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# RAMAC directional logging in borehole KLX05 and RAMAC and BIPS logging in borehole HLX20

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June 2005

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*Keywords:* BIPS, RAMAC, Radar, TV.

# Reading instruction

For revision no 1 of this report a recalculation of the directional radar data has been done. The strike angle between the line of the plane’s cross-section with the surface and the Magnetic North direction was earlier counted counter-clockwise but it is now recalculated as such it counts clockwise, see Figure 5-2. New values for strike and dip are therefore updated in Table 5-2.

# Abstract

This report includes the data gained in geophysical logging operations performed within the site investigation at Oskarshamn. The logging operations presented here includes borehole directional radar (RAMAC) logging in the core drilled borehole KLX05 and borehole radar (RAMAC) and BIPS logging in the percussion drilled borehole HLX20. All measurements were conducted by Malå Geoscience AB/RAYCON during May 2005.

The objective of the radar surveys is to achieve information on the rock mass around the borehole. Borehole radar is used to investigate the nature and the structure of the rock mass enclosing the boreholes.

The objective of the BIPS logging is to achieve information of the borehole including occurrence of rock types as well as determination of fracture distribution and orientation.

This report describes the equipment used as well as the measurement procedures and data gained. For the BIPS survey, the result is presented as images. Radar data is presented in radargrams and the identified reflectors are listed.

The borehole radar data quality from KLX05 and HLX20 was relatively satisfying, but in large parts of lower quality due to more conductive conditions. This conductive environment of course reduces the possibility to distinguish and interpret possible structures in the rock mass which otherwise could give a reflection. However, the borehole radar measurements resulted in 45 identified and orientated (strike/dip) radar reflectors and in KLX05. In HLX20 41 radar reflectors were identified.

The BIPS images from HLX20 are of good quality down to a depth of 117. 5 m. From that level down to the position were the logging was stopped the water quality is very bad and it is impossible to get any information from the borehole walls.

# Sammanfattning

Denna rapport omfattar geofysiska loggningar inom platsundersökningsprogrammet för Oskarshamn. Mätningarna som presenteras här omfattar borrhålsradarmätningar med riktantenn (RAMAC) i borrhål KLX05 och borrhålsradarmätningar (RAMAC) och BIPS-loggningar i HLX20. Alla mätningar är utförda av Malå Geoscience AB/RAYCON under maj 2005.

Syftet med radarmätningarna är att samla information om bergmassan runt borrhålet. Borrhålsradar används till att karakterisera bergets egenskaper och strukturer i bergmassan närmast borrhålet.

Syftet med BIPS loggningen är att skaffa information om borrhålet inkluderande förekommande bergarter och bestämning av sprickors fördelning och deras orientering.

Rapporten beskriver utrustningen som använts liksom mätprocedurer och en beskrivning och tolkning av data som erhållits. För BIPS loggningen presenteras data som plottar längs med borrhålet. Radardata presenteras i radargram och en lista över tolkade radarreflektorer ges.

Borrhålsradardata från KLX05 och HLX20 var relativt tillfredställande, men i stora delar av sämre kvalité troligen till stor del beroende på en konduktiv miljö. En konduktiv miljö minskar möjligheterna att identifiera strukturer från borrhålsradardata. Dock har 45 radarreflektorer identifierats och orienteras (med strykning/stupning) i KLX05. I HLX20 har 41 radarreflektorer identifierats.

BIPS bilderna från HLX20 är av god kvalitet ner till 117,5 m där mycket grumligt vatten helt förstör förutsättningar för loggning med BIPS kameran.

# Contents

# 1 Introduction

This document reports the data gained in geophysical logging operations, which is one of the activities performed within the site investigation at Oskarshamn. The logging operations presented here includes borehole directional radar (RAMAC) measurements in the core drilled borehole KLX05 and borehole radar (RAMAC) and TV-logging (BIPS) in the percussion drilled borehole HLX20. The work was carried out in accordance with activity plan AP PS 400-05-004. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

This report includes measurements from 100 to 1,000 m in KLX05 and from 0 to 190 m in HLX20. The borehole KLX05 is percussion drilled with a diameter of 195 mm down to 75.1 m, from there the borehole is core drilled with a diameter of 76 mm. The borehole HLX20 is percussion drilled with a diameter of 138 mm.

All measurements were conducted by Malå Geoscience AB/RAYCON during May 2005. The investigation site and location of the boreholes is shown in Figure 1-1.

The used investigation techniques comprised:

- Borehole radar measurements (Malå Geoscience AB:s RAMAC system) with dipole and directional radar antennas.
- Borehole TV logging with the so-called BIP-system (Borehole Image Processing System), which is a high resolution, side viewing, colour borehole TV system.

The delivered raw and processed data have been inserted in the database of SKB (SICADA) and data are traceable by the activity plan number.

**Table 1-1. Controlling documents for the performance of the activity (SKB internal controlling documents).**

| Activity plan | Number | Version |
|---|---|---|
| Borrhålsradar och BIPS i KLX05 | AP PS 400-05-004 | 1.0 |
| Tilllägg till Aktivitetsplan AP PS 400-05-004 (Borrhålsradar och BIPS KLX05) | | |
| **Method descriptions** | **Number** | **Version** |
| Metodbeskrivning för TV- loggning med BIPS | SKB MD 222.006 | 1.0 |
| Metodbeskrivning för borrhålsradar | SKB MD 252.020 | 1.0 |


***Figure 1-1.*** *General overview over the Simpevarp and Laxemar subareas in Oskarshamn with the location of the boreholes KLX05 and HLX20 in Laxemar.*

# 2 Objective and scope

The objective of the radar and BIPS surveys is to achieve information on the borehole conditions (borehole wall) as well as on the rock mass around the borehole. Borehole radar is engaged to investigate the nature and the structure of the rock mass enclosing the boreholes, and borehole TV for geological surveying of the borehole including determination of rock types as well as fracture distribution and orientation.

This report describes the equipment used as well as the measurement procedures and data gained. For the BIPS survey, the result is presented as images. Radar data is presented in radargrams and the identified reflectors are listed.

# 3 Equipment

## 3.1 Radar measurements RAMAC

The RAMAC GPR system owned by SKB is a fully digital GPR system where emphasis has been laid on fast survey speed and easy field operation. The system operates dipole and directional antennas (see Figure 3-1). A system description is given in the SKB internal controlling document MD 252.021.

The borehole radar system consists of a transmitter and a receiver antenna. During operation an electromagnetic pulse, within the frequency range of 20 MHz up to 250 MHz, is emitted into the bedrock. Once a feature, e.g. a water-filled fracture, with sufficiently different electrical properties is encountered, the pulse is reflected back to the receiver and recorded.

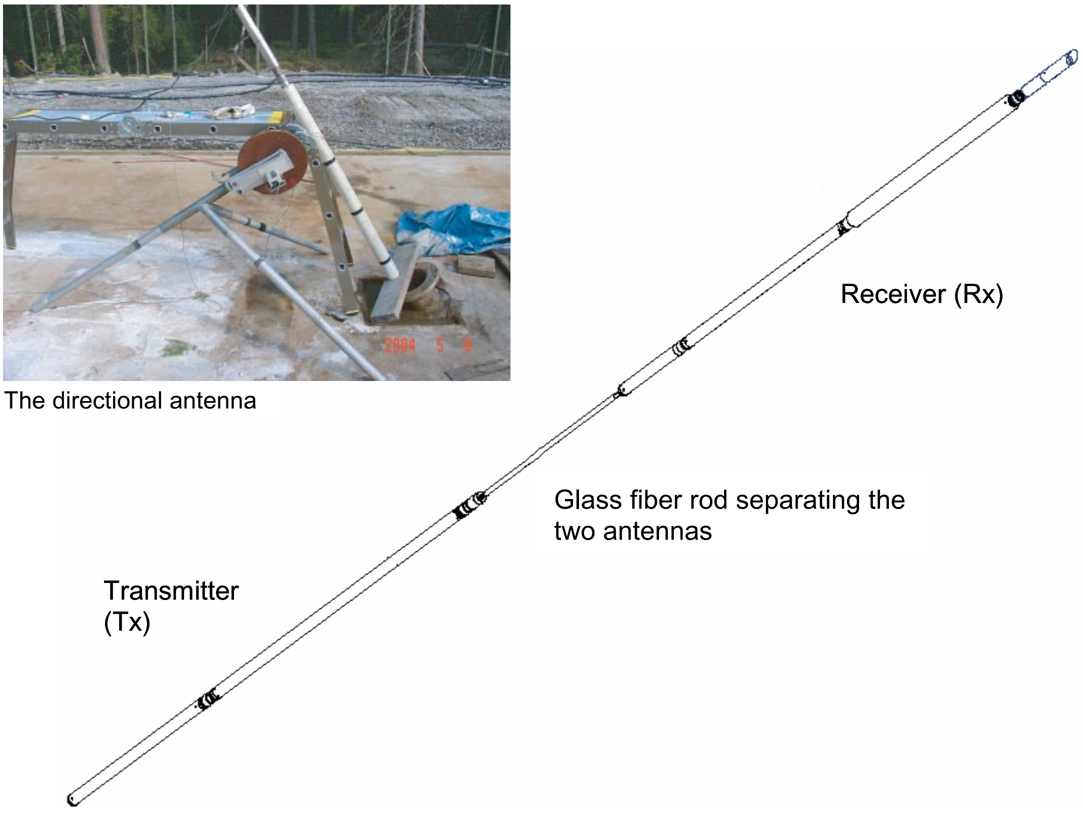



***Figure 3-1.*** *Example of a borehole radar antenna.*

## 3.2 TV-Camera, BIPS

The BIPS 1500 system used is owned by SKB and described in SKB internal controlling document MD 222.005. The BIPS method for borehole logging produces a digital scan of the borehole wall. In principle, a standard CCD video camera is installed in the probe in front of a conical mirror (see Figure 3-2). An acrylic window covers the mirror part and the borehole image is reflected through the window and displayed on the cone, from where it is recorded. During the measuring operation, pixel circles are grabbed with a resolution of 360 pixels/circle.

The system orientates the BIPS images according to two alternative methods, either using a compass (vertical boreholes) or with a gravity sensor (inclined boreholes).

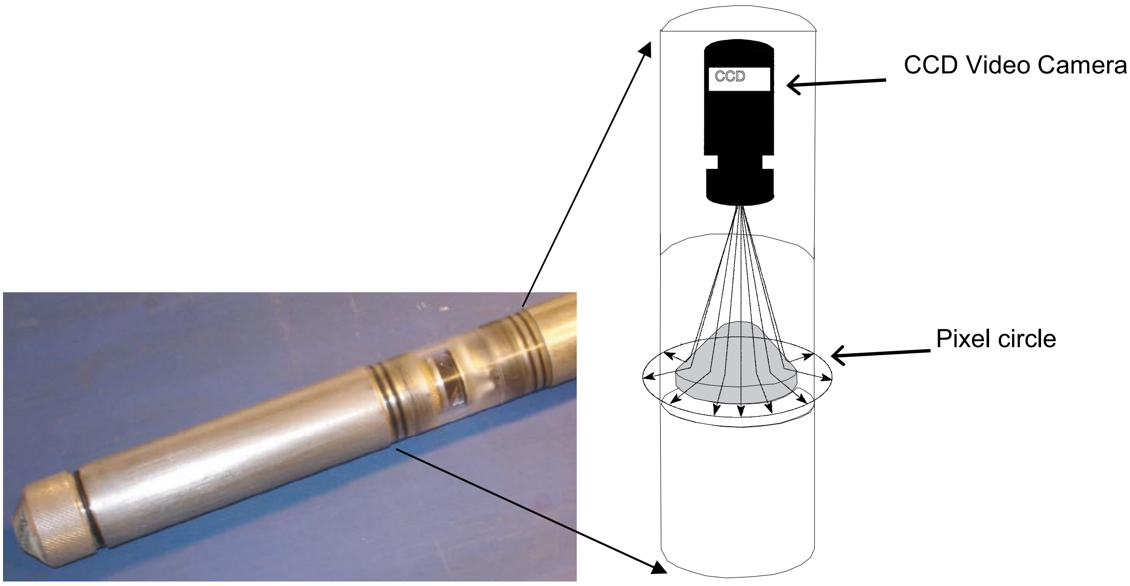



***Figure 3-2.*** *The BIP-system. Illustration of the conical mirror scanning.*

# 4 Execution

## 4.1 General

### 4.1.1 RAMAC Radar

The measurements in HLX20 were carried out with dipole radar antennas, with frequencies of 250, 100 and 20 MHz. In KLX05 the measurements were carried out using the directional antenna, with a central frequency of 60 MHz.

During logging the dipole antennas (transmitter and receiver) were lowered continuously into the borehole and data were recorded on a field PC along the measured interval. The measurement with the directional antenna is made step wise, with a short pause for each measurement occasion. The antennas (transmitter and receiver, both for dipole and directional) are kept at a fixed separation by glass fiber rods according to Table 4-1. See also Figure 3-1 and 4-1.

All measurements were performed in accordance with the instructions and guidelines from SKB (internal document MD 252.020). All cleaning of the antennas and cable was performed according to the internal document SKB MD 600.004 before the logging operation.

The functionality of the directional antenna was tested before measurements in KLX05. This is done by measurements in the air, where the receiver antenna and the transmitter antenna are placed apart. While transmitting and measuring the receiver antenna is turned around and by that giving the direction from the receiver antenna to the transmitter antenna. The difference in direction is measured by compass and the result difference achieved from the directional antenna was about 1 degree. This can be considered as very good due to the disturbed environment, with metallic objects etc at the test site.

For more information on system settings used in the investigation of KLX05 and HLX20, see Tables 4-1 and 4-2 below.

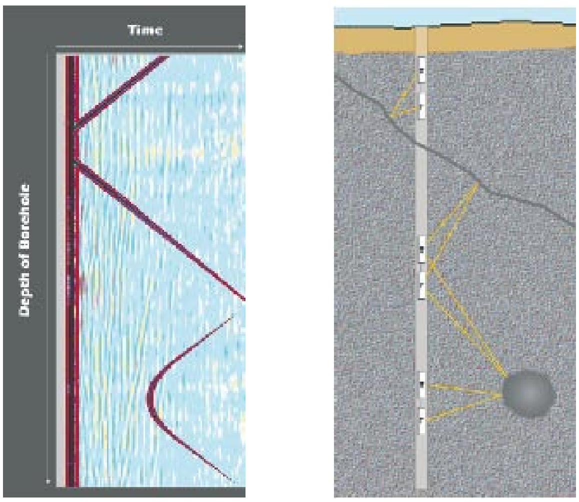



***Figure 4-1.*** *The principle of radar borehole reflection survey and an example of result.*

**Table 4-1. Radar logging information from KLX05.**

| | | | |
|---|---|---|---|
| **Site:** | **Oskarshamn** | **Logging company:** | **RAYCON** |
| **BH:** | **KLX05** | **Equipment:** | **SKB RAMAC** |
| **Type:** | **Directional** | **Manufacturer:** | **MALÅ GeoScience** |
| **Operator:** | **CG** | **Antenna** | |
| | | **Directional** | |
| Logging date: | | 05-05-18–05-05-19 | |
| Reference: | | T.O.C | |
| Sampling frequency (MHz): | | 615 | |
| Number of samples: | | 512 | |
| Number of stacks: | | 32 | |
| Signal position: | | 410.51 | |
| Logging from (m): | | 111.4 | |
| Logging to (m): | | 991.4 | |
| Trace interval (m): | | 0.5 | |
| Antenna separation (m): | | 5.73 | |

**Table 4-2. Radar logging information from HLX20.**

| | | | | |
|---|---|---|---|---|
| **Site:** | **Oskarshamn** | **Logging company:** | **RAYCON** | |
| **BH:** | **HLX20** | **Equipment:** | **SKB RAMAC** | |
| **Type:** | **Dipole** | **Manufacturer:** | **MALÅ GeoScience** | |
| **Operator:** | **CG** | **Antenna** | | |
| | | **250 MHz** | **100 MHz** | **20 MHz** |
| Logging date: | | 05-05-18 | 05-05-18 | 05-05-18 |
| Reference: | | T.O.C. | T.O.C. | T.O.C. |
| Sampling frequency (MHz): | | 2,424 | 891 | 239 |
| Number of samples: | | 619 | 518 | 518 |
| Number of stacks: | | Auto | Auto | Auto |
| Signal position: | | –0.34 | –0.35 | –1.40 |
| Logging from (m): | | 1.5 | 2.6 | 6.25 |
| Logging to (m): | | 196.1 | 195.6 | 191.65 |
| Trace interval (m): | | 0.1 | 0.2 | 0.25 |
| Antenna separation (m): | | 2.4 | 3.9 | 10.05 |

### 4.1.2 BIPS

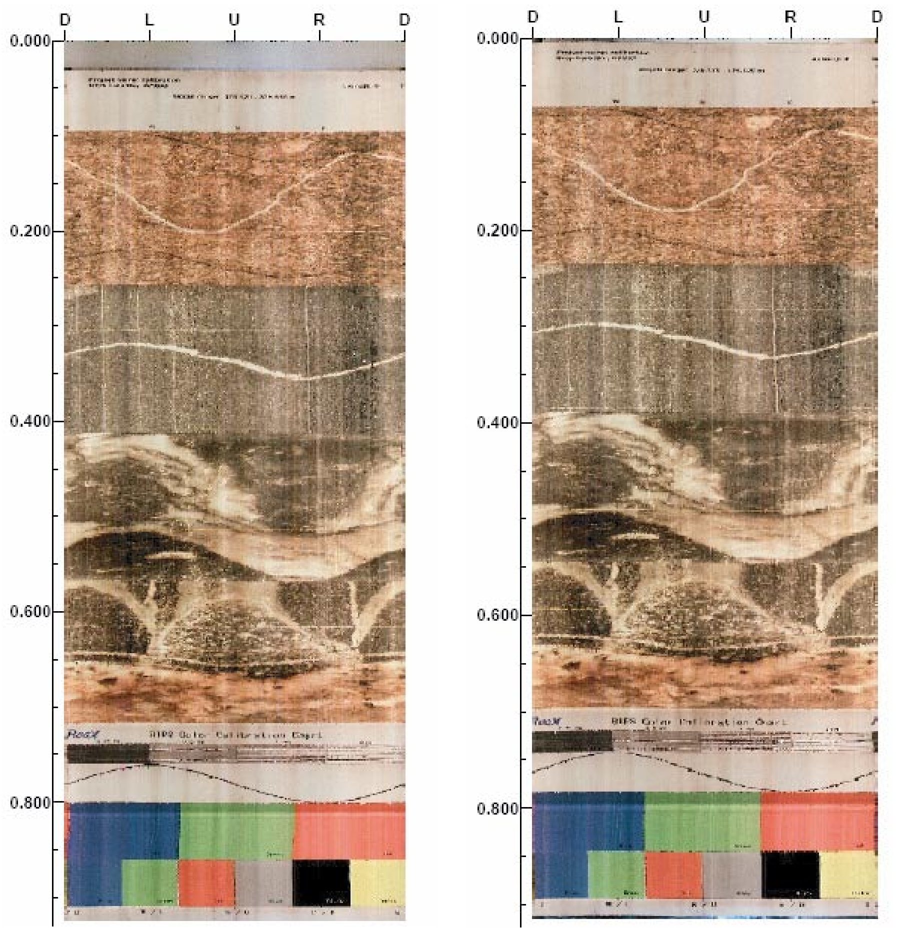
All measurements were performed in accordance with the instructions and guidelines from SKB (internal document MD 222.006). All cleaning of the probe and cable was performed according to the internal document SKB MD 600.004 before the logging operation.

During the measurement, a pixel circle with a resolution of 360 pixels/circle was used and the digital circles were stored at every 1 mm on a MO-disc in the surface unit. The maximum speed during data collection was 1.5 m/minute.

A gravity sensor was used to measure the orientation of the images in the borehole HLX20.

In order to control the quality of the system, calibration measurements were performed in a test pipe before logging and after logging. Figure 4-2 corresponds to the test logging performed before and after the logging of HLX20. The results showed no difference regarding the colours and focus of the images. Results of the test loggings were included in the delivery of the raw data.

The BIPS logging information is found in the header for every single borehole presented in Appendix 3 in this report.




**Before** **After**

***Figure 4-2.*** *Results from logging in the test pipe before and after the logging campaign in May 2005.*

### 4.1.3 Length measurements

During logging the depth recording for the RAMAC systems is taken care of by a measuring wheel mounted on the cable winch. The logging is measured from TOC (Top of Casing). The length is adjusted to the bottom of casing when visible in the BIPS image.

During the BIPS logging in coredrilled boreholes, where the reference marks in the borehole wall is visible on the image, the position where the depth mark is visible is marked with scotch tape on the logging cable. During BIPS logging the measured length was adjusted to true length according to depth mark visible in the BIPS image. The adjusted true length is marked with red in the image plot together with the non adjusted measured length which is marked with black as seen in Appendix 3. The tape marks on the logging cable are then used for controlling the RAMAC measurement.

The experience we have from earlier measurements with dipole antennas in the core drilled boreholes in Forsmark and Oskarshamn for the radar logging is that the depth divergence is less than 50 cm in the deepest parts of the boreholes.

The depth divergence is taken into account in the resulting tables in Chapter 5.

## 4.2 Analyses and interpretation

### 4.2.1 Radar

The result from radar measurements is most often presented in the form of a radargram where the position of the probes is shown along one axis and the propagation is shown along the other axis. The amplitude of the received signal is shown in the radargram with a grey scale where black colour corresponds to the large positive signals and white colour to large negative signals. Grey colour corresponds to no reflected signals.

The presented data in this report is adjusted for the measurement point of the antennas. The measurement point is defined to be the central point between the transmitter and the receiver antenna.

The two basic patterns to interpret in borehole measurements are point and plane reflectors. In the reflection mode, borehole radar essentially gives a high-resolution image of the rock mass, showing the geometry of plane structures which may or may not, intersect the borehole (contact between layers, thin marker beds, fractures) or showing the presence of local features around the borehole (cavities, lenses etc).

The distance to a reflecting object or plane is determined by measuring the difference in arrival time between the direct and the reflected pulse. The basic assumption is that the speed of propagation is the same everywhere.

There are several ways to determine the radar wave propagation velocity. Each of them has its advantages and its disadvantages. In this project the velocity determination was performed by keeping the transmitter fixed in the borehole while moving the receiver downwards in the borehole. The result is plotted in Figure 4-3 and the calculation shows a velocity of 120 m/micro seconds. The velocity measurement was performed in borehole KSH01B with the 100 MHz antennas /1/.

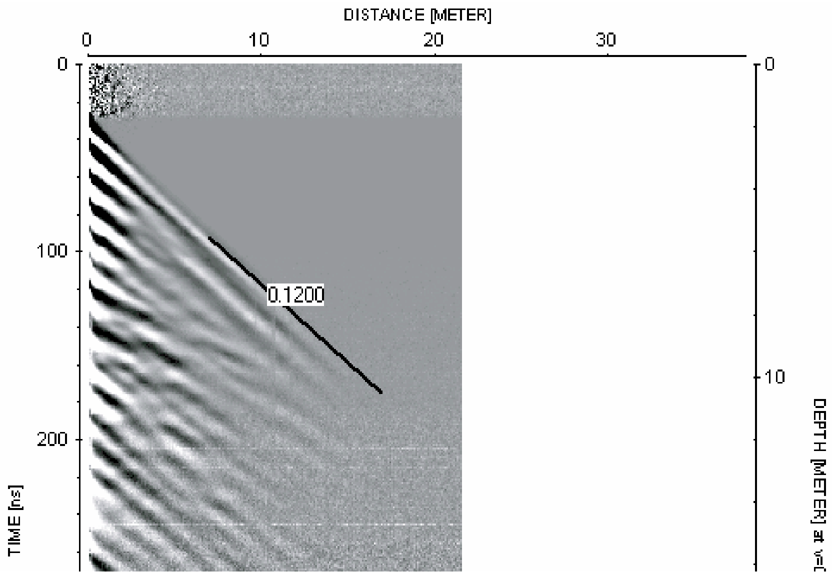



*Figure 4-3. Results from velocity measurements in KSH01B with 100 MHz dipole antennas /1/.*

The visualization of data is made with ReflexWin, a Windows based processing software for filtering and analysis of borehole radar data. The processing steps are shown in Table 4-3 and 4-4. It should be observed that the processing steps in Table 4-4 below refer to Appendix 2 in this report. The filters applied affect the whole borehole length and are not always suitable in all parts, depending on the geological conditions and conductivity of the borehole fluid. During interpretation further processing can be done, most often in form of bandpass filtering. This filtering can be applied just in parts of the borehole, where needed.

For the interpretation of the intersection angle between the borehole axis and the planes visible on the radargrams the RadinterSKB software has been used. The interpreted intersection points and intersection angles of the detected structures are presented in the Tables 5-2 and 5-3 and are also visible on the radargrams in Appendix 2 (HLX20). For visualisation of KLX05 see Appendix 1 /2/ and complemetary information in Figure 5-3.

**Table 4-3. Processing steps for borehole radar data from KLX05.**

| | | | |
|---|---|---|---|
| **Site:** | **Oskarshamn** | **Logging company:** | **RAYCON** |
| **BH:** | **KLX05** | **Equipment:** | **SKB RAMAC** |
| **Type:** | **Directional** | **Manufacturer:** | **MALÅ GeoScience** |
| **Interpret:** | **JG** | **Antenna Directional** | |
| Processing: | | DC adjustment (400–500) | |
| | | Time gain (linear 150 exp1) | |
| | | FIR | |

**Table 4-4. Processing steps for borehole radar data from HLX20.**

| | | | | |
|---|---|---|---|---|
| **Site:** | **Oskarshamn** | **Logging company:** | **RAYCON** | |
| **BH:** | **HLX20** | **Equipment:** | **SKB RAMAC** | |
| **Type:** | **Dipole** | **Manufacturer:** | **MALÅ GeoScience** | |
| **Interpret:** | **JG** | **Antenna** | | |
| | | **250 MHz** | **100 MHz** | **20 MHz** |
| Processing: | | DC removal (190–250) | DC removal (490–570) | DC removal (1,800–2,000) |
| | | Move start time (–23) | Move start time (–37) | Move start time (–85) |
| | | Gain (Stat 20 Linear 0.1 exp 1.7) | Gain (Start 68 linear 2.4 exp 0.6) | Gain (Start 140 Linear 1.1, exp 0.3) |

### 4.2.2 BIPS

The visualization of data is made with BDPP, a Windows based processing software for filtering, presentation and analysis of BIPS data. As no fracture mapping of the BIPS image is performed, the raw data was delivered on a CD-ROM together with printable pictures in *.pdf format before the field crew left the investigation site.

The printed results were delivered with measured length, together with adjusted length according to the length marks visible in the BIPS image. For printing of the BIPS images the printing software BIPP from RaaX was used.

## 4.3 Nonconformities

In HLX20 the logging activity was stopped already at 130 m due to dirty water present in the borehole from 117.5 m. The length of the borehole is 202.2 m.

For revision no 1 of this report a recalculation of the directional radar data has been done. The strike angle between the line of the plane’s cross-section with the surface and the Magnetic North direction was earlier counted counter-clockwise but it is now recalculated as such it counts clockwise, see Figure 5-2. New values for strike and dip are therefore updated in Table 5-2.

# 5 Results

The results from the BIPS measurements were delivered as raw data (*.bip-files) on CD-ROM:s to SKB together with printable BIPS pictures in *.pdf format before the field crew left the investigation site. The information of the measurements was registered in SICADA, and the CD-ROM:s stored by SKB.

The RAMAC radar data was delivered as raw data (file format *.rd3 or *.rd5) for KLX05 and HLX20 with corresponding information files (file format *.rad) whereas the data processing steps and results are presented in this report. Relevant information, including the interpretation presented in this report, was inserted into the SKB database SICADA.

The delivered raw and processed data have been inserted in the database of SKB (SICADA) and data are traceable by the activity plan number.

## 5.1 RAMAC logging

The results of the interpretation of the radar measurements are presented in Tables 5-1 to 5-4. Radardata is also visualized in Appendices 1 and 2. For the identified structures in KLX05 with the dipole antenna see also /2/ and Figure 5-3 for visualization.

It should be remembered that the images in Appendices 1 and 2 and in /2/ are only a composite picture of all events 360 degrees around the borehole, and do not reflect the orientation of the structures.

Only the larger clearly visible structures are interpreted in RadinterSKB. A number of minor structures also exist, indicated in Appendices 1 and 2 and in /2/. Often a number of structures can be noticed, but most probably lying so close to each other that it is impossible to distinguish one from the other. Larger structures parallel to the borehole are also indicated in Appendices 1 and 2 and in /2/. It should also be pointed out that reflections interpreted will always get an intersection point with the borehole, but being located further away. They may in some cases not reach the borehole.

The data quality from KLX05 and HLX20, (as seen in Appendices 1 and 2 and in /2/) is relatively satisfying, but in large parts of lower quality due to more conductive conditions. A conductive environment makes the radar wave to attenuate, which decreases the penetration. This is for instance seen very clearly in the 250 MHz data from HLX20 This conductive environment of course also reduces the possibility to distinguish and interpret possibly structures in the rock which otherwise could give a reflection.

This effect is also seen in the directional antenna for KLX05, which makes it more difficult to interpret the direction to the identified structures. See Figure 5-1 right.

Further on, depending on the size of the borehole, the conductivity and the antenna frequency, so called ringing can be achieved, which again makes the interpretation of single structures quite complicated. This is seen for instance in the dipole component of the directional antenna in KLX05 from a depth of 315 m, Figure 5-1 left.

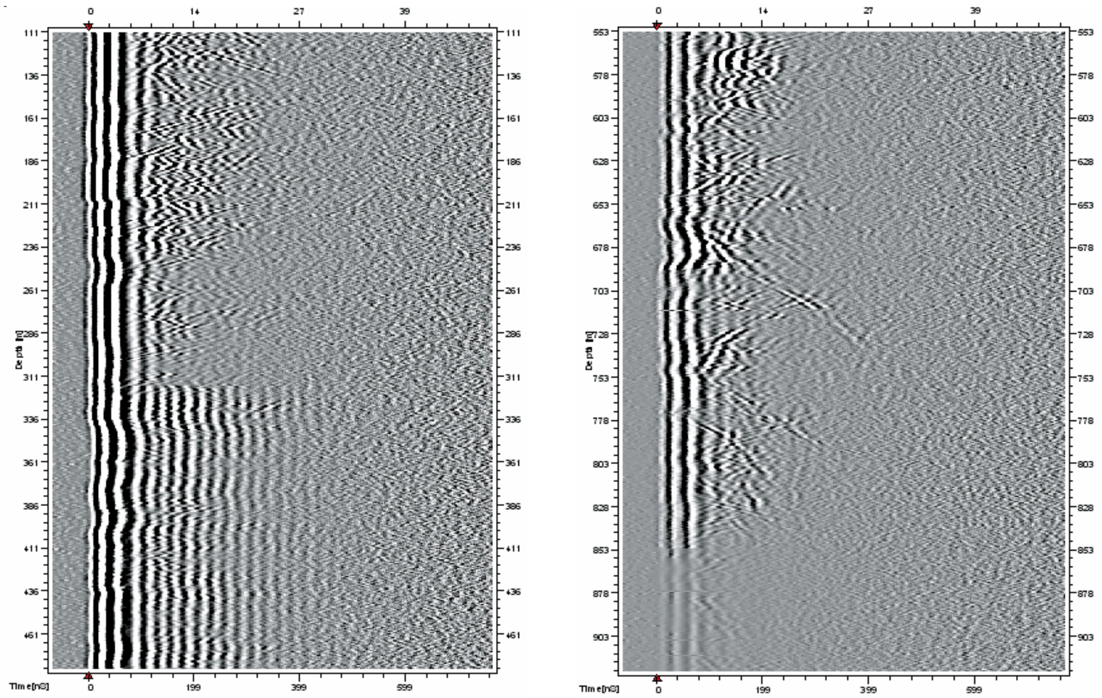


*__Figure 5-1.__ Data from KLX05, the dipole component of the directional antenna. Left: Example of ringing from 315 m and downwards. Right: Example of decreased penetration depth from 850 m and downwards.*

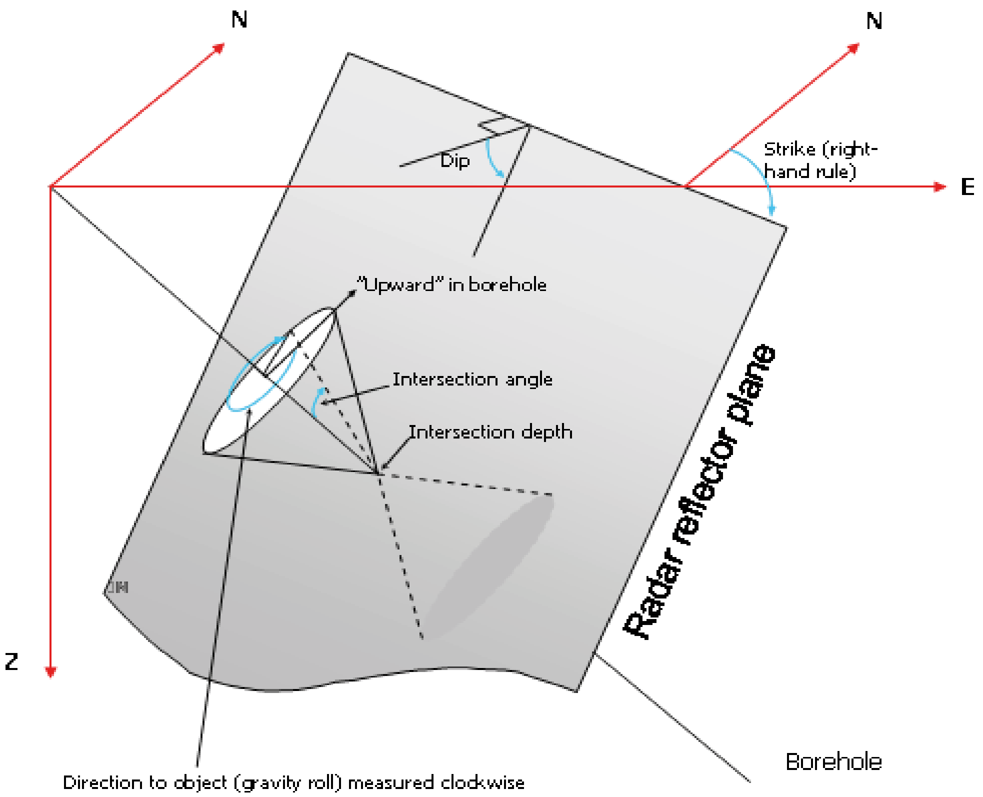



*__Figure 5-2.__ Definition of intersection angle, direction to object using gravity roll, dip and strike using the right hand rule as presented in Table 5-2.*

As also seen in Appendices 1 and 2 and in /2/ the resolution and penetration of radar waves depend on the antenna frequency used. Low antenna frequency gives less resolution but higher penetration depth compared to a higher frequency. If structures can be identified with all three antenna-frequencies, it can probably be explained by that the structure is quite significant.

In Table 5-1 below the distribution of identified structures along the borehole are listed for HLX20. For KLX05, see /2/.

**Table 5-1. Identified structures as a function of depth in HLX20.**

| Depth (m) | No of structures |
|---|---|
| –20 | 3 |
| 20–40 | 2 |
| 40–60 | 7 |
| 60–80 | 2 |
| 80–100 | 2 |
| 100–120 | 6 |
| 120–140 | 5 |
| 140–160 | 3 |
| 160–180 | 5 |
| 180–200 | 4 |
| 200– | 2 |

Table 5-2 and 5-3 summarises the interpretation of radar data from KLX05 and HLX20. As seen some radar reflectors in Table 5-2 are marked with ±, which indicates an uncertainty in the interpretation of the direction to the reflector. The direction can in these cases be ±180 degrees. The direction to the reflector (the plane) is defined in Figure 5-2. As the borehole inclination for KLX05 is less than 85° the direction to object is calculated using gravity roll. This direction and the intersection angle are also recalculated to strike and dip, also given in Table 5-2 below. The plane strike is the angle between line of the plane's cross-section with the surface and the Magnetic North direction. It counts clockwise and can be between 0 and 359 degrees. A strike of 0 degrees implies a dip to the east while a strike of 180 degrees implies a dip to the west. The plane dip is the angle between the plane and the surface. It can vary between 0 and 90 degrees. Observe that a structure can have several different angles, if the structure is undulating, and thereby also different intersection depths. This is seen for structure 120r in Table 5-2 and Figure 5-3. To this structure, most likely, also structure 120x belongs.

**Table 5-2. Interpretation of radar reflectors from the directional antenna in borehole KLX05.**

| RADINTER MODEL INFORMATION (20, 100 and 250 MHz Dipole Antennas and directional antenna) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Site: | | Oskarshamn | | | | | |
| Borehole name: | | KLX05 | | | | | |
| Nominal velocity (m/μs): | | 120.0 | | | | | |
| Name | Intersection depth | Intersection angle | Direction to object (gravity roll) | Interpreted Dip 1 | Interpreted Strike 1 | Interpreted Dip 2 | Interpreted Strike 2 |
| 42 | 37.4 | | 309± | 76 | 52 | 72 | 50 |
| 1 | 97.2 | | 336 | 77 | 254 | | |
| 6 | 114.7 | | 288 | 67 | 225 | | |
| 18 | 167.6 | | 207± | 26 | 153 | 73 | 304 |
| 23 | 180.8 | | 192 | 22 | 128 | | |
| 30 | 185.6 | | 210± | 15 | 189 | 56 | 301 |
| 203 | 200.4 | | 258 | 58 | 198 | | |
| 42x | 210.7 | | 297± | 87 | 41 | 69 | 33 |
| 31 | 213.2 | | 276± | 52 | 223 | 47 | 352 |
| 34 | 231.0 | | 96 | 32 | 328 | | |
| 204 | 236.0 | | 198 | 11 | 163 | | |
| 44 | 260.6 | | 153 | 31 | 58 | | |
| 48 | 297.8 | | 279± | 75 | 212 | 67 | 12 |
| 52 | 311.5 | | 6 | 64 | 279 | | |
| 59 | 355.8 | | 3± | 32 | 270 | 17 | 268 |
| 68 | 419.0 | | 321± | 46 | 248 | 16 | 340 |
| 69x | 434.1 | | 159± | 25 | 66 | 69 | 269 |
| 79 | 506.8 | | 198± | 18 | 144 | 64 | 298 |
| 82 | 516.4 | | 81± | 49 | 341 | 42 | 215 |
| 83 | 518.5 | | 24± | 45 | 297 | 10 | 227 |
| 87 | 529.9 | | 192± | 21 | 129 | 69 | 294 |
| 92 | 562.7 | | 207± | 32 | 148 | 75 | 307 |
| 197 | 579.9 | | 162 | 18 | 35 | | |
| 103 | 591.7 | | 12± | 73 | 289 | 24 | 123 |
| 120x | 628.3 | 14 | 291 | 86 | 215 | | |
| 116 | 648.1 | | 201 | 38 | 106 | | |
| 760 | 650.7 | 6 | 21 | 72 | 122 | | |
| 120r | 663.8 | | 192± | 6 | 211 | 47 | 261 |
| 124 | 692.9 | | 243 | 73 | 172 | | |
| 102 | 695.4 | | 270 | 53 | 212 | | |
| 126 | 696.8 | | 114 | 63 | 50 | | |
| 139 | 727.1 | | 324 | 79 | 250 | | |
| 132 | 730.2 | 10 | 276 | 84 | 200 | | |
| 660 | 733.9 | | 123 | 49 | 26 | | |
| 138x | 746.3 | | 150 | 45 | 60 | | |
| 138 | 754.1 | | 102 | 61 | 42 | | |
| 145 | 766.8 | | 174± | 10 | 80 | 62 | 276 |
| 154 | 811.8 | | 321± | 59 | 254 | 23 | 22 |
| 153 | 816.9 | | 201± | 22 | 142 | 70 | 296 |
| 155 | 828.8 | | 195± | 41 | 156 | 88 | 148 |

| RADINTER MODEL INFORMATION (20, 100 and 250 MHz Dipole Antennas and directional antenna) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Site:** | **Oskarshamn** | | | | | | |
| **Borehole name:** | **KLX05** | | | | | | |
| **Nominal velocity (m/μs):** | **120.0** | | | | | | |
| **Name** | **Intersection depth** | **Intersection angle** | **Direction to object (gravity roll)** | **Interpreted Dip 1** | **Interpreted Strike 1** | **Interpreted Dip 2** | **Interpreted Strike 2** |
| 156 | 841.0 | | 204± | 35 | 172 | 83 | 335 |
| 162 | 874.6 | | 351 | 66 | 308 | 13 | 109 |
| 164 | 890.5 | | 45± | 53 | 342 | 22 | 233 |
| 186 | 996.9 | 24 | 294 | 78 | 222 | | |
| 173 | 941.5 | | 294± | 62 | 265 | 43 | 42 |

**Table 5-3. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz borehole HLX20.**

| RADINTER MODEL INFORMATION (20, 100 and 250 MHz Dipole Antennas) | | | |
|---|---|---|---|
| **Site:** | **Oskarshamn** | | |
| **Borehole name:** | **HLX20** | | |
| **Nominal velocity (m/μs):** | **120.00** | | |
| **Object type** | **Name** | **Intersection depth** | **Intersection angle** |
| PLANE | 1 | 10.8 | 58 |
| PLANE | 2 | 13.5 | 49 |
| PLANE | 3 | 17.2 | 50 |
| PLANE | 8x | 36.7 | 15 |
| PLANE | 6 | 36.8 | 60 |
| PLANE | 4 | 44.5 | 49 |
| PLANE | 8 | 44.8 | 21 |
| PLANE | 5 | 47.1 | 70 |
| PLANE | 7 | 51.7 | 48 |
| PLANE | 10 | 58.0 | 39 |
| PLANE | 39 | 58.2 | 50 |
| PLANE | 9 | 59.7 | 77 |
| PLANE | 11 | 71.8 | 53 |
| PLANE | 12 | 78.4 | 67 |
| PLANE | 13 | 88.2 | 47 |
| PLANE | 14 | 93.7 | 51 |
| PLANE | 16 | 104.3 | 76 |
| PLANE | 40 | 107.1 | 23 |
| PLANE | 15 | 108.9 | 46 |
| PLANE | 18 | 111.7 | 71 |
| PLANE | 17 | 119.4 | 59 |
| PLANE | 19 | 119.7 | 86 |
| PLANE | 20 | 124.8 | 79 |
| PLANE | 22 | 125.1 | 78 |
| PLANE | 21 | 127.5 | 58 |
| PLANE | 23 | 131.0 | 50 |
| PLANE | 24 | 136.7 | 81 |

| RADINTER MODEL INFORMATION<br>(20, 100 and 250 MHz Dipole Antennas) | | | |
|---|---|---|---|
| **Site:** | **Oskarshamn** | | |
| **Borehole name:** | **HLX20** | | |
| **Nominal velocity (m/µs):** | **120.00** | | |
| **Object type** | **Name** | **Intersection depth** | **Intersection angle** |
| PLANE | 25 | 142.3 | 30 |
| PLANE | 28 | 155.8 | 58 |
| PLANE | 26 | 157.6 | 50 |
| PLANE | 27 | 160.7 | 44 |
| PLANE | 30 | 165.2 | 58 |
| PLANE | 31 | 167.4 | 27 |
| PLANE | 29 | 170.0 | 59 |
| PLANE | 32 | 178.7 | 53 |
| PLANE | 35 | 189.0 | 61 |
| PLANE | 34 | 193.5 | 38 |
| PLANE | 33 | 195.9 | 54 |
| PLANE | 36 | 199.7 | 64 |
| PLANE | 37 | 205.3 | 61 |
| PLANE | 41 | 221.2 | 49 |

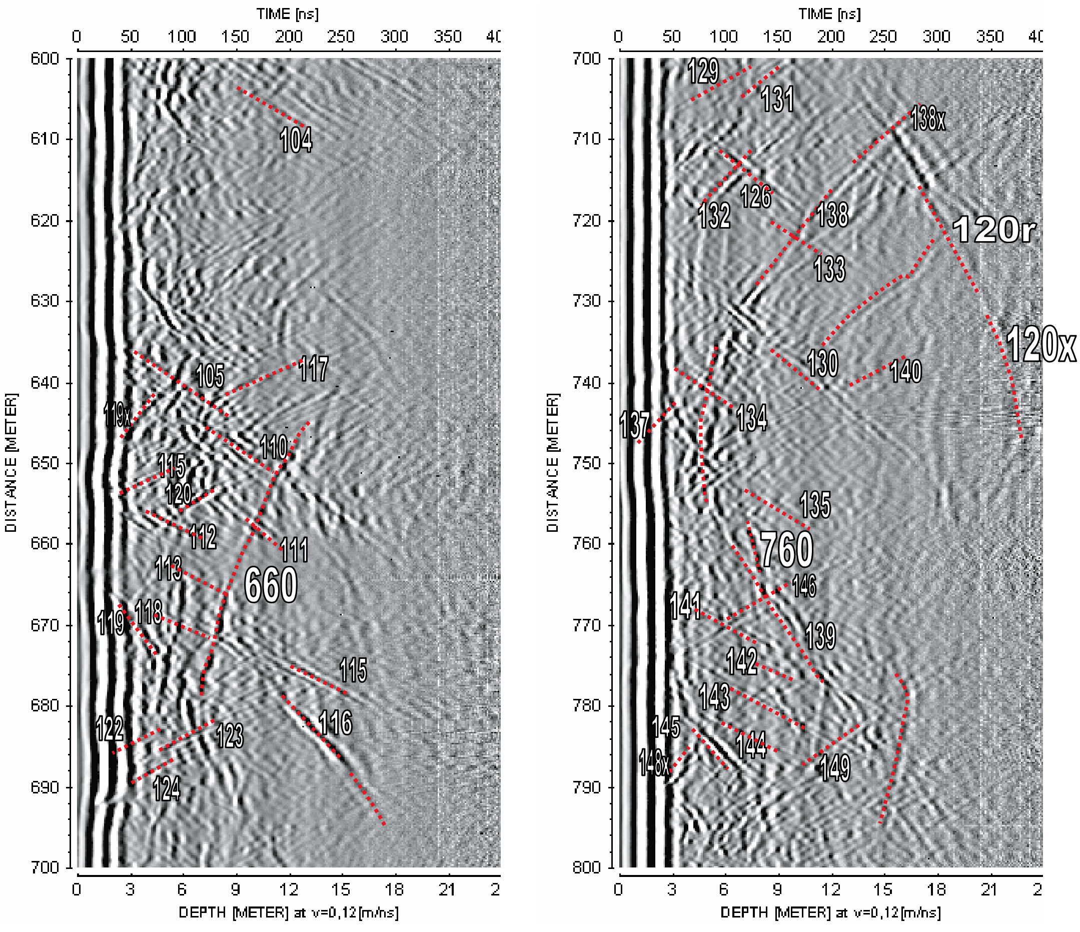



*Figure 5-3.* *Two sections of Appendix 1 and in /2/ showing the 100 MHz dipole data. The sections are supplemented with the structures 660, 760, 120r and 120x also seen in Table 5-2 which not is shown in /2/.*

In Appendix 2, the amplitude of the first arrival is plotted against the depth, for the 250 MHz dipole antennas. The amplitude variation along the borehole indicates changes of the electrical conductivity of the volume of rock surrounding the borehole. A decrease in this amplitude may indicate fracture zones, clay or rock volumes with increases in water content, i.e. increases in electric conductivity. The decrease in amplitude is shown in Table 5-4. For decrease in amplitude in KLX05 see Appendix 1 and /2/.

**Table 5-4. Borehole length intervals in HLX20 with decreased amplitude for the 250 MHz antenna.**

| Length (m) | Length (m) |
|---|---|
| 15 | 145 |
| 40–55 | 165 |
| 75 | 180 |
| 90 | 190 |
| 115–135 | |

## 5.2 BIPS logging

The BIPS pictures from HLX20 are presented in Appendix 3.

In order to control the quality of the system, calibration measurements were performed in a test pipe before and after the logging. The resulting images displayed with no difference regarding the colours and focus of the images. Results of the test loggings were included in the delivery of the raw data.

To get the best possible depth accuracy, the BIPS images are adjusted to the reference mark at 110 m on the logging cable.

The BIPS images in the appendix are adjusted for the tension of the cable and error of the depth readings from the measuring wheel. The adjusted depth is showed in red colour and the recording depth have black colour in the printouts.

Down to 117.5 m the images are of good quality (See Appendix 3). At that position the probe enter in to a zone where the water quality is very bad and it is impossible to get any good images in the rest of the borehole. The borehole has been pumped to clean out the dirty water. But most probably this only affected the top part of the borehole, and clean formation water was pumped from the 117.5-m zone, which left dirty water in the bottom part the borehole.

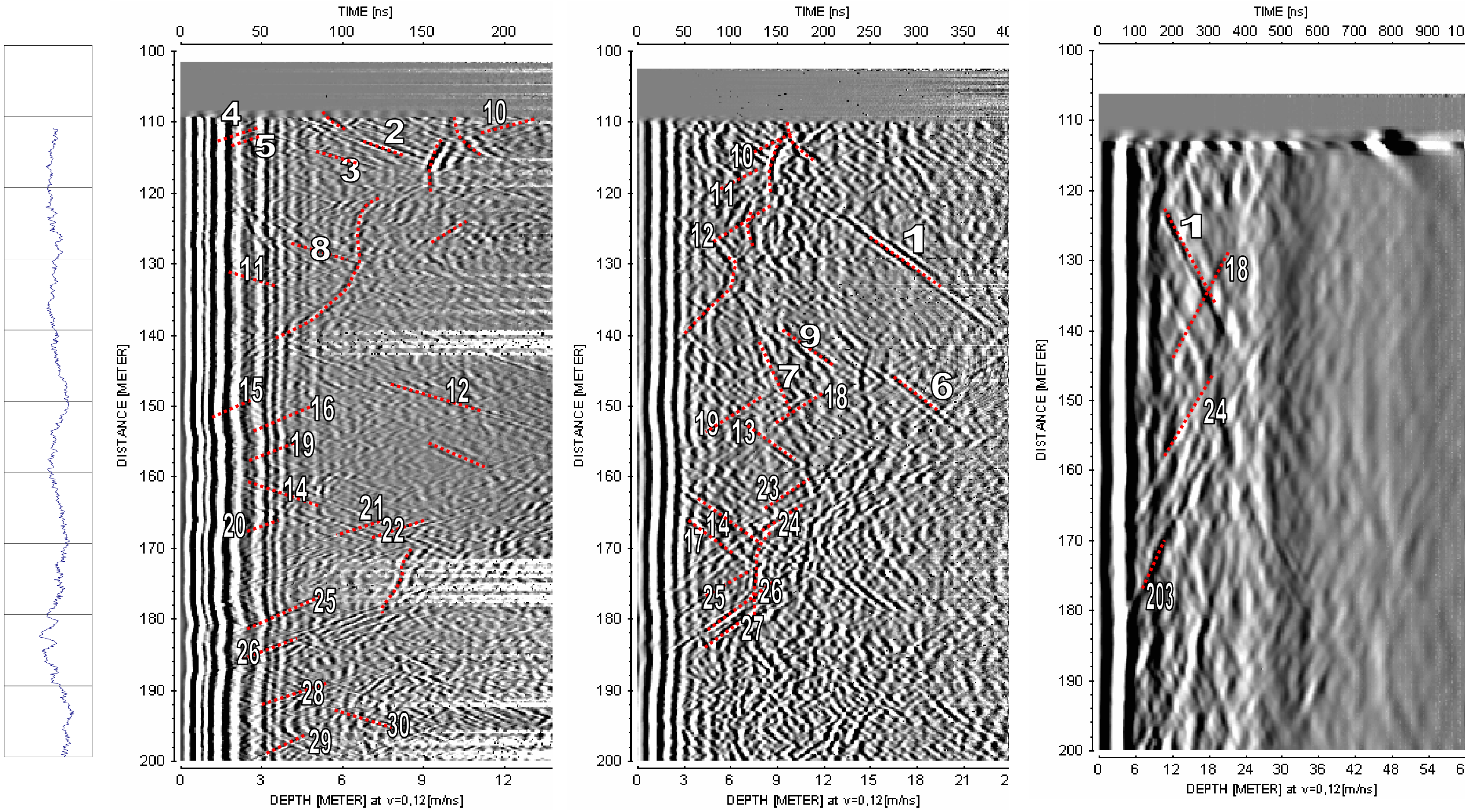
# References

/1/ **Aaltonen J, Gustafsson C, Nilsson P, 2003.** Oskarshamn site investigation. RAMAC and BIPS logging and deviation measurements in boreholes KSH01A, KSH01B and the upper part of KSH02. SKB P-03-73. Svensk Kärnbränslehantering AB.

/2/ **Gustafsson J, Gustafsson C, 2005.** Oskarshamn site investigation. RAMAC and BIPS logging in boreholes KLX05 and HLX32. SKB P-05-82. Svensk Kärnbränslehantering AB.

# Radar logging in KLX05, 100 to 990 m, dipole antennas 250, 100 and 20 MHz

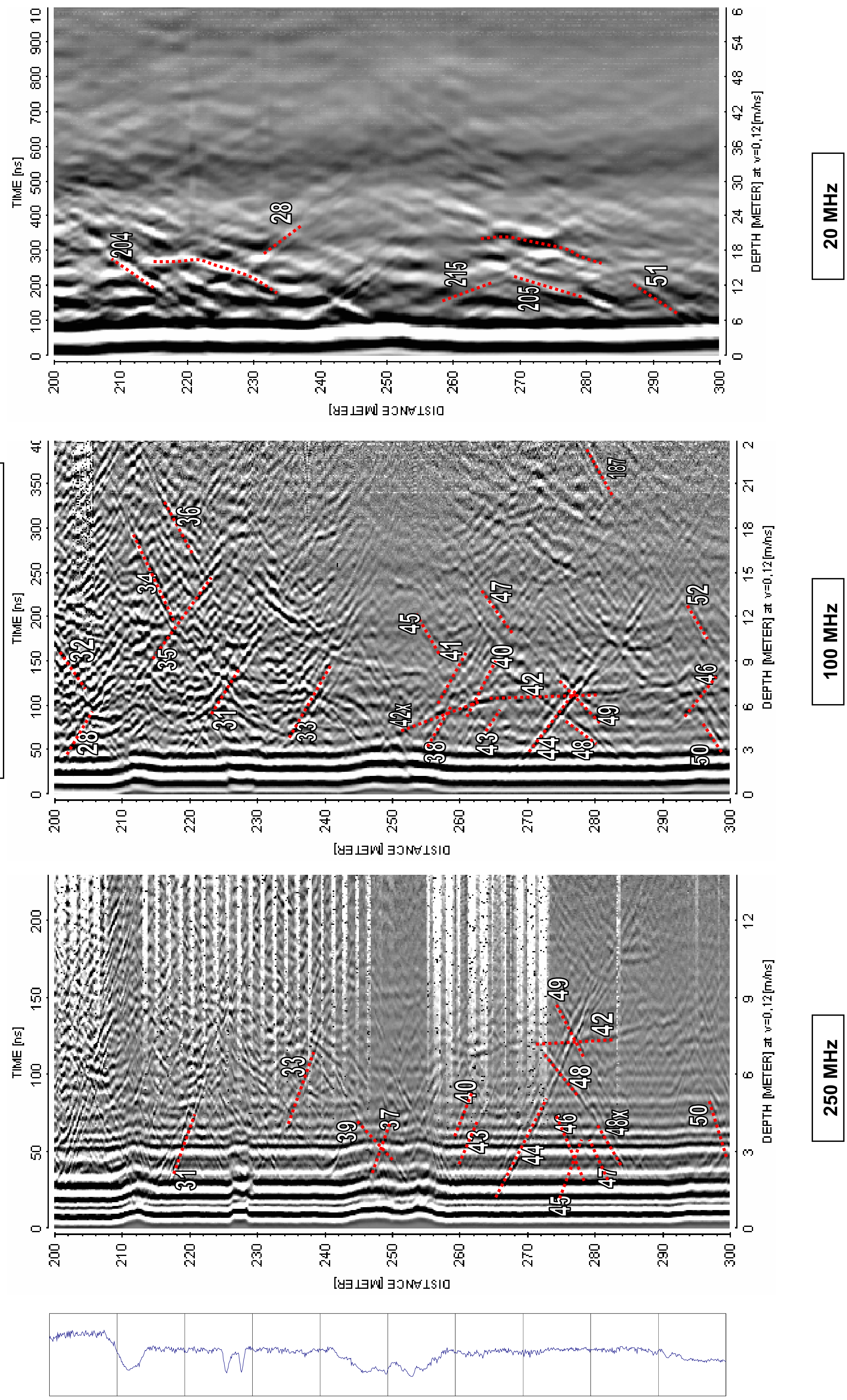
LAXEMAR KLX05



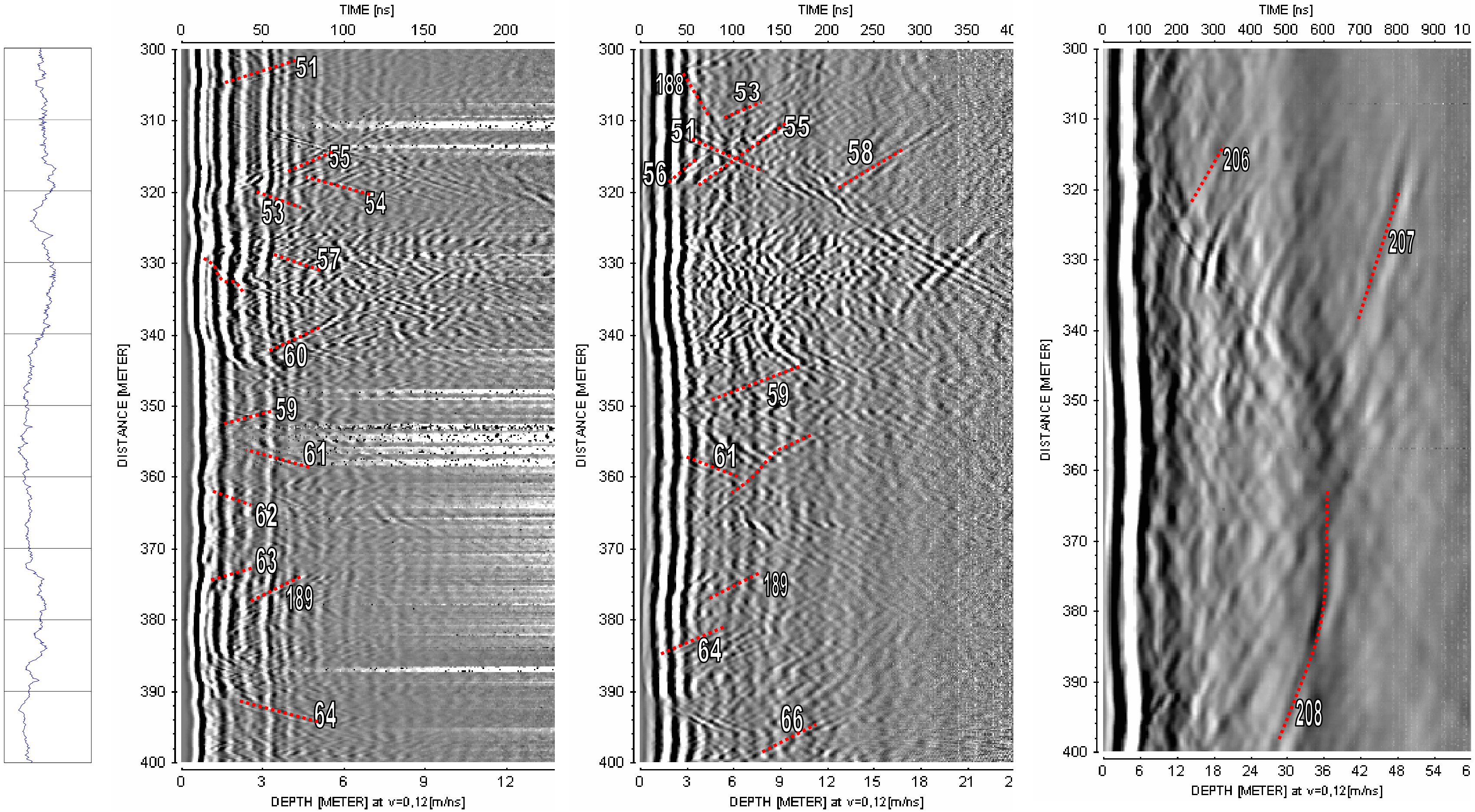

250 MHz

100 MHz

20 MHz


LAXEMAR KLX05
250 MHz
100 MHz
20 MHz
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,12[m/ns]

**LAXEMAR KLX05**

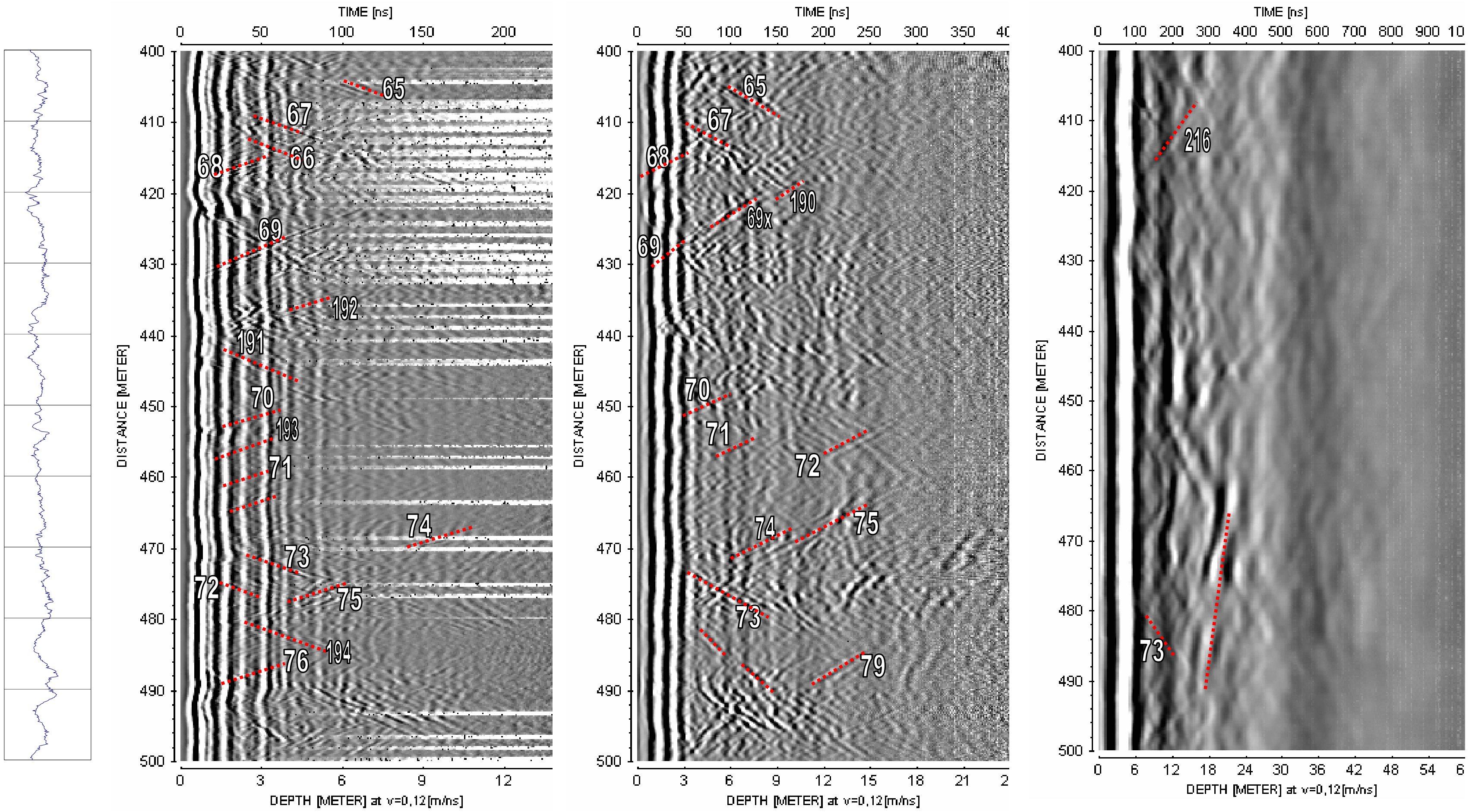



**250 MHz**

**100 MHz**

**20 MHz**

**LAXEMAR KLX05**

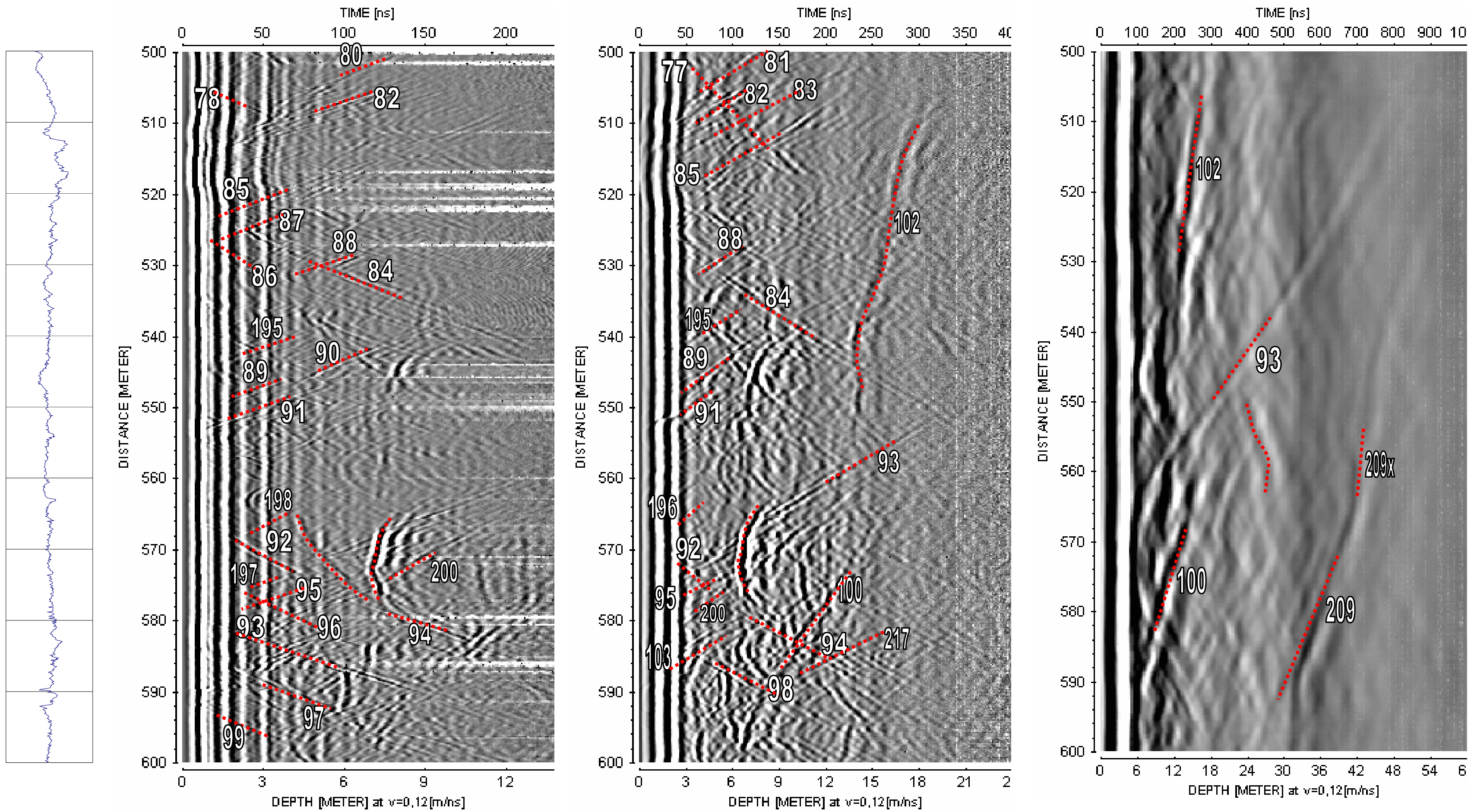



**250 MHz**

**100 MHz**

**20 MHz**

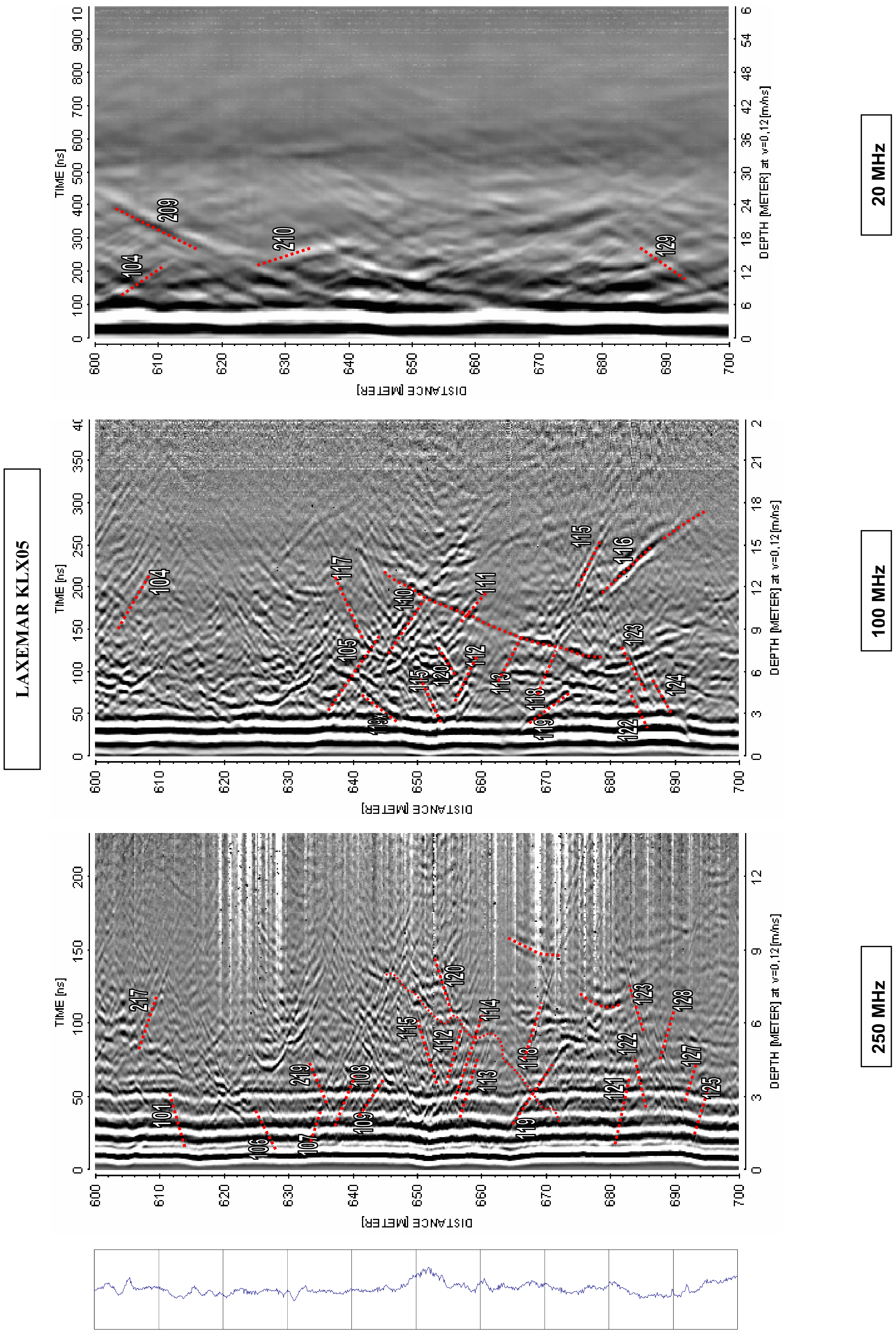
## LAXEMAR KLX05



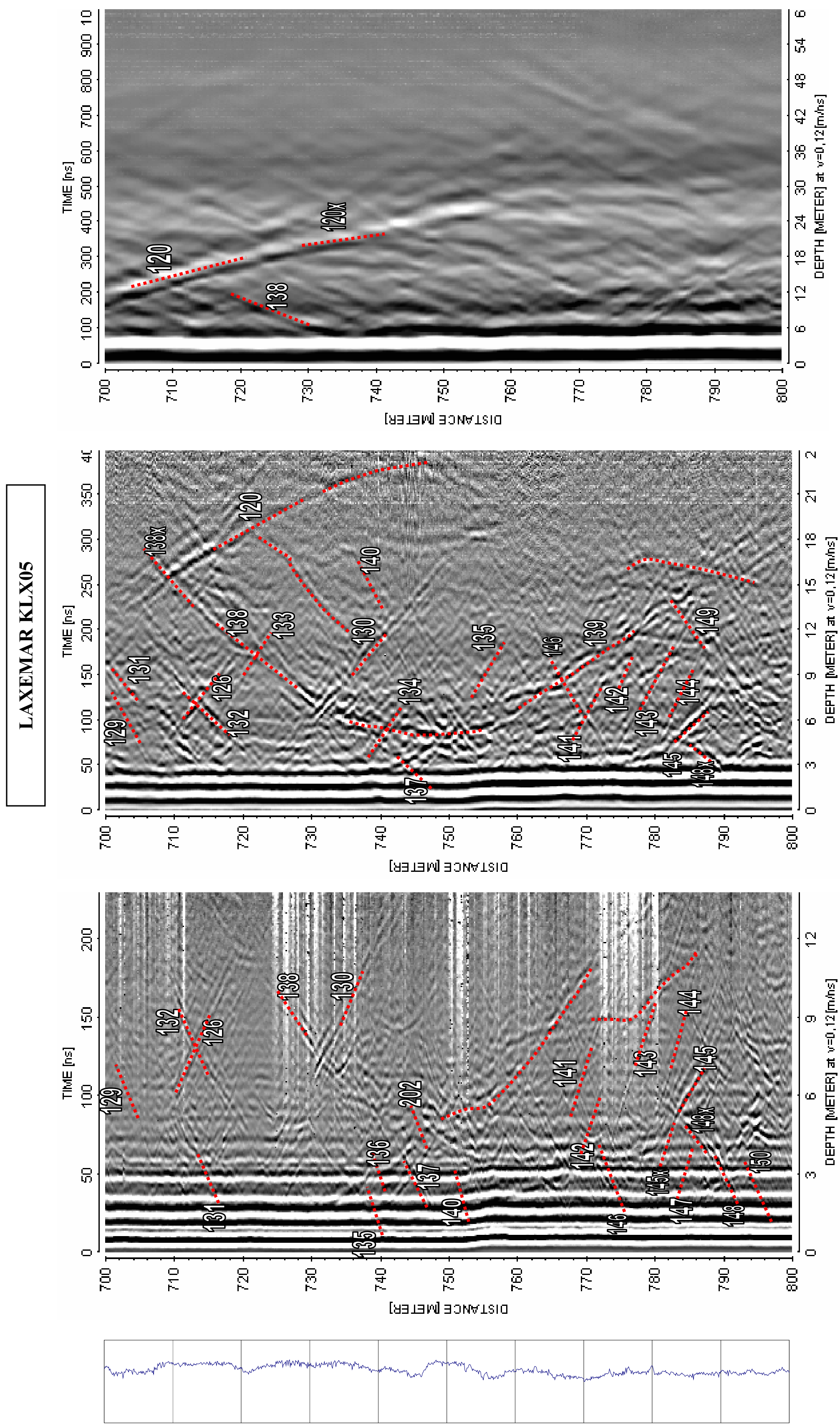

250 MHz

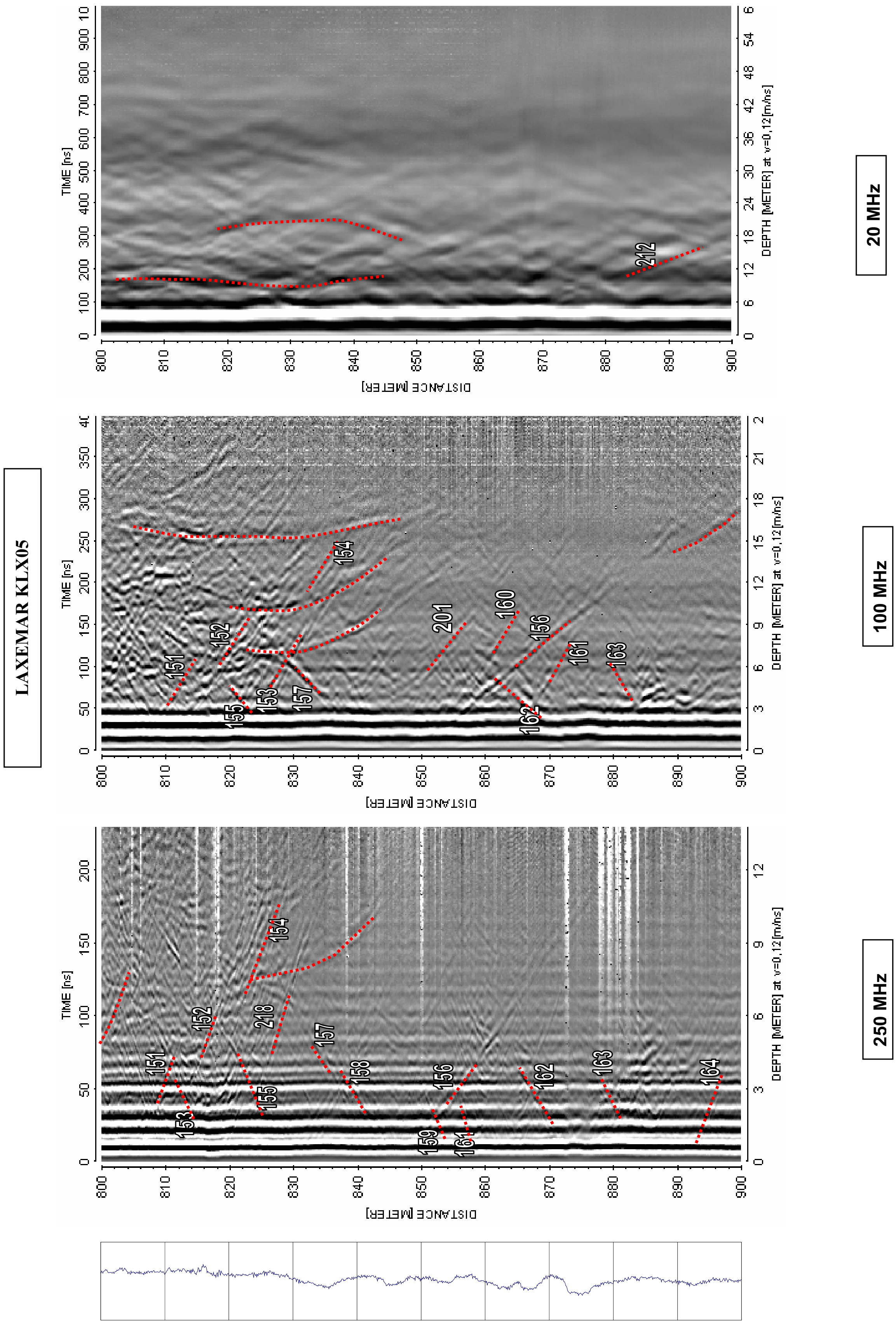
100 MHz

20 MHz

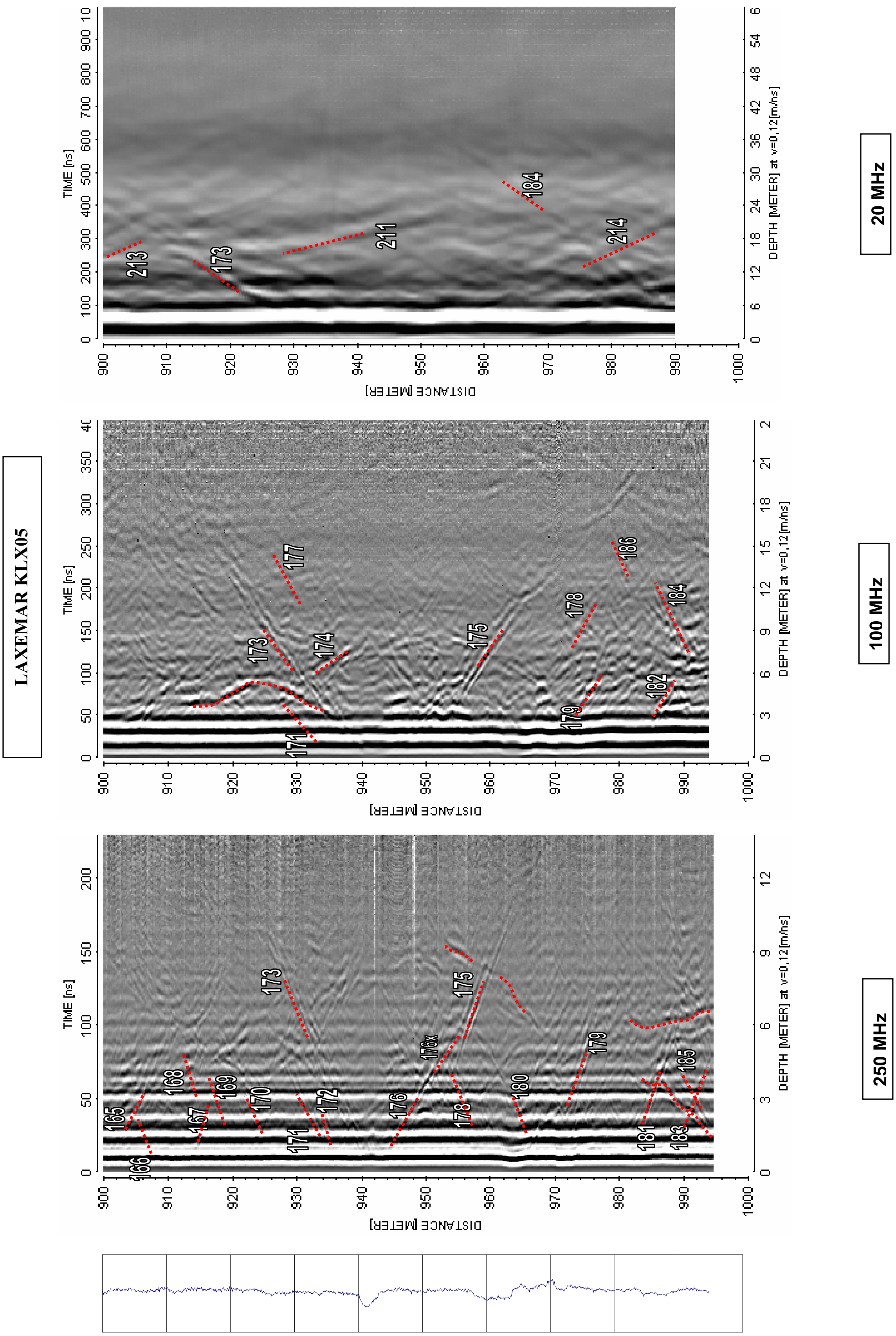


LAXEMAR KLX05
250 MHz
100 MHz
20 MHz
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,12[m/ns]


LAXEMAR KLX05
250 MHz
100 MHz
20 MHz
113
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,12[m/ns]

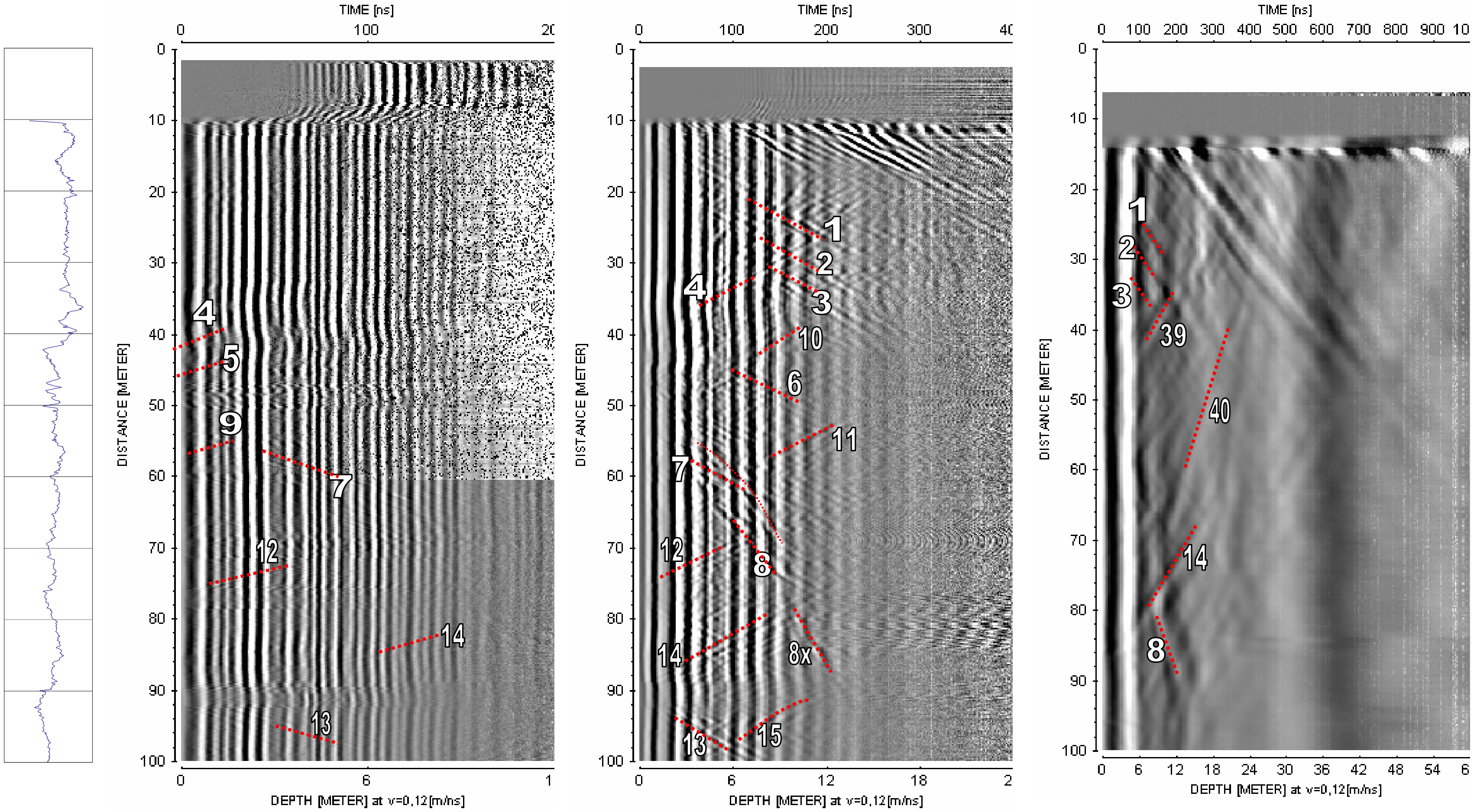


LAXEMAR KLX05
250 MHz
100 MHz
20 MHz
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,12[m/ns]

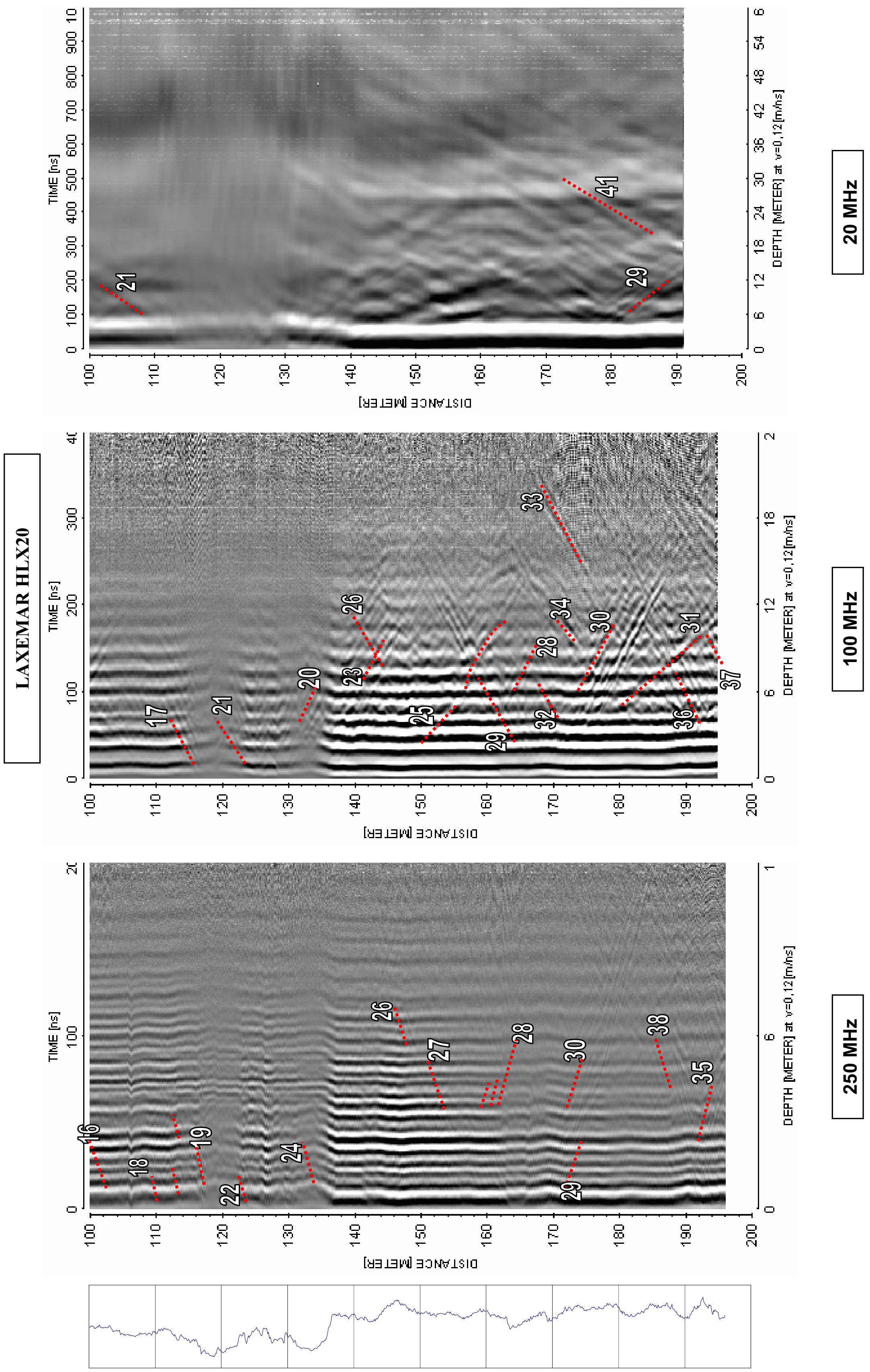

LAXEMAR KLX05
250 MHz
100 MHz
20 MHz
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,12[m/ns]

# Radar logging in HLX20, 0 to 190 m, dipole antennas 250, 100 and 20 MHz

**LAXEMAR HLX20**




**250 MHz** **100 MHz** **20 MHz**


LAXEMAR HLX20
250 MHz
100 MHz
20 MHz
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,12[m/ns]

## Appendix 3

# BIPS logging in HLX20, 9 to 130 m

**Project name: Laxemar**

| | |
|---|---|
| Image file | : c:\work\r5397o~1\hlx20\bips\hlx20.bip |
| BDT file | : c:\work\r5397o~1\hlx20\bips\hlx20.bdt |
| Locality | : LAXEMAR |
| Bore hole number | : HLX20 |
| Date | : 05/05/18 |
| Time | : 10:32:00 |
| Depth range | : 9.000 - 129.995 m |
| Azimuth | : 0 |
| Inclination | : -60 |
| Diameter | : 140.0 mm |
| Magnetic declination | : 0.0 |
| Span | : 4 |
| Scan interval | : 0.25 |
| Scan direction | : To bottom |
| Scale | : 1/25 |
| Aspect ratio | : 100 % |
| Pages | : 7 |
| Color | : +0 +0 +0 |

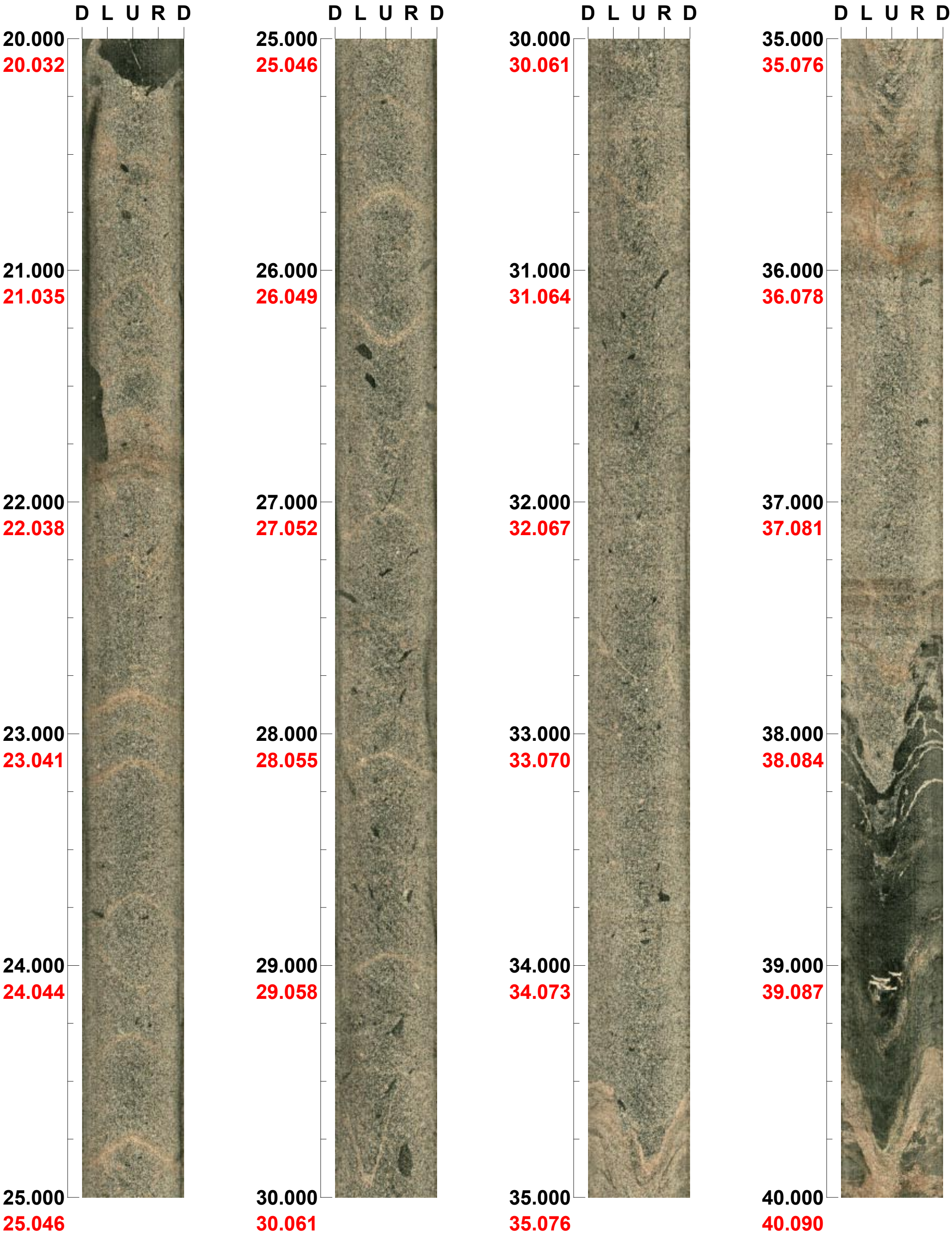
**Project name: Laxemar**
**Bore hole No.: HLX20** **Azimuth: 0** **Inclination: -60**

**Depth range: 0.000 - 20.000 m**


**( 1 / 7 )** **Scale: 1/25** **Aspect ratio: 100 %**

**Project name: Laxemar**
**Bore hole No.: HLX20** **Azimuth: 0** **Inclination: -60**

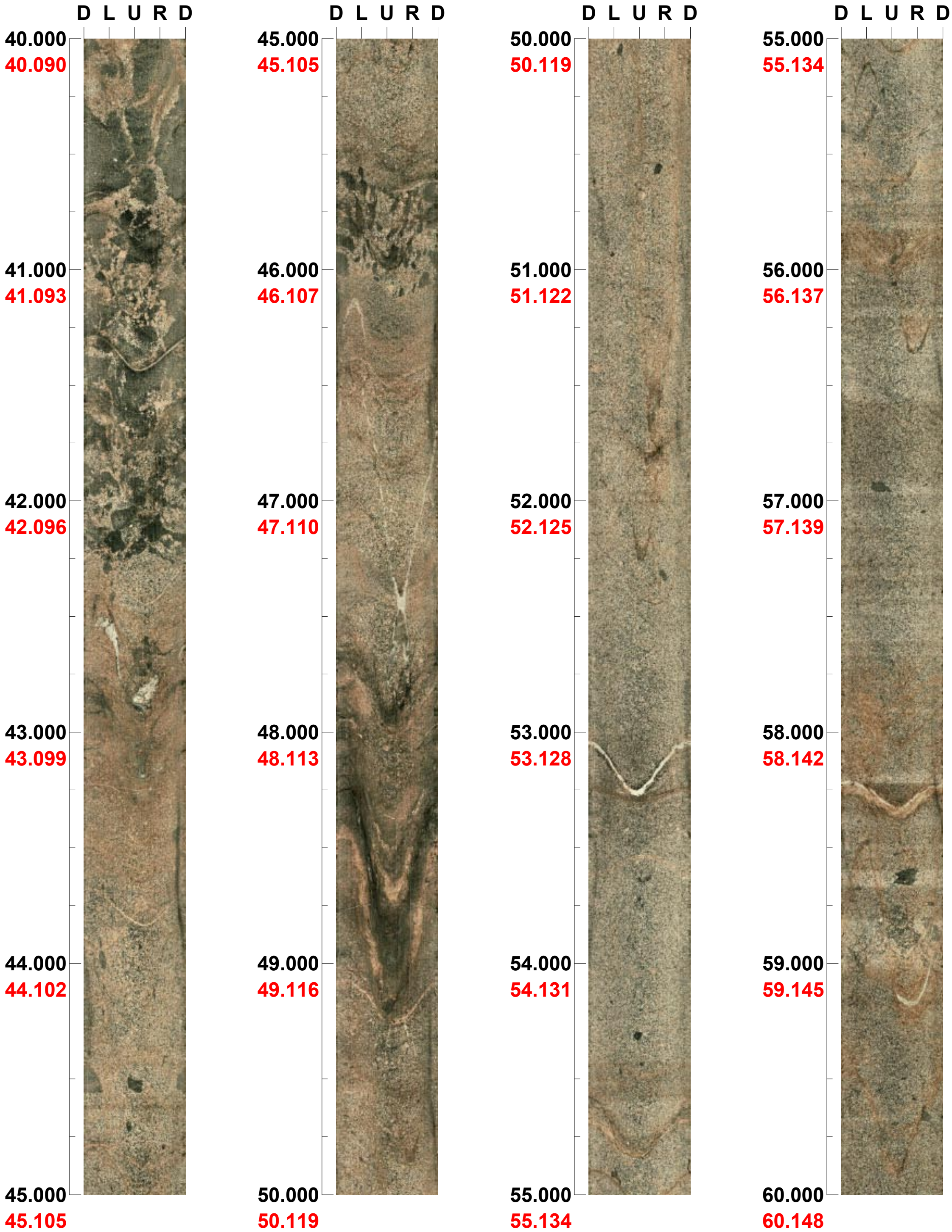
**Depth range: 20.000 - 40.000 m**




**( 2 / 7 )** **Scale: 1/25** **Aspect ratio: 100 %**

**Project name: Laxemar**
**Bore hole No.: HLX20** **Azimuth: 0** **Inclination: -60**

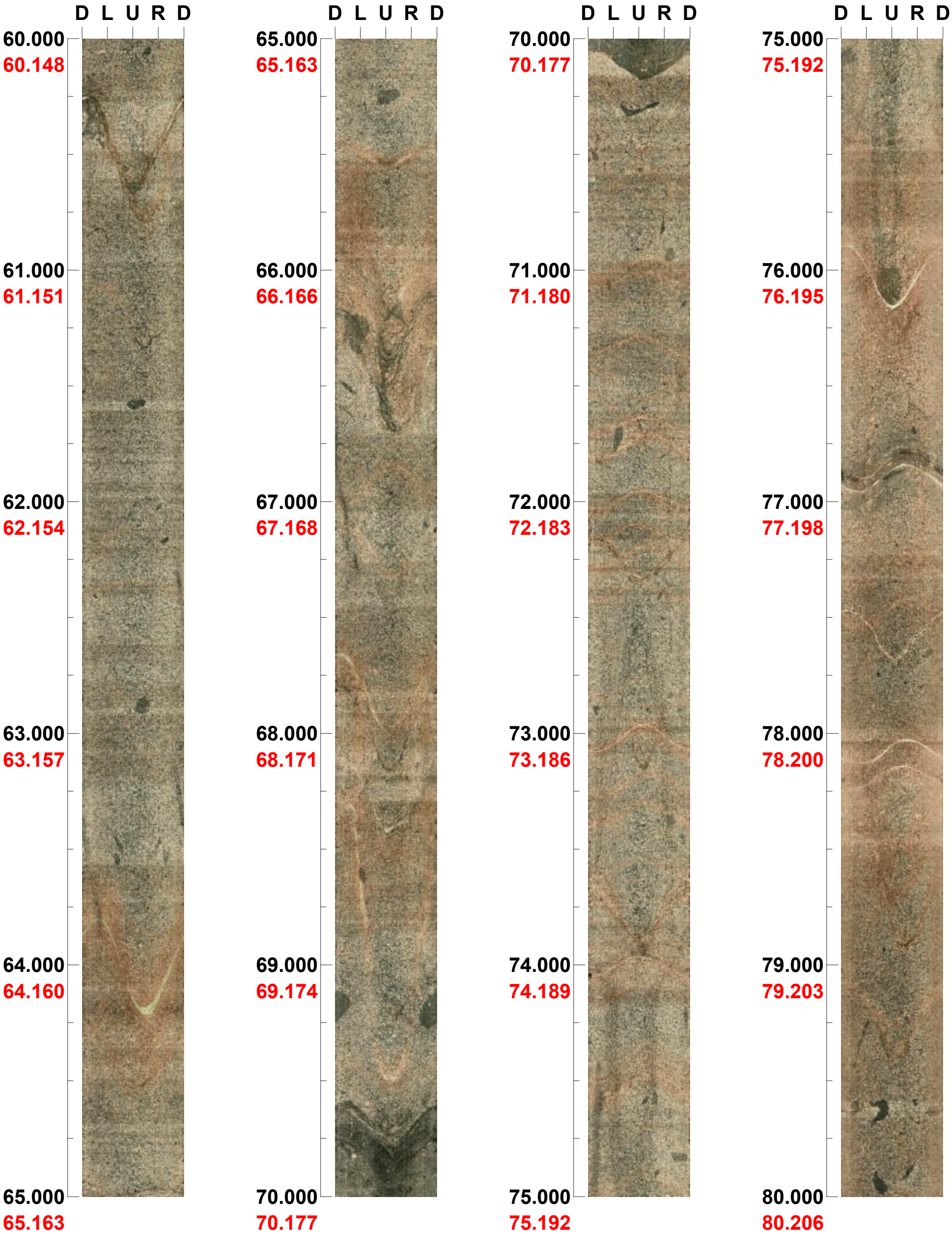
**Depth range: 40.000 - 60.000 m**




**( 3 / 7 )** **Scale: 1/25** **Aspect ratio: 100 %**

**Project name: Laxemar**
**Bore hole No.: HLX20** **Azimuth: 0** **Inclination: -60**

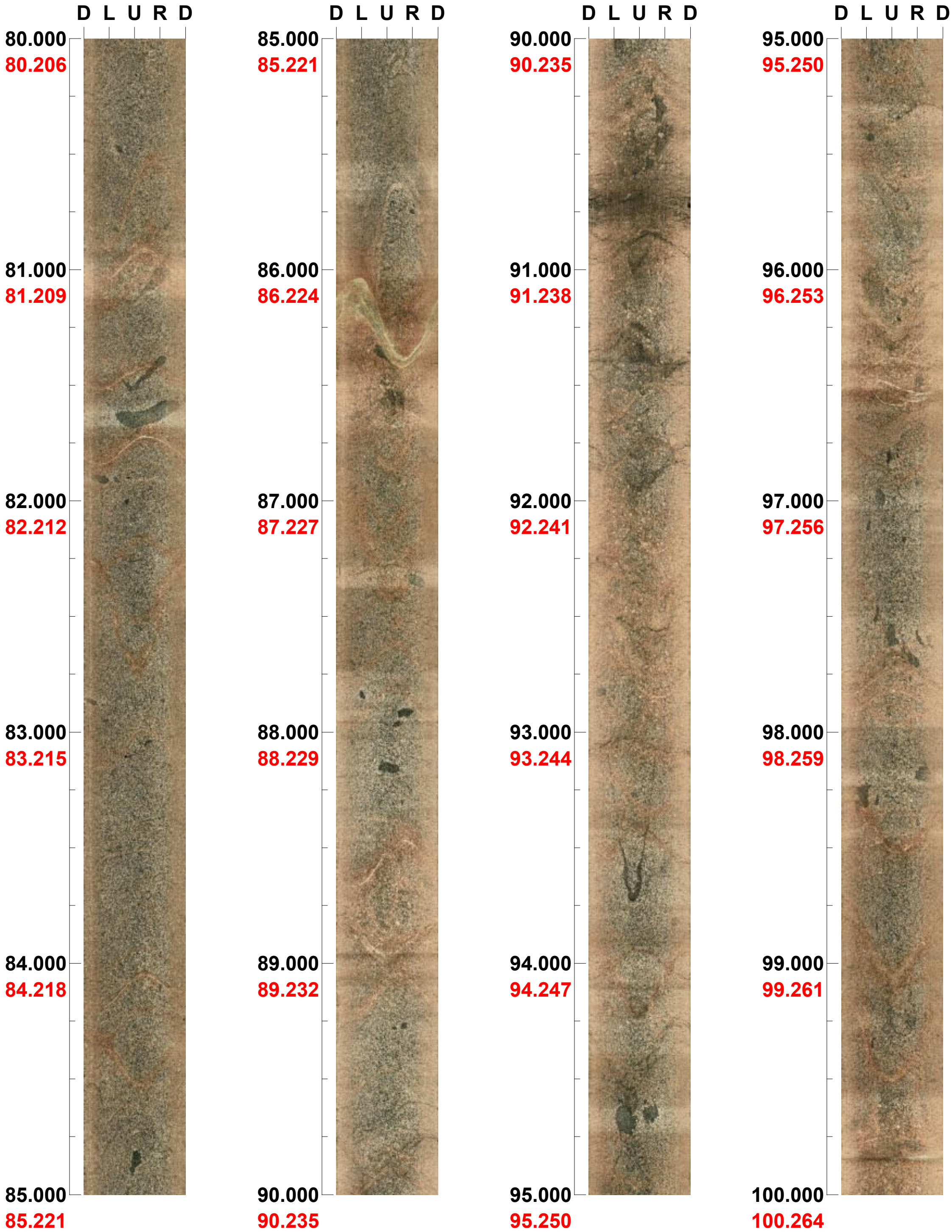
**Depth range: 60.000 - 80.000 m**




**( 4 / 7 )** **Scale: 1/25** **Aspect ratio: 100 %**

**Project name: Laxemar**
**Bore hole No.: HLX20** **Azimuth: 0** **Inclination: -60**

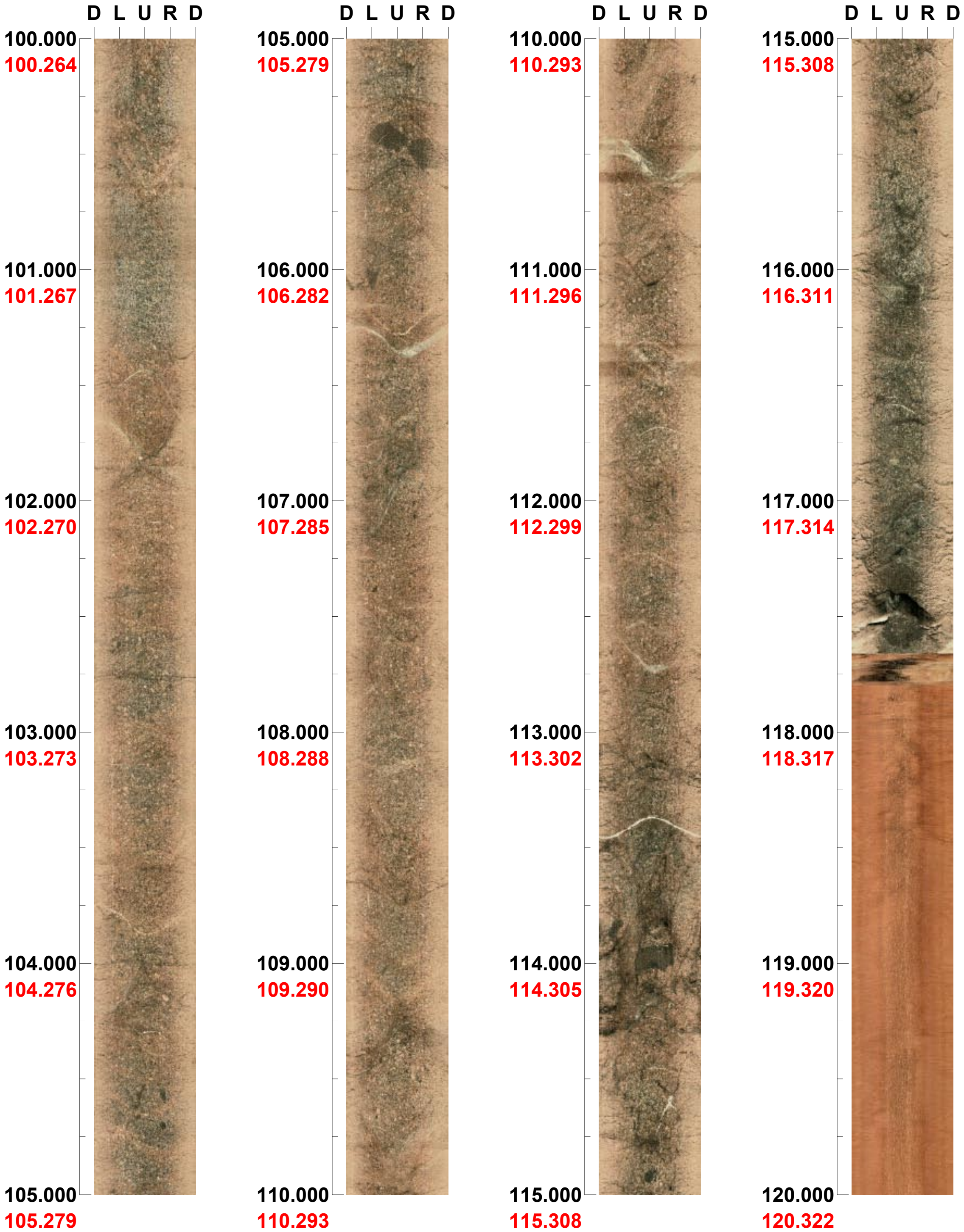
**Depth range: 80.000 - 100.000 m**




**( 5 / 7 )** **Scale: 1/25** **Aspect ratio: 100 %**

**Project name: Laxemar**
**Bore hole No.: HLX20** **Azimuth: 0** **Inclination: -60**

**Depth range: 100.000 - 120.000 m**

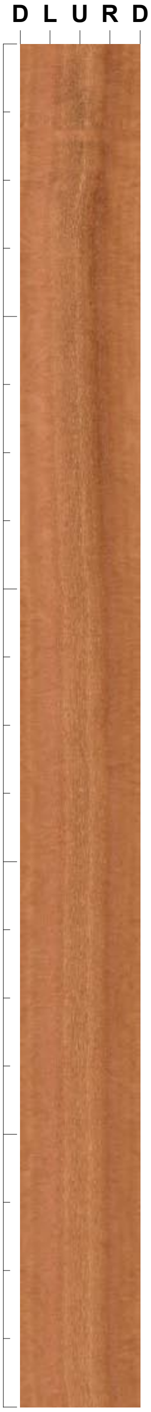



**( 6 / 7 )** **Scale: 1/25** **Aspect ratio: 100 %**

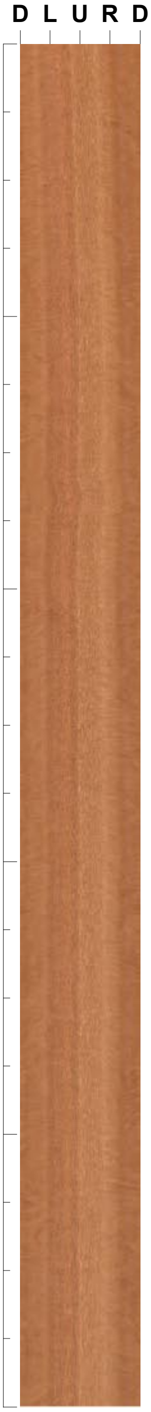
**Project name: Laxemar**
**Bore hole No.: HLX20** **Azimuth: 0** **Inclination: -60**

**Depth range: 120.000 - 129.995 m**

120.000
120.322
121.000
121.325
122.000
122.328
123.000
123.331
124.000
124.334
125.000
125.337




125.000
125.337
126.000
126.340
127.000
127.343
128.000
128.346
129.000
129.349




**( 7 / 7 )** **Scale: 1/25** **Aspect ratio: 100 %**