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Forsmark site investigation

RAMAC and BIPS logging in boreholes KFM10A, HFM35 and HFM38

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August 2006

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Keywords: BIPS, RAMAC, Radar, TV, Forsmark, AP PF 400-06-046.

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.

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Abstract

This report includes the data gained in geophysical logging operations performed within the site investigation at Forsmark. The logging operations presented here includes BIPS and borehole radar (RAMAC) logging in the core-drilled borehole KFM10A and in the percussion drilled boreholes HFM35 and HFM38. All measurements were conducted by Malå Geoscience AB during June and July 2006.

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 surveys, the results are presented as images. Radar data is presented in radargrams and the identified reflectors are listed.

The borehole radar data quality from KFM10A, HFM35, and HFM38 varied from rather satisfying to quite good. The lower quality is most probably due to more conductive conditions. This conductive environment 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: 126 reflectors were identified in KFM10A of which 21 were orientated (dip/strike). 62 reflectors were identified in HFM35, and 58 reflectors in HFM38.

BIPS logging has been performed twice in KFM10A. The first logging resulted in defected images, due to mud covering the lower most part of the borehole wall. The second run, after nitrogen-blowing in the borehole, resulted in improved images except for the discoloring effects induced by the drilling. The images in HFM35 and HFM38 were relatively good due to clean water and no mud coverage on the walls.

Sammanfattning

Denna rapport omfattar geofysiska loggningar inom platsundersökningsprogrammet för Forsmark. Mätningarna som presenteras här omfattar BIPS-loggning och borrhålsradar-mätningar (RAMAC) i kärnborrhålet KFM10A och i hammarborrhålen HFM35 och HFM38. Alla mätningar är utförda av Malå Geoscience AB under juni och juli 2006.

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 loggningarna presenteras data i form av plottar längs med borrhålet. Radardata presenteras i radargram, och en lista över tolkade radarreflektorer ges.

Borrhålsradardata från KFM10A, HFM35 och HFM38 varierade från tillfredställande till bra. Den dåliga kvalitén beror troligen till stor del på en konduktiv miljö. En konduktiv miljö minskar möjligheterna att identifiera strukturer från borrhålsradardata. Totalt har 126 radar-reflektorer identifierats i KFM10A varav 21 är orienterade (strykning och stupning). I HFM35 identifierades 62 strukturer och i HFM38 identifierades 58 strukturer.

Två BIPS-loggningar har utförts i KFM10A. Den första loggningen resulterade i dåliga bilder, men efter ytterligare kvävgasblåsningar blev bilderna betydligt bättre vid den andra loggningen. Dock påverkas bildkvalitén av missfärgningar orsakade av borrningen. Bildkvalitén i HFM35 och HFM38 blev bra tack vare rent vatten och relativt lite kvarvarande borrhålskax.

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 Forsmark. The logging operations presented here includes TV-logging (BIPS) and borehole radar (RAMAC) in the core-drilled borehole KFM10A and in the percussion drilled boreholes HFM35 and HFM38. The work was carried out in accordance with activity plans AP PF 400-06-046. In Table 1-1 the 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 493 m in borehole KFM10A. This core-drilled borehole has a diameter of approximately 76 mm. In HFM35 the measurements includes 0 to 196 m and in HFM38 0 to 191 m. These percussion-drilled boreholes have a diameter of approximately 139 mm.

Malå Geoscience AB conducted all measurements during June and July 2006. Figure 1-1 shows the borehole locations.

The used investigation techniques comprised:

- Borehole radar measurements (Malå Geoscience AB:s RAMAC system) with dipole and directional antennas.
- Borehole TV logging with the Borehole Image Processing System (BIPS) 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
BIPS- och RADARloggning i KFM08C och KFM10A samt HFM30, HFM31 och HFM33, med tillägg avseende HFM34, HFM35 och HFM38	AP PF 400-06-046	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för TV- loggning med BIPS	SKB MD 222.006	1.0
Metodbeskrivning för borrhålsradar	SKB MD 252.020	2.0

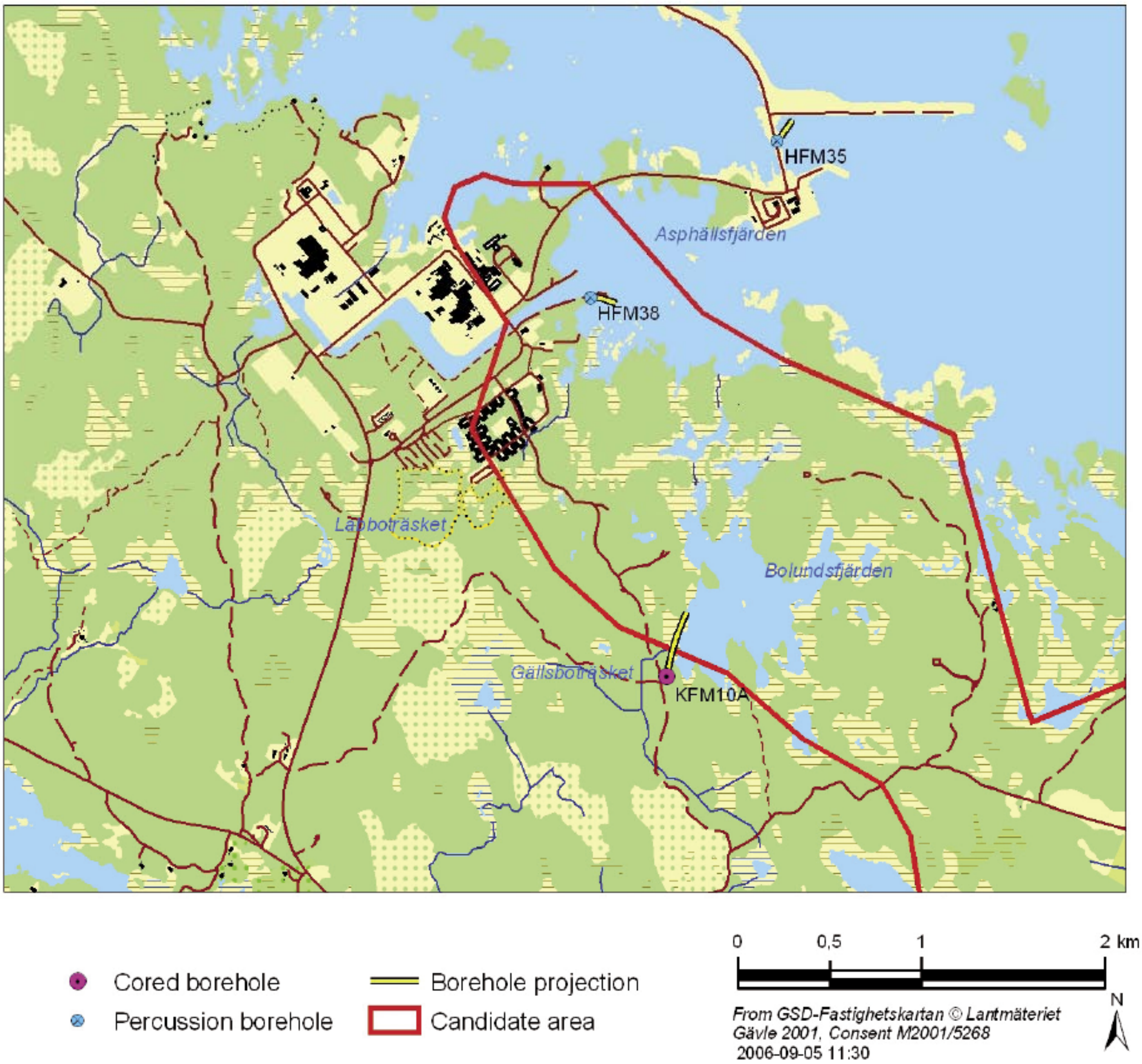


Figure 1-1. *Overview over the Forsmark investigation area, showing the location of the boreholes KFM10A, HFM35 and HFM38 surveyed and presented in this report.*

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 fracture distribution and orientation.

This report describes the equipment used as well the measurement procedures and data gained. For the BIPS surveys, the results are presented as images. Radar data are 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.

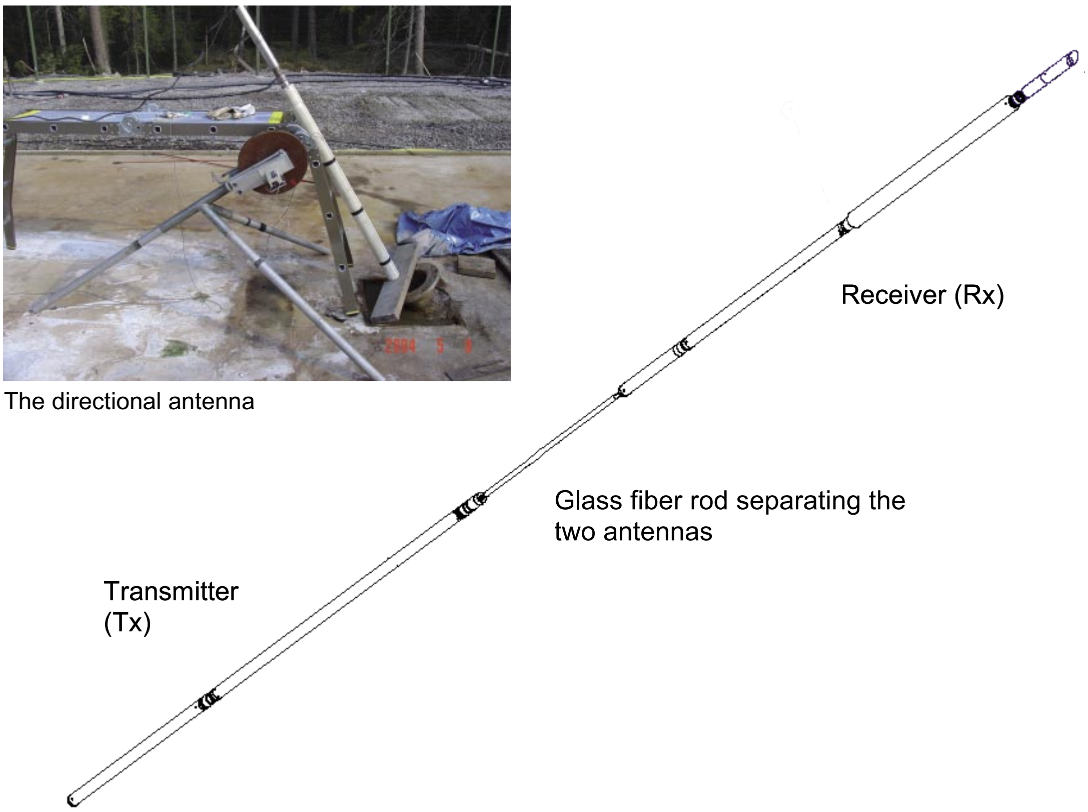


Figure 3-1. *Example of a borehole radar antenna.*

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 one pixel per degree.

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

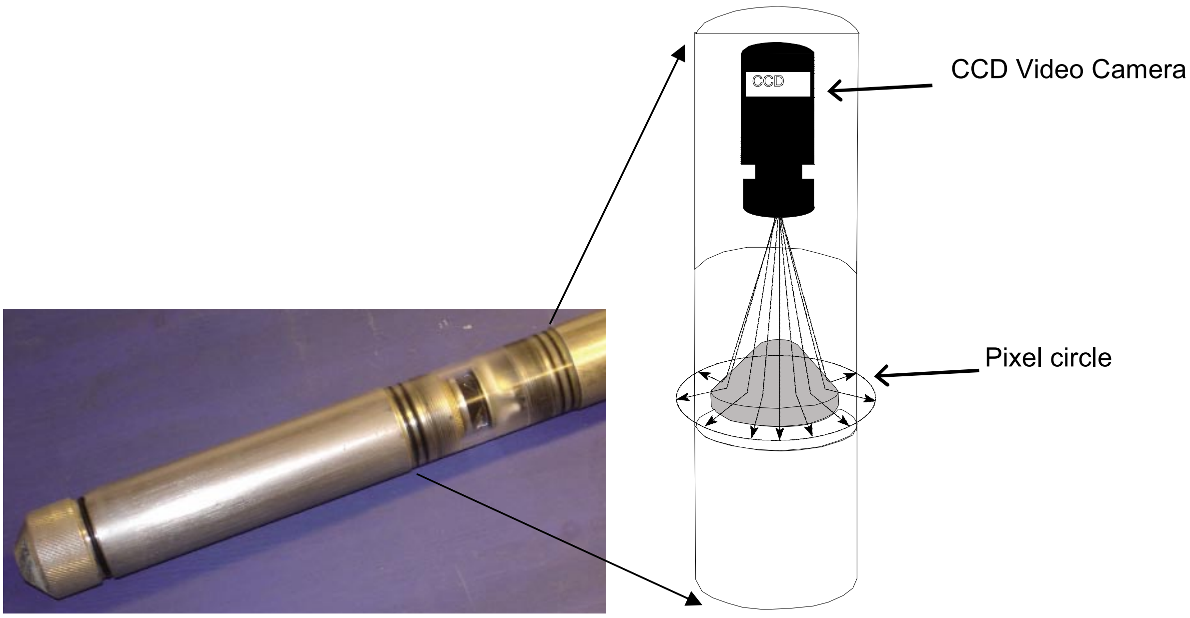


Figure 3-2. *The BIP-system. To the right a sketch showing the principles of the conical mirror.*

4 Execution

4.1 General

4.1.1 RAMAC Radar

The measurements in KFM10A, HFM35 and HFM38 were carried out with dipole radar antennas, with frequencies of 250, 100 and 20 MHz. In KFM10A the measurements were also carried out using the directional antenna with a central frequency of 60 MHz.

During logging the dipole antennas (transmitter and receiver) were lowered continuously into the borehole and data were recorded on a field PC along the measured interval. The measurement with the directional antenna is made step wise, with a short pause for each measurement occasion. The antennas (transmitter and receiver, both for dipole and directional) are kept at a fixed separation by glass fibre rods according to Tables 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). Before the logging operation, the antennas and cable were cleaned according to the internal document SKB MD 600.004.

The functionality of the directional antenna was tested before measurements in KFM10A. This test was performed by taking measurements in the air, with the receiver antenna and the transmitter antenna placed several metres apart. While transmitting and measuring, the receiver antenna was rotated slowly. The difference between the direction measured with the directional antenna and the direction measured with the compass was about 1 degree. This can be considered to be very good, considering the disturbed environment with metallic objects etc at the test site.

For more information on system settings used in the investigation of KFM10A, HFM35, and HFM38, see Tables 4-1 to 4-3 below.

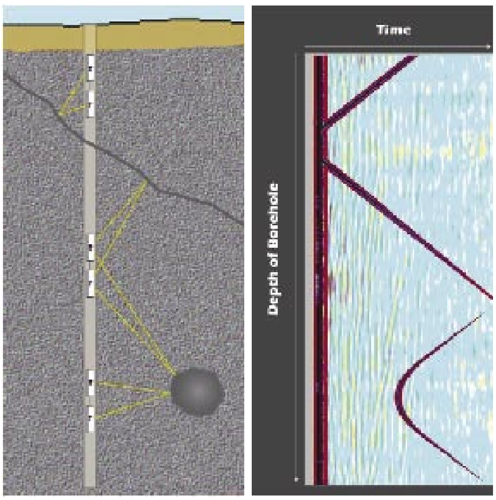


Figure 4-1. *The principle of radar borehole reflection survey (left) and an example of result (right).*

Table 4-1. Radar logging information from KFM10A.

Site: Forsmark	Logging company:	Malå Geoscience AB		
BH: KFM10A	Equipment:	SKB RAMAC		
Type: Directional/Dipole	Manufacturer:	MALÅ GeoScience		
Operator: CG	Antenna			
	Directional	250 MHz	100 MHz	20 MHz
Logging date:	2006-06-13	2006-07-21	2006-07-21	2006-06-13
Reference:	T.O.C.	T.O.C.	T.O.C.	T.O.C.
Sampling frequency (MHz):	615	2,424	891	239
Number of samples:	512	619	518	518
Number of stacks:	32	Auto	Auto	Auto
Signal position:	410.5	–0.35	–0.36	–1.42
Logging from (m):	63.4	1.5	2.6	66.25
Logging to (m):	483.4	495.7	494.2	491.7
Trace interval (m):	0.5	0.1	0.2	0.25
Antenna separation (m):	5.73	2.4	3.9	10.05

Table 4-2. Radar logging information from HFM35.

Site: Forsmark	Logging company:	Malå Geoscience AB	
BH: HFM35	Equipment:	SKB RAMAC	
Type: Dipole	Manufacturer:	MALÅ GeoScience	
Operator: CG	Antenna		
	250 MHz	100 MHz	20 MHz
Logging date:	2006-07-19	2006-07-19	2006-07-19
Reference:	T.O.C.	T.O.C.	T.O.C.
Sampling frequency (MHz):	2,424	891	239
Number of samples:	619	518	518
Number of stacks:	Auto	Auto	Auto
Signal position:	–0.35	–0.36	–1.42
Logging from (m):	1.5	2.6	6.25
Logging to (m):	197.4	195.6	192.35
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 HFM38.

Site: Forsmark	Logging company:	Malå Geoscience AB	
BH: HFM38	Equipment:	SKB RAMAC	
Type: Dipole	Manufacturer:	MALÅ GeoScience	
Operator: CG	Antenna		
	250 MHz	100 MHz	20 MHz
Logging date:	2006-07-20	2006-07-20	2006-07-20
Reference:	T.O.C.	T.O.C.	T.O.C.
Sampling frequency (MHz):	2,424	891	239
Number of samples:	619	518	518
Number of stacks:	Auto	Auto	Auto
Signal position:	–0.35	–0.36	–1.42
Logging from (m):	1.5	2.6	6.25
Logging to (m):	192.2	191.2	187.4
Trace interval (m):	0.1	0.2	0.25
Antenna separation (m):	2.4	3.9	10.05

4.1.2 BIPS

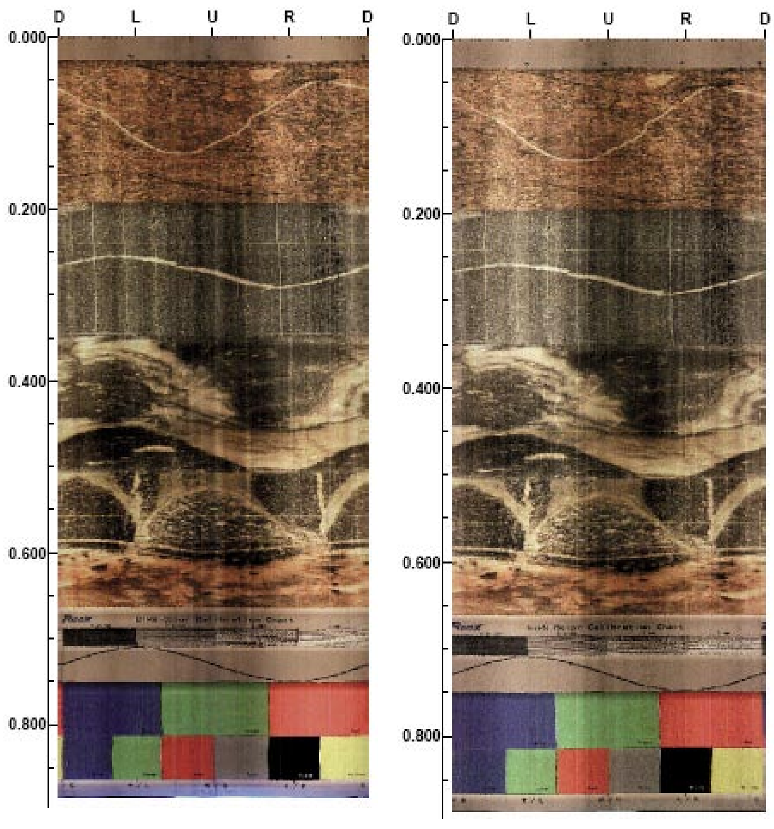
All measurements were performed in accordance with the instructions and guidelines from SKB (internal document MD 222.006). All cleaning of the probe and cable was performed according to the internal document SKB MD 600.004 before the logging operation.

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 KFM10A, HFM35 and HFM38.

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

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



Before logging in HFM35

After logging in KFM10A

Figure 4-2. *Results from logging in the test pipe before and after the logging campaign in July, 2006. The length scales are not essential in the test measurements*

4.1.3 Length measurements

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

During the BIPS logging in core drilled boreholes, where the reference marks in the borehole wall is visible on the image, the position where the length 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 length mark visible in the BIPS image. The adjusted true length is marked with red in the image plot together with the non-adjusted measured length. The non-adjusted length is marked with black as seen in Appendices 4 to 6. The tape marks on the logging cable are then used for controlling the RAMAC measurement.

The experience we have from earlier measurements with dipole antennas in the core drilled boreholes in Forsmark and Oskarshamn for the radar logging is that the length divergence is less than 100 cm in the deepest parts of a 1,000 meter deep borehole.

The length 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 probe 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 constant.

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 128 m/µs (metres per microsecond) /1/. The velocity measurement was performed with the 100 MHz antenna.

The visualization of data in Appendices 1 to 3 is made with ReflexWin, a Windows based processing software for filtering and analysis of borehole radar data. The processing steps for the data presented in Appendices 1 to 3 are given in Tables 4-4 to 4-6. The filters applied affect the whole borehole length and are not always suitable in all parts, depending on the geological

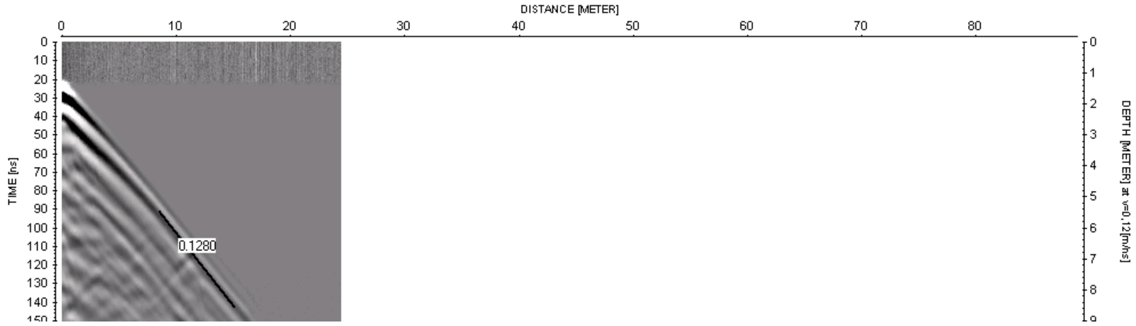


Figure 4-3. *Results from velocity measurements in HFM03 /1/.*

conditions and conductivity of the borehole fluid. During interpretation further processing can be done, most often in form of bandpass filtering. This filtering can be applied just in parts of the borehole, where needed.

For the interpretation of the intersection angle between the borehole axis and the planes visible on the radargrams the RadinterSKB software has been used. The interpreted intersection points and intersection angles of the detected structures are presented in the Tables 5-4 to 5-6 and are also visible on the radargrams in Appendices 1 to 3.

Table 4-4. Processing steps for borehole radar data from KFM10A.

Site:	**Forsmark**	**Logging company:**	**Malå Geoscience AB**		
BH:	**KFM10A**	**Equipment:**	**SKB RAMAC**		
Type:	**Directional/Dipole**	**Manufacturer:**	**MALÅ Geoscience**		
Interpret:	**JG**	**Antenna**			
		Directional	**250 MHz**	**100 MHz**	**20 MHz**
Processing:		Move start time (–41 samples)	Move start time (–24.7)	Move start time (–42.6)	Move start time (–75.6)
		DC shift (350–511)	DC shift (190–240)	DC shift (460–520)	DC shift (1,800–2,100)
		Time gain (start 81 lin 100 exp 1)	Gain (start 18 lin 3.6 exp 1)	Gain (start 56 lin 1 exp 1)	Gain (start 149 lin 1.7 exp 0.09)
		(FIR)			

Table 4-5. Processing steps for borehole radar data from HFM35.

Site:	**Forsmark**	**Logging company:**	**MALÅ GeoScience AB**	
BH:	**HFM35**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ Geoscience**	
Interpret:	**JG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
Processing:		Move start time (–22.5)	Move start time (–34)	Move start time (–90)
		DC shift (190–240)	DC shift (460–520)	DC shift (1,800–2,100)
		Gain (start 23 lin 3 exp 1)	Gain (start 40 lin 2 exp 0.7)	Gain (start 100 lin 1.7 exp 0.2)
				Bandpass 5/120

Table 4-6. Processing steps for borehole radar data from HFM38.

Site:	**Forsmark**	**Logging company:**	**MALÅ GeoScience AB**	
BH:	**HFM38**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ Geoscience**	
Interpret:	**JG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
Processing:		Move start time (–19.9)	Move start time (–36.5)	Move start time (–90)
		DC shift (190–240)	DC shift (460–520)	DC shift (1,800–2,100)
		Gain (start 18 lin 2.1 exp 1)	Gain (start 24 lin 1.7 exp 0.6)	Gain (start 130 lin 1 exp 0.13)
				Bandpass 5/120

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 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.

4.3 Nonconformities

No non-conformities occured during the logging of the reported boreholes.

5 Results

The results from the BIPS measurements in KFM10A, HFM35 and HFM38 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 KFM10A, HFM35 and HFM38 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.

5.1 RAMAC logging

The results of the interpretation of the radar measurements are presented in Tables 5-1 to 5-10. Radar data are also visualized in Appendices 1 to 3. It should be remembered that the images in Appendices 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. Overviews of the three boreholes are given in Figure 5-1 below.

A number of minor structures also exist, indicated in Appendices 1 to 3. Often a number of structures can be noticed, but most probably lying so close to each other that it is impossible to distinguish one from the other. Larger structures parallel to the borehole, if present, are also indicated in Appendices 1 to 3. It should also be pointed out that interpreted reflectors always have an intersection point with the borehole, although this can be located out of the physical borehole length.

The data quality from KFM10A, HFM35 and HFM38 (as seen in Figure 5-1 and Appendices 1 to 3) varies from satisfying to good. In all holes parts are found with a lower quality due to more conductive conditions. A conductive environment causes an attenuation of the radar wave, which in turn decreases the penetration. This conductive environment of course also reduces the possibility to distinguish and interpret possible structures in the rock which otherwise could give a reflection.

This effect is also seen in the directional antenna for KFM10A, which makes it more difficult to interpret the direction to the identified structures.

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

As also seen in Appendices 1 to 3 the resolution and penetration of radar waves depend on the antenna frequency used. Low antenna frequency gives less resolution but better penetration compared to a higher frequency. If structures can be identified with all three antenna frequencies, it can probably be concluded that the structure is quite significant.

In Tables 5-1 to 5-3 below the distribution of identified structures along the boreholes are listed for KFM10A, HFM35 and HFM38.

Table 5-1. Identified structures as a function of borehole intersection length in KFM10A.

Length (m)	No. of structures
50–100	8
100–150	16
150–200	17
200–250	14
250–300	15
300–350	16
350–400	14
400–450	14
450–	12

Table 5-2. Identified structures as a function of borehole intersection length in HFM35.

Length (m)	No. of structures
0–20	1
20–40	5
40–60	5
60–80	3
80–100	7
100–120	8
120–140	5
140–160	10
160–180	7
180–	11

Table 5-3. Identified structures as a function of borehole intersection length in HFM38.

Length (m)	No. of structures
0–20	5
20–40	7
40–60	10
60–80	1
80–100	4
100–120	6
120–140	6
140–160	5
160–180	7
180–	7

Tables 5-4 to 5-6 summarises the interpretation of radar data from KFM10A, HFM35 and HFM38. In the tables the borehole length and intersection angle to the identified structures are listed.

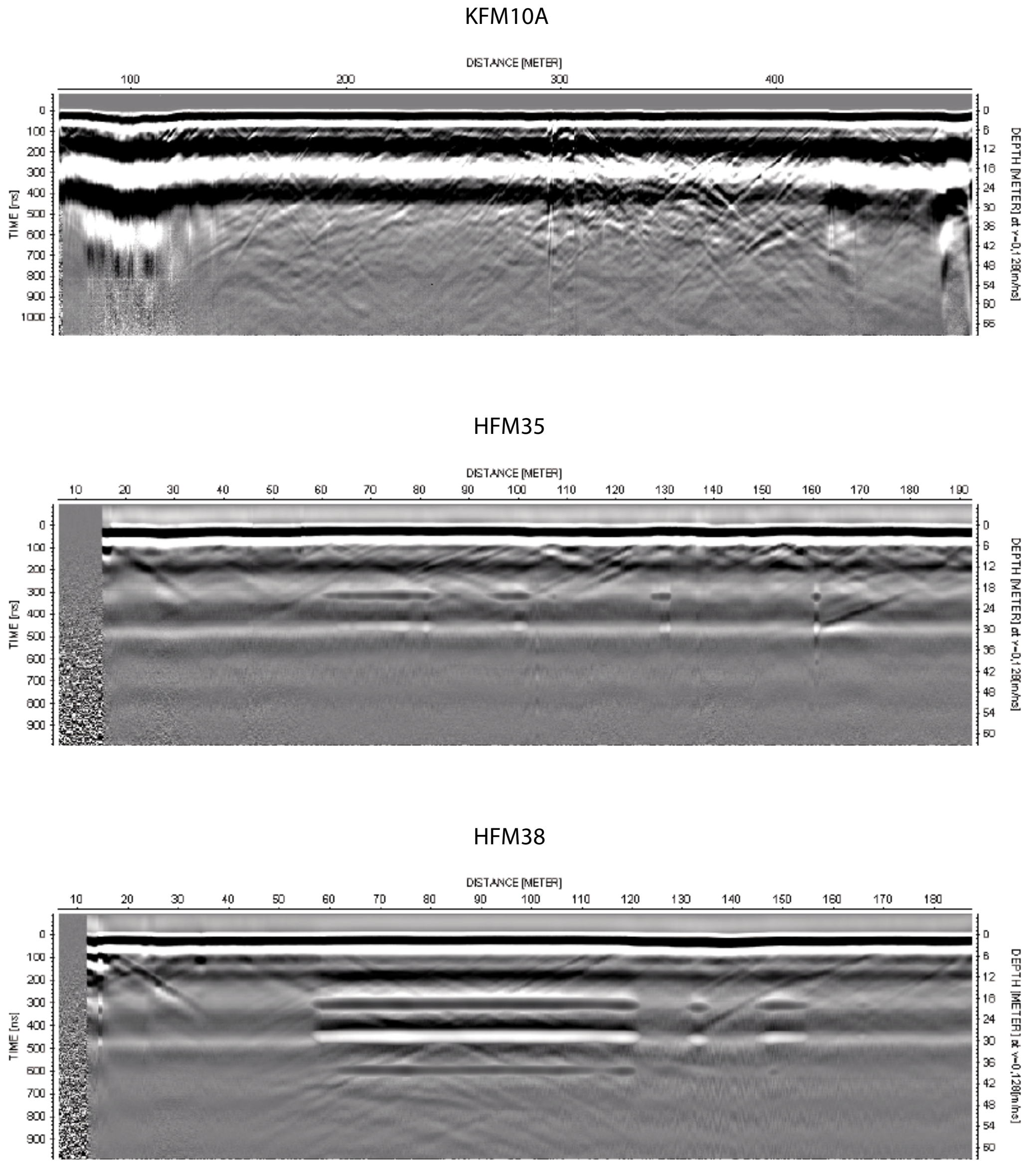


Figure 5-1. *An overview (20 MHz data) of the radar data for the three boreholes KFM10A, HFM35 and HFM38. Observe that the borehole length (x-scale) and depth (y-scale) differs between the different boreholes.*

For KFM10A the direction to the objects identified is also given. As seen some radar reflectors in Table 5-4 is marked with ±, which indicates an uncertainty in the interpretation of direction. The direction can in these cases be ±180 degrees. The direction to the object (the plane) is defined in Figure 5-2. This direction and the intersection angle are recalculated to strike and dip, also given in the tables below. The plane strike is the angle between the line of the plane's intersection with the surface and the Magnetic North direction. A strike of 0 degrees implies a dip to the east while a strike of 180 degrees implies a dip to the west (right-hand rule). The strike is measured clockwise and can vary from 0 to 359 degrees. The dip of the plane is the angle between the ground surface and the plane, and can vary from 0 to 90 degrees.

Observe that the interpretation of an undulating structure can result in several different angles and different intersection lengths. An example of this phenomenon is seen in Table 5-4 and Appendix 1: the reflectors named 19, 19x and 19xx most likely originates from the same geological structure.

Table 5-4. Interpretation of radar reflectors from the dipole antennas 250, 100 and 20 MHz in borehole KFM10A.

Radinter model information (Directional and dipole antennas)							
Site:		Forsmark					
Borehole name:		KFM10A					
Nominal velocity (m/μs):		128.0					
Name	**Intersection length**	**Intersection angle**	**RadInter direction to object (gravity roll)**	**Dip 1**	**Strike 1**	**Dip 2**	**Strike 2**
2	60.6	62					
3	66.4	57					
4	70.8	57					
1	78.3	46	255 ±	48	30	63	133
5	82.3	48					
6	86.8	52	262	50	34		
7	92.4	78					
8	98.1	46					
10	105.0	54					
9	106.1	85	240 ±	41	85	44	92
11	107.0	80					
12	113.3	66					
13	116.6	62					
14	124.7	46					
15	130.7	45					
16	133.3	49	261	51	33		
17	135.0	51					
18	139.4	45					
21	140.7	42					
19	143.9	45	258	51	28		
19xx	144.5	54					
19x	145.2	35					
20	147.4	54					
22	149.6	56					
23	152.3	46	261	54	28		
24	155.7	53					
25	157.0	56					
26	172.2	44	264	55	29		
27	174.7	67	51 ±	58	109	32	56
28	176.6	36					
29	177.6	57					
30	181.6	65					
119	183.9	58					
31	184.7	66					
35x	185.9	19					
32	186.2	75					
33	188.9	56					
36	196.2	61					
34	197.8	63	264	45	56		
37	198.8	67					
39	199.8	73					

Radinter model information (Directional and dipole antennas)							
Site:		**Forsmark**					
Borehole name:		**KFM10A**					
Nominal velocity (m/μs):		**128.0**					
Name	**Intersection length**	**Intersection angle**	**RadInter direction to object (gravity roll)**	**Dip 1**	**Strike 1**	**Dip 2**	**Strike 2**
35	200.5	13					
40	205.5	68					
41	208.0	63					
114	211.5	78					
42	212.6	45					
38	218.7	15					
44	219.4	13	306	74	222		
43	219.5	55	261 ±	48	39	57	132
45	226.6	70					
46	232.5	67					
47	234.2	58					
48	240.4	63					
51	244.8	61					
49	248.8	58					
50	250.9	67					
52	262.0	55					
54	264.2	67					
53	264.8	57					
115	266.0	61					
55	268.0	58					
56	270.1	55					
58	272.9	46					
57	275.8	55					
59	276.9	55					
60x	279.6	60					
60	281.4	49					
61	283.8	50	258	51	43		
62	287.6	48					
63	289.4	48					
65	300.3	41					
64	302.1	57					
66	308.1	56	279 ±	61	54	51	145
67	310.8	90					
68	315.0	48					
72	320.5	81					
116	323.1	57					
70	325.1	64					
69	326.3	53	249 ±	45	44	67	134
71	331.1	72					
117	332.2	56					
73	334.3	57					
77	339.2	61					
75	340.0	66					

Radinter model information
(Directional and dipole antennas)

Site: Forsmark
Borehole name: KFM10A
Nominal velocity (m/μs): 128.0

Name	Intersection length	Intersection angle	RadInter direction to object (gravity roll)	Dip 1	Strike 1	Dip 2	Strike 2
74	342.2	56	243	41	44		
76	348.6	61	48 ±	69	120	34	58
78	350.9	57					
79	358.2	48					
81	360.6	56	69 ±	65	133	45	49
80	362.8	69					
85	363.6	58					
82	365.6	67					
84	368.8	54					
83	369.6	66					
86	373.1	42	234 ±	39	28	81	134
87	375.0	55					
89	377.2	65					
91	390.9	45					
88	392.3	40	249 ±	51	32	78	146
90	395.1	58					
92	401.0	69					
121	407.3	50					
93	412.1	70					
107	419.4	21					
97	420.8	72					
95	421.1	50					
98	431.9	39					
98x	433.1	37					
96	435.4	35	189 ±	9	337	74	287
120	435.9	60					
94	436.4	16					
99	442.1	72					
100	447.8	32					
106	448.0	43					
105	459.7	62					
118	461.8	78					
109	469.3	57					
111	472.9	74					
104	476.4	34					
113	478.0	90					
110	478.8	78					
102	480.3	33					
101	480.7	35	192 ±	11	345	74	290
112	485.5	61					
103	489.7	27					
108	556.2	10					

Table 5-5. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz borehole HFM35.

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

Site: Forsmark
Borehole name: HFM35
Nominal velocity (m/μs): 128.00

Object type	Name	Intersection depth	Intersection angle
PLANE	1	7.8	58
PLANE	2	22.5	65
PLANE	3	26.6	70
PLANE	4	29.7	74
PLANE	5	31.2	45
PLANE	6	31.3	53
PLANE	7	42.0	56
PLANE	9x	45.4	34
PLANE	8	49.1	72
PLANE	9	49.8	50
PLANE	10	55.1	73
PLANE	11	60.7	68
PLANE	12	68.7	63
PLANE	13	75.7	56
PLANE	16x	81.1	17
PLANE	16xx	81.3	20
PLANE	14	83.8	48
PLANE	15	87.6	47
PLANE	20	89.4	48
PLANE	16	90.0	34
PLANE	17	92.3	42
PLANE	18	100.9	71
PLANE	19	103.5	50
PLANE	23	104.4	37
PLANE	21	109.2	90
PLANE	24	110.6	56
PLANE	22	111.8	51
PLANE	27	115.2	33
PLANE	26	116.4	44
PLANE	25	121.8	40
PLANE	28	126.1	42
PLANE	28x	127.4	61
PLANE	29x	135.6	59
PLANE	29	137.1	44
PLANE	30	140.4	41
PLANE	31	142.0	53
PLANE	32	143.9	57
PLANE	52	146.6	48
PLANE	50	146.7	53
PLANE	33	149.2	34
PLANE	33x	152.4	48
PLANE	35	152.8	36

Radinter model information (20, 100 and 250 MHz Dipole Antennas)			
Site:		**Forsmark**	
Borehole name:		**HFM35**	
Nominal velocity (m/μs):		**128.00**	
Object type	**Name**	**Intersection depth**	**Intersection angle**
PLANE	51	153.8	52
PLANE	34	155.7	47
PLANE	36	162.8	51
PLANE	38	167.4	39
PLANE	37	167.6	66
PLANE	53	170.6	77
PLANE	40	172.1	62
PLANE	39	172.6	37
PLANE	41	179.6	64
PLANE	42	181.7	64
PLANE	55	183.9	52
PLANE	43	186.2	55
PLANE	44	188.0	60
PLANE	43x	188.2	38
PLANE	46	189.5	78
PLANE	45	191.6	67
PLANE	47	194.8	90
PLANE	49	199.8	67
PLANE	48	201.0	45
PLANE	54	225.7	31

Table 5-6. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz borehole HFM38.

Radinter model information (20, 100 and 250 MHz Dipole Antennas)			
Site:		**Forsmark**	
Borehole name:		**HFM38**	
Nominal velocity (m/μs):		**128.00**	
Object type	**Name**	**Intersection depth**	**Intersection angle**
PLANE	2	5.0	76
PLANE	3	5.1	90
PLANE	1	5.9	62
PLANE	4	14.9	66
PLANE	5	16.3	65
PLANE	6	21.3	57
PLANE	7	25.4	51
PLANE	8	28.9	42
PLANE	9	29.3	55
PLANE	10	33.2	40
PLANE	11	37.3	61
PLANE	12	39.3	54
PLANE	54	40.1	55
PLANE	13	45.7	65
PLANE	14	48.9	62

Radinter model information (20, 100 and 250 MHz Dipole Antennas)			
Site:	**Forsmark**		
Borehole name:	**HFM38**		
Nominal velocity (m/μs):	**128.00**		
Object type	**Name**	**Intersection depth**	**Intersection angle**
PLANE	17	50.8	55
PLANE	15	52.2	57
PLANE	16	53.4	59
PLANE	18	56.1	77
PLANE	19	56.3	51
PLANE	56	58.4	40
PLANE	27	59.1	38
PLANE	20	70.0	42
PLANE	21	80.7	58
PLANE	22	83.0	57
PLANE	23	92.5	37
PLANE	25	99.4	47
PLANE	26	101.3	69
PLANE	24	102.8	50
PLANE	28	109.9	54
PLANE	29	112.1	66
PLANE	30	112.9	67
PLANE	31	113.6	60
PLANE	33	120.0	49
PLANE	32	123.3	68
PLANE	34	124.8	71
PLANE	32x	125.7	45
PLANE	35	128.5	57
PLANE	36	136.2	78
PLANE	37	140.3	88
PLANE	38	149.9	90
PLANE	39	153.8	54
PLANE	55	155.2	60
PLANE	40	157.9	62
PLANE	41	160.7	66
PLANE	42	163.0	54
PLANE	51	164.8	56
PLANE	47x	172.6	55
PLANE	43	176.6	70
PLANE	44	178.1	68
PLANE	53	179.3	80
PLANE	45	181.6	73
PLANE	46	183.7	72
PLANE	47	185.9	29
PLANE	52	188.5	59
PLANE	48	191.2	66
PLANE	49	196.6	73
PLANE	50	204.8	65

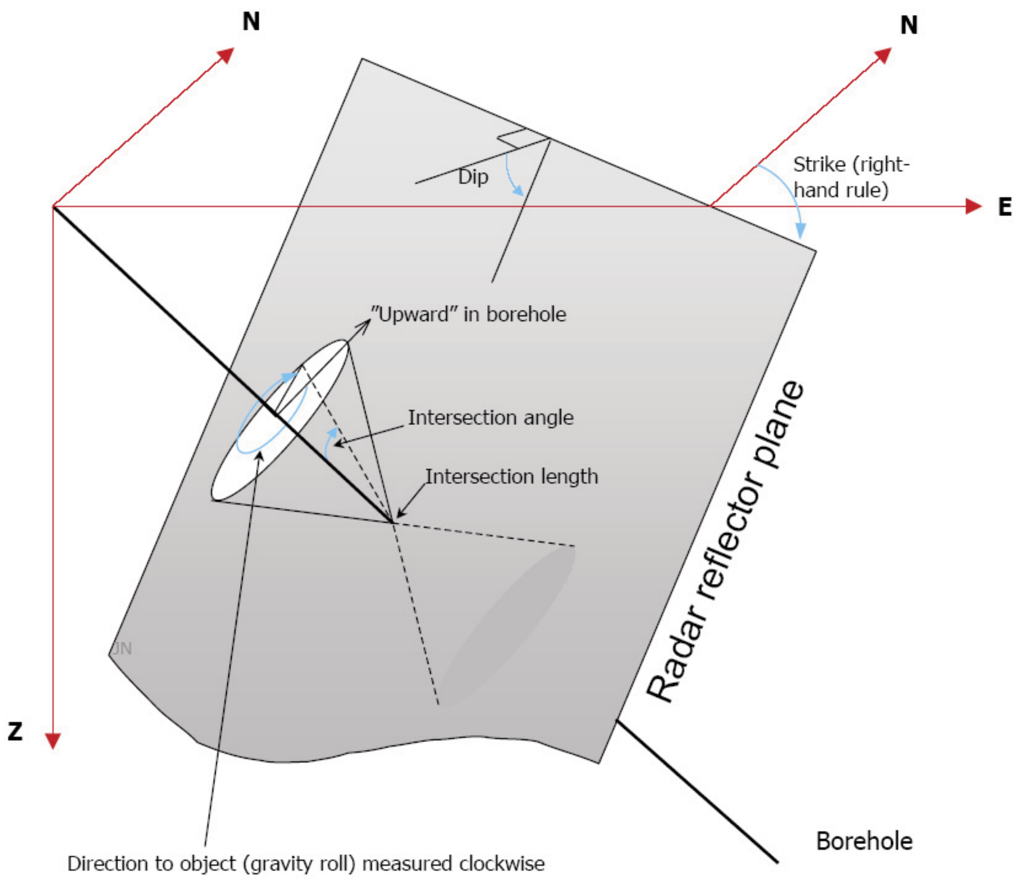


Figure 5-2. *Definition of direction to reflector (gravity roll) as presented in Table 5-4.*

In Appendices 1 to 3, the amplitude of the first arrival is plotted against the borehole length, for the 250 MHz dipole antennas. The amplitude variation along the borehole indicates changes of the electrical conductivity of the rock volume surrounding the borehole. A decrease in this amplitude may indicate fracture zones, clay or rock volumes with increased water content, i.e. increased electric conductivity. The borehole length intervals showing decreased amplitude are listed in Tables 5-7 to 5-9.

Finally, the structures considered as the most important (clear in the radargram, identified with several antenna frequencies, stretching out far from the borehole wall etc.) are listed in Table 5-10 below.

Table 5-7. Borehole length intervals in KFM10A with decreased amplitude for the 250 MHz antenna.

Length (m)	Length (m)
80–110	300–305
110–125	325
135	340–345
145	430
195	485

Table 5-8. Borehole length intervals in HFM35 with decreased amplitude for the 250 MHz antenna.

Length (m)	Length (m)
20–30	125
45	135
50	145
90	155–160
105	165–175
115	180
120	185–190

Table 5-9. Borehole length intervals in HFM38 with decreased amplitude for the 250 MHz antenna.

Length (m)	Length (m)
30	135–145
40	185
125	

Table 5-10. Some important structures in KFM10A, HFM35 and HFM38.

Borehole	KFM10A	HFM35	HFM38
Structures	16, 17, 19, 21, 23, 26, 34, 35, 35x, 38, 44, 60, 60x, 76, 96, 98, 98x, 101, 102, 103 and 104	9, 9x, 20, 22, 23, 29, 29x, 32, 37, 38 and 54	1, 2, 10, 17, 32, 32x, 40, 47, 47x and 49

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

5.2 BIPS logging

The BIPS pictures are presented in Appendices 4 to 6.

To get the best possible length accuracy, the BIPS images are adjusted to the reference marks on the logging cable. Additionally the marks on the borehole wall created by the drill rig in core-drilled boreholes are visible on the BIPS screen. The recorded length is adjusted to these visible marks.

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 in the campaign. The resulting images displayed no difference regarding the colours and focus of the images. The results of the test logging were included in the delivery of the field data and are also presented in Figure 4-2 in this report.

The values for inclination and azimuth of the boreholes, presented in the heading in Appendices 4-6, are based on preliminary specifications.

The first BIPS logging in KFM10A resulted in bad images due to mud covering the lower most part on the borehole wall. Before the second logging, one month after the first run, the borehole were cleaned several times by nitrogen blowing. The cleaning procedure resulted in a second logging with an improved image quality. The only remaining quality problem on the images are the typical discolouring effects (caused by the drilling) on the borehole wall. The images in HFM35 and HFM38 were relatively good due to clean water and no mud coverage of the walls.

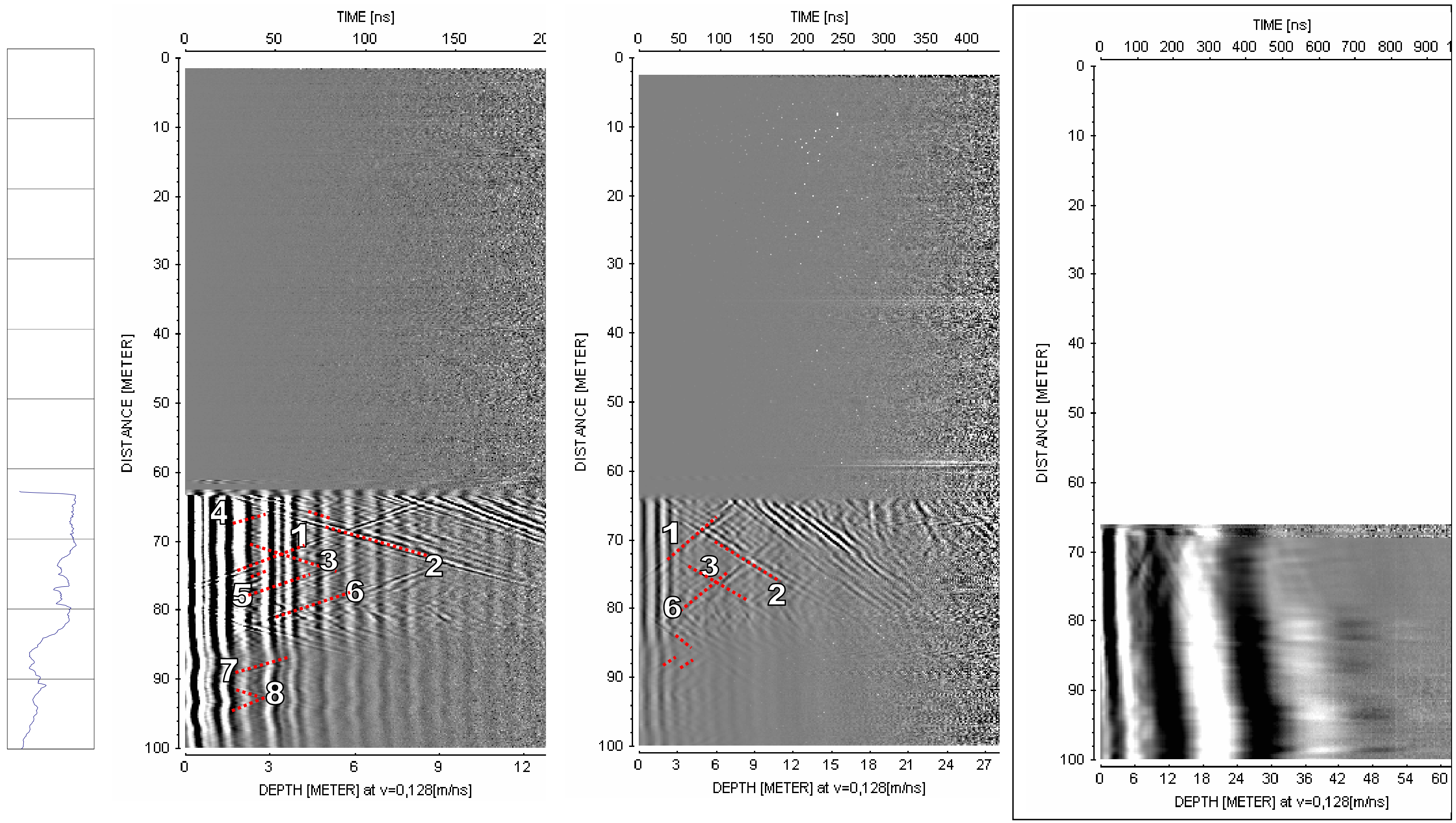
References

/1/ **Gustafsson C, Nilsson P, 2003.** Geophysical Radar and BIPS logging in borehole HFM01. HFM02. HFM03 and the percussion drilled part of KFM01A. SKB P-03-39. Svensk Kärnbränslehantering AB.

Radar logging in KFM10A. 0 to 493 m, dipole antennas 250. 100 and 20 MHz

FORSMARK KFM10A

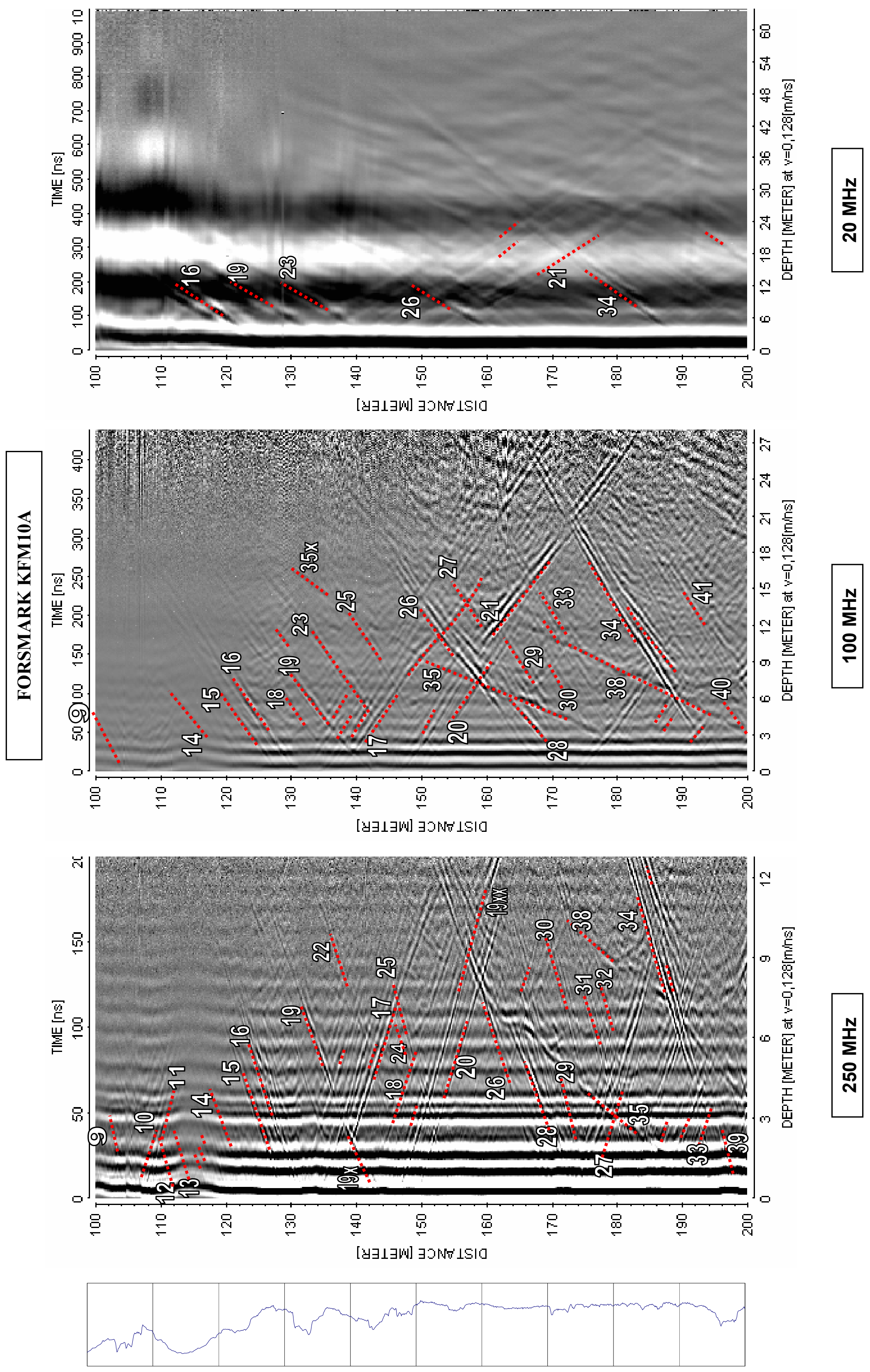
Appendix 1

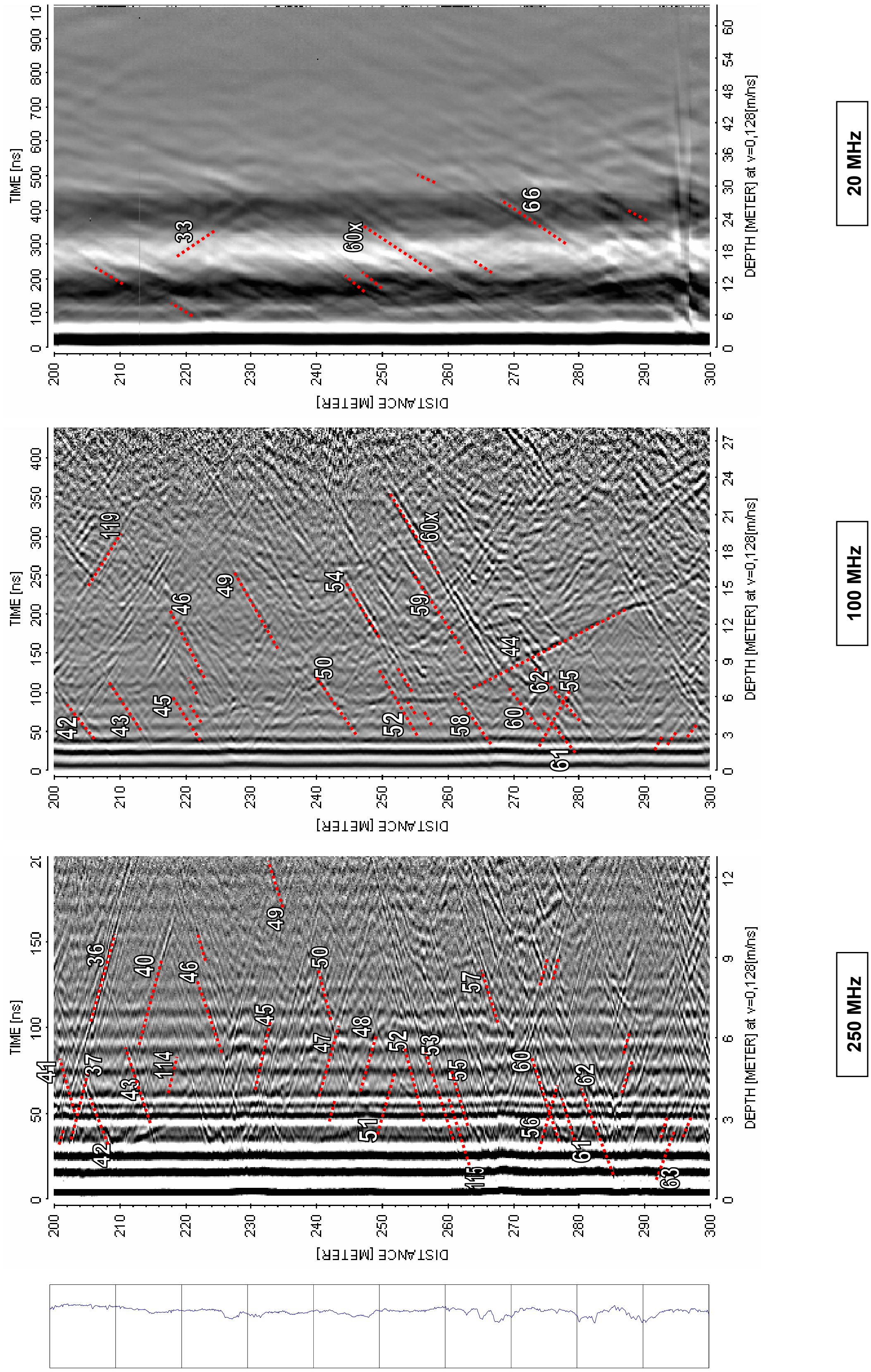


250 MHz

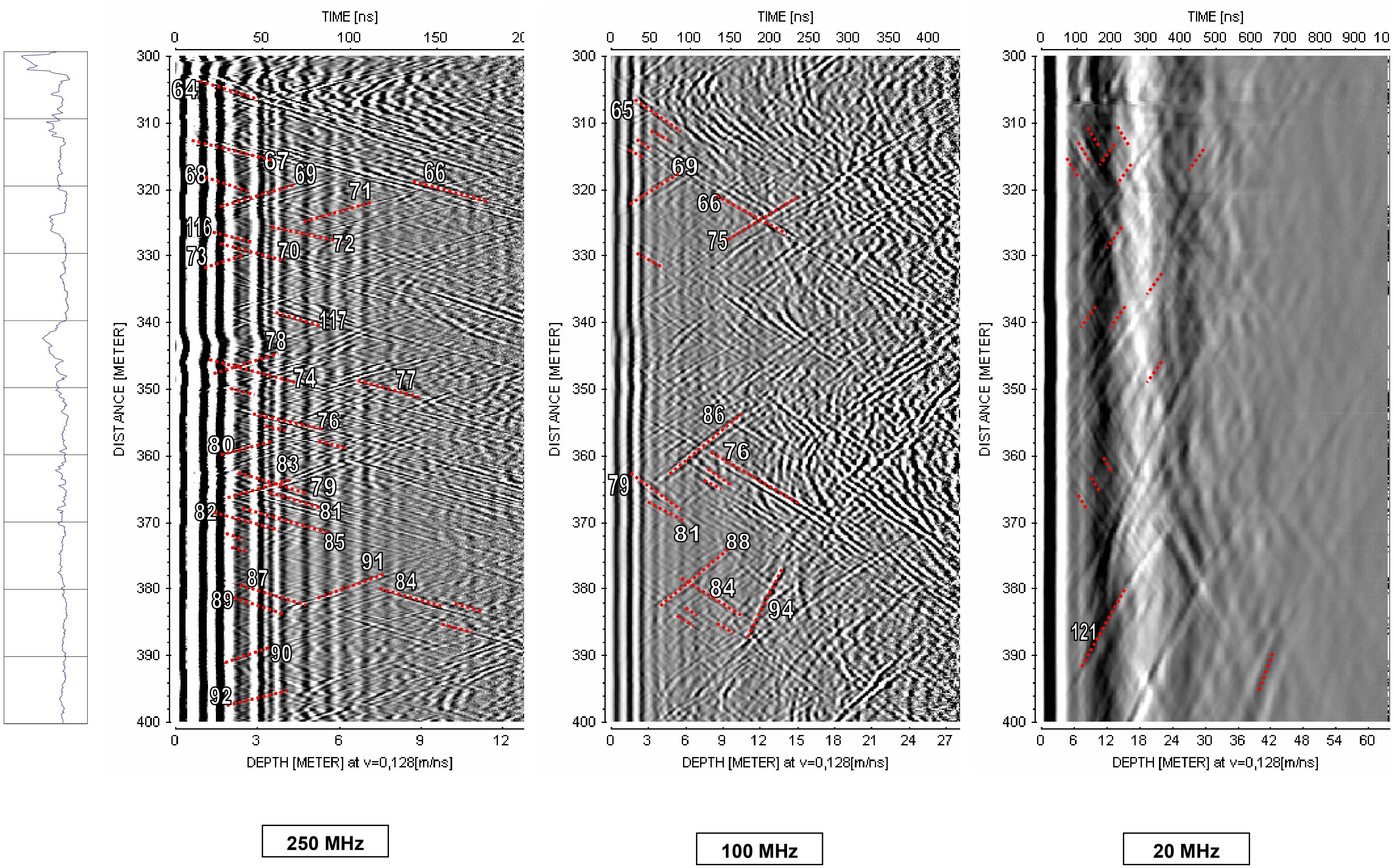
100 MHz

20 MHz

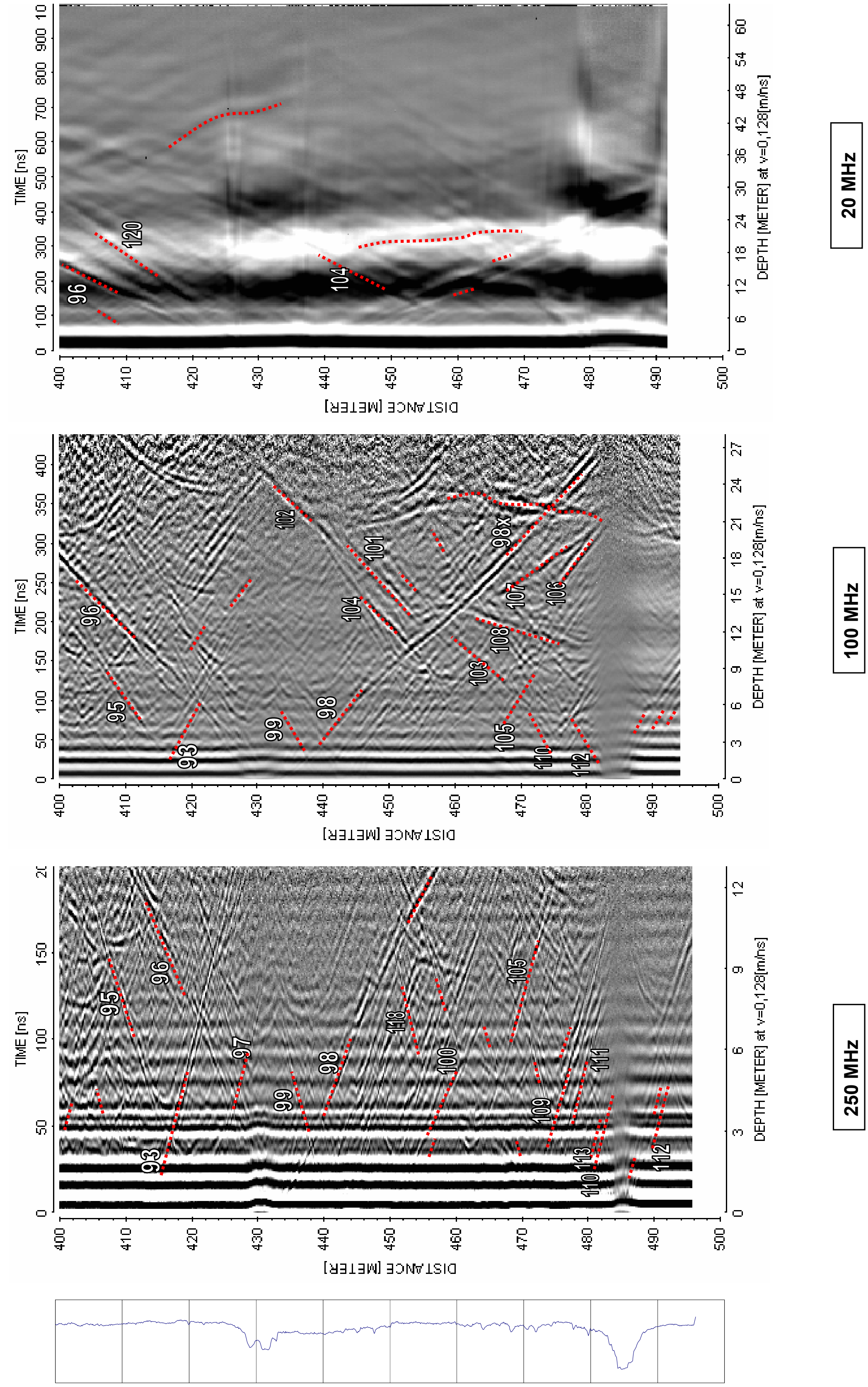

FORSMARK KFM10A
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,128[m/ns]
250 MHz
100 MHz
20 MHz


FORSMARK KFM10A
250 MHz
100 MHz
20 MHz
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,128[m/ns]

FORSMARK KFM10A



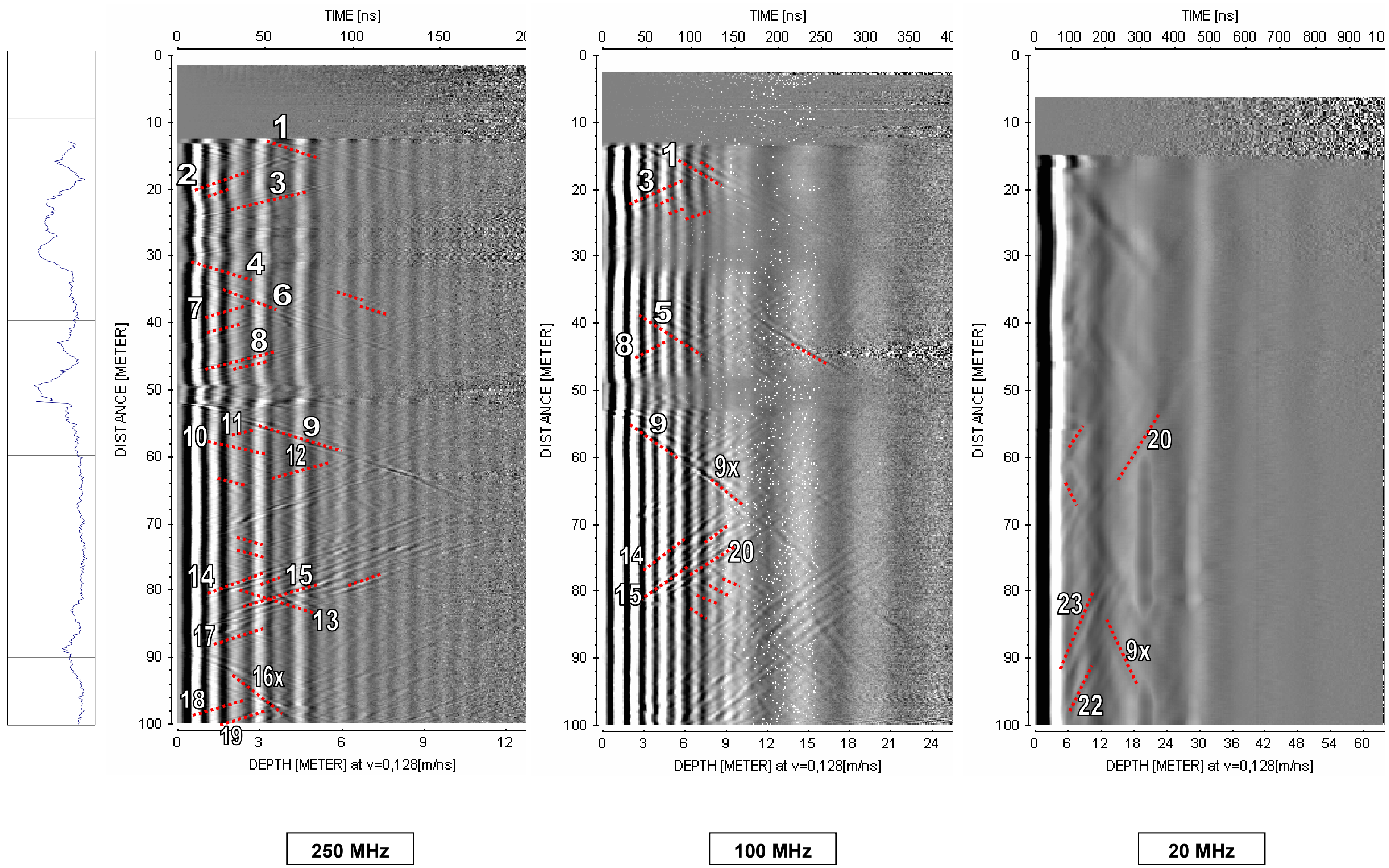
FORSMARK KFM10A

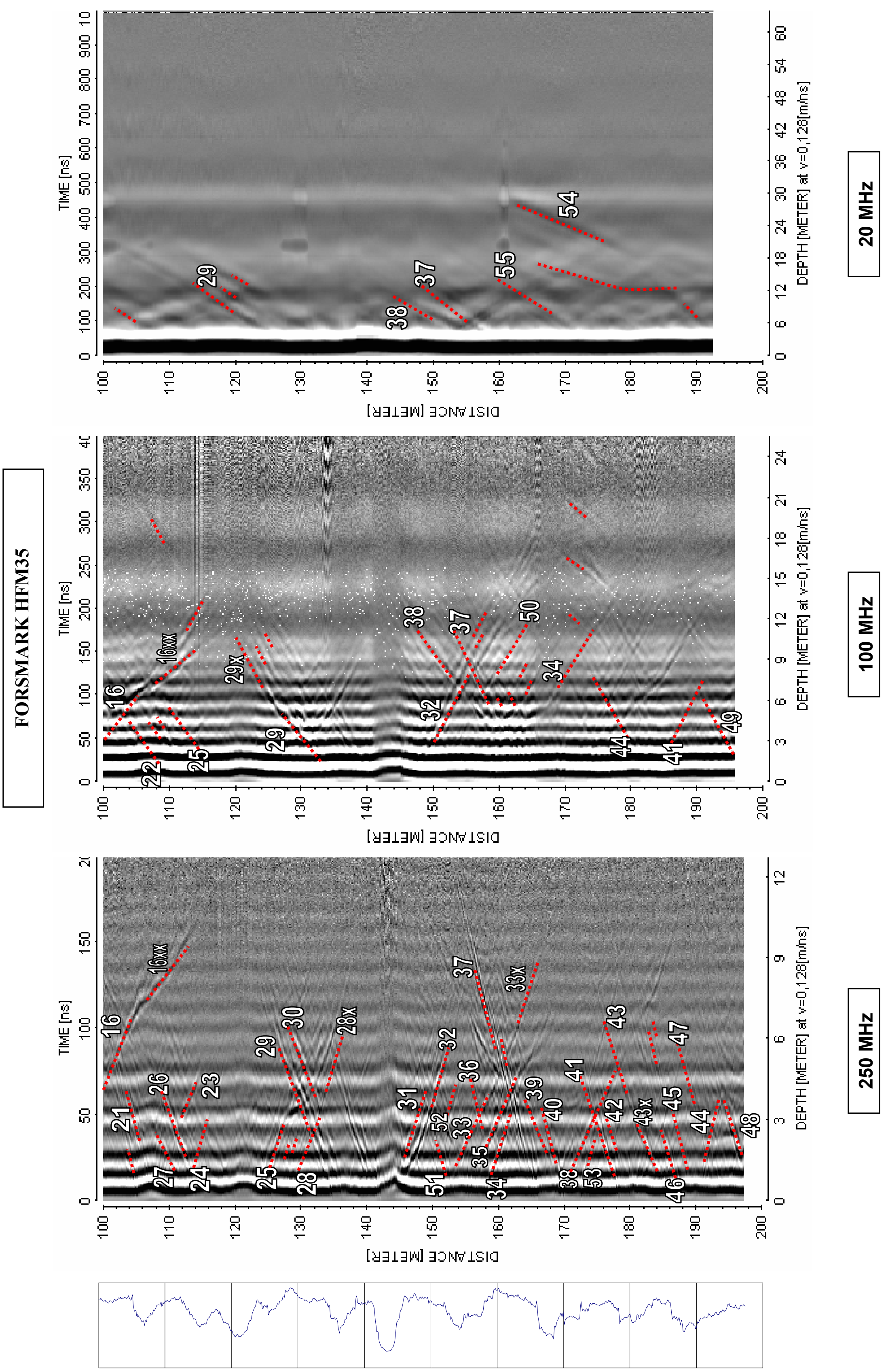


Radar logging in HFM35. 0 to 196 m, dipole antennas 250. 100 and 20 MHz

Appendix 2

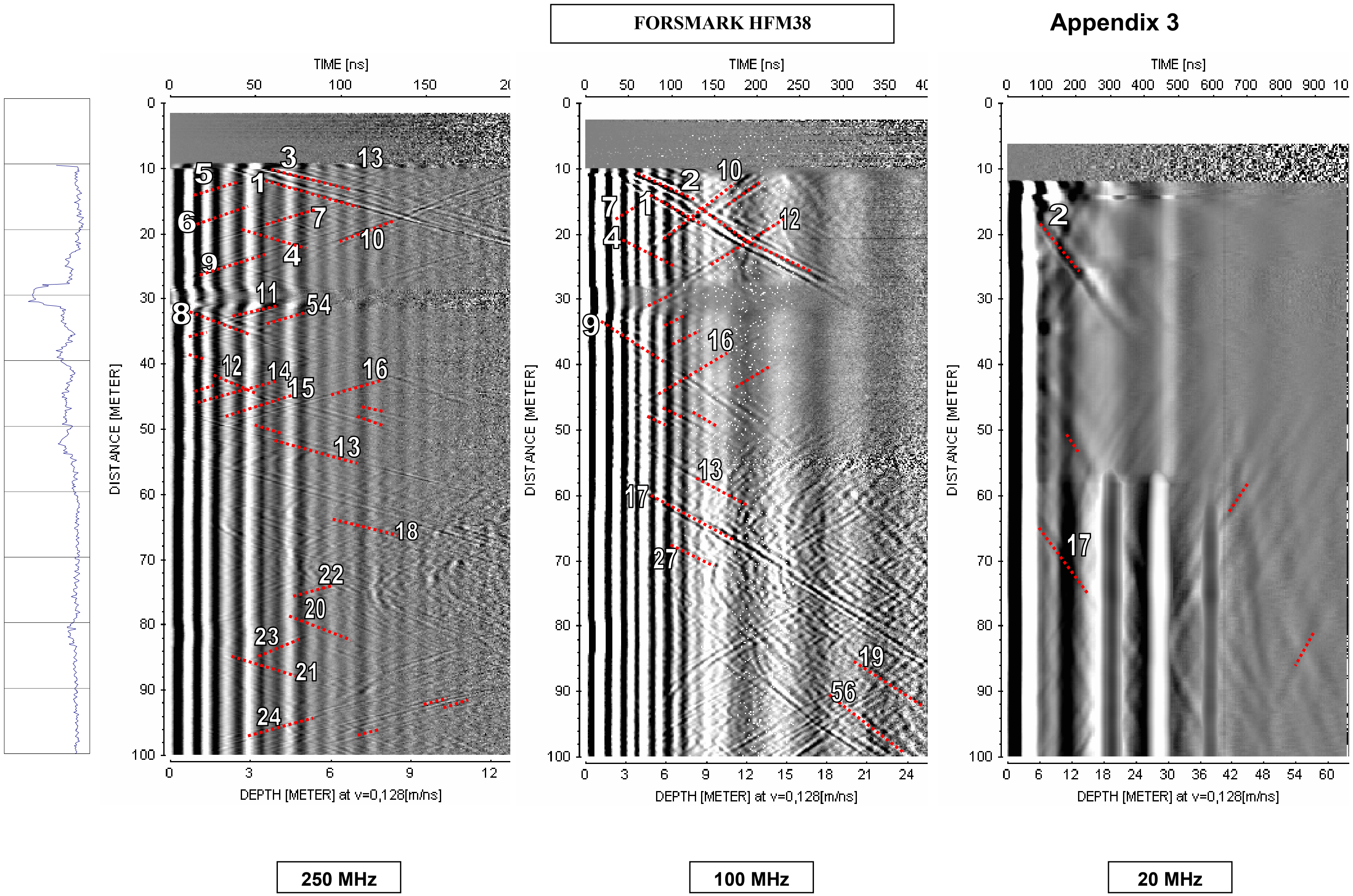
FORSMARK HFM35



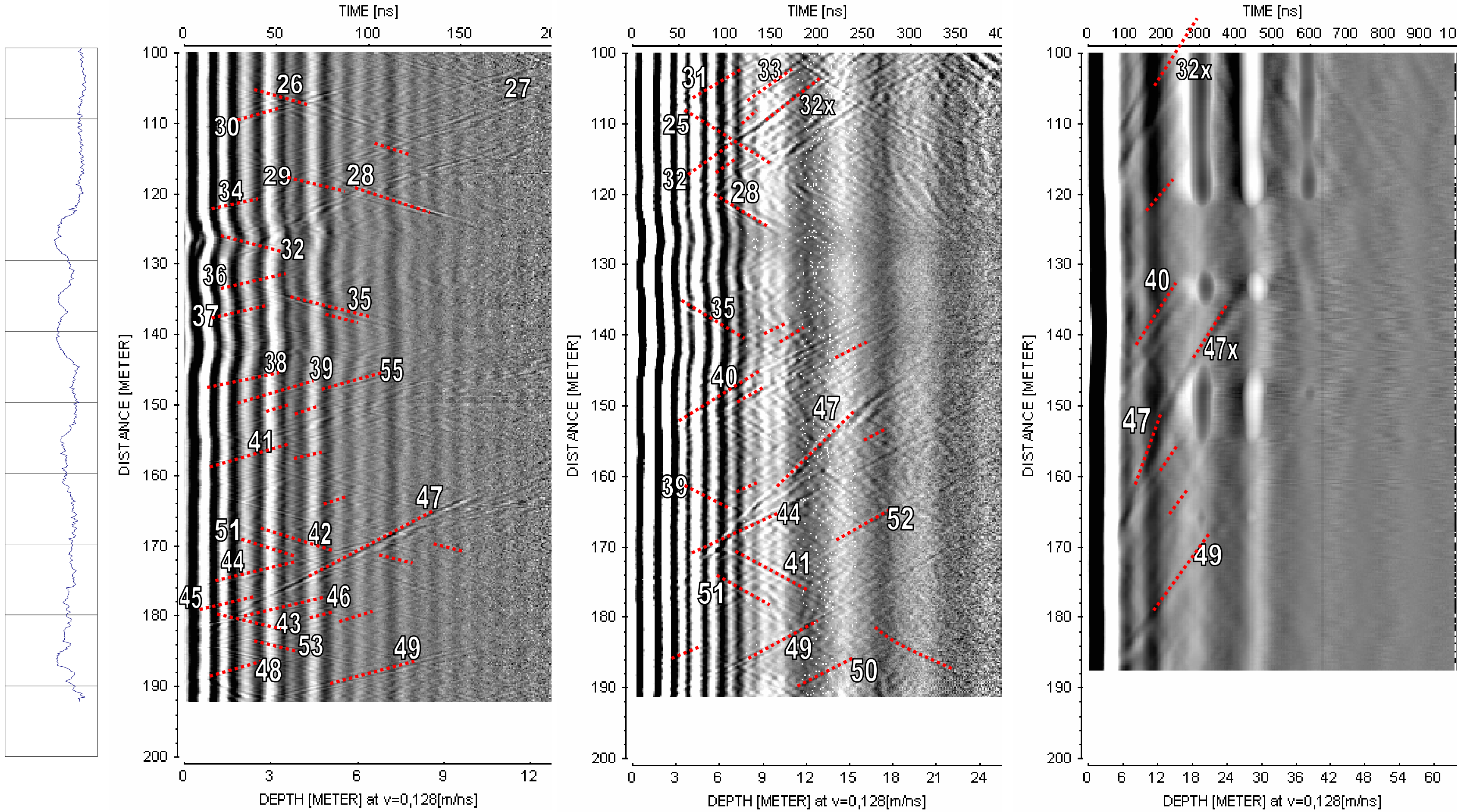


FORSMARK HFM35
250 MHz
100 MHz
20 MHz
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,128[m/ns]

Radar logging in HFM38. 0 to 191 m, dipole antennas 250. 100 and 20 MHz



FORSMARK HFM38



250 MHz

100 MHz

20 MHz

Appendix 4

BIPS logging in KFM10A. 62 to 496 m

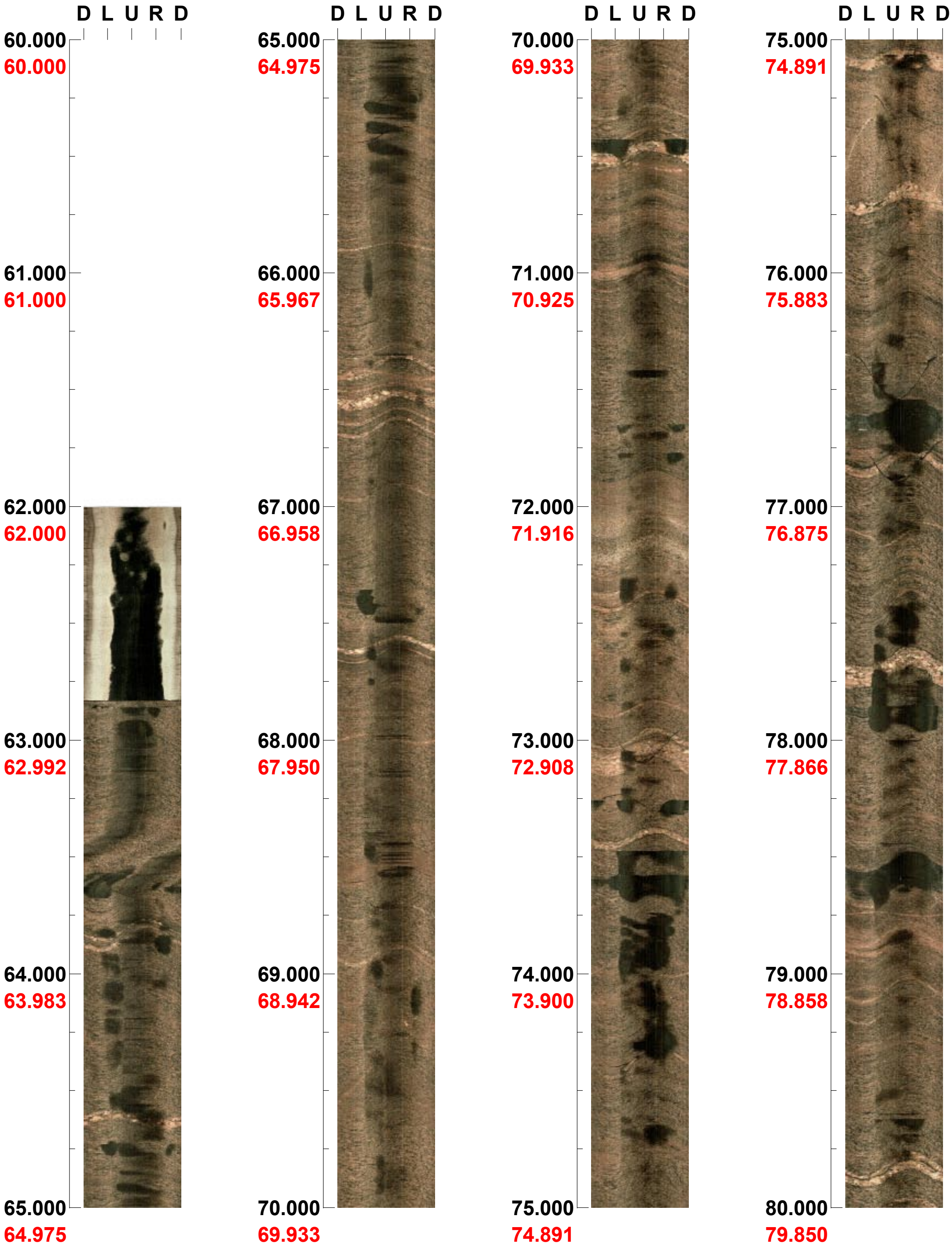
Project name: Forsmark

Image file	: c:\work\r5537f~1\bips\kfm10a\060721\kfm10a.bip
BDT file	: c:\work\r5537f~1\bips\kfm10a\060721\kfm10a.bdt
Locality	: FORSMARK
Bore hole number	: KFM10A
Date	: 06/07/21
Time	: 08:12:00
Depth range	: 62.000 - 497.001 m
Azimuth	: 10
Inclination	: -50
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	: 22
Color	: +0 +0 +0

Project name: Forsmark
Bore hole No.: KFM10A

Azimuth: 10 Inclination: -50

Depth range: 60.000 - 80.000 m

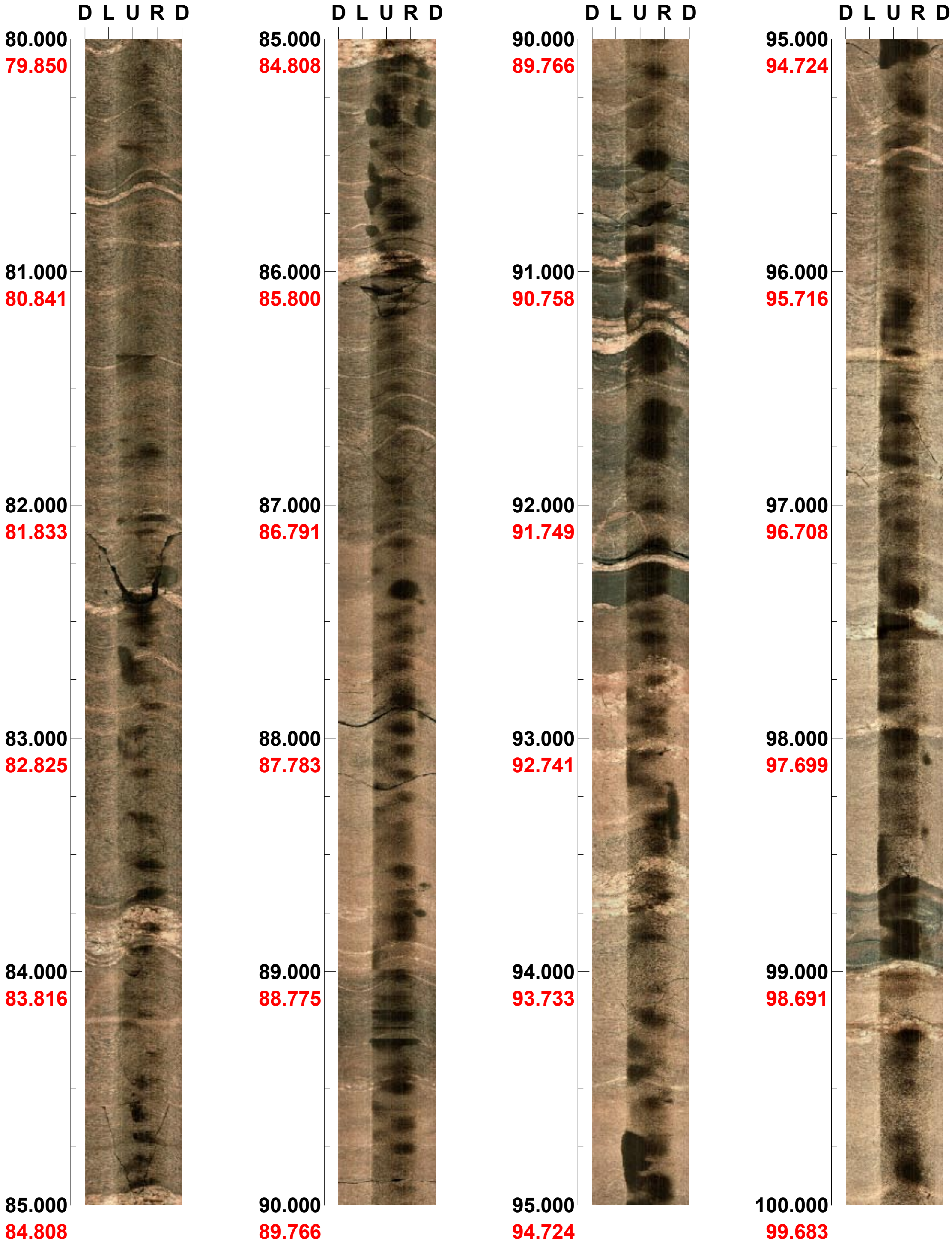


(1 / 22) Scale: 1/25 Aspect ratio: 175 %

Project name: Forsmark

Bore hole No.: KFM10A **Azimuth: 10** **Inclination: -50**

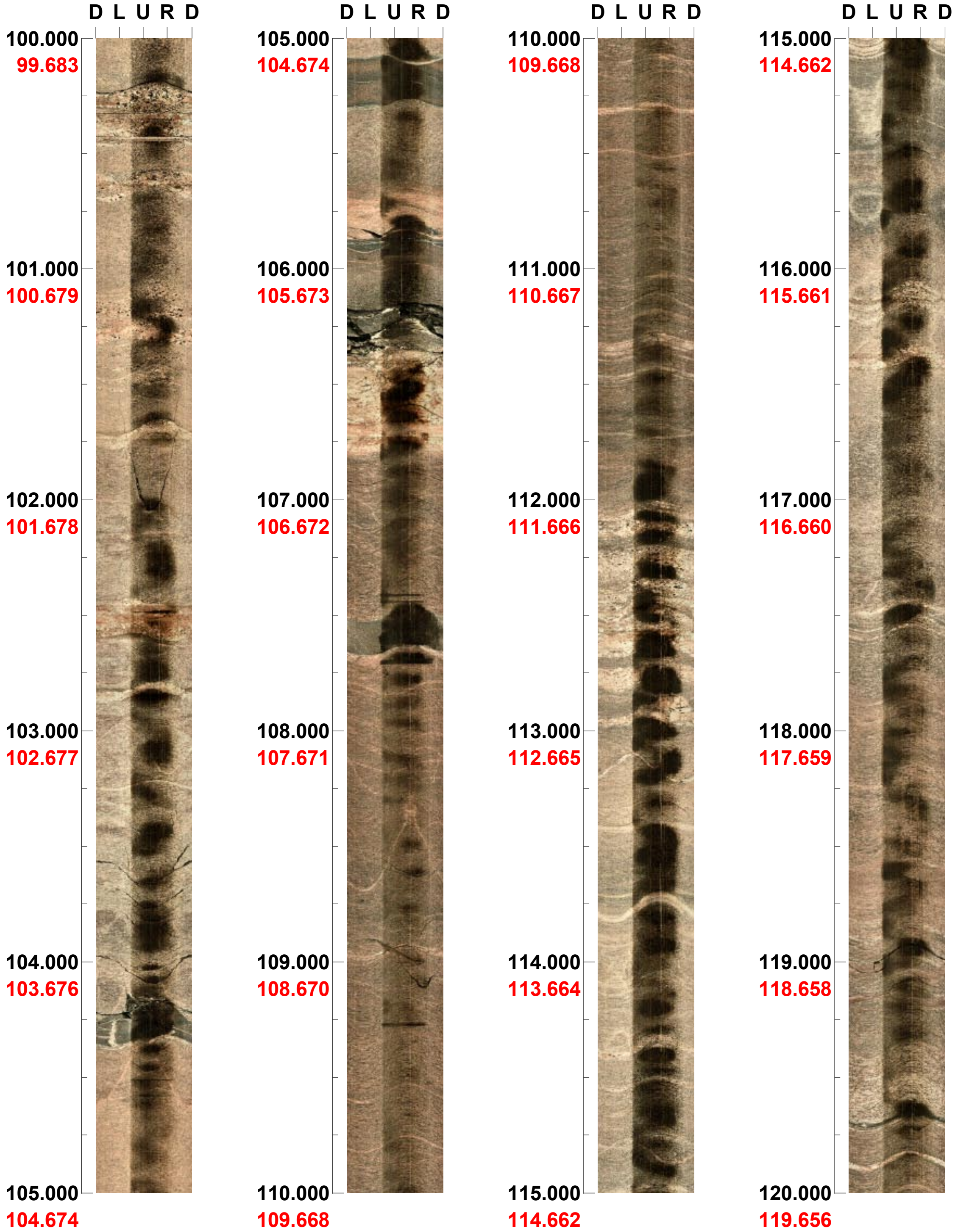
Depth range: 80.000 - 100.000 m



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

Project name: Forsmark
Bore hole No.: KFM10A **Azimuth: 10** **Inclination: -50**

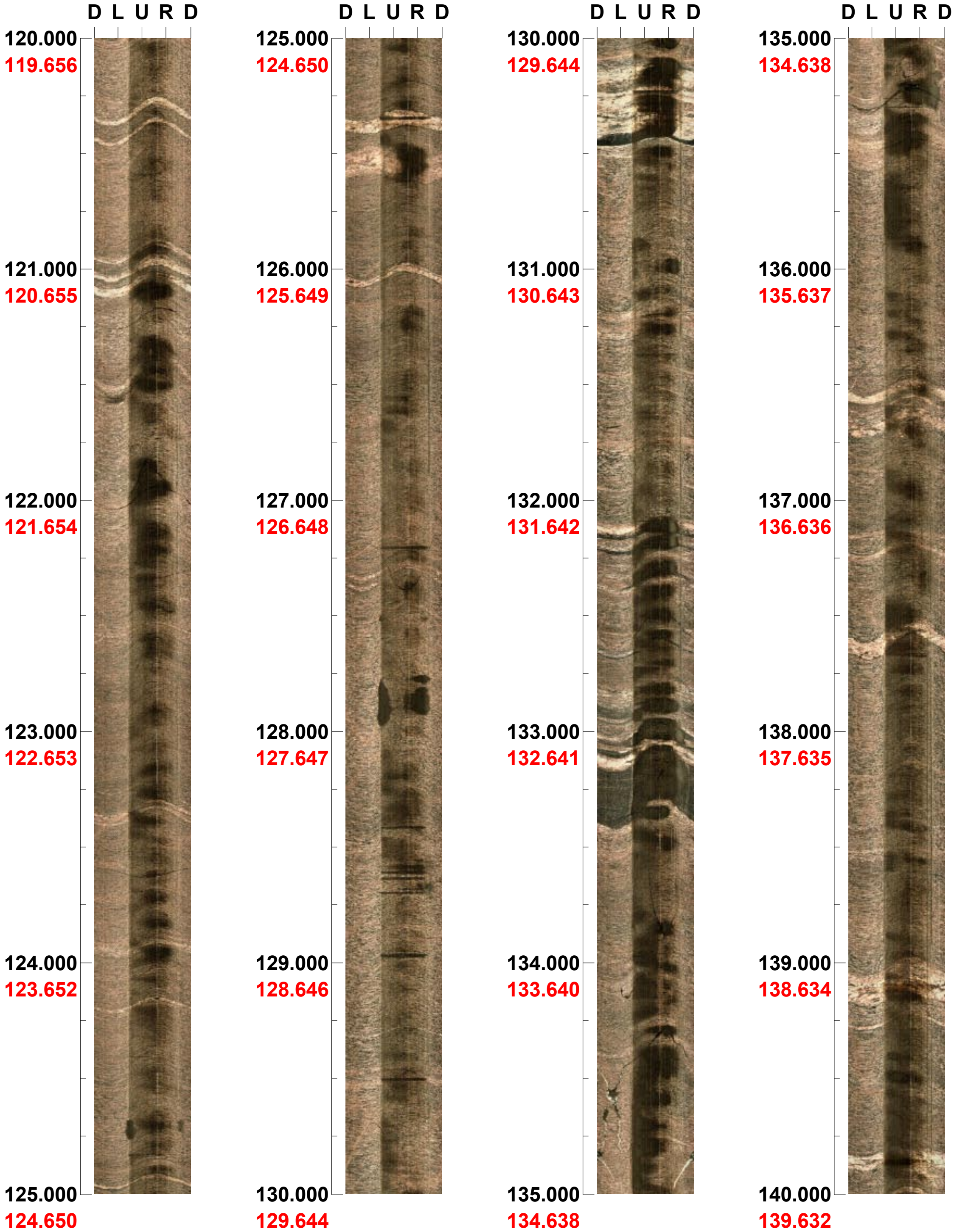
Depth range: 100.000 - 120.000 m



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

Project name: Forsmark
Bore hole No.: KFM10A **Azimuth: 10** **Inclination: -50**

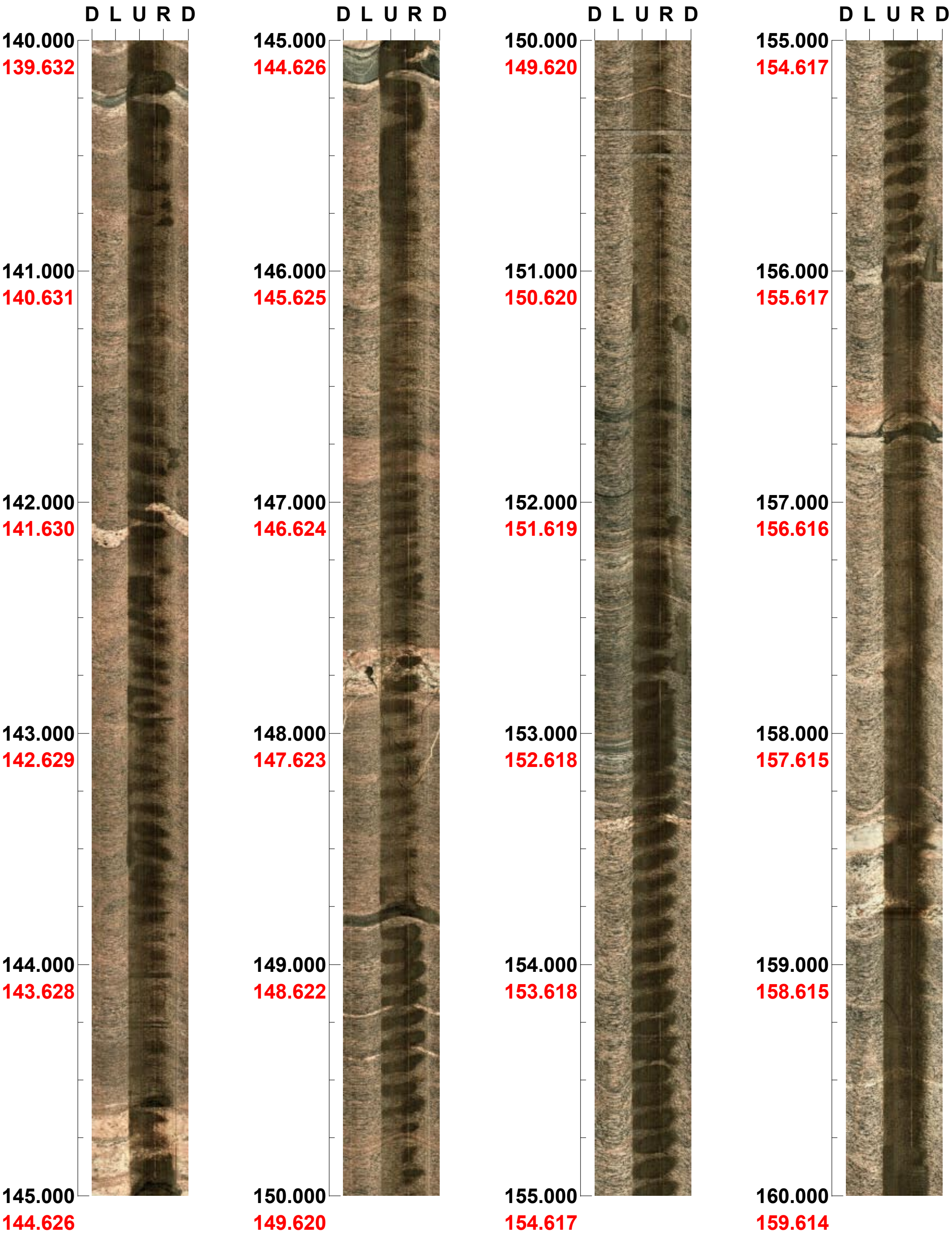
Depth range: 120.000 - 140.000 m



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

Project name: Forsmark
Bore hole No.: KFM10A **Azimuth: 10** **Inclination: -50**

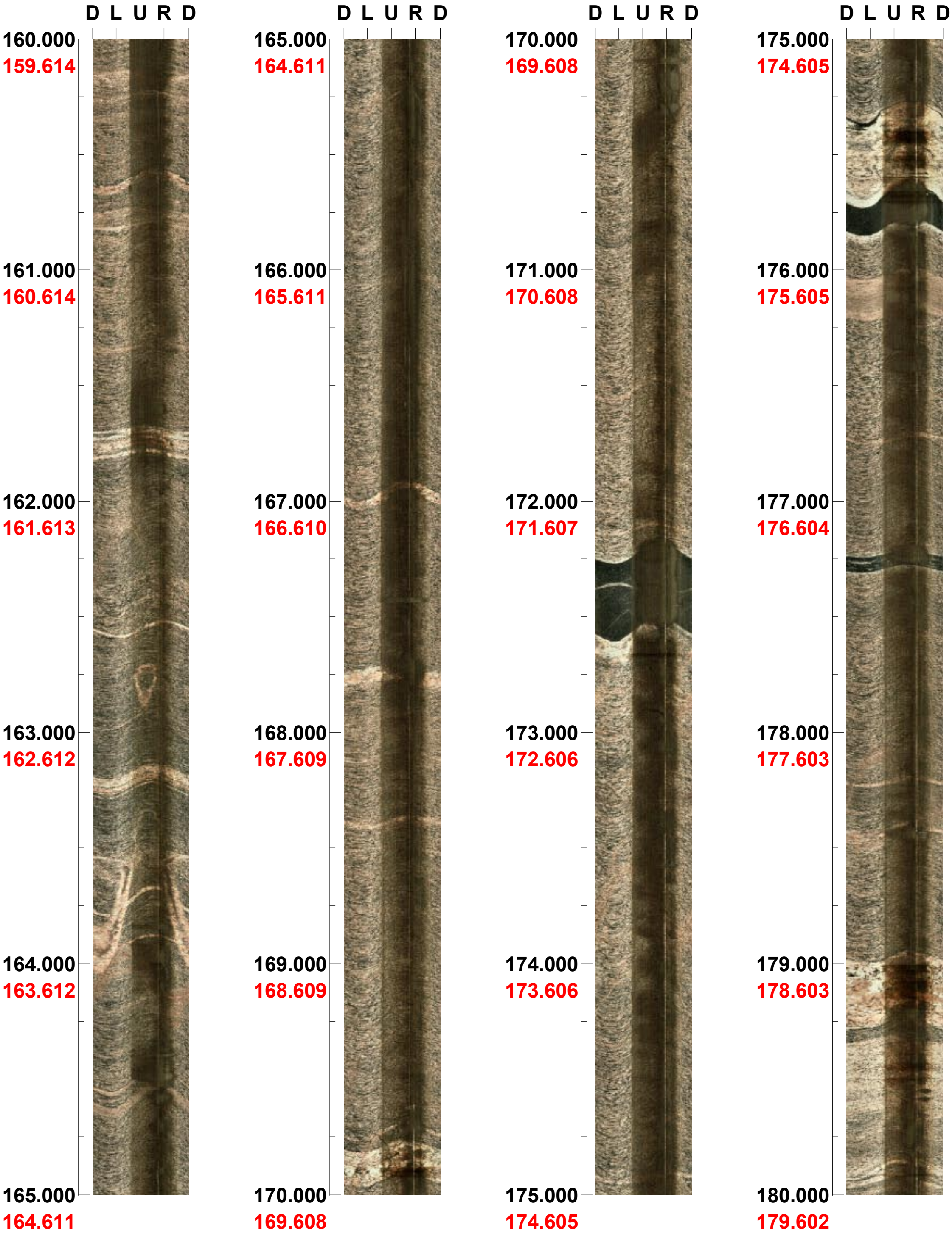
Depth range: 140.000 - 160.000 m



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

Project name: Forsmark
Bore hole No.: KFM10A Azimuth: 10 Inclination: -50

Depth range: 160.000 - 180.000 m

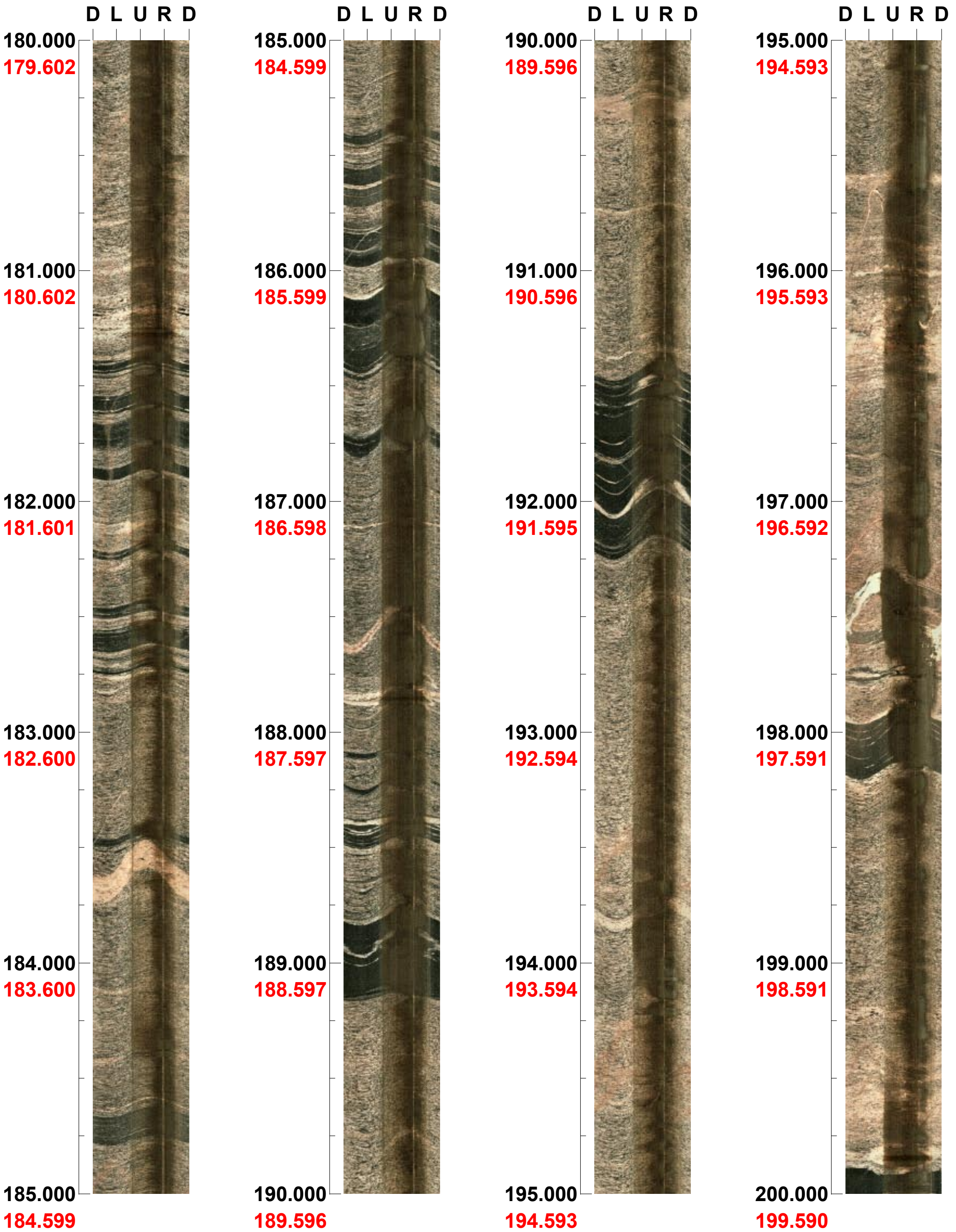


(6 / 22) Scale: 1/25 Aspect ratio: 175 %

Project name: Forsmark

Bore hole No.: KFM10A **Azimuth: 10** **Inclination: -50**

Depth range: 180.000 - 200.000 m



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

Project name: Forsmark
Bore hole No.: KFM10A **Azimuth: 10** **Inclination: -50**

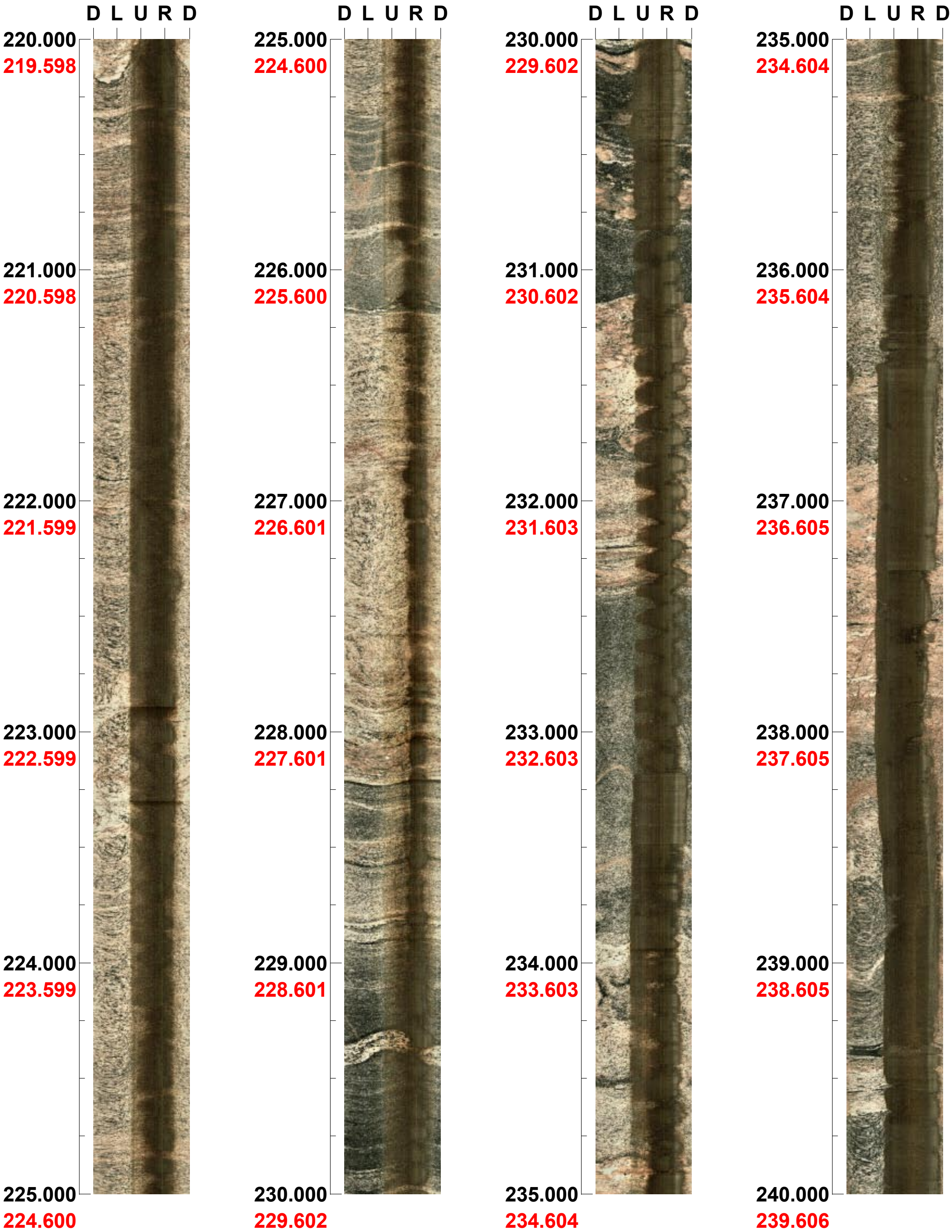
Depth range: 200.000 - 220.000 m

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

Project name: Forsmark

Bore hole No.: KFM10A **Azimuth: 10** **Inclination: -50**

Depth range: 220.000 - 240.000 m

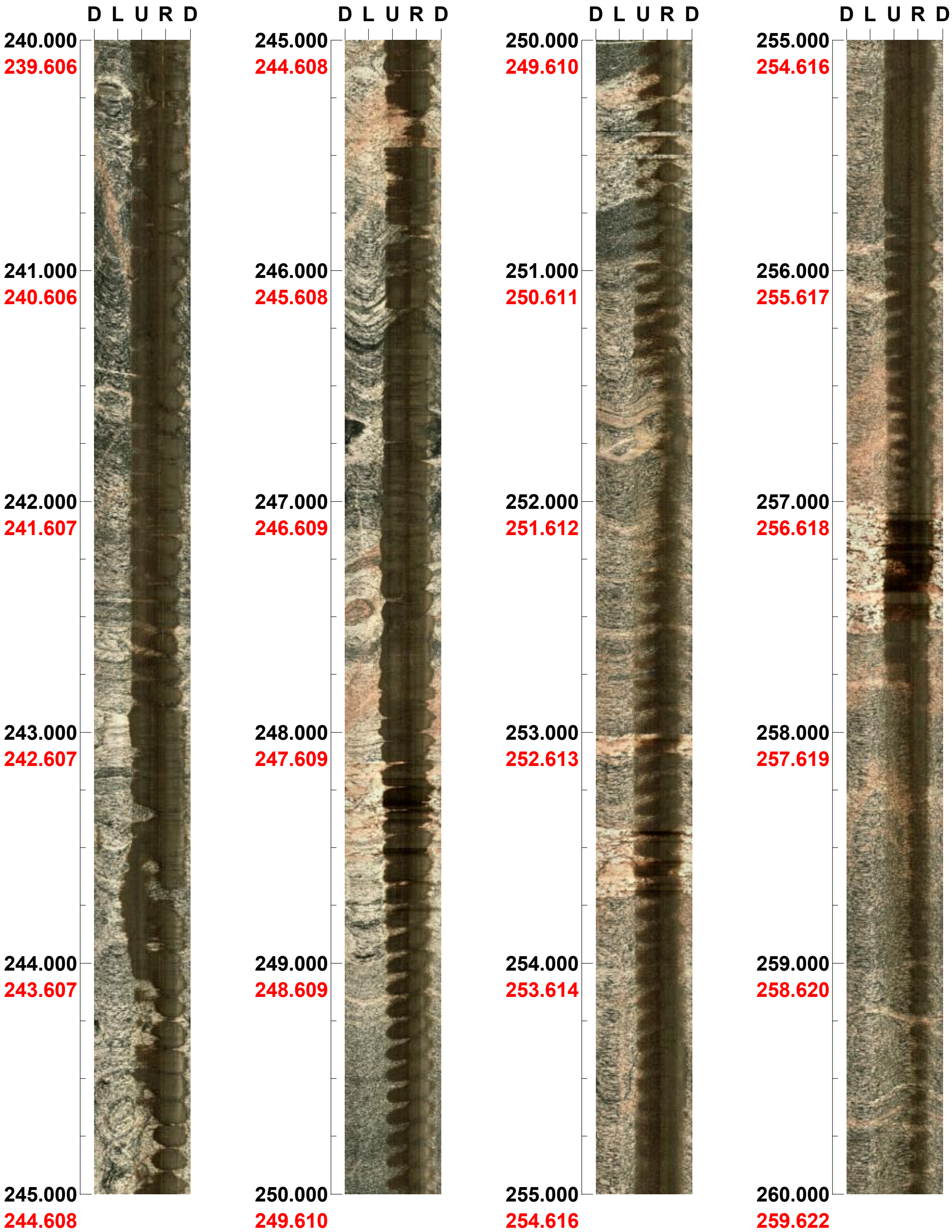


(9 / 22) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFM10A **Azimuth: 10** **Inclination: -50**

Depth range: 240.000 - 260.000 m



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

Project name: Forsmark
Bore hole No.: KFM10A **Azimuth: 10** **Inclination: -50**

Depth range: 260.000 - 280.000 m

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

Project name: Forsmark
Bore hole No.: KFM10A **Azimuth: 10** **Inclination: -50**

Depth range: 280.000 - 300.000 m

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

Project name: Forsmark
Bore hole No.: KFM10A **Azimuth: 10** **Inclination: -50**

Depth range: 300.000 - 320.000 m

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

Project name: Forsmark

Bore hole No.: KFM10A **Azimuth: 10** **Inclination: -50**

Depth range: 320.000 - 340.000 m

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

Project name: Forsmark

Bore hole No.: KFM10A **Azimuth: 10** **Inclination: -50**

Depth range: 340.000 - 360.000 m

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

Project name: Forsmark
Bore hole No.: KFM10A **Azimuth: 10** **Inclination: -50**

Depth range: 360.000 - 380.000 m

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

Project name: Forsmark

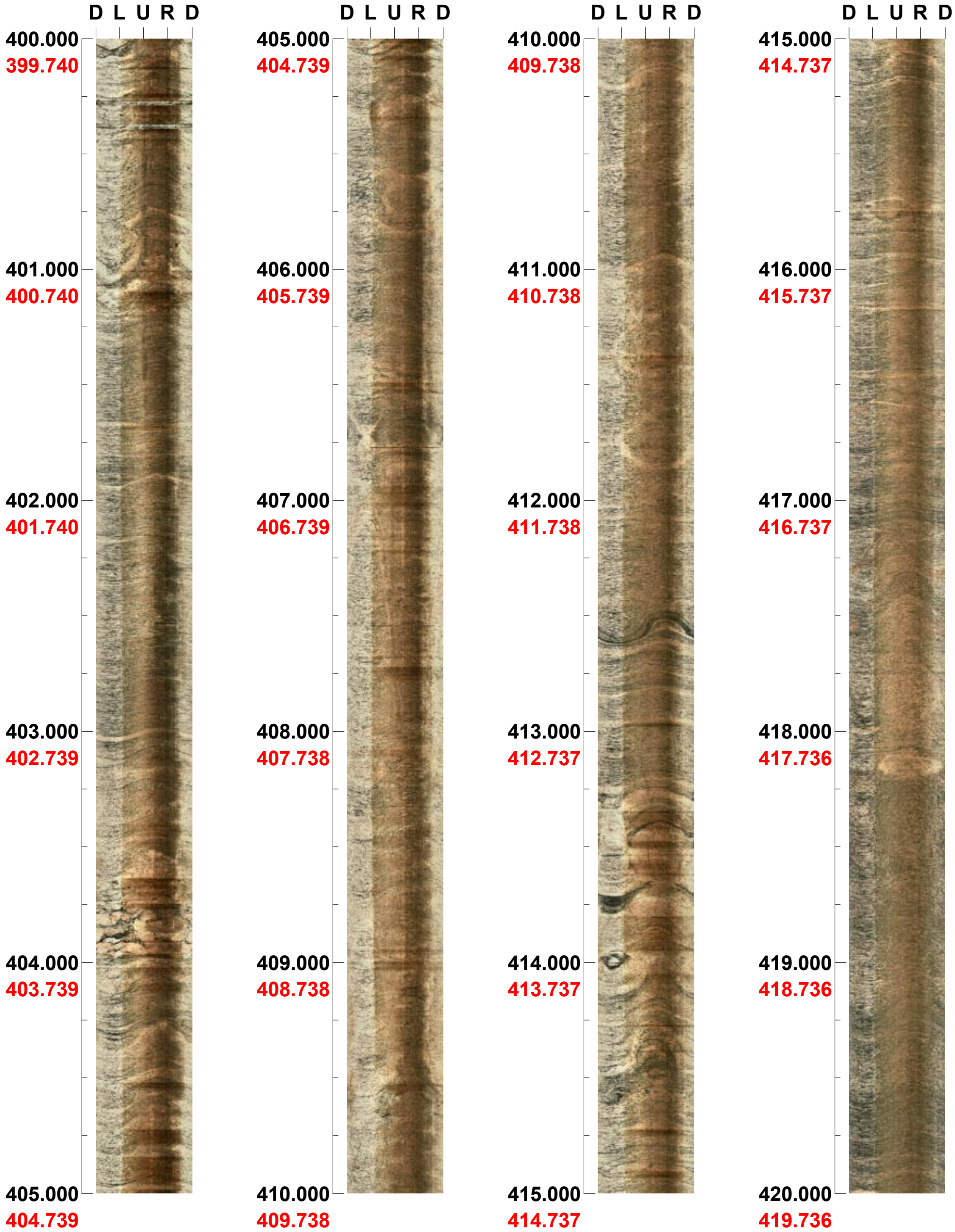
Bore hole No.: KFM10A **Azimuth: 10** **Inclination: -50**

Depth range: 380.000 - 400.000 m

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

Project name: Forsmark
Bore hole No.: KFM10A **Azimuth: 10** **Inclination: -50**

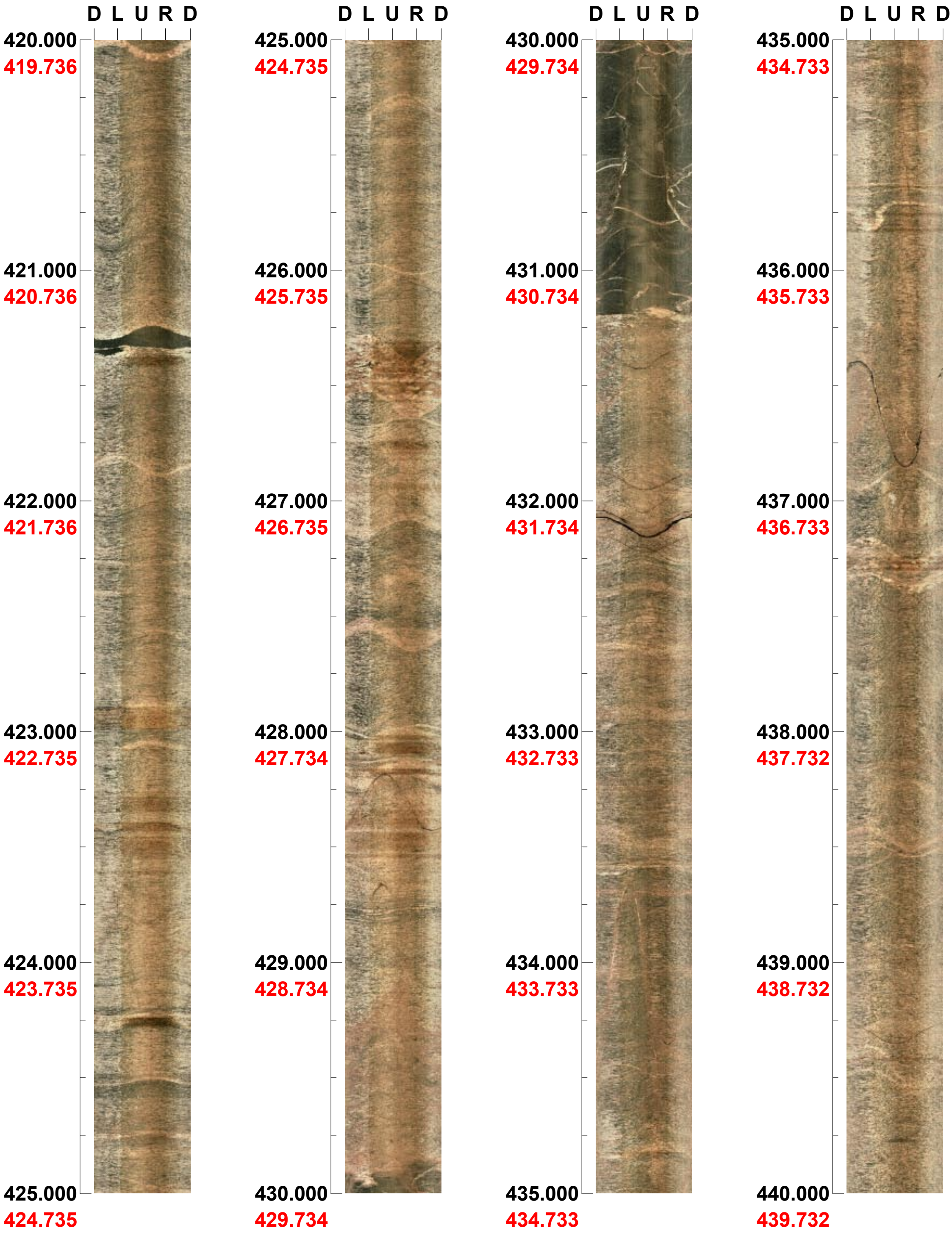
Depth range: 400.000 - 420.000 m



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

Project name: Forsmark
Bore hole No.: KFM10A   Azimuth: 10   Inclination: -50

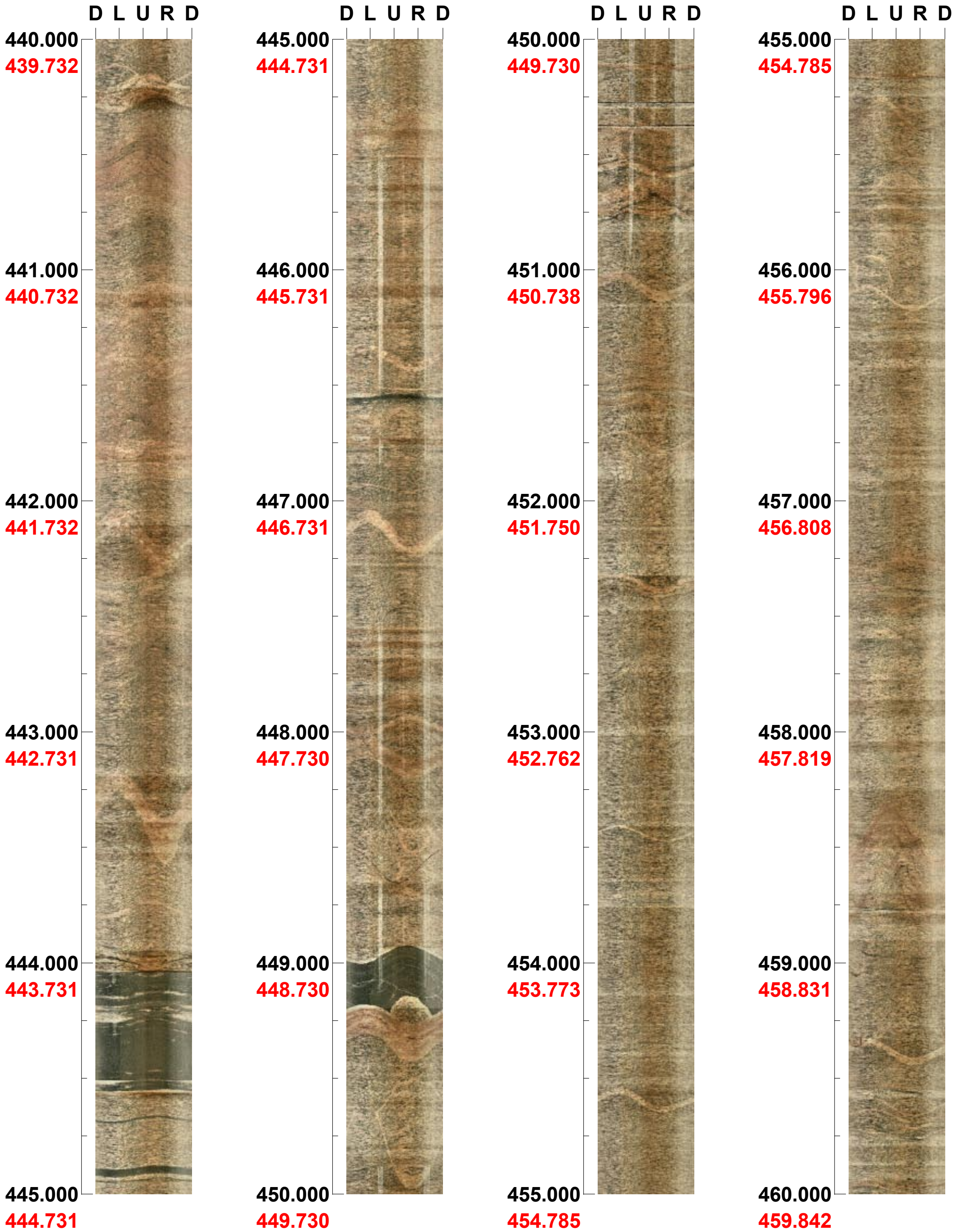
Depth range: 420.000 - 440.000 m



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

Project name: Forsmark
Bore hole No.: KFM10A **Azimuth: 10** **Inclination: -50**

Depth range: 440.000 - 460.000 m



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

Project name: Forsmark
Bore hole No.: KFM10A **Azimuth: 10** **Inclination: -50**

Depth range: 460.000 - 480.000 m

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

Project name: Forsmark
Bore hole No.: KFM10A   Azimuth: 10   Inclination: -50

Depth range: 480.000 - 497.001 m

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

BIPS logging in HFM35. 12 to 199 m

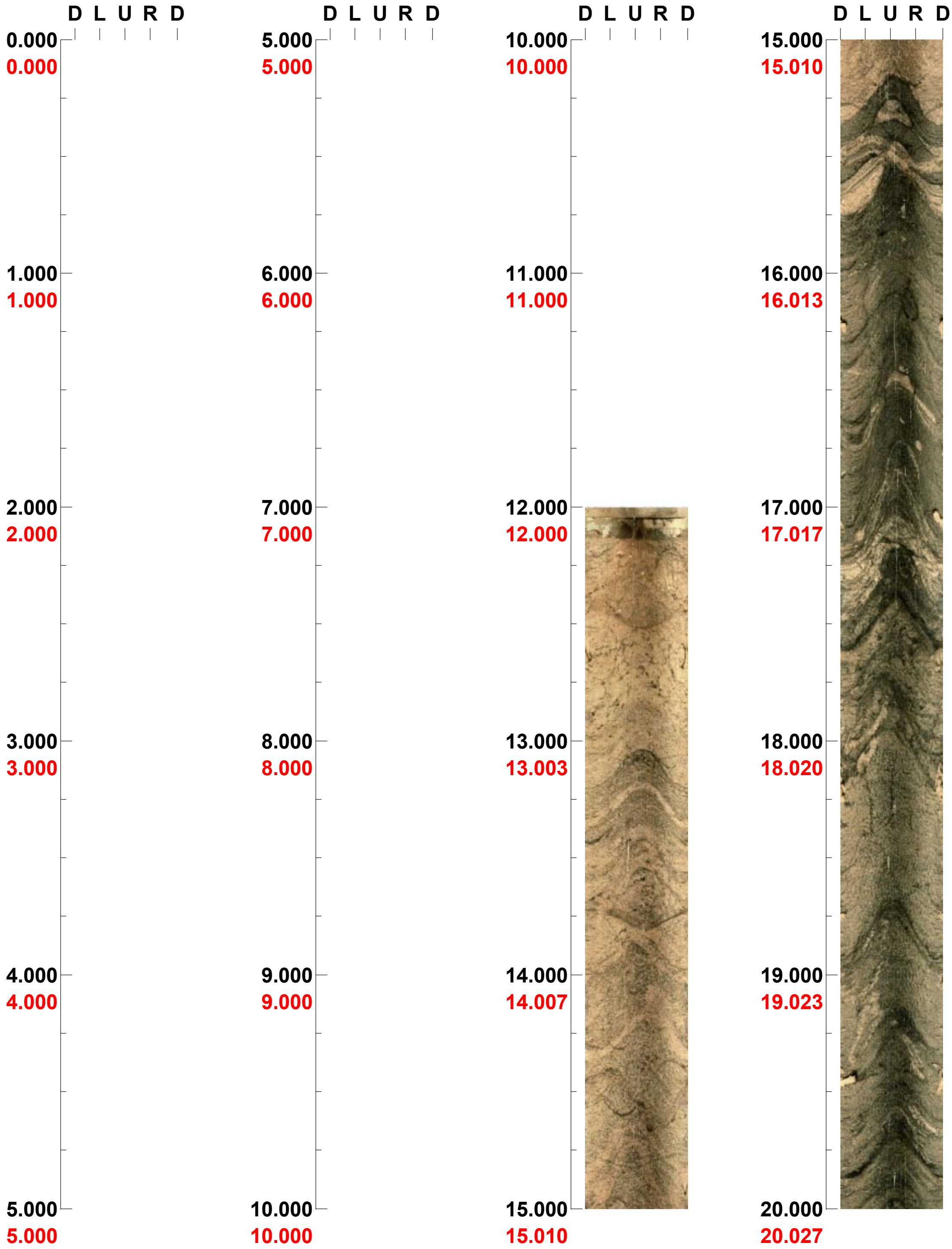
Project name: Forsmark

Image file	: c:\work\r5537f~1\bips\hfm35\hfm35.bip
BDT file	: c:\work\r5537f~1\bips\hfm35\hfm35.bdt
Locality	: FORSMARK
Bore hole number	: HFM35
Date	: 06/07/19
Time	: 19:05:00
Depth range	: 12.000 - 199.379 m
Azimuth	: 32
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: Forsmark

Bore hole No.: HFM35 **Azimuth: 32** **Inclination: -59**

Depth range: 0.000 - 20.000 m

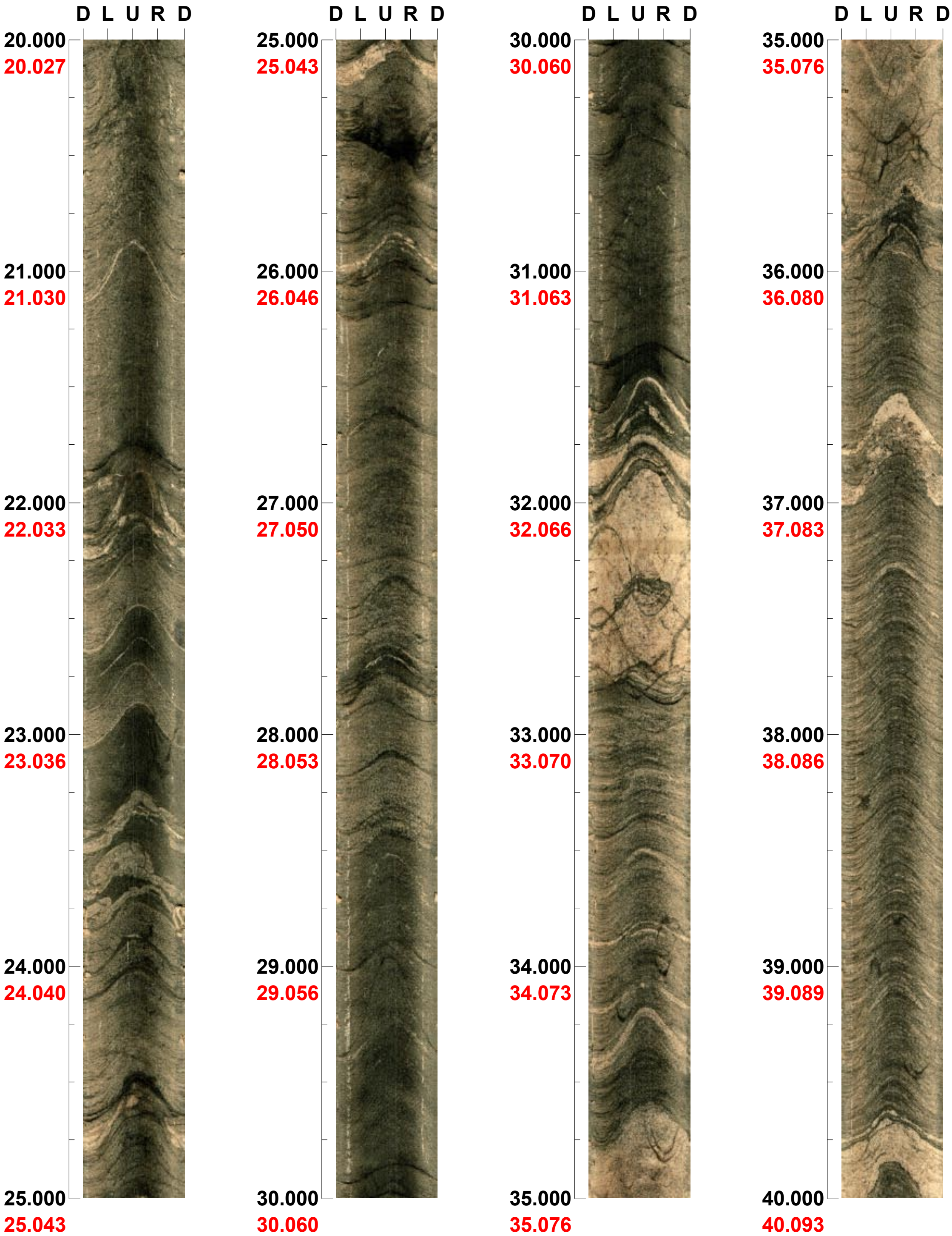


(1 / 10) Scale: 1/25 Aspect ratio: 100 %

Project name: Forsmark

Bore hole No.: HFM35 **Azimuth: 32** **Inclination: -59**

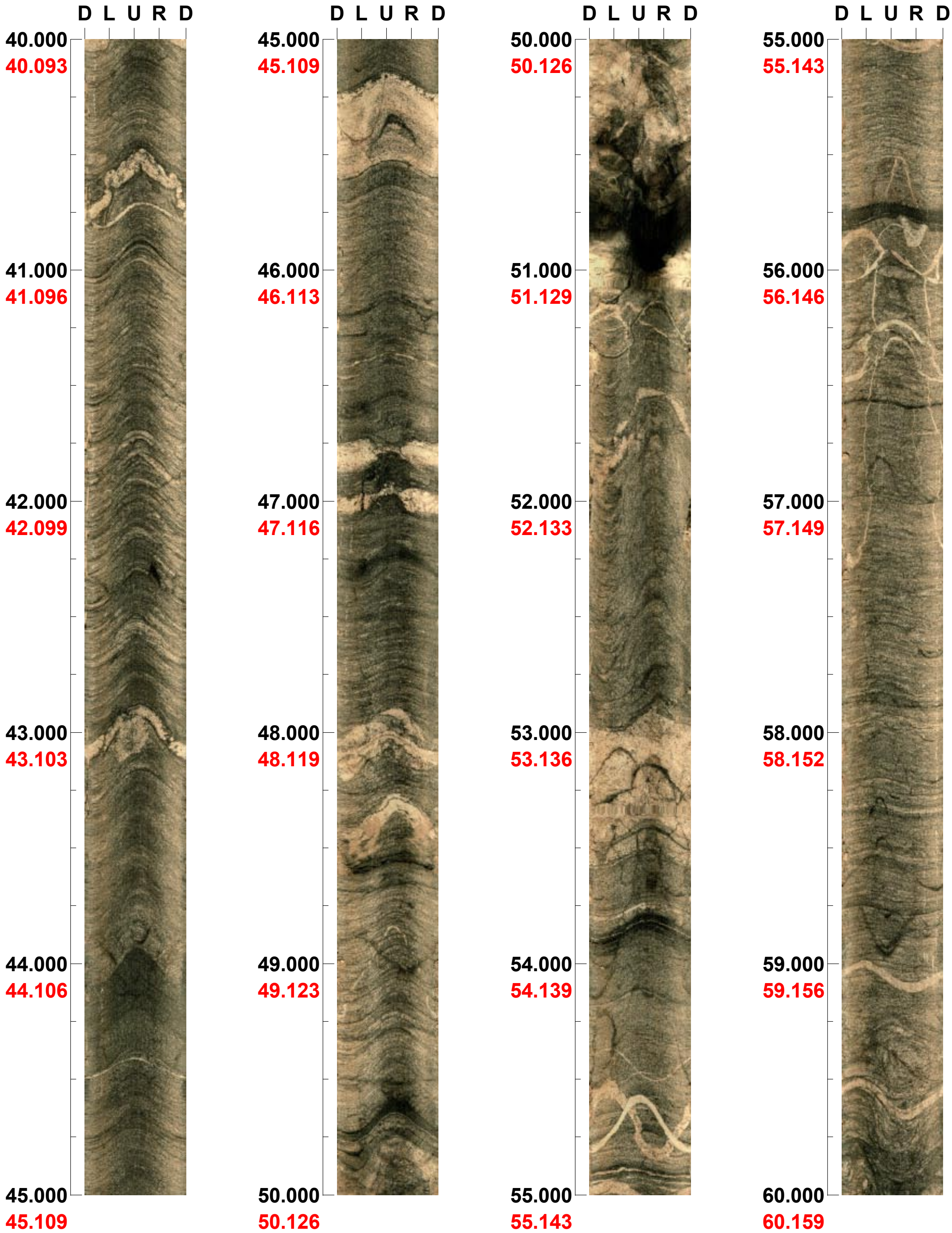
Depth range: 20.000 - 40.000 m



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

Project name: Forsmark
Bore hole No.: HFM35 **Azimuth: 32** **Inclination: -59**

Depth range: 40.000 - 60.000 m

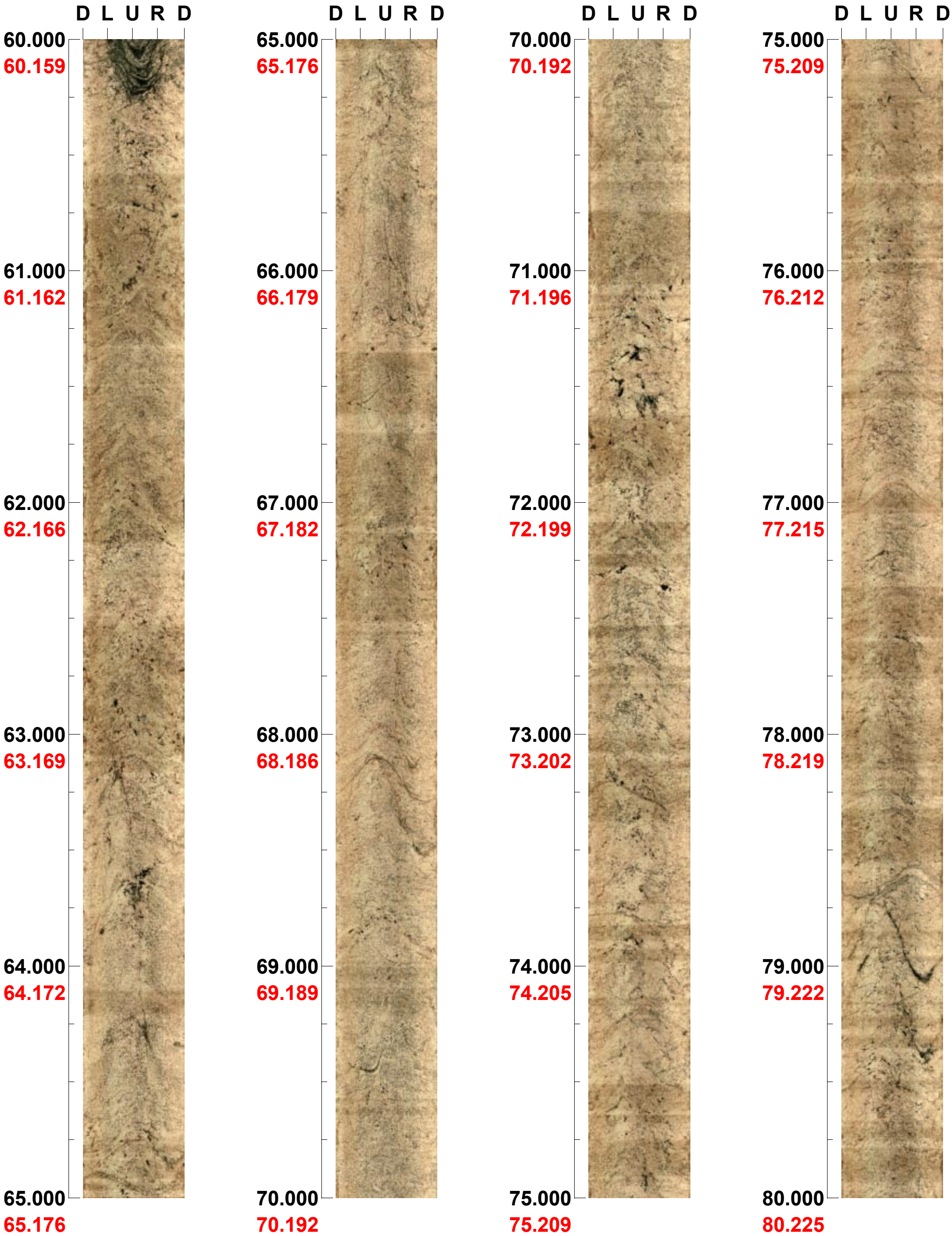


(3 / 10) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark

Bore hole No.: HFM35 **Azimuth: 32** **Inclination: -59**

Depth range: 60.000 - 80.000 m

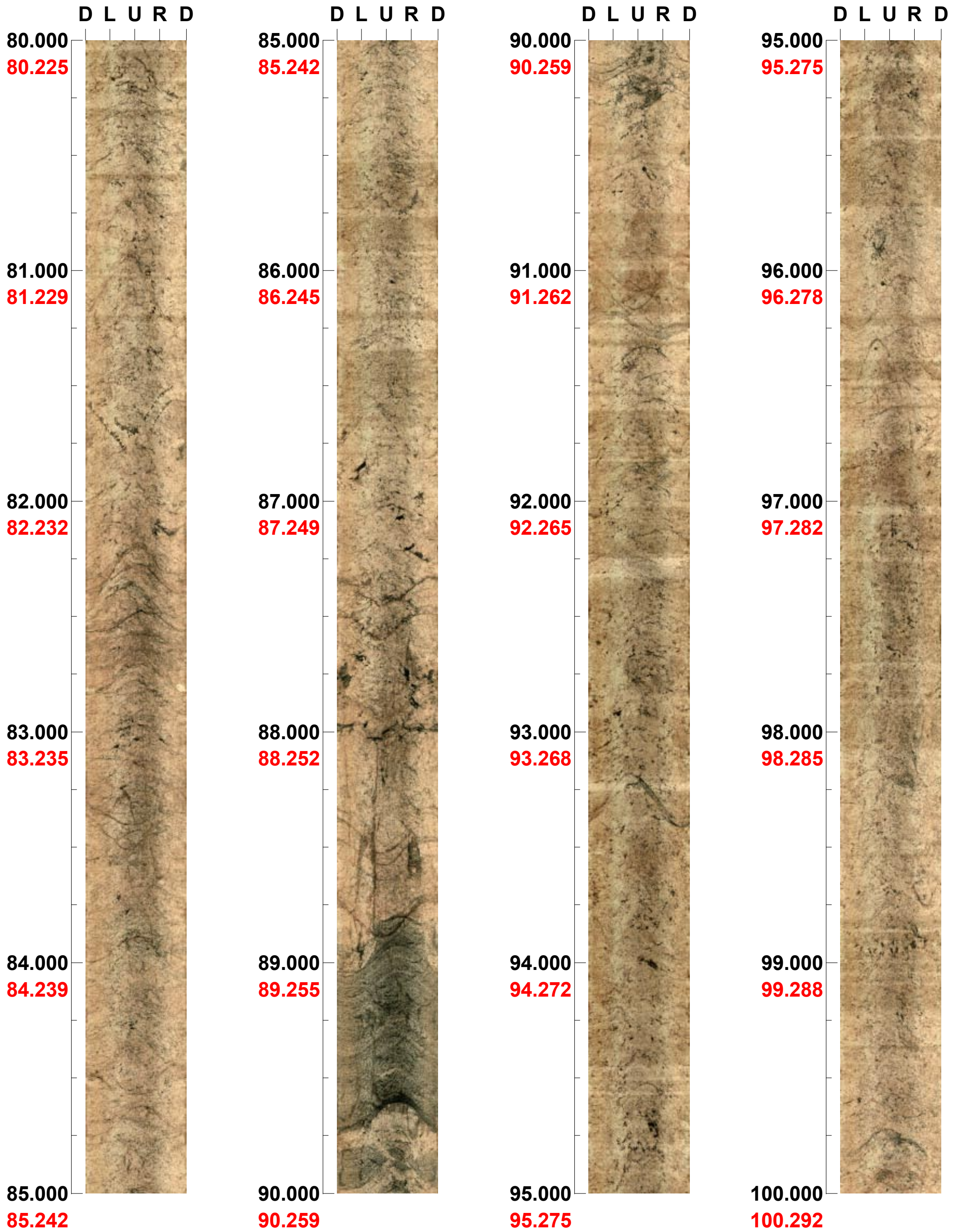


(4 / 10) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark

Bore hole No.: HFM35 **Azimuth: 32** **Inclination: -59**

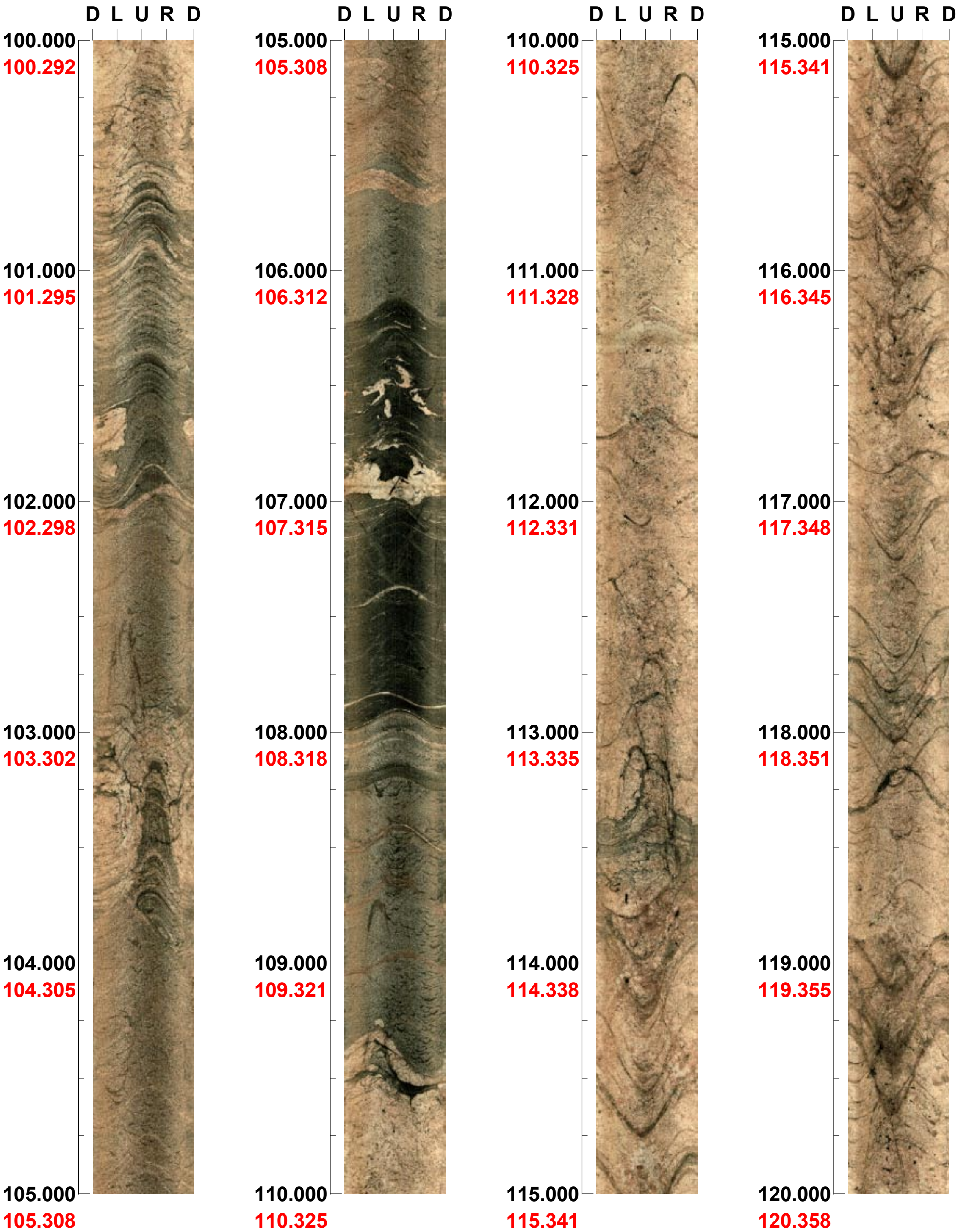
Depth range: 80.000 - 100.000 m



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

Project name: Forsmark
Bore hole No.: HFM35 **Azimuth: 32** **Inclination: -59**

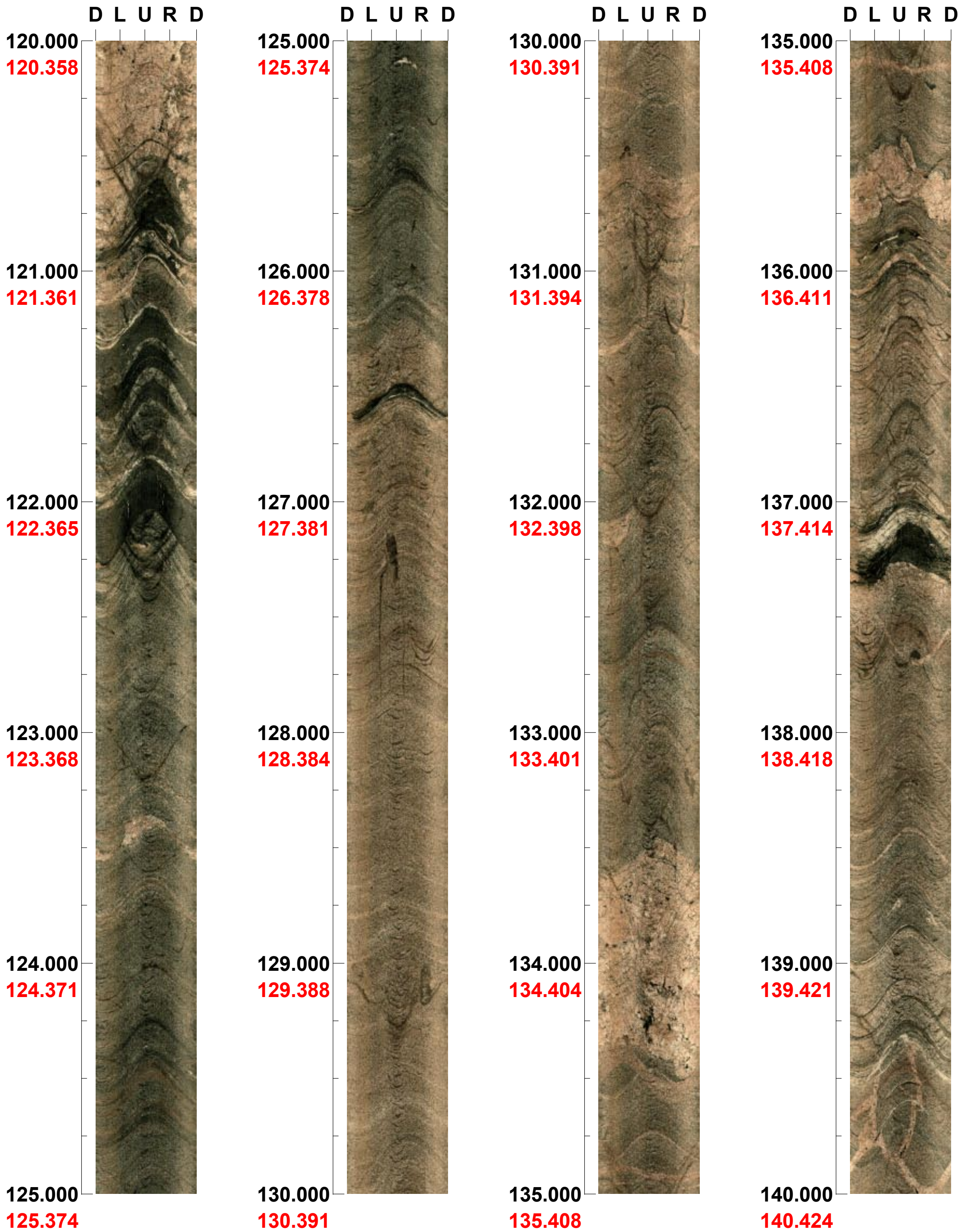
Depth range: 100.000 - 120.000 m



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

Project name: Forsmark
Bore hole No.: HFM35 **Azimuth: 32** **Inclination: -59**

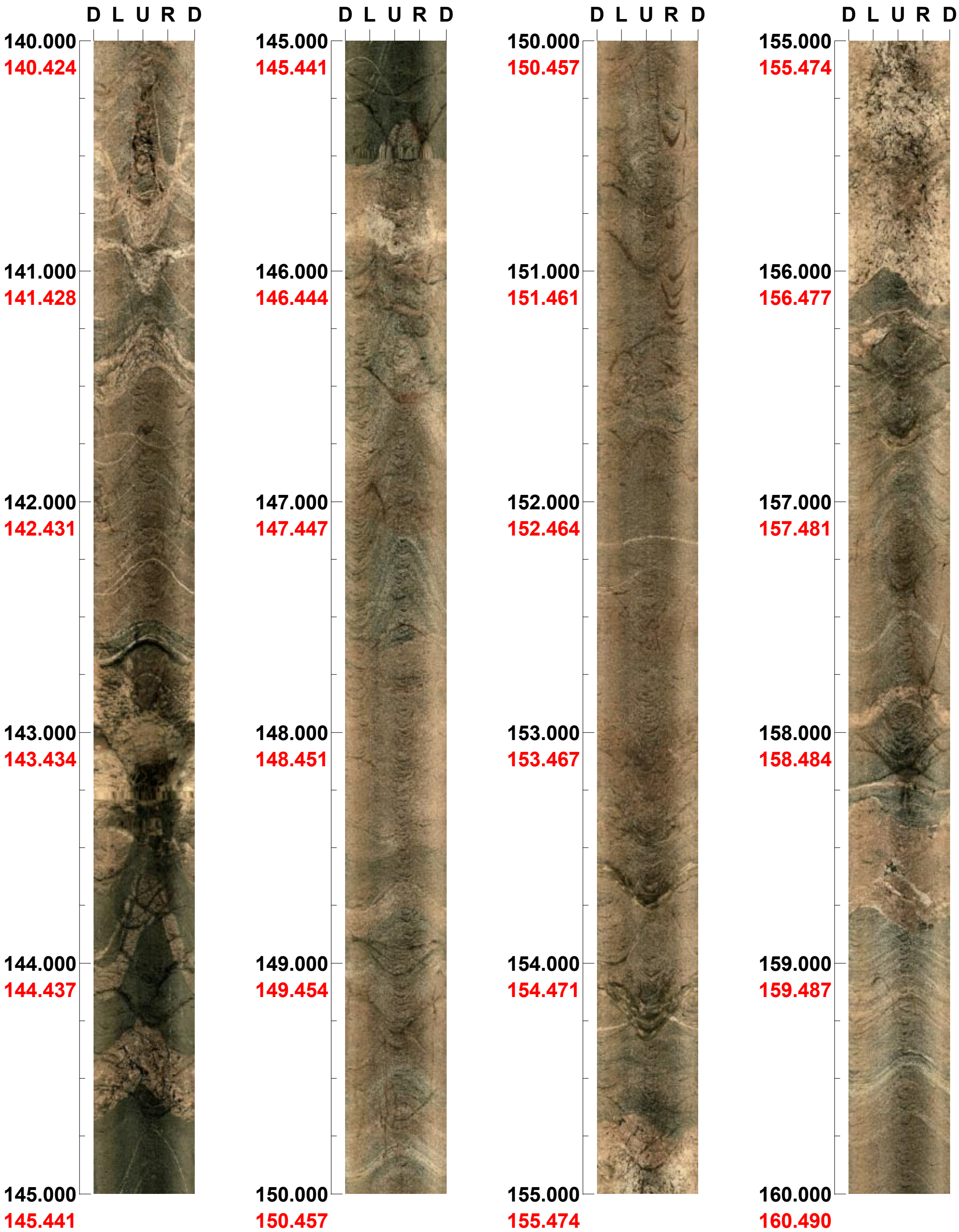
Depth range: 120.000 - 140.000 m



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

Project name: Forsmark
Bore hole No.: HFM35 **Azimuth: 32** **Inclination: -59**

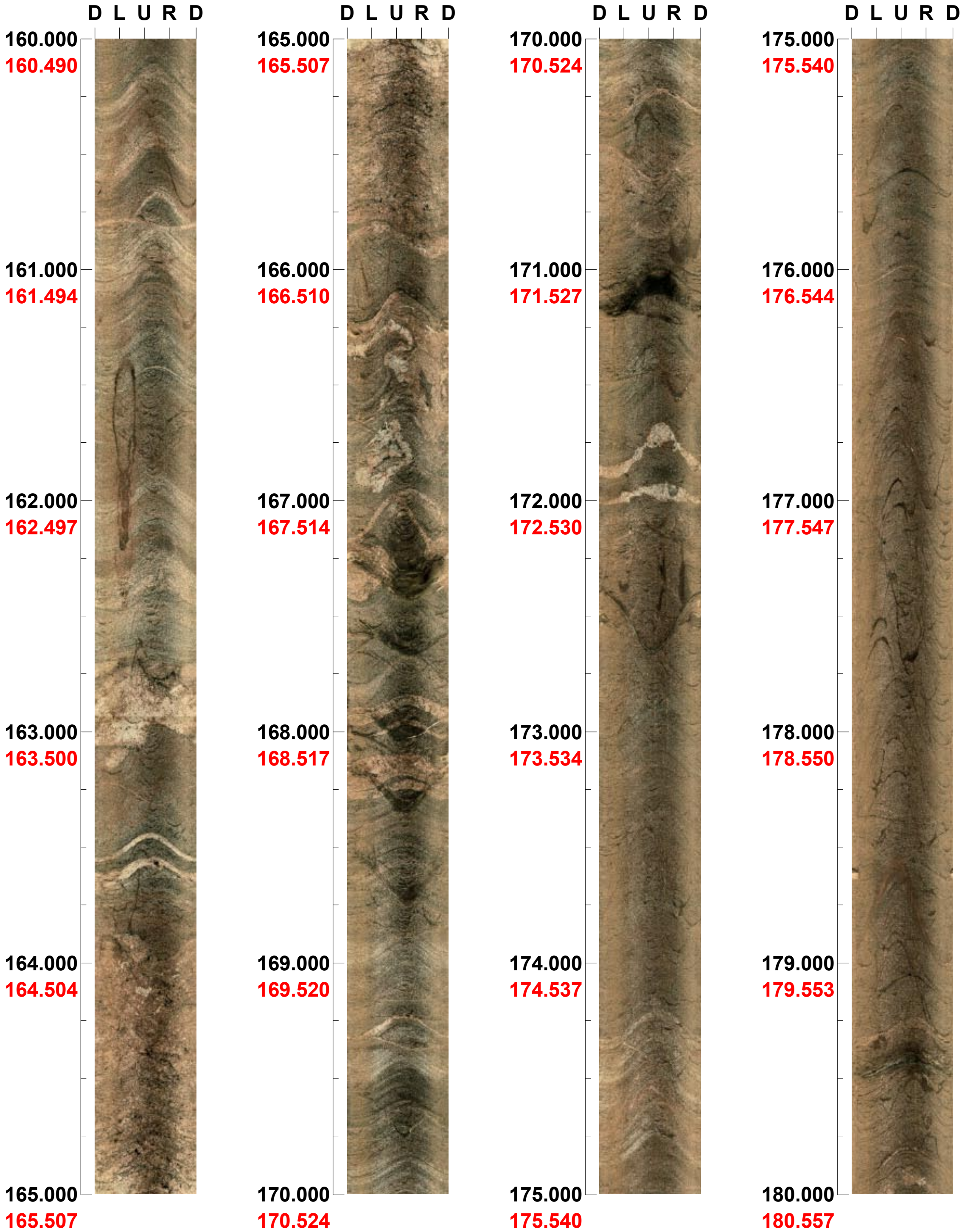
Depth range: 140.000 - 160.000 m



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

Project name: Forsmark
Bore hole No.: HFM35 **Azimuth: 32** **Inclination: -59**

Depth range: 160.000 - 180.000 m



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

Project name: Forsmark

Bore hole No.: HFM35 **Azimuth: 32** **Inclination: -59**

Depth range: 180.000 - 199.379 m

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

Appendix 6

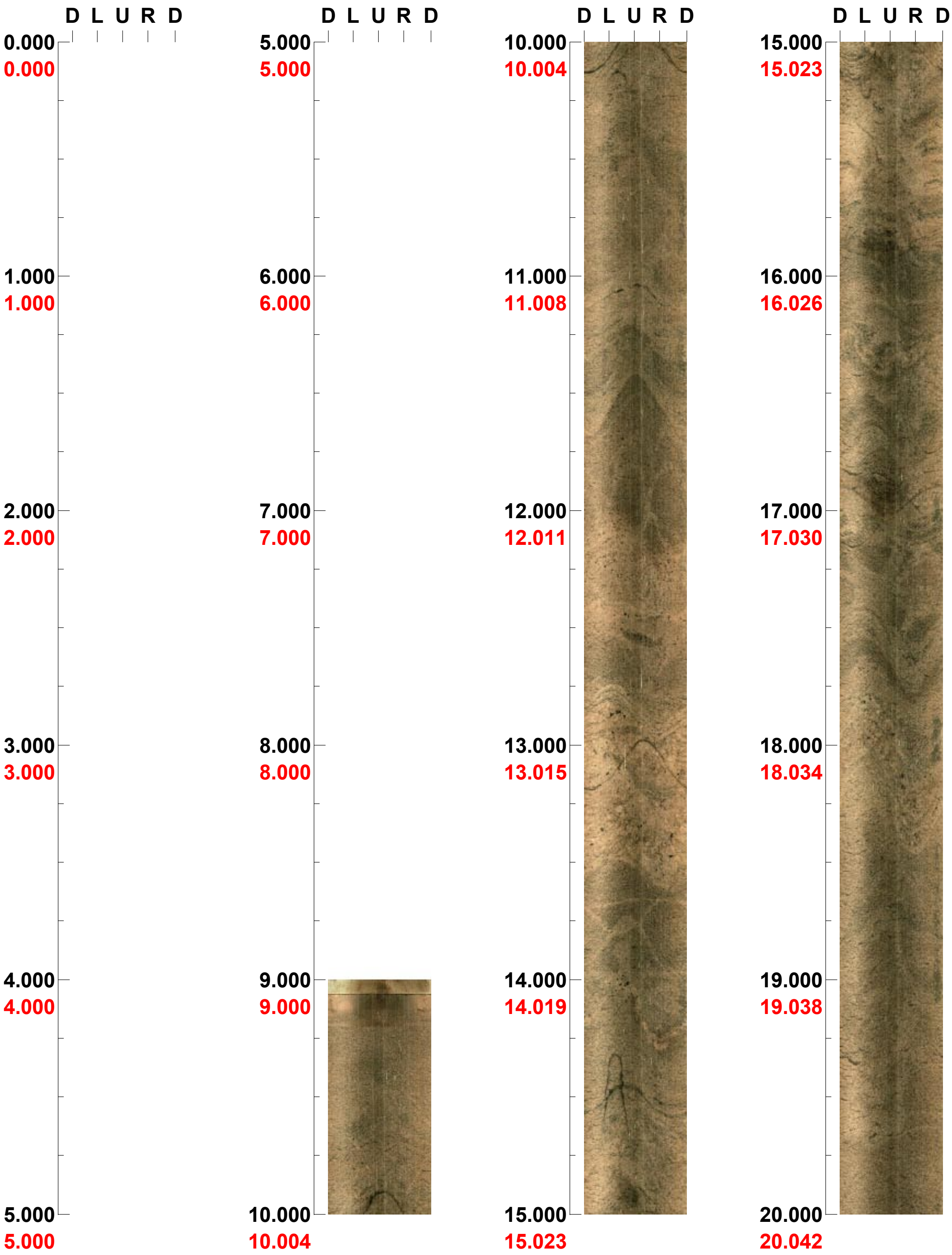
BIPS logging in HFM38. 9 to 194 m

Project name: Forsmark

Image file	: c:\work\r5537f~1\bips\hfm38\hfm38.bip
BDT file	: c:\work\r5537f~1\bips\hfm38\hfm38.bdt
Locality	: FORSMARK
Bore hole number	: HFM38
Date	: 06/07/20
Time	: 09:30:00
Depth range	: 9.000 - 194.413 m
Azimuth	: 94
Inclination	: -54
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: Forsmark
Bore hole No.: HFM38 **Azimuth: 94** **Inclination: -54**

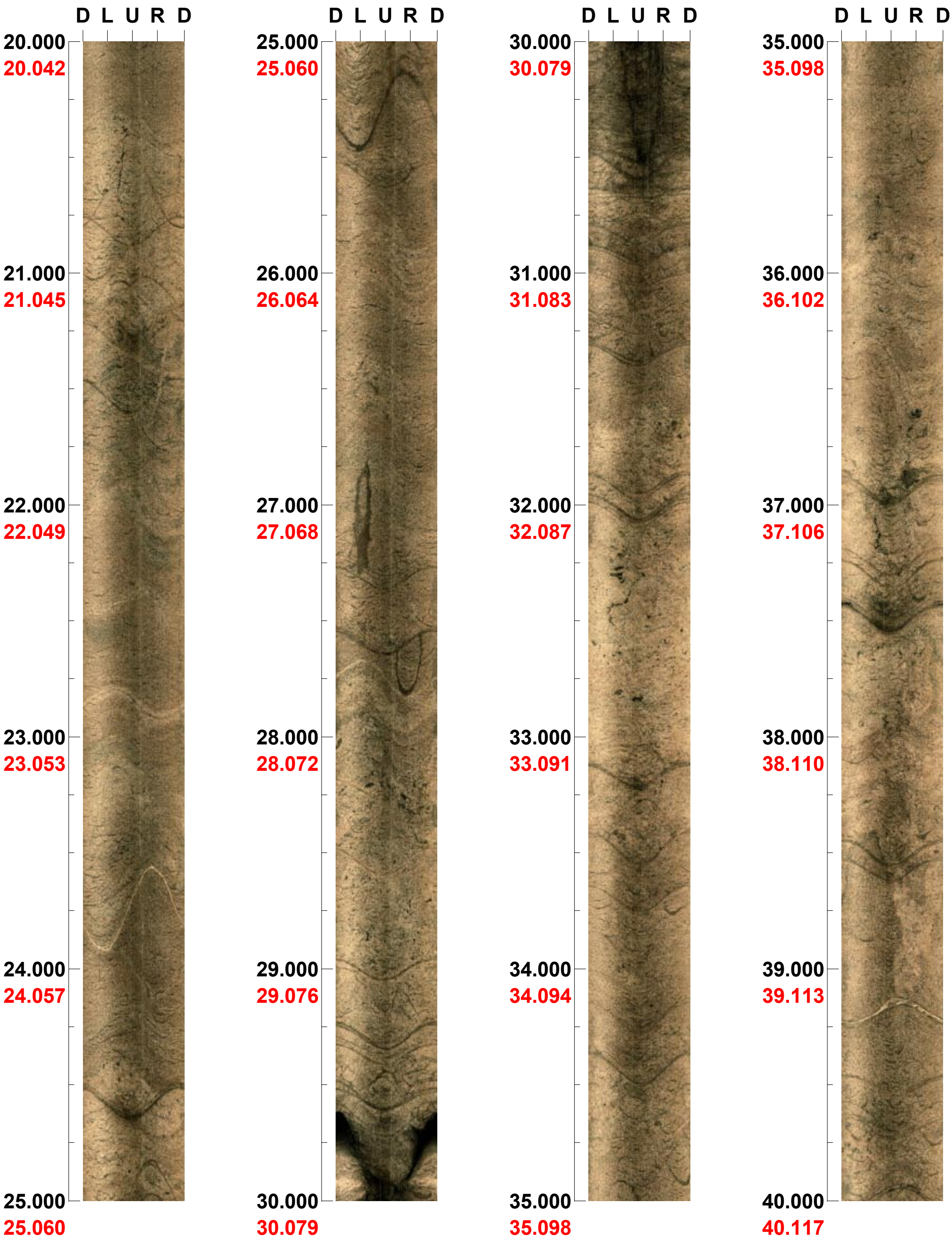
Depth range: 0.000 - 20.000 m



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

Project name: Forsmark
Bore hole No.: HFM38 Azimuth: 94 Inclination: -54

Depth range: 20.000 - 40.000 m

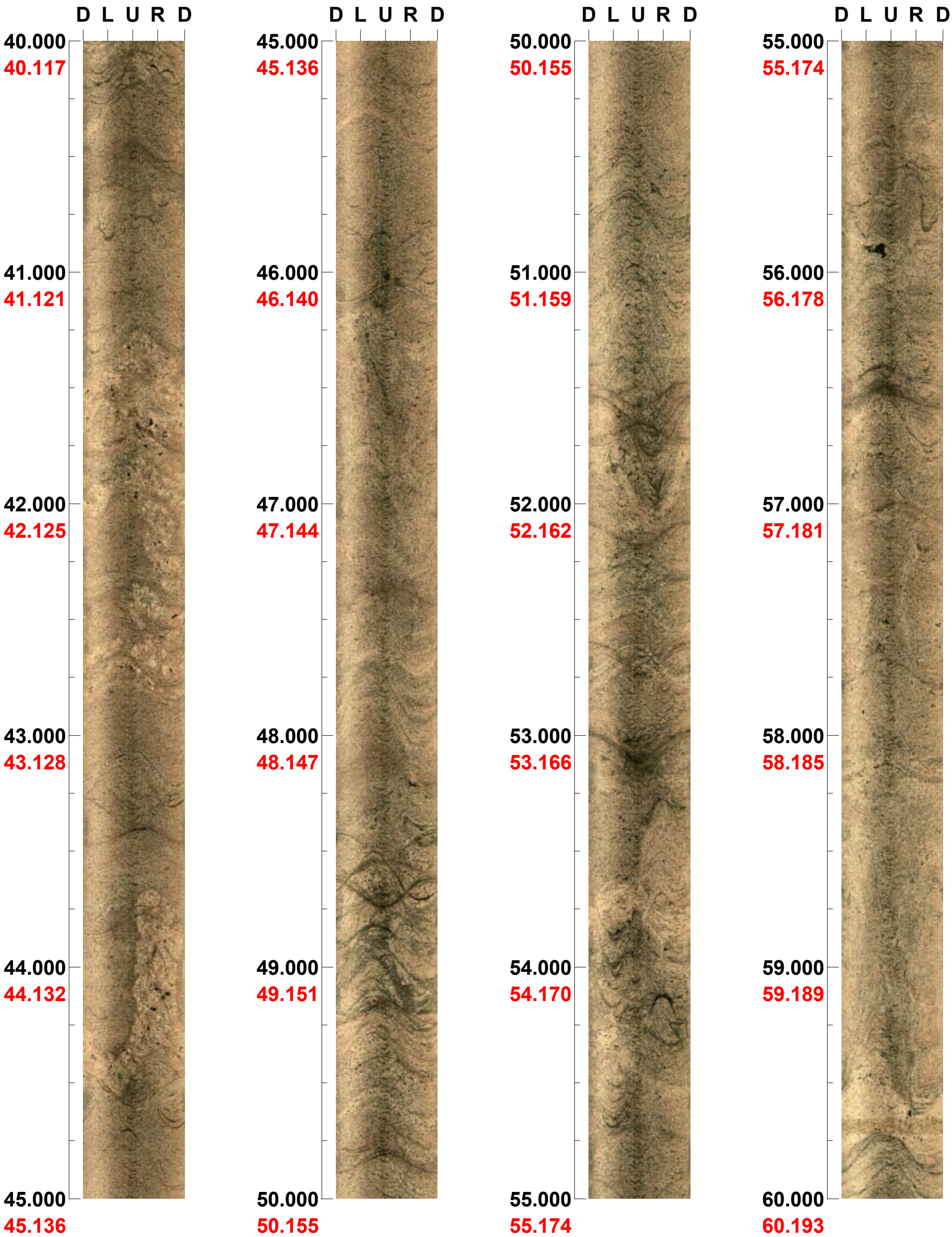


(2 / 10) Scale: 1/25 Aspect ratio: 100 %

Project name: Forsmark

Bore hole No.: HFM38 **Azimuth: 94** **Inclination: -54**

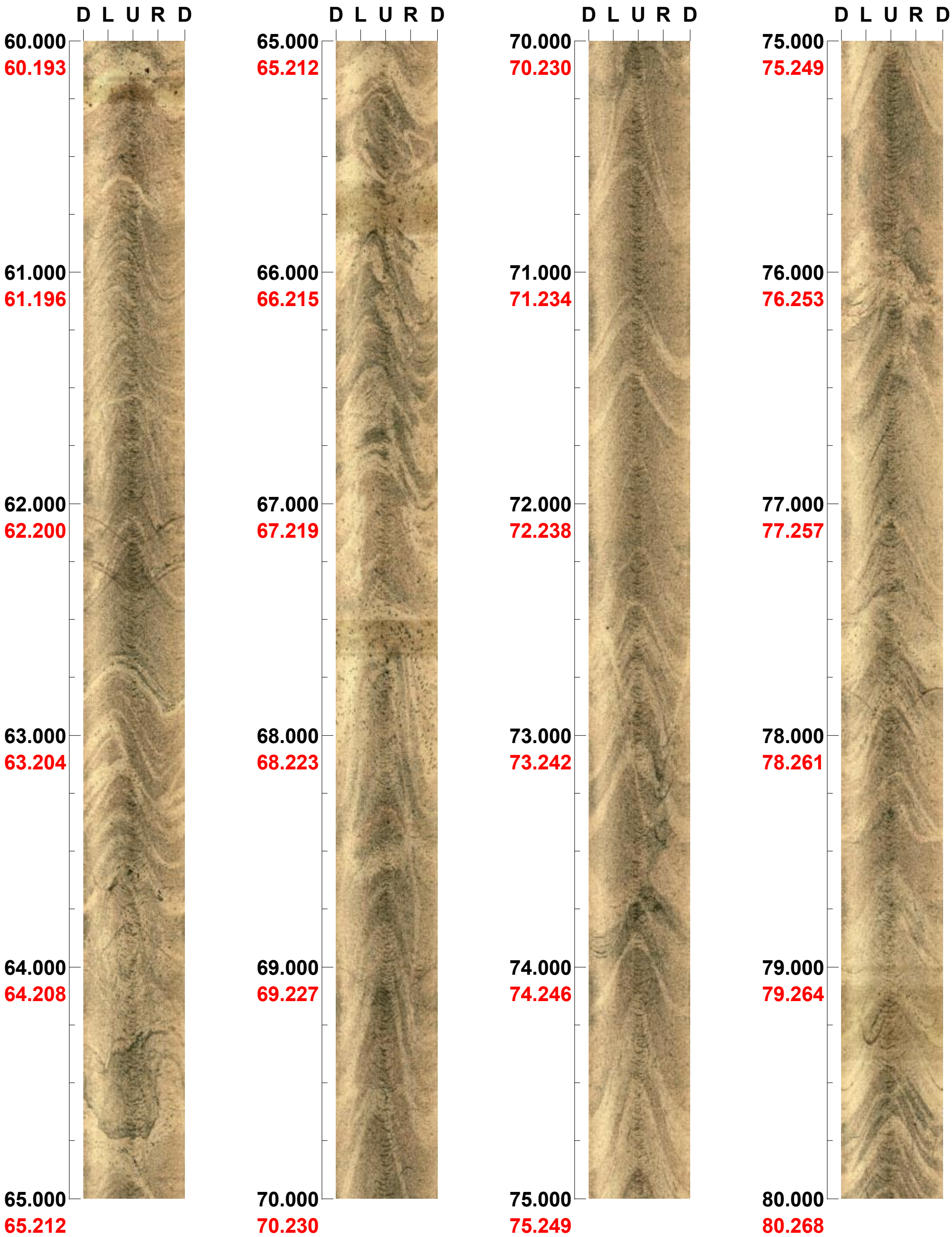
Depth range: 40.000 - 60.000 m



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

Project name: Forsmark
Bore hole No.: HFM38 **Azimuth: 94** **Inclination: -54**

Depth range: 60.000 - 80.000 m

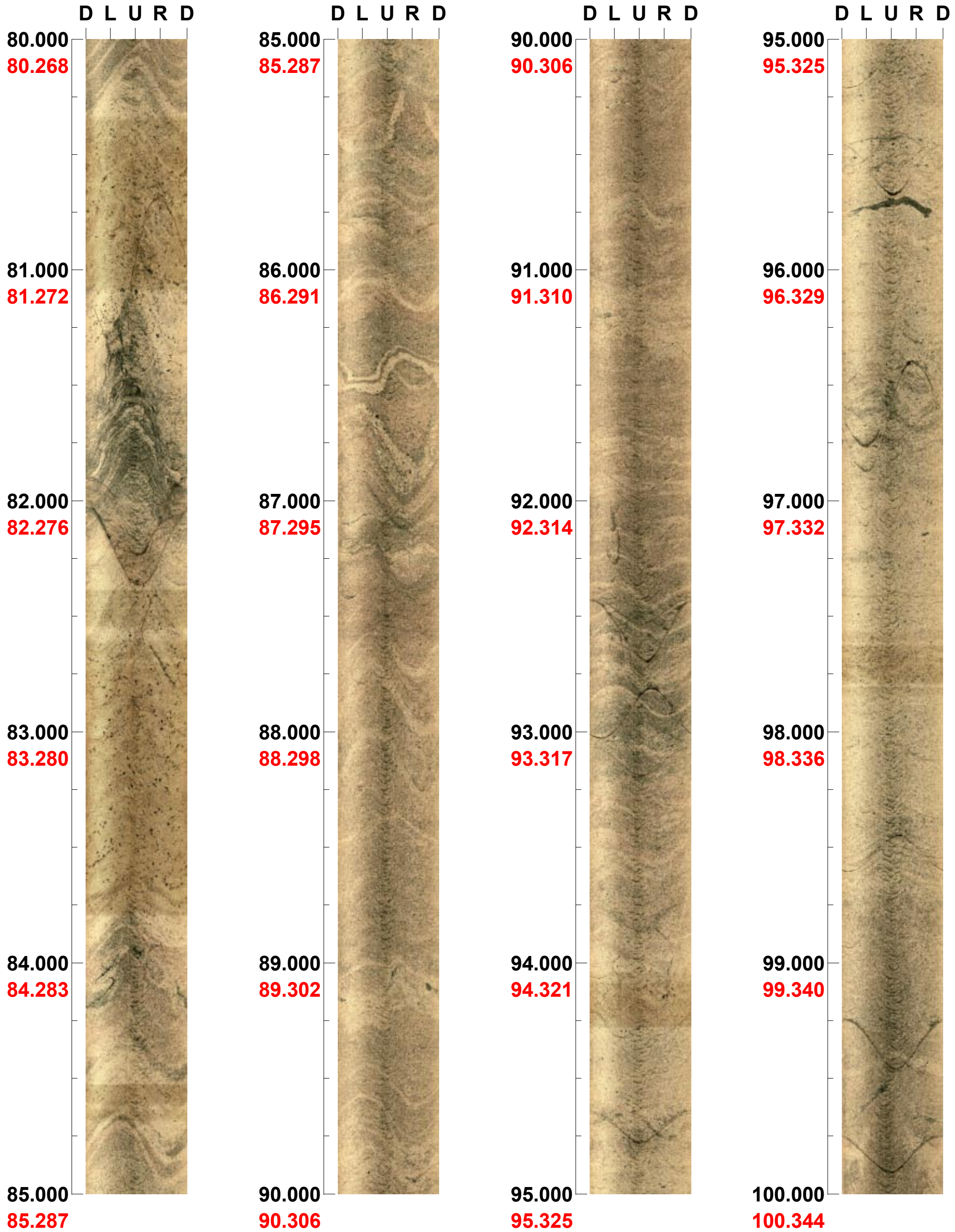


(4 / 10) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark

Bore hole No.: HFM38 **Azimuth: 94** **Inclination: -54**

Depth range: 80.000 - 100.000 m

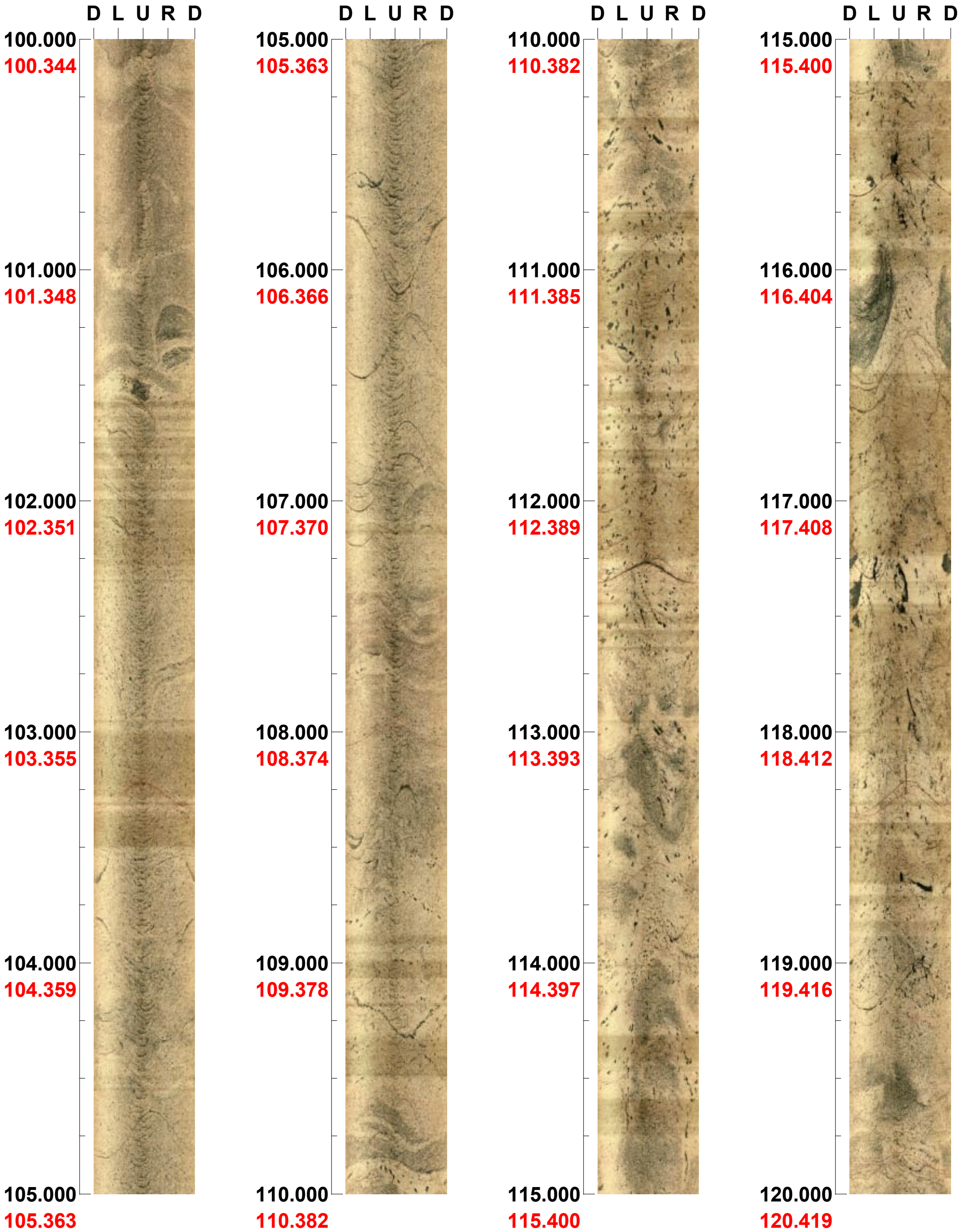


(5 / 10) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark

Bore hole No.: HFM38 **Azimuth: 94** **Inclination: -54**

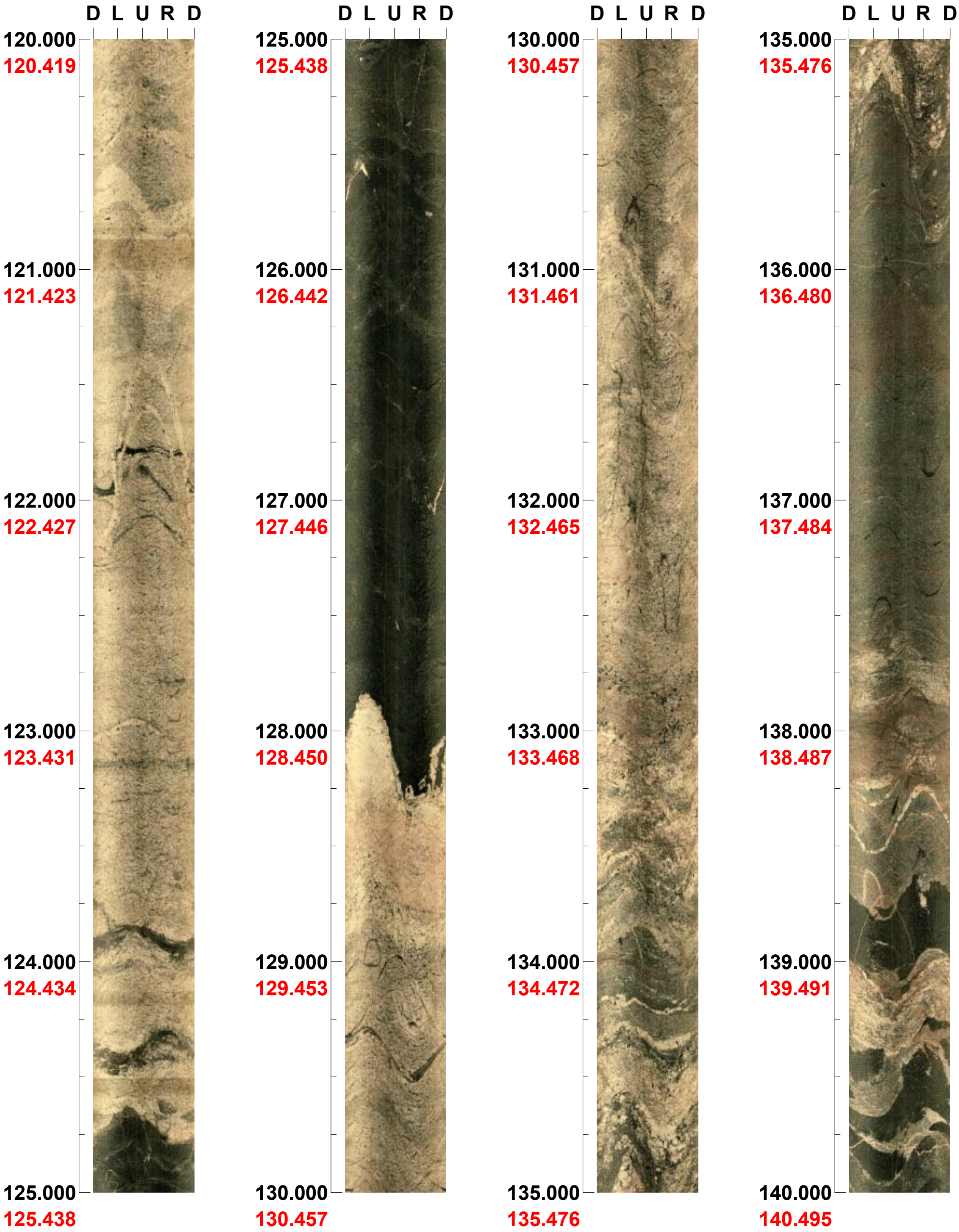
Depth range: 100.000 - 120.000 m



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

Project name: Forsmark
Bore hole No.: HFM38 **Azimuth: 94** **Inclination: -54**

Depth range: 120.000 - 140.000 m

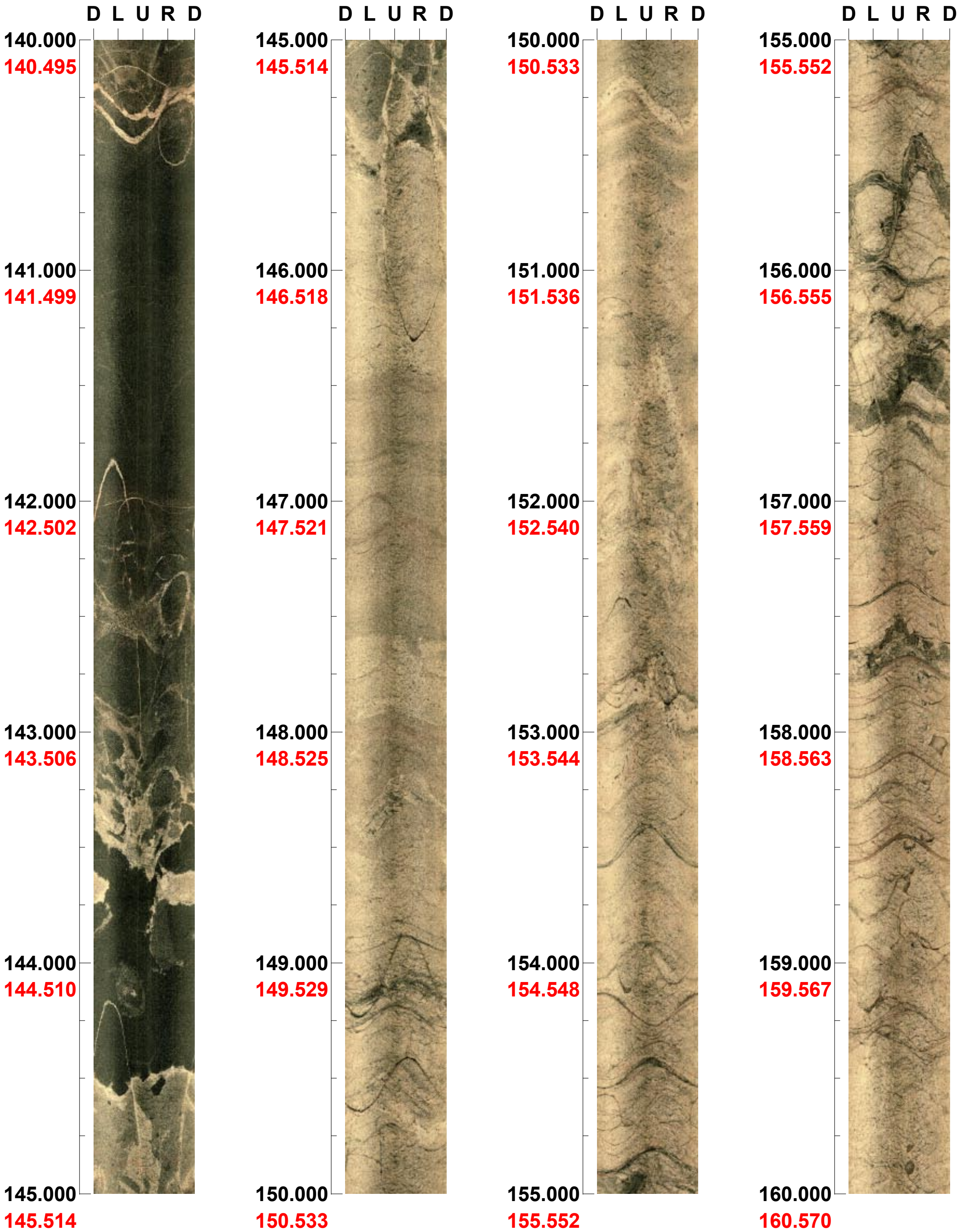


(7 / 10) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark

Bore hole No.: HFM38 **Azimuth: 94** **Inclination: -54**

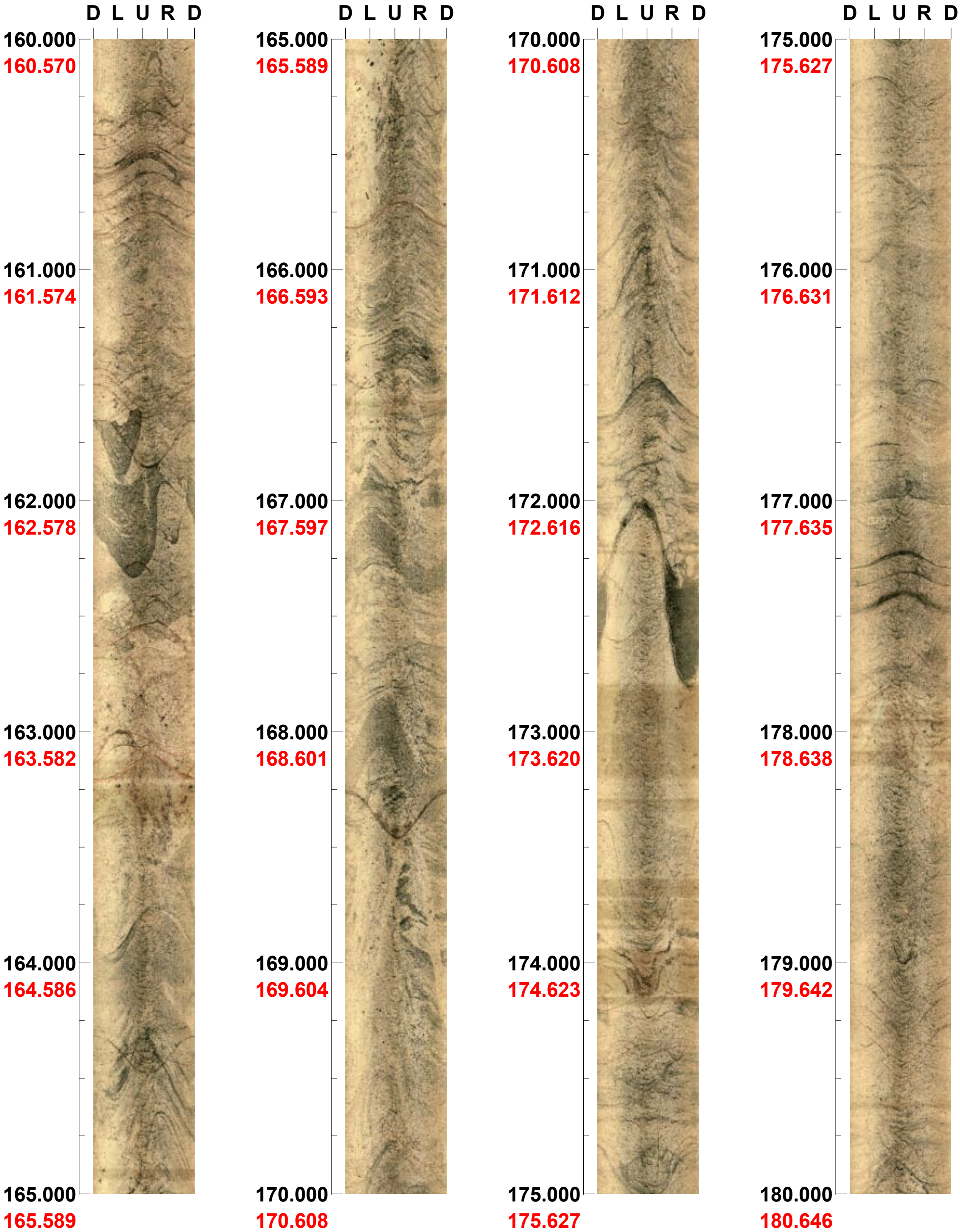
Depth range: 140.000 - 160.000 m



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

Project name: Forsmark
Bore hole No.: HFM38 **Azimuth: 94** **Inclination: -54**

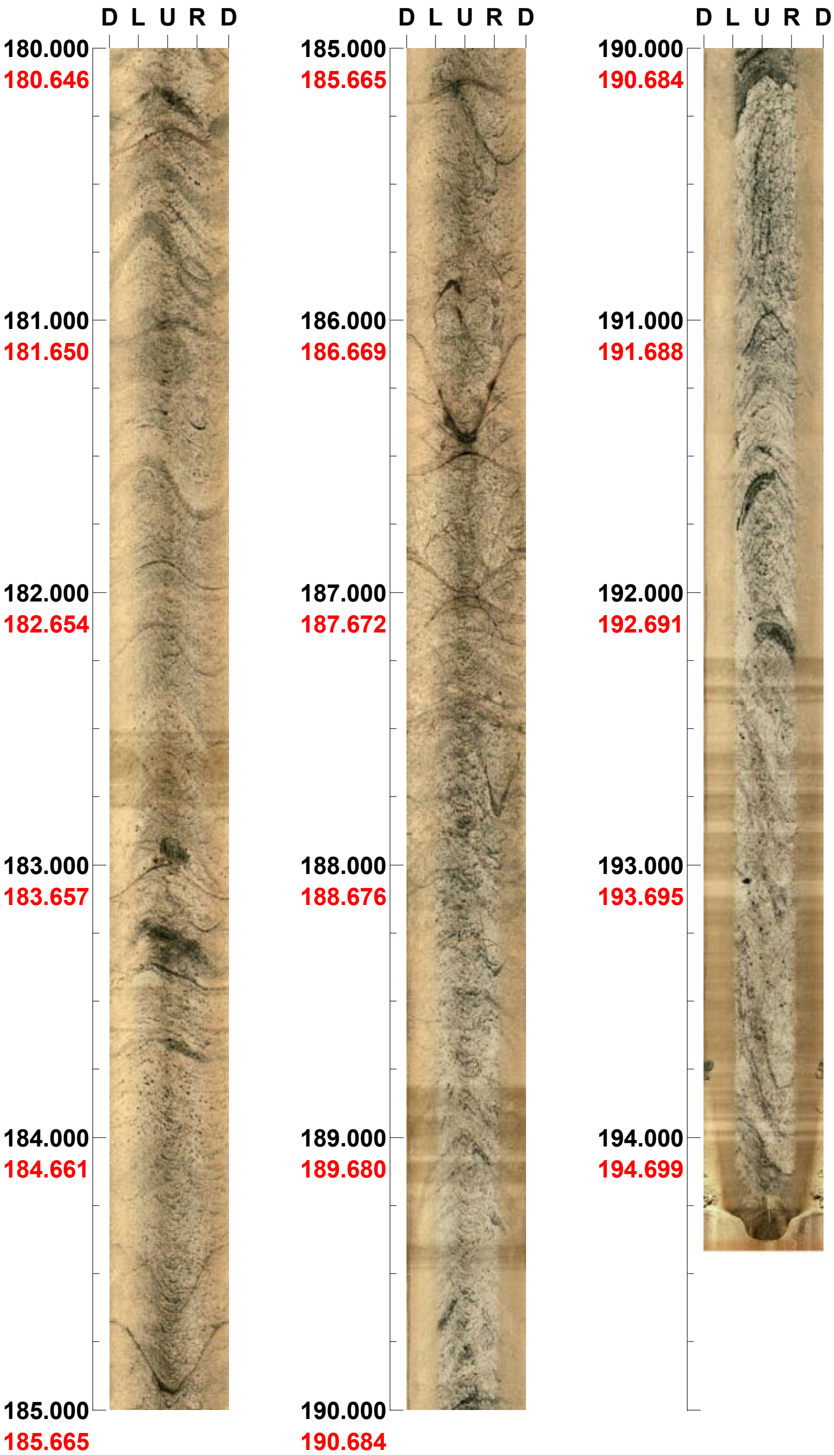
Depth range: 160.000 - 180.000 m



Project name: Forsmark

Bore hole No.: HFM38 **Azimuth: 94** **Inclination: -54**

Depth range: 180.000 - 194.413 m



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