P-04-68

Forsmark site investigation

RAMAC and BIPS logging in borehole HFM13, HFM14 and HFM15

Jaana Gustafsson and Christer Gustafsson
Malå Geoscience AB/RAYCON

April 2004

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

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Keywords: BIPS, RAMAC, Radar, TV, Geophysical logging.

Contents

1 Introduction

This document reports data gained during geophysical logging, which is one of the activities performed within the site investigation at Forsmark. The logging operations presented here include borehole radar (RAMAC) and TV-logging (BIPS) and was carried out in the percussion drilled boreholes HFM13, HFM14 and HFM15, see Table 1-1 and Figure 1-1. Borehole HFM13 was primarily drilled to investigate lineaments interpreted from an airborne geophysical survey and HFM14 and HFM15 to investigate possible fracture zones in the vicinity of drill site 5 which was the intended site for the deep cored borehole KFM05A. The boreholes were also intended for flushing water supply and for monitoring purposes.

The borehole radar measurements and BIPS measurements were conducted by Malå Geoscience AB/RAYCON during October 2003, according to activity plan AP PF 400-03-87 (SKB internal controlling document).

The applied investigation techniques comprised:

- Borehole radar with dipole radar antennas.
- Borehole TV logging with the so-called BIP-system (Borehole Image Processing System), which is a high resolution, side viewing, colour borehole TV system.

Table 1-1. Investigated boreholes.

Borehole ID	Azimuth (degrees from north)	Inclination (degrees from horizontal)	Length (metres)	Investigated section (metres)
HFM13	51	59	176	10–170
HFM14	332	60	150	0–150
HFM15	314	44	100	0–99

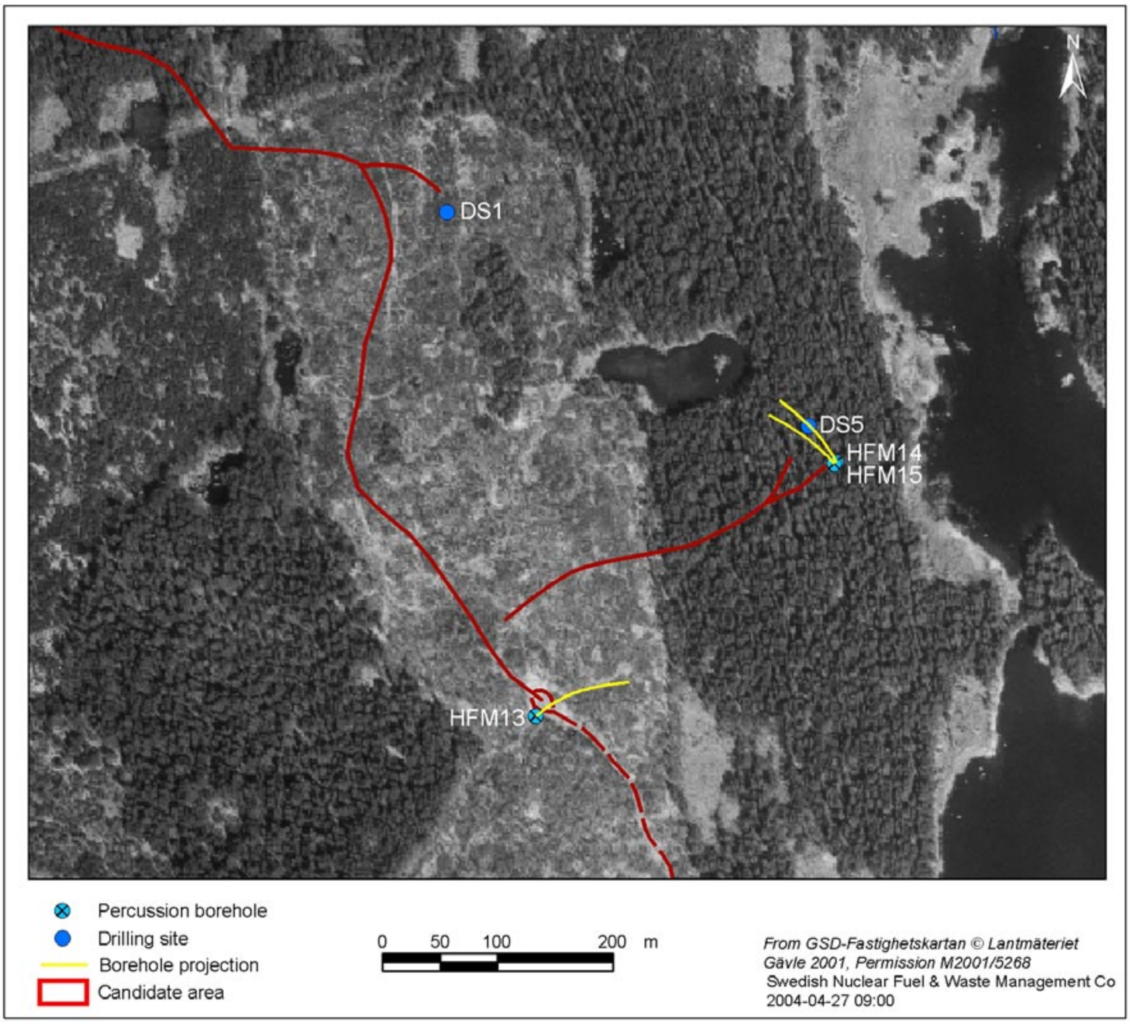


Figure 1-1. *Location of the investigated boreholes. HFM13, HFM14 and HFM15 in the Forsmark area. DS1 and DS5 is drill site 1 and 5, respectively.*

2 Objective and scope

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

This report describes the equipment used as well the measurement procedures and data gained.

3 Equipment

3.1 Borehole radar – RAMAC

The RAMAC GPR system owned by SKB is fully digital, and emphasis has been laid on high survey speed and smooth field operation. The system operates dipole and directional antennas (see Figure 3-1). A system description is given in the method description "Metodbeskrivning för borrhålsradar" (SKB MD 252.020, Version 1.0).

The borehole radar system consists of a transmitter and a receiver. During operation, an electromagnetic pulse, within the frequency range 20 to 250 MHz, is emitted and penetrates the bedrock. The resolution and penetration of the radar waves depend on the antenna frequency used. A low antenna frequency results in lower resolution but higher penetration rate compared to a higher frequency. If a feature, e.g. a water-filled fracture, with anomalous electrical properties compared to the surrounding is encountered, the pulse is reflected back to the receiver and recorded.

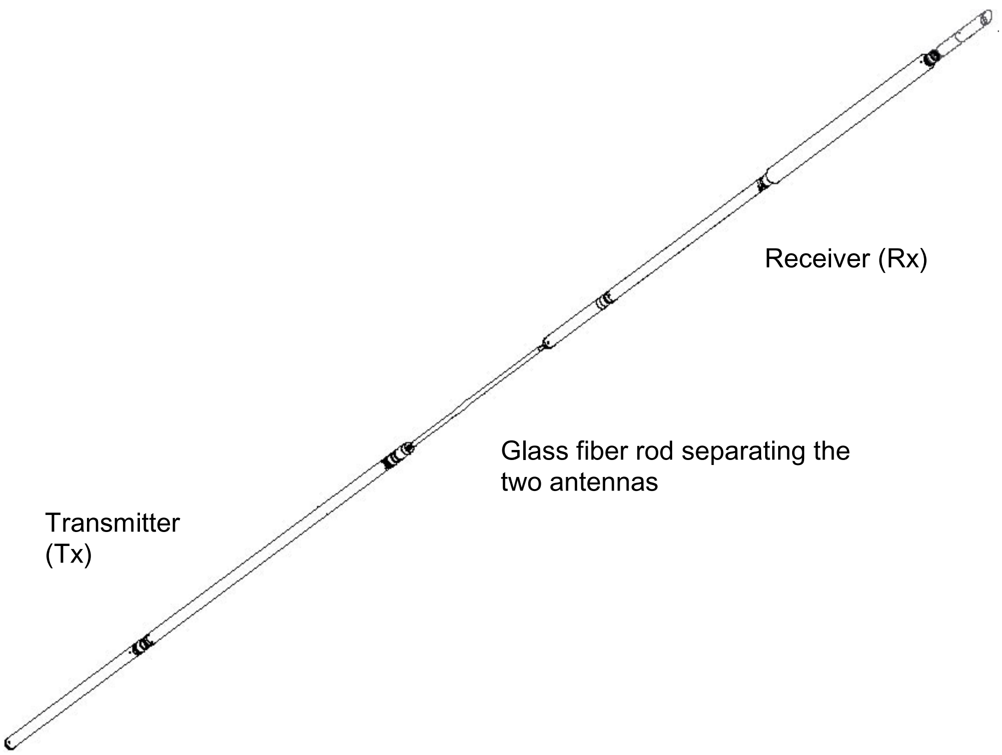


Figure 3-1. *Example of a borehole antenna.*

3.2 TV-Camera – BIPS

The BIPS 1500 system used is owned by SKB and described in the method description "Metodbeskrivning för TV-loggning med BIPS" (SKB MD 222.006, Version 1.0). 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 BIPS images can be orientated by means of to two alternative methods, either with a compass (vertical and sub-vertical boreholes) or with a gravity sensor (inclined boreholes).

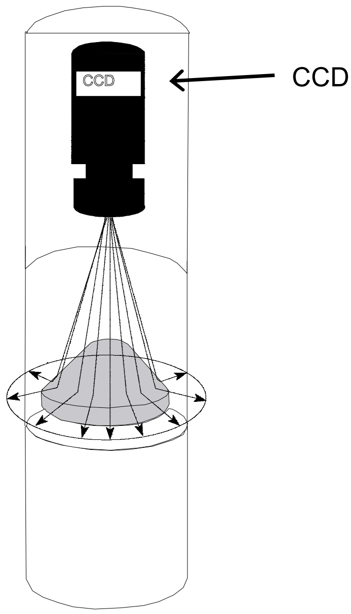


Figure 3-2. *The BIP-system. Illustration of the conical mirror scanning.*

4 Execution

4.1 Data aquisition

RAMAC

For the borehole radar measurements, dipole antennas were engaged. The dipole antennas used have central frequencies of 20 MHz, 100 MHz and 250 MHz respectively.

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

For detailed information see the SKB MD 252.020 for method description and MD 600.004 ("Instruktion för rengöring av borrhålsutrustning och viss markbaserad utrustning") for cleaning of equipment.

Information on the system settings for the different antennas used in the investigation of HFM13, HFM14, and HFM15 is presented in Table 4-1 to 4-3 below.

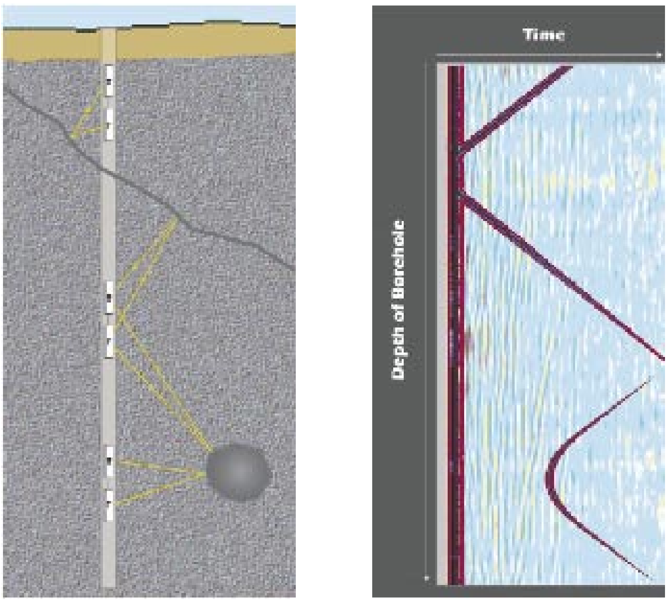


Figure 4-1. *The principle of radar borehole reflection survey (left) and a resulting radargram (right).*

Table 4-1. Radar logging information from HFM13.

Site:	**Forsmark**	**Logging company:**	**RAYCON**	
BH:	**HFM13**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Operators:	**CG/JA**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Logging date:	03-10-22	03-10-22	03-10-22
	Reference:	T.O.C.	T.O.C.	T.O.C.
	Sampling frequency (MHz):	2588	951	257
	Number of samples:	619	518	518
	Number of stacks:	Auto	Auto	Auto
	Signal position:	–0.317	–0.32	–1.43
	Logging from (m):	11.5	12.6	16.25
	Logging to (m):	173.5	172.7	168.7
	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 HFM14.

Site:	**Forsmark**	**Logging company:**	**RAYCON**	
BH:	**HFM14**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Operators:	**CG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Logging date:	03-10-20	03-10-20	03-10-20
	Reference:	T.O.C.	T.O.C.	T.O.C.
	Sampling frequency (MHz):	2588	951	257
	Number of samples:	Auto	Auto	Auto
	Number of stacks:	619	518	518
	Signal position:	–0.317	–0.32	–1.43
	Logging from (m):	1.5	2.6	6.25
	Logging to (m):	147.4	146.4	142.3
	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 HFM15.

Site:	**Forsmark**	**Logging company:**	**RAYCON**	
BH:	**HFM15**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Operators:	**CG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Logging date:	03-10-20	03-10-20	03-10-20
	Reference:	T.O.C.	T.O.C.	T.O.C.
	Sampling frequency (MHz):	2588	951	257
	Number of samples:	619	518	518
	Number of stacks:	Auto	Auto	Auto
	Signal position:	–0.317	–0.32	–1.43
	Logging from (m):	1.5	2.6	6.25
	Logging to (m):	97.4	96.4	92.2
	Trace interval (m):	0.1	0.2	0.25
	Antenna separation (m):	2.4	3.9	10.05

BIPS

For detailed information on BIPS measurements see the SKB MD 222.006 for a method description and MD 600.004 for cleaning of equipment.

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

The boreholes investigated are all inclined, c. 45–60 degrees from horizontal, and, therefore, the gravity sensor was used for the orientation of the BIPS camera.

Depth measurements

The depth recording for the RAMAC and BIPS systems is taken care of by a measuring wheel mounted on the cable winch. In core drilled boreholes, there are reference marks at approximately every 50 metres. When the BIPS logging is made, the logging cable is marked with a piece of scotch tape for every single depth mark. These marks are then used for controlling the depth of the RAMAC logging. The same marks are used to controll both BIPS and RAMAC loggings in percussion drilled boreholes.

As the measured boreholes are less than 200 m deep, the divergences in depth measurements are assumed to be very small.

4.2 Analyses and Interpretation

Radar

The results from radar measurements are commonly presented in the form of a radargram, where the position of the probes is displayed along one axis and the propagation along the other. The amplitude of the received signal is shown 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 signal.

The data presented in this report is related to the "measurement point", which is defined to be the central point between the transmitter and the receiver antenna.

In the reflection mode, borehole radar primarily offer a high-resolution image of the rock mass, visualizing the geometry of plane structures (contacts between rock units of different lithology, thin marker beds, fractures, fracture zones etc), which may or may not intersect the borehole, or showing the presence of local features (cavities, lenses etc) around the borehole.

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 consistent in the rock volume investigated.

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 a borehole at drill site No. 1 (the percussion drilled borehole HFM03) while moving the receiver downwards in the borehole. The result is plotted in Figure 4-2. The calculation shows a velocity of 128 m/micro second. The velocity measurement was performed with the 100 MHz antenna /1/.

The visualization of data in Appendix 1 to 3 is made with REFLEX, a Windows based processing software for filtering and analysis of radar data. The processing steps are shown in Table 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 Table 5-4 to 5-6 and also visible on the radargrams in Appendix 1 to 3.

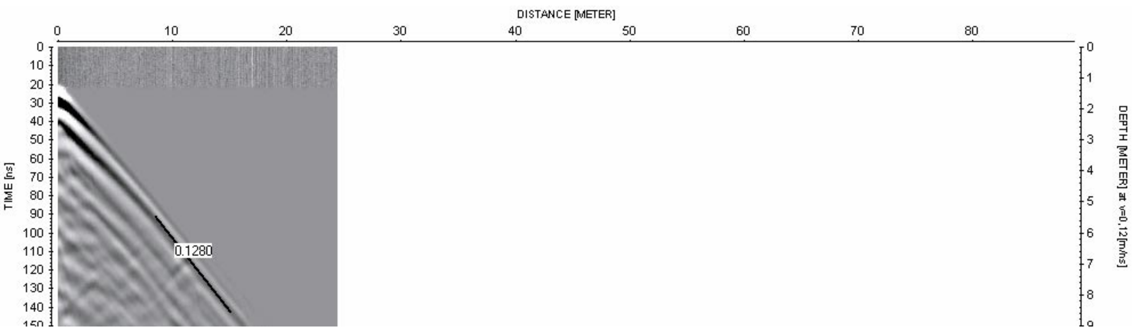


***Figure 4-2.** Results from velocity measurements in HFM03 /1/.*

Table 4-4. Processing steps for borehole radar data from HFM13.

Site:	**Forsmark**	**Logging company:**	**RAYCON**	
BH:	**HFM13**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Interpret:	**JG**	**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
		Mean filter		

Table 4-5. Processing steps for borehole radar data from HFM14.

Site:	**Forsmark**	**Logging company:**	**RAYCON**	
BH:	**HFM14**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Interpret:	**JG**	**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 HFM15.

Site:	**Forsmark**	**Logging company:**	**RAYCON**	
BH:	**HFM15**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Interpret:	**JG**	**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

BIPS

The visualization of data (see Appendix 4 to 6) is made with BDPP, a Windows based processing software for filtering, presentation and analyzing of BIPS data. No fracture mapping based on the BIPS images has been performed.

5 Results and data delivery

The results from the radar and BIPS measurements were delivered as raw data (*.bip-files) on CD-ROMs to SKB together with printable BIPS pictures in *.pdf format before the field crew left the investigation site. The information on the measurements is registered in SICADA and the VHS-tapes, MO-disks and CD-ROMs are stored by SKB.

RAMAC radar data has been delivered as raw data (fileformat *.rd3 or *.rd5) with corresponding information files (file format *.rad), whereas the data processing steps and results are presented in this report. Relevant information, including the interpretation presented in this report, has been inserted into the SKB database SICADA.

The SICADA reference to the BIPS and RAMAC logging activities in HFM13, HFM14 and HFM15 is Field note Forsmark No. 193.

5.1 RAMAC logging

The results of the interpretation of the radar measurements are presented in Table 5-1 to 5-6. Radar data is also visualized in Appendix 1 to 3. It should be remembered that the images in Appendix 1 to 3 are only composite pictures of all events, 360 degrees around the borehole, and do not reflect the true orientation of the structures.

Only the major, clearly visible structures are interpreted in RadinterSKB. A number of minor structures were encountered as well as indicated in Appendix 1 to 3.

The data quality, as seen in Appendix 1 to 3, is relatively satisfying. However, the measurements in parts of the boreholes suffer from deteriorated quality due to increased electrical conductivity in the rock or borehole fluid. A conductive environment entails attenuation of the radar waves, resulting in decreased penetration. See for example the 250 MHz data in Appendix 1 (HFM13). The conductive environment decreases the possibility to map the structures in the borehole.

As also seen in Appendix 1 to 3, the resolution and penetration of the radar waves depend of the antenna frequency used. A high frequency will result in a high resolution but a lower penetration rate compared to a lower frequency.

Table 5-1. Identified structures as a function of depth in HFM13.

Depth (m)	No. of structures
10–30	1
30–40	5
40–50	1
50–60	1
60–70	2
70–80	3
80–90	3
90–100	1
100–110	2
110–120	1
120–130	2
130–140	-
140–150	2
150–160	2
160–170	2
170–180	2
180–190	-
190–200	-
200–	2

Table 5-2. Identified structures as a function of depth in HFM14.

Depth (m)	No. of structures
0–20	3
20–30	2
30–40	1
40–50	-
50–60	3
60–70	5
70–80	2
80–90	2
90–100	2
100–110	4
110–120	1
120–130	3
130–140	1
140–150	2
150–160	3
160–170	-
170–180	1
180–190	-
190–200	1
200–	2

Table 5-3. Identified structures as a function of depth in HFM15.

Depth (m)	No. of structures
0–20	2
20–30	2
30–40	-
40–50	2
50–60	1
60–70	4
70–80	2
80–90	2
90–100	2
100–110	-
110–120	1
120–130	-
130–140	-
140–150	-
150–160	-
160–170	1
170–180	-
180–190	1

Table 5-4 to 5-6 summarises the interpretation of radar data from HFM13, HFM14 and HFM15. Many structures can be identified in the data from more than one antenna frequency.

Table 5-4. Model information from dipole antennas 20, 100 and 250 MHz, HFM13.

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

Site: **Forsmark**
Borehole name: **HFM13**
Nominal velocity (m/μs): **128.00**

Object type	Name	Intersection depth	Intersection angle
PLANE	A	19.9	55
PLANE	B	31.4	49
PLANE	C	33.5	50
PLANE	D	35.8	57
PLANE	E	37.2	74
PLANE	BB	37.8	50
PLANE	EE	49.6	44
PLANE	G	58.4	83
PLANE	H	60.3	63
PLANE	F	62.6	37
PLANE	I	74.5	51
PLANE	II	75.4	68
PLANE	1	75.4	24
PLANE	Q	84.4	26
PLANE	5	87.1	39
PLANE	J	90.0	52
PLANE	JJ	96.9	60
PLANE	KK	100.6	50
PLANE	K	104.3	44
PLANE	4	109.8	50
PLANE	L	121.6	48
PLANE	M	126.8	50
PLANE	P	143.5	54
PLANE	O	145.1	35
PLANE	R	151.4	54
PLANE	N	152.1	17
PLANE	T	159.0	55
PLANE	U	160.6	48
PLANE	S	164.0	58
PLANE	V	172.6	47
PLANE	2	205.9	39
PLANE	3	227.8	7

Names in table according to Appendix 1.

Table 5-5. Model information from dipole antennas 20, 100 and 250 MHz, HFM14.

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

Site:	**Forsmark**
Borehole name:	**HFM14**
Nominal velocity (m/μs):	**128.00**

Object type	Name	Intersection depth	Intersection angle
PLANE	10	–38.8	65
PLANE	A	3.2	66
PLANE	AA	4.8	29
PLANE	AAA	6.7	75
PLANE	B	21.6	79
PLANE	BB	23.3	89
PLANE	C	26.1	78
PLANE	E	39.1	36
PLANE	G	50.3	58
PLANE	F	51.2	25
PLANE	H	56.4	68
PLANE	6	63.6	54
PLANE	J	66.2	32
PLANE	K	66.5	65
PLANE	D	68.9	17
PLANE	L	69.2	80
PLANE	II	76.4	16
PLANE	III	76.6	44
PLANE	I	82.8	17
PLANE	WW	86.3	51
PLANE	7	95.7	50
PLANE	8	99.3	55
PLANE	MM	101.4	63
PLANE	M	102.8	56
PLANE	N	105.8	60
PLANE	O	106.3	28
PLANE	1	116.5	42
PLANE	P	120.1	78
PLANE	QQ	124.5	83
PLANE	Q	126.7	68
PLANE	9	133	63
PLANE	S	144.6	54
PLANE	R	146.5	60
PLANE	4	151.6	41
PLANE	V	151.7	49
PLANE	T	154.1	29
PLANE	3	175.9	48
PLANE	2	190.6	54
PLANE	U	203.2	6
PLANE	5	240.6	23

Names in table according to Appendix 2.

Table 5-6. Model information from dipole antennas 20, 100 and 250 MHz, HFM15.

RADINTER MODEL INFORMATION (20, 100 and 250 MHz Dipole Antennas)			
Site:		**Forsmark**	
Borehole name:		**HFM15**	
Nominal velocity (m/µs):		**128,00**	
Object type	**Name**	**Intersection depth**	**Intersection angle**
PLANE	AA	3.9	51
PLANE	AAA	6	55
PLANE	A	11.3	65
PLANE	B	23.3	68
PLANE	C	25.9	66
PLANE	CC	27	69
PLANE	E	42.6	41
PLANE	EE	44.5	49
PLANE	4	53.9	60
PLANE	F	64.8	54
PLANE	D	64.9	45
PLANE	6	66.7	53
PLANE	H	68.5	42
PLANE	5	71.2	76
PLANE	G	73.1	49
PLANE	I	82.3	54
PLANE	J	86.9	49
PLANE	7	94.2	54
PLANE	K	98.5	52
PLANE	1	115.7	42
PLANE	3	166.7	34
PLANE	2	186.2	11

Names in table according to Appendix 3.

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 material. A decrease in this amplitude may indicate fracture zones, clay or rock volumes with increased water content. The decrease in amplitude is seen for the following sections in HFM13:

Depth (m)
20
32
45
55–60
75
85–90
100–110
150
160–

For HFM14:

Depth (m)
20–25
55–60
65–80
80–85
95
100–105
125

And for HFM15:

Depth (m)
10
15
20–30
65–70
70–75
85–90
95

5.2 BIPS logging

To get the best possible depth accuracy, the BIPS images are adjusted to the reference labels on the logging cable. The experience during the IPLU work is that these labels differ very little compared to the results from operations in core drilled boreholes. At present, the cable is labelled at 110, 150 and 200 metres.

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 borehole. The resulting images displayed with no difference regarding the colours and focus of the images. Results of the test loggings were included in the delivery of the raw data.

The logging in HFM13 was performed 03-10-21. The data was collected a couple of weeks after the drilling and the water conditions were good. The only quality problem is mud that covers the lowermost part of the borehole wall from the casing shoe down to about 80 meter. After 80 meter the images are almost as perfect as can be expected in percussion drilled boreholes, see Figure 5-1.

The logging in HFM14 was performed 03-10-21. The results are the best ones obtained during the logging campaign, see Figure 5-2.

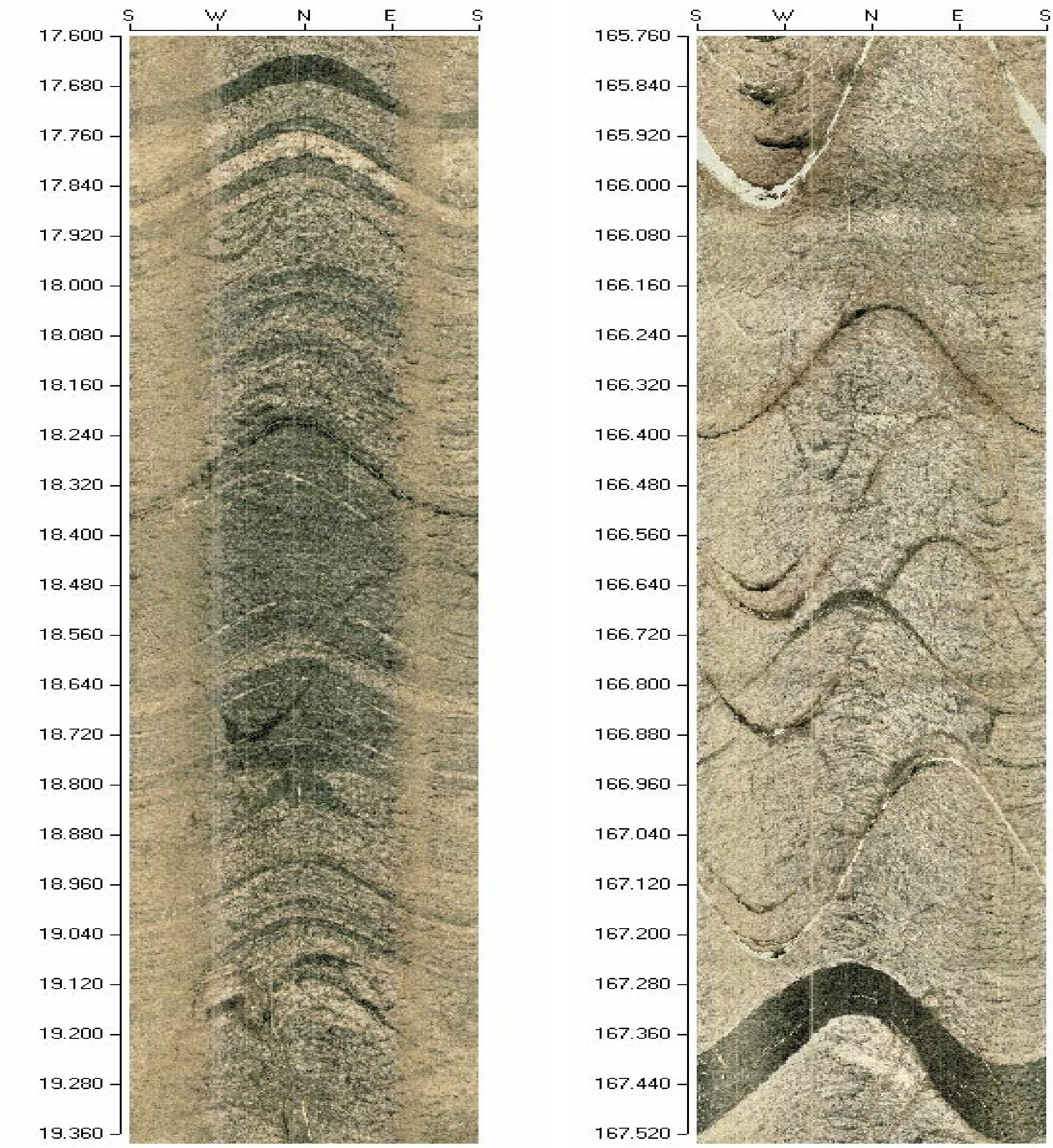


Figure 5-1. *Differences in the image quality between the top and bottom part of borehole HFM13.*

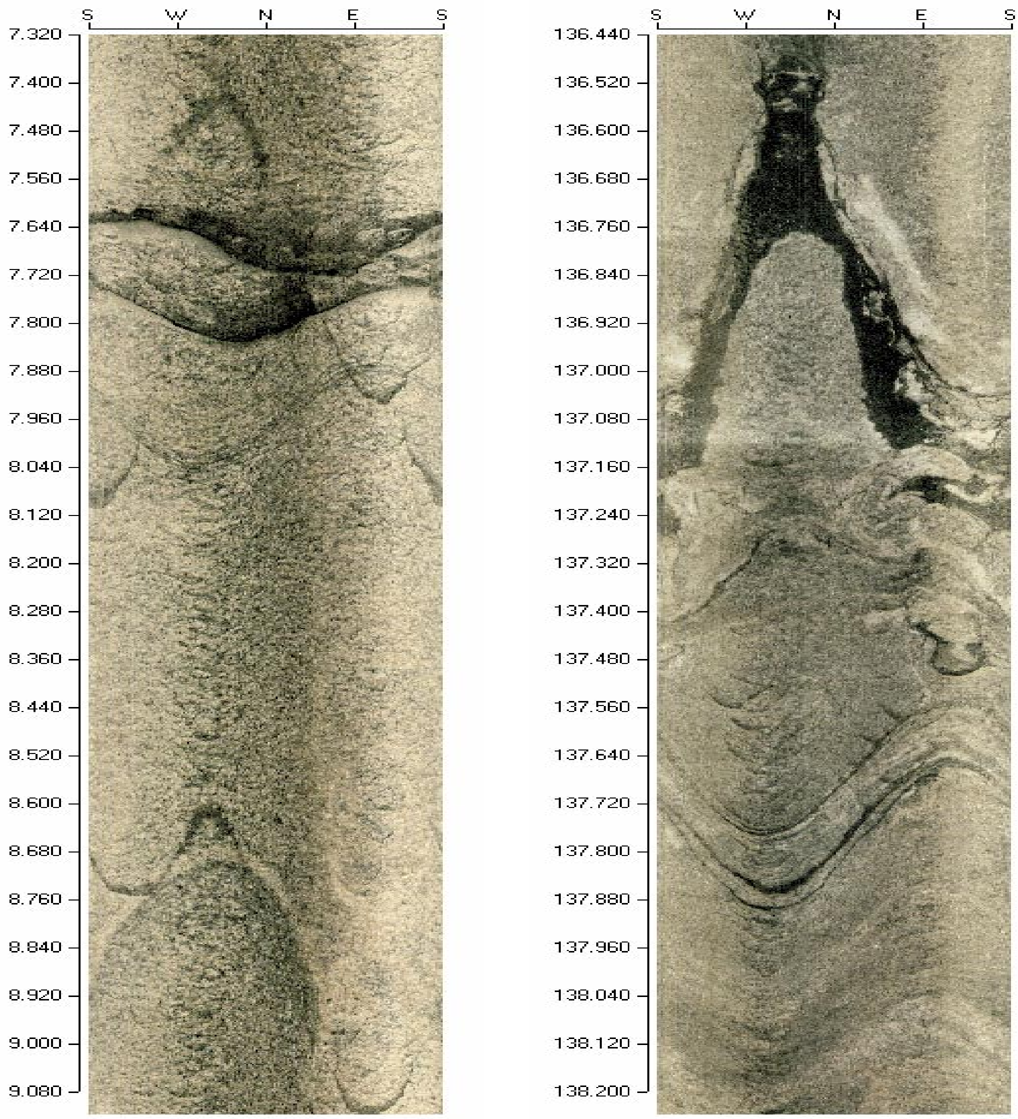


Figure 5-2. *Differences in the image quality between the top and bottom part of borehole HFM14.*

The logging in HFM15 was performed 03-10-21. The water quality was good in the upper part of the borehole but the quality of the images drops towards depth, see Figure 5-3. The problem is that mud is covering the lowermost part of the borehole wall. It should, however, be stated that even if the borehole wall is covered with mud up to 50 %, mapping with good resolution is still possible. The software, BDPP (Bips Data Processing Program) that is used for the orientation of structures needs only 180 degree of the complete 360 degrees picture to orientate plane structures.

The camera operated very well despite the low borehole inclination, only 45°. The speed of the camera synchronized surprisingly well to the movement of the cable-measuring device at the surface.

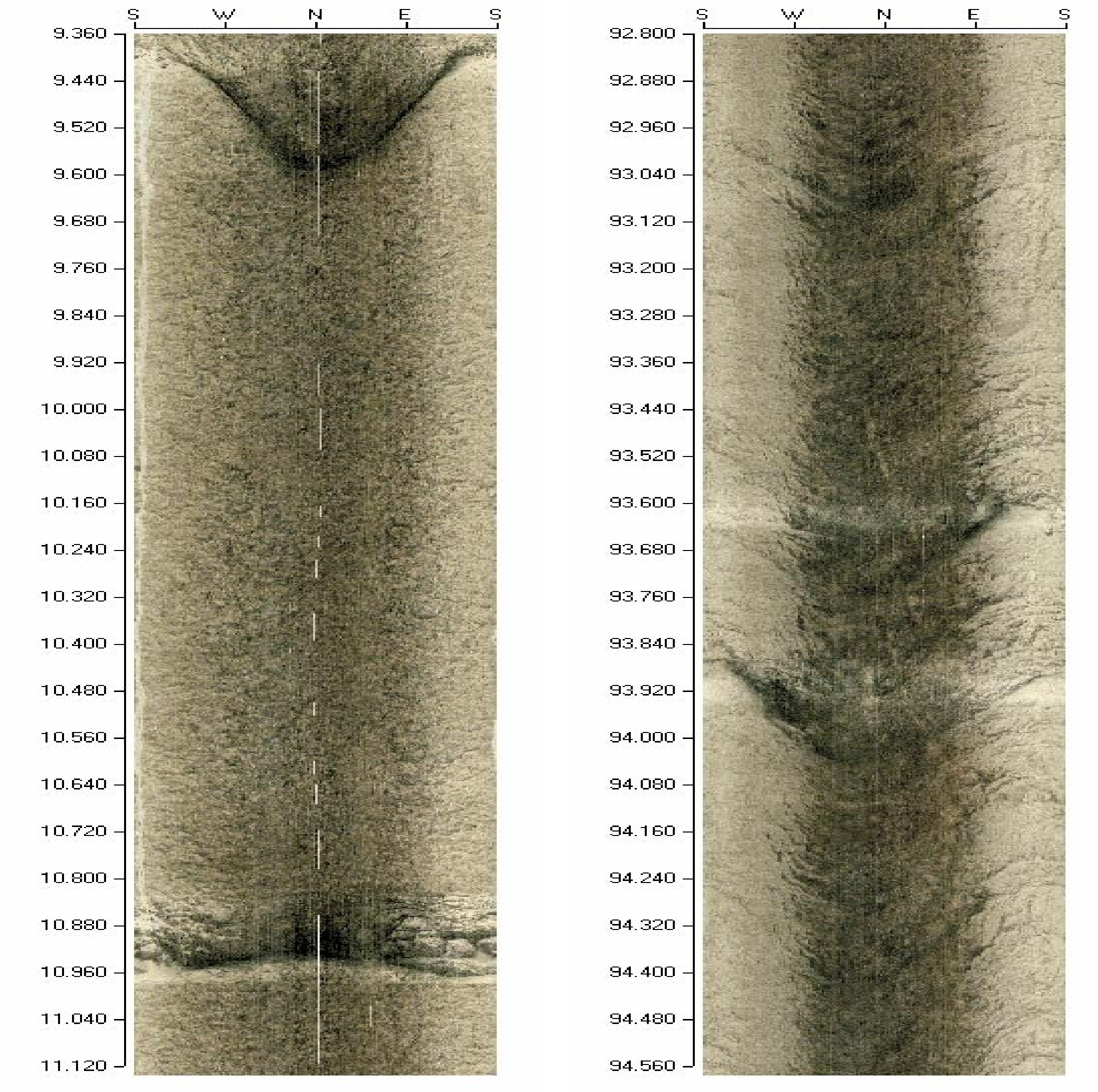


Figure 5-3. *Differences in the image quality between the top and bottom part of borehole HFM15.*

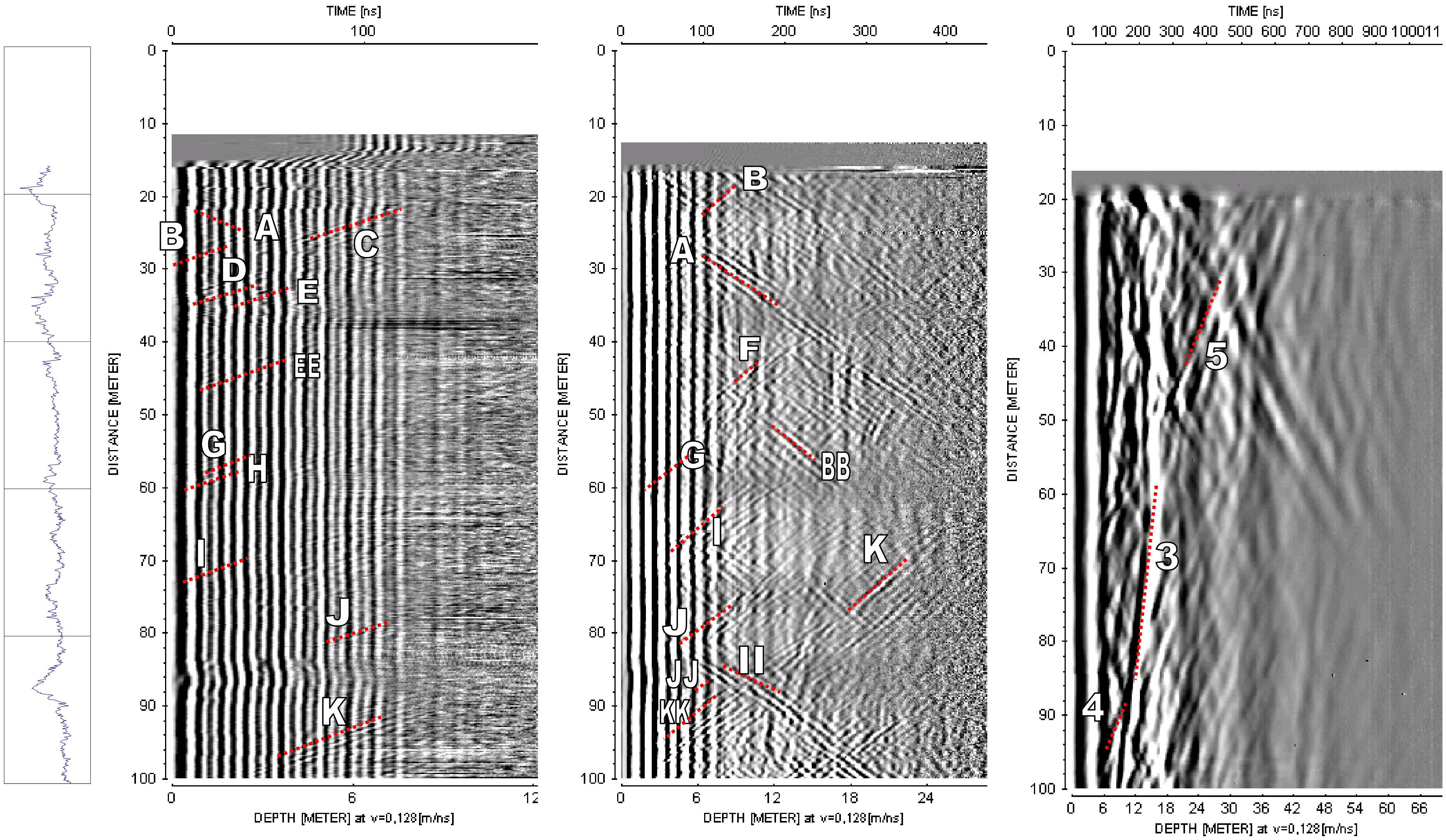
6 References

/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.

Appendix 1

Radar logging of HFM13, 10 to 170 m
Dipole antennas 250, 100 and 20 MHz

FORSMARK HFM13 with interpretation

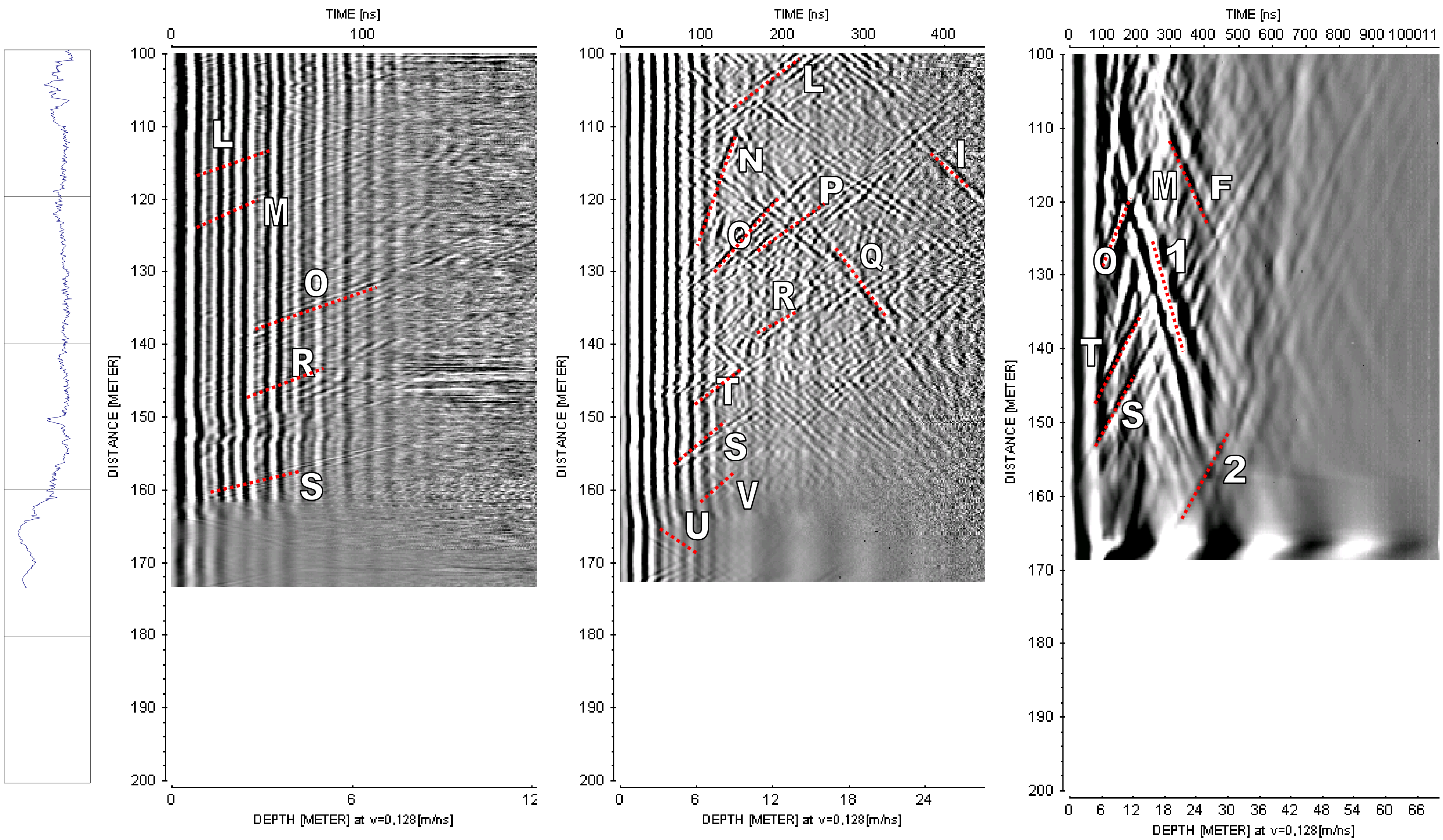


250 MHz

100 MHz

20 MHz

FORSMARK HFM13 with interpretation

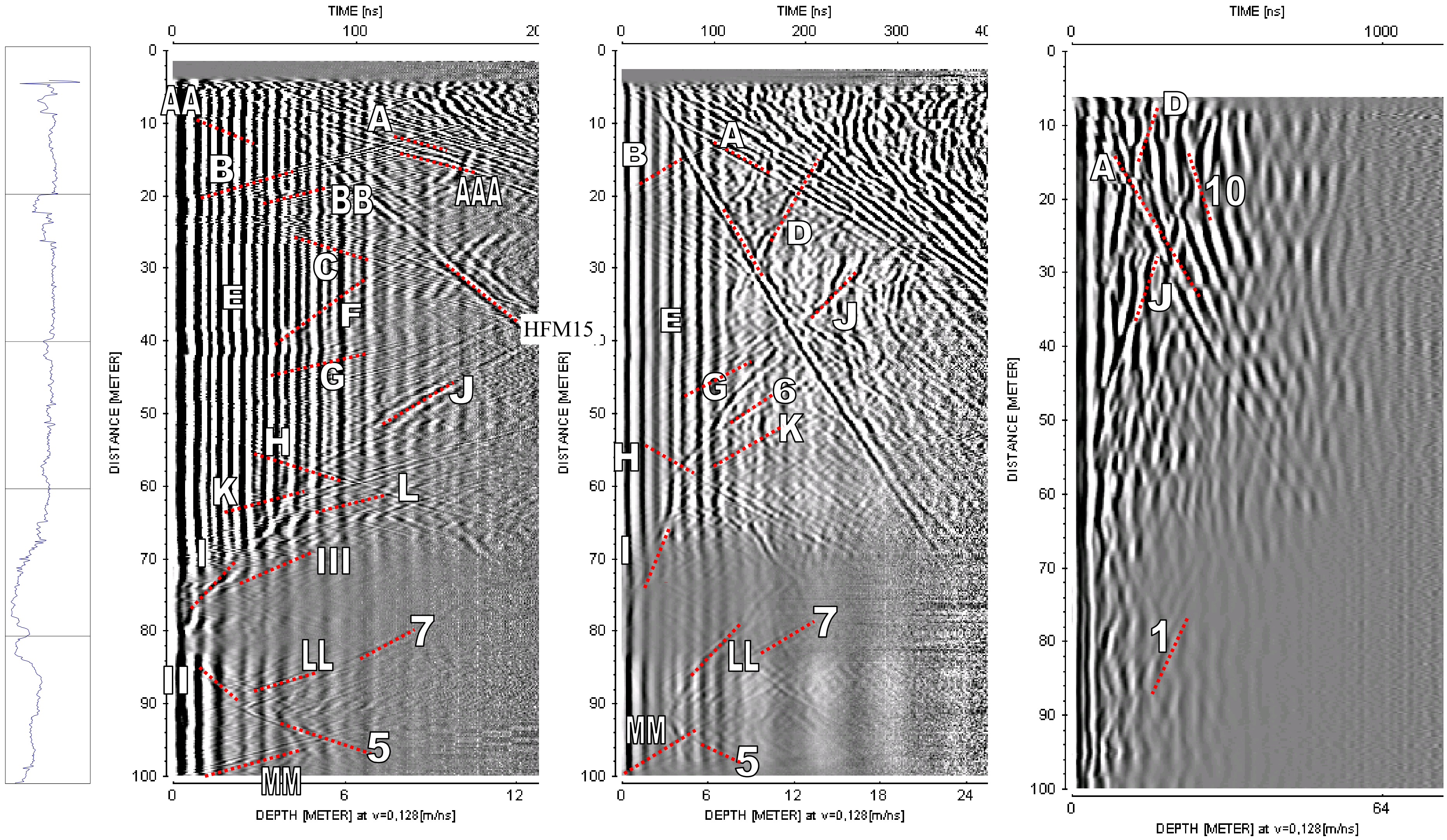


250 MHz **100 MHz** **20 MHz**

Appendix 2

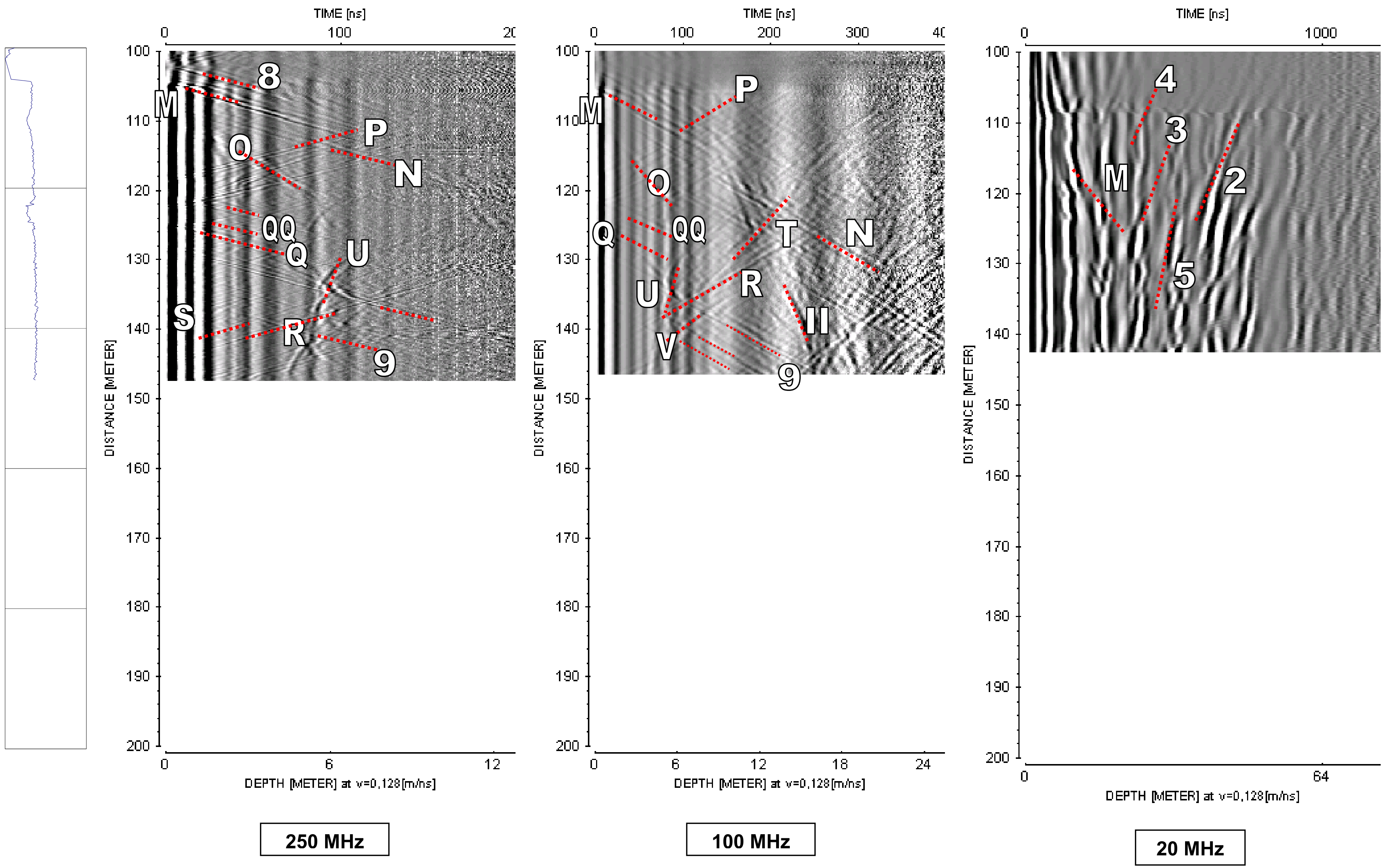
Radar logging of HFM14, 0 to 150 m
Dipole antennas 250, 100 and 20 MHz

FORSMARK HFM14 with interpretation



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

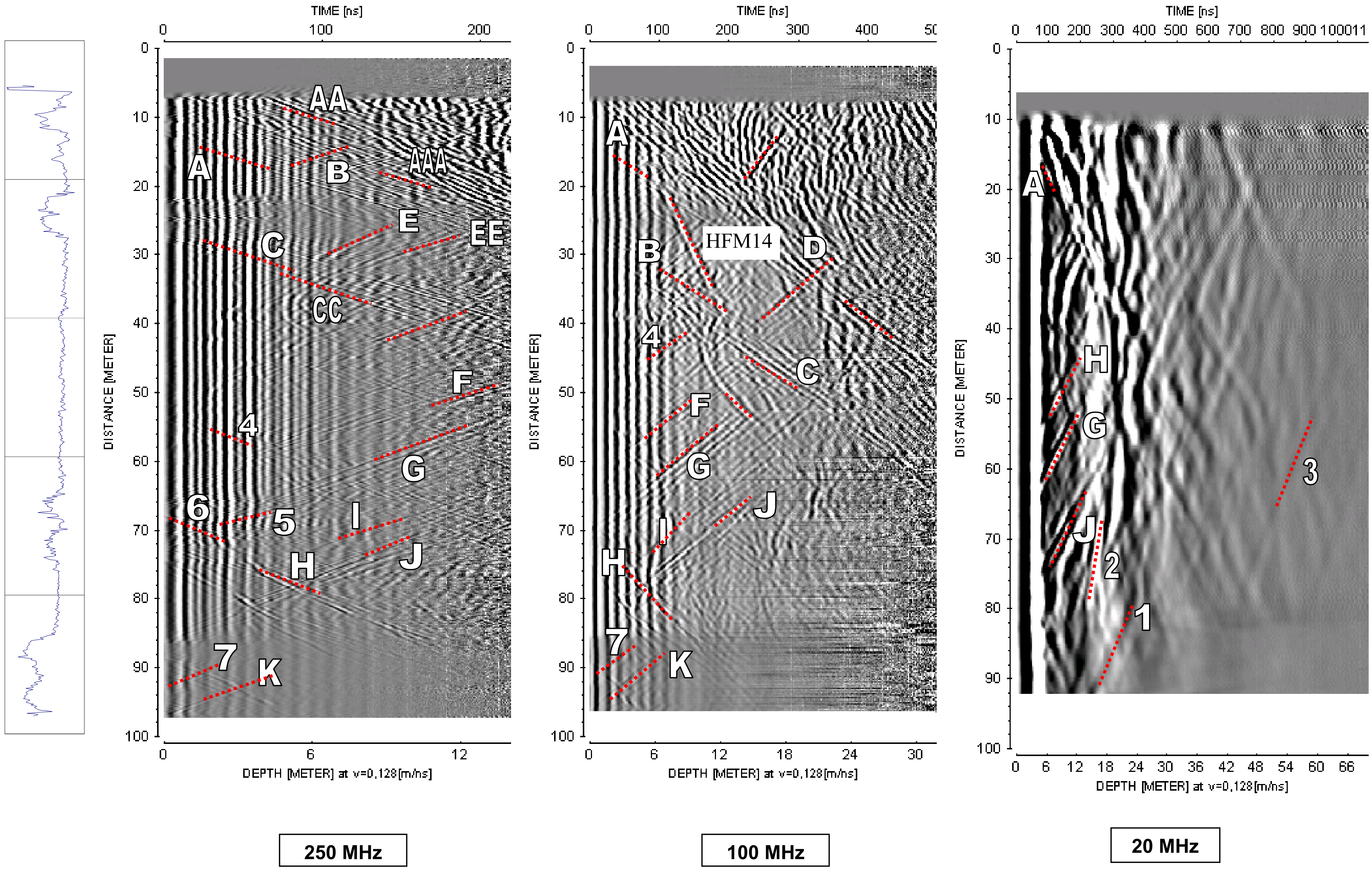
FORSMARK HFM14 with interpretation



Appendix 3

Radar logging of HFM15, 0 to 100 m
Dipole antennas 250, 100 and 20 MHz

FORSMARK HFM15 with interpretation



BIPS logging in HFM13

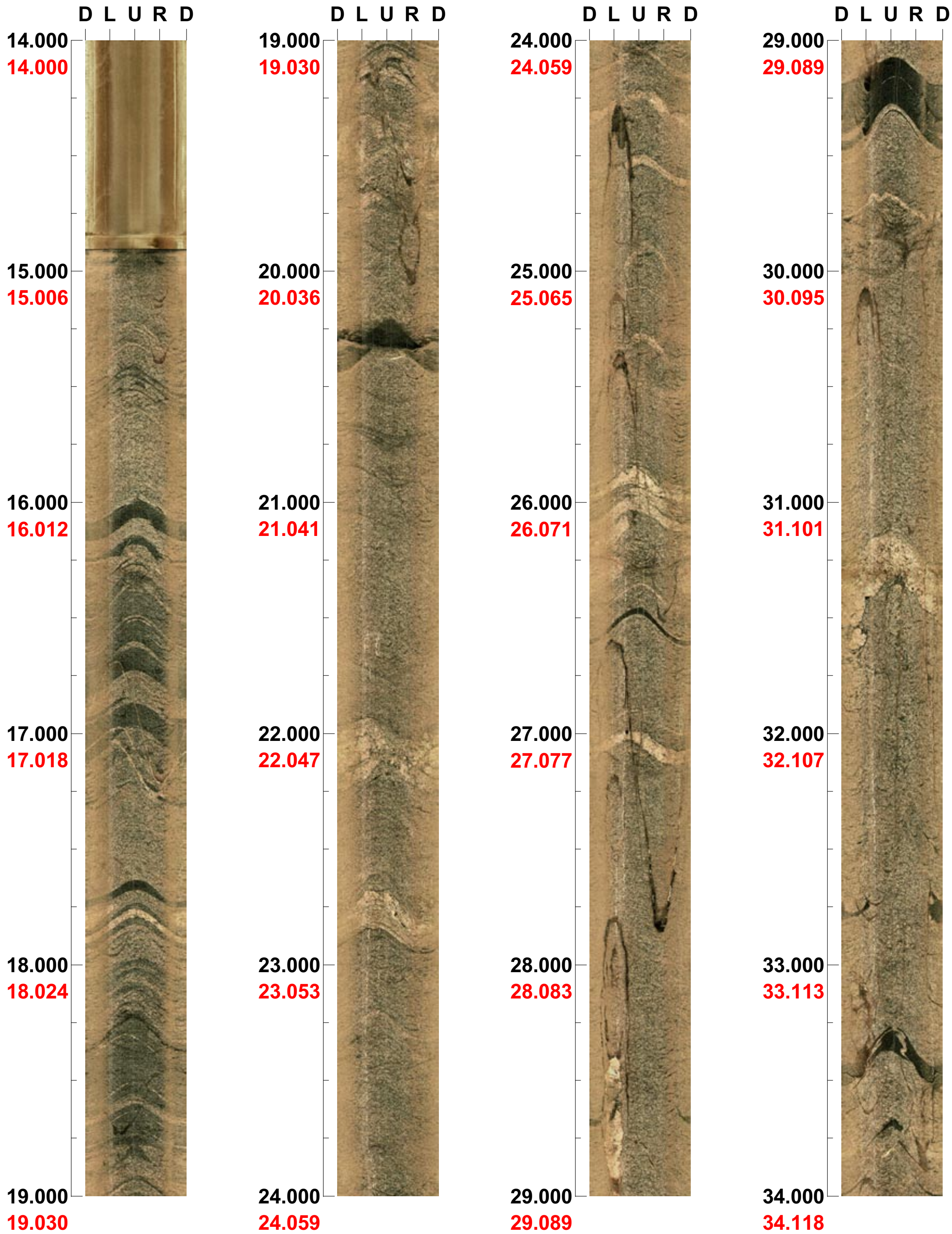
Project name: Forsmark

Image file	: h:\work\hfm13\hfm13.bip
BDT file	: h:\work\hfm13\hfm13.bdt
Locality	: FORSMARK
Bore hole number	: HFM13
Date	: 03/10/21
Time	: 14:42:00
Depth range	: 14.000 - 174.472 m (red figures = corrected values)
Azimuth	: 45
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: Forsmark

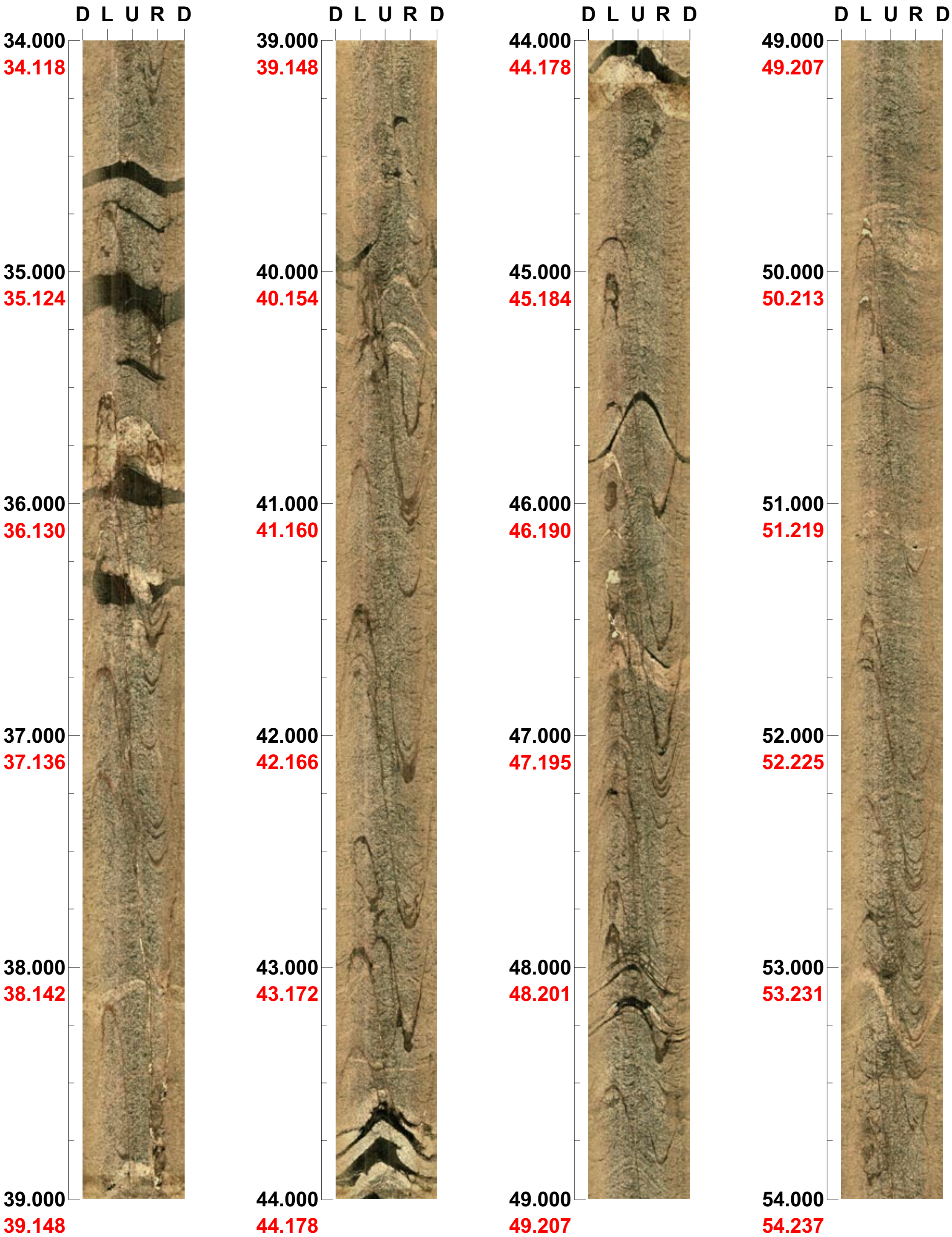
Bore hole No.: HFM13 **Azimuth: 45** **Inclination: -60**

Depth range: 14.000 - 34.000 m



Project name: Forsmark
Bore hole No.: HFM13 **Azimuth: 45** **Inclination: -60**

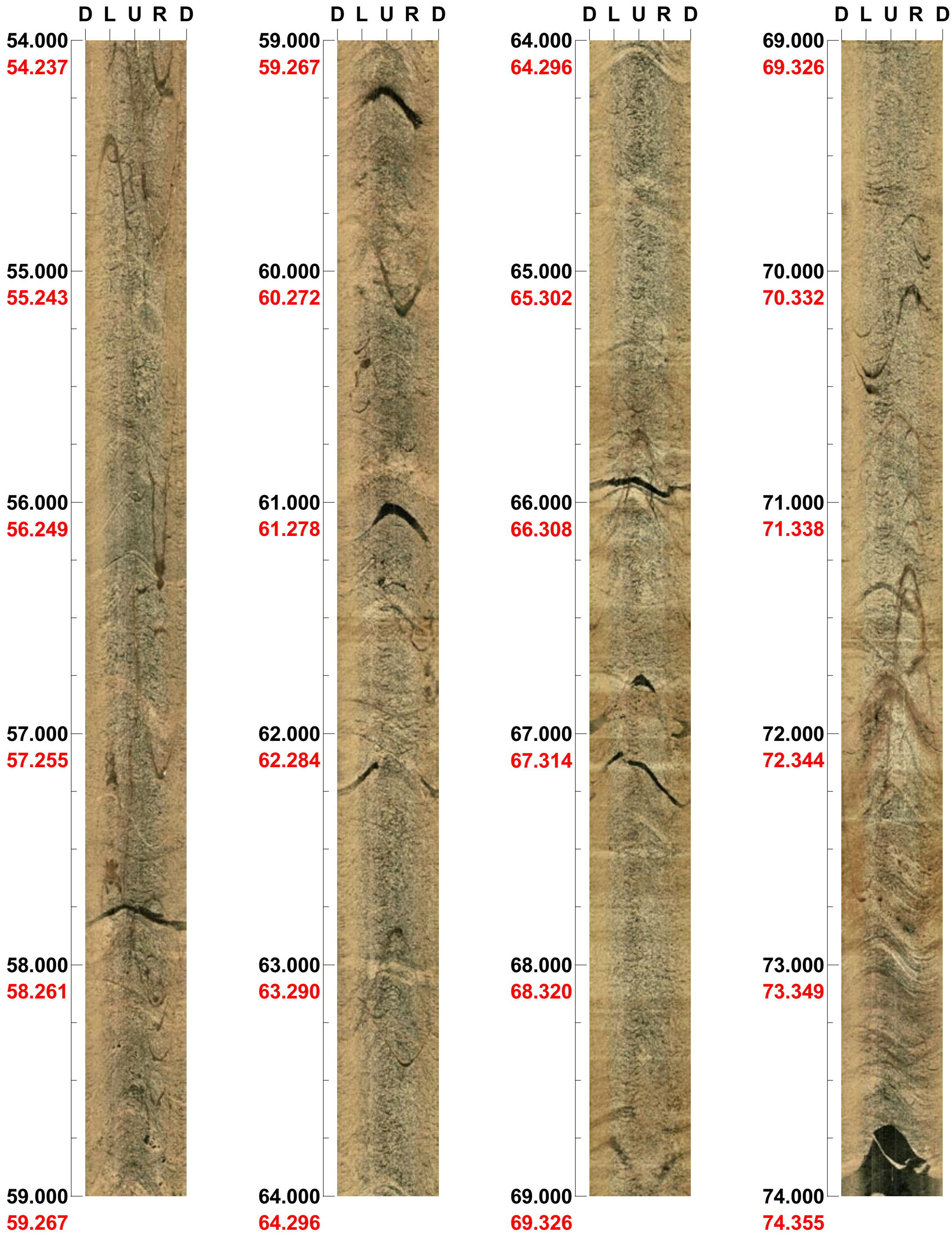
Depth range: 34.000 - 54.000 m



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

Project name: Forsmark
Bore hole No.: HFM13 Azimuth: 45 Inclination: -60

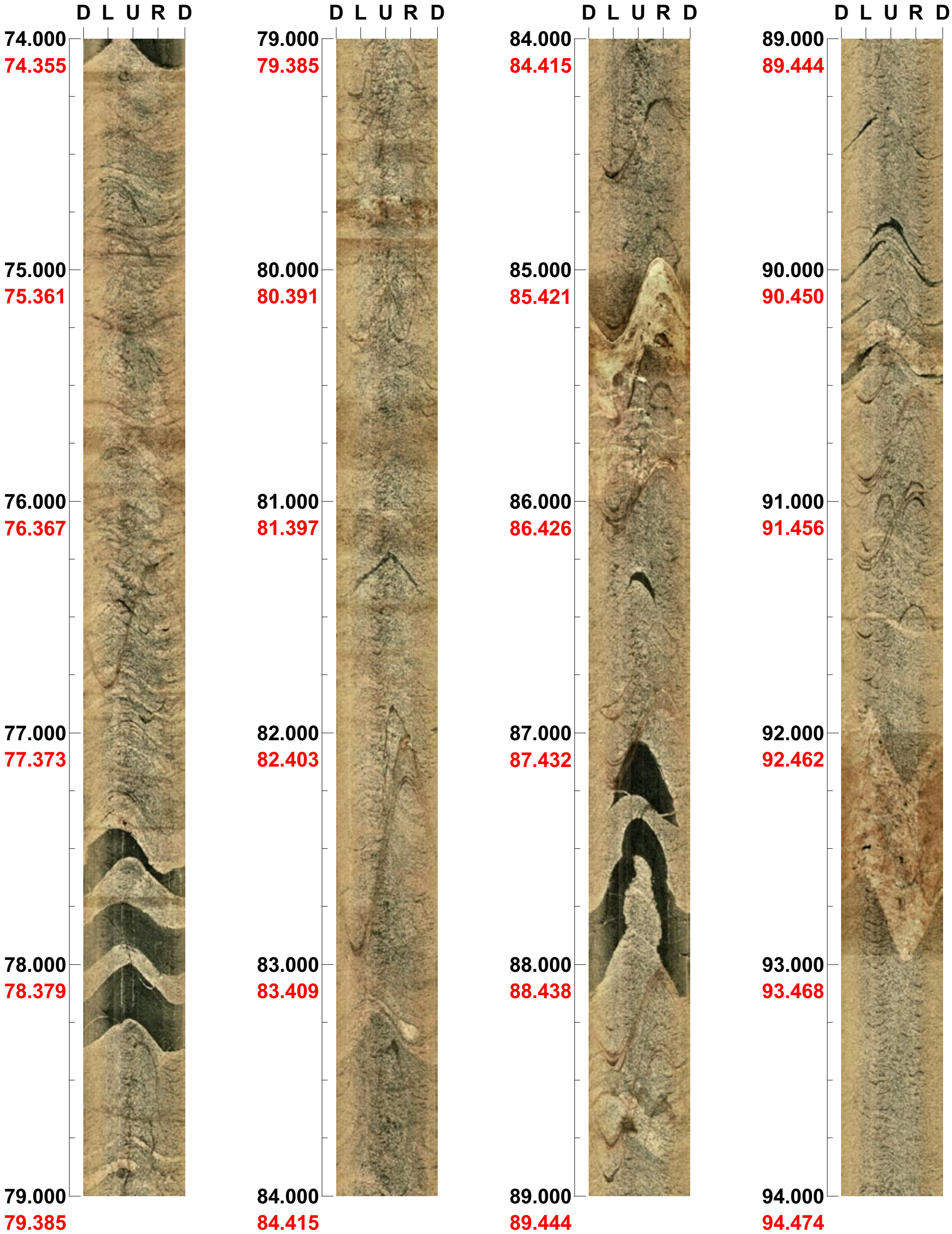
Depth range: 54.000 - 74.000 m



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

Project name: Forsmark
Bore hole No.: HFM13 **Azimuth: 45** **Inclination: -60**

Depth range: 74.000 - 94.000 m

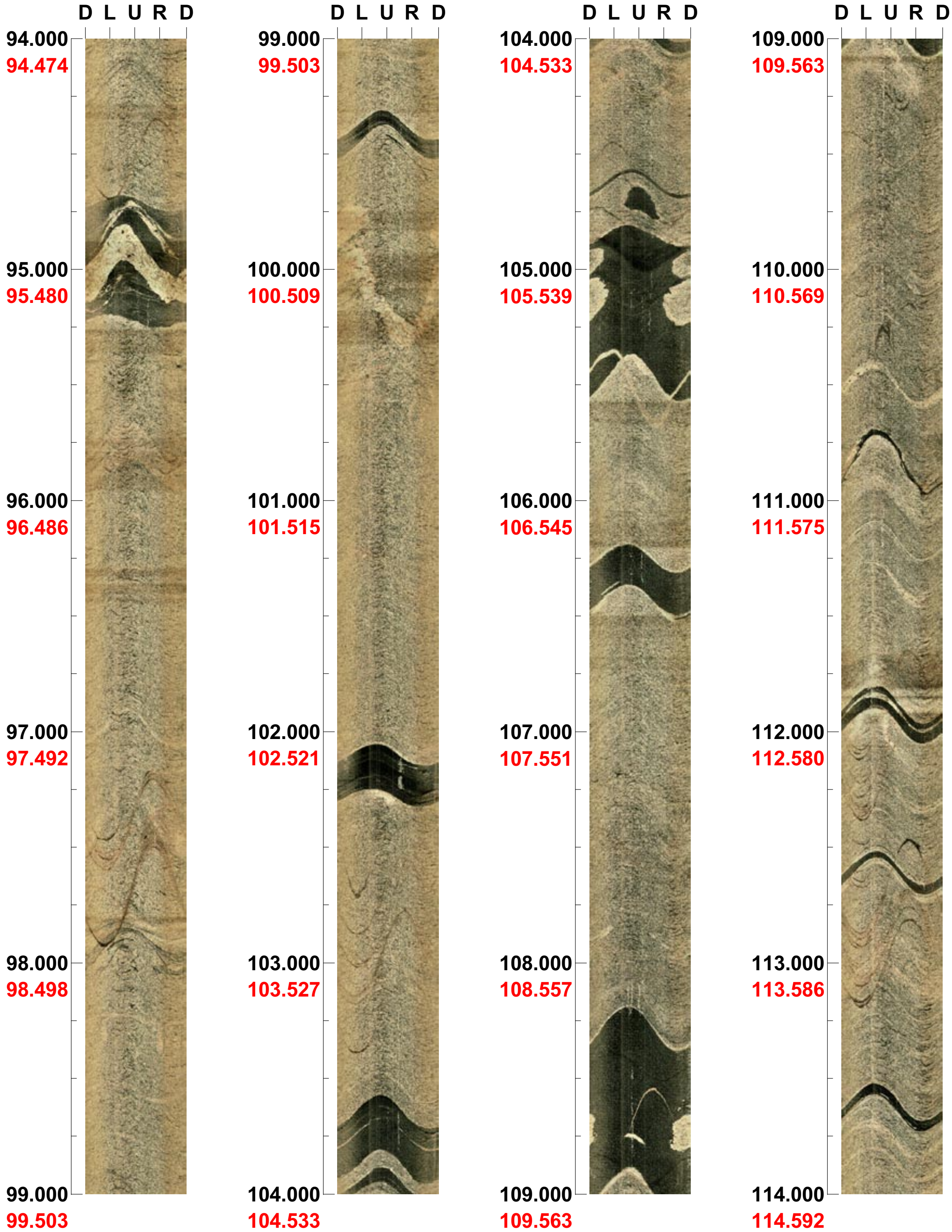


(4 / 9) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark

Bore hole No.: HFM13 **Azimuth: 45** **Inclination: -60**

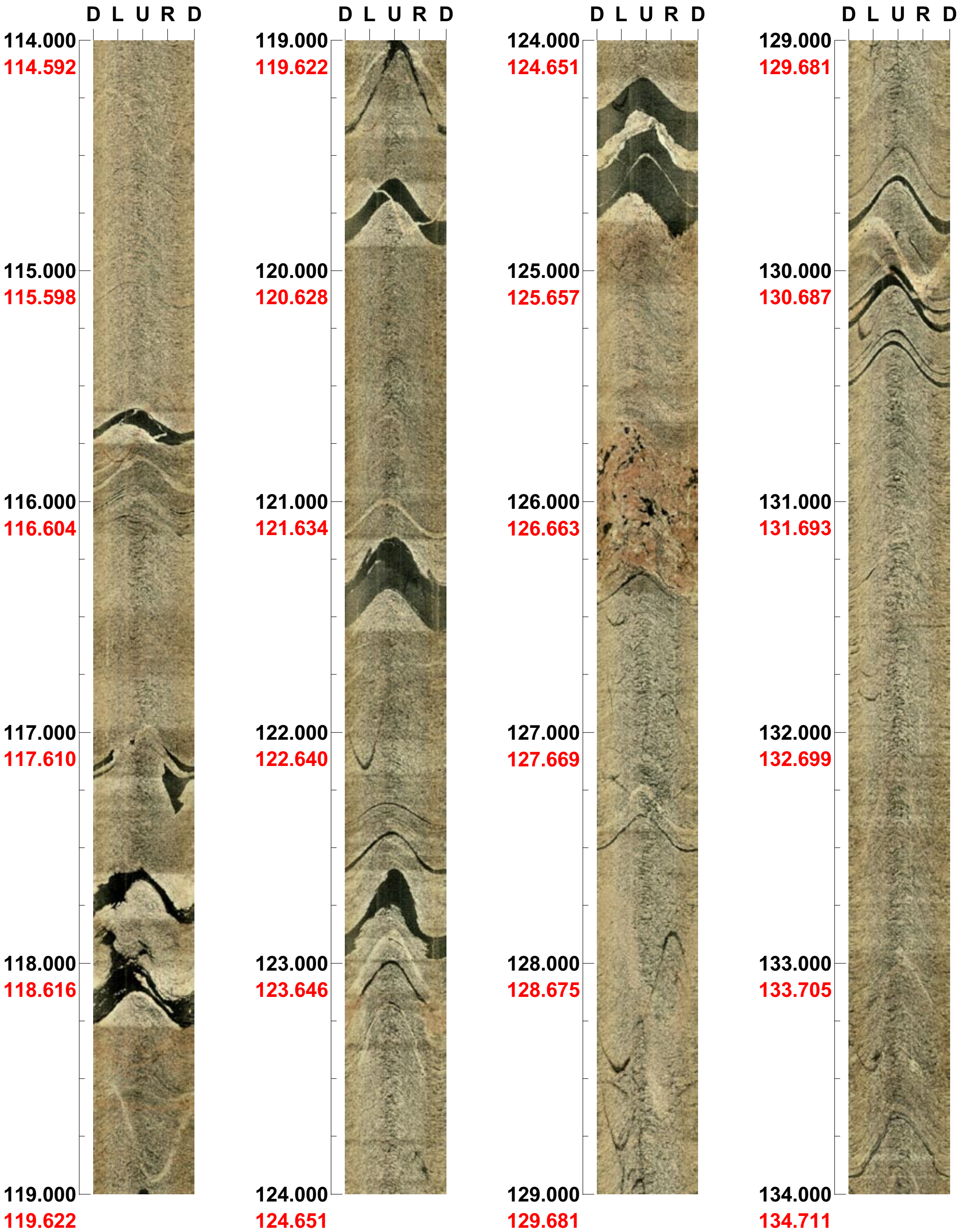
Depth range: 94.000 - 114.000 m



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

Project name: Forsmark
Bore hole No.: HFM13 **Azimuth: 45** **Inclination: -60**

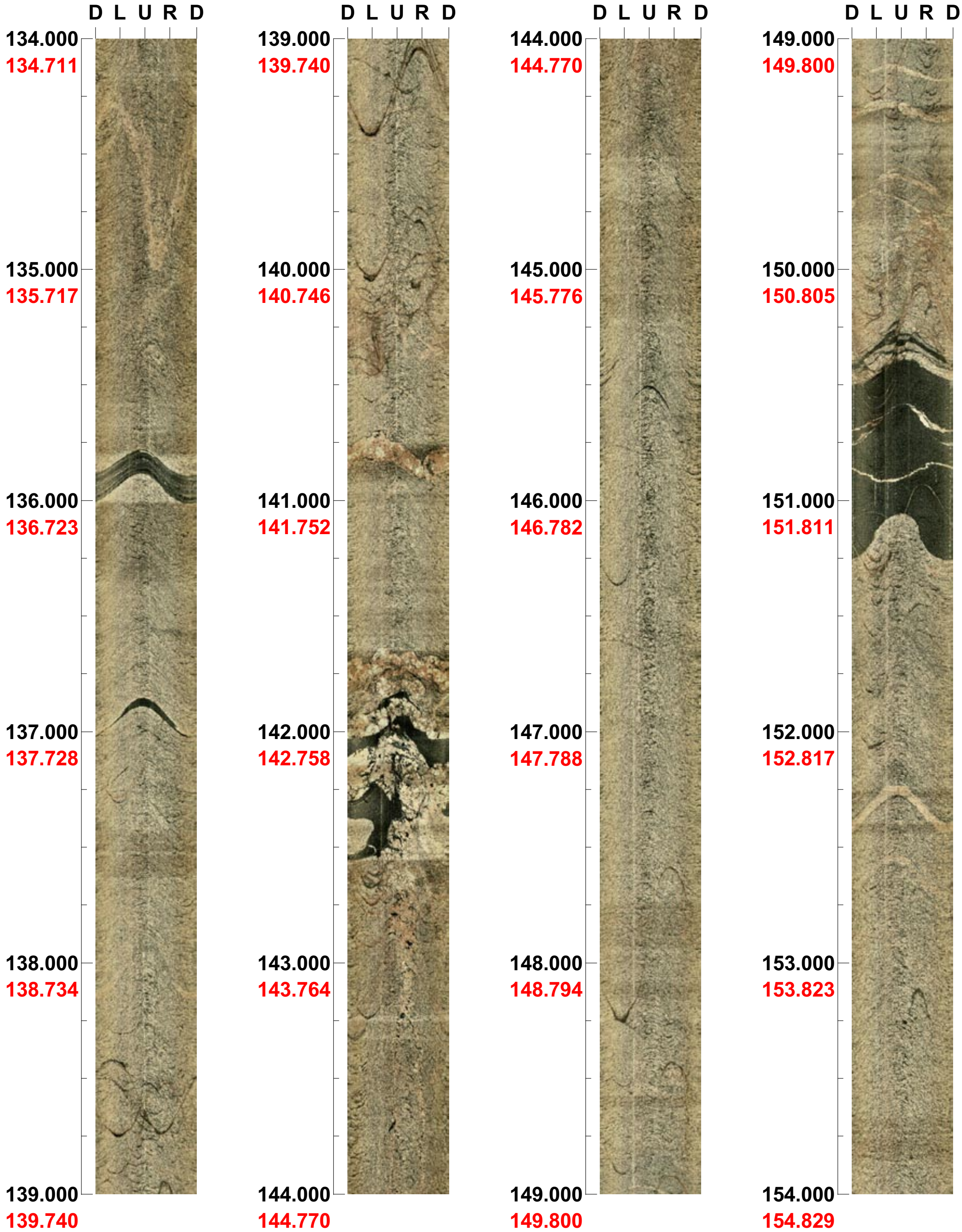
Depth range: 114.000 - 134.000 m



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

Project name: Forsmark
Bore hole No.: HFM13 **Azimuth: 45** **Inclination: -60**

Depth range: 134.000 - 154.000 m

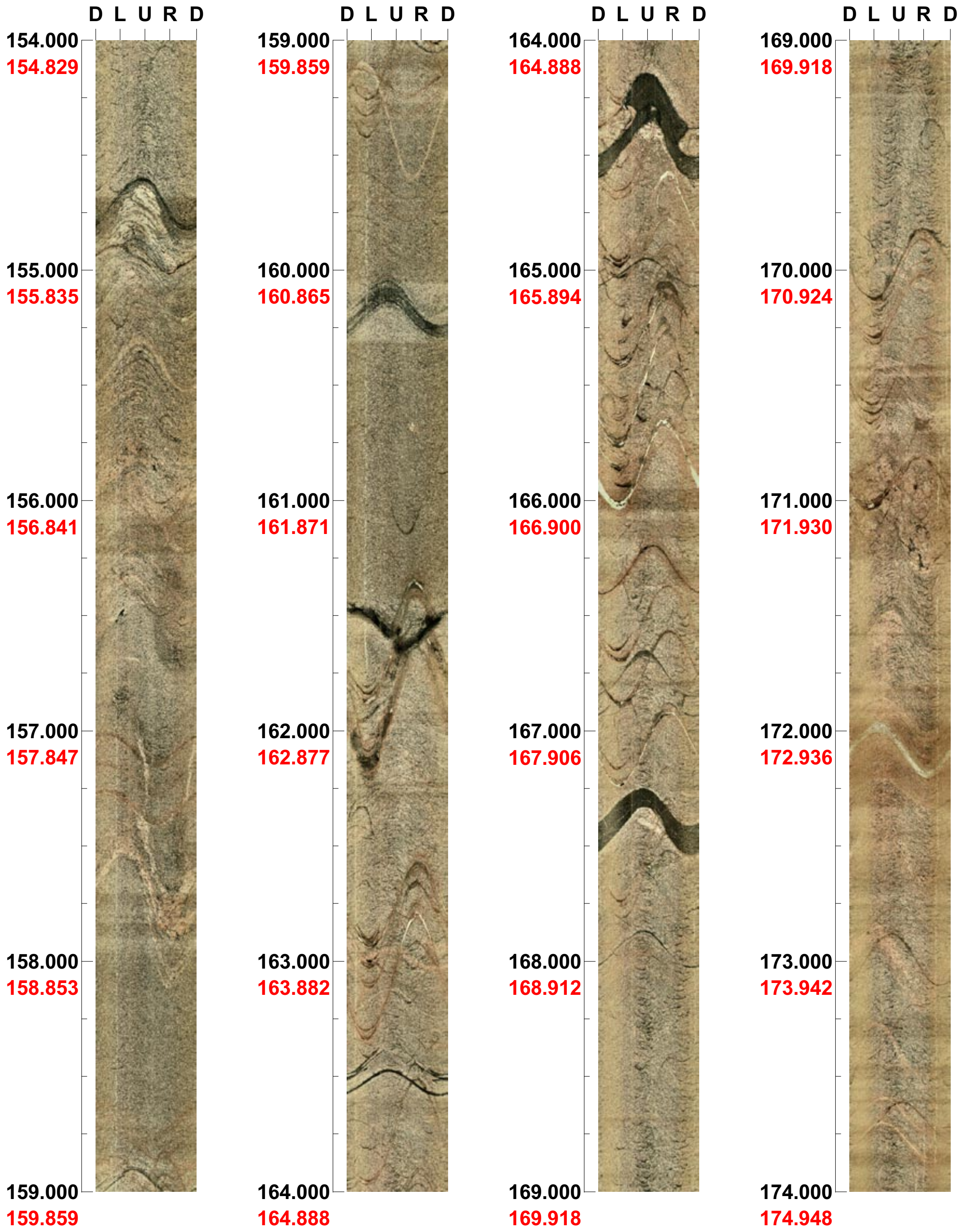


(7 / 9) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark

Bore hole No.: HFM13 **Azimuth: 45** **Inclination: -60**

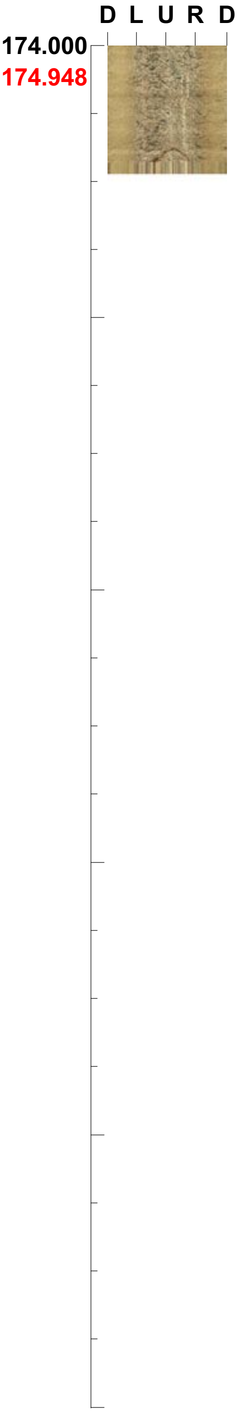
Depth range: 154.000 - 174.000 m



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

Project name: Forsmark
Bore hole No.: HFM13 **Azimuth: 45** **Inclination: -60**

Depth range: 174.000 - 174.472 m



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

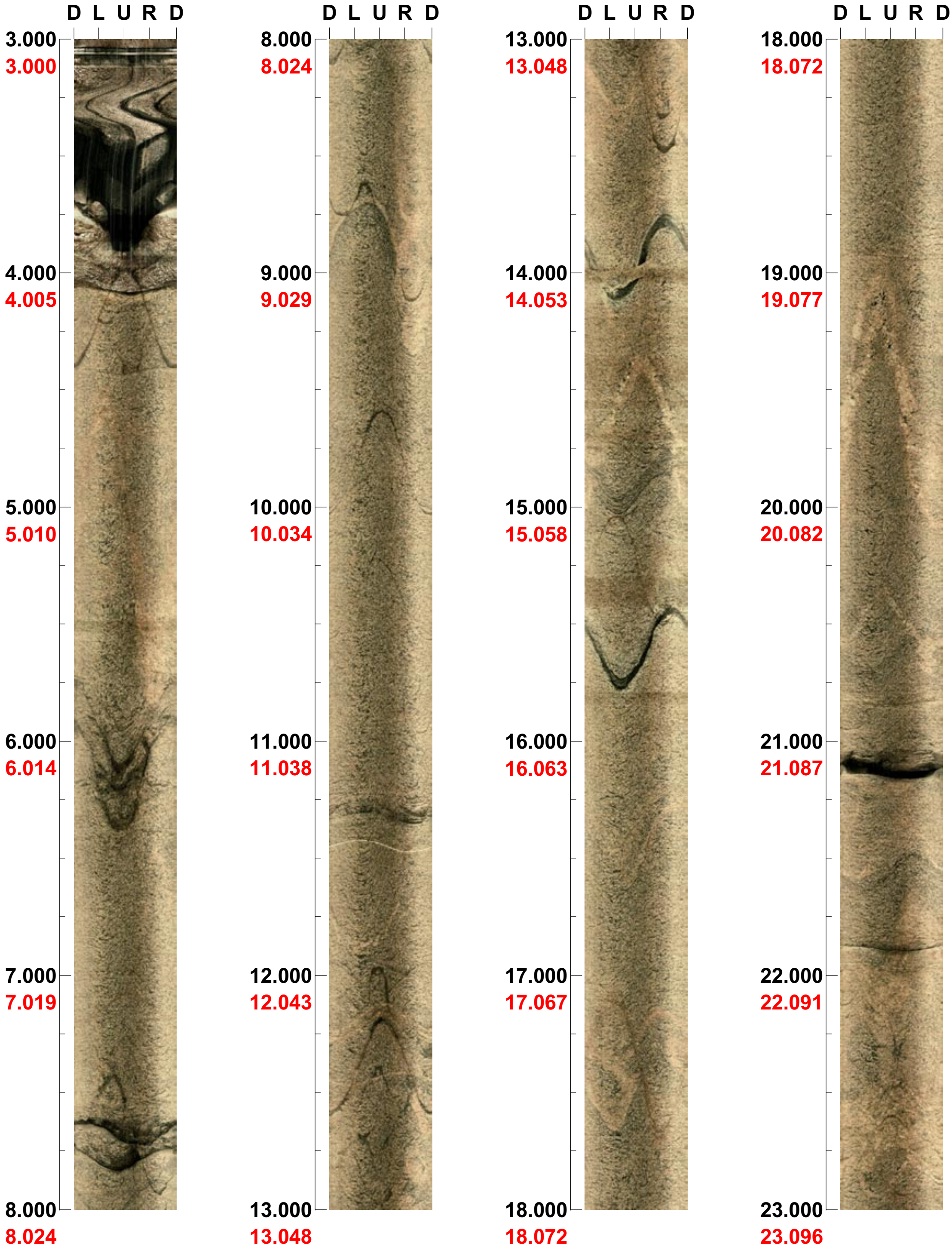
BIPS logging in HFM14

Project name: Forsmark

Image file	: h:\work\hfm14\hfm14.bip
BDT file	: h:\work\hfm14\hfm14.bdt
Locality	: FORSMARK
Bore hole number	: HFM14
Date	: 03/10/21
Time	: 10:44:00
Depth range	: 3.000 - 148.581 m (red figures = corrected values)
Azimuth	: 330
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	: 8
Color	: +0 +0 +0

Project name: Forsmark
Bore hole No.: HFM14 **Azimuth: 330** **Inclination: -60**

Depth range: 3.000 - 23.000 m

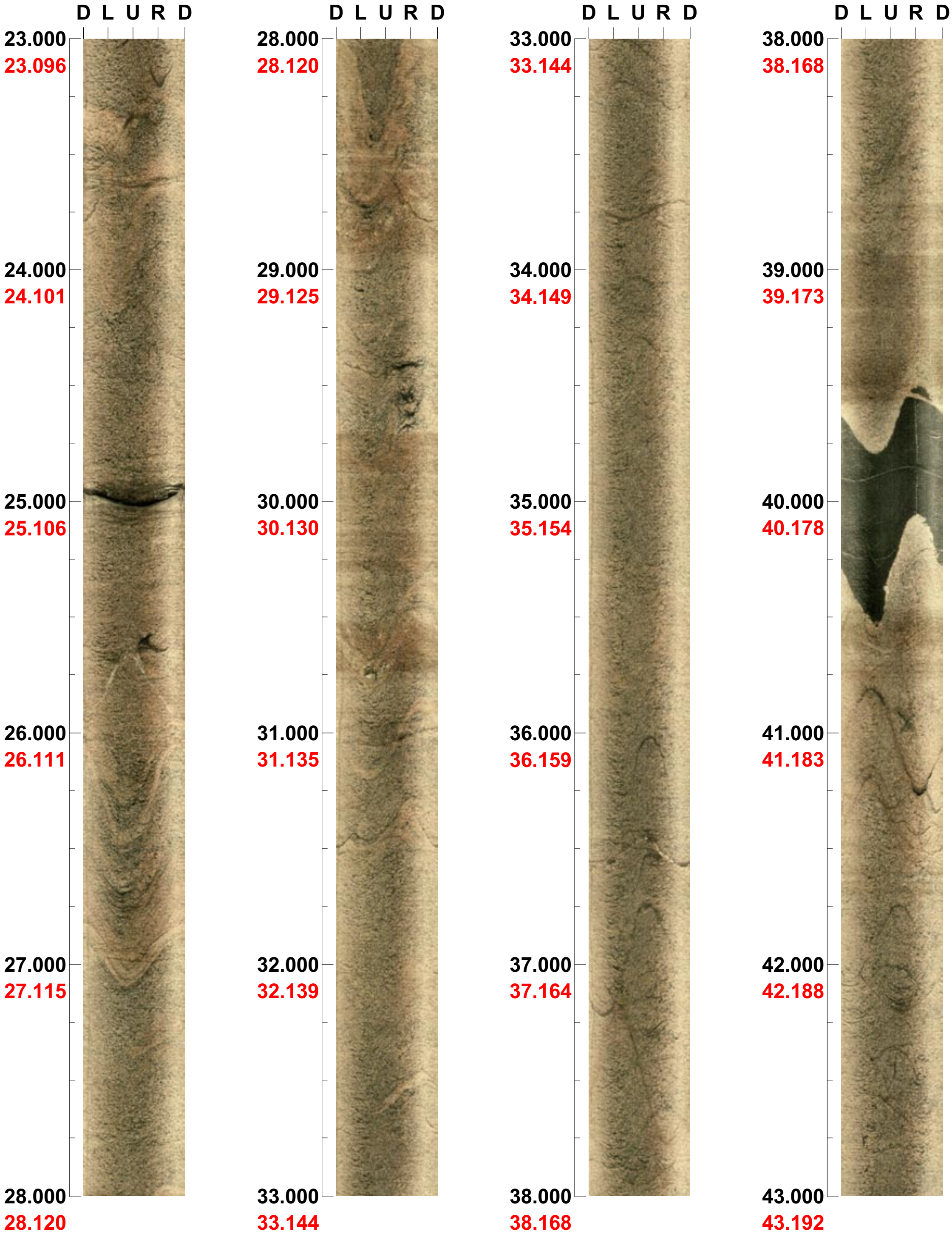


(1 / 8) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark

Bore hole No.: HFM14 **Azimuth: 330** **Inclination: -60**

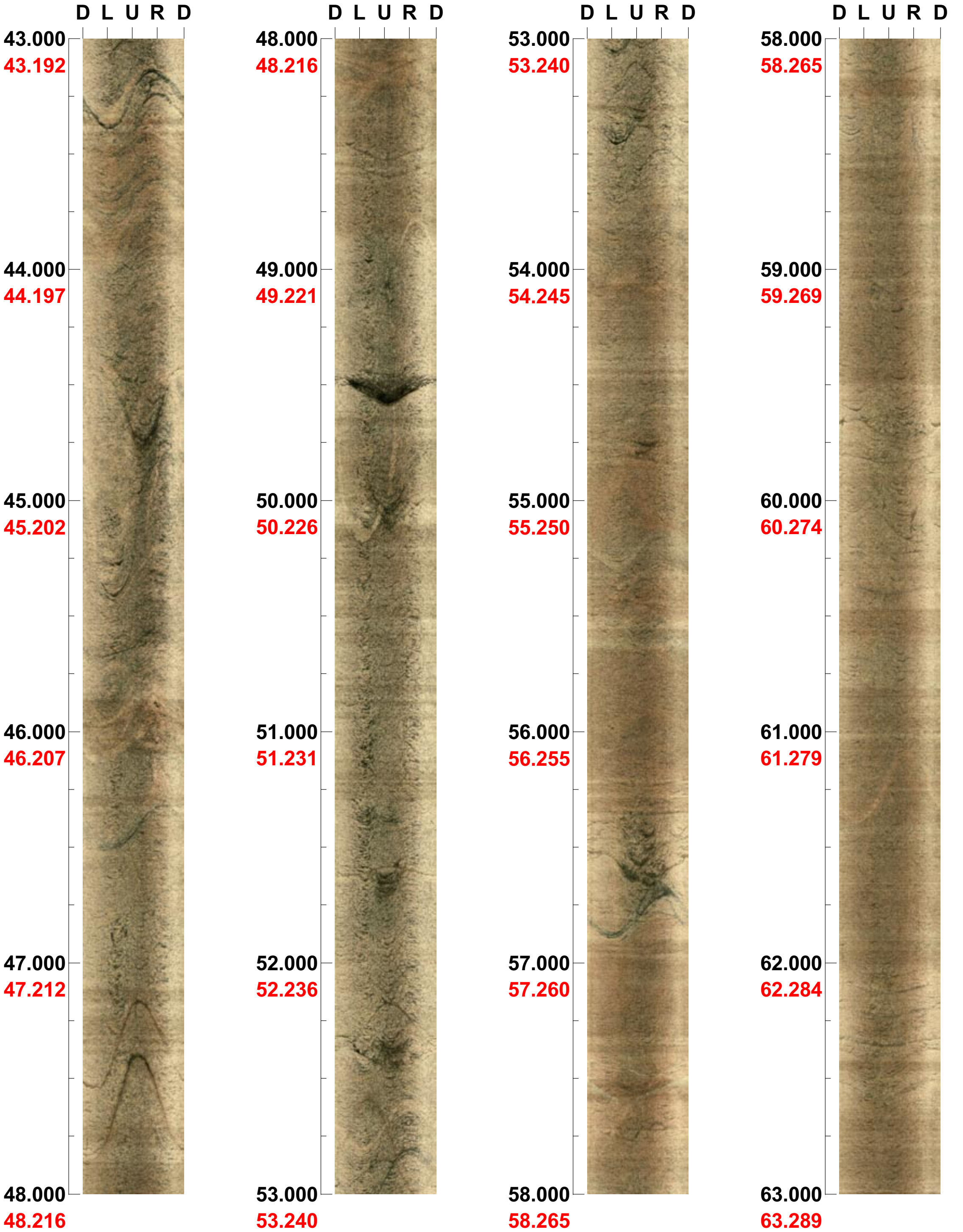
Depth range: 23.000 - 43.000 m



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

Project name: Forsmark
Bore hole No.: HFM14 **Azimuth: 330** **Inclination: -60**

Depth range: 43.000 - 63.000 m

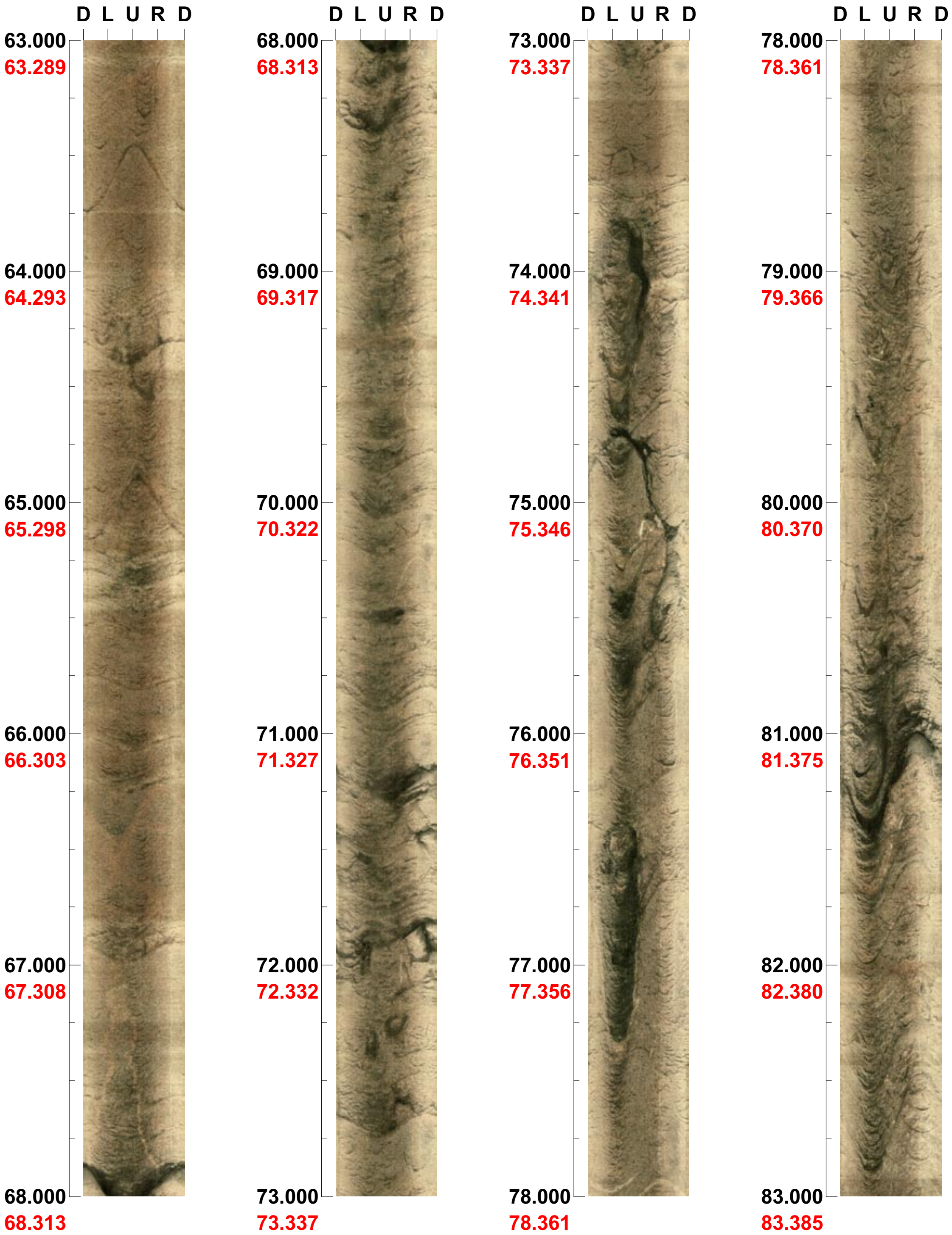


(3 / 8) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark

Bore hole No.: HFM14 **Azimuth: 330** **Inclination: -60**

Depth range: 63.000 - 83.000 m

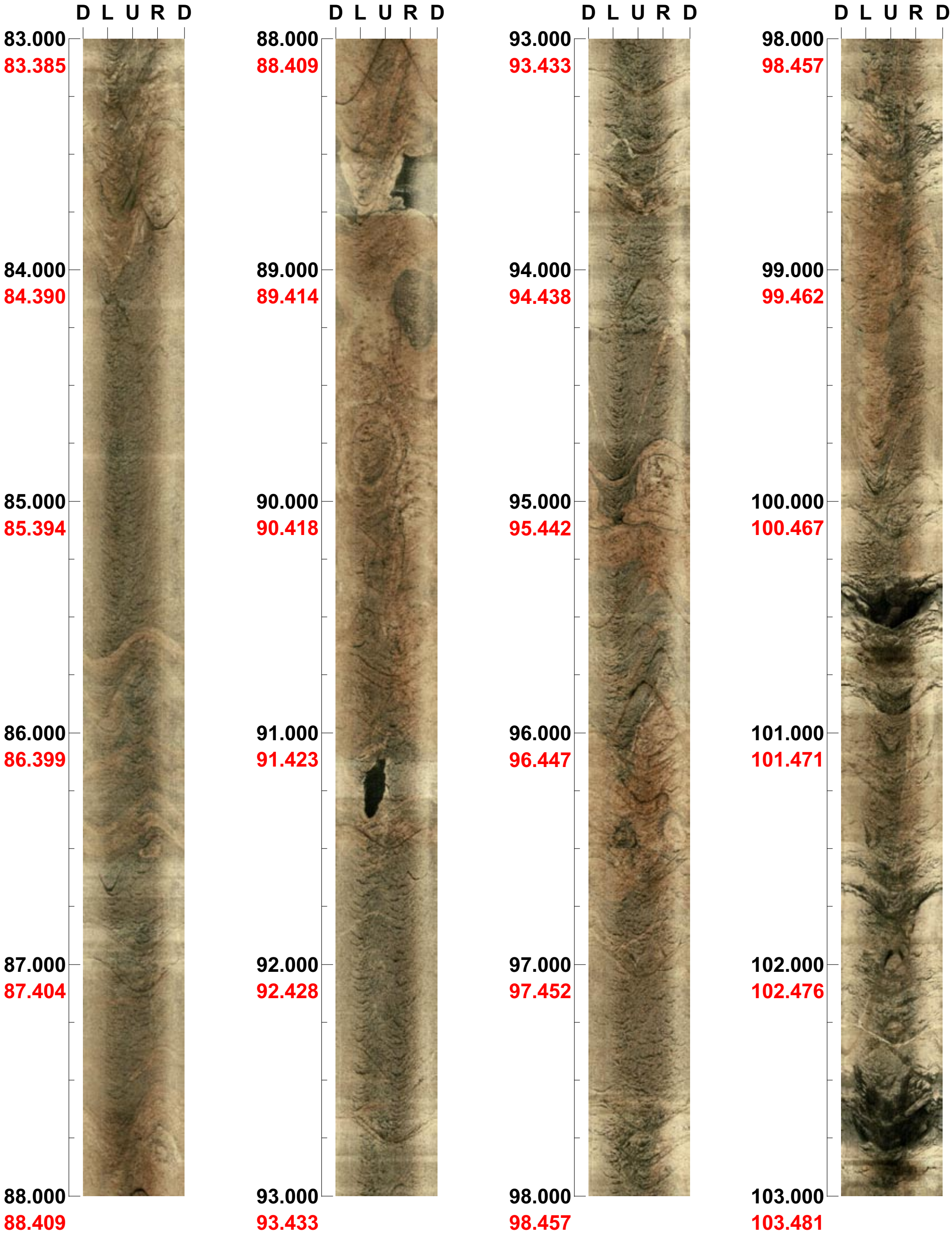


(4 / 8) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark

Bore hole No.: HFM14 **Azimuth: 330** **Inclination: -60**

Depth range: 83.000 - 103.000 m

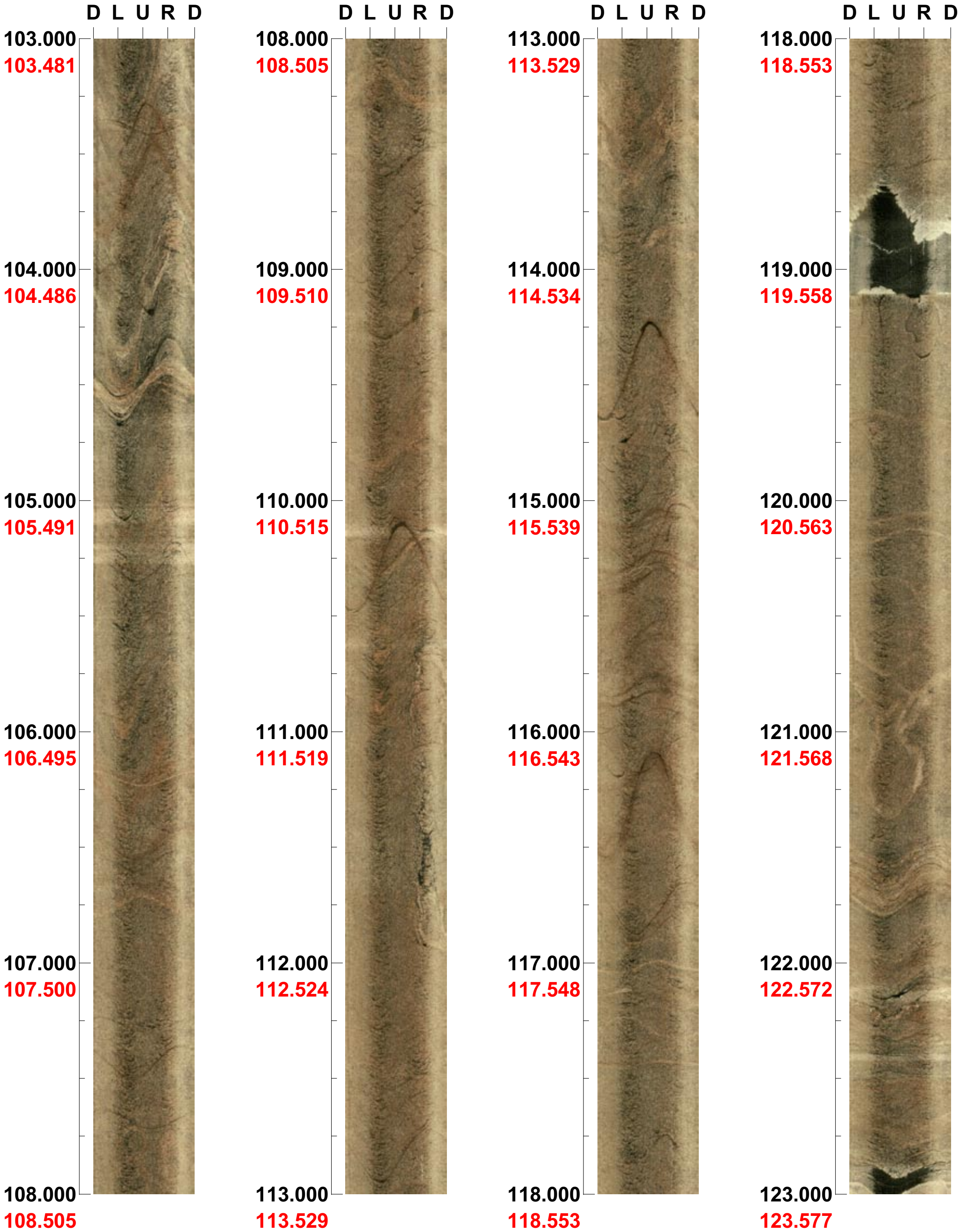


(5 / 8) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark

Bore hole No.: HFM14 **Azimuth: 330** **Inclination: -60**

Depth range: 103.000 - 123.000 m

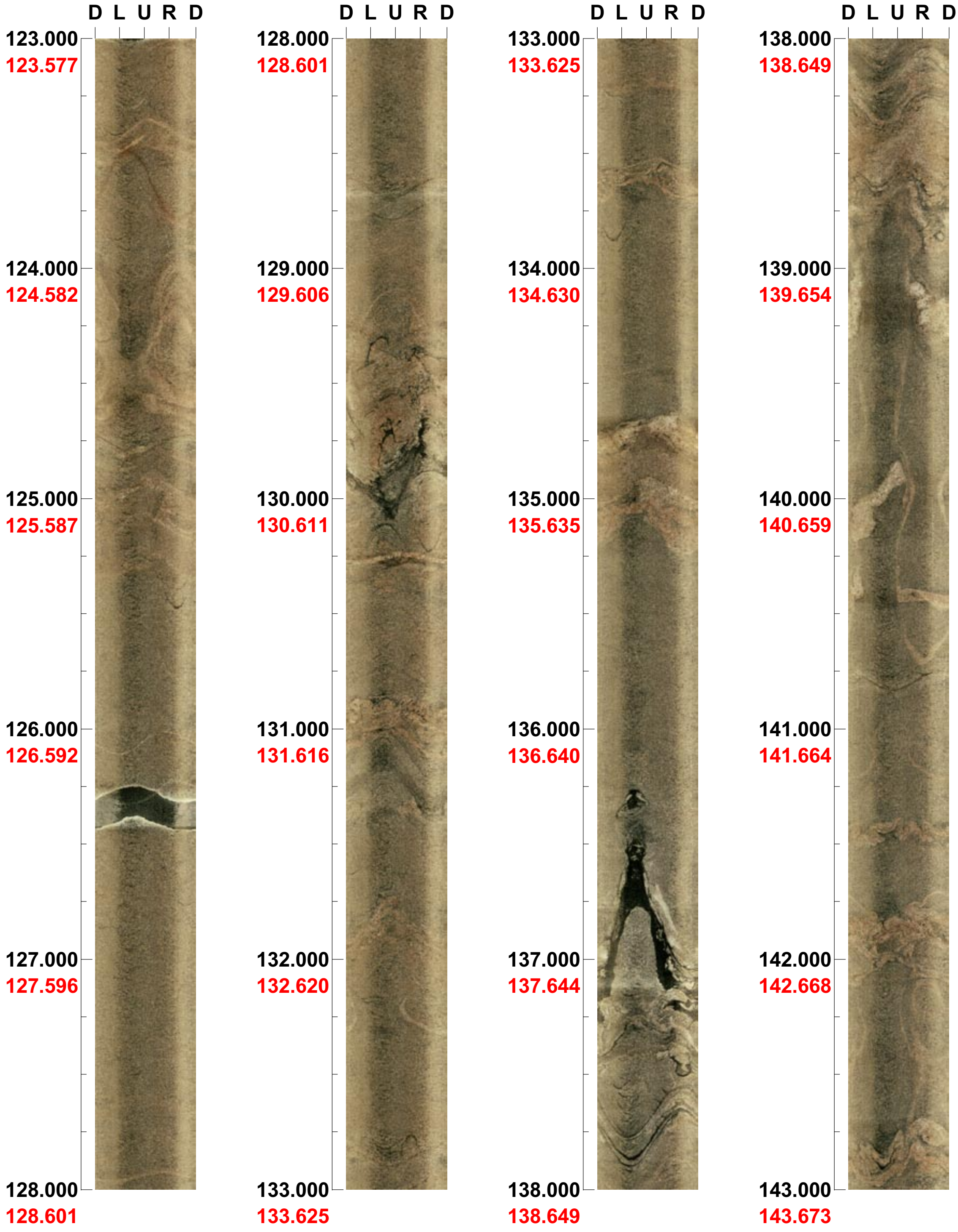


(6 / 8) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark

Bore hole No.: HFM14 **Azimuth: 330** **Inclination: -60**

Depth range: 123.000 - 143.000 m

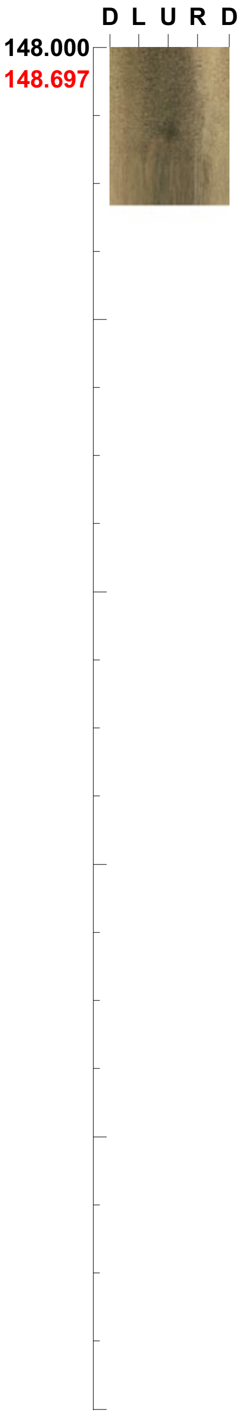


(7 / 8) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark

Bore hole No.: HFM14 **Azimuth: 330** **Inclination: -60**

Depth range: 143.000 - 148.581 m



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

Appendix 6

BIPS logging in HFM15

Project name: Forsmark

Image file	: h:\work\hfm15\hfm15.bip
BDT file	: h:\work\hfm15\hfm15.bdt
Locality	: FORSMARK
Bore hole number	: HFM15
Date	: 03/10/21
Time	: 09:17:00
Depth range	: 4.000 - 98.564 m (red figures = corrected values)
Azimuth	: 320
Inclination	: -45
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	: 5
Color	: +0 +0 +0

Project name: Forsmark
Bore hole No.: HFM15 **Azimuth: 320** **Inclination: -45**

Depth range: 4.000 - 24.000 m

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

Project name: Forsmark

Bore hole No.: HFM15 **Azimuth: 320** **Inclination: -45**

Depth range: 24.000 - 44.000 m

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

Project name: Forsmark
Bore hole No.: HFM15 **Azimuth: 320** **Inclination: -45**

Depth range: 44.000 - 64.000 m

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

Project name: Forsmark

Bore hole No.: HFM15 **Azimuth: 320** **Inclination: -45**

Depth range: 64.000 - 84.000 m

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

Project name: Forsmark
Bore hole No.: HFM15 **Azimuth: 320** **Inclination: -45**

Depth range: 84.000 - 98.564 m

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