P-03-71

Oskarshamn site investigation

Reflection seismic surveys on Simpevarpshalvön 2003 using the vibroseismic method

Thomas Vangkilde-Pedersen, Rambøll

July 2003

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ISSN 1651-4416
SKB P-03-71

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Keywords: reflection seismics, vibroseismic, Pulled Array Seismic method, reflectors.

Contents

1 Introduction

This document reports the data gained in “Reflection seismic surveys on Simpevarps-halvön 2003 using the vibroseismic method” which is one of the activities performed within the site investigations at Oskarshamn. On behalf of SKB, RAMBØLL has excuted a reflection seismic survey at and around the OKG powerplant using the Pulled Array Seismic method. RAMBØLL is acting as subcontractor to ÅF-IPK.

The reflection seismic survey comprised 10 seismic lines LSM000066–LSM000075 with a total nominal length of 9 250 m. See Figure 1-1 for the location of the investigation area and Drawing no. 1.1 in Appendix A for the detailed location of lines.

The fieldwork was carried out during the period 23–30 March 2003 in agreement with the instructions and guidelines from SKB (activity plan AP PS 400-02-005 and applicable parts of method description SKB MD 241.004, SKB internal controlling documents) and under supervision of Leif Stenberg, SKB. There is no existing method description of the Pulled Array Seismic method. The work has been carried out in accordance with RAMBØLLs guidelines and standards for Pulled Array Seismic operations. Processing and interpretation of data has been carried out during April and May, 2003.

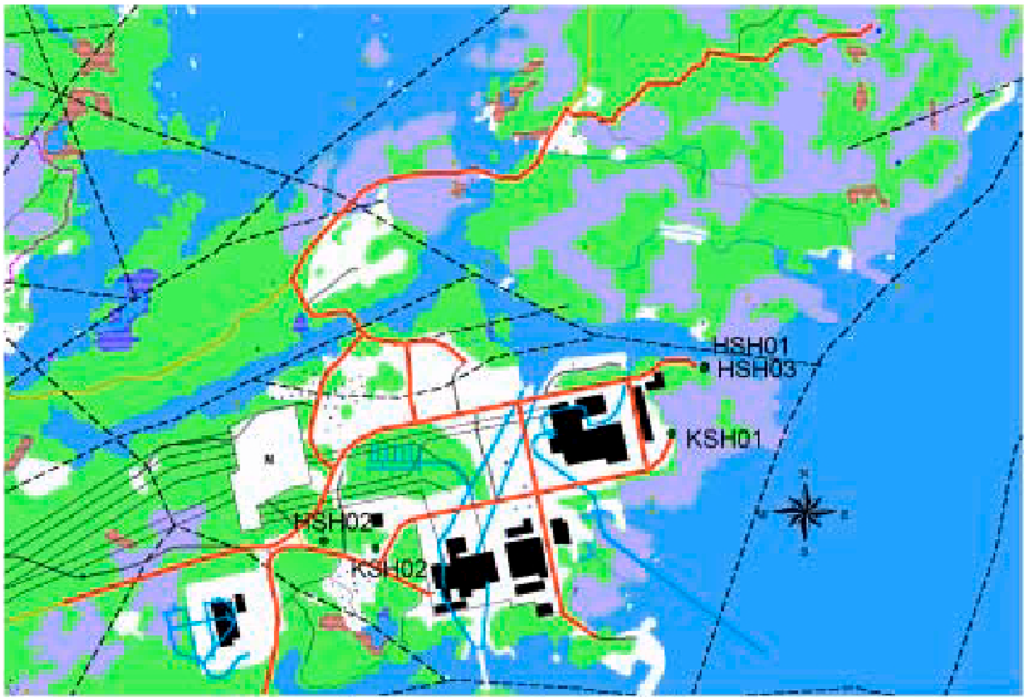


***Figure 1-1.** Map showing the investigation area (OKG) and location of the Pulled Array seismic lines (thick red lines).*

2 Objective and scope

SKB has initiated site investigations in the Simpevarp area. A general description of SKB's site investigation program including a presentation of specific investigation methods can be found in reference /1/. A site-specific geo-scientific program for the investigations in Simpevarp can be found in reference /2/. An important part of these investigations is reflection seismics. The main objective of the reflection seismic survey is localization of low dipping reflectors which can be caused by fracture zones or contacts between different rocktypes in the crystalline bedrock. A reason for using the Vibroseismic method was that explosives was restricted to be used at parts of the Simpevarp peninsula as well as drilling of shotholes.

The scope of the present investigation has been to acquire a total of approximately 9 km reflection seismic data with the Pulled Array Seismic method (Vibroseismics) on a number of seismic profiles located on Simpevarpshalvön and on the islands Ävrö and Hålö. The aim has been to map reflecting structures from ground level and down to several hundred metres of depth.

The location of the profiles has been chosen with respect to the local infrastructure and all profiles are placed along existing roads on Simpvarpshalvön. One profile reaches from Simpevarpshalvön, along the road, to Ävrö in order to try to tie the present survey to a previous reflection seismic survey with explosive charges as energy source performed on Ävrö /3/.

3 Equipment

3.1 Description of equipment

The Pulled Array Seismic method is based on a seismic vibrator as energy source and a land streamer with geophones mounted on steel plates. The land streamer is connected to the vibrator, which is pulled by a Land Rover. When the vibrator is moved forward to the next vibration point, the land streamer with geophones is pulled along.

The seismic vibrator is an IVI Minivib T7000 with a total hold down weight of 3.5 ton. The land streamer has 94 geophone groups, each with one 14 Hz L-10 AI geophone from Mark Products. The first channel on the land streamer is, however, used to record the so-called pilot-trace from the vibrator, and data are recorded on 93 channels. The geophone group spacing is 2.5 m and the offset from the vibration point to channel 1 is 2.5 m. Thus, the offset to the first and last active channel is 5 and 235 m, respectively and the total length of the active section is 230 m. A Geometrics StrataVisor NZ seismic instrument supplemented with two 24 channels Geometrics Geodes was used for data acquisition. During data acquisition kinematic GPS data was recorded with a Trimble 4700 GPS instrument for later post-processing.

4 Execution

4.1 Preparations

Prior to data acquisition a parameter and function test was carried out. The test was carried out after laying out the land streamer on the eastern part of Line LSM000066, on a small gravel road in the forest on Ävrö. All equipment was found to function well and subsequently a sweep test was carried out in order to decide the optimal sweep parameters. A number of different sweeps, both linear and non-linear, was carried out and evaluated on paper copies of shotgathers. The signal to noise ratio was generally low and very little difference between individual sweeps observed. Hence, a standard linear 5 second up-sweep from 10–350 Hz was chosen.

4.2 Execution of tests/measurements

The data acquisition has generally been carried out with an *end-of-line, roll-along* geometry, cf. the principle of the Pulled Array Seismic method with the vibrator towing the land streamer from vibration point to vibration point. On very short lines, however, and in the ends of lines adjacent to other seismic lines, *split-spread* shooting has been performed along the land streamer in one or both ends of the line in order to increase the fold coverage in the end of the lines. At every vibration point, an automated sequence of 5 sweeps has been performed and stacked into one shotgather, in order to increase the signal to noise ratio. With 93 active channels, a geophone group spacing of 2.5 m and a vibration point spacing of 10 m, the distance between individual Common-Mid-Point (CMP) gathers are 5 m and the general stacking fold is ranging between 45 and 48 for *end-of-line, roll-along* data, when using 4 times CMP-binning. Detailed information about acquisition parameters are found on the individual seismic profiles in drawings nos. 2.1–2.10 and 3.1–3.10 in Appendix B and C respectively.

4.3 Datahandling

The data processing has been performed in the WinSeis version 1.5 Turbo seismic processing software from Kansas Geological Survey and for presentation of data the Seismic Processing Workshop from Parallel Geosciense Corporation has been used.

The kinematic GPS data has been post-processed using the GPSurvey software from Trimble and correction data from Lantmäteriets reference station in Oskarshamn. By correlation between time-stamps on the seismic records and the processed GPS co-ordinates, every vibration-point has been assigned an X, Y co-ordinate. Subsequently an X, Y co-ordinate has been calculated for every theoretical CMP location, assuming that the CMP locations are evenly spaced between the vibration points. Finally Z co-ordinates have been extracted from the digital terrain model facilitated by SKB for all calculated CMP locations. X, Y, Z co-ordinates for every CMP location are delivered in an Excel-file on CD (SICADA Field note no. 54). The accuracy of the post-processed X, Y co-ordinates and the theoretical CMP locations are better/generally better than 0.10 m. The vertical accuracy naturally depends on resolution and accuracy of the digital terrain model. A good guess is that the vertical accuracy is better than 0.25 m.

Basically a standard processing sequence for Pulled Array Seismic has been applied. The processing sequence has, however, been supplemented with processing steps and tests aimed at the local conditions and present scope of work.

The processing includes manually designed mutes and manually editing of noisy traces on all shotgathers, as well as continuously velocity analyses based on constant velocity stack panels. The following processing sequence has been used:

- Import of zero phase rawdata
- Definition of geometry
- Bandpass filter
- Gain, AGC
- First arrival alignment static correction
- Trace edit
- Mute
- CMP sorting
- Velocity analysis
- Surface consistent static correction
- Velocity analysis
- Surface consistent static correction
- Residual static correction
- CMP stacking
- Bandpass-filter

Detailed information about processing parameters are found on the individual seismic profiles in drawings nos. 2.1–2.10 and 3.1–3.10 in Appendix B and C respectively.

A loop with NMO correction, based on velocities derived from constant velocity stacks, followed by surface consistent residual statics has been carried out two times by applying the calculated static values to data without NMO correction.

4.4 Analyses and interpretation

Significant and strong direct arrivals are observed on all shotgathers and on most shotgathers relatively strong refracted arrivals can be seen too, see examples in Appendix D. For reflected arrivals however, the signal to noise ratio in data is generally low and only very weak reflections can be observed on the final stacked sections in drawings nos. 2.1–2.10 in Appendix B.

The interpretation of the final stacked sections shown in drawings nos. 3.1–3.10 in Appendix C has been carried out under the assumption, that low dipping reflectors which could be caused by fracture zones or contacts between different rocktypes appears as reflected events on the seismic profiles. Due to the generally low signal to noise ratio in data the interpretation of reflectors are, however, subject to some uncertainty and there is a risk that coherent noise events can be misinterpreted as reflections or vice versa. The interpretation has especially been difficult on the short profiles.

Several dipping reflectors have been interpreted on the seismic profiles. Most significantly on lines LSM000066, LSM000067 and LSM000070. The interpretation does not include a geometrical study of the possible fracture pattern, but correlation of interpreted reflectors from profile to profile have been made and has generally been possible. No attempts have been made to distinguish between reflections from fracture zones and geological boundaries.

Raw data from the measurements were delivered directly after the termination of the field activities. The delivered data have been inserted in the database (SICADA) of SKB. The SICADA reference to the present activity is Field note no. 54.

5 Results

5.1 Discussion

In the geometry assignment to the seismic data during the processing, a straight line is assumed. Thus, the crooked nature of some of the lines has not been taken into account. Therefore the calculated offsets are not always correct. The effect of this is probably comparable to the effect of a varying thickness of the low velocity layer. Both the first arrival alignment static correction and the surface consistent and residual static corrections serve to reduce such effects.

The seismic datum for all lines is ground level. There are not observed any significant long period static variations (variations exeeding the length of the geophone spread) along the seismic lines and refraction statics have not been deemed necessary. The surface consistent and residual static corrections applied to data are designed to correct for short wavelength statics variations (variations affecting each trace separately). The first arrival alignment statics applied to data are designed to correct for medium wavelength static variations (variations that occur within the length of a geophone spread) such as variations in the thickness of a very-low velocity layer above a bedrock surface as is the case in the present data.

For depth calculations it is recommended that velocity information from other sources are used rather than using NMO-velocities derived from the processing. Due to the relatively low signal to noise ratio and the short offsets in the Pulled Array Seismic data compared to the depths of investigation and the very high seismic velocities in the bedrock, the NMO-velocities are not very well defined. Furthermore, when reflectors are steeply dipping as is the case in the present data set, NMO-velocities does not represent RMO-velocities well.

Migration has been tested on all the seismic profiles. Due to the signal to noise ratio the migration has rendered the geological interpretation more difficult. Migration results have thus not been used and are not presented in the present report.

Examples of raw shot gathers FFN1071 in LSM000066, FFN1206 in LSM000067, FFN1287 in LSM000067, FFN1622 in LSM000070 and FFN1903 in LSM000073 respectively are shown in Appendix D.

References

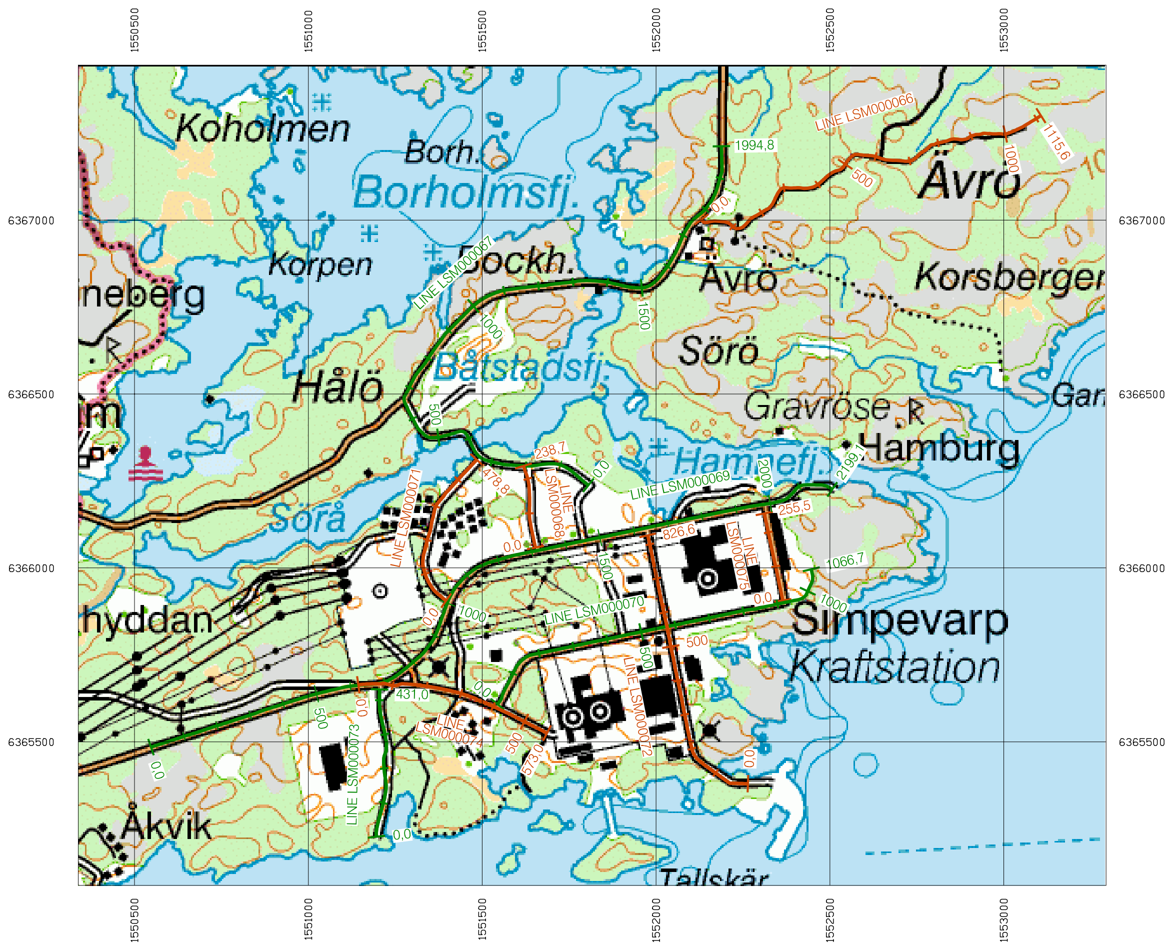
/1/ **SKB, 2001.** Platsundersökningar. Undersökningsmetoder och generellt genomförandeprogram. SKB R-01-10, Svensk Kärnbränslehantering AB.

/2/ **SKB, 2001.** Geovetenskapligt program för platsundersökning vid Simpevarp. SKB R-01-44, Svensk Kärnbränslehantering AB.

/3/ **Juhlin C and Palm H, 1999.** 3D structure below Ävrö island from high resolution reflection seismic studies, southeastern Sweden. Geophysics: 64, 662–667.

Appendix A

Drawing no. 1.1. Location plan



LEGEND

Pulled Array Seismic line with station no.

Coordinate system: RT 90, 2,5 gon west. Heights in RH70

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1	28.05.2003	JMN/FDH	UTN	TVP

Job 360211C Scale 1:10.000

SVENSK KÄRNBRÄNSLEHANTERING AB

Reflection seismic on Simpevarpshalvön 2003 - vibroseismic
Location plan

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Drawing No.: 1.1

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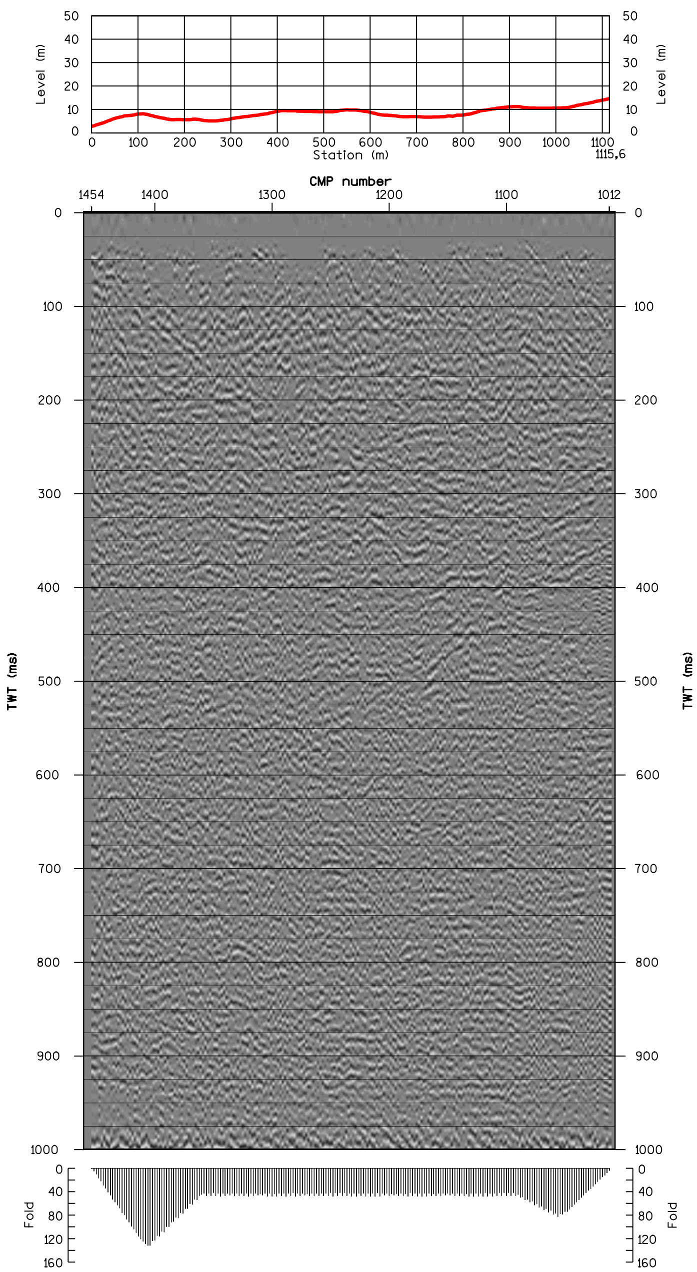
Appendix B

Drawing no. 2.1-2.10. Line LSM000066-LSM000075



ACQUISITION PARAMETERES

- Recorded by: RAMBØLL
- Instrument: Geometrics StrataVisor NZ/2 Geodes, 112 channels
- Source: IVI MiniVib T7000, 5 sek. sweep, 10-350 Hz
- Vibration point spacing: 10 m
- No. of channels: 94
- Samples/trace 2048
- Date: March 2003
- Acquisition filters: None
- Geophones/group: 1 x 14 Hz L-10 Al
- Group spacing: 2.5 m
- Sample interval: 0.5 ms
- Fold: 47 (4 x CMP-binning)
- Geometry: End of line, 235.....2.5..x (distance/m) 94.....1..x (channel no.)

PROCESSING PARAMETERS

- Import of rawdata, zero phase
- Definition of geometry
- Bandpassfilter, 50-75-250-350 Hz
- Gain, AGC 100 ms window
- Trace edit
- First arrival alignment static correction
- Mute
- CMP sorting, 4 x CMP-binning
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Stretch mute
- Invers NMO
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Residual static correction Maximum shift 3 ms, pilot trace 3 CMP gathers, window 100-400 ms
- CMP stacking
- Bandpassfilter, 30-50-150-250 Hz

PLOT PARAMETERS

- Horizontal scale: 20 traces/cm
- Polarity: Reverse (compaction plotted as white)
- Vertical scale: 20 cm/sec.
- Gain: AGC 100 ms window

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0	28.05.2003	JMN/JIJ	UTN	TVP

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Line LSM000066

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Drawing No.:
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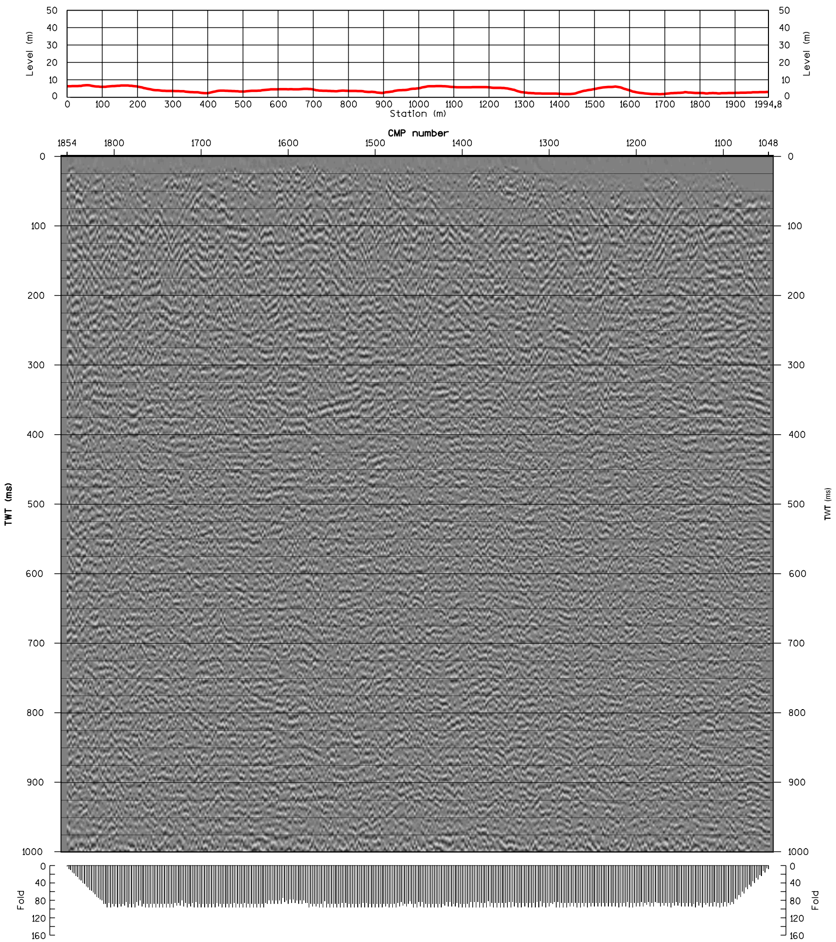

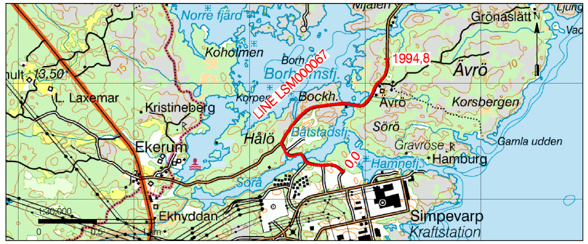

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- Date: March 2003
- Acquisition filters: None
- Geophones/group: 1 x 14 Hz L-10 AI
- Group spacing: 2.5 m
- Sample interval: 0.5 ms
- Fold: 47 (4 x CMP-binning)

PROCESSING PARAMETERS

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- Definition of geometry
- Bandpassfilter, 50-75-250-350 Hz
- Gain, AGC 100 ms window
- Trace edit
- First arrival alignment static correction
- Mute
- CMP sorting, 4 x CMP-binning
- NMO correction, velocities from constant velocity stack panels
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- Stretch mute
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- Residual static correction Maximum shift 3 ms, pilot trace 3 CMP gathers, window 100-400 ms
- CMP stacking
- Bandpassfilter, 30-50-150-250 Hz

PLOT PARAMETERS

- Horizontal scale: 20 traces/cm
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- Gain: AGC 100 ms window

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Reflection seismic on Simpevarpshalvön 2003 - vibroseismic
Line LSM000067

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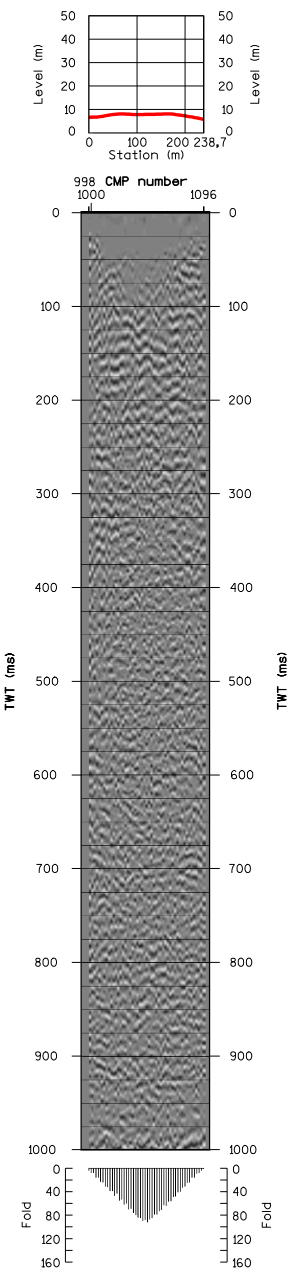

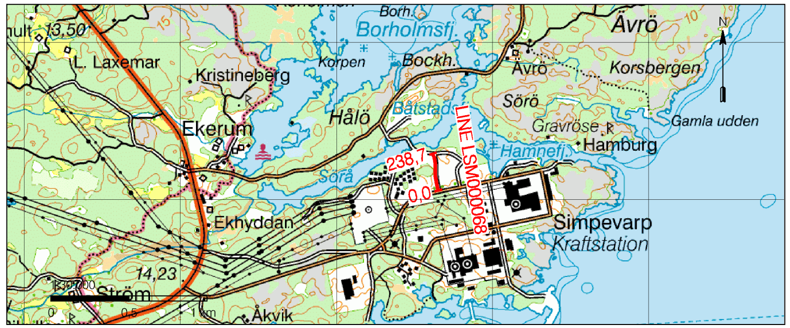

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PROCESSING PARAMETERS

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PLOT PARAMETERS

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0	28.05.2003	JMN/JIJ	UTN	TVP

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Reflection seismic on Simpevarpshalvön 2003 - vibroseismic

Line LSM000068

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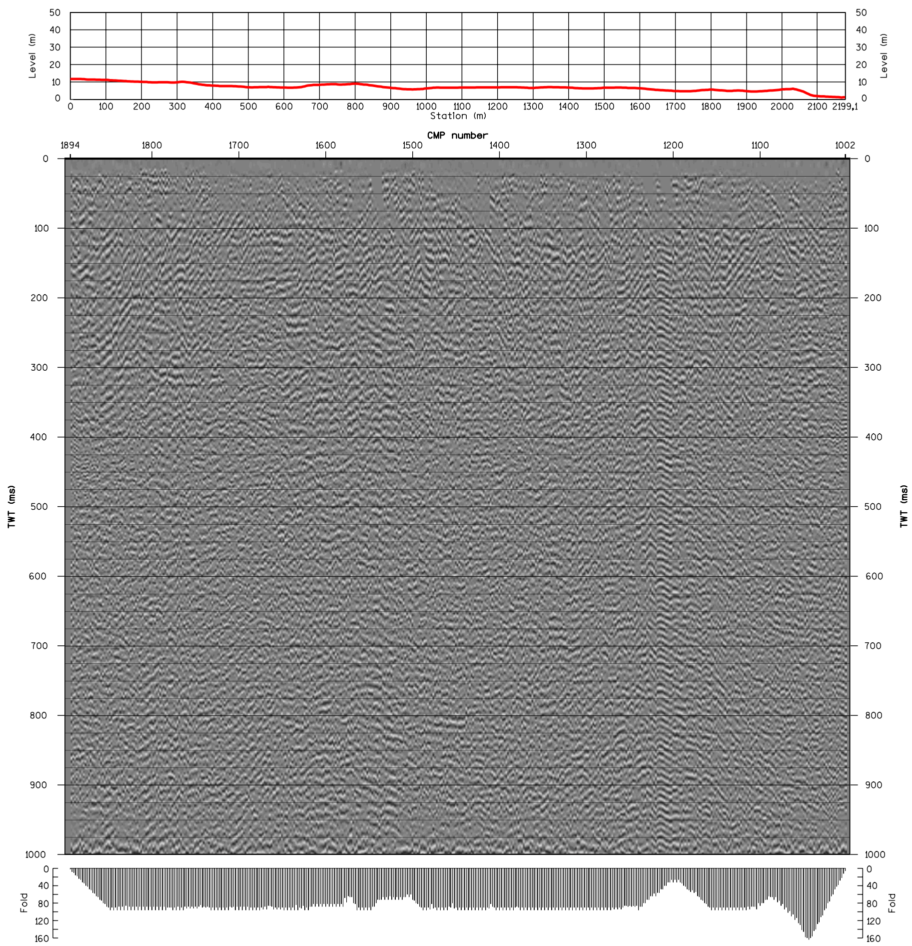

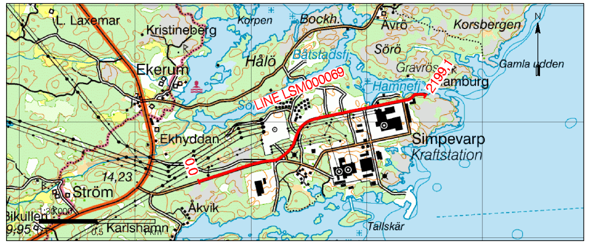

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- Samples/trace 2048
- Date: March 2003
- Acquisition filters: None
- Geophones/group: 1 x 14 Hz L-10 AI
- Group spacing: 2.5 m
- Sample interval: 0.5 ms
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- Geometry: End of line, 235.....2.5..x (distance/m) 94.....1..x (channel no.)

PROCESSING PARAMETERS

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Reflection seismic on Simpevarpshalvön 2003 - vibroseismic
Line LSM000069

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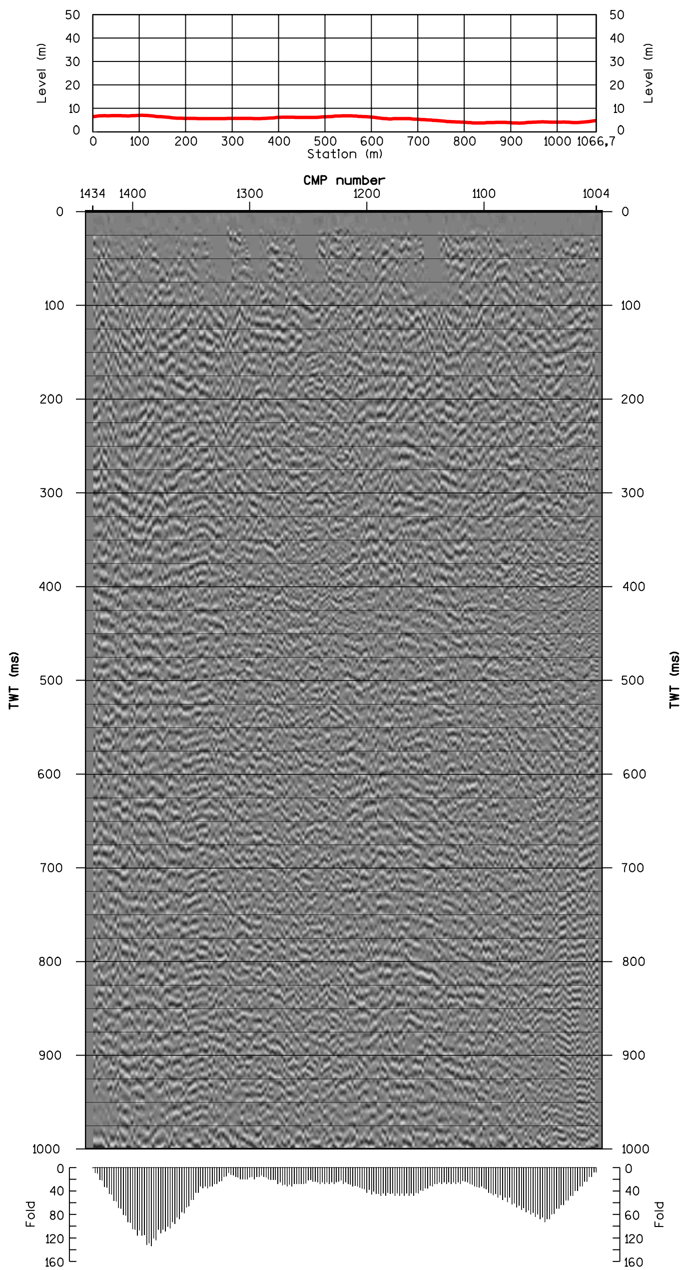

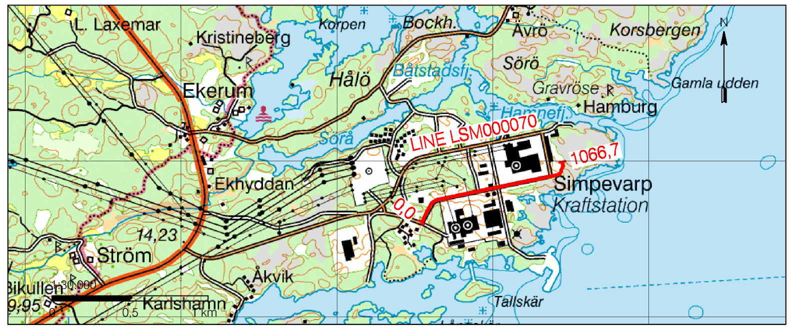

ACQUISITION PARAMETERES

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Reflection seismic on Simpevarpshalvön 2003 - vibroseismic
Line LSM000070

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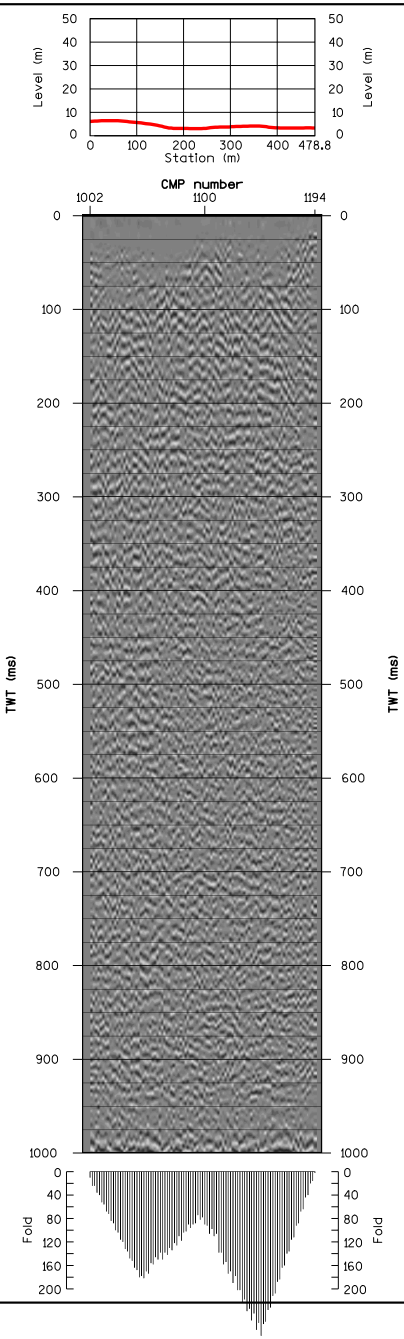

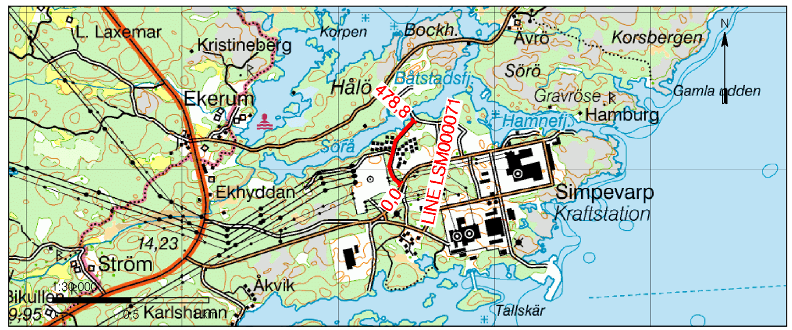

ACQUISITION PARAMETERES

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- Samples/trace 2048
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- Acquisition filters: None
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- Group spacing: 2.5 m
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- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Stretch mute
- Invers NMO
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Residual static correction Maximum shift 3 ms, pilot trace 3 CMP gathers, window 100-400 ms
- CMP stacking
- Bandpassfilter, 30-50-150-250 Hz

PLOT PARAMETERS

- Horizontal scale: 20 traces/cm
- Polarity: Reverse (compaction plotted as white)
- Vertical scale: 20 cm/sec.
- Gain: AGC 100 ms window

Rev.	Date	Drawn by	Control	Approved
0	28.05.2003	JMN/JIJ	UTN	TVP

Job 360211C

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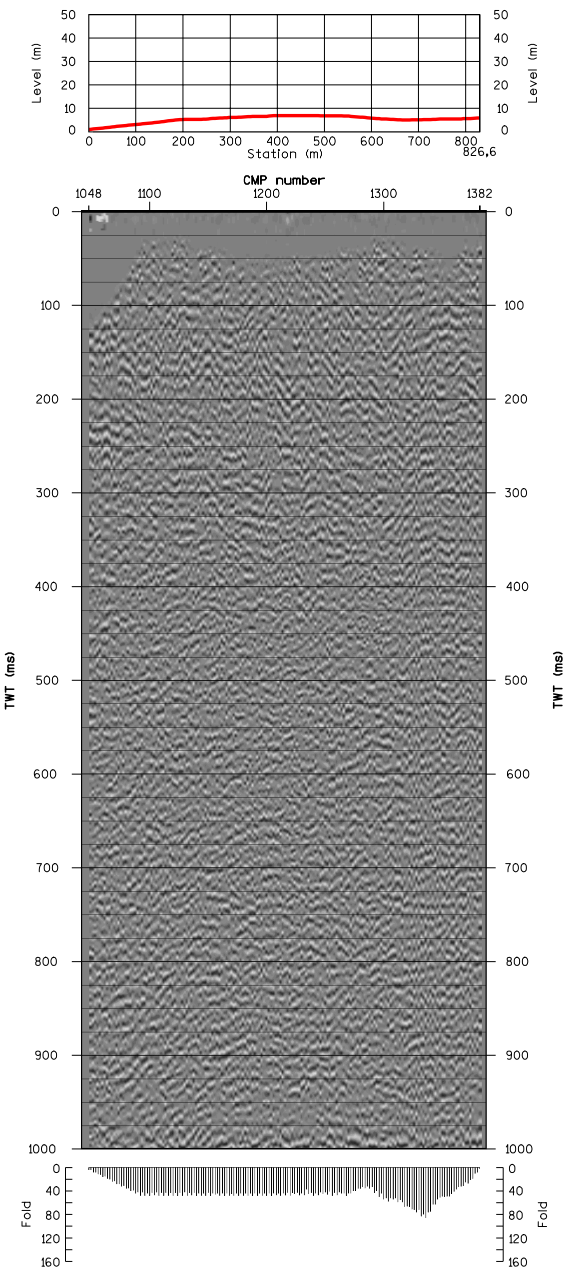
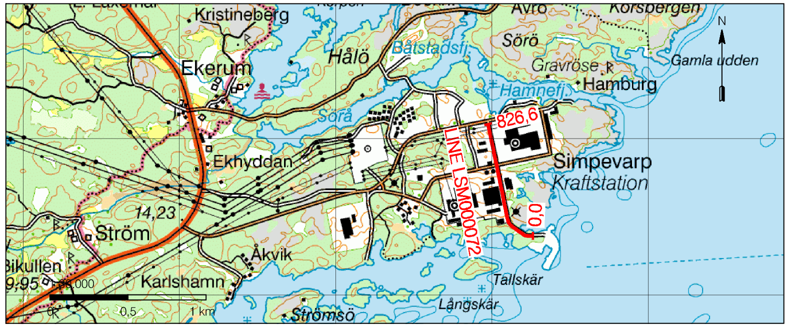
Reflection seismic on Simpevarpshalvön 2003 - vibroseismic
Line LSM000071

Drawing No.: 2.6

G:\GEO\2003\360211C SKB Seismik\Cad\2_6.dgn 28-MAY-2003 14:49 JMN





ACQUISITION PARAMETERES

- Recorded by: RAMBØLL
- Instrument: Geometrics StrataVisor NZ/2 Geodes, 112 channels
- Source: IVI MiniVib T7000, 5 sek. sweep, 10-350 Hz
- Vibration point spacing: 10 m
- No. of channels: 94
- Samples/trace 2048
- Geometry: End of line, 235.....2.5..x (distance/m) 94.....1..x (channel no.)

- Date: March 2003
- Acquisition filters: None
- Geophones/group: 1 x 14 Hz L-10 Al
- Group spacing: 2.5 m
- Sample interval: 0.5 ms
- Fold: 47 (4 x CMP-binning)

PROCESSING PARAMETERS

- Import of rawdata, zero phase
- Definition of geometry
- Bandpassfilter, 50-75-250-350 Hz
- Gain, AGC 100 ms window
- Trace edit
- First arrival alignment static correction
- Mute
- CMP sorting, 4 x CMP-binning
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Stretch mute
- Invers NMO
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Residual static correction Maximum shift 3 ms, pilot trace 3 CMP gathers, window 100-400 ms
- CMP stacking
- Bandpassfilter, 30-50-150-250 Hz

PLOT PARAMETERS

- Horizontal scale: 20 traces/cm
- Polarity: Reverse (compaction plotted as white)
- Vertical scale: 20 cm/sec.
- Gain: AGC 100 ms window

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Reflection seismic on Simpevarpshalvön 2003 - vibroseismic

Line LSM000072

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Drawing No.: 2.7

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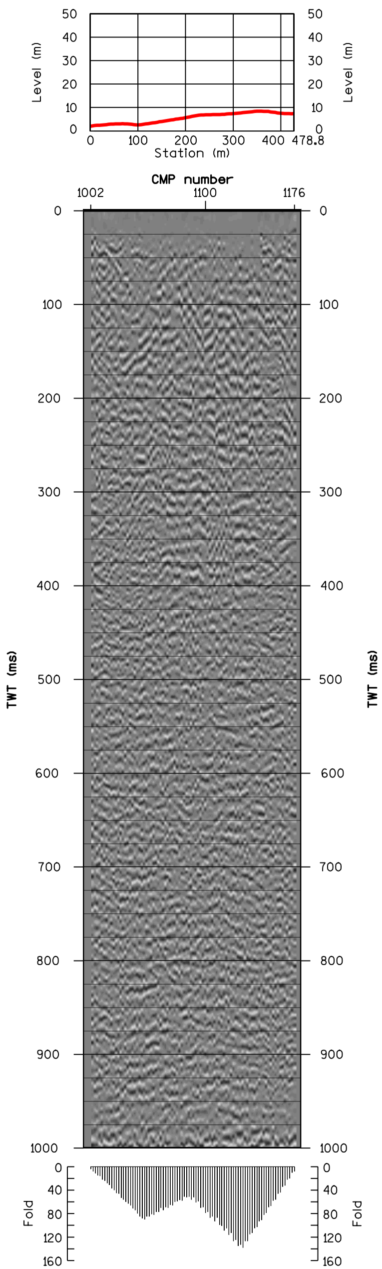

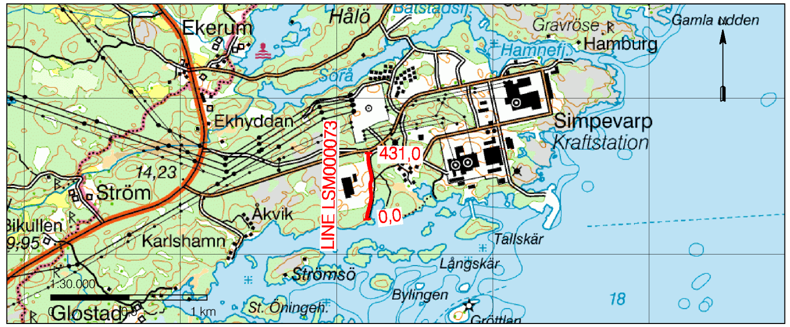

ACQUISITION PARAMETERES

- Recorded by: RAMBØLL
- Instrument: Geometrics StrataVisor NZ/2 Geodes, 112 channels
- Source: IVI MiniVib T7000, 5 sek. sweep, 10-350 Hz
- Vibration point spacing: 10 m
- No. of channels: 94
- Samples/trace 2048
- Date: March 2003
- Acquisition filters: None
- Geophones/group: 1 x 14 Hz L-10 Al
- Group spacing: 2.5 m
- Sample interval: 0.5 ms
- Fold: 47 (4 x CMP-binning)
- Geometry: End of line, 235.....2.5..x (distance/m) 94.....1..x (channel no.)

PROCESSING PARAMETERS

- Import of rawdata, zero phase
- Definition of geometry
- Bandpassfilter, 50-75-250-350 Hz
- Gain, AGC 100 ms window
- Trace edit
- First arrival alignment static correction
- Mute
- CMP sorting, 4 x CMP-binning
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Stretch mute
- Invers NMO
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Residual static correction Maximum shift 3 ms, pilot trace 3 CMP gathers, window 100-400 ms
- CMP stacking
- Bandpassfilter, 30-50-150-250 Hz

PLOT PARAMETERS

- Horizontal scale: 20 traces/cm
- Polarity: Reverse (compaction plotted as white)
- Vertical scale: 20 cm/sec.
- Gain: AGC 100 ms window

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Reflection seismic on Simpevarpshalvön 2003 - vibroseismic

Line LSM000073

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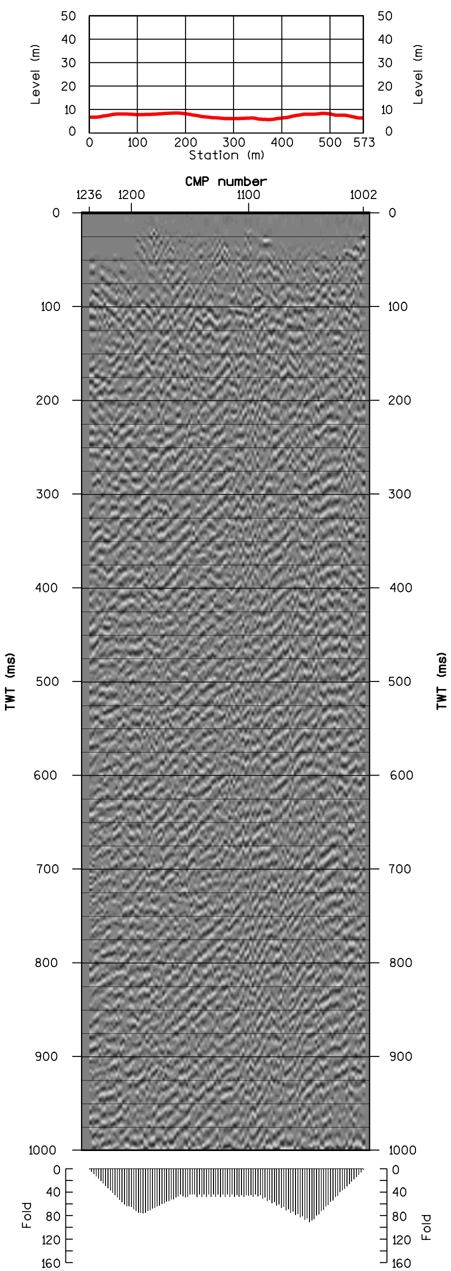
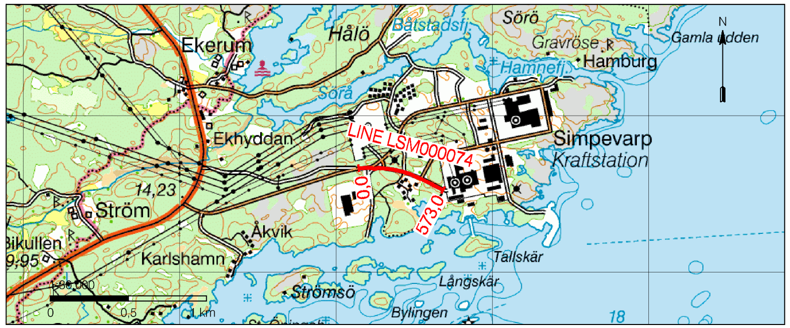
Drawing No.: 2.8

G:\GEO\2003\360211C SKB Seismik\Cad\2_8.dgn 28-MAY-2003 14:50 JMN





ACQUISITION PARAMETERES

- Recorded by: RAMBØLL
- Instrument: Geometrics StrataVisor NZ/2 Geodes, 112 channels
- Source: IVI MiniVib T7000, 5 sek. sweep, 10-350 Hz
- Vibration point spacing: 10 m
- No. of channels: 94
- Samples/trace 2048
- Date: March 2003
- Acquisition filters: None
- Geophones/group: 1 x 14 Hz L-10 Al
- Group spacing: 2.5 m
- Sample interval: 0.5 ms
- Fold: 47 (4 x CMP-binning)
- Geometry: End of line, 235.....2.5..x (distance/m) 94.....1..x (channel no.)

PROCESSING PARAMETERS

- Import of rawdata, zero phase
- Definition of geometry
- Bandpassfilter, 50-75-250-350 Hz
- Gain, AGC 100 ms window
- Trace edit
- First arrival alignment static correction
- Mute
- CMP sorting, 4 x CMP-binning
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Stretch mute
- Invers NMO
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- CMP stacking
- Bandpassfilter, 30-50-150-250 Hz

PLOT PARAMETERS

- Horizontal scale: 20 traces/cm
- Polarity: Reverse (compaction plotted as white)
- Vertical scale: 20 cm/sec.
- Gain: AGC 100 ms window

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0	28.05.2003	JMN/JIJ	UTN	TVP

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Reflection seismic on Simpevarpshalvön 2003 - vibroseismic
Line LSM000074

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Drawing No.: 2.9

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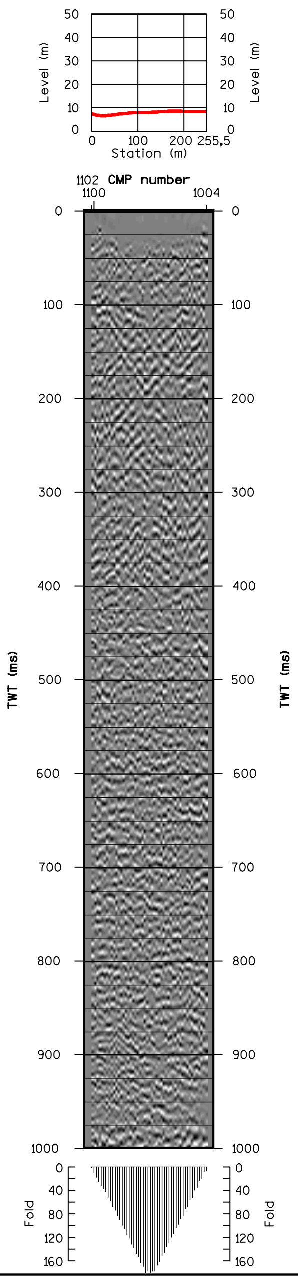

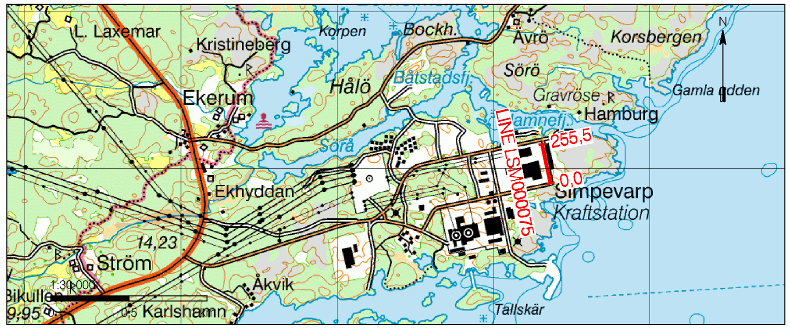

ACQUISITION PARAMETERES

- Recorded by: RAMBØLL
- Instrument: Geometrics StrataVisor NZ/2 Geodes, 112 channels
- Source: IVI MiniVib T7000, 5 sek. sweep, 10-350 Hz
- Vibration point spacing: 10 m
- No. of channels: 94
- Samples/trace 2048
- Geometry: End of line, 235.....2.5..x (distance/m) 94.....1..x (channel no.)

- Date: March 2003
- Acquisition filters: None
- Geophones/group: 1 x 14 Hz L-10 Al
- Group spacing: 2.5 m
- Sample interval: 0.5 ms
- Fold: 47 (4 x CMP-binning)

PROCESSING PARAMETERS

- Import of rawdata, zero phase
- Definition of geometry
- Bandpassfilter, 50-75-250-350 Hz
- Gain, AGC 100 ms window
- Trace edit
- First arrival alignment static correction
- Mute
- CMP sorting, 4 x CMP-binning
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Stretch mute
- Invers NMO
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Residual static correction Maximum shift 3 ms, pilot trace 3 CMP gathers, window 100-400 ms
- CMP stacking
- Bandpassfilter, 30-50-150-250 Hz

PLOT PARAMETERS

- Horizontal scale: 20 traces/cm
- Polarity: Reverse (compaction plotted as white)
- Vertical scale: 20 cm/sec.
- Gain: AGC 100 ms window

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Reflection seismic on Simpevarpshalvön 2003 - vibroseismic
Line LSM000075

Drawing No.: 2.10

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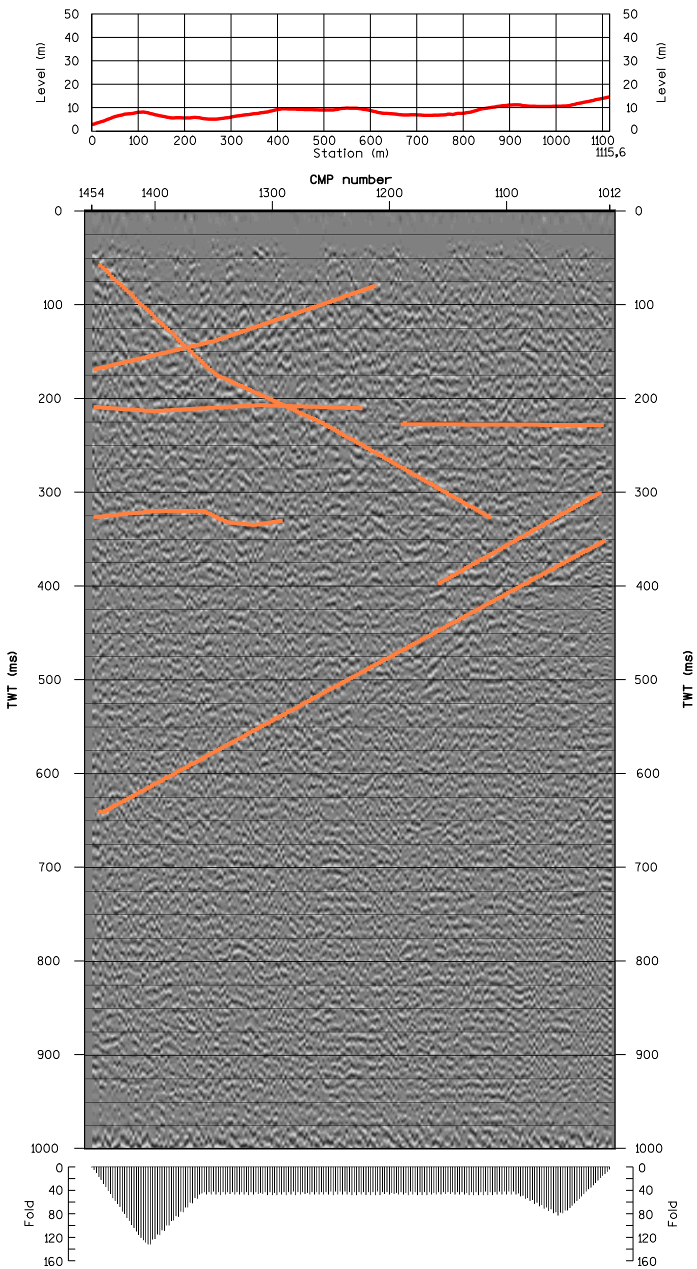
Appendix C

Drawing no. 3.1-3.10. Line LSM000066-LSM000075 with interpretation



ACQUISITION PARAMETERES

- Recorded by: RAMBØLL
- Instrument: Geometrics StrataVisor NZ/2 Geodes, 112 channels
- Source: IVI MiniVib T7000, 5 sek. sweep, 10-350 Hz
- Vibration point spacing: 10 m
- No. of channels: 94
- Samples/trace 2048
- Date: March 2003
- Acquisition filters: None
- Geophones/group: 1 x 14 Hz L-10 AI
- Group spacing: 2.5 m
- Sample interval: 0.5 ms
- Fold: 47 (4 x CMP-binning)
- Geometry: End of line, 235.....2.5..x (distance/m) 94.....1..x (channel no.)

PROCESSING PARAMETERS

- Import of rawdata, zero phase
- Definition of geometry
- Bandpassfilter, 50-75-250-350 Hz
- Gain, AGC 100 ms window
- Trace edit
- First arrival alignment static correction
- Mute
- CMP sorting, 4 x CMP-binning
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Stretch mute
- Invers NMO
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Residual static correction Maximum shift 3 ms, pilot trace 3 CMP gathers, window 100-400 ms
- CMP stacking
- Bandpassfilter, 30-50-150-250 Hz

PLOT PARAMETERS

- Horizontal scale: 20 traces/cm
- Polarity: Reverse (compaction plotted as white)
- Vertical scale: 20 cm/sec.
- Gain: AGC 100 ms window

Rev.	Date	Drawn by	Control	Approved
0	28.05.2003	JMN/JIJ	UTN	TVP

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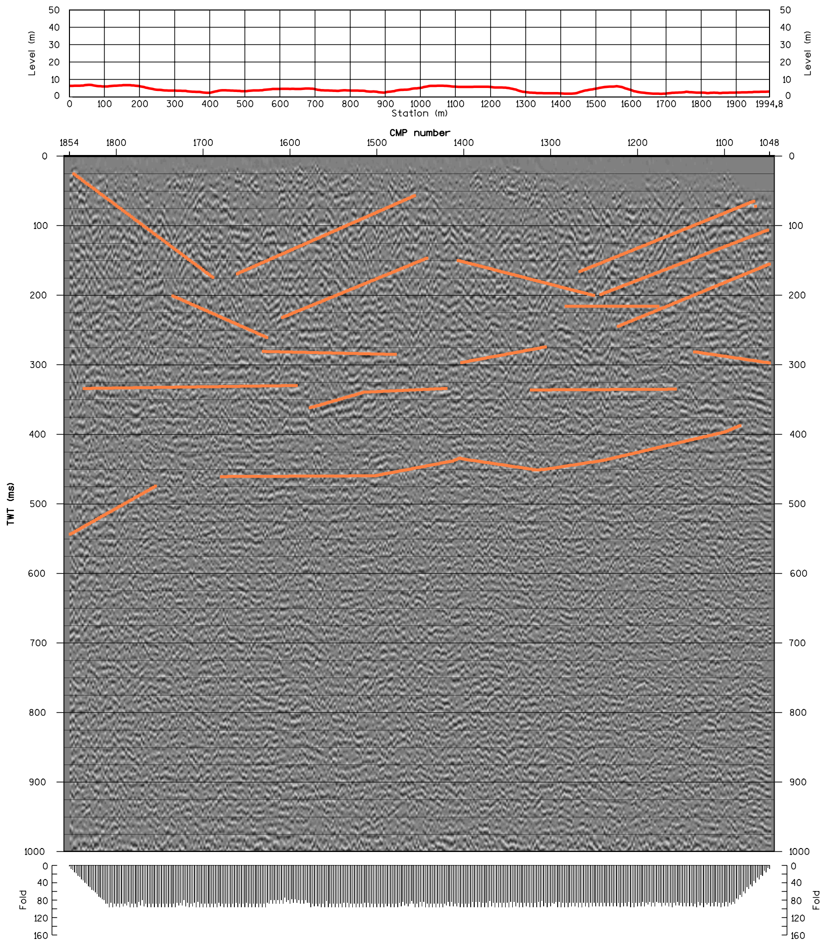
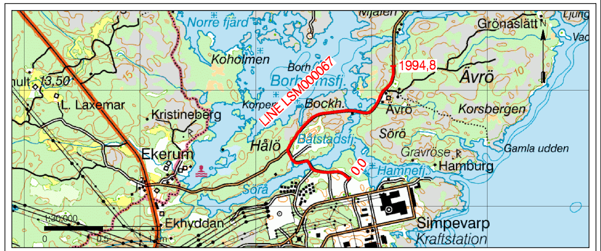
Reflection seismic on Simpevarpshalvön 2003 - vibroseismic
Line LSM000066 with interpretation

Drawing No.: 3.1

G:\GEO\2003\360211C SKB Seismik\Cad\3_1.dgn 28-MAY-2003 14:52 JMN





ACQUISITION PARAMETERES

- Recorded by: RAMBØLL
- Instrument: Geometrics StrataVisor NZ/2 Geodes, 112 channels
- Source: IVI MiniVib T7000, 5 sek. sweep, 10-350 Hz
- Vibration point spacing: 10 m
- No. of channels: 94
- Samples/trace 2048
- Date: March 2003
- Acquisition filters: None
- Geophones/group: 1 x 14 Hz L-10 AI
- Group spacing: 2.5 m
- Sample interval: 0.5 ms
- Fold: 47 (4 x CMP-binning)
- Geometry: End of line, 235.....2.5..x (distance/m) 94.....1..x (channel no.)

PROCESSING PARAMETERS

- Import of rawdata, zero phase
- Definition of geometry
- Bandpassfilter, 50-75-250-350 Hz
- Gain, AGC 100 ms window
- Trace edit
- First arrival alignment static correction
- Mute
- CMP sorting, 4 x CMP-binning
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Stretch mute
- Invers NMO
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Residual static correction Maximum shift 3 ms, pilot trace 3 CMP gathers, window 100-400 ms
- CMP stacking
- Bandpassfilter, 30-50-150-250 Hz

PLOT PARAMETERS

- Horizontal scale: 20 traces/cm
- Polarity: Reverse (compaction plotted as white)
- Vertical scale: 20 cm/sec.
- Gain: AGC 100 ms window

Rev.	Date	Drawn by	Control	Approved
0	28.05.2003	JMN/JIJ	UTN	TVP

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Reflection seismic on Simpevarpshalvön 2003 - vibroseismic
Line LSM000067 with interpretation

Drawing No.: 3.2

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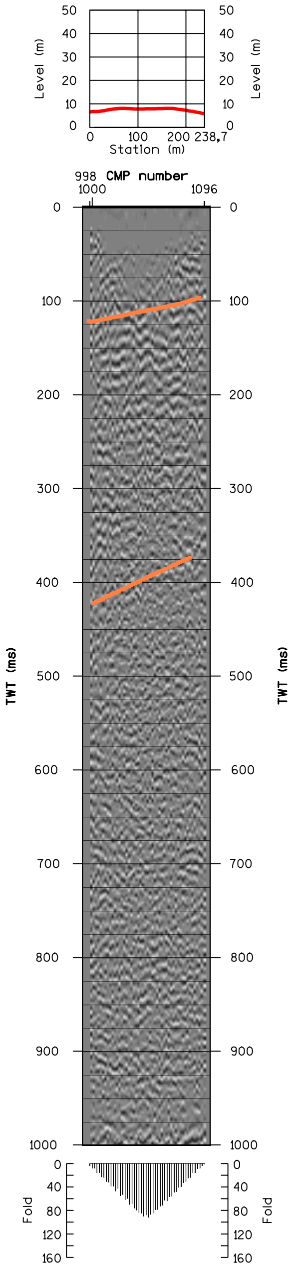

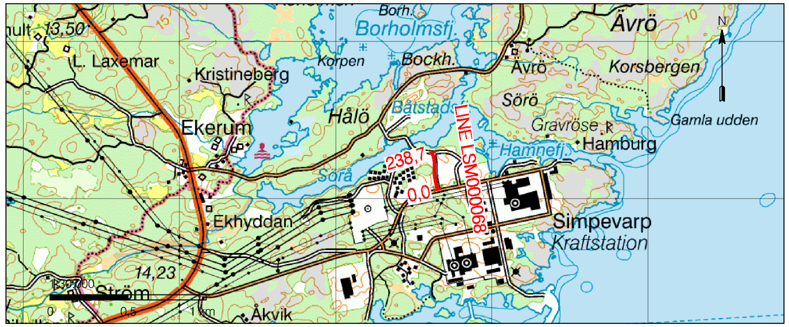

ACQUISITION PARAMETERES

- Recorded by: RAMBØLL
- Instrument: Geometrics StrataVisor NZ/2 Geodes, 112 channels
- Source: IVI MiniVib T7000, 5 sek. sweep, 10-350 Hz
- Vibration point spacing: 10 m
- No. of channels: 94
- Samples/trace 2048
- Date: March 2003
- Acquisition filters: None
- Geophones/group: 1 x 14 Hz L-10 Al
- Group spacing: 2.5 m
- Sample interval: 0.5 ms
- Fold: 47 (4 x CMP-binning)
- Geometry: End of line, 235.....2.5..x (distance/m) 94.....1..x (channel no.)

PROCESSING PARAMETERS

- Import of rawdata, zero phase
- Definition of geometry
- Bandpassfilter, 50-75-250-350 Hz
- Gain, AGC 100 ms window
- Trace edit
- First arrival alignment static correction
- Mute
- CMP sorting, 4 x CMP-binning
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Stretch mute
- Invers NMO
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Residual static correction Maximum shift 3 ms, pilot trace 3 CMP gathers, window 100-400 ms
- CMP stacking
- Bandpassfilter, 30-50-150-250 Hz

PLOT PARAMETERS

- Horizontal scale: 20 traces/cm
- Polarity: Reverse (compaction plotted as white)
- Vertical scale: 20 cm/sec.
- Gain: AGC 100 ms window

Rev.	Date	Drawn by	Control	Approved
0	28.05.2003	JMN/JIJ	UTN	TVP

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Reflection seismic on Simpevarpshalvön 2003 - vibroseismic
Line LSM000068 with interpretation

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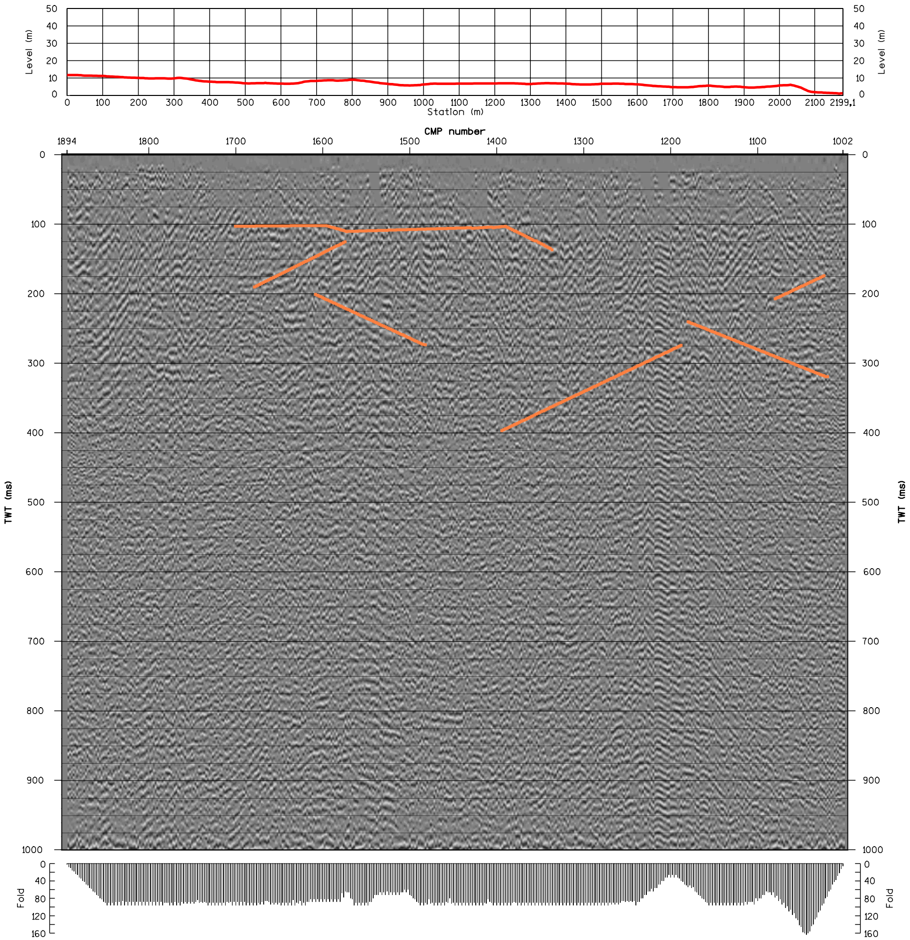
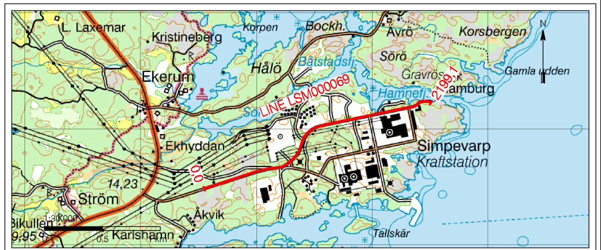
Drawing No.: 3.3

G:\GEO\2003\360211C SKB Seismik\Cad\3_3.dgn 28-MAY-2003 14:54 JMN





ACQUISITION PARAMETERES

- Recorded by: RAMBØLL
- Instrument: Geometrics StrataVisor NZ/2 Geodes, 112 channels
- Source: IVI MiniVib T7000, 5 sek. sweep, 10-350 Hz
- Vibration point spacing: 10 m
- No. of channels: 94
- Samples/trace 2048
- Date: March 2003
- Acquisition filters: None
- Geophones/group: 1 x 14 Hz L-10 AI
- Group spacing: 2.5 m
- Sample interval: 0.5 ms
- Fold: 47 (4 x CMP-binning)
- Geometry: End of line, 235.....2.5..x (distance/m) 94.....1..x (channel no.)

PROCESSING PARAMETERS

- Import of rawdata, zero phase
- Definition of geometry
- Bandpassfilter, 50-75-250-350 Hz
- Gain, AGC 100 ms window
- Trace edit
- First arrival alignment static correction
- Mute
- CMP sorting, 4 x CMP-binning
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Stretch mute
- Invers NMO
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Residual static correction Maximum shift 3 ms, pilot trace 3 CMP gathers, window 100-400 ms
- CMP stacking
- Bandpassfilter, 30-50-150-250 Hz

PLOT PARAMETERS

- Horizontal scale: 20 traces/cm
- Polarity: Reverse (compaction plotted as white)
- Vertical scale: 20 cm/sec.
- Gain: AGC 100 ms window

Rev.	Date	Drawn by	Control	Approved
0	28.05.2003	JMN/JIJ	UTN	TVP

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Reflection seismic on Simpevarpshalvön 2003 - vibroseismic
Line LSM000069 with interpretation

Drawing No.: 3.4

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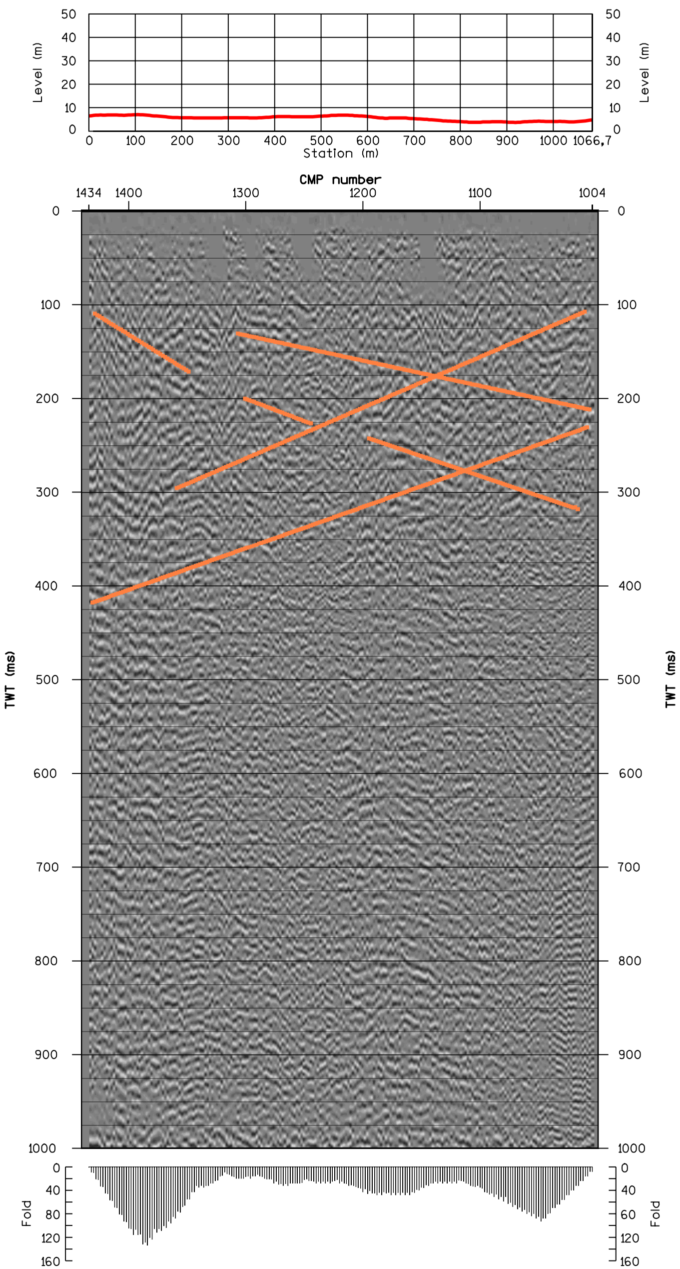

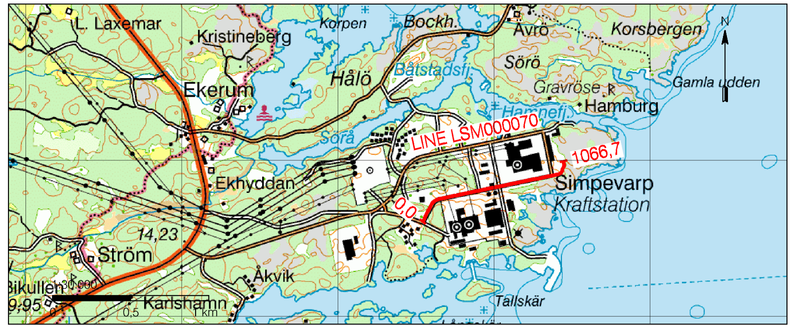

ACQUISITION PARAMETERES

- Recorded by: RAMBØLL
- Instrument: Geometrics StrataVisor NZ/2 Geodes, 112 channels
- Source: IVI MiniVib T7000, 5 sek. sweep, 10-350 Hz
- Vibration point spacing: 10 m
- No. of channels: 94
- Samples/trace 2048
- Geometry: End of line, 235.....2.5..x (distance/m) 94.....1..x (channel no.)
- Date: March 2003
- Acquisition filters: None
- Geophones/group: 1 x 14 Hz L-10 AI
- Group spacing: 2.5 m
- Sample interval: 0.5 ms
- Fold: 47 (4 x CMP-binning)

PROCESSING PARAMETERS

- Import of rawdata, zero phase
- Definition of geometry
- Bandpassfilter, 50-75-250-350 Hz
- Gain, AGC 100 ms window
- Trace edit
- First arrival alignment static correction
- Mute
- CMP sorting, 4 x CMP-binning
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Stretch mute
- Invers NMO
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Residual static correction Maximum shift 3 ms, pilot trace 3 CMP gathers, window 100-400 ms
- CMP stacking
- Bandpassfilter, 30-50-150-250 Hz

PLOT PARAMETERS

- Horizontal scale: 20 traces/cm
- Polarity: Reverse (compaction plotted as white)
- Vertical scale: 20 cm/sec.
- Gain: AGC 100 ms window

Rev.	Date	Drawn by	Control	Approved
0	28.05.2003	JMN/JIJ	UTN	TVP

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Reflection seismic on Simpevarpshalvön 2003 - vibroseismic
Line LSM000070 with interpretation

Drawing No.: 3.5

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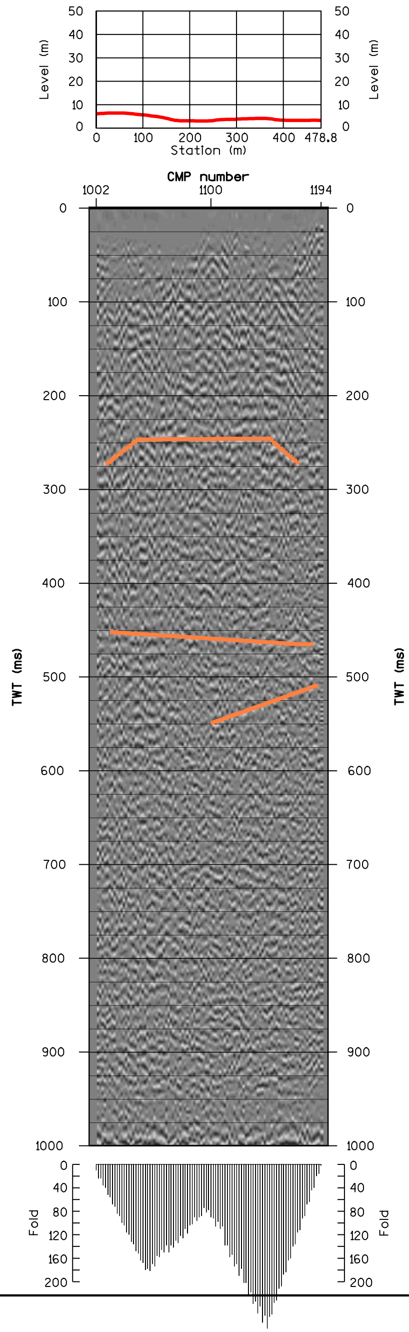

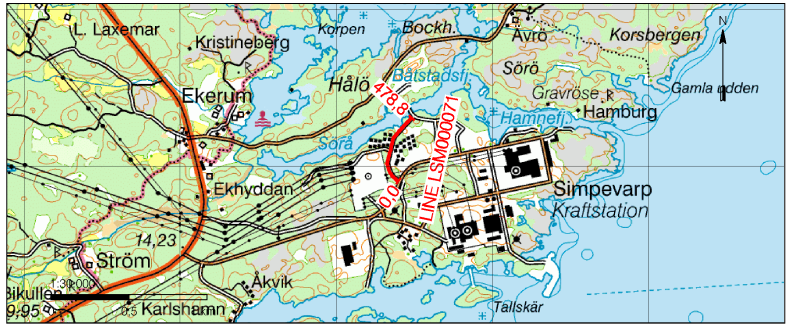

ACQUISITION PARAMETERES

- Recorded by: RAMBØLL
- Instrument: Geometrics StrataVisor NZ/2 Geodes, 112 channels
- Source: IVI MiniVib T7000, 5 sek. sweep, 10-350 Hz
- Vibration point spacing: 10 m
- No. of channels: 94
- Samples/trace 2048
- Geometry: End of line, 235.....2.5..x (distance/m) 94.....1..x (channel no.)
- Date: March 2003
- Acquisition filters: None
- Geophones/group: 1 x 14 Hz L-10 Al
- Group spacing: 2.5 m
- Sample interval: 0.5 ms
- Fold: 47 (4 x CMP-binning)

PROCESSING PARAMETERS

- Import of rawdata, zero phase
- Definition of geometry
- Bandpassfilter, 50-75-250-350 Hz
- Gain, AGC 100 ms window
- Trace edit
- First arrival alignment static correction
- Mute
- CMP sorting, 4 x CMP-binning
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Stretch mute
- Invers NMO
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Residual static correction Maximum shift 3 ms, pilot trace 3 CMP gathers, window 100-400 ms
- CMP stacking
- Bandpassfilter, 30-50-150-250 Hz

PLOT PARAMETERS

- Horizontal scale: 20 traces/cm
- Polarity: Reverse (compaction plotted as white)
- Vertical scale: 20 cm/sec.
- Gain: AGC 100 ms window

Rev.	Date	Drawn by	Control	Approved
0	28.05.2003	JMN/JIJ	UTN	TVP

Job 360211C

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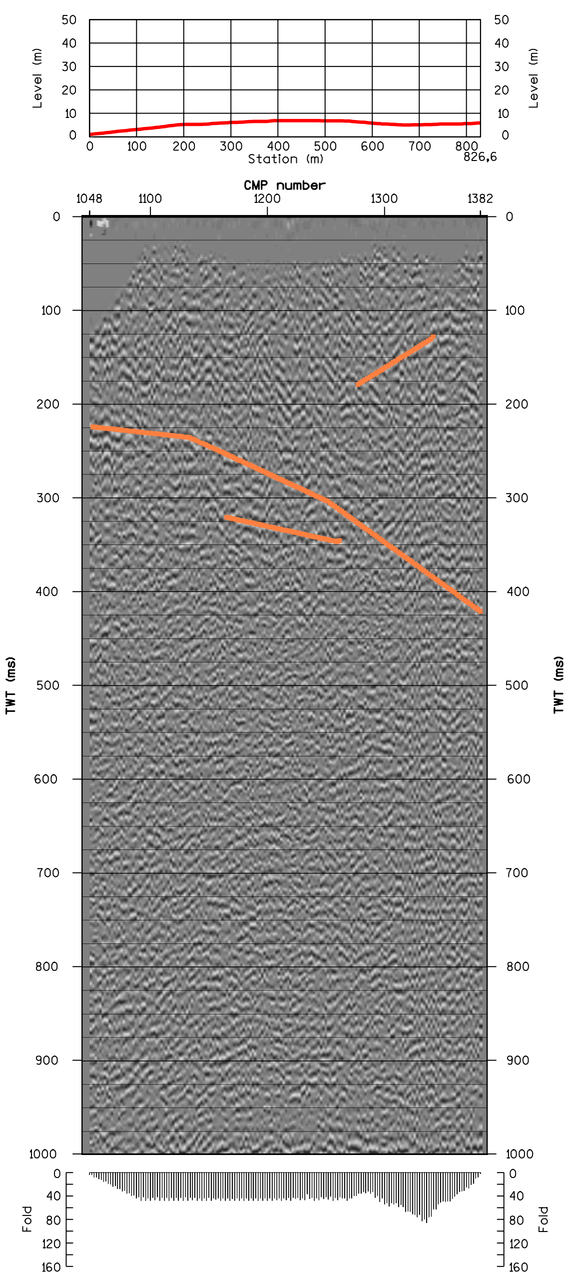
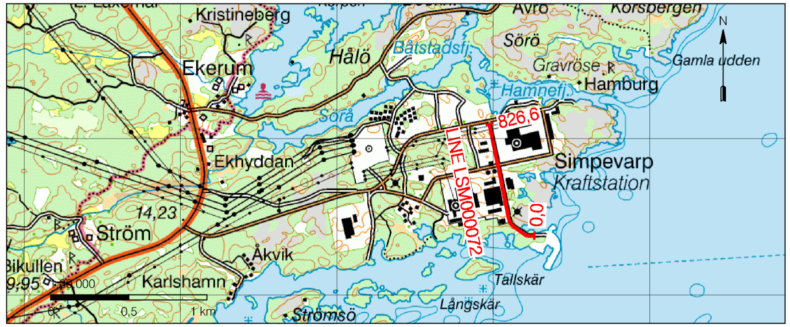
Reflection seismic on Simpevarpshalvön 2003 - vibroseismic
Line LSM000071 with interpretation

Drawing No.: 3.6

G:\GEO\2003\360211C SKB Seismik\Cad\3_6.dgn 28-MAY-2003 14:56 JMN





ACQUISITION PARAMETERES

- Recorded by: RAMBØLL
- Instrument: Geometrics StrataVisor NZ/2 Geodes, 112 channels
- Source: IVI MiniVib T7000, 5 sek. sweep, 10-350 Hz
- Vibration point spacing: 10 m
- No. of channels: 94
- Samples/trace 2048
- Geometry: End of line, 235.....2.5..x (distance/m) 94.....1..x (channel no.)

- Date: March 2003
- Acquisition filters: None
- Geophones/group: 1 x 14 Hz L-10 AI
- Group spacing: 2.5 m
- Sample interval: 0.5 ms
- Fold: 47 (4 x CMP-binning)

PROCESSING PARAMETERS

- Import of rawdata, zero phase
- Definition of geometry
- Bandpassfilter, 50-75-250-350 Hz
- Gain, AGC 100 ms window
- Trace edit
- First arrival alignment static correction
- Mute
- CMP sorting, 4 x CMP-binning
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Stretch mute
- Invers NMO
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Residual static correction Maximum shift 3 ms, pilot trace 3 CMP gathers, window 100-400 ms
- CMP stacking
- Bandpassfilter, 30-50-150-250 Hz

PLOT PARAMETERS

- Horizontal scale: 20 traces/cm
- Polarity: Reverse (compaction plotted as white)
- Vertical scale: 20 cm/sec.
- Gain: AGC 100 ms window

Rev.	Date	Drawn by	Control	Approved
0	28.05.2003	JMN/JIJ	UTN	TVP

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SVENSK KÄRNBRÄNSLEHANTERING AB

Reflection seismic on Simpevarpshalvön 2003 - vibroseismic
Line LSM000072 with interpretation

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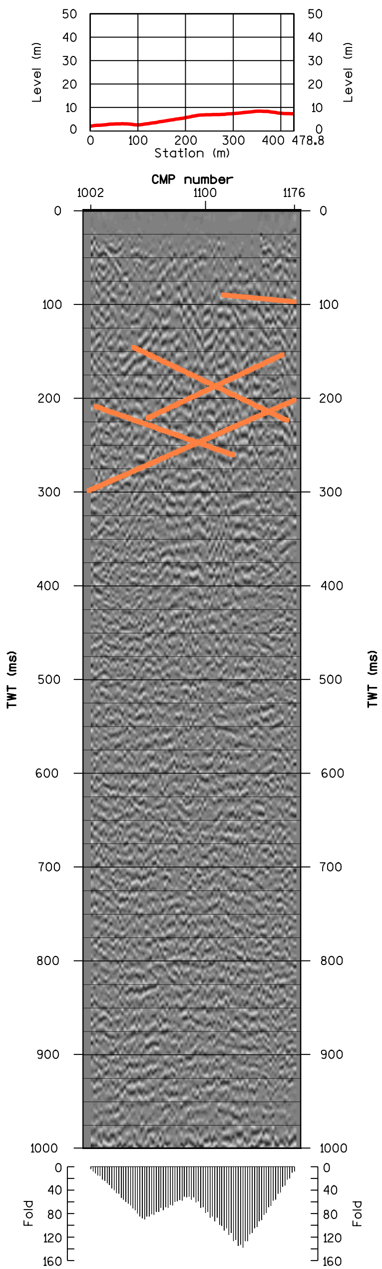
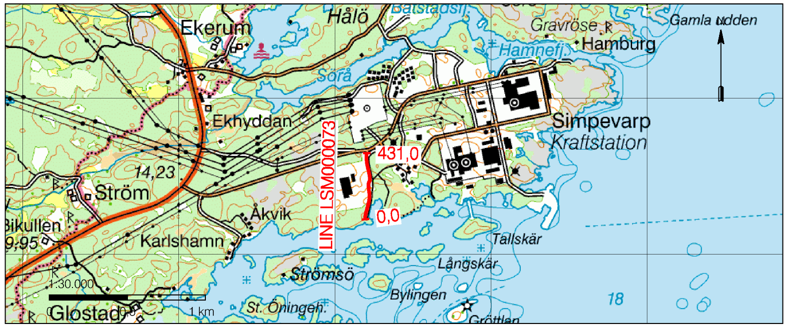
Drawing No.: 3.7

G:\GEO\2003\360211C SKB Seismik\Cad\3_7.dgn 28-MAY-2003 14:57 JMN





ACQUISITION PARAMETERES

- Recorded by: RAMBØLL
- Instrument: Geometrics StrataVisor NZ/2 Geodes, 112 channels
- Source: IVI MiniVib T7000, 5 sek. sweep, 10-350 Hz
- Vibration point spacing: 10 m
- No. of channels: 94
- Samples/trace 2048
- Date: March 2003
- Acquisition filters: None
- Geophones/group: 1 x 14 Hz L-10 AI
- Group spacing: 2.5 m
- Sample interval: 0.5 ms
- Fold: 47 (4 x CMP-binning)
- Geometry: End of line, 235.....2.5..x (distance/m) 94.....1..x (channel no.)

PROCESSING PARAMETERS

- Import of rawdata, zero phase
- Definition of geometry
- Bandpassfilter, 50-75-250-350 Hz
- Gain, AGC 100 ms window
- Trace edit
- First arrival alignment static correction
- Mute
- CMP sorting, 4 x CMP-binning
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Stretch mute
- Invers NMO
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Residual static correction Maximum shift 3 ms, pilot trace 3 CMP gathers, window 100-400 ms
- CMP stacking
- Bandpassfilter, 30-50-150-250 Hz

PLOT PARAMETERS

- Horizontal scale: 20 traces/cm
- Polarity: Reverse (compaction plotted as white)
- Vertical scale: 20 cm/sec.
- Gain: AGC 100 ms window

Rev.	Date	Drawn by	Control	Approved
0	28.05.2003	JMN/JIJ	UTN	TVP

Job 360211C

SVENSK KÄRNBRÄNSLEHANTERING AB

Reflection seismic on Simpevarpshalvön 2003 - vibroseismic
Line LSM000073 with interpretation

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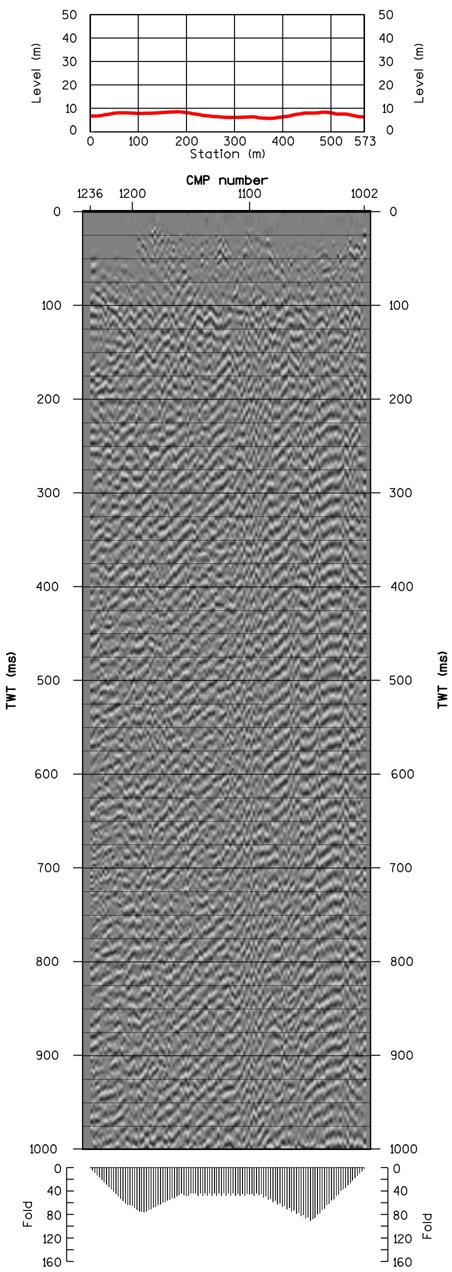
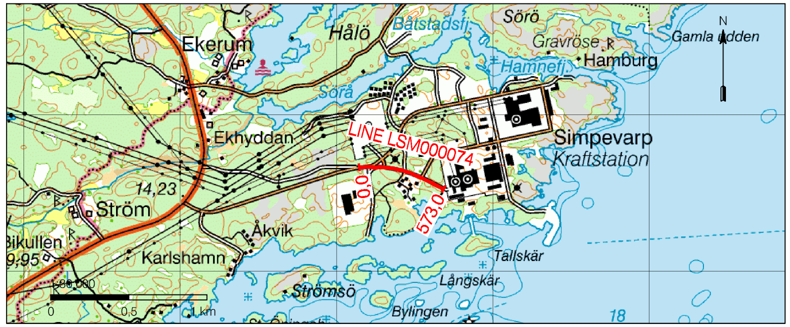
Drawing No.: 3.8

G:\GEO\2003\360211C SKB Seismik\Cad\3_8.dgn 28-MAY-2003 14:57 JMN





ACQUISITION PARAMETERES

- Recorded by: RAMBØLL
- Instrument: Geometrics StrataVisor NZ/2 Geodes, 112 channels
- Source: IVI MiniVib T7000, 5 sek. sweep, 10-350 Hz
- Vibration point spacing: 10 m
- No. of channels: 94
- Samples/trace 2048
- Geometry: End of line, 235.....2.5..x (distance/m) 94.....1..x (channel no.)
- Date: March 2003
- Acquisition filters: None
- Geophones/group: 1 x 14 Hz L-10 Al
- Group spacing: 2.5 m
- Sample interval: 0.5 ms
- Fold: 47 (4 x CMP-binning)

PROCESSING PARAMETERS

- Import of rawdata, zero phase
- Definition of geometry
- Bandpassfilter, 50-75-250-350 Hz
- Gain, AGC 100 ms window
- Trace edit
- First arrival alignment static correction
- Mute
- CMP sorting, 4 x CMP-binning
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Stretch mute
- Invers NMO
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- CMP stacking
- Bandpassfilter, 30-50-150-250 Hz

PLOT PARAMETERS

- Horizontal scale: 20 traces/cm
- Polarity: Reverse (compaction plotted as white)
- Vertical scale: 20 cm/sec.
- Gain: AGC 100 ms window

Rev.	Date	Drawn by	Control	Approved
0	28.05.2003	JMN/JIJ	UTN	TVP

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Reflection seismic on Simpevarpshalvön 2003 - vibroseismic
Line LSM000074 with interpretation

Drawing No.: 3.9

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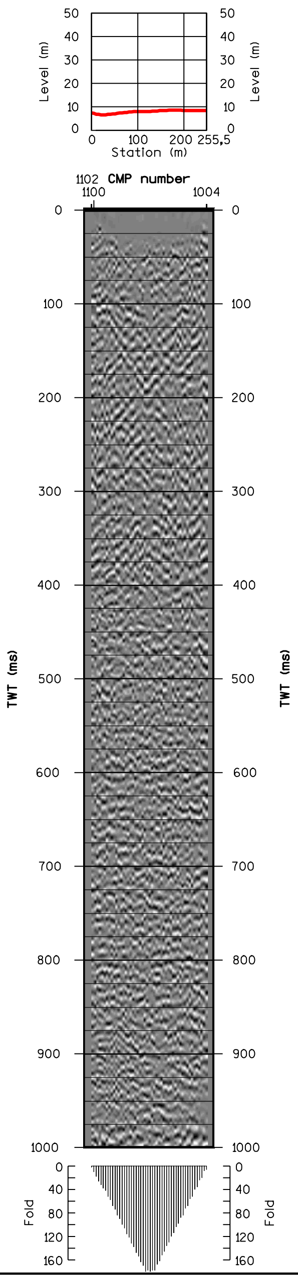

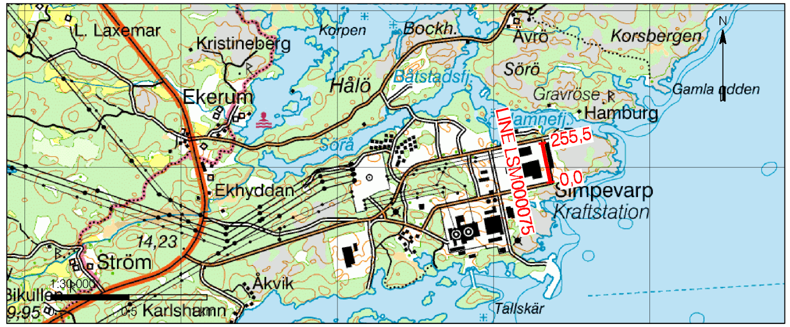

ACQUISITION PARAMETERES

- Recorded by: RAMBØLL
- Instrument: Geometrics StrataVisor NZ/2 Geodes, 112 channels
- Source: IVI MiniVib T7000, 5 sek. sweep, 10-350 Hz
- Vibration point spacing: 10 m
- No. of channels: 94
- Samples/trace 2048
- Date: March 2003
- Acquisition filters: None
- Geophones/group: 1 x 14 Hz L-10 Al
- Group spacing: 2.5 m
- Sample interval: 0.5 ms
- Fold: 47 (4 x CMP-binning)
- Geometry: End of line, 235.....2.5..x (distance/m) 94.....1..x (channel no.)

PROCESSING PARAMETERS

- Import of rawdata, zero phase
- Definition of geometry
- Bandpassfilter, 50-75-250-350 Hz
- Gain, AGC 100 ms window
- Trace edit
- First arrival alignment static correction
- Mute
- CMP sorting, 4 x CMP-binning
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Stretch mute
- Invers NMO
- NMO correction, velocities from constant velocity stack panels
- Surface consistent static correction Maximum shift 5 ms, pilot trace 3 CMP gathers, window 100-400 ms
- Residual static correction Maximum shift 3 ms, pilot trace 3 CMP gathers, window 100-400 ms
- CMP stacking
- Bandpassfilter, 30-50-150-250 Hz

PLOT PARAMETERS

- Horizontal scale: 20 traces/cm
- Polarity: Reverse (compaction plotted as white)
- Vertical scale: 20 cm/sec.
- Gain: AGC 100 ms window

Rev.	Date	Drawn by	Control	Approved
0	28.05.2003	JMN/JIJ	UTN	TVP

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Reflection seismic on Simpevarpshalvön 2003 - vibroseismic
Line LSM000075 with interpretation

Drawing No.: 3.10

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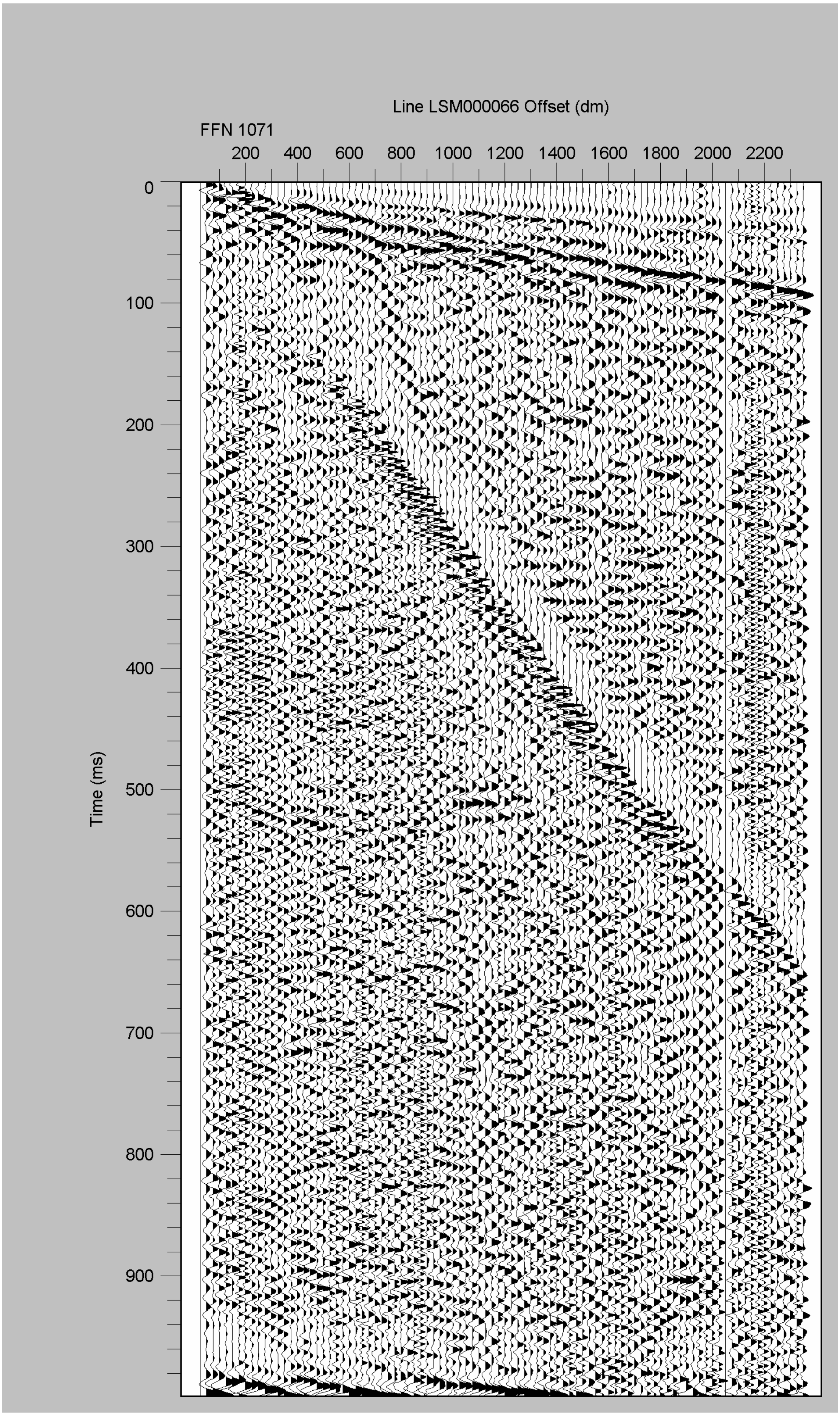
Appendix D

Examples of raw shotgathers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2200
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400
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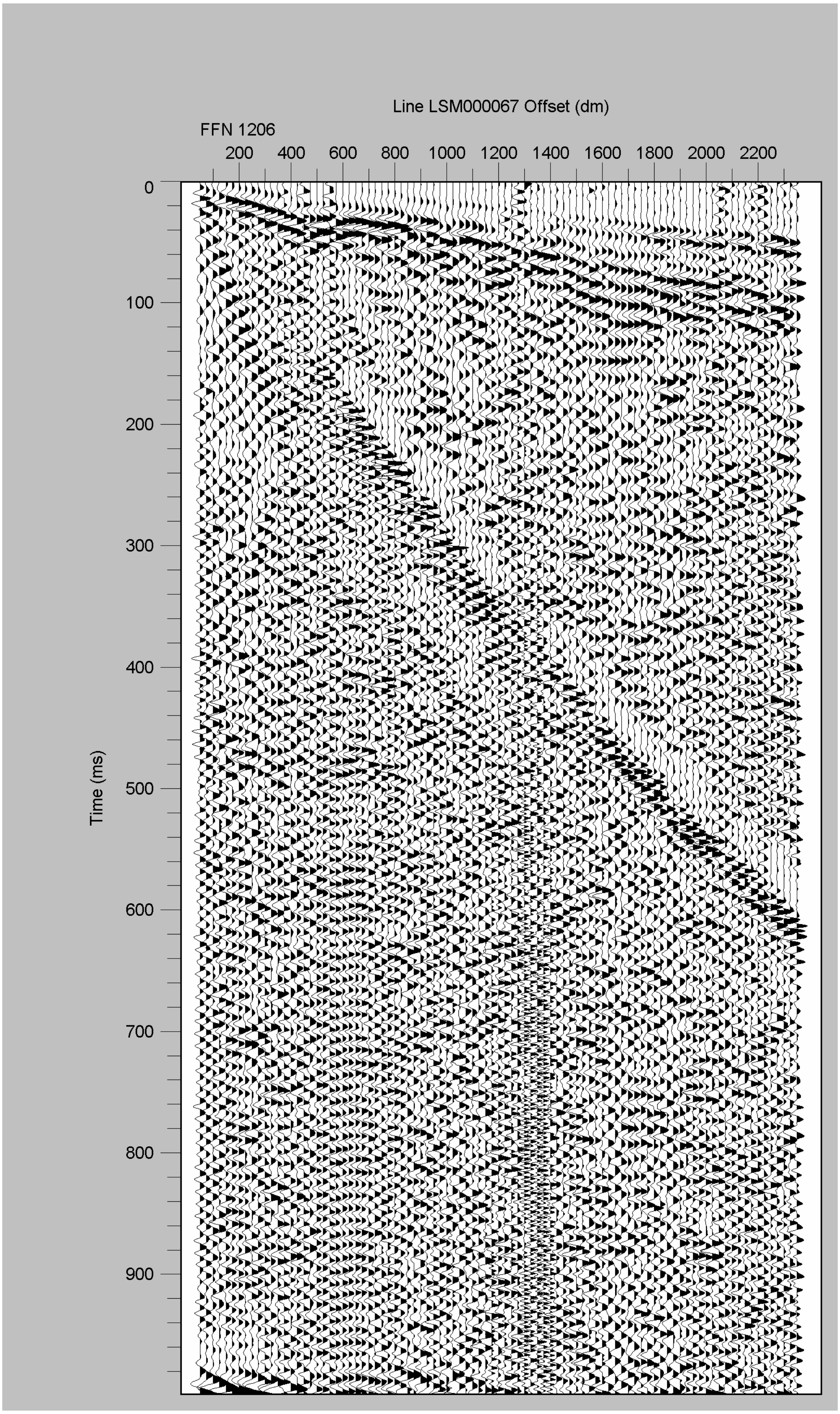
600
700
800
900
Time (ms)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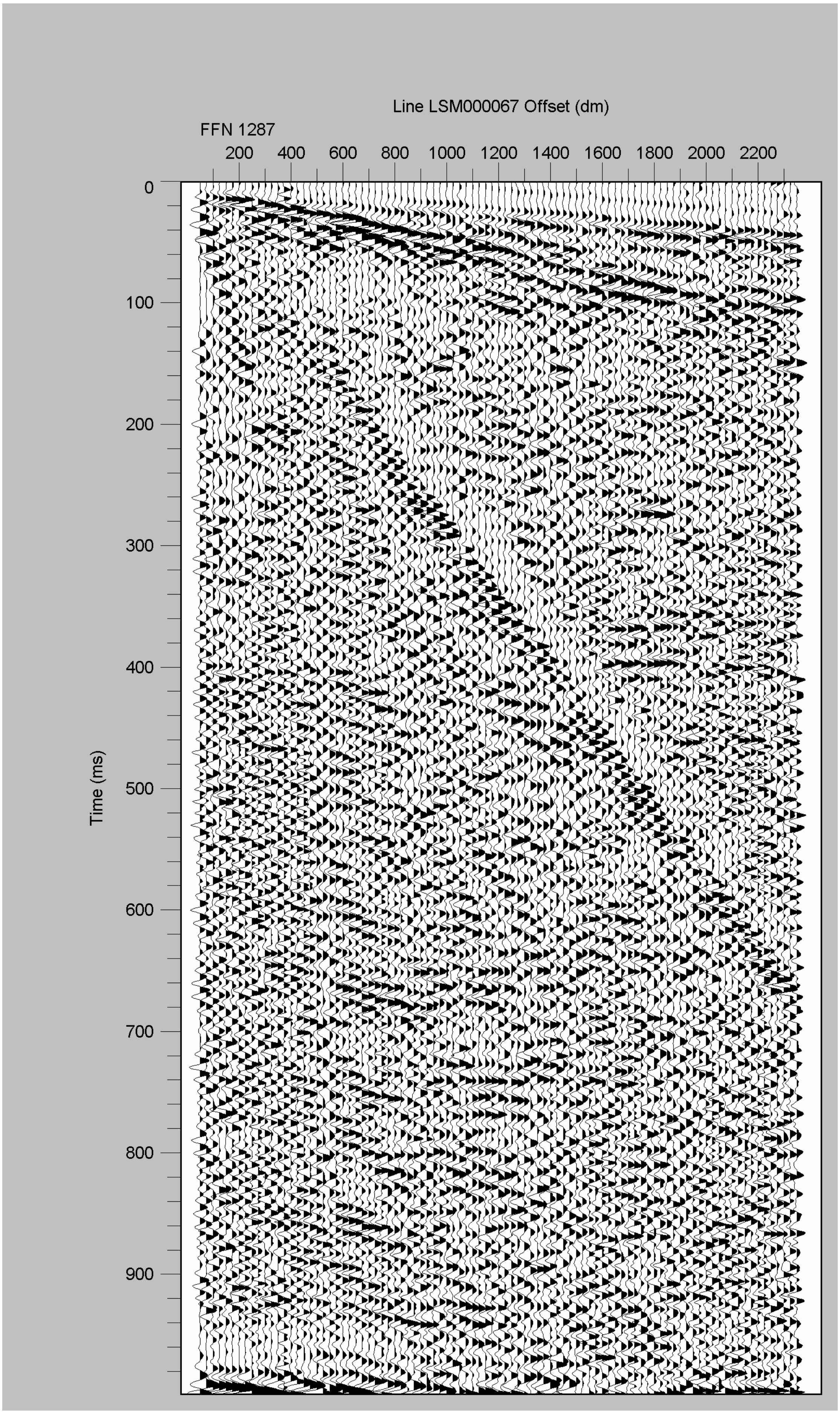
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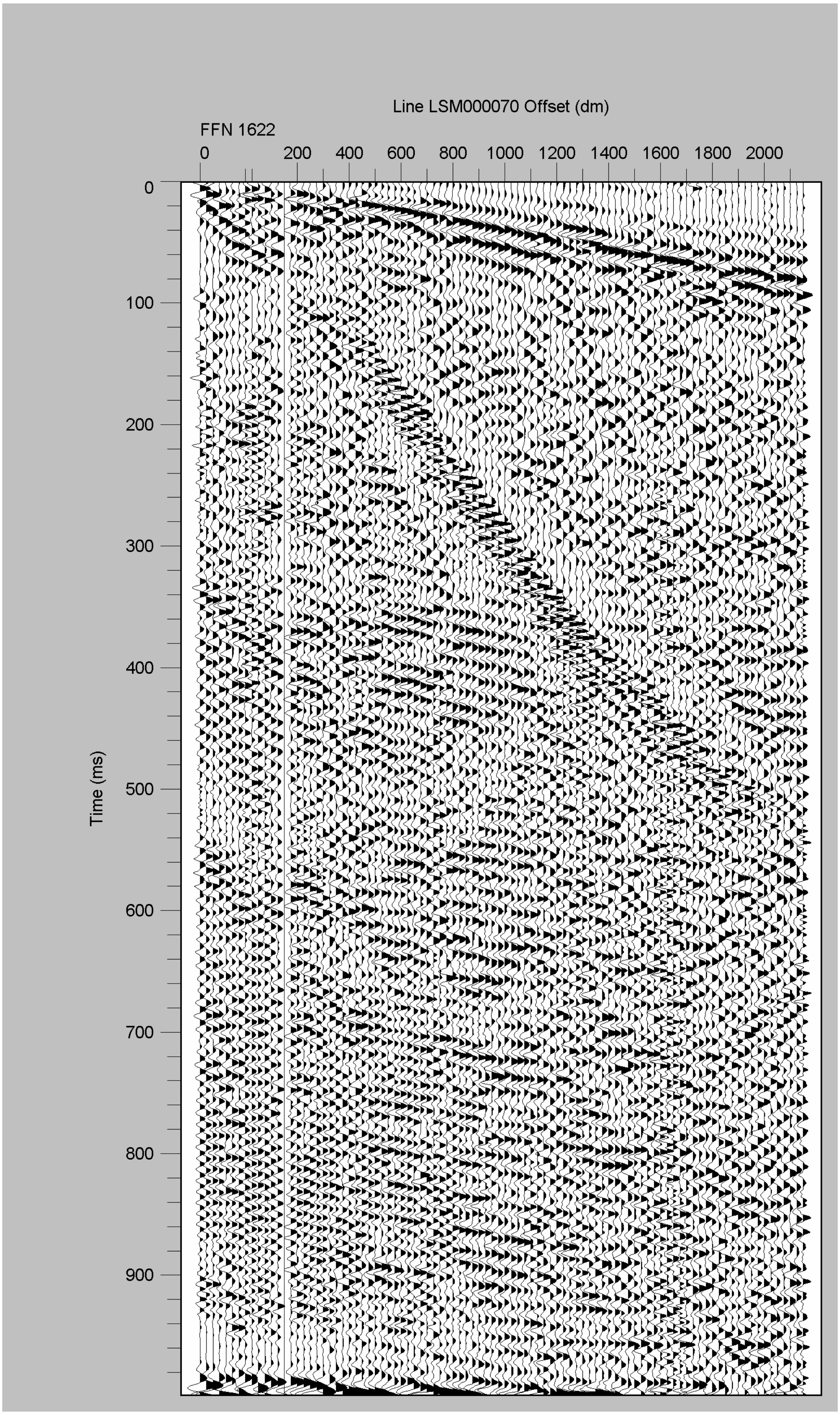
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1400
1600
1800
2000
Time (ms)
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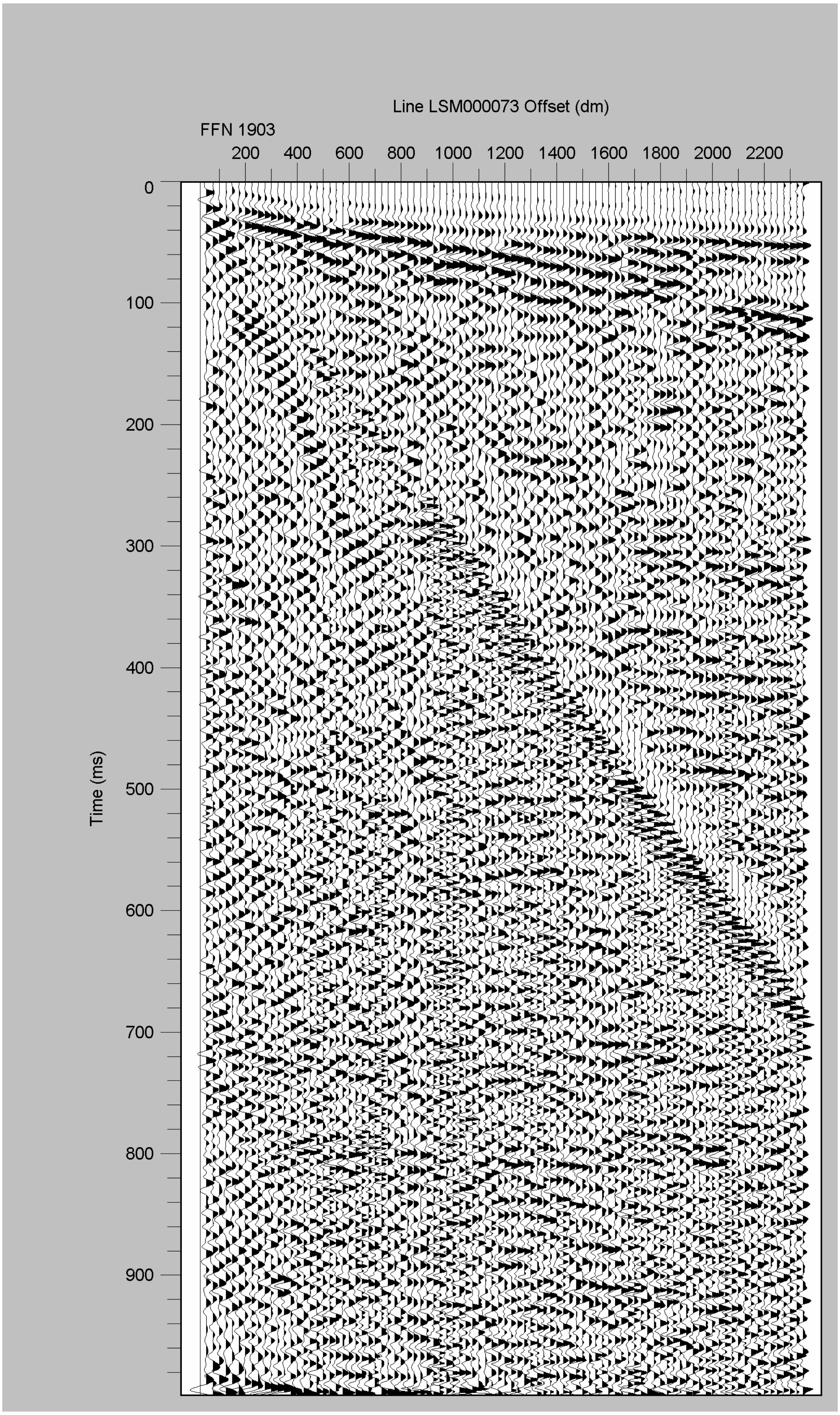
200
300
400
500
600
700
800
900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