P-05-30

Revised April 2006

Oskarshamn site investigation

RAMAC and BIPS logging in borehole KLX06

Jaana Gustafsson, Christer Gustafsson

Malå Geoscience AB / RAYCON

January 2005

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

ISSN 1651-4416
SKB P-05-30

Revised April 2006

Oskarshamn site investigation

RAMAC and BIPS logging in borehole KLX06

Jaana Gustafsson, Christer Gustafsson
Malå Geoscience AB / RAYCON

January 2005

Keywords: BIPS, RAMAC, radar, TV.

This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the authors and do not necessarily coincide with those of the client.

A pdf version of this document can be downloaded from www.skb.se

Reading instructions

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

Abstract

This report includes the data gained in geophysical logging operations performed within the site investigation at Oskarshamn. The logging operations presented here includes borehole radar (RAMAC) and BIPS logging in the core-drilled borehole KLX06. All measurements were conducted by Malå Geoscience AB/RAYCON during December 2004.

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 KLX06 was relatively satisfying, but in large parts of lower quality due to more conductive conditions. This conductive environment of course reduces the possibility to distinguish and interpret possible structures in the rock mass which otherwise could give a reflection. However, the borehole radar measurements resulted in a number of identified radar reflectors and over 200 radar reflectors were identified and a part of them were also orientated (strike/dip).

The BIPS images shows a medium quality due to discoloring and mud covering, which can make the geological mapping more difficult, especially in the lower parts of the borehole.

Sammanfattning

Denna rapport omfattar geofysiska loggningar inom platsundersökningsprogrammet för Oskarshamn. Mätningarna som presenteras här omfattar borrhålsradarmätningar (RAMAC) och BIPS- loggningar i borrhål KLX06. Alla mätningar är utförda av Malå Geoscience AB/RAYCON under december 2004.

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 KLX06 var relativt tillfredställande, men tidvis av sämre kvalité troligen till stor del beroende på en konduktiv miljö. En konduktiv miljö minskar möjligheterna att identifiera strukturer från borrhålsradardata. Dock har drygt 200 radarreflektorer identifierats i KLX06, varav en del har kunnat orienteras (med strykning/ stupning).

BIPS bilderna uppvisar en jämförelsevis låg kvalité på grund av missfärgning och lera på borrhålsväggarna. Detta kan försvåra den geologiska kartläggningen, speciellt i borrhålets lägre delar.

Contents

1	**Introduction**	7
2	**Objective and scope**	9
3	**Equipment**	11
3.1	Radar measurements RAMAC	11
3.2	TV-Camera, BIPS	12
4	**Execution**	13
4.1	General	13
	4.1.1 RAMAC Radar	13
	4.1.2 BIPS	14
	4.1.3 Length measurements	15
4.2	Analyses and Interpretation	16
	4.2.1 Radar	16
	4.2.2 BIPS	17
4.3	Nonconformities	17
5	**Results**	19
5.1	RAMAC logging	19
5.2	BIPS logging	27
References		29
Appendix 1	Radar logging in KLX06, 0 to 990 m, dipole antennas 250, 100 and 20 MHz	31
Appendix 2	BIPS logging in KLX06, 11 to 961 m	41

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 coredrilled borehole KLX06. The work was carried out in accordance with activity plan AP PS 400-04-120. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

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

Activity plan	Number	Version
Borrhålsradar och BIPS i KLX06	AP PS 400-04-120	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

This report includes measurements from 0 to 1,000 m in KLX06. The borehole KLX06 is percussion drilled with a diameter of 195 mm down to 100 m, from there the borehole is coredrilled with a diameter of 76 mm. All measurements were conducted by Malå Geoscience AB/RAYCON during December 2004. The investigation site and location of the borehole is shown in Figure 1-1 and 1-2.

Figure 1-1. *Picture of the borehole site KLX06, with the BIPS camera visible.*

***Figure 1-2.** General overview over the Simpevarp and Laxemar subareas in Oskarshamn with the location of the borehole KLX06 in Laxemar.*

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.

2 Objective and scope

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

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

3 Equipment

3.1 Radar measurements RAMAC

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

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

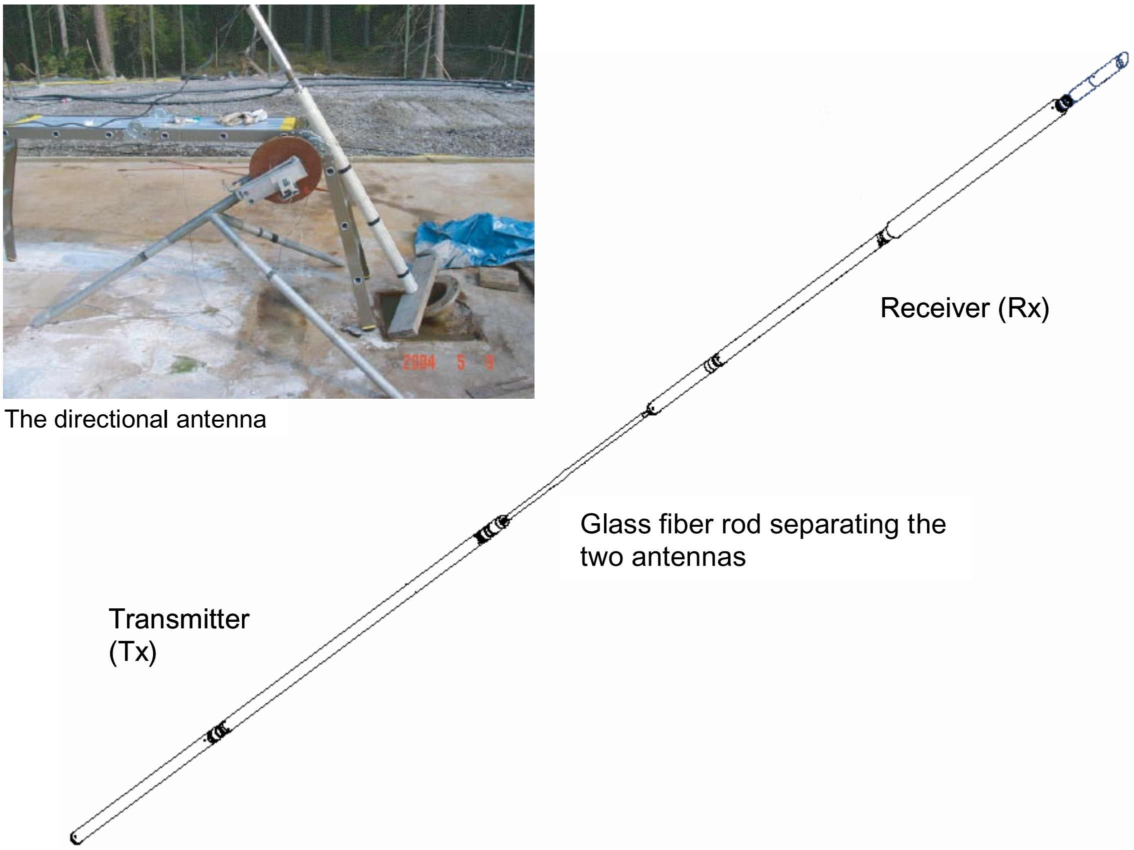


Figure 3-1. *Example of a borehole radar antenna.*

3.2 TV-Camera, BIPS

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

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

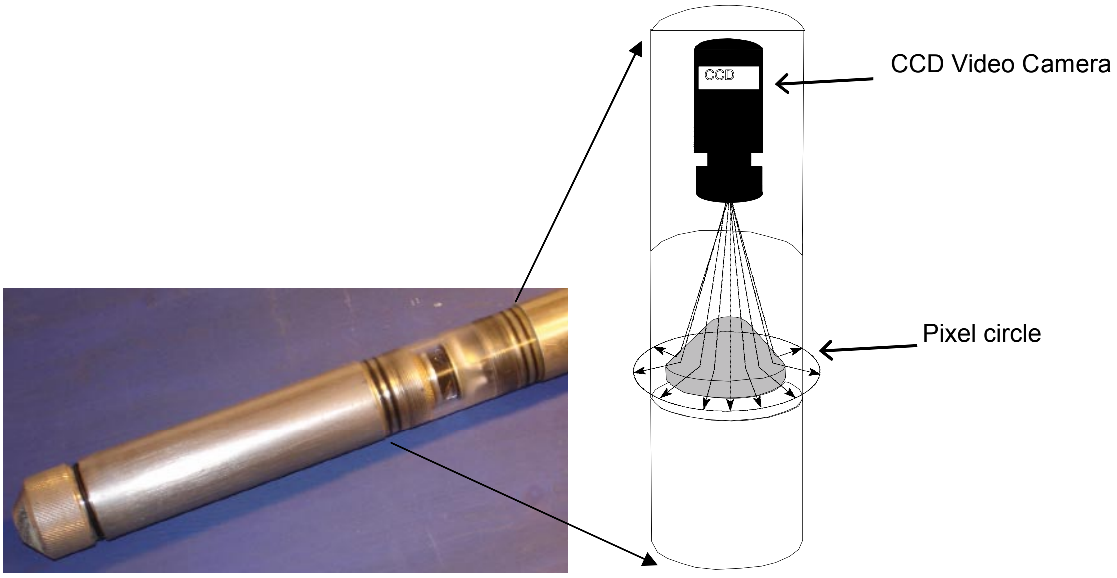


Figure 3-2. *The BIP-system. Illustration of the conical mirror scanning.*

4 Execution

4.1 General

4.1.1 RAMAC Radar

The measurements in KLX06 were carried out with dipole radar antennas, with frequencies of 250, 100 and 20 MHz, and also using the directional antenna, with a central frequency of 60 MHz.

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

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

The functionality of the directional antenna was tested before measurements in KLX06. This is done by measurements in the air, where the receiver antenna and the transmitter antenna are placed apart. While transmitting and measuring the receiver antenna is turned around and by that giving the direction from the receiver antenna to the transmitter antenna. The difference in direction measured by compass and the result achieved from the directional antenna was about 7 degrees. This can be considered as 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 KLX06, see Table 4-1 below.

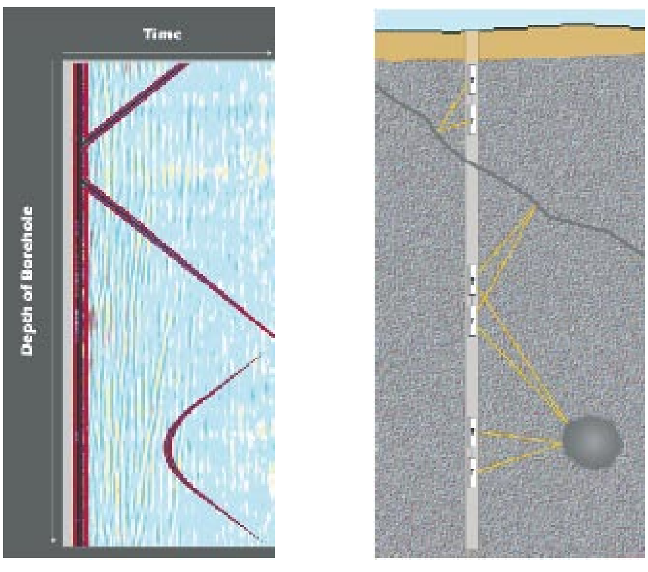


Figure 4-1. The principle of radar borehole reflection survey and an example of result.

Table 4-1. Radar logging information from KLX06.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**		
BH:	**KLX06**	**Equipment:**	**SKB RAMAC**		
Type:	**Directional/Dipole**	**Manufacturer:**	**MALÅ GeoScience**		
Operator:	**CG**	**Antenna**			
		Directional	**250 MHz**	**100 MHz**	**20 MHz**
Logging date:		04-12-29 and 30	04-12-28 and 30	04-12-29	04-12-29
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:		390.48	–0.35	–0.35	1.54
Logging from (m):		3.4	1.5	2.6	6.25
Logging to (m):		983.4	992.5	992.4	987.15
Trace interval (m):		0.5	0.1	0.2	0.25
Antenna separation (m):		5.73	2.4	3.9	10.05

4.1.2 BIPS

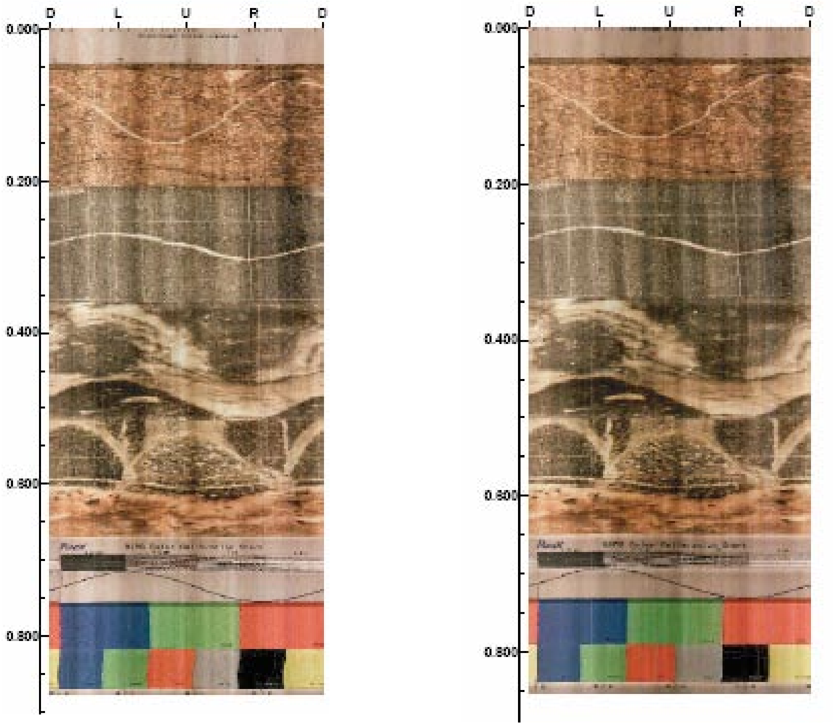
All measurements were performed in accordance with the instructions and guidelines from SKB (internal document MD 222.006). All cleaning of the probe and cable was performed according to the internal document SKB MD 600.004 before the logging operation.

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

A gravity sensor was used to measure the orientation of the images in the borehole KLX06.

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 KLX06. 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 2 in this report.



Before **After**

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

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 Appendix 2. The tape marks on the logging cable are then used for controlling the RAMAC measurement.

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

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

4.2 Analyses and Interpretation

4.2.1 Radar

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

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

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

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

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

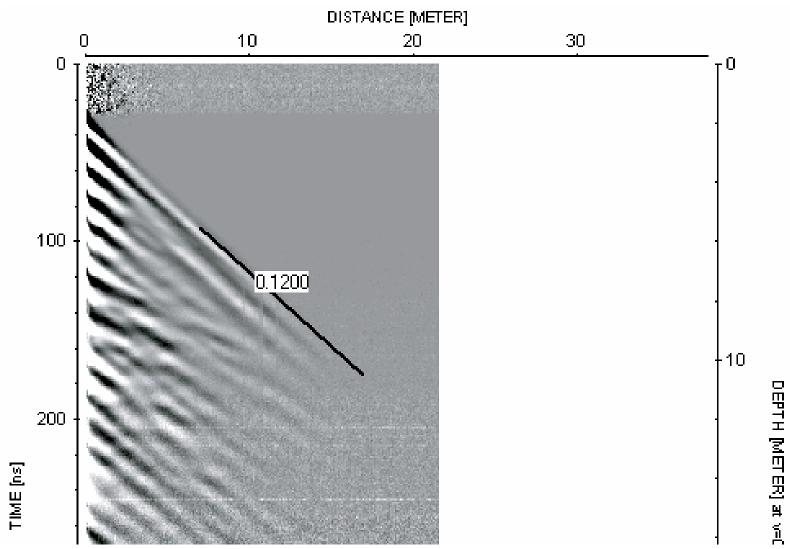


Figure 4-3. *Results from velocity measurements in KSH01B with 100 MHz dipole antennas /1/.*

The visualization of data in Appendix 1 is made with ReflexWin, a Windows based processing software for filtering and analysis of borehole radar data. The processing steps are shown in Table 4-2. It should be observed that the processing steps below refer to Appendix 1. 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 Table 5-2 and are also visible on the radargrams in Appendix 1.

Table 4-2. Processing steps for borehole radar data from KLX06.

Site: Oskarshamn	Logging company:	RAYCON		
BH: KLX06	Equipment:	SKB RAMAC		
Type: Directional/Dipole	Manufacturer:	MALÅ GeoScience		
Interpret: JG	Antenna			
	Directional	250 MHz	100 MHz	20 MHz
Processing:	DC removal	DC removal	DC removal	DC removal
	Time gain	Move start time	Move start time	Move start time
	FIR	Gain	Gain	Gain

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

There were no nonconformities during radar logging in KLX06. These were carried out according to the activity plan.

The BIPS logging stopped at 961 m because the probe jammed, probably due to small rock pieces and the dip of the borehole (less then 40 degrees).

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

5 Results

The results from the BIPS measurements were delivered as raw data (*.bip). 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 KLX06 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 and 5-3. Radardata is also visualized in Appendix 1. It should be remembered that the images in Appendix 1 is only a composite picture of all events 360 degrees around the borehole, and do not reflect the orientation of the structures.

Only the larger clearly visible structures are interpreted in RadinterSKB. A number of minor structures also exist, indicated in Appendix 1. See for instance 450 to 480 m, both 250 and 100 MHz data, where a number of structures can be noticed, but most probably lying so close to each other that it is impossible to distinguish one from the other. Larger structures parallel to the borehole are also indicated in Appendix 1. 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 KLX06, (as seen in Appendix 1) is relatively satisfying, but in parts of lower quality due to more conductive conditions. A conductive environment makes the radar wave to attenuate, which decreases the penetration. This is for instance seen very clearly in the 250 MHz data from 0 to 100 m and from 350 to 420 m. This zone is also clearly visible in the BIPS data, especially around 380 and 390 m. 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, 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 on data from the 250 MHz antenna (Appendix 1).

As also seen in Appendix 1 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.

It should be observed that the location of the borehole cone (between the percussion and core drilled parts) is clearly seen in Appendix 1 at a depth of approximately 97 to 102 m.

In Tables 5-1 below the distribution of identified structures along the borehole are listed for KLX06.

Table 5-1. Identified structures as a function of depth in KLX06.

Depth (m)	No of structures
–100	11
100– 50	10
150 –200	18
200–250	13
250–300	7
300–350	10
350–400	8
400–450	14
450–500	12
500–550	14
550–600	11
600–650	16
650–700	11
700–750	9
750–800	10
800–850	14
850–900	9
900–950	12
950–	8

Table 5-2 summarises the interpretation of radar data from KLX06. As seen some radar reflectors 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 (the plane) is defined in Figure 5-1. As the borehole inclination for KLX06 is less than 85 degrees the direction to object is calculated using gravity roll. This direction and the intersection angle are also recalculated to strike and dip, also given in Table 5-2 below. The plane strike is the angle between line of the plane's cross-section with the surface and the Magnetic North direction. It counts clockwise and can be between 0 and 359 degrees. A strike of 0 degrees implies a dip to the east while a strike of 180 degrees implies a dip to the west. The plane dip is the angle between the plane and the surface. It can vary between 0 and 90 degrees.

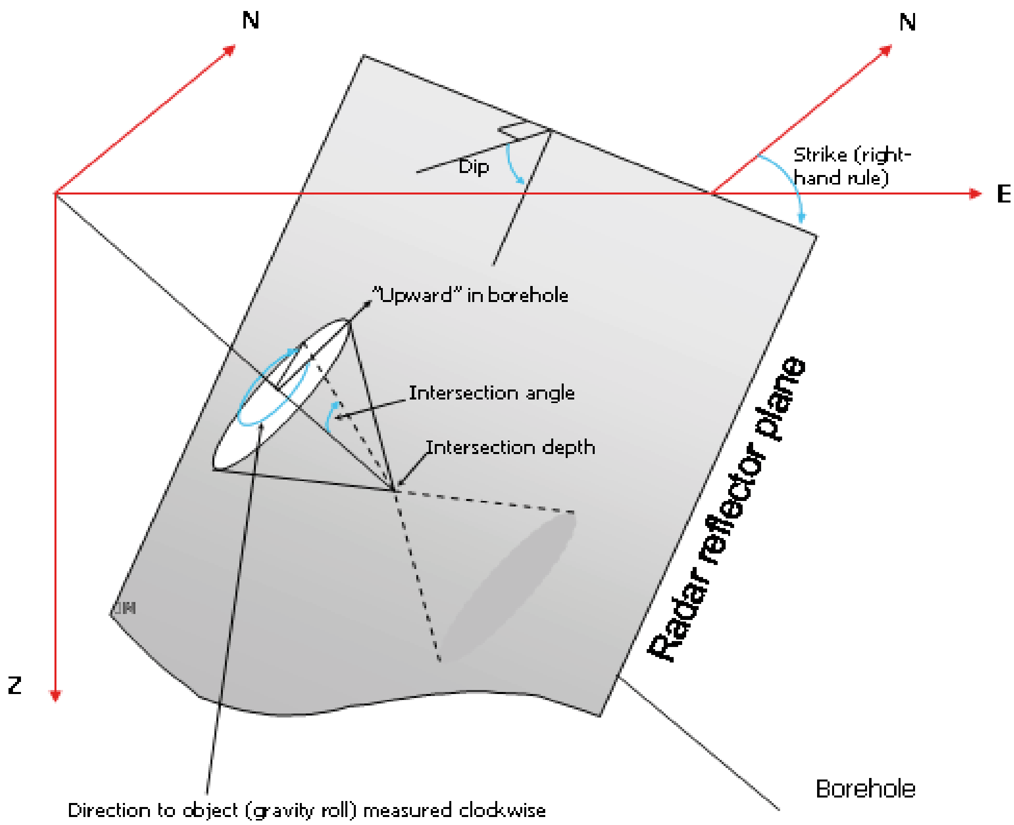


Figure 5-1. *Definition of intersection angle, direction to object using gravity roll, dip and strike using the right hand rule as presented in Table 5-2.*

Table 5-2. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz and the directional antenna in borehole KLX06.

Radinter model information
(20, 100 and 250 MHz Dipole Antennas and Directional antenna)

Site: Oskarshamn
Borehole name: KLX06
Nominal velocity (m/μs): 120.0

Name	Intersection depth	Intersection angle	Object direction	Dip 1	Strike 1	Dip 2	Strike 2
1	22.20	81					
2	24.70	74					
3	46.50	61					
4	49.10	59					
5	53.00	65					
5x	53.30	50					
196	63.60	48					
6	83.40	49					
8	84.60	19	15 ±	46	278	84	284
7	84.70	69					
195	99.20	42					
9	107.50	59					
10	108.40	62					

Radinter model information (20, 100 and 250 MHz Dipole Antennas and Directional antenna)							
Site:		**Oskarshamn**					
Borehole name:		**KLX06**					
Nominal velocity (m/μs):		**120.0**					
Name	**Intersection depth**	**Intersection angle**	**Object direction**	**Dip 1**	**Strike 1**	**Dip 2**	**Strike 2**
11	114.40	60					
12	127.70	52	195 ±	15	260	65	108
13	133.50	59					
14	134.80	69					
17	137.20	45					
20	146.00	37					
19	148.60	62					
15	148.70	48					
16x	152.30	33					
15x	154.10	28					
16	154.60	40	204	26	255		
18	161.10	61					
23	162.40	49					
22	164.20	66					
25	166.60	61					
21	169.50	52					
23x	169.80	40					
24	172.30	51					
26	178.60	63	249 ±	30	180	44	79
194	184.20	27					
29	185.60	54	45 ±	57	89	25	212
27	185.80	22					
30	187.80	41					
28	188.20	24					
31	190.90	57	216	18	210		
32	196.80	43					
34	202.10	44					
33x	204.40	40					
33	205.00	47	210 ±	22	238	65	97
35x	214.60	23					
35	214.90	28					
40	221.70	28					
39	225.30	28					
41	229.50	70					
36x	231.70	41					
36	236.50	30					
38	240.30	48					
37	240.50	37	216 ±	33	241	75	89
42	243.30	47					

Radinter model information
(20, 100 and 250 MHz Dipole Antennas and Directional antenna)

Site: **Oskarshamn**
Borehole name: **KLX06**
Nominal velocity (m/μs): **120.0**

Name	Intersection depth	Intersection angle	Object direction	Dip 1	Strike 1	Dip 2	Strike 2
44	259.60	24	237	52	224		
43	265.50	41	231 ±	36	220	67	80
45	272.40	38					
45x	273.10	47	357 ±	66	120	13	306
46	284.20	41					
48	285.90	43					
47	288.00	54					
49	300.60	60					
50	308.50	44	198	20	257		
53	310.30	58					
52	311.80	35					
51	314.80	35					
54	315.90	56					
55	332.50	20					
57	333.90	42					
58	341.20	43					
59	346.10	43					
56	357.50	17	210 ±	49	254	82	265
60	362.00	66					
61	367.30	36					
62	365.90	52	39 ±	62	88	23	209
65	373.70	61					
63	376.40	58					
64	381.00	56					
66	397.40	59					
67	404.50	39					
67x	404.90	53					
68	412.00	41					
69	417.30	54					
69x	417.80	46					
71	419.30	60					
70	420.30	53	234 ±	30	187	59	74
72	426.40	66					
73	430.10	51					
74	433.30	39					
75	437.20	61					
76	445.60	53					
77	446.10	56					
78	449.70	57					

Radinter model information
(20, 100 and 250 MHz Dipole Antennas and Directional antenna)

Site: Oskarshamn
Borehole name: KLX06
Nominal velocity (m/μs): 120.0

Name	Intersection depth	Intersection angle	Object direction	Dip 1	Strike 1	Dip 2	Strike 2
81	454.70	43					
79	459.90	56					
80	463.70	51					
82	466.80	59					
83	471.60	55					
88	473.20	25					
84	477.10	50					
85	481.40	32					
86	491.70	45					
86x	491.30	76					
87	496.00	46					
197	497.60	69	180 ±	12	107	51	107
92x	503.40	83					
92	504.00	54	240 ±	34	170	61	65
89	509.50	15					
93	508.10	48					
90	510.00	44					
91	512.90	63					
94	516.90	65					
95	519.60	61					
96	522.60	52	66 ±	57	65	36	177
187	529.40	55					
97	532.10	66	192	10	135		
98	537.30	58					
100	544.50	47					
99	544.70	53	24 ±	69	87	14	196
103	552.30	52					
101	556.00	56					
102	557.40	53	207 ±	16	187	69	85
106	560.90	54					
104	562.50	48					
105	567.40	49					
108	578.90	52					
109	589.40	57					
110	590.70	45					
140x	591.70	4	90 ±	87	9	87	183
107	596.60	37	186	18	267		
111	603.30	51					
112	606.30	50					

Radinter model information (20, 100 and 250 MHz Dipole Antennas and Directional antenna)							
Site:	**Oskarshamn**						
Borehole name:	**KLX06**						
Nominal velocity (m/μs):	**120.0**						
Name	**Intersection depth**	**Intersection angle**	**Object direction**	**Dip 1**	**Strike 1**	**Dip 2**	**Strike 2**
115	608.10	20					
113	612.20	50					
117	615.40	48					
116	618.30	63					
118	621.10	60					
119	633.10	53					
119x	633.40	46	186	13	258		
122	634.40	15					
120	636.80	58					
198	640.80	31	186	21	266		
188	642.20	33					
121	642.50	57					
199	644.80	24	291 ±	83	157	58	9
123	649.50	45					
124	652.00	44					
125	657.10	72					
126	659.90	58	195	9	169	71	90
127	662.20	56					
131	672.80	23	309	88	323		
129	674.00	44					
128	676.30	30	117	52	6		
130	682.80	60					
114	684.40	12	204	45	246		
132	689.50	47					
136	699.60	35	276 ±	68	160	61	27
134	702.40	44					
135	707.10	49					
189	707.90	21					
137	714.90	55	186 ±	7	125	75	94
133	721.80	45	51	73	65		
139	725.20	22					
138	727.70	55					
141	730.50	57					
140	737.70	22	252	62	187		
142	752.50	49					
143	756.50	19					
144	768.10	39					
145	770.70	27	255 ±	62	176	81	36

Radinter model information
(20, 100 and 250 MHz Dipole Antennas and Directional antenna)

Site: Oskarshamn
Borehole name: KLX06
Nominal velocity (m/μs): 120.0

Name	Intersection depth	Intersection angle	Object direction	Dip 1	Strike 1	Dip 2	Strike 2
148	775.90	43					
145x	776.70	36					
146	780.2	48					
147	782.40	48					
149	790.90	52					
150	796.70	48					
151	806.00	46	219	28	169		
152	808.60	33					
155	809.60	43					
154	812.90	43					
153	814.60	42	240 ±	43	165	79	55
156	818.00	42					
157	821.20	55	12 ±	81	89	14	125
159	823.70	41					
190	832.80	30					
158	833.00	52	21 ±	82	83	17	142
161	835.80	39	255	57	168		
158x	837.70	39	189	8	212		
160	838.60	47	45 ±	80	68	31	160
162	841.60	39					
163	857.80	47					
201	865.80	40	117	47	26		
171	873.30	53					
200	879.40	31	291	83	150		
164	880.70	51					
165	885.30	59	102 ±	49	51	60	133
166	886.30	49					
172	891.10	59					
167	898.70	47					
168	900.40	55					
169	903.60	32					
170	906.20	47	300	79	136		
173	909.20	58					
175	913.70	73	192 ±	34	101	64	92
174	914.70	61					
193	921.50	44					
176	924.90	35					
177	930.80	39					
178	937.10	60					

Radinter model information (20, 100 and 250 MHz Dipole Antennas and Directional antenna)							
Site:		Oskarshamn					
Borehole name:		KLX06					
Nominal velocity (m/μs):		120.0					
Name	**Intersection depth**	**Intersection angle**	**Object direction**	**Dip 1**	**Strike 1**	**Dip 2**	**Strike 2**
179	945.20	47	171 ±	7	26	85	282
180	947.10	35					
181	964.80	33	192 ±	11	206	78	266
183	967.80	35					
182	970.10	58	357 ±	81	97	18	90
184	977.10	46					
186	985.20	46					
185	991.70	47					
191	1,033.10	38					
192	1,043.60	46					

In Appendix 1, the amplitude of the first arrival is plotted against the depth, for the 250 MHz dipole antennas. The amplitude variation along the borehole indicates changes of the electrical conductivity of the volume of rock surrounding the borehole. A decrease in this amplitude may indicate fracture zones, clay or rock volumes with increases in water content, i.e. increases in electric conductivity. The decrease in amplitude is shown in Table 5-3.

Table 5-3. Borehole length intervals in KLX06 with decreased amplitude for the 250 MHz antenna.

Depth (m)	
25	405
35–40	410
50	420
90–95	425
150–155	445
165	535
185–195	545
205	630–645
225–240	675
255	735–740
265	810
290	830
305	870
310	885–890
340–370	905
375	965
380–400	985

5.2 BIPS logging

The BIPS pictures are presented in Appendix 2.

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.

During the drilling of the borehole it was indicated that a section from around 383 m was problematic due to a clay zone. Dummy logging after the drilling did prove that this part of the borehole needed to be handled with care. Therefore an inspection with the front viewing camera was performed in-between 380 m and 390 m. The aim was to observe if there were any pieces of rock that could jam probes. This inspection showed no objects pointing out from the borehole wall, and the decision was to scan this section with the BIPS camera. The result from the BIPS showed an unusual result when the images were compared with the cores. The BIPS images showed several open sections but the cores were more or less intact. The biggest open section was 0.7 m long.

The logging in KLX06 was performed during three runs. The first run was performed 04-12-27, from 11 m down to 97 m. This section of the borehole is drilled with a percussion drill rig and the borehole diameter is 195 mm. The images are of bad quality due to the big borehole diameter. The main reason is the lack of light on the walls due to large distances from the light source and the borehole wall.

In the core-drilled part of the borehole run number two (04-12-28) from 101 m ended at 407.6 m were the batteries in the probe went down. The last run from 407.5 m stopped at 961 m because the probe jammed probably due to small rock peaces and the dip of the borehole (less then 40 degrees). It is very difficult to make the probe operate smoothly in low angled boreholes; mud and small rock peaces can easily stop the probe. According from the results from inclinometer sensor in the directional borehole radar antenna the dip of the borehole is 37° in the bottom. This fact makes it very difficult to provide a smooth movement of the probe at a low logging speed that is needed for the BIPS probe. Maximum speed is 1.6 m/minute and the friction on the probe and the cable has a strong effect on the image quality in low angle boreholes.

In general the images is of reasonable quality. From 600 m down to the bottom of the borehole mud is covering the lowermost part of the borehole wall, which limits the visibility. The induced colouring effect from the drilling is also reducing the quality along the borehole.

The BIPS Images in Appendix 2 is adjusted for the tension of the cable and error of the depth readings from the measuring wheel. The adjusted depth is showed in red colour and the recording depth have black colour in the printouts. Comments on the BIPS results are referred to the recording depths in this report.

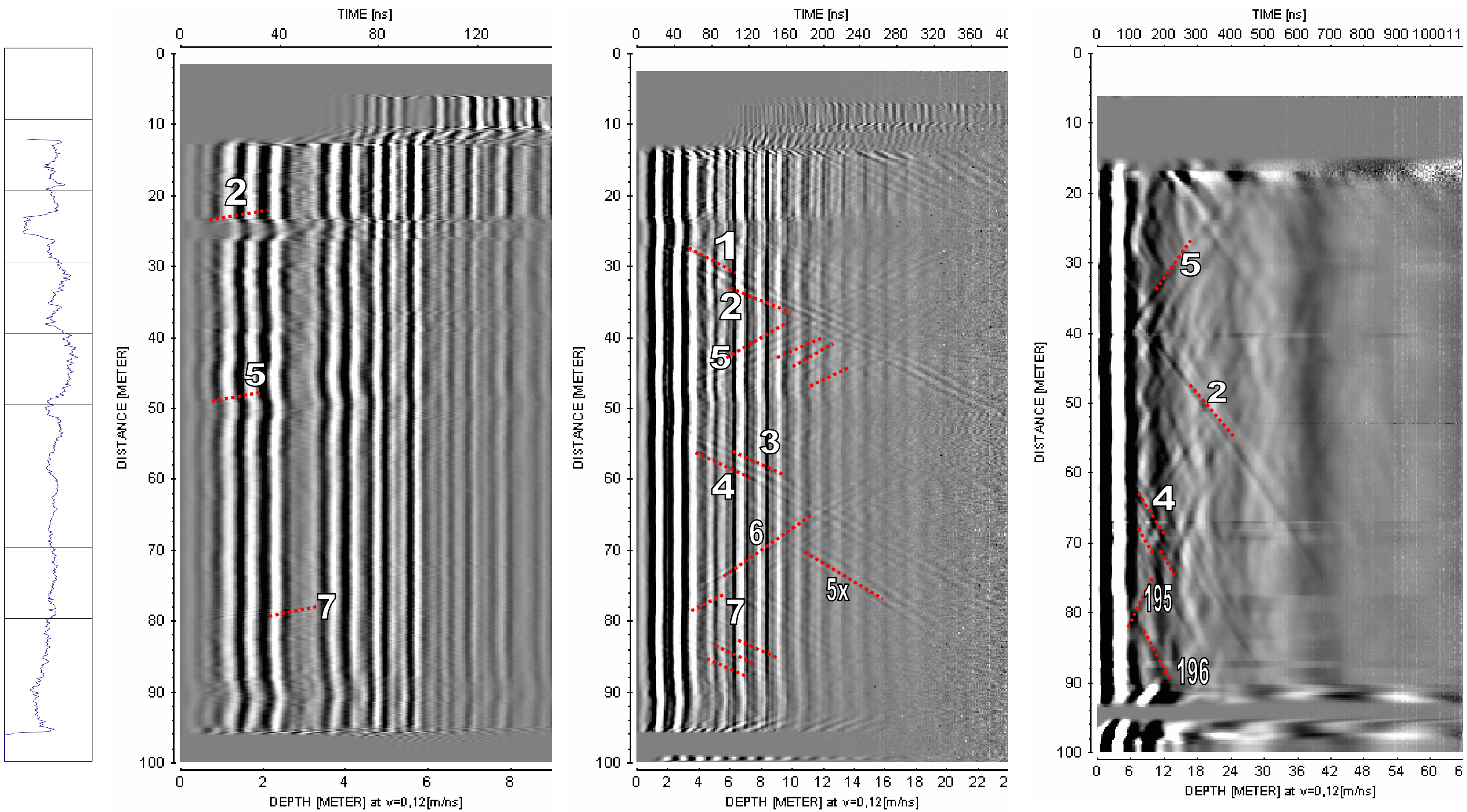
References

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

Radar logging in KLX06, 0 to 990 m, dipole antennas 250, 100 and 20 MHz

Appendix 1

LAXEMAR KLX06

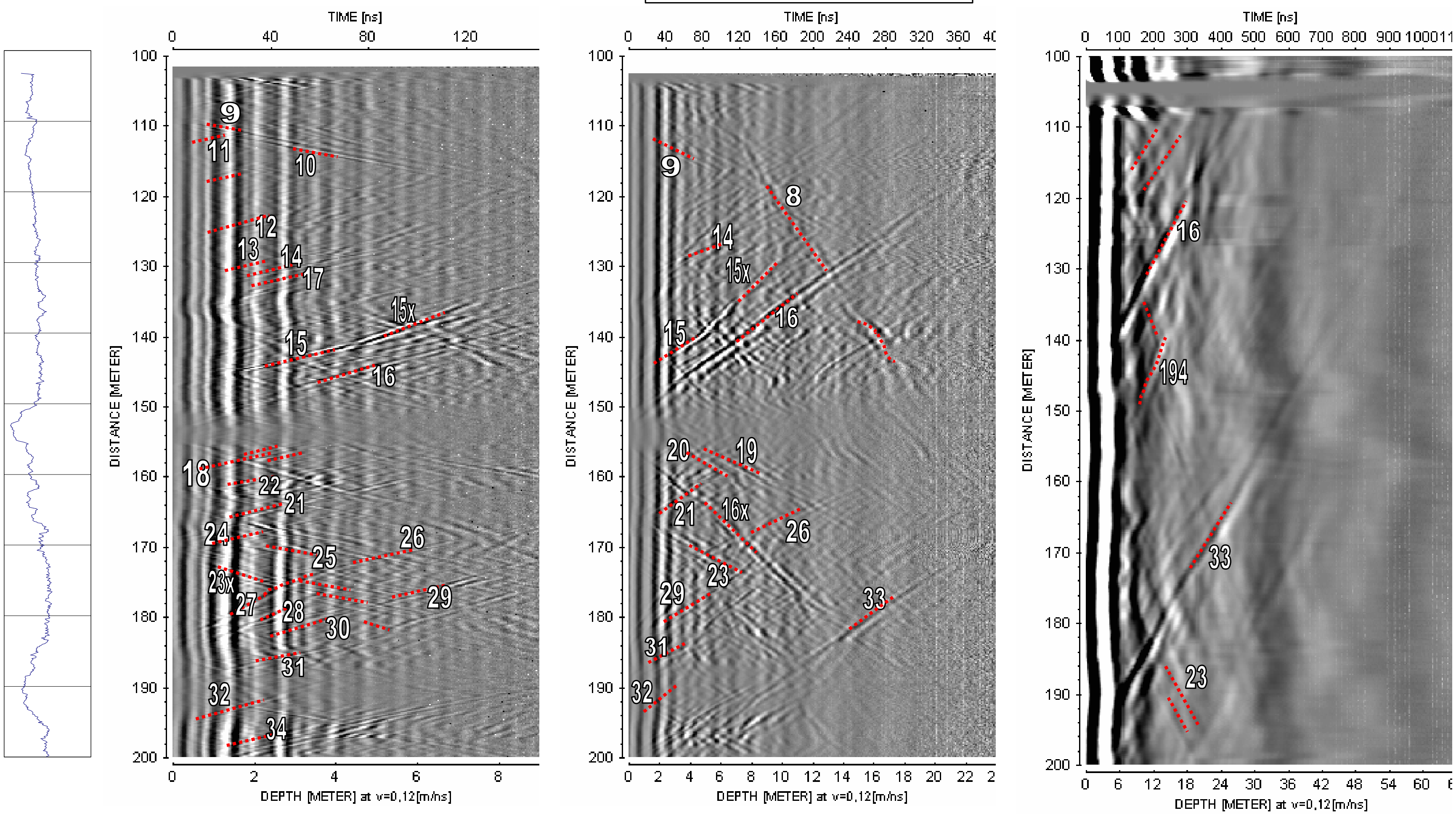


250 MHz

100 MHz

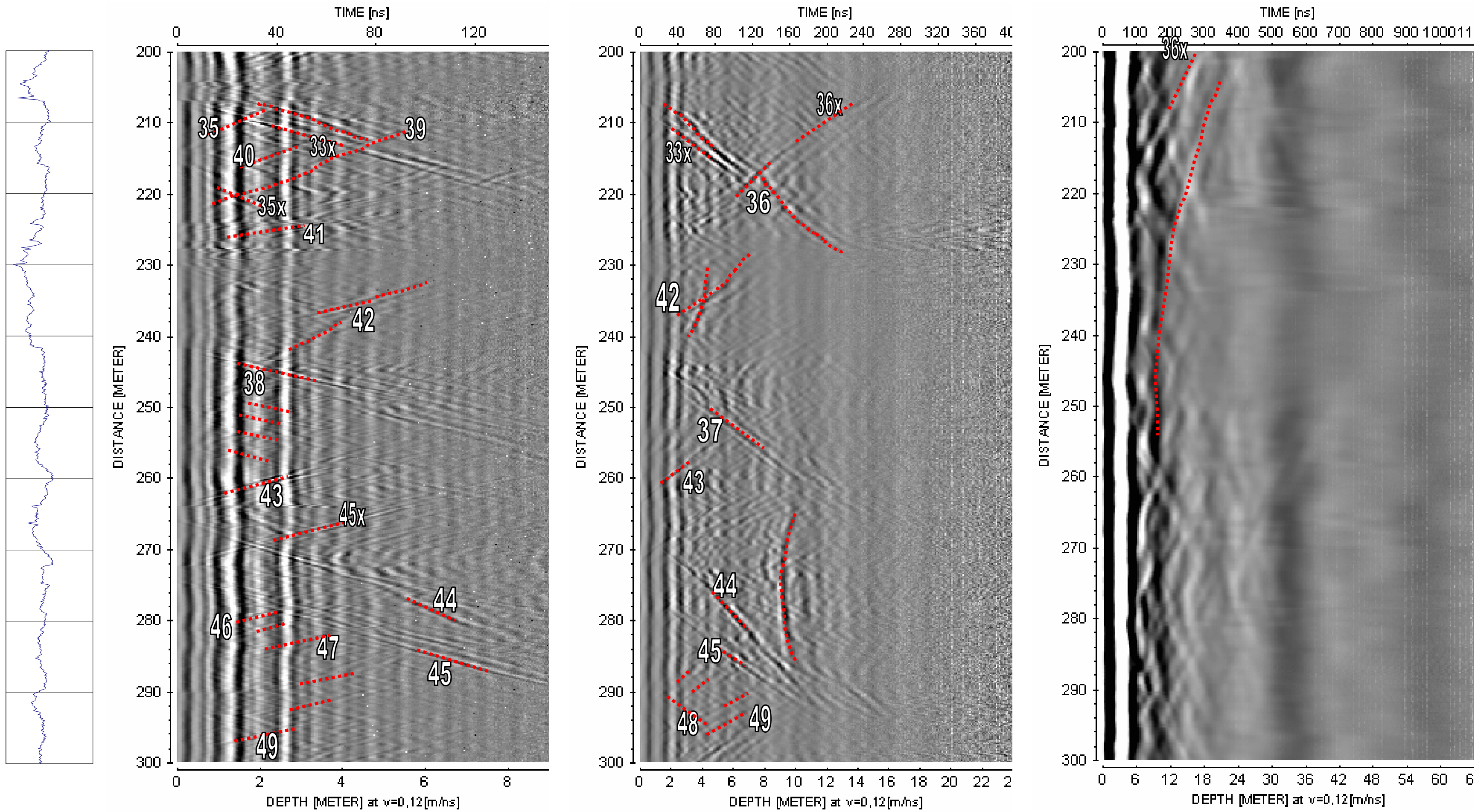
20 MHz

LAXEMAR KLX06



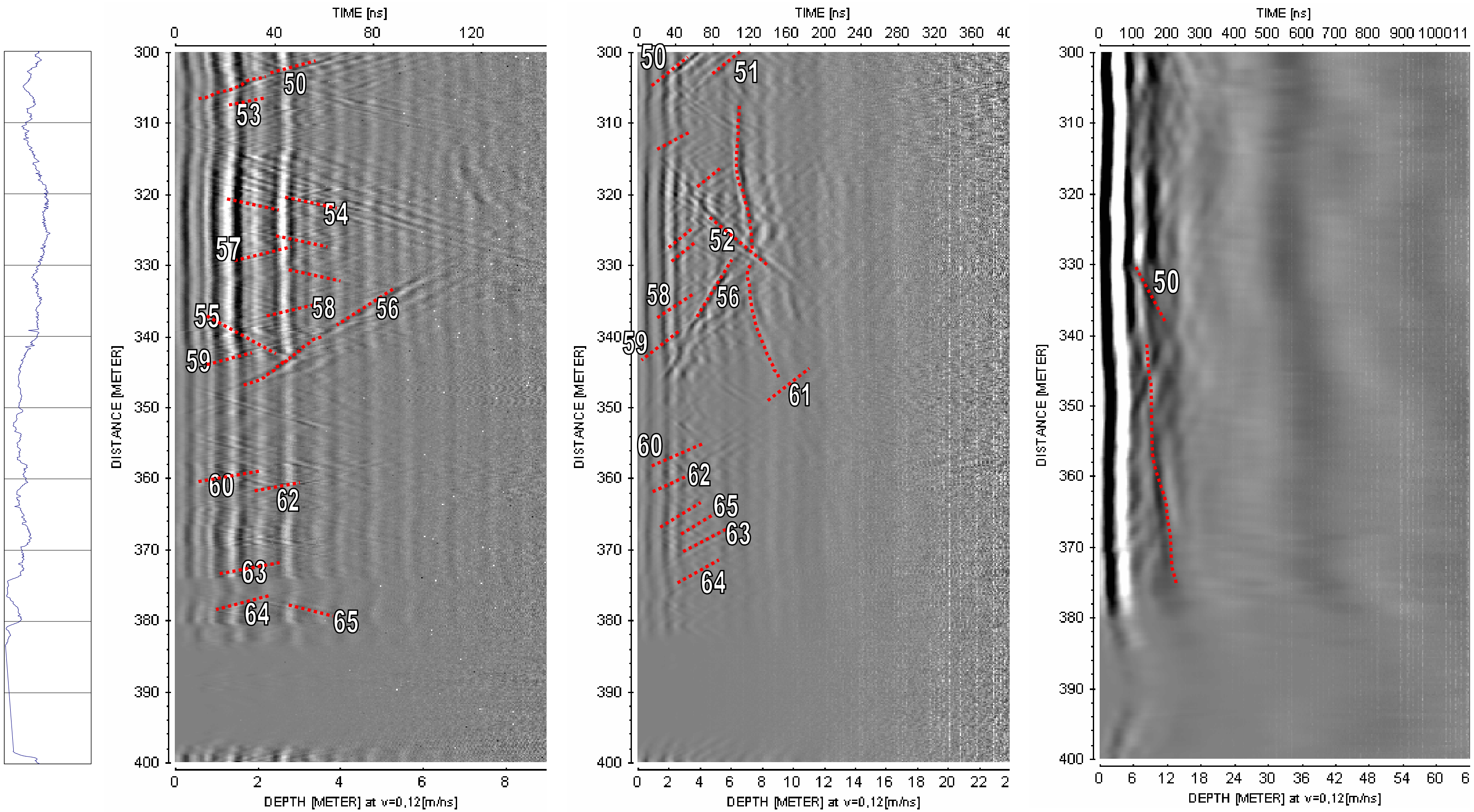
250 MHz 100 MHz 20 MHz

LAXEMAR KLX06



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

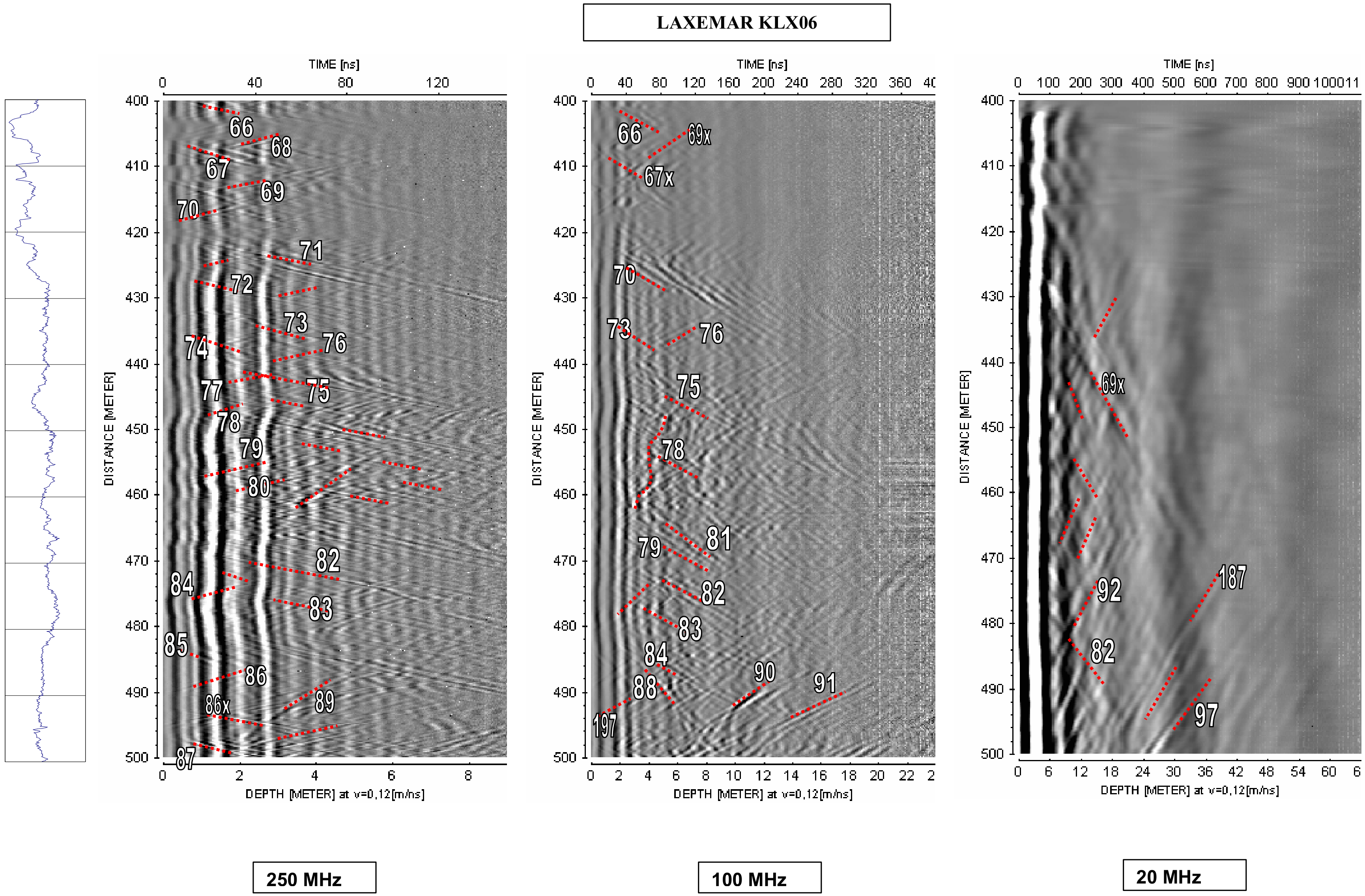
LAXEMAR KLX06



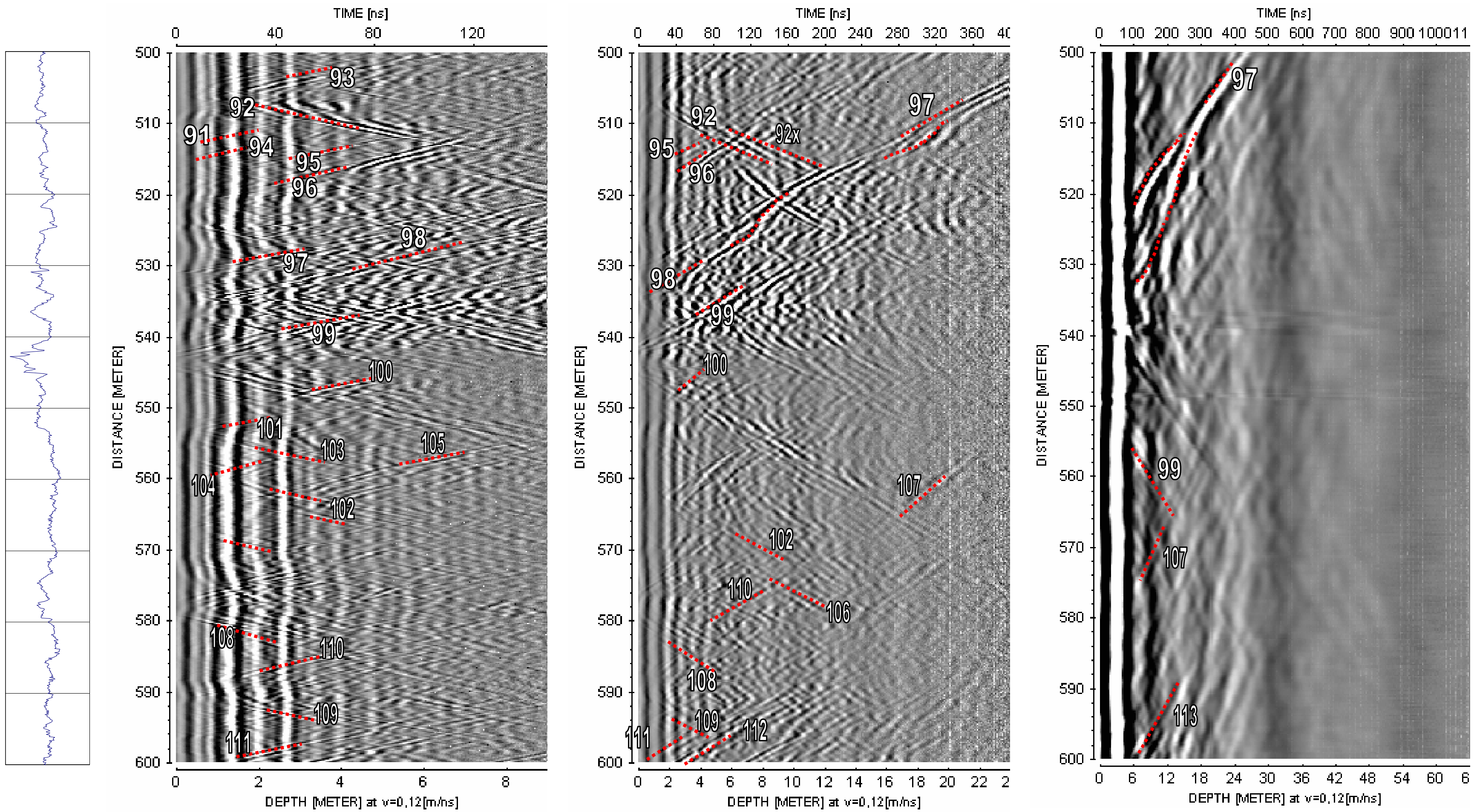
250 MHz

100 MHz

20 MHz

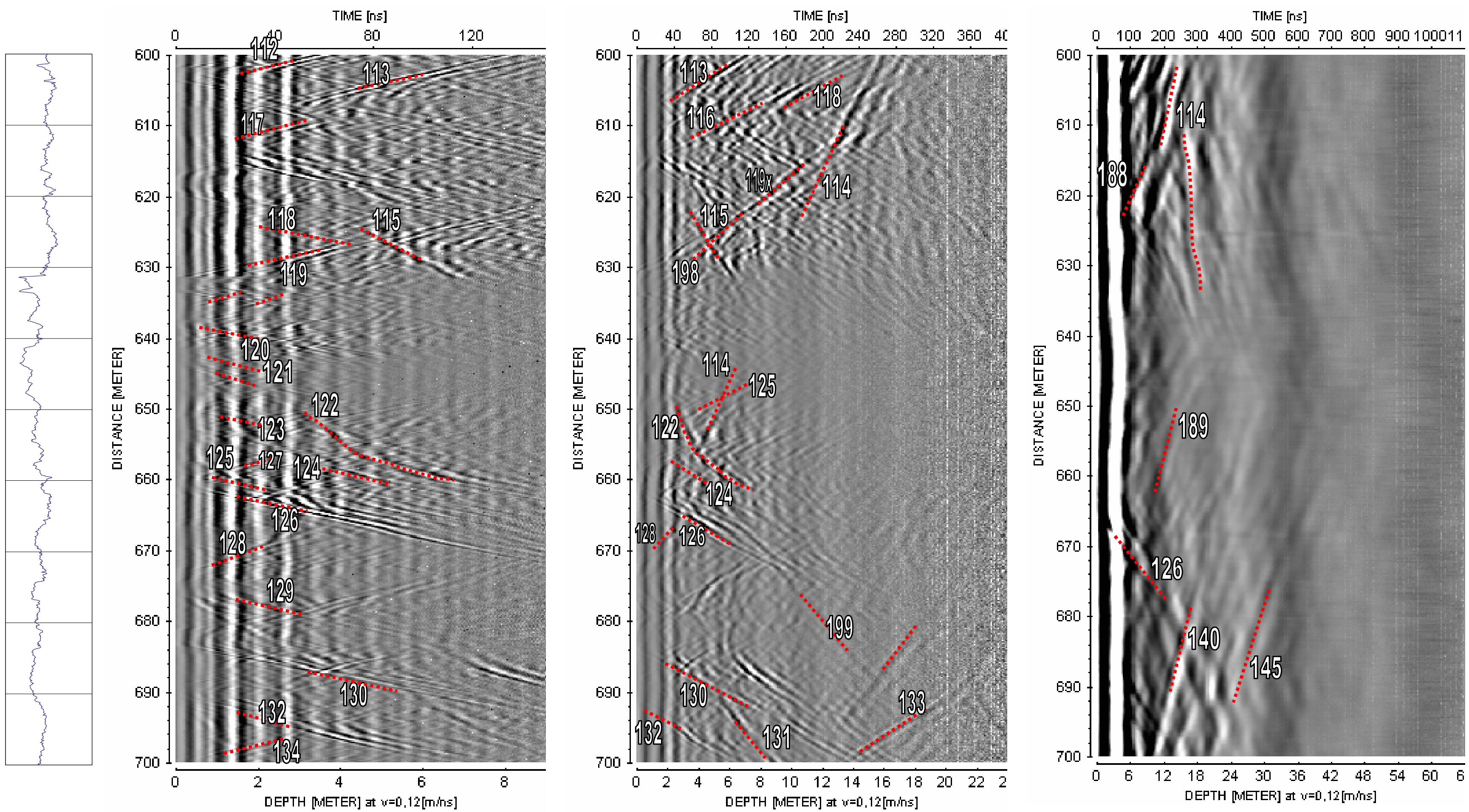

LAXEMAR KLX06
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,12[m/ns]
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
82
83
84
85
86
86x
87
89
69x
67x
81
88
90
91
197
92
187
97
250 MHz
100 MHz
20 MHz

LAXEMAR KLX06



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

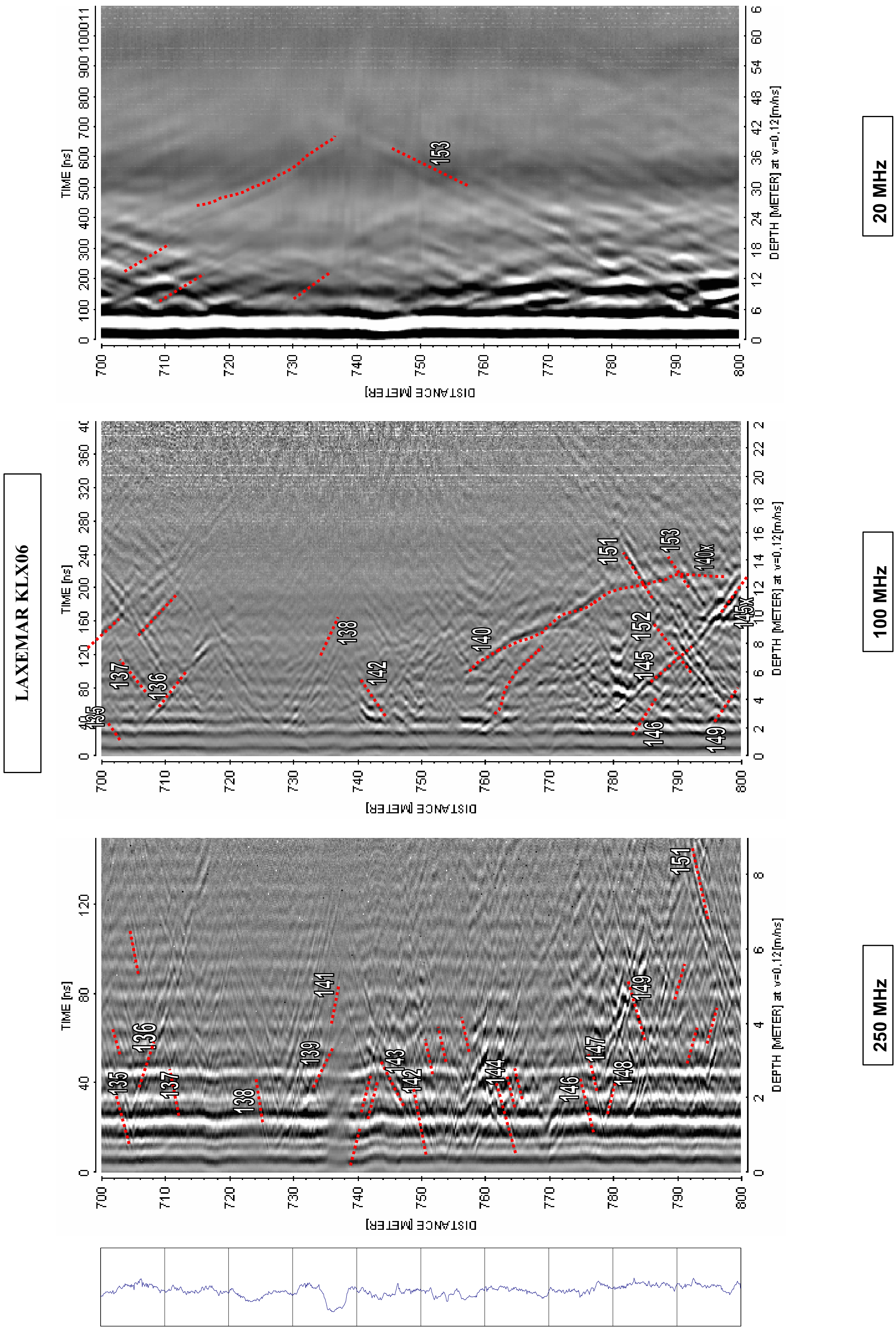
LAXEMAR KLX06



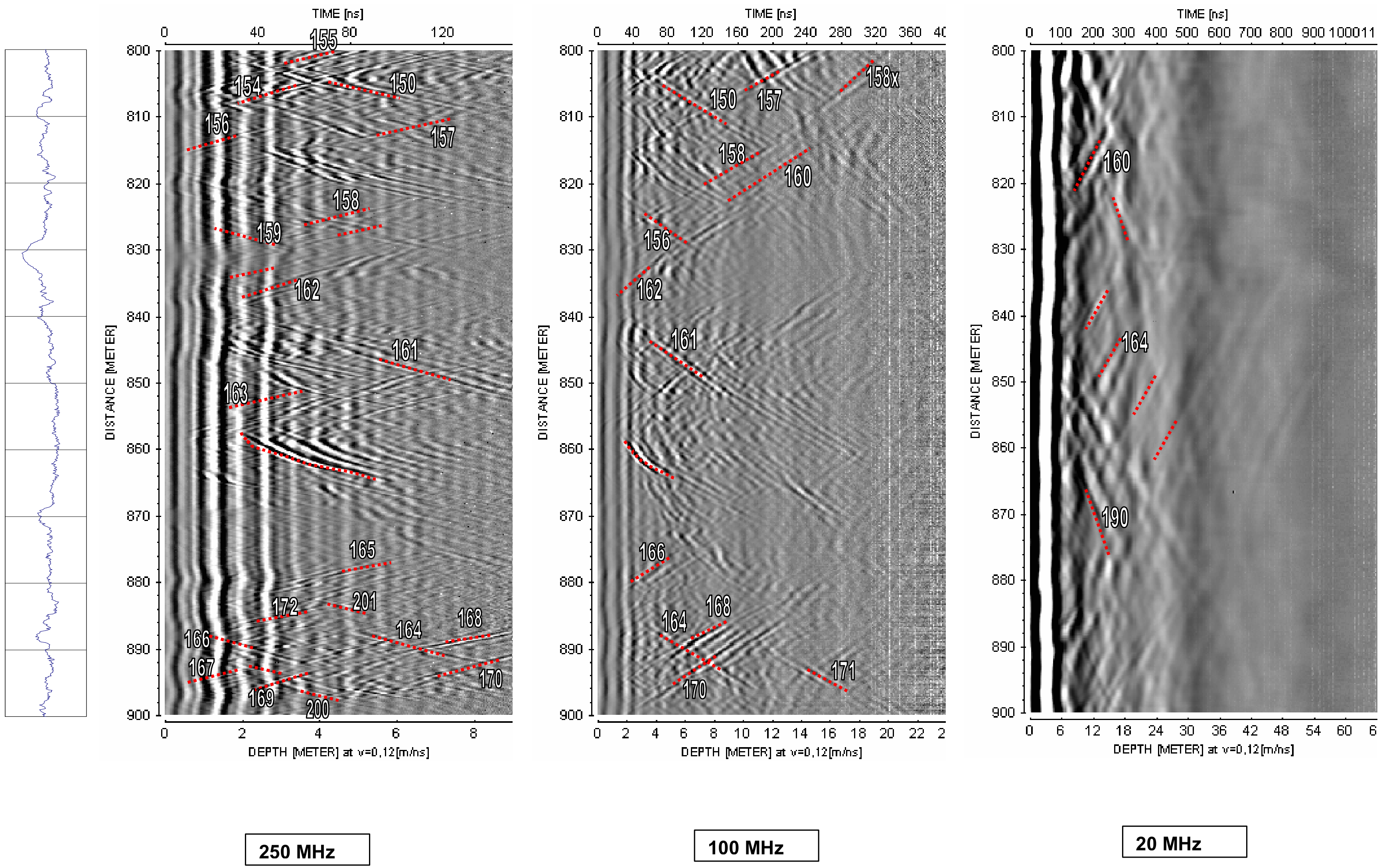
250 MHz

100 MHz

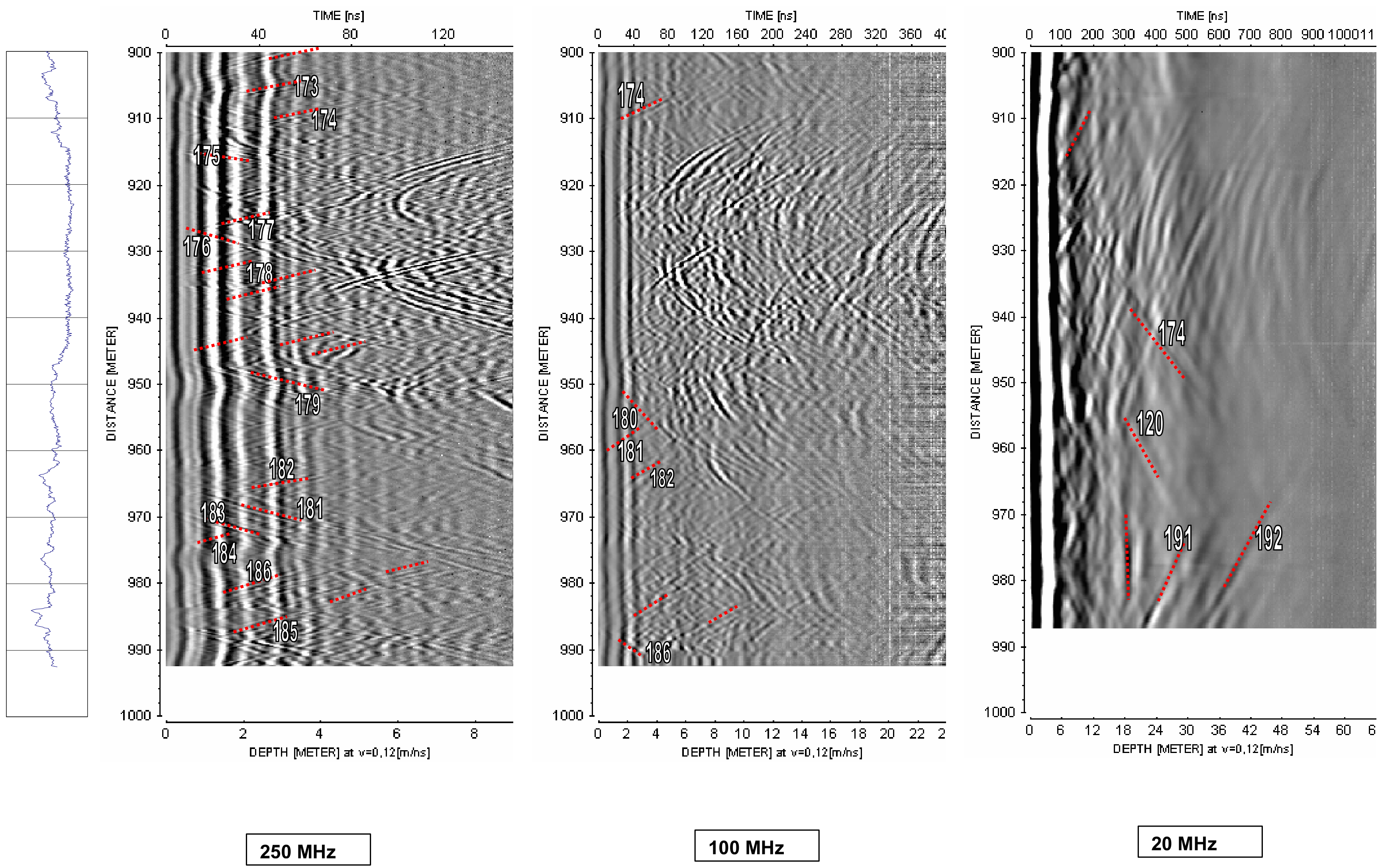
20 MHz


LAXEMAR KLX06
250 MHz
100 MHz
20 MHz
DISTANCE [METER]
TIME [ns]
DEPTH [METER] at v=0,12[m/ns]

LAXEMAR KLX06



LAXEMAR KLX06



Appendix 2

BIPS logging in KLX06, 11 to 961 m

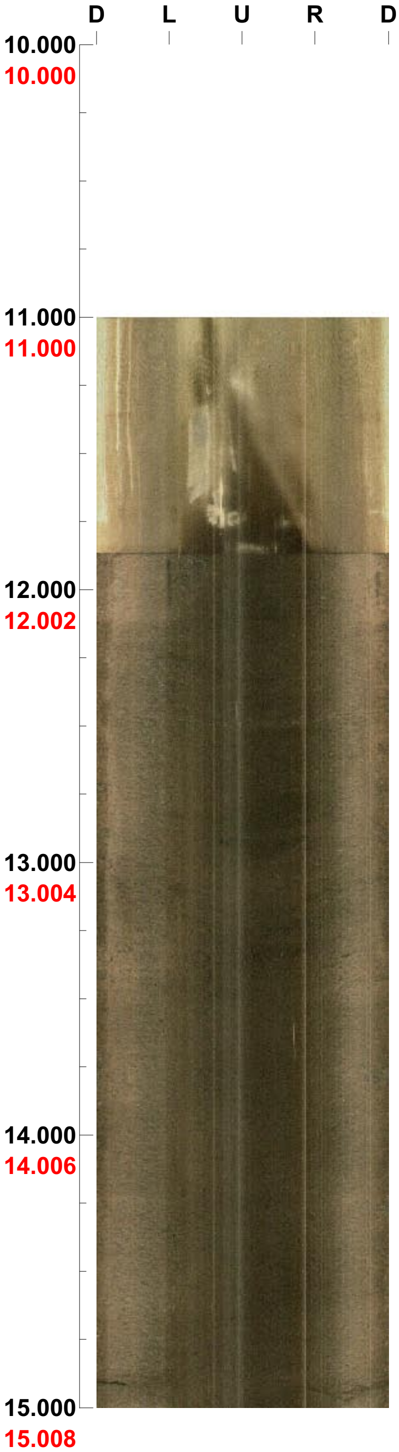
Project name: Laxemar

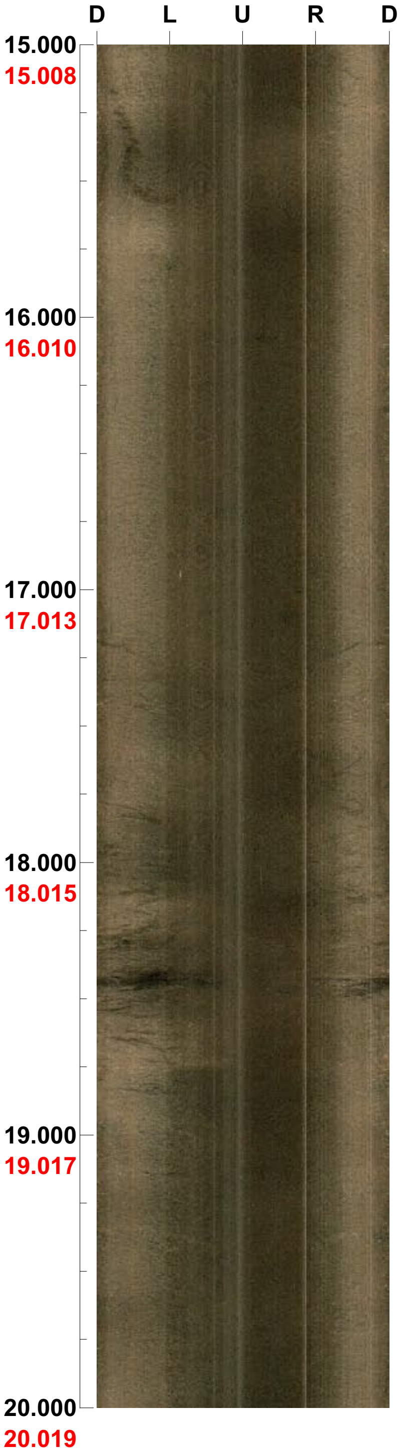
Image file	: c:\work\r5382s~1\bips\11_97m.bip
BDT file	: c:\work\r5382s~1\bips\11_97m.bdt
Locality	: LAXEMAR
Bore hole number	: KLX06
Date	: 04/12/27
Time	: 15:27:00
Depth range	: 11.000 - 97.007 m
Azimuth	: 330
Inclination	: -65
Diameter	: 195.0 mm
Magnetic declination	: 0.0
Span	: 4
Scan interval	: 0.25
Scan direction	: To bottom
Scale	: 1/25
Aspect ratio	: 175 %
Pages	: 9
Color	: +0 +0 +0

Project name: Laxemar

Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 10.000 - 20.000 m

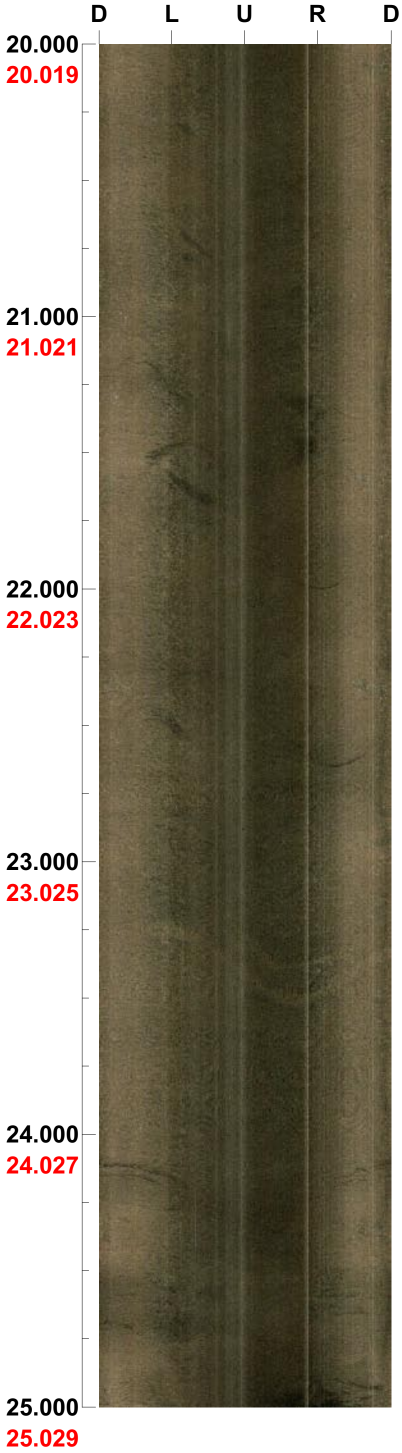


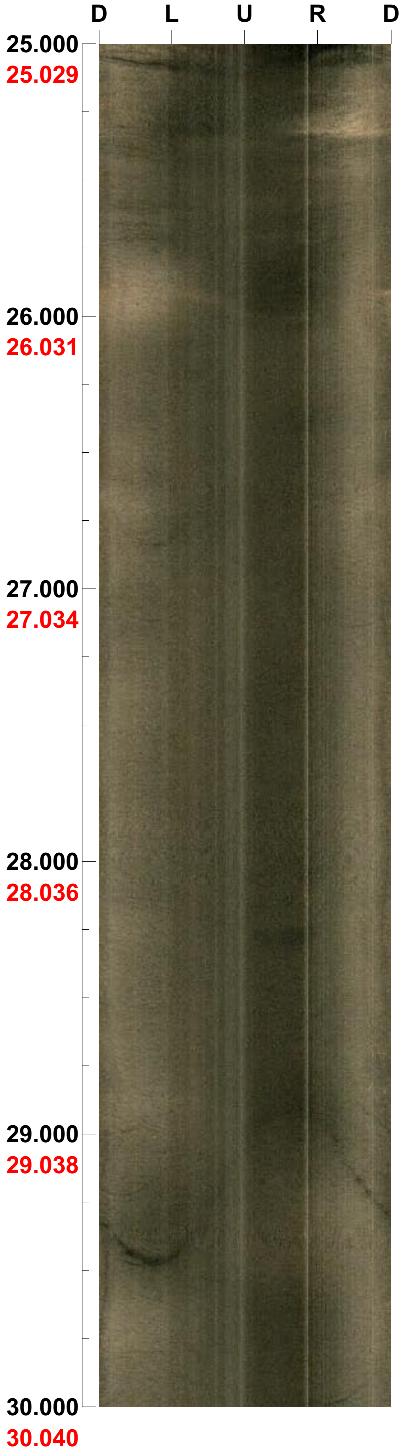


(1 / 9) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar
Bore hole No.: KLX06 Azimuth: 330 Inclination: -65

Depth range: 20.000 - 30.000 m

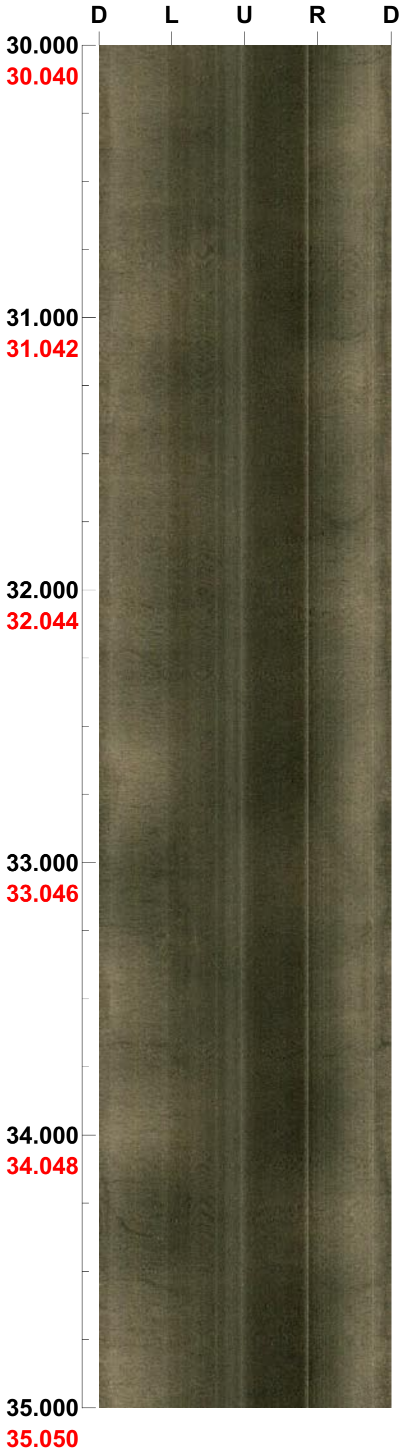


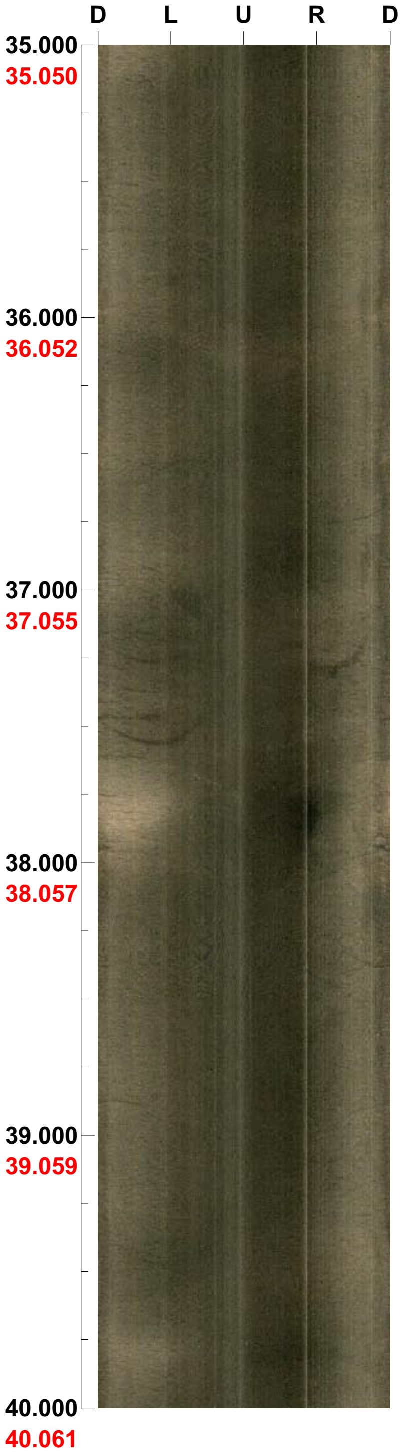


(2 / 9) Scale: 1/25 Aspect ratio: 175 %

Project name: Laxemar
Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 30.000 - 40.000 m

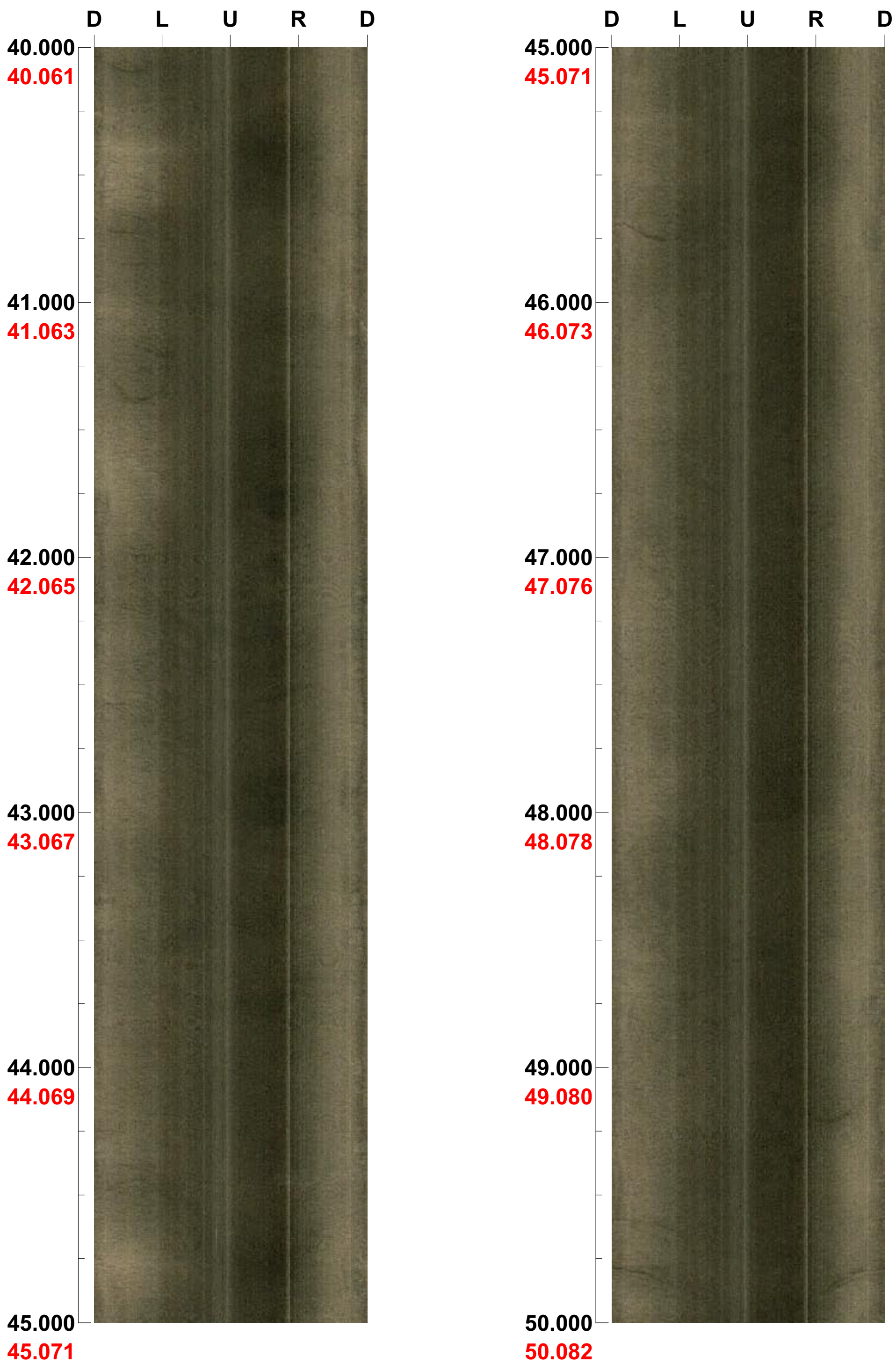




(3 / 9) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar
Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 40.000 - 50.000 m



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

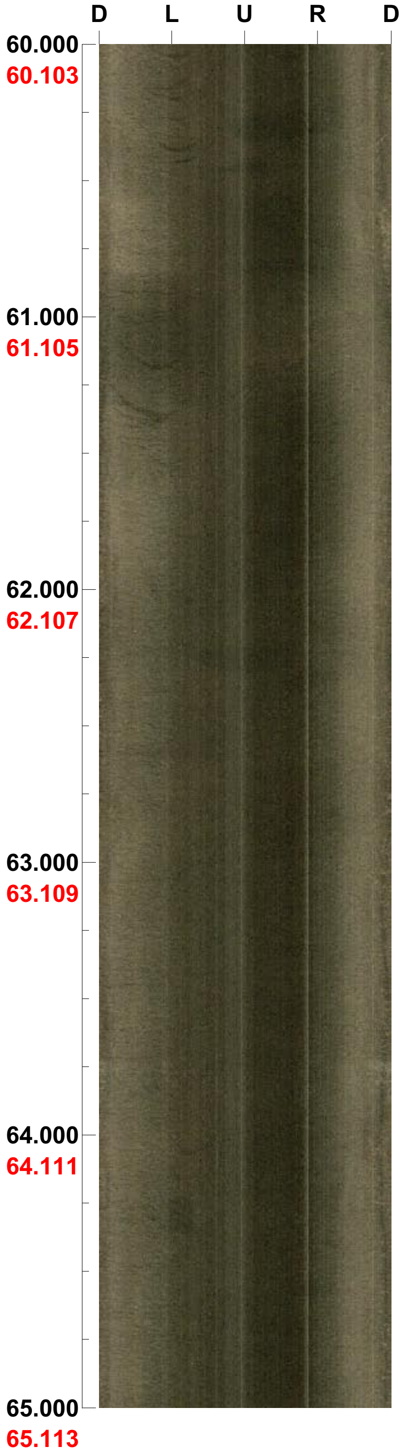
Project name: Laxemar
Bore hole No.: KLX06 Azimuth: 330 Inclination: -65

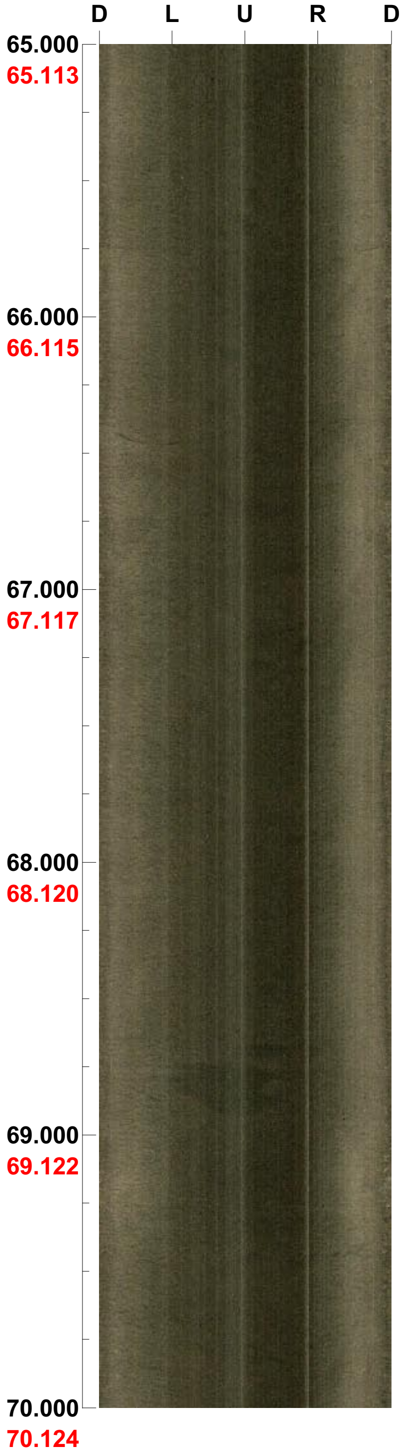
Depth range: 50.000 - 60.000 m

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

Project name: Laxemar
Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 60.000 - 70.000 m



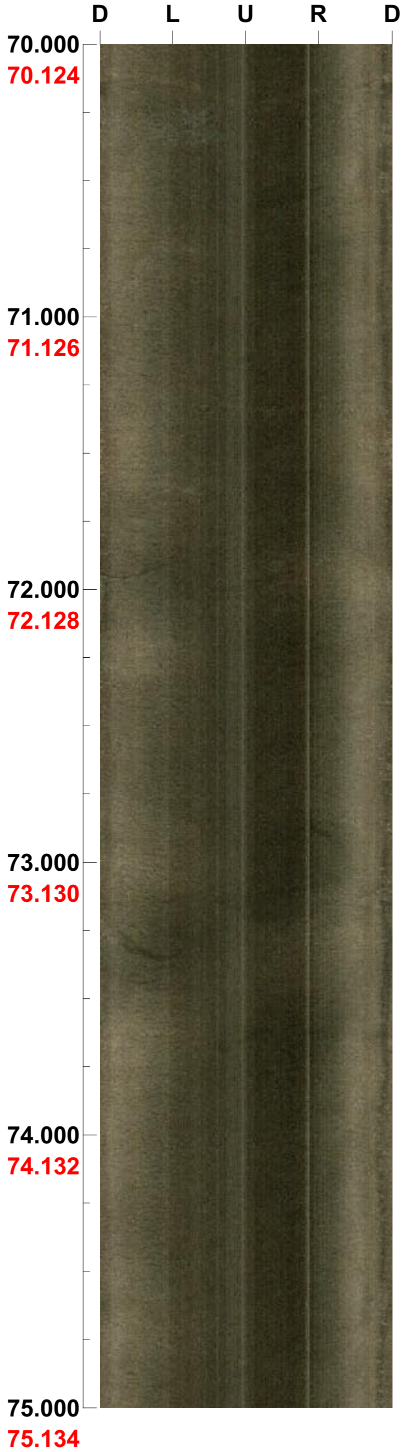


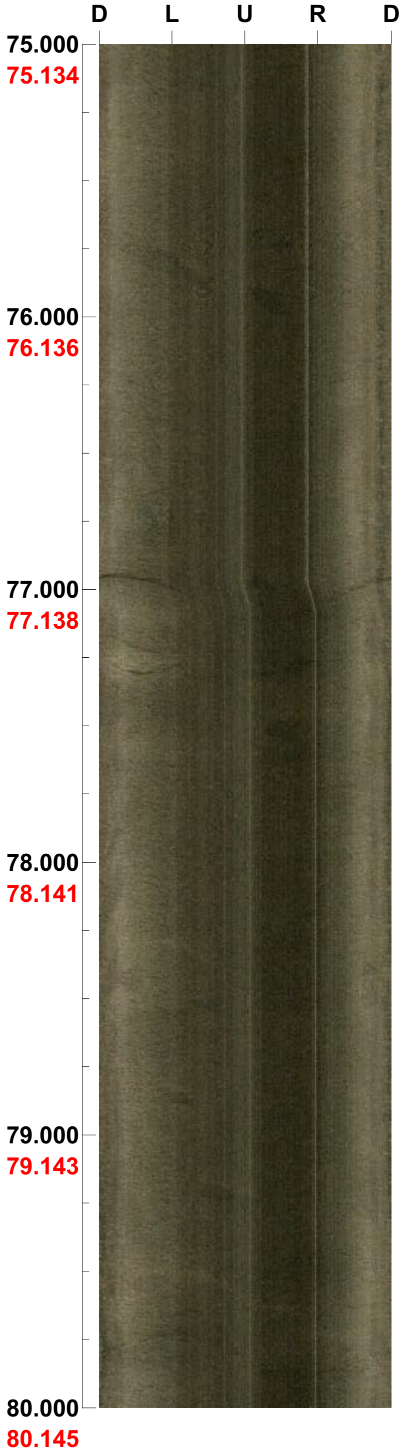
(6 / 9) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar

Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 70.000 - 80.000 m

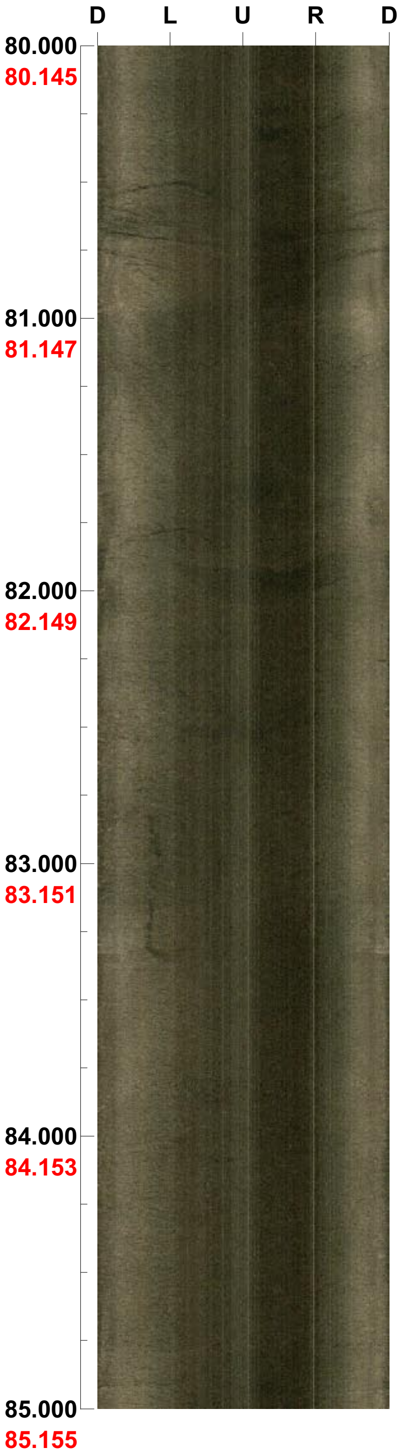


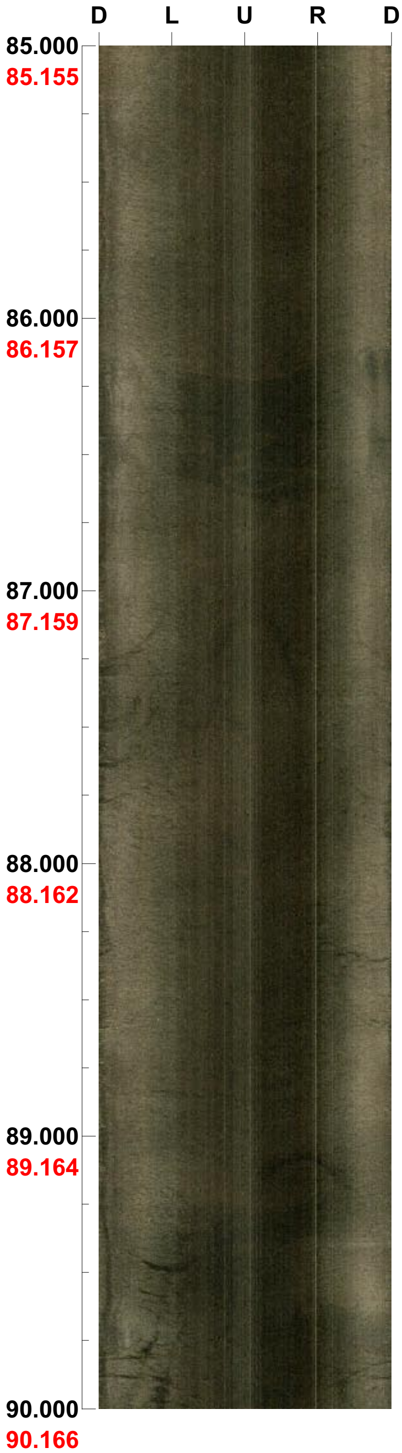


(7 / 9) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar
Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 80.000 - 90.000 m

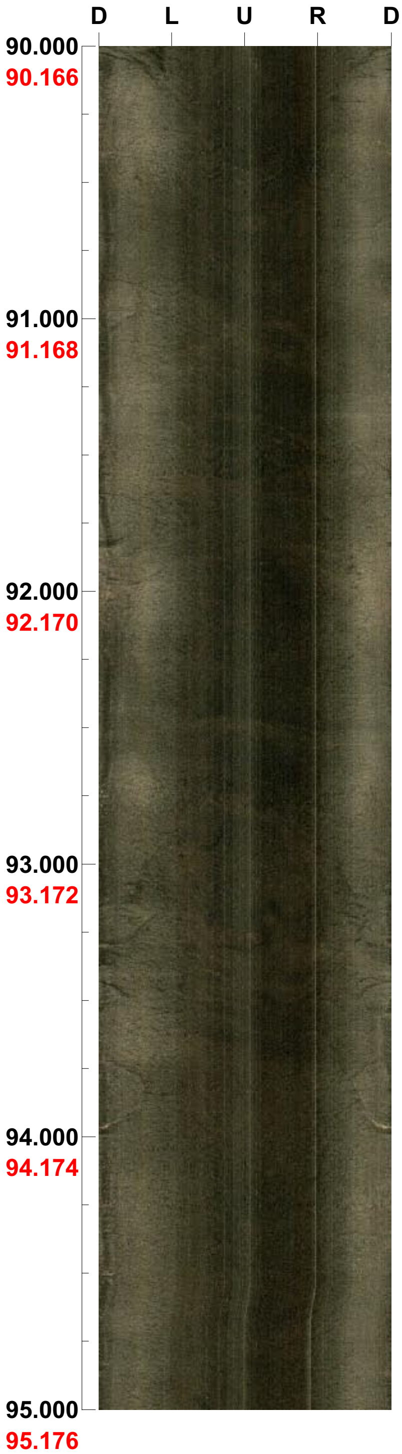


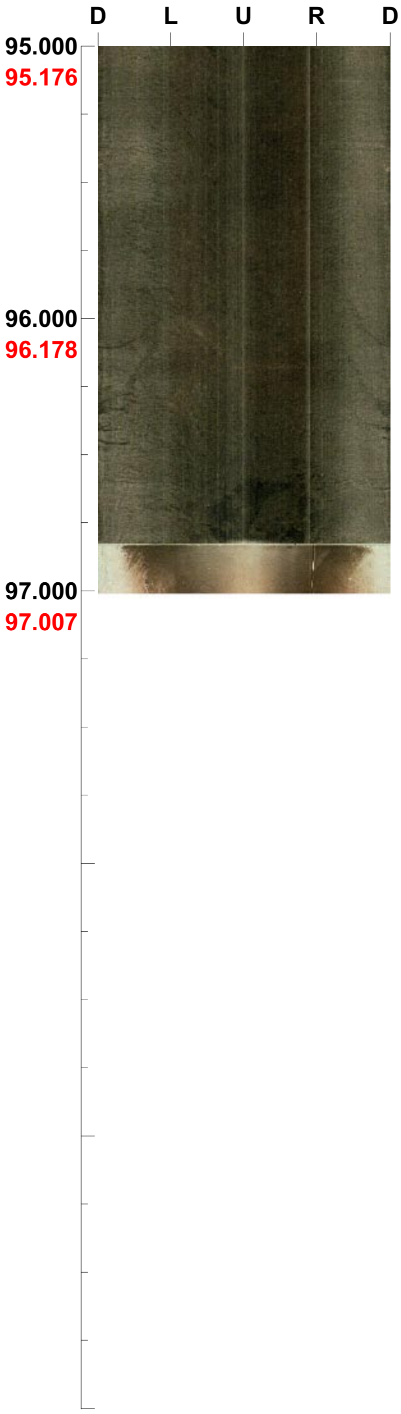


(8 / 9) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar
Bore hole No.: KLX06 Azimuth: 330 Inclination: -65

Depth range: 90.000 - 97.007 m





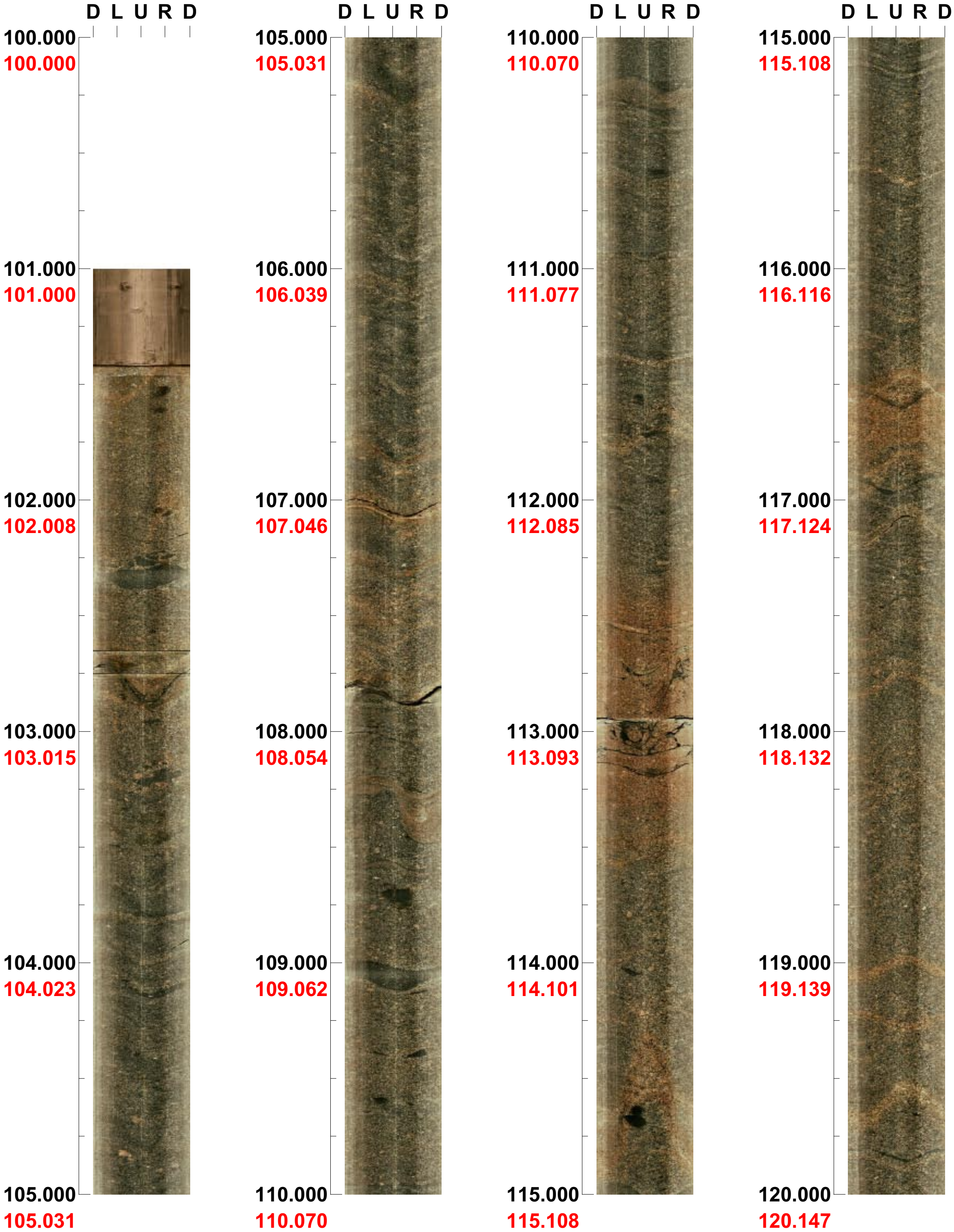
(9 / 9) Scale: 1/25 Aspect ratio: 175 %

Project name: Laxemar

Image file	: c:\work\r5382s~1\bips\101_407.bip
BDT file	: c:\work\r5382s~1\bips\101_407.bdt
Locality	: LAXEMAR
Bore hole number	: KLX06
Date	: 04/12/28
Time	: 07:51:00
Depth range	: 101.000 - 407.641 m
Azimuth	: 330
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	: 16
Color	: +0 +0 +0

Project name: Laxemar
Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 100.000 - 120.000 m



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

Project name: Laxemar
Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 120.000 - 140.000 m

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

Project name: Laxemar
Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 140.000 - 160.000 m

D L U R D

140.000
140.302
141.000
141.309
142.000
142.317
143.000
143.325
144.000
144.333
145.000
145.340

D L U R D

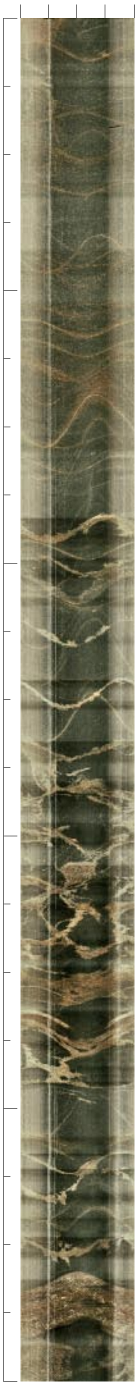
145.000
145.340
146.000
146.348
147.000
147.356
148.000
148.364
149.000
149.371
150.000
150.379

D L U R D

150.000
150.379
151.000
151.387
152.000
152.395
153.000
153.402
154.000
154.410
155.000
155.418

D L U R D

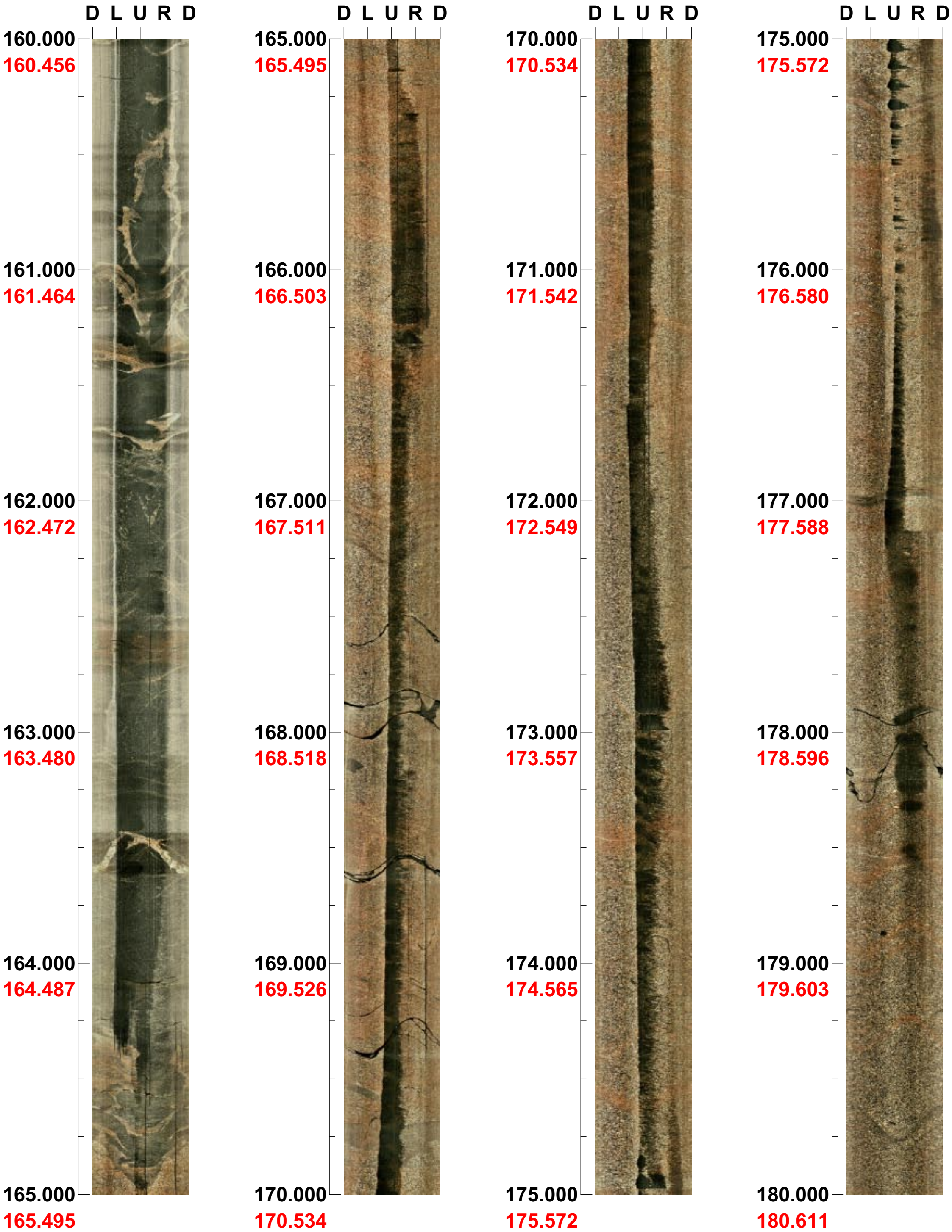
155.000
155.418
156.000
156.425
157.000
157.433
158.000
158.441
159.000
159.449
160.000
160.456



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

Project name: Laxemar
Bore hole No.: KLX06 Azimuth: 330 Inclination: -65

Depth range: 160.000 - 180.000 m



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

Project name: Laxemar
Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 180.000 - 200.000 m

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

Project name: Laxemar

Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 200.000 - 220.000 m

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

Project name: Laxemar

Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 220.000 - 240.000 m

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

Project name: Laxemar
Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 240.000 - 260.000 m

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

Project name: Laxemar
Bore hole No.: KLX06 Azimuth: 330 Inclination: -65

Depth range: 260.000 - 280.000 m

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

Project name: Laxemar
Bore hole No.: KLX06 Azimuth: 330 Inclination: -65

Depth range: 280.000 - 300.000 m

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

Project name: Laxemar

Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 300.000 - 320.000 m

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

Project name: Laxemar
Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 320.000 - 340.000 m

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

Project name: Laxemar
Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

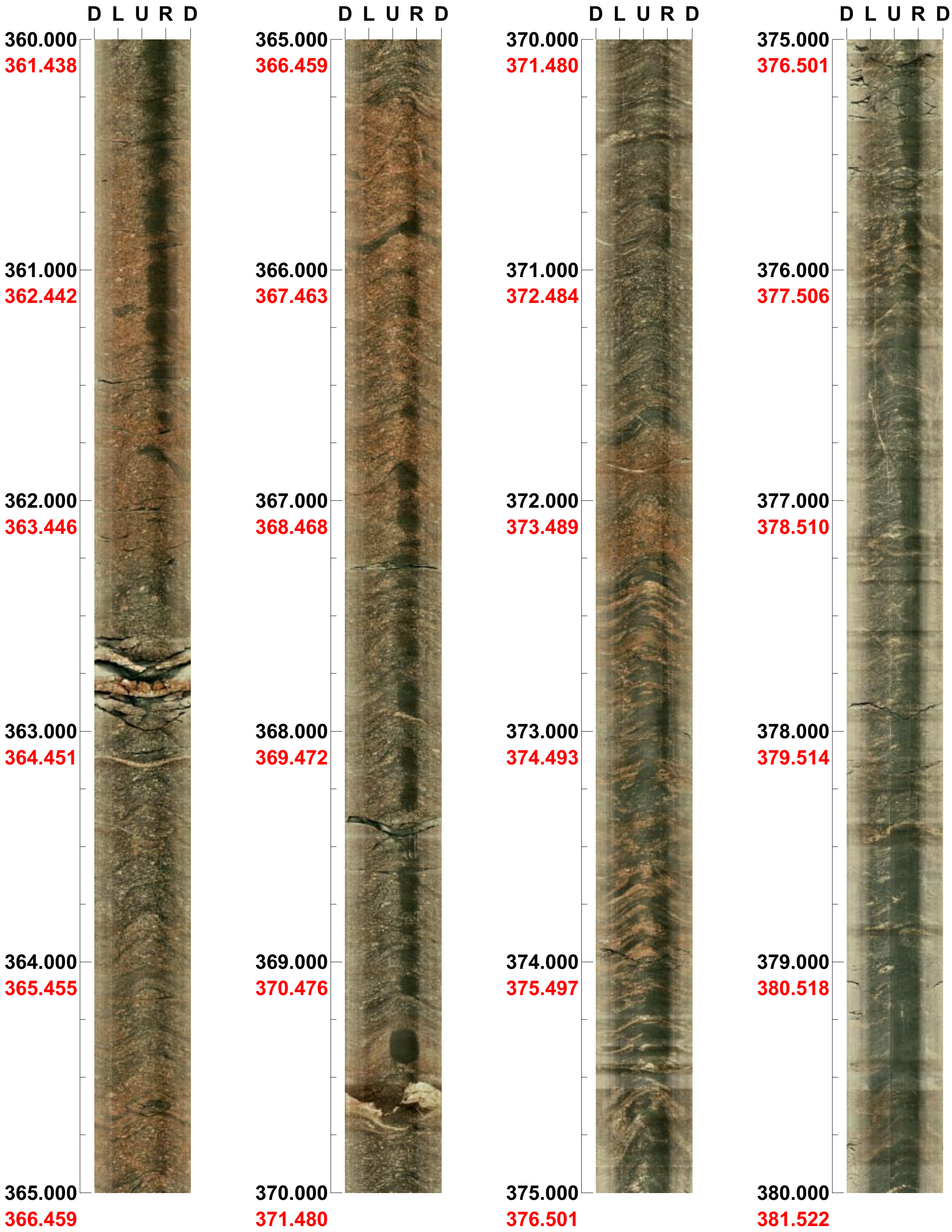
Depth range: 340.000 - 360.000 m

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

Project name: Laxemar

Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 360.000 - 380.000 m



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

Project name: Laxemar
Bore hole No.: KLX06 Azimuth: 330 Inclination: -65

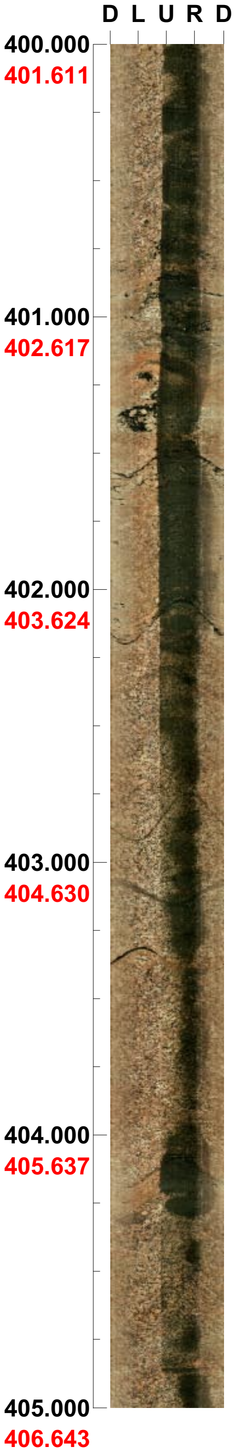
Depth range: 380.000 - 400.000 m

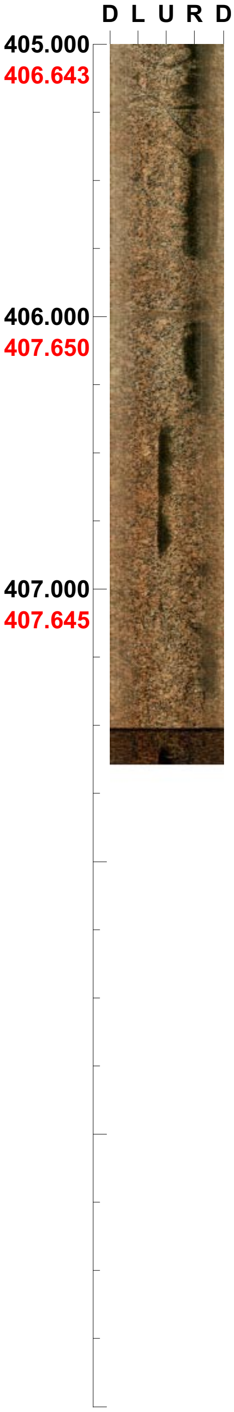
(15 / 16) Scale: 1/25 Aspect ratio: 175 %

Project name: Laxemar
Bore hole No.: KLX06

Azimuth: 330 Inclination: -65

Depth range: 400.000 - 407.641 m

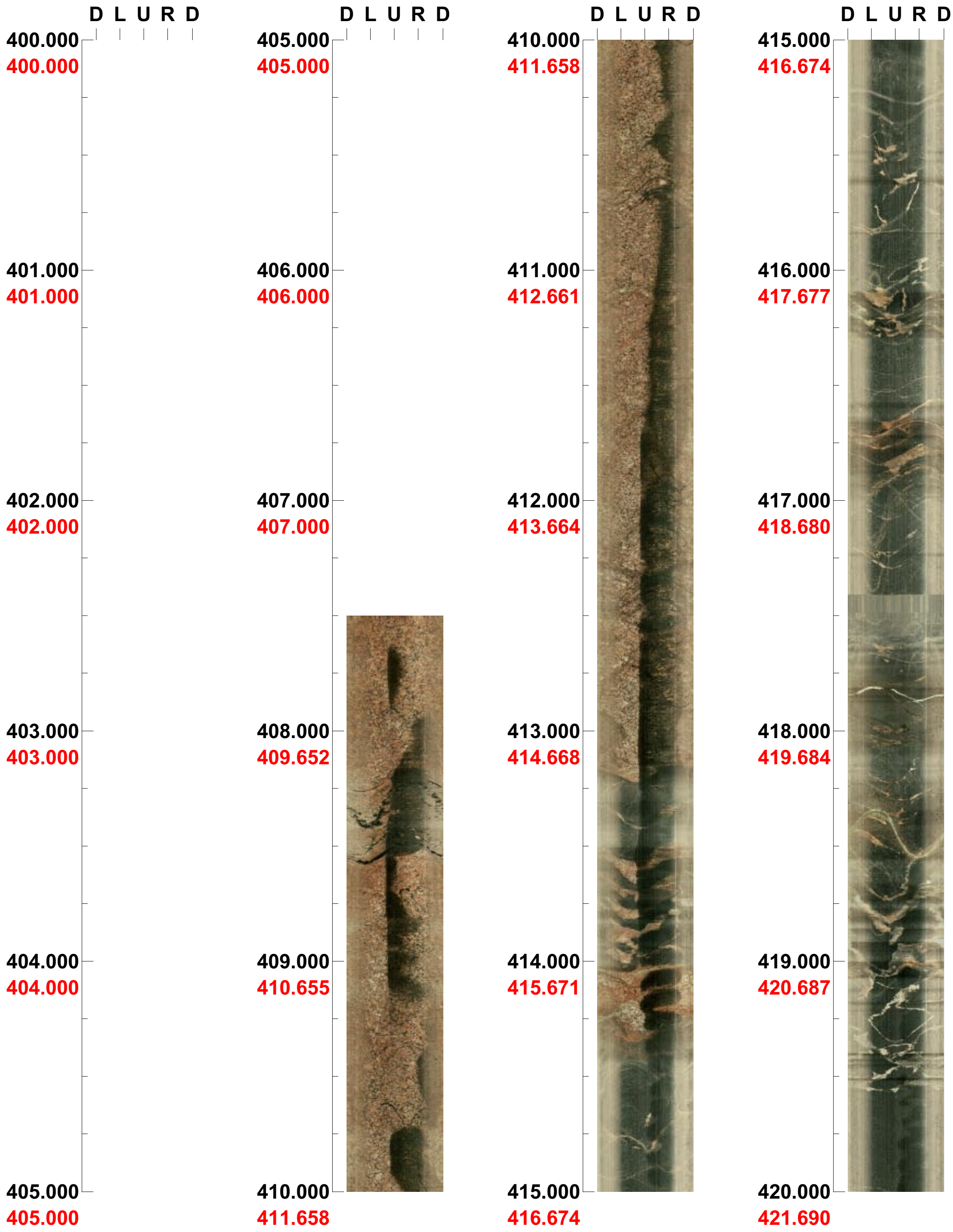




(16 / 16) Scale: 1/25 Aspect ratio: 175 %

Project name: Laxemar
Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 400.000 - 420.000 m



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

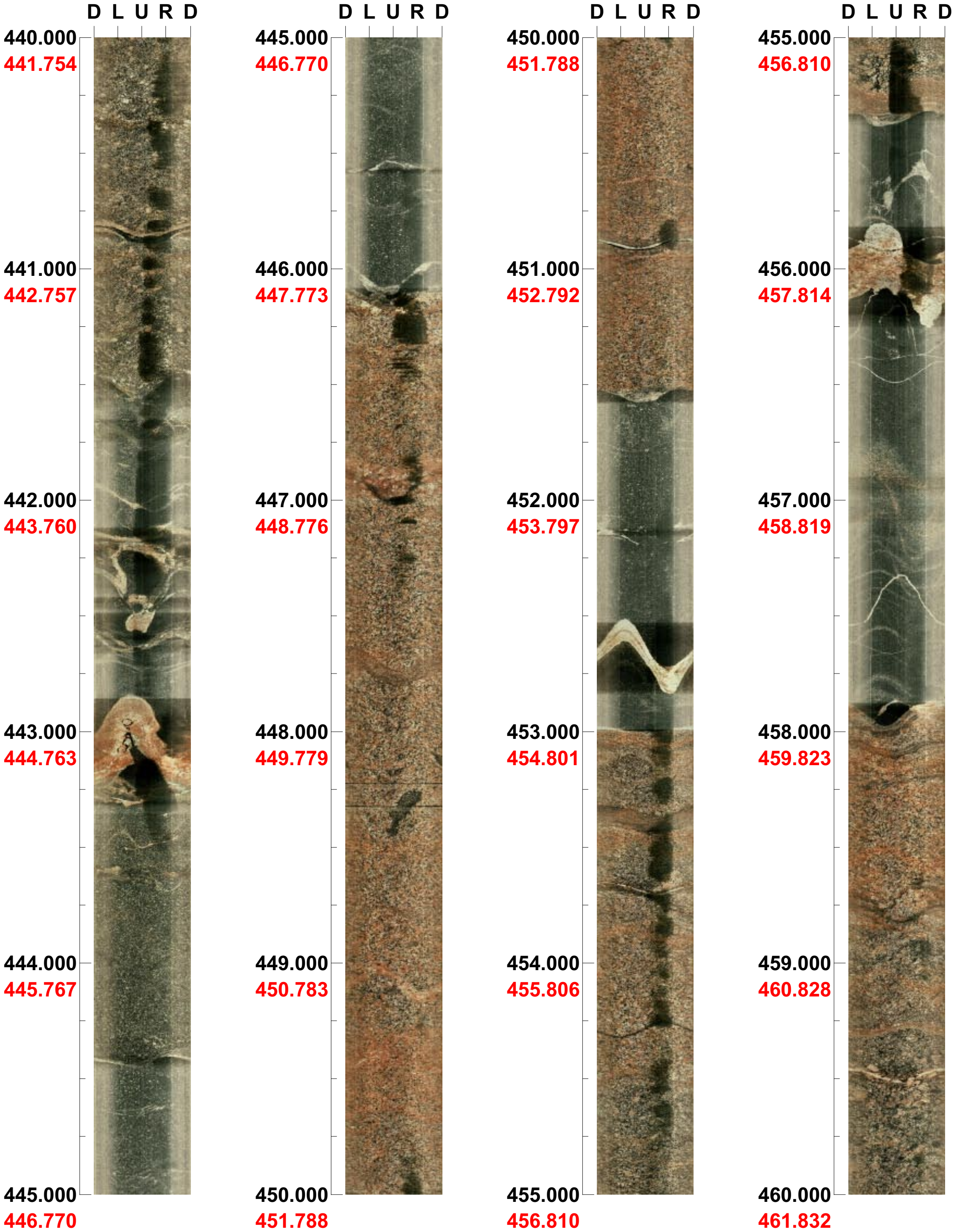
Project name: Laxemar
Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 420.000 - 440.000 m

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

Project name: Laxemar
Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 440.000 - 460.000 m

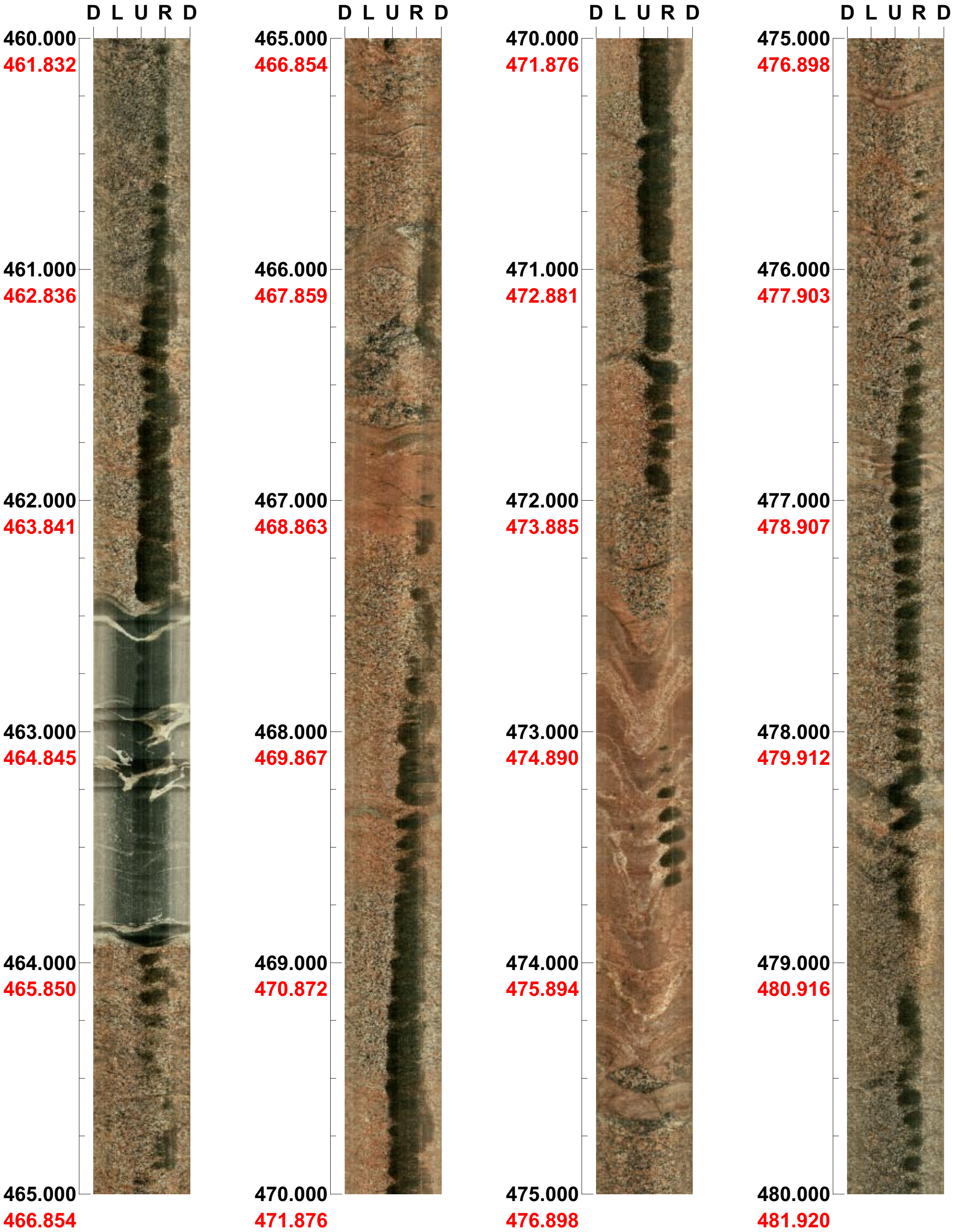


(3 / 10) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar

Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 460.000 - 480.000 m



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

Project name: Laxemar

Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

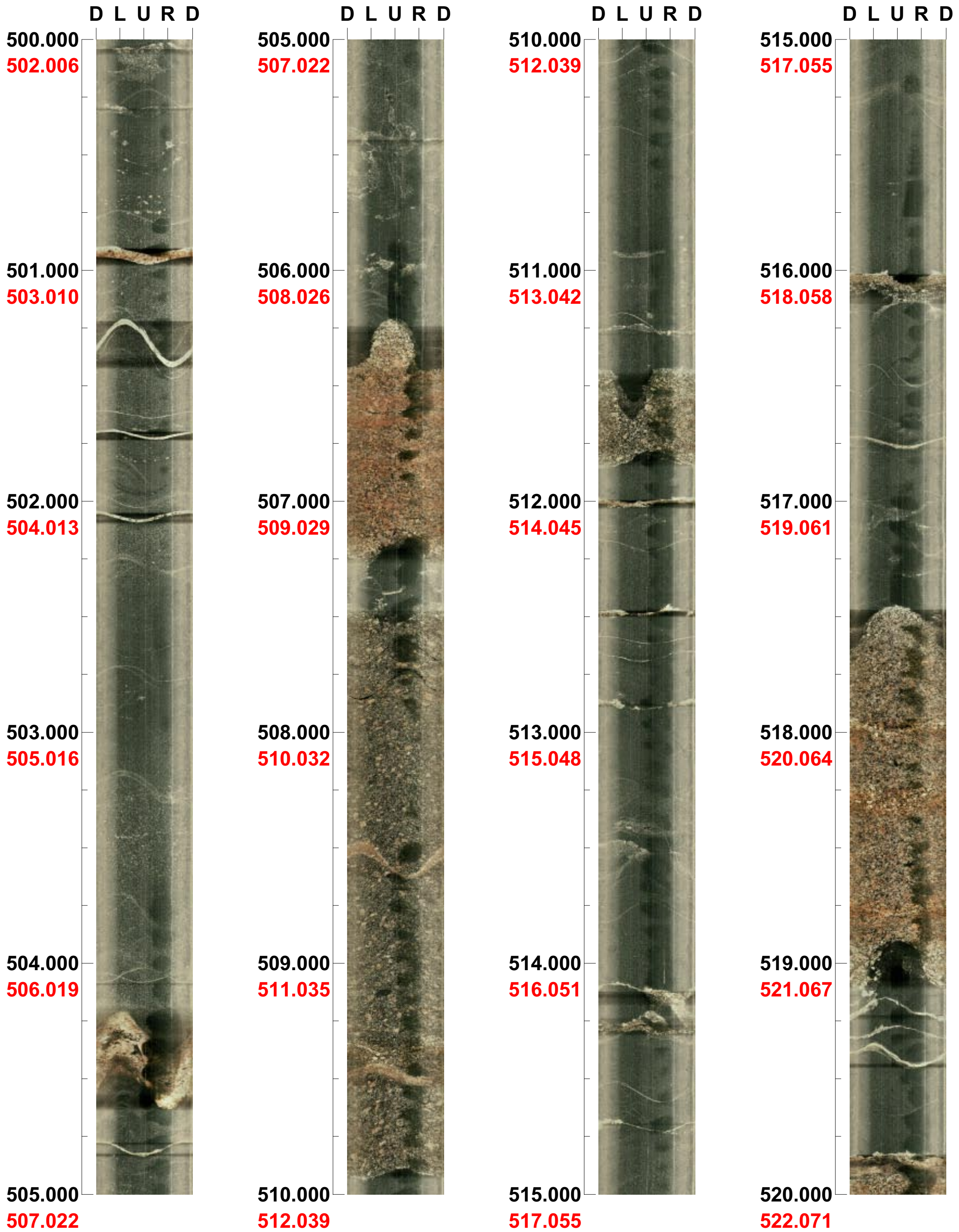
Depth range: 480.000 - 500.000 m

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

Project name: Laxemar

Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 500.000 - 520.000 m



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

Project name: Laxemar

Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 520.000 - 540.000 m

D L U R D

520.000
522.071

521.000
523.074

522.000
524.077

523.000
525.080

524.000
526.083

525.000
527.087

D L U R D

525.000
527.087

526.000
528.090

527.000
529.093

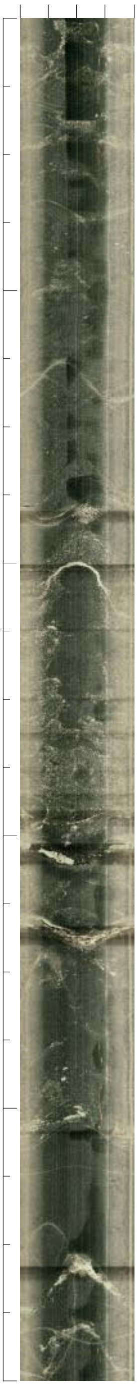
528.000
530.096

529.000
531.100

530.000
532.103

D L U R D

530.000
532.103



531.000
533.106

532.000
534.109

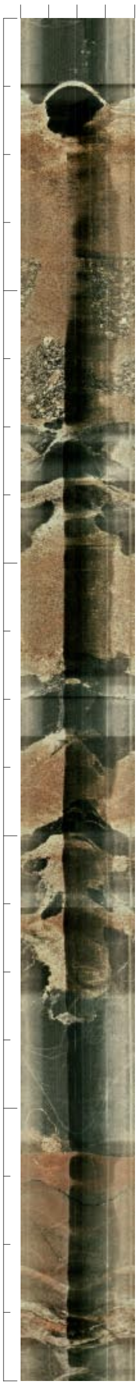
533.000
535.112

534.000
536.116

535.000
537.119

D L U R D

535.000
537.119



536.000
538.122

537.000
539.125

538.000
540.128

539.000
541.132

540.000
542.135

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

Project name: Laxemar
Bore hole No.: KLX06

Azimuth: 330 Inclination: -65

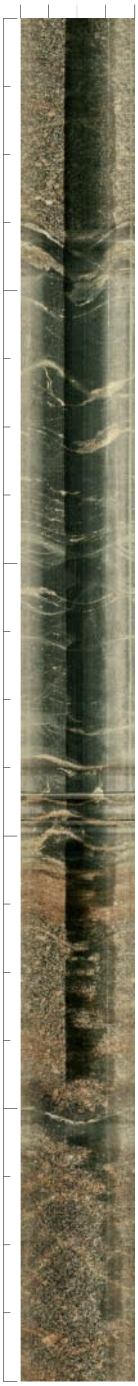
Depth range: 540.000 - 560.000 m

D L U R D

540.000
542.135
541.000
543.138
542.000
544.141
543.000
545.144
544.000
546.148
545.000
547.151

D L U R D

545.000
547.151
546.000
548.154
547.000
549.157
548.000
550.160
549.000
551.163
550.000
552.166



D L U R D

550.000
552.166
551.000
553.169
552.000
554.172
553.000
555.174
554.000
556.177
555.000
557.180

D L U R D

555.000
557.180
556.000
558.183
557.000
559.186
558.000
560.189
559.000
561.191
560.000
562.194

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

Project name: Laxemar
Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

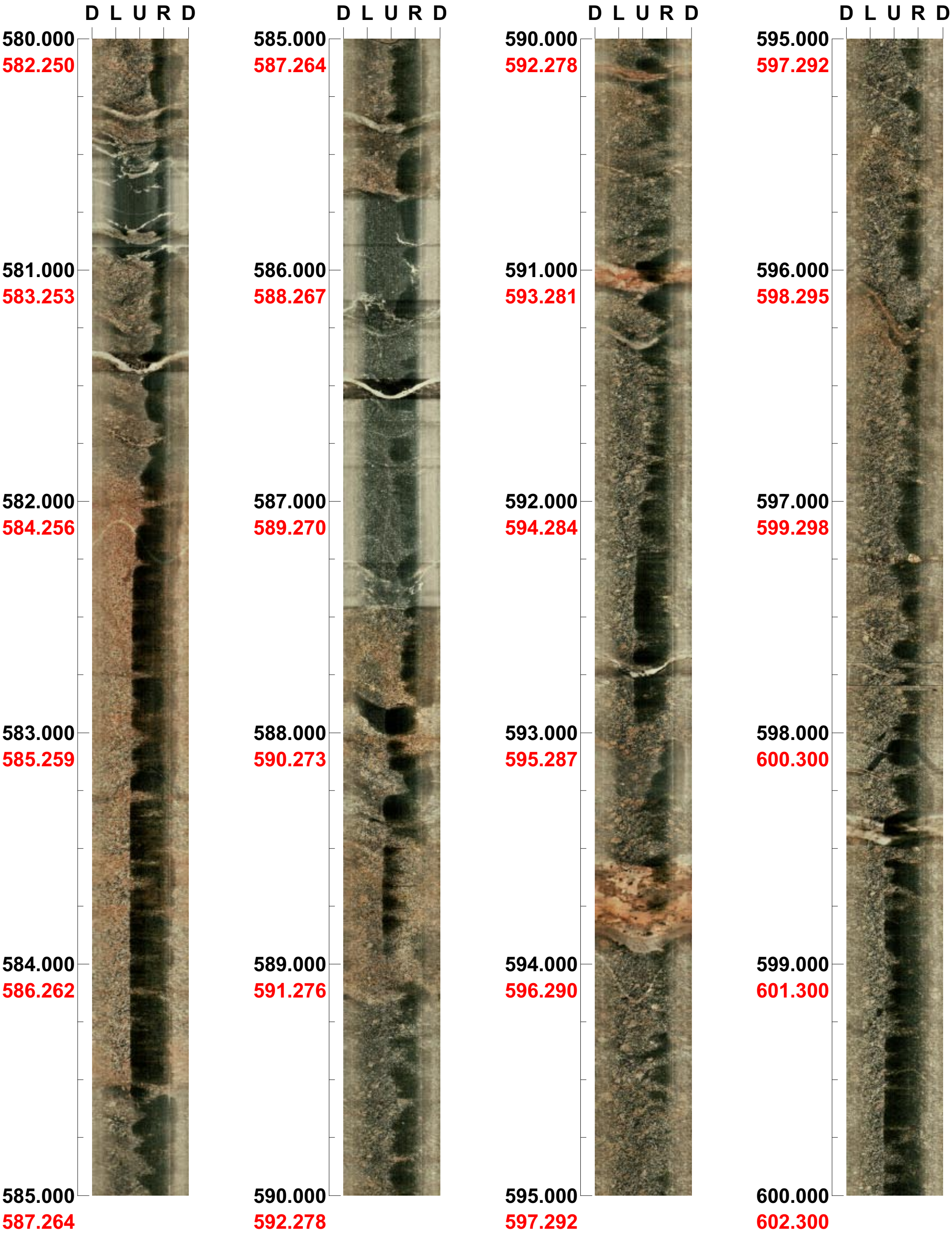
Depth range: 560.000 - 580.000 m

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

Project name: Laxemar

Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 580.000 - 600.000 m



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

Project name: Laxemar

Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 600.000 - 620.000 m

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

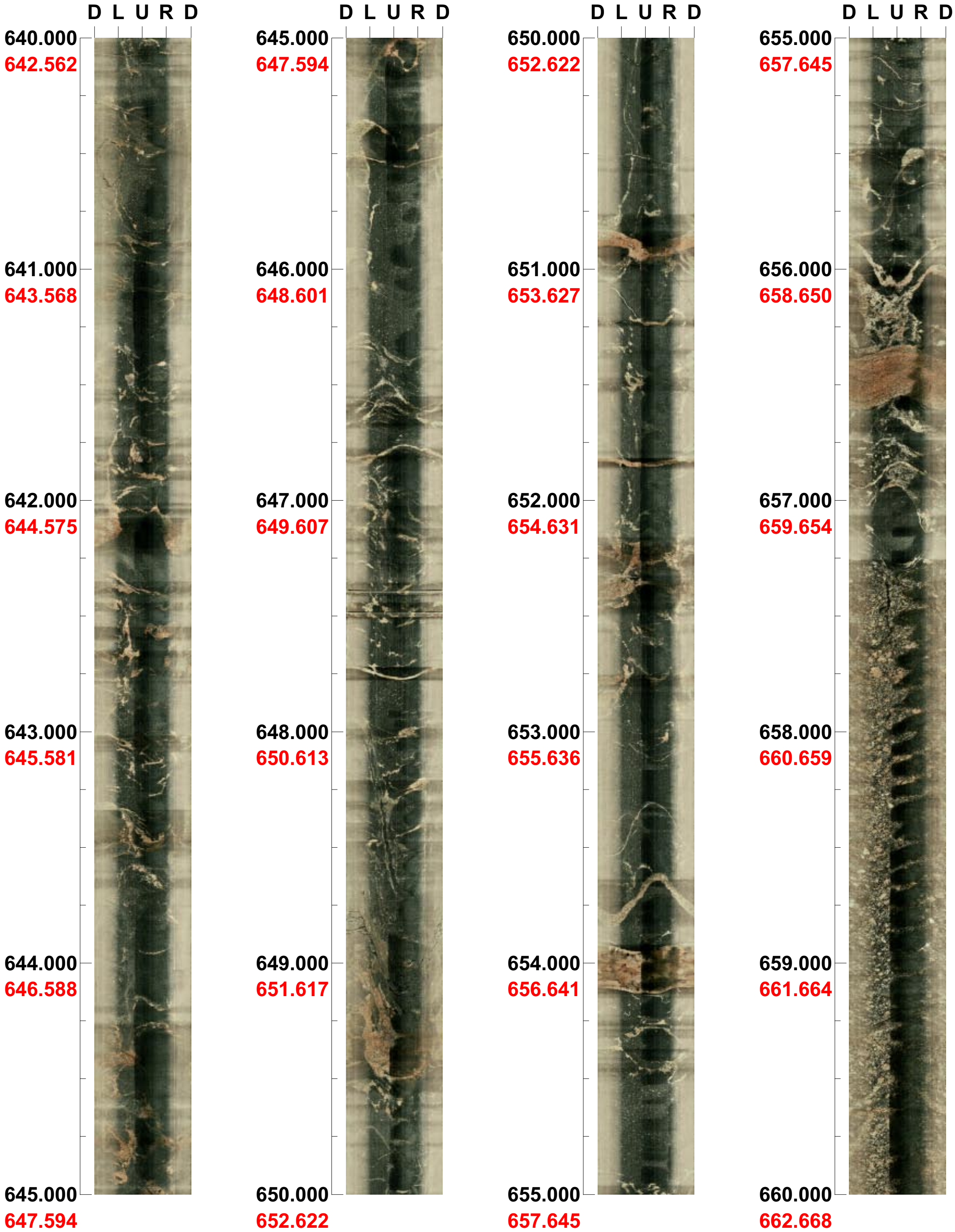
Project name: Laxemar
Bore hole No.: KLX06 Azimuth: 330 Inclination: -65

Depth range: 620.000 - 640.000 m

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

Project name: Laxemar
Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

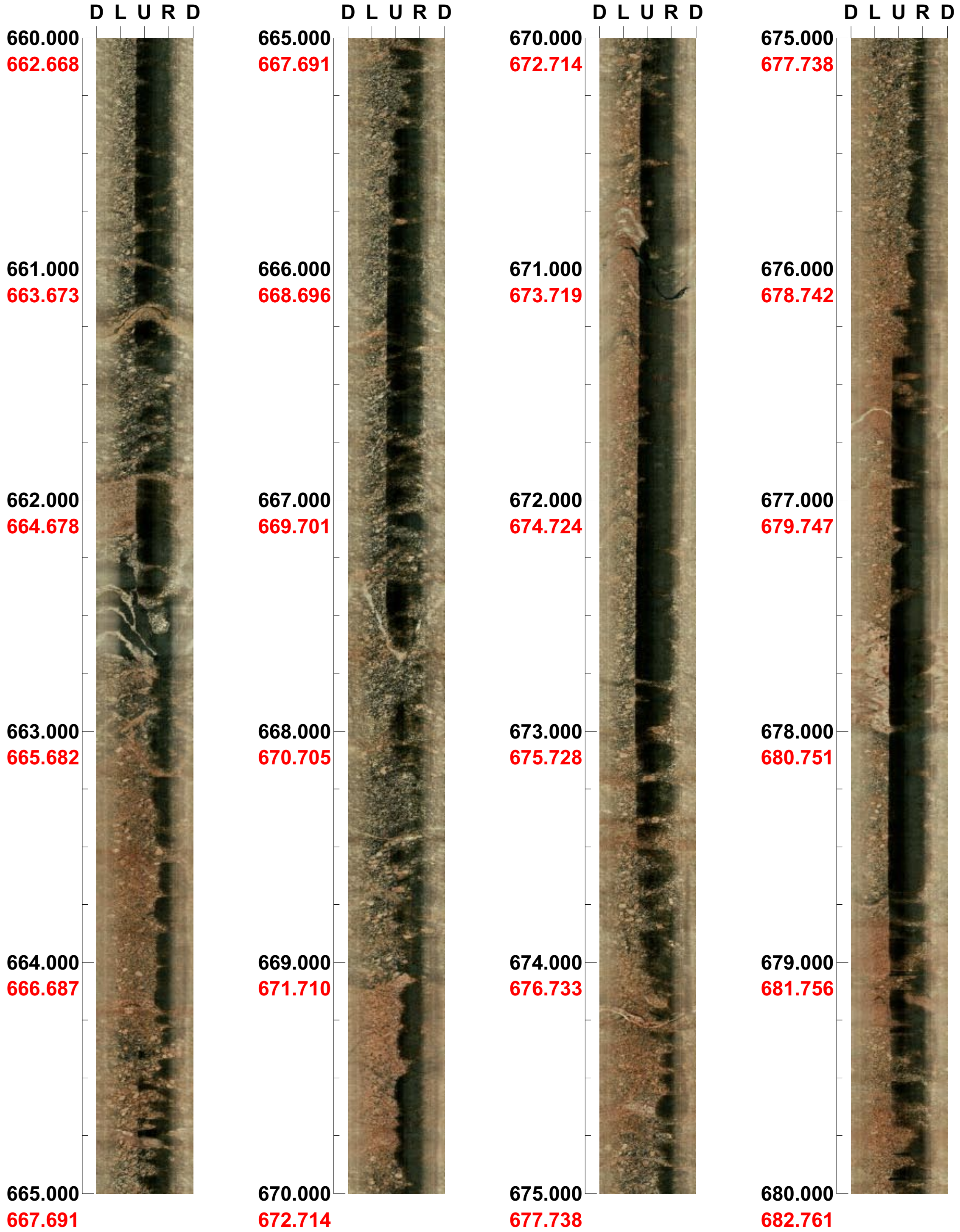
Depth range: 640.000 - 660.000 m



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

Project name: Laxemar
Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 660.000 - 680.000 m



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

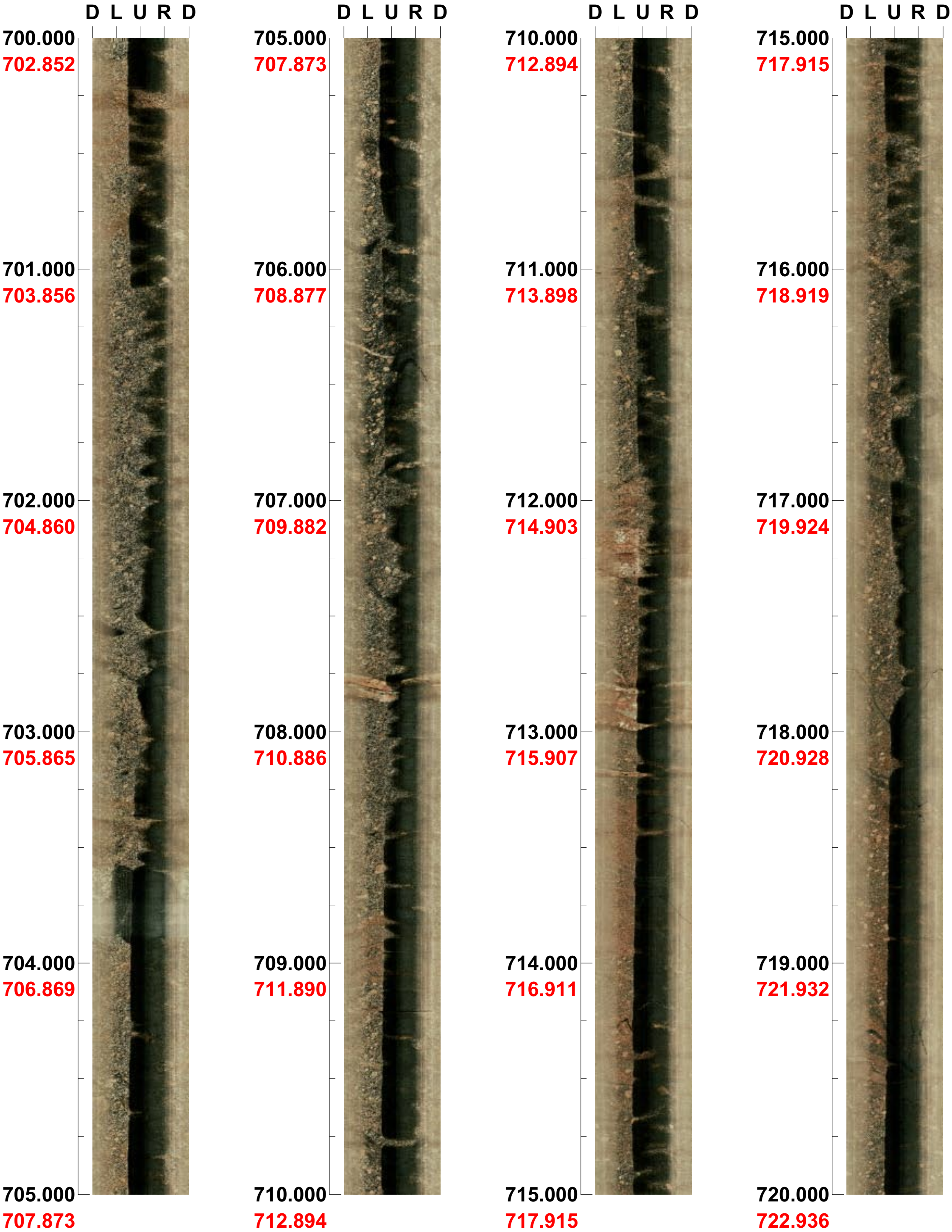
Project name: Laxemar
Bore hole No.: KLX06 Azimuth: 330 Inclination: -65

Depth range: 680.000 - 700.000 m

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

Project name: Laxemar
Bore hole No.: KLX06 Azimuth: 330 Inclination: -65

Depth range: 700.000 - 720.000 m



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

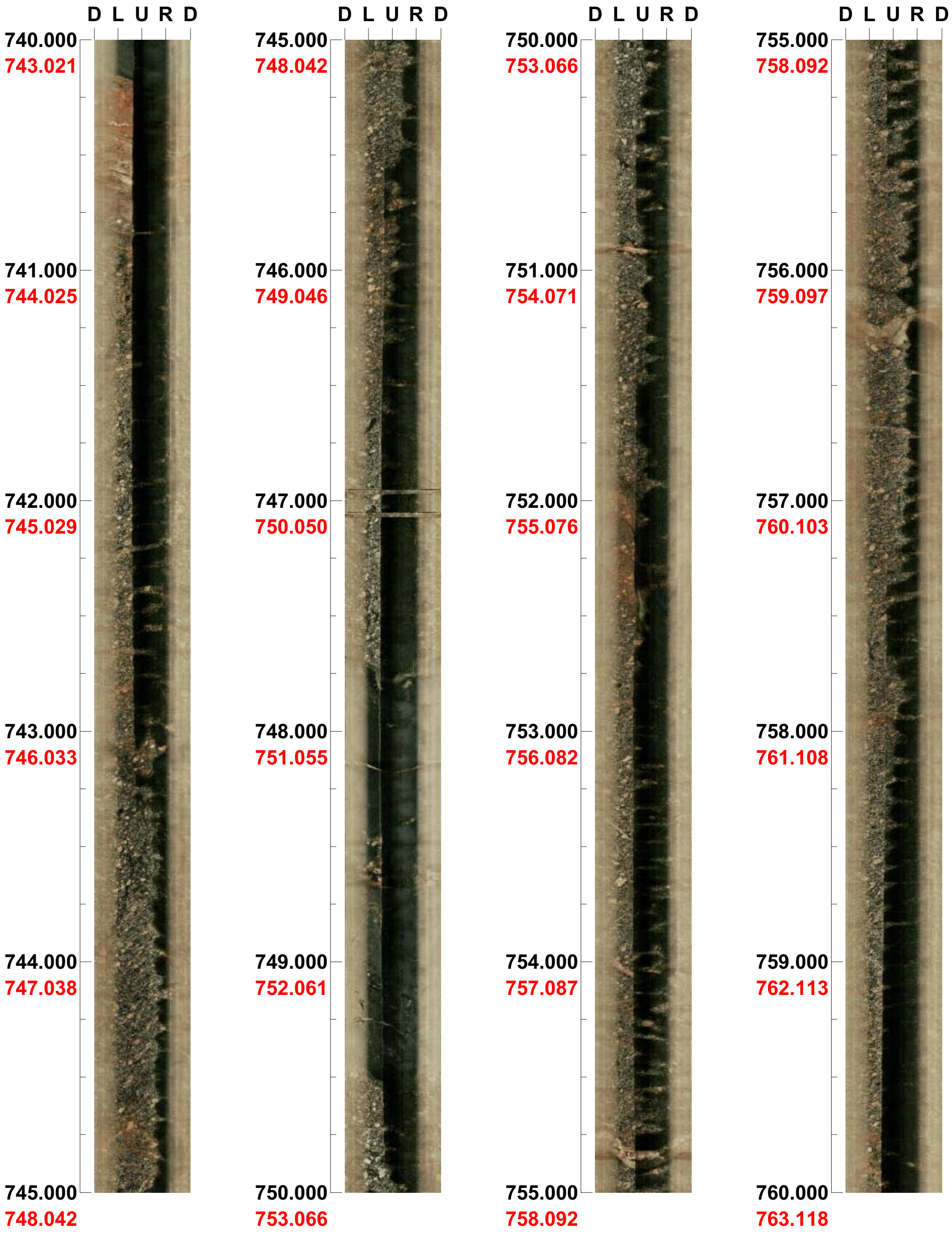
Project name: Laxemar
Bore hole No.: KLX06 Azimuth: 330 Inclination: -65

Depth range: 720.000 - 740.000 m

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

Project name: Laxemar
Bore hole No.: KLX06 Azimuth: 330 Inclination: -65

Depth range: 740.000 - 760.000 m

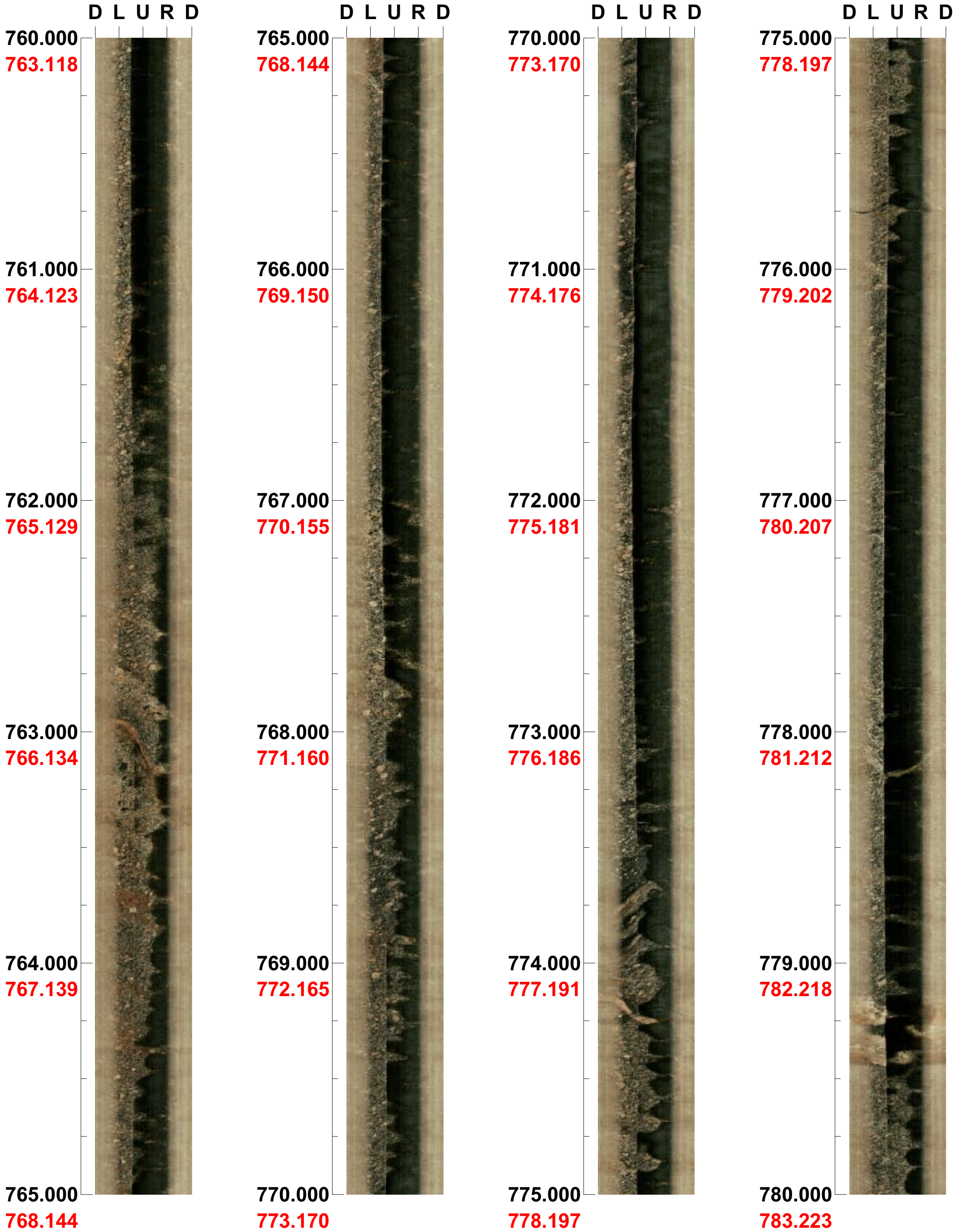


(8 / 19) Scale: 1/25 Aspect ratio: 175 %

Project name: Laxemar

Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

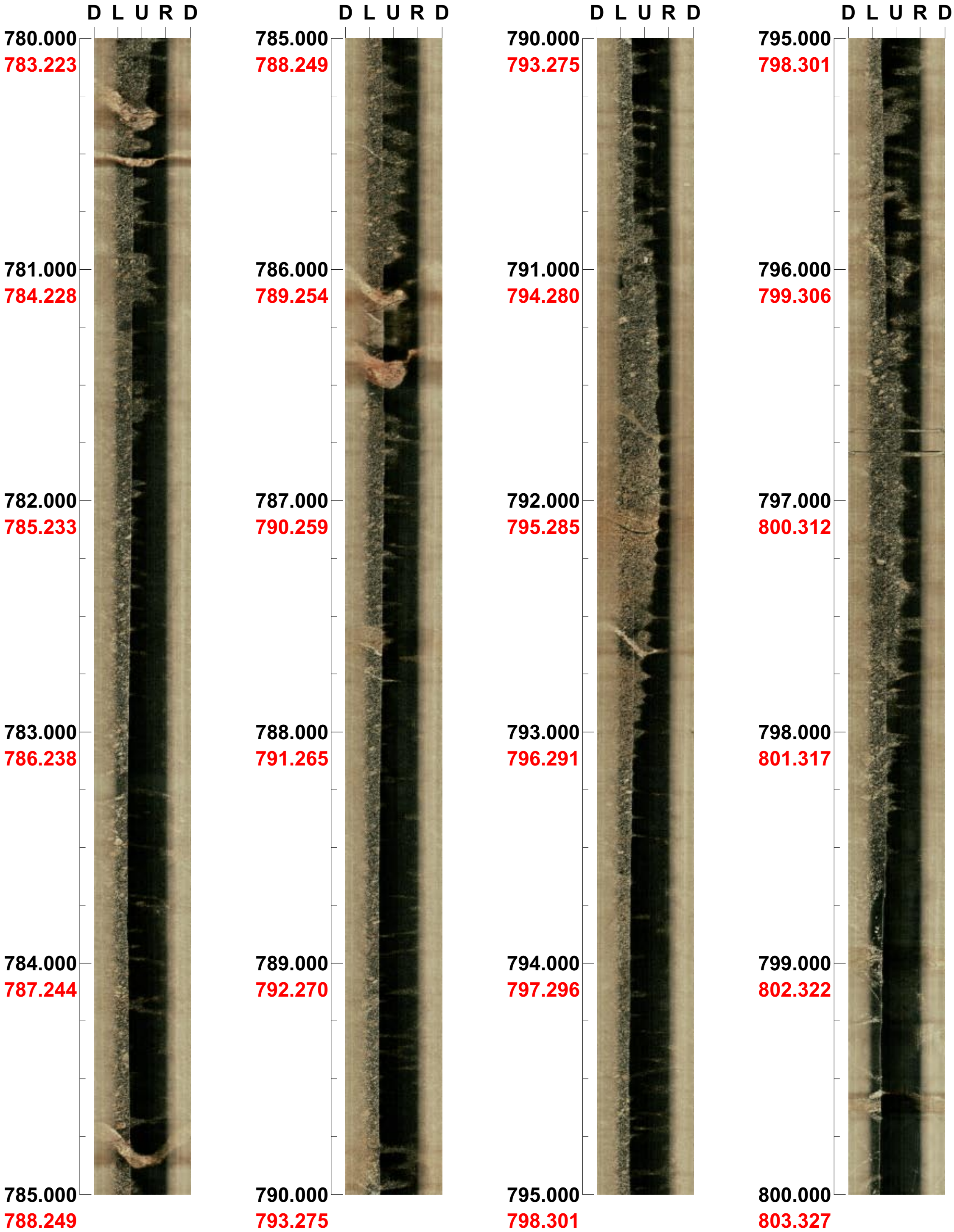
Depth range: 760.000 - 780.000 m



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

Project name: Laxemar
Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 780.000 - 800.000 m



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

Project name: Laxemar
Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

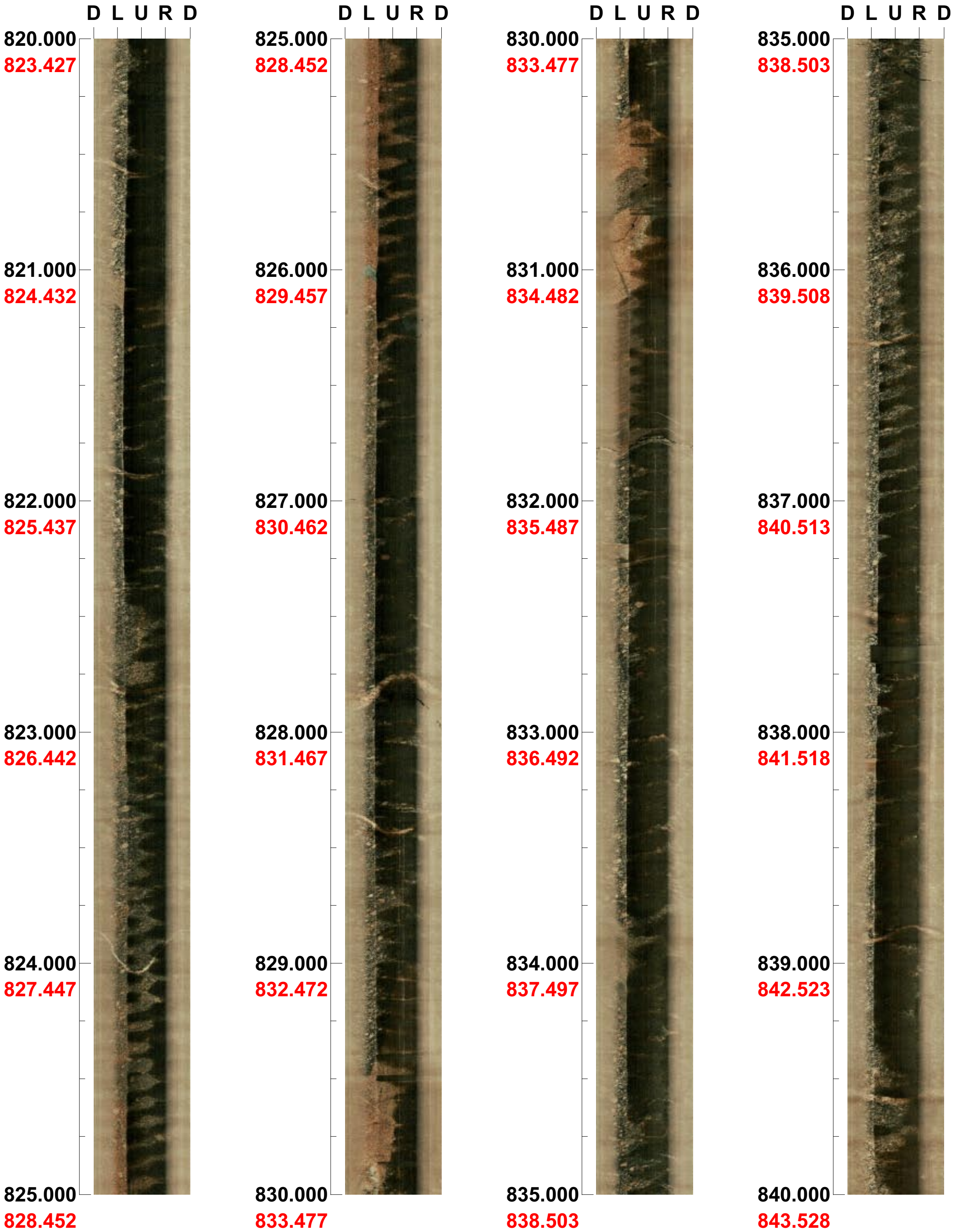
Depth range: 800.000 - 820.000 m

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

Project name: Laxemar

Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 820.000 - 840.000 m



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

Project name: Laxemar

Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 840.000 - 860.000 m

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

Project name: Laxemar

Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 860.000 - 880.000 m

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

Project name: Laxemar

Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 880.000 - 900.000 m

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

Project name: Laxemar
Bore hole No.: KLX06 Azimuth: 330 Inclination: -65

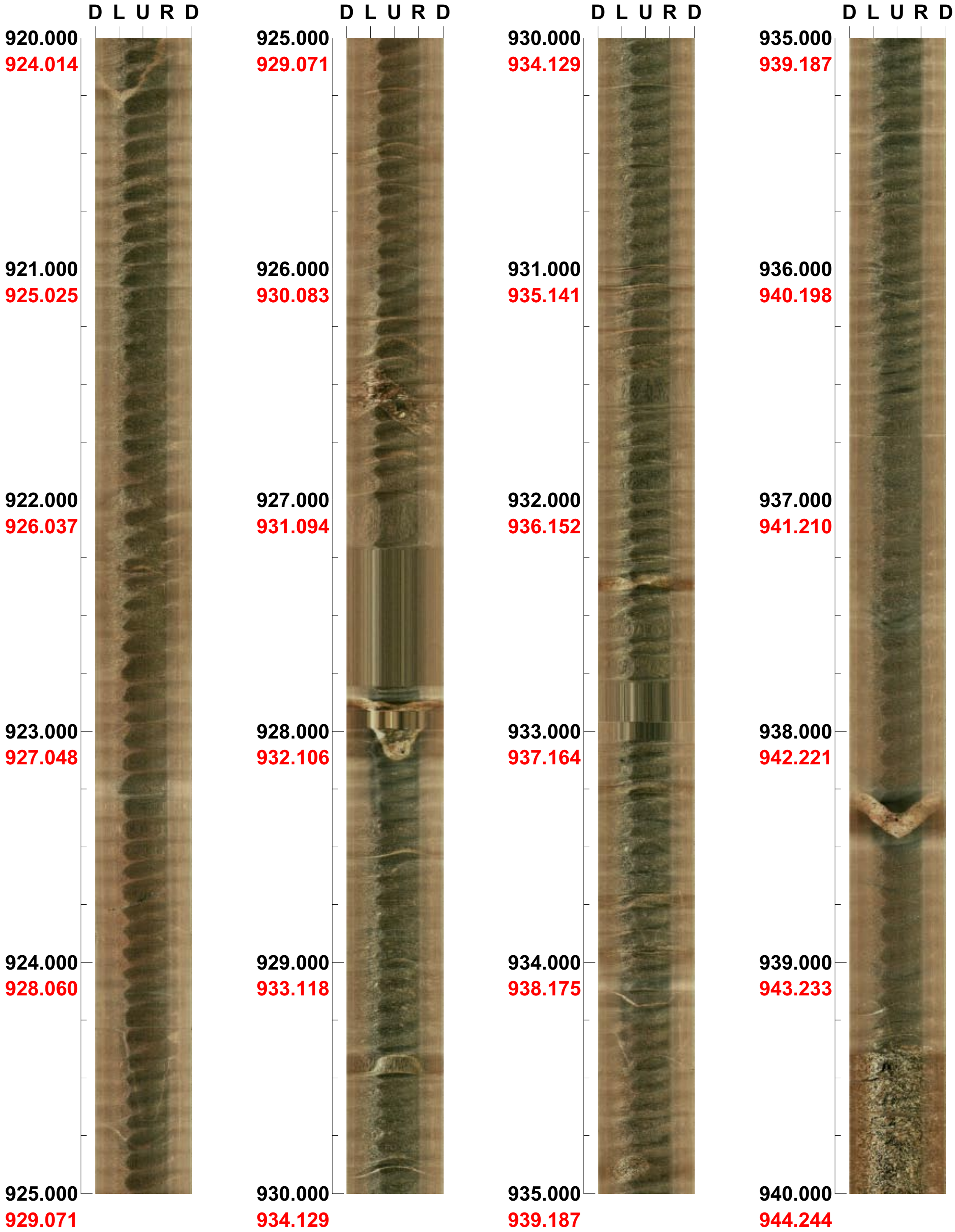
Depth range: 900.000 - 920.000 m

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

Project name: Laxemar

Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 920.000 - 940.000 m

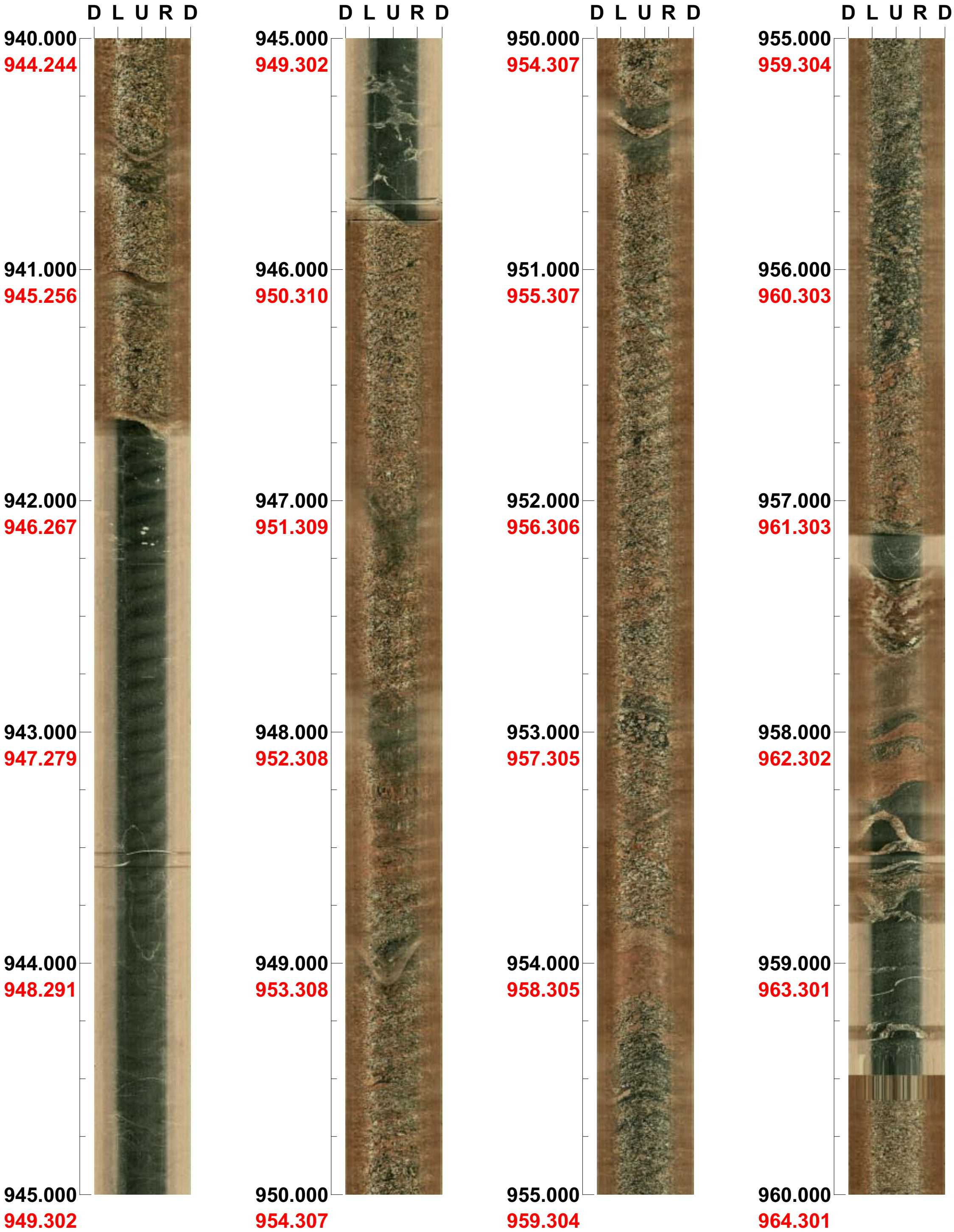


(17 / 19) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Laxemar

Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

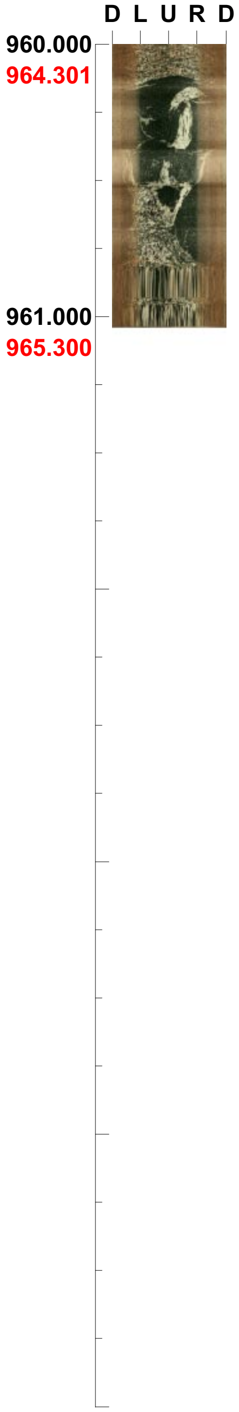
Depth range: 940.000 - 960.000 m



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

Project name: Laxemar
Bore hole No.: KLX06 **Azimuth: 330** **Inclination: -65**

Depth range: 960.000 - 961.038 m



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