P-04-279

Oskarshamn site investigation

RAMAC and BIPS logging in boreholes HLX17, HLX18 and HLX19

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October 2004

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ISSN 1651-4416
SKB P-04-279

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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 percussion-drilled boreholes HLX17, HLX18 and HLX19. All measurements were conducted by Malå Geoscience AB / RAYCON during June and September 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 HLX17, HLX18 and HLX19 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 a number of identified radar reflectors. 49 radar reflectors were identified in HLX17 and the corresponding numbers for HLX18 and HLX19 are 29 and 20.

Sammanfattning

Denna rapport omfattar geofysiska loggningar inom platsundersökningsprogrammet för Oskarshamn. Mätningarna som presenteras här omfattar borrhålsradarmätningar (RAMAC) och BIPS-loggningar i borrhålen HLX17, HLX18 och HLX19. Alla mätningar är utförda av Malå Geoscience AB /RAYCON under juni och september 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 HLX17, HLX18 och HLX19 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 49 radarreflektorer identifierats i HLX17. Motsvarande antal för HLX18 och HLX19 är 29 och 20.

Contents

1 Introduction

This document reports the data gained in geophysical logging operations, which is one of the activities performed within the site investigation at Oskarshamn. The logging operations presented here includes borehole radar (RAMAC) and TV-logging (BIPS) in the percussion-drilled boreholes HLX17, HLX18 and HLX19. The work was carried out in accordance with activity plan AP PS 400- 04-069. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

This report includes measurements from 0 to approximately 200 m in borehole HLX17. In HLX18 the loggings were performed to approximately 180 m depth and to 180 m depth in HLX19. The boreholes are drilled with a diameter of approximately 140 mm.

All measurements were conducted by Malå Geoscience AB / RAYCON during June and September 2004. The location of the boreholes is shown in Figure 1-1.

The used investigation techniques comprised:

- Borehole radar measurements (Malå Geoscience AB:s RAMAC system) with dipole 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.

Table 1-1. Controlling documents for the performance of the activity.

Activity plan	Number	Version
Borrhålsradar och BIPS i HLX17, HLX18 och HLX19	AP PS 400-04-069	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

Table 1-2. Data references.

Subactivity	Database	Field note no
Logging of radar and BIPS in HLX17 and HLX18	SICADA	FN 413
Logging of radar and BIPS in HLX19	SICADA	FN 489

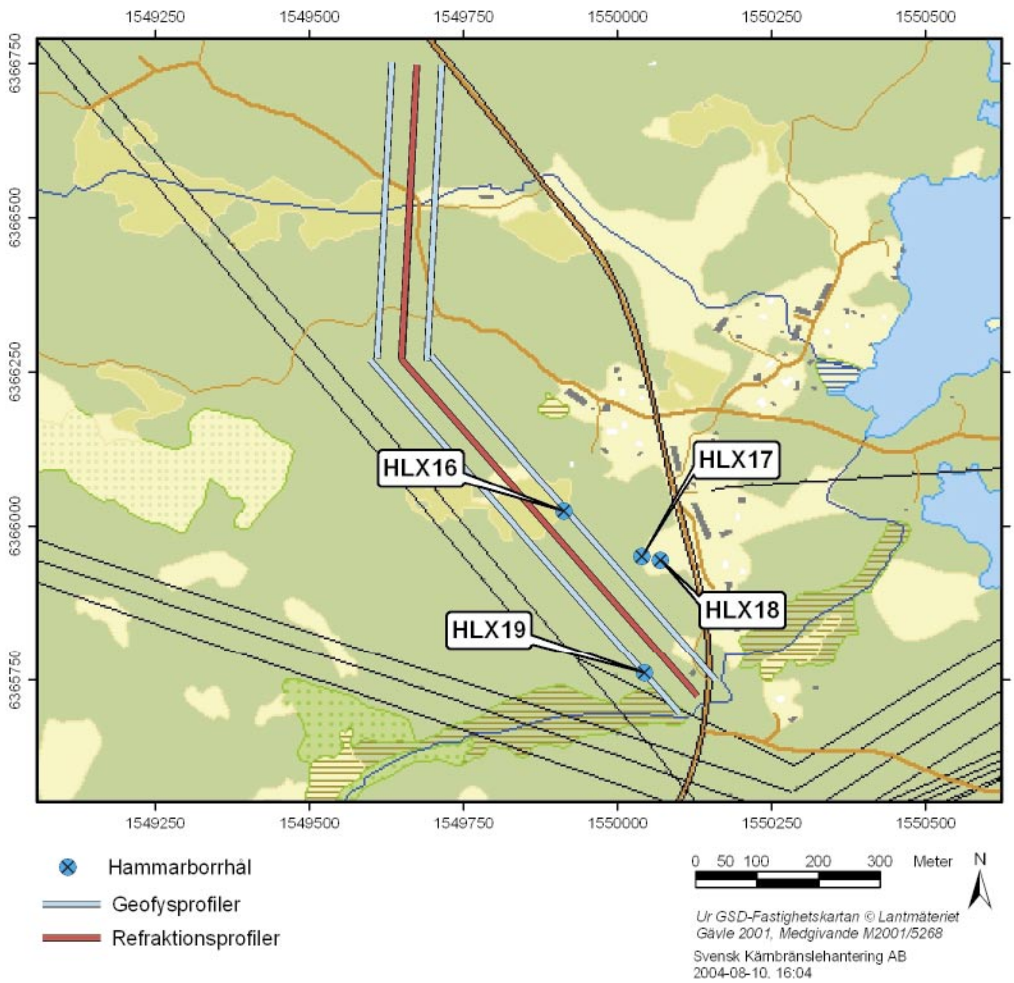


Figure 1-1. *General overview over the Simpevarp and Laxemar subareas in Oskarshamn with the location of the boreholes HLX17, HLX18 and HLX19.*

2 Objective and scope

The objective of the radar and BIPS surveys is to gather information on the borehole conditions (borehole wall) as well as 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, and borehole TV for geological surveying of the borehole including 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.

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.

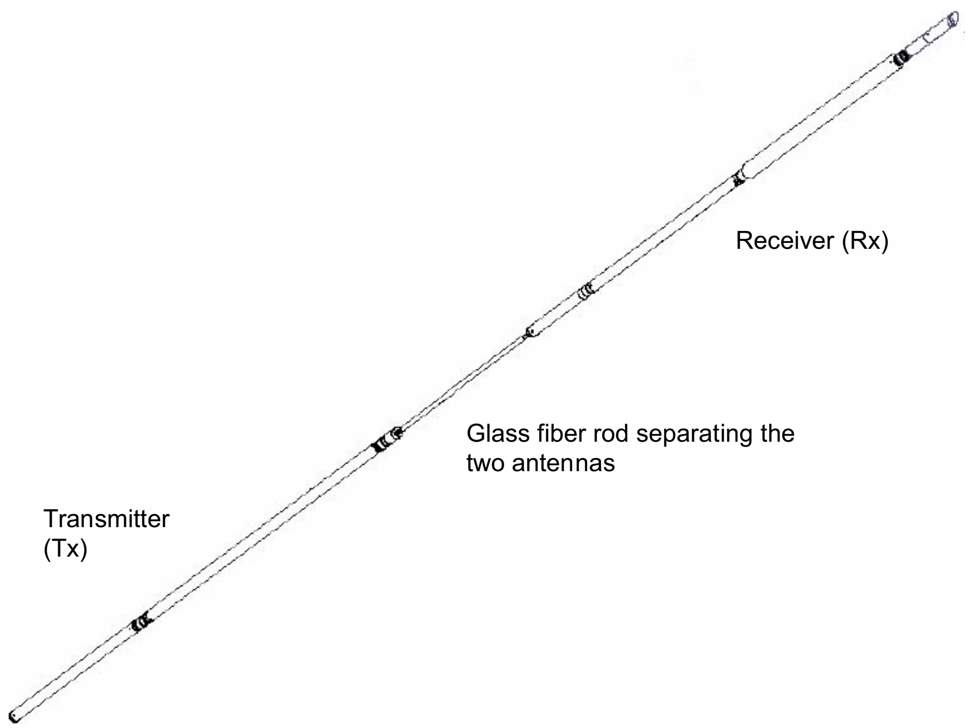


Figure 3-1. *Example of a borehole radar antenna.*

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).

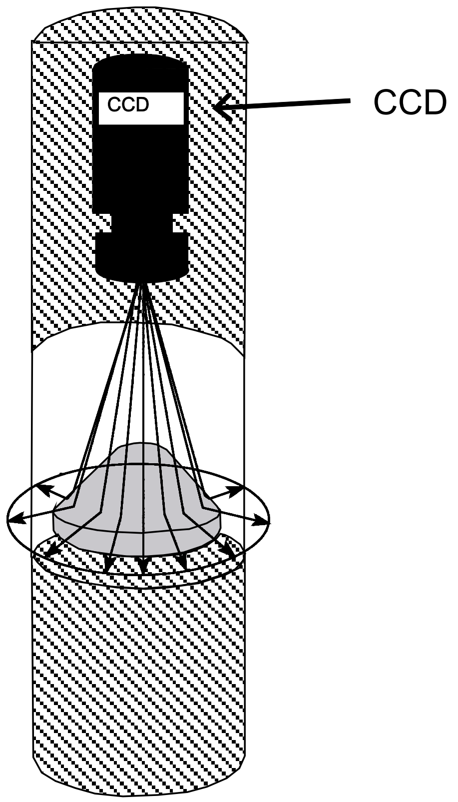


Figure 3-2. *The BIP-system. Illustration of the conical mirror scanning.*

4 Execution

4.1 General

4.1.1 RAMAC Radar

The measurements in HLX17, HLX18 and HLX19 were carried out with dipole radar antennas, with frequencies of 250, 100 and 20 MHz.

During logging the dipole antennas (transmitter and receiver) were lowered continuously into the borehole and data were recorded on a field PC along the measured interval. The antennas (transmitter and receiver) are kept at a fixed distance separation by glass fiber rods according to Table 4-1 to 4-3. See also Figure 3-1 and 4-1.

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

For more information on system settings used in the investigation of HLX17, HLX18 and HLX19, see Table 4-1 to 4-3 below.

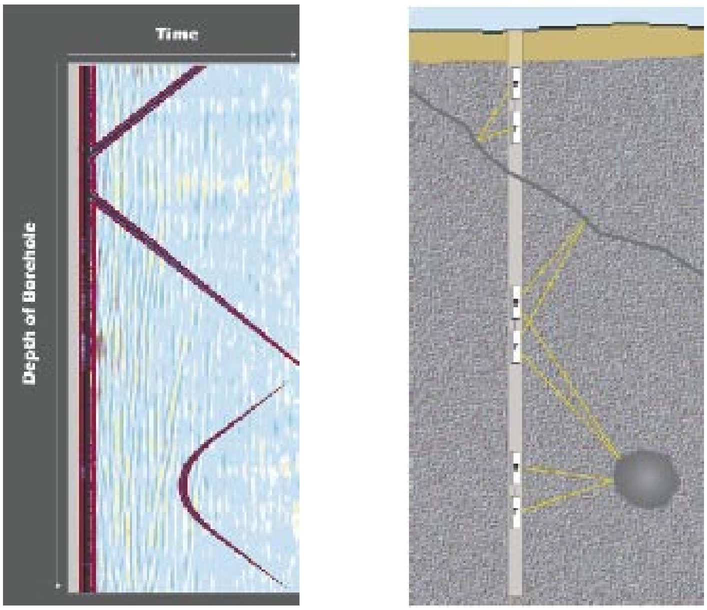


Figure 4-1. *The principle of radar borehole reflection survey and an example of result.*

Table 4-1. Radar logging information from HLX17.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**	
BH:	**HLX17**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Operator:	**CG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
Logging date:		04-07-14	04-07-14	04-07-14
Reference:		T.O.C.	T.O.C.	T.O.C.
Sampling frequency (MHz):		2424	891	239
Number of samples:		619	518	518
Number of stacks:		Auto	Auto	Auto
Signal position:		–0.34	–0.35	–1.54
Logging from (m):		1.5	2.6	6.25
Logging to (m):		200.5	199.6	195.5
Trace interval (m):		0.1	0.2	0.25
Antenna separation (m):		2.4	3.9	10.05

Table 4-2. Radar logging information from HLX18.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**	
BH:	**HLX18**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Operator:	**CG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
Logging date:		04-07-14	04-07-14	04-07-14
Reference:		T.O.C.	T.O.C.	T.O.C.
Sampling frequency (MHz):		2424	891	239
Number of samples:		619	518	518
Number of stacks:		Auto	Auto	Auto
Signal position:		–0.34	–0.34	–1.54
Logging from (m):		1.5	2.6	6.25
Logging to (m):		179.5	174.8	174.8
Trace interval (m):		0.1	0.2	0.25
Antenna separation (m):		2.4	3.9	10.05

Table 4-3. Radar logging information from HLX19.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**	
BH:	**HLX19**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Operator:	**CG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
Logging date:		04-09-30	04-09-30	04-09-30
Reference:		T.O.C.	T.O.C.	T.O.C.
Sampling frequency (MHz):		2424	891	239
Number of samples:		619	518	518
Number of stacks:		Auto	Auto	Auto
Signal position:		–0.34	–0.35	–1.54
Logging from (m):		1.5	2.6	6.25
Logging to (m):		199.3	150.9	142.3
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 HLX17, HLX18 and HLX19.

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 HLX17 and HLX18 performed in July and Figure 4-3 for the logging campaign in October when HLX19 was logged. 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.

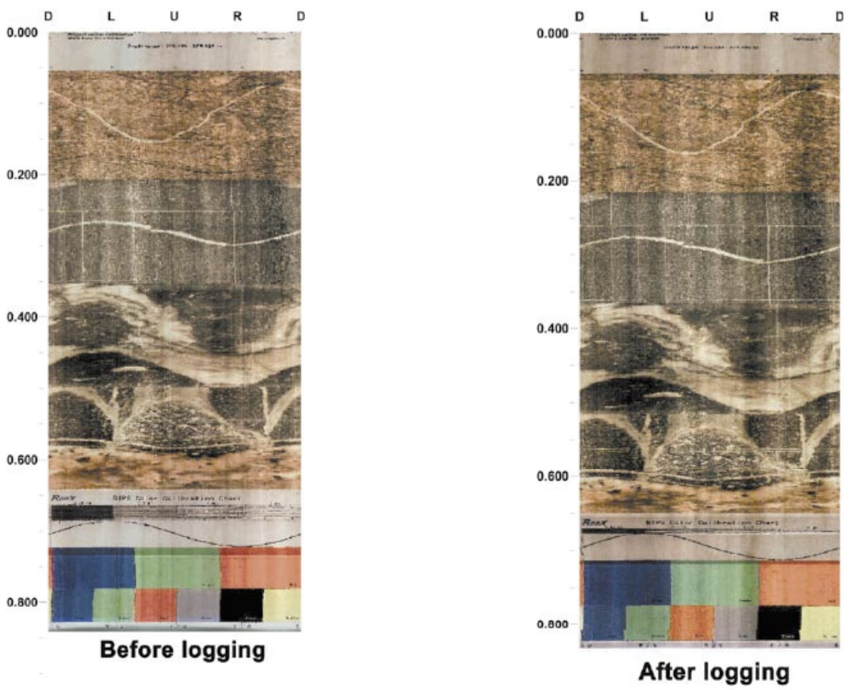


Figure 4-2. *Results from logging in the test pipe before and after the logging campaign in July.*

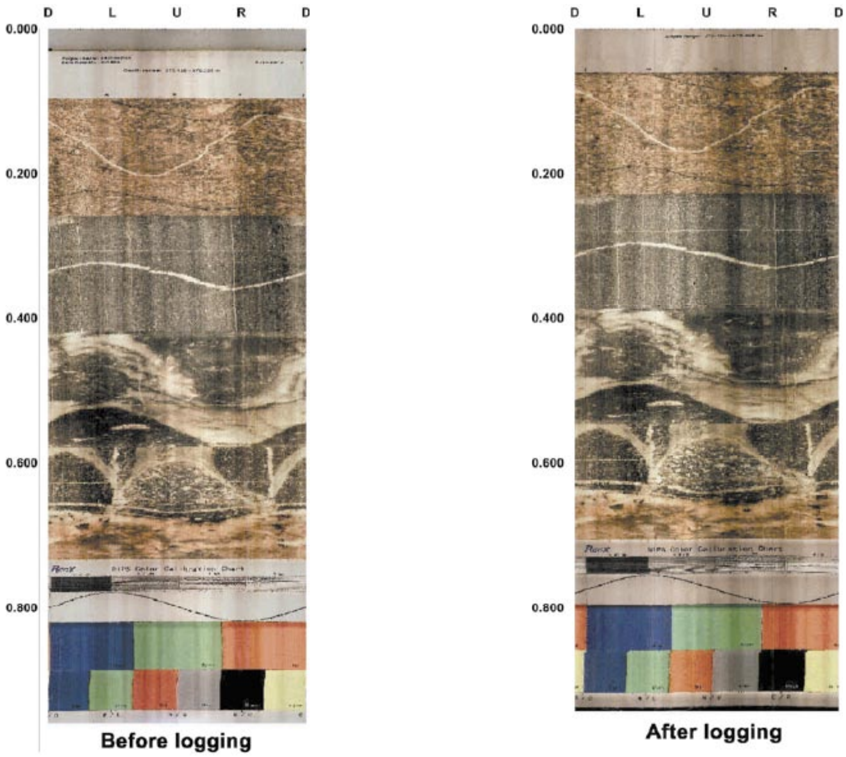


Figure 4-3. *Results from logging in the test pipe before and after the logging campaign in October.*

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.

During the BIPS logging in core-drilled boreholes, were the reference marks in the borehole wall is visible on the image, the logging cable is marked with scotch tape. These tape marks are then used for controlling the RAMAC and BIPS measurements in percussion-drilled boreholes. The depth marks (presented in the Appendix 4 to 6) in the BIPS images represent the recorded depth (in black) and adjusted depth (in red).

As all the measured boreholes are less than 200 m, the depth divergence is very slight, in the deepest parts of the boreholes.

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 color corresponds to the large positive signals and white color to large negative signals. Grey color 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/.

The visualization of data in Appendix 1 to 3 is made with ReflexWin, a Windows based processing software for filtering and analysis of borehole radar data. The processing steps are shown in Tables 4-4 to 4-6.

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 5-1 to 5-6 and are also visible on the radargrams in Appendix 1 to 3.

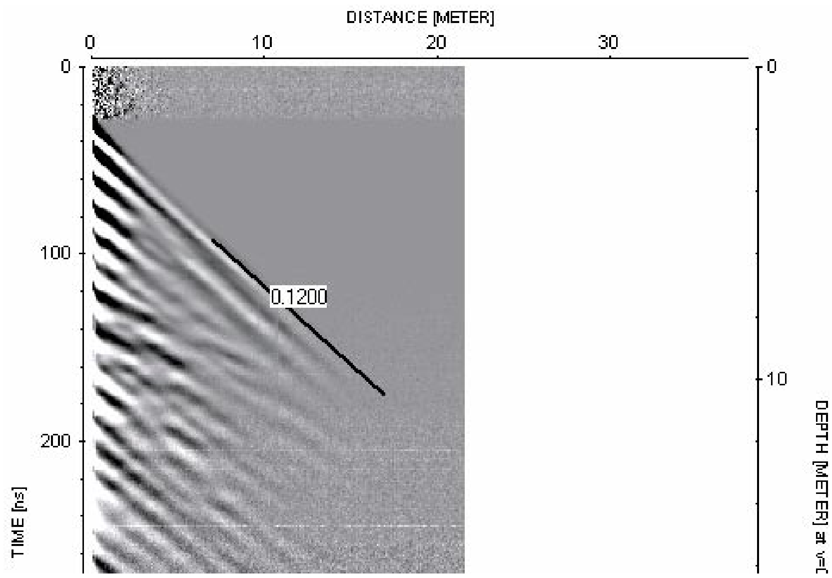


***Figure 4-4.** Results from velocity measurements in KSH01B with 100 MHz dipole antennas /1/.*

Table 4-4. Processing steps for borehole radar data from HLX17.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**	
BH:	**HLX17**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Interpret:	**JA**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
Processing:		DC removal	DC removal	DC removal
		Move start time	Move start time	Move start time
		Gain	Gain	Gain

Table 4-5. Processing steps for borehole radar data from HLX18.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**	
BH:	**HLX18**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Interpret:	**JA**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
Processing:		DC removal	DC removal	DC removal
		Move start time	Move start time	Move start time
		Gain	Gain	Gain

Table 4-6. Processing steps for borehole radar data from HLX19.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**	
BH:	**HLX19**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Interpret:	**JA**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
Processing:		DC removal	DC removal	DC removal
		Move start time	Move start time	Move start time
		Gain	Gain	Gain

4.2.2 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 HLX17, HLX18 to HLX19.

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 made on the cable when logging core drilled boreholes (where the length marks are visible in the BIPS image). For printing of the BIPS images the printing software PDPP from RaaX was used.

The BIPS logging information is found in the header for every single borehole presented in Appendix 4 to 6 in this report.

4.3 Nonconformities

During the logging activity in HLX19 parts of the equipment get stuck in the borehole at a depth of approximately 149 m. Due to this only the radar measurement with the 250 MHz antenna was done to a depth of 198 m.

5 Results

The results from the BIPS measurements in HLX17, HLX18 and HLX19 were delivered as raw data (*.bip-files) 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 for HLX17, HLX18 and HLX19 was delivered as raw data (file format *.rd3 or *.rd5) with corresponding information files (file format *.rad) on CD-ROM: s to SKB before the field crew left the investigation site, 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.

Results from the activity is stored in the SICADA database under field note no 413 (HLX17 and HLX18) and field note no 489 (HLX19).

5.1 RAMAC logging

The results of the interpretation of the radar measurements are presented in Tables 5-1 to 5-6. Radar data is also visualized in Appendix 1 to 3. It should be remembered that the images in Appendix 1 to 3 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 to 3. 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 HLX17, HLX18 and HLX19, (as seen in Appendix 1 to 3) is satisfying, but some parts with lower quality exist due to more conductive conditions. A conductive environment will attenuate the radar wave, which decreases the penetration. This is for instance seen very clearly in the data from HLX18 throughout the borehole and in HLX19 from a depth of 120 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.

As also seen in Appendix 1 to 3 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.

In Tables 5-1 to 5-3 below the distribution of identified structures along the borehole are listed for HLX17, HLX18 and HLX19.

Table 5-1. Identified structures as a function of depth in HLX17.

Depth (m)	No of structures
–20	3
20–40	6
40–60	7
60–80	4
80–100	4
100–120	7
120–140	4
140–160	7
160–180	4
180–200	1
200–	2

Table 5-2. Identified structures as a function of depth in HLX18.

Depth (m)	No of structures
–20	1
20–40	3
40–60	4
60–80	4
80–100	7
100–120	4
120–140	2
140–160	2
160–180	2
180–200	–
200–	–

Table 5-3. Identified structures as a function of depth in HLX19.

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

Tables 5-4 to 5-5 summarises the interpretation of radar data from HLX17, HLX18 and HLX19. In the tables the depth and intersection angle to the identified structures are listed.

Table 5-4. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz borehole HLX17.

RADINTER MODEL INFORMATION (20, 100 and 250 MHz Dipole Antennas)			
Site:		**Oskarshamn**	
Borehole name:		**HLX17**	
Nominal velocity (m/μs):		**120.00**	
Object type	**Name**	**Intersection depth**	**Intersection angle**
PLANE	A	9.90	81
PLANE	B	14.40	71
PLANE	Bx	19.20	37
PLANE	C	27.30	42
PLANE	D	28.20	61
PLANE	E	28.90	34
PLANE	I	37.40	53
PLANE	F	38.70	27
PLANE	G	39.50	72
PLANE	H	41.30	56
PLANE	J	45.30	64
PLANE	Kx	50.70	41
PLANE	Lx	53.40	57
PLANE	Kxx	54.20	42
PLANE	K	55.80	27
PLANE	L	58.20	47
PLANE	M	67.70	68
PLANE	N	68.70	51
PLANE	O	71.30	81
PLANE	P	77.30	86
PLANE	Q	91.20	38
PLANE	R	91.30	60
PLANE	S	94.30	67
PLANE	T	99.20	55
PLANE	V	105.50	47
PLANE	Wx	107.20	49
PLANE	U	110.80	27
PLANE	W	111.20	50
PLANE	1	112.40	47
PLANE	X	114.80	85
PLANE	Y	115.50	85
PLANE	2	126.90	52
PLANE	3	131.30	60
PLANE	4x	133.10	70
PLANE	4	134.00	59
PLANE	5	141.50	57
PLANE	5x	143.90	71
PLANE	6	145.40	50
PLANE	7	150.70	56
PLANE	8	156.90	58
PLANE	9	156.90	82
PLANE	10	158.90	72
PLANE	11	162.40	81
PLANE	12	168.60	59
PLANE	13	174.40	82
PLANE	14	178.20	77s
PLANE	15	187.80	48
PLANE	16	208.40	41
PLANE	17	215.20	43

Table 5-5. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz in borehole HLX18.

RADINTER MODEL INFORMATION (20, 100 and 250 MHz Dipole Antennas)			
Site: Oskarshamn **Borehole name: HLX18** **Nominal velocity (m/μs): 120.00**			
Object type	**Name**	**Intersection depth**	**Intersection angle**
PLANE	A	16.20	81
PLANE	Ax	27.90	50
PLANE	B	32.30	78
PLANE	C	38.00	48
PLANE	D	42.20	54
PLANE	E	43.50	44
PLANE	F	48.60	90
PLANE	Gx	58.00	70
PLANE	G	62.70	55
PLANE	Ix	71.80	49
PLANE	I	77.00	51
PLANE	H	77.80	56
PLANE	J	83.80	65
PLANE	K	86.40	83
PLANE	Lx	87.90	41
PLANE	L	88.40	76
PLANE	M	93.40	74
PLANE	N	99.10	45
PLANE	Nx	99.50	64
PLANE	Ox	100.20	78
PLANE	O	100.50	58
PLANE	P	109.90	60
PLANE	Q	113.90	84
PLANE	R	120.90	76
PLANE	S	124.90	45
PLANE	T	147.80	22
PLANE	U	157.70	66
PLANE	V	165.40	90
PLANE	W	179.30	43

Table 5-6. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz in borehole HLX19.

RADINTER MODEL INFORMATION (20, 100 and 250 MHz Dipole Antennas)			
Site: Oskarshamn			
Borehole name: HLX19			
Nominal velocity (m/μs): 120.00			
Object type	**Name**	**Intersection depth**	**Intersection angle**
PLANE	A	14.80	42
PLANE	B	32.00	36
PLANE	C	36.40	70
PLANE	D	45.90	65
PLANE	E	61.00	90
PLANE	F	73.60	50
PLANE	O	76.90	40
PLANE	G	77.90	54
PLANE	H	82.00	59
PLANE	I	84.50	74
PLANE	P	86.70	59
PLANE	Q	88.00	51
PLANE	R	97.30	59
PLANE	S	102.00	64
PLANE	J	102.90	36
PLANE	K	103.60	68
PLANE	L	114.10	60
PLANE	M	122.90	52
PLANE	N	125.90	58
PLANE	T	130.80	38

In Appendix 1 to 3, 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 5-7 to 5-9.

Table 5-7. Decrease in amplitude for the 250 MHz antenna for borehole HLX17.

Depth (m)
25–30
55
65–70
115
135
170
175–180
185–

Table 5-8. Decrease in amplitude for the 250 MHz antenna for borehole HLX18.

Depth (m)
35
55–65
75–80
85
95–105
125
145–150
165

Table 5-9. Decrease in amplitude for the 250 MHz antenna for borehole HLX19.

Depth (m)
15
30
40
125–

5.2 BIPS logging

The BIPS pictures are presented in Appendix 4 to 6.

To get the best possible depth accuracy, the BIPS images are adjusted to the reference marks on the logging cable. The reference marks are placed according to the marks on the borehole wall in core-drilled boreholes created by the drill rig, which are visible on the BIPS screen. The recorded length is adjusted to these visible marks. In percussion drilled boreholes we use these marks on the cable as reference for the depth adjustment. The experience from one year of logging is that the marks on the logging cable is very good and differs very little compared with the results from core-drilled boreholes. At present we have marks at 110, 150 and 200 m on the logging cable that are used for depth adjustments of the BIPS results in percussion drilled boreholes.

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 of the last borehole. The resulting images displayed no difference regarding the colours and focus of the images. Results of the test loggings were included in the delivery of the field data and are also presented in Figures 4-2 and 4-3 in this report.

Data for the inclination and azimuth presented in this report for the boreholes are only preliminary, as deviation measurements were not yet made at the time of BIPS logging.

HLX17

The BIPS logging shows reasonably good images for geological and fracture mapping. The main defect is that mud covers the lowermost part of the borehole. This effect is visible from the upper part and has an increasing negative effect of the data quality along the borehole.

HLX18

The image is affected by dirty water from the casing shoe to approximate 35 m. Below 35 m the image has good quality down to the last 40 m where mud covering the lowermost part of the borehole decreases the visibility.

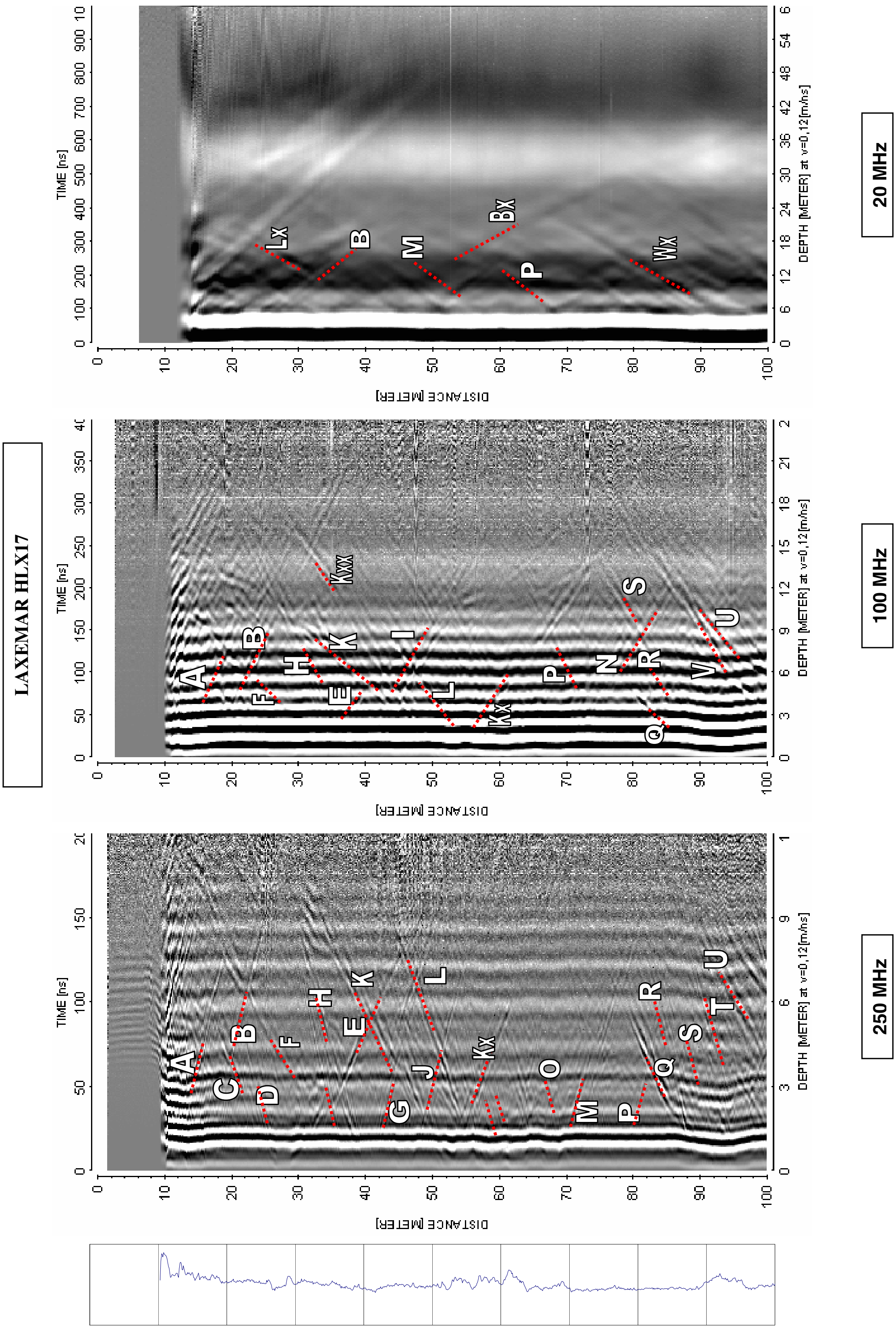
HLX19

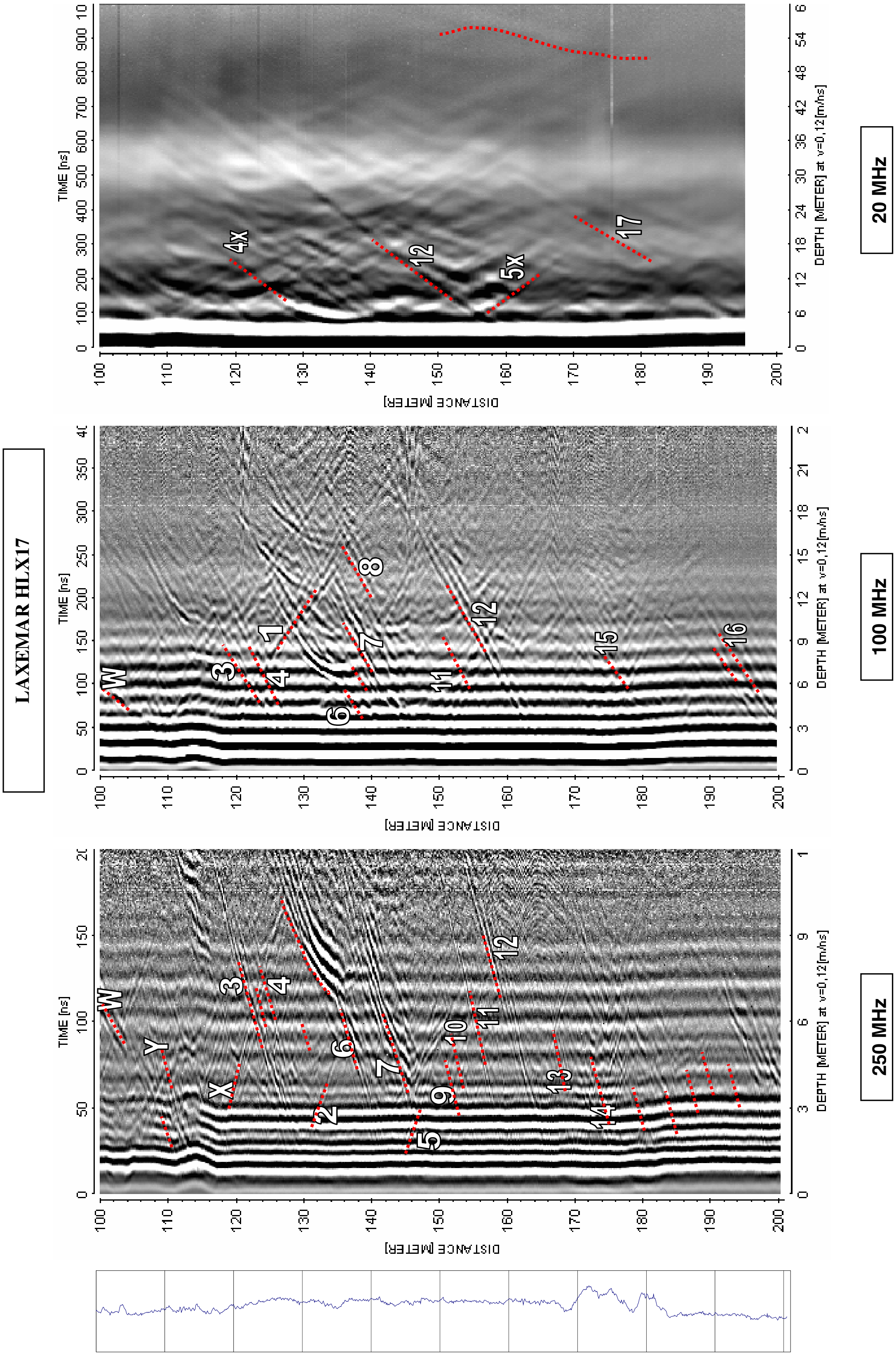
It was not possible to log the complete borehole due to that the probe jammed and stopped at 149 m. Several attempts to pass this section failed. The image quality is acceptable along the borehole despite that the colour of the borehole changes very much, from dark to very pale colours.

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.

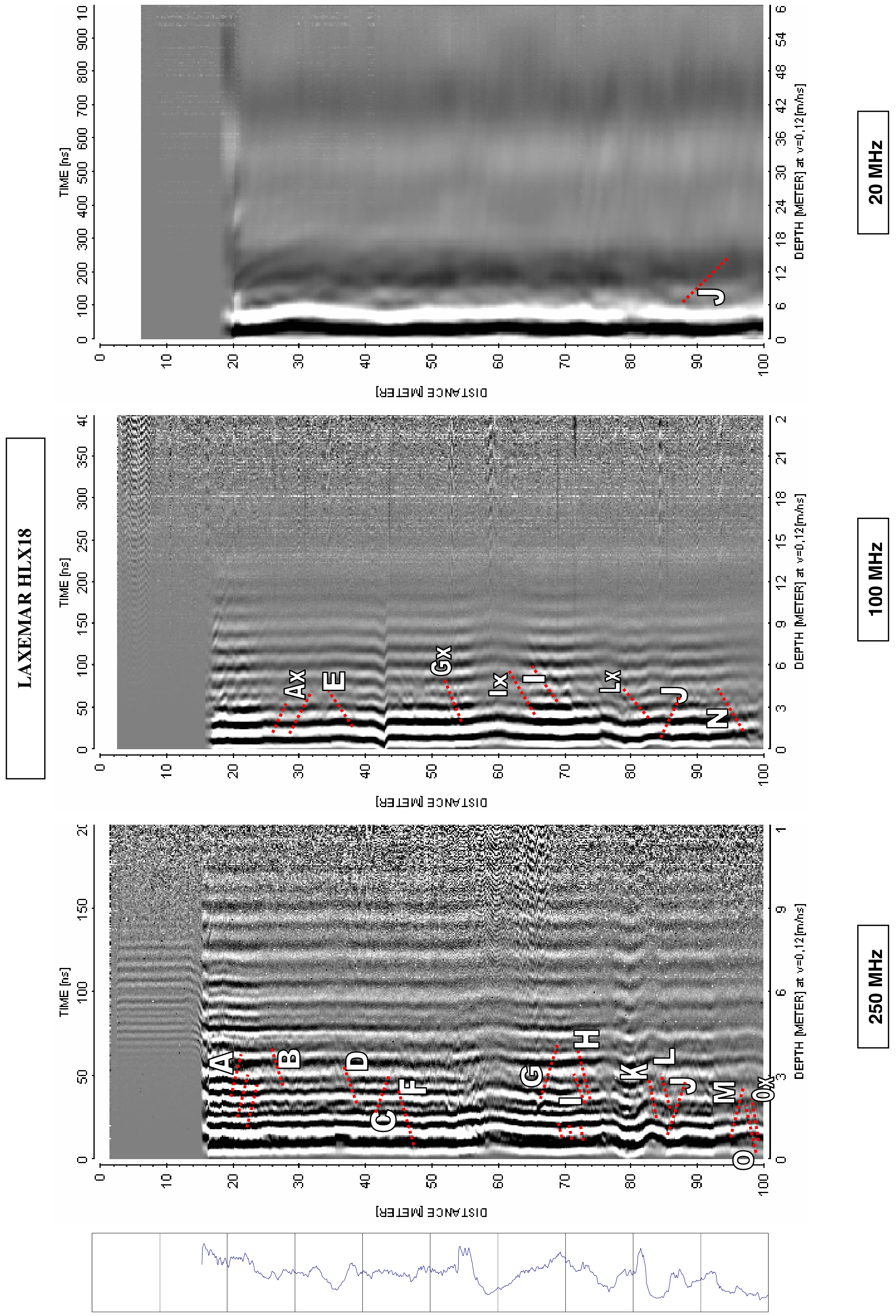
Radar logging in HLX17, 0 to 200 m, dipole antennas 250, 100 and 20 MHz

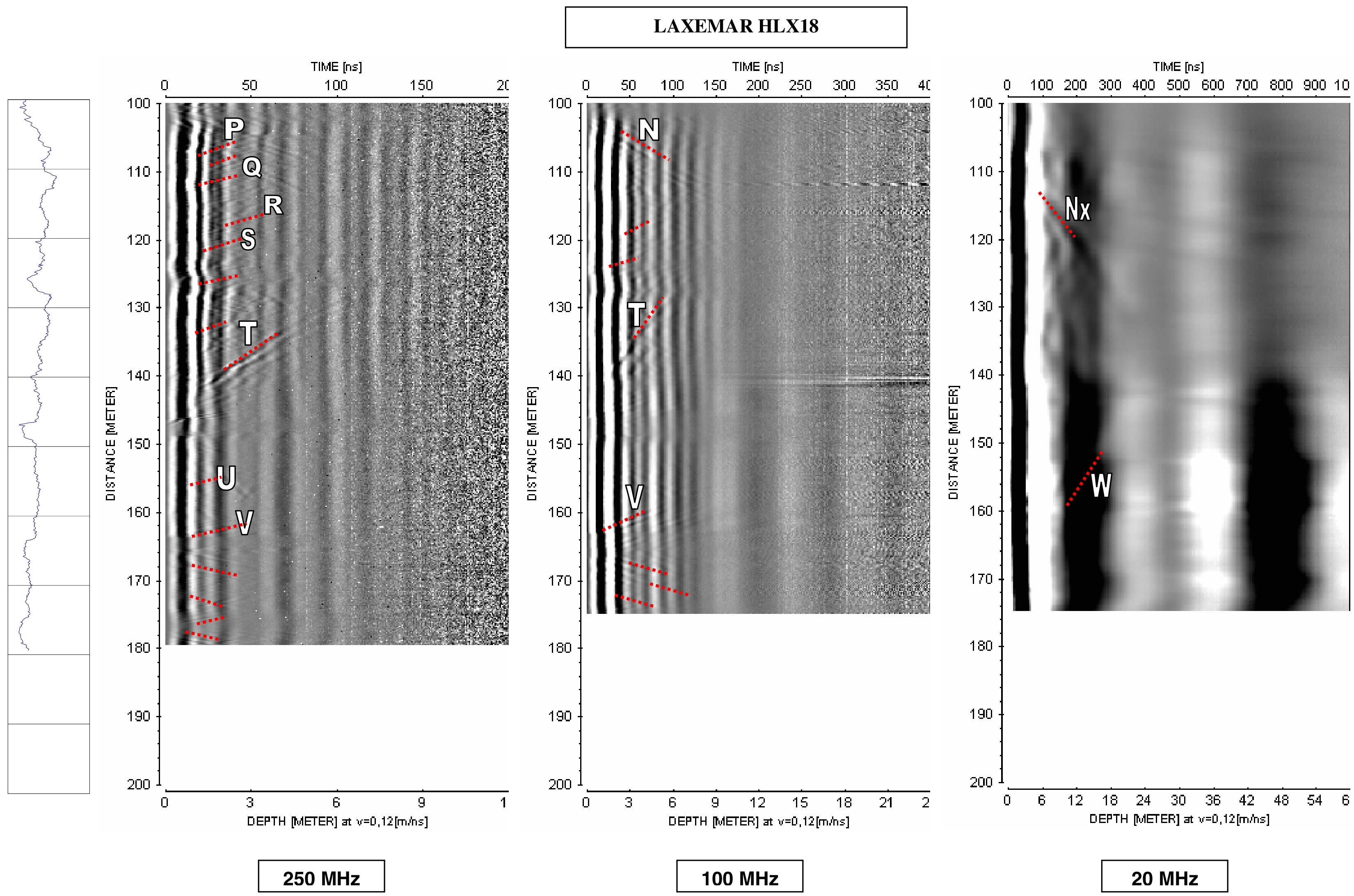



LAXEMAR HLX17
250 MHz
100 MHz
20 MHz
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,12[m/ns]
W
Y
X
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
4x
5x

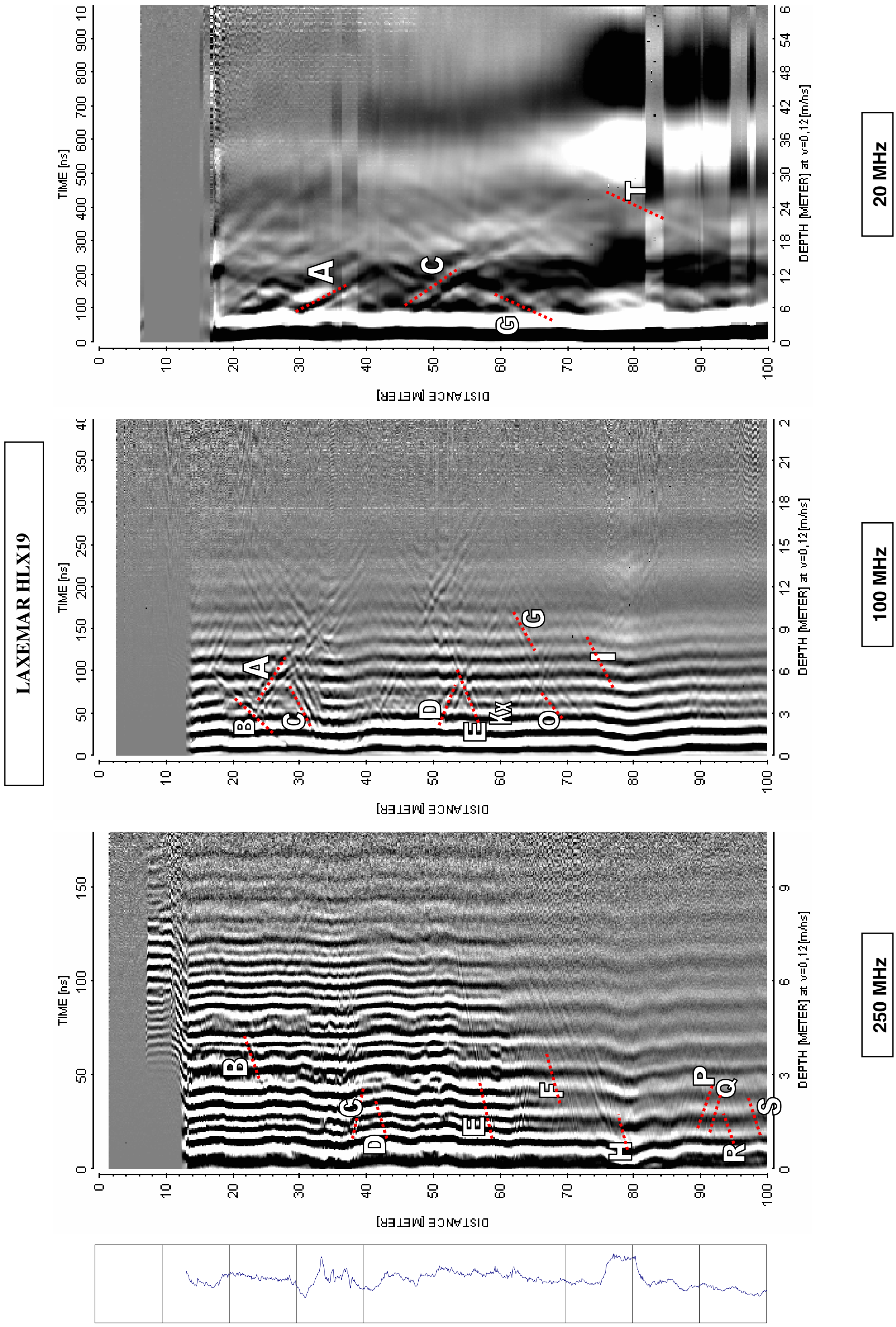
Appendix 2

Radar logging in HLX18, 0 to 180 m, dipole antennas 250, 100 and 20 MHz

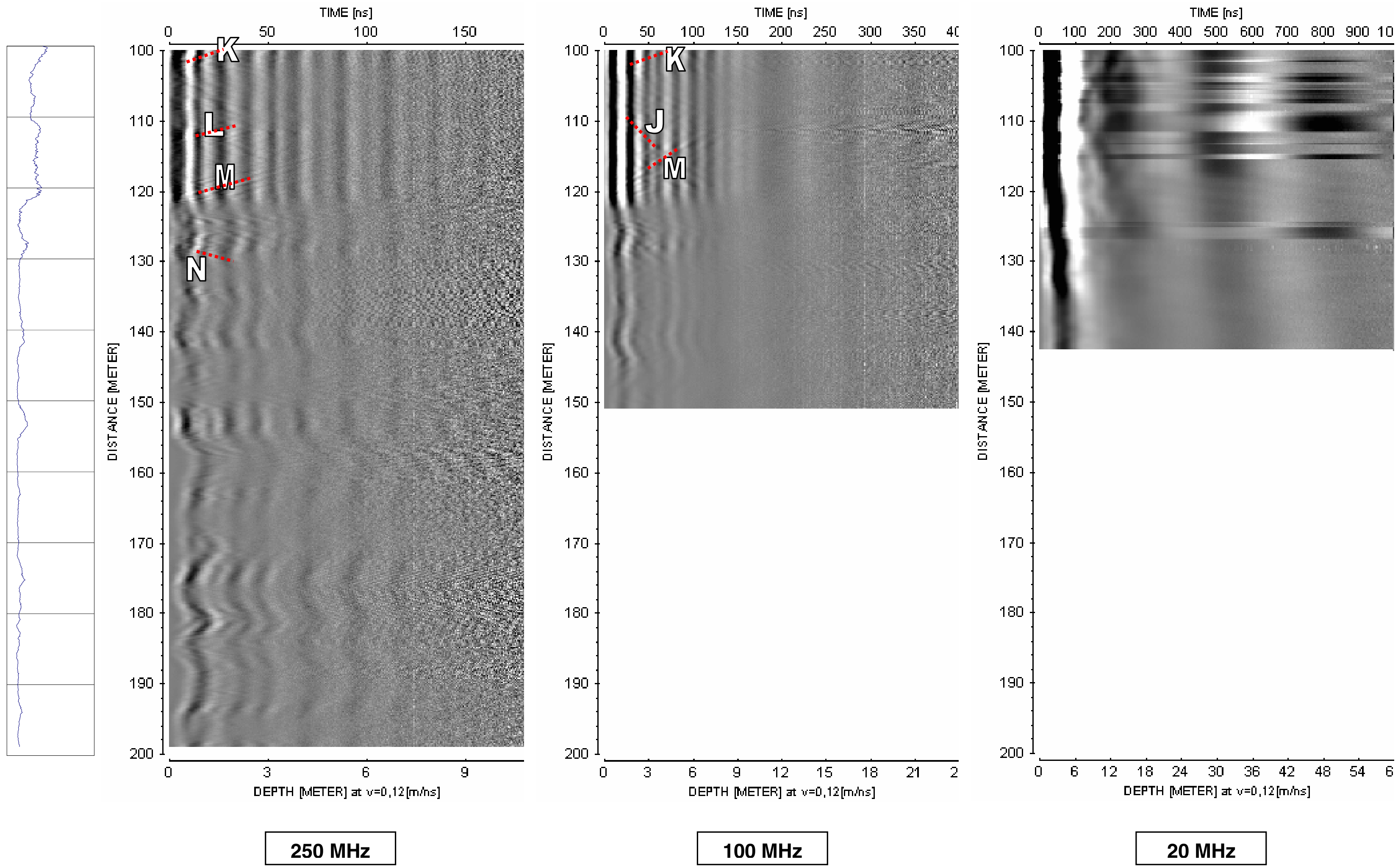



LAXEMAR HLX18
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,12[m/ns]
P
Q
R
S
T
U
V
N
Nx
W
250 MHz
100 MHz
20 MHz

Radar logging in HLX19, 0 to 180 m, dipole antennas 250, 100 and 20 MHz



LAXEMAR HLX19



Appendix 4

BIPS logging in HLX17, 8 to 201 m

Project name: Laxemar

Image file	: c:\work\r53__l~2\hlx17\bips\hlx17.bip
BDT file	: c:\work\r53__l~2\hlx17\bips\hlx17.bdt
Locality	: LAXEMAR
Bore hole number	: HLX17
Date	: 04/07/15
Time	: 07:06:00
Depth range	: 8.000 - 201.214 m
Azimuth	: 311
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	: 10
Color	: +0 +0 +0

Project name: Laxemar
Bore hole No.: HLX17 **Azimuth: 311** **Inclination: -59**

Depth range: 8.000 - 28.000 m

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

Project name: Laxemar
Bore hole No.: HLX17 **Azimuth: 311** **Inclination: -59**

Depth range: 28.000 - 48.000 m

D L U R D

28.000
28.104

29.000
29.109
30.000
30.114
31.000
31.119
32.000
32.124
33.000
33.130

D L U R D

33.000
33.130

34.000
34.135
35.000
35.140
36.000
36.145
37.000
37.150
38.000
38.155

D L U R D

38.000
38.155

39.000
39.161
40.000
40.166
41.000
41.171
42.000
42.176
43.000
43.181

D L U R D

43.000
43.181

44.000
44.187
45.000
45.192
46.000
46.197
47.000
47.202
48.000
48.207

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

Project name: Laxemar
Bore hole No.: HLX17 **Azimuth: 311** **Inclination: -59**

Depth range: 48.000 - 68.000 m

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

Project name: Laxemar
Bore hole No.: HLX17 **Azimuth: 311** **Inclination: -59**

Depth range: 68.000 - 88.000 m

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

Project name: Laxemar
Bore hole No.: HLX17 **Azimuth: 311** **Inclination: -59**

Depth range: 88.000 - 108.000 m

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

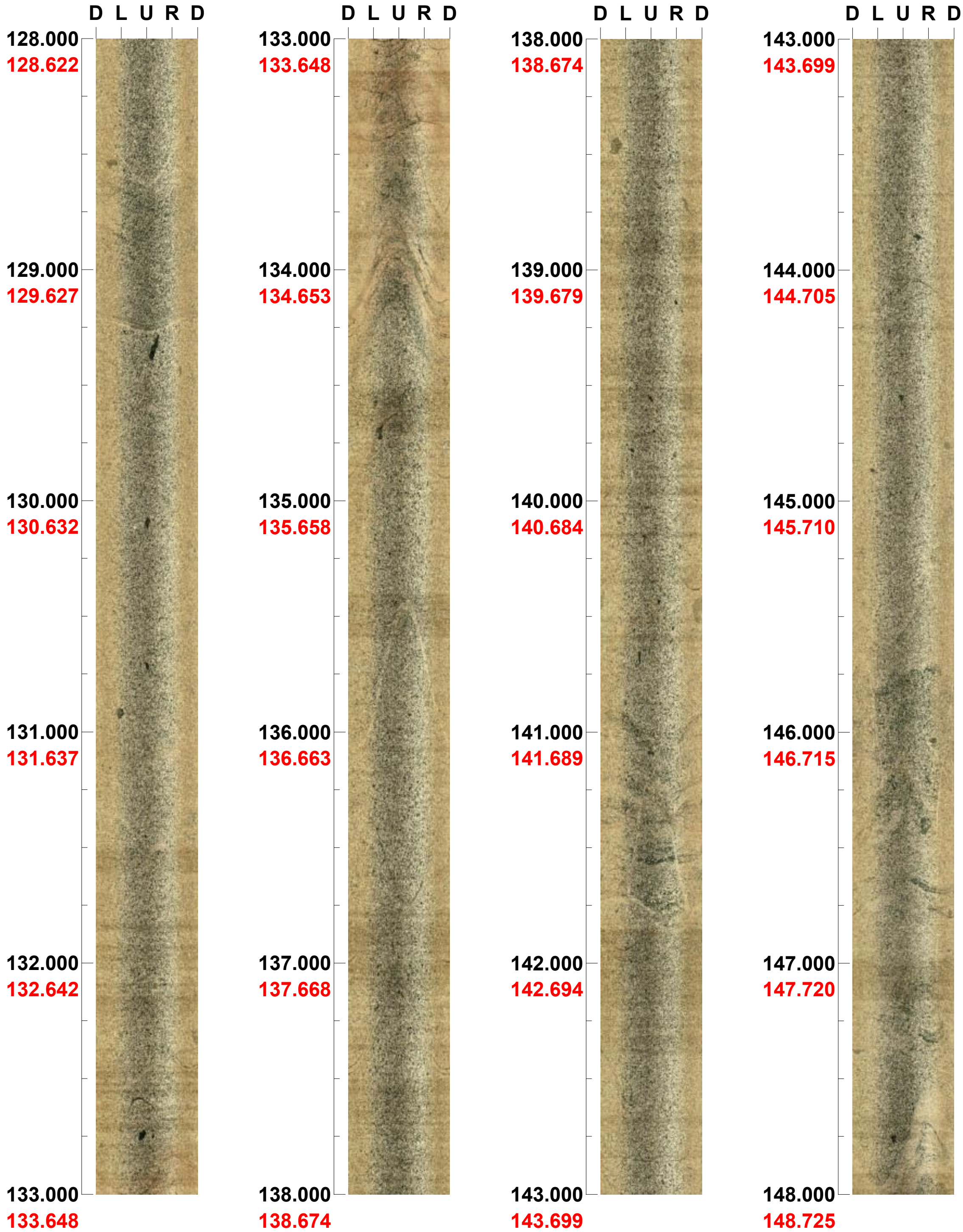
Project name: Laxemar
Bore hole No.: HLX17 Azimuth: 311 Inclination: -59

Depth range: 108.000 - 128.000 m

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

Project name: Laxemar
Bore hole No.: HLX17 **Azimuth: 311** **Inclination: -59**

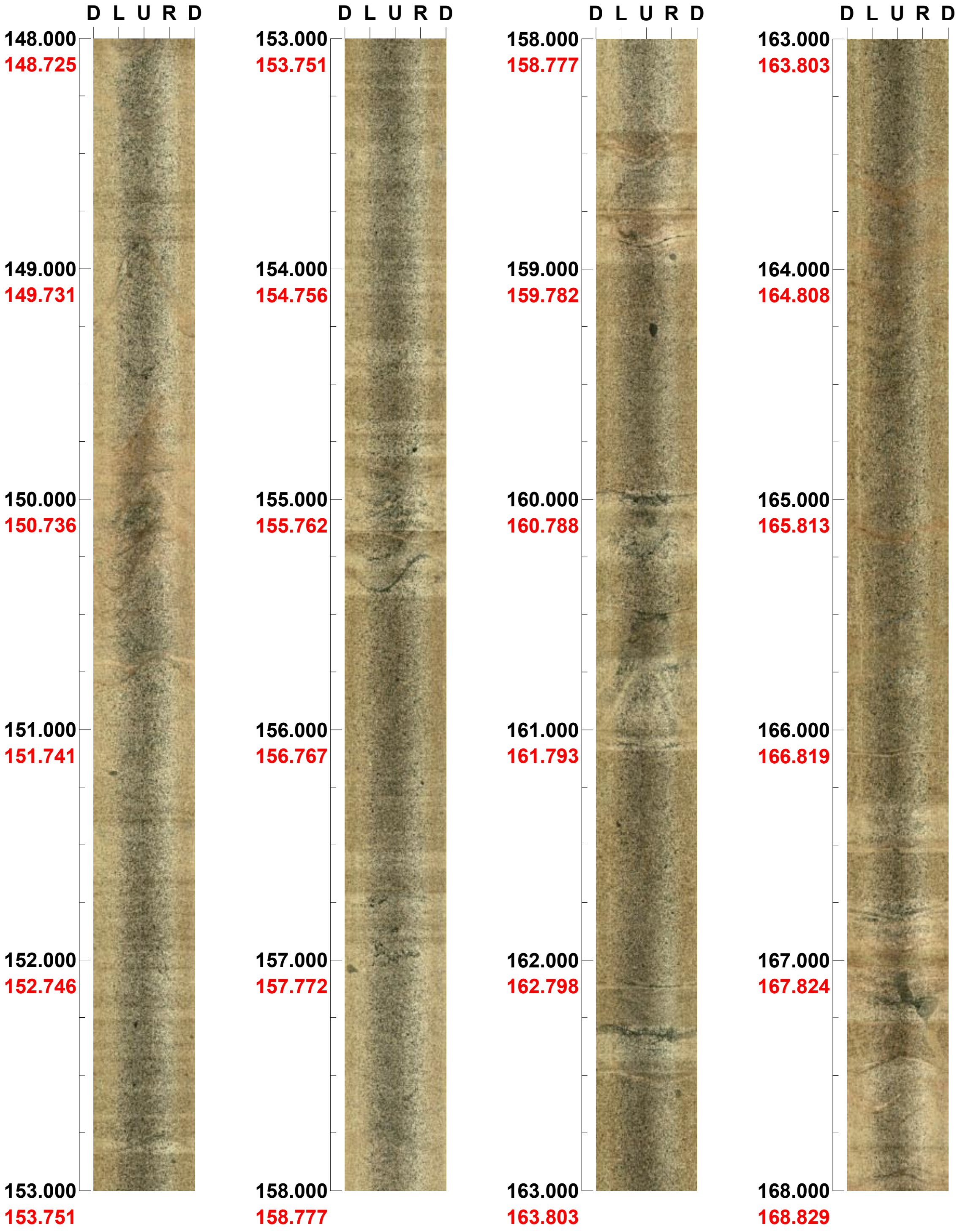
Depth range: 128.000 - 148.000 m



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

Project name: Laxemar
Bore hole No.: HLX17 **Azimuth: 311** **Inclination: -59**

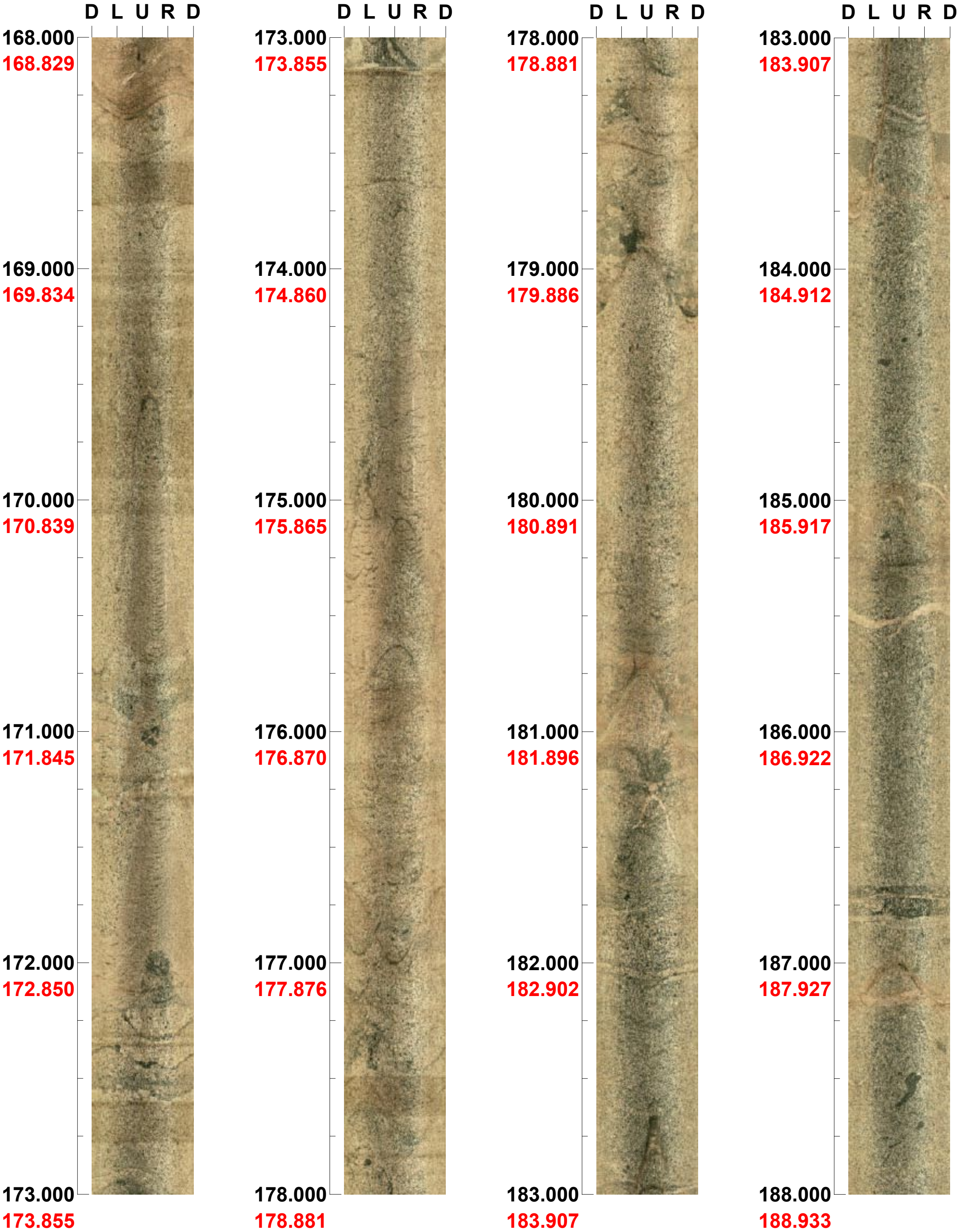
Depth range: 148.000 - 168.000 m



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

Project name: Laxemar
Bore hole No.: HLX17 **Azimuth: 311** **Inclination: -59**

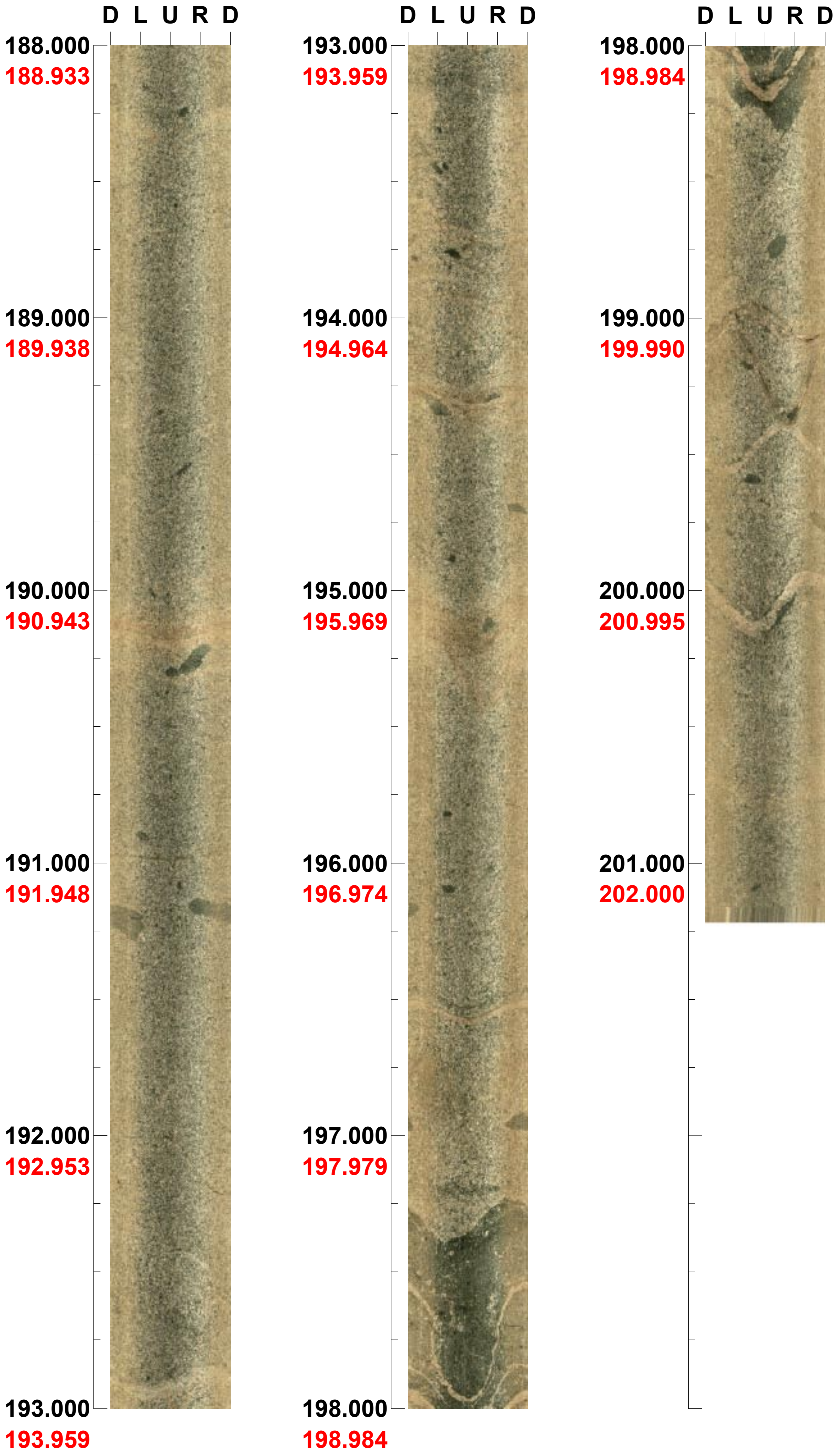
Depth range: 168.000 - 188.000 m



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

Project name: Laxemar
Bore hole No.: HLX17 **Azimuth: 311** **Inclination: -59**

Depth range: 188.000 - 201.214 m



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

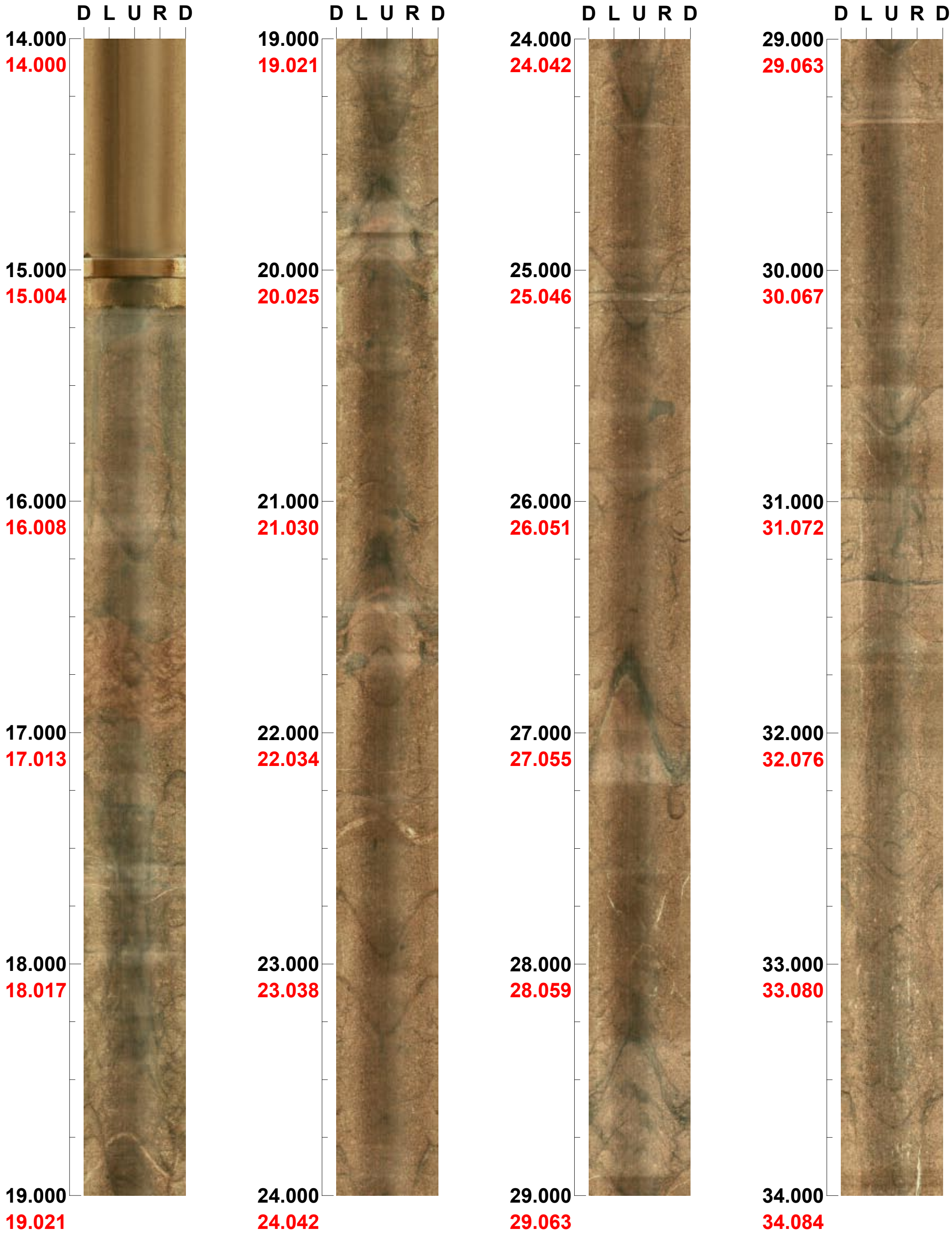
BIPS logging in HLX18, 14 to 180 m

Project name: Laxemar

Image file	: c:\work\r53__l~2\hlx18\bips\hlx18.bip
BDT file	: c:\work\r53__l~2\hlx18\bips\hlx18.bdt
Locality	: LAXEMAR
Bore hole number	: HLX18
Date	: 04/07/14
Time	: 12:29:00
Depth range	: 14.000 - 180.311 m
Azimuth	: 135
Inclination	: -60
Diameter	: 140.0 mm
Magnetic declination	: 0.0
Span	: 4
Scan interval	: 0.25
Scan direction	: To bottom
Scale	: 1/25
Aspect ratio	: 100 %
Pages	: 9
Color	: +0 +0 +0

Project name: Laxemar
Bore hole No.: HLX18 **Azimuth: 135** **Inclination: -60**

Depth range: 14.000 - 34.000 m

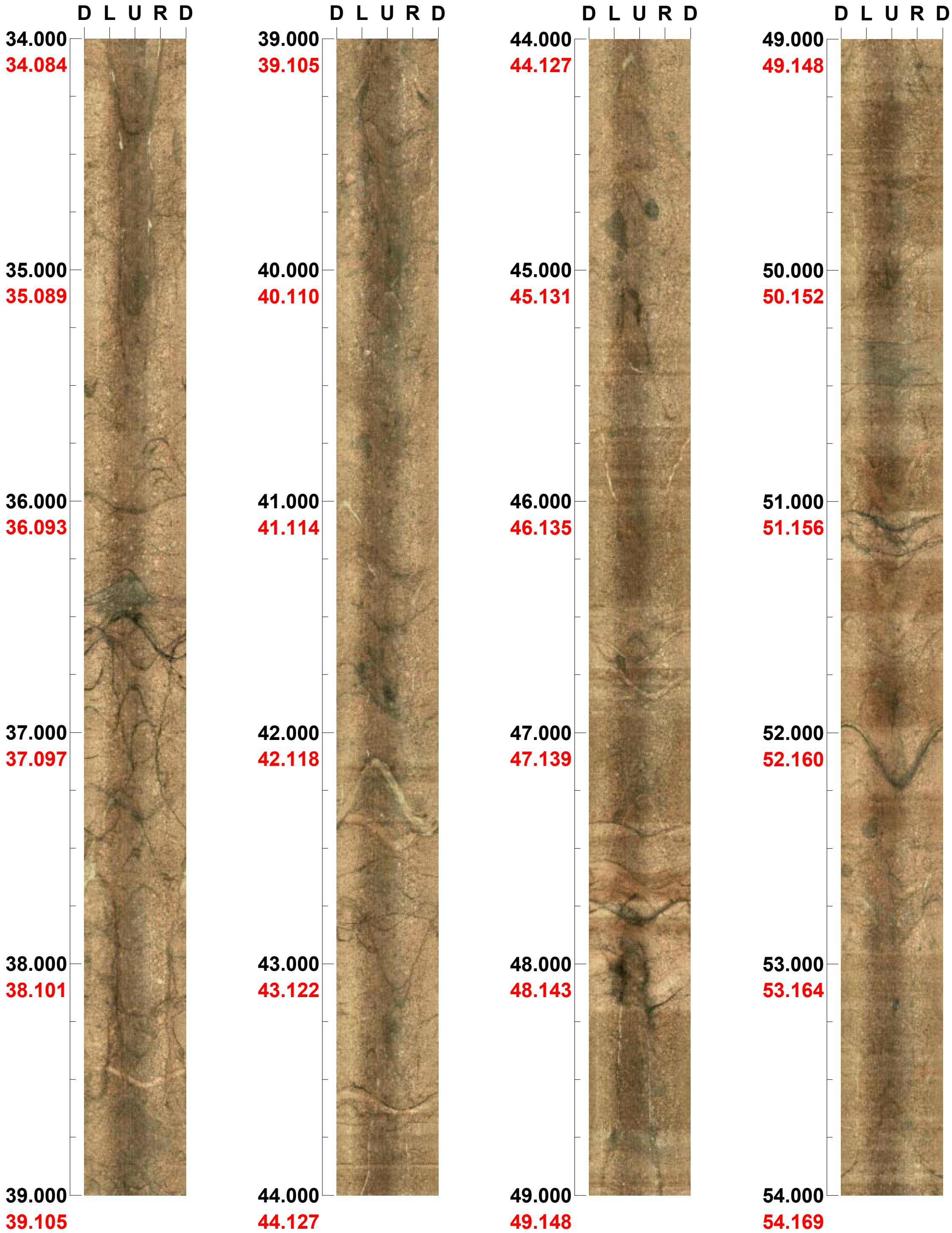


(1 / 9) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Laxemar

Bore hole No.: HLX18 **Azimuth: 135** **Inclination: -60**

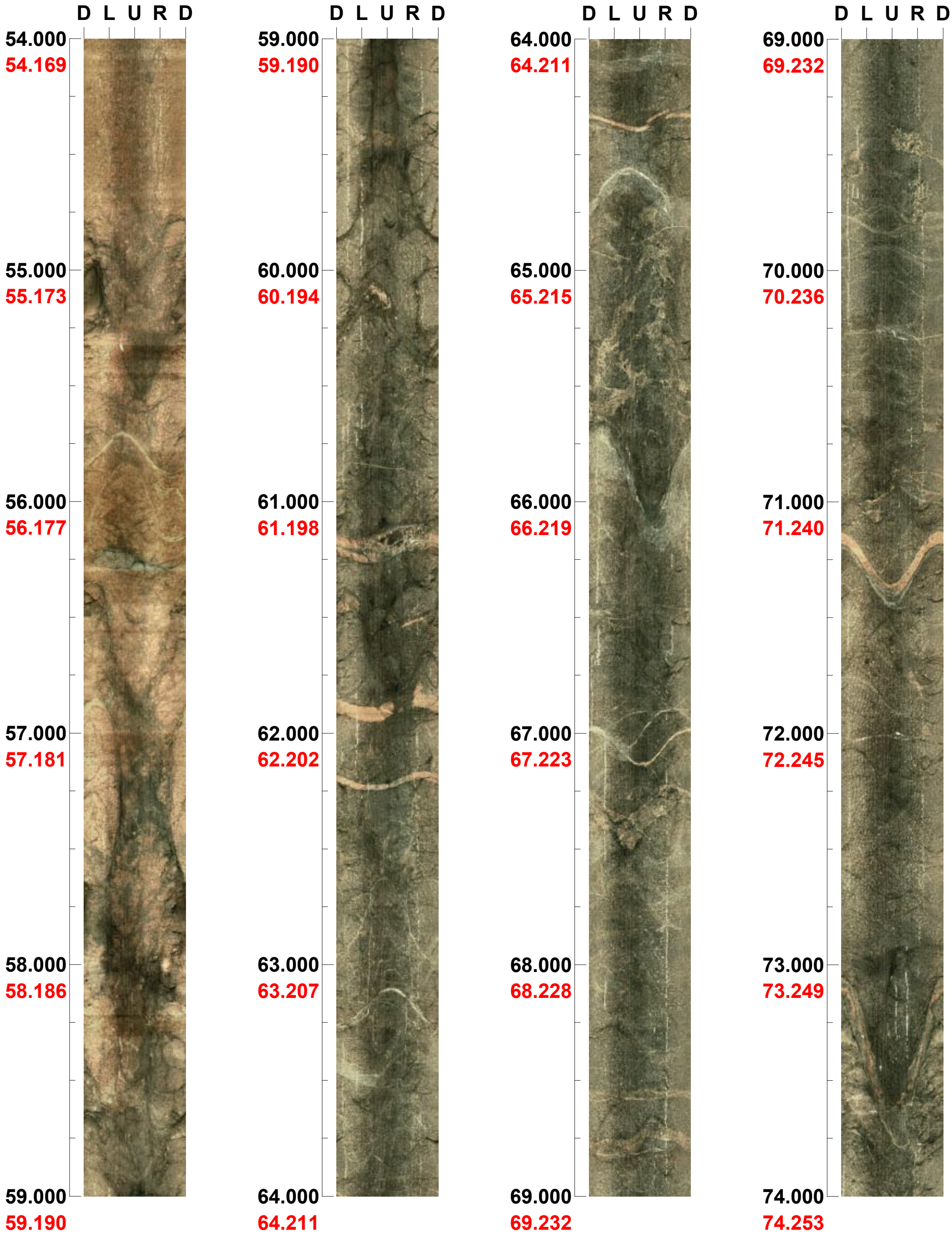
Depth range: 34.000 - 54.000 m



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

Project name: Laxemar
Bore hole No.: HLX18 **Azimuth: 135** **Inclination: -60**

Depth range: 54.000 - 74.000 m

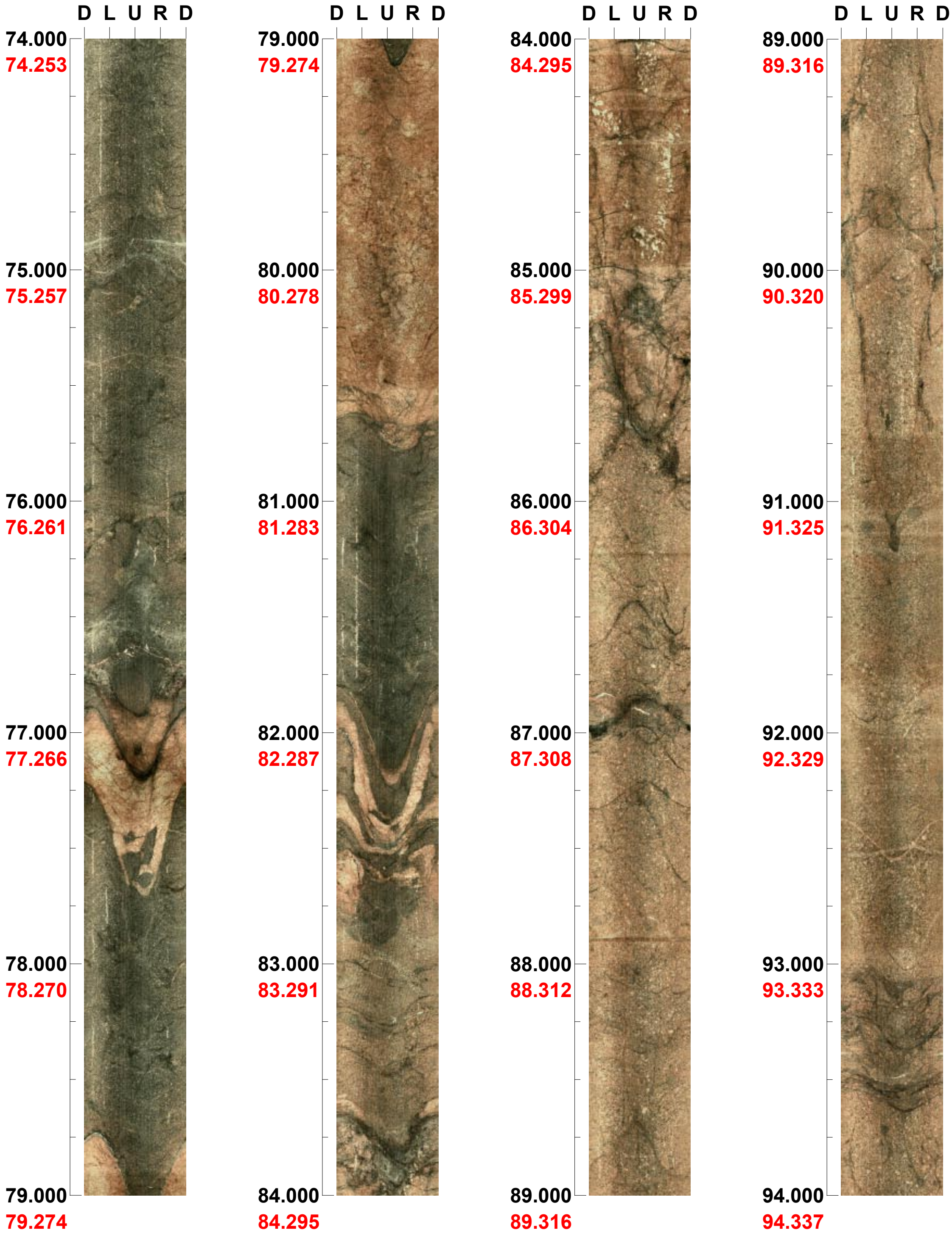


(3 / 9) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Laxemar

Bore hole No.: HLX18 **Azimuth: 135** **Inclination: -60**

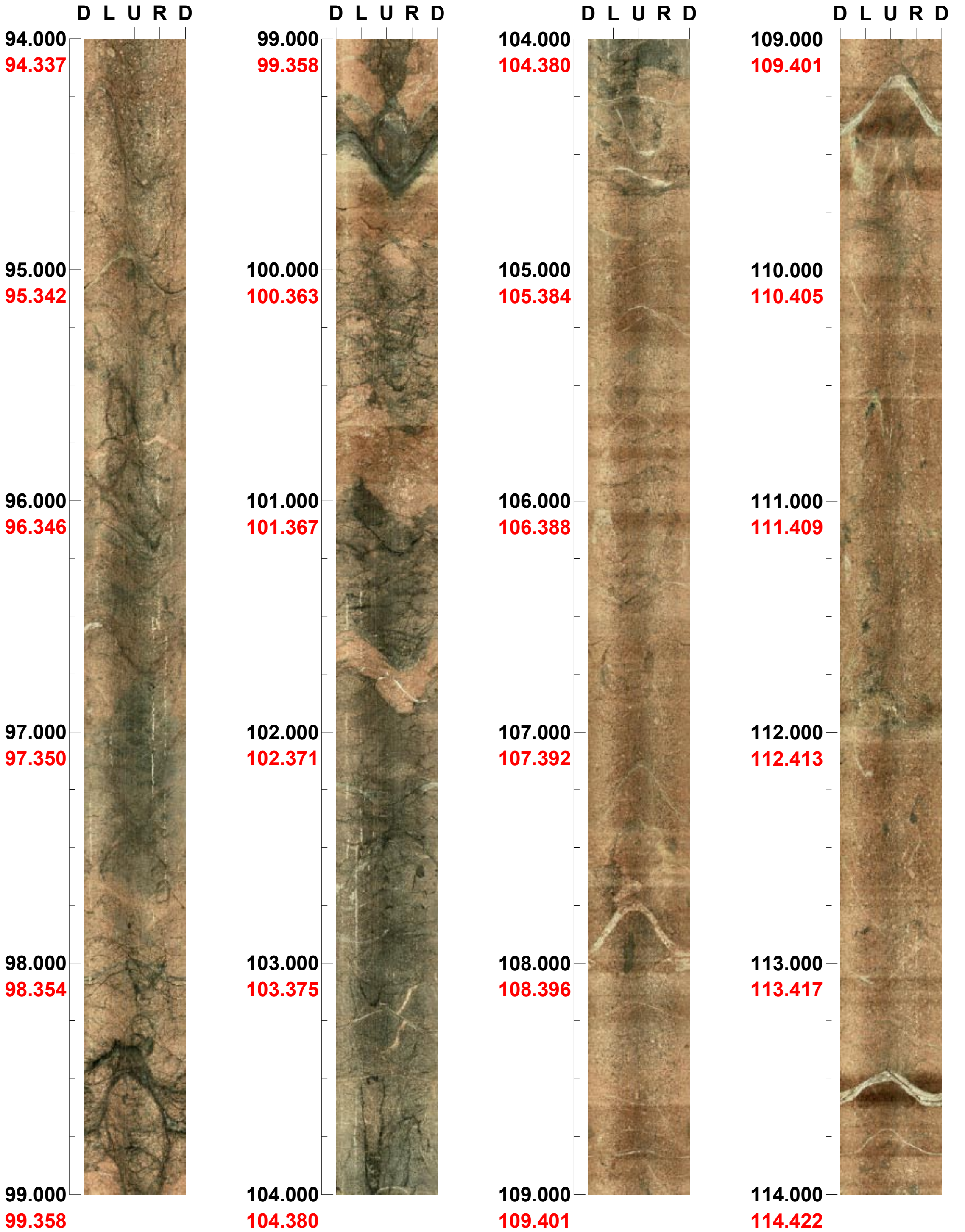
Depth range: 74.000 - 94.000 m



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

Project name: Laxemar
Bore hole No.: HLX18 **Azimuth: 135** **Inclination: -60**

Depth range: 94.000 - 114.000 m

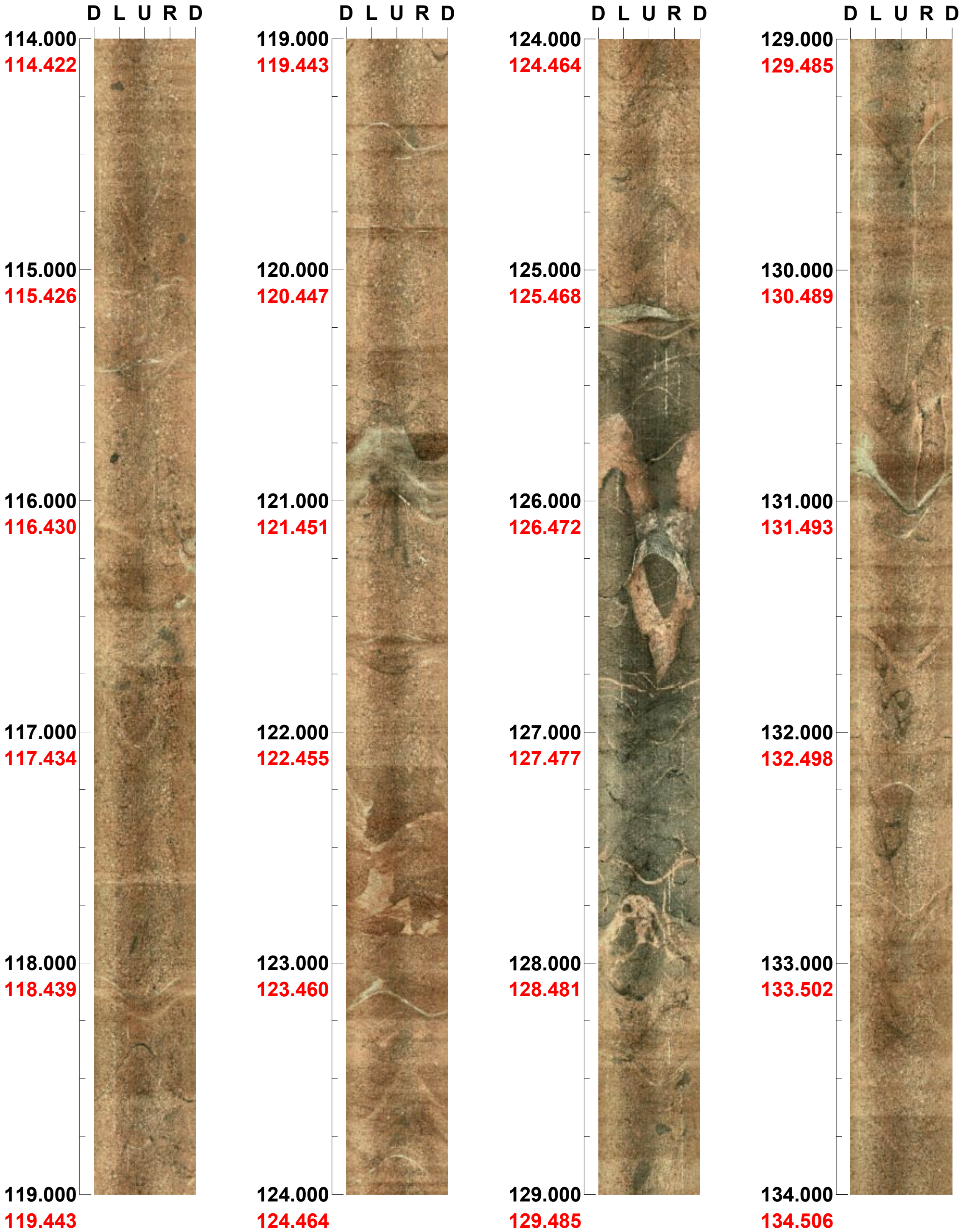


(5 / 9) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Laxemar
Bore hole No.: HLX18

Azimuth: 135 Inclination: -60

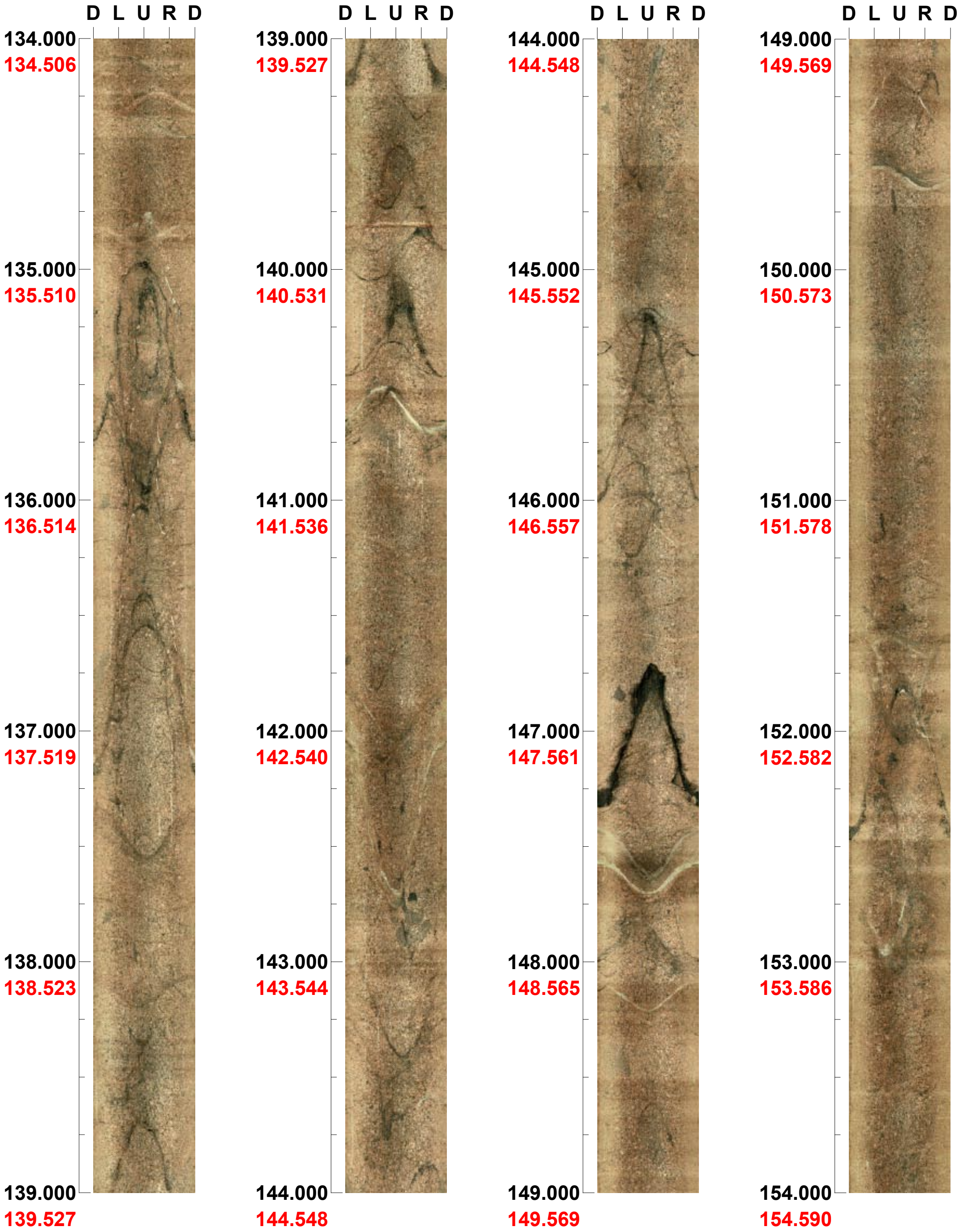
Depth range: 114.000 - 134.000 m



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

Project name: Laxemar
Bore hole No.: HLX18 **Azimuth: 135** **Inclination: -60**

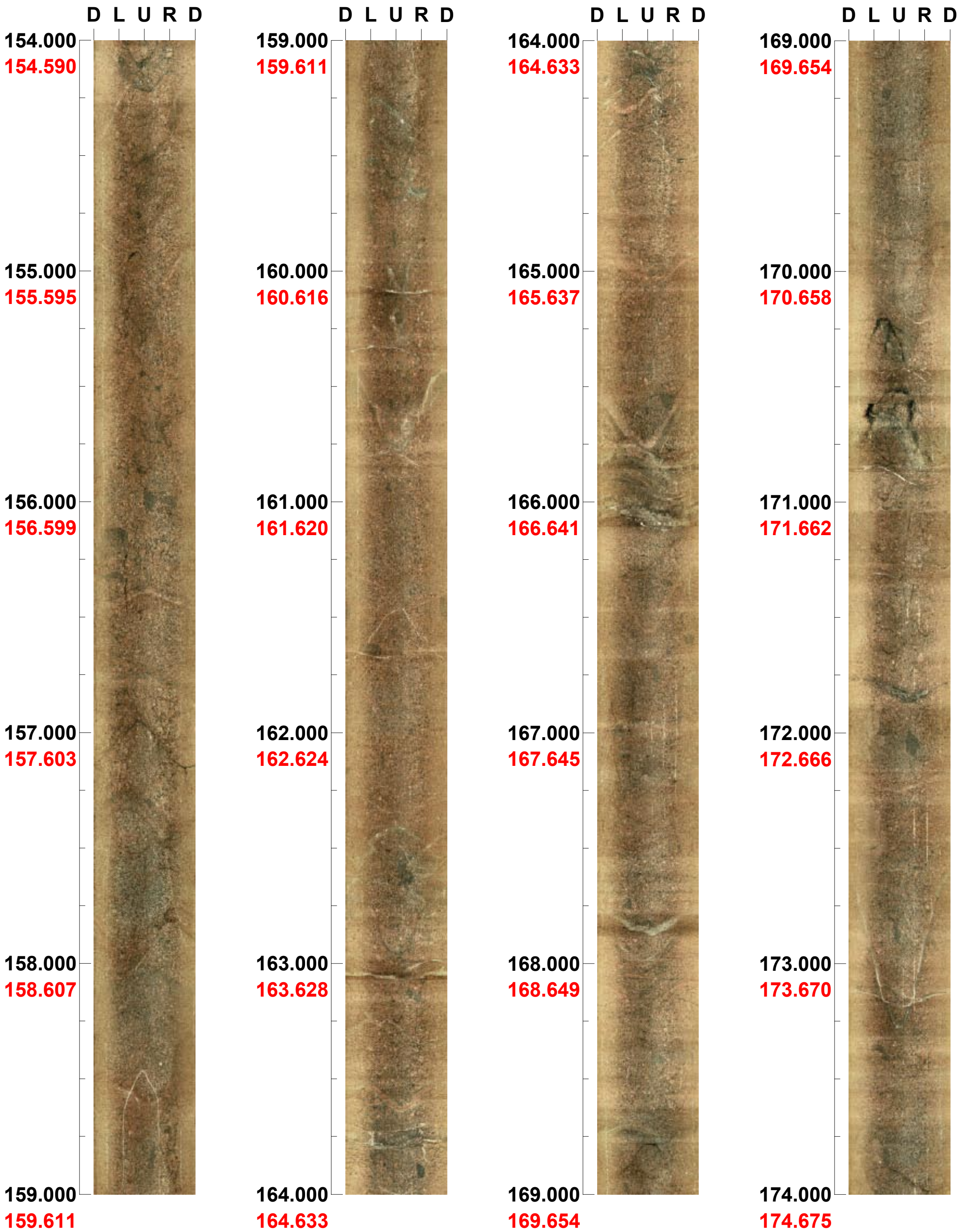
Depth range: 134.000 - 154.000 m



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

Project name: Laxemar
Bore hole No.: HLX18 **Azimuth: 135** **Inclination: -60**

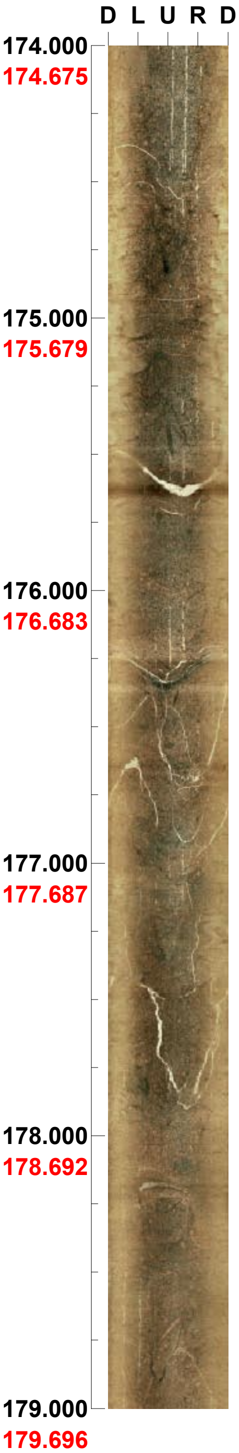
Depth range: 154.000 - 174.000 m

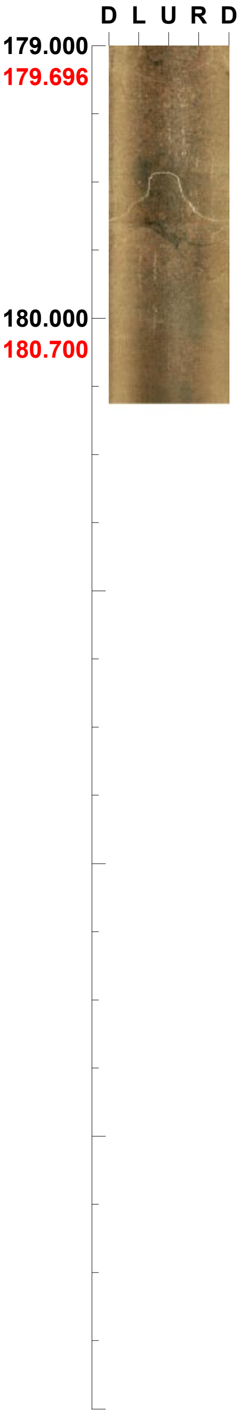


(8 / 9) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Laxemar
Bore hole No.: HLX18　　　　**Azimuth: 135**　　**Inclination: -60**

Depth range: 174.000 - 180.311 m





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

Appendix 6

BIPS logging in HLX19, 12 to 149 m

Project name: Laxemar

Image file	: c:\work\r5327l~1\hlx19\bips\hlx19.bip
BDT file	: c:\work\r5327l~1\hlx19\bips\hlx19.bdt
Locality	: LAXEMAR
Bore hole number	: HLX19
Date	: 04/09/30
Time	: 16:22:00
Depth range	: 12.000 - 148.940 m
Azimuth	: 130
Inclination	: -58
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

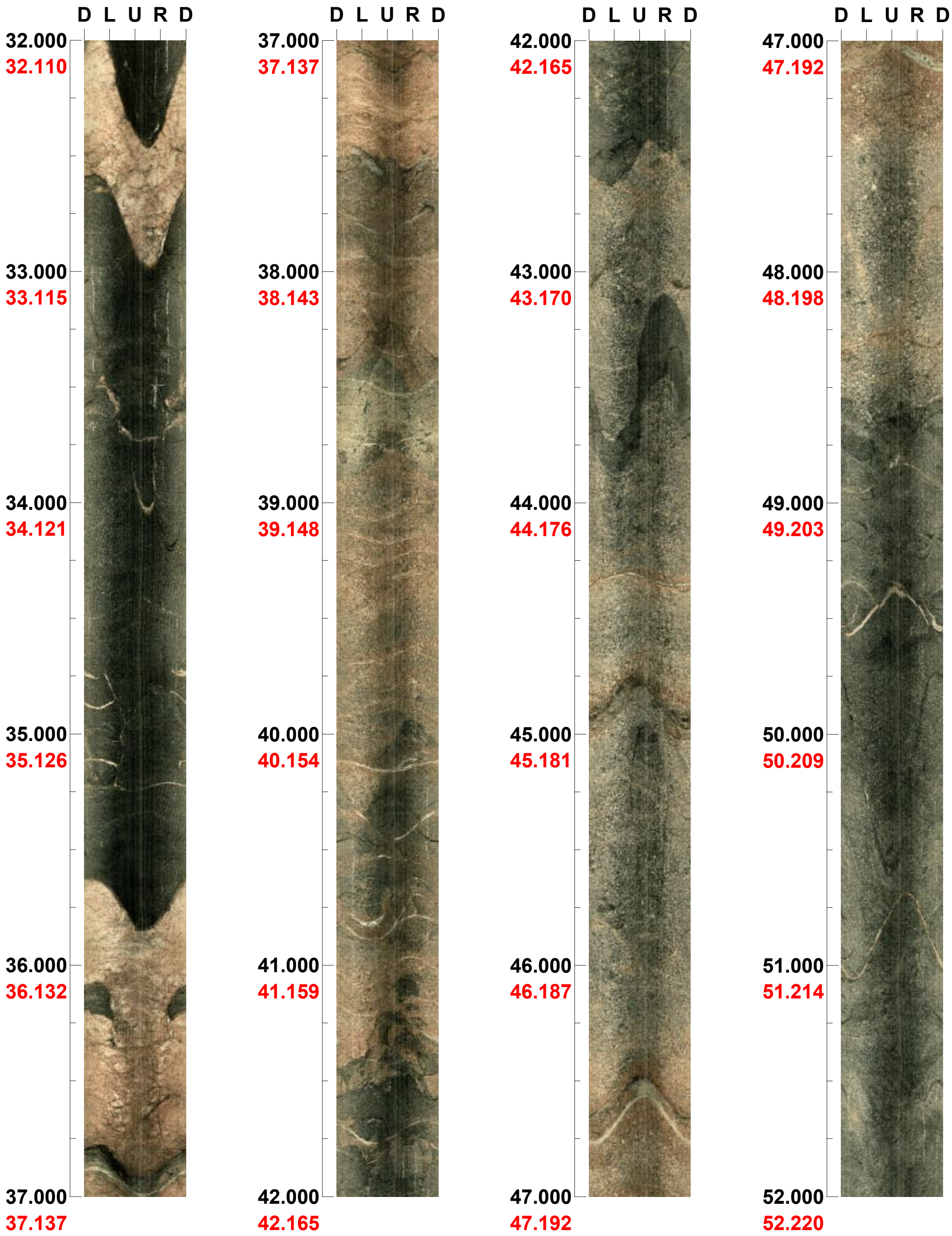
Project name: Laxemar
Bore hole No.: HLX19 Azimuth: 130 Inclination: -58

Depth range: 12.000 - 32.000 m

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

Project name: Laxemar
Bore hole No.: HLX19 **Azimuth: 130** **Inclination: -58**

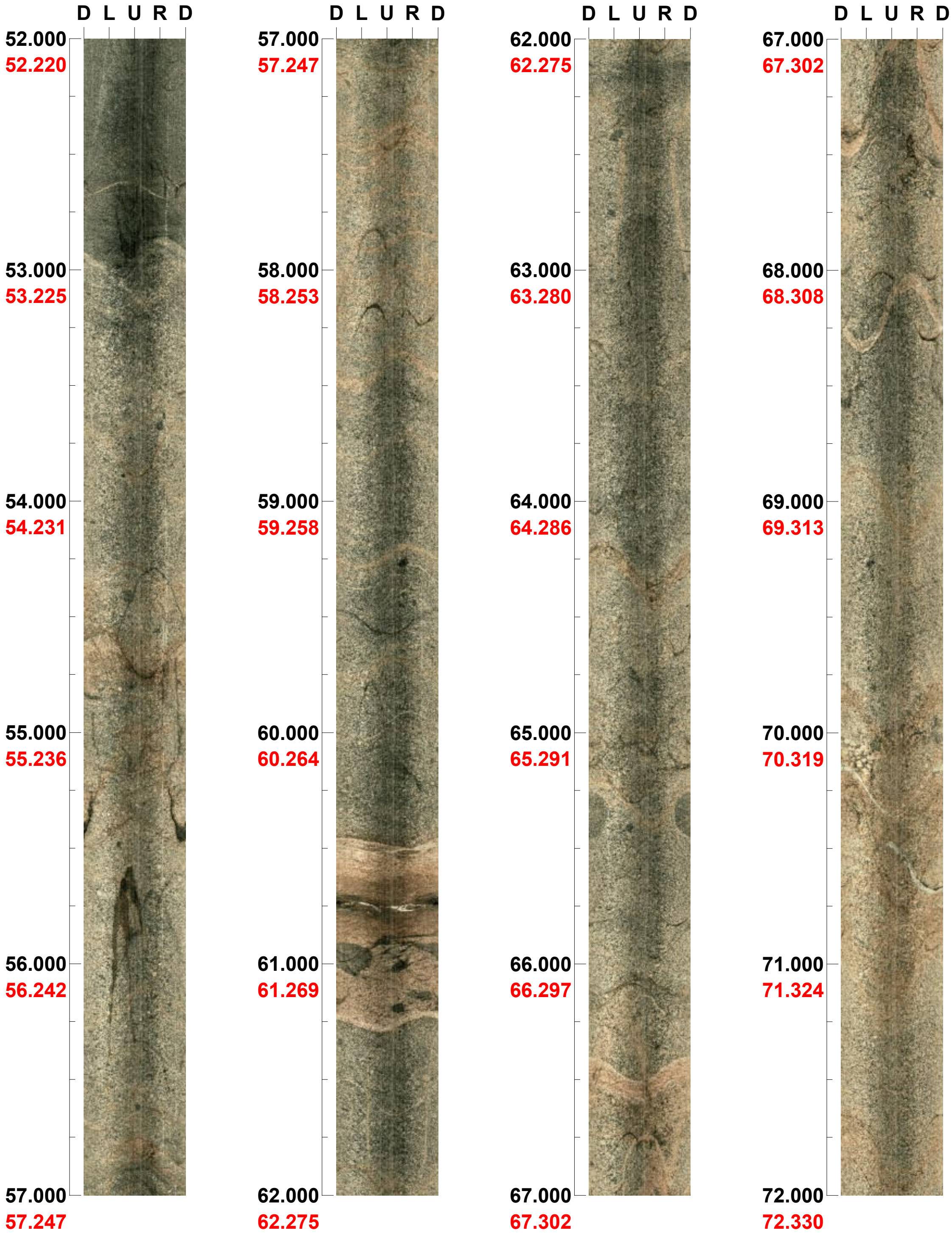
Depth range: 32.000 - 52.000 m



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

Project name: Laxemar
Bore hole No.: HLX19 **Azimuth: 130** **Inclination: -58**

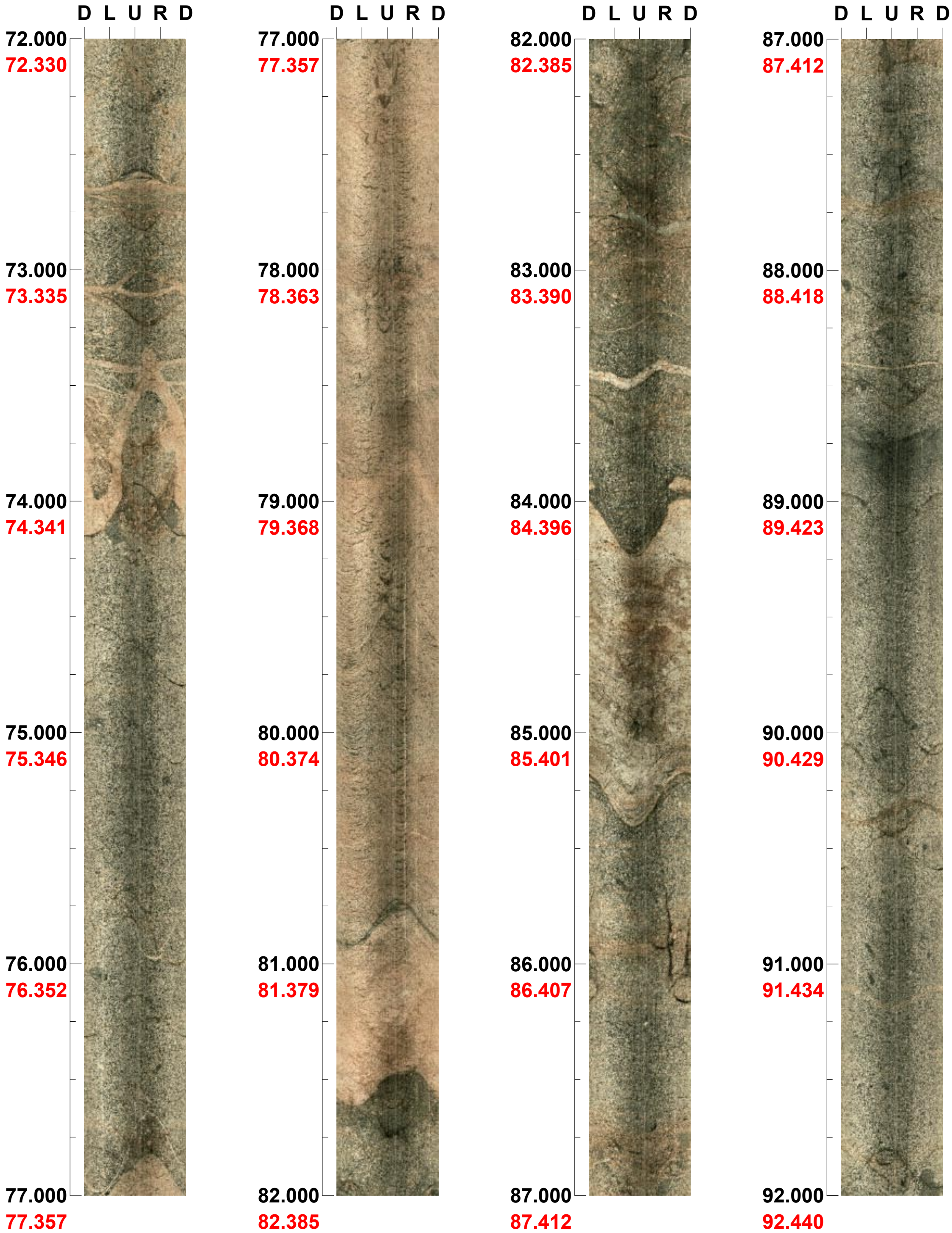
Depth range: 52.000 - 72.000 m



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

Project name: Laxemar
Bore hole No.: HLX19 **Azimuth: 130** **Inclination: -58**

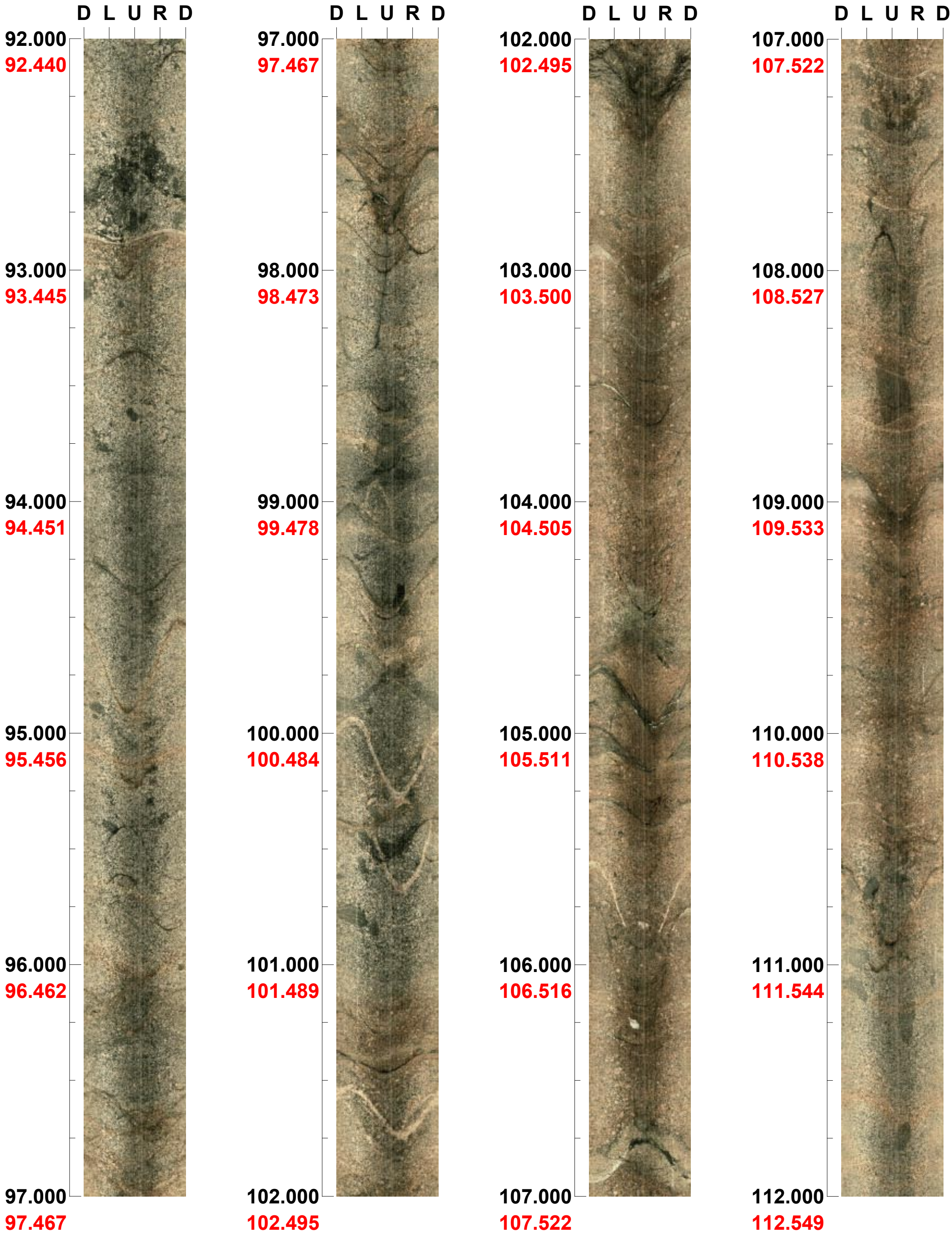
Depth range: 72.000 - 92.000 m



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

Project name: Laxemar
Bore hole No.: HLX19 Azimuth: 130 Inclination: -58

Depth range: 92.000 - 112.000 m

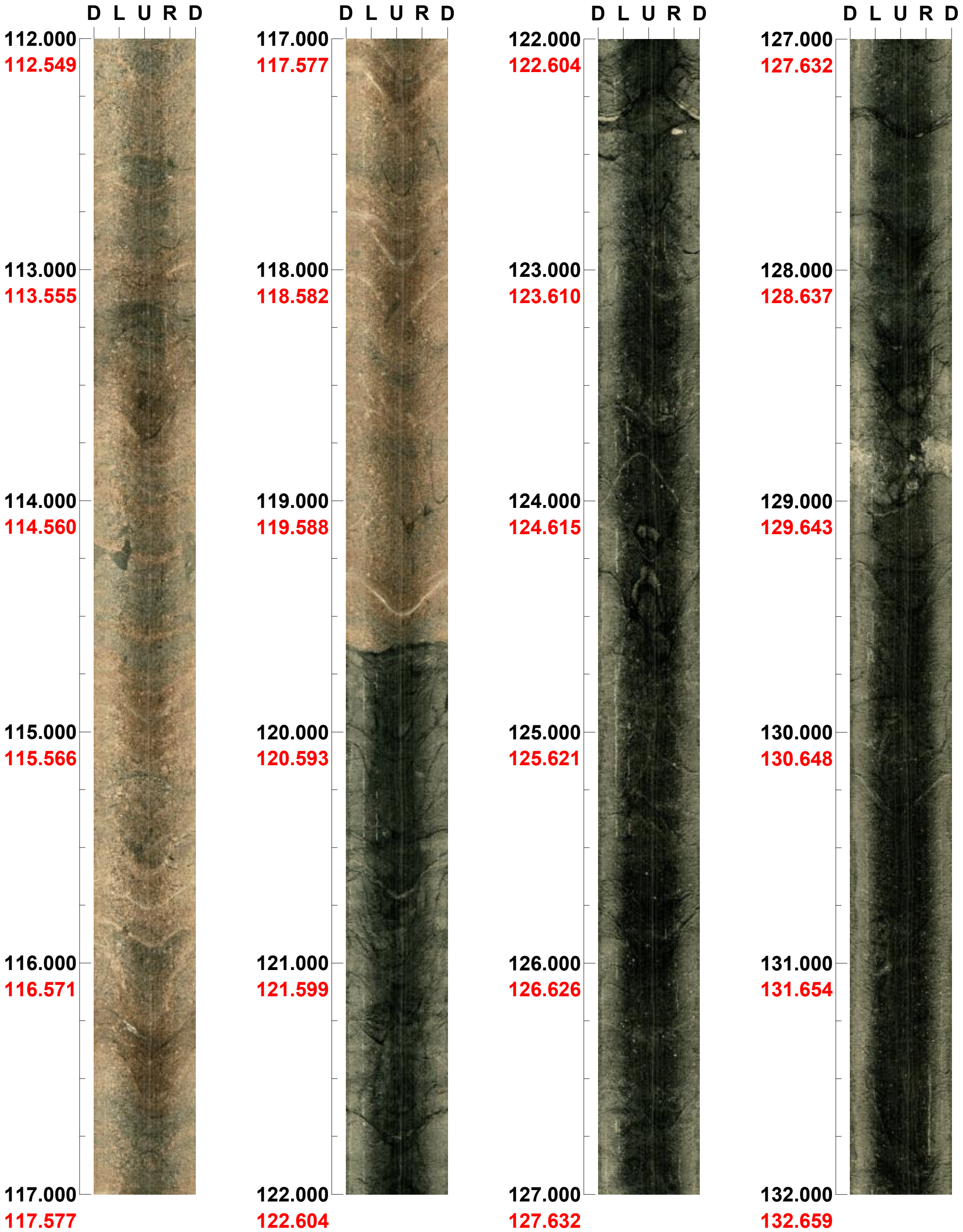


(5 / 7) Scale: 1/25 Aspect ratio: 100 %

Project name: Laxemar

Bore hole No.: HLX19 **Azimuth: 130** **Inclination: -58**

Depth range: 112.000 - 132.000 m



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

Project name: Laxemar
Bore hole No.: HLX19 **Azimuth: 130** **Inclination: -58**

Depth range: 132.000 - 148.940 m

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