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Oskarshamn site investigation

RAMAC and BIPS logging in boreholes KLX10 and HLX31

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February 2006

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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 KLX10 and in the percussion drilled borehole HLX31. All measurements were conducted by Malå Geoscience AB/RAYCON during October and November 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 KLX10 and HLX31 was relatively satisfying, but in some 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 250 identified radar reflectors in KLX10 and of these 34 were orientated (strike/dip). In HLX31 38 radar reflectors were identified.

The BIPS images from KLX10 and HLX31 is of very good quality and makes the geological core logging very easy to perform.

Sammanfattning

Denna rapport omfattar geofysiska loggningar inom platsundersökningsprogrammet för Oskarshamn. Mätningarna som presenteras här omfattar borrhålsradarmätningar (RAMAC), och BIPS-loggningar i kärnborrhålet KLX10, samt i hammarborrhålet HLX31. Alla mätningar är utförda av Malå Geoscience AB/RAYCON under oktober och november 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 KLX10 och HLX31 var relativt tillfredställande, men bitvis med sämre djuppenetration troligen till stor del beroende på en konduktiv miljö. En konduktiv miljö minskar möjligheterna att identifiera strukturer från borrhålsradardata. Dock har 250 radarreflektorer identifierats i KLX10 och av dessa har 34 orienterats (med strykning/stupning). I HLX31 har 38 radarreflektorer identifierats.

BIPS-bilderna från KLX10 och KLX31 är av mycket bra kvalitet vilket gör den geologiska borrkärnekarteringen enkel.

Contents

1 Introduction

This report presents 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 BIPS in the core drilled borehole KLX10 and in the percussion drilled borehole HLX31.

The work was carried out in accordance with activity plan AP PS 400-05-058 and AP PS 400-05-089. In Table 1-1 controlling documents for performing this activity are listed. Both activity plans and method descriptions are SKB's internal controlling documents.

This report includes measurements from 100 to 1,000 m in KLX10 and from 0 to 130 in HLX31. The results from the measurements in KLX08, HLX30 and HLX33 are presented earlier in another report /1/.

The borehole KLX10 are percussion drilled with a diameter of 197 mm down to 100.6 m, from there the borehole is core drilled with a diameter of 76 mm. The percussion drilled borehole HLX31 is drilled with diameter of 139 mm.

All measurements were conducted by Malå Geoscience AB/RAYCON during October and November 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 KLX08, HLX30, HLX31 och HLX33	AP PS 400-05-058	1.0
Borrhålsradar och BIPS i KLX10	AP PS 400-05-089	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	2.0

Figure 1-1. *Map of the location of the boreholes KLX10 and HLX31, in the Laxemar subarea, Oskarshamn.*

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 for the radar and BIPS 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.

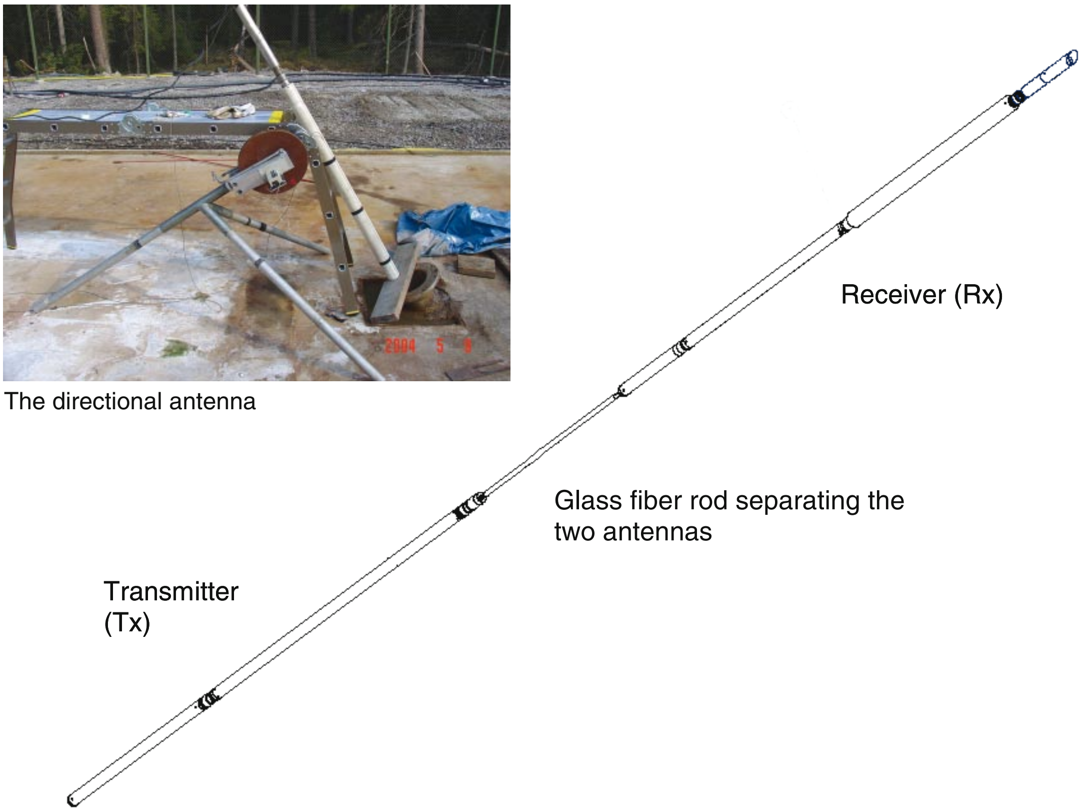


Figure 3-1. *Example of a borehole radar antenna.*

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).

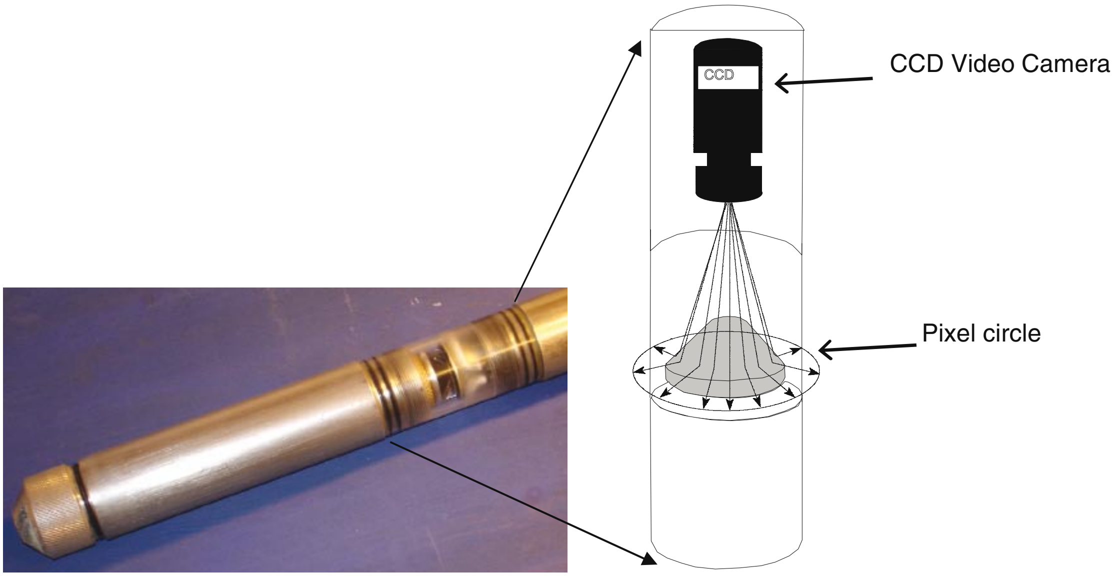


Figure 3-2. *The BIP-system. Illustration of the conical mirror scanning.*

4 Execution

4.1 General

4.1.1 RAMAC Radar

The measurements in KLX10 and HLX31 were carried out with dipole radar antennas, with frequencies of 250, 100 and 20 MHz. In KLX10 measurements were also 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 Tables 4-1 to 4-3. See also Figures 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 KLX10. This was performed 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 8 degrees. This can be considered to be 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 KLX10 and HLX31, see Tables 4-1 and 4-2 below.

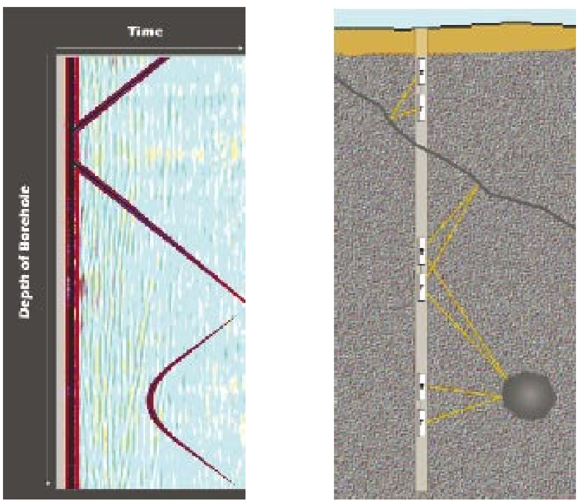


Figure 4-1. *The principle of radar borehole reflection survey and an example of result.*

Table 4-1. Radar logging information from KLX10.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**		
BH:	**KLX10**	**Equipment:**	**SKB RAMAC**		
Type:	**Directional/Dipole**	**Manufacturer:**	**MALÅ GeoScience**		
Operator:	**CG**	**Antenna**			
		Directional	**250 MHz**	**100 MHz**	**20 MHz**
Logging date:		05-11-23	05-11-24	05-11-24	05-11-24
Reference:		T.O.C.	T.O.C.	T.O.C.	T.O.C.
Sampling frequency (MHz):		615	2,424	891	239
Number of samples:		512	619	518	518
Number of stacks:		32	Auto	Auto	Auto
Signal position:		410.5	–0.34	–0.35	–1.42
Logging from (m):		103.4	1.5	2.6	6.25
Logging to (m):		988.4	994.5	992.6	987.2
Trace interval (m):		0.5	0.1	0.2	0.25
Antenna separation (m):		5.73	2.4	3.9	10.05

Table 4-2. Radar logging information from HLX31.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**	
BH:	**HLX31**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Operator:	**CG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
Logging date:		05-10-20	05-10-20	05-10-20
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):		130.9	130.1	126.1
Trace interval (m):		0.1	0.2	0.25
Antenna separation (m):		2.4	3.9	10.05

4.1.2 BIPS

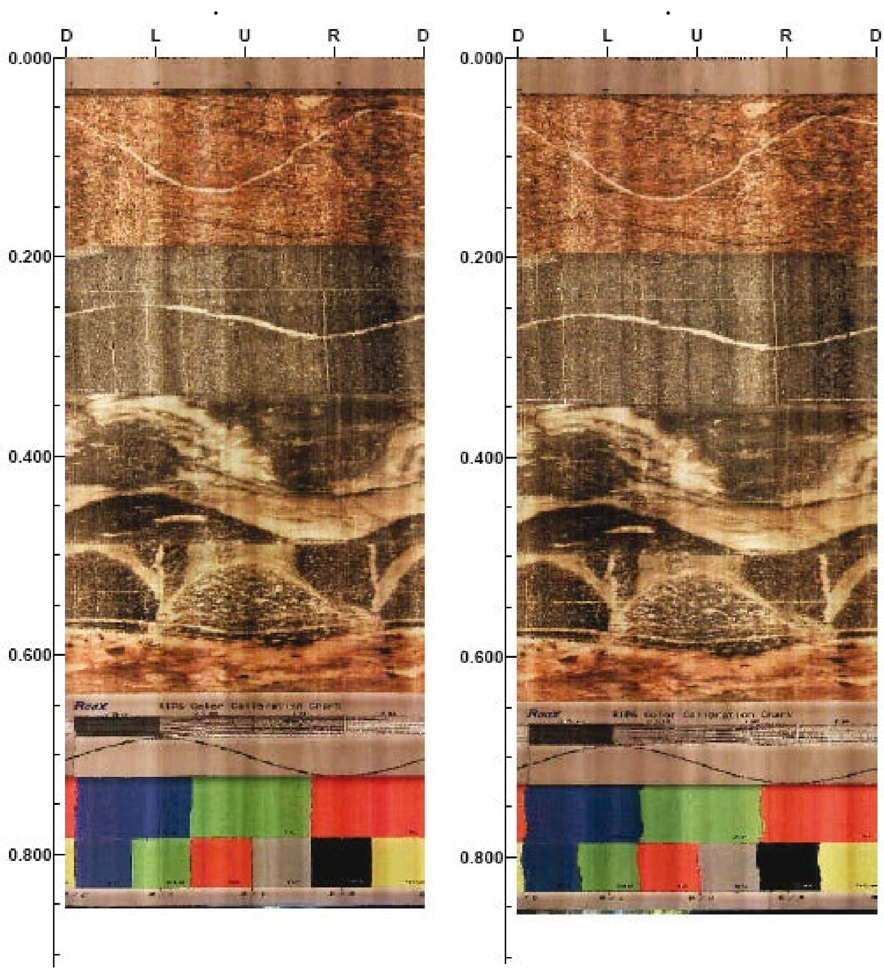
All measurements were performed in accordance with the instructions and guidelines from SKB (internal document MD 222.006). All cleaning of the probe and cable was performed according to the internal document SKB MD 600.004 before the logging operation.

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 KLX10 and HLX31.

In order to control the quality of the system, calibration measurements were performed in a test pipe before logging and after logging. Figures 4-3 and 4-4 show the results of the test logging performed before and after the logging of HLX31 and KLX10. 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 Appendices 3 and 4 in this report.



Before HLX31 **After HLX31**

Figure 4-3. *Results from logging in the test pipe before and after the logging campaign in October 20th, 2005.*

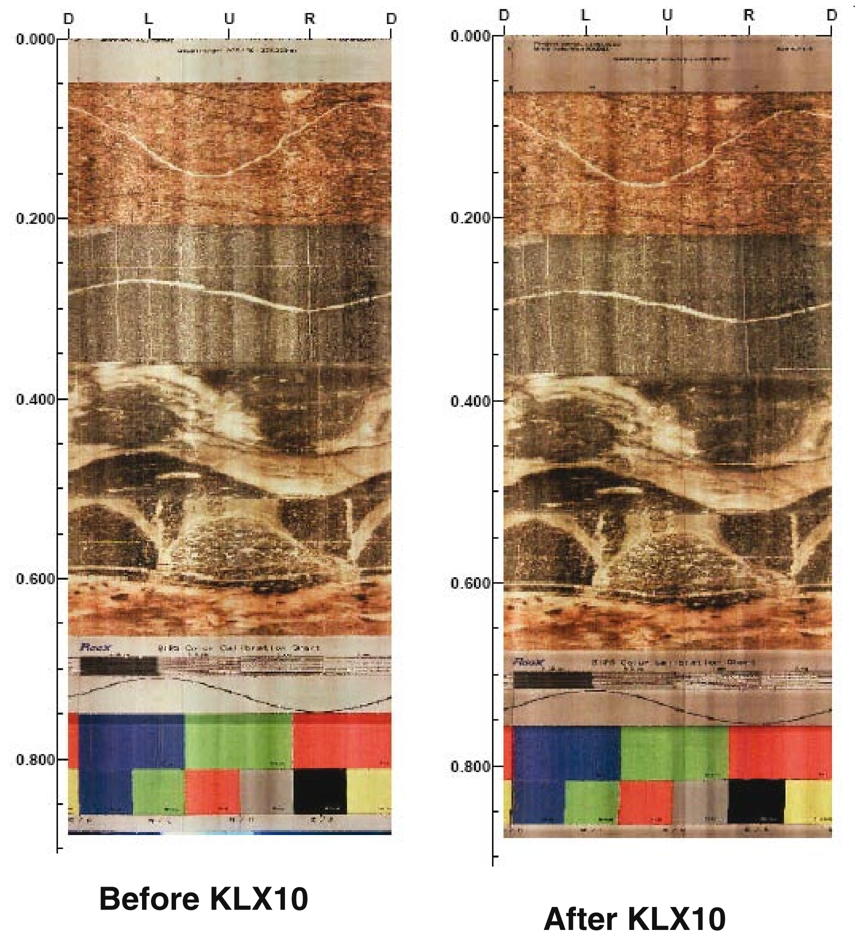


Figure 4-4. Results from logging in the test pipe before and after the logging campaign in November 22th to 24th, 2005.

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 core drilled 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. The non-adjusted length is marked with black as seen in Appendices 3 to 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 depth divergence is less than 100 cm in the deepest parts of a 1,000 m deep borehole.

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

4.2 Analyses and Interpretatoin

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 radar wave propagation and reflection 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. For this logging campaign the velocity determination was performed between KLX07A and KLX07B by keeping the transmitter fixed in one borehole while moving the receiver downwards in a nearby borehole. The velocity measurement was performed with the 20 MHz antennas in boreholes KLX07A and KLX07B /2/.

The result is plotted in Figure 4-5 and the calculation shows a velocity varying between 110 and 117 m/micro seconds. The lower velocities most probably represent a fracture zone in the depth interval 40 to 60 m.

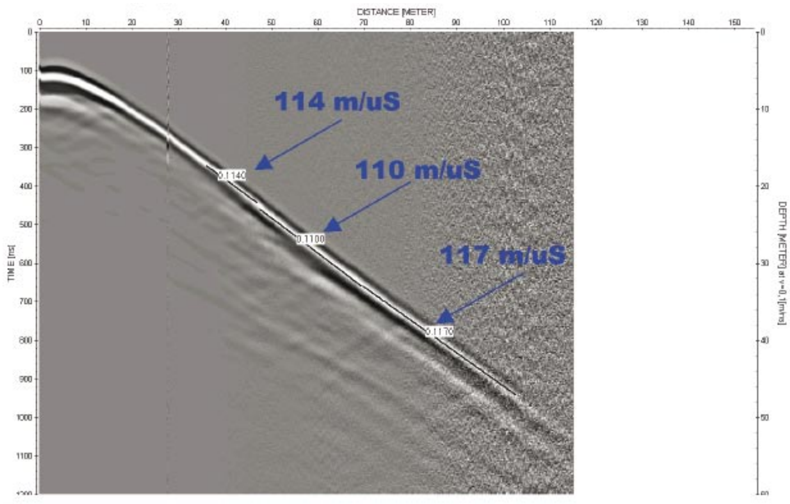


__Figure 4-5.__ Results from velocity measurements /2/.

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 Tables 4-3 and 4-4. It should be observed that the processing steps in Tables 4-3 and 4-4 below refer to Appendices 1 and 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 5-3 and 5-4 and are also visible on the radargrams in Appendices 1 and 2.

Table 4-3. Processing steps for borehole radar data from KLX10.

Site:	**Oskarshamn**		**Logging company:**	**RAYCON**	
BH:	**KLX10**		**Equipment:**	**SKB RAMAC**	
Type:	**Directional/Dipole**		**Manufacturer:**	**MALÅ GeoScience**	
Interpret:	**JG**		**Antenna**		
		Directional	**250 MHz**	**100 MHz**	**20 MHz**
Processing:		Move start time (–56 samples)	Move start time (–22.7)	Move start time (–43.6)	Move start time (–99.9)
		DC shift (400–510)	DC shift (190–230)	DC shift (470–530)	DC shift (1,800–2,000)
		Time gain (start 99 lin 150 exp 1)	Gain (start 20 lin 2.1 exp 0.6)	Gain (start 60 lin 2.5 exp 0.6)	Gain (start 122 lin 6.2 exp 0.17)
		(FIR)			

Table 4-4. Processing steps for borehole radar data from HLX31.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**	
BH:	**HLX31**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Interpret:	**JG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
Processing:		Move start time (–24)	Move start time (–45.6)	Move start time (–79.4)
		DC removal (200–250)	DC removal (475–525)	DC removal (1,800–2,000)
		Gain (start 32 linear 2 exp. 1.1)	Gain (start 48 linear 2.5 exp 0.6)	Gain (start 146 linear 3.6, exp 0.2)

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

No nonconformities occurred during the two logging campaigns in October and November.

5 Results

The results from the BIPS measurements for KLX10 and HLX31 were delivered as raw data (*.bip-files) on CD-ROM disks and MO-disks 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 digital data and VHS tapes stored by SKB.

The RAMAC radar data was delivered as raw data (file format *.rd3 or *.rd5) for KLX10 and HLX31 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 and in Table 5-7. Radar data is also visualized in Appendices 1 and 2. It should be remembered that the images in Appendices 1 and 2 are only a composite picture of all events 360 degrees around the borehole, and do not reflect the orientation of the structures.

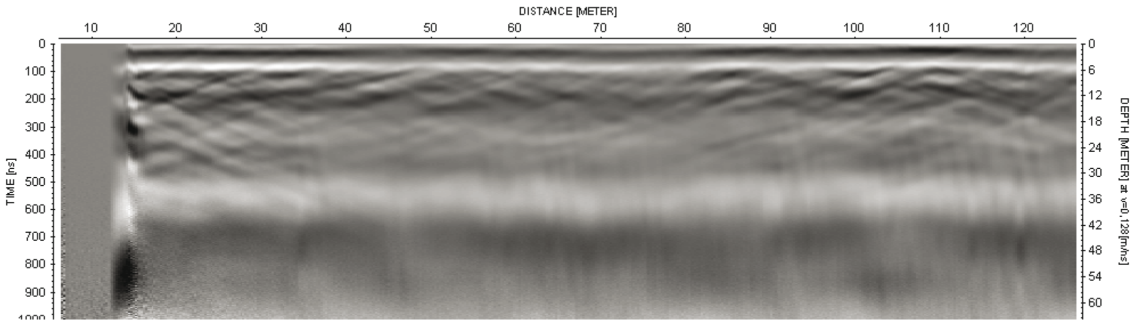
Only the larger visible structures are interpreted in RadinterSKB. Overviews of the two different boreholes are given in Figure 5-1 below. A number of minor structures also exist but not interpreted as indicated in Appendices 1 and 2. Often a number of structures can be noticed, but most probably lying so close to each other that it is impossible to distinguish one from the other (see Figure 5-2). Larger structures parallel to the borehole, if present, are also indicated in Appendices 1 and 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 KLX10 and HLX31, (as seen in Appendices 1 and 2) is satisfying, but in relatively large parts of lower quality due to more conductive conditions. This is seen for both boreholes (see for instance 250 MHz data in Appendices 1 and 2). A conductive environment makes the radar wave to attenuate, which decreases the penetration. This conductive environment of course also reduces the possibility to distinguish and interpret possibly structures in the rock which otherwise could give a reflection.

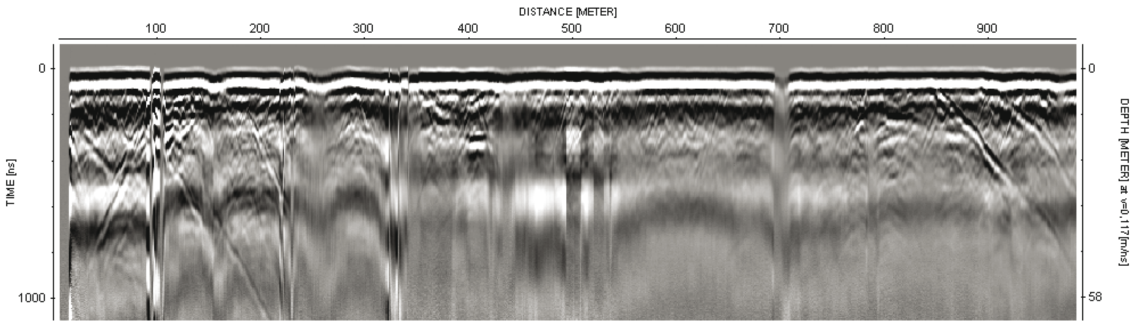
This effect is also seen in the directional antenna for KLX10, which makes it more difficult to interpret the direction to the identified structures.

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 data from KLX10, (250 and 100 MHz data) for the first 100 m, where the borehole diameter is larger, see Figure 5-3.

In parts with an increased conductivity and thereby a decreased depth penetration most often only the edges of structures can be distinguished, giving an intersection angle of 90 degrees.



HLX31



KLX10

Figure 5-1. *An overview (20 MHz data) of the radar data for the two different boreholes; HLX31 and KLX10. Observe that the length (x-scale)and depth (y-scale) differs between the different boreholes.*

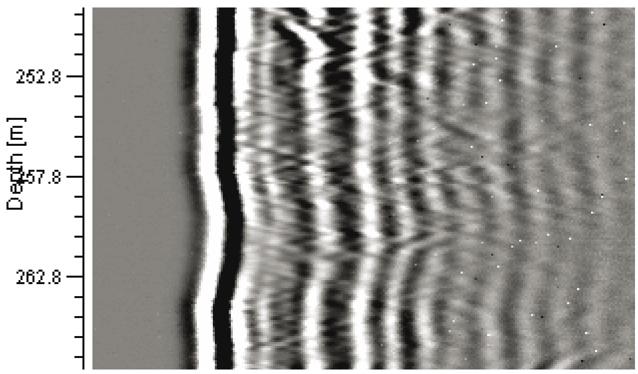


Figure 5-2. *Example of data from KLX10 (250 MHz data) where a number of structures are seen but lying so close to each other, that one can not be distinguished from the other.*

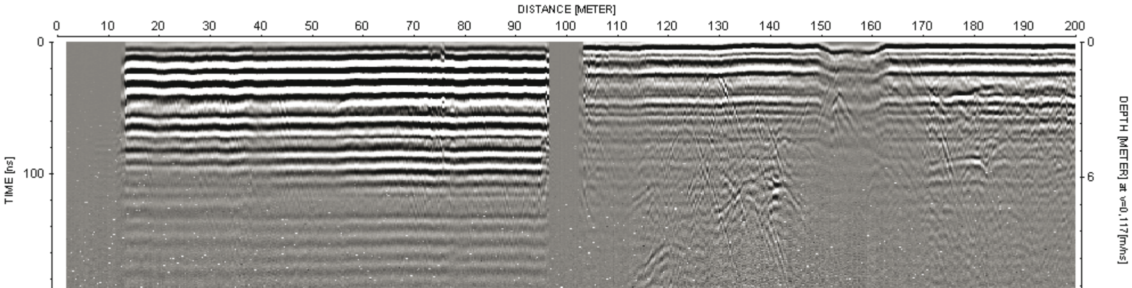


Figure 5-3. *Example of data from KLX10, 250 MHz. The effect of the two different borehole diameters are clearly seen, in the amount of so called ringing, in the upper part compared to the lower part of the picture.*

In Appendix 1, KLX10, three distinct anomalies can be identified for all antenna frequencies, at depths of 226, 328 and 338 m. These are due to perforated steel plates placed in the borehole to prevent the borehole walls to collapse.

As also seen in Appendices 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 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 and 5-2 below the distribution of identified structures along the borehole are listed for KLX10 and HLX31.

Table 5-1. Identified structures as a function of depth in KLX10.

Depth (m)	No. of structures
–100	16
100–150	11
150–200	12
200–250	9
250–300	11
300–350	17
350–400	13
400–450	16
450–500	13
500–550	14
550–600	14
600–650	9
650–700	14
700–750	15
750–800	20
800–850	7
850–900	16
900–950	14
950–	9

Table 5-2. Identified structures as a function of depth in HLX31.

Depth (m)	No. of structures
–20	1
20–40	8
40–60	7
60–80	6
80–100	7
100–120	3
120–140	5
140–160	1

Tables 5-3 and 5-4 summarises the interpretation of radar data from KLX10 and HLX31. For KLX10 the direction to the reflector (object) is also given. As seen some radar reflectors in Table 5-3 are marked with ±, which indicates an uncertainty in the interpretation of direction. The direction can in these cases be ± 180 degrees. The direction to the reflector (object) is defined in Figure 5-4. As the borehole inclination is less than 85 degrees the direction to object is calculated using gravity roll. The direction to object and the intersection angle are recalculated to strike and dip, also given in Table 5-3. 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 is given. This is seen for structure 20 in Table 5-3 and Appendix 1. To this structure, most likely, also structure 20x belongs.

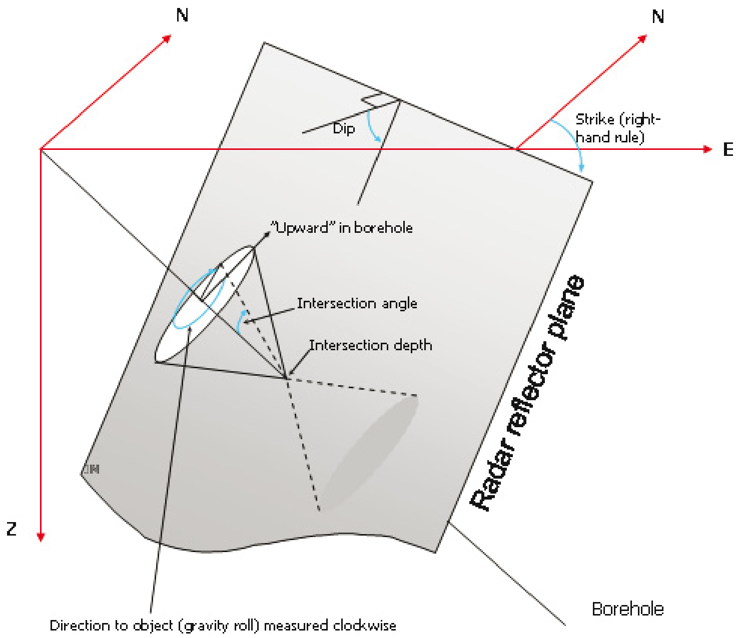


Figure 5-4. *Definition of intersection angle, direction to object using gravity roll, dip and strike using the right hand rule as presented in Table 5-3.*

Table 5-3. Interpretation of radar reflectors from the dipole antennas 250, 100 and 20 MHz, and the directional antenna 60 MHz in borehole KLX10.

RADINTER MODEL INFORMATION
(Directional antenna)

Site:	**Oskarshamn**
Borehole name:	**KLX10**
Nominal velocity (m/μs):	**117.0**

Name	Intersection depth	Intersection angle	RadInter direction to object (gravity roll)	Dip 1	Strike 1	Dip 2	Strike 2
238	–34.1	19					
1	22.6	69					
2	29.4	63					
3	37.8	74					
11	38.1	45					
5	38.2	45					
4	42.2	67					
7	57.1	39					
6	57.8	56					
243	71.9	31					
9	74.0	74					
10	78.2	55					
239	83.0	49					
8	91.1	54					
241	92.3	49					
240	99.2	61					
12	107.1	53					
13	110.6	58					
14	117.9	48	297 ±	43	301	37	105
17	119.3	66					
15	120.8	58					
242	124.2	35					
237	124.9	37					
16	124.6	62					
18	130.6	55					
110	132.6	62	102 ±	27	84	30	292
19	134.3	65					
22	151.7	58					
20x	152.3	51					
20	152.7	42					
21	155.0	46					
23	166.2	47					
244	167.1	43					
25	169.1	50	282 ±	44	287	41	91
24	176.3	75	69 ±	20	46	15	273
248	182.1	36					
247	192.2	50	60 ±	43	50	36	246
26	193.2	44					
27	199.7	54					
30	202.2	55					

RADINTER MODEL INFORMATION
(Directional antenna)

Site: **Oskarshamn**
Borehole name: **KLX10**
Nominal velocity (m/μs): **117.0**

Name	Intersection depth	Intersection angle	RadInter direction to object (gravity roll)	Dip 1	Strike 1	Dip 2	Strike 2
28	203.3	56					
29	211.8	46					
31	216.3	60					
32	223.2	58	240 ±	31	248	38	48
34	229.8	59					
36	233.5	62					
33	239.0	68					
35	245.1	52					
38	252.2	54					
37	253.6	71					
39	257.8	63					
42	264.9	48					
41	266.5	57					
40	267.5	65	108 ±	24	100	29	308
44	276.0	53					
43	282.2	55	258 ±	32	277	35	75
46	285.1	53					
49	286.7	29					
45	292.2	56					
112	301.9	66					
111	302.4	46					
52	303.2	58					
47	304.2	52					
48	305.4	63					
54	306.8	61					
50	309.1	54	252 ±	35	263	39	66
51	312.6	68					
53	322.8	57					
55	324.9	53					
56	326.5	86					
69	327.7	8	258 ±	80	261	83	79
57	328.0	52					
58	339.0	62					
60	344.4	59					
59	346.4	57					
61	348.7	66					
251	355.5	36	192 ±	47	195	61	13
66	358.2	69					
62	362.2	51					
63	362.2	28					
64	365.5	40					
65	368.5	55					
68	372.1	15					

RADINTER MODEL INFORMATION
(Directional antenna)

Site:	**Oskarshamn**
Borehole name:	**KLX10**
Nominal velocity (m/μs):	**117.0**

Name	Intersection depth	Intersection angle	RadInter direction to object (gravity roll)	Dip 1	Strike 1	Dip 2	Strike 2
73	393.5	54					
70	395.1	52					
71	398.3	63					
74	398.3	64					
250	398.5	3	63	90	238		
245	399.1	54					
67	403.9	14					
76	405.6	53					
75	408.0	66					
77	410.6	49					
78	416.9	78					
79	418.8	52					
246	422.1	46					
80	422.8	77					
81	423.5	79					
82	428.8	60	351 ±	36	344	23	160
83	430.4	57					
84	434.0	58	240 ±	32	250	39	54
88	438.6	56					
85	442.3	53					
86	444.2	54					
87	446.2	49					
90	454.1	81					
89	454.5	59					
93	457.4	58					
92	460.1	66					
91	460.4	44					
94	463.7	55					
96	467.2	57					
95	474.2	58					
99	476.9	60					
100	480.0	50					
97	482.5	48					
98	484.8	57					
101	488.0	70	270 ±	22	279	22	64
102	501.0	58					
115	508.7	67	132 ±	19	108	29	313
107	509.1	62					
106	509.3	50					
114	516.9	56	84 ±	36	66	36	265
113	519.8	56					
116	526.9	58					
120	528.2	49					

RADINTER MODEL INFORMATION
(Directional antenna)

Site: **Oskarshamn**
Borehole name: **KLX10**
Nominal velocity (m/μs): **117.0**

Name	Intersection depth	Intersection angle	RadInter direction to object (gravity roll)	Dip 1	Strike 1	Dip 2	Strike 2
118	531.6	54					
117	531.9	34					
122	533.5	58					
119	534.0	43					
121	534.2	52					
123	548.3	58					
128	557.6	41					
124	559.6	56					
253	565.3	42	327 ±	54	317	42	130
126	568.7	48					
127	570.6	45					
129	577.0	47					
125	579.4	41					
132	579.6	64					
130	582.6	51					
131	584.3	75					
133	586.7	44					
134	592.2	44					
136	595.1	66	324	29	319		
135	597.7	51					
137	605.0	46					
138	609.1	64	150 ±	20	127	33	323
142	620.0	30					
143	625.6	61					
139	614.8	63					
140	631.3	64					
141	636.9	52	285 ±	38	273	35	74
144	646.6	71					
146	647.7	60					
145	650.0	70					
147	654.5	68					
148	656.2	62	315	35	302		
149	660.3	61					
150	663.0	59					
151	668.8	72					
152	673.8	50					
234	676.2	69					
153	679.3	47	294 ±	45	280	39	85
154	680.4	60					
155	686.9	45					
160	692.8	58					
156	693.6	52	309 ±	43	285	33	91
235	698.7	53					

RADINTER MODEL INFORMATION
(Directional antenna)

Site: **Oskarshamn**
Borehole name: **KLX10**
Nominal velocity (m/μs): **117.0**

Name	Intersection depth	Intersection angle	RadInter direction to object (gravity roll)	Dip 1	Strike 1	Dip 2	Strike 2
158	700.2	56					
157	701.1	46	297	46	274		
159	703.9	53					
162	713.6	60					
163	715.4	46					
161	722.5	63					
164	724.8	57					
165	726.5	87					
249	728.8	68	33 ±	29	356	17	196
166	729.9	69					
167	734.2	69	180 ±	14	150	29	330
168	737.7	64					
169	740.7	70					
170	749.9	52					
172	750.6	77					
171	752.9	67					
173	757.0	62					
174	759.4	59					
176	760.7	53					
175	762.3	66					
177	768.2	65	270 ±	31	277	30	72
179	771.3	50					
178	772.3	65					
180	773.4	62					
181	782.0	54					
183	782.9	46	30	50	22		
182	783.1	60					
187	788.1	90					
189	788.1	69					
184	790.2	62					
191	791.5	71					
185	797.4	43					
188	798.9	43					
186	799.8	57					
190	809.9	53					
192	816.2	47					
193	821.4	58					
197	824.9	18					
194	826.8	58					
195	828.8	60					
196	838.5	43	6	80	1		
198	854.1	52					
202	859.7	51					

RADINTER MODEL INFORMATION
(Directional antenna)

Site: **Oskarshamn**
Borehole name: **KLX10**
Nominal velocity (m/μs): **117.0**

Name	Intersection depth	Intersection angle	RadInter direction to object (gravity roll)	Dip 1	Strike 1	Dip 2	Strike 2
205	862.7	50					
199	864.4	50					
214	868.8	14	357	84	353		
206	871.9	44					
203	873.4	45					
200	877.8	19					
208	880.4	59					
204	881.9	50					
201	888.1	16					
207	888.8	53					
210	890.4	49					
209	893.2	47					
236	895.3	49					
211	899.1	60					
213	903.0	61					
212	903.4	44					
252	905.3	12	27	85	22		
214x	908.6	28					
215	915.7	54					
218	917.7	62					
217	921.7	81					
219	925.5	75					
216	926.9	57					
220	930.7	57					
221	940.9	61	339	36	339		
222	942.8	49					
223	945.1	57					
225	948.7	63					
224	950.8	47					
228	959.7	51					
226	967.5	54					
233	971.1	61					
232	973.6	65					
227	974.9	55					
229	982.5	51					
230	993.7	63	300 ±	31	308	24	100
231	999.6	61					

Table 5-4. Interpretation of radar reflectors from the dipole antennas 250, 100 and 20 MHz, in borehole HLX31.

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

Site:	**Oskarshamn**
Borehole name:	**HLX31**
Nominal velocity (m/µs):	**117.0**

Object type	Name	Intersection depth	Intersection angle
PLANE	1	10.8	62
PLANE	10	20.1	60
PLANE	5	22.6	60
PLANE	2	27.9	64
PLANE	3	28.9	59
PLANE	4	29.3	50
PLANE	6	31.9	61
PLANE	7	34.0	56
PLANE	29	39.9	51
PLANE	9	40.2	35
PLANE	8	40.7	45
PLANE	11	49.5	44
PLANE	13	52.9	50
PLANE	14	54.3	56
PLANE	35	56.9	64
PLANE	15	57.1	54
PLANE	37	66.1	31
PLANE	38	74.5	41
PLANE	32	74.8	35
PLANE	12	76.7	18
PLANE	19	77.2	50
PLANE	28	79.4	53
PLANE	20	82.9	48
PLANE	16	86.4	56
PLANE	18	89.2	74
PLANE	17	90.2	67
PLANE	27	93.0	55
PLANE	25	96.5	63
PLANE	21	98.1	57
PLANE	22	100.4	57
PLANE	30	115.0	68
PLANE	26	115.6	52
PLANE	23	115.9	54
PLANE	33	118.2	78
PLANE	24	120.0	58
PLANE	34	120.4	43
PLANE	31	121.0	51
PLANE	36	142.3	57

In Appendices 1 and 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 Tables 5-5 and 5-6.

Finally, the structures considered as the most important (clear in the radargram, identified with several antenna frequencies, stretching out far from the borehole wall etc) are listed in Table 5-7 below.

Table 5-5. Borehole length intervals in KLX10 with decreased amplitude for the 250 MHz antenna.

Length (m)	Length (m)
105–115	445
145–165	455
165–170	460
175	520
220–230	530
240–280	550
310	560
320–350	695–715
365	725
395	745
425	790
430	920
435–440	960–980

Table 5-6. Borehole length intervals in HLX31 with decreased amplitude for the 250 MHz antenna.

Length (m)	Length (m)
15	85
25–30	95–100
40–45	110
60–65	115–130
70–80	

Table 5-7. Some important structures in KLX10 and HLX31.

Borehole	KLX10	HLX31
Structures	22, 43, 52, 60, 65, 98, 107, 123, 125, 147, 149, 197, 199, 214, 214x, 215, 221, 238, 242, 243, 244, 247	8, 12, 26 and 37

Observe that it can be very difficult to classify different structures in an objective manner, along a borehole. This is due to the fact that the water quality (the conductivity) amongst others varies along the borehole length and by that reason affects the results of the radar logging, by for instance attenuating the radar waves differently. Also the intersection angle of the identified structures affects the amplitude on the resulting radargram. A small angle will most often give a increased amplitude than a larger angle, and by that a more clear structure.

5.2 BIPS logging

The BIPS pictures from KLX10 and HLX31 are presented in Appendices 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 raw data.

To get the best possible depth accuracy, the BIPS images are adjusted to the reference mark on the cable for the logging in KLX10. For HLX31 the marks on the logging cable at 110 m was used for adjustment of the depth.

The error in the depth recording depends mainly on 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.

Several inspections in KLX10 has been performed with the BIPS during the drilling phase. The aim was to check the stability of the borehole walls. This inspections resulted that perforated steel plates was placed at 226 m, 328 m and 338 m to avoid rock pieces to enter in to the borehole and cause equipment to jam. The BIPS images from the boreholes are of very good quality. No discolouring on the borehole wall in combination with very good water quality results in very good images and makes the geological core logging very easy to perform.

Also in HLX31 the water condition is perfect and resulted in images of very high quality.

References

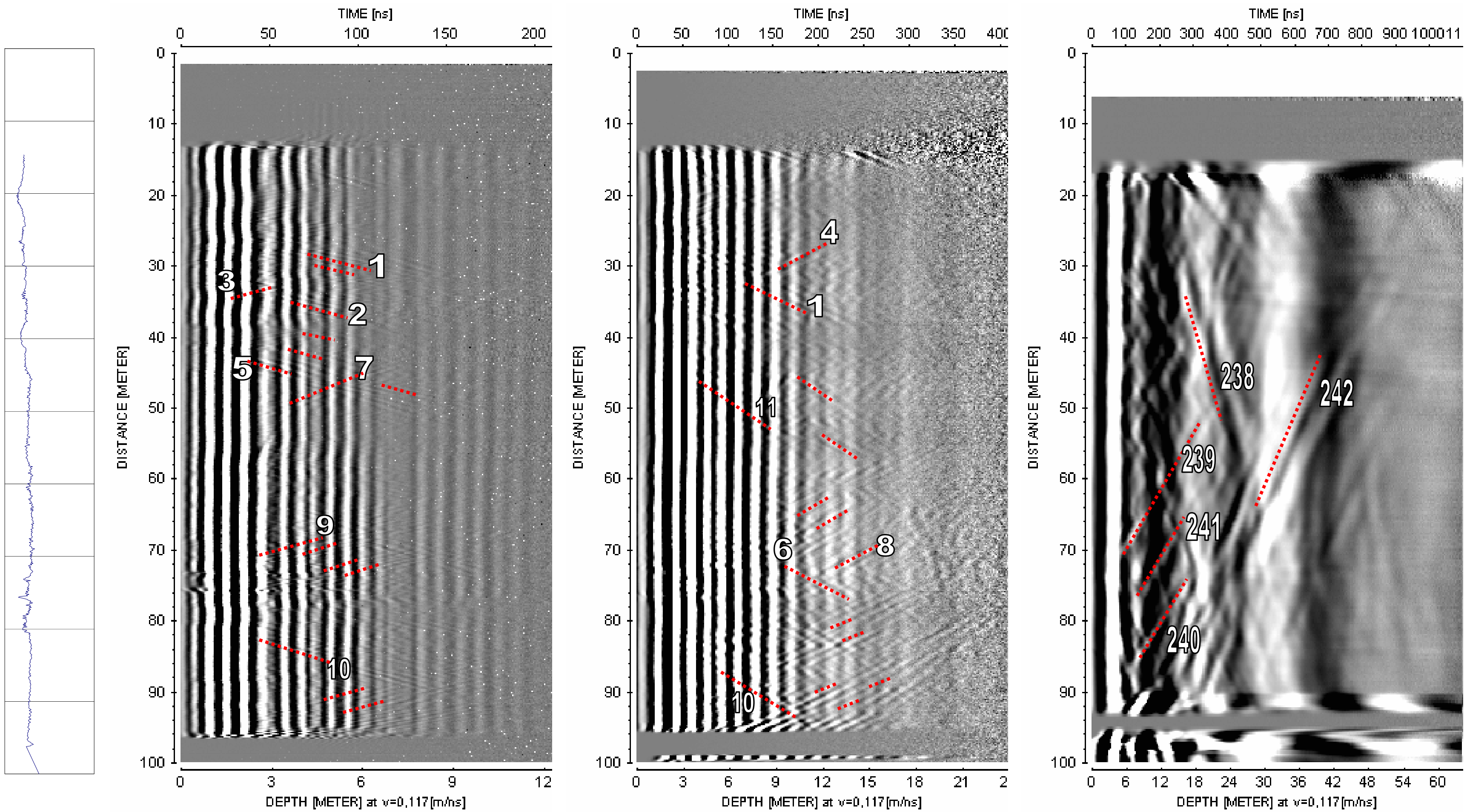
1 **Gustafsson J, Gustafsson C, 2005.** Oskarshamn site investigation. RAMAC and BIPS logging in boreholes KLX08, HLX30 and HLX33 and deviation logging in boreholes HLX30 and HLX33. SKB P-05-240, Svensk Kärnbränslehantering AB.

2 **Gustafsson J, Gustafsson C, 2005.** Oskarshamn site investigation. RAMAC and BIPS logging in boreholes KLX07A, KLX07B, HLX34 and HLX35 and deviation logging in boreholes KLX07B, HLX34 and HLX35. SKB P-05-231, Svensk Kärnbränslehantering AB.

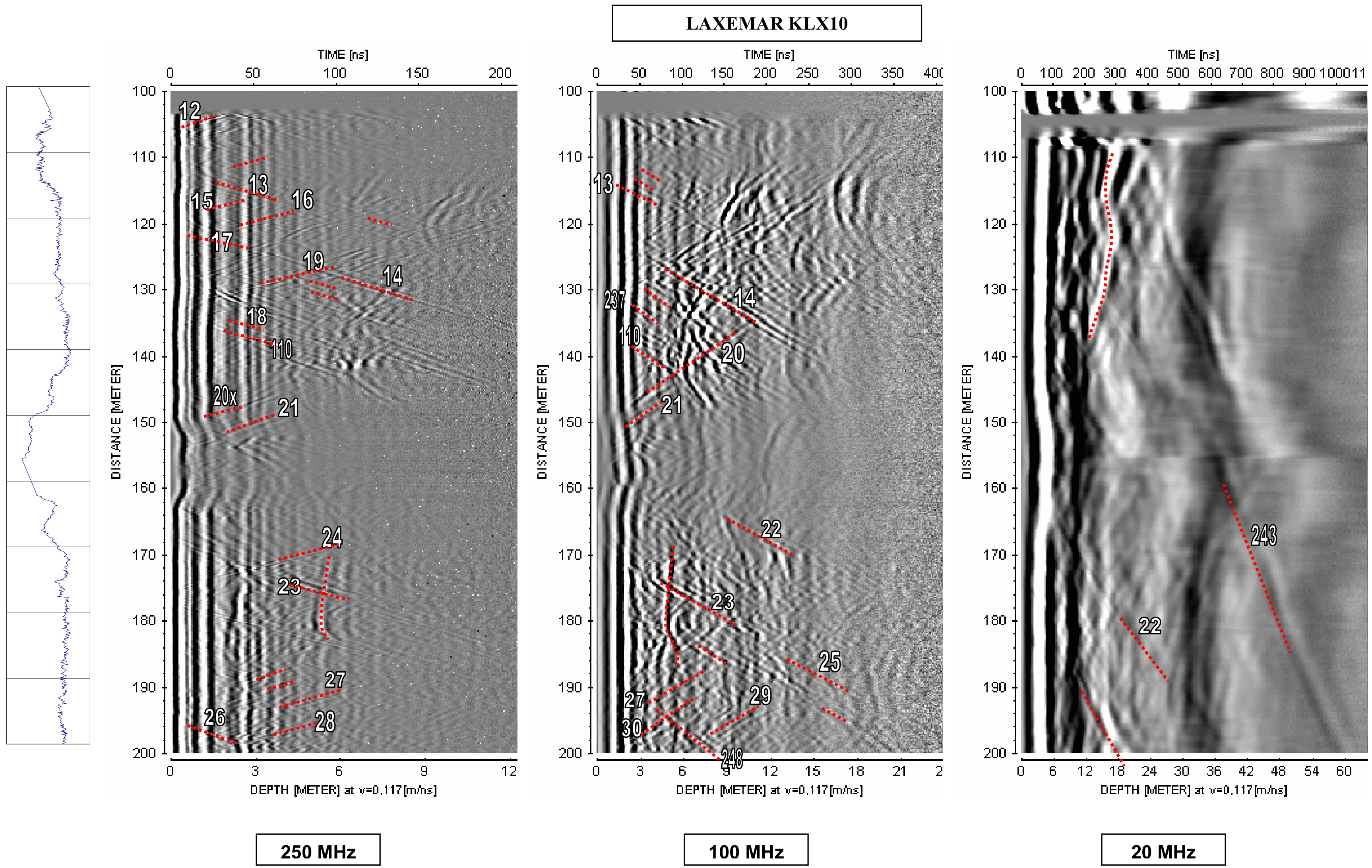
Appendix 1

Radar logging in KLX10, 0 to 993 m, dipole antennas 250, 100 and 20 MHz

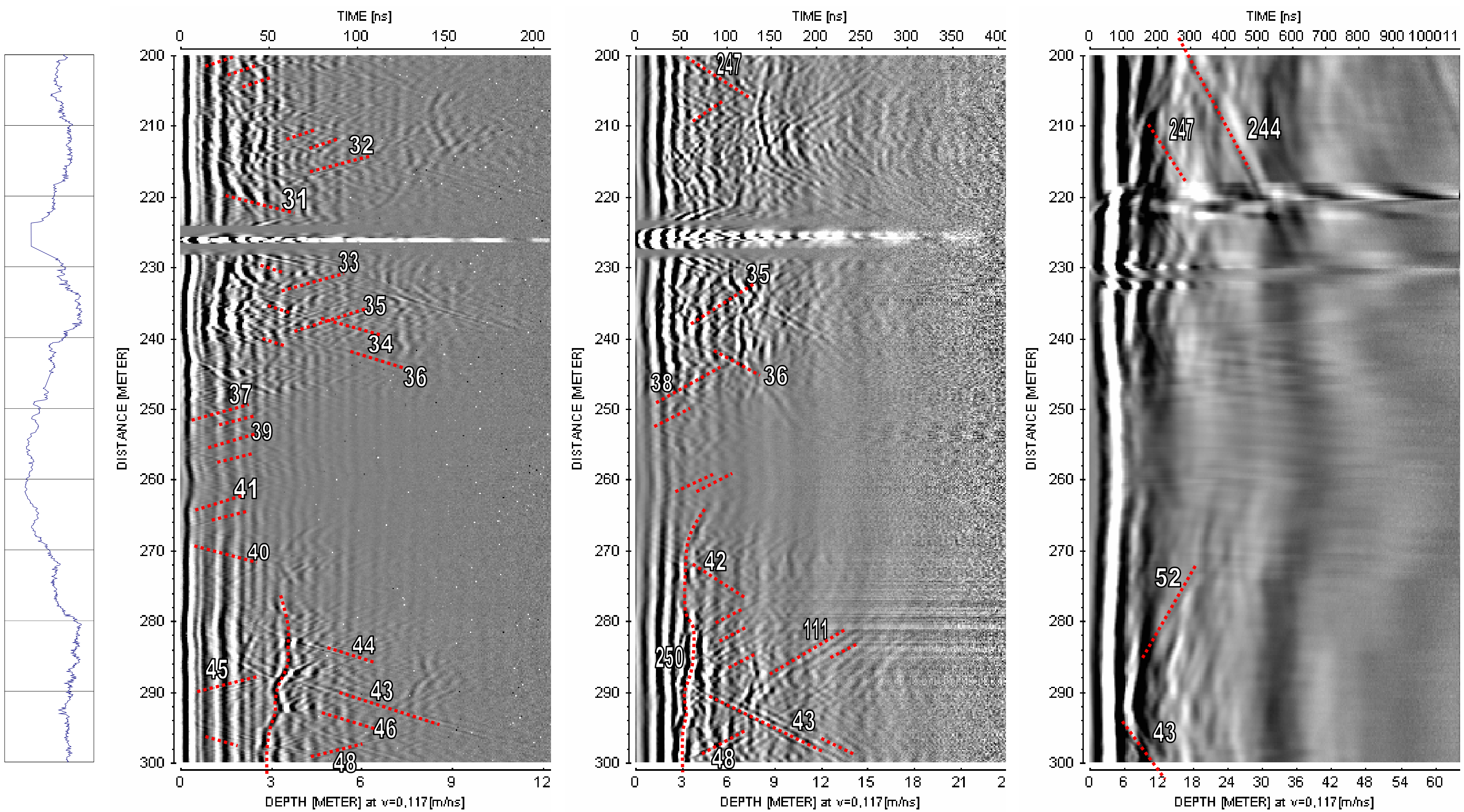
LAXEMAR KLX10



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

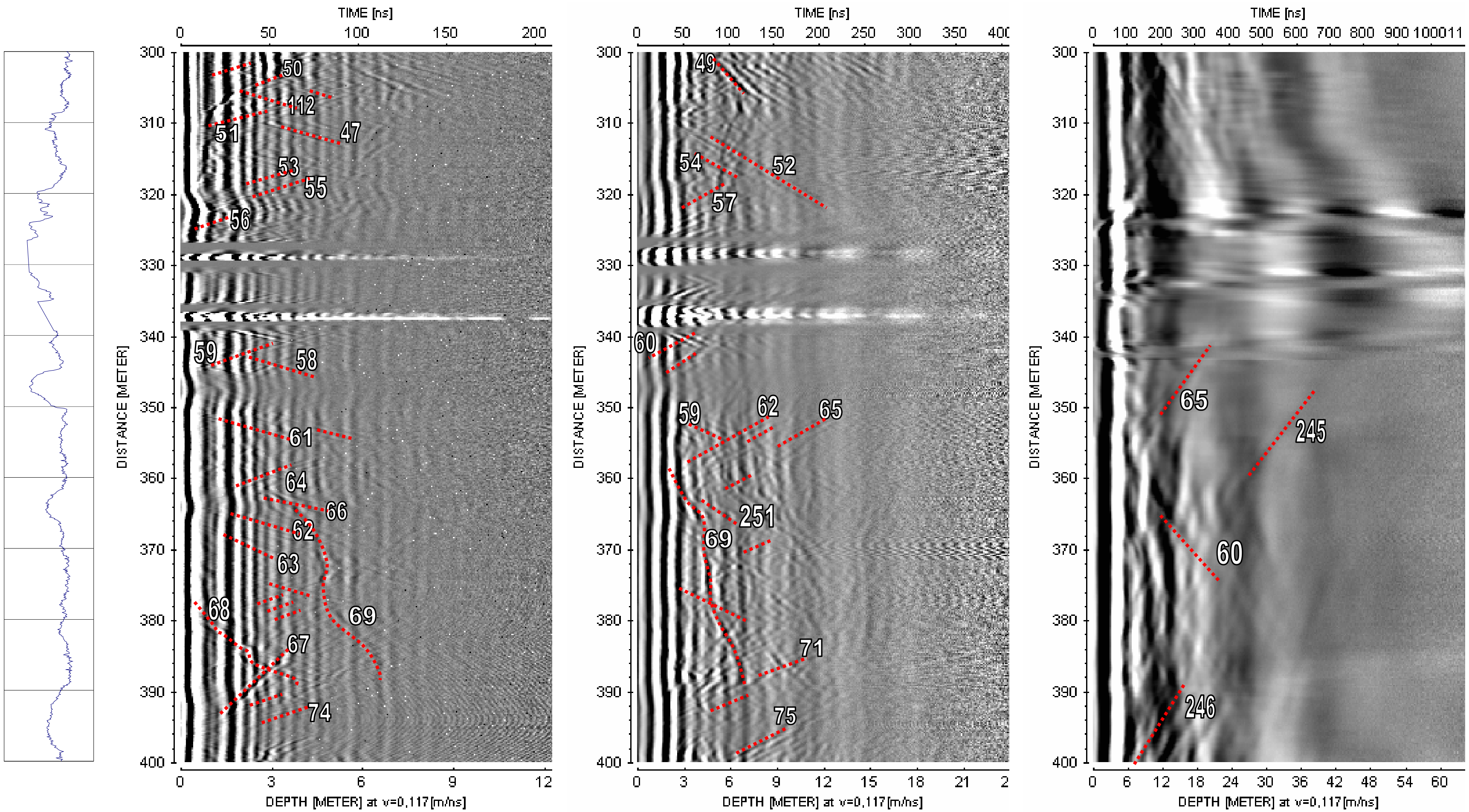

LAXEMAR KLX10
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,117[m/ns]
250 MHz
100 MHz
20 MHz

LAXEMAR KLX10



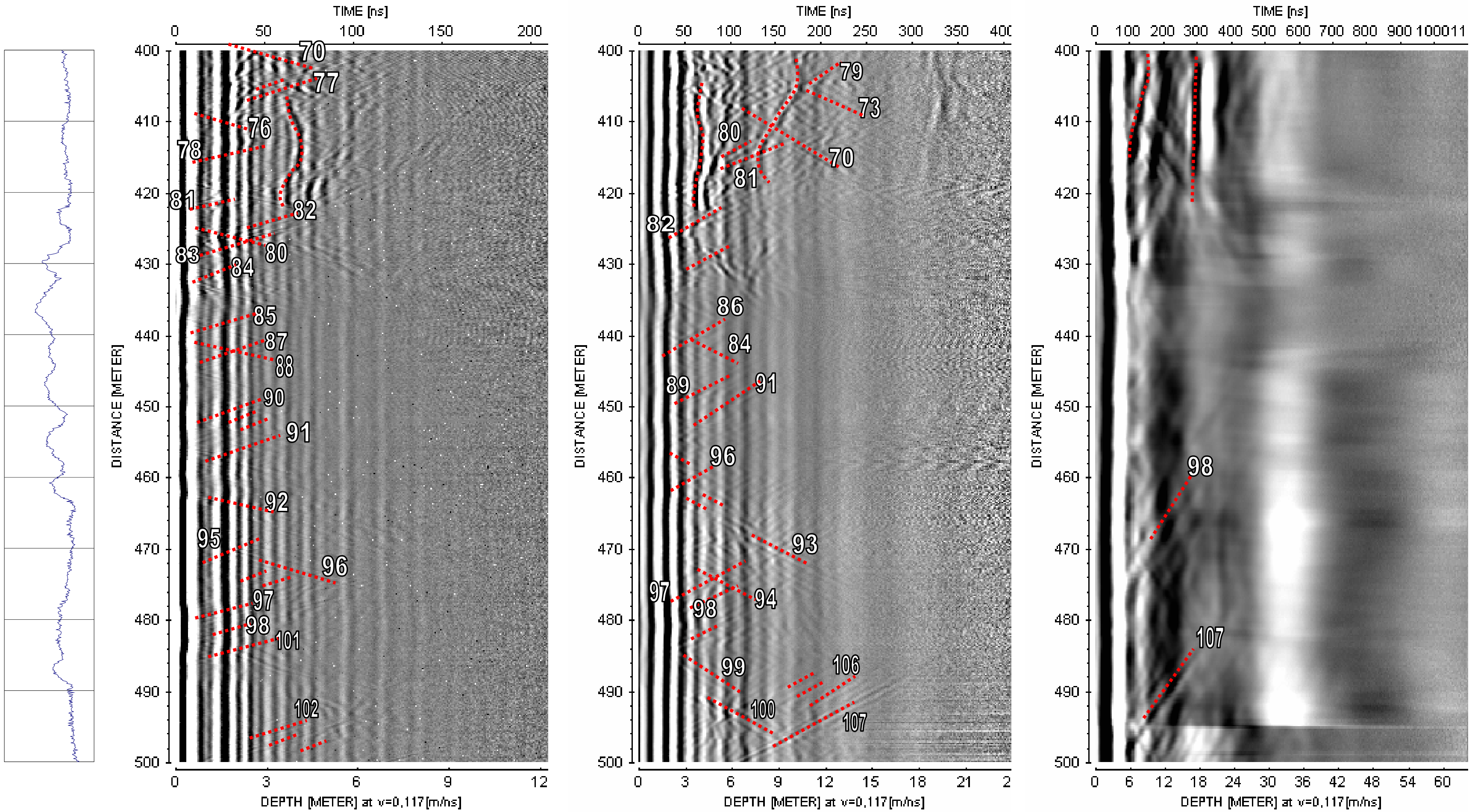
250 MHz | **100 MHz** | **20 MHz**

LAXEMAR KLX10



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

LAXEMAR KLX10

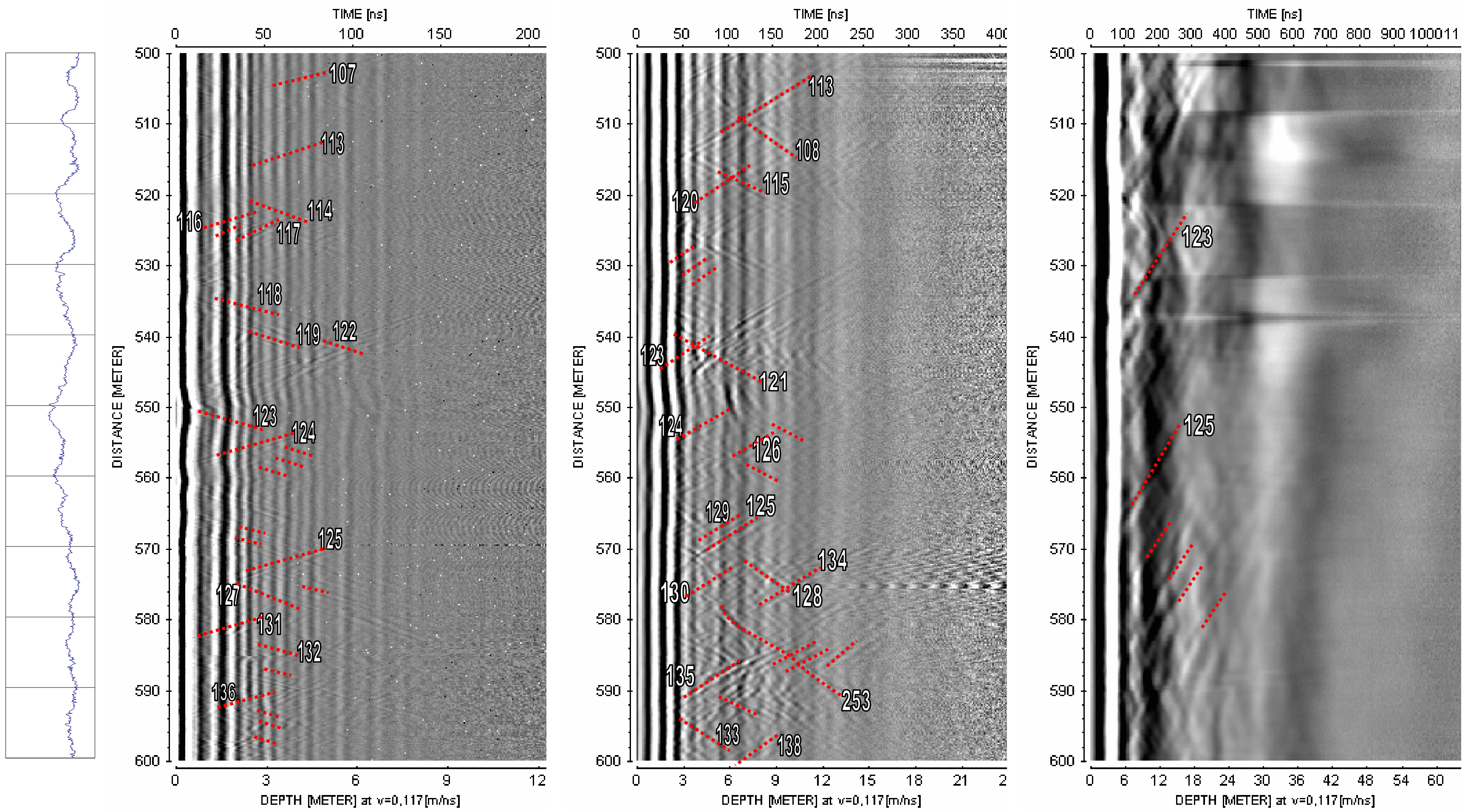


250 MHz

100 MHz

20 MHz

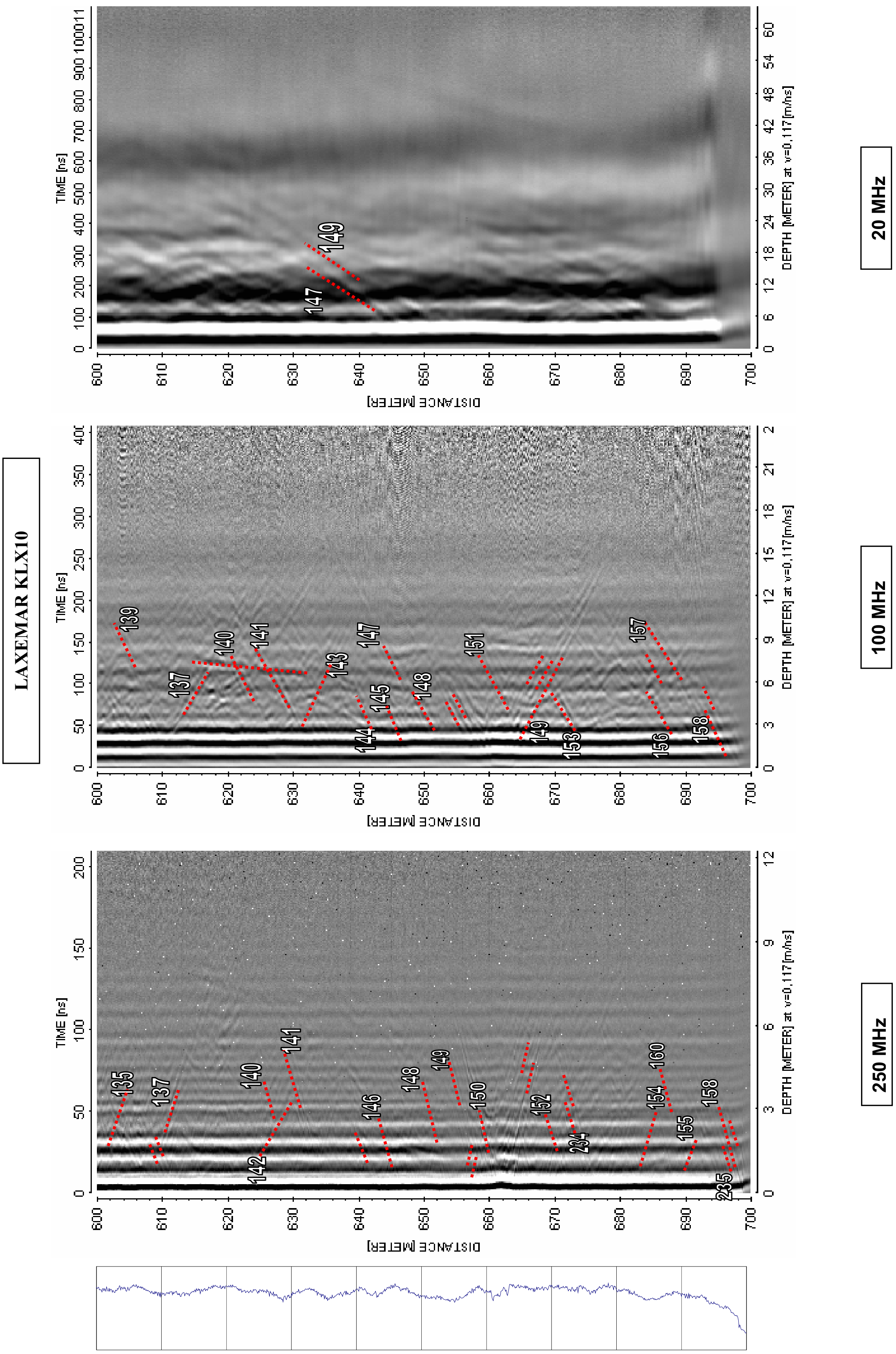
LAXEMAR KLX10

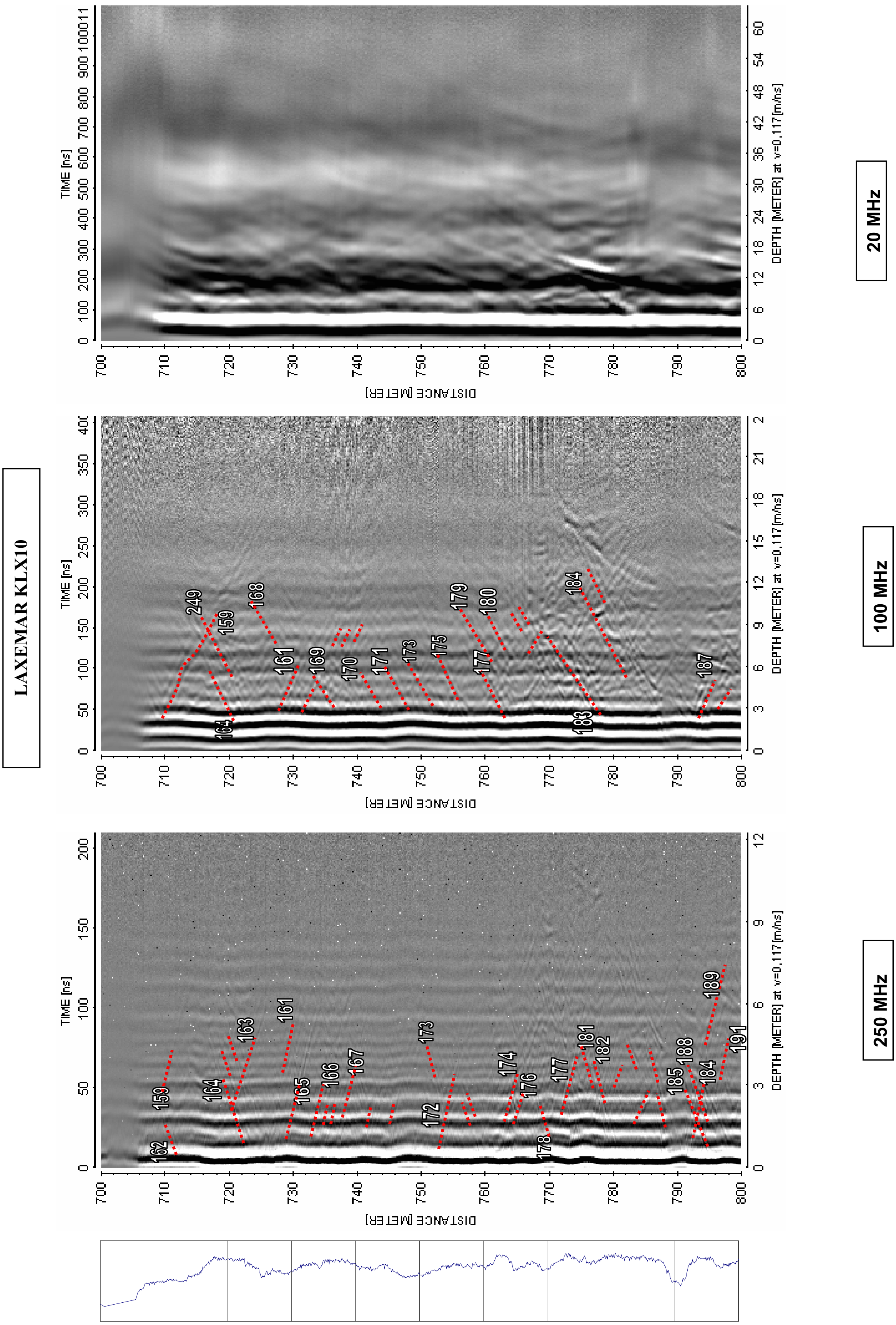


250 MHz

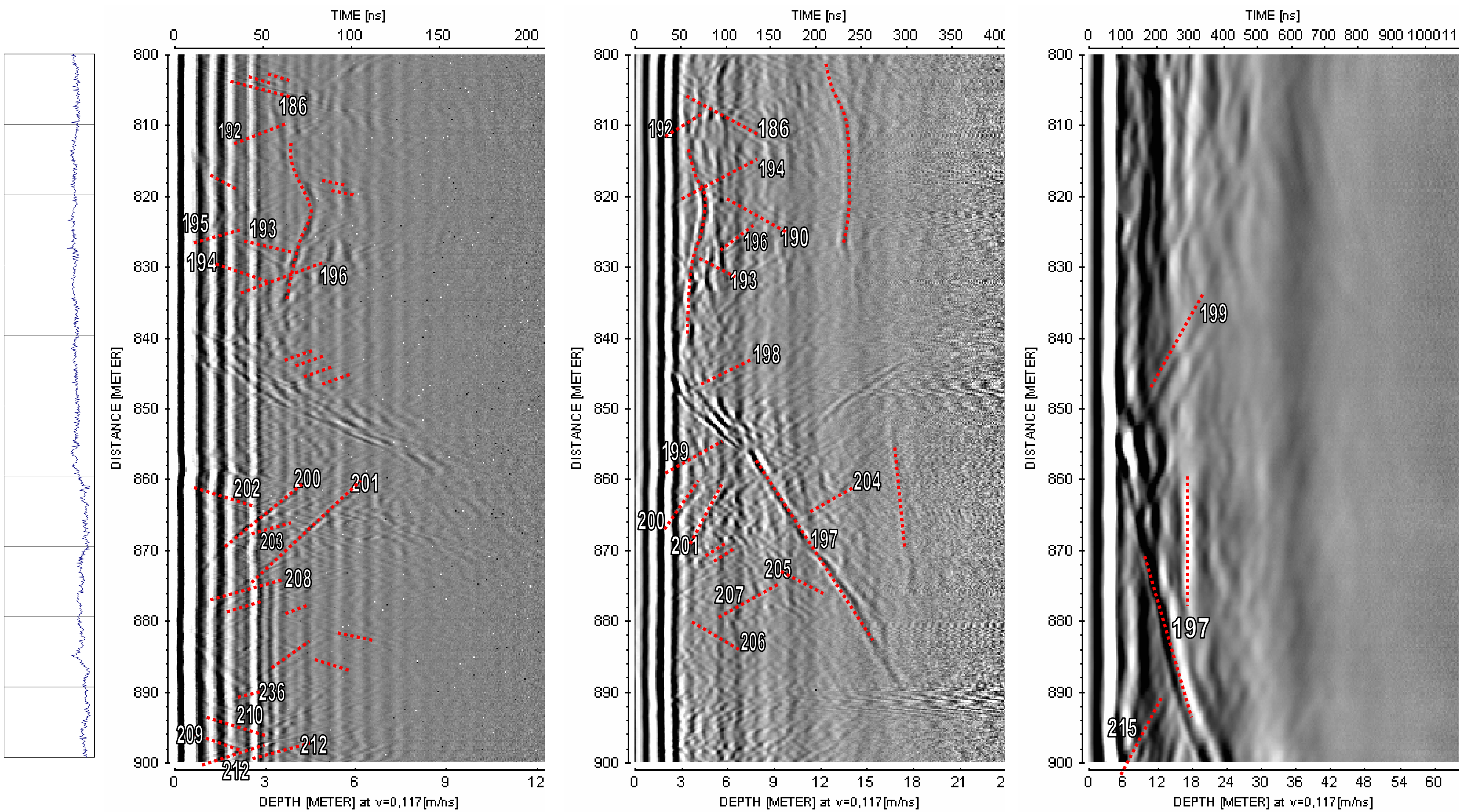
100 MHz

20 MHz


LAXEMAR KLX10
250 MHz
100 MHz
20 MHz
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,117 [m/ns]

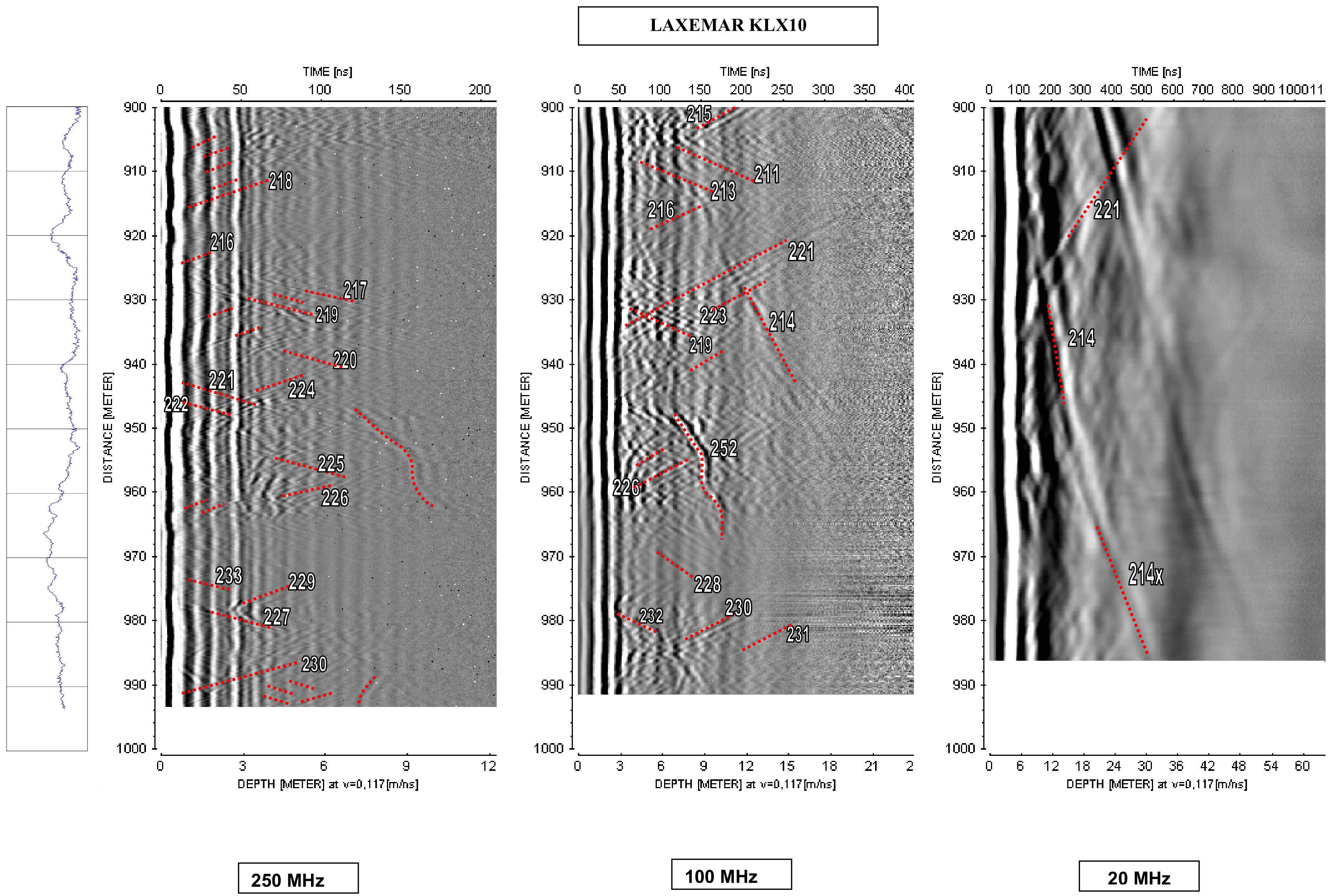

LAXEMAR KLX10
250 MHz
100 MHz
20 MHz
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,117 [m/ns]

LAXEMAR KLX10



250 MHz

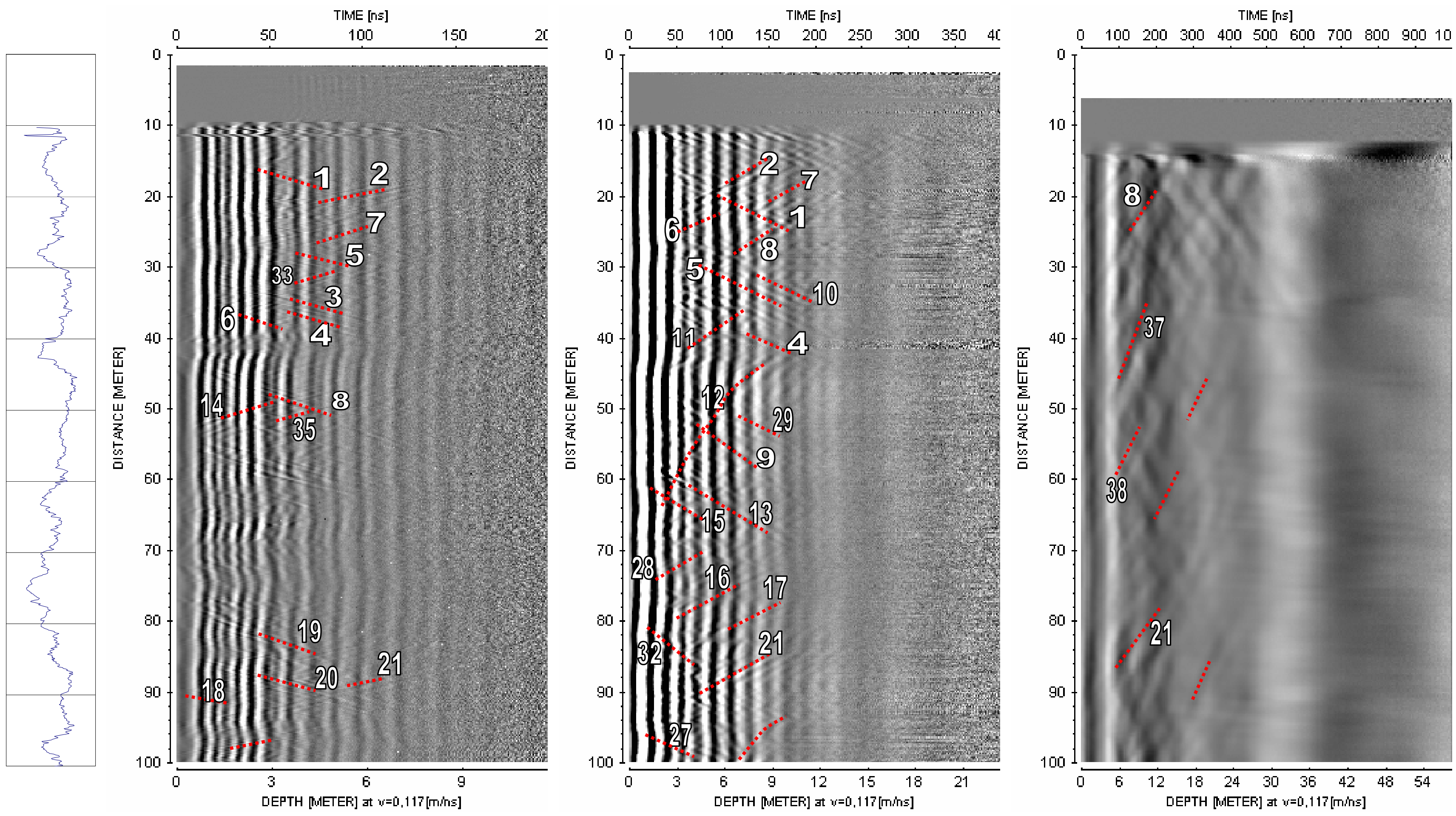
100 MHz


LAXEMAR KLX10
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,117[m/ns]
218
216
217
219
220
221
222
224
225
226
233
229
227
230
215
211
213
223
214
252
228
232
231
214x
250 MHz
100 MHz
20 MHz

Appendix 2

Radar logging in HLX30, 0 to 129 m, dipole antennas 250, 100 and 20 MHz

LAXEMAR HLX31

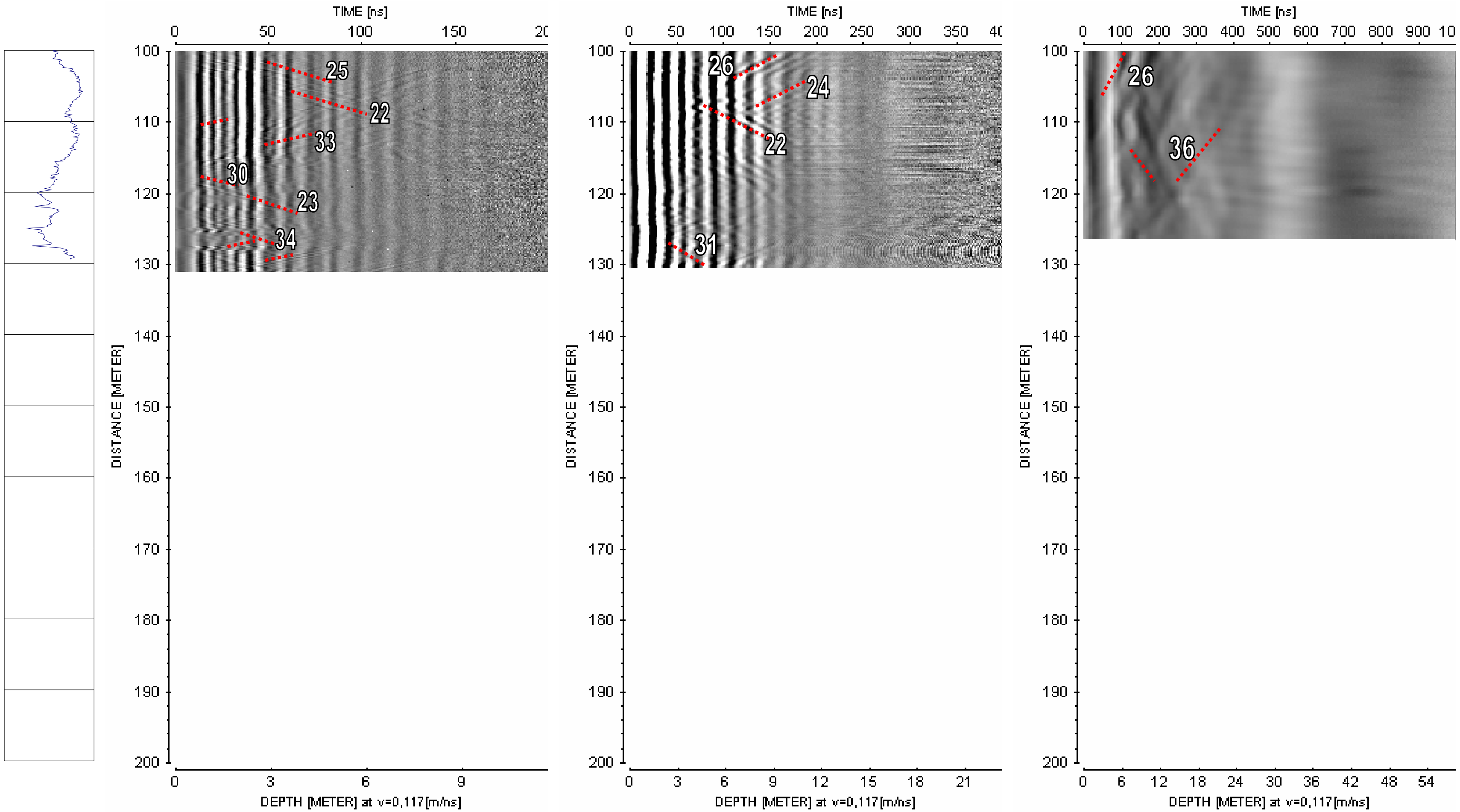


250 MHz

100 MHz

20 MHz

LAXEMAR HLX31



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

Appendix 3

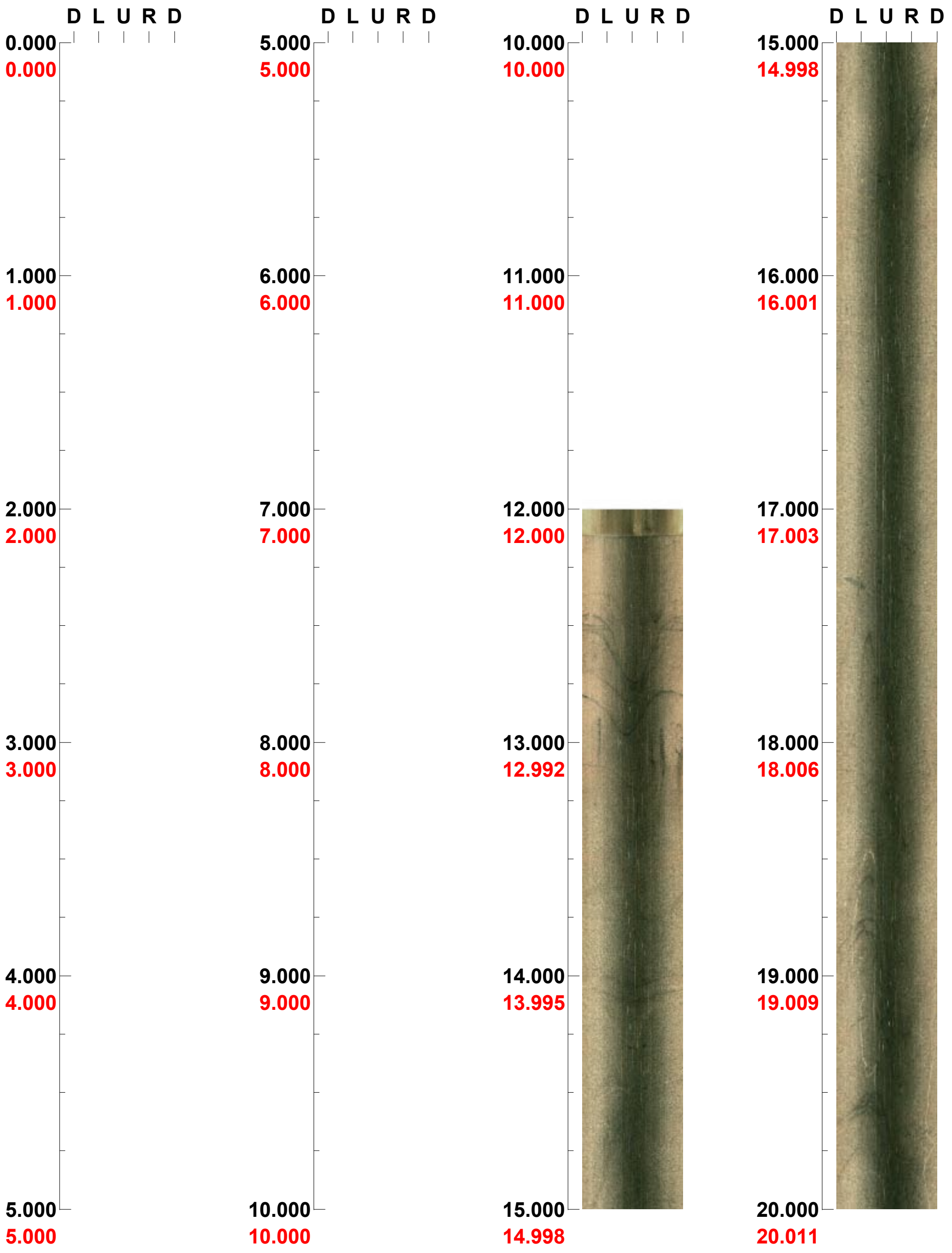
BIPS logging in KLX10, 12 to 992 m

Project name: Laxemar

Image file	**: c:\work\r5483o~1\bips\klx10_a.bip**
BDT file	**: c:\work\r5483o~1\bips\klx10_a.bdt**
Locality	**: LAXEMAR**
Bore hole number	**: KLX10**
Date	**: 05/11/22**
Time	**: 09:09:00**
Depth range	**: 12.000 - 97.745 m**
Azimuth	**: 251**
Inclination	**: -85**
Diameter	**: 197.0 mm**
Magnetic declination	**: 0.0**
Span	**: 4**
Scan interval	**: 0.25**
Scan direction	**: To bottom**
Scale	**: 1/25**
Aspect ratio	**: 70 %**
Pages	**: 5**
Color	**: +0 +0 +0**

Project name: Laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 0.000 - 20.000 m



(1 / 5) **Scale: 1/25** **Aspect ratio: 70 %**

Project name: Laxemar
Bore hole No.: KLX10 Azimuth: 251 Inclination: -85

Depth range: 20.000 - 40.000 m

(2 / 5) Scale: 1/25 Aspect ratio: 70 %

Project name: Laxemar

Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 40.000 - 60.000 m

(3 / 5) **Scale: 1/25** **Aspect ratio: 70 %**

Project name: Laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 60.000 - 80.000 m

(4 / 5) **Scale: 1/25** **Aspect ratio: 70 %**

Project name: Laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 80.000 - 97.745 m

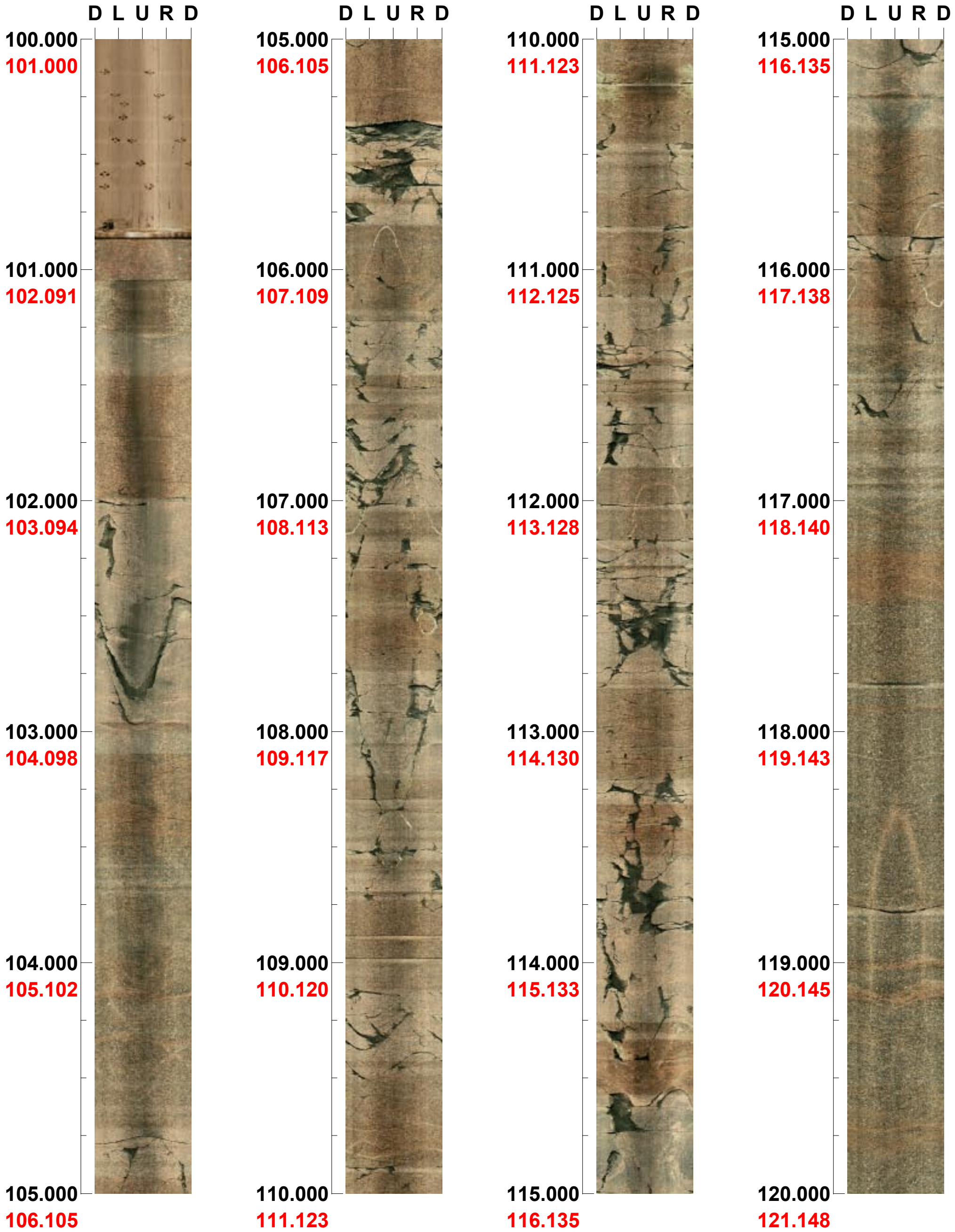
(5 / 5) **Scale: 1/25** **Aspect ratio: 70 %**

Project name: Laxemar

Image file	**: c:\work\r5483o~1\bips\klx10_b.bip**
BDT file	**: c:\work\r5483o~1\bips\klx10_b.bdt**
Locality	**: LAXEMAR**
Bore hole number	**: KLX10**
Date	**: 05/11/22**
Time	**: 10:44:00**
Depth range	**: 100.000 - 992.002 m**
Azimuth	**: 251**
Inclination	**: -85**
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	**: 19**
Color	**: +0 +0 +0**

Project name: Laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 100.000 - 120.000 m

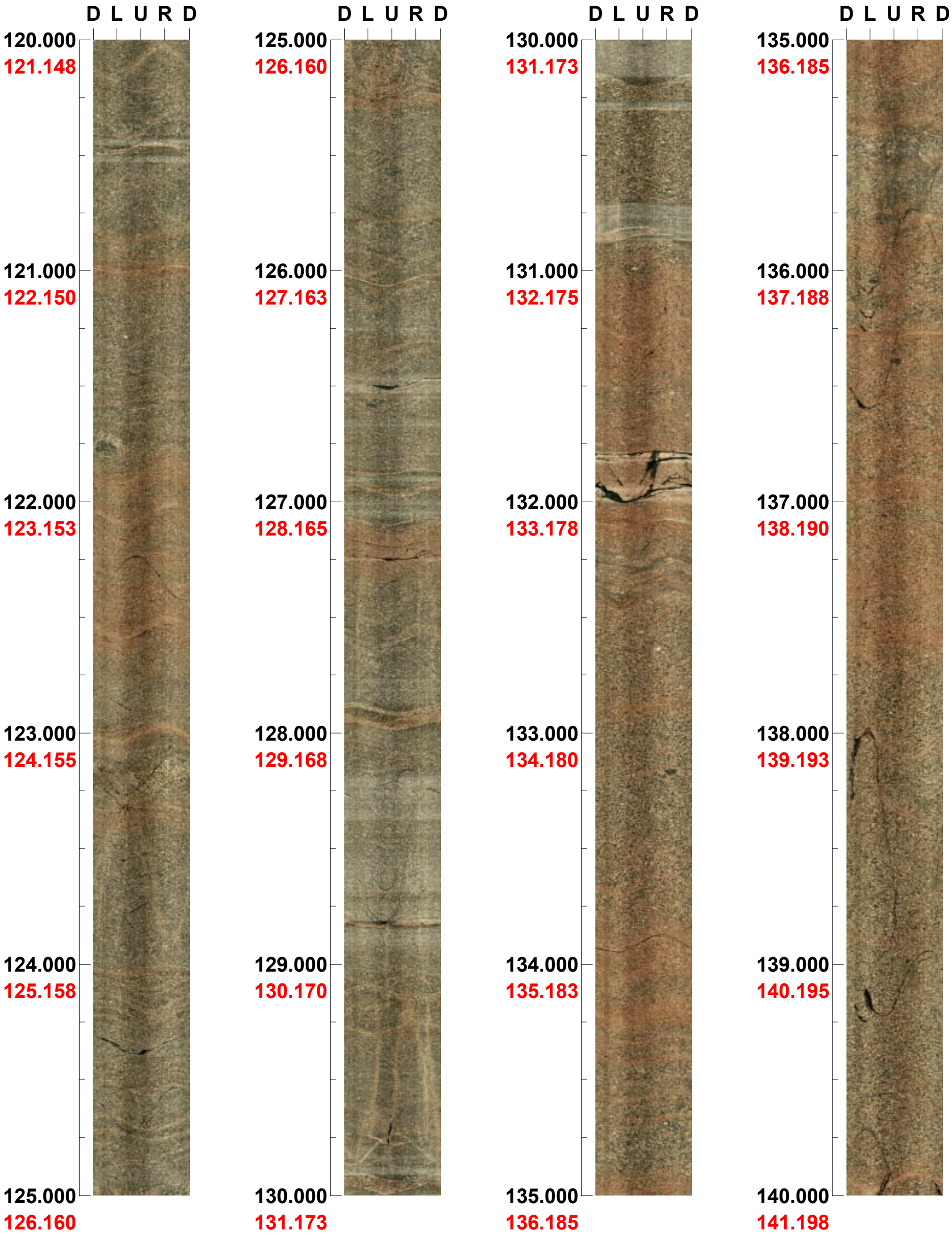


(1 / 19) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar

Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

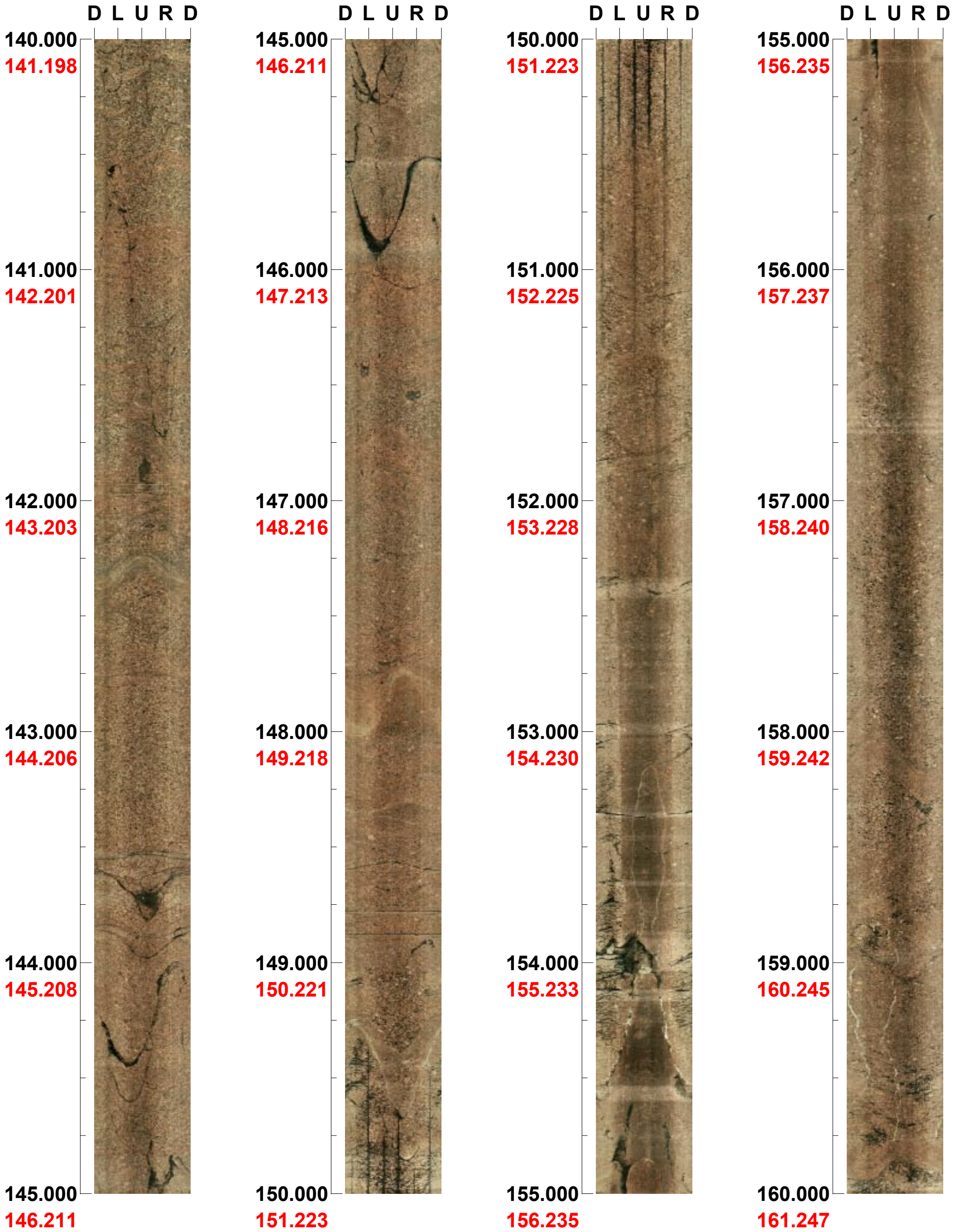
Depth range: 120.000 - 140.000 m



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

Project name: Laxemar
Bore hole No.: KLX10 Azimuth: 251 Inclination: -85

Depth range: 140.000 - 160.000 m



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

Project name: Laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 160.000 - 180.000 m

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

Project name: Laxemar

Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 180.000 - 200.000 m

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

Project name: Laxemar

Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 200.000 - 220.000 m

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

Project name: Laxemar

Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 220.000 - 240.000 m

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

Project name: Laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 240.000 - 260.000 m

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

Project name: Laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 260.000 - 280.000 m

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

Project name: Laxemar
Bore hole No.: KLX10 Azimuth: 251 Inclination: -85

Depth range: 280.000 - 300.000 m

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

Project name: Laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 300.000 - 320.000 m

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

Project name: Laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 320.000 - 340.000 m

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

Project name: Laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 340.000 - 360.000 m

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

Project name: Laxemar
Bore hole No.: KLX10 Azimuth: 251 Inclination: -85

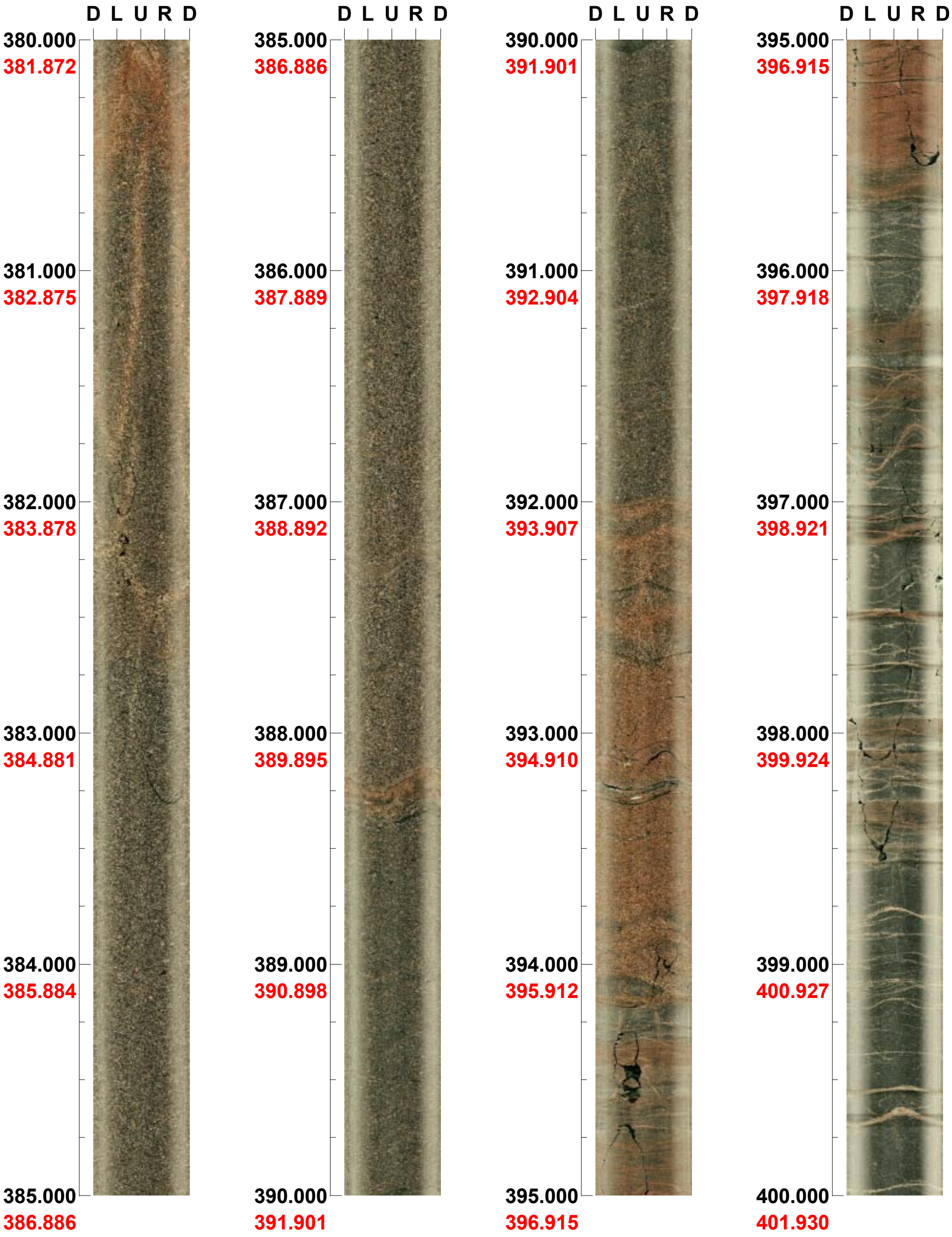
Depth range: 360.000 - 380.000 m

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

Project name: Laxemar

Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 380.000 - 400.000 m



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

Project name: Laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 400.000 - 420.000 m

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

Project name: Laxemar

Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 420.000 - 440.000 m

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

Project name: Laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 440.000 - 460.000 m

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

Project name: laxemar
Bore hole No.: KLX10 Azimuth: 251 Inclination: -85

Depth range: 460.000 - 480.000 m

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

Project name: laxemar

Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 480.000 - 500.000 m

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

Project name: laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 500.000 - 520.000 m

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

Project name: laxemar
Bore hole No.: KLX10 Azimuth: 251 Inclination: -85

Depth range: 520.000 - 540.000 m

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

Project name: laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 540.000 - 560.000 m

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

Project name: laxemar
Bore hole No.: KLX10 Azimuth: 251 Inclination: -85

Depth range: 560.000 - 580.000 m

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

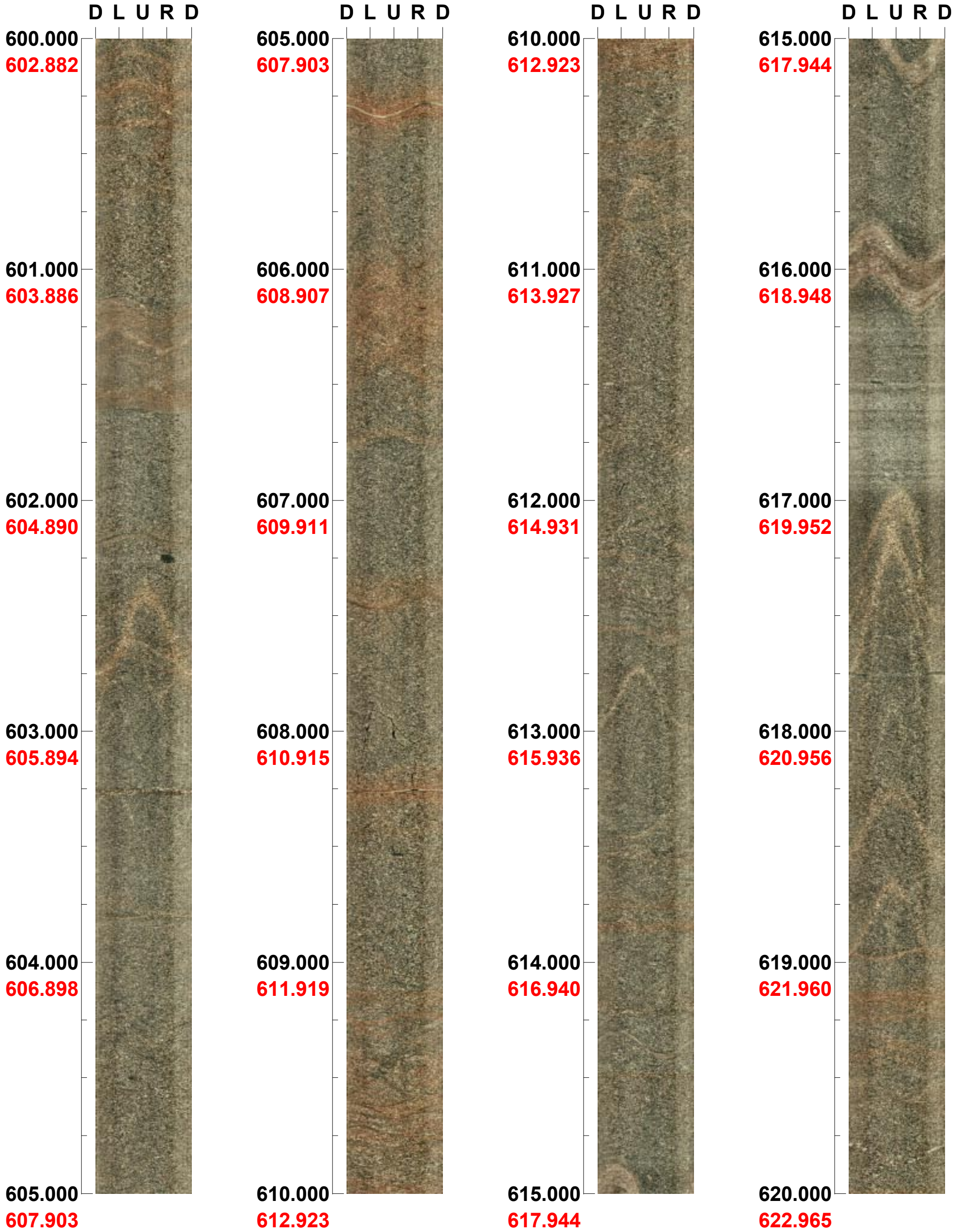
Project name: laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 580.000 - 600.000 m

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

Project name: laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

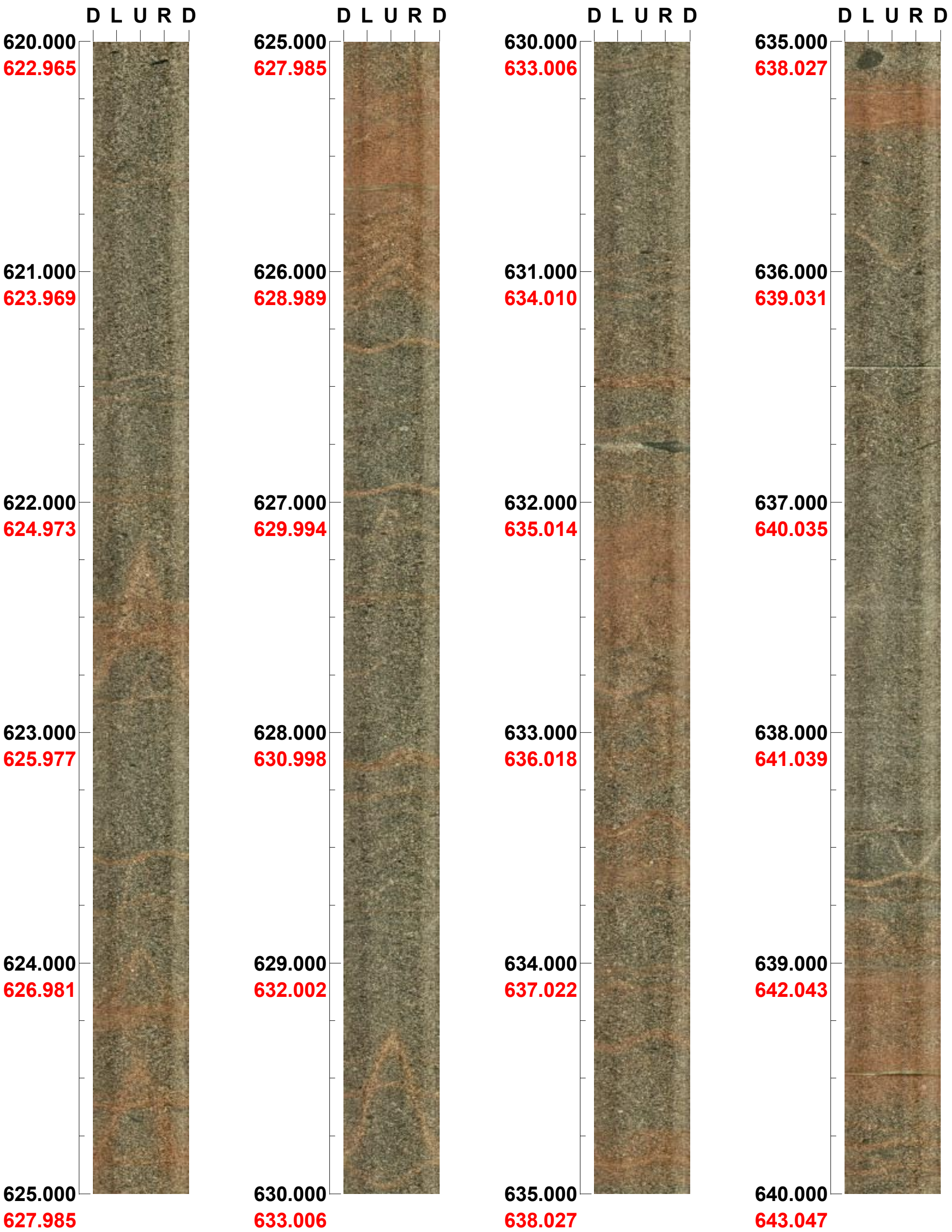
Depth range: 600.000 - 620.000 m



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

Project name: laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

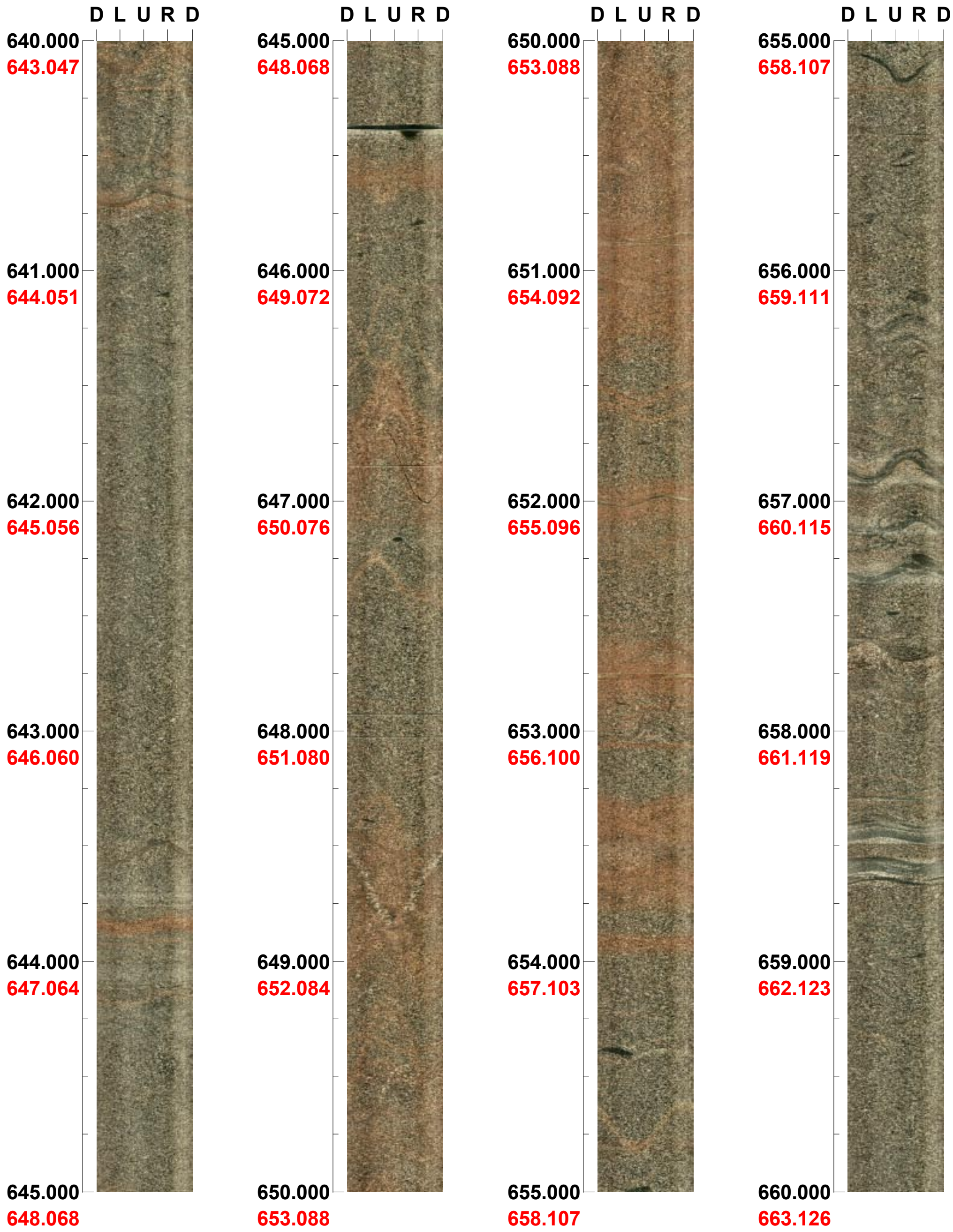
Depth range: 620.000 - 640.000 m



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

Project name: laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

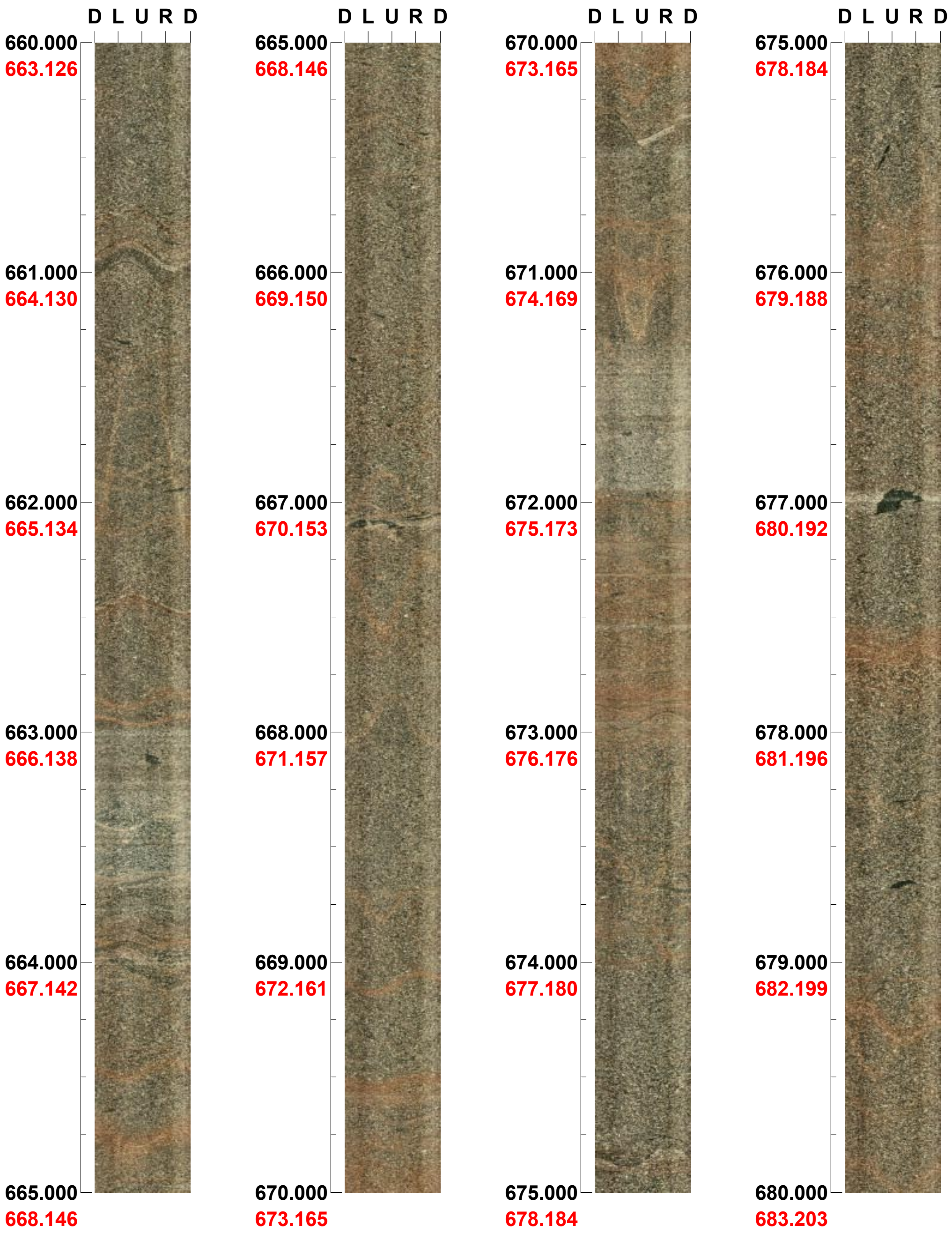
Depth range: 640.000 - 660.000 m



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

Project name: laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

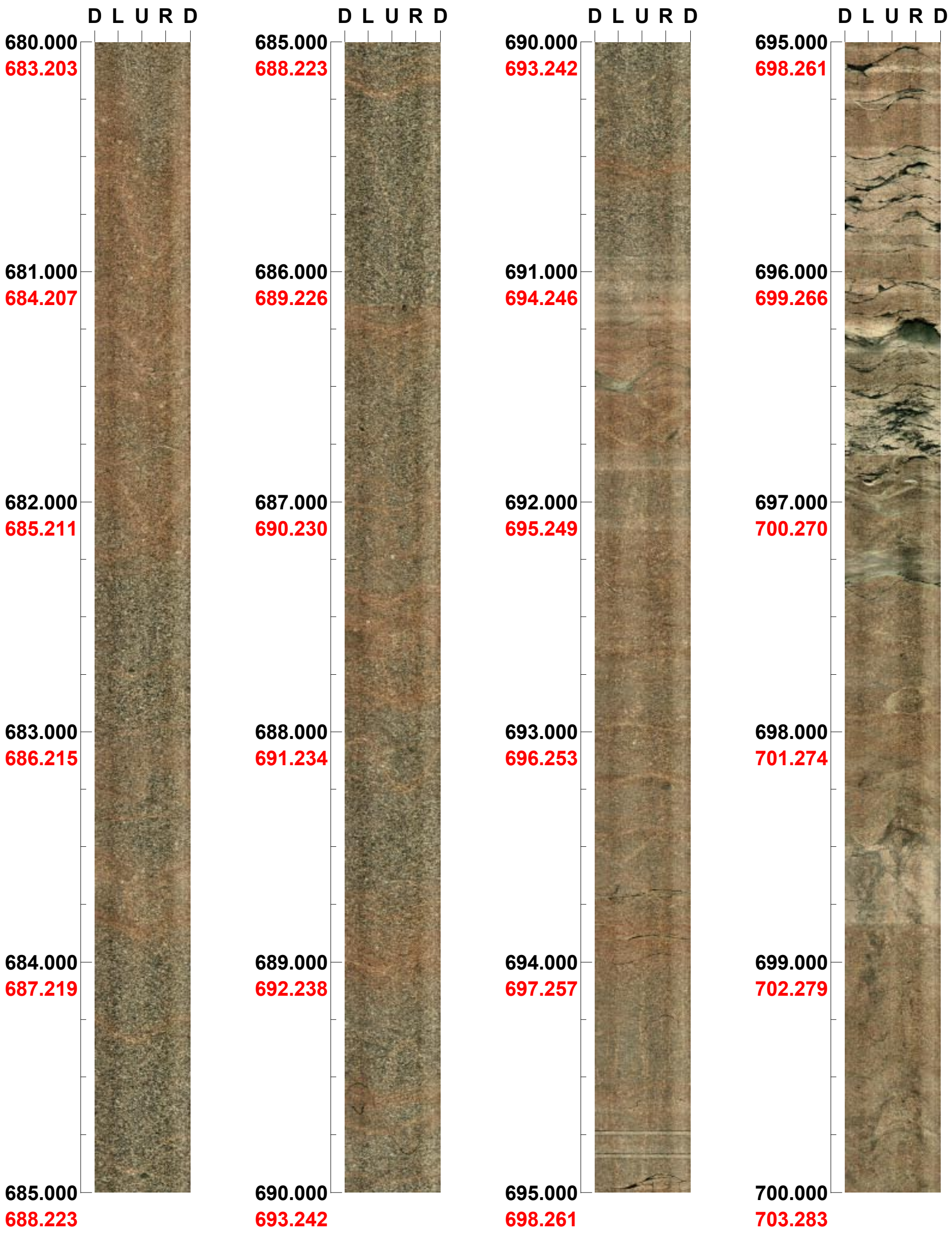
Depth range: 660.000 - 680.000 m



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

Project name: laxemar
Bore hole No.: KLX10 Azimuth: 251 Inclination: -85

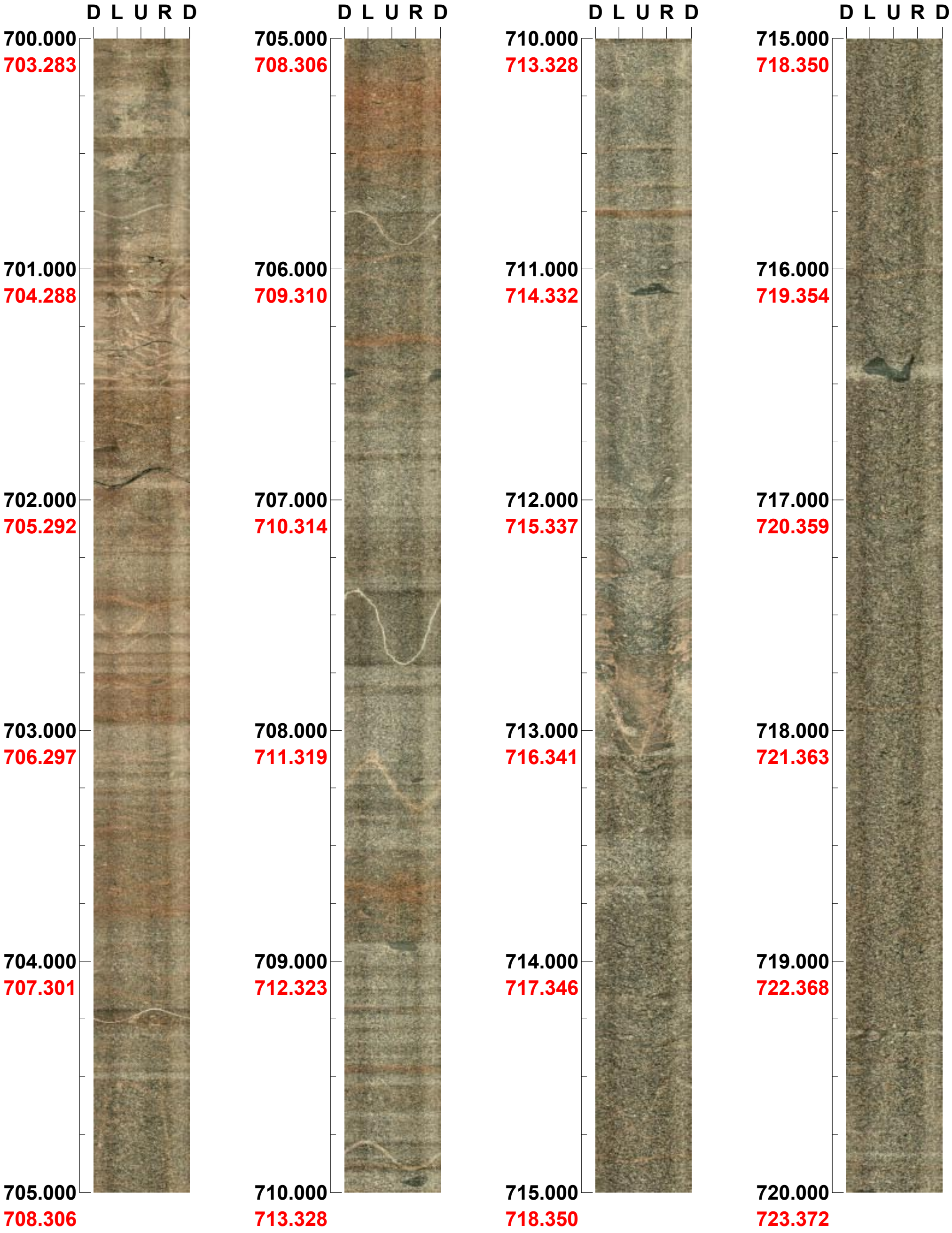
Depth range: 680.000 - 700.000 m



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

Project name: laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 700.000 - 720.000 m

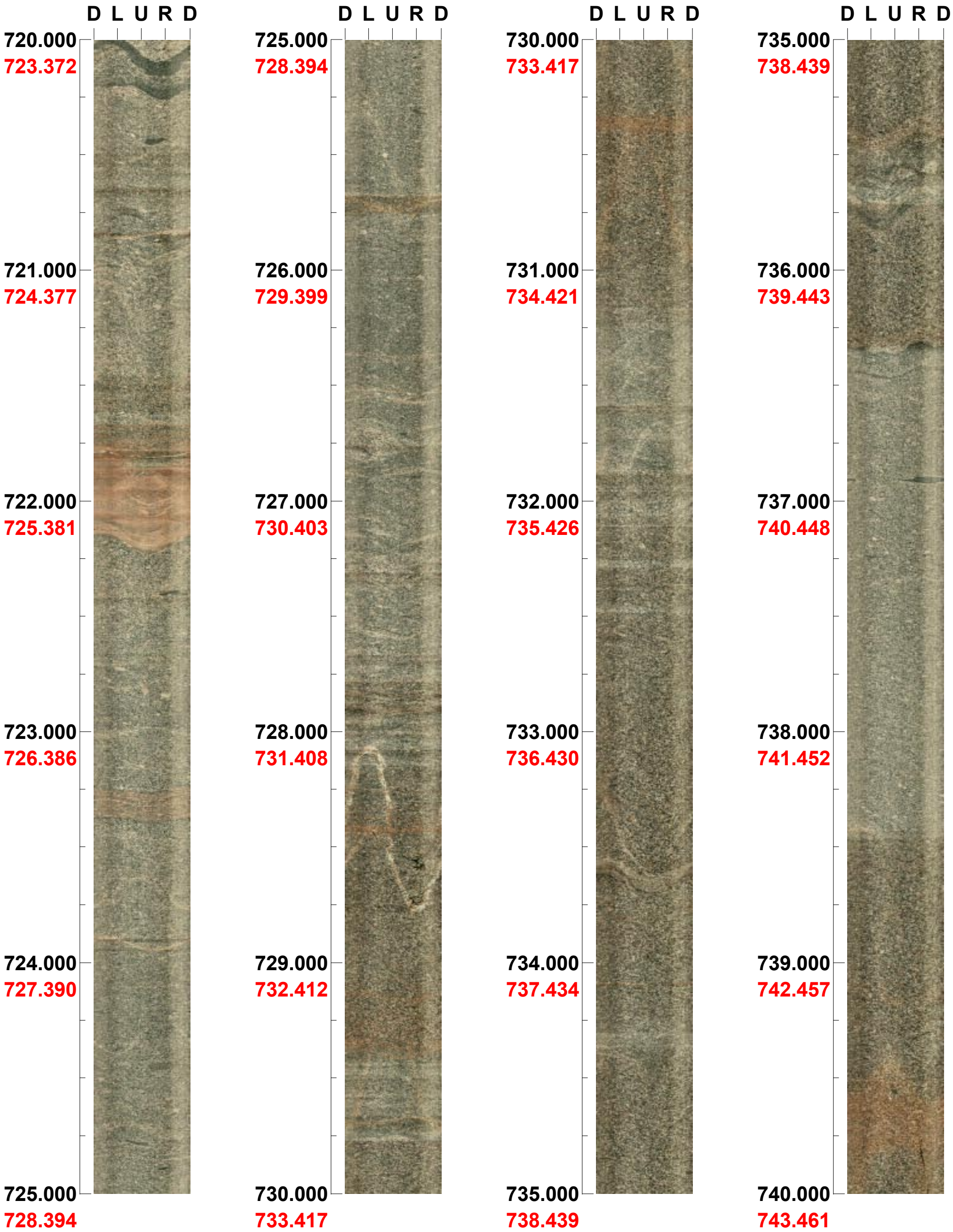


(13 / 25) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: laxemar

Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

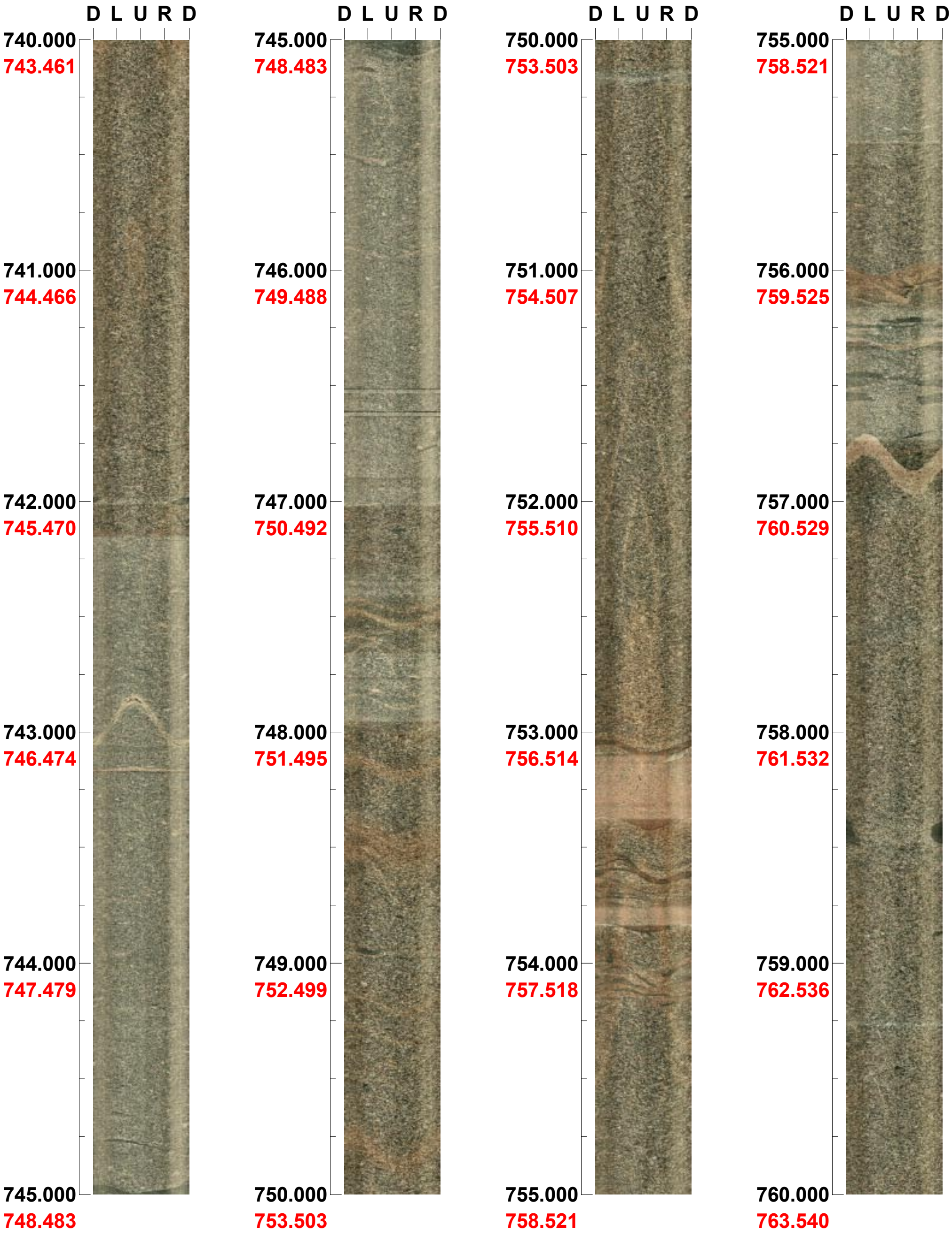
Depth range: 720.000 - 740.000 m



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

Project name: laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 740.000 - 760.000 m



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

Project name: laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

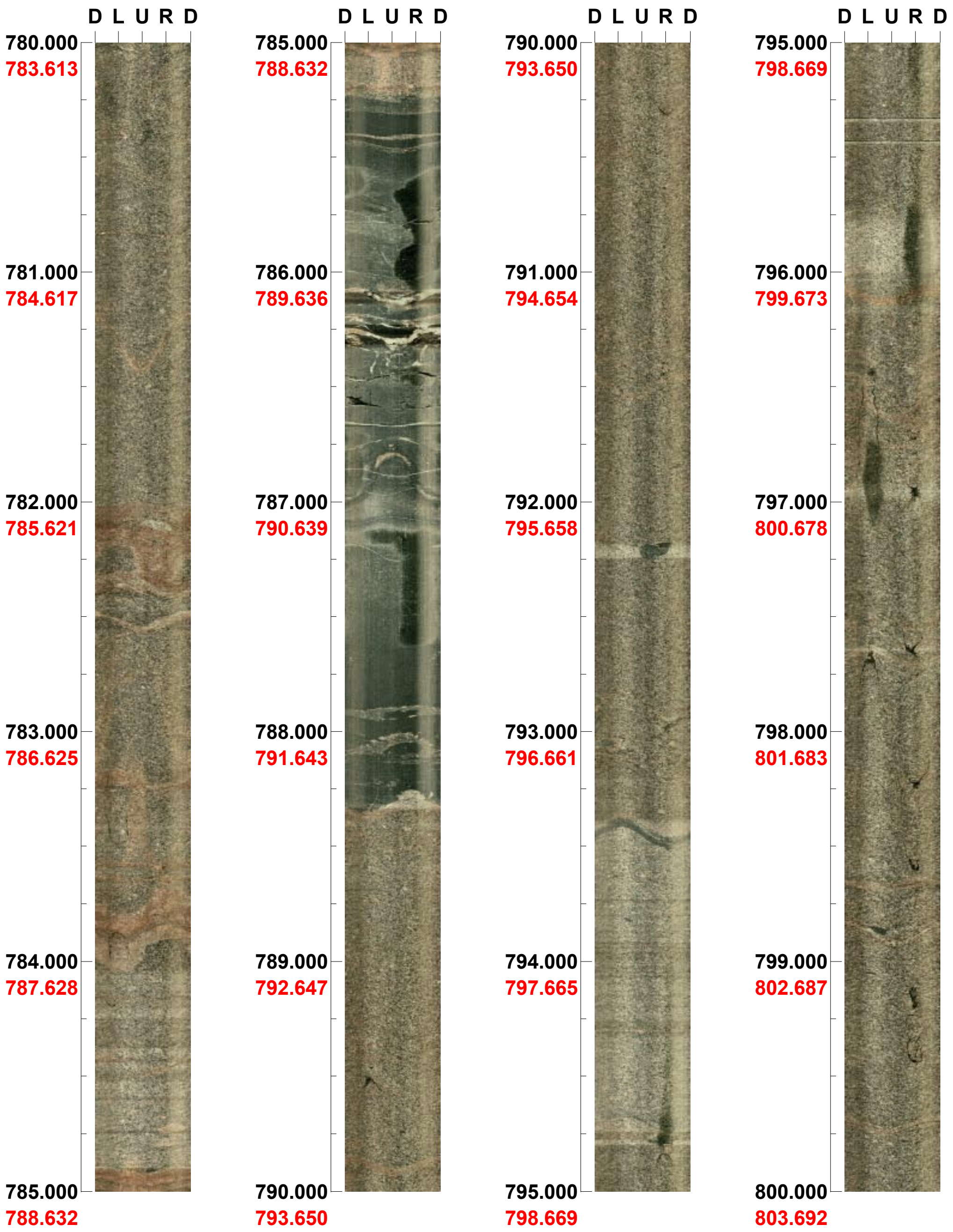
Depth range: 760.000 - 780.000 m

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

Project name: laxemar

Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

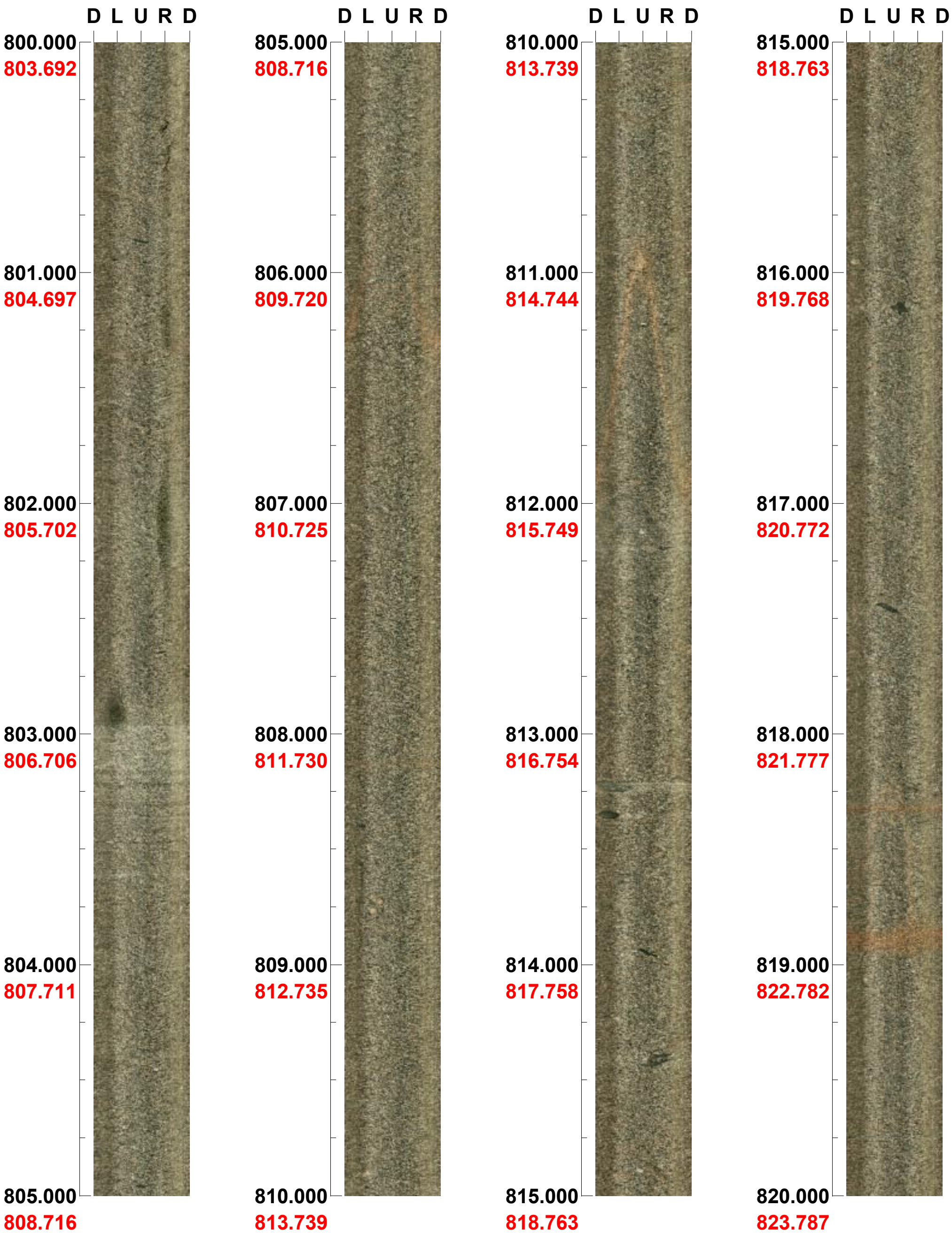
Depth range: 780.000 - 800.000 m



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

Project name: laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 800.000 - 820.000 m



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

Project name: laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 820.000 - 840.000 m

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

Project name: laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 840.000 - 860.000 m

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

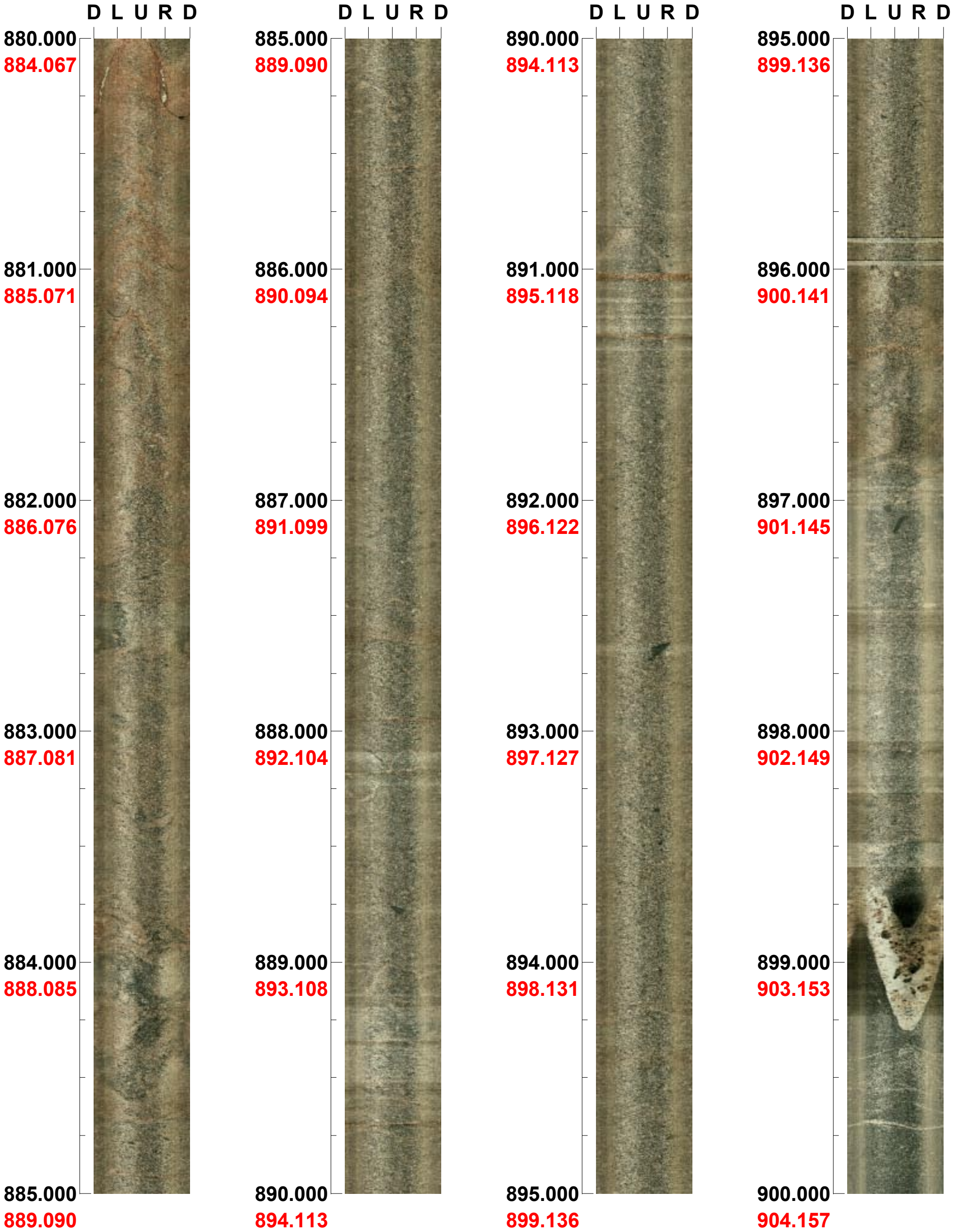
Project name: laxemar
Bore hole No.: KLX10 Azimuth: 251 Inclination: -85

Depth range: 860.000 - 880.000 m

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

Project name: laxemar
Bore hole No.: KLX10 Azimuth: 251 Inclination: -85

Depth range: 880.000 - 900.000 m

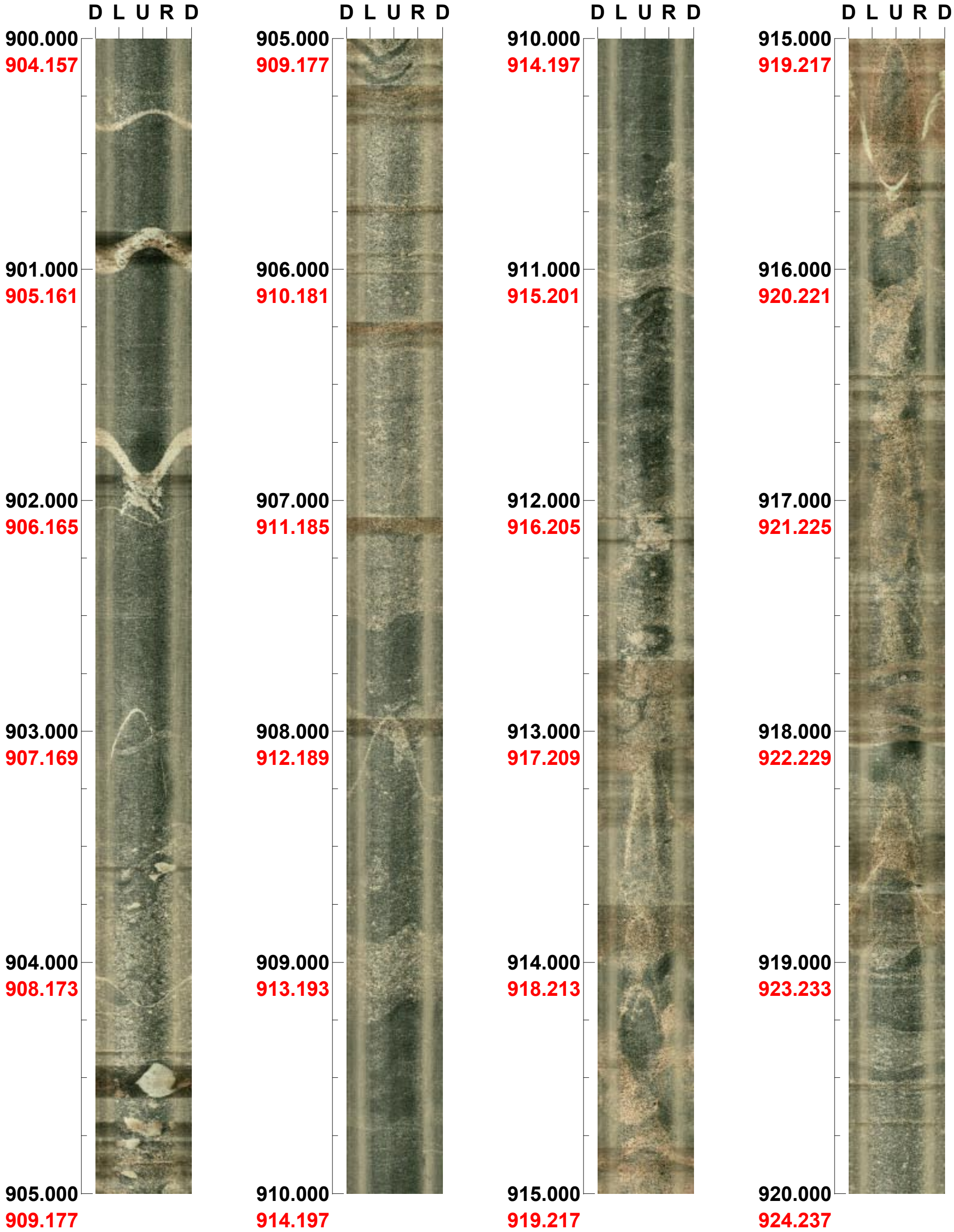


(22 / 25) Scale: 1/25 Aspect ratio: 175 %

Project name: laxemar

Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 900.000 - 920.000 m

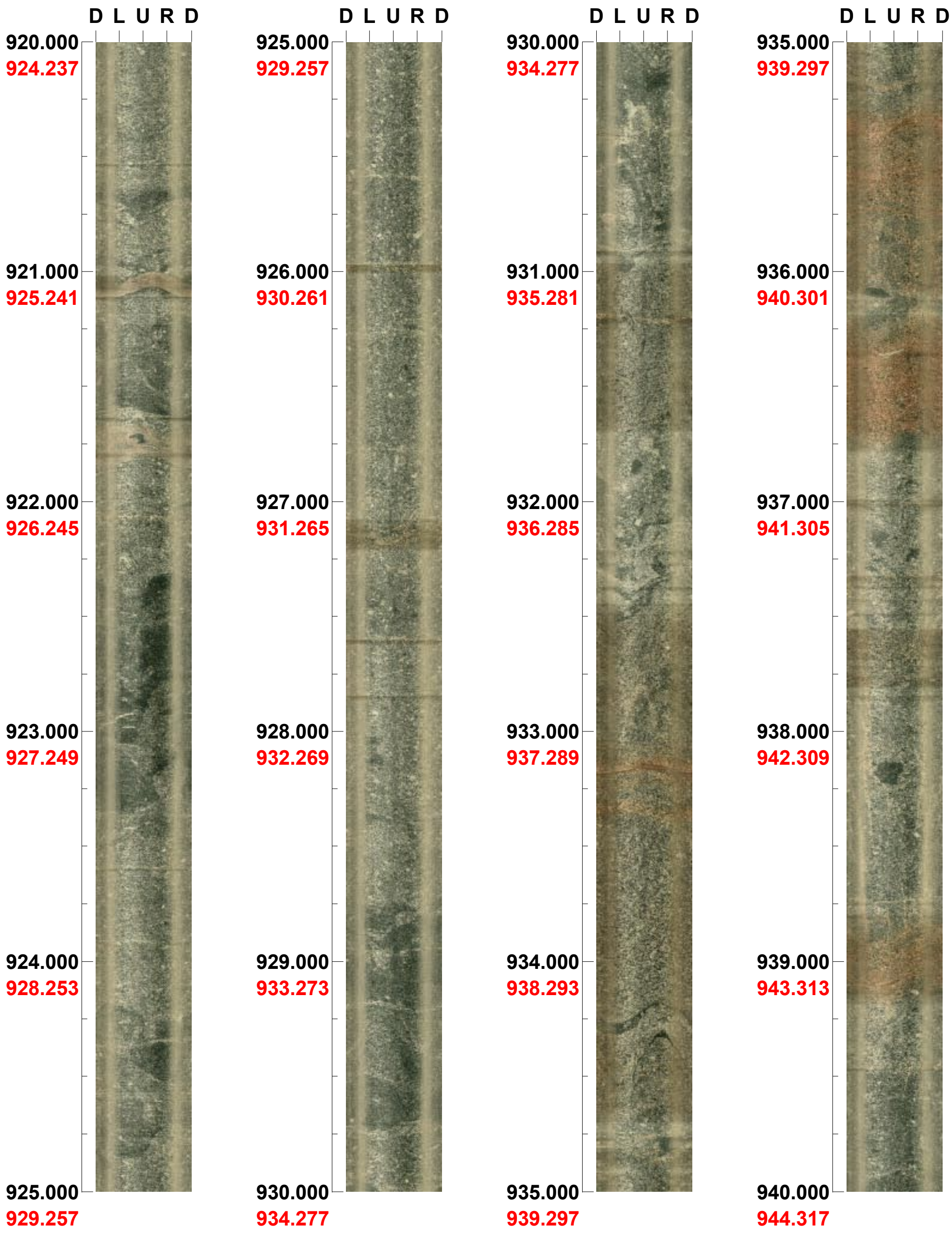


(23 / 25) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: laxemar

Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 920.000 - 940.000 m

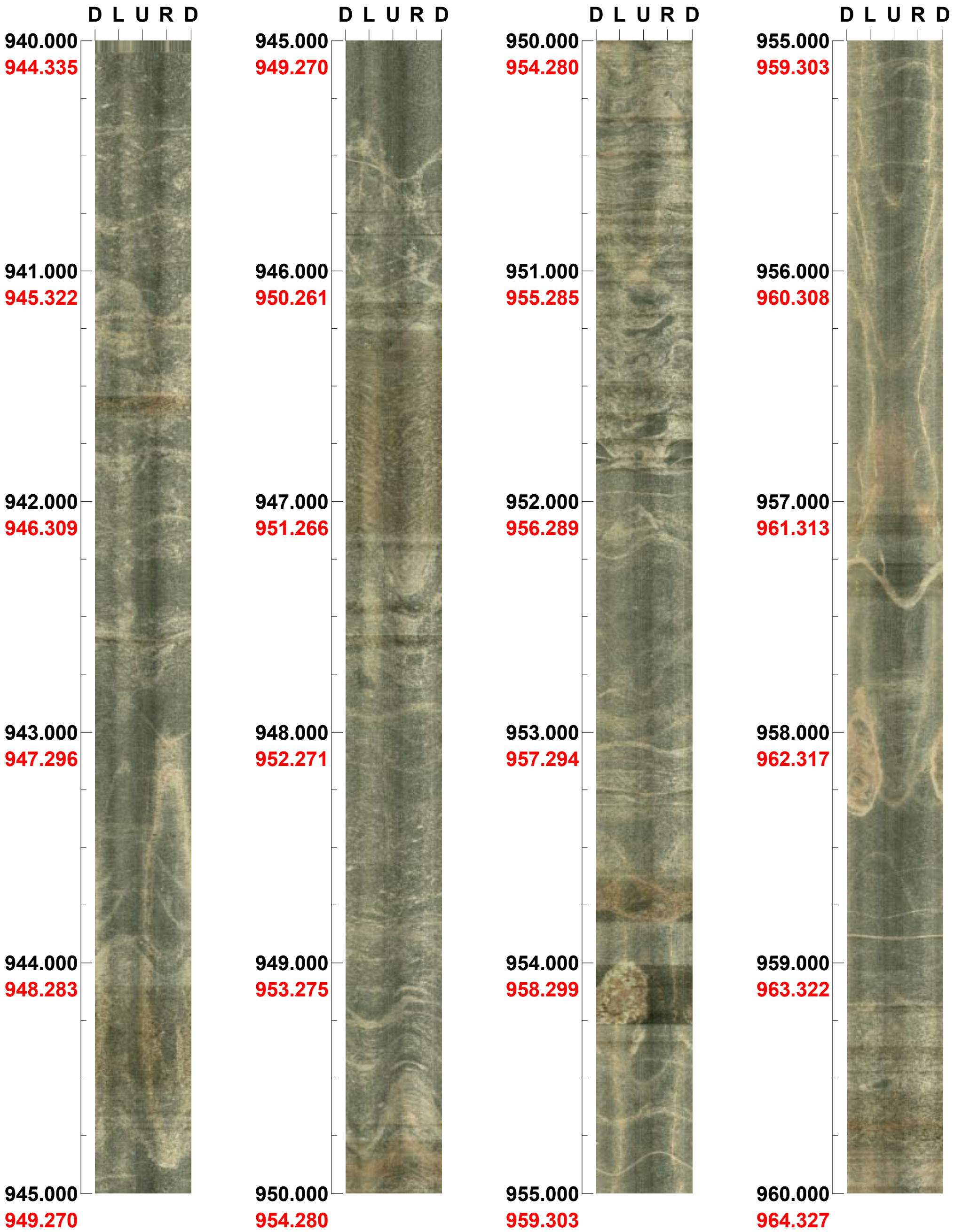


(24 / 25) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: laxemar

Bore hole No.: KLX10 **Azimuth: 0** **Inclination: -90**

Depth range: 940.000 - 960.000 m

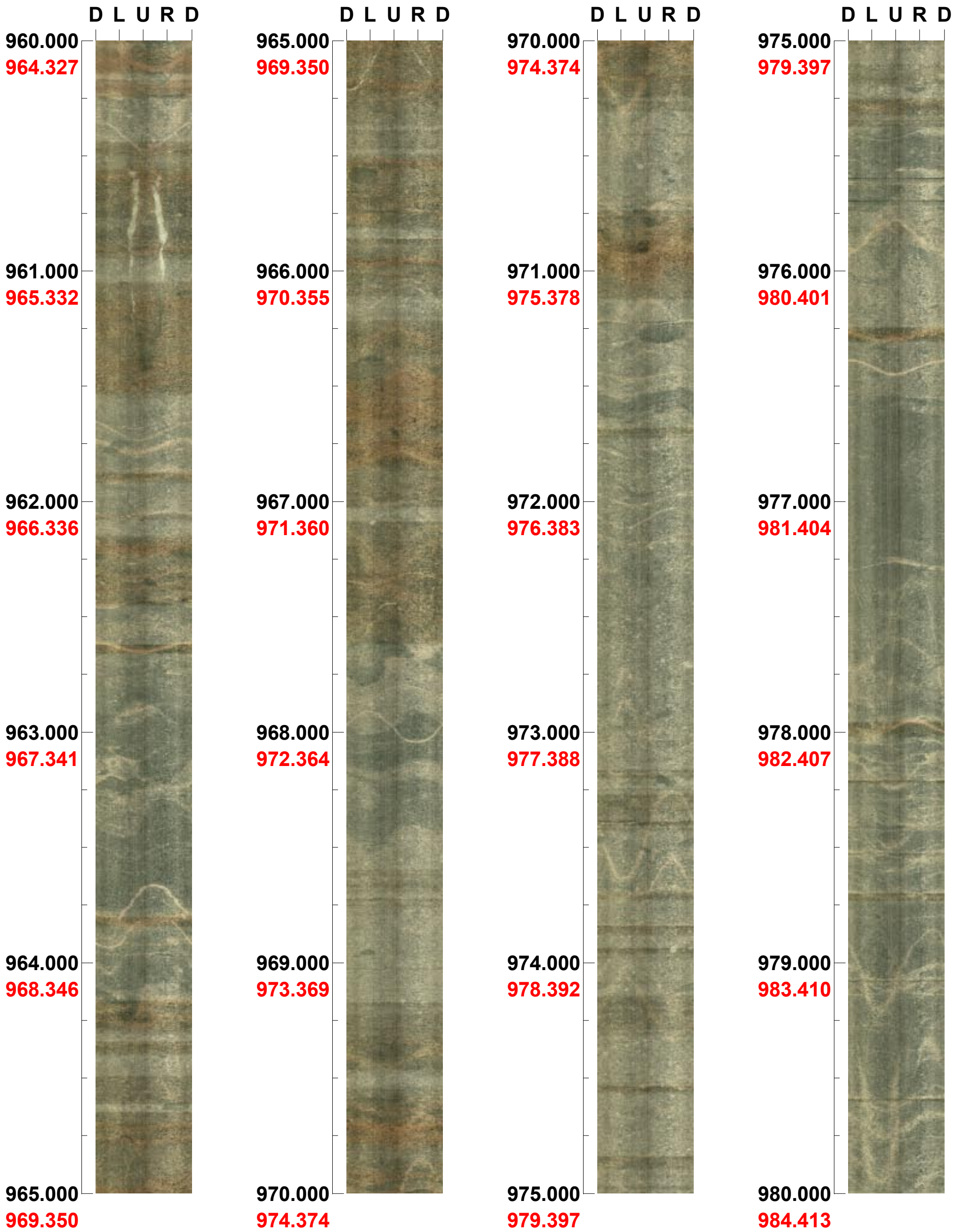


(1 / 3) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: laxemar

Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

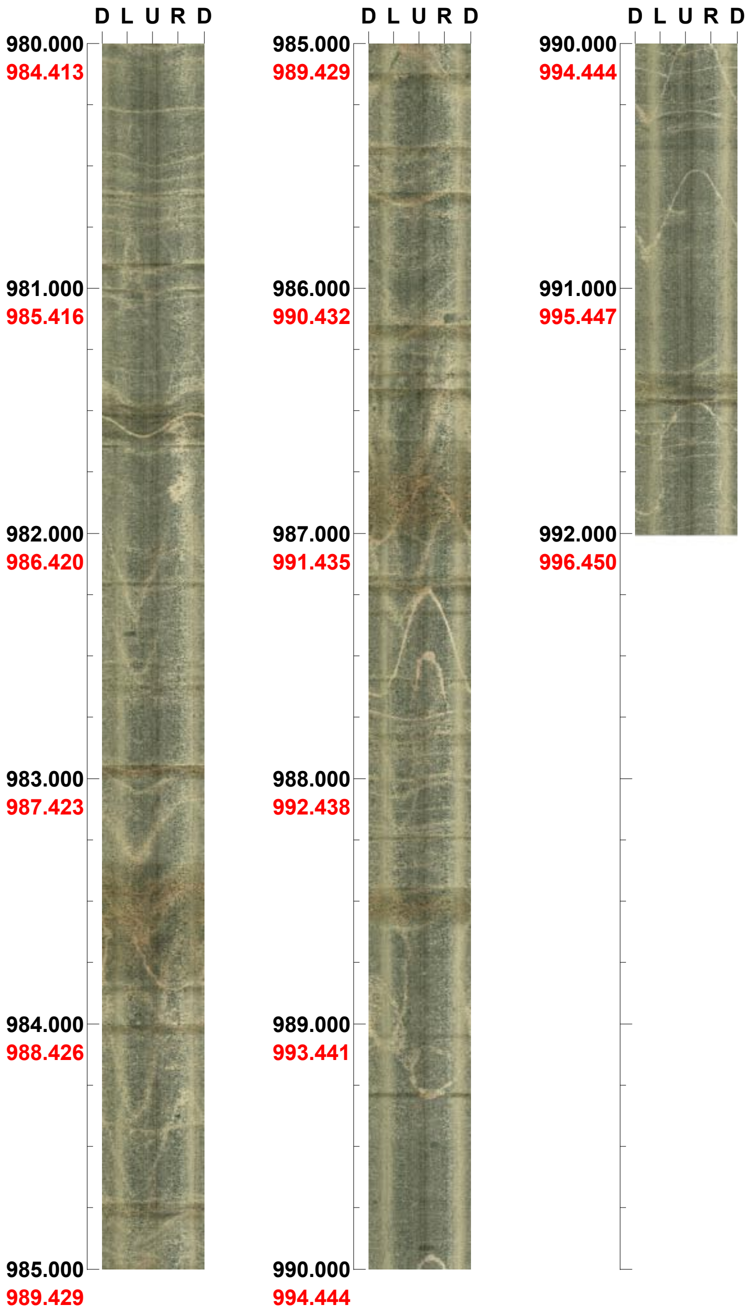
Depth range: 960.000 - 980.000 m



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

Project name: laxemar
Bore hole No.: KLX10 **Azimuth: 251** **Inclination: -85**

Depth range: 980.000 - 992.005 m



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

Appendix 4

BIPS logging in HLX31, 9 to 128 m

Project name: Laxemar

Image file	: c:\work\r5450l~1\bips\hlx31.bip
BDT file	: c:\work\r5450l~1\bips\hlx31.bdt
Locality	: LAXEMAR
Bore hole number	: HLX31
Date	: 05/10/20
Time	: 09:58:00
Depth range	: 9.000 - 128.135 m
Azimuth	: 232
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	: 7
Color	: +0 +0 +0

Project name: Laxemar
Bore hole No.: HLX31 **Azimuth: 232** **Inclination: -59**

Depth range: 0.000 - 20.000 m

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

Project name: Laxemar
Bore hole No.: HLX31 **Azimuth: 232** **Inclination: -59**

Depth range: 20.000 - 40.000 m

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

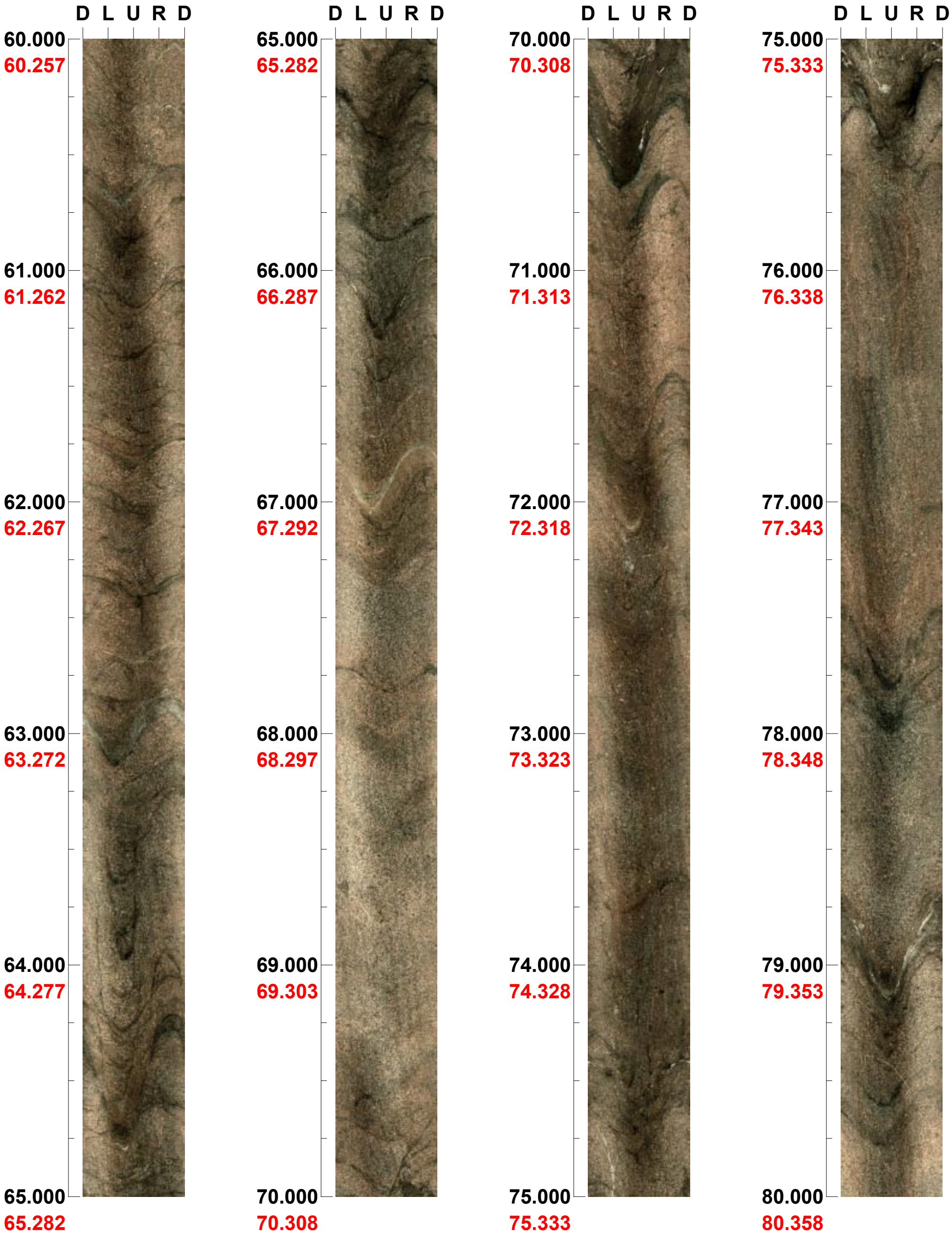
Project name: Laxemar
Bore hole No.: HLX31 **Azimuth: 232** **Inclination: -59**

Depth range: 40.000 - 60.000 m

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

Project name: Laxemar
Bore hole No.: HLX31 **Azimuth: 232** **Inclination: -59**

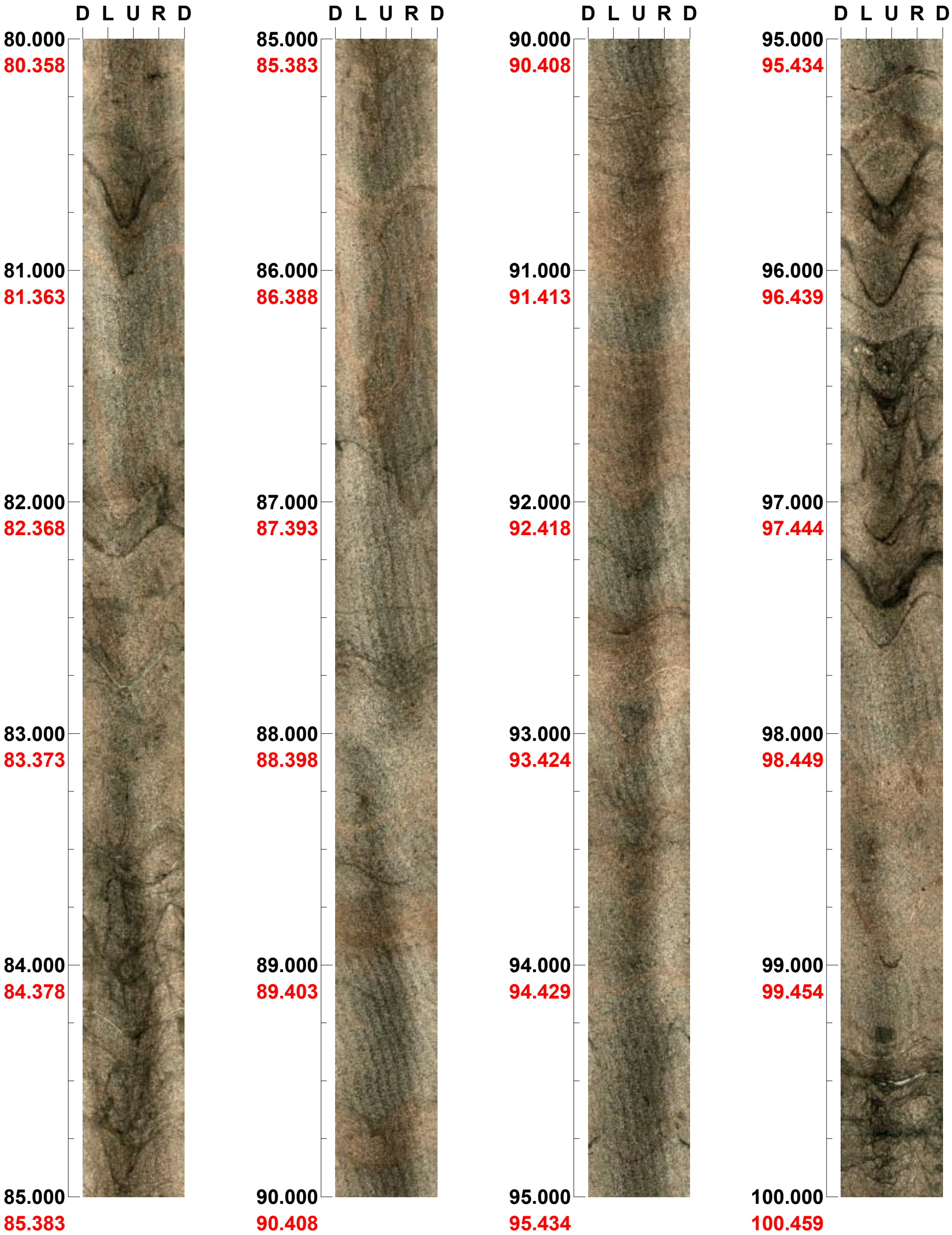
Depth range: 60.000 - 80.000 m



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

Project name: Laxemar
Bore hole No.: HLX31 **Azimuth: 232** **Inclination: -59**

Depth range: 80.000 - 100.000 m



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

Project name: Laxemar
Bore hole No.: HLX31 **Azimuth: 232** **Inclination: -59**

Depth range: 100.000 - 120.000 m

D L U R D

100.000 100.459

101.000 101.464
102.000 102.469
103.000 103.474
104.000 104.479
105.000 105.484

D L U R D

105.000 105.484

106.000 106.489
107.000 107.494
108.000 108.499
109.000 109.504
110.000 110.509

D L U R D

110.000 110.509

111.000 111.514
112.000 112.519
113.000 113.524
114.000 114.529
115.000 115.534

D L U R D

115.000 115.534

116.000 116.539
117.000 117.545
118.000 118.550
119.000 119.555
120.000 120.560

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

Project name: Laxemar

Bore hole No.: HLX31 **Azimuth: 232** **Inclination: -59**

Depth range: 120.000 - 128.135 m

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