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Oskarshamn site investigation

RAMAC and BIPS logging in boreholes KLX05 and HLX32

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April 2005

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Keywords: BIPS, RAMAC, Radar, TV.

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 radar (RAMAC) and BIPS logging in the core drilled borehole KLX05 and percussion drilled borehole HLX32. All measurements were conducted by Malå Geoscience AB/ RAYCON during March 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 HLX32 was relatively satisfying, but in large parts of lower quality due to more conductive conditions (especially in HLX32). 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 a number of identified radar reflectors and over 200 radar reflectors were identified in KLX05, and almost 40 in HLX32.

The BIPS images shows a medium quality due to discoloring, mud covering (in KLX05) and dirty water (HLX32), which can make the geological mapping more difficult, especially in the lower parts of the boreholes.

Sammanfattning

Denna rapport omfattar geofysiska loggningar inom platsundersökningsprogrammet för Oskarshamn. Mätningarna som presenteras här omfattar borrhålsradarmätningar (RAMAC) och BIPS-loggningar i kärnborrhål KLX05 och hammarborrhål HLX32. Alla mätningar är utförda av Malå Geoscience AB / RAYCON under mars 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 HLX32 var relativt tillfredställande, men tidvis av sämre kvalité troligen till stor del beroende på en konduktiv miljö (framförallt i HLX32). En konduktiv miljö minskar möjligheterna att identifiera strukturer från borrhålsradardata. Dock har drygt 200 radarreflektorer identifierats i KLX05 och nästan 40 i HLX32.

BIPS bilderna uppvisar en jämförelsevis låg kvalité på grund av missfärgning och borrkax på borrhålsväggarna (KLX05) och smutsigt vatten (HLX32). Detta kan försvåra den geologiska kartläggningen, speciellt i borrhålens djupare delar.

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 radar (RAMAC) and TV-logging (BIPS) in the core drilled borehole KLX05 and percussion drilled borehole HLX32. 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 990 m in KLX05 and from 0 to 160 m in HLX32. The borehole KLX05 has a diameter of 76 mm, and HLX32 a diameter of 140 mm. All measurements were conducted by Malå Geoscience AB / RAYCON during March 2005. The 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 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 plus tillägg	1.0
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

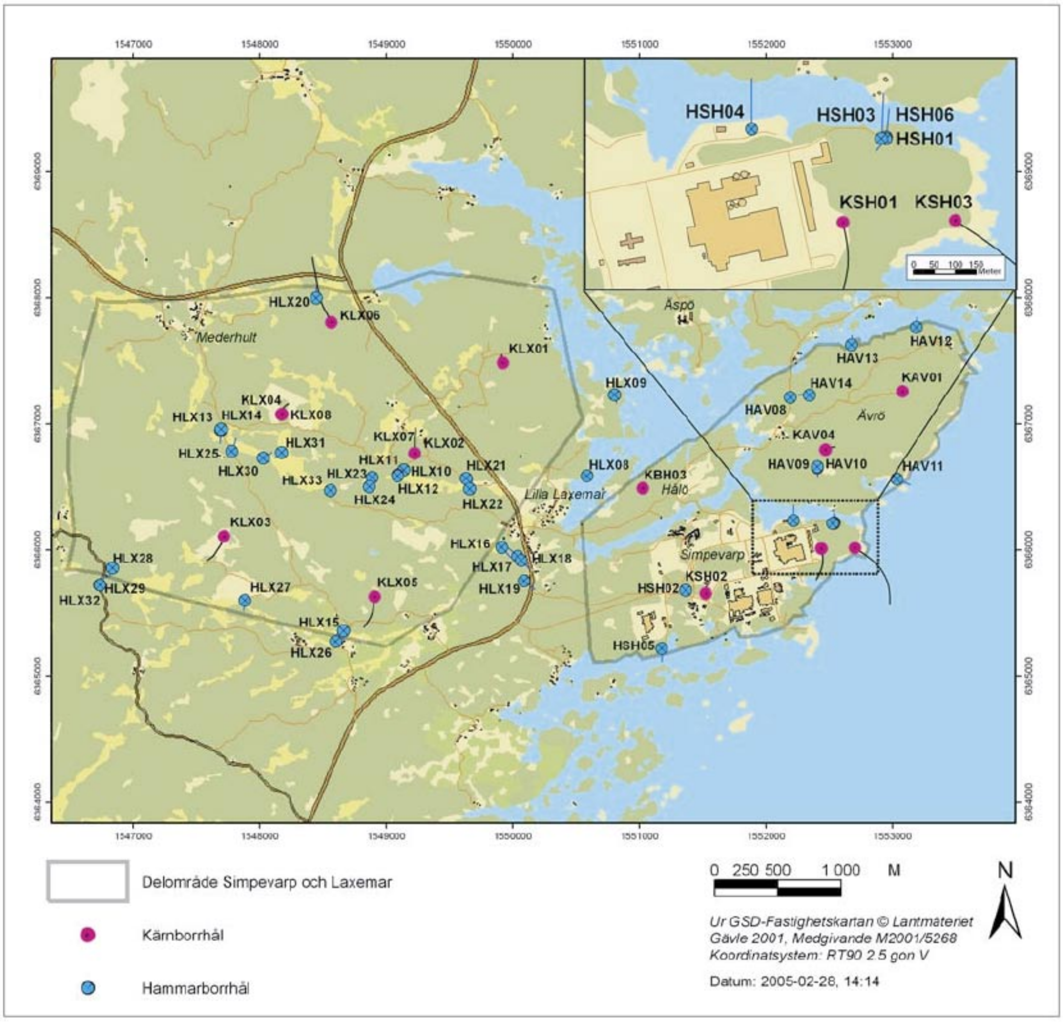


Figure 1-1. *General overview over the Simpevarp and Laxemar subareas in Oskarshamn with the location of the borehole KLX05 and HLX32 in Laxemar.*

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.

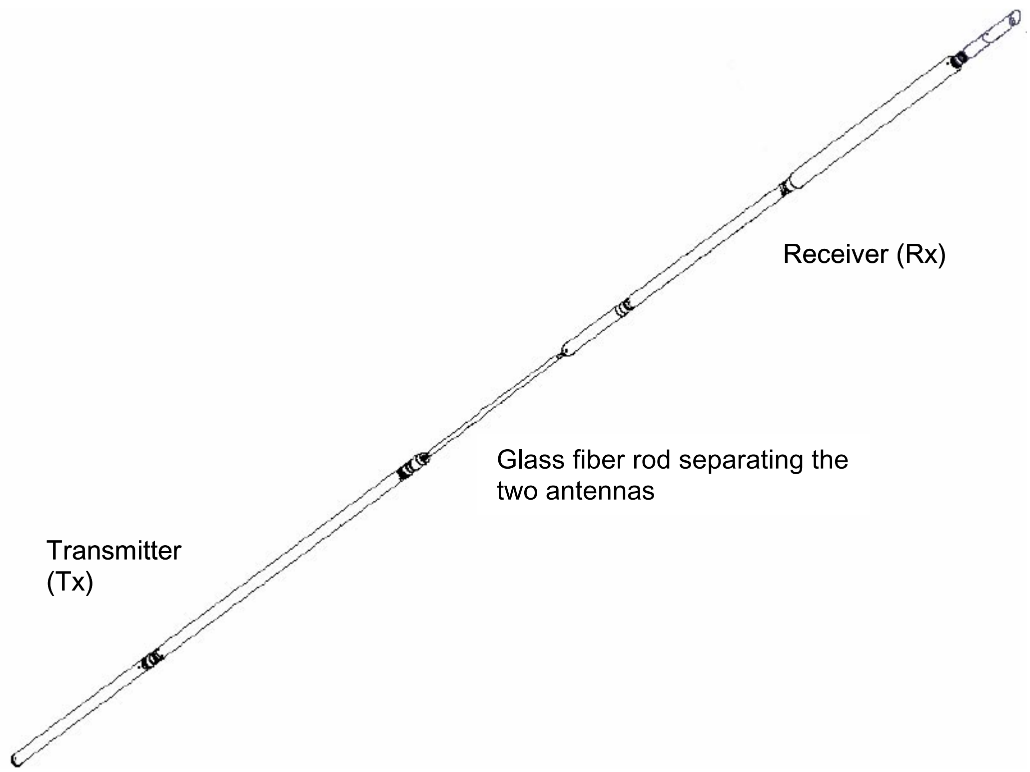


Figure 3-1. *Example of a borehole radar antenna.*

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 speed of the logging is 1.5 m/minute.

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

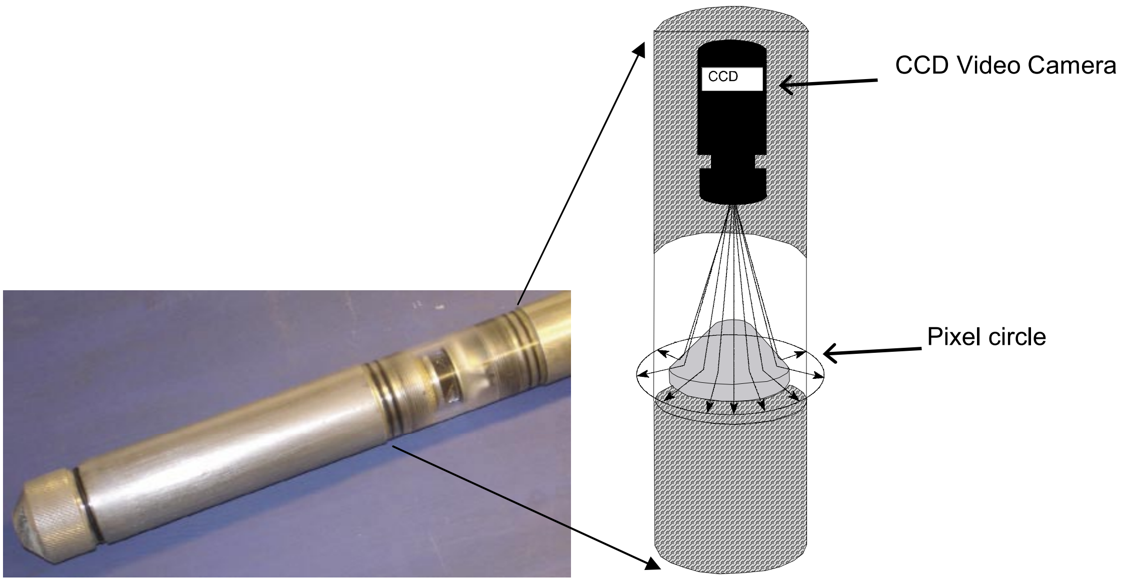


Figure 3-2. *Illustration of the conical mirror scanning.*

4 Execution

4.1 General

4.1.1 RAMAC Radar

The measurements in KLX05 and HLX32 were carried out with dipole radar antennas, with frequencies of 250, 100 and 20 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 antennas (transmitter and receiver) 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.

For more information on system settings used in the investigation of KLX05 and HLX32, see Table 4-1 and 4-2 below.

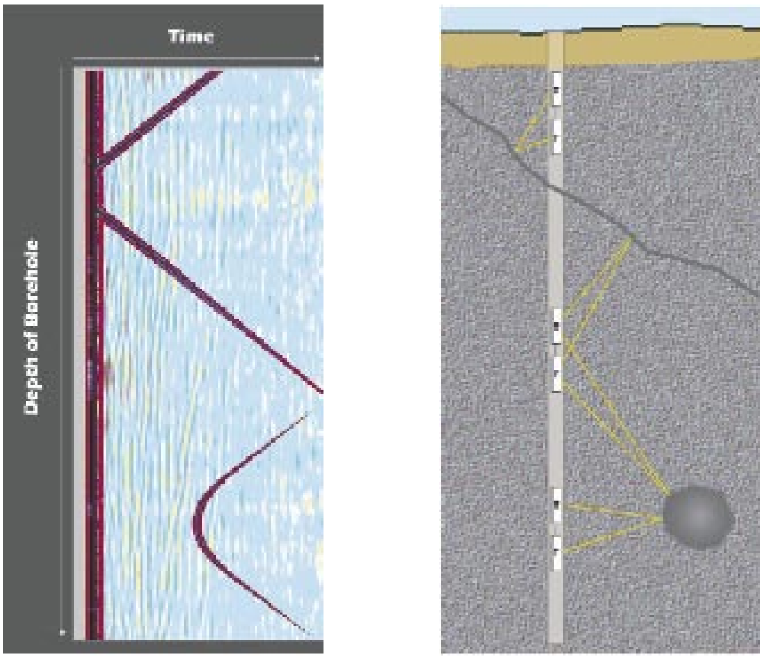


***Figure 4-1.** The principle of radar borehole reflection survey and an example of result.*

Table 4-1. Radar logging information from KLX05.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**	
BH:	**KLX05**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Operator:	**CG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
Logging date:		05-03-30	05-03-31	05-03-31
Reference:		T.O.C.	T.O.C.	T.O.C.
Sampling frequency (MHz):		2,424	891	238
Number of samples:		619	518	518
Number of stacks:		Auto	Auto	Auto
Signal position:		–0.37	–0.37	–1.40
Logging from (m):		1.5	2.6	6.25
Logging to (m):		994.7	993.8	989.8
Trace interval (m):		0.1	0.2	0.25
Antenna separation (m):		2.4	3.9	10.05

Table 4-2. Radar logging information from HLX32.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**	
BH:	**HLX32**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Operator:	**CG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
Logging date:		05-03-21	05-03-21	05-03-21
Reference:		T.O.C.	T.O.C.	T.O.C.
Sampling frequency (MHz):		2,424	891	238
Number of samples:		619	518	518
Number of stacks:		Auto	Auto	Auto
Signal position:		–0.30	–0.32	–1.40
Logging from (m):		1.5	2.6	6.25
Logging to (m):		161.3	160.2	155.95
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 boreholes KLX05 and HLX32.

In order to control the quality of the system, calibration measurements were performed in a test pipe before logging the first borehole and after logging the last one. Figure 4-2 corresponds to the test logging performed before and after the logging in HLX32 and KLX05. 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 and 4 in this report.

4.1.3 Length measurements

During logging the length recording for the RAMAC and BIPS systems is taken care of by a measuring wheel mounted on the cable winch.

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 Appendices 3 and 4. 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 length divergence is less than 50 cm in the deepest parts of the boreholes.

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

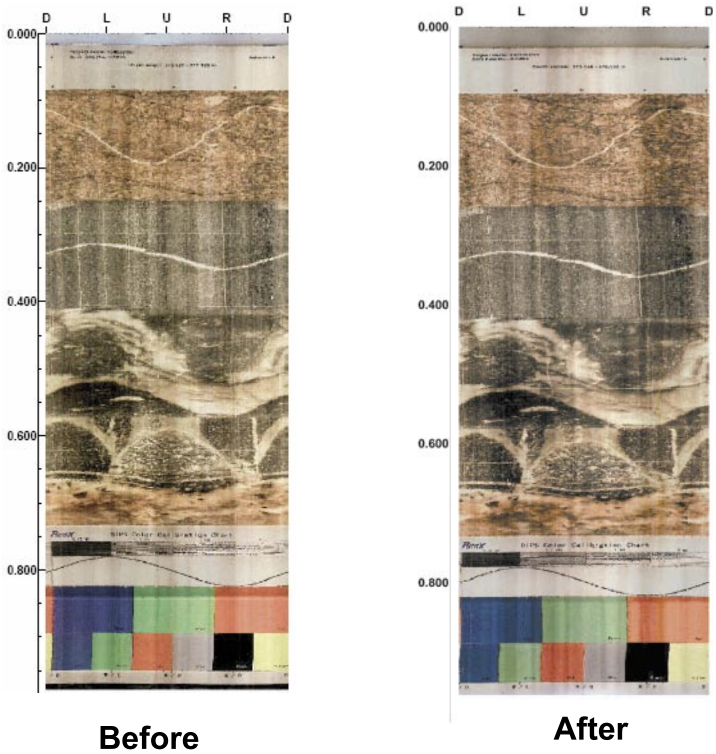


Figure 4-2. *Results from logging in the test pipe before and after the logging campaign in March 2005.*

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/.

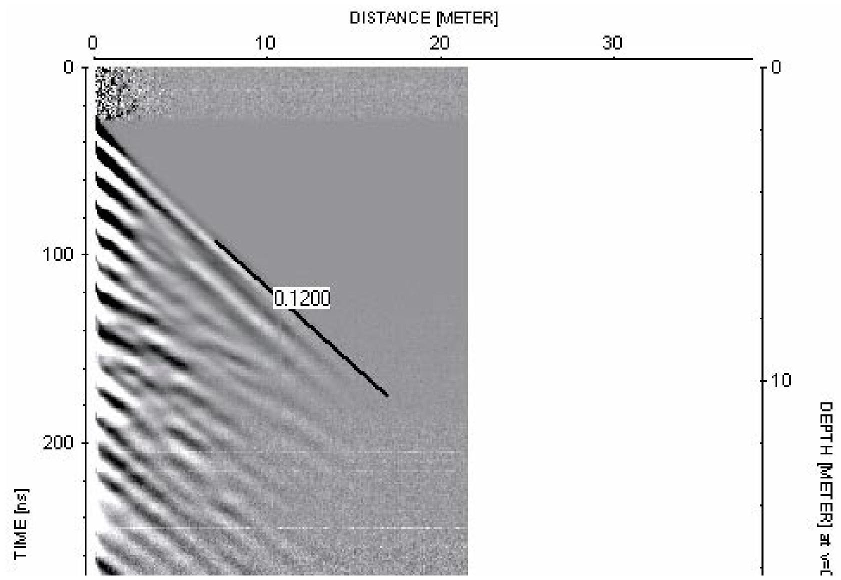


Figure 4-3. *Results from velocity measurements in KSH01B with 100 MHz dipole antennas /1/.*

The visualization of data in Appendix 1 and 2 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 below refer to the Appendix 1 and 2. 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 band-pass 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 Tables 5-3 and 5-4 and are also visible on the radargrams in Appendix 1 and 2.

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

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**	
BH:	**KLX05**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Interpret:	**JA**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
Processing:		DC removal (190–240)	DC removal (450–550)	DC removal (1,700–2,000)
		Move start time (–17)	Move start time (–29)	Move start time (–116)
		Gain (start 16/linear 1.2/exp 0.96)	Gain (start 38/linear 1.44/exp 0.64)	Gain (start 121/linear 2.98/exp 0.17)

Table 4-4. Processing steps for borehole radar data from HLX32.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**	
BH:	**HLX32**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Interpret:	**JA**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
Processing:		DC removal (190–240)	DC removal (450–550)	DC removal (1,700–2,000)
		Move start time (–19)	Move start time (–43)	Move start time (–115)
		Gain (start 18/linear 0.96/exp 1)	Gain (start 60/linear 3.12/exp 0.21)	Gain (start 135/linear 1.7/exp 0.2)
			Median (3x3)	Median (3x3)

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

During this logging activity also radar measurements with the directional antennas was supposed to be carried out. However, some error occurred during the start up, so the system was sent for service, and the measurements will be carried out and reported at a later occasion.

There were no nonconformities during the BIPS logging.

The start of the logging and hence the reporting according to the time table was delayed due to trouble with drilling operations in KLX05 which was not expected when the activity was planned to be performed.

The percussion drilled borehole HLX20 could not be accessed due to transport to the borehole was not possible due to bad conditions for transportation in the forest.

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 HLX32 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 Table 5-1 to 5-6. Radar data is also visualized in Appendix 1 and 2. It should be remembered that the images in Appendix 1 and 2 is only a composite picture of all events 360 degrees around the borehole, and do not reflect the orientation of the structures. An overview of KLX05 (20 MHz data) is given in Figure 5-1 below, showing several large-scale structures between 300 and 800 m length.

Only the larger clearly visible structures are interpreted in RadinterSKB. A number of minor structures also exist, indicated in Appendix 1 and 2. See for instance, HLX32 between 40 and 50 m, 250 MHz data, where a number of structures can be noticed, but most probably lying so close to each other it is impossible to distinguish one from the other. 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.

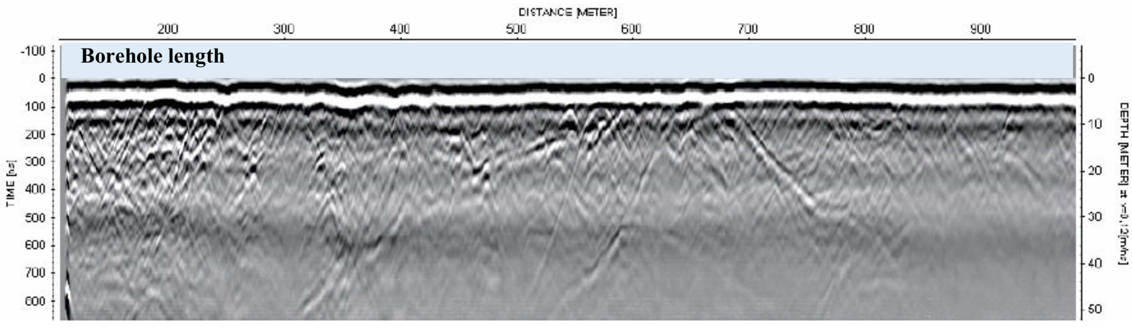


Figure 5-1. *Results from KLX05, 20 MHz data.*

The data quality from KLX05 and HLX32, (as seen in Appendix 1 and 2) is relatively satisfying, but in parts of lower quality due to more conductive conditions. This is true especially for HLX32. 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 HLX32, but also in parts in the KLX05 data. This conductive environment of course also reduces the possibility to distinguish and interpret possibly structures in the rock which otherwise could give a reflection.

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 on data from the 250 MHz antenna in HLX32 (Appendix 2).

As also seen in Appendix 1 and 2 the resolution and penetration of radar waves depend on the antenna frequency used. Low antenna frequency gives less resolution but higher penetration rate 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 Tables 5-1 and 5-2 below the distribution of identified structures along the borehole are listed for KLX05 and HLX32.

Table 5-1. Identified structures as a function of length in KLX05.

Length (m)	No of structures
–100	3
100–50	11
150–200	17
200–250	13
250–300	11
300–350	12
350–400	8
400–450	9
450–500	10
500–550	12
550–600	17
600–650	13
650–700	17
700–750	9
750–800	14
800–850	13
850–900	10
900–950	13
950–	10

Table 5-2. Identified structures as a function of length in HLX32.

Length (m)	No of structures
–20	–
20–40	5
40–60	10
60–80	2
80–100	5
100–120	4
120–140	6
140–160	3
160–180	2
180–200	–
200–	1

Tables 5-3 and 5-4 summarises the interpretation of radar data from KLX05 and HLX32. 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 176 in Table 5-3. To this structure, most likely, also structure 176x belongs.

Table 5-3. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz borehole KLX05.

RADINTER MODEL INFORMATION (20, 100 and 250 MHz Dipole Antennas)			
Site:		**Oskarshamn**	
Borehole name:		**KLX05**	
Nominal velocity (m/μs):		**120.00**	
Object type	**Name**	**Intersection length**	**Intersection angle**
PLANE	42	36.5	2
PLANE	1	98.4	39
PLANE	7	100.8	15
PLANE	2	102.3	50
PLANE	3	106.6	56
PLANE	6	113.9	35
PLANE	4	116.0	50
PLANE	5	116.9	52
PLANE	8	121.4	70
PLANE	9	122.4	41
PLANE	10	125.7	59
PLANE	11	129.5	53
PLANE	13	138.8	41
PLANE	12	136.1	46
PLANE	15	154.1	42
PLANE	14	154.6	47
PLANE	17	157.2	39
PLANE	16	159.6	50
PLANE	19	162.8	46

RADINTER MODEL INFORMATION
(20, 100 and 250 MHz Dipole Antennas)

Site: Oskarshamn
Borehole name: KLX05
Nominal velocity (m/µs): 120.00

Object type	Name	Intersection length	Intersection angle
PLANE	18	167.6	42
PLANE	20	171.8	56
PLANE	21	176.4	58
PLANE	22	177.9	62
PLANE	23	179.5	43
PLANE	24	180.0	49
PLANE	30	184.9	60
PLANE	25	185.7	49
PLANE	26	190.5	43
PLANE	27	193.2	43
PLANE	28	196.8	51
PLANE	35	197.3	42
PLANE	203	200.5	31
PLANE	29	206.3	36
PLANE	31	212.6	46
PLANE	42x	213.5	10
PLANE	32	218.7	41
PLANE	215	226.3	27
PLANE	33	227.7	51
PLANE	34	231.9	72
PLANE	204	236.1	57
PLANE	37	241.7	38
PLANE	36	242.1	58
PLANE	41	245.8	49
PLANE	38	246.8	43
PLANE	40	252.9	52
PLANE	39	259.2	21
PLANE	43	254.6	43
PLANE	44	261.3	35
PLANE	45	272.0	43
PLANE	46	281.2	38
PLANE	188	286.1	17
PLANE	47	287.7	40
PLANE	48x	290.2	32
PLANE	49	293.4	32
PLANE	48	294.9	21
PLANE	187	304.4	42
PLANE	50	304.7	49
PLANE	51	305.8	68
PLANE	54	310.7	64
PLANE	52	312.1	52
PLANE	53	317.5	64

RADINTER MODEL INFORMATION
(20, 100 and 250 MHz Dipole Antennas)

Site:	**Oskarshamn**
Borehole name:	**KLX05**
Nominal velocity (m/μs):	**120.00**

Object type	Name	Intersection length	Intersection angle
PLANE	205	323.1	21
PLANE	56	324.0	37
PLANE	57	323.6	57
PLANE	55	325.1	49
PLANE	58	337.6	49
PLANE	60	348.5	40
PLANE	61	351.2	68
PLANE	206	351.4	46
PLANE	59	355.1	81
PLANE	62	359.4	73
PLANE	63	376.4	66
PLANE	189	383.3	60
PLANE	64	387.6	66
PLANE	65	393.5	51
PLANE	67	403.7	53
PLANE	66	408.0	70
PLANE	68	419.4	65
PLANE	216	431.5	70
PLANE	69	433.1	40
PLANE	69x	433.6	43
PLANE	190	435.5	43
PLANE	191	438.6	40
PLANE	192	442.7	51
PLANE	70	455.2	80
PLANE	208	456.5	36
PLANE	193	460.0	64
PLANE	71	463.5	68
PLANE	73	466.6	59
PLANE	72	471.8	66
PLANE	74	478.7	72
PLANE	75	482.0	61
PLANE	207	489.1	18
PLANE	77	490.3	30
PLANE	78	502.3	44
PLANE	79	506.3	46
PLANE	80	510.4	78
PLANE	81	513.3	40
PLANE	82	515.3	50
PLANE	83	517.9	65
PLANE	84	519.5	44
PLANE	86	523.9	39
PLANE	85	524.7	49

RADINTER MODEL INFORMATION
(20, 100 and 250 MHz Dipole Antennas)

Site: Oskarshamn
Borehole name: KLX05
Nominal velocity (m/μs): 120.00

Object type	Name	Intersection length	Intersection angle
PLANE	87	529.1	43
PLANE	88	536.8	51
PLANE	195	546.6	47
PLANE	89	551.9	43
PLANE	90	553.4	41
PLANE	91	554.7	46
PLANE	92	562.4	35
PLANE	94	566.2	51
PLANE	96	570.3	37
PLANE	196	572.8	33
PLANE	98	576.2	54
PLANE	93	578.4	47
PLANE	197	579.9	47
PLANE	95	581.4	52
PLANE	97	584.3	60
PLANE	104	587.4	52
PLANE	200	588.6	31
PLANE	99	590.2	65
PLANE	103	591.4	42
PLANE	217	599.1	55
PLANE	102	600.6	56
PLANE	100	615.0	22
PLANE	101	615.7	56
PLANE	105	627.1	43
PLANE	110	628.9	37
PLANE	106	629.6	44
PLANE	107	631.5	43
PLANE	109	632.9	25
PLANE	108	634.3	42
PLANE	111	634.3	35
PLANE	219	640.0	57
PLANE	117	647.1	47
PLANE	116	648.1	28
PLANE	112	649.3	61
PLANE	114	650.8	64
PLANE	113	652.7	56
PLANE	119	656.2	23
PLANE	115	657.1	65
PLANE	119x	657.8	21
PLANE	209	658.3	32
PLANE	118	659.4	72
PLANE	120	663.5	51

RADINTER MODEL INFORMATION
(20, 100 and 250 MHz Dipole Antennas)

Site: Oskarshamn
Borehole name: KLX05
Nominal velocity (m/µs): 120.00

Object type	Name	Intersection length	Intersection angle
PLANE	121	677.4	79
PLANE	128	681.5	77
PLANE	127	687.1	81
PLANE	122	688.6	70
PLANE	125	690.0	74
PLANE	123	690.8	72
PLANE	124	692.9	67
PLANE	102	695.6	6
PLANE	126	697.0	40
PLANE	133	703.9	52
PLANE	129	711.1	50
PLANE	130	714.4	35
PLANE	131	719.6	34
PLANE	134	726.9	38
PLANE	139	727.9	18
PLANE	132	730.4	28
PLANE	135	741.4	48
PLANE	138x	744.0	29
PLANE	137	751.0	37
PLANE	138	752.4	23
PLANE	202	753.4	44
PLANE	140	754.5	63
PLANE	141	757.7	54
PLANE	142	760.9	60
PLANE	143	765.1	53
PLANE	145	767.3	30
PLANE	144	771.3	65
PLANE	145x	775.6	71
PLANE	146	777.9	59
PLANE	147	781.0	56
PLANE	148	796.3	36
PLANE	150	798.9	47
PLANE	151	801.9	47
PLANE	148x	802.2	19
PLANE	152	806.3	44
PLANE	149	808.5	34
PLANE	154	811.3	53
PLANE	153	816.7	56
PLANE	218	819.1	60
PLANE	155	827.1	44
PLANE	201	835.7	39
PLANE	156	841.4	23

RADINTER MODEL INFORMATION (20, 100 and 250 MHz Dipole Antennas)			
Site:		**Oskarshamn**	
Borehole name:		**KLX05**	
Nominal velocity (m/µs):		**120.00**	
Object type	**Name**	**Intersection length**	**Intersection angle**
PLANE	157	844.4	28
PLANE	160	844.7	43
PLANE	158	846.5	29
PLANE	159	855.5	40
PLANE	213	855.9	28
PLANE	212	857.0	34
PLANE	211	857.1	17
PLANE	161	858.3	55
PLANE	209x	869.4	9
PLANE	162	874.0	32
PLANE	163	887.9	50
PLANE	164	890.6	50
PLANE	165	898.4	39
PLANE	174	907.6	20
PLANE	166	908.9	48
PLANE	167	910.9	62
PLANE	168	917.8	71
PLANE	169	921.8	51
PLANE	170	926.3	39
PLANE	171	936.7	33
PLANE	172	937.3	57
PLANE	176x	938.6	26
PLANE	173	940.2	40
PLANE	176	940.3	32
PLANE	175	944.2	44
PLANE	214	940.4	33
PLANE	177	955.3	39
PLANE	178	962.0	38
PLANE	179	966.3	38
PLANE	180	968.4	51
PLANE	182	973.4	37
PLANE	181	979.2	52
PLANE	183	984.2	38
PLANE	186	997.2	56
PLANE	185	998.4	33
PLANE	184	1,000.0	52

Table 5-4. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz borehole HLX32.

RADINTER MODEL INFORMATION
(20, 100 and 250 MHz Dipole Antennas)

Site: Oskarshamn
Borehole name: HLX32
Nominal velocity (m/μs): 120.00

Object type	Name	Intersection length	Intersection angle
PLANE	37	20.4	69
PLANE	1	23.3	68
PLANE	2	23.7	46
PLANE	3	25.7	57
PLANE	4	32.2	57
PLANE	5	42.7	56
PLANE	6	42.8	41
PLANE	33	44.9	55
PLANE	7	46.0	51
PLANE	8	49.0	69
PLANE	38	49.0	38
PLANE	35	50.8	33
PLANE	10	52.9	63
PLANE	9	55.3	59
PLANE	11	57.6	49
PLANE	12	67.6	55
PLANE	13	76.2	49
PLANE	14	80.4	49
PLANE	15	84.3	58
PLANE	16	87.6	56
PLANE	17	91.9	54
PLANE	19	95.8	65
PLANE	20	101.0	81
PLANE	36	102.1	58
PLANE	34	105.3	77
PLANE	21	115.2	66
PLANE	25	121.2	13
PLANE	23	121.5	69
PLANE	24	125.9	62
PLANE	32	132.4	56
PLANE	27	132.6	57
PLANE	28	138.2	56
PLANE	26	141.4	50
PLANE	29	144.2	58
PLANE	40	154.3	41
PLANE	30	161.1	50
PLANE	31	163.6	48
PLANE	39	1,231.0	2

In Appendix 1 and 2, the amplitude of the first arrival is plotted against the length, 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 5-5 and 5-6.

Table 5-5. Borehole length intervals in KLX05 with decreased amplitude for the 250 MHz antenna.

Length (m)	Length (m)
155–165	500–505
180–190	545
210–215	590
225–230	680–695
240–260	745
295–310	755
320–325	830
340–375	845
385–400	860–870
420	875
435–440	940–945
485	960
495	

Table 5-6. Borehole length intervals in HLX32 with decreased amplitude for the 250 MHz antenna.

Length (m)	Length (m)
25–35	80–110
45–55	110–125

5.2 BIPS logging

The BIPS pictures are presented in Appendix 3 and 4.

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 field data and are also presented in Figure 4-2 in this report.

Data for the inclination and azimuth presented in Appendix 3 and 4 are preliminary for the BIPS images.

The images in KLX05 are affected to some extent by the drilling discolouring of the borehole. What really limits the visibility of the borehole wall is mud covering the deeper parts of the boreholes.

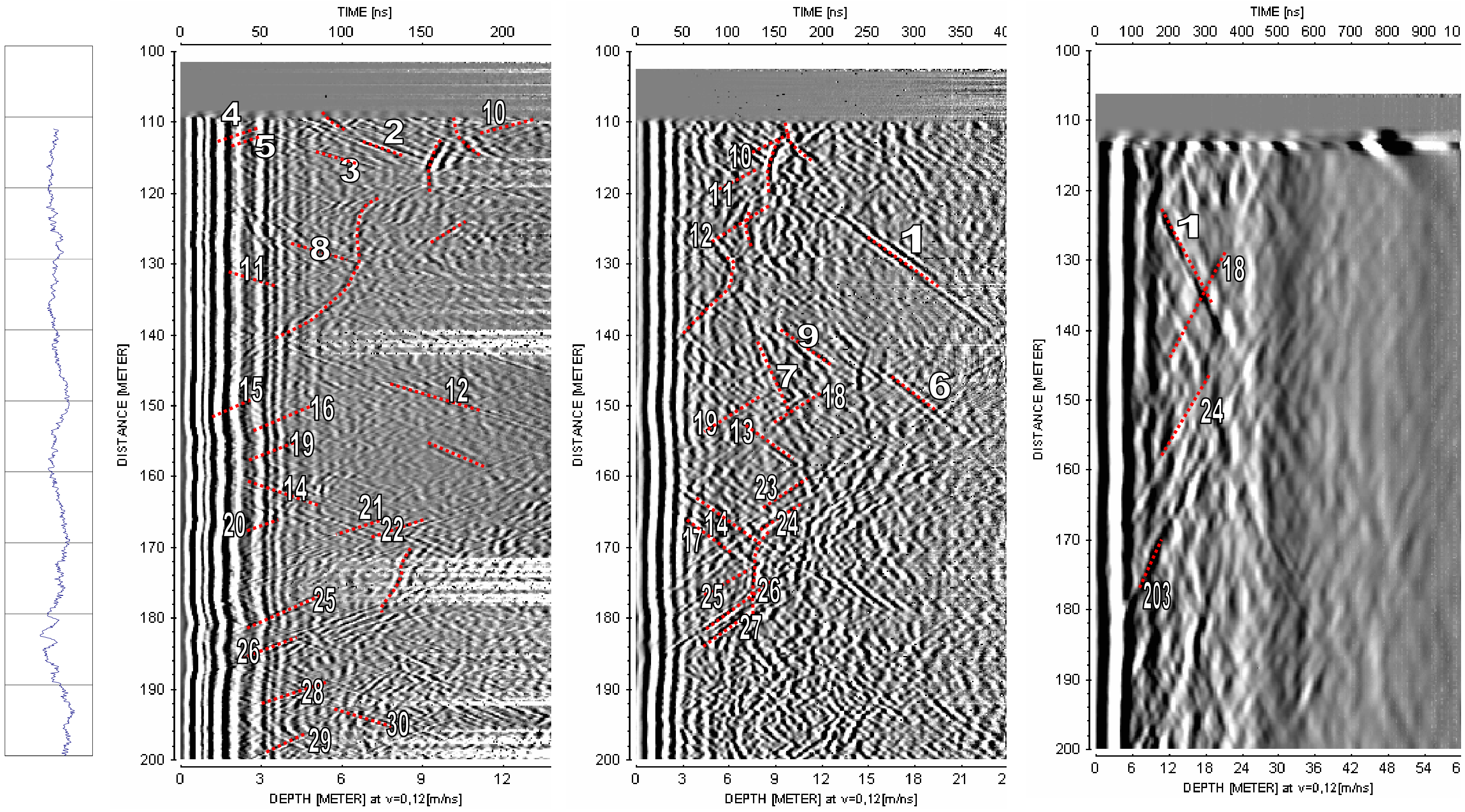
In borehole HLX32, 30 m is more or less impossible to see and get any information from the images. This is due to very dirty water. This problem may be overcome if the borehole can rest for a couple of weeks before logging.

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.

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

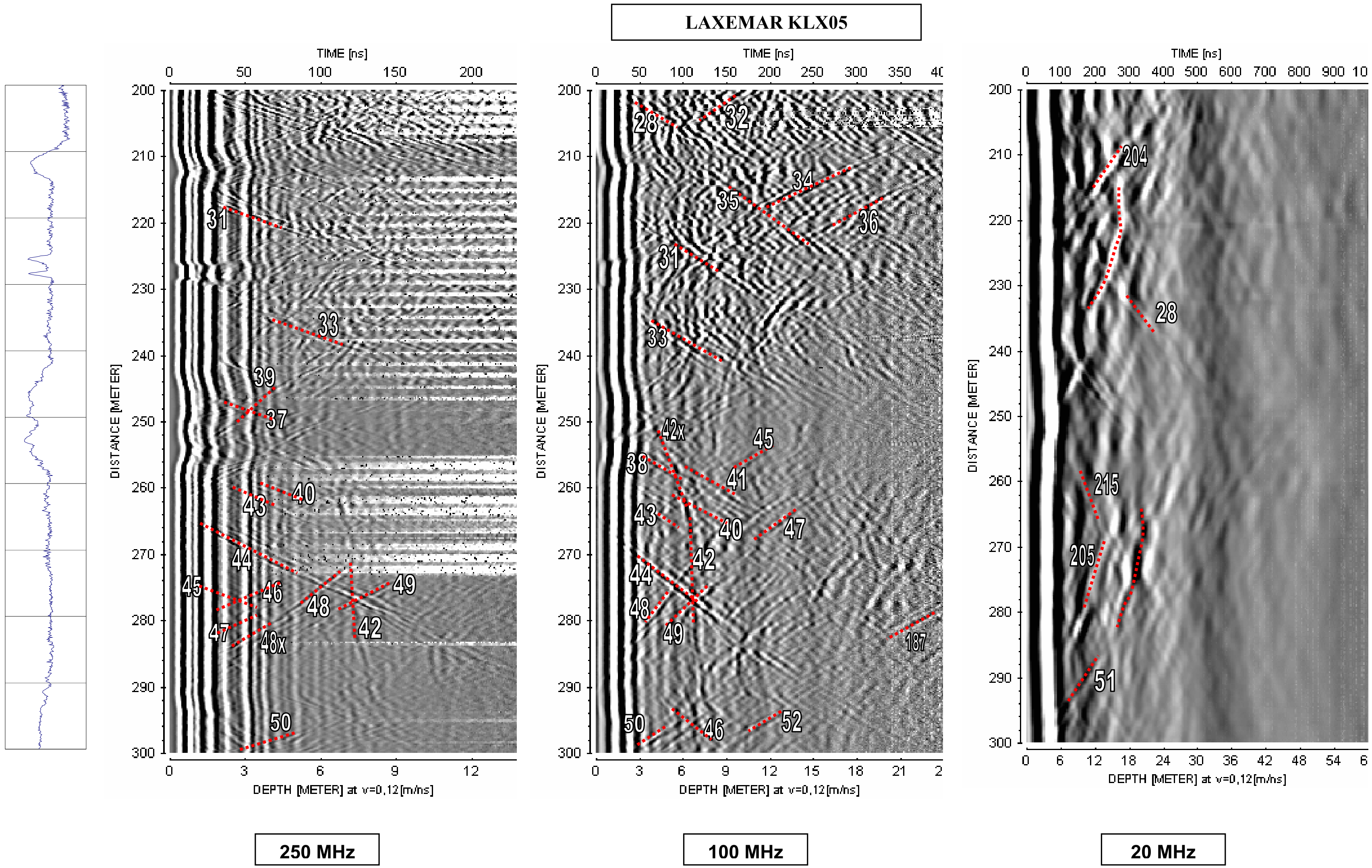
LAXEMAR KLX05

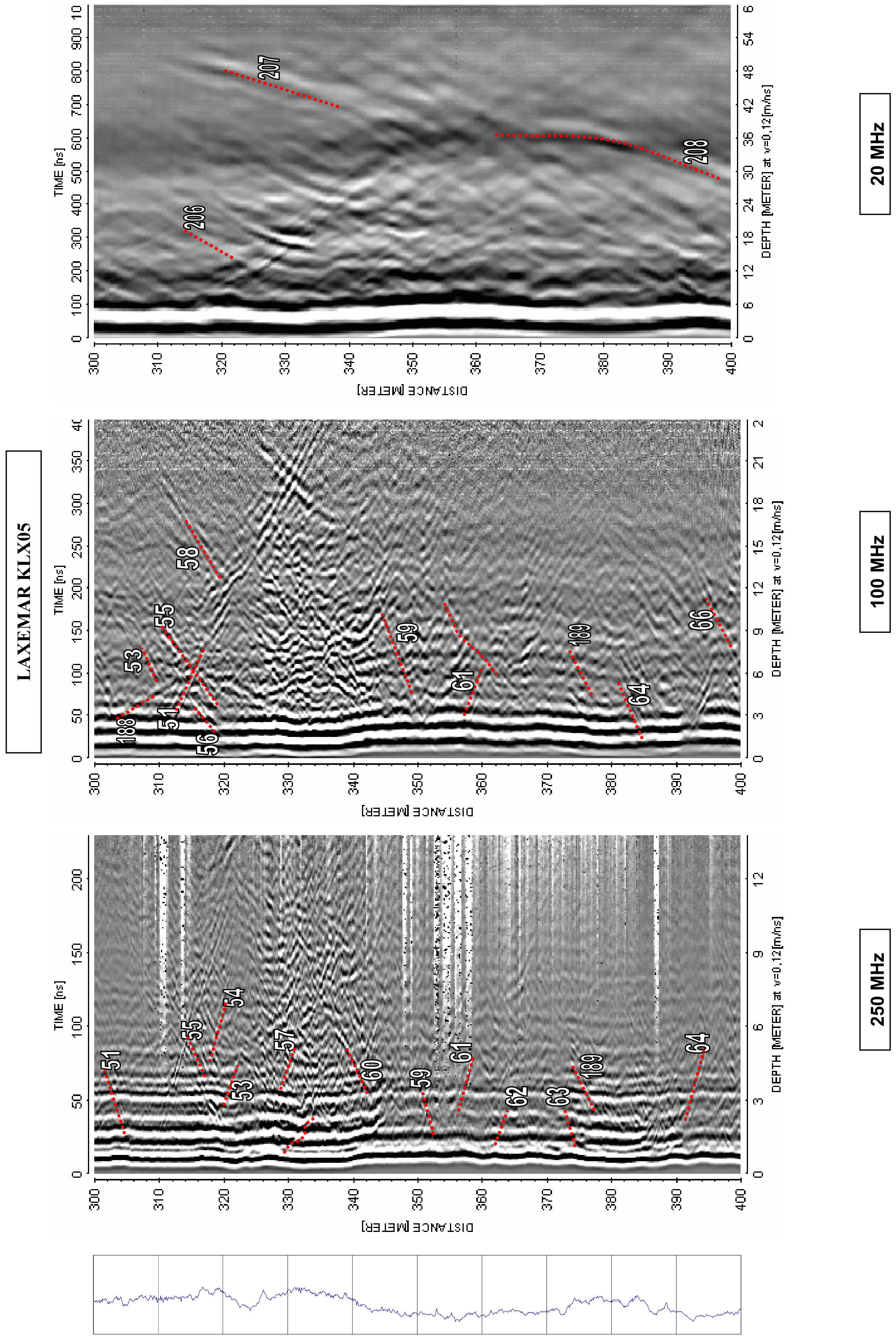


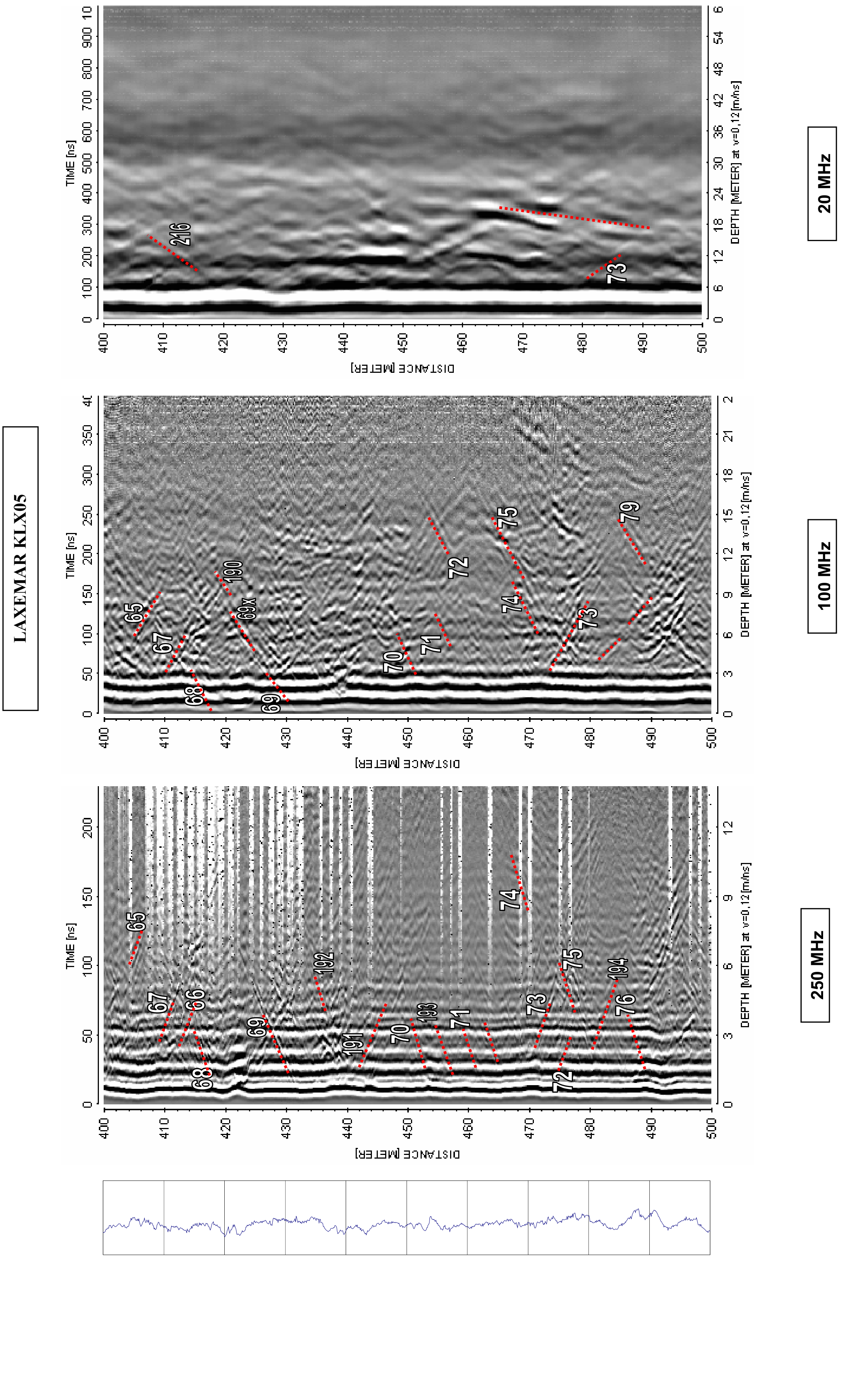
250 MHz

100 MHz

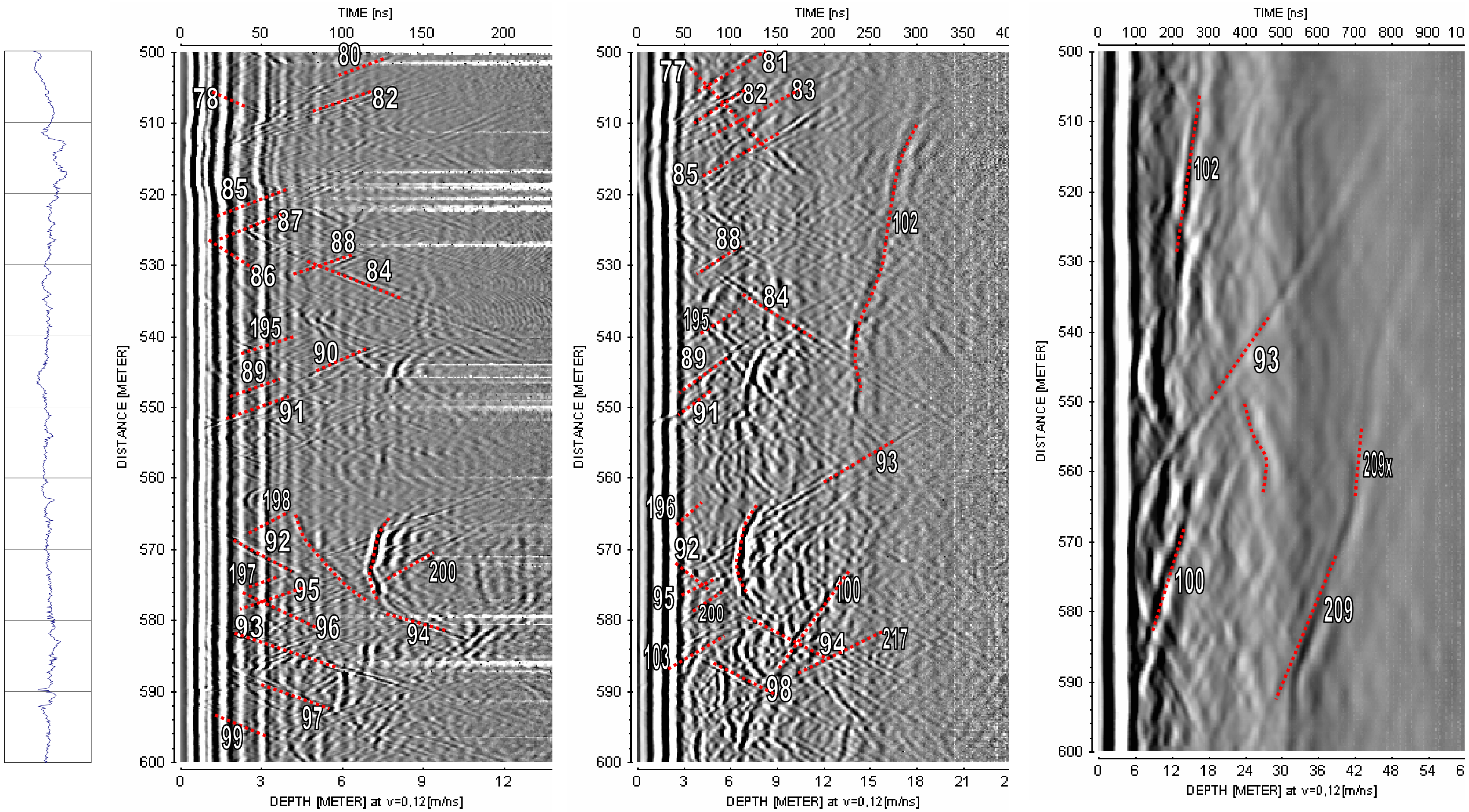
20 MHz


LAXEMAR KLX05
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,12[m/ns]
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]
51
53
54
55
57
59
60
61
62
63
64
189
188
56
58
66
206
207
208


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

LAXEMAR KLX05

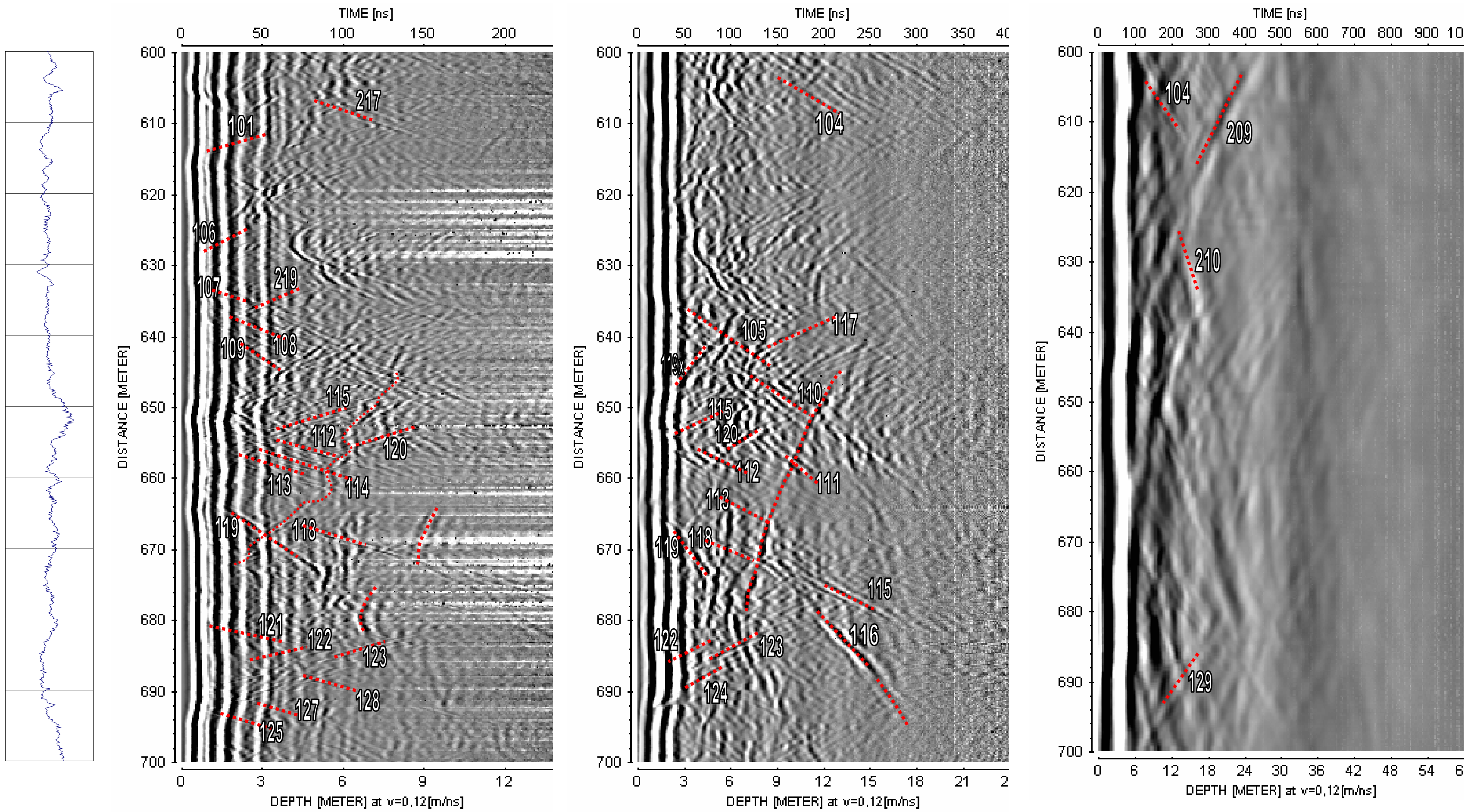


250 MHz

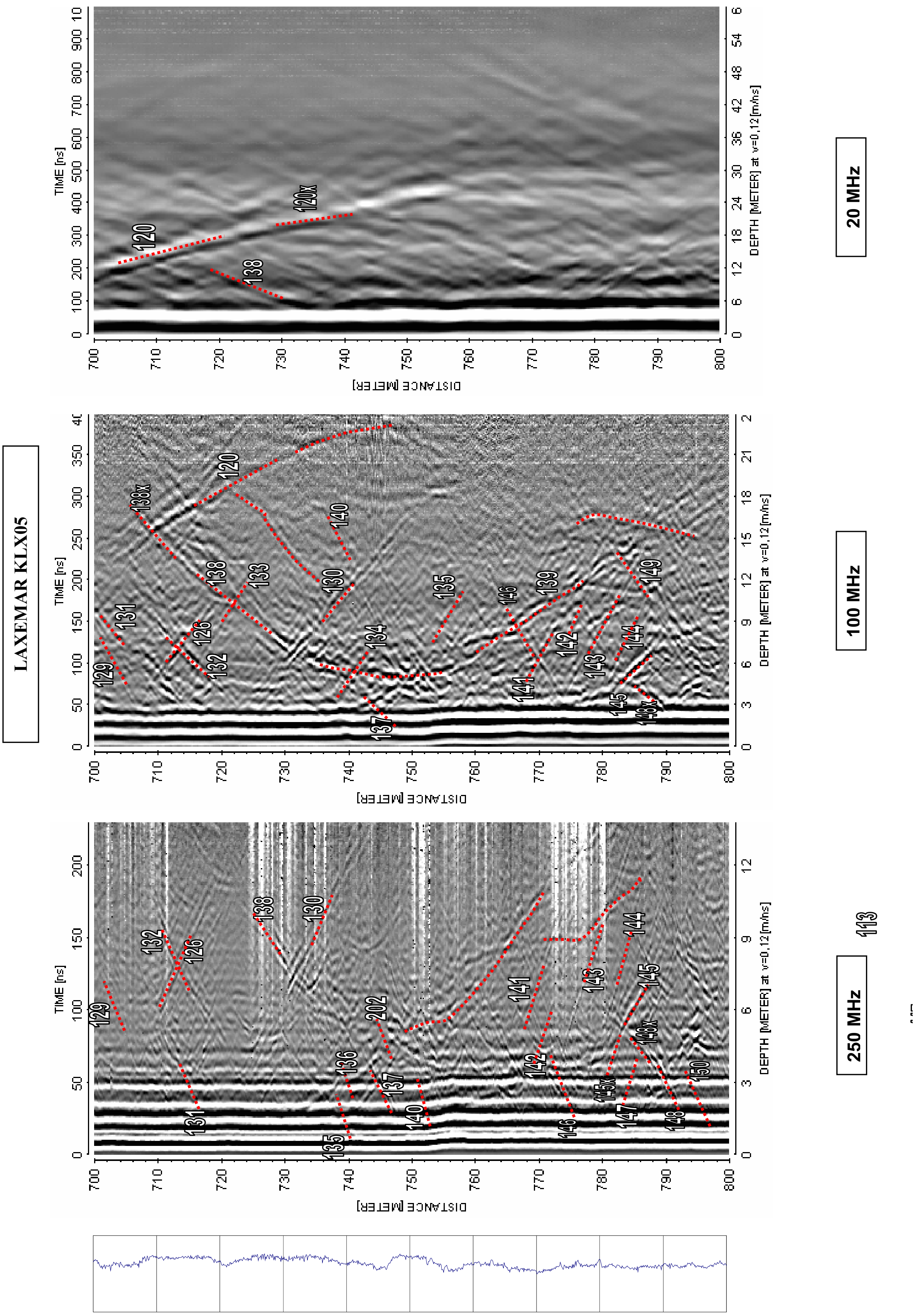
100 MHz

20 MHz

LAXEMAR KLX05

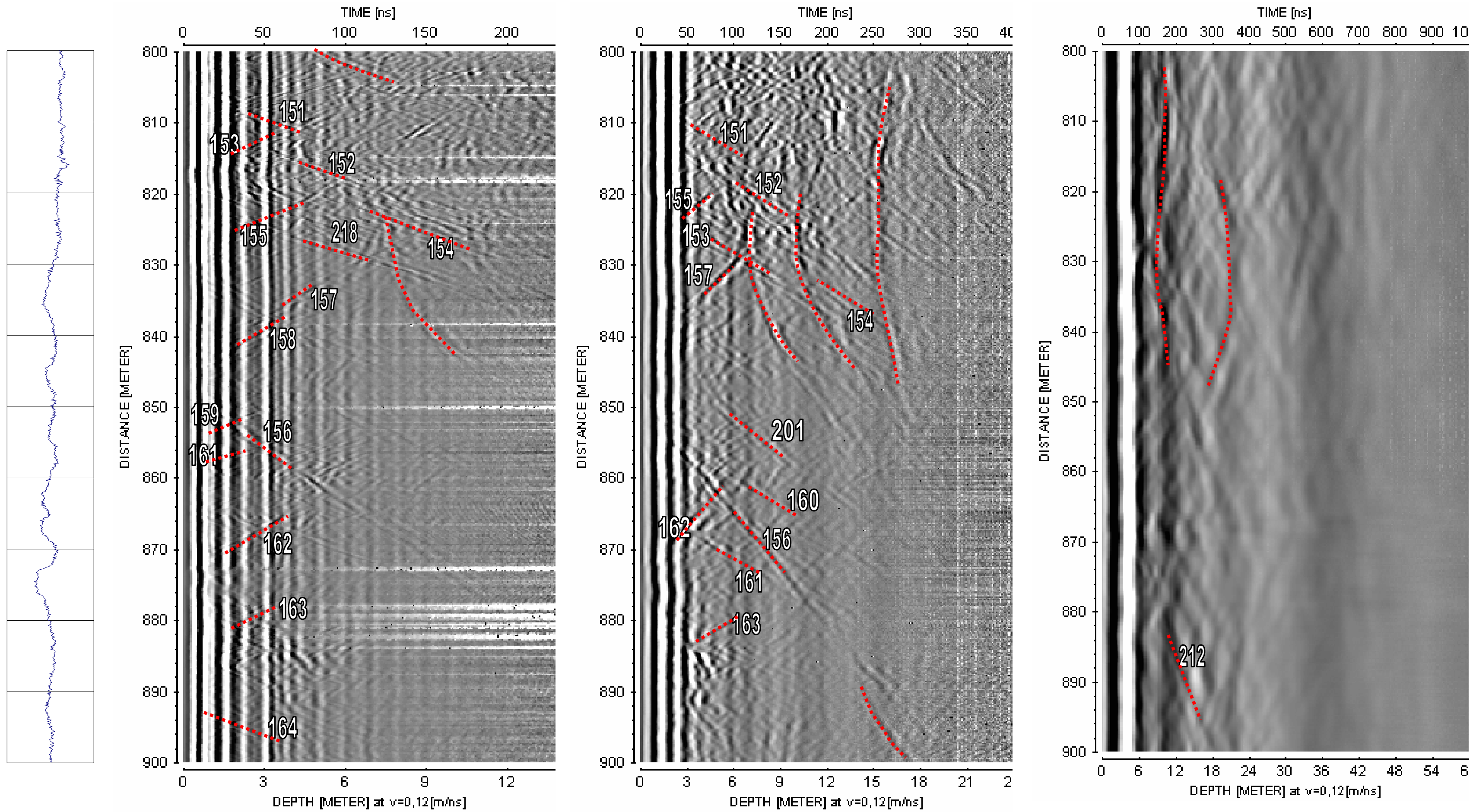


250 MHz **100 MHz** **20 MHz**



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

LAXEMAR KLX05

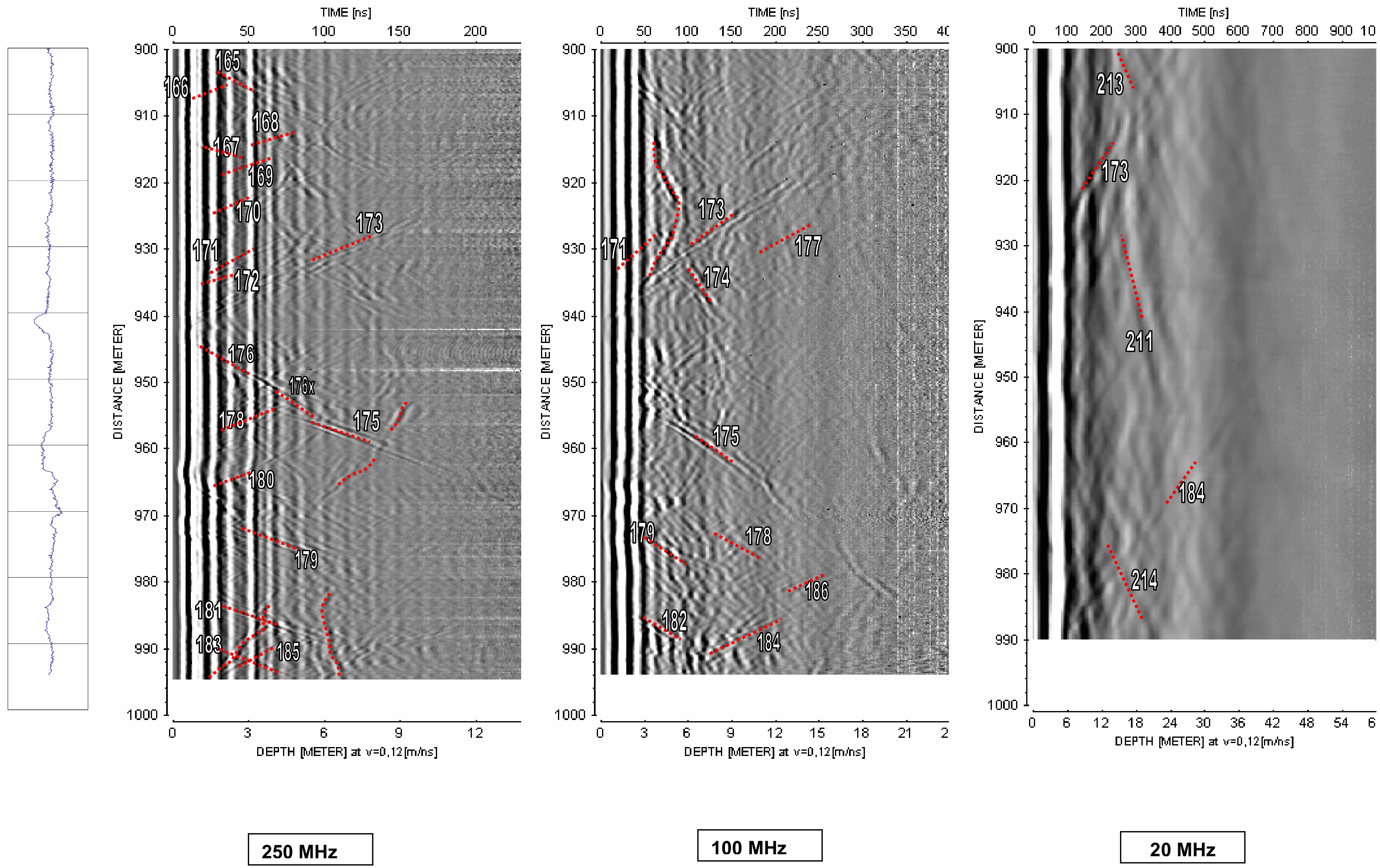


250 MHz

100 MHz

20 MHz

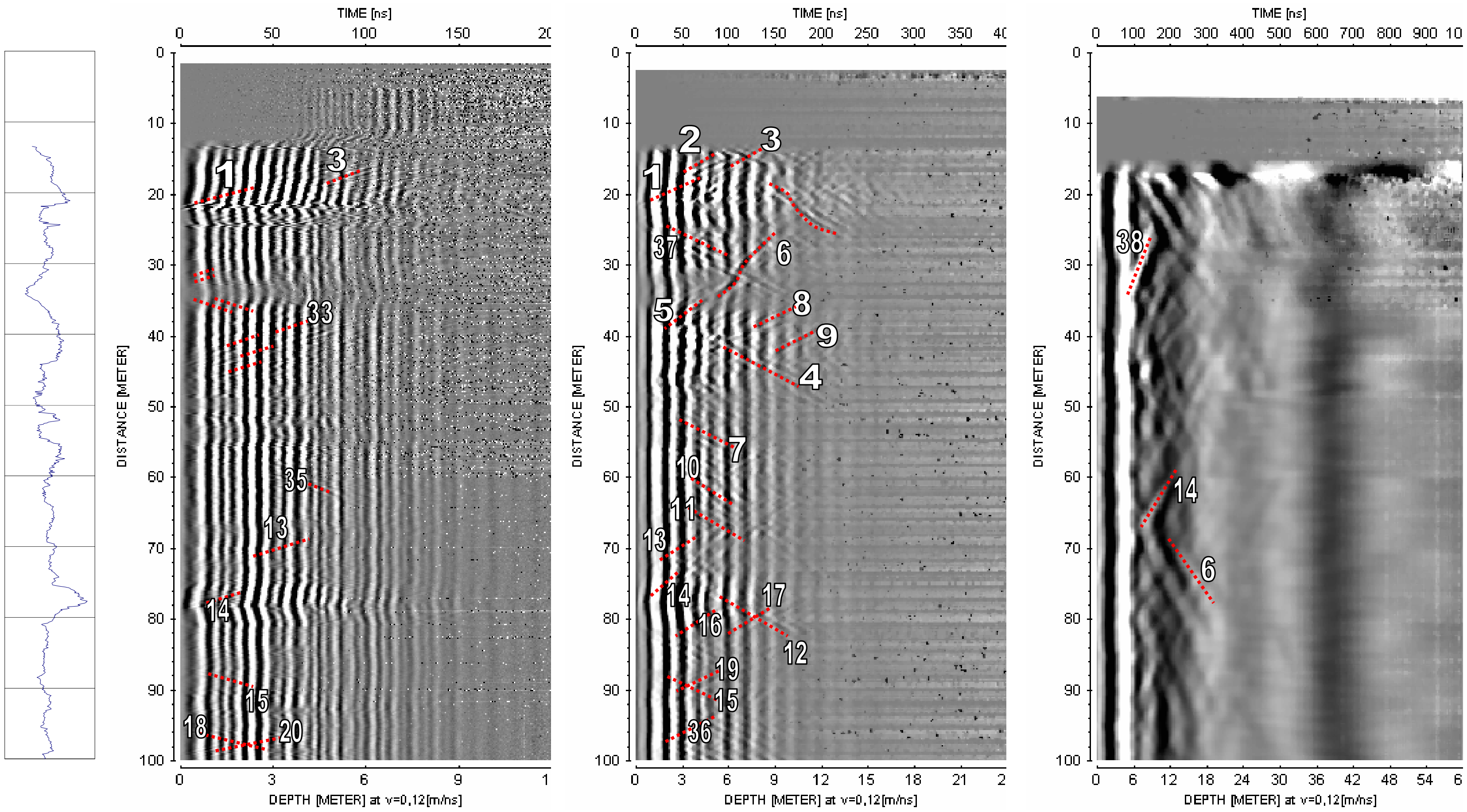
LAXEMAR KLX05



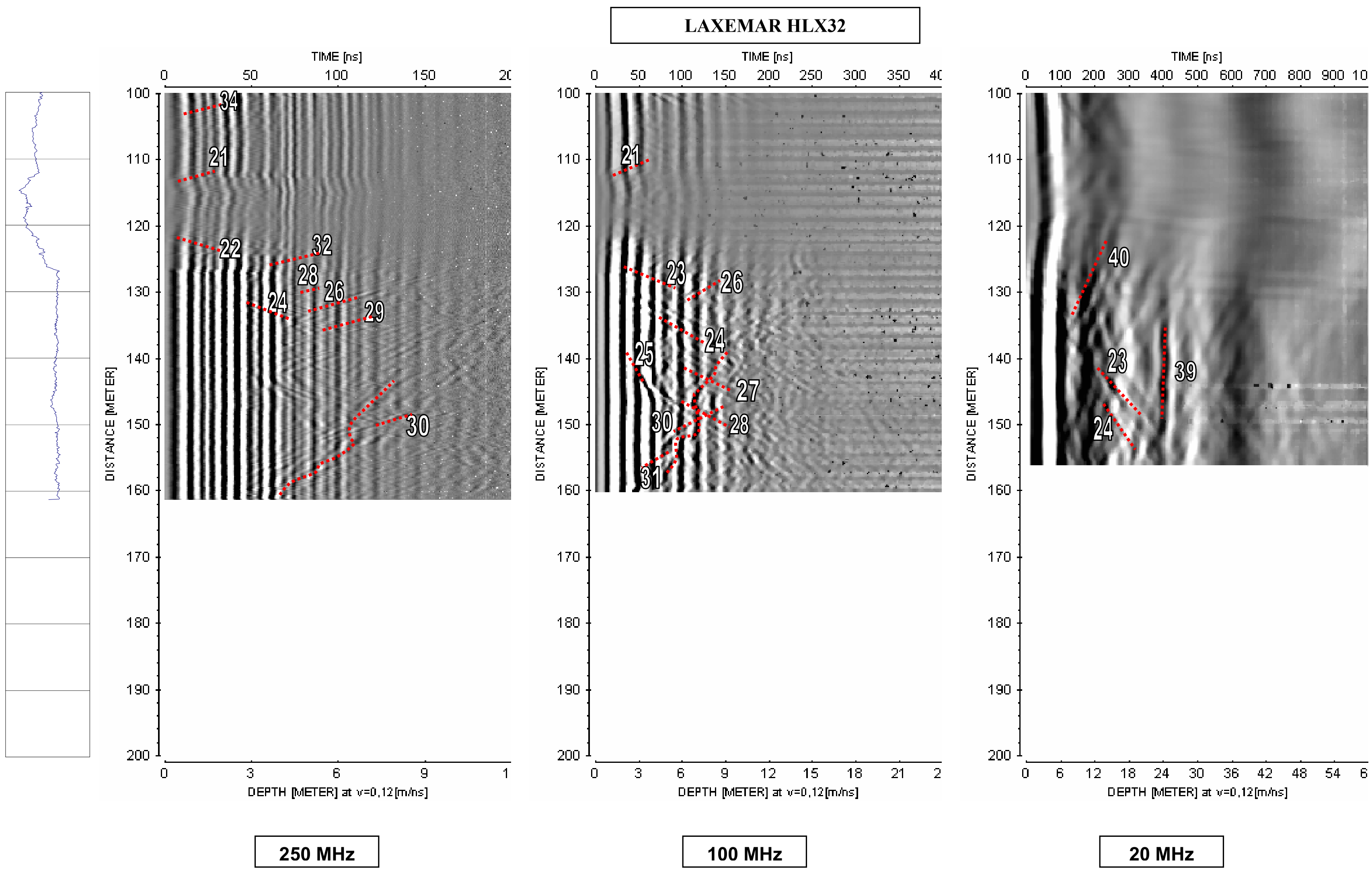
Appendix 2

Radar logging in HLX32, 10 to 155 m, dipole antennas 250, 100 and 20 MHz

LAXEMAR HLX32



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


LAXEMAR HLX32
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,12[m/ns]
34
21
22
32
28
26
24
29
30
23
25
27
31
40
39
250 MHz
100 MHz
20 MHz

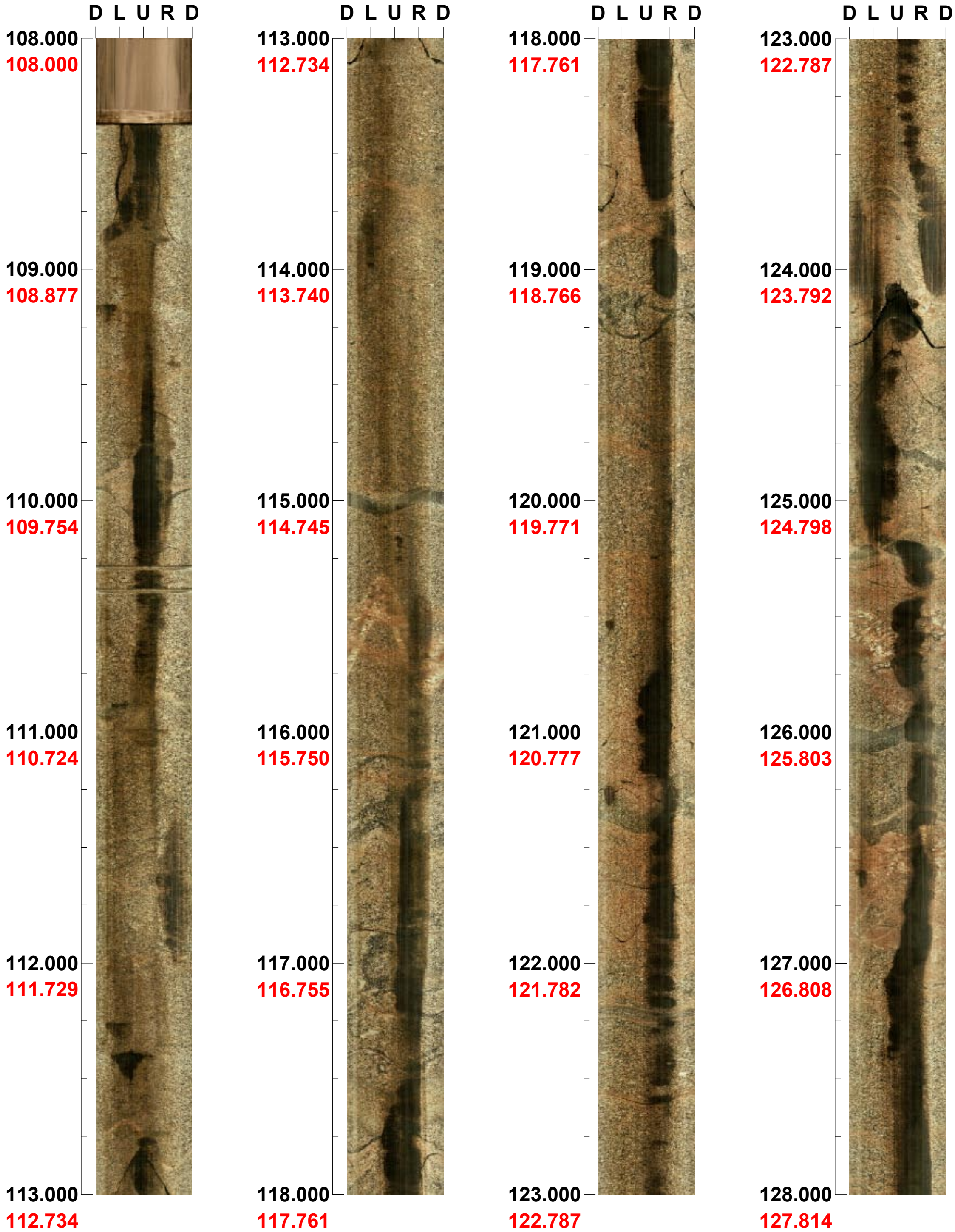
BIPS logging in KLX05, 108 to 991 m

Project name: Laxemar

Image file	: c:\work\apps40~1\klx5\klx05_a.bip
BDT file	: c:\work\apps40~1\klx5\klx05_a.bdt
Locality	: LAXEMAR
Bore hole number	: KLX05
Date	: 05/03/23
Time	: 09:02:00
Depth range	: 108.000 - 991.529m
Azimuth	: 190
Inclination	: -65
Diameter	: 76.0 mm
Magnetic declination	: 0.0
Span	: 4
Scan interval	: 0.25
Scan direction	: To bottom
Scale	: 1/25
Aspect ratio	: 175 %
Pages	: 20
Color	: +0 +0 +0

Project name: Laxemar
Bore hole No.: KLX05 **Azimuth: 190** **Inclination: -65**

Depth range: 108.000 - 128.000 m



(1 / 20) **Scale: 1/25** **Aspect ratio: 175 %**

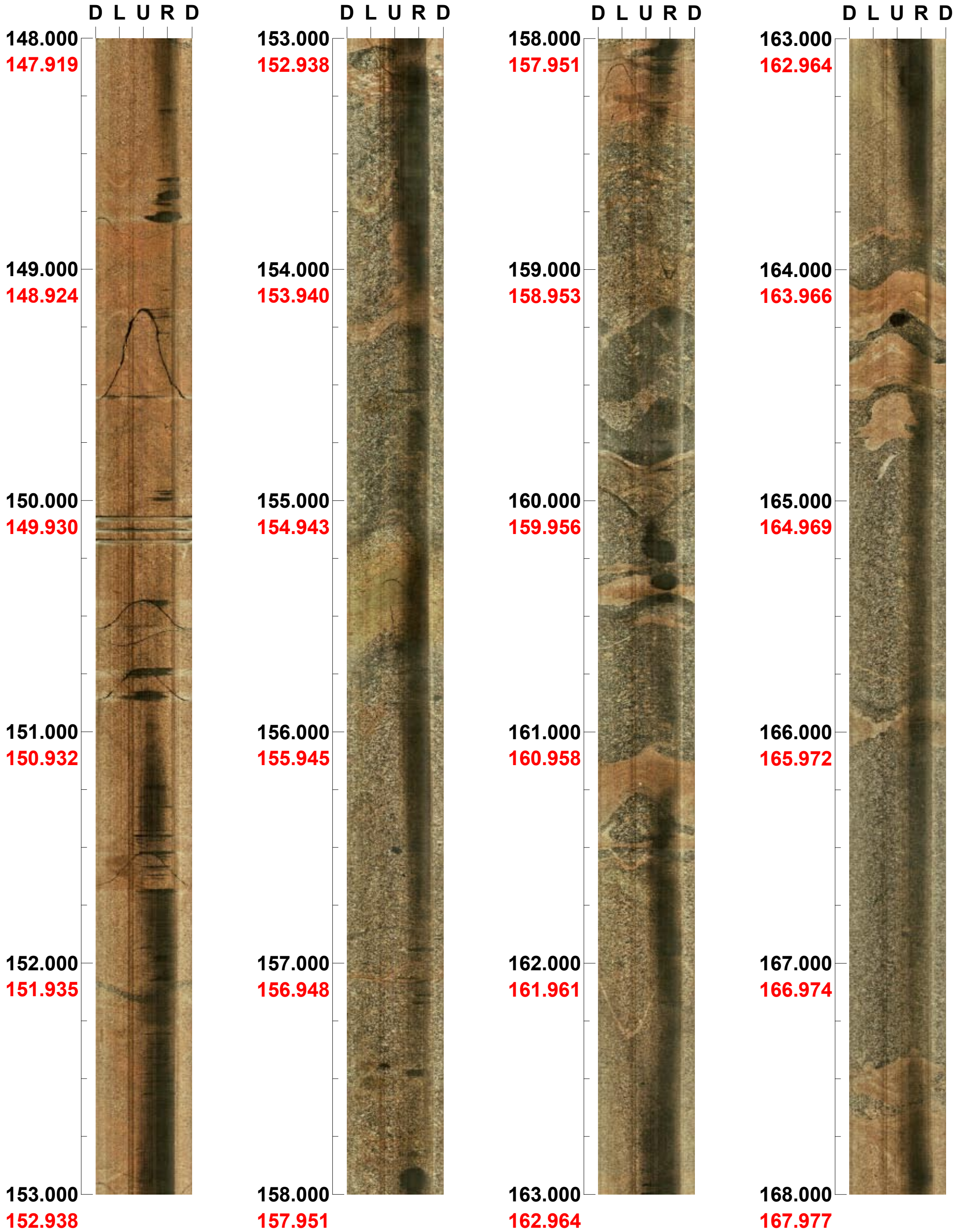
Project name: Laxemar
Bore hole No.: KLX05 **Azimuth: 190** **Inclination: -65**

Depth range: 128.000 - 148.000 m

(2 / 20) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar
Bore hole No.: KLX05 Azimuth: 190 Inclination: -65

Depth range: 148.000 - 168.000 m



(3 / 20) Scale: 1/25 Aspect ratio: 175 %

Project name: Laxemar
Bore hole No.: KLX05 **Azimuth: 190** **Inclination: -65**

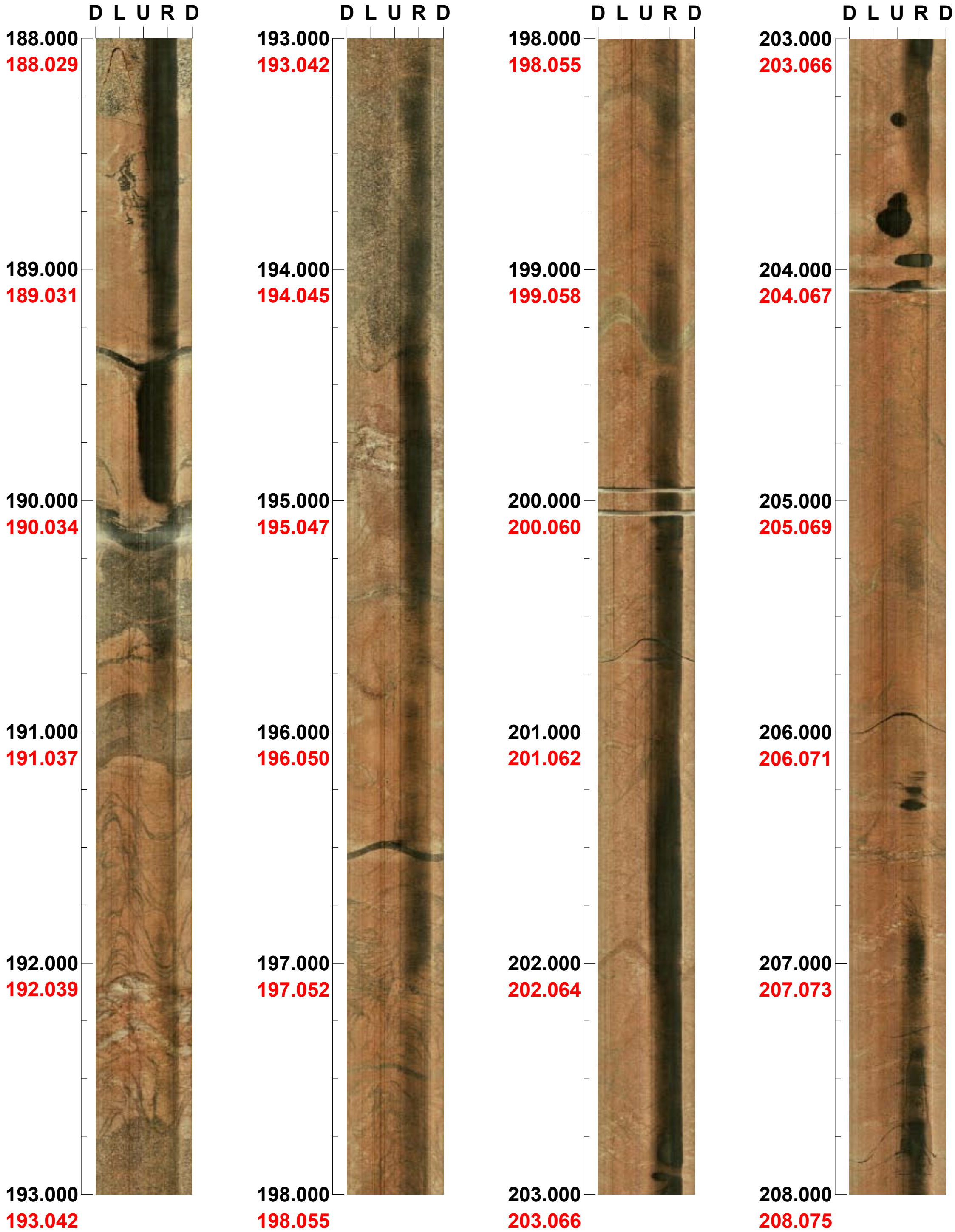
Depth range: 168.000 - 188.000 m

(4 / 20) Scale: 1/25 Aspect ratio: 175 %

Project name: Laxemar

Bore hole No.: KLX05 **Azimuth: 190** **Inclination: -65**

Depth range: 188.000 - 208.000 m



(5 / 20) **Scale: 1/25** **Aspect ratio: 175 %**

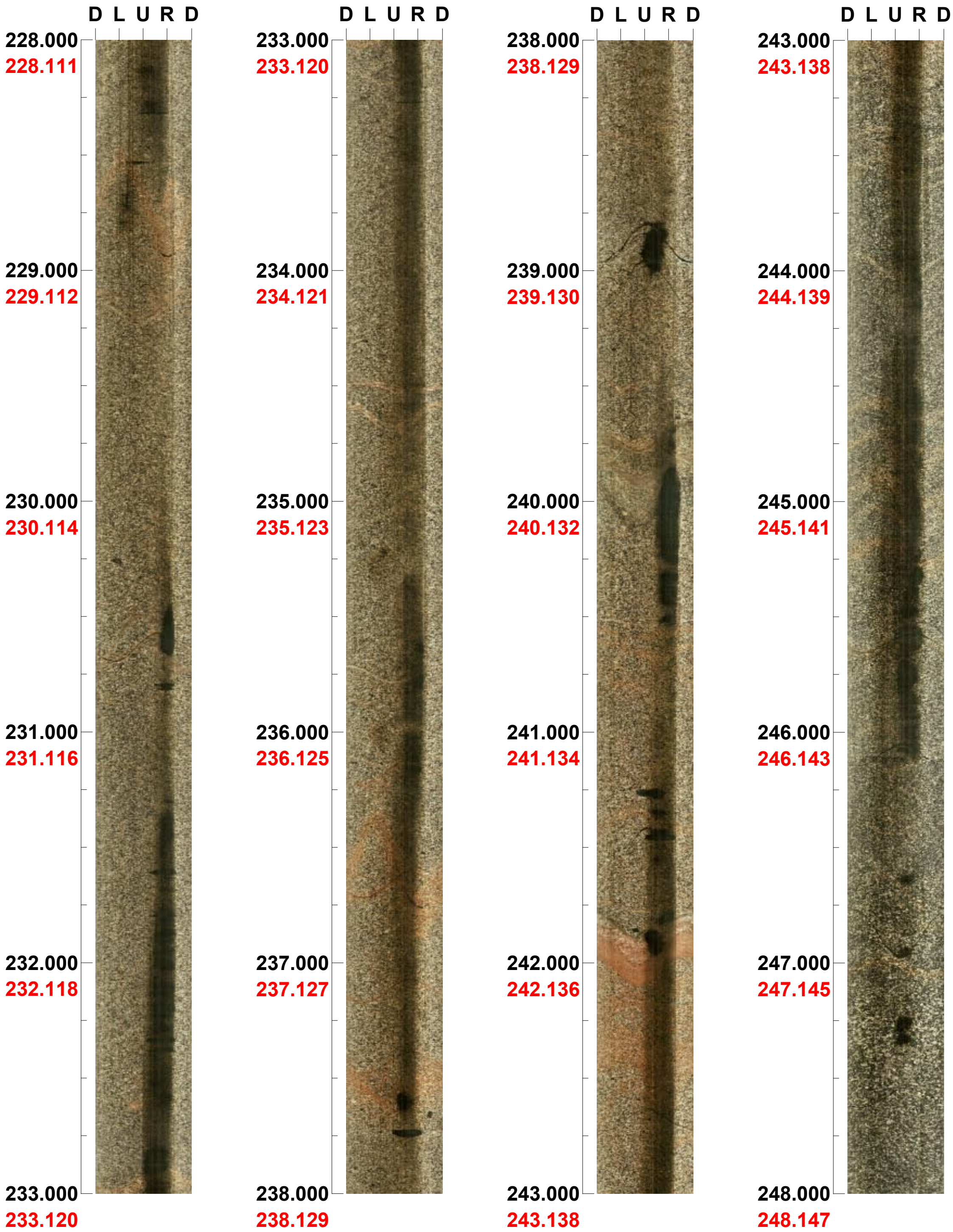
Project name: Laxemar
Bore hole No.: KLX05 **Azimuth: 190** **Inclination: -65**

Depth range: 208.000 - 228.000 m

(6 / 20) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar
Bore hole No.: KLX05 Azimuth: 190 Inclination: -65

Depth range: 228.000 - 248.000 m



(7 / 20) Scale: 1/25 Aspect ratio: 175 %

Project name: Laxemar
Bore hole No.: KLX05 **Azimuth: 190** **Inclination: -65**

Depth range: 248.000 - 268.000 m

(8 / 20) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar
Bore hole No.: KLX05 Azimuth: 190 Inclination: -65

Depth range: 268.000 - 288.000 m

(9 / 20) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar
Bore hole No.: KLX05 **Azimuth: 190** **Inclination: -65**

Depth range: 288.000 - 308.000 m

(10 / 20) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar
Bore hole No.: KLX05 **Azimuth: 190** **Inclination: -65**

Depth range: 308.000 - 328.000 m

(11 / 20) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar
Bore hole No.: KLX05 Azimuth: 190 Inclination: -65

Depth range: 328.000 - 348.000 m

(12 / 20) Scale: 1/25 Aspect ratio: 175 %

Project name: Laxemar
Bore hole No.: KLX05 **Azimuth: 190** **Inclination: -65**

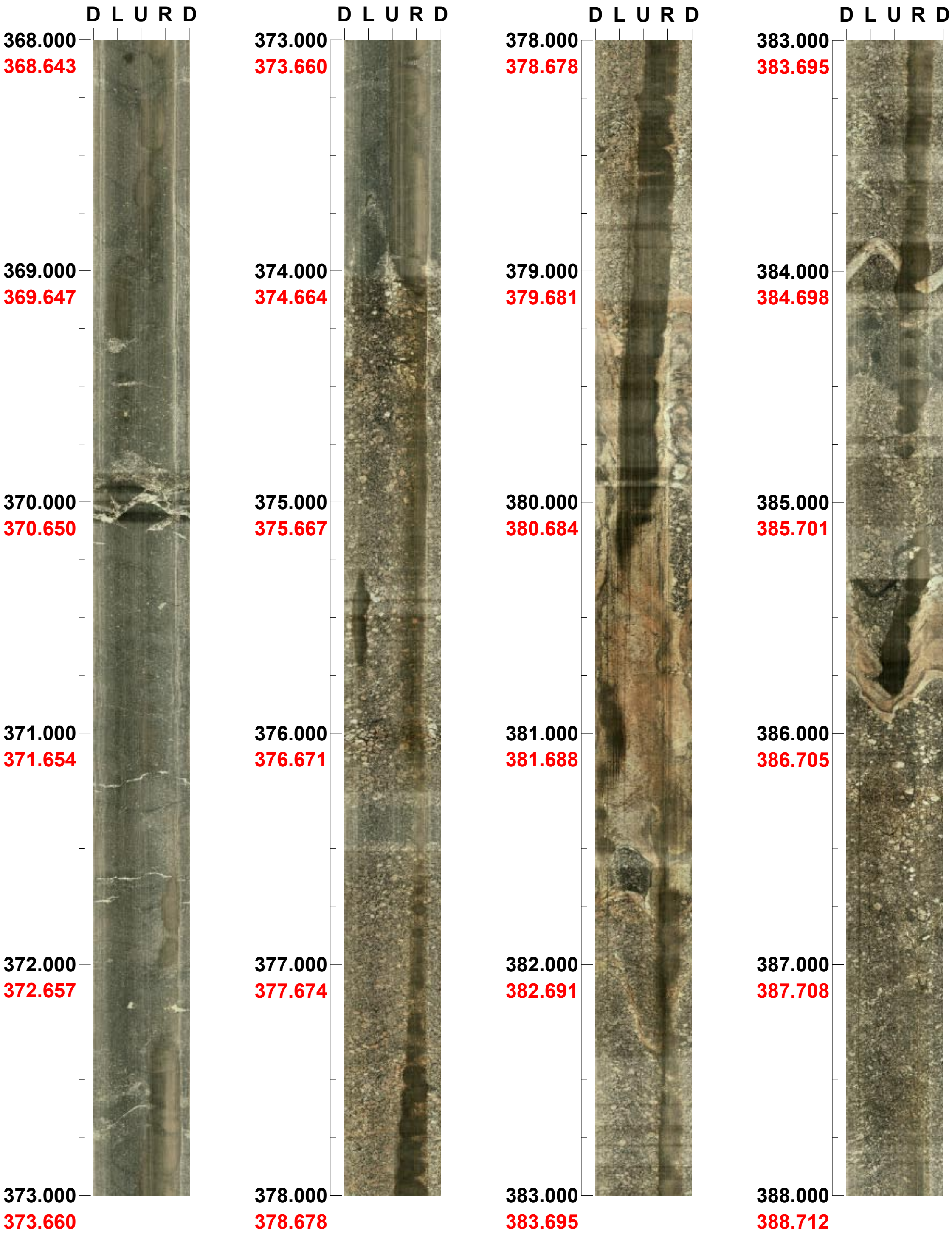
Depth range: 348.000 - 368.000 m

(13 / 20) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar

Bore hole No.: KLX05 **Azimuth: 190** **Inclination: -65**

Depth range: 368.000 - 388.000 m



(14 / 20) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar

Bore hole No.: KLX05 **Azimuth: 190** **Inclination: -65**

Depth range: 388.000 - 408.000 m

(15 / 20) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar

Bore hole No.: KLX05 **Azimuth: 190** **Inclination: -65**

Depth range: 408.000 - 428.000 m

(16 / 20) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar
Bore hole No.: KLX05 **Azimuth: 190** **Inclination: -65**

Depth range: 428.000 - 448.000 m

D L U R D

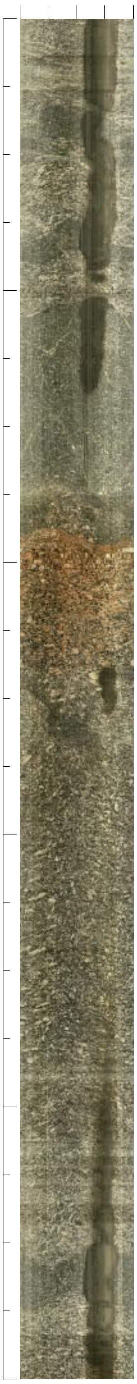
428.000 428.860
429.000 429.863
430.000 430.867
431.000 431.871
432.000 432.875
433.000 433.879

D L U R D

433.000 433.879
434.000 434.883
435.000 435.886
436.000 436.890
437.000 437.894
438.000 438.898

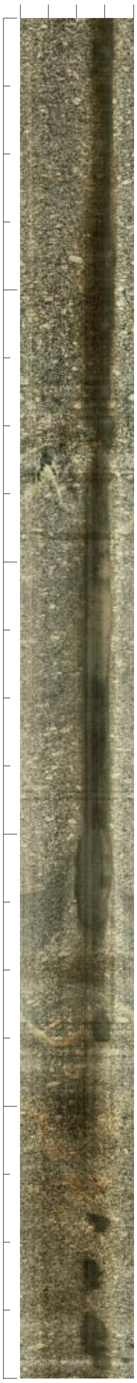
D L U R D

438.000 438.898
439.000 439.902
440.000 440.905
441.000 441.909
442.000 442.913
443.000 443.917



D L U R D

443.000 443.917
444.000 444.921
445.000 445.925
446.000 446.928
447.000 447.932
448.000 448.936



(17 / 20) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar
Bore hole No.: KLX05 **Azimuth: 190** **Inclination: -65**

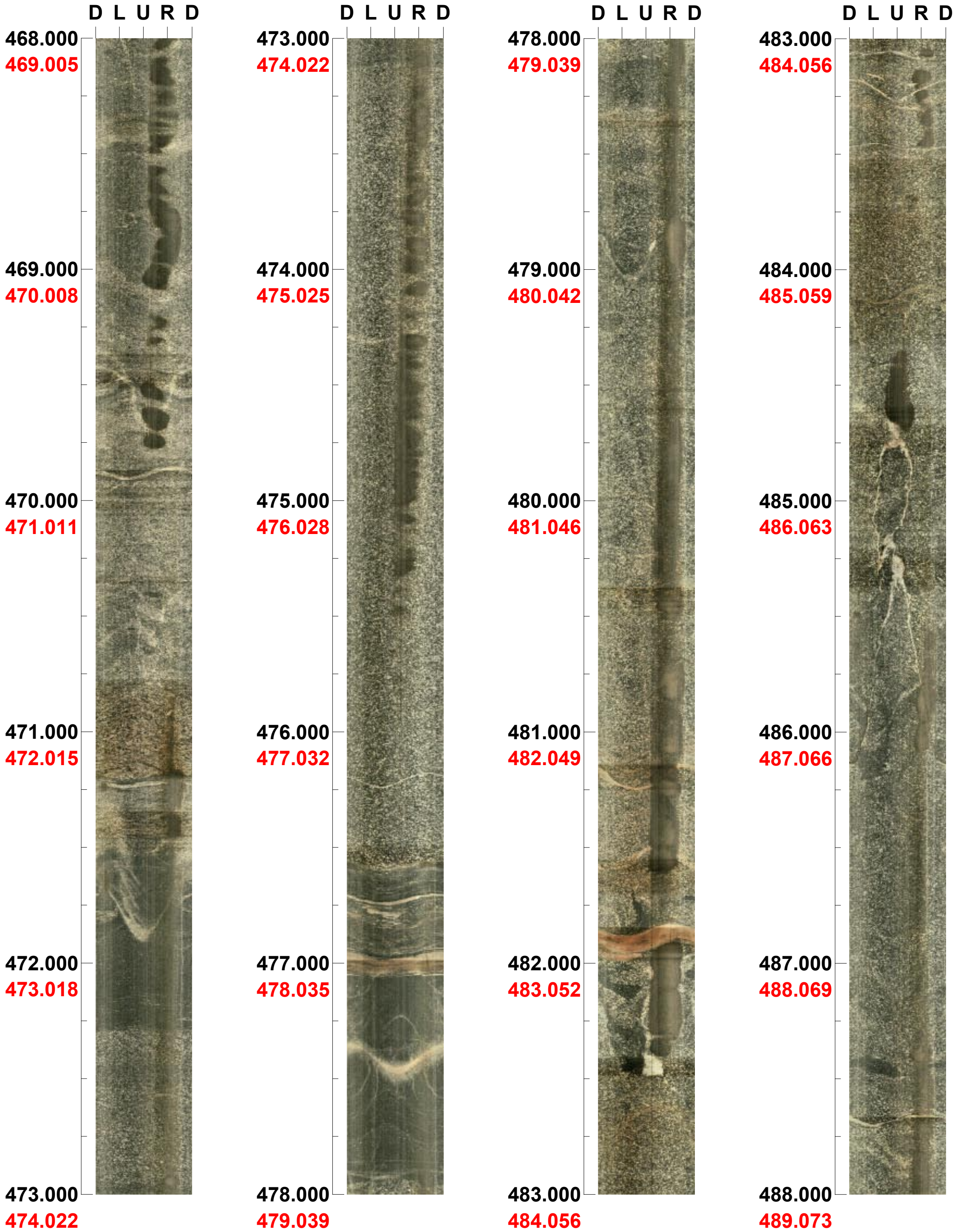
Depth range: 448.000 - 468.000 m

(18 / 20) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar

Bore hole No.: KLX05 **Azimuth: 190** **Inclination: -65**

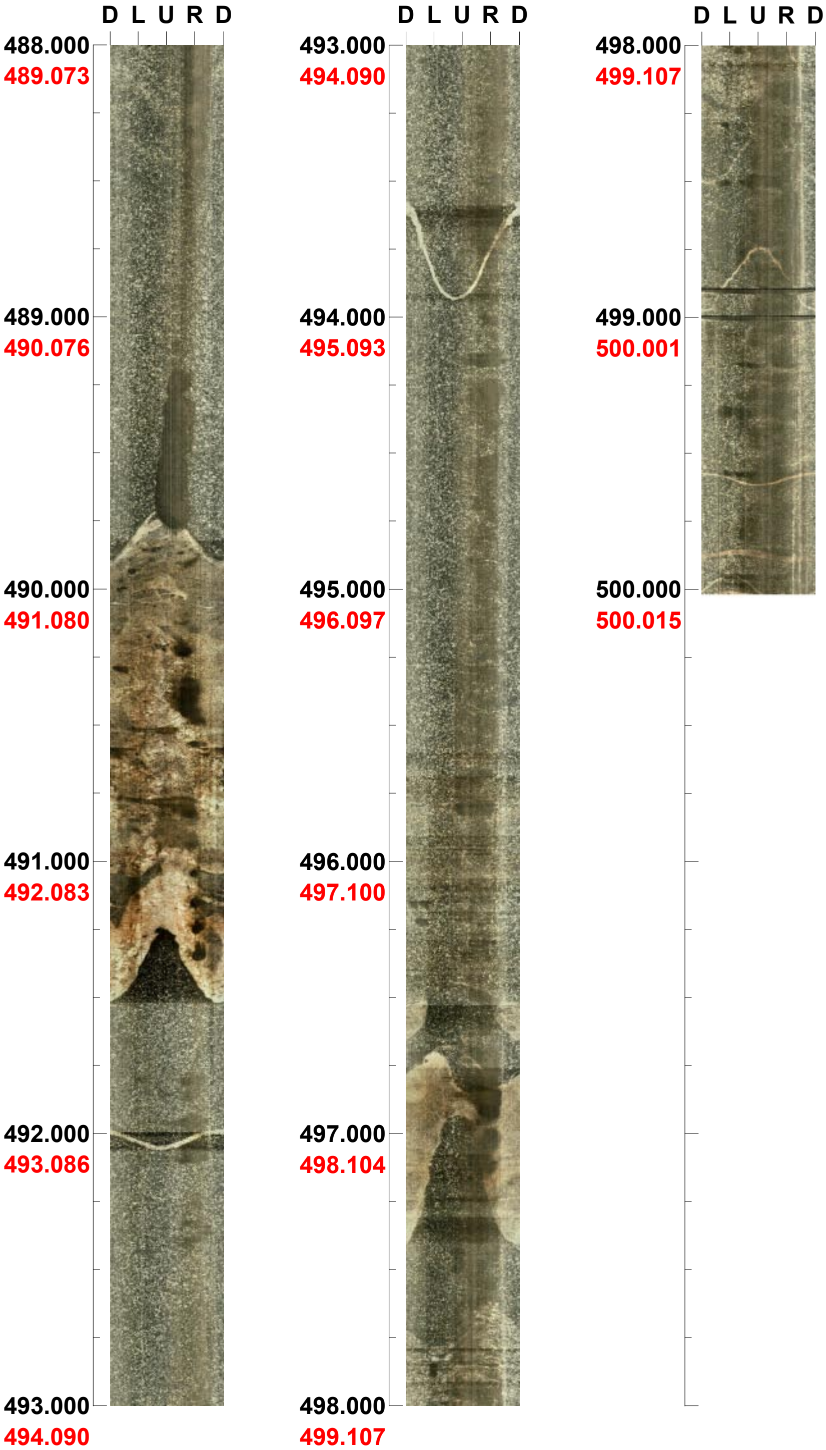
Depth range: 468.000 - 488.000 m



(19 / 20) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar
Bore hole No.: KLX05 Azimuth: 190 Inclination: -65

Depth range: 488.000 - 500.015 m



(20 / 20) Scale: 1/25 Aspect ratio: 175 %

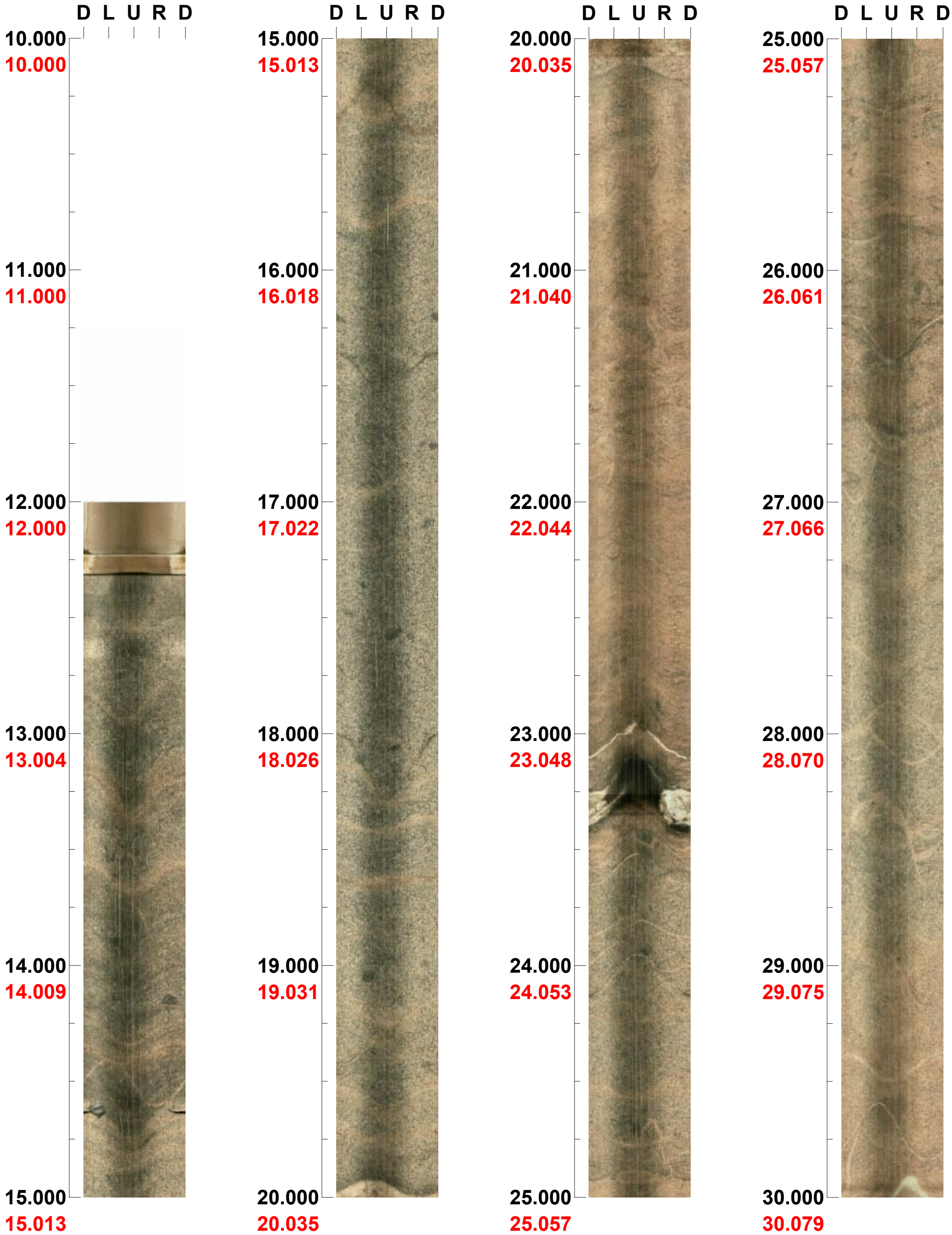
BIPS logging in HLX32, 12 to 161 m

Project name: Laxemar

Image file	: c:\work\apps40~1\hlx32\hlx32.bip
BDT file	: c:\work\apps40~1\hlx32\hlx32.bdt
Locality	: LAXEMAR
Bore hole number	: HLX32
Date	: 05/03/21
Time	: 14:22:00
Depth range	: 12.000 - 161.013 m
Azimuth	: 29
Inclination	: -59
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	: 8
Color	: +0 +0 +0

Project name: Laxemar
Bore hole No.: HLX32 **Azimuth: 29** **Inclination: -59**

Depth range: 10.000 - 30.000 m

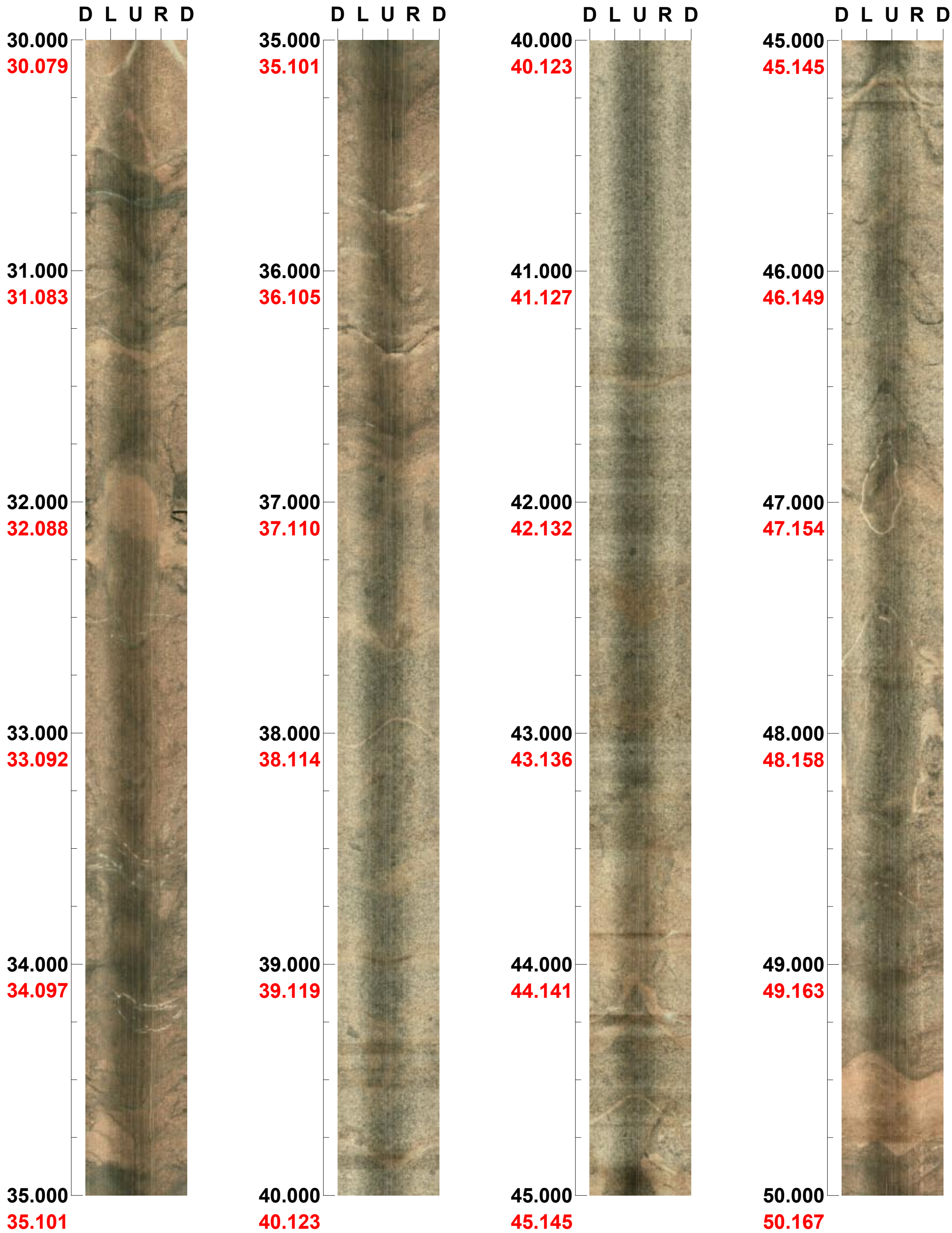


(1 / 8) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Laxemar

Bore hole No.: HLX32 **Azimuth: 29** **Inclination: -59**

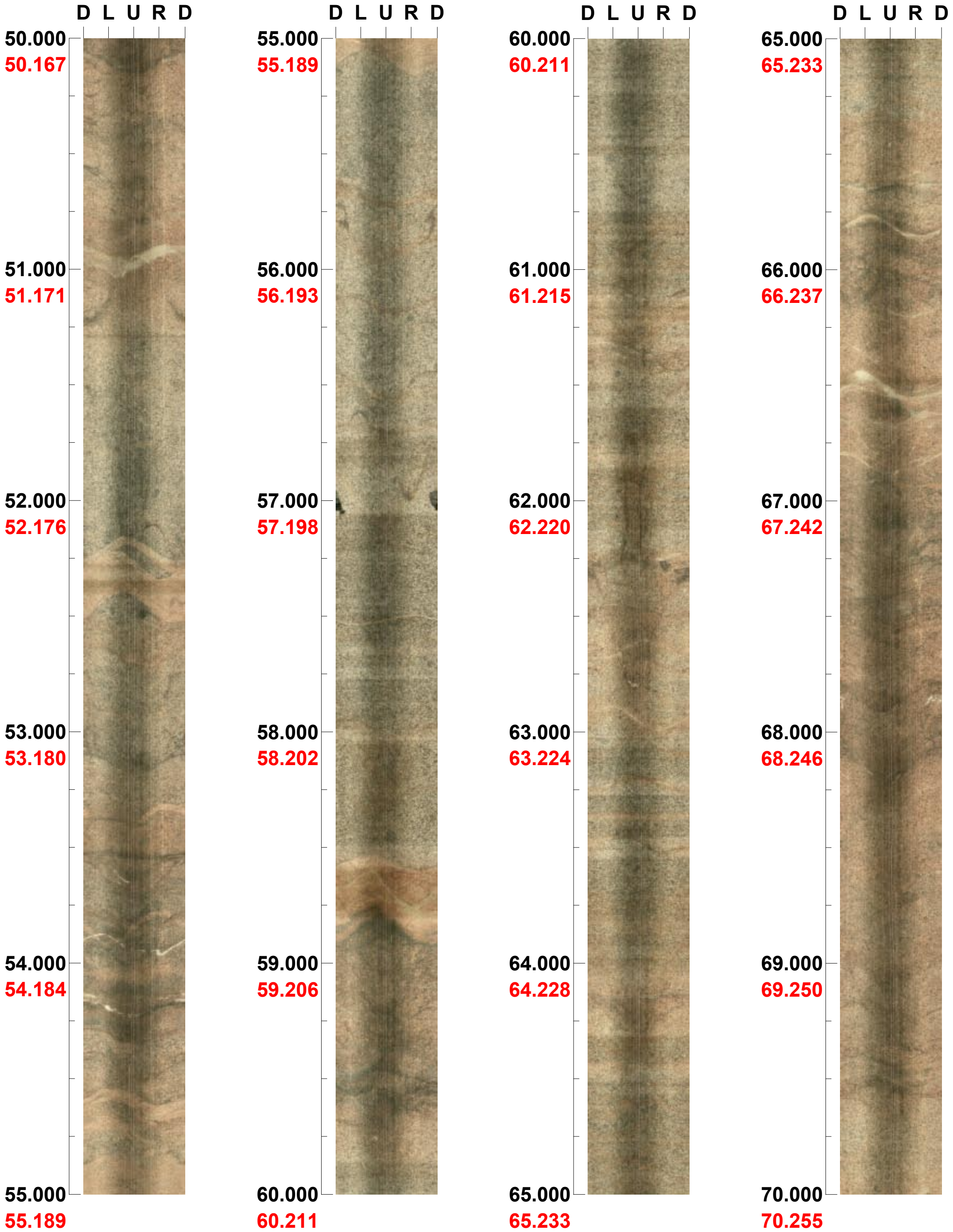
Depth range: 30.000 - 50.000 m



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

Project name: Laxemar
Bore hole No.: HLX32 **Azimuth: 29** **Inclination: -59**

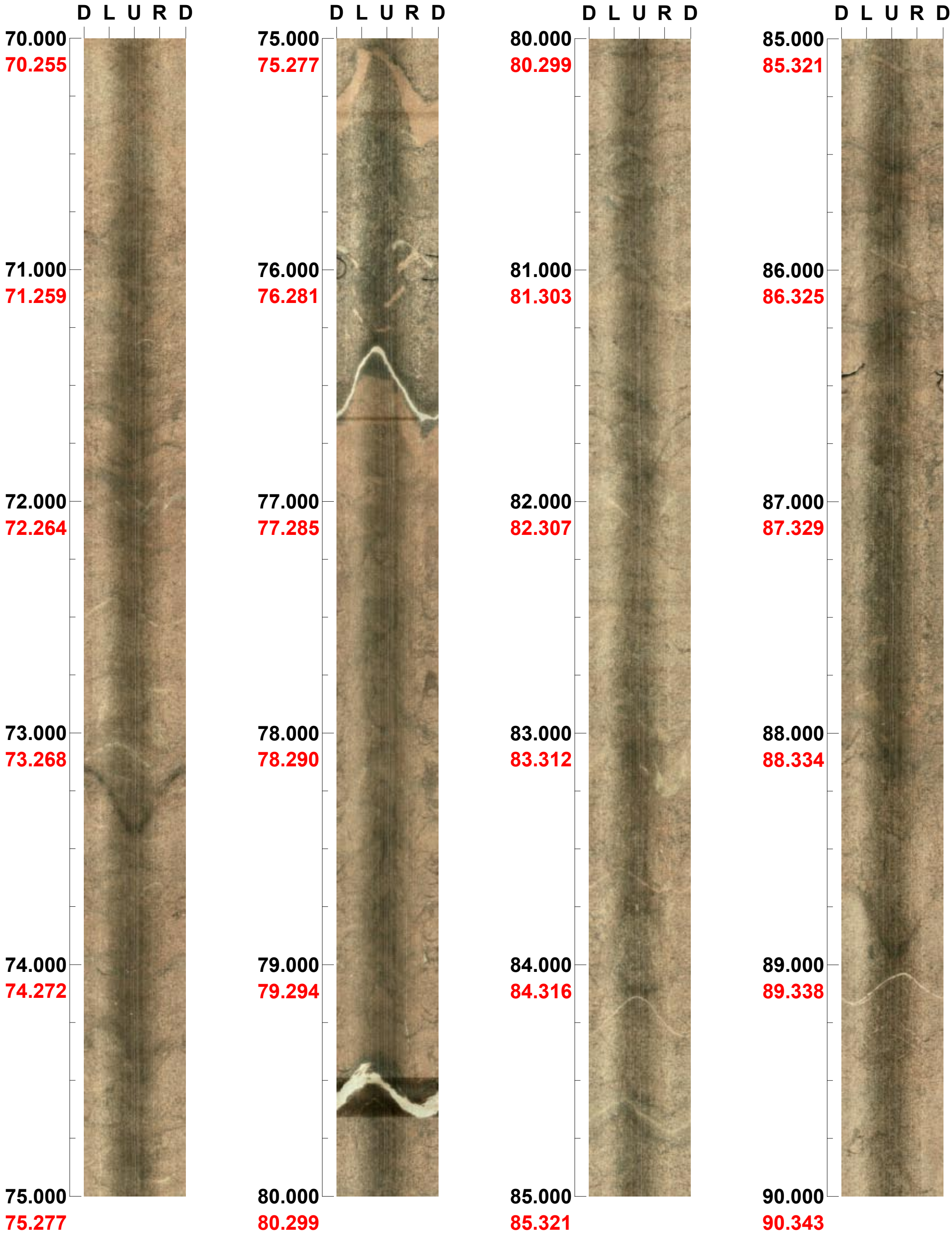
Depth range: 50.000 - 70.000 m



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

Project name: Laxemar
Bore hole No.: HLX32 **Azimuth: 29** **Inclination: -59**

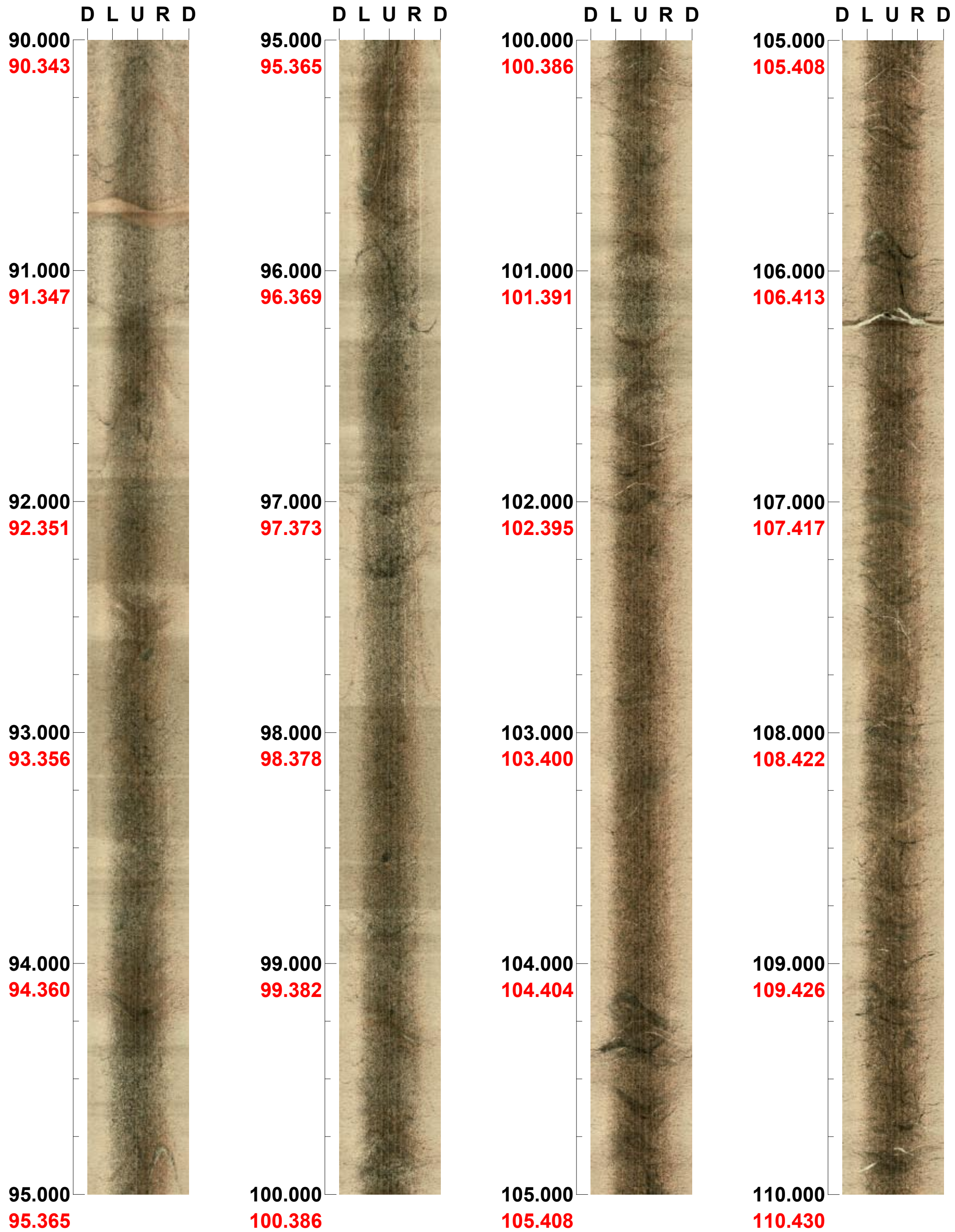
Depth range: 70.000 - 90.000 m



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

Project name: Laxemar
Bore hole No.: HLX32 **Azimuth: 29** **Inclination: -59**

Depth range: 90.000 - 110.000 m



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

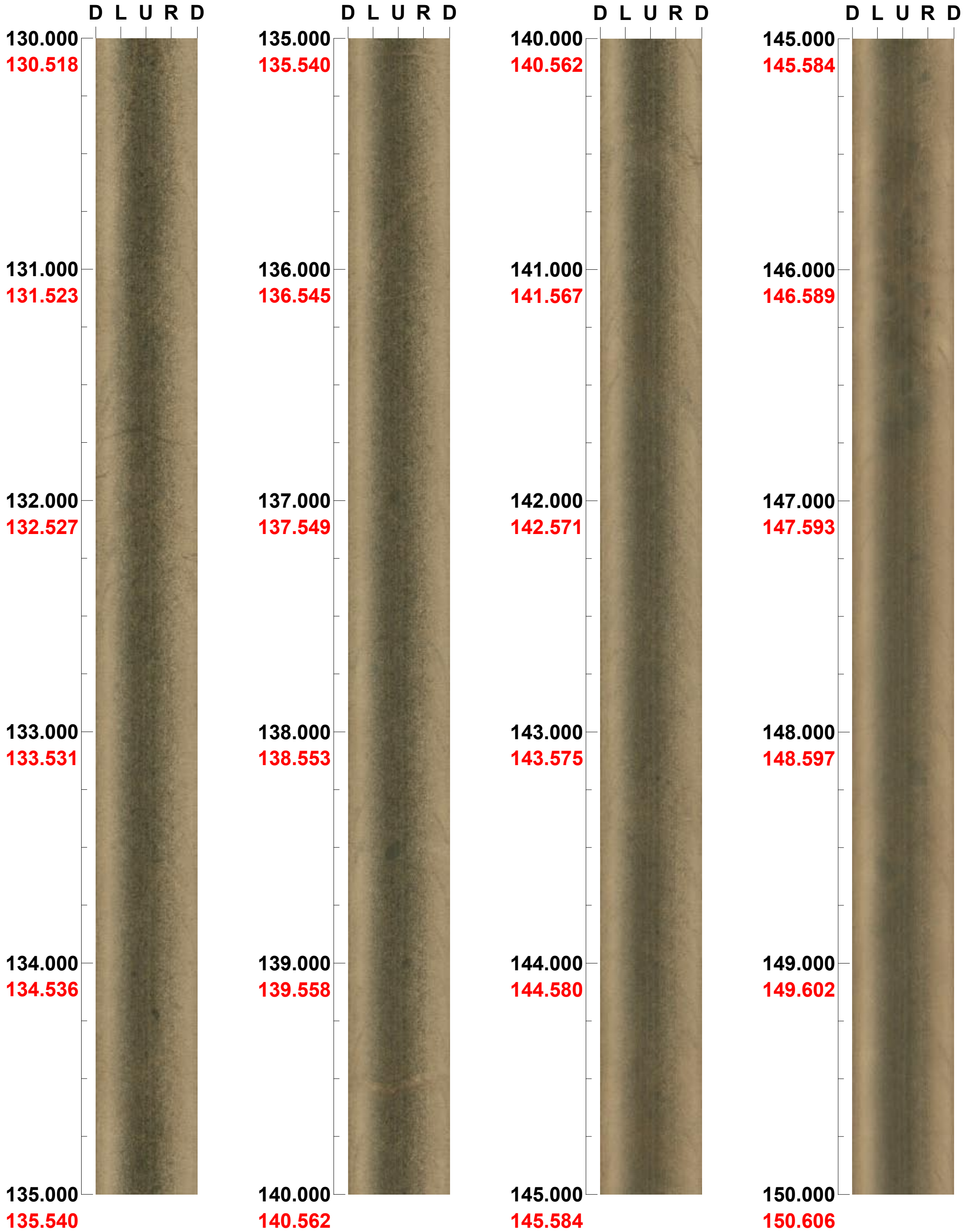
Project name: Laxemar
Bore hole No.: HLX32 **Azimuth: 29** **Inclination: -59**

Depth range: 110.000 - 130.000 m

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

Project name: Laxemar
Bore hole No.: HLX32 **Azimuth: 29** **Inclination: -59**

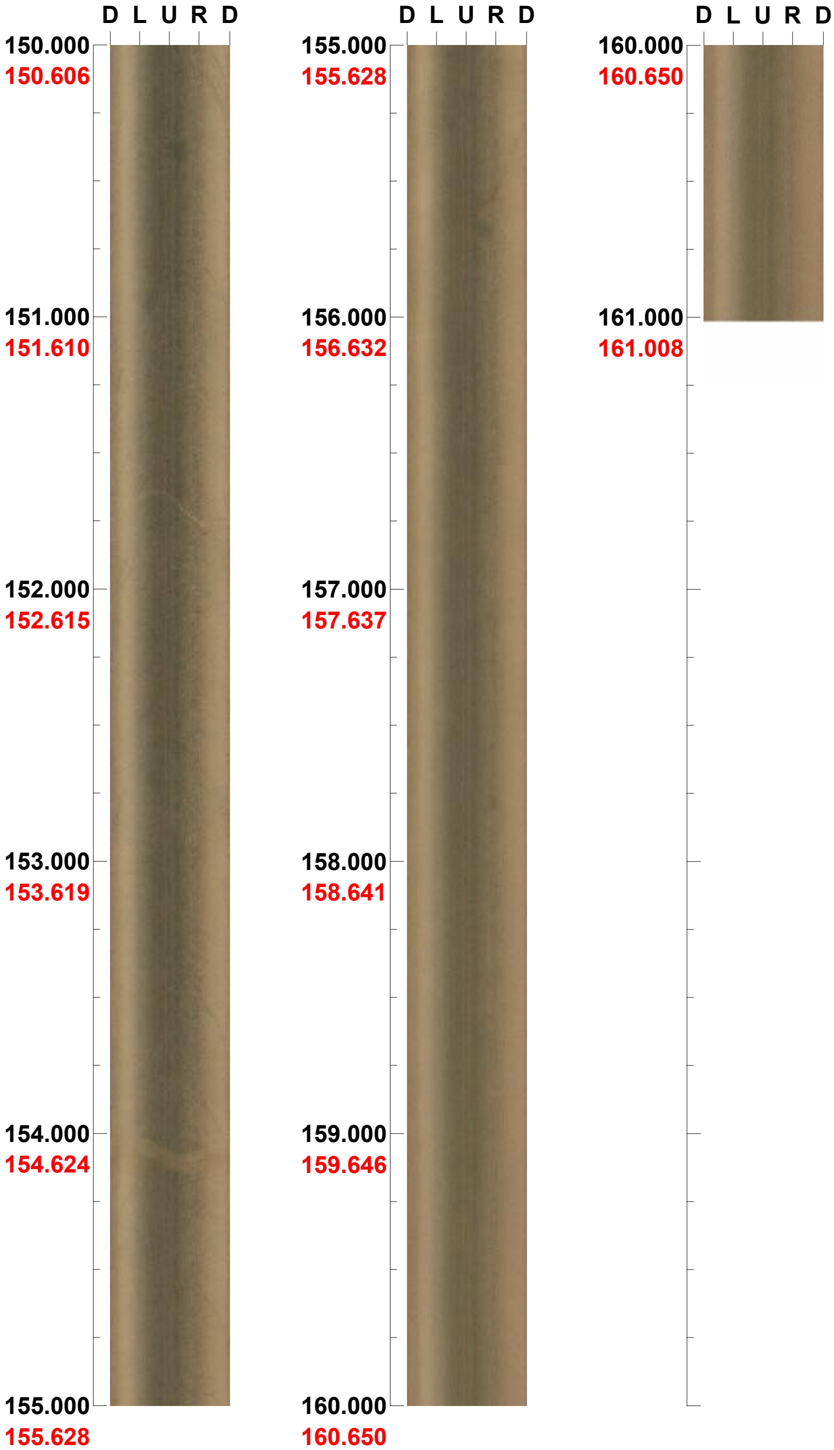
Depth range: 130.000 - 150.000 m



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

Project name: Laxemar
Bore hole No.: HLX32 **Azimuth: 29** **Inclination: -59**

Depth range: 150.000 - 161.013 m



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