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Forsmark site investigation

RAMAC and BIPS logging in boreholes KFM06A and HFM22

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Keywords: BIPS, RAMAC, Radar, TV, Geophysical borehole logging, Forsmark, AP PF 400-04-47.

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

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

Abstract

This report includes the data gained in geophysical logging operations performed within the site investigation at Forsmark. The logging operations presented here includes TV-logging (BIPS) and borehole radar (RAMAC) in the cored drilled borehole KFM06A and in the percussion drilled borehole HFM22. All measurements were conducted by Malå Geoscience AB / RAYCON during November 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 KFM06A and HFM22 was satisfying, but in some minor 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. More than 200 reflectors were identified in KFM06A, and around 60 of them have been oriented. The corresponding number for HFM22 is 66.

The basic conditions of the BIPS logging for geological mapping and orientation of structures are satisfying for borehole KFM06A, although induced effects from the drilling on the borehole walls limit the visibility. In HFM22 the BIPS images is of very good quality.

Sammanfattning

Denna rapport omfattar geofysiska loggningar inom platsundersökningsprogrammet för Forsmark. Mätningarna som presenteras här omfattar borrhålsradar- och BIPS-mätningar i borrhålen KFM06A och HFM22. Alla mätningar är utförda av Malå Geoscience AB / RAYCON under november 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 KFM06A och HFM22 var tillfredställande, men i mindre delar av sämre kvalité troligen till stor del beroende på en konduktiv miljö. En konduktiv miljö minskar möjligheterna att identifiera strukturer från borrhålsradardata. Dock har mer än 200 radarreflektorer identifierats i KFM06A, varav ca 60 är orienterade. Motsvarande antal för HFM22 är 66 stycken.

BIPS-bilderna visar att förutsättningarna för geologisk kartering och sprickorientering är goda för KFM06A, även om det finns svärtningar på borrhålsväggen som försämrar kvalitén på bilderna. För HFM22 är förutsättningarna perfekta tack vara bra kvalitet på vattnet längs hela borrhålet.

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 borehole radar (RAMAC) and TV-logging (BIPS) in the core-drilled borehole KFM06A and in the percussion-drilled borehole HFM22. The work was carried out in accordance with activity plan AP PF 400-04-47. 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 100 to approximately 1,000 m in borehole KFM06A. In HFM22 the loggings were performed from about 10 m to approximately 200 m depth. The boreholes are drilled with a diameter of approximately 78 and 140 mm, respectively.

All measurements were conducted by Malå Geoscience AB / RAYCON during November 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 antennas.
- Borehole TV logging with the so-called BIPS-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
Borrhålsloggning med BIPS och radar i teleskopborrhålen KFM05A och KFM06A (100–1,000 m) samt KFM06B (0–100 m)	AP PF 400-04-47	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

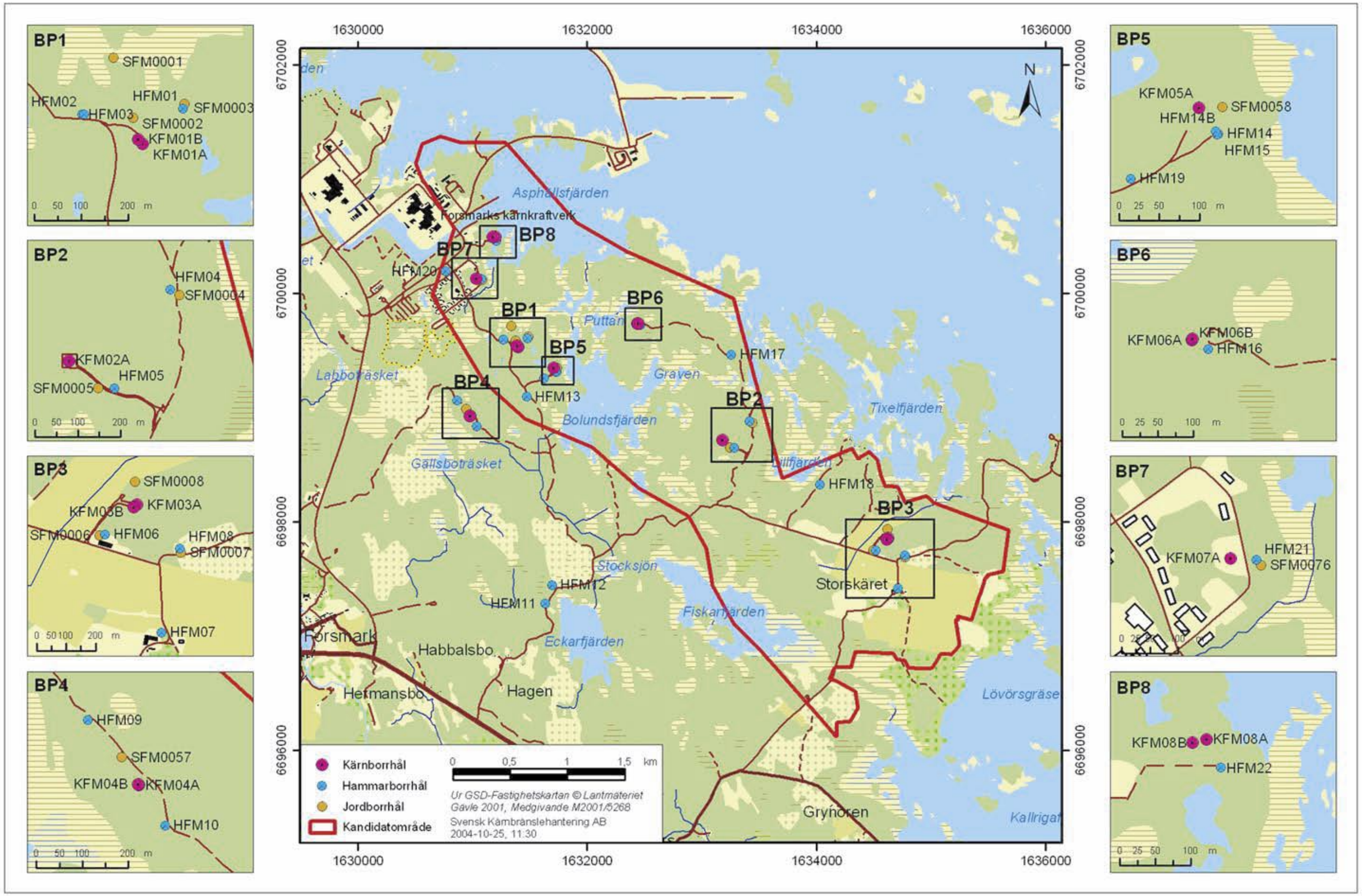


Figure 1-1. *General overview over the Forsmark area with the location of the boreholes KFM06A and HFM22.*

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 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 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.

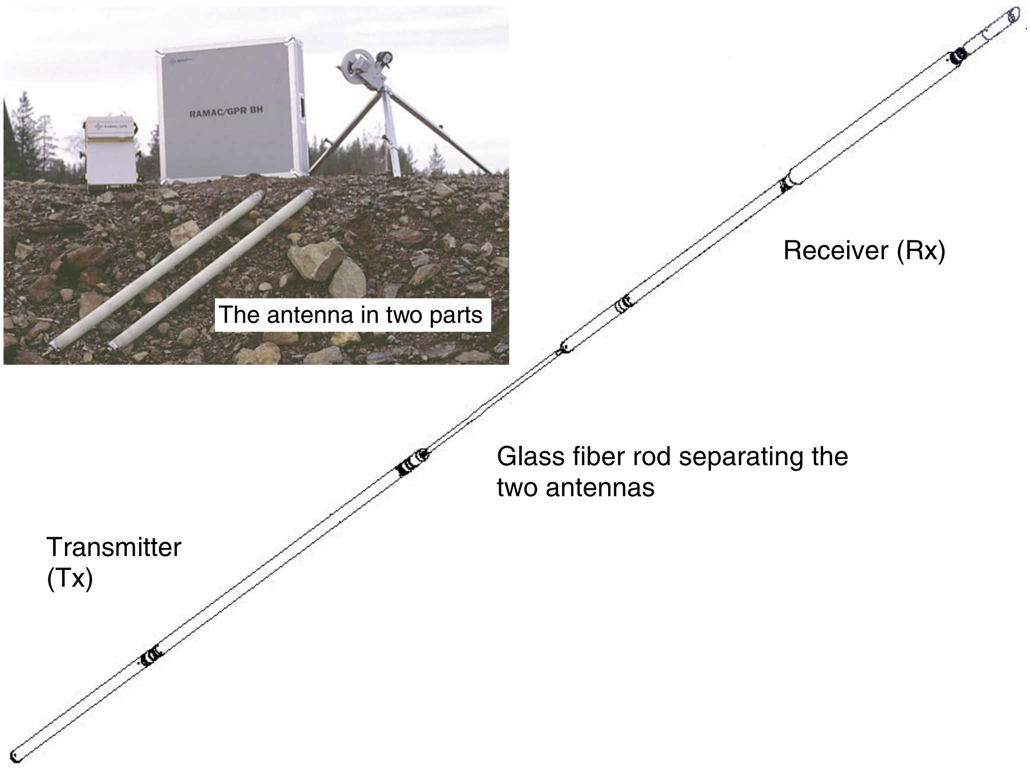


Figure 3-1. *Example of a borehole radar antenna.*

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, a circle of pixels is 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).

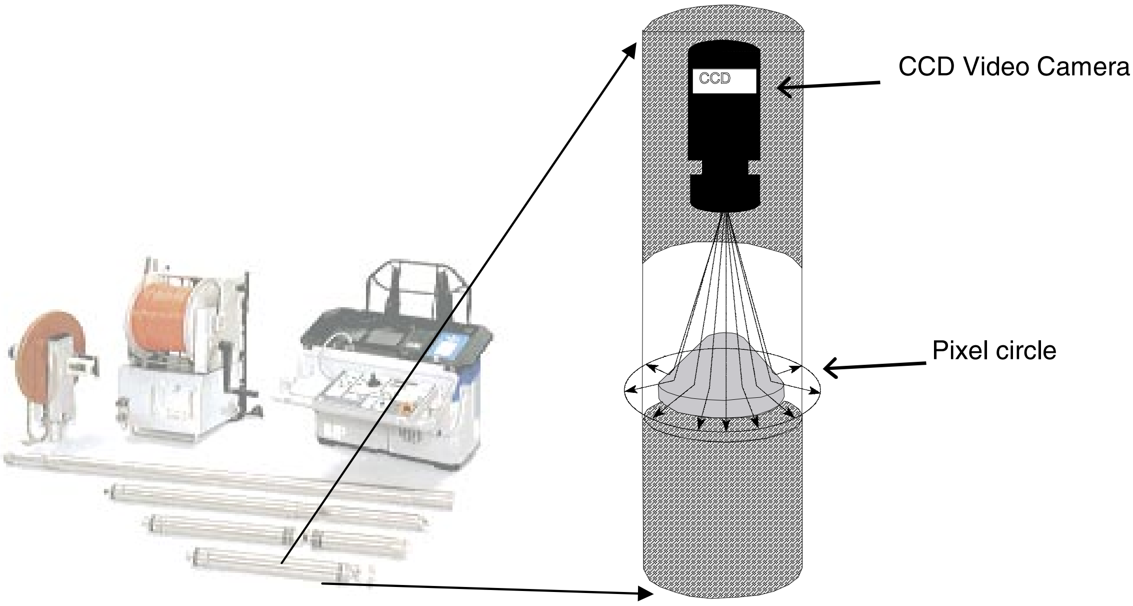


Figure 3-2. *The BIPS-system. To the right an illustration of the conical mirror scanning.*

4 Execution

4.1 General

4.1.1 RAMAC Radar

The measurements in KFM06A and HFM22 were carried out with dipole radar antennas, with frequencies of 250, 100 and 20 MHz. In KFM06A also the directional antenna were used, 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) are kept at a fixed separation by glass fiber rods according to Table 4-1 and 4-2. See also Figure 3-1 and 4-1.

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

The functionality of the directional antenna was tested before measurements in KFM06A. This is done by measurements in the air, where the receiver antenna and the transmitter antenna are placed apart. While transmitting and measuring the receiver antenna is turned around and by that giving the direction from the receiver antenna to the transmitter antenna. The difference in direction measured by compass and the result achieved from the directional antenna was about 15 degrees. This can be considered as good due to the disturbed environment, with metallic objects etc at the test site.

For more information on system settings used in the investigation of KFM06A and HFM22, see Table 4-1 and 4-2 below.

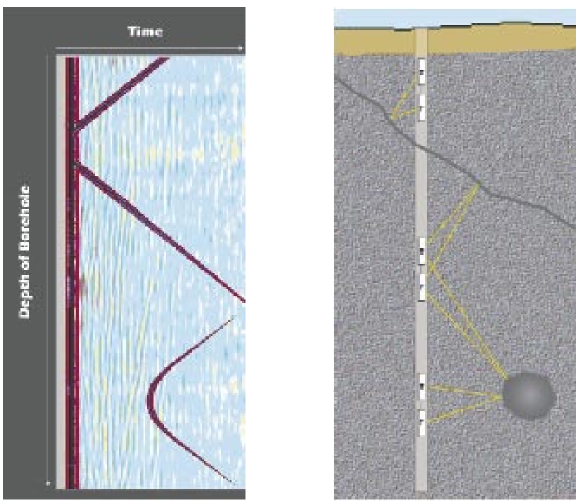


Figure 4-1. *The principle of radar borehole reflection survey and an example of result.*

Table 4-1. Radar logging information from KFM06A.

Site:	**Forsmark**	**Logging company:**	**RAYCON**		
BH:	**KFM06A**	**Equipment:**	**SKB RAMAC**		
Type:	**Directional/Dipole**	**Manufacturer:**	**MALÅ GeoScience**		
Operator:	**CG**	**Antenna**			
		Directional	**250 MHz**	**100 MHz**	**20 MHz**
	Logging date:	04-11-04	04-11-03	04-11-02	04-11-03
	Reference:	T.O.C.	T.O.C.	T.O.C.	T.O.C.
	Sampling frequency (MHz):	615	2,424	891	239
	Number of samples:	512	619	518	518
	Number of stacks:	32	Auto	Auto	Auto
	Signal position:	390.48	–0.34	–0.35	1.54
	Logging from (m):	103.4	101.5	102.6	106.25
	Logging to (m):	988.4	994.6	992.8	995.6
	Trace interval (m):	0.5	0.25	0.2	0.1
	Antenna separation (m):	5.73	1.9 2.9	10.05	

Table 4-2. Radar logging information from HFM22.

Site:	**Forsmark**	**Logging company:**	**RAYCON**		
BH:	**HFM22**	**Equipment:**	**SKB RAMAC**		
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**		
Operator:	**CG**	**Antenna**			
			250 MHz	**100 MHz**	**20 MHz**
	Logging date:		04-11-05	04-11-05	04-11-05
	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:		–0.29	–0.35	–1.54
	Logging from (m):		1.5 2.6	6.25	
	Logging to (m):		214	213.8	309.35
	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 circle of pixels 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.

In order to control the quality of the system, calibration measurements were performed in a test pipe before logging the first borehole and after logging the last one. Figure 4-2 corresponds to the test pipe logging before and after the logging of KFM06A and HFM22 in November. 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.

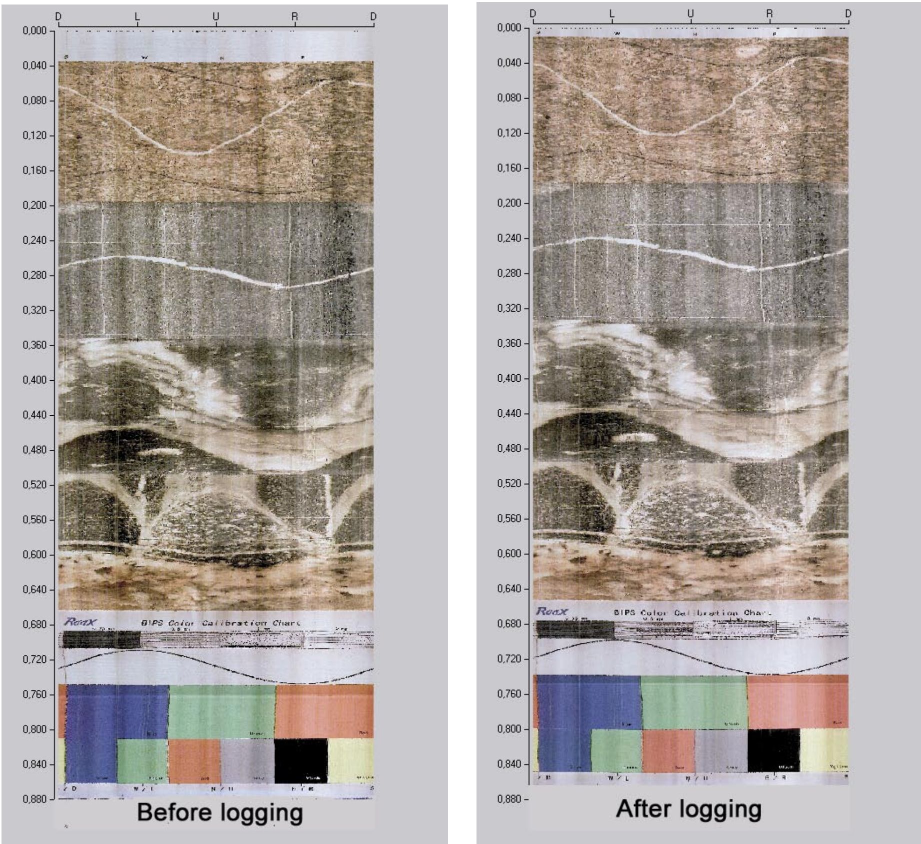


Figure 4-2. *Results from logging in the test pipe before and after the logging campaign in November.*

The BIPS logging information is found in the header for every single borehole presented in Appendix 4 and 5 in this report.

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 cored 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 and 5) in the BIPS images represent the recorded depth (in black) and adjusted depth (in red).

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

The results from KFM06A, the depth to identified structures, are corrected according to the present depth divergence. As HFM22 is less than 220 m, the depth divergence is very slight, in the deepest parts of this borehole.

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 128 m/µs. The velocity measurement was performed with the 100 MHz antenna /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 4-3 and 4-4. It should be observed that the processing steps below refer to the Appendix 1 to 3. The filters applied affect the whole borehole length and are not always suitable in all parts, depending on the geological conditions and conductivity of the borehole fluid. During interpretation further processing can be done, most often in form of bandpass filtering. This filtering can be applied just in parts of the borehole, where needed.

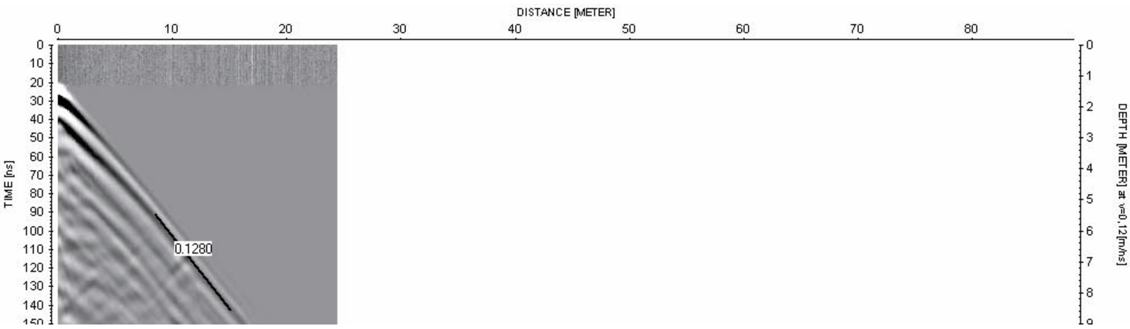


Figure 4-3. Results from velocity measurements in HFM03 /1/.

Table 4-3. Processing steps for borehole radar data from KFM06A.

Site:	**Forsmark**	**Logging company:**	**RAYCON**		
BH:	**KFM06A**	**Equipment:**	**SKB RAMAC**		
Type:	**Directional/Dipole**	**Manufacturer:**	**MALÅ GeoScience**		
Interpret:	**JA**	**Antenna**			
		Directional	**250 MHz**	**100 MHz**	**20 MHz**
	Processing:	DC removal	DC removal	DC removal	DC removal
		Move start time	Move start time	Move start time	Move start time
		Gain	Gain	Gain	Gain
		FIR			

Table 4-4. Processing steps for borehole radar data from HFM22.

Site:	**Forsmark**	**Logging company:**	**RAYCON**		
BH:	**HFM22**	**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

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 and 5-2 and are also visible on the radargrams in Appendix 1 to 3.

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 BIPP from RaaX was used.

4.3 Nonconformities

In this logging activity also KFM06B was included, see Activity Plan AP PF 400-04-47. However, during logging in KFM06B the BIPS probe jammed at a depth of 56 meter.
A fishing operation was organized and the probe was retrieved two weeks after the incident. After this incident the decision was to stop logging activities in the borehole before it has been stabilized. The stabilizing procedure is planned to start beginning of 2005.

BIPS data from KFM06B was delivered down to 56 m, but is not presented in this report.

5 Results

The results from the BIPS measurements in KFM06A and HFM22 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 KFM06A and HFM22 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 5-4. 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 or other also exist. 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 KFM06A and HFM22, (as seen in Appendix 1 to 3) is relatively satisfying, but in some parts of lower quality due to more conductive conditions. A conductive environment makes the radar wave to attenuate, which decreases the penetration. This is for instance seen very clearly in the data from KFM06A from 880 m and downwards and in HFM22 between 110 and 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. If structures can be identified with all three antenna frequencies, it can probably be explained by that the structure is quite significant.

In Tables 5-1 and 5-2 below the distribution of identified structures along the boreholes KFM06A and HFM22 are listed.

Table 5-1. Identified structures as a function of depth in KFM06A.

Depth (m)	No of structures
0–50	3
50–100	1
100–150	16
150–200	10
200–250	11
250–300	16
300–350	13
350–400	11
400–450	17
450–500	9
500–550	11
550–600	11
600–650	9
650–700	11
700–750	15
750–800	13
800–850	10
850–900	11
900–950	9
950–1,000	8
1,000–	1

Table 5-2. Identified structures as a function of depth in HFM22.

Depth (m)	No of structures
0–20	3
20–40	4
40–60	2
60–80	5
80–100	5
100–120	7
120–140	2
140–160	6
160–180	–
180–200	4
200–	8

Tables 5-3 and 5-4 summarises the interpretation of radar data from KFM06A and HFM22. In the tables the depth and intersection angle to the identified structures are listed. As seen some radar reflectors are marked with ±, which indicates an uncertainty in the interpretation of direction. The direction can in these cases be ±180 degrees. The direction to the object (the plane) is defined in Figure 5-1. This direction and the intersection angle are also given as strike and dip, also given in the tables below.

Observe that a structure can have several different angles, if the structure is undulating, and thereby also different intersection depths. This is seen for structure 136 in Table 5-3. To this structure, most likely, also structures 136x and 136xx belong.

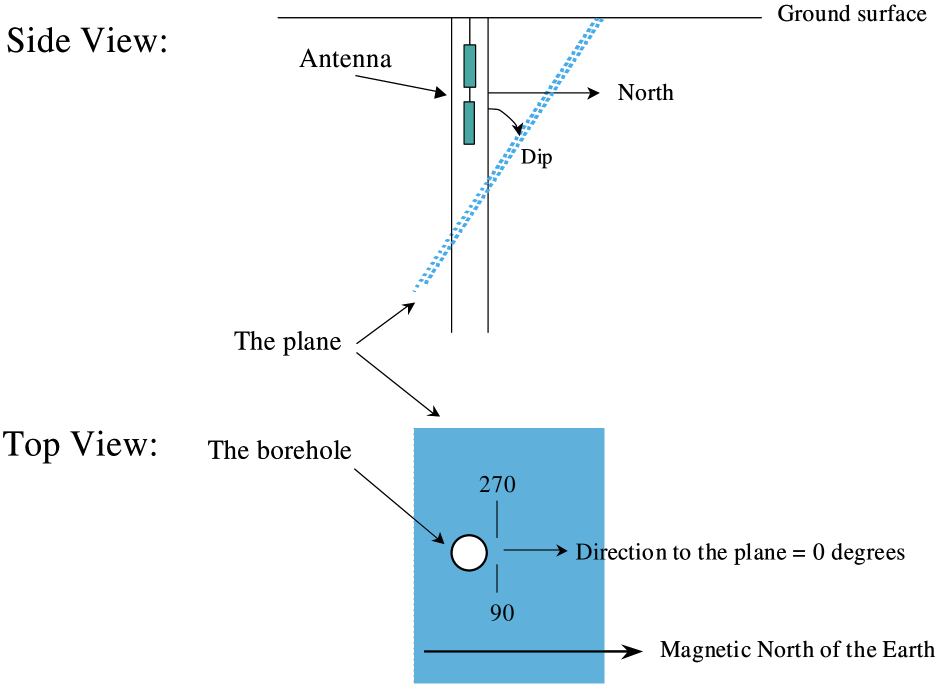


Figure 5-1. *Definition of direction to object as presented in Table 5-3.*

Table 5-3. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz and the directional antenna in borehole KFM06A.

RADINTER MODEL INFORMATION (20, 100 and 250 MHz Dipole Antennas and Directional antenna)
Site: **Forsmark**
Borehole name: **KFM06A**
Nominal velocity (m/μs): **128.0**

Name	Intersection depth	Intersection angle	Object direction	Dip 1	Strike 1	Dip 2	Strike 2
A	–17	6					
104	28.80	54					
B	43.9	18					
C	87.70	18	15	80	309		
Lxx	102.80	23					
Cx	104.50	64					
I	110.10	32					
D	112.00	34					
Dx	112.20	48	351	76	150		
E	117.30	67					
H	127.80	80					
F	128.80	77					
G	129.90	78					
J	133.60	63	213±	16	200	53	22
Lx	142.60	42	18	75	130		
Kxx	145.10	79					
Kx	145.50	53					
K	145.60	30	333	84	166		
L	145.90	46	9	72	137		
Ix	148.80	16					
M	153.90	66					
N	157.70	78					
O	162.10	62					
P	165.70	75	18±	50	136	13	171
Q	169.20	81					
R	177.80	76					
S	180.90	69	168	11	119		
T	185.90	58					
U	189.90	53					
V	196.80	68					
W	203.00	74					
X	206.00	78	183	15	147		
Y	213.30	25					
1	215.40	70					
2	218.80	73	171±	16	135	45	148
3	221.10	70					
Z	225.90	21	174±	38	333	81	329
14	226.00	25	207±	85	312	66	124
5	238.80	63	9±	51	139	10	162
4	240.90	27					
6	243.70	55	345	65	153		

Name	Intersection depth	Intersection angle	Object direction	Dip 1	Strike 1	Dip 2	Strike 2
7	252.20	66					
15	254.30	51					
8	255.00	72					
9	257.90	70					
10	261.60	46					
11	269.30	46	180	9	323		
11x	269.40	75	15	47	137		
12	271.50	68					
18	282.90	22	6	82	318		
16	283.20	56					
17	288.00	47					
17x	287.50	57	153	14	68		
17xx	288.80	41					
13	291.50	25	336	85	343		
18x	294.10	33	15	88	129		
19	297.50	68					
20	303.80	72					
21	307.00	67					
22	308.80	69	162±	14	112	51	149
23	321.30	66					
152	325.00	43					
24	328.80	56					
149	329.30	33					
25	332.80	56					
27	335.60	33	174±	26	331	89	146
26	336.80	63					
41	341.60	8					
29	346.70	52					
28	349.70	24					
152x	350.90	30					
31	353.10	73					
28xx	354.00	20	348±	79	331	38	338
30	356.20	60					
28x	359.00	31					
51	364.50	29					
150	367.70	31					
35	372.80	45					
33	377.20	32					
34	383.00	30	330±	86	165	31	11
36	386.40	38	150	25	22		
37	393.50	65					
38	400.70	68					
40	401.20	50					
39	403.70	46					
42	411.50	55					
43	412.40	57	162	10	53		
44x	413.00	51					

Name	Intersection depth	Intersection angle	Object direction	Dip 1	Strike 1	Dip 2	Strike 2
44	416.40	59	153±	14	75	59	154
153	420.20	32					
45	421.60	56					
46	423.80	73					
54	428.50	61					
52	431.00	60					
47	434.40	75					
48	436.60	68	162	14	110		
49	438.00	81					
50	438.90	68					
55	449.90	55					
53	457.00	48	63	65	91		
57	473.90	68	69	54	95		
56	474.30	31					
58	480.30	46					
59	483.70	72					
60	485.40	69	330±	54	147	18	98
65	494.30	56	108	38	76		
61	497.00	66					
62	499.20	57					
63	504.00	61					
64	509.50	75					
66	516.50	73	171	16	124		
67	523.50	47					
67x	523.80	36					
68x	527.90	53					
68	528.20	88	216	29	142		
69	534.60	47					
70	538.40	66					
71	542.80	53	270±	48	186	47	83
72	548.10	86					
73	553.60	47	267±	49	191	51	81
155	557.60	70					
74	558.10	64					
75	559.50	62	273	45	178		
76	562.20	50					
77	570.70	34					
78	575.90	53					
79	582.80	56					
80	586.40	62	348±	61	140	9	97
163	596.40	9	159	13	37		
81	599.70	72					
82	604.30	65					
83	611.60	70					
84	612.80	61					
154	618.30	30					
85x	622.60	38	342	81	331		

Name	Intersection depth	Intersection angle	Object direction	Dip 1	Strike 1	Dip 2	Strike 2
85	624.00	37	132	42	63		
86	627.10	70					
87	630.70	56					
85xx	633.20	32					
88x	656.20	38	354	88	133		
88	658.10	31	168±	25	333	88	323
89x	672.70	64	270±	43	167	43	87
89	675.10	57					
97	677.00	26	264	66	207		
90	680.80	68					
91	682.90	73					
97x	684.00	37	264±	56	197	63	65
96	686.80	63					
160	696.40	66					
93	699.80	83					
95	700.40	85					
98	703.80	75					
100	714.90	65	27	58	112		
101	722.20	63					
103	726.10	54					
102	726.30	70					
99	731.30	22					
108	738.00	14	213	46	255		
109	738.00	58					
161	738.30	23					
105	743.40	40	159	25	12		
105x	743.20	59					
106	746.00	60					
107	747.30	64					
108x	748.40	26					
105xx	756.70	25	15	80	291		
157	753.90	34					
110	760.90	31					
112	770.40	60					
164	771.20	37	180±	17	304	89	123
111x	772.30	70	252±	35	153	44	100
111	772.40	57	255	39	169		
156	775.60	25					
113	777.50	66					
114	785.90	77					
115	789.60	72					
115x	790.00	50					
116	797.40	57					
158	799.90	44					
117	811.60	47	81	60	68		
118	814.90	56					
119	822.30	67					

Name	Intersection depth	Intersection angle	Object direction	Dip 1	Strike 1	Dip 2	Strike 2
120	826.60	51	189±	5	202	73	116
121	831.10	71					
159	835.60	35					
122	836.70	54					
123	838.80	72					
124	841.90	53					
125	848.40	64	270	43	159		
126	855.10	79					
128	861.40	72					
127	864.40	68	63±	52	93	33	157
129	867.00	68					
130	869.70	60					
131	874.40	52					
132	877.00	54					
137	886.10	16	36±	76	264	45	246
133	887.20	29	180±	23	299	81	299
133x	893.90	16					
134	895.10	26					
135	908.30	26					
138	915.40	67					
139	920.10	59					
136	925.70	23	357	76	301		
136x	930.70	16					
151	930.90	55					
136xx	942.70	15	6	68	292		
142	947.20	62					
136xxx	949.80	19					
140	952.70	54					
141	954.90	58					
143	959.60	54					
144	962.50	68	180±	10	118	66	118
145	968.00	35					
148	975.70	60					
146	978.50	58					
147	993.80	13					
162	1,019.00	29					

Table 5-4. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz in borehole HFM22.

RADINTER MODEL INFORMATION (20, 100 and 250 MHz Dipole Antennas)
Site: **Forsmark**
Borehole name: **HFM22**
Nominal velocity (m/μs): **128.00**

Object type	Name	Intersection depth	Intersection angle
PLANE	13	10.00	65
PLANE	A	12.90	41
PLANE	B	17.20	66
PLANE	Cx	21.10	69
PLANE	C	22.00	61
PLANE	D	28.80	71
PLANE	E	38.00	69
PLANE	F	40.80	60
PLANE	Gx	59.90	51
PLANE	G	62.50	55
PLANE	H	68.90	48
PLANE	Hx	70.60	49
PLANE	I	73.30	51
PLANE	J	76.00	53
PLANE	K	85.30	53
PLANE	L	90.80	47
PLANE	M	92.60	54
PLANE	N	96.40	59
PLANE	Nxx	96.80	46
PLANE	Nx	100.40	43
PLANE	R	102.10	46
PLANE	O	106.60	57
PLANE	P	108.40	55
PLANE	Q	111.00	54
PLANE	S	118.00	41
PLANE	T	119.90	59
PLANE	U	124.20	48
PLANE	V	129.00	42
PLANE	W	141.90	39
PLANE	X	144.60	47
PLANE	Xx	145.10	39
PLANE	Y	147.10	49
PLANE	Z	152.50	47
PLANE	1	158.60	52
PLANE	2x	181.80	43
PLANE	2	182.30	43
PLANE	3	189.20	44
PLANE	4	198.30	57
PLANE	8	201.80	72
PLANE	9	204.90	70
PLANE	5	205.00	62
PLANE	7	210.60	62
PLANE	10	213.50	43
PLANE	6	217.10	82
PLANE	11	229.30	49
PLANE	12	241.90	53

In Appendix 1 and 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 5-5 and 5-6.

Table 5-5. Borehole length intervals in KFM06A with decreased amplitude for the 250 MHz antenna.

Depth (m)	
110–115	595
130	610
135	620–825
145	655
220	700
230	745
235–240	770–775
245	795–800
265–270	855
285–290	885
330–340	890–900
350–360	925–930
435–440	965–970
540	980
585	

Table 5-6. Borehole length intervals in HFM22 with decreased amplitude for the 250 MHz antenna.

Depth (m)	
35–40	115
60–65	125
70	145
85	185

5.2 BIPS logging

The BIPS pictures are presented in Appendix 4 and 5.

To get the best possible depth 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 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 meter 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 Figure 4-2 in this report.

Data for the inclination and azimuth presented in this report for the boreholes are only preliminary (reference from AP PF 400-04-47).

5.2.1 KFM06A

The images from the borehole are heavily affected by the drilling induced discolouring of the borehole wall. In the most affected parts, it can be problematic to map thin structures. A bad part is showed in Figure 5-2, and as seen in this section it is problematic to map thin geological structures special if the rock colour is dark. Still thin fractures are easy to map.

5.2.2 HFM22

The images are as good they can be in percussion drilled boreholes mainly depending on the very good water quality.

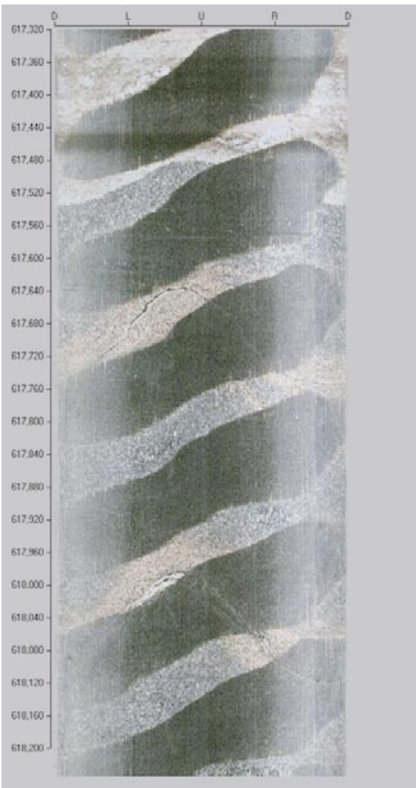


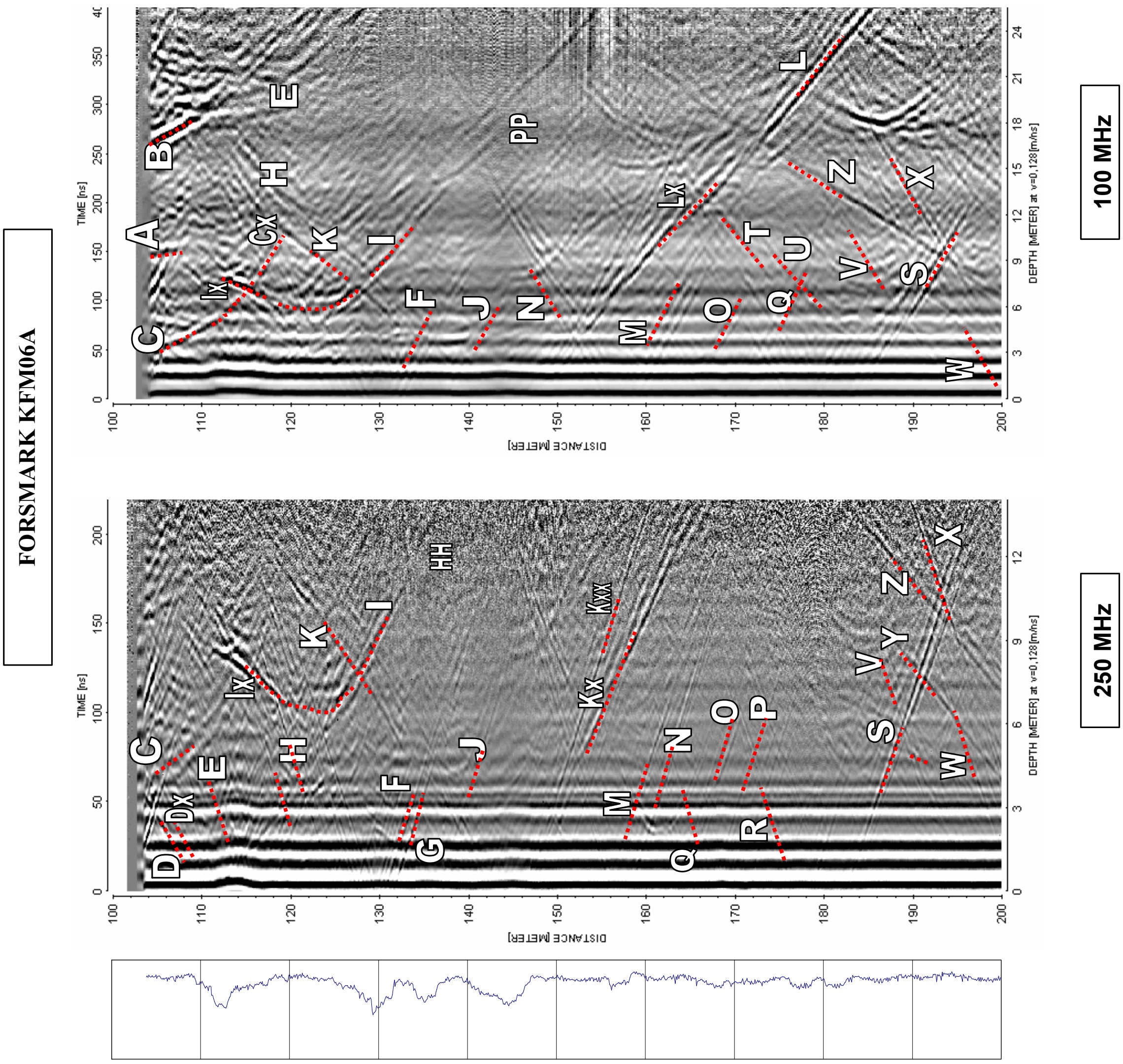
Figure 5-2. *Discolouring of the borehole wall in KFM06A.*

References

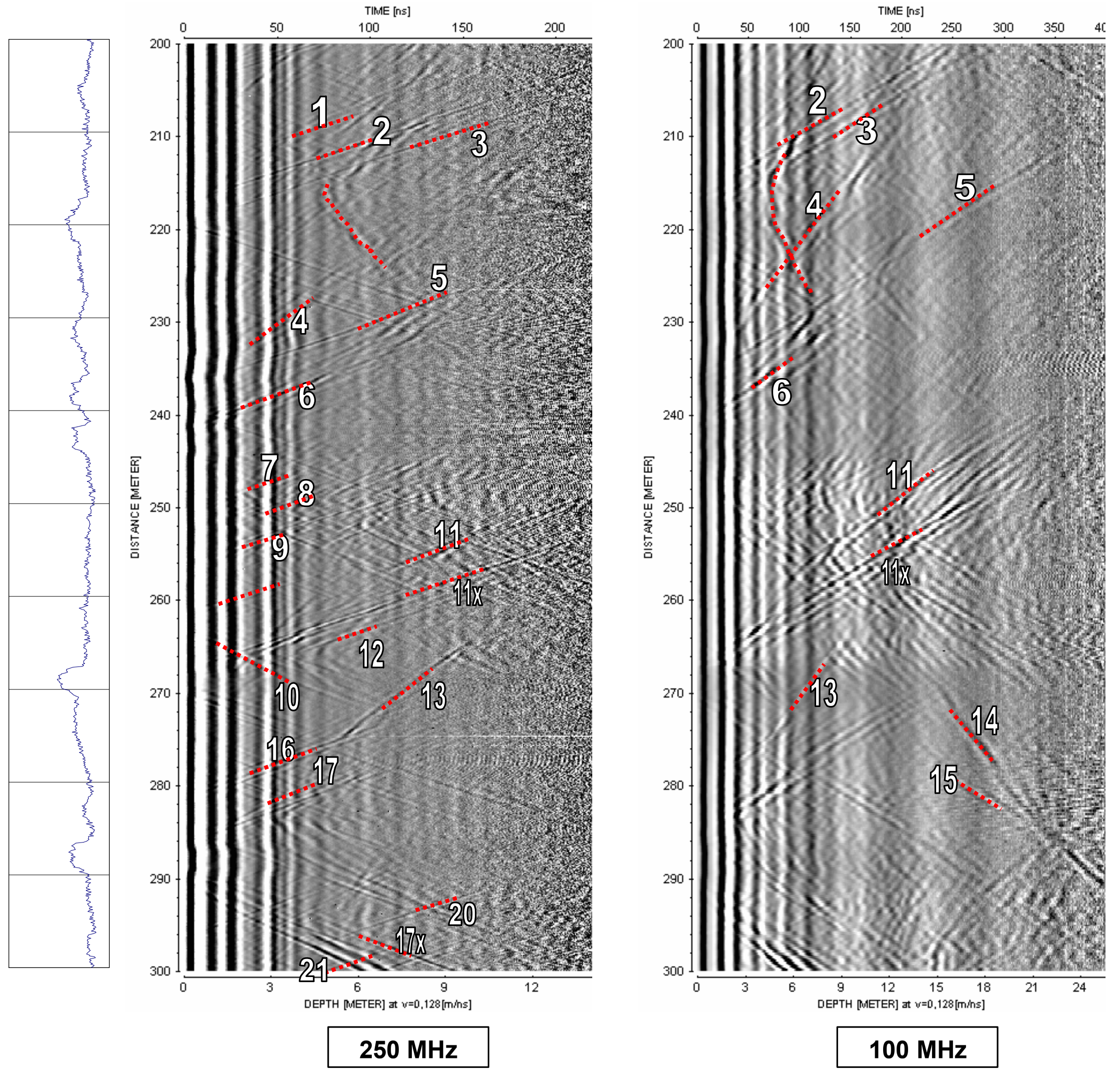
/1/ **Gustafsson C, Nilsson P, 2003.** Geophysical Radar and BIPS logging in borehole HFM01, HFM02, HFM03 and the percussion drilled part of KFM01A. SKB P-03-39. Svensk Kärnbränslehantering AB.

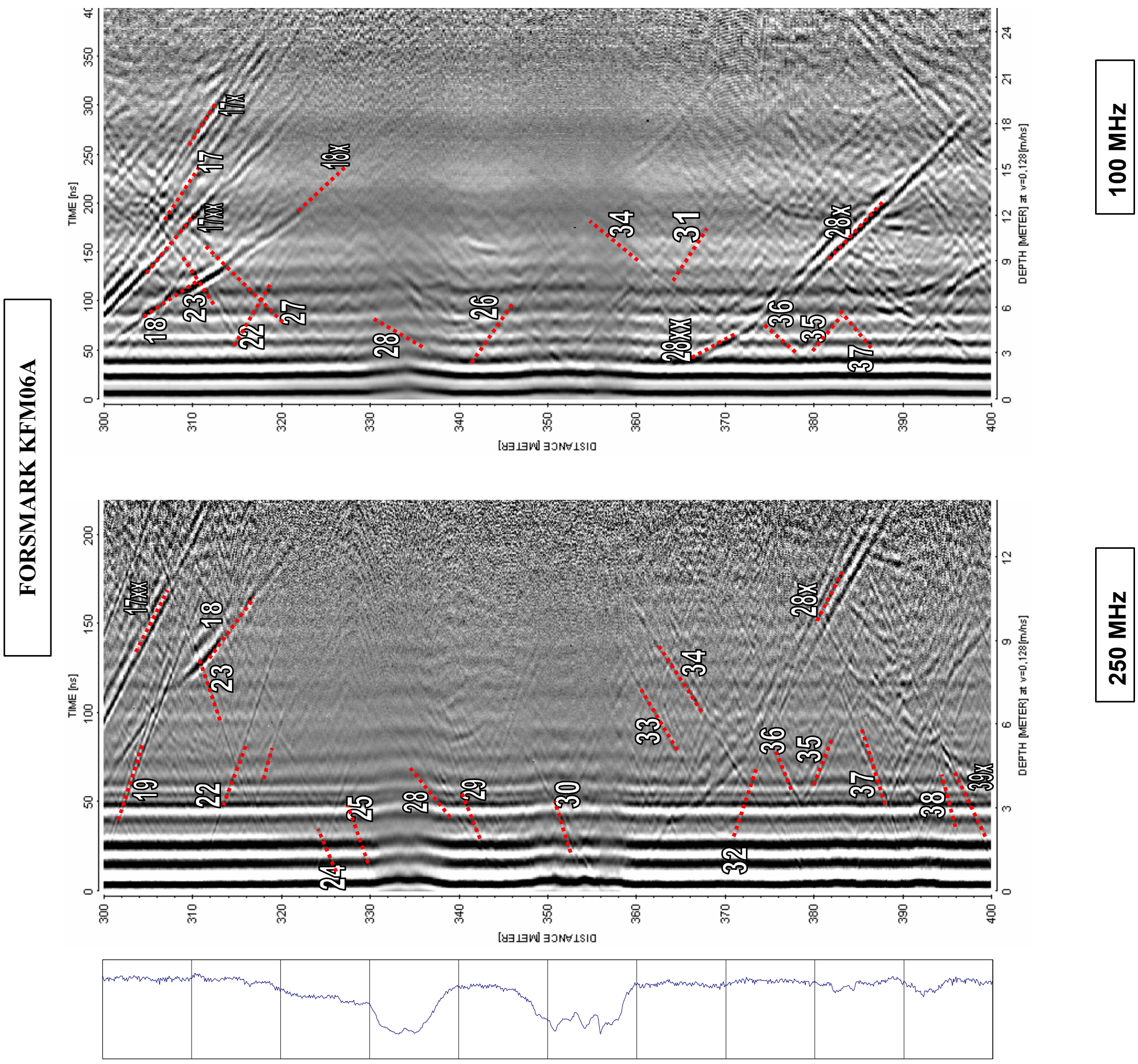
Appendix 1

Radar logging in KFM06A, 100 to 990 m, dipole antennas 250 and 100 MHz

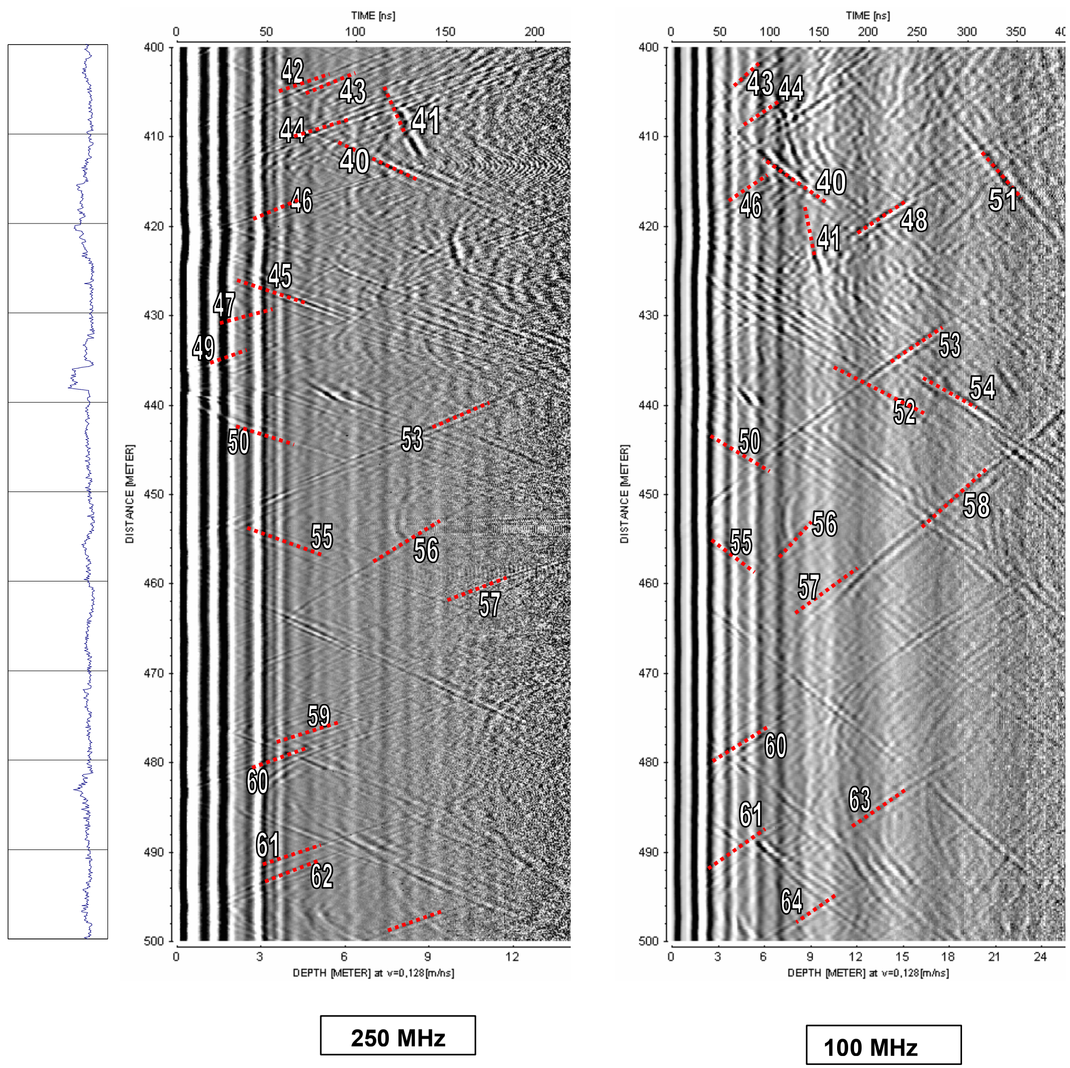


FORSMARK KFM06A

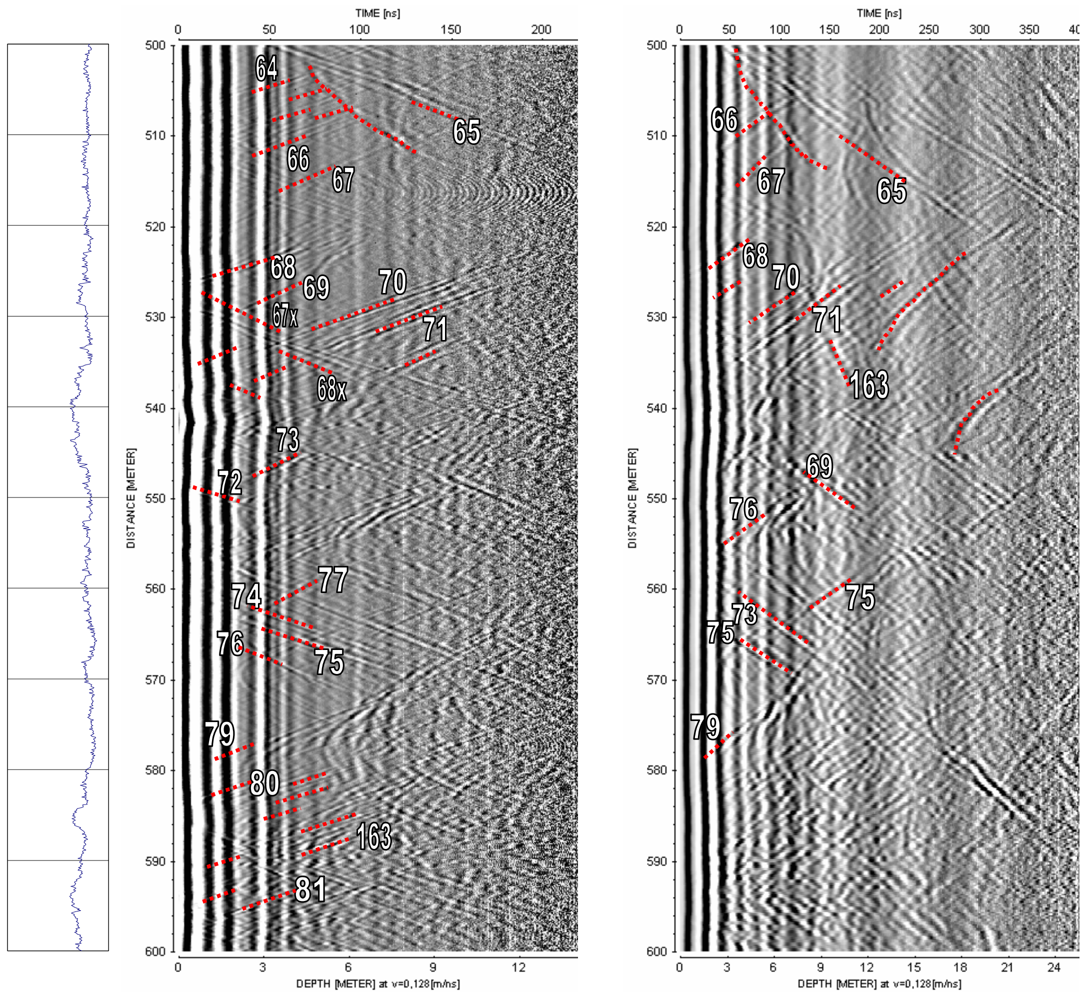



FORSMARK KFM06A
250 MHz
100 MHz
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,128[m/ns]

FORSMARK KFM06A



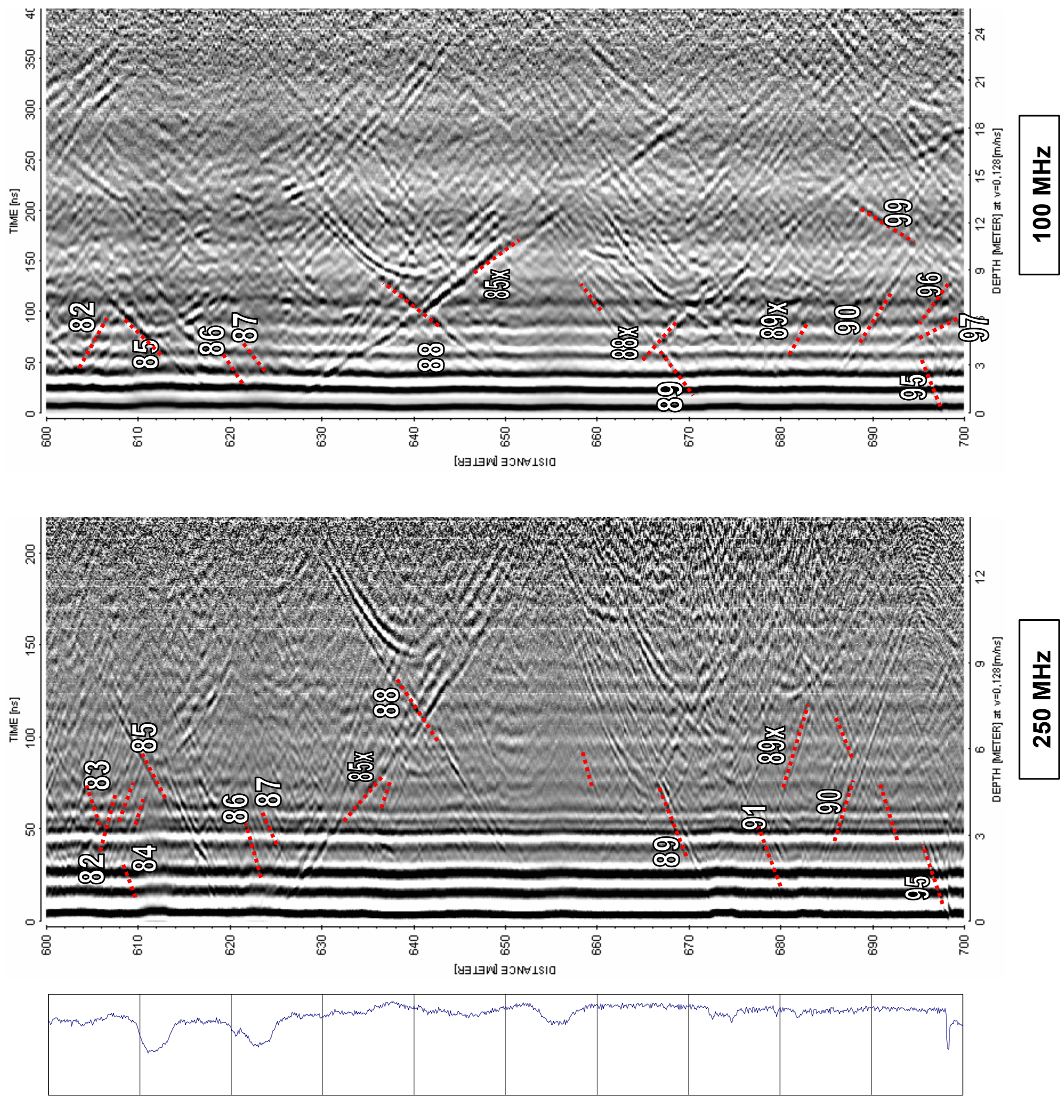
FORSMARK KFM06A



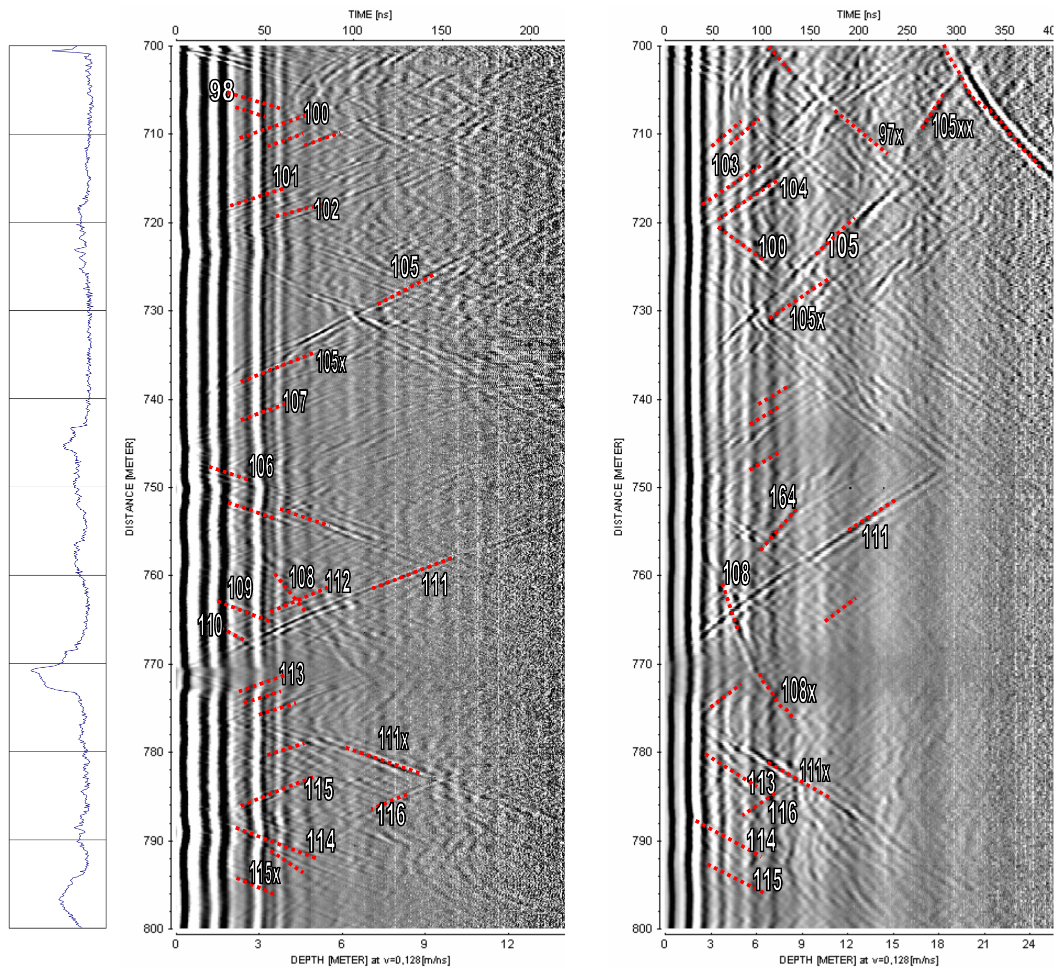
250 MHz

100 MHz

FORSMARK KFM06A



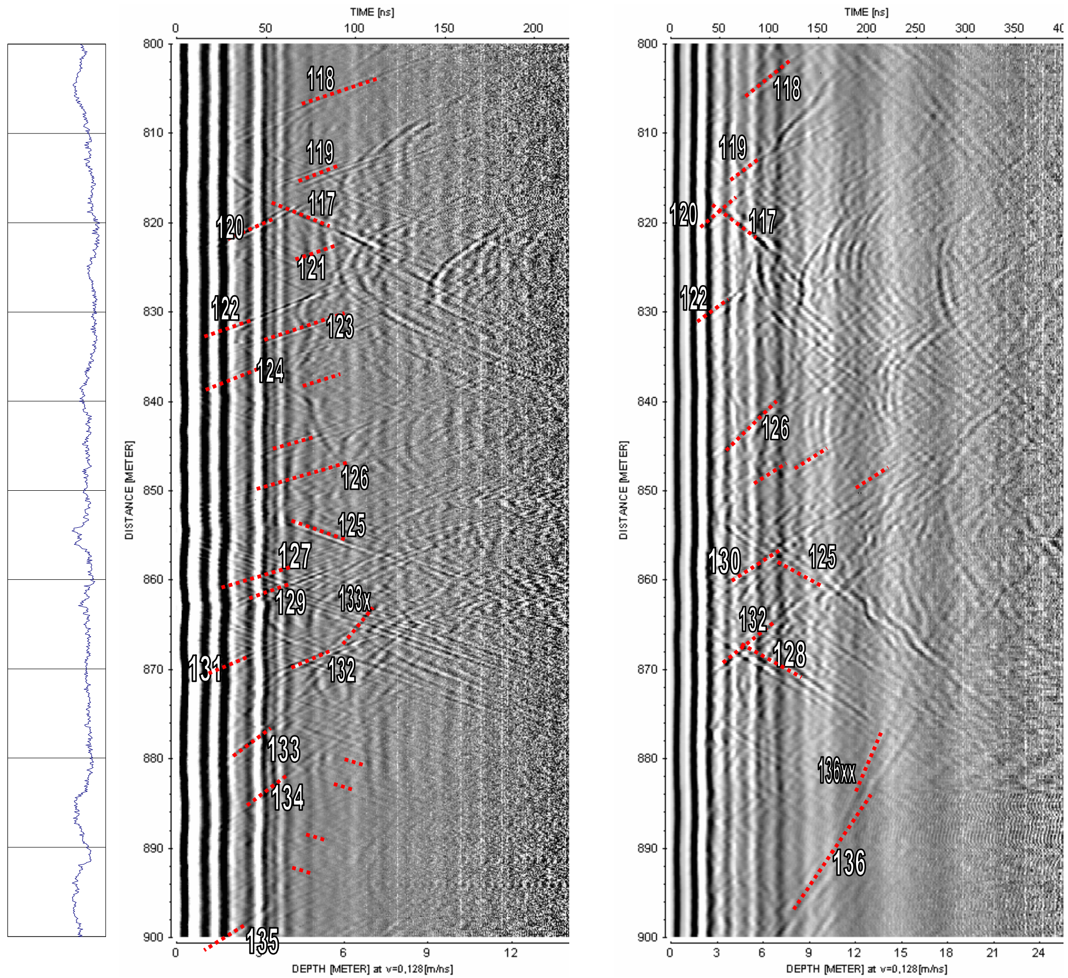
FORSMARK KFM06A



250 MHz

100 MHz

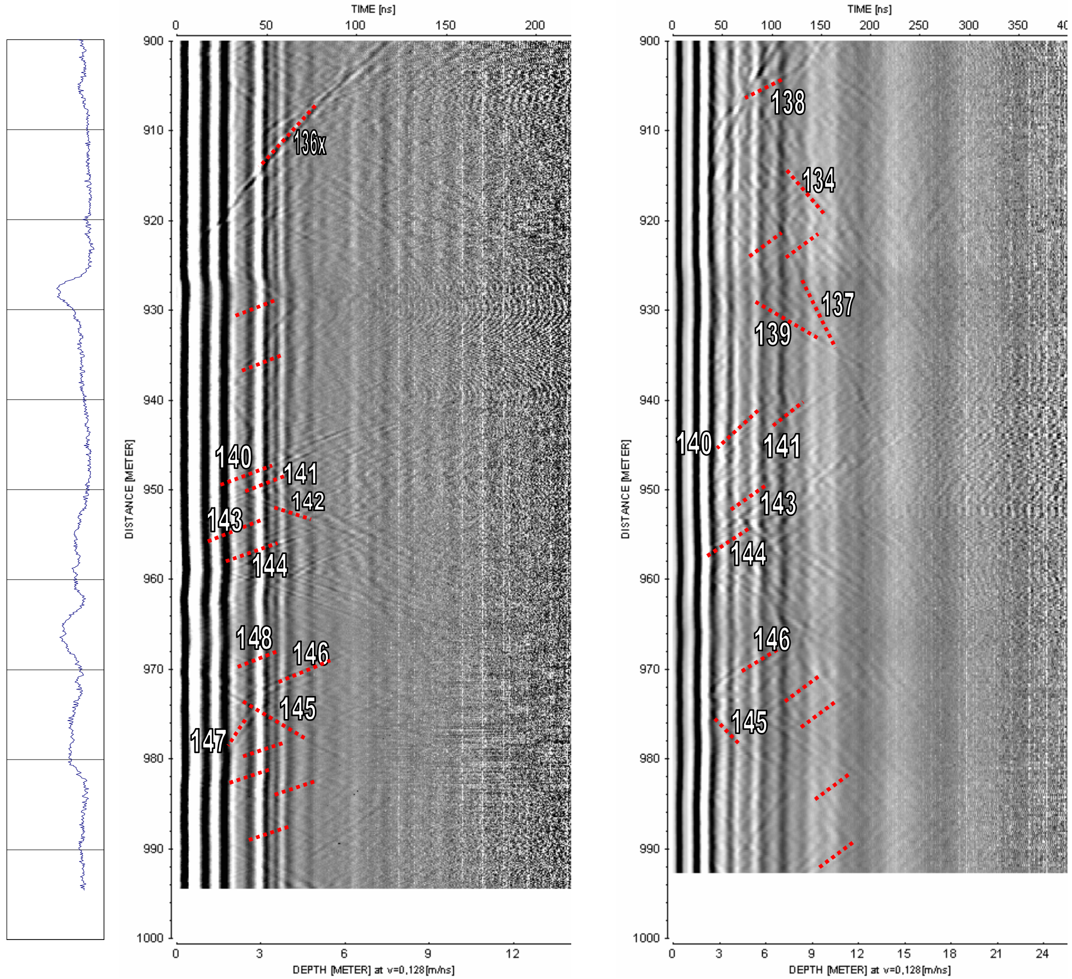
FORSMARK KFM06A



250 MHz

100 MHz

FORSMARK KFM06A



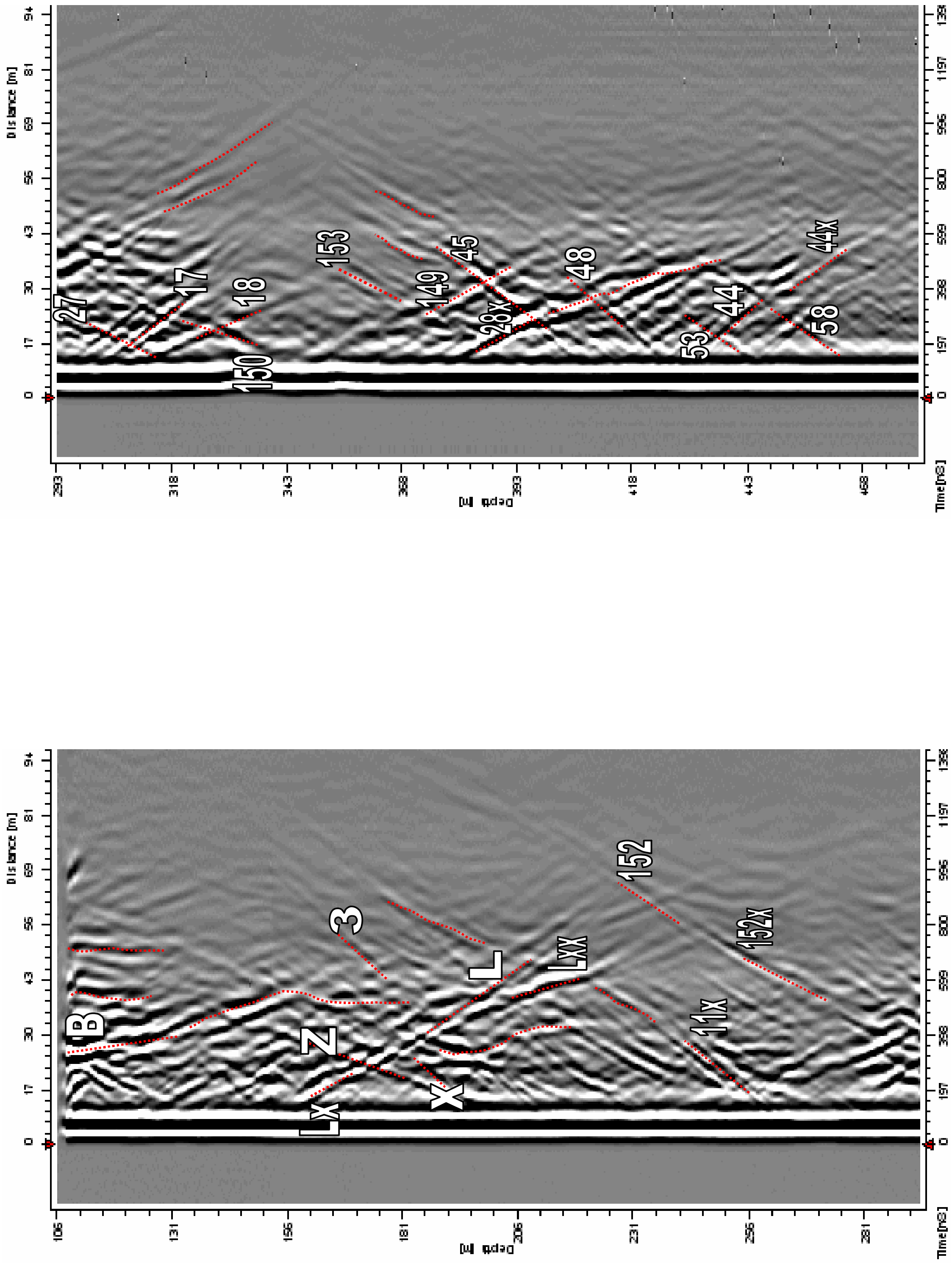
250 MHz

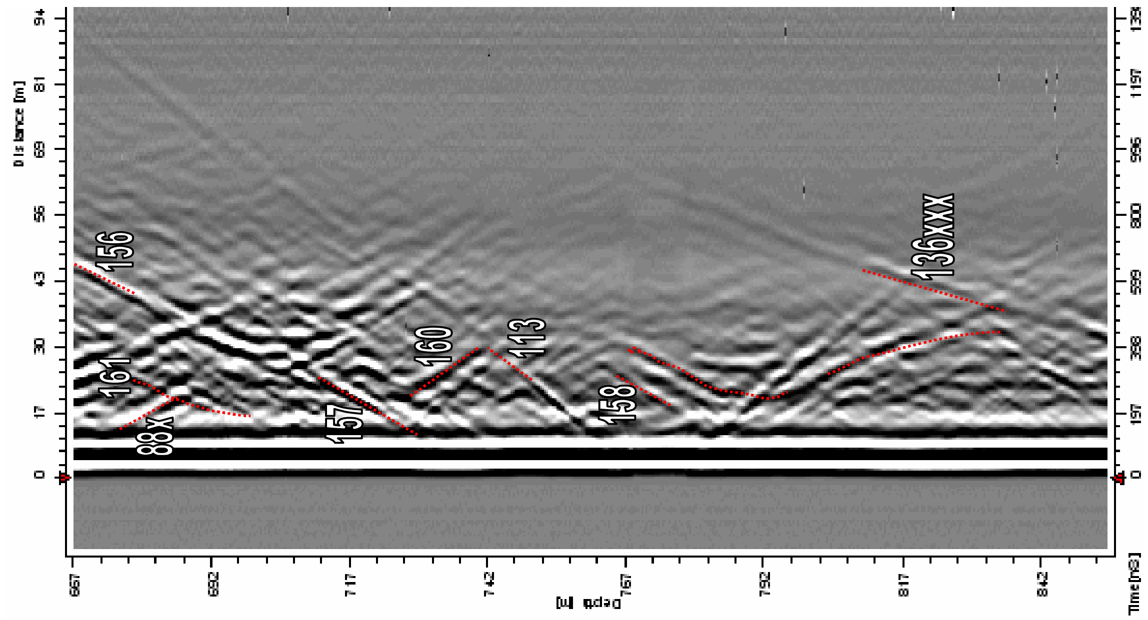
100 MHz

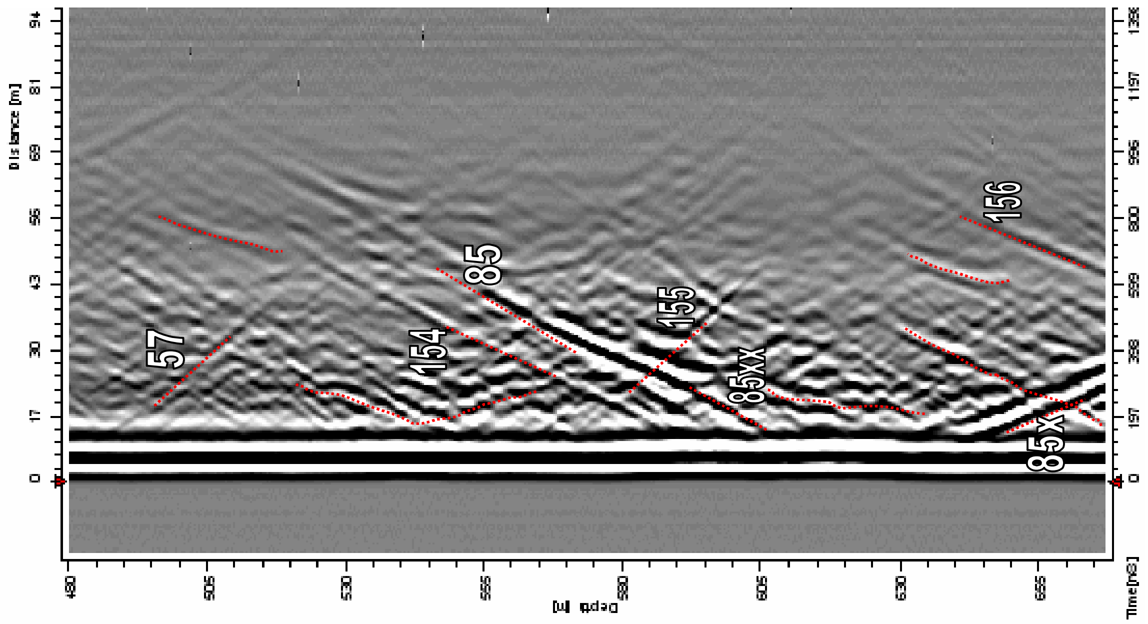
Appendix 2

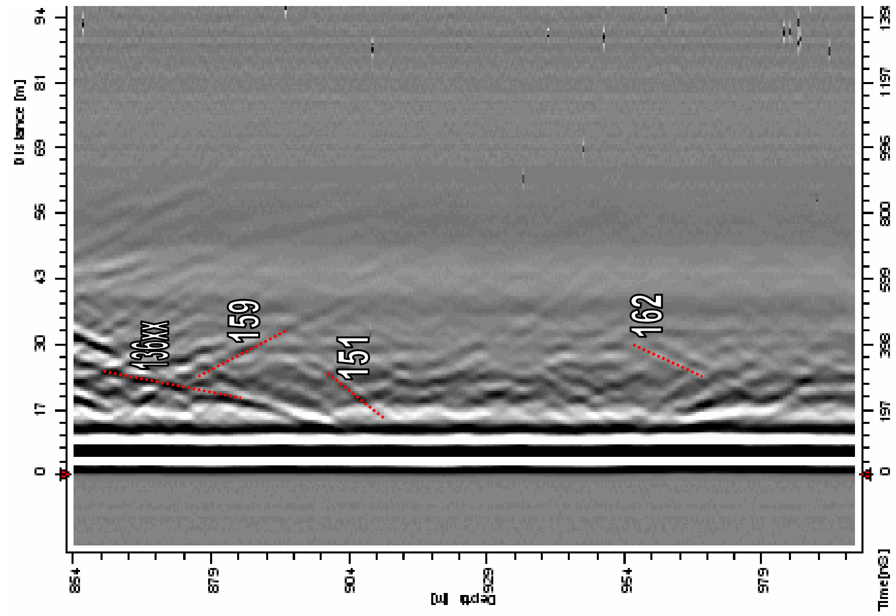
Radar logging in KFM06A, 100 to 990 m, dipole antenna 20 MHz

Forsmark KFM06A -20MHz dipole antenna with interpretation



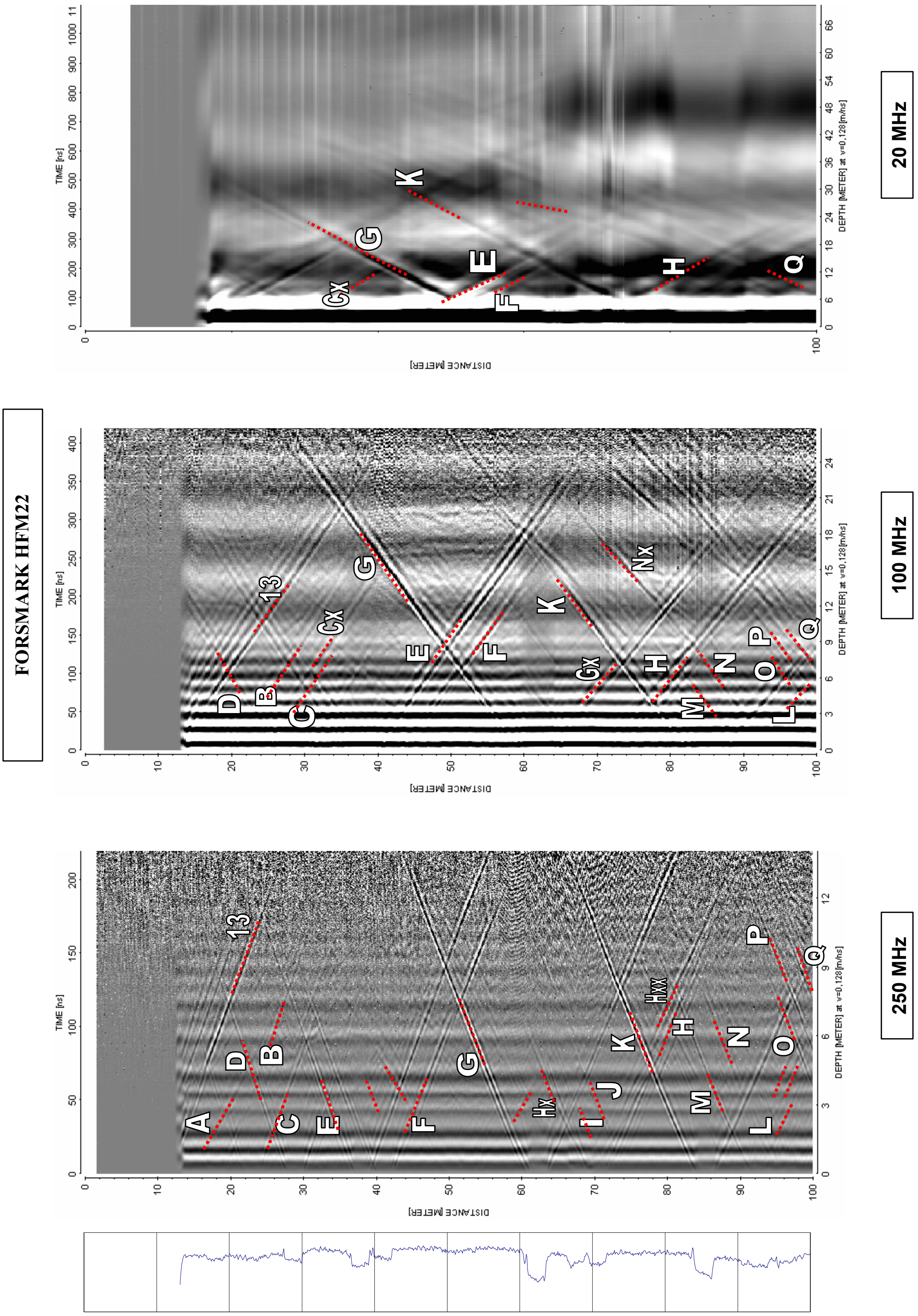

Distance [m]
Depth [m]
Time[nS]
156
161
88x
157
160
113
158
136xxx

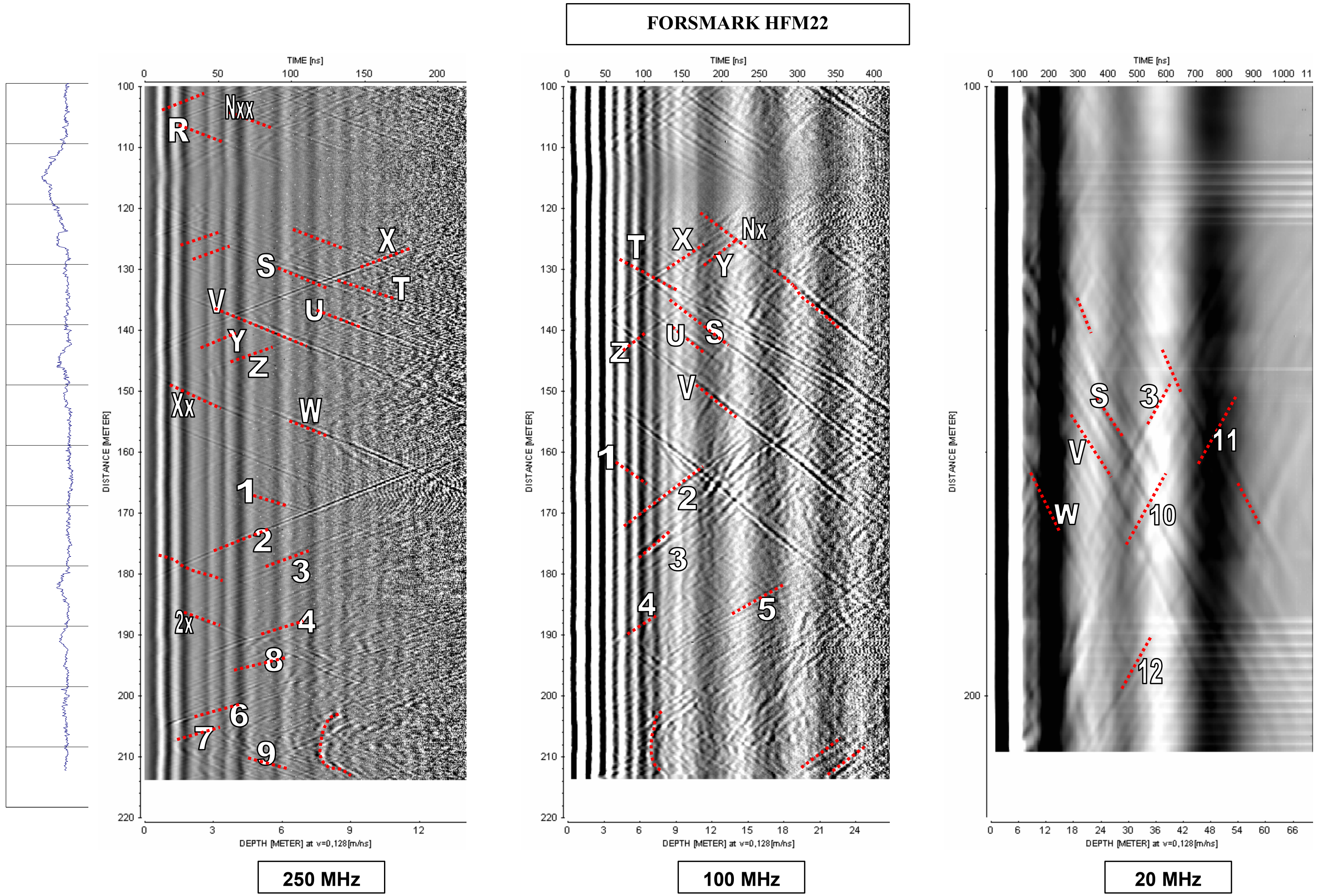

Distance [m]
Depth [m]
Time[nS]
57
154
85
155
85xx
85x
156



Distance [m]
Depth [m]
Time[nS]
136XX
159
151
162
0
17
30
43
56
69
81
94
854
879
904
929
954
979
197
398
599
800
996
1197

Radar logging in HFM22, 0 to 210 m, dipole antennas 250, 100 and 20 MHz




FORSMARK HFM22
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,128[m/ns]
250 MHz
100 MHz
20 MHz
R
Nxx
S
X
T
V
U
Y
Z
Xx
W
1
2
3
4
2x
8
6
7
9
Nx
5
10
11
12

Appendix 4

BIPS logging in KFM06A, 102 to 994 m

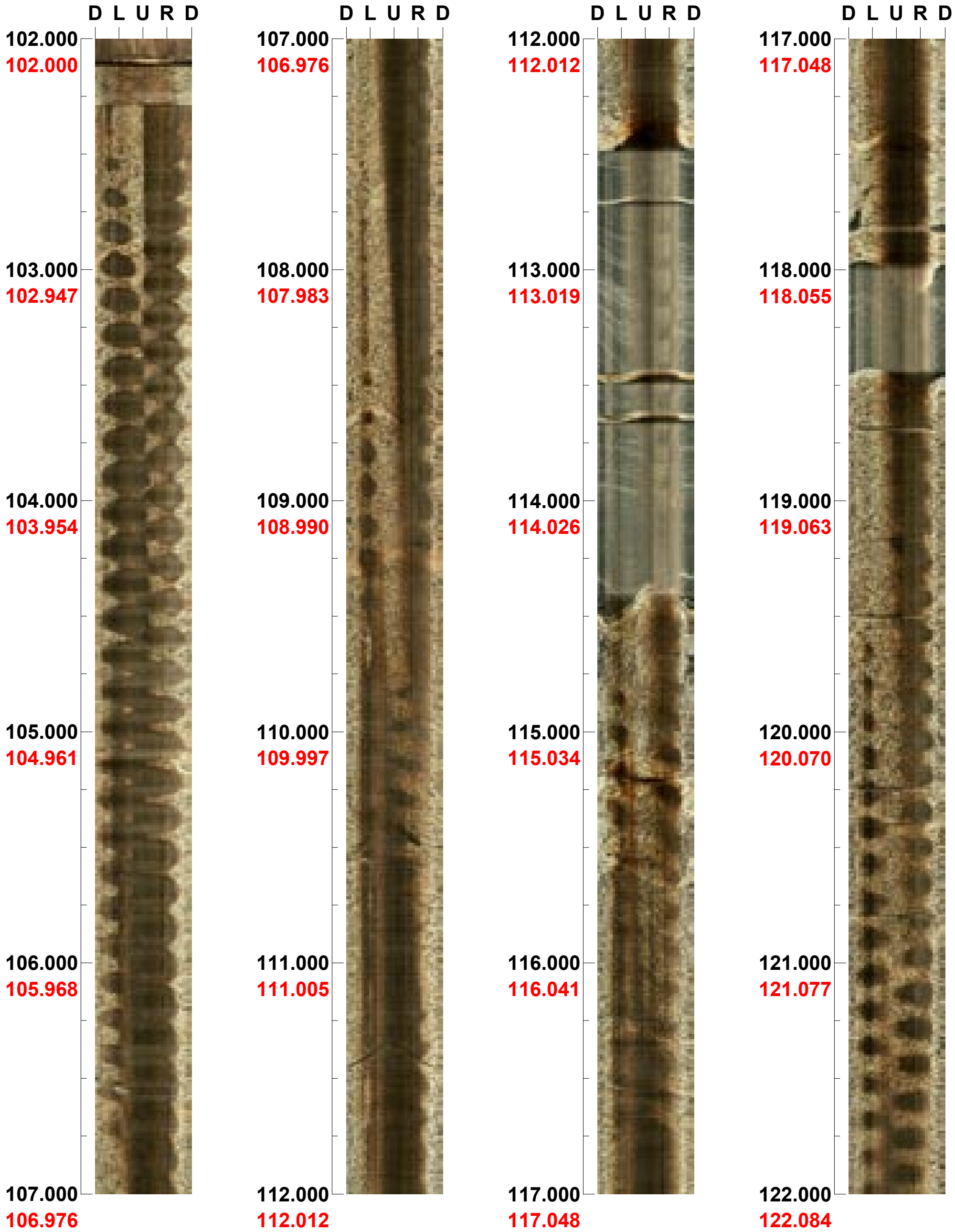
Project name: Forsmark

Image file	: c:\work\r5282s~1\kfm06a\bips\kfm06a-1.bip
BDT file	: c:\work\r5282s~1\kfm06a\bips\kfm06a-1.bdt
Locality	: FORSMARK
Bore hole number	: KFM06A
Date	: 04/11/01 and 02
Time	: 13:34:00
Depth range	: 102.000 - 994.260 m
Azimuth	: 301
Inclination	: -60
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	: 45
Color	: +0 +0 +0

Appendix 4

Project name: Forsmark
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 102.000 - 122.000 m

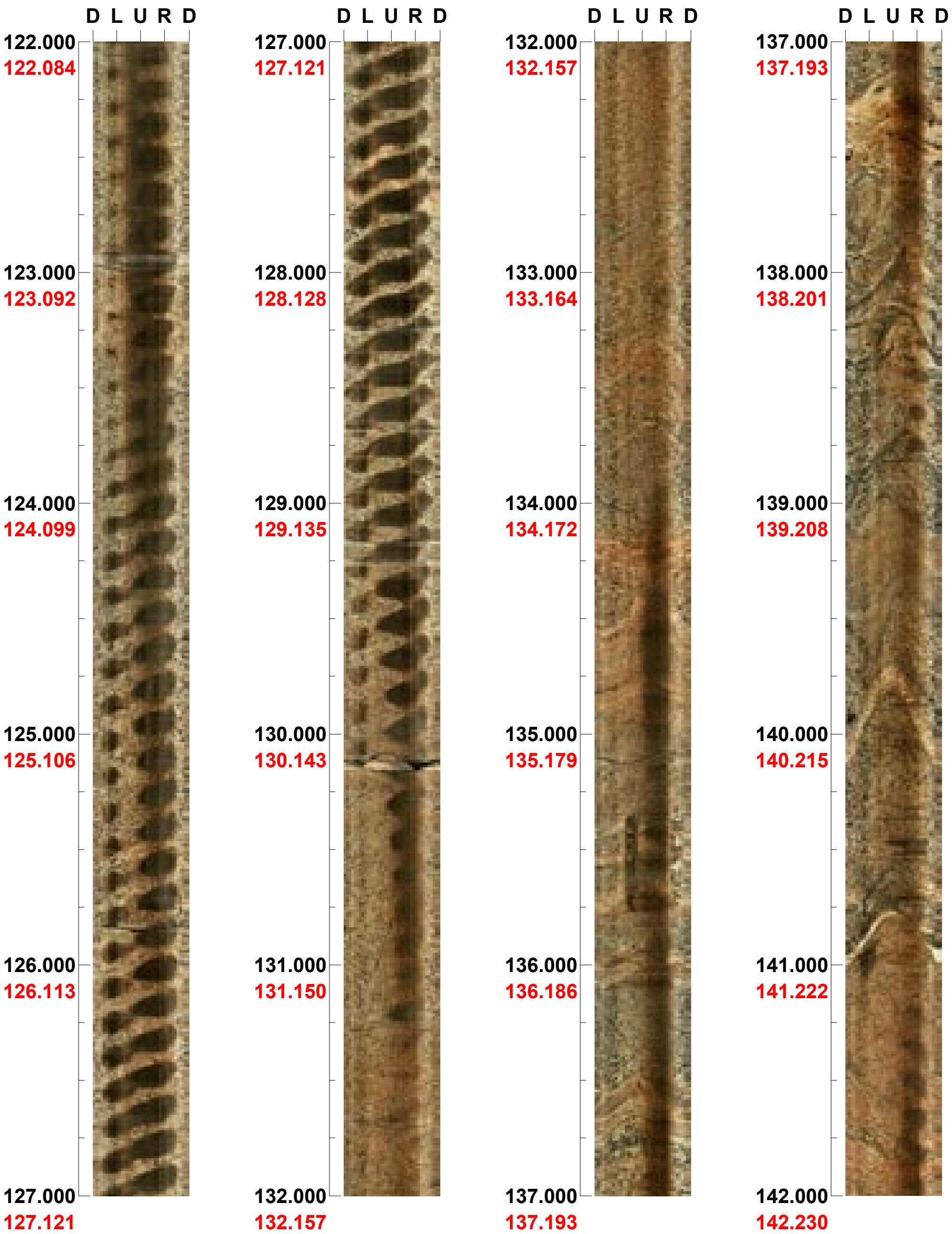


(1 / 20) **Scale: 1/25** **Aspect ratio: 175 %**

Appendix 4 **Project name: Forsmark**

Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

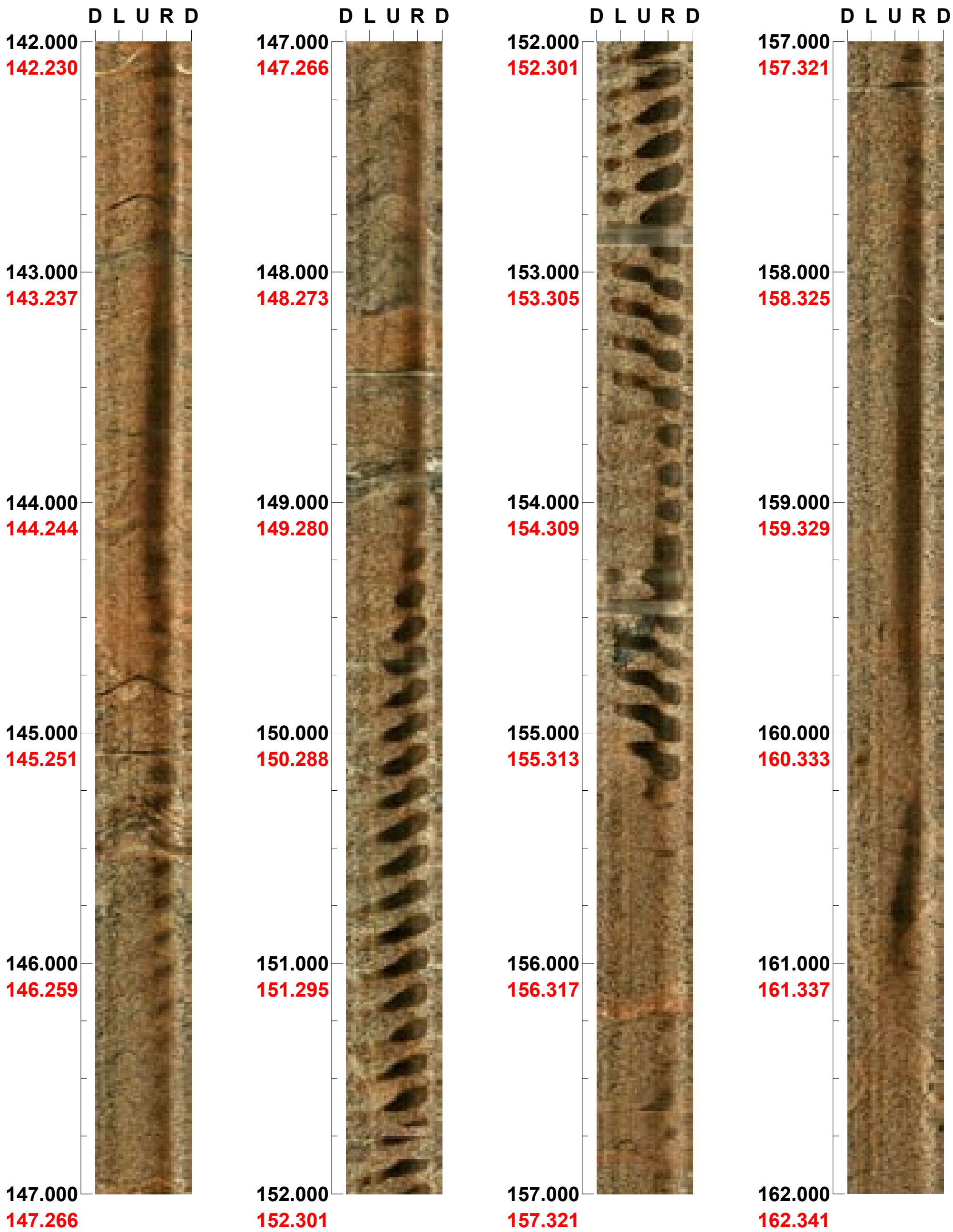
Depth range: 122.000 - 142.000 m



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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 142.000 - 162.000 m



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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 162.000 - 182.000 m

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

Appendix 4

Project name: Forsmark
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 182.000 - 202.000 m

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

Appendix 4

Project name: Forsmark

Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 202.000 - 222.000 m

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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 222.000 - 242.000 m

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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 242.000 - 262.000 m

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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 262.000 - 282.000 m

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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 282.000 - 302.000 m

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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 302.000 - 322.000 m

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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 322.000 - 342.000 m

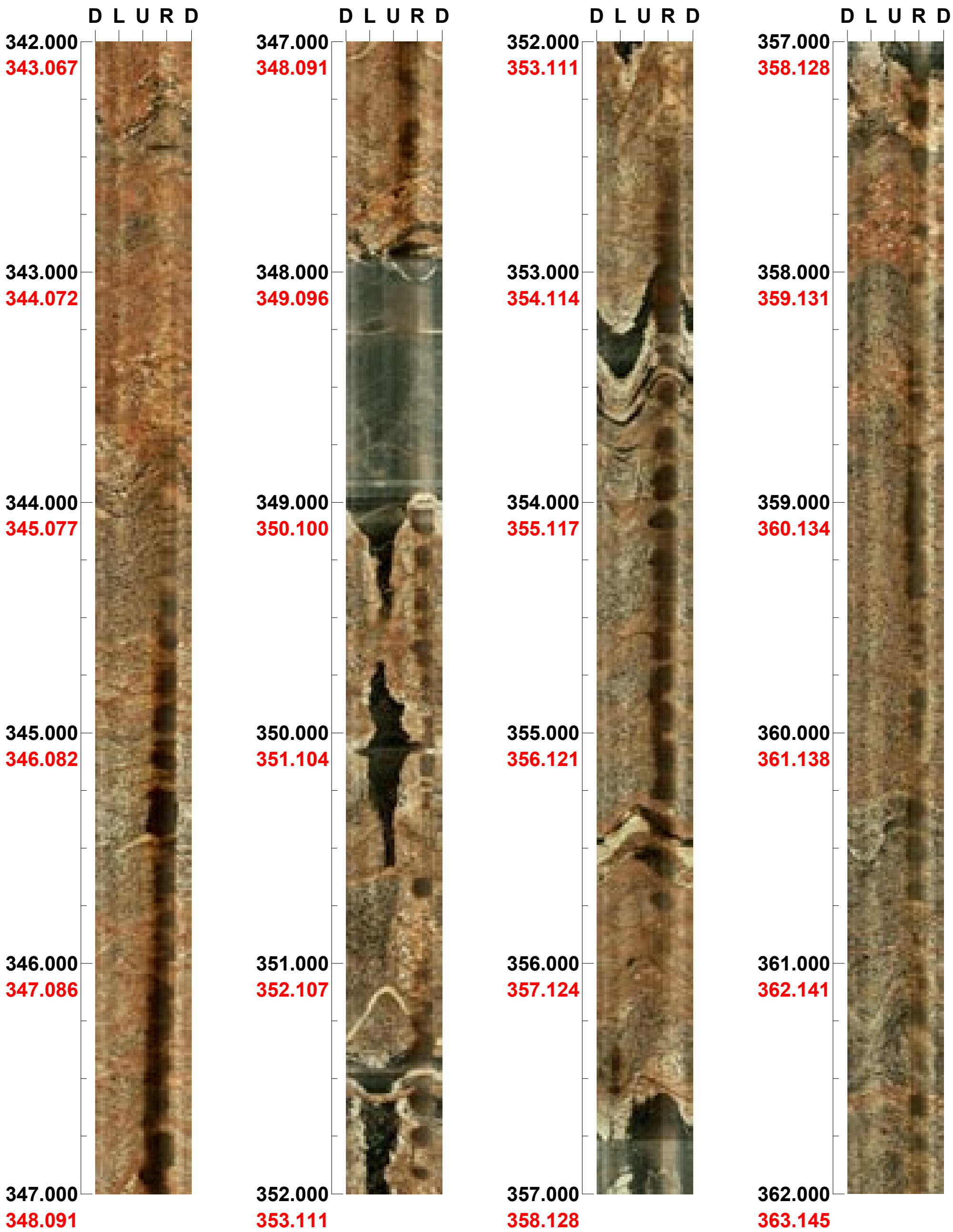
(12 / 20) **Scale: 1/25** **Aspect ratio: 175 %**

Appendix 4

Project name: Forsmark

Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

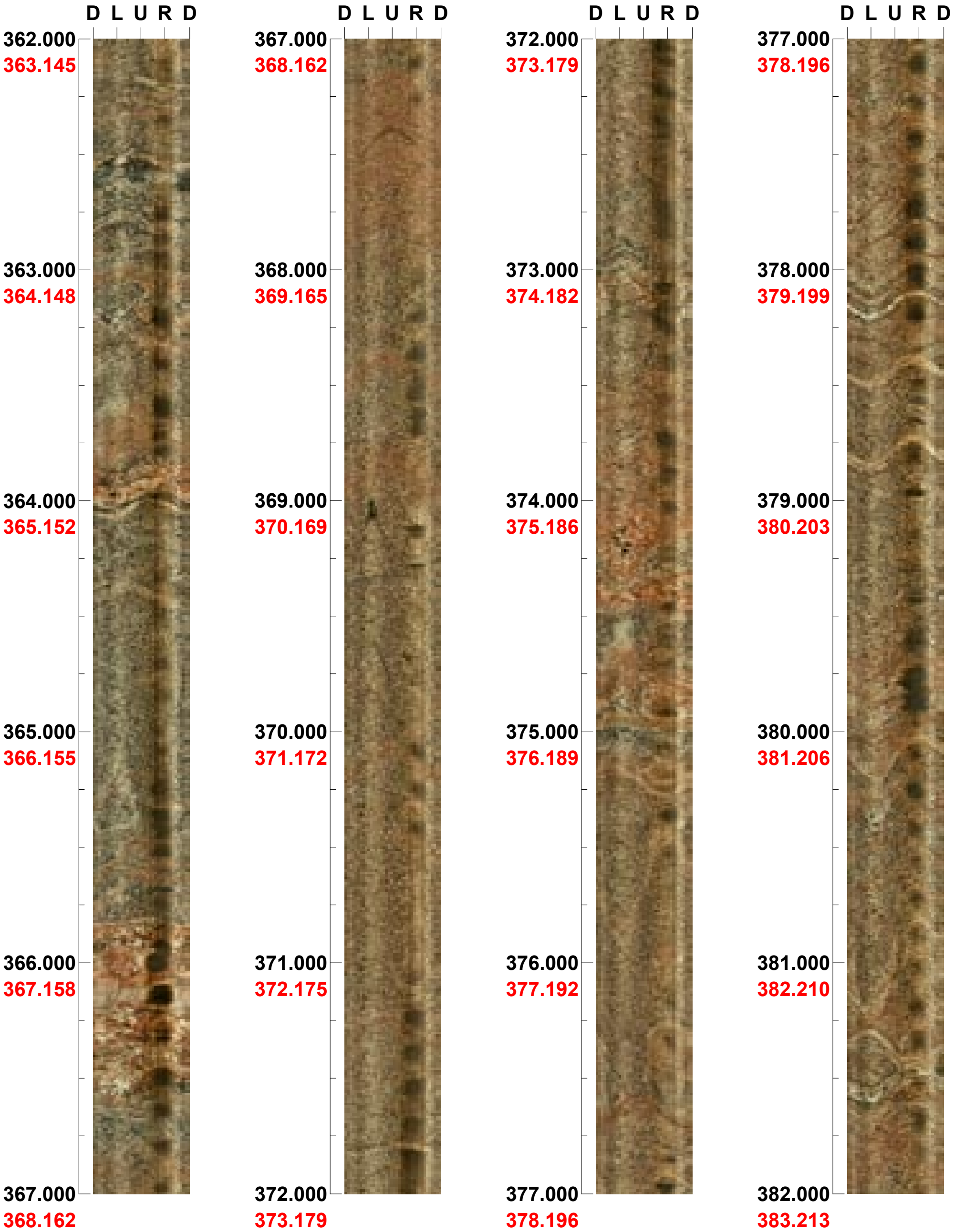
Depth range: 342.000 - 362.000 m



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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 362.000 - 382.000 m



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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 382.000 - 402.000 m

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

Appendix 4

Project name: Forsmark

Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 402.000 - 422.000 m

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

Appendix 4 **Project name: Forsmark**

Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 422.000 - 442.000 m

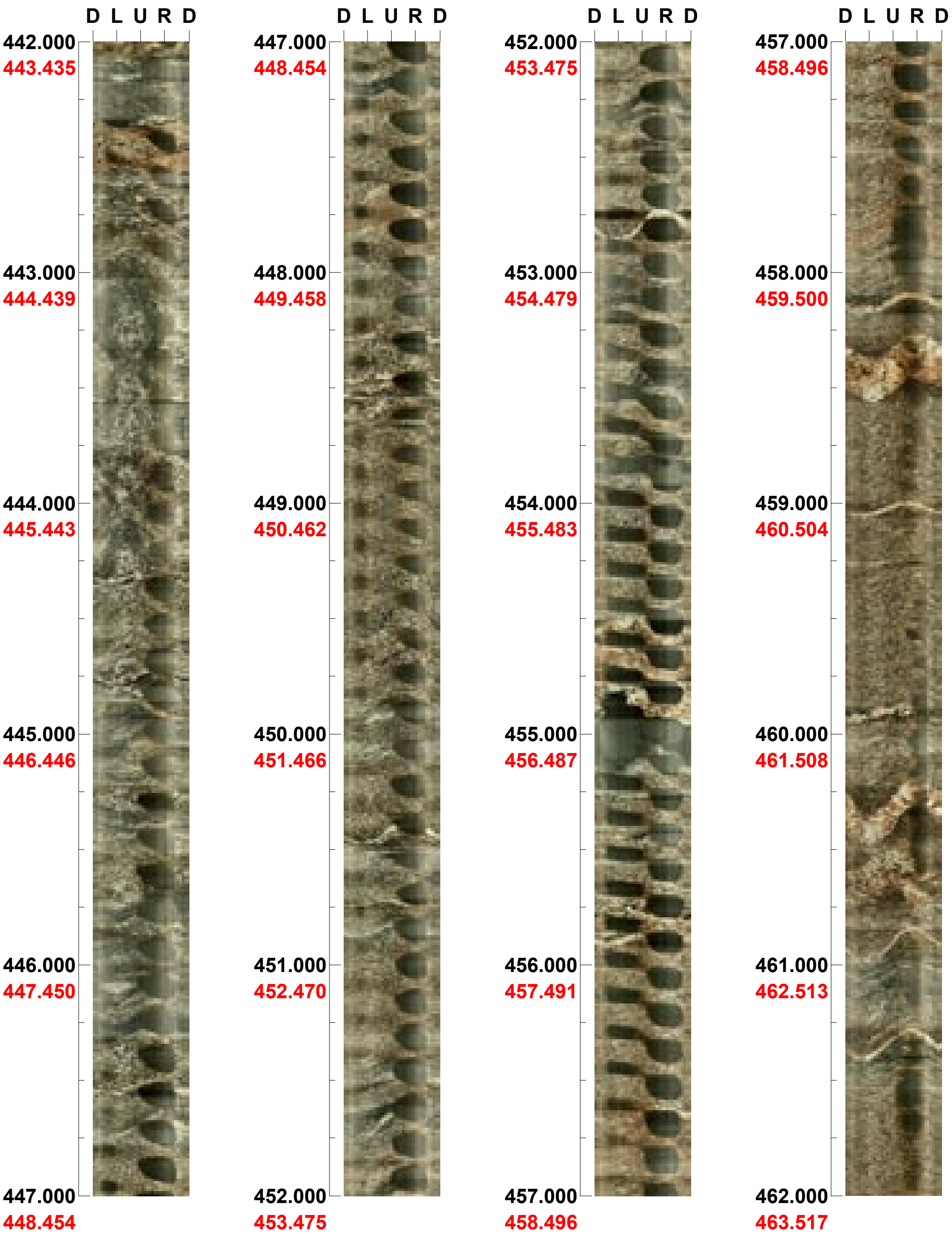
(17 / 20) **Scale: 1/25** **Aspect ratio: 175 %**

Appendix 4

Project name: Forsmark

Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 442.000 - 462.000 m

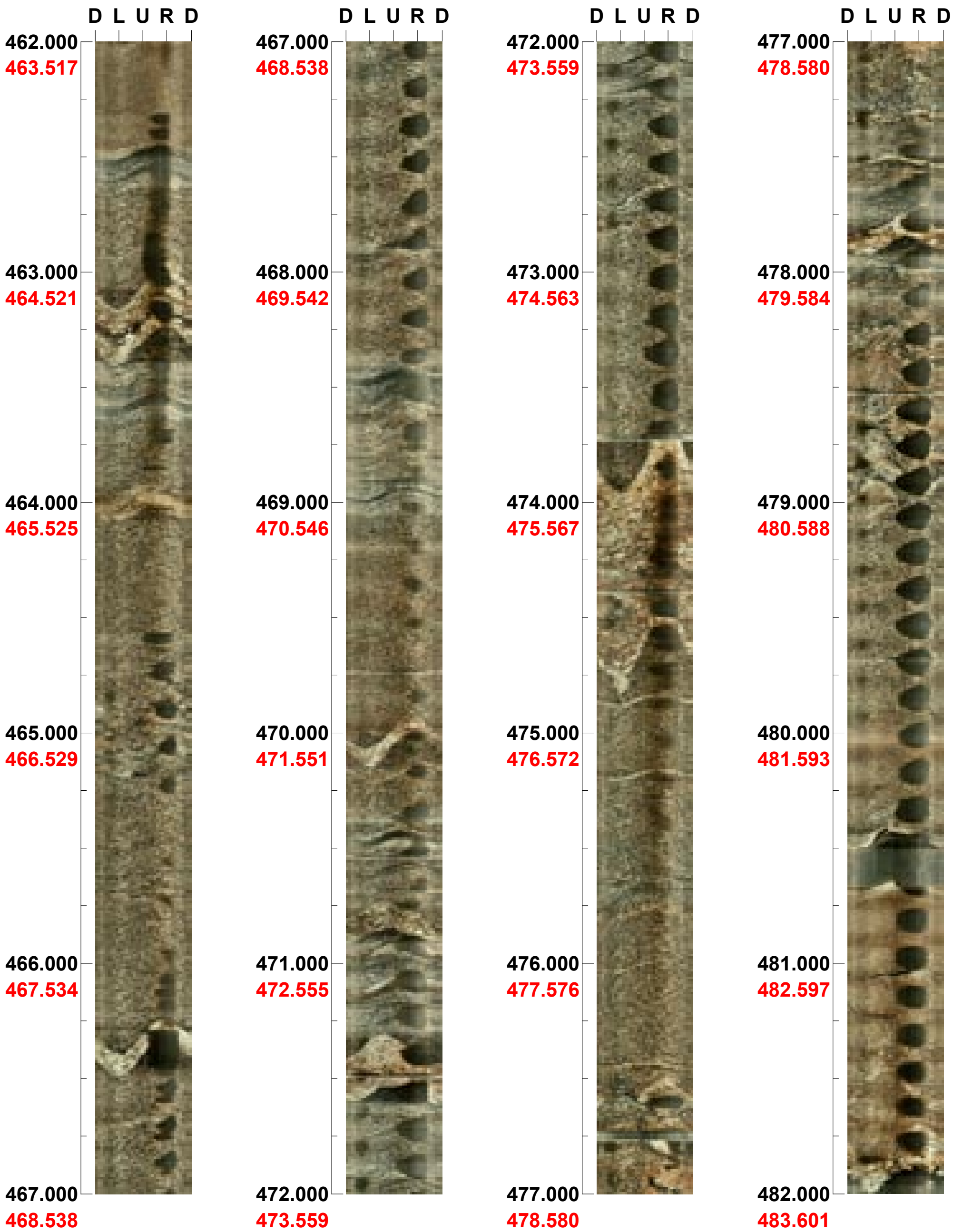


(18 / 20) **Scale: 1/25** **Aspect ratio: 175 %**

Appendix 4

Project name: Forsmark
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 462.000 - 482.000 m



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

Appendix 4

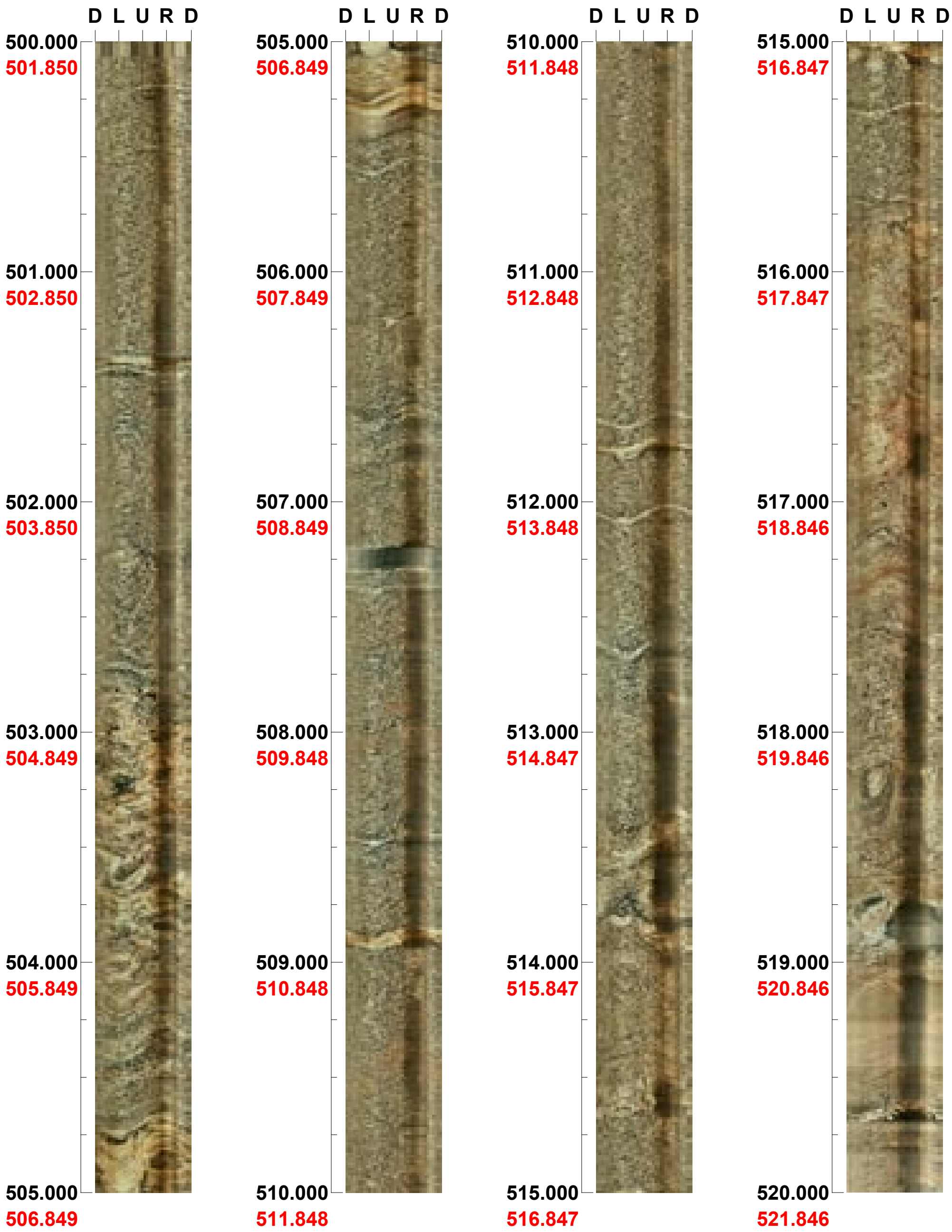
Project name: Forsmark
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 482.000 - 500.081 m

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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 500.000 - 520.000 m



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

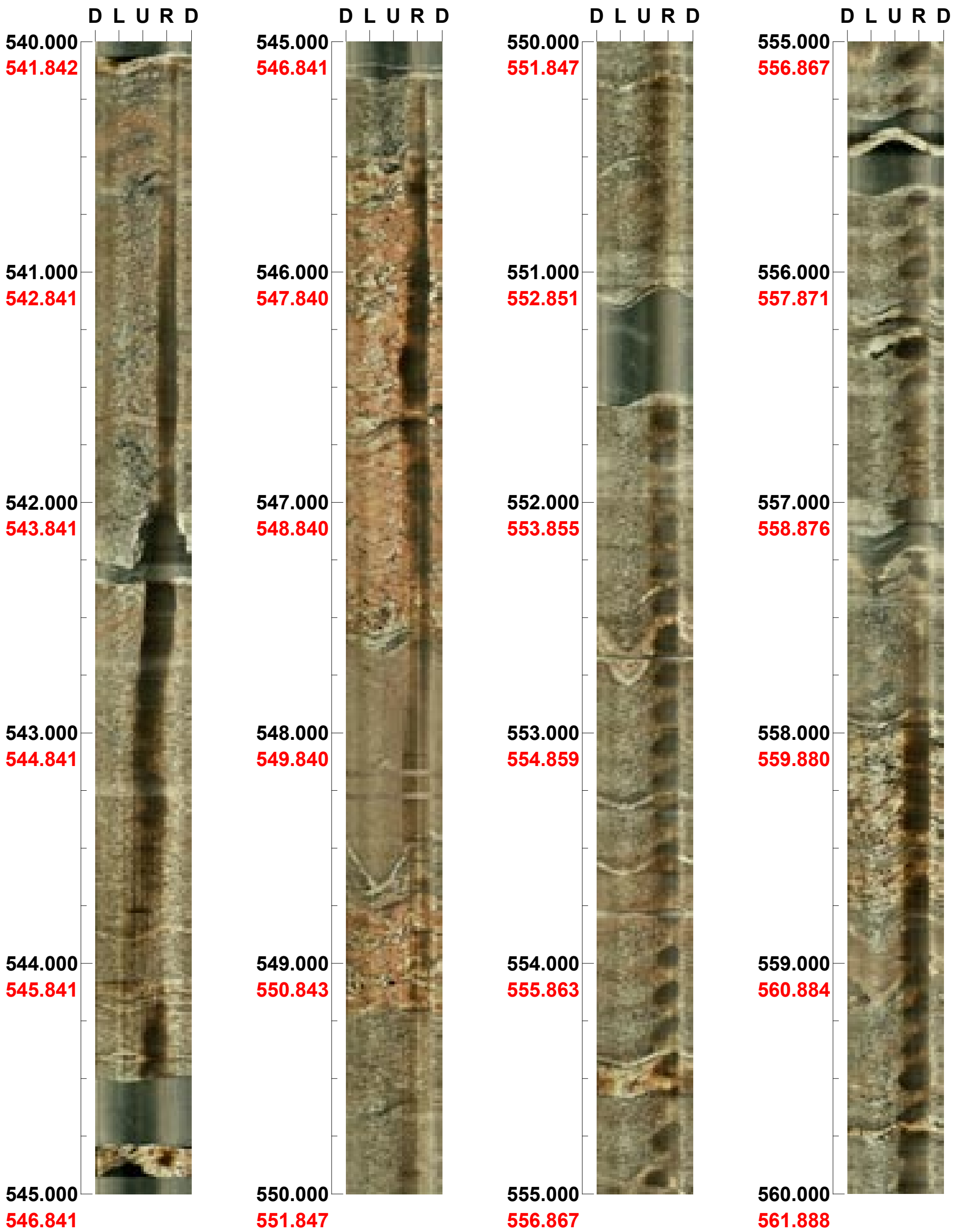
Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 520.000 - 540.000 m

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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 540.000 - 560.000 m



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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 560.000 - 580.000 m

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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 580.000 - 600.000 m

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

Appendix 4 **Project name: Forsmark**

Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 600.000 - 620.000 m

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

Appendix 4 **Project name: Forsmark**

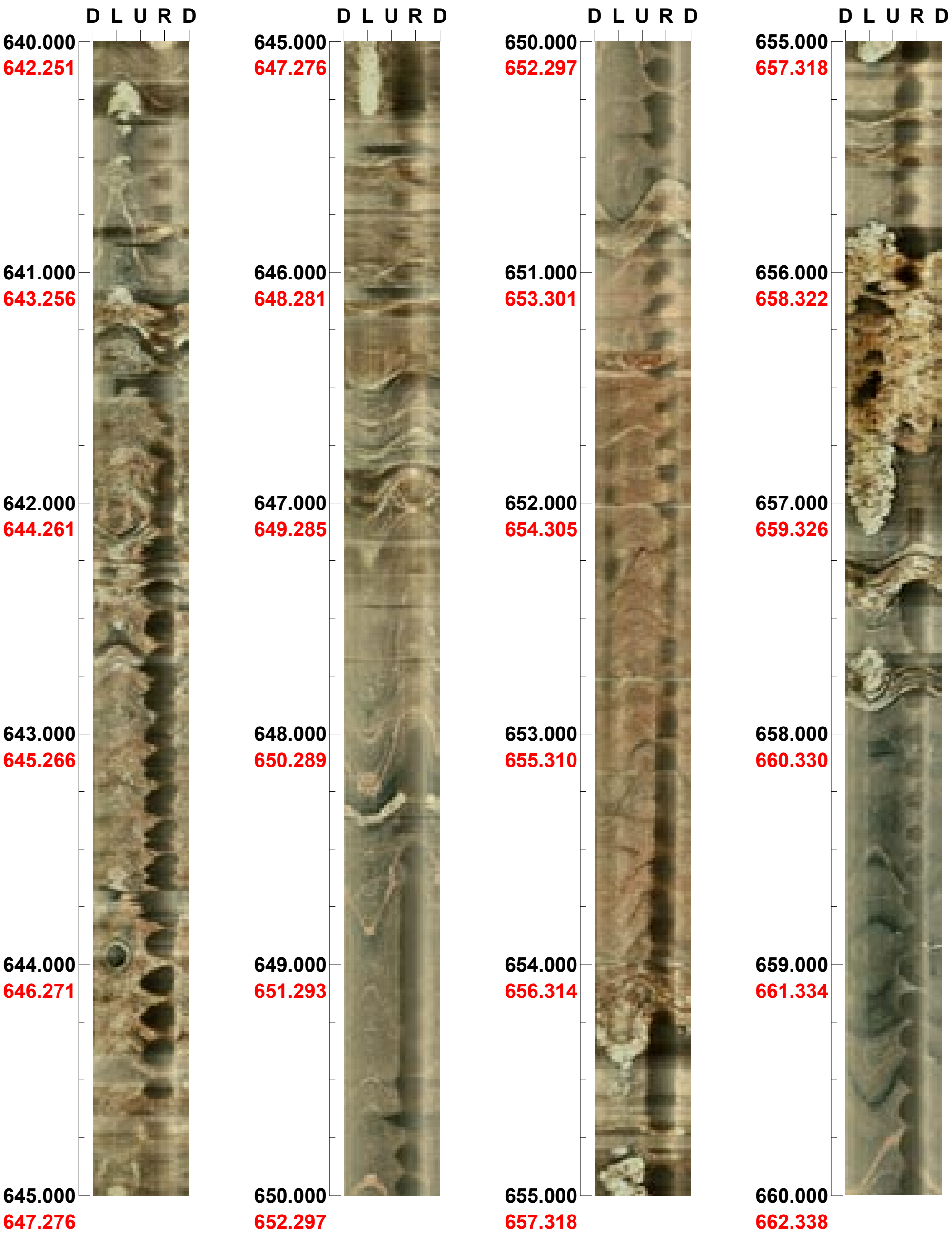
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 620.000 - 640.000 m

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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 640.000 - 660.000 m



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

Appendix 4

Project name: Forsmark

Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 660.000 - 680.000 m

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

Appendix 4

Project name: Forsmark
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 680.000 - 700.000 m

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

Appendix 4

Project name: Forsmark

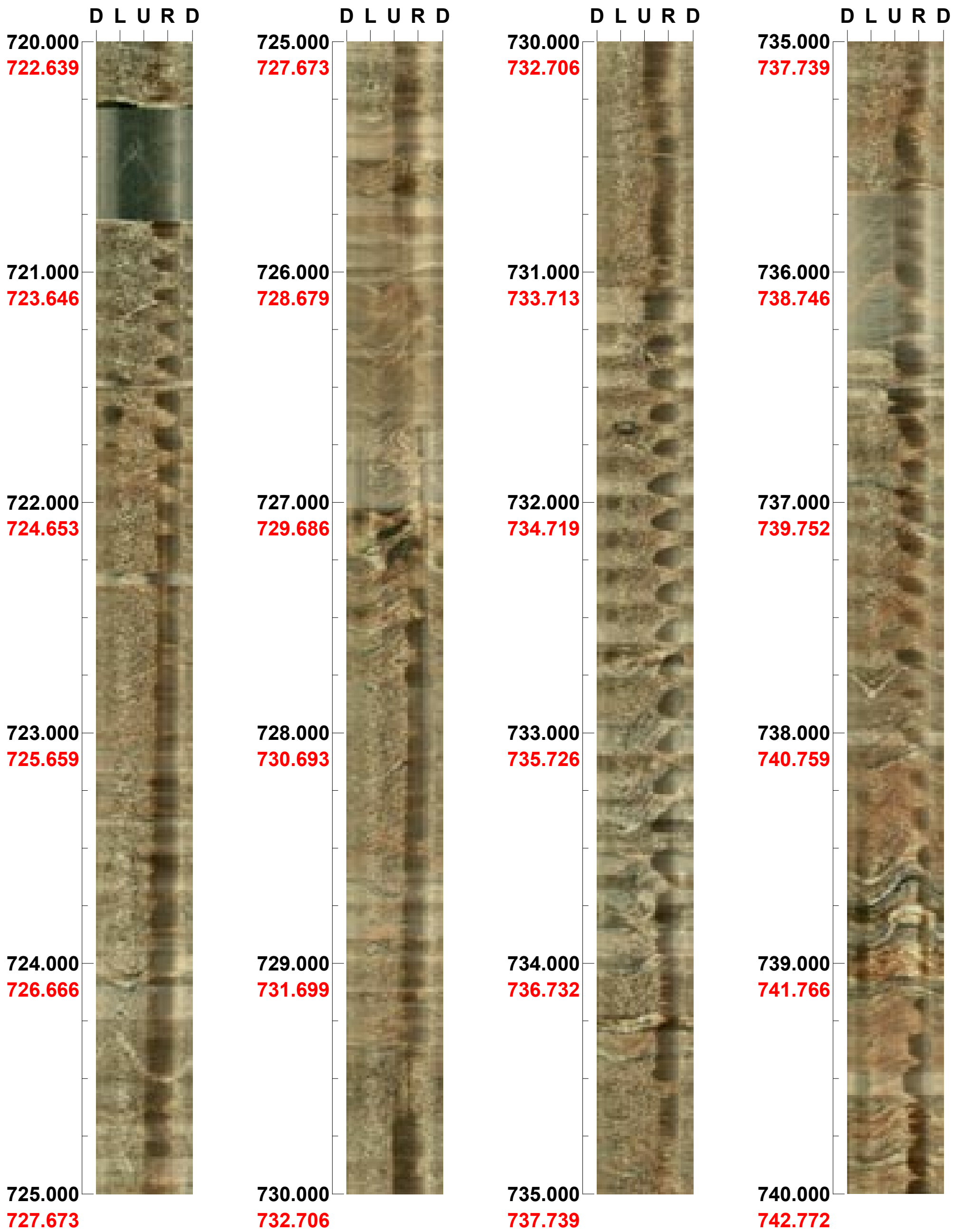
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 700.000 - 720.000 m

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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 720.000 - 740.000 m



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

Appendix 4

Project name: Forsmark

Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 740.000 - 760.000 m

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

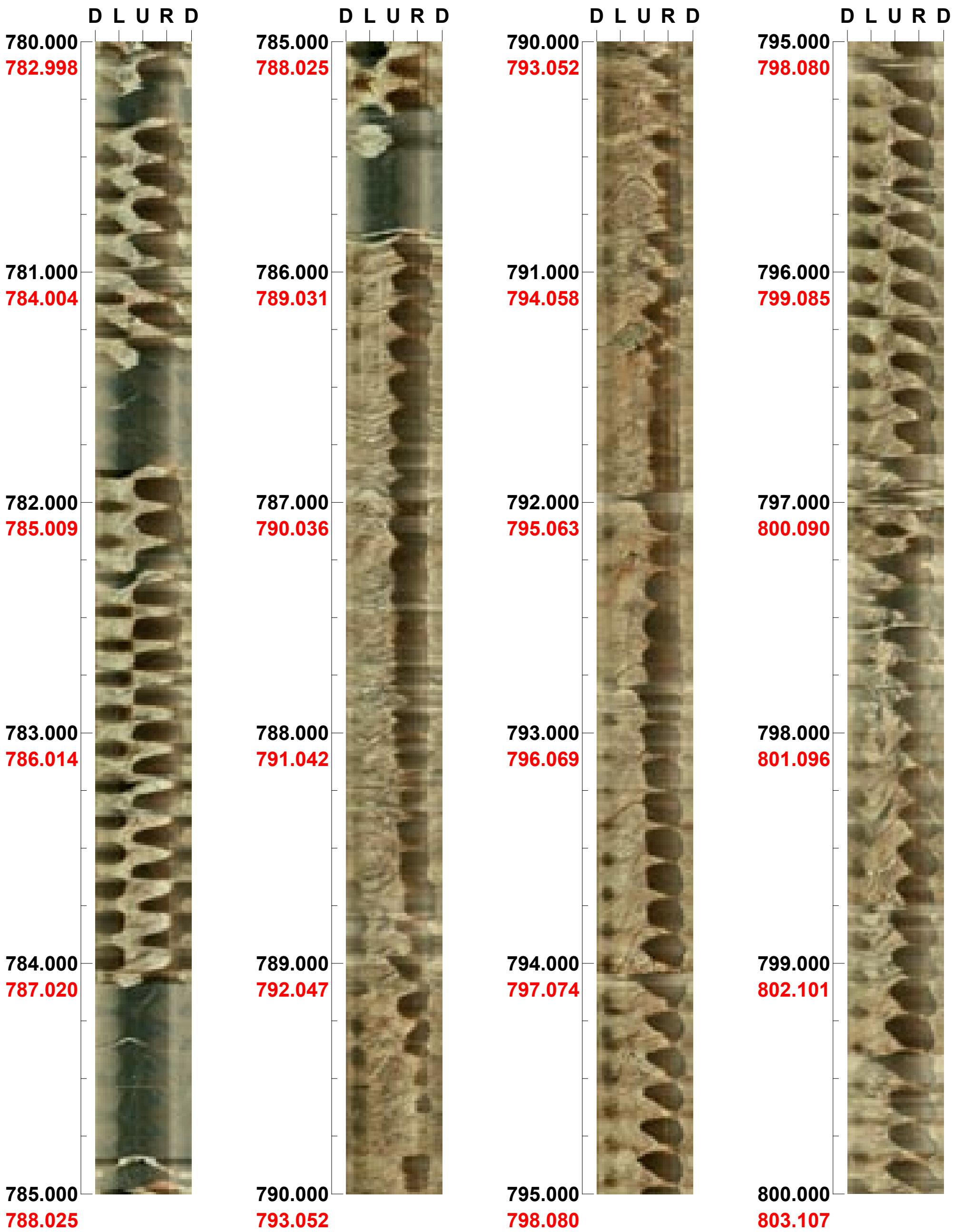
Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 760.000 - 780.000 m

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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

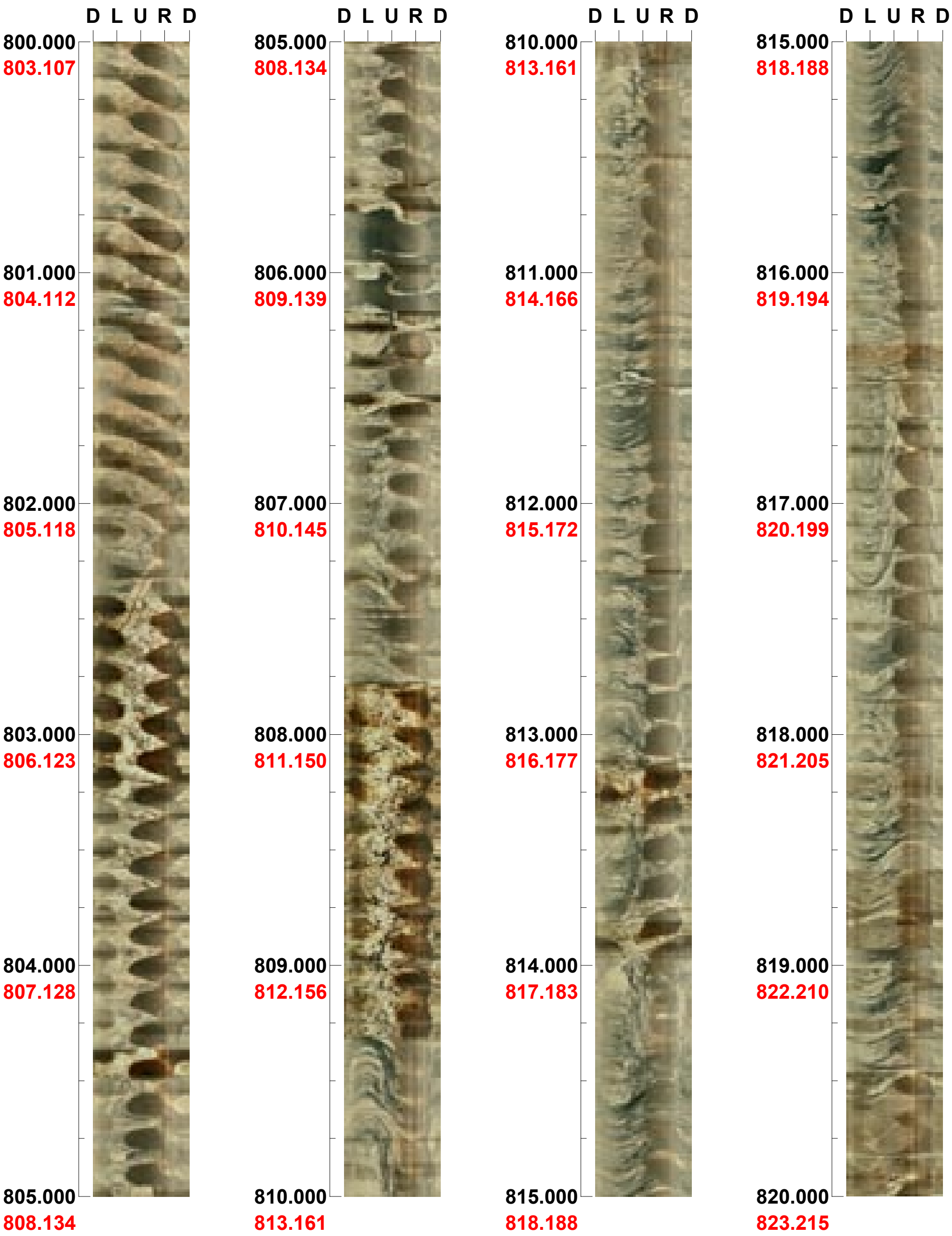
Depth range: 780.000 - 800.000 m



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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 800.000 - 820.000 m



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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 820.000 - 840.000 m

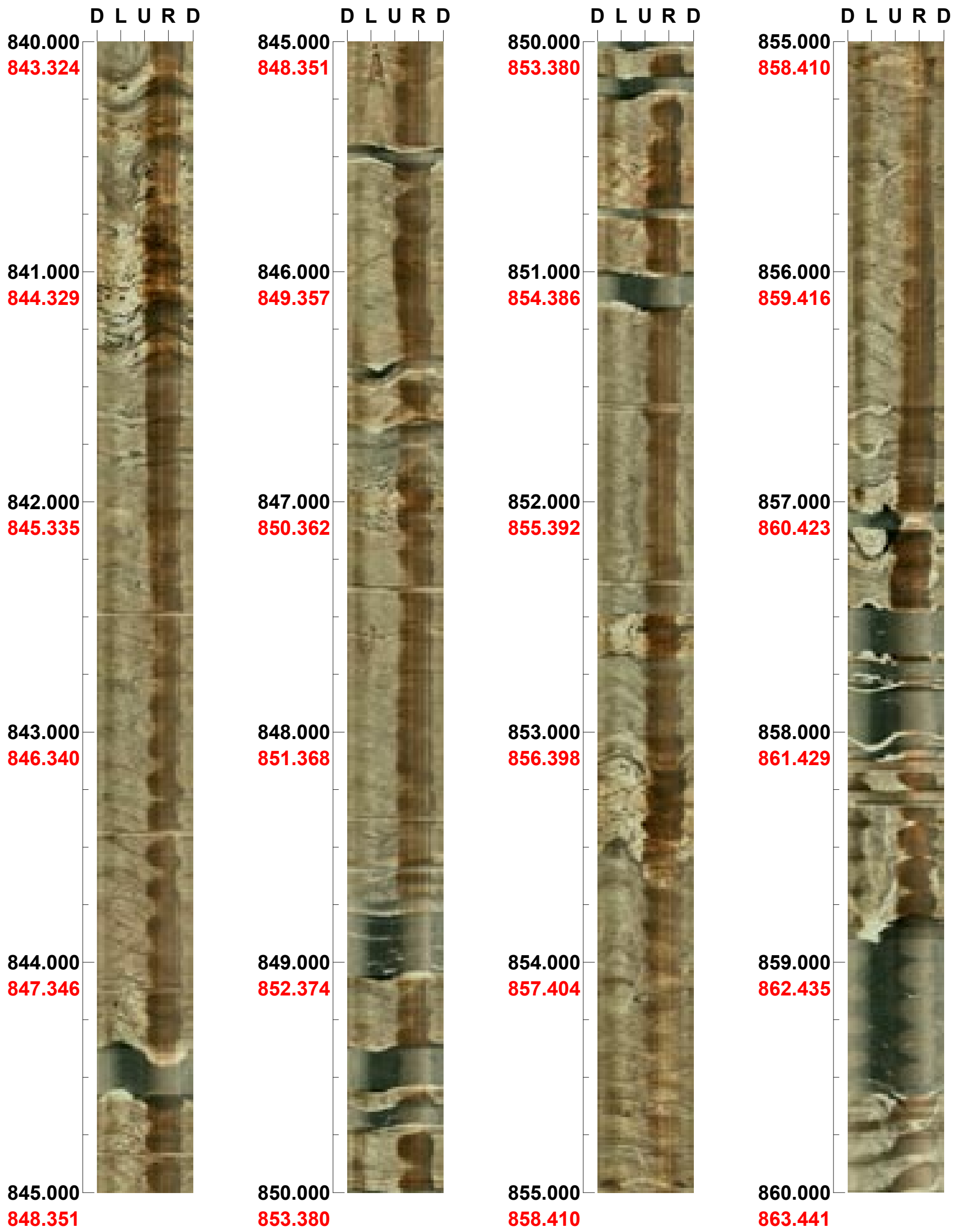
(17 / 25) **Scale: 1/25** **Aspect ratio: 175 %**

Appendix 4

Project name: Forsmark

Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 840.000 - 860.000 m



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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

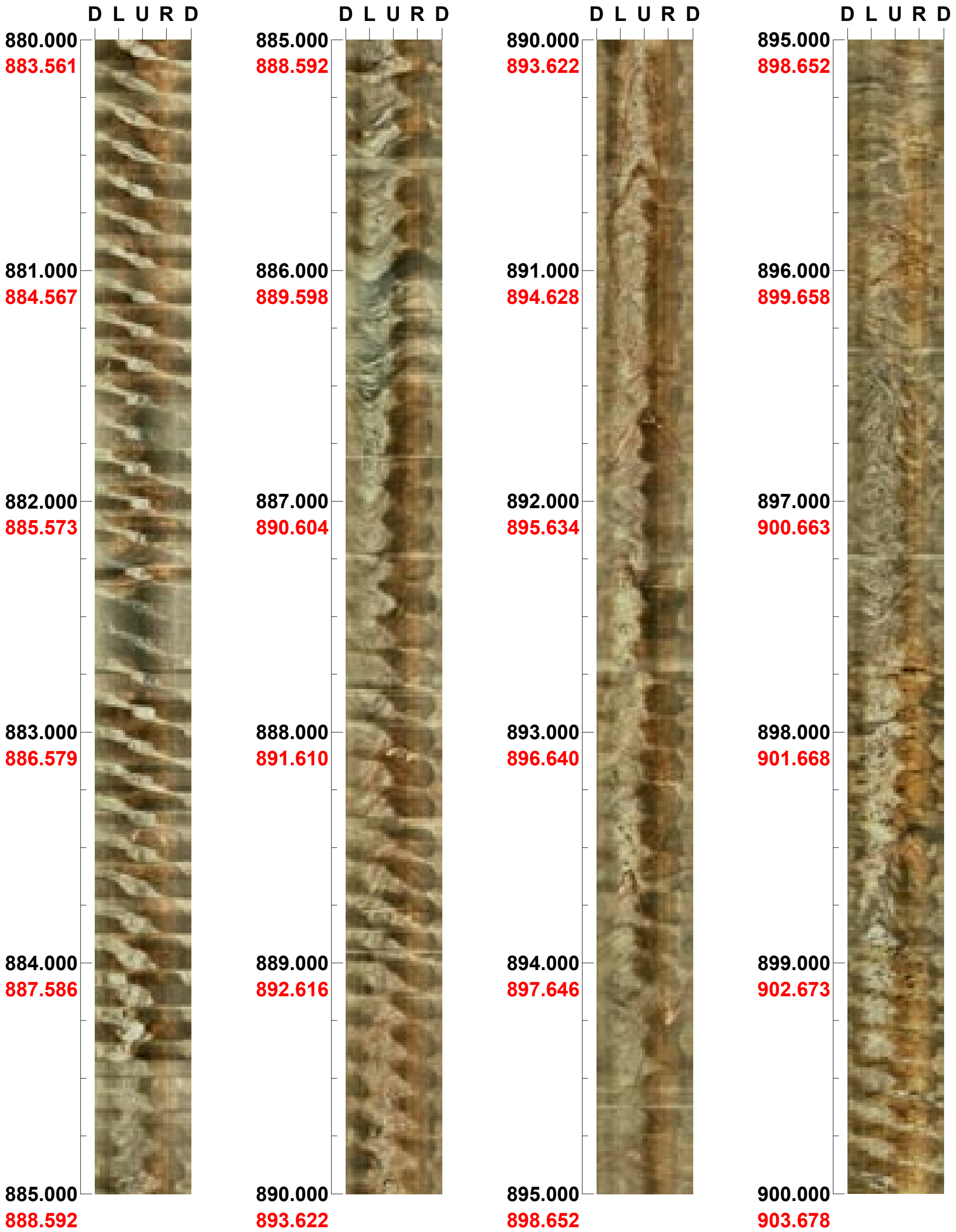
Depth range: 860.000 - 880.000 m

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

Appendix 4 **Project name: Forsmark**

Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 880.000 - 900.000 m



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

Appendix 4 **Project name: Forsmark**

Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 900.000 - 920.000 m

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

Appendix 4

Project name: Forsmark
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

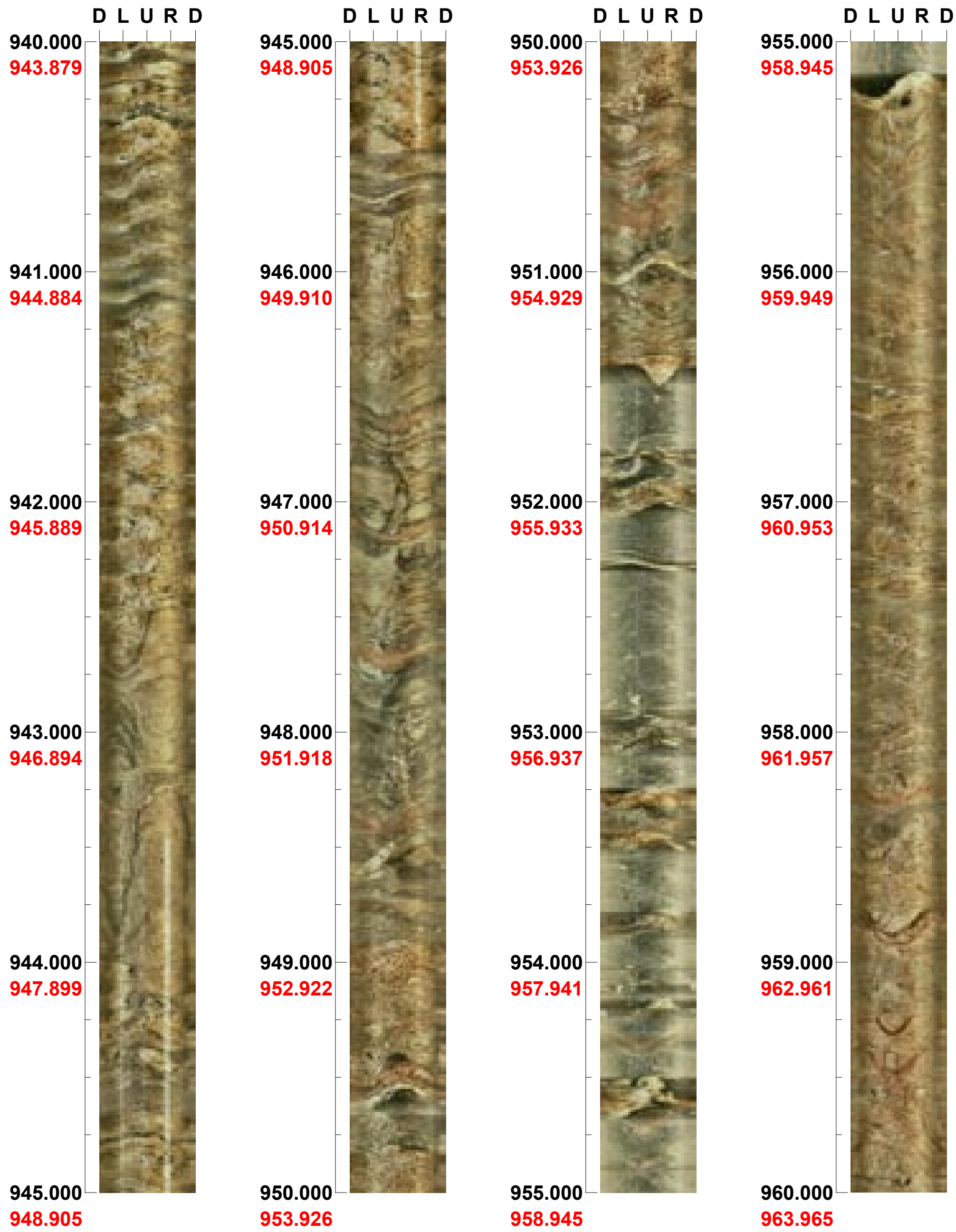
Depth range: 920.000 - 940.000 m

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

Appendix 4 **Project name: Forsmark**

Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

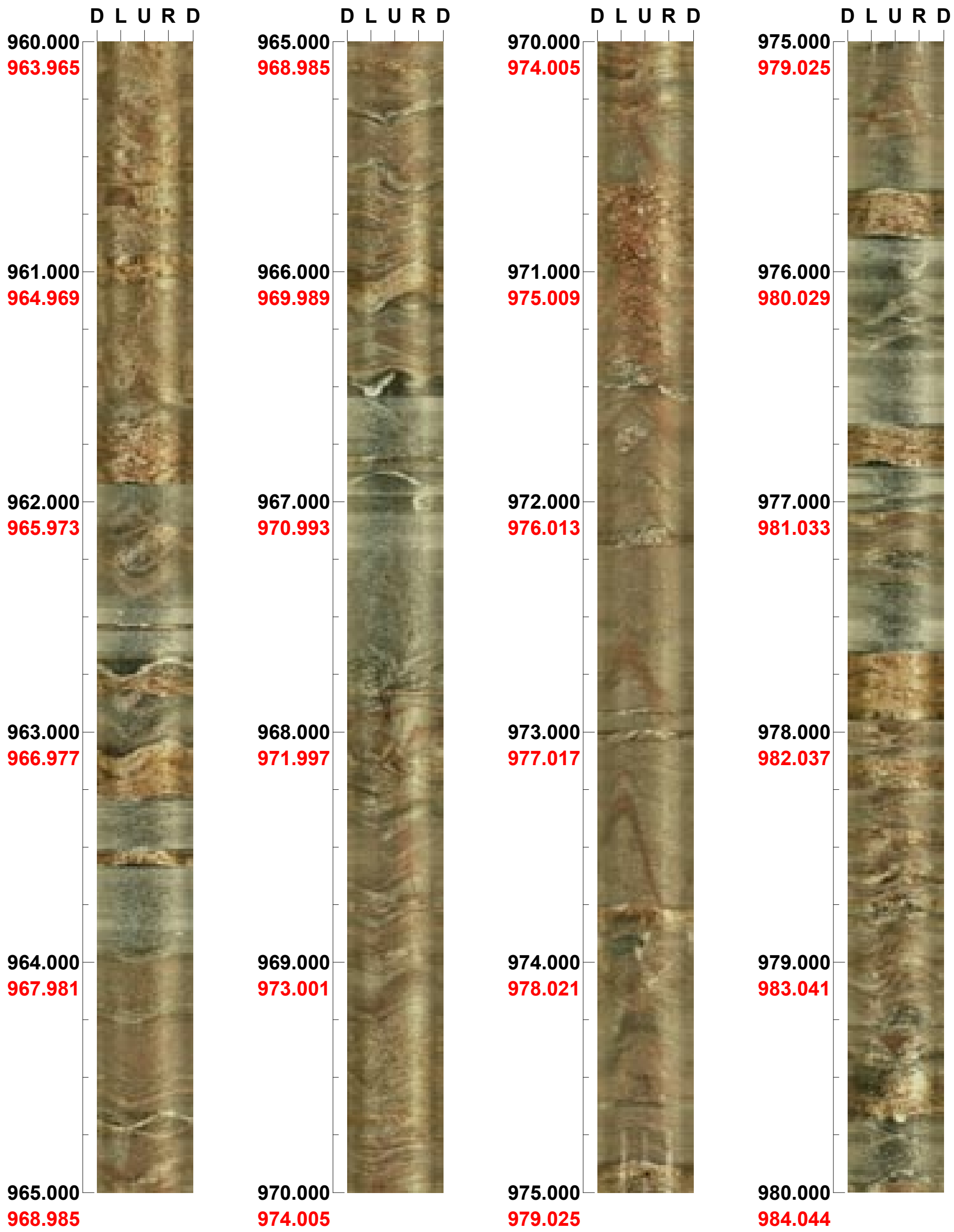
Depth range: 940.000 - 960.000 m



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

Appendix 4 **Project name: Forsmark**
Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 960.000 - 980.000 m



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

Appendix 4 **Project name: Forsmark**

Bore hole No.: KFM06A **Azimuth: 301** **Inclination: -60**

Depth range: 980.000 - 994.261 m

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

Appendix 5

BIPS logging in HFM22, 11 to 212 m

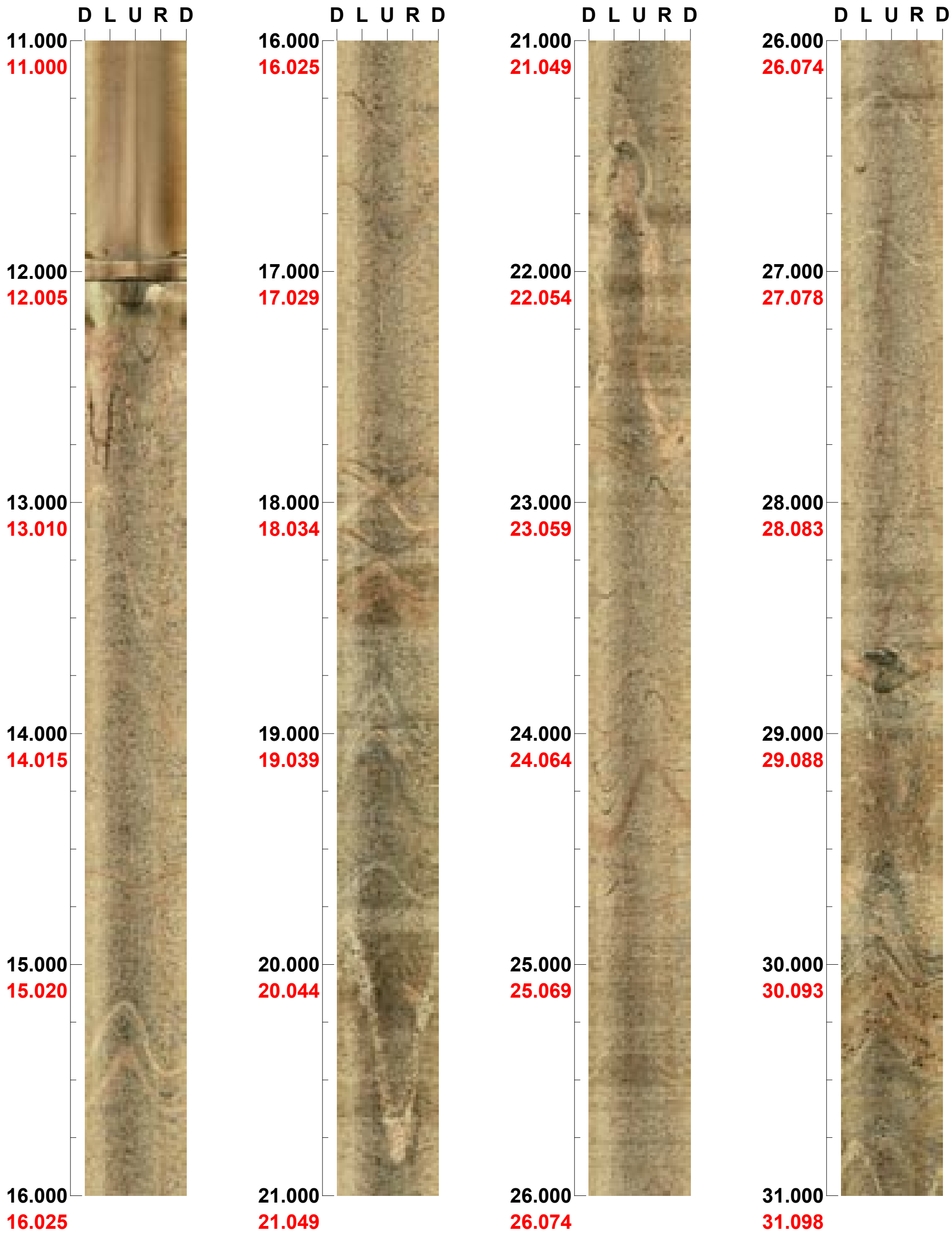
Project name: Forsmark

Image file	**: c:\work\r5282s~1\hfm22\bips\hfm22.bip**
BDT file	**: c:\work\r5282s~1\hfm22\bips\hfm22.bdt**
Locality	**: FORSMARK**
Bore hole number	**: HFM22**
Date	**: 04/11/05**
Time	**: 11:09:00**
Depth range	**: 11.000 - 215.113 m**
Azimuth	**: 90**
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	**: 11**
Color	**: +0 +0 +0**

Appendix 5 **Project name: Forsmark**

Bore hole No.: HFM22 **Azimuth: 90** **Inclination: -59**

Depth range: 11.000 - 31.000 m

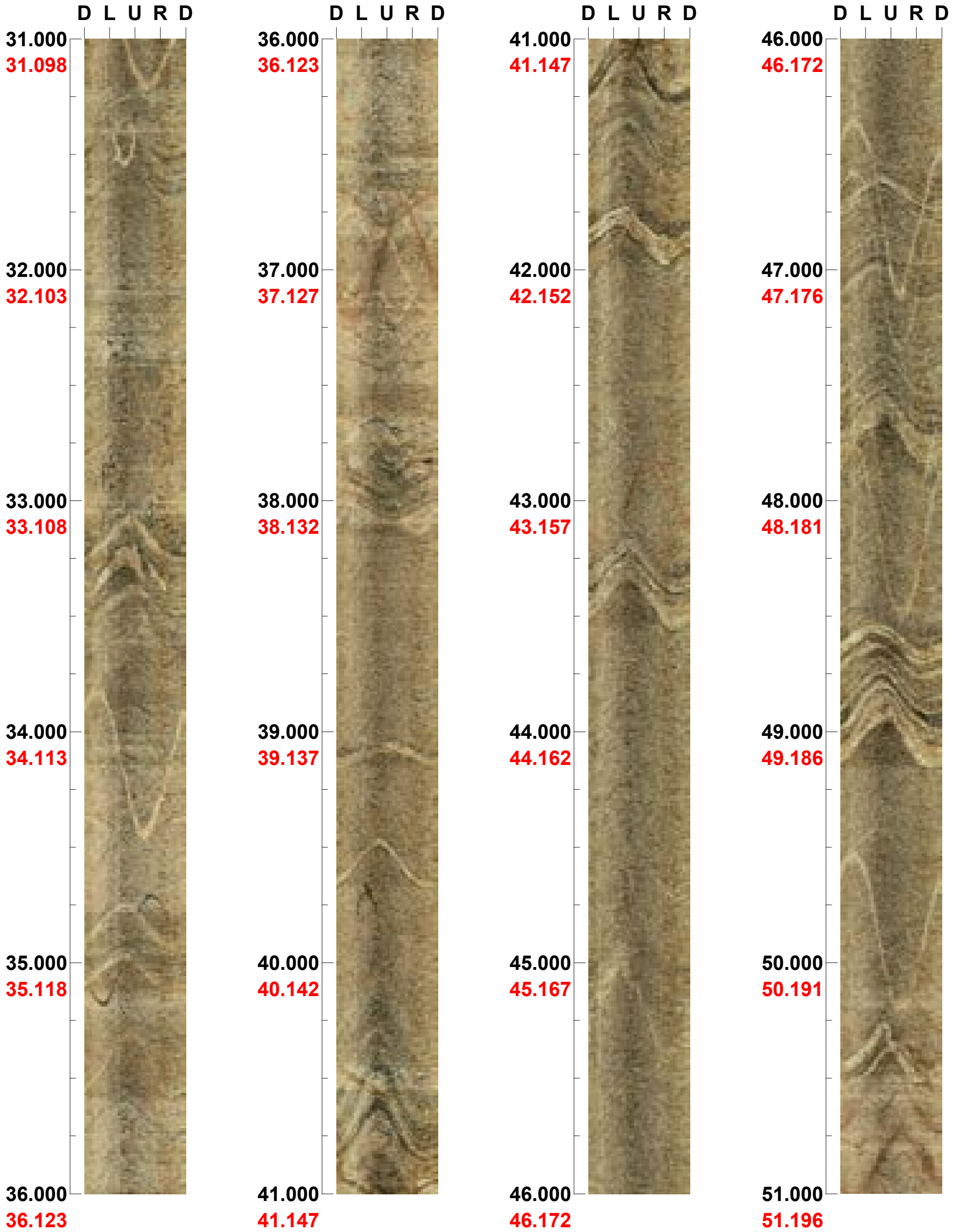


(1 / 11) **Scale: 1/25** **Aspect ratio: 100 %**

Appendix 5 **Project name: Forsmark**

Bore hole No.: HFM22 **Azimuth: 90** **Inclination: -59**

Depth range: 31.000 - 51.000 m



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

Appendix 5 **Project name: Forsmark**

Bore hole No.: HFM22 **Azimuth: 90** **Inclination: -59**

Depth range: 51.000 - 71.000 m

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

Appendix 5 **Project name: Forsmark**

Bore hole No.: HFM22 **Azimuth: 90** **Inclination: -59**

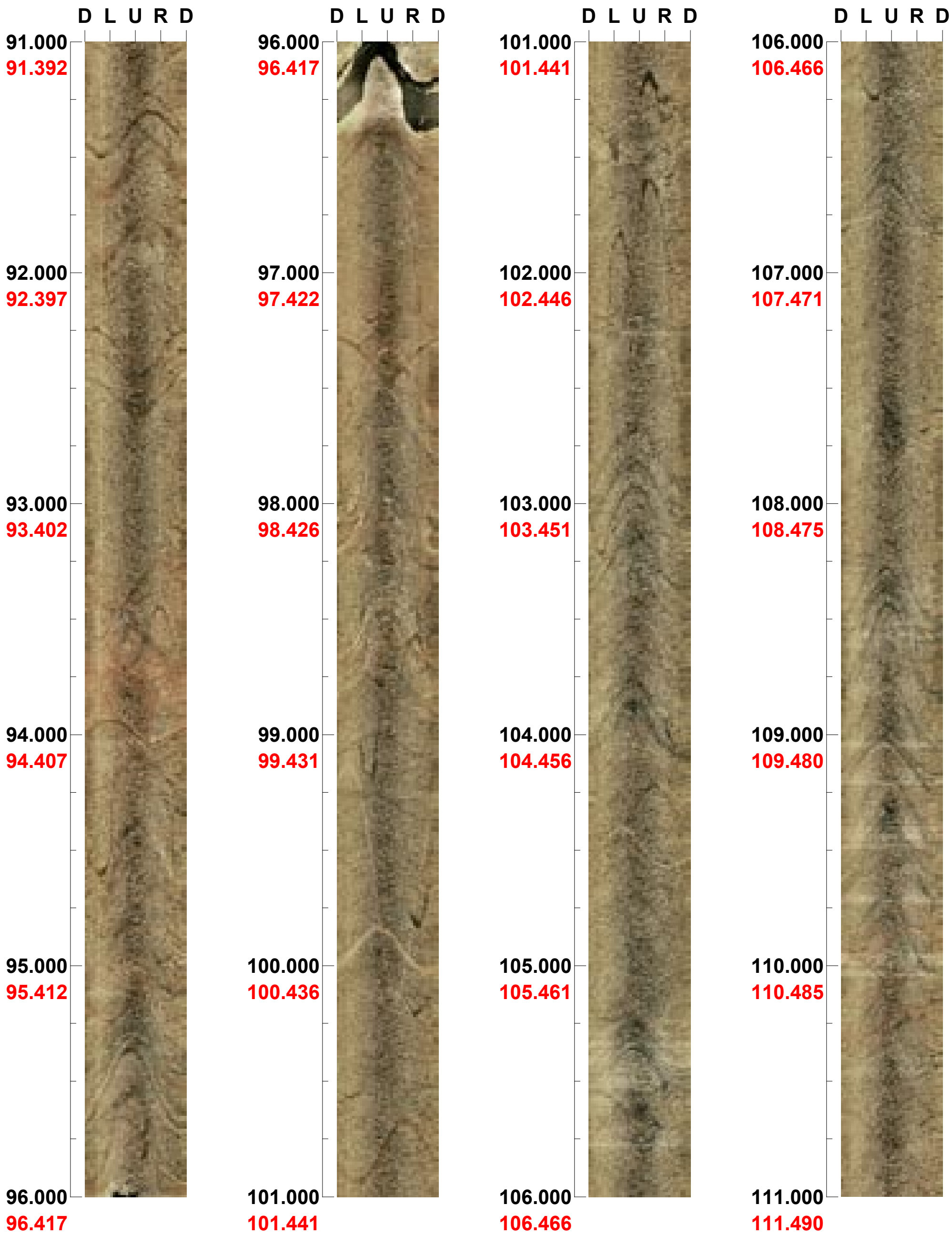
Depth range: 71.000 - 91.000 m

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

Appendix 5 **Project name: Forsmark**

Bore hole No.: HFM22 **Azimuth: 90** **Inclination: -59**

Depth range: 91.000 - 111.000 m



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

Appendix 5 **Project name: Forsmark**

Bore hole No.: HFM22 **Azimuth: 90** **Inclination: -59**

Depth range: 111.000 - 131.000 m

D L U R D

111.000
111.490

112.000
112.495

113.000
113.500

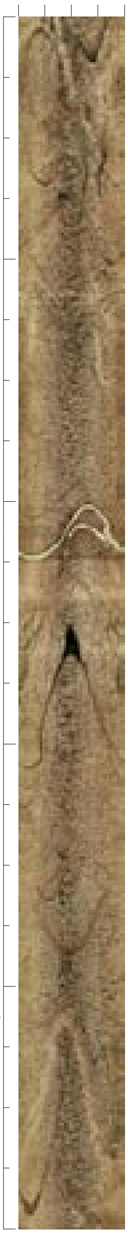
114.000
114.505

115.000
115.510

116.000
116.515

D L U R D

116.000
116.515



117.000
117.520

118.000
118.525

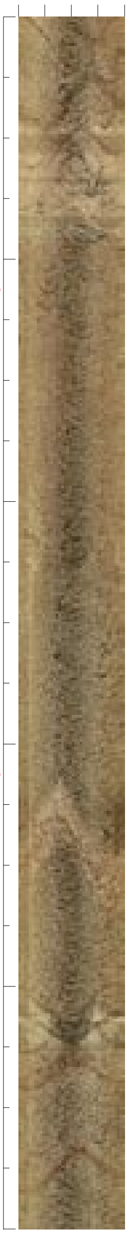
119.000
119.529

120.000
120.534

121.000
121.539

D L U R D

121.000
121.539



122.000
122.544

123.000
123.549

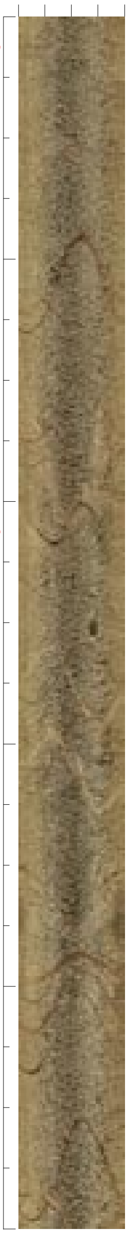
124.000
124.554

125.000
125.559

126.000
126.564

D L U R D

126.000
126.564



127.000
127.569

128.000
128.574

129.000
129.578

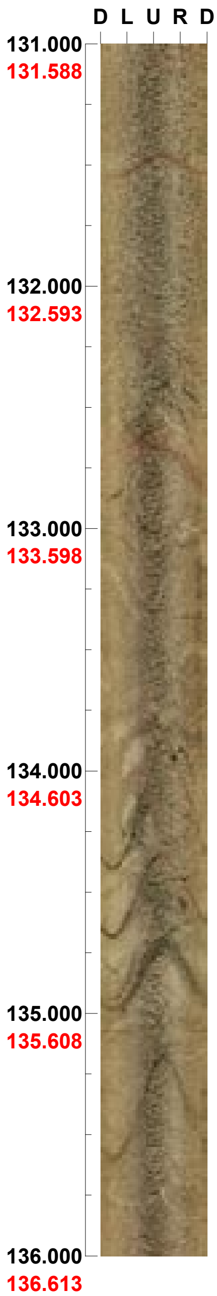
130.000
130.583

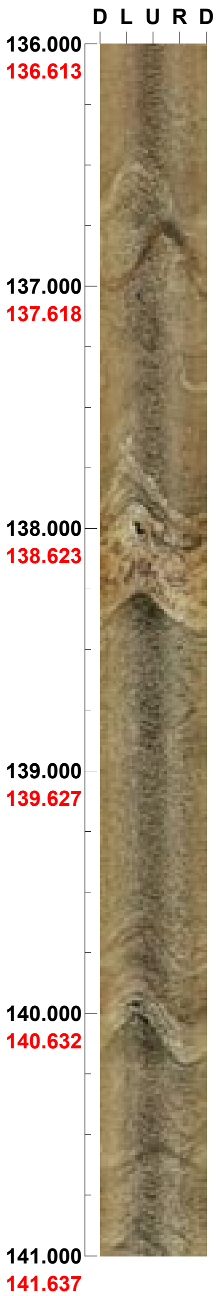
131.000
131.588

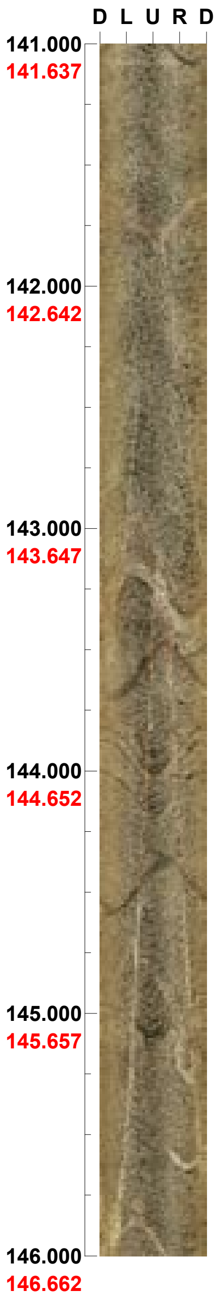
(6 / 11) **Scale: 1/25** **Aspect ratio: 100 %**

Appendix 5 **Project name: Forsmark**
Bore hole No.: HFM22 **Azimuth: 90** **Inclination: -59**

Depth range: 131.000 - 151.000 m





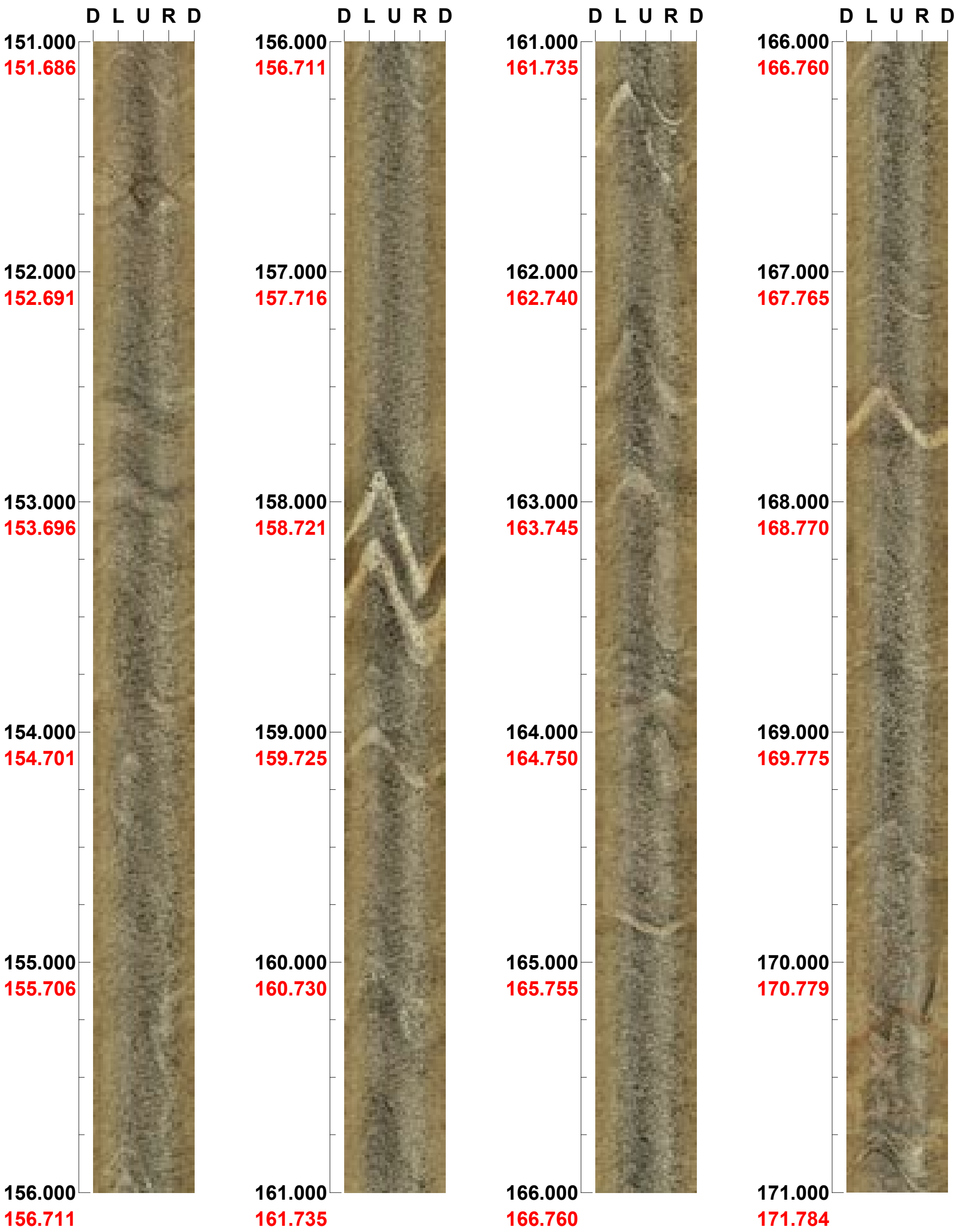


(7 / 11) **Scale: 1/25** **Aspect ratio: 100 %**

Appendix 5 **Project name: Forsmark**

Bore hole No.: HFM22 **Azimuth: 90** **Inclination: -59**

Depth range: 151.000 - 171.000 m



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

Appendix 5 **Project name: Forsmark**

Bore hole No.: HFM22 **Azimuth: 90** **Inclination: -59**

Depth range: 171.000 - 191.000 m

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

Appendix 5 **Project name: Forsmark**

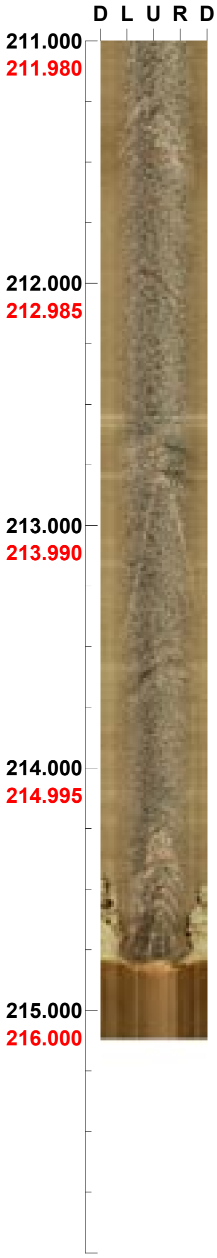
Bore hole No.: HFM22 **Azimuth: 90** **Inclination: -59**

Depth range: 191.000 - 211.000 m

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

Appendix 5 **Project name: Forsmark**
Bore hole No.: HFM22 **Azimuth: 90** **Inclination: -59**

Depth range: 211.000 - 215.113 m



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