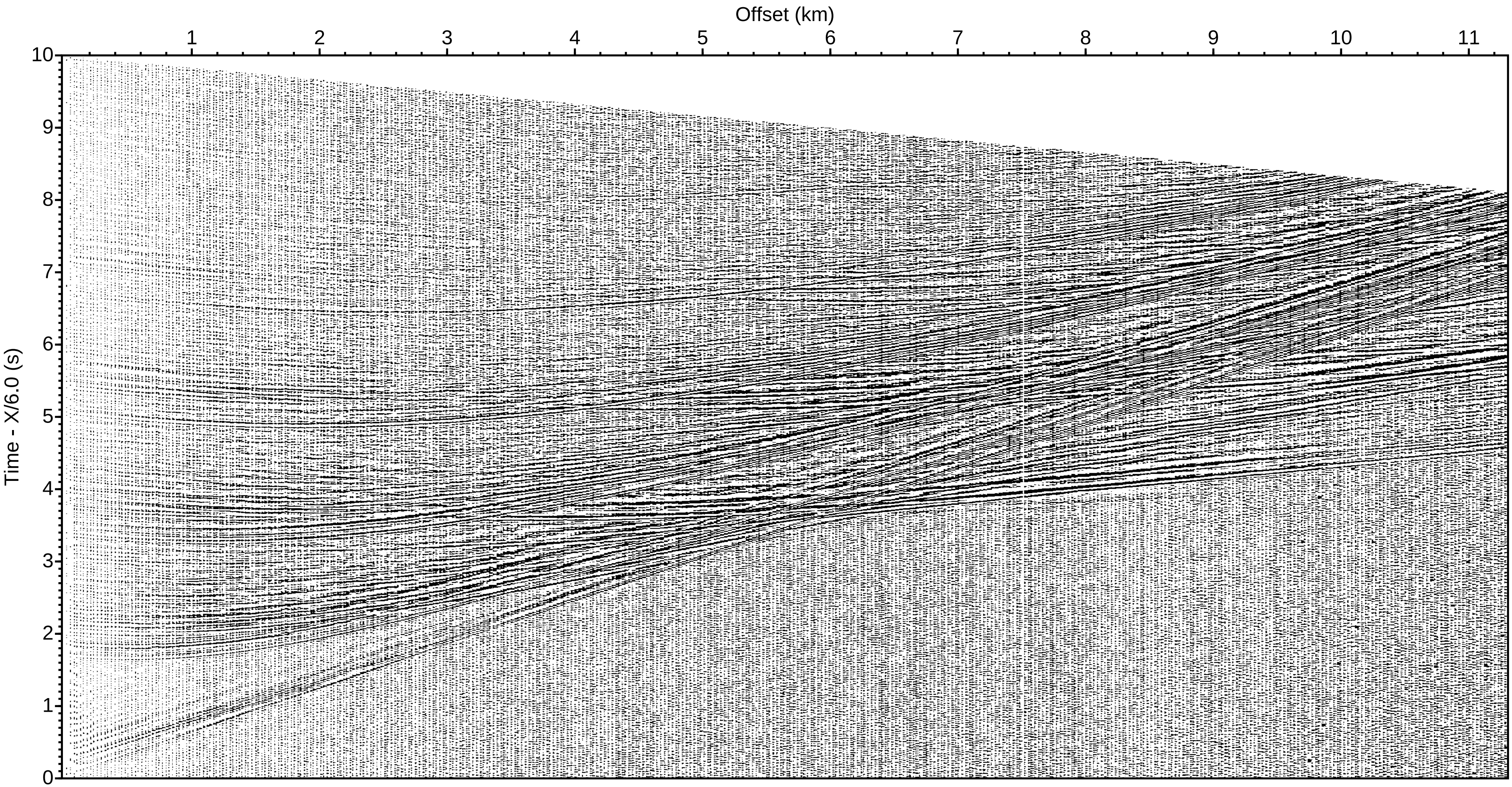
EAGER 2011 - Sonobuoy 3B-36aux2-p1 (deconv., bpf 5-36 Hz)



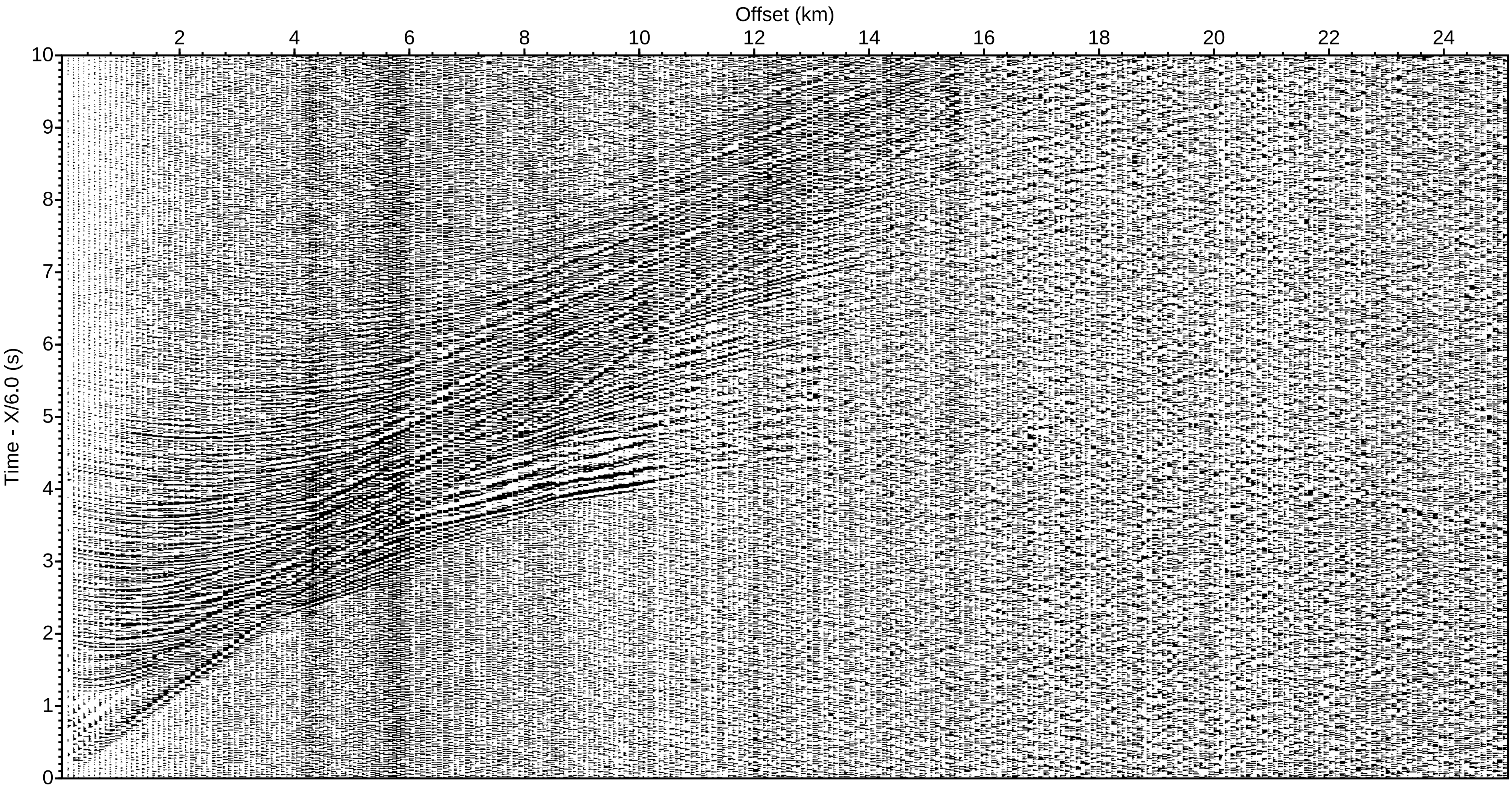
EAGER 2011 - Sonobuoy 3B-37aux3 (deconv., bpf 5-36 Hz)



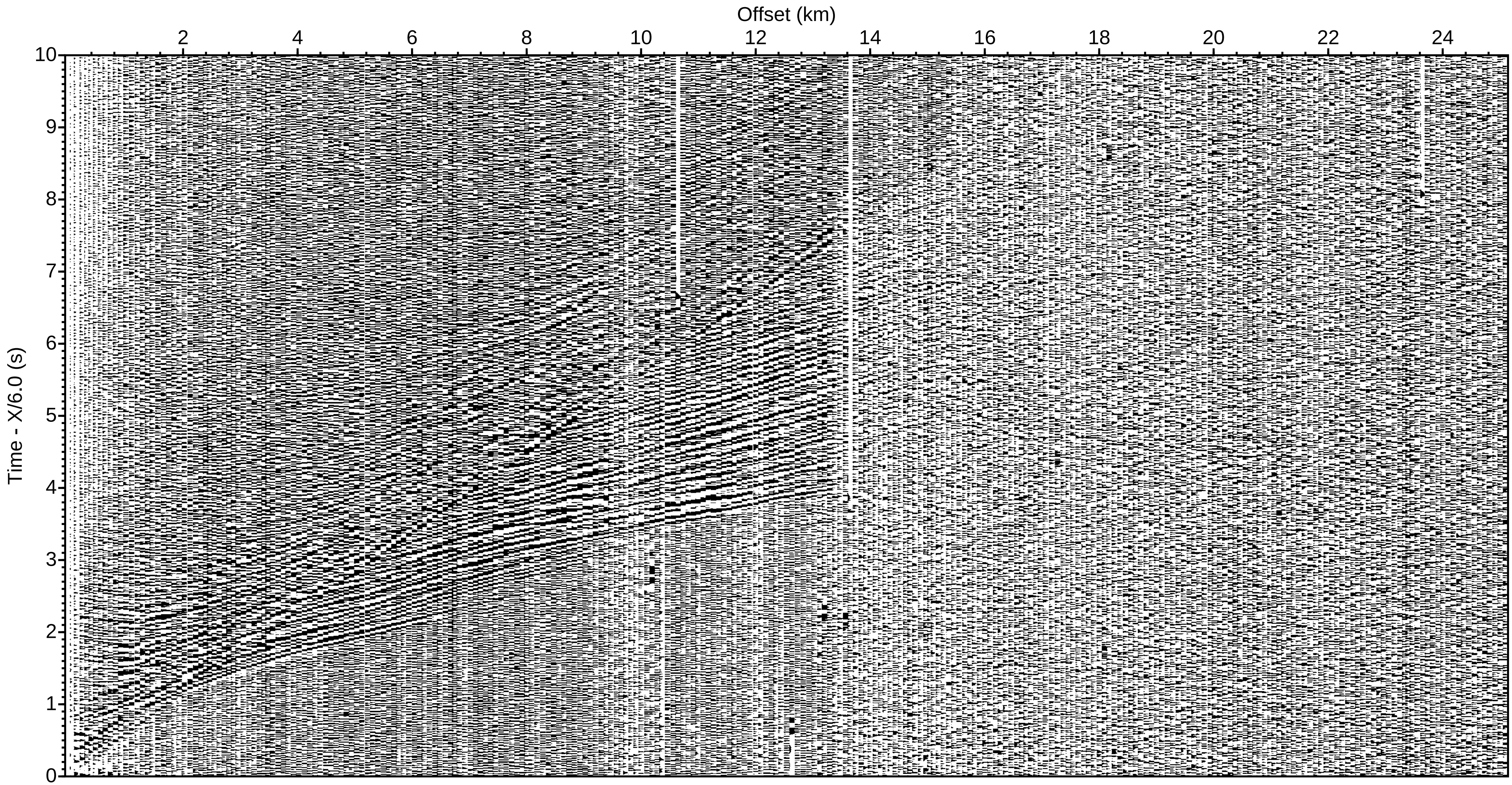
EAGER 2011 - Sonobuoy 3C-38aux4 (deconv., bpf 5-36 Hz)



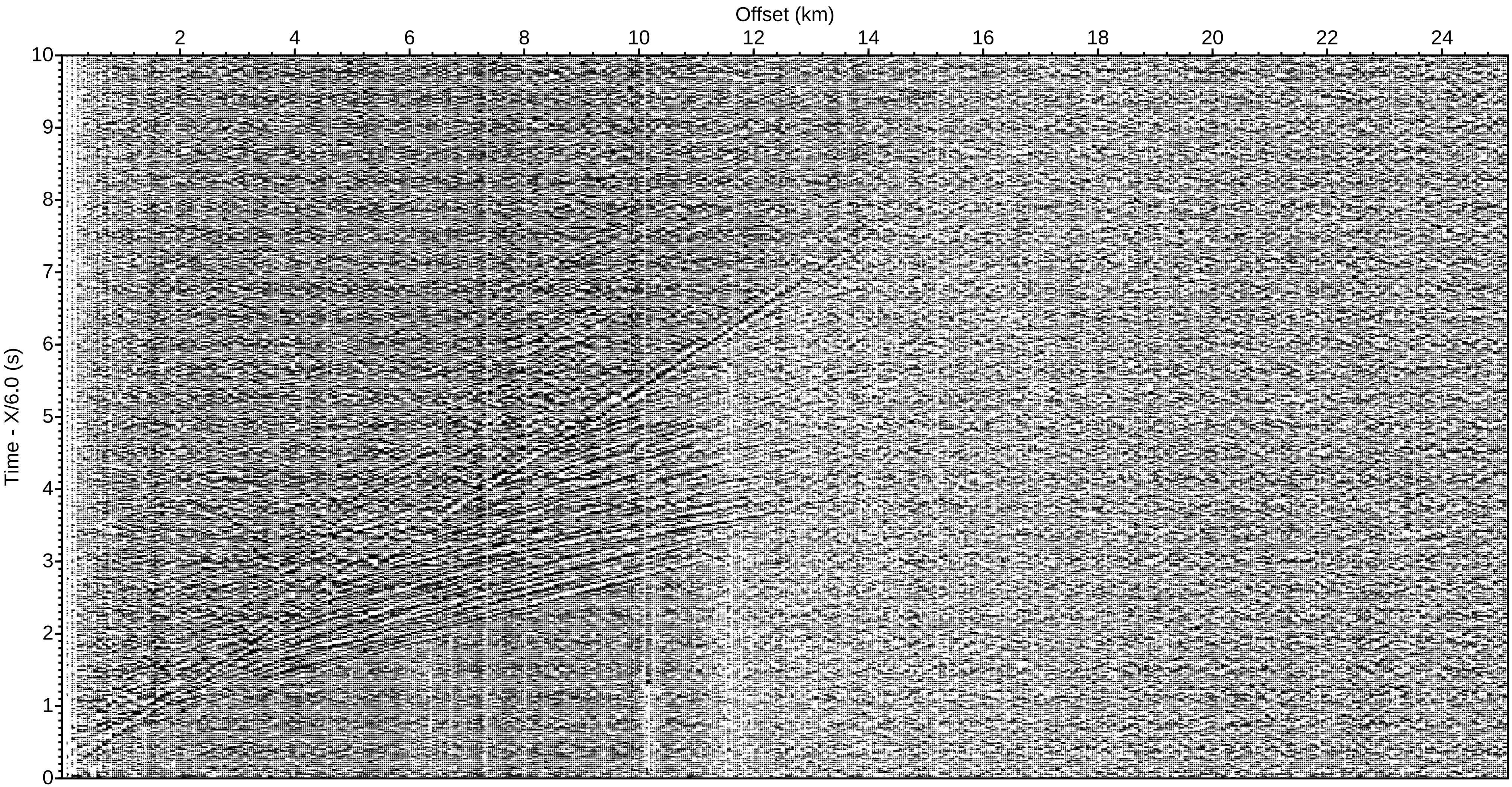
EAGER 2011 - Sonobuoy 3C-39aux1 (deconv., bpf 5-36 Hz)



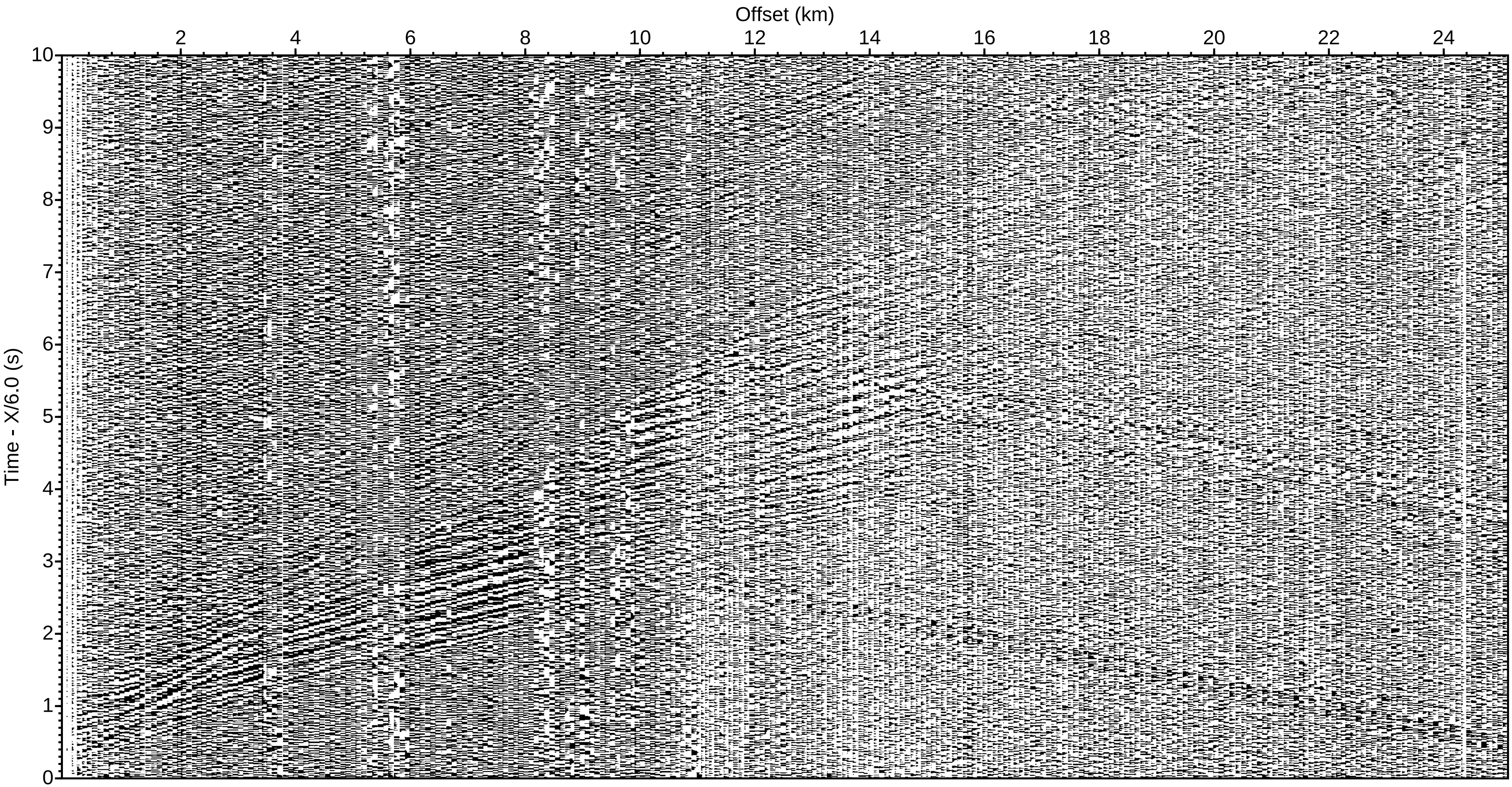
EAGER 2011 - Sonobuoy 3D-40aux2 (deconv., bpf 5-36 Hz)



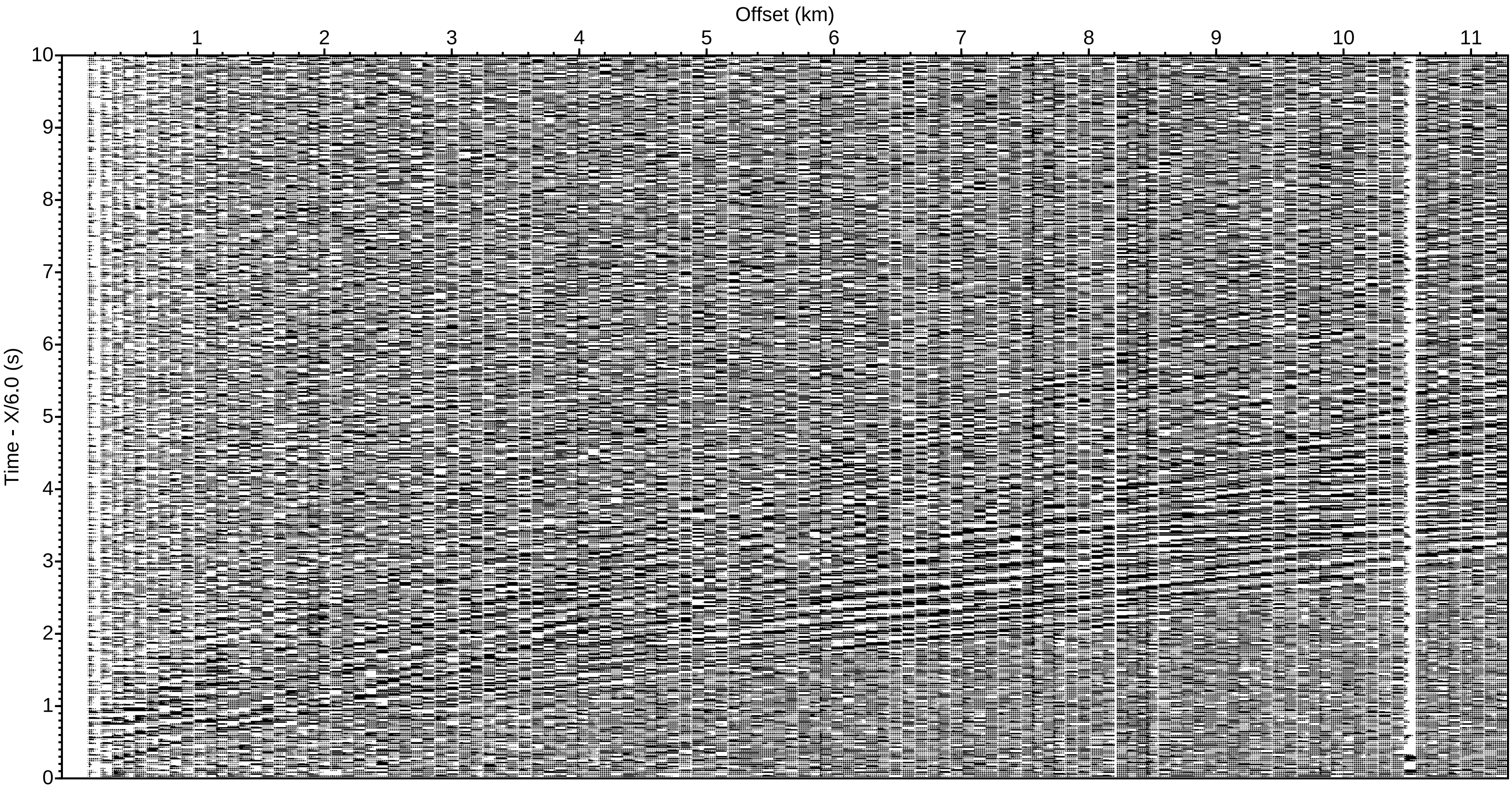
EAGER 2011 - Sonobuoy 3D-41aux3 (deconv., bpf 5-36 Hz)



EAGER 2011 - Sonobuoy 3D-43aux4 (deconv., bpf 5-36 Hz)



EAGER 2011 - Sonobuoy 3D-44aux1 (deconv., bpf 5-36 Hz)

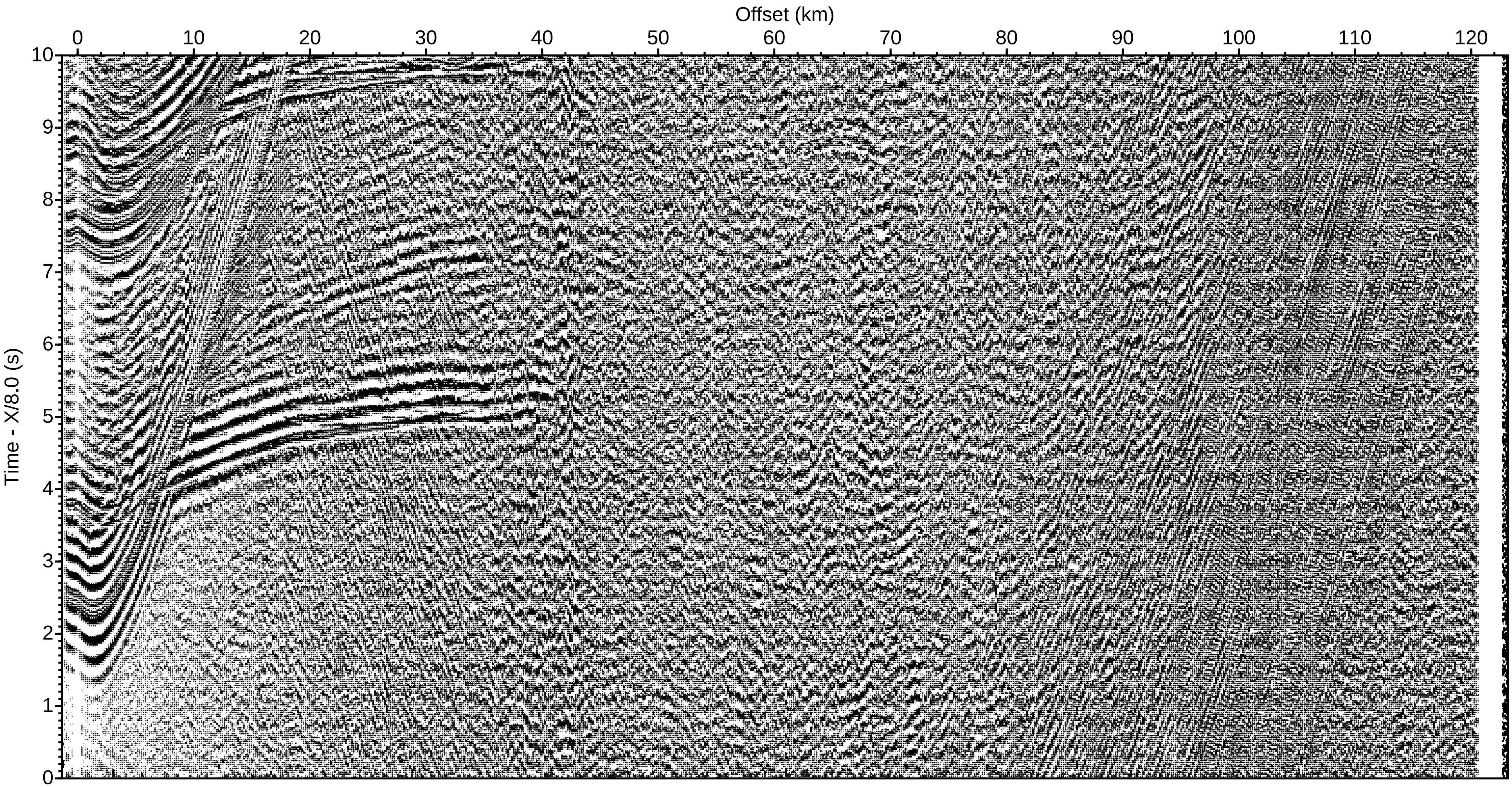


EAGER 2011 - Sonobuoy 3D-46aux2 (deconv., bpf 5-36 Hz)

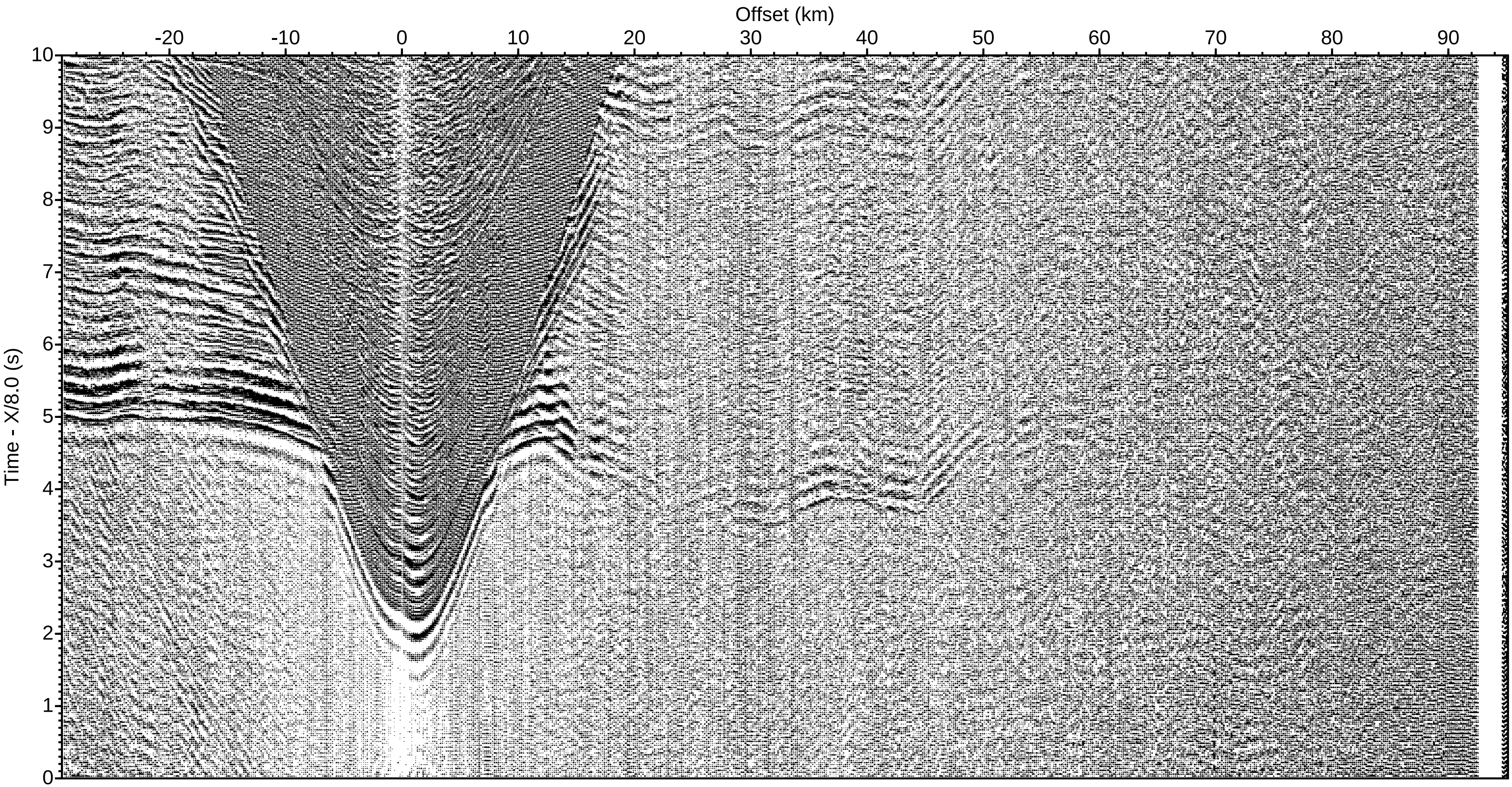
Appendix V-B

Raw Record Sections of Selected Ocean Bottom Seismometers

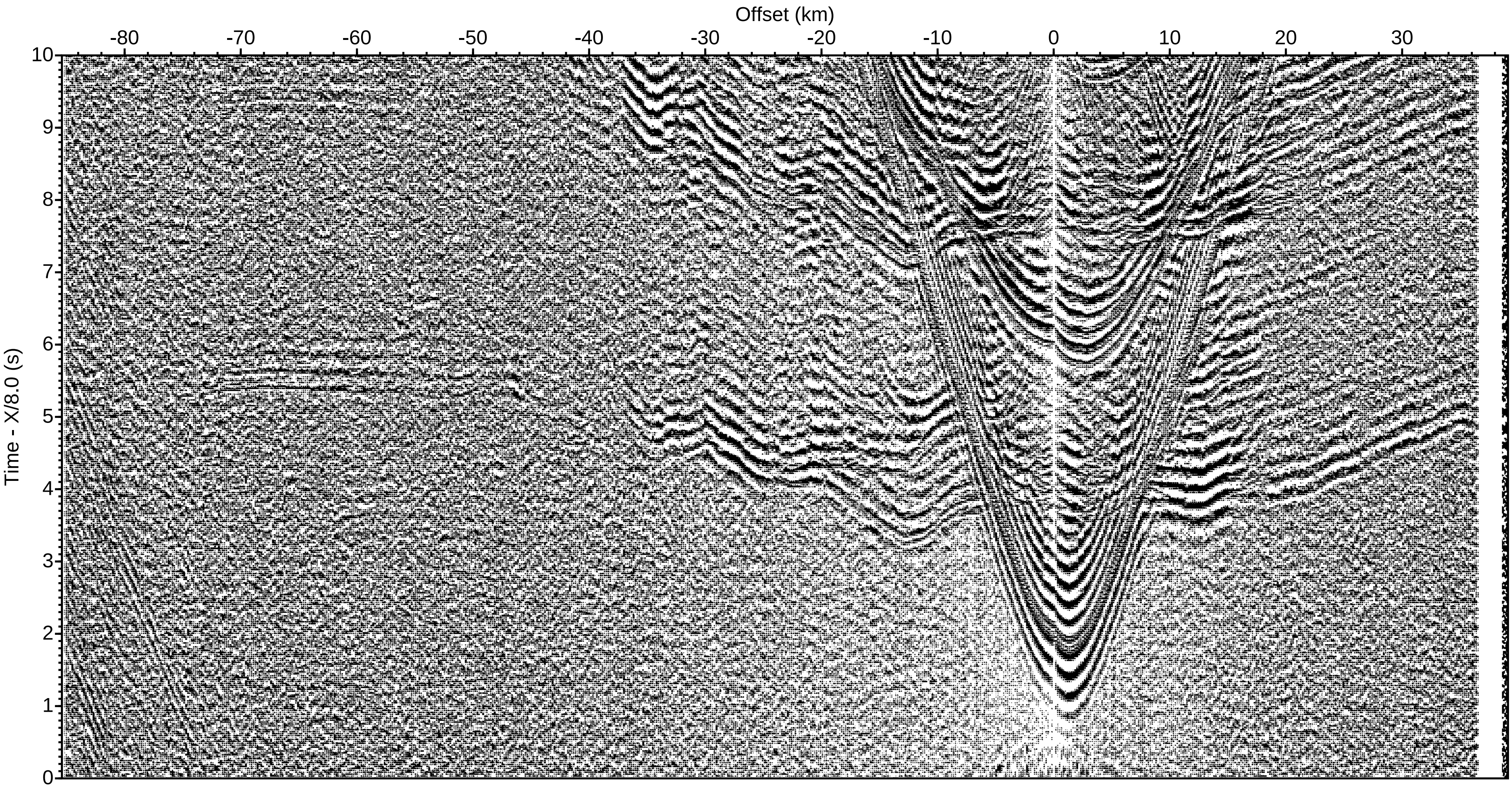
Vertical scale is the travel time reduced with a reduction velocity of 8.0 km/s. Shot-receiver distances (offsets) are calculated from the deployment position of the OBS. No instrument relocalization at the seafloor was carried out.



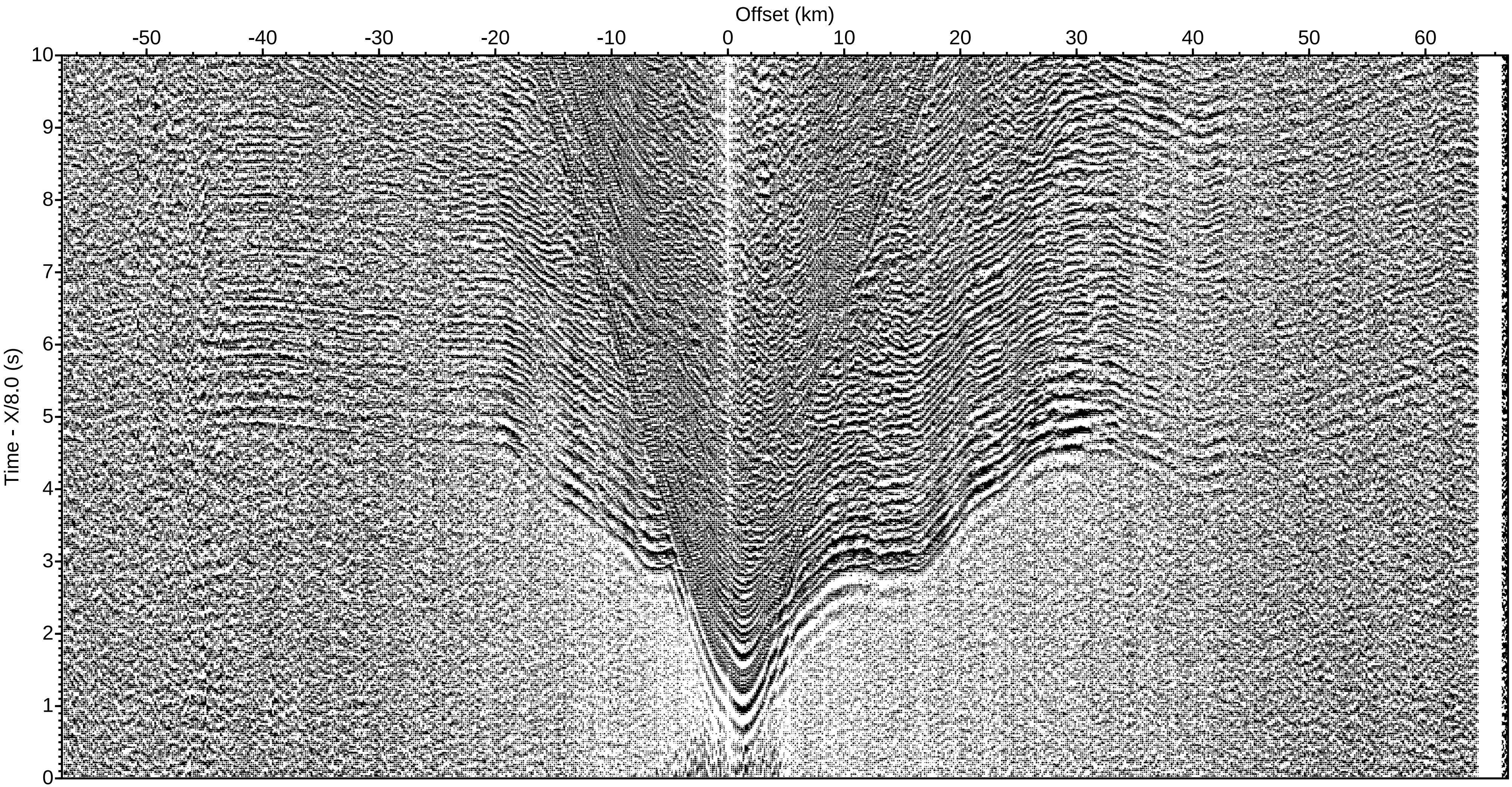
EAGER 2011 OBS 101 Line 1A channel h (bpf 4-15 Hz, scaling by range factor 0.15)



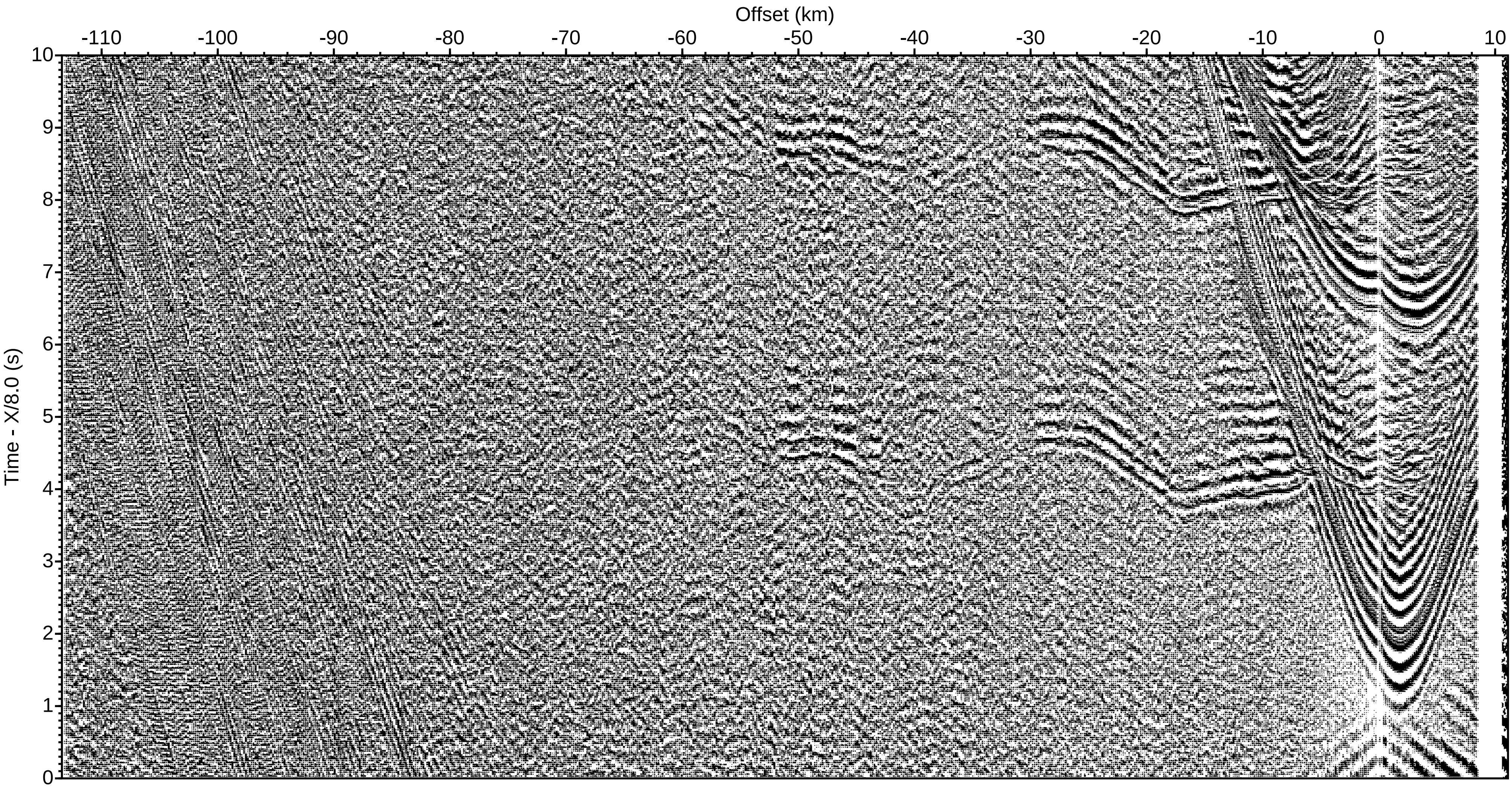
EAGER 2011 OBS 102 Line 1A channel z (bpf 4-15 Hz, scaling by range factor 0.3)



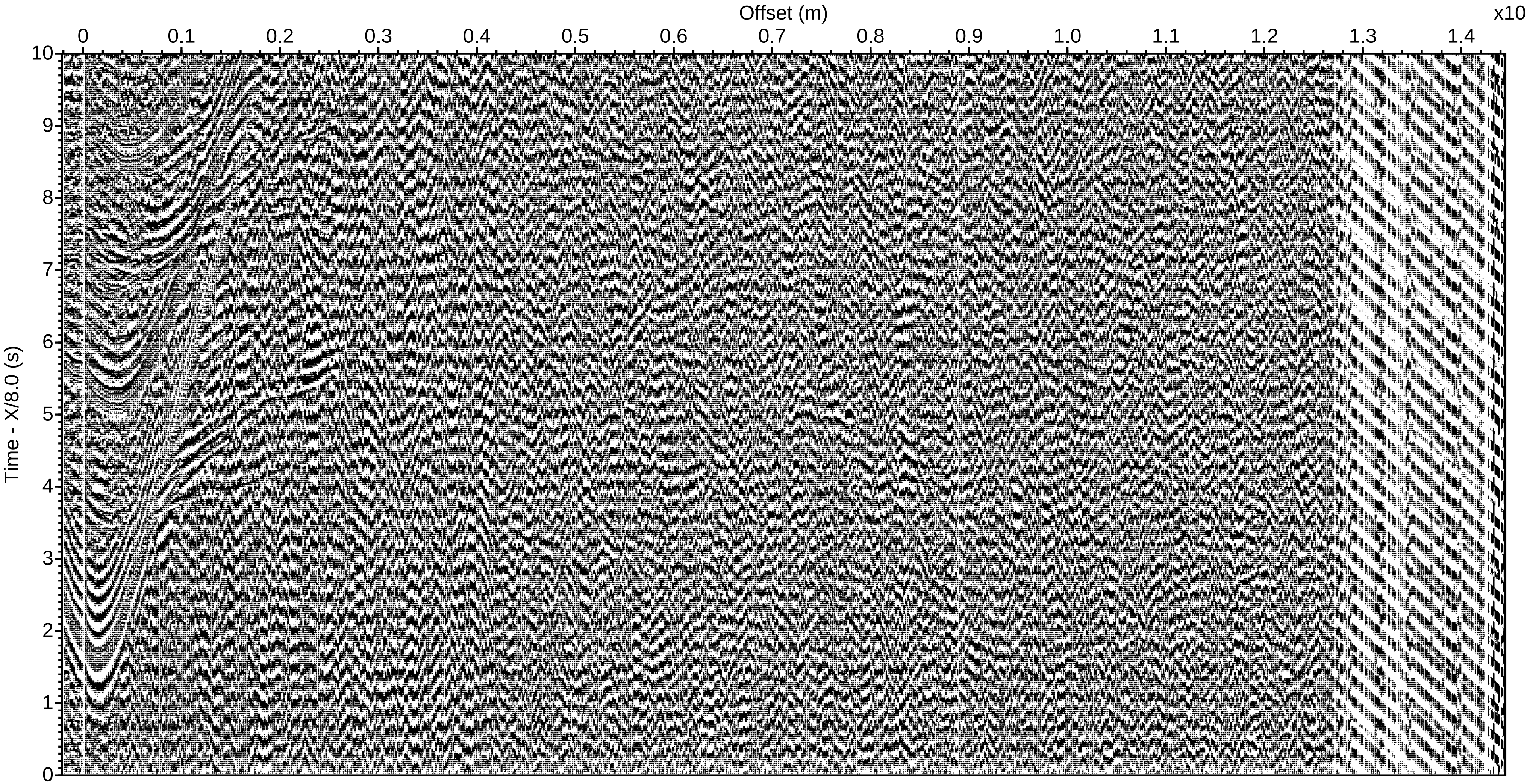
EAGER 2011 OBS 104 Line 1A channel h (bpf 4-15 Hz, scaling by range factor 0.15)



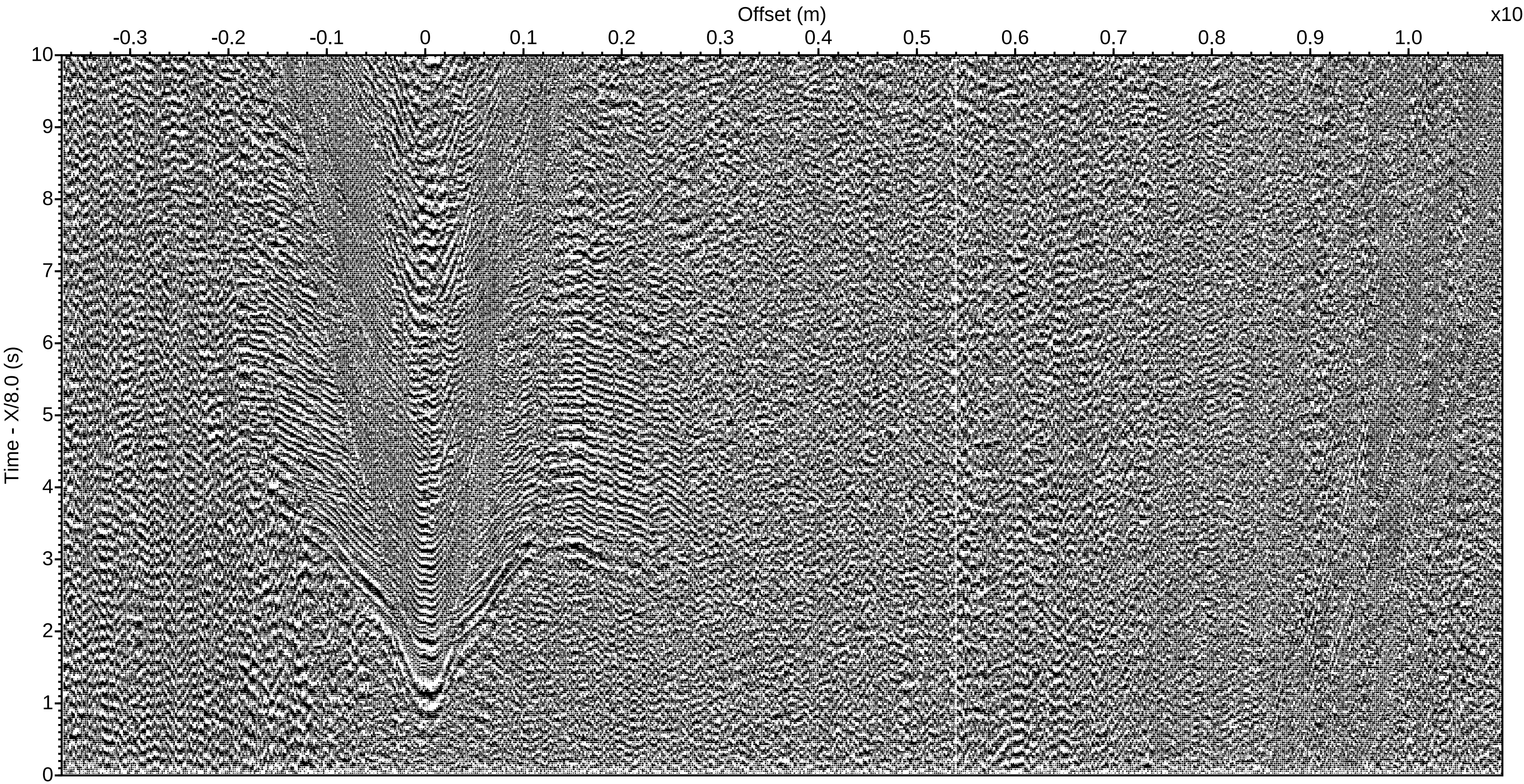
EAGER 2011 OBS 103 Line 1A channel z (bpf 4-15 Hz, scaling by range factor 0.3)



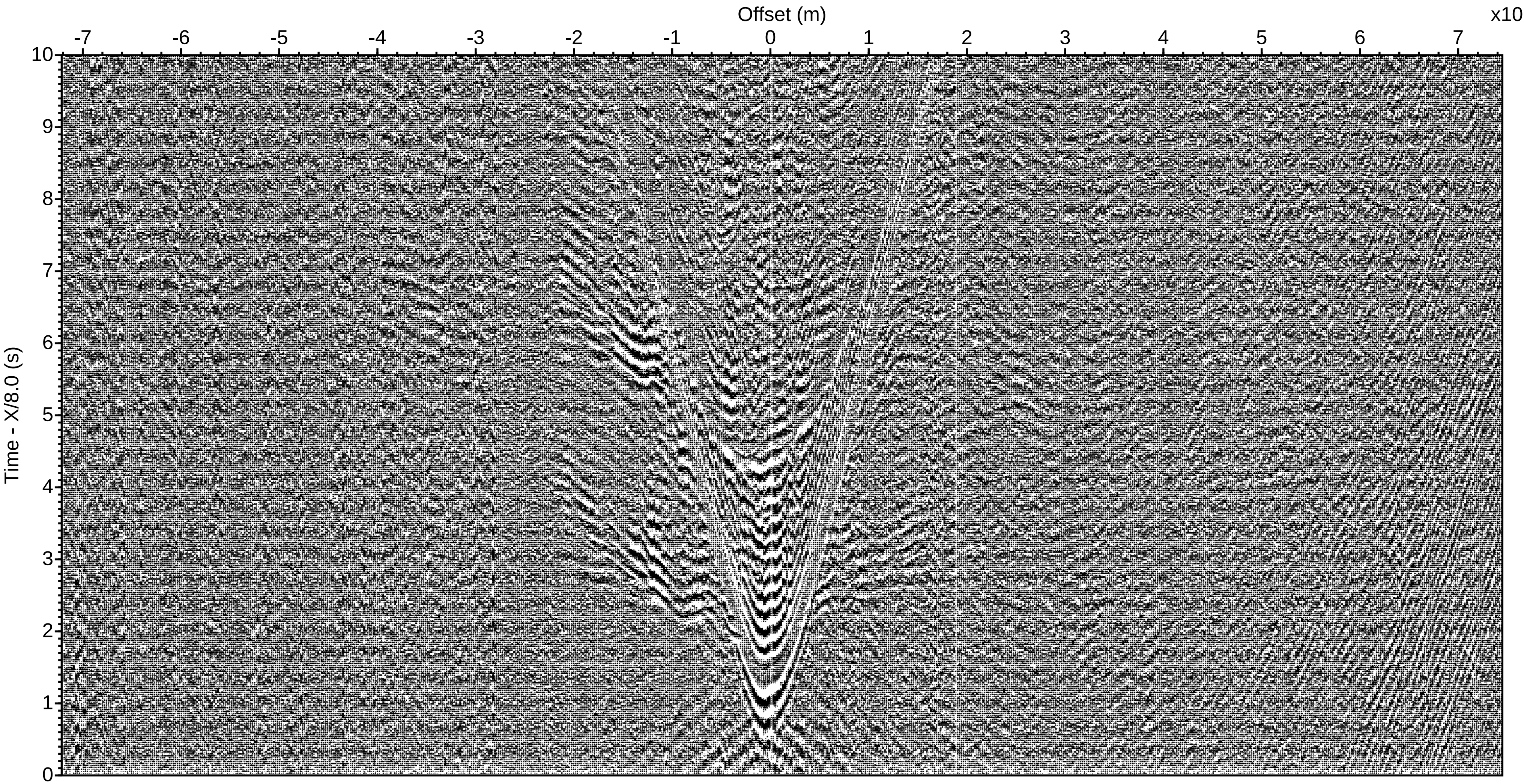
EAGER 2011 OBS 105 Line 1A channel h (bpf 4-15 Hz, scaling by range factor 0.15)



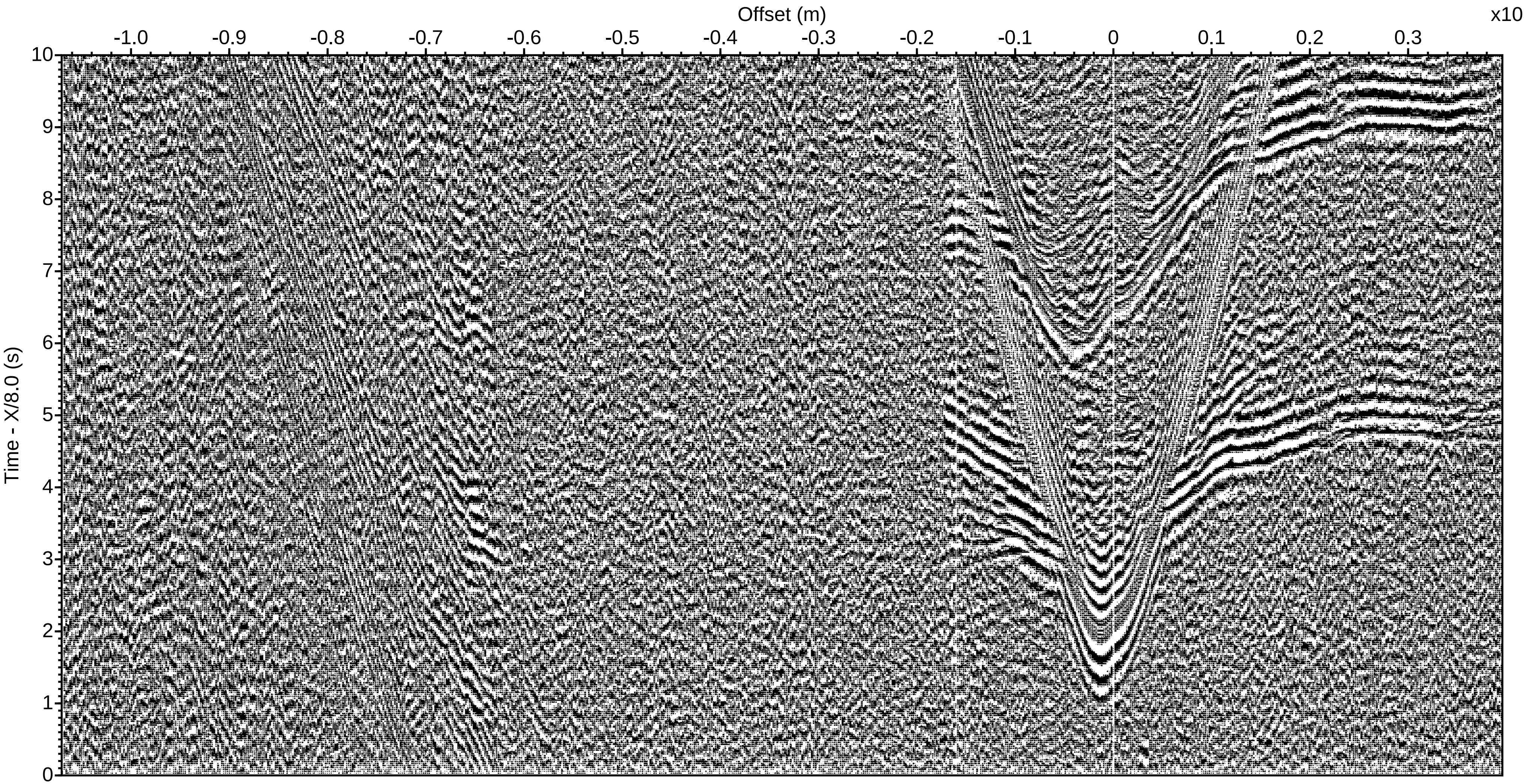
EAGER 2011 OBS 201 Line 2A channel h (bpf 4-15 Hz, scaling factor 100)



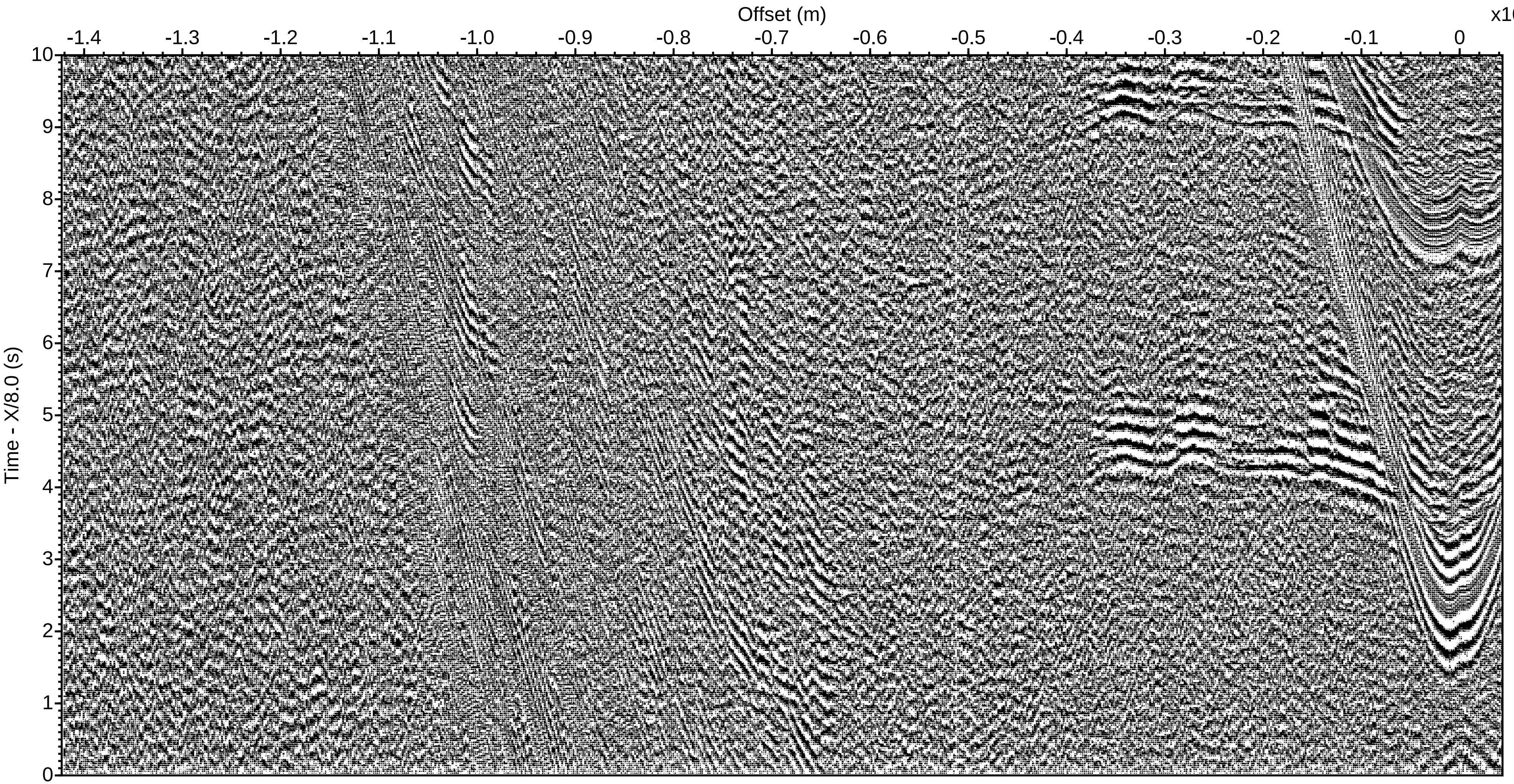
EAGER 2011 OBS 202 Line 2A channel z (bpf 4-15 Hz, scaling factor 100)



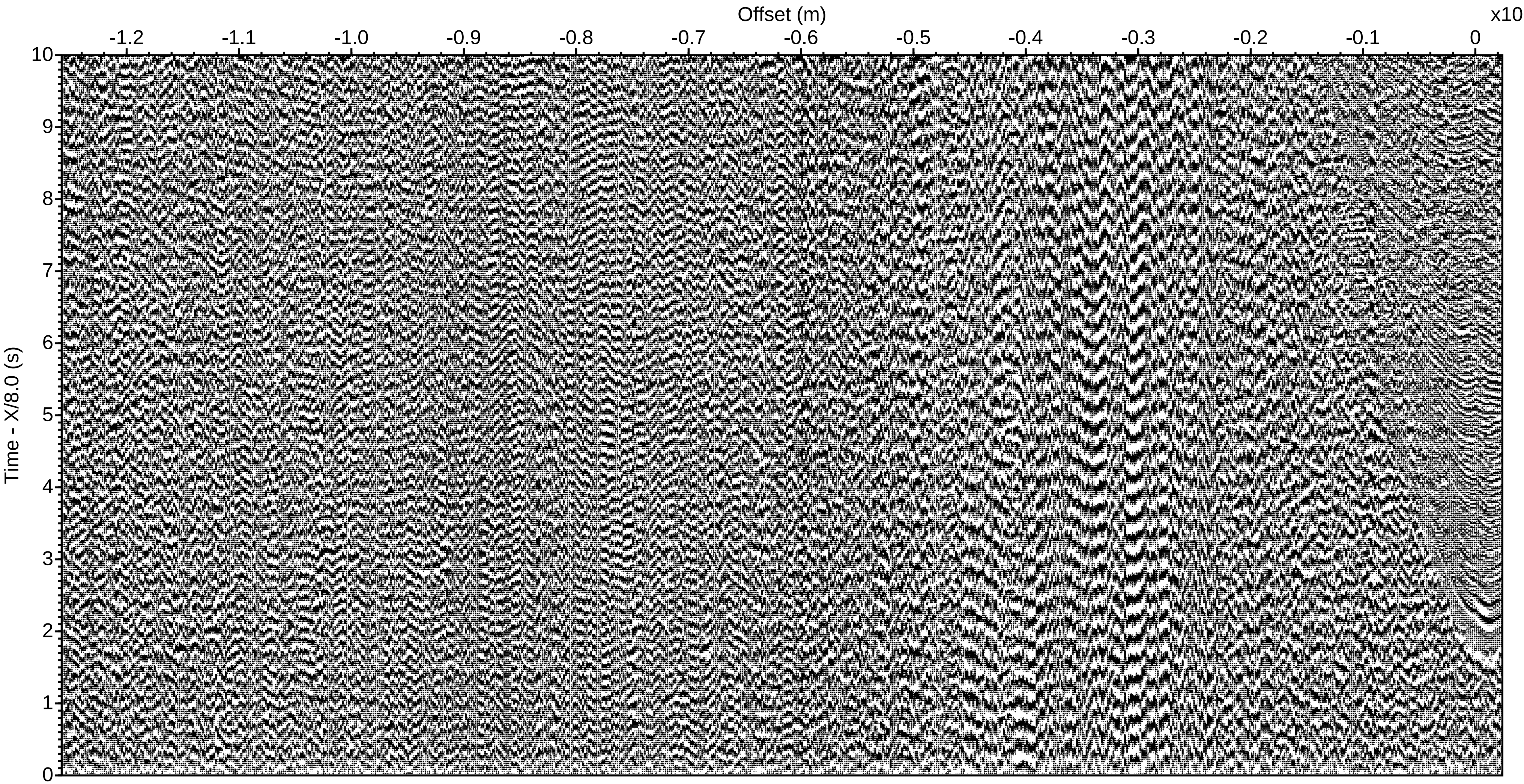
EAGER 2011 OBS 203 Line 2A channel h (bpf 4-24 Hz, scaling factor 100)



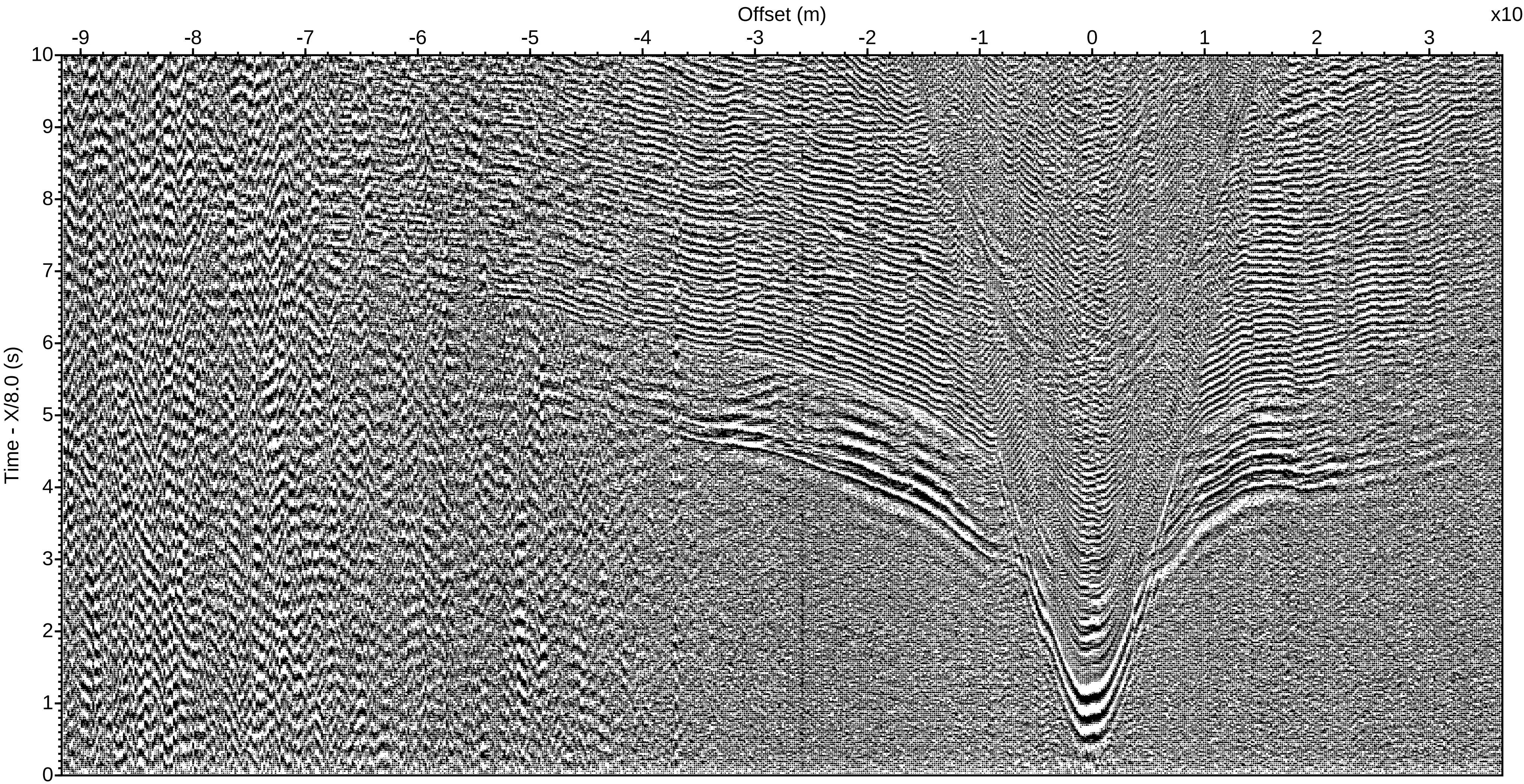
EAGER 2011 OBS 204 Line 2A channel h (bpf 4-15 Hz, scaling factor 100)



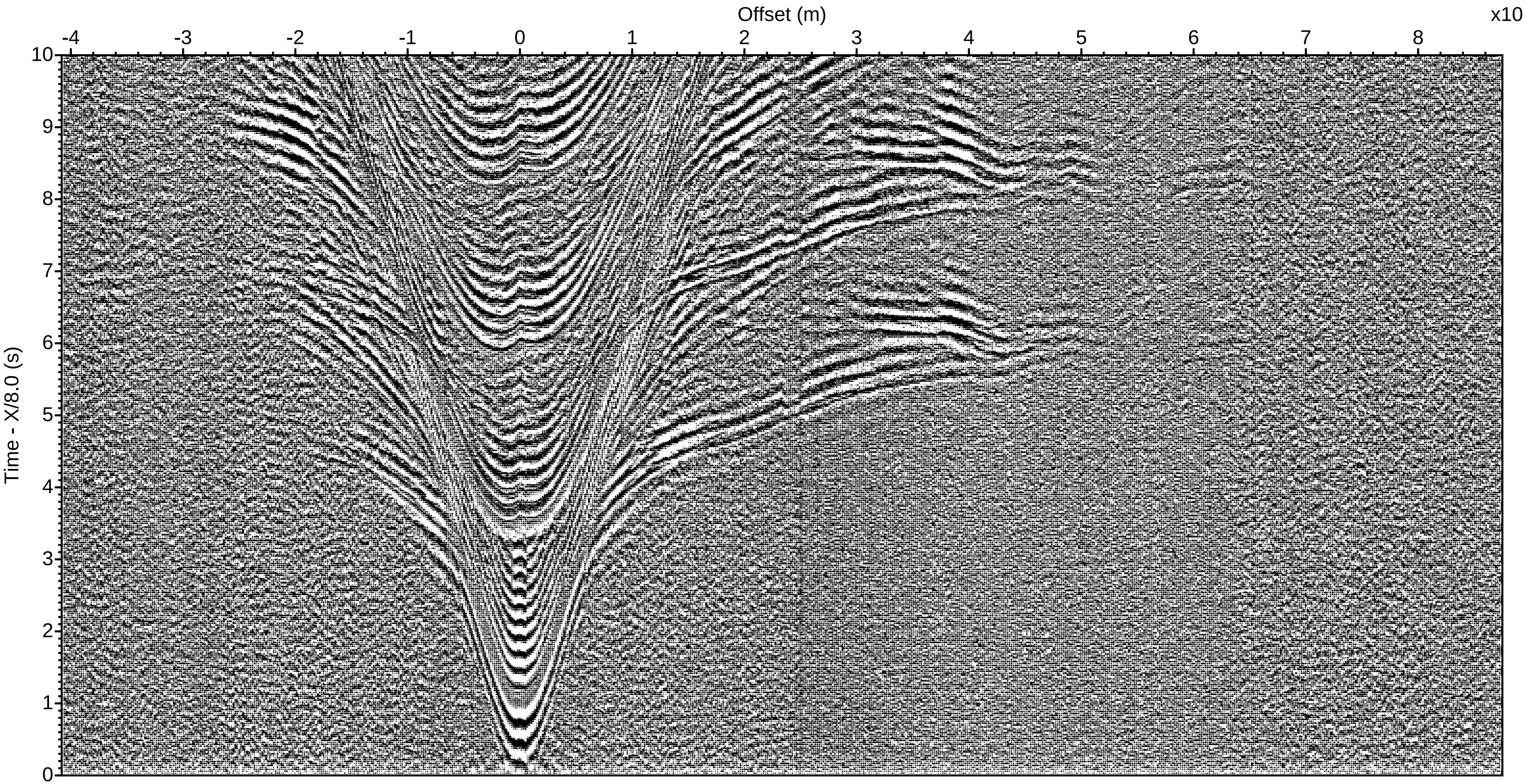
EAGER 2011 OBS 205 Line 2A channel h (bpf 4-15 Hz, scaling factor 100)



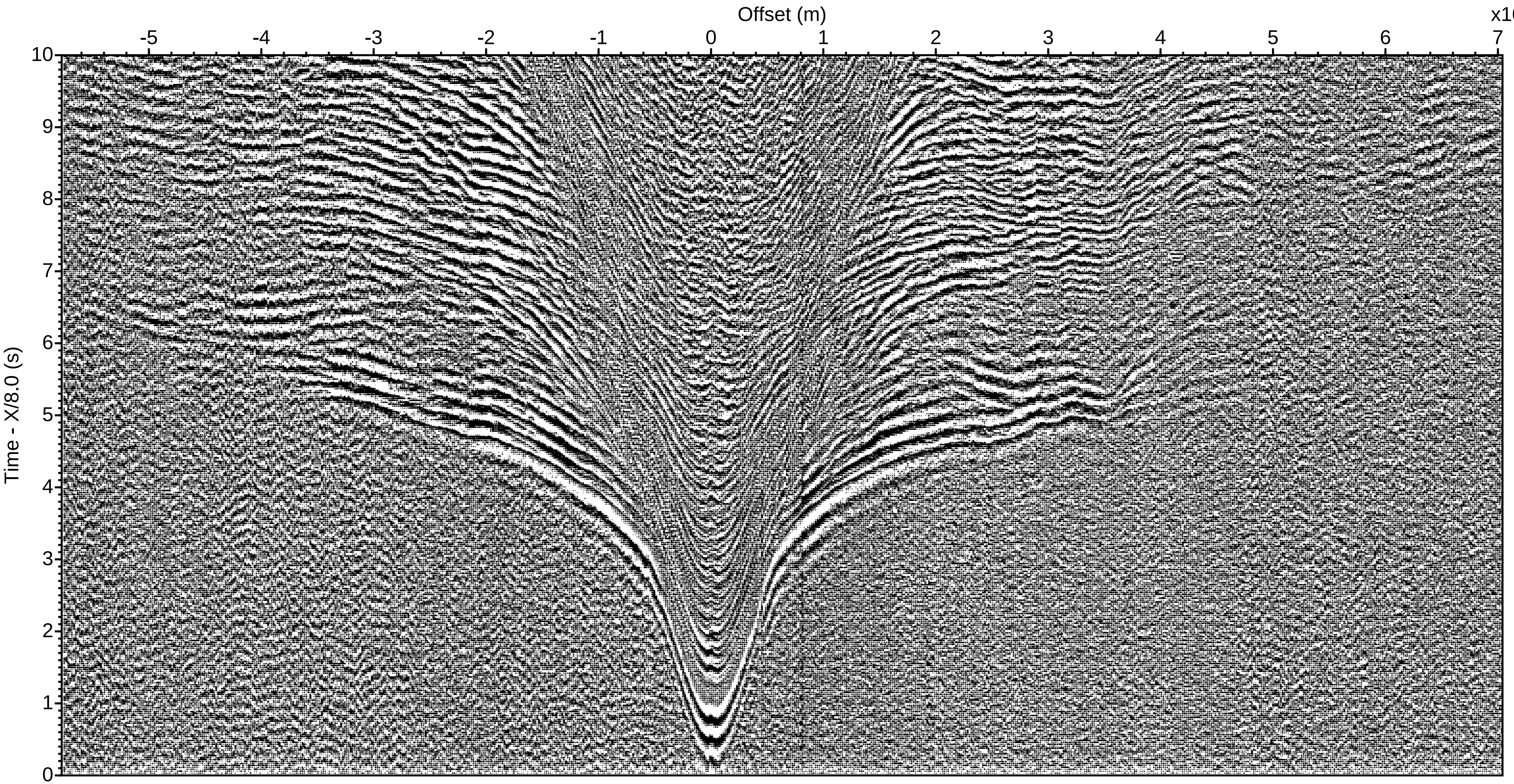
EAGER 2011 OBS 301 Line 3A channel z (bpf 4-24 Hz, scaling factor 100)



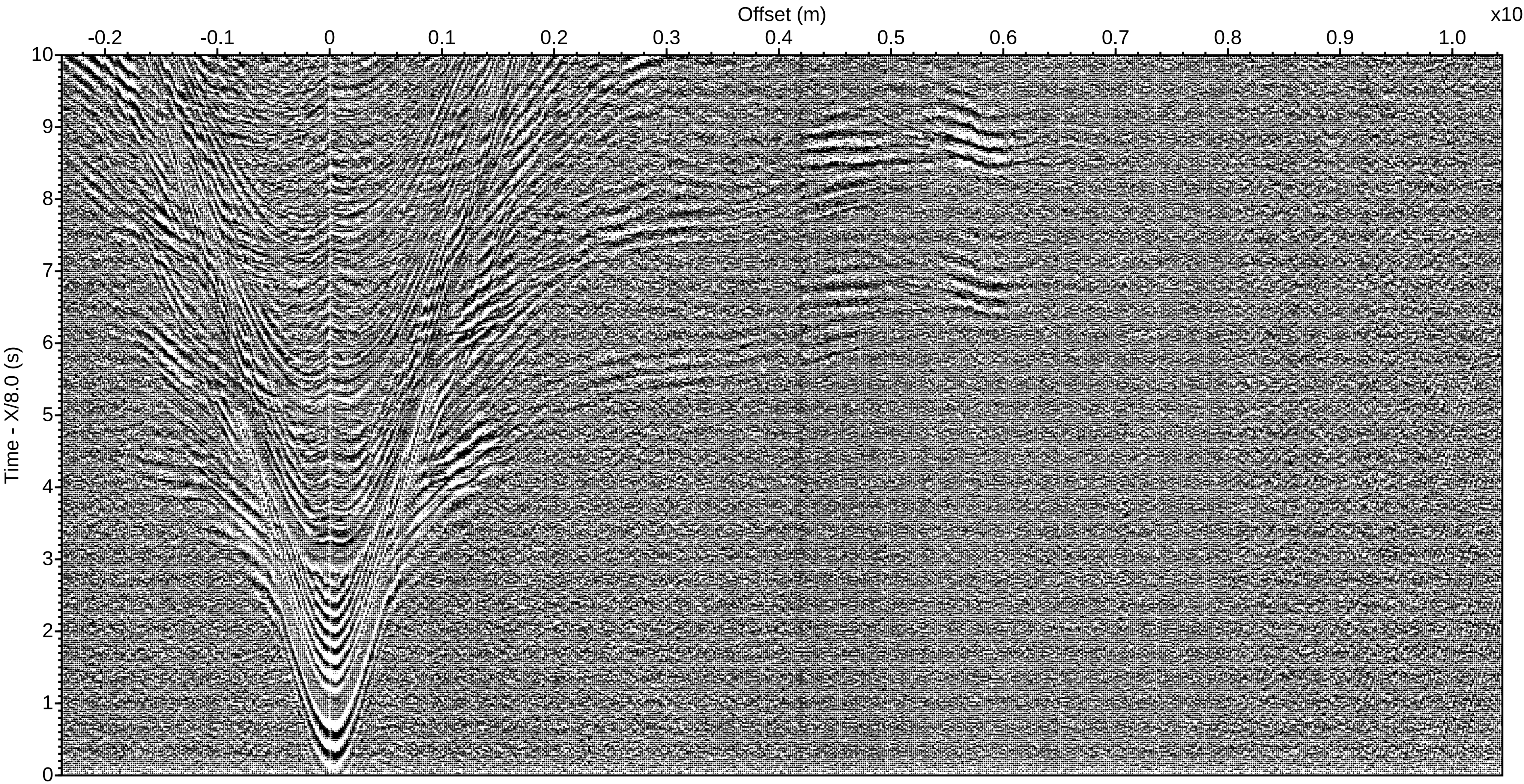
EAGER 2011 OBS 302 Line 3A channel z (bpf 4-24 Hz, scaling factor 100)



EAGER 2011 OBS 304 Line 3A channel h (bpf 4-24 Hz, scaling factor 100)



EAGER 2011 OBS 303 Line 3A channel z (bpf 4-24 Hz, scaling factor 100)

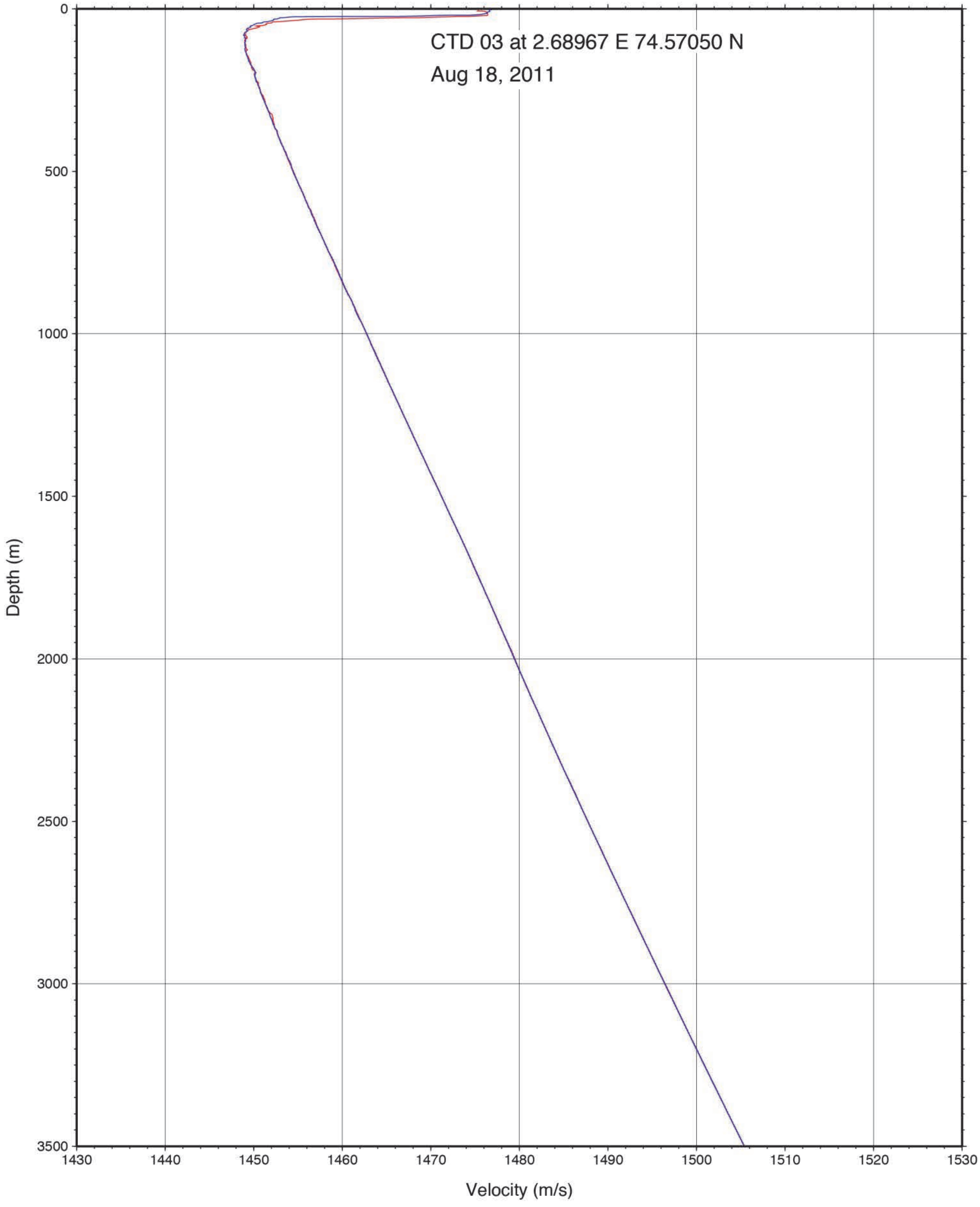


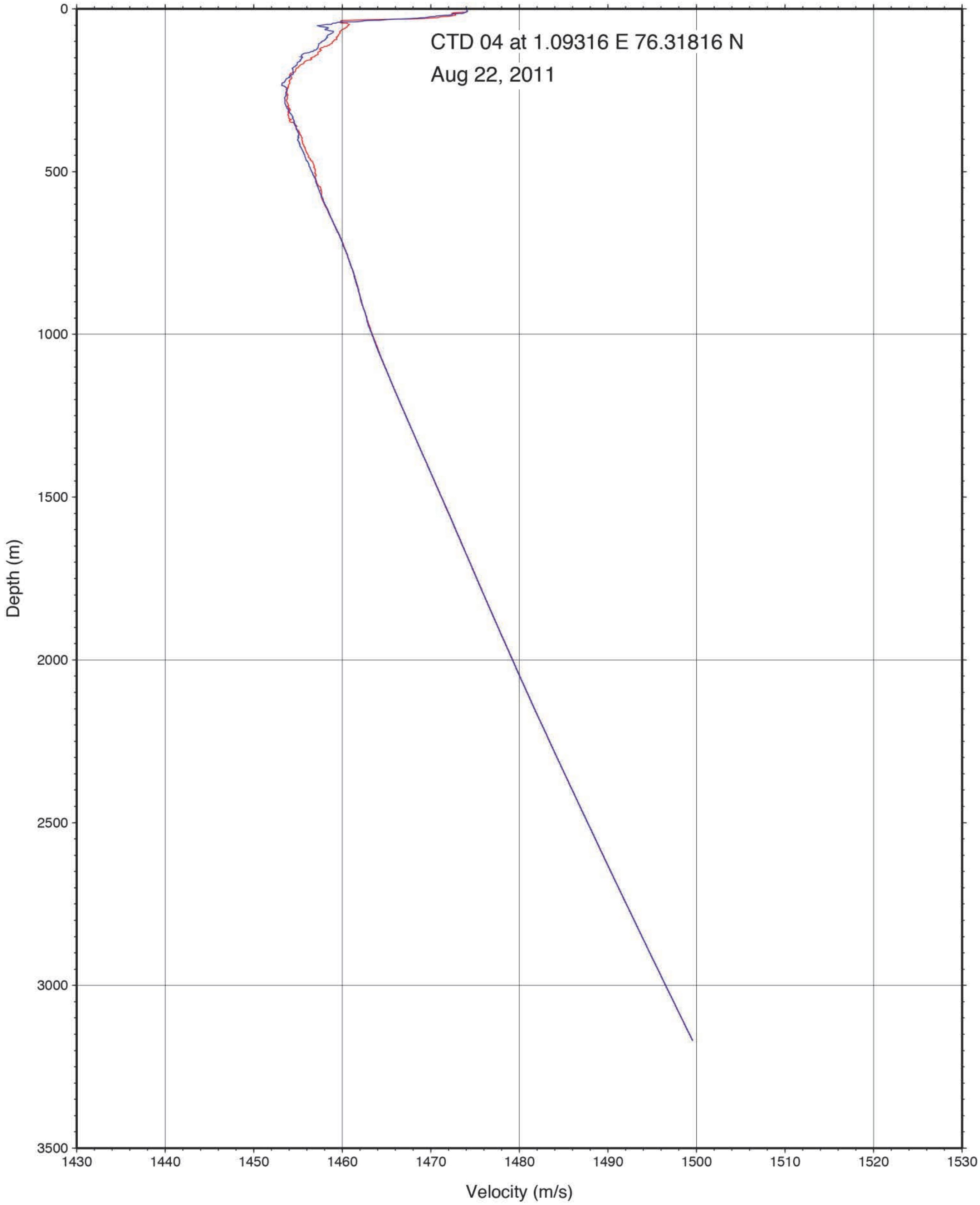
EAGER 2011 OBS 305 Line 3A channel h (bpf 4-24 Hz, scaling factor 100)

Appendix V-C

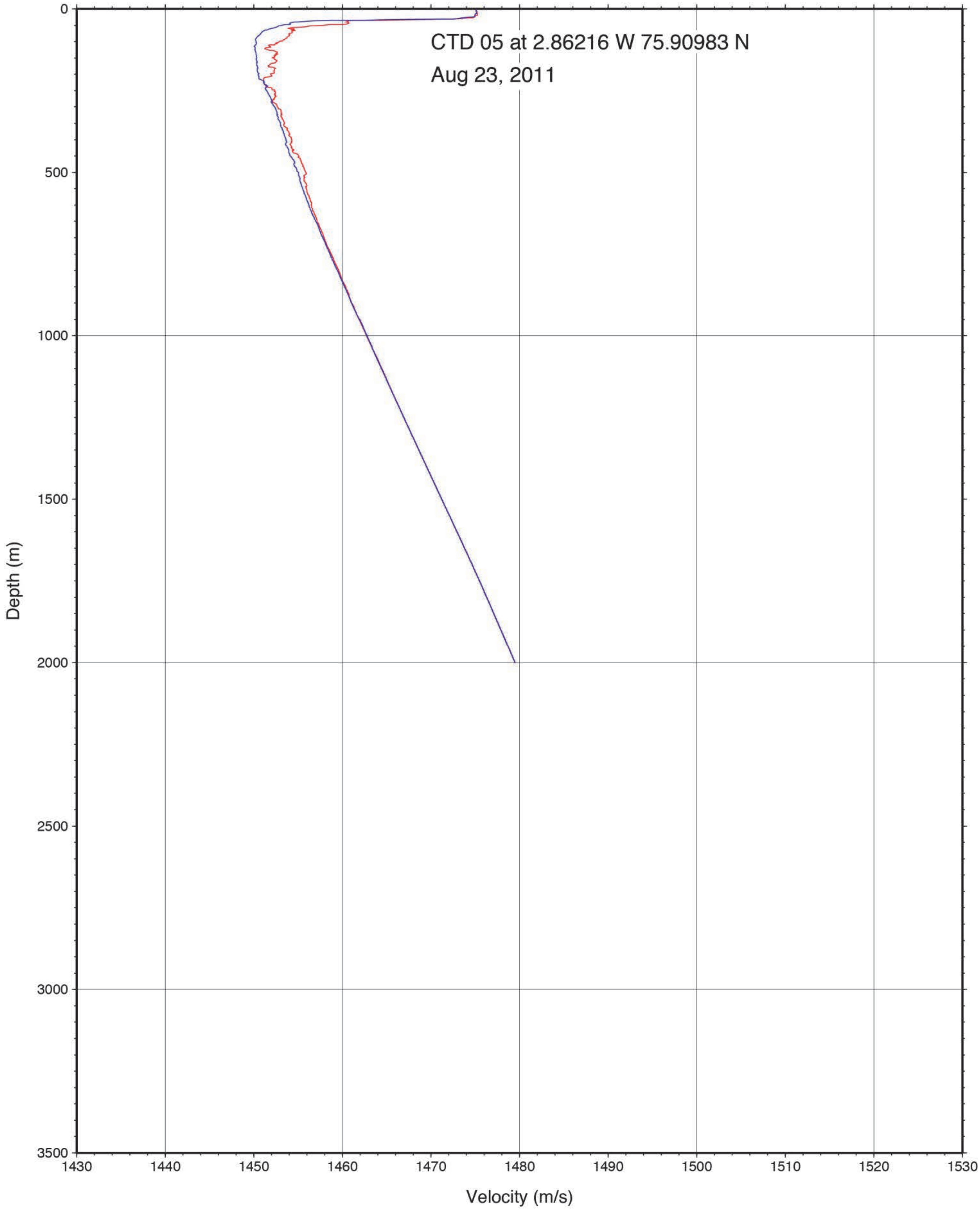
Water Velocities from CTD Measurements

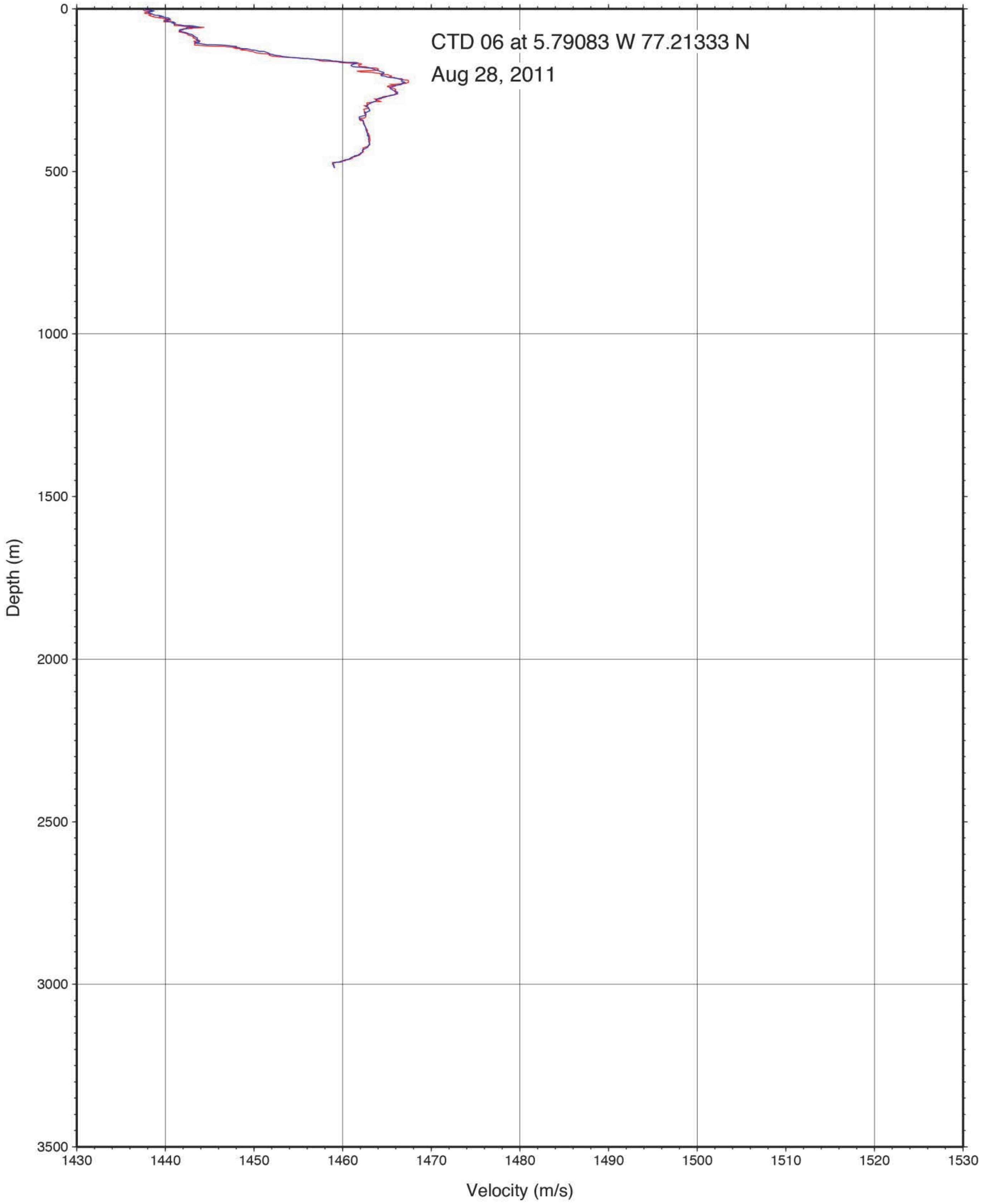
Velocity-depth functions obtained from CTD measurements carried out during the EAGER 2011 expedition. Red and blue curves show the down and up going measurements, respectively.

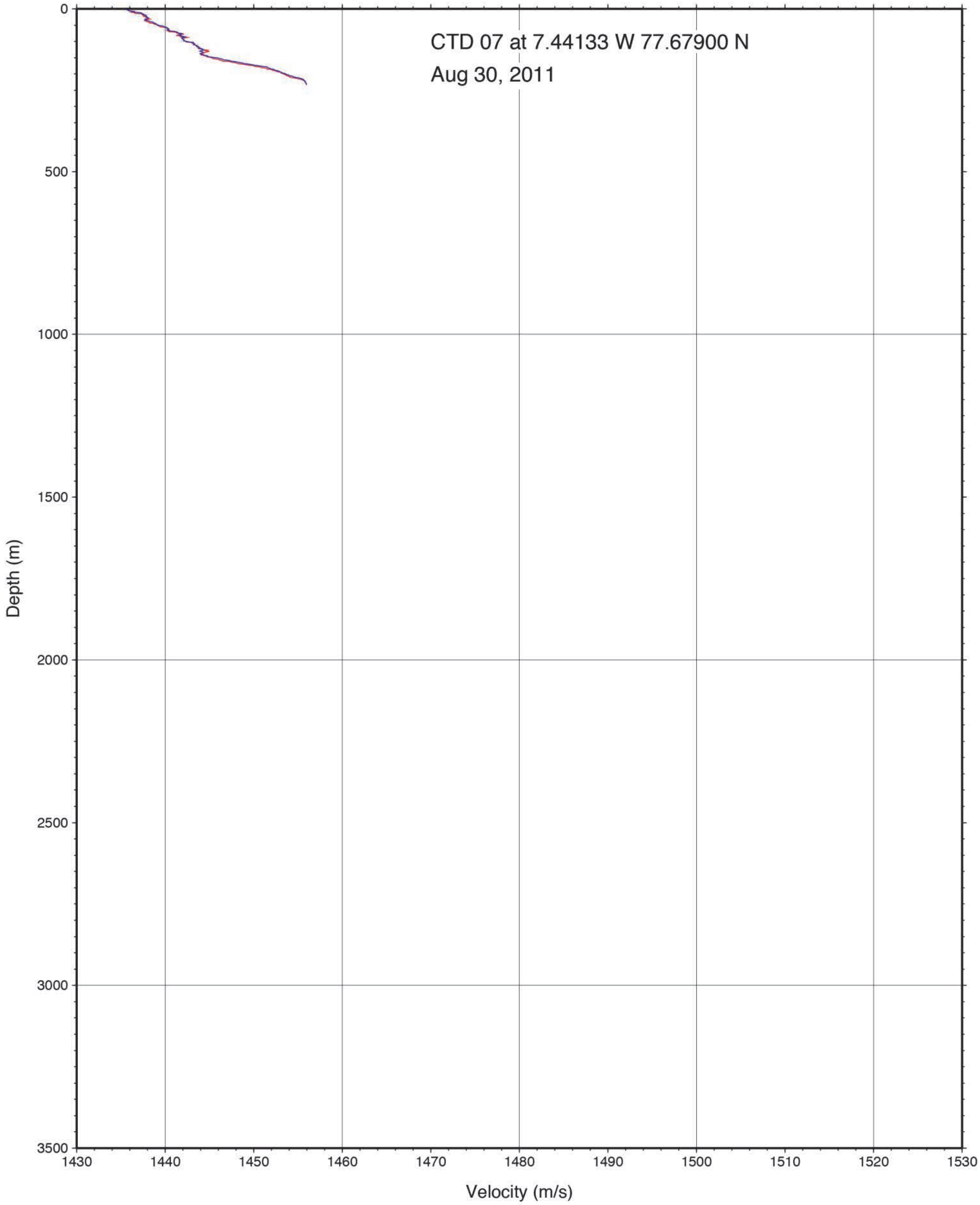

CTD 03 at 2.68967 E 74.57050 N
Aug 18, 2011
0
500
1000
1500
2000
2500
3000
3500
Depth (m)
1430
1440
1450
1460
1470
1480
1490
1500
1510
1520
1530
Velocity (m/s)



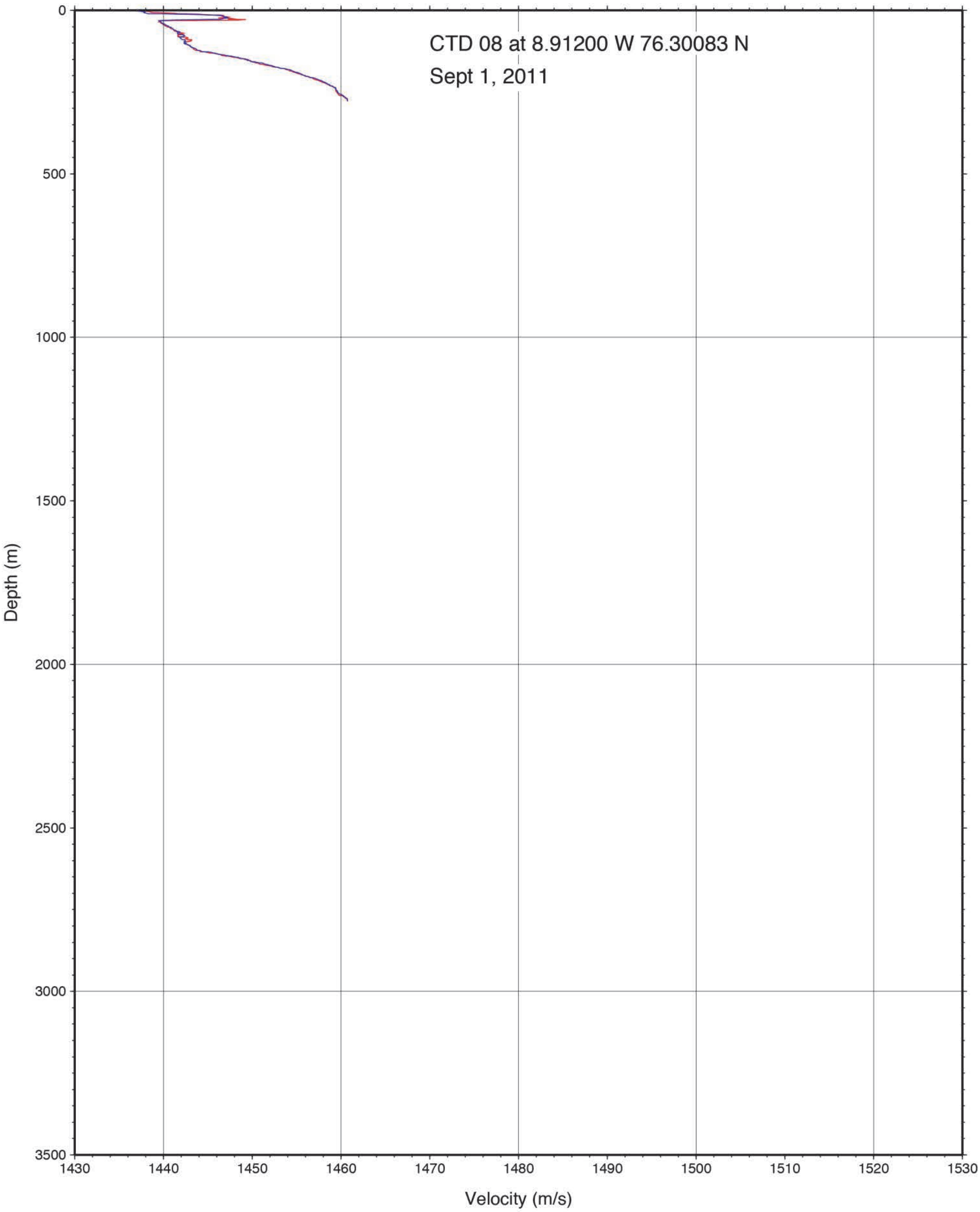
CTD 04 at 1.09316 E 76.31816 N
Aug 22, 2011
Depth (m)
0
500
1000
1500
2000
2500
3000
3500
1430
1440
1450
1460
1470
1480
1490
1500
1510
1520
1530
Velocity (m/s)

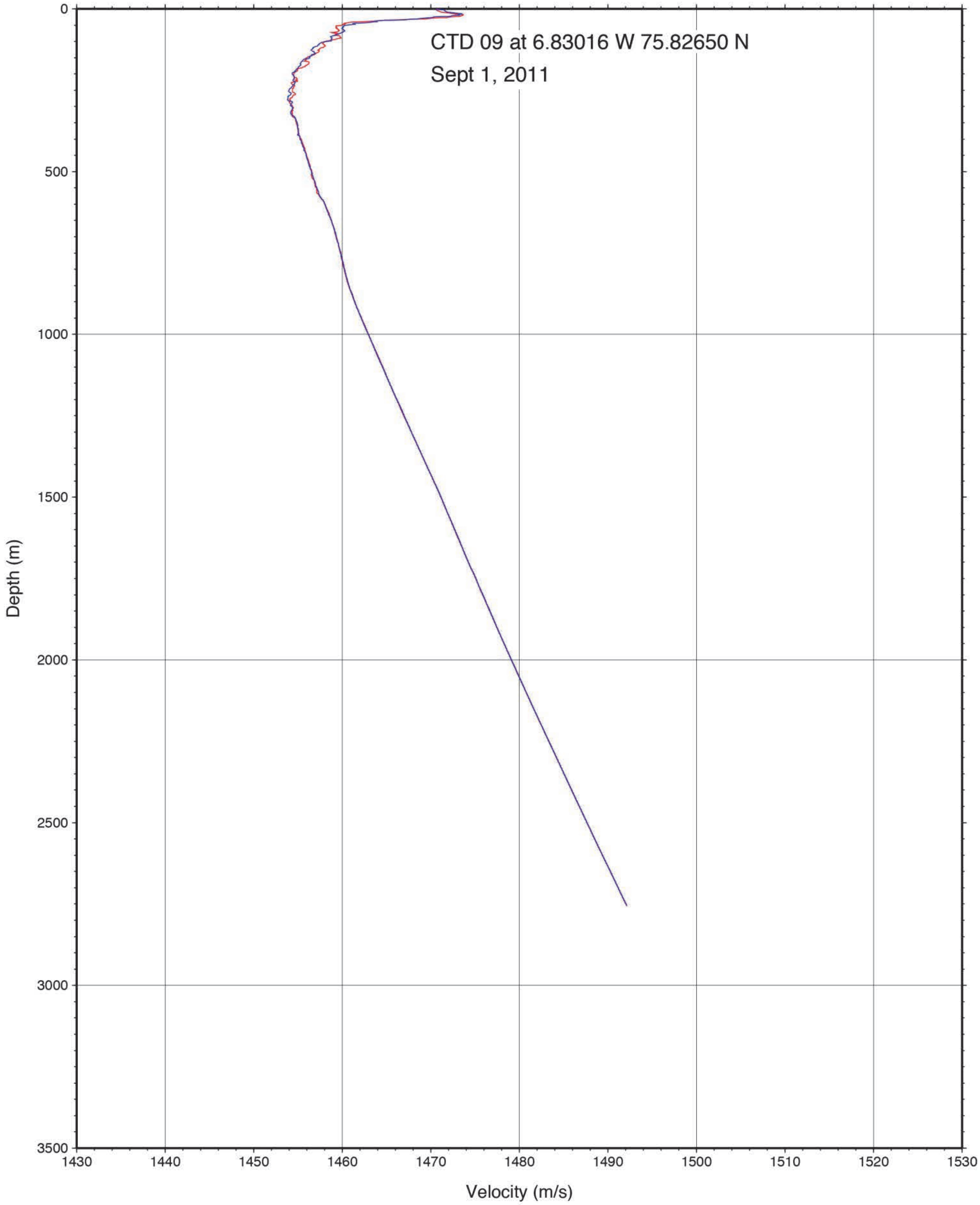

CTD 05 at 2.86216 W 75.90983 N
Aug 23, 2011
Depth (m)
0
500
1000
1500
2000
2500
3000
3500
1430
1440
1450
1460
1470
1480
1490
1500
1510
1520
1530
Velocity (m/s)

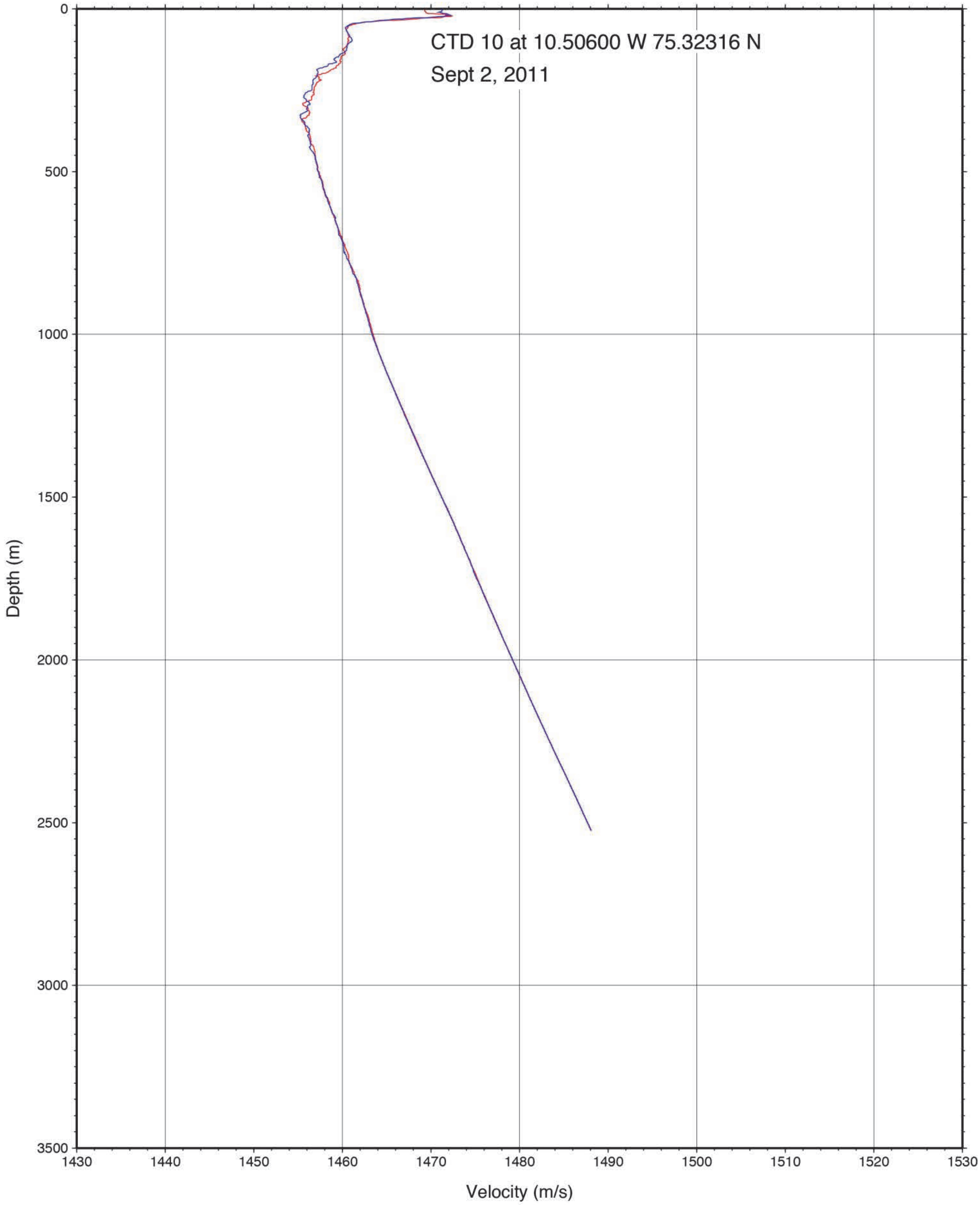

CTD 06 at 5.79083 W 77.21333 N
Aug 28, 2011
Depth (m)
Velocity (m/s)
0
500
1000
1500
2000
2500
3000
3500
1430
1440
1450
1460
1470
1480
1490
1500
1510
1520
1530



CTD 07 at 7.44133 W 77.67900 N
Aug 30, 2011
0
500
1000
1500
2000
2500
3000
3500
Depth (m)
1430
1440
1450
1460
1470
1480
1490
1500
1510
1520
1530
Velocity (m/s)


CTD 08 at 8.91200 W 76.30083 N
Sept 1, 2011
Depth (m)
0
500
1000
1500
2000
2500
3000
3500
1430
1440
1450
1460
1470
1480
1490
1500
1510
1520
1530
Velocity (m/s)


CTD 09 at 6.83016 W 75.82650 N
Sept 1, 2011
Depth (m)
0
500
1000
1500
2000
2500
3000
3500
1430
1440
1450
1460
1470
1480
1490
1500
1510
1520
1530
Velocity (m/s)


CTD 10 at 10.50600 W 75.32316 N
Sept 2, 2011
Depth (m)
0
500
1000
1500
2000
2500
3000
3500
1430
1440
1450
1460
1470
1480
1490
1500
1510
1520
1530
Velocity (m/s)

Appendix V-D

Technical Specifications Sonobuoy Receiver WR-2902e

WR-2902e

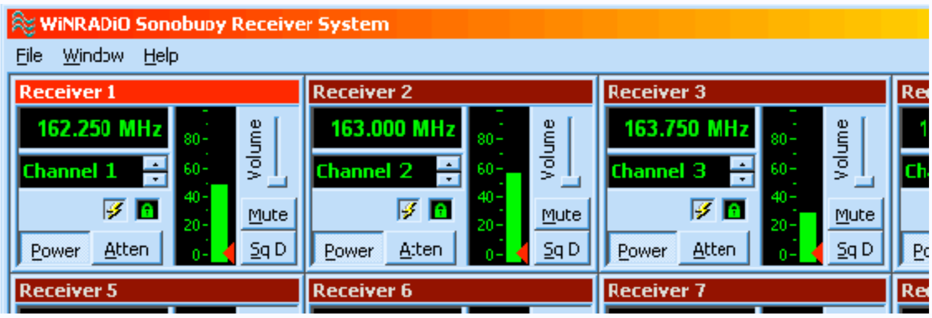
The WiNRADiO WR-2902e VHF/UHF Sonobuoy Telemetry Receiver is designed to receive signals from analogue (DIFAR) and digital (BARRA) sonobuoy transmitters, operating in the 136 to 173.5 MHz frequency range. This standard frequency range can be easily extended up to 1.5 GHz to suit special requirements.

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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Kanata Ontario, Canada K2K 2A1
613-592-6776
Fax: 613-592-5929
info@nanometrics.ca
www.nanometrics.ca

Appendix V-F

Technical Specifications Sonobuoy AN/SSQ-53D(3) from ULTRA Electronics

Technical Information on Modified 53D(3) Sonobuoy For Ocean Bottom Seismic Refraction Application

1 SONOBUOY DESCRIPTION

The Special Purpose AN/SSQ-53D(3) buoy is a modified version of the stock AN/SSQ-53D(3) DIFAR sonobuoy (details provided in Appendix). The omni channel response is altered to be suitable for the amplitude and frequency response of acoustic seismic refraction measurement. Details of the modifications are as follows:

1.1.1 Omni channel sonic shape

Frequency response is changed to increase omni channel low frequency sensitivity up to 15 dB in the 5-60 Hz band of interest. High frequency response above 200 Hz is suppressed. See Fig 1.

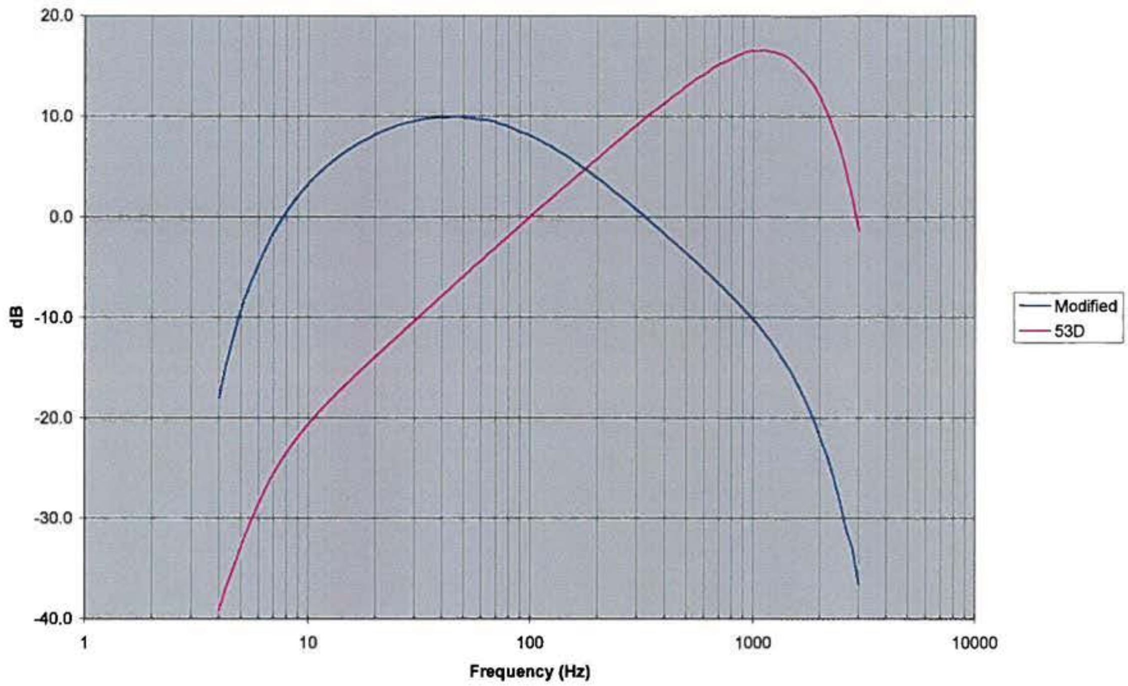
1.1.2 Directional hydrophone

Directional channel operation is disabled to allow available FM deviation to be dedicated to the omni channel.

1.1.3 Composite DIFAR Signal

Transmission of base band omni 5-2400 Hz is unchanged, however there is no directional channel modulation. The 7.5 kHz Frequency and 15 kHz Phase Pilots are left intact to satisfy sonobuoy demultiplexer requirements at the receiver-end. There is no impact on the sonobuoy VHF FM receiver operation. A standard AN/ARR-75 type sonobuoy receiver is assumed.

Fig. 1 Relative Sensitivity



2 TECHNICAL DISCUSSION

2.1.1 Frequency response

Fig.1 shows the standard 53D sonobuoy frequency response in violet. UEMS 53D(3) sonobuoy complies with this response specified by the US Navy production sonobuoy spec (PSS).

The modified response is plotted in Fig.1 in blue. The 53D response has its 0dB reference point at 100 Hz. The modified response is +8 dB at 100 Hz compared to the 53D. The modified response is nominally +15 dB over the 5 to 60 Hz range compared to the 53D. Peak response of the modified buoy occurs at approximately 50 Hz, above which the high frequency response rolls off.

The extent of sonic shape modification possible is limited by the existing 53D(3) filter/ amplifier circuit topology. To affect the sensitivity change, adjustments are made to existing circuit component values without impacting the circuit board layout. As a result, the modified gain curve can be readily shifted upward or downward, but its overall *shape* cannot be easily changed. UEMS has selected a nominal 15 dB low frequency gain increase for this application in the absence of a hard, defined requirement.

2.1.2 FM Deviation

The 53D(3) sonobuoy has its 0dB sensitivity reference point defined at 100 Hz. The standard reference acoustic input signal for testing sonobuoys is: 122 ± 3 dB re 1 uPa RMS at 100 Hz. Interpretation of its use is as follows:

An acoustic signal in the water at 100 Hz with a sound pressure level of 122 ± 3 dB re 1 uPa RMS produces 25 KHz of peak FM deviation in the omni channel and 40 KHz in the directional channel.

In the case of the modified response, which is +8 dB at 100 Hz, the same reference input acoustic signal will now produce 62.8 KHz of peak FM deviation from the omni channel.

The peak FM deviation level for DIFAR sonobuoy transmission is 75 kHz. This level is allowed by sonobuoy / receiver system design, and represents up to 5% distortion in the composite DIFAR signal. At greater deviation levels, distortion increases and the onset of clipping occurs. The sonobuoy transmitter, by spec requirement, will not modulate greater than 105 KHz of FM deviation. This represents hard clipping, and is highly distorted.

The omni response of the modified seismic buoy is nominally given below for different FM deviation levels. Note that no deviation is consumed by the directional channels, and approximately 10 kHz of deviation is used by the two pilots.

	Supported Acoustic SPL in dB re 1uPa RMS		
Freq (Hz)	25 kHz peak deviation <5% distortion	40 kHz peak deviation <10% distortion	75 kHz peak deviation clipping level
5	131.5	135.6	141.0
10	118.9	123.0	128.5
50	112.3	116.4	121.8
100	**114.0**	**118.1**	**123.5**
200	118.1	122.2	127.7
1000	132.2	136.3	141.8

2.1.3 Self-Noise

Attention is drawn to the fact that the low frequency sensitivity increase of 15 dB in the 5 to 60 Hz range makes the modified buoy more susceptible to the possible saturating effects of low frequency *ambient noise* (ie. sea-state and shipping related noise). It is possible that the modified buoy may be on the clipper (ie. producing > 75 kHz of deviation) due to amplification of low frequency ambient noise, whereas a collocated standard 53D(3) buoy may not be in clipping.

The increased low frequency omni gain may also result in degraded flow noise performance (in the 5 – 10 Hz area), as the buoy's mechanical self noise in the omni channel will be amplified by 15 dB.

Disabling of the directional channel sensors makes the modified buoy immune to low frequency mechanical noise (strum) contributed by the suspension system in very high flow rates / shear. There is no concern for available FM deviation being used up by this noise source.

2.1.4 Buoy Settings

The UEMS 53D(3) expendable sonobuoy operates with 4 selectable deployment depths (30, 60, 120 and 300 meters). It transmits on any of 99 preselectable VHF channels in the sonobuoy range 136 to 173.5 MHz with 1 Watt minimum radiated RF power output. The scuttling period is fixed at 8 hours after splash. Operating life (ie. RF transmission on time) is pre-selectable as 0.5, 1, 2, 4, or 8 hours.

2.1.5 OTS (Over-the-side) Deployment Procedure

Remove the buoy from the sonobuoy launch container (SLC), then remove the lanyard strap and wind flap. Fully extend parachute canopy before deploying over the side. Do not remove the parachute. Gravity launch bare buoy into ocean in an approximately vertical orientation, bottom end first, allowing parachute to act as an in-water decelerator. Deploy from side of ship taking care that sonobuoy does not strike the hull of the ship. Do not deploy from aft of ship, where the buoy can be damaged by propeller wash.

Note: Manufacturing arrangements can be made in the modified electronics assembly to permit the buoy to be aircraft launched, if customer required.

2.1.6 RF Transmission and Reception Range

The VHF transmitting aerial structure is 17.7" (449.6 mm) in length (nominally cut for ¼ wavelength at mid-band 154 MHz). By specification, the antenna vertical radiation pattern has a 20 dB minimum null between 60 to 90 degrees, with peak radiating response at 10 degrees elevation above from sea surface. Major lobe -3dB beam width occurs between 3 and 15 degrees elevation angle from the sea surface. This low radiation angle can present problems with shipboard reception beyond 10 km unless a high mast mounted VHF antenna is used to offset Earth's curvature effect. A directional Yagi antenna tuned for selected channels within the sonobuoy VHF band is recommended for use. Sonobuoy RF transmission is typically designed for high altitude aircraft reception.

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

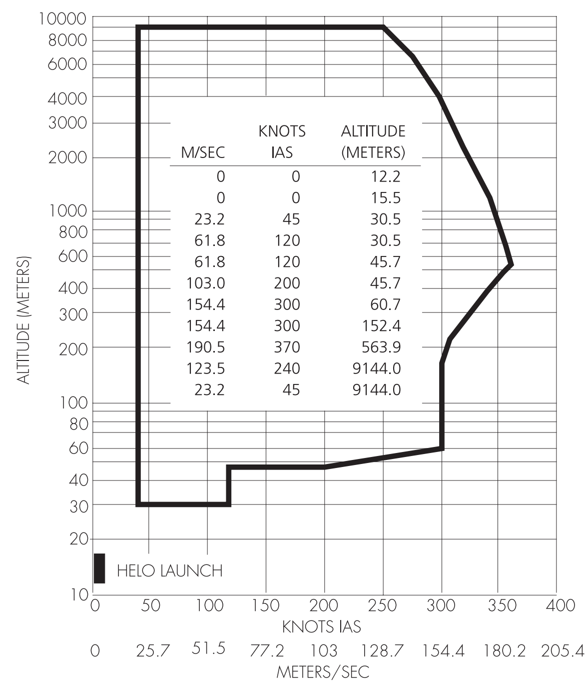
Acoustic Frequency .... *5-2400 Hz Range*

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)
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Appendix V-G

Technical Specifications VHF Antenna MD G3

MOONRAKER

Type MD-G3

High Gain Broadband Collinear
for marine or land VHF Marine Band communications

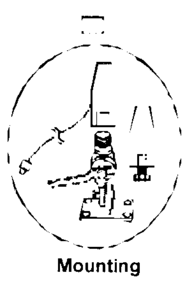
A rugged lightweight 5/8 wave ground independent collinear to give efficient and dependable performance.

The type MD-G3 has been designed as a robust, high gain antenna system and is ideally suited for base station and marine mobile use. It is constructed of marine grade, low corrosion, tempered aluminium alloy tubing which is completely coated with black (option of white) PVC to provide maximum protection from harsh environments and ultra-violet radiation. all metal parts are at DC earth potential for static discharge and fittings are of nylon and chromed bronze.

Mounting is easily effected by way of nylon side mount insulators,(or by straps or clamps to mast or tower section), by 12mm metric base bolt or by a heavy duty stainless steel swingdown mount adjustable in two planes.

Specifications

VHF Band	**150-170 MHz**
Overall Length	2.78 metres (9.12 ft)
Base Section Diameter	22.24 (7/8 in)
Top Section Diameter	10 mm (0.4 in)
Pattern	Omnidirectional
Polarisation	Vertical
Frequency Range	Standard Version: full marine band 156-162 MHz
Bandwidth	7 MHz at <1.5:1 VSWR; 20 MHz at <2:1 VSWR
Gain	5 dBi
Impedance	50Ω nominal
Wind Loading	2.35 kg at 100 km/h (5.2 lbs at 60 mph) 3.56 kg at 120 km/h (7.8 lbs at 75 mph)
Power Capability	75 watts
Mountings	Either two 63 mm (2.5 in) nylon clamp type insulators, 35 mm diameter (1 3/8 in), threaded to take M10 set screw, or heavy duty galvanised hose clamps (recommended spacing not less than 25 cm (9.8 in) apart); stainless steel swingdown mount (1" thread) adjustable in both planes (not supplied); or base mounted 12mm metric bolt (not supplied).
Connection	5 metres RG58 coaxial cable with PL259 (UHF) connector; or female N Type connector permanently fitted in base of mounting tube (sidemount type)
Packed Weight	3 kg (6.6 lbs)



Mounting options

Specifications subject to change 5/04

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