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Forsmark site investigation

RAMAC and BIPS logging in borehole KFM07A

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March 2005

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Keywords: BIPS, RAMAC, Radar, TV, Forsmark, AP PF 400-05-002.

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 logging and borehole radar (RAMAC) measurements in the core-drilled borehole KFM07A. All measurements were conducted by Malå Geoscience AB/RAYCON during January and February 2005.

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 KFM07A 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 170 reflectors were identified in KFM07A, and around 50 of them oriented.

The basic conditions of the BIPS logging for geological mapping and orientation of structures are satisfying for borehole KFM07A. Induced effects from the drilling on the borehole walls limits the visibility and to some extent mud that covers the lower most part of the borehole wall.

Sammanfattning

Denna rapport omfattar geofysiska loggningar inom platsundersökningsprogrammet för Forsmark. Mätningarna som presenteras här omfattar BIPS- och radarloggningar i borrhålet KFM07A. Alla mätningar är utförda av Malå Geoscience AB/RAYCON under januari 2005.

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 KFM07A var tillfredställande, men i 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 170 radarreflektorer identifierats i KFM07A, varav ca 50 är orienterade.

BIPS bilderna visar att förutsättningarna för geologisk kartering och sprickorientering är goda för KFM07A. Det är svärtningarna på borrhålsväggen som försämrar kvalitén på bilderna och i viss mån även lösa fragment av berg som lägger sig på liggsidan.

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 KFM07A. The work was carried out in accordance with activity plan AP PF 400-05-002. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

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

Activity plan	**Number**	**Version**
BIPS och RAMAC loggning i KFM07A	AP PF 400-05-002	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för TV-loggning med BIPS	SKB MD 222.006	1.0
Metodbeskrivning för borrhålsradar	SKB MD 252.020	1.0

This report includes measurements from 100 to approximately 1,000 m in borehole KFM07A. The borehole is drilled with an inclination of 59 degrees from the horizontal, a bearing of 261 degrees and a diameter of approximately 77 mm.

All measurements were conducted by Malå Geoscience AB/RAYCON during January and February 2005. 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.

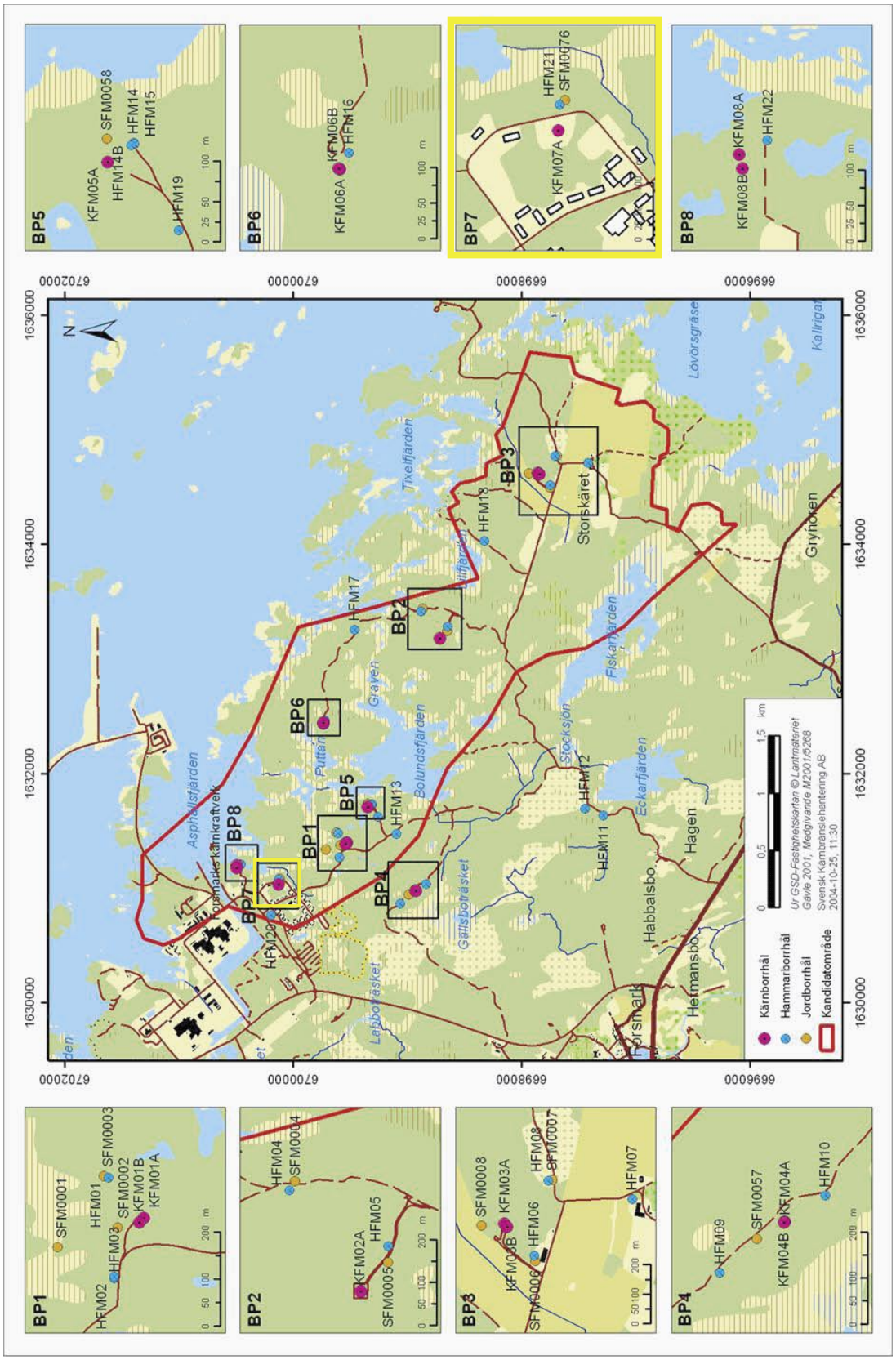


Figure 1-1. *General overview over the Forsmark area with the location of the borehole KFM07A.*

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 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.

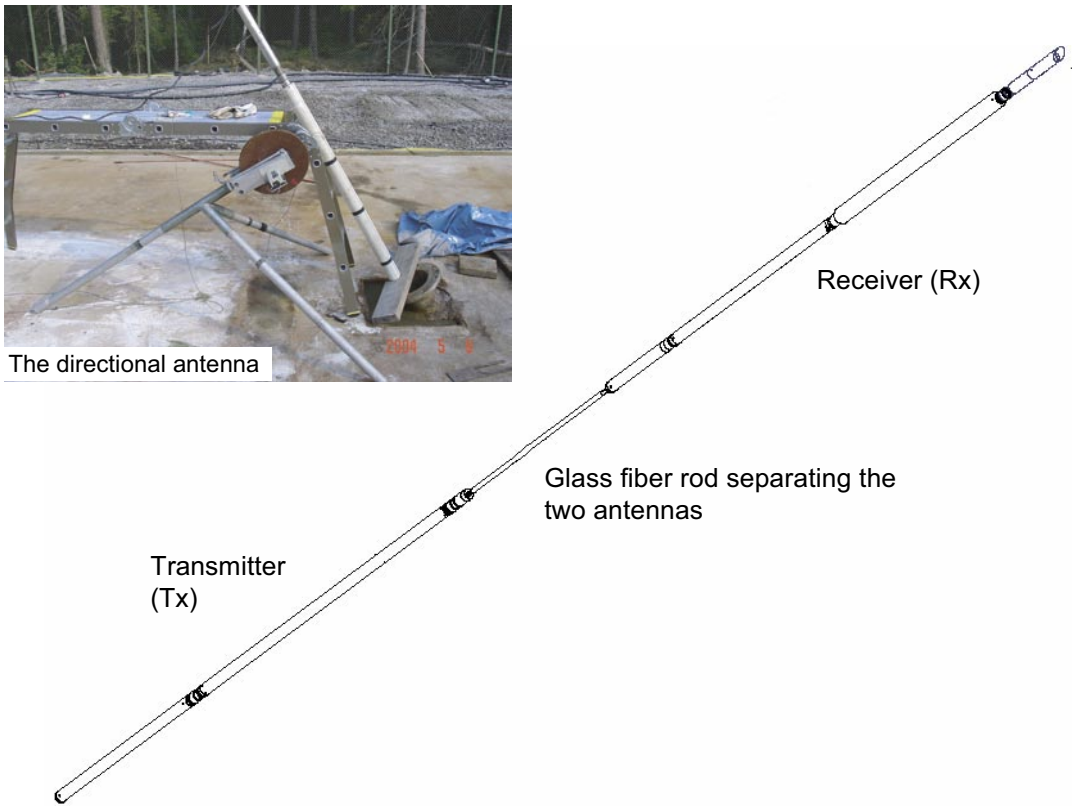


Figure 3-1. *Example of a borehole radar antenna.*

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, 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).

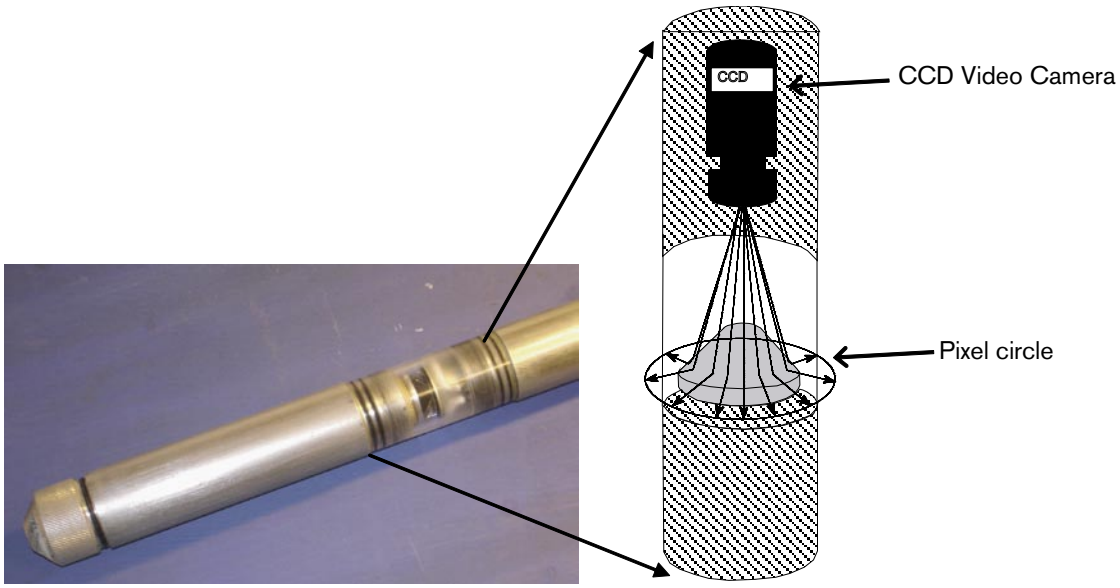


Figure 3-2. *The BIPS-system. To the right an illustration of the conical mirror scanning.*

4 Execution

4.1 General

4.1.1 RAMAC Radar

The measurements in KFM07A were carried out with dipole radar antennas, with frequencies of 250, 100 and 20 MHz. The directional antenna was also 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. 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 KFM07A. 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 4 degrees. This can be considered as very 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 KFM07A see Table 4-1.

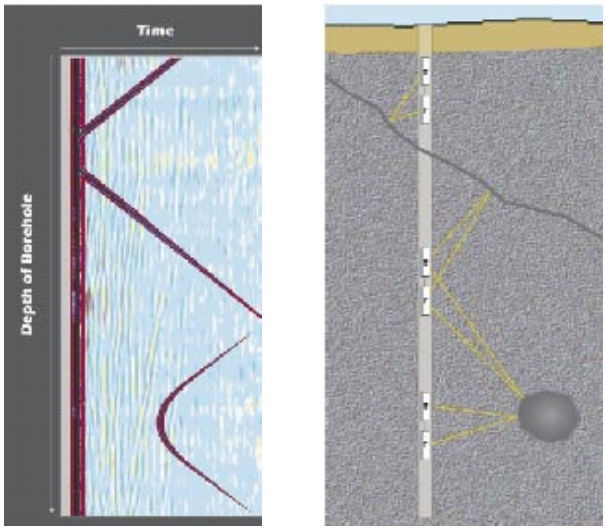


Figure 4-1. *The principle of radar borehole reflection survey and an example of result.*

Table 4-1. Radar logging information from KFM07A.

Site:	**Forsmark**	**Logging company:**	**RAYCON**		
BH:	**KFM07A**	**Equipment:**	**SKB RAMAC**		
Type:	**Directional / Dipole**	**Manufacturer:**	**MALÅ GeoScience**		
Operator:	**CG**	**Antenna**			
		Directional	**250 MHz**	**100 MHz**	**20 MHz**
	Logging date:	05-01-14	05-01-14	05-01-14	05-01-14
	Reference:	T.O.C.	T.O.C.	T.O.C.	T.O.C.
	Sampling frequency (MHz):	615	2,424	891	239
	Number of samples:	512	619	518	518
	Number of stacks:	32	Auto	Auto	Auto
	Signal position:	390.48	–0.35	–0.37	–1.40
	Logging from (m):	103.4	101.5	102.6	106.25
	Logging to (m):	988.4	995.6	992.9	991.35
	Trace interval (m):	0.5	0.25	0.2	0.1
	Antenna separation (m):	5.73	1.9	2.9	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.

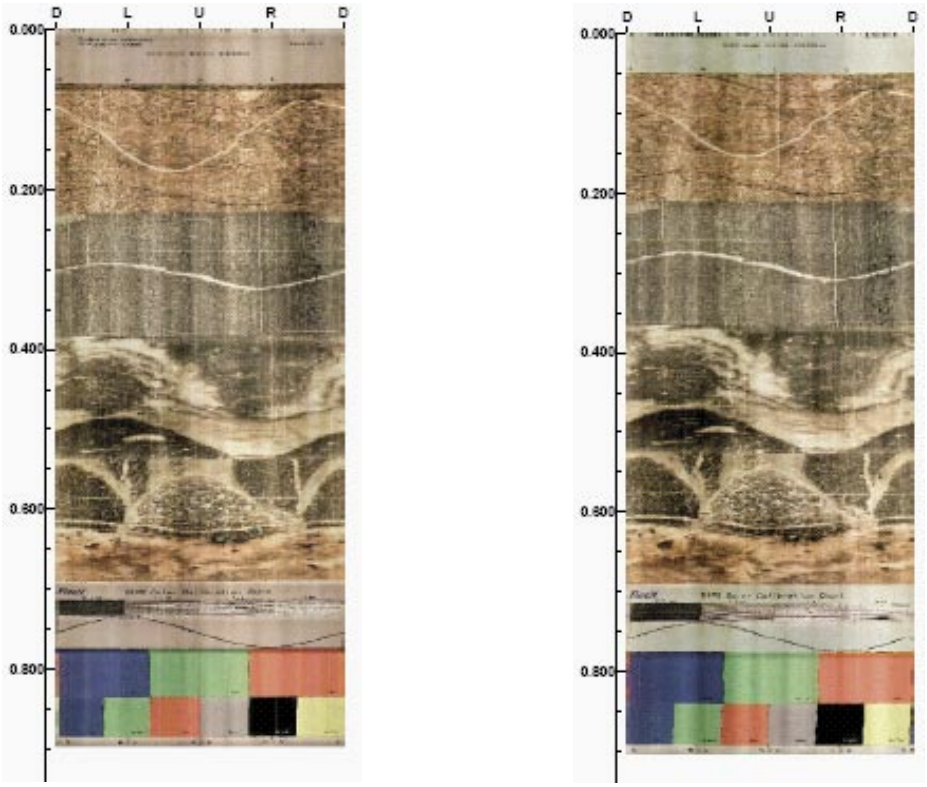
In order to control the quality of the system, calibration measurements were performed in a test pipe before logging the first borehole and after logging the last one. Figure 4-2 corresponds to the test pipe logging before and after the logging of KFM07A in January. The results showed no difference regarding the colours and focus of the images. Results of the test loggings were included in the delivery of the raw data.

The BIPS logging information is found in the header for every single borehole presented in Appendix 3 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 core drilled boreholes, where the reference marks in the borehole wall is visible on the image, the position where the depth mark is visible is marked with scotch tape on the logging cable. During BIPS logging the measured length was adjusted to true length according to depth mark visible in the BIPS image. The adjusted true length is marked with red in the image plot together with the non adjusted measured length which is marked with black as seen in Appendix 3. The tape marks on the logging cable are then used for controlling the RAMAC measurement.



Before **After**

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

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.

For the results from KFM07A, the depth to identified structures are corrected according to the present depth divergence, as stated in the field notes, delivered to SKB/SICADA. The correction is done by a change in the radar information file, *.rad.

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 is made with ReflexWin, a Windows based processing software for filtering and analysis of borehole radar data. The processing steps are shown in Table 4-2. It should be observed that the processing steps below refer to the Appendix 1. The filters applied affect the whole borehole length and are not always suitable in all parts, depending on the geological conditions and conductivity of the borehole fluid. During interpretation further processing can be done, most often in form of bandpass filtering. This filtering can be applied just in parts of the borehole, where needed.

The Appendix 2 is created within the software RadInter SKB, which is also used for the interpretation of the intersection angle between the borehole axis and the planes visible on the radargrams. 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 and 2.

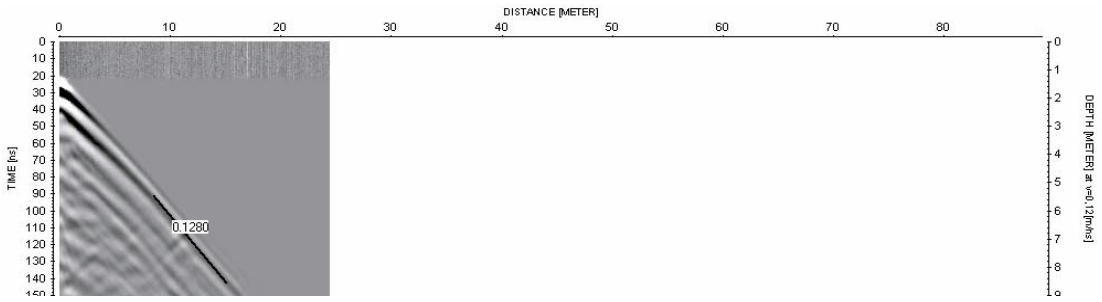


Figure 4-3. *Results from velocity measurements in HFM03 /1/.*

Table 4-2. Processing steps for borehole radar data from KFM07A.

Site:	**Forsmark**	**Logging company:**	**RAYCON**	
BH:	**KFM07A**	**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
	(185–500)	(200–250)	(400–540)	(200–500)
	Move start time	Move start time	Move start time	Move start time
	(–40)	(–14.5)	(–36)	(–20)
	Gain	Gain	Gain	Gain
	(from 66, linear 200, exp 2)	(from 17, linear 2, exp 0)	(from 41, linear 2.9, exp 0.4)	(from 66, linear 100, exp 0)
	FIR (backg rem 5, lowpass 5)			FIR (backg rem 10, lowpass 5)

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

The radar logging with the directional antenna in KFM07A was interrupted at a depth 802 m, due to large risk that the antenna would get stuck in a probable zone at that level. The logging activity with the directional antenna was interrupted after a dialogue with SKB.

5 Results

The results from the BIPS measurements in KFM07A 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 KFM07A 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 5-3. Radar data is also visualized in Appendix 1 and 2. It should be remembered that the images in Appendix 1 and 2 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 KFM07A, (as seen in Appendix 1 and 2) 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 250 MHz data along the whole borehole. In the 100 MHz data the depth penetration is quite low from 580 to 700 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 and 2 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 Table 5-1 below, the distribution of identified structures along the boreholes KFM07A is showed.

Table 5-1. Identified structures as a function of depth in KFM07A.

Depth (m)	No of structures
0–50	1
50–100	3
100–150	11
150–200	10
200–250	13
250–300	16
300–350	8
350–400	11
400–450	9
450–500	8
500–550	11
550–600	7
600–650	1
650–700	11
700–750	11
750–800	8
800–850	16
850–900	11
900–950	8
950–1,000	5

Table 5-2 summarises the interpretation of radar data from KFM07A. In the table 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.

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 72 in Table 5-2. To this structure, most likely, also structures 72x belongs.

Table 5-2. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz and the directional antenna in borehole KFM07A.

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

Site: **Forsmark**
Borehole name: **KFM07A**
Nominal velocity (m/µs): **128.0**

Name	Intersection depth	Intersection angle	Object direction	Dip 1	Strike 1	Dip 2	Strike 2
5x	–12.80	5	90	86	102		
5xx	61.60	8					
141	72.20	10					
1	99.70	79					
146	105.80	19					
5	108.00	15	321	82	47		
2	111.60	71	207 ±	18	214	45	179
2x	112.70	68					
3	119.90	62					
3x	120.90	65	345	55	197		
141x	129.60	18					
4	133.40	55	198 ±	10	290	63	178
8	134.20	14	351	73	19		
6	143.10	43					
8xx	145.10	17					
7	154.90	43					
8x	159.30	37	348	82	198		
11	164.90	10					
9	167.90	26					
18	169.60	18	336	80	32		
10	178.40	68	210	15	237		
12	183.00	70					
16	184.50	58					
13	185.60	59					
14	198.20	39					
15	203.00	30	351	87	197		
144	211.80	27					
149	212.90	32	6	89	182		
17	215.20	29	3	90	187		
19	217.80	27					
144x	222.30	30					
20	224.90	35					
140	233.70	13					
21xx	239.40	39	177±	20	15	81	191
21	239.80	32	12	89	178		
22	241.90	35					
21x	247.00	22	6	83	3		
23	247.30	27					
25	257.20	32	6	88	183		
24	261.70	48	12	74	179		

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

Site: **Forsmark**
Borehole name: **KFM07A**
Nominal velocity (m/µs): **128.0**

Name	Intersection depth	Intersection angle	Object direction	Dip 1	Strike 1	Dip 2	Strike 2
26	263.70	27					
27	269.00	40					
33	270.90	36					
28	274.80	25					
29	278.80	42	345±	77	199	19	44
142	279.90	19					
34	280.00	29	321±	85	218	38	67
39x	280.10	15	69	87	297		
39	282.00	14	123	60	73		
143	284.50	31					
29x	295.00	19					
35	295.40	51	174±	7	36	70	188
30	296.50	11					
31	297.60	28					
32	300.80	30					
36	303.20	70					
40	304.50	53					
37	319.40	37	357	85	188		
38x	326.60	40	357	82	188		
38	331.90	28					
41	345.50	67					
42	348.80	90					
44	353.10	31					
151	354.40	42	12	79	175		
44x	358.50	55					
45	369.60	20					
46	371.70	58					
47	372.50	23					
48	380.30	54					
49	385.60	34	159±	27	41	87	197
146x	386.20	17					
50	390.90	37					
150	392.00	19	354	78	10		
51	401.90	30					
52	405.10	29					
43	410.40	8					
51x	411.00	20	6	79	356		
54	418.70	48					
53	419.90	30	354	89	5		
145	429.30	25					
55	440.60	34	60	73	133		
147	445.40	25					

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

Site: **Forsmark**
Borehole name: **KFM07A**
Nominal velocity (m/µs): **128.0**

Name	Intersection depth	Intersection angle	Object direction	Dip 1	Strike 1	Dip 2	Strike 2
152	451.90	33	348	90	10		
58	457.00	41					
56	461.00	45	33	72	157		
60	466.20	38	348	87	186		
57x	475.30	35	354	87	184		
57	489.90	22	354	81	5		
154	491.90	50	252	42	242		
133	499.90	71					
59	500.00	21					
153	500.30	42	24	80	158		
62	500.70	20					
70	504.90	18					
61	514.50	75					
63	522.30	56					
64x	531.40	48	24	72	160		
64	532.30	41	33	77	152		
65	537.30	26	351	84	4		
134	547.60	76					
66	549.90	30	345	89	8		
148	551.70	40					
135	554.30	76					
67	557.50	30					
68	571.00	32	315	86	212		
155	591.60	41	324	79	198		
69	591.90	31					
71	595.00	34					
73	630.70	48					
72	652.70	20					
74	659.30	38					
78	661.30	41	156	20	53		
74x	662.90	30	357	85	354		
75	663.70	42	3	82	169		
72x	669.30	13					
76	674.70	34					
77	675.30	44	354	82	175		
79	681.20	20					
80	686.10	68					
79x	690.30	36					
81	704.10	78					
82	711.80	59					
83	719.50	47					
156	722.80	18	234	55	279		

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

Site: **Forsmark**
Borehole name: **KFM07A**
Nominal velocity (m/µs): **128.0**

Name	Intersection depth	Intersection angle	Object direction	Dip 1	Strike 1	Dip 2	Strike 2
88	730.10	63					
84	731.10	49	30	74	148		
85	734.20	61					
136	738.20	69					
86	740.60	60	24	66	154		
137	746.40	70					
87	747.90	59	213±	19	221	61	153
89	763.00	65					
90	767.90	84					
91	773.80	79					
93	781.60	72					
94	782.90	50					
92	783.80	42					
95	784.40	49					
92x	790.30	26					
98	800.60	77					
99	803.40	80					
96	805.90	53					
100	805.90	88					
97	809.90	51					
103	814.80	36					
101	817.20	78					
102	818.90	82					
112	819.80	15					
104	824.10	84					
157	827.10	29	18	85	332		
105	836.20	44					
106	839.30	84					
107	842.10	32					
108	843.10	79					
109	846.70	56					
110	855.90	79					
111	857.80	81					
113	864.60	46					
114	871.70	43					
115	879.30	49					
138	882.90	56					
117	883.40	30					
116	884.50	39					
119	892.30	80					
121	896.90	20					
120	898.20	74					

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

Site:	**Forsmark**
Borehole name:	**KFM07A**
Nominal velocity (m/µs):	**128.0**

Name	Intersection depth	Intersection angle	Object direction	Dip 1	Strike 1	Dip 2	Strike 2
139	903.90	86					
118	904.70	37					
122	919.70	47					
123	922.80	58					
124	923.80	80					
125	926.50	66					
126	936.20	82					
127	948.40	67					
130	970.80	32					
129	970.90	79					
132	991.90	84					
131	993.20	76					
128	996.20	33					

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

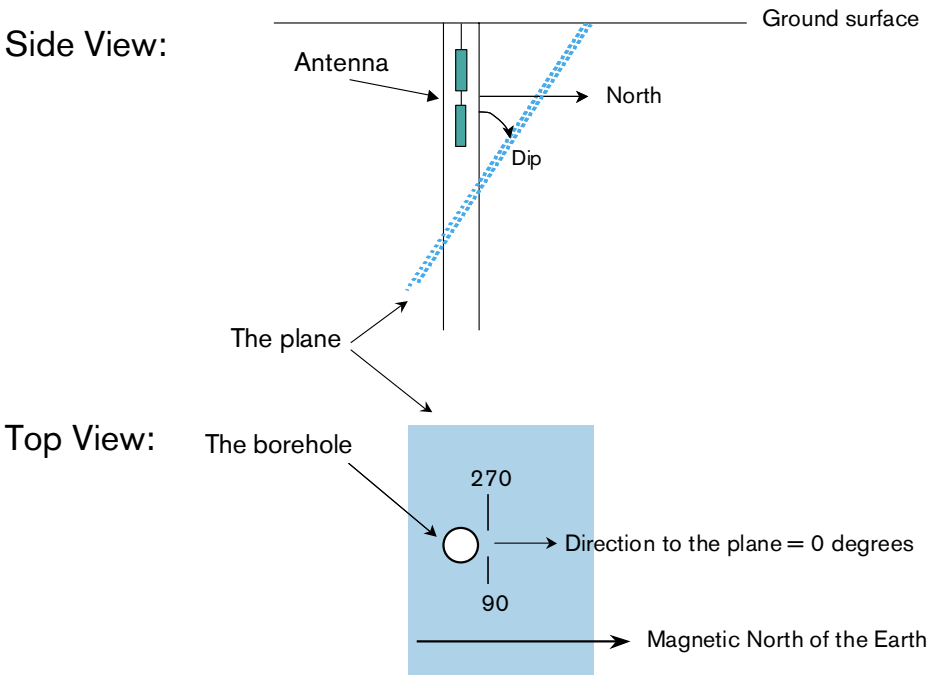


Figure 5-1. *Definition of direction to object as presented in Table 5-2.*

Table 5-3. Borehole length intervals in KFM07A with decreased amplitude for the 250 MHz antenna.

Depth (m)	
110–115	765–770
120	805–810
155–170	825
180	840
195–205	855–860
260	875–880
295	880–885
330–345	895–900
420	920
440	935–940
555	960–975
735	990

5.2 BIPS logging

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.

The BIPS pictures are presented in Appendix 3.

To get the best possible depth accuracy, the BIPS images are adjusted (red figures in Appendix 3) to the reference marks on the logging cable.

Totally two runs with the BIPS were performed in the borehole. The first run (2005-01-10) was stopped at 950 due to very bad quality of the water in-between 700 meters and the bottom. Figure 5-2 shows the BIPS image at 700 m and illustrates the differences in the two logging runs.

The quality of the water was very much improved at the time for run number two (2005-02-10). This logging was performed from 550 meter to the bottom of the borehole. The improvement of the water quality is due to the cleaning procedure (with Nitrogen gas) in-between the logging runs but also the fact that it is well documented that the water quality improves over a time. The known effect of discolouring of parts of the borehole due to the drilling is however still seen. To summarise the BIPS logging, the images is of reasonable good quality for the core logging procedure.

Appendix 3 presents the BIPS logging dated 2005-01-10 from 101 m to 560 m and the logging dated 2005-02-10 from 550 m to 993 m.

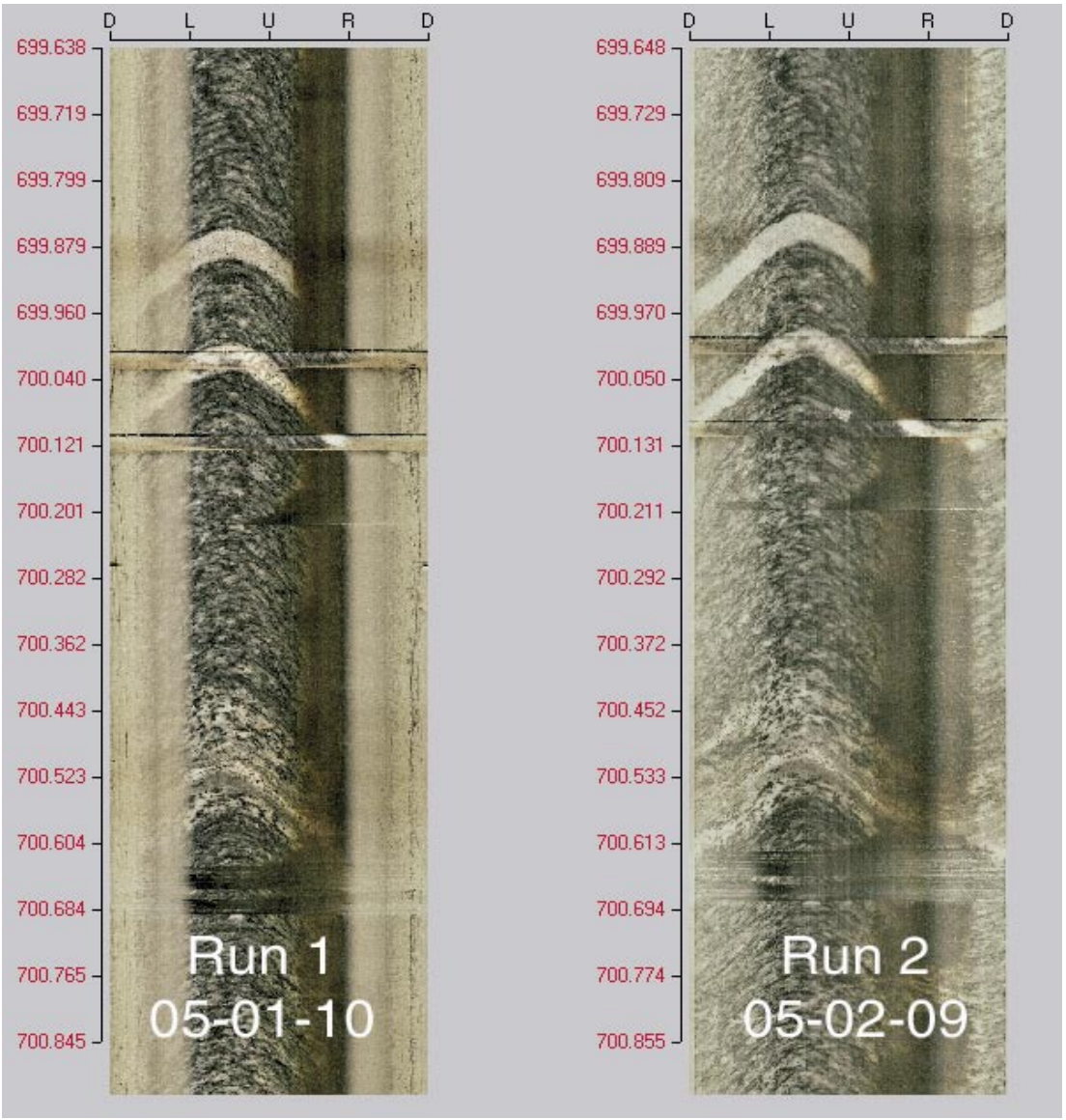
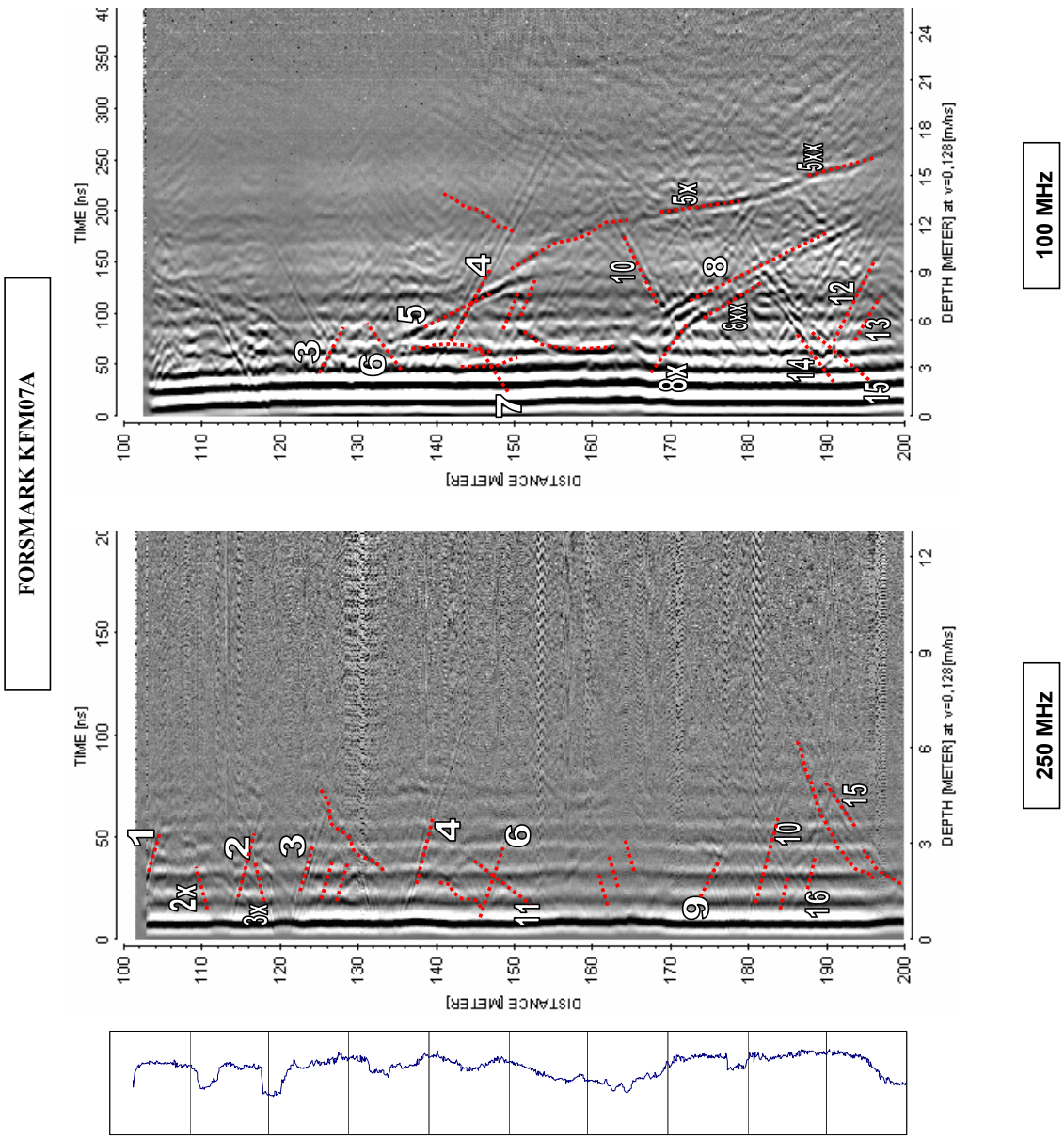


Figure 5-2. *BIPS image at 700 meter.*

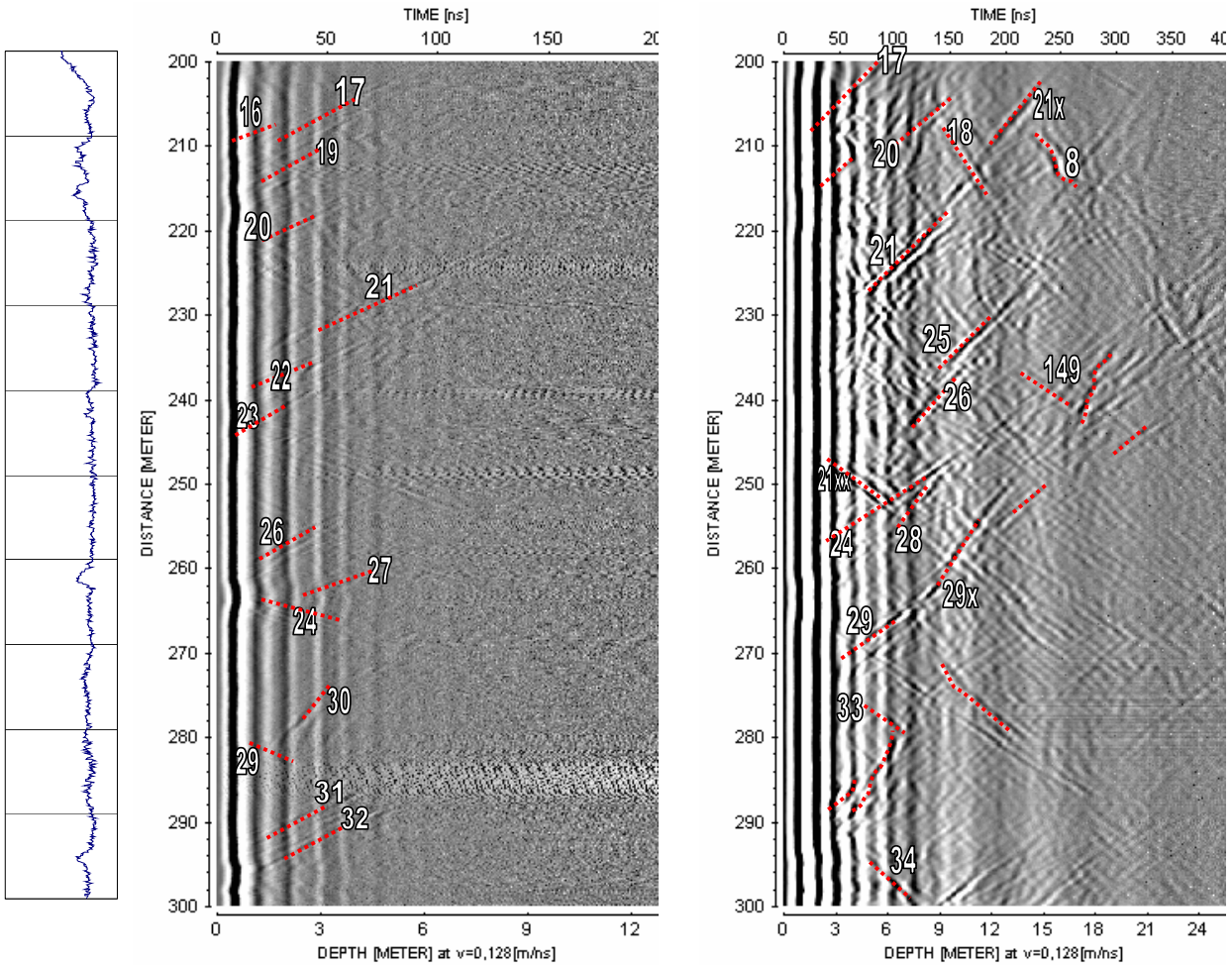
References

/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 KFM07A, 100 to 990 m, dipole antennas 250 and 100 MHz



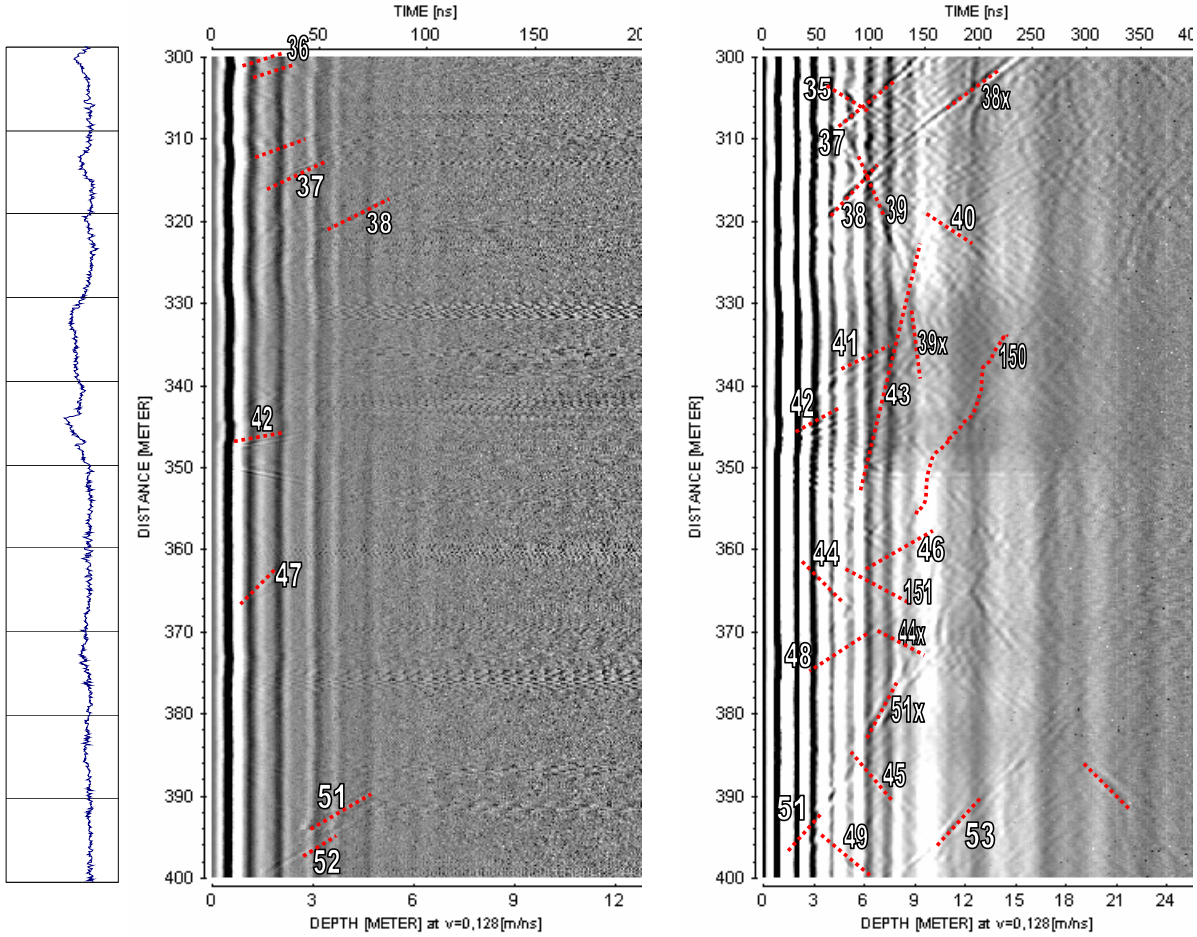
FORSMARK KFM07A



250 MHz

100 MHz

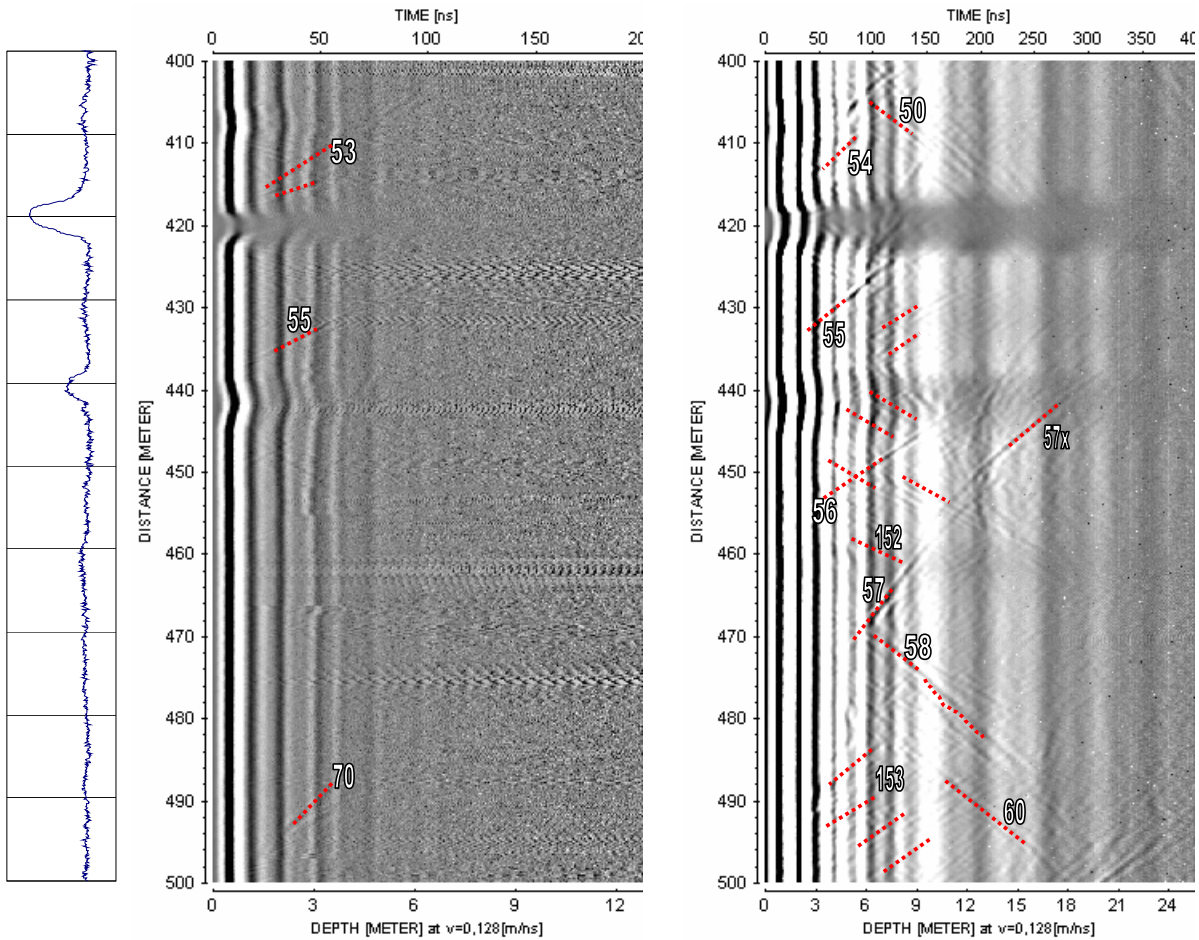
FORSMARK KFM07A



250 MHz

100 MHz

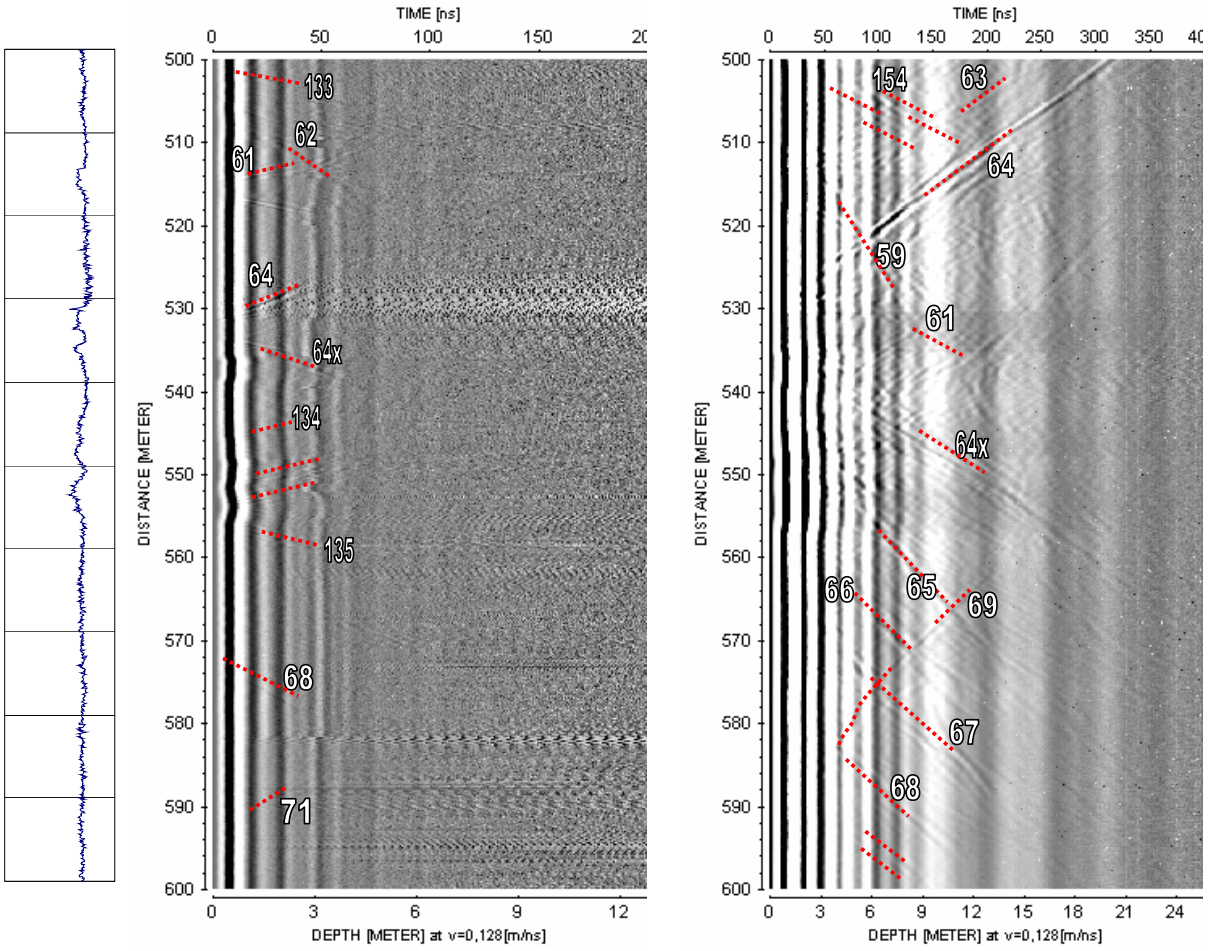
FORSMARK KFM07A



250 MHz

100 MHz

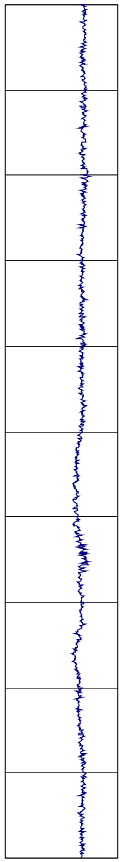
FORSMARK KFM07A

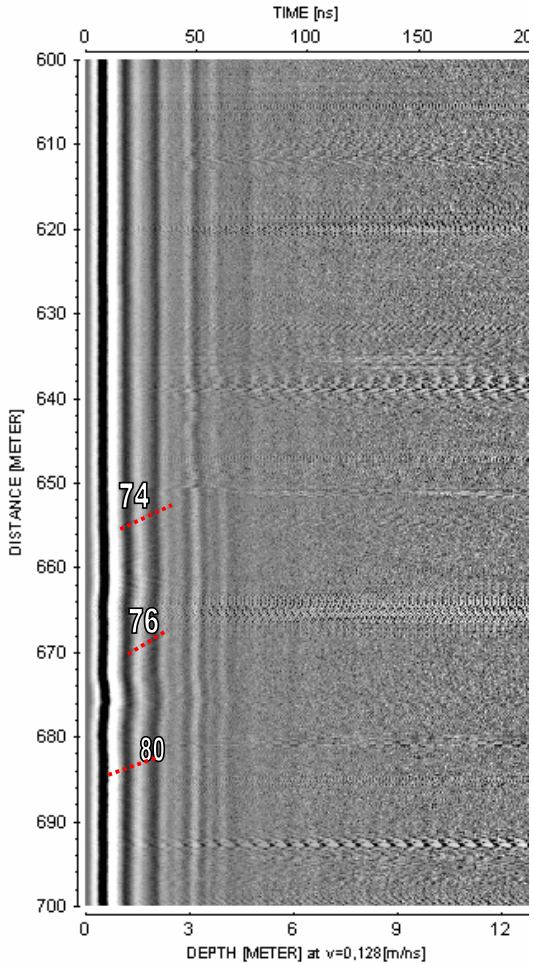


250 MHz

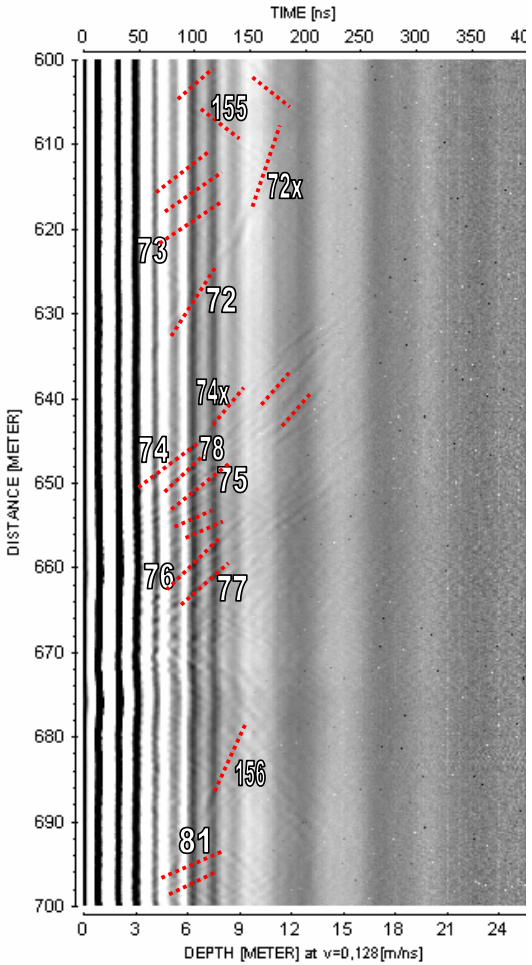
100 MHz

FORSMARK KFM07A



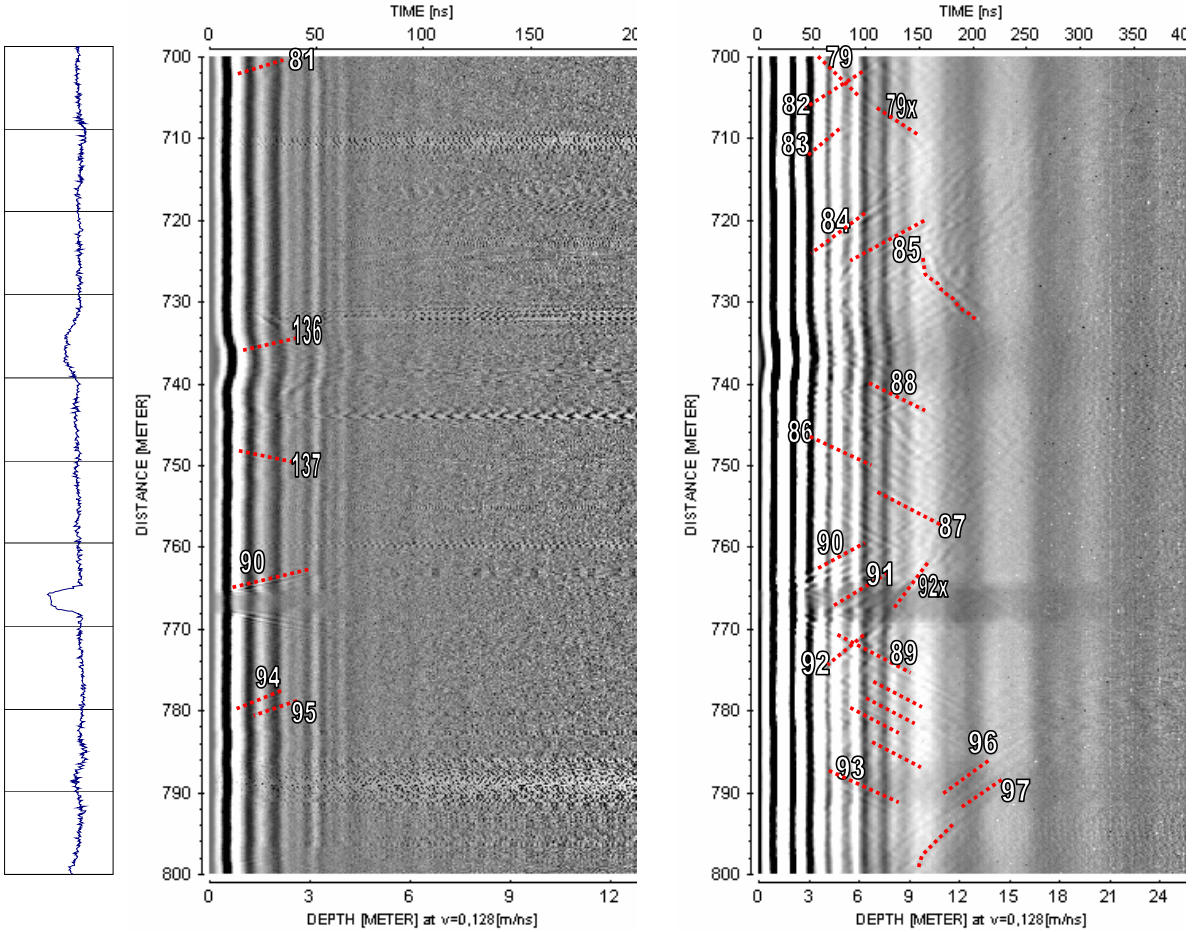


250 MHz



100 MHz

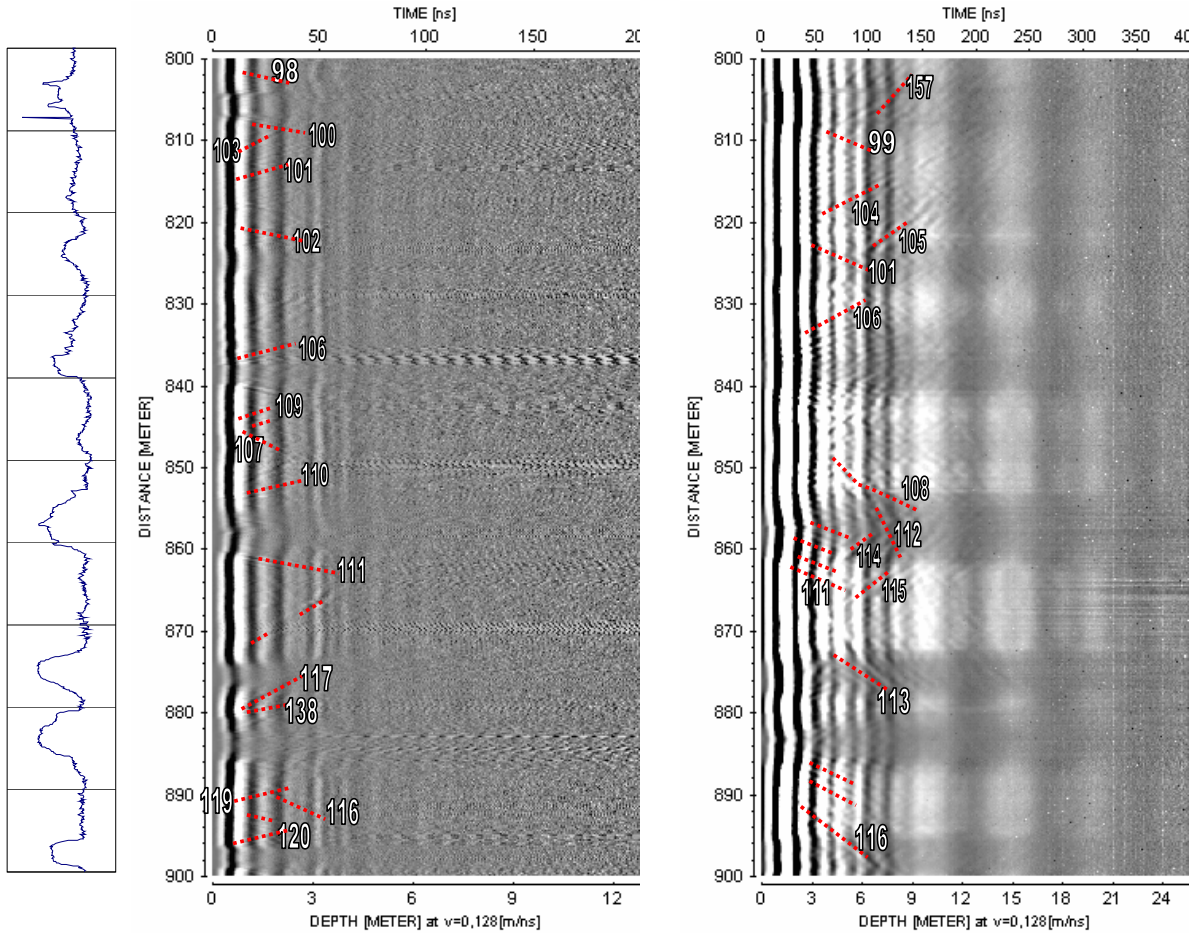
FORSMARK KFM07A



250 MHz

100 MHz

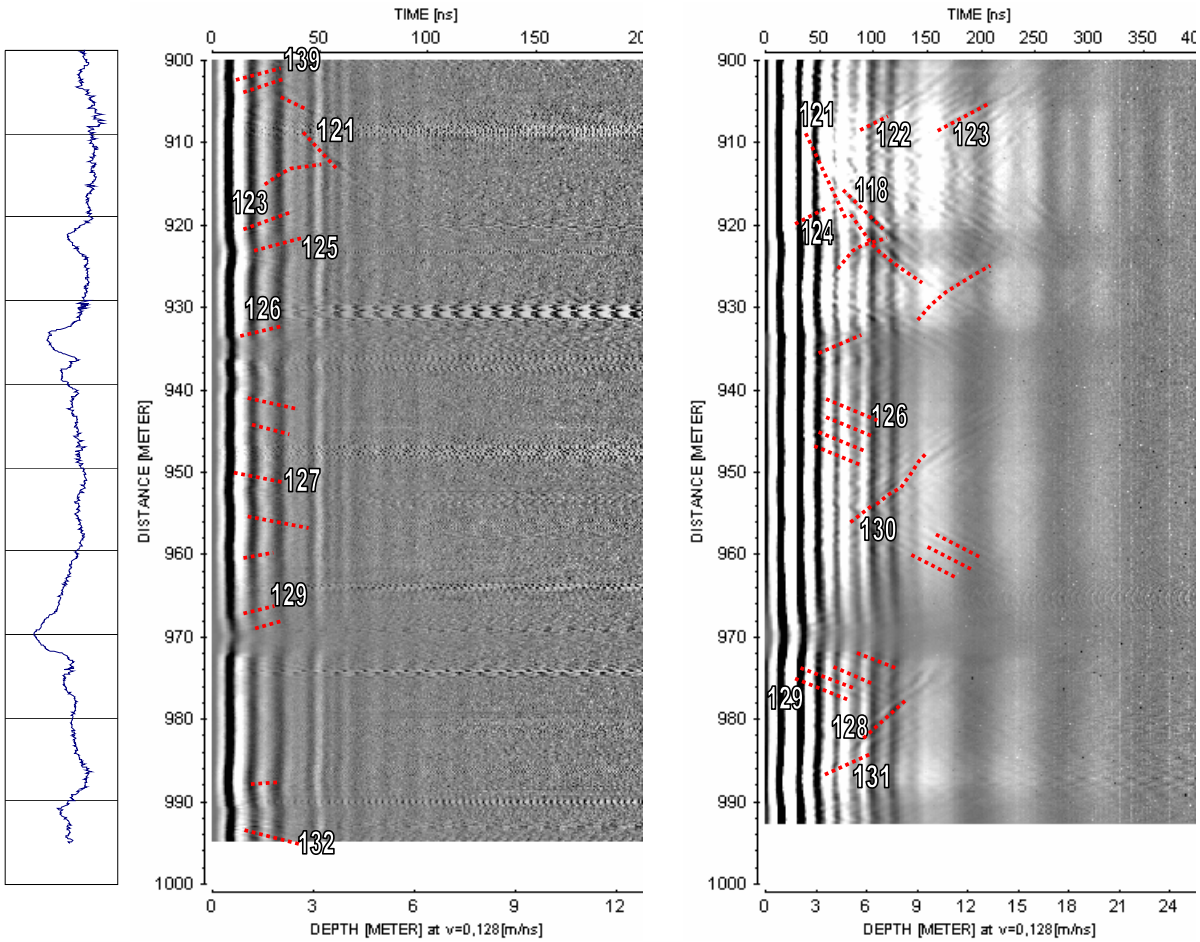
FORSMARK KFM07A



250 MHz

100 MHz

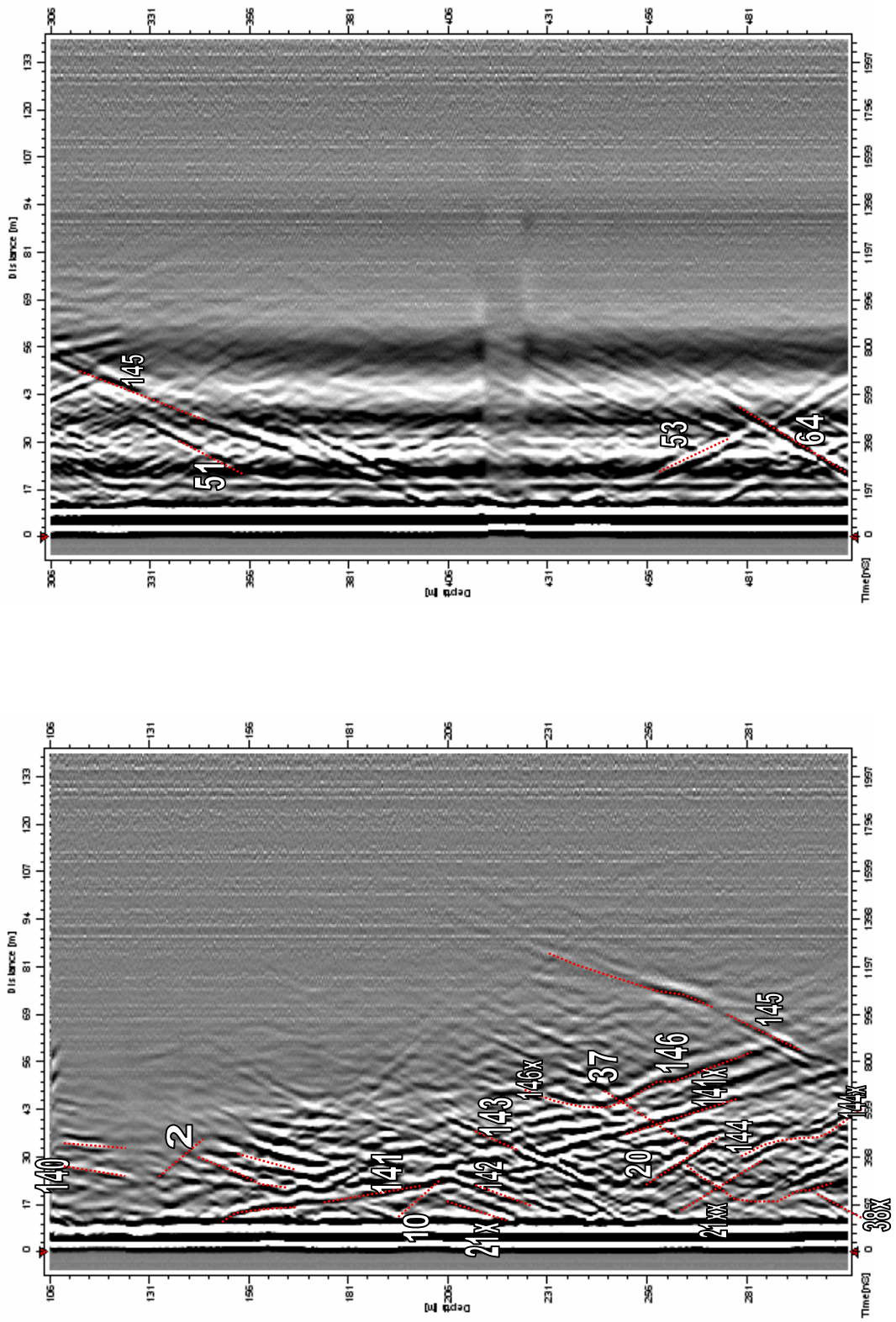
FORSMARK KFM07A

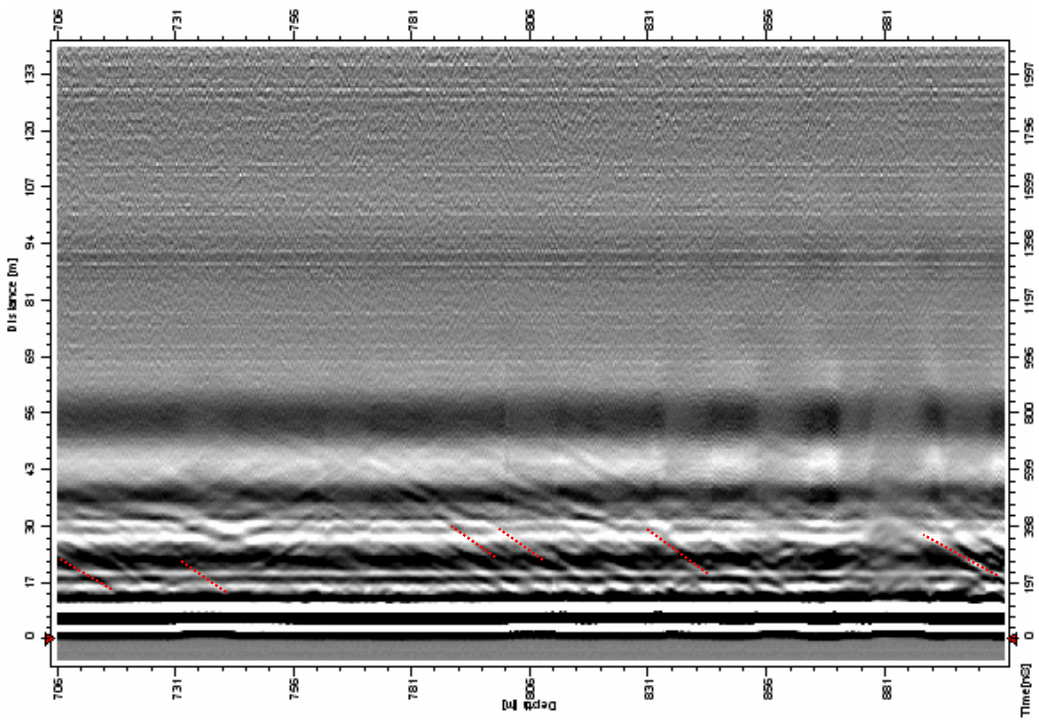


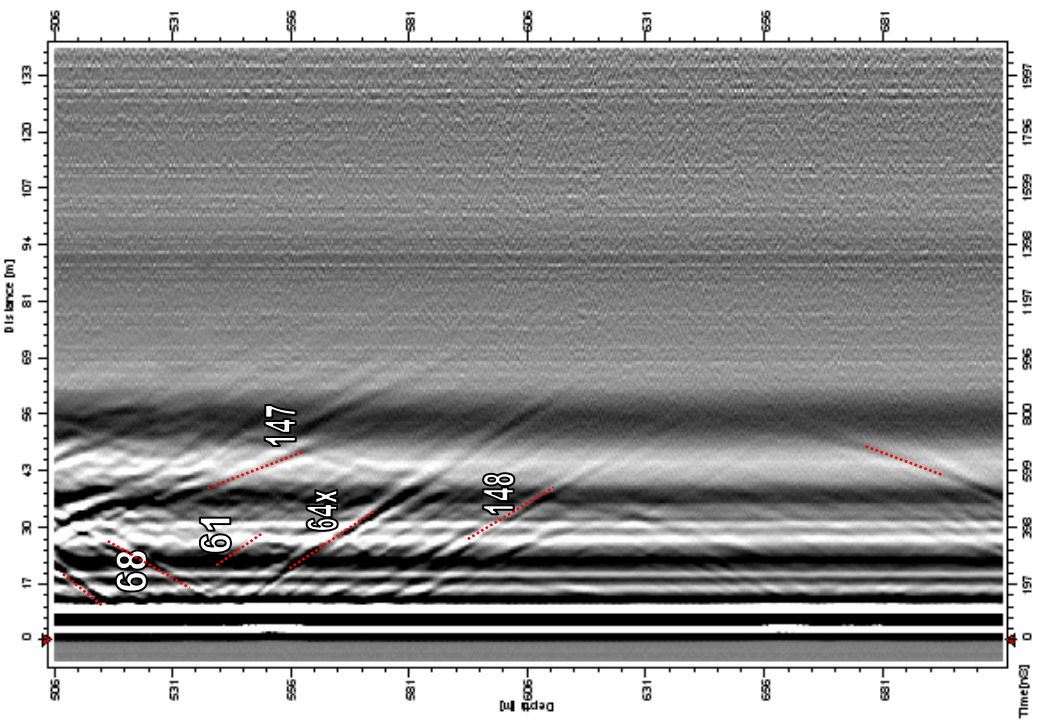
250 MHz

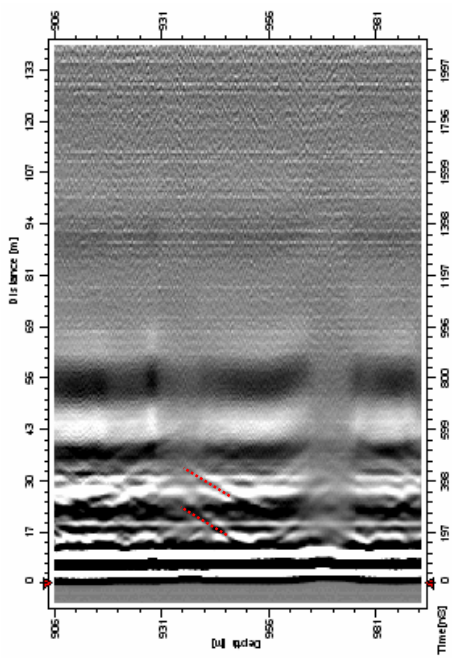
100 MHz

Radar logging in KFM07A, 100 to 985 m, dipole antenna 20 MHz




Distance [m]
Depth [m]
Time [ns]


68
61
147
64x
148
Distance [m]
Depth [m]
Time [ns]


Distance [m]
Depth [m]
Time [ns]

Appendix 3

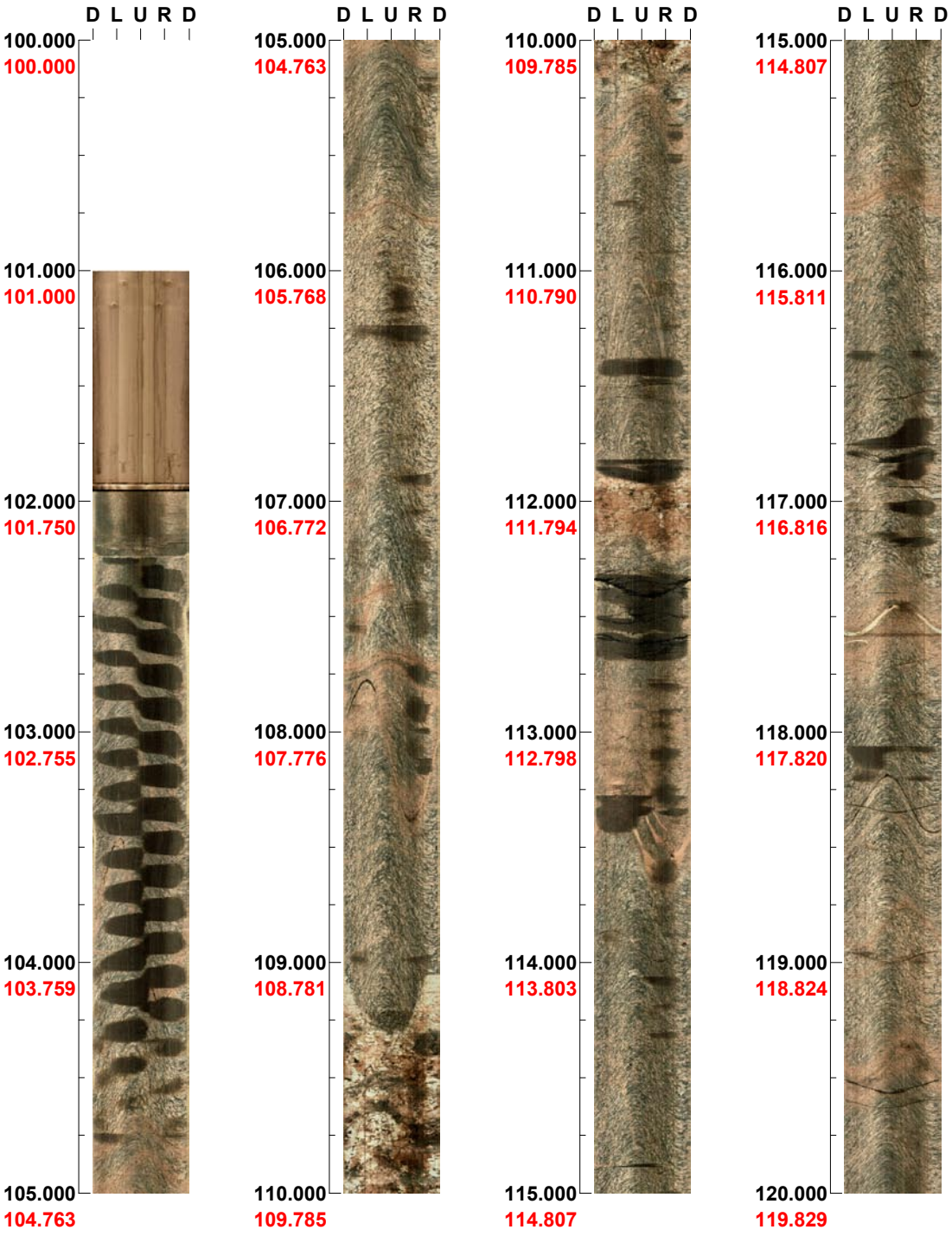
BIPS logging in KFM07A, 101 to 993 m

Project name: Forsmark

Image file	**: c:\work\r53__s~1\bips\kfm07a~1.bip**
BDT file	**: c:\work\r53__s~1\bips\kfm07a~1.bdt**
Locality	**: FORSMARK**
Bore hole number	**: KFM07A**
Date	**: 05/01/10**
Time	**: 13:11:00**
Depth range	**: 101.000 - 949.812 m**
Azimuth	**: 261**
Inclination	**: -59**
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	**: 43**
Color	**: +0 +0 +0**

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

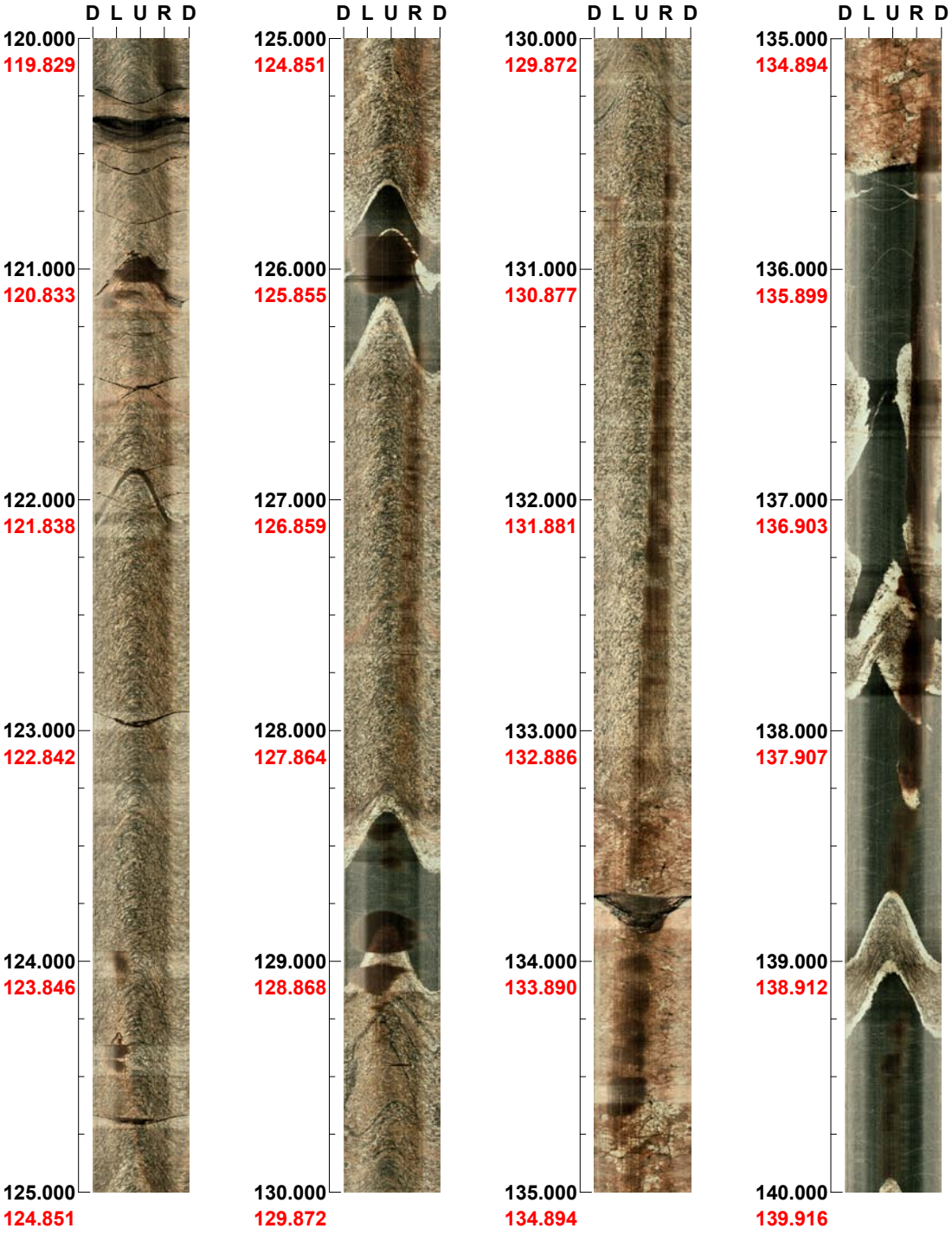
Depth range: 100.000 - 120.000 m



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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

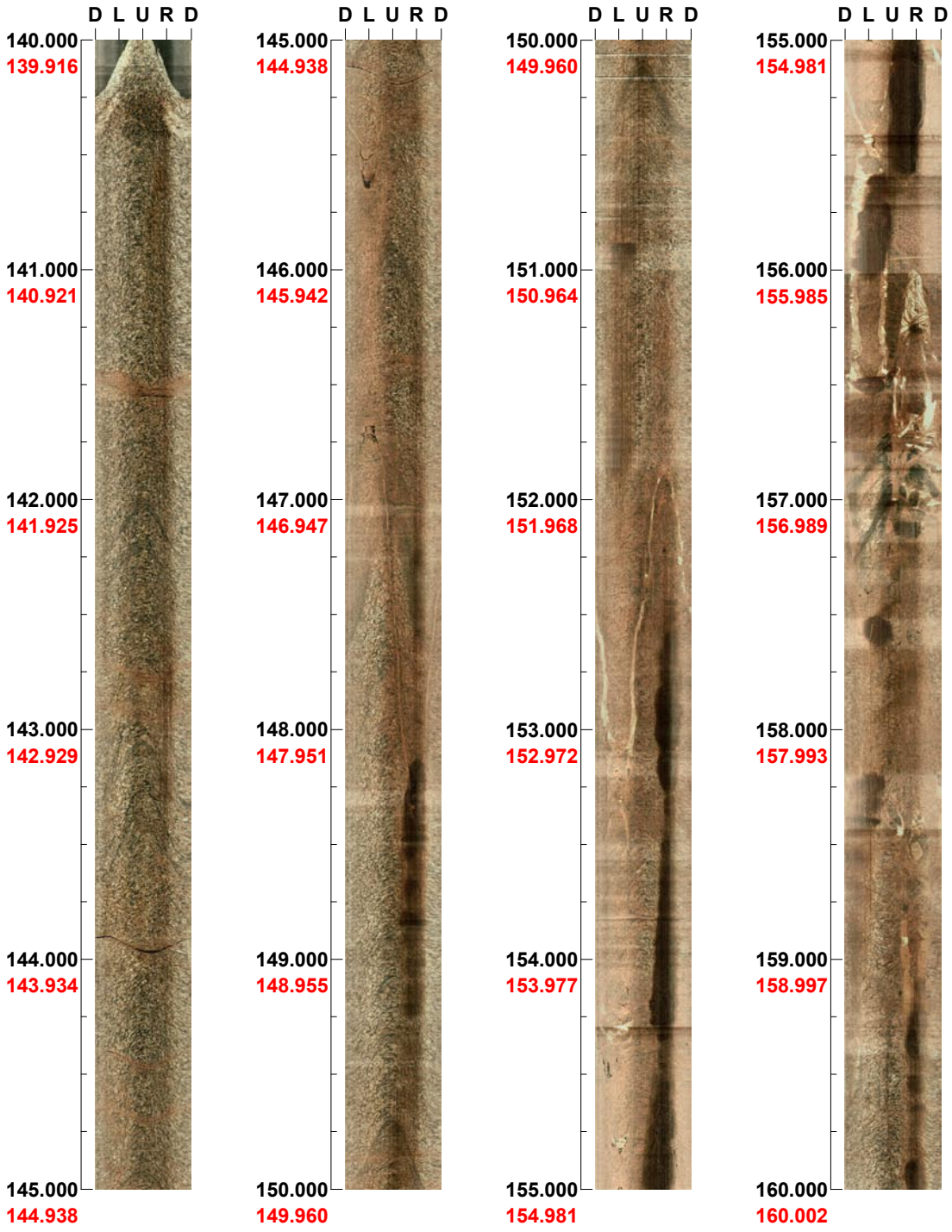
Depth range: 120.000 - 140.000 m



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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

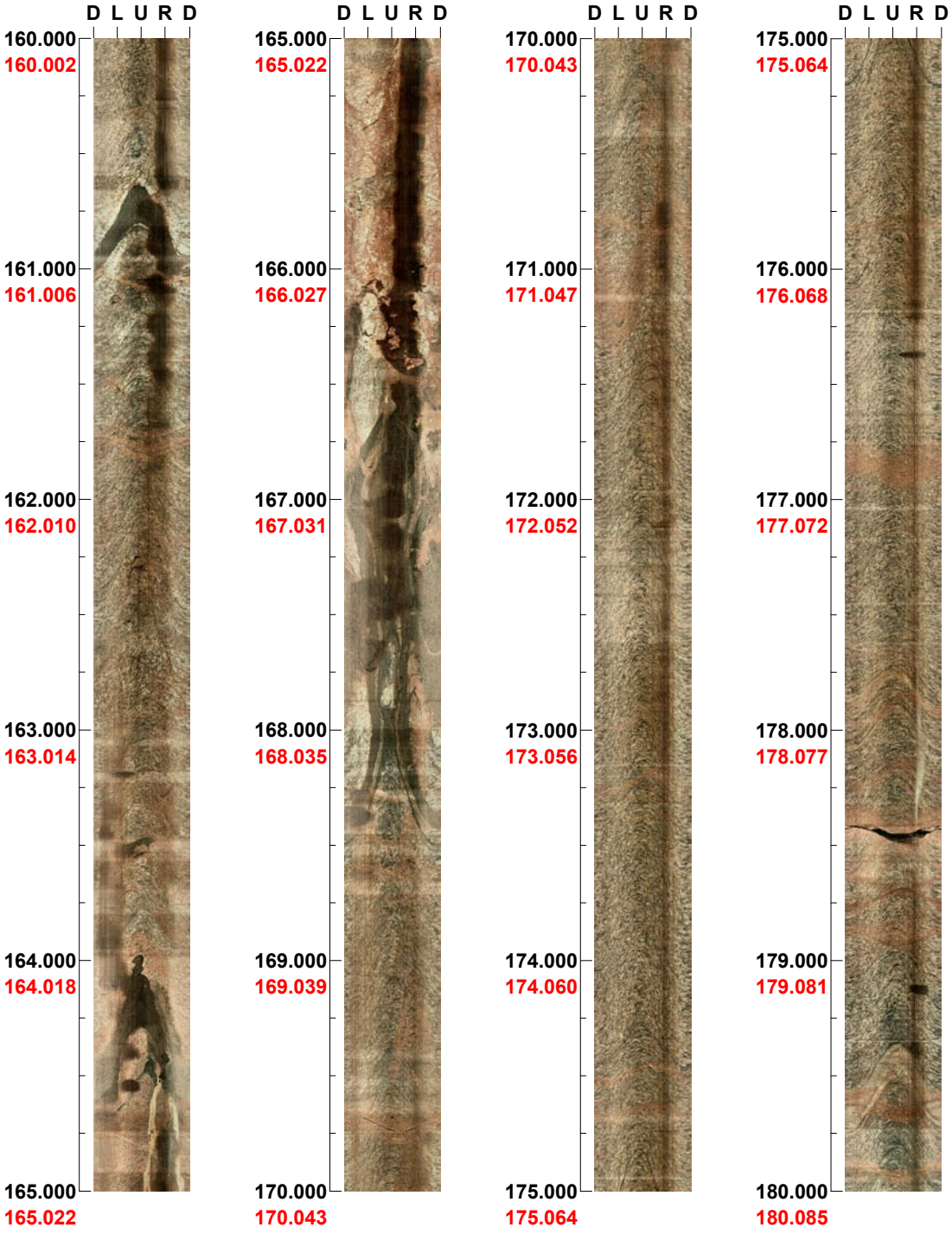
Depth range: 140.000 - 160.000 m



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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

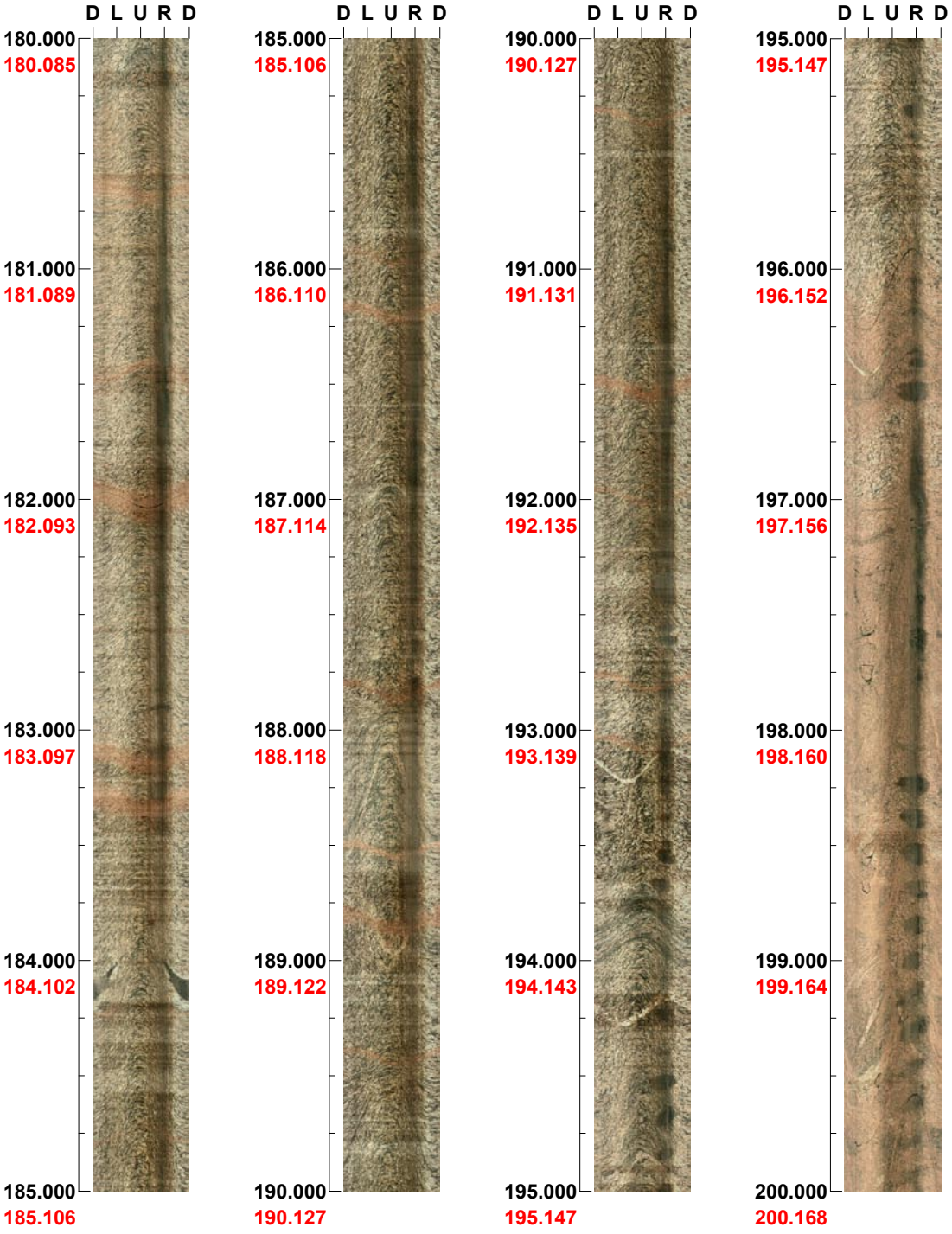
Depth range: 160.000 - 180.000 m



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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

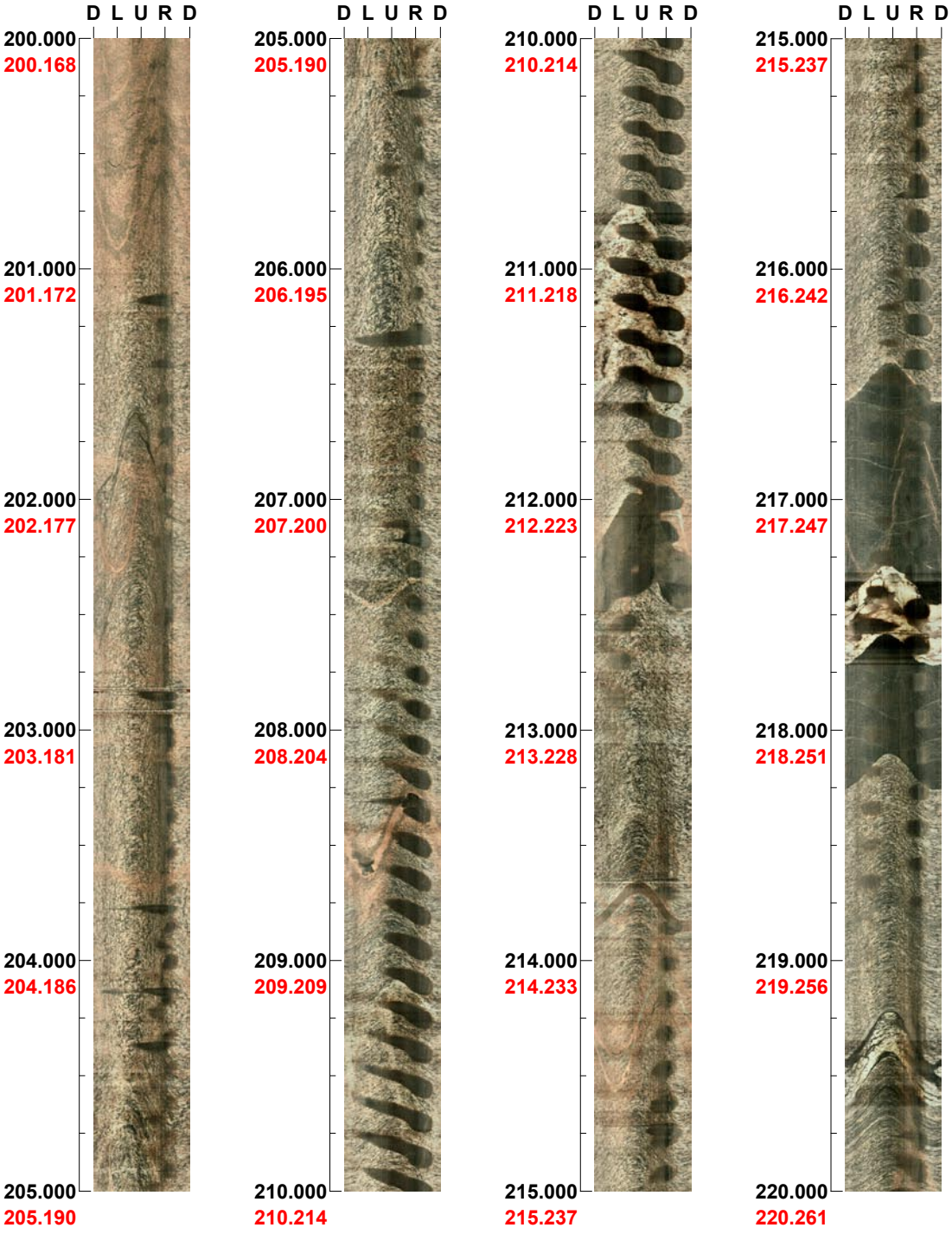
Depth range: 180.000 - 200.000 m



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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 200.000 - 220.000 m



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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 220.000 - 240.000 m

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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 240.000 - 260.000 m

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

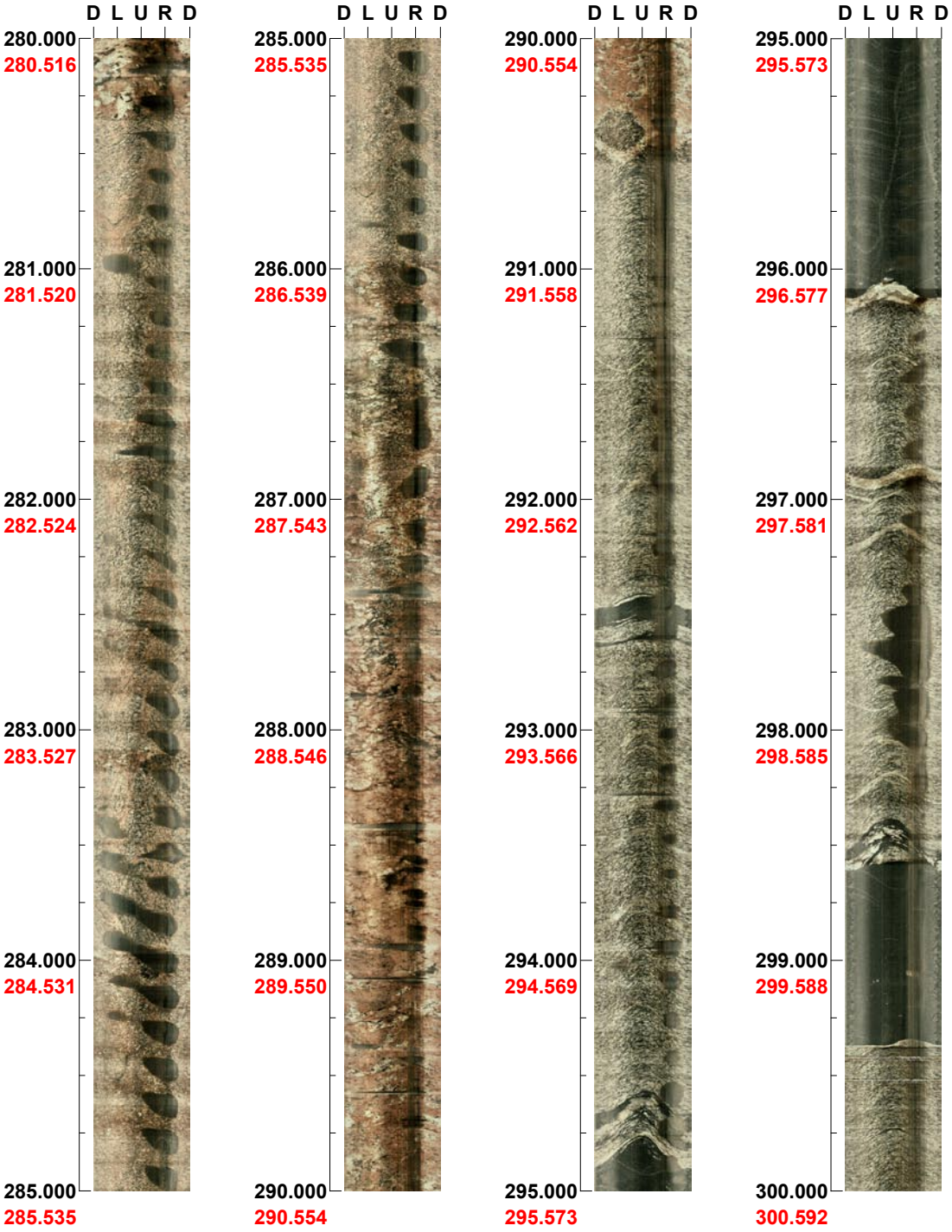
Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 260.000 - 280.000 m

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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

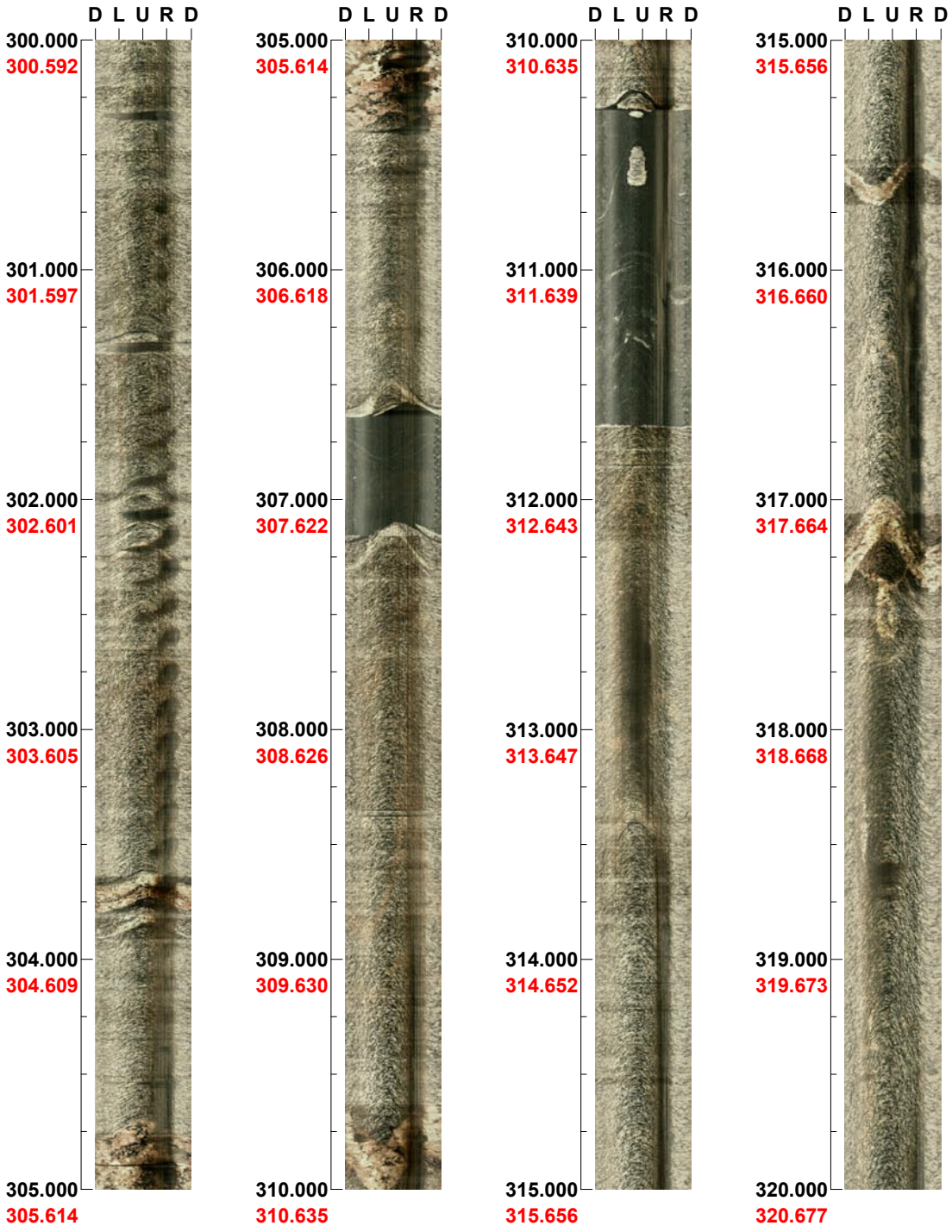
Depth range: 280.000 - 300.000 m



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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

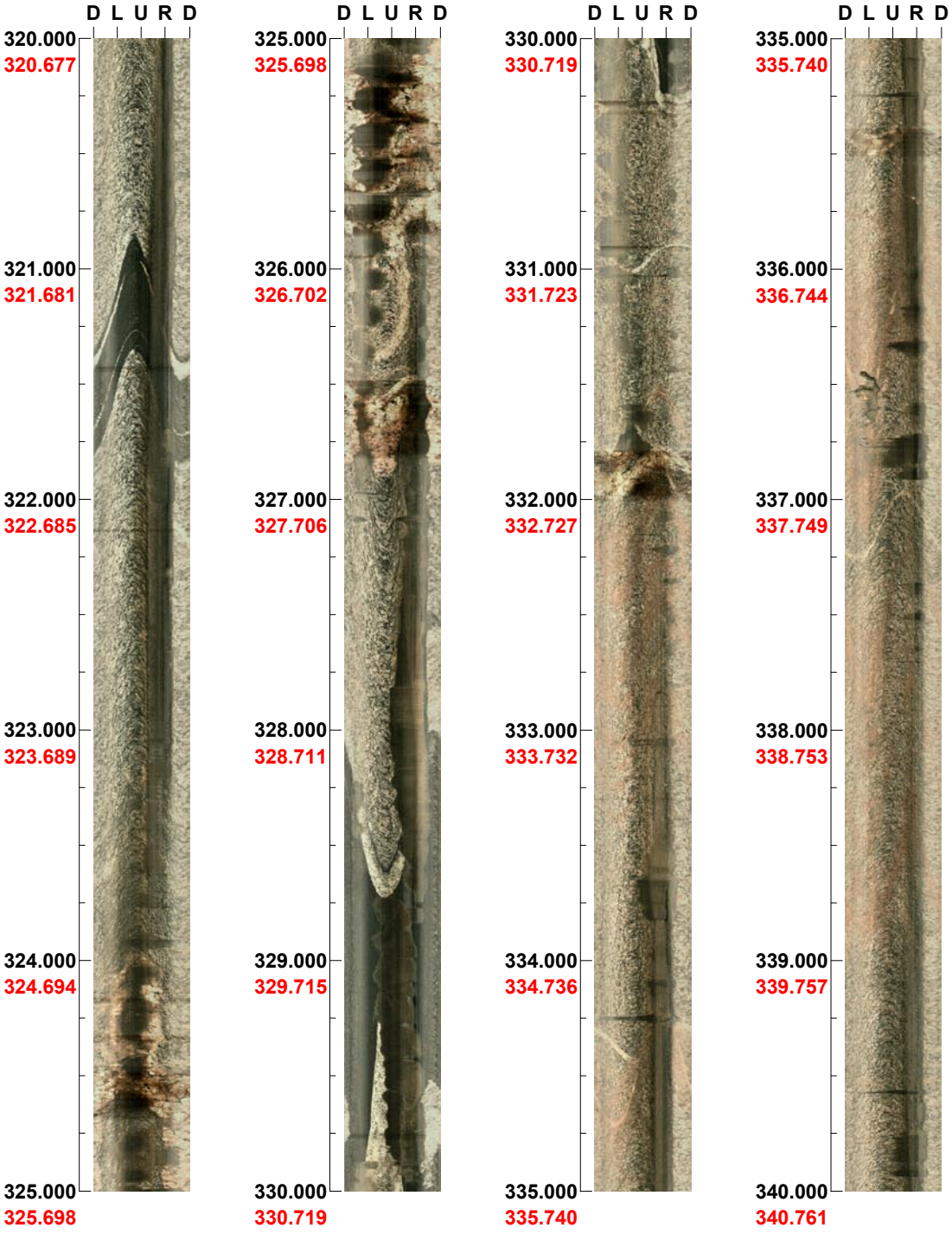
Depth range: 300.000 - 320.000 m



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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 320.000 - 340.000 m



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

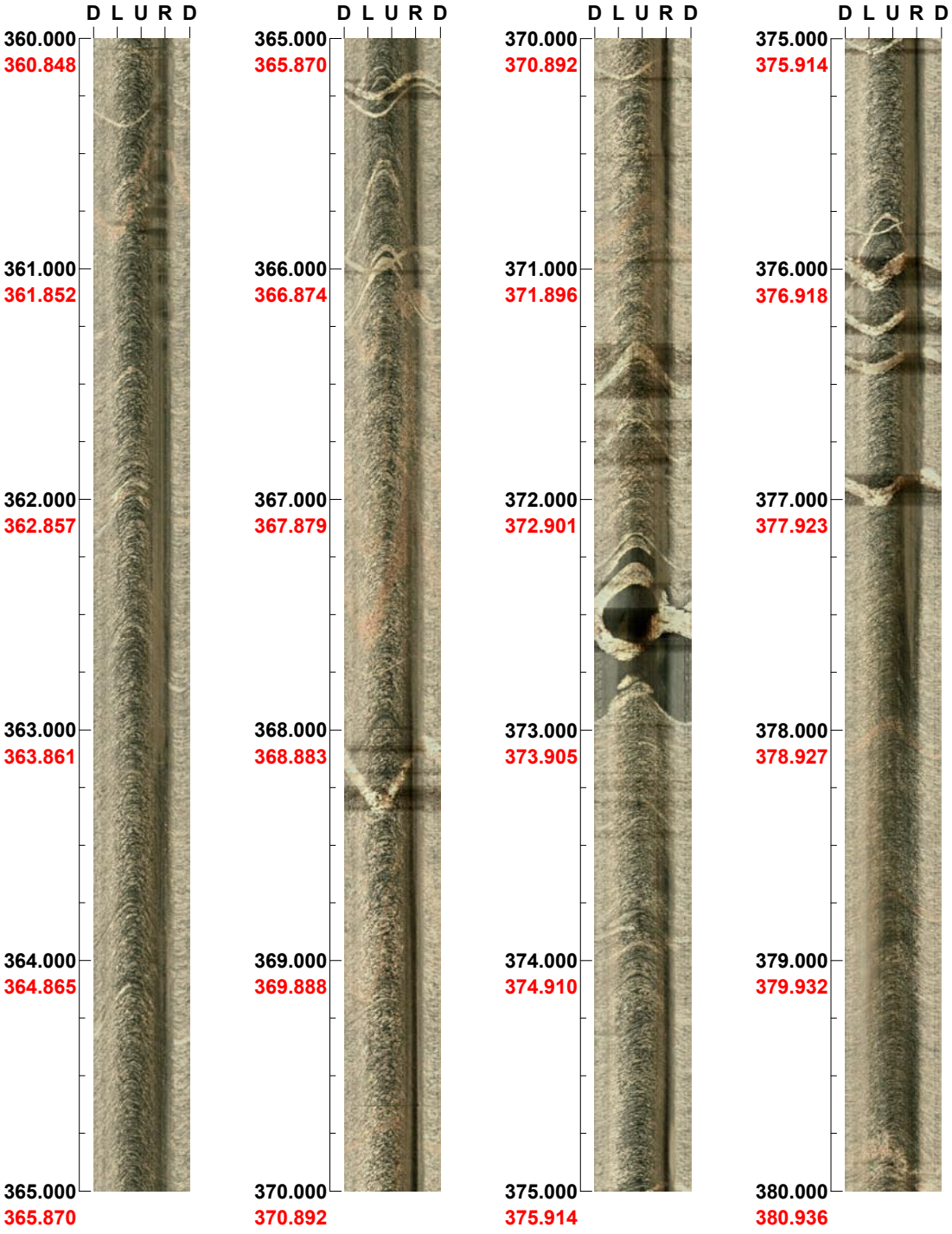
Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 340.000 - 360.000 m

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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 360.000 - 380.000 m



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

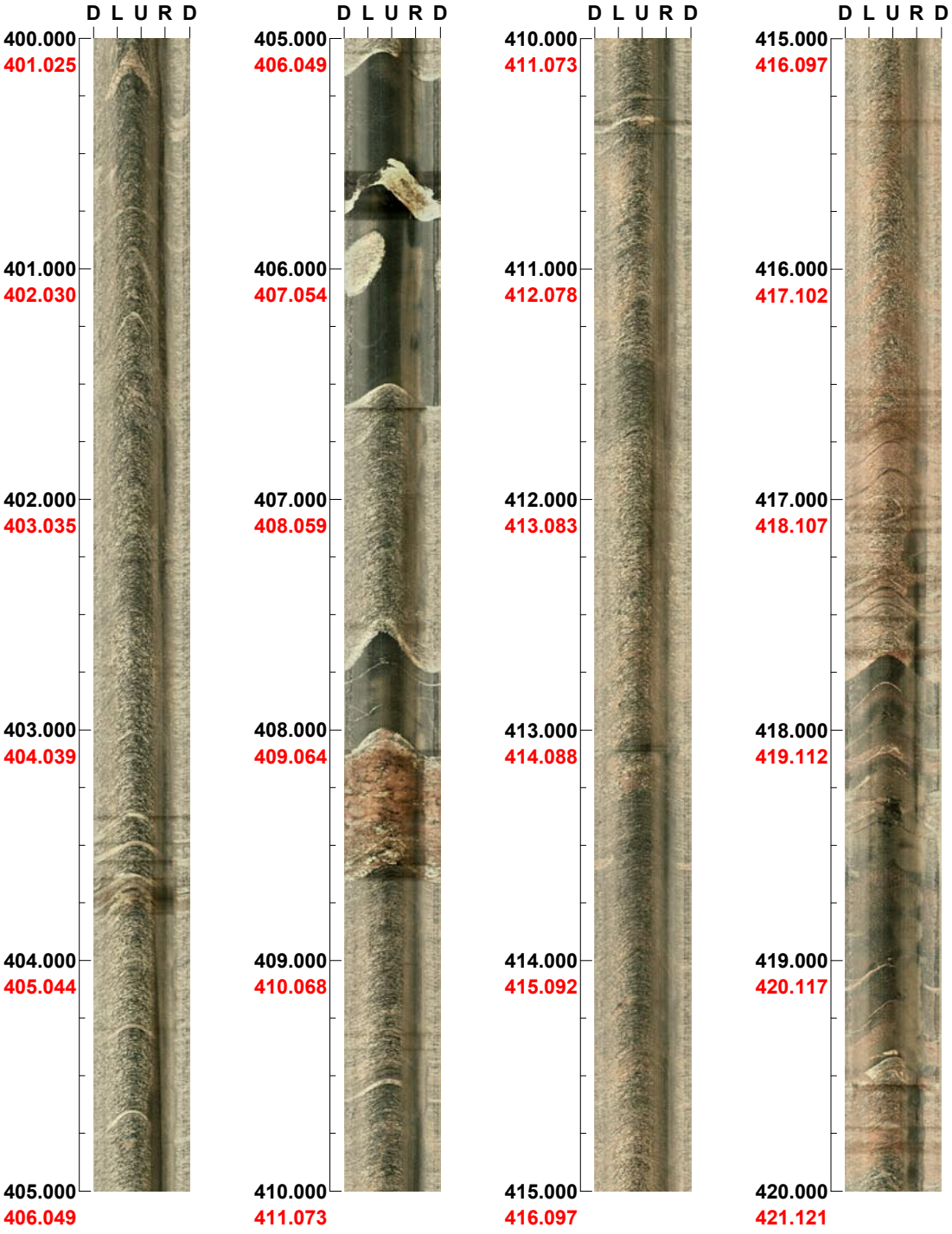
Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 380.000 - 400.000 m

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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 400.000 - 420.000 m



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

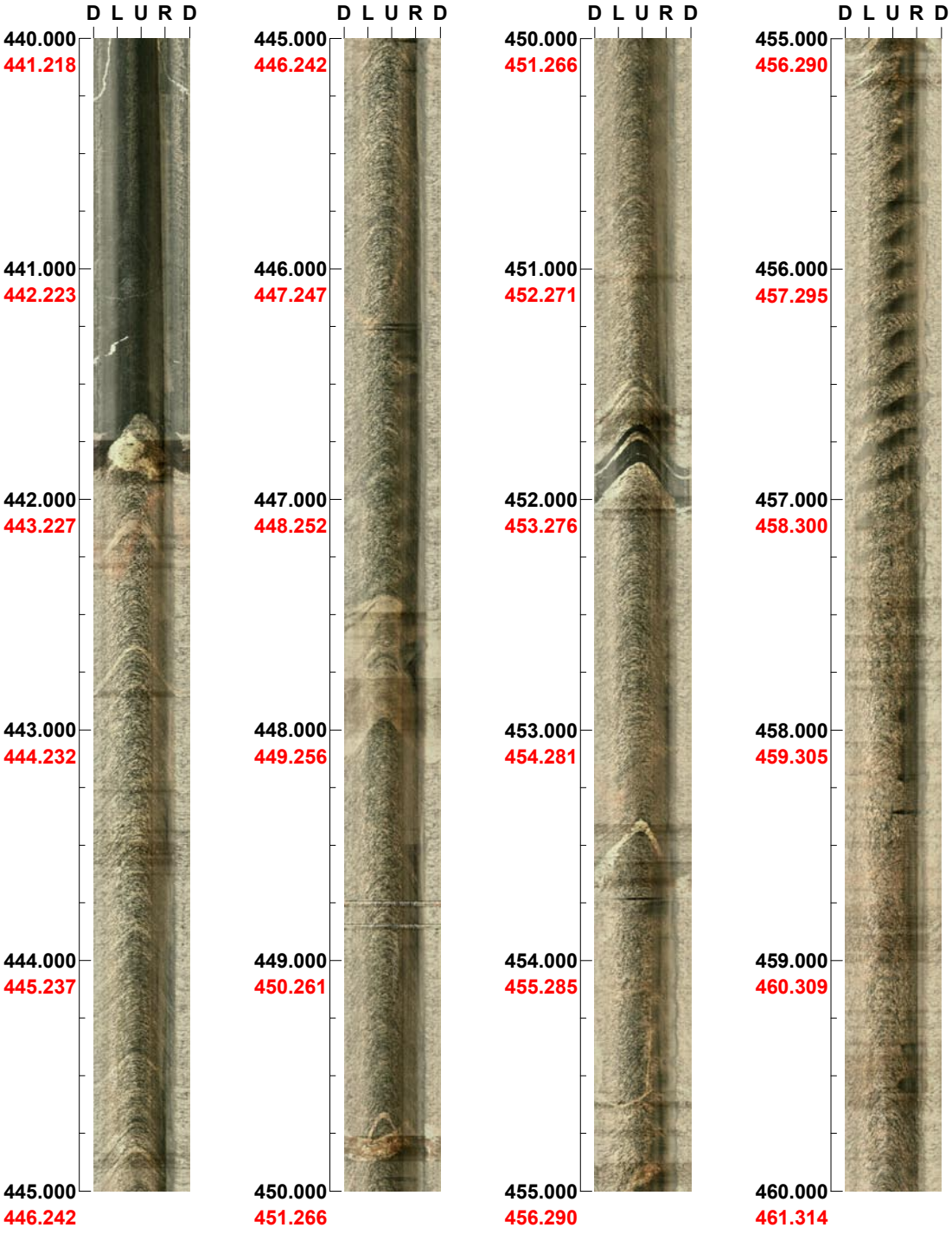
Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 420.000 - 440.000 m

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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 440.000 - 460.000 m



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

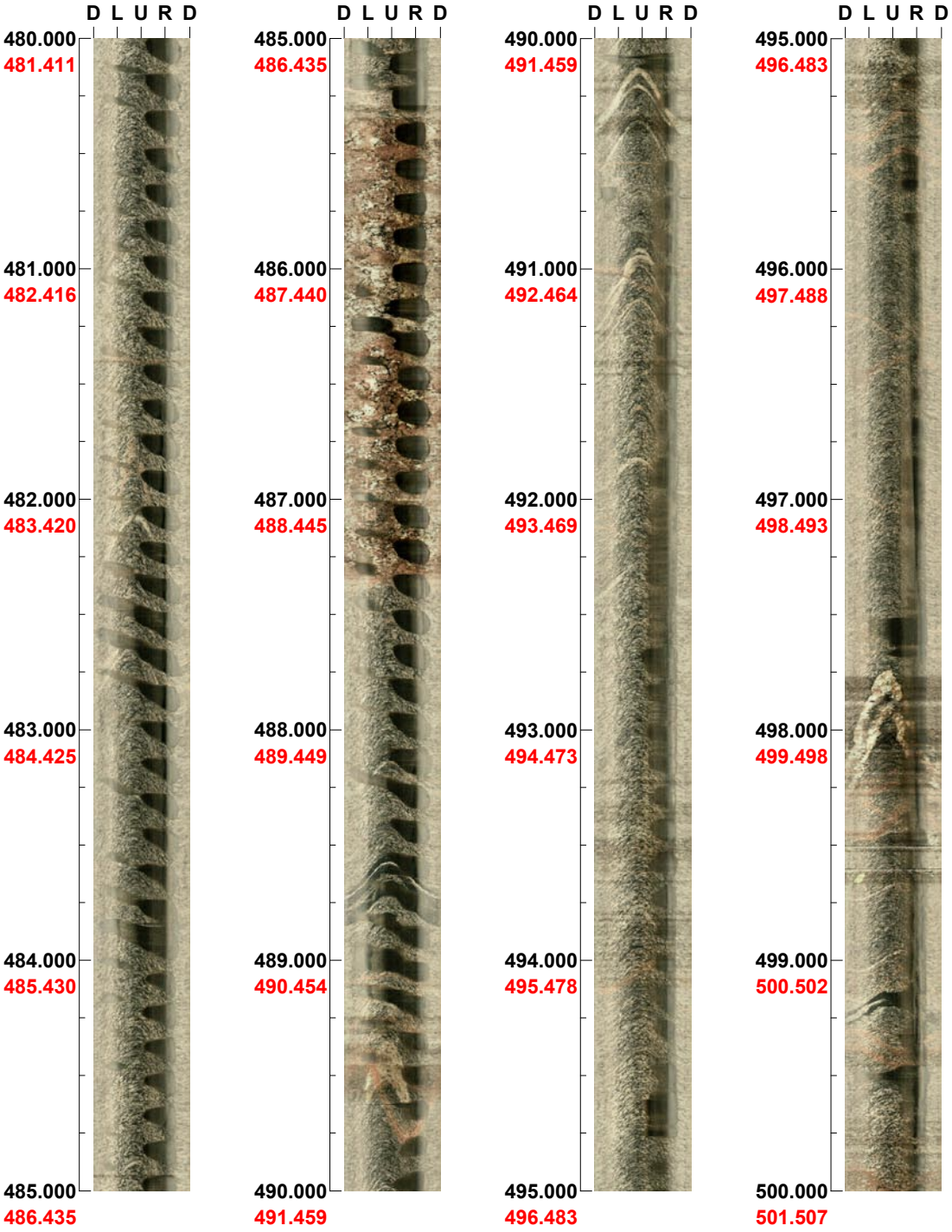
Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 460.000 - 480.000 m

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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

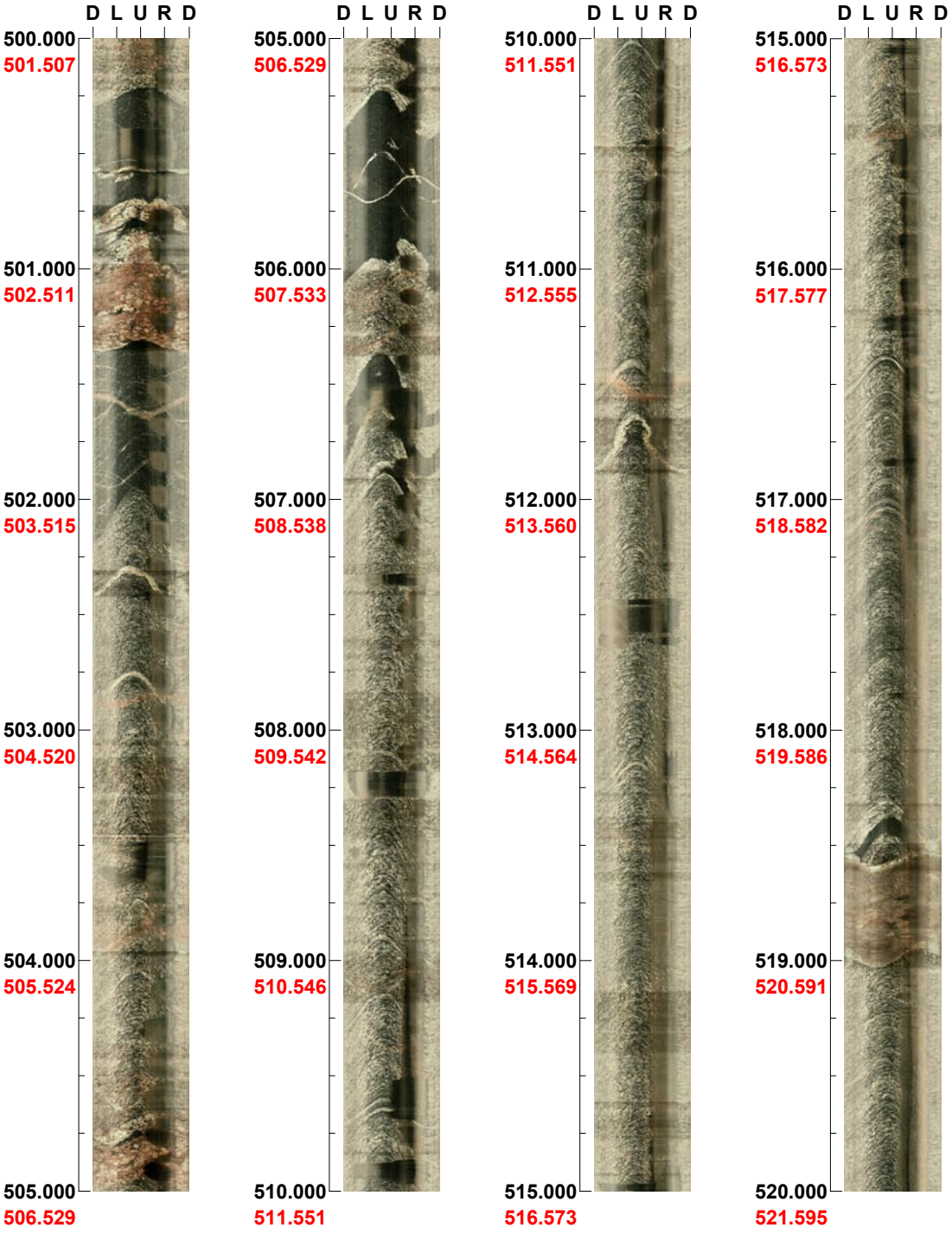
Depth range: 480.000 - 500.000 m



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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 500.000 - 520.000 m



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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 520.000 - 540.000 m

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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 540.000 - 560.000 m

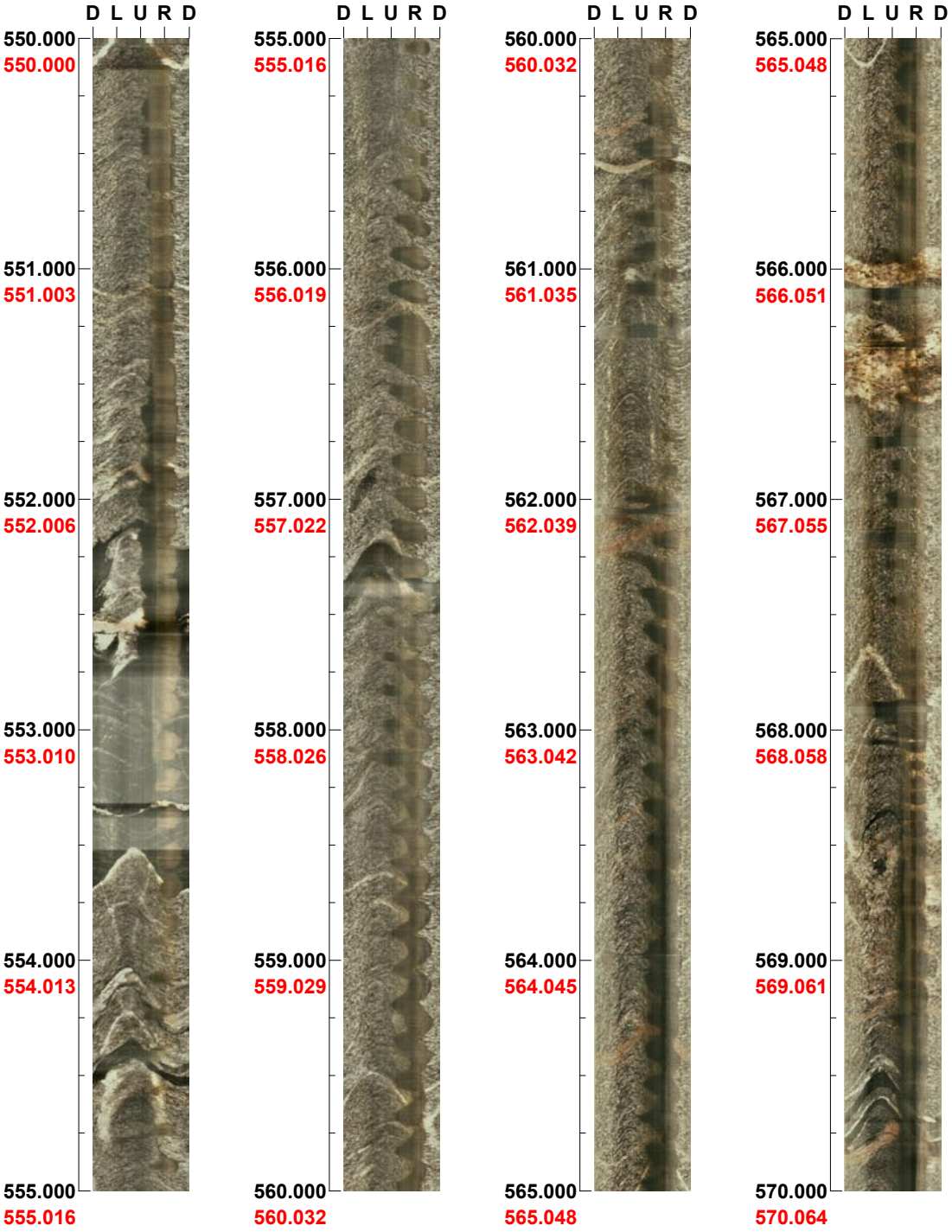
(23 / 28) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Image file	**: c:\work\r5390s~1\bips\05-02-10\kfm07a.bip**
BDT file	**: c:\work\r5390s~1\bips\05-02-10\kfm07a.bdt**
Locality	**: FORSMARK**
Bore hole number	**: KFM07A**
Date	**: 05/02/10**
Time	**: 16:02:00**
Depth range	**: 550.000 - 993.284 m**
Azimuth	**: 261**
Inclination	**: -59**
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	**: 23**
Color	**:**  **+0 +0 +0**

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 550.000 - 570.000 m



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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 570.000 - 590.000 m

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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 590.000 - 610.000 m

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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 610.000 - 630.000 m

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

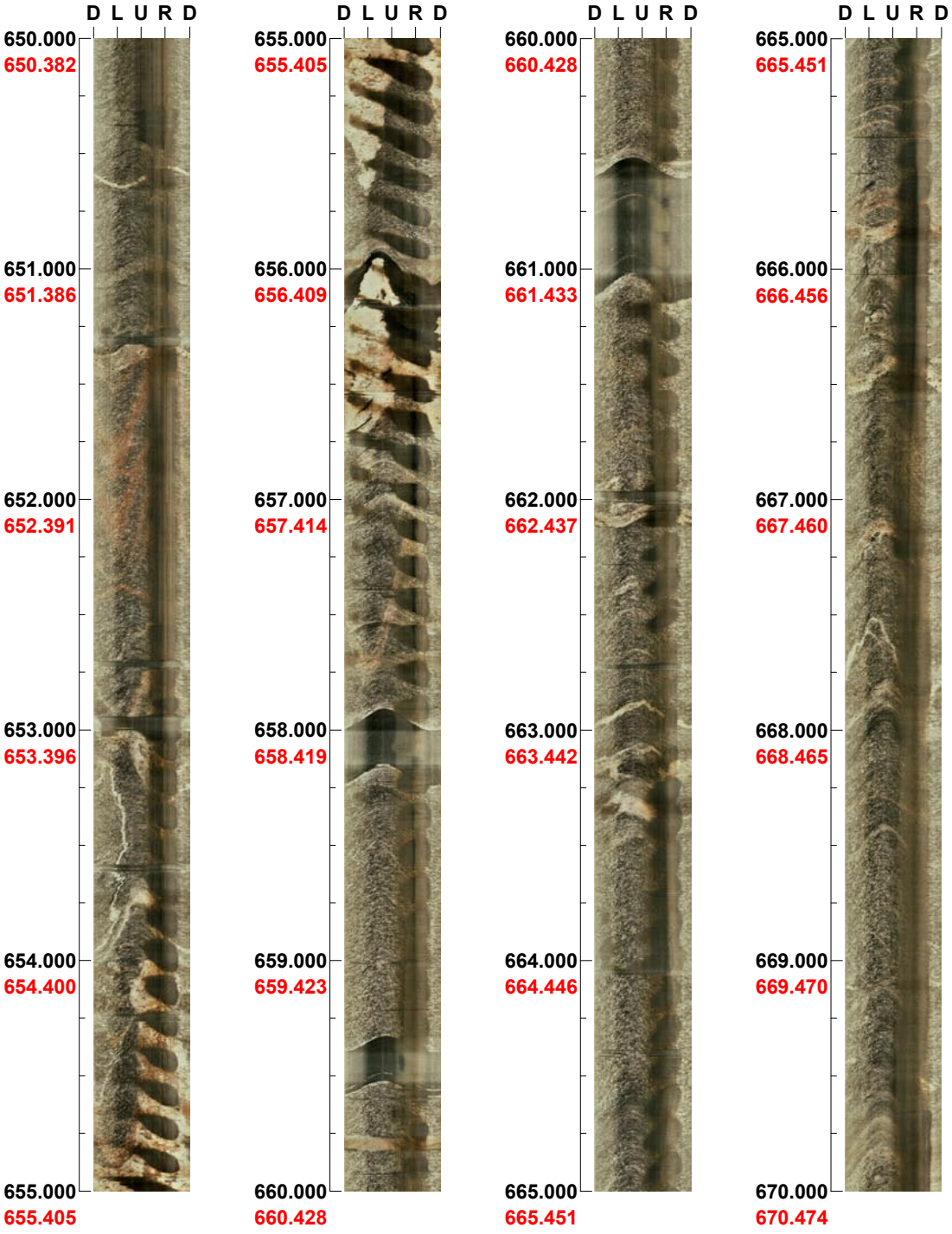
Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 630.000 - 650.000 m

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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 650.000 - 670.000 m



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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 670.000 - 690.000 m

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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 690.000 - 710.000 m

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

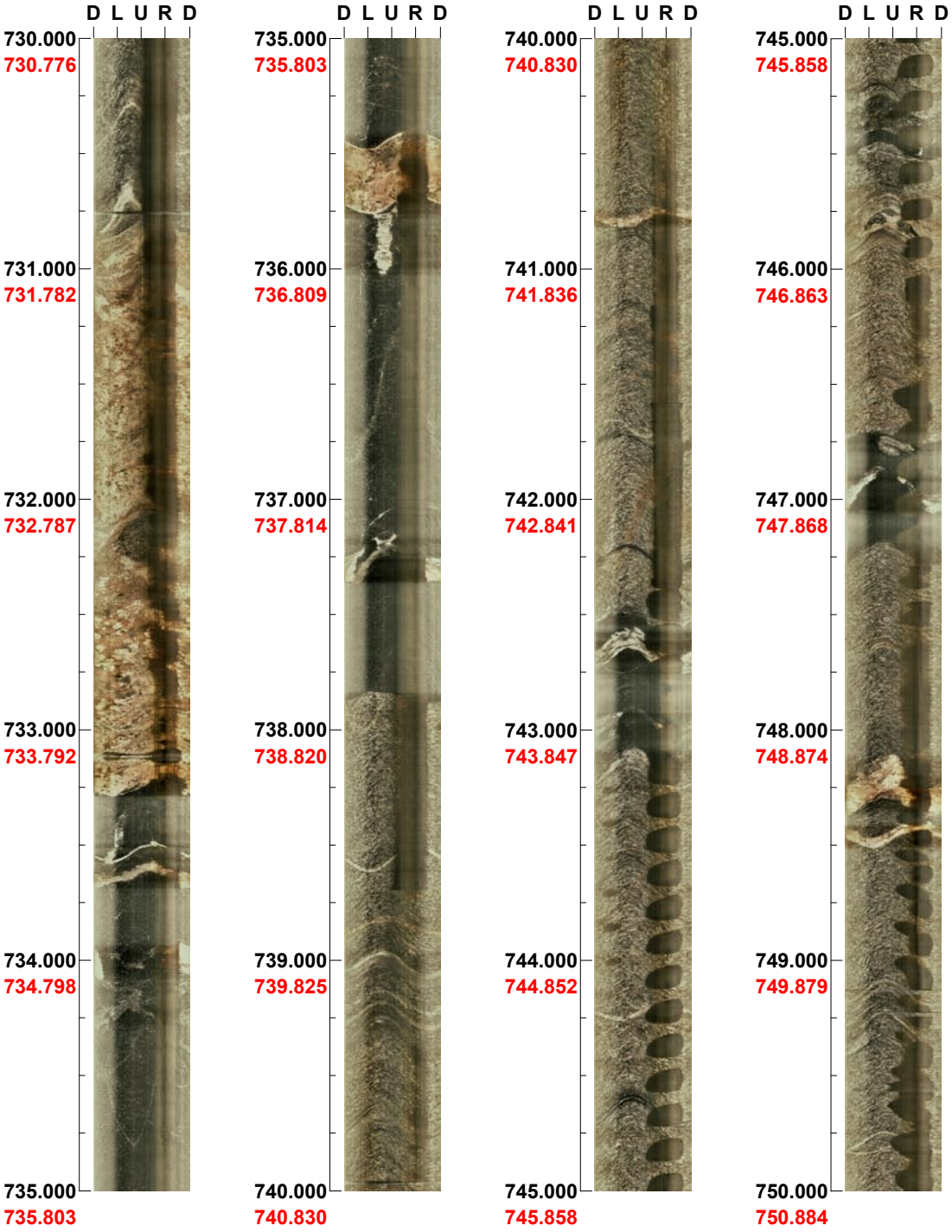
Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 710.000 - 730.000 m

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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 730.000 - 750.000 m



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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 750.000 - 770.000 m

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

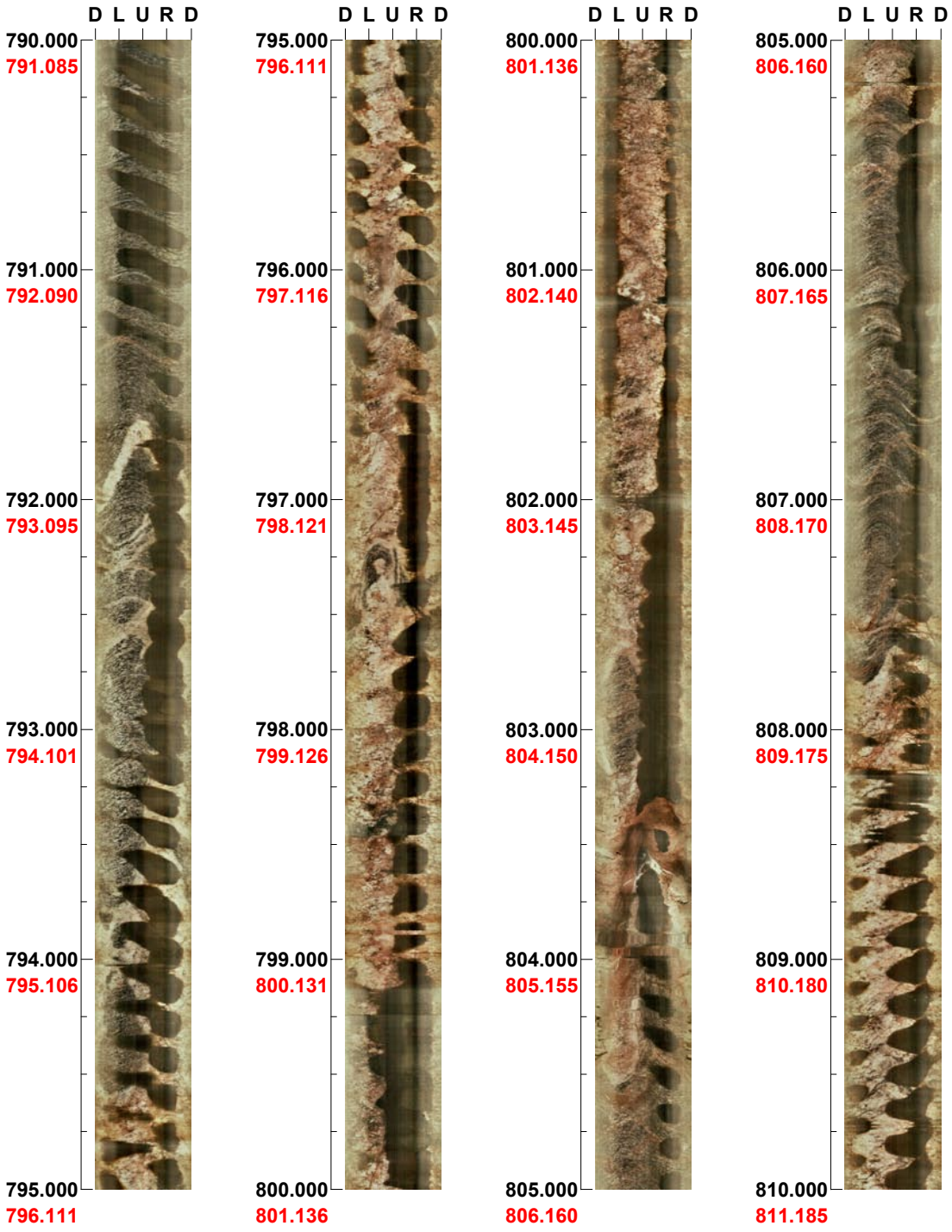
Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 770.000 - 790.000 m

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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

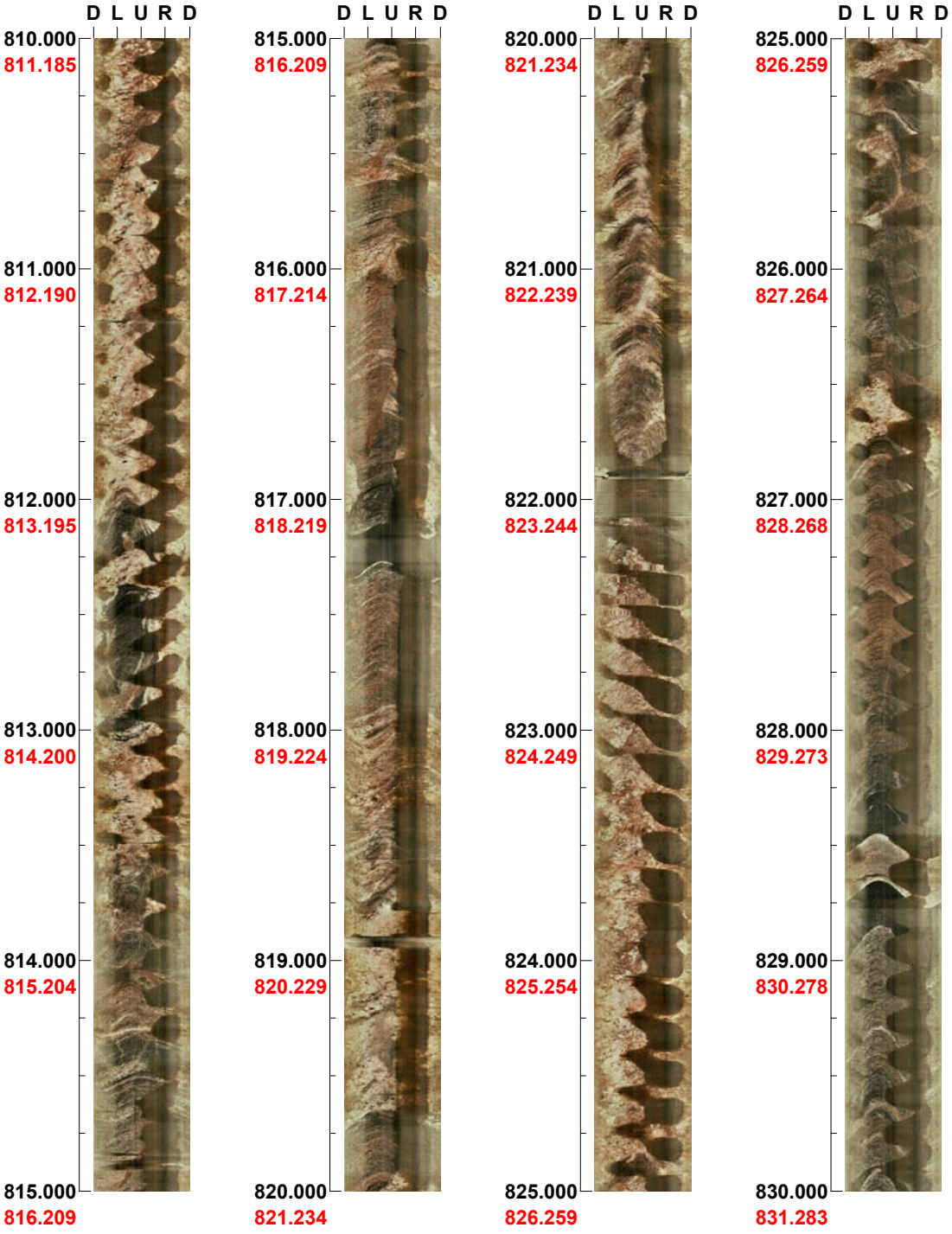
Depth range: 790.000 - 810.000 m



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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 810.000 - 830.000 m



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

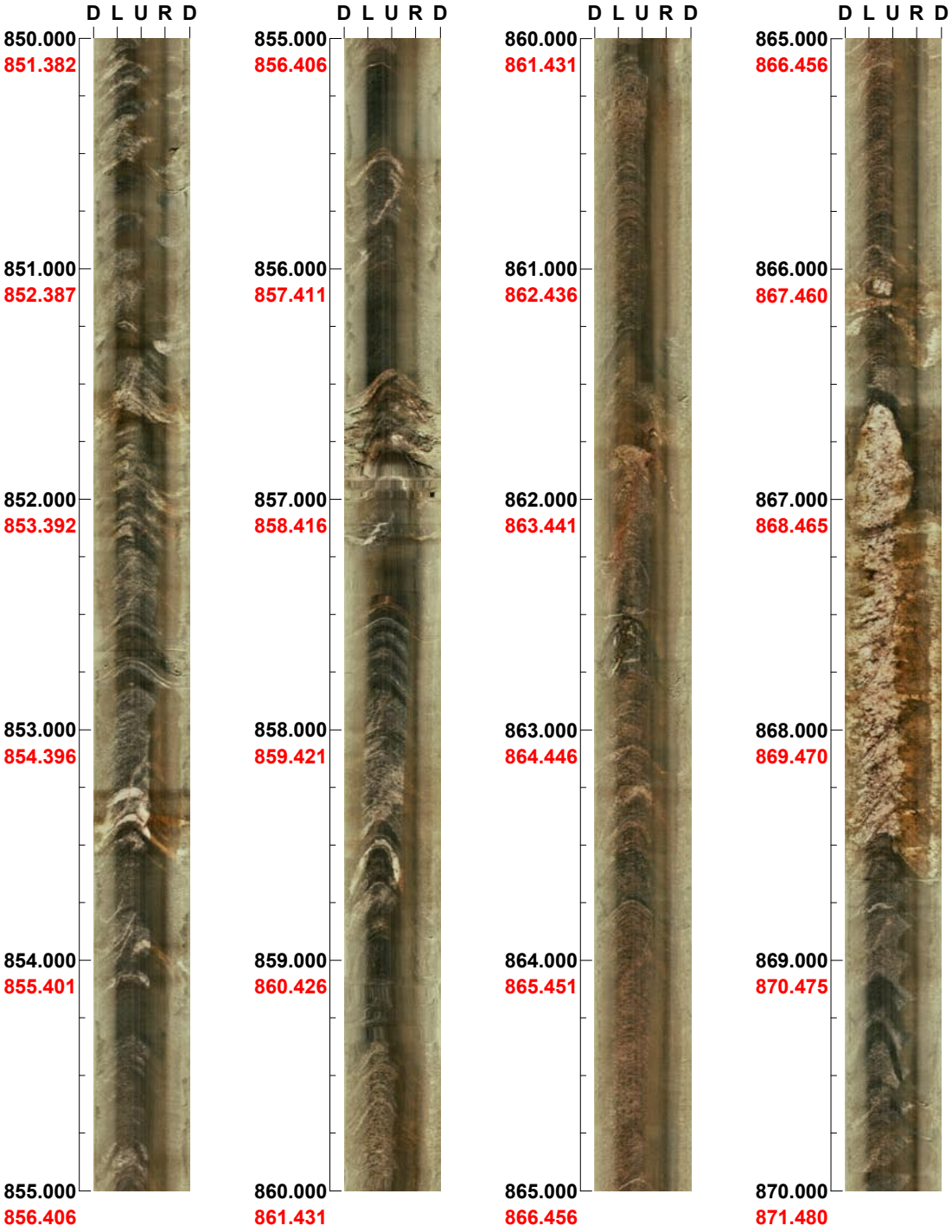
Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 830.000 - 850.000 m

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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 850.000 - 870.000 m



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

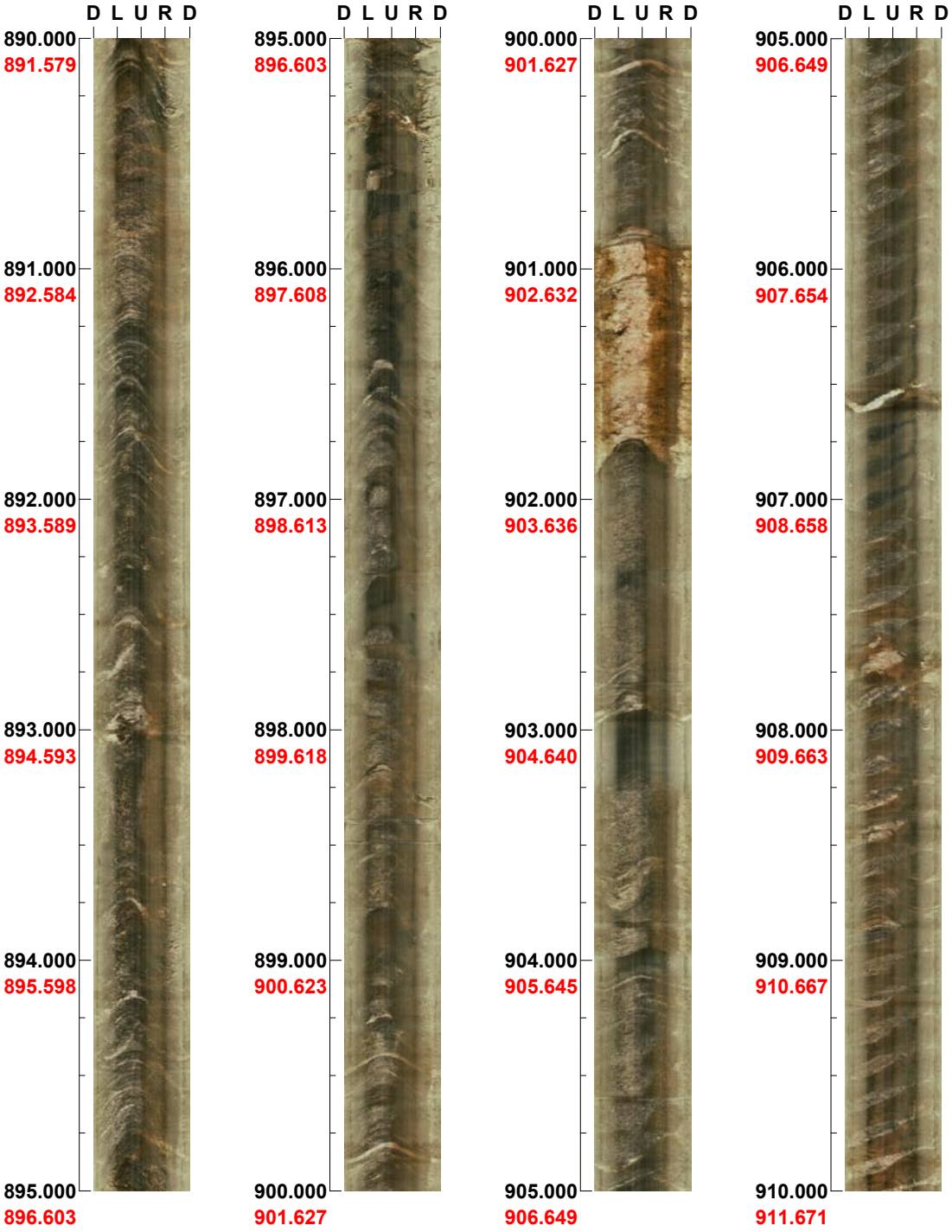
Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 870.000 - 890.000 m

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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 890.000 - 910.000 m



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

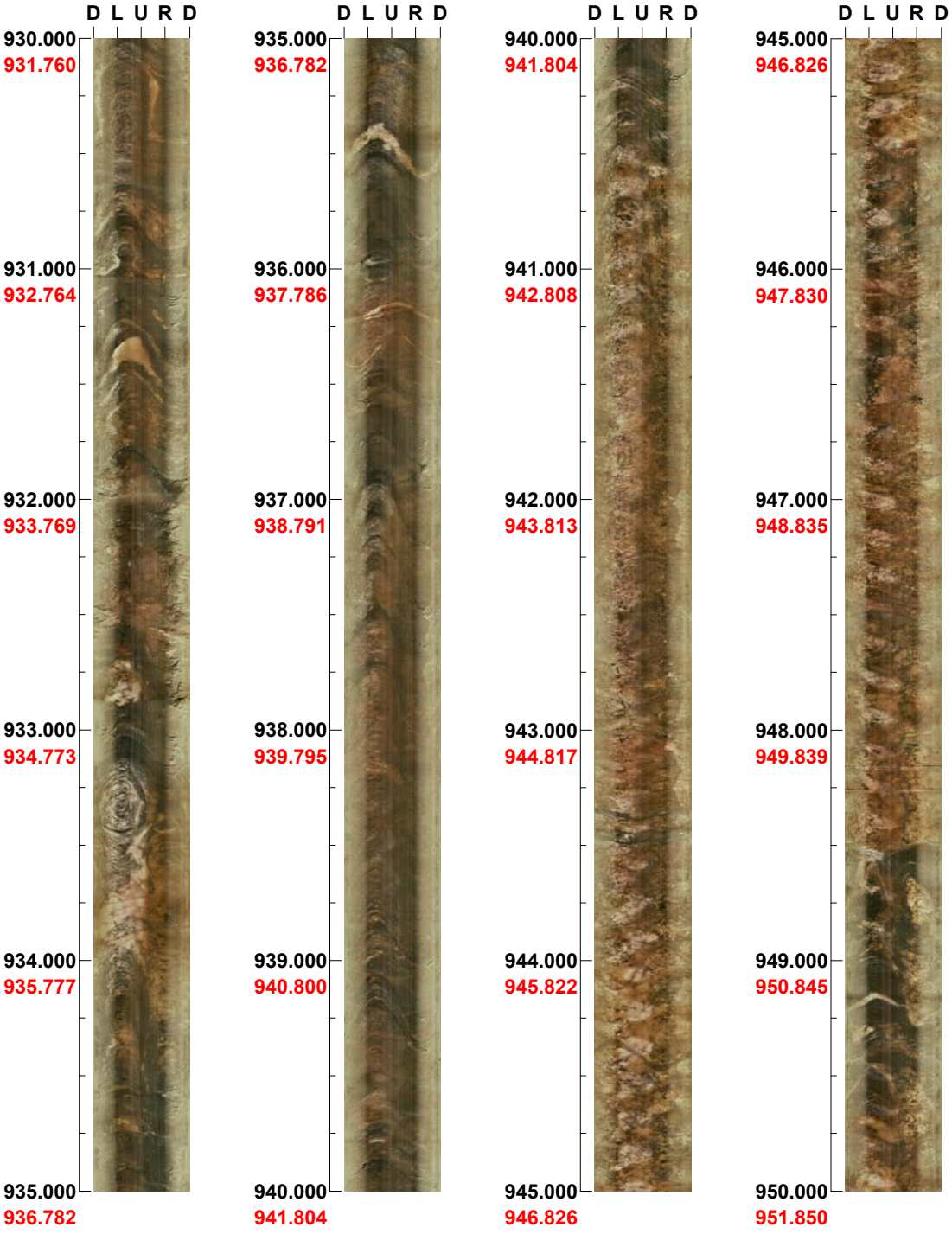
Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 910.000 - 930.000 m

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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 930.000 - 950.000 m



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

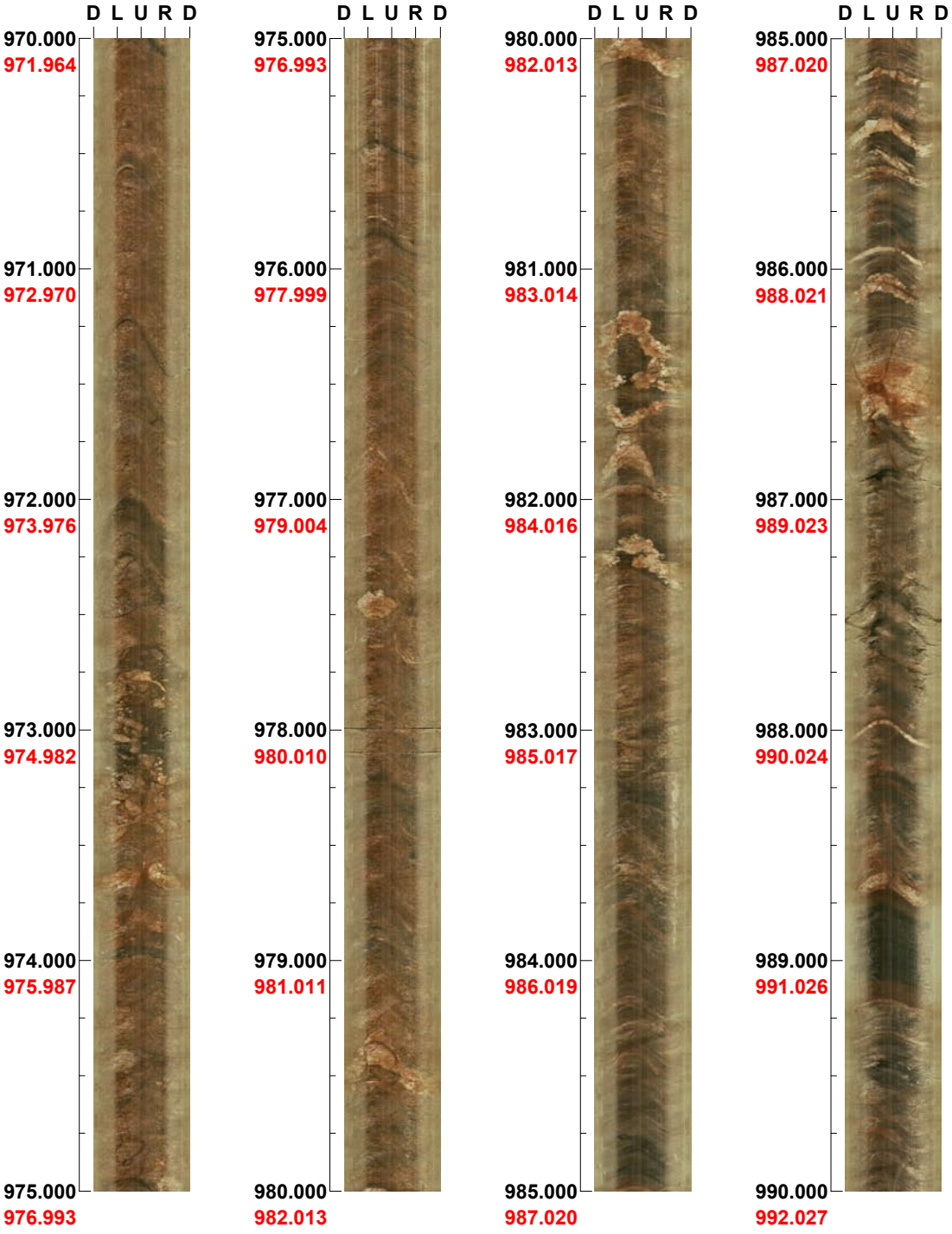
Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 950.000 - 970.000 m

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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 970.000 - 990.000 m



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

Project name: Forsmark
Bore hole No.: KFM07A **Azimuth: 261** **Inclination: -59**

Depth range: 990.000 - 993.284 m

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